PRESENTED

TO

W. H. Cole Esqre M. A.

Asstt. Supdt. 1st Grade Great Trigl. Survey

BY AUTHORITY OF

HIS EXCELLENCY

THE VICEROY

AND

GOVERNOR GENERAL OF INDIA

IN COUNCIL

A. D. 1871.

GEOGRAPHICAL
No. 31.

INDIA OFFICE,
LONDON, 6TH DECEMBER 1871.

To

HIS EXCELLENCY THE RIGHT HON'BLE
THE GOVR. GENL. OF INDIA IN COUNCIL.

MY LORD,—

With reference to your Excellency's Despatch dated the 3rd of August (No. 7) 1871. I have now to inform you that two hundred copies of the first volume of Colonel Walker's account of the operations of the Great Trigonometrical Survey of India have arrived, and that eighty-one have been distributed in accordance with list A, attached to the letter from Major Montgomerie, which was transmitted with your despatch. A copy has also been sent to the Meteorological Office. Each copy bears an inscription to the effect that it is presented under my authority.

2. The account of the origin and early operations of the Survey in the first part of this volume, forms a narrative of general interest; and the exhaustive discussions on the standards of length, and on the base lines measured in India give a scientific importance to the publication of work, which will be appreciated throughout Europe. I have caused my sense of the value of his labors to be conveyed to Colonel Walker, who is now on furlough, and I request that Mr. Hennessey, Mr. Cole and Captain Herschel, may be informed that I fully appreciate the value of the assistance they have rendered to Colonel Walker in the preparation of the work. Their devotion to the service, and their accurate and conscientious discharge of very laborious duties, is most praiseworthy.

I have &c.
(Sd.) ARGYLL.

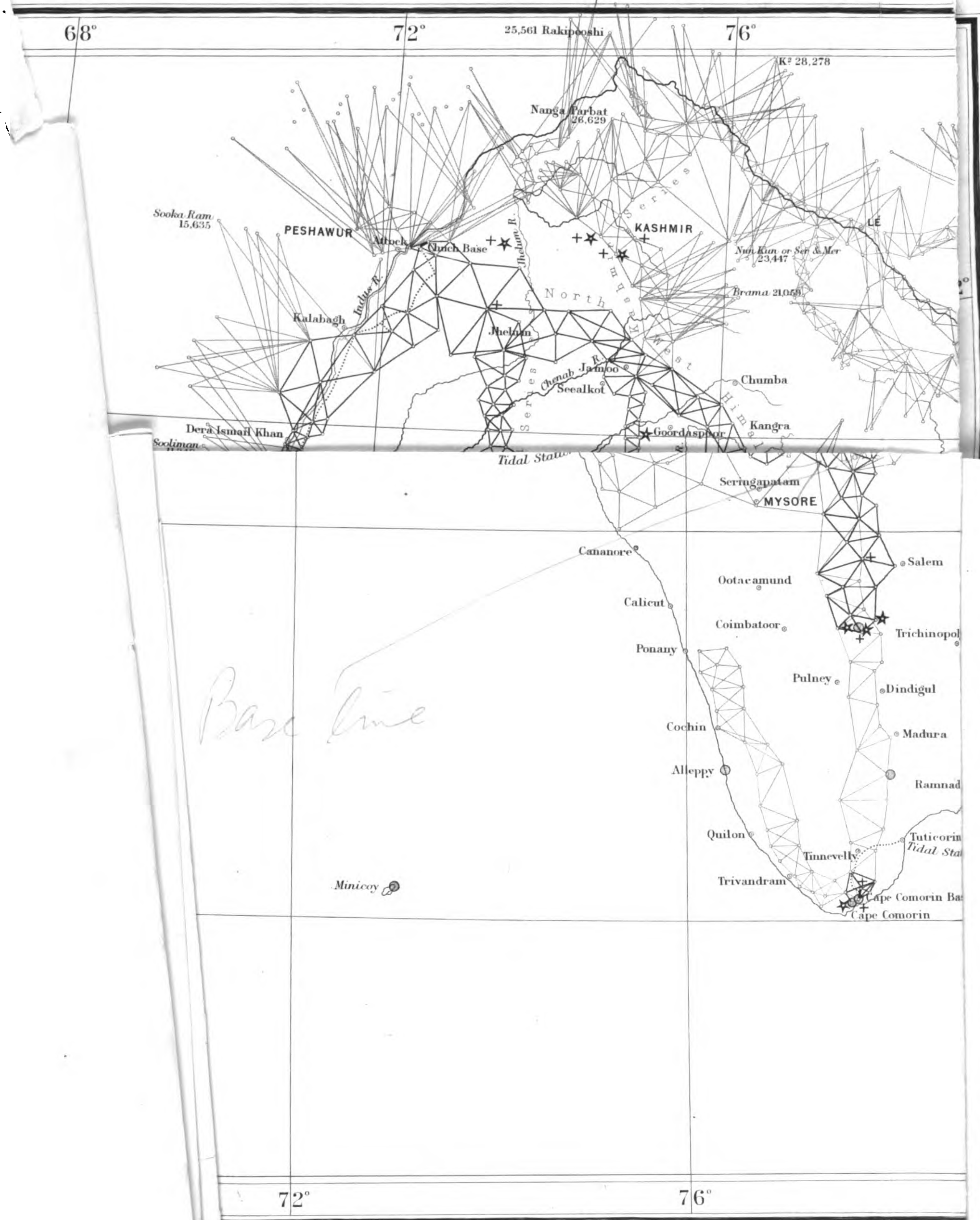
No. 36.

Copy forwarded to the Officiating Superintendent Great Trigonometrical Survey, (with reference to his letter No. 79-620 dated 19th May last) for information and communication to the Officers concerned.

By order

DEPARTMENT OF AGRICULTURE,
REVENUE AND COMMERCE (SURVEYS)
Fort William 17th January 1872.

(Sd.) P. WHALLEY,
Offg. Under Secy. to the Govt. of India.


68°
72°
76°
25,561 Rakipooshi
K² 28,278
Nanga Parbat 26,629
Sooka Ram 15,635
PESHAWUR
Attock
Nuch Base
KASHMIR
LE
Nun Kun or Ser & Mer 23,447
Brama 21,059
Kalabagh
Indus R.
Jhelum R.
Jhelum
Chenab R.
Jamoo
Seealkot
Chumba
Kangra
Goordaspoor
Dera Ismail Khan
Soliman
Seringapatam
MYSORE
Cananore
Ootacamund
Salem
Calicut
Coimbatoor
Ponany
Pulney
Dindigul
Cochin
Madura
Alleppy
Ramnad
Quilon
Tuticorin
Tinnevelly
Trivandram
Cape Comorin
Minicoy
72°
76°

COMPILED UNDER THE ORDERS OF COL. J. T. WALKER R.E., F.R.S. &c. SUPERINTENDENT GREAT TRIGONOMETRICAL SURVEY OF INDIA AT DEHRA DOON, AUGUST 1870.

Outline by H. James, Writing by J. M. Dalziel
Engraved under the Superintendence of C. W. Coard

Engraved at the Surveyor General's Office
Calcutta Novr. 1870.

ACCOUNT OF THE OPERATIONS OF

THE GREAT TRIGONOMETRICAL SURVEY OF INDIA

VOLUME I.

THE

STANDARDS OF MEASURE

AND THE

BASE-LINES.

ALSO AN INTRODUCTORY ACCOUNT OF

THE EARLY OPERATIONS OF THE SURVEY

DURING THE PERIOD 1800-1830.

BY COLONEL J. T. WALKER, R.E., F.R.S., &c., &c.,

SUPERINTENDENT OF THE SURVEY.

Dehra Doon:
PRINTED AT THE OFFICE OF THE GREAT TRIGONOMETRICAL SURVEY
M. J. O'CONNOR.
1870.

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SECTION I. THE STANDARDS OF MEASURE.

Chapter II. The Thermal Expansions of the Standards.

Chapter III. Comparisons of the Standards.

SECTION II. THE MEASUREMENT OF THE BASE-LINES.

Chapter V. The Base-Lines which were measured with Chains.

THE CALCUTTA BASE-LINE

THE DEHRA DOON BASE-LINE

THE SIRONJ BASE-LINE

THE BIDER BASE-LINE

THE SONAKHODA BASE-LINE

THE CHACH OR ATTOK BASE-LINE

THE KARACHI BASE-LINE

THE VIZAGAPATAM BASE-LINE

THE BANGALORE BASE-LINE

THE CAPE COMORIN BASE-LINE

APPENDICES

PLATES

ERRATA.

Page.					
XIX,	line 3 from bottom	*for*	Geodotic	*read*	Geodetic
XXIV,	„ 4 „	„	$0''\cdot29$	„	$0''\cdot19$
XXX,	„ 14 from top	„	chieftans	„	chieftains.
XXXI,	„ 10 „	„	in course	„	in the course.
XXXII,	foot note	*after*	this section	*dele*	1.
(13)	3rd para. line 3	*for*	proof the	*read*	proof of the.
(17)	line 7 from top	„	The expansion	„	The coefficient of expansion.
(18)	„ 14 from bottom	„	the expansion	„	the change of expansion.
(20)	„ 17 „	„	practise	„	practice.
(27)	„ 13 „	„	standard yard	„	standard yard at 62° F.
(28)	head of last column	„	$\frac{1}{100}\,\mathfrak{M}$	„	$\frac{1}{1000}\,\mathfrak{M}$
(44)	line 2 from below	„	a greater length	„	a shorter length.
(59)	„ 13 from above	„	$T + 62°$	„	$T_a + 62°$
ib.	„ 12 from below	„	$X = B - A$	„	$x = B - A$
ib.	„ 10 „	„	$X = B' - A'$ &c.	„	$x = B' - A'$ &c.
(73)	equation (20)	„	$51\cdot4\left(\frac{[ot]}{r} + 1\cdot1\right)$	„	$\left(51\cdot4\frac{[ot]}{r} + 1\cdot1\right)$
„	„	„	$\left(2\cdot9\frac{[ot]}{r} - 0\cdot1\right)de'_i$	„	$\left(2\cdot9\frac{[ot]}{r} + 0\cdot1\right)de'_i$
(74)	line 5 from above	„	12°	„	7°
(84)	last line	„	[*an.a*]	„	[*an.u*]
(85)	equation (25)	„	$\frac{\rho^2}{F^2} \times e.m.\, s^2$ of F	„	$\frac{\rho^2}{F^2} \times p.e.^2$ of F
(88)	2nd line of foot note	„	of end sections	„	of the end sections
(103)	line 8 from below	„	form Madras	„	from Madras
III$_{4}$	last line	„	43′	„	43 min.
V$_{2}$	line 3	„	Rámgunj	„	Rámganj
V$_{32}$	line 5	„	Station γ	„	Auxiliary Station γ
„	9	„	Station δ	„	Auxiliary Station δ
VIII$_{3}$	line 12 of Introduction	„	at the end of the 173rd set	„	near the end of the 266th set
VIII$_{7}$	last line	„	$+52\cdot9\, dE_a$	„	$-52\cdot9\, dE_a$
VIII$_{30}$	first line of foot note	„	$+\frac{(dx)^2}{2x^2}$	„	$-\frac{(dx)^2}{2x^2}$
X$_{5}$	lines 4, 6, 8 of foot note	„	thermometer iron	„	thermometer on iron
„	line 9 do.	„	2406 *and* 4216	„	7347 *and* 7349
X$_{19}$	foot note		X$_{19}$	„	X$_{20}$

Appendices, page 1 last line *for* working in collars above the object glass *read* which are usualy attached to the bars
„ 49 last line *for* practise *read* practice
„ 50 5th line from below „ unite „ unit

ADDENDA ET CORRIGENDA.

Page I$_{3}$ The height adopted for South-End Calcutta base-line, $13\cdot0$ feet, is the value above mean sea level at Karáchi, and is deduced through the spirit levelling operations from Karáchi viâ Kydd's Dock Calcutta to the terminus of the base-line above named.

Page II$_{3}$ The East-End of Dehra Doon base-line was connected with mean sea level at Karáchi by the spirit levelling operations in 1862 (see page II$_{47}$).

Page VI$_{3}$ The South-West-End of Chach or Attock base-line was connected with mean sea level at Karáchi by the spirit levelling operations in 1860 (see page VI$_{31}$).

Page VII$_{8}$ It may be understood from what is stated on this page, that the height of the base-line adopted in reducing the measured length to mean sea level, was deduced by means of the vertical angles connecting the base-line with Manora tide-gauge; whereas, the values of height employed are those obtained from the spirit levelling operations of 1860 (see page VII$_{30}$). J. B. N. H.

PREFACE.

The Chart which faces the title page of this volume is an Index to the principal triangulation and the geodetic operations of the Great Trigonometrical Survey of India, from the commencement of the 'Mathematical and Geographical Survey of the Peninsula' in the year 1800, up to the termination of the field season of 1869-70.

The net-work of triangulation in the southern Peninsula, which is shown on the chart by fine lines, was executed during the three first decades of the progress of the Survey, and was completed before the year 1830. Up to that year the instruments which were respectively used for the linear and the angular measurements, though good for the time, were much inferior to those which were then constructed for the Survey, under Colonel Everest's superintendence, in England, and which even at the present time are scarcely surpassed by the best modern instruments. And, with the introduction of the new instruments, a new system of observation was introduced, which was more rigorous and refined and better calculated to give accurate and precise results than the less laborious and unsystematic methods of procedure which had been previously followed.

Thus the year 1830 marks an epoch of transition in the history of the Trigonometrical Survey of India which is of very considerable importance. The Index Chart has therefore been prepared so as to permit of the operations before and after that year being readily distinguished; it shows that the net-work system of triangulation was succeeded by a system of chains of triangles, following certain obligatory meridians and parallels and the coast and frontier lines, and forming what is known as 'the gridiron system of triangulation'. These chains are indicated on the chart by strong lines. In order that the chart—which is necessarily on a very small scale, viz. $\frac{1}{6,082,560}$ — might not be confused with too many details, all secondary triangulation—both before and after the year 1830—has been omitted, with the exception of that to the peaks of the Himalayan and the Soolimani mountain ranges, which lie beyond the chains of the principal triangles. But the stations at which the latitude or the azimuth has been determined by astronomical observations, and those at which pendulums have been swung to determine the force of gravity, are all shown.

Of the several operations the only portions which have hitherto been published in detail are those relating to the central meridional chain of triangles which extends from Cape Comorin to the Himalayas—generally known as 'the Great Arc'—and the triangulation which was executed in the southern parts of the Peninsula, shortly after the commencement of the Survey. By far the greater portion of the work has not yet been published in detail, and a very large portion has not been published in any shape whatever.

For many years it was the custom to prepare three copies of the results of the operations, in manuscript, one for the use of the Geographer to the India Office in London, another for the Surveyor General's Office in Calcutta, and a third for the Head Quarter's Office of the Trigonometrical Survey in Dehra Doon; copies of such portions as were required for the use of Topographical Surveyors were also prepared in manuscript whenever wanted. But of late years preliminary charts of the triangulation, containing full numerical data of the latitudes, longitudes, azimuths and distances of the stations and other permanent points of reference, have been photozincographed for general use. Thus the requirements of all the persons who were most directly interested in the results of the operations have been fully satisfied, and any further publication of the result has been postponed until the operations were sufficiently advanced to permit of final results being arrived at.

It is obvious that every operation of a survey must necessarily be fallible, and therefore that all newly obtained facts of observation, that are susceptible of being combined with those which have been previously acquired, are liable to disturb the results which were previously arrived at: every additional base-line and every new chain of triangles must necessarily exercise some influence on the operations generally, and more particularly on those in their immediate neighborhood. Thus therefore before a triangulation can be finally reduced and all it's parts harmonized, it is necessary either that the whole of the angular and of the linear measurements shall have been completed, or that they shall have so nearly approached completion that what remains to be done may hereafter be fitted into what has already been done, without any serious violation of principle. It is only of late years that the operations of this Survey have been sufficiently advanced towards completion to justify the commencement of the final reductions; these reductions are however being now proceeded with, and the time has arrived when publication may be commenced.

The present volume is intended to be the first of a series which, when completed, will give full details of the operations of this Survey, from the preliminary stage of the actual observations and measurements to the most probable—and therefore the final—results. It commences with a general account of the early operations, or those executed during the first thirty years of the existence of the Survey, mostly under the superintendence of Colonel Lambton, but partly under Captain Everest. These operations must eventually be reduced on the basis of the modern triangulation, but this will probably be one of the last stages to be taken in the general reduction of the operations of the Survey. The remainder of this volume is devoted to a consideration of, *first,* the Standards of Length, their thermal expansions and their relations to the European Standards, and, *secondly,* the Base-Lines, both those which were measured with chains before the year 1830, and those measured with the apparatus of compensation bars and microscopes after that year. It is intended that the details and results of the triangulation and of the astronomical and the pendulum observations shall be given in the subsequent volumes.

As regards the present volume I must express my obligations to Colonel Thuillier, the Surveyor General of India, for the accompanying Index Chart of the operations of this Survey, which he kindly undertook to have engraved at his office; also to Major General Sir Henry James, Director of the Ordnance Survey of Great Britain and Ireland, for permitting certain standards, which were constructed in 1864 for the Trigonometrical Survey of India, to be compared, in his Office, with the Ordnance and with other European standards.

To Captain A. R. Clarke R.E. of the Ordnance Survey, I am very much indebted for his most elaborate and exact comparisons of the new Indian standards of length with those of the Ordnance Survey, for his determinations of the thermal expansions of the principal of these standards, and for calibrating a new thermometer as a standard of reference for this Survey. The whole of these operations are fully described in sections XVI, XVIII, XIX and XX of his *Comparisons of the Standards of Length of England, France, Belgium, Prussia, Russia, India and Australia; London* 1866. Captain Clarke's labors have materially facilitated the operations in this country, and have not only relieved us of much labor, but have supplied us with results which apparently possess the utmost accuracy that is practically attainable.

To the Officers of the Great Trigonometrical Survey who have had a share in the operations discussed in this volume, I am most indebted to J. B. N. Hennessey, Esquire, who has for many years past been in charge of the Computing Office at the Head Quarters of the Department, and whose constant self-devotion to his work, and accurate and conscientious discharge of his duties, I cannot praise too highly. He has either supervised or taken a principal share in the whole of the comparisons of standards which have been made in India since the year 1866, and are here described; he has also re-investigated the factor of expansion of the principal standards of length of this Survey, his account of which operation is given in Appendix No. 6; and he has superintended the reduction of most of the ten base-lines of which the details are given in this volume, and has prepared the whole of them for publication. In these duties he has received much and valuable assistance from W. H. Cole, Esquire M. A., to whom several of the appendices to this volume are due.

To Captain J. P. Basevi, R.E., I am indebted for the Appendix on the Practical Errors of the Measurement of the Cape Comorin base-line; he supervised the operations of the measurement, which were purposely so conducted as to ascertain, in every possibly way, the probable errors of the linear measurements with the compensation apparatus. To Captain J. Herschel, R.E., I am also much indebted for his assistance in the practical operations of that base-line, and in the reduction of the observations, in which his ready aid and thoughtful suggestions were always very valuable.

Dehra Doon,
1*st December* 1870.

J. T. WALKER, *Colonel, R.E.,*
Superintendent Great Trigonometrical Survey of India.

INTRODUCTION.

AN ACCOUNT OF THE EARLY OPERATIONS

OF THE

GREAT TRIGONOMETRICAL SURVEY OF INDIA,

UP TO THE YEAR 1830.

AN ACCOUNT OF THE OPERATIONS FROM THE COMMENCEMENT OF THE SURVEY TO THE YEAR 1830.

1.

Origin, and proposed objects of the Survey.

Towards the close of the year 1799, Major Lambton, of H. M's. 33rd Regiment of Foot, drew up a project for a Geographical Survey of the southern Peninsula of India, from the coast of Coromandel to the Malabar coast, which was submitted, with the approval and recommendation of his Commanding Officer, the Hon'ble Colonel Wellesley—afterwards the great Duke of Wellington—to the consideration of Lord Clive—afterwards Earl Powis—who was then Governor of Madras. The Trigonometrical Survey of India owes its origin to Major Lambton's proposals, and to the circumstance that at the time when they were submitted to the Madras Government, a large accession of territory, in the centre of the Peninsula, which opened a free communication with the Malabar Coast, had been recently acquired, by the success of the British arms in the Mysore Campaign; thus the Government was readily convinced of the necessity for a survey to be undertaken with the object of furnishing a basis for the geography of the Peninsula, and for connecting the local surveys which were being commenced in the newly acquired provinces, with those of other portions of the Madras Presidency which had been completed or were then in progress.

The earliest document in the records of this Department is a letter—dated 10th February 1800—from 'Brigade-Major' Lambton to the Madras Government, communicating his proposals for a 'Mathematical and Geographical Survey' to be extended across the Presidency under his direction, "with a view to determine the exact positions of all the great objects "that appeared best calculated to become permanent geographical marks, to be hereafter guides "for facilitating a general survey of the Peninsula."

In this letter he alludes to previous correspondence on the subject, which had led to his being called on to submit a definite scheme of operations, and he observes that "the utility of "such a work, and the advantage and information which the nation would derive therefrom, "are so clearly understood that no argument is necessary to demonstrate it's advantages. "The Surveyors of particular districts will be spared much labor when they know the position "of some leading points to which they can refer, because when these points are laid down in "the exact situations in which they are upon the globe, all other objects of whatever deno-"minations, such as towns, forts, rivers &c., which have a relation to those points, will also "have their situations true in Latitude and Longitude."

He then proceeds to give an exposition of the principles on which he proposes to carry out the operations. And first he discards all attempts to fix the positions of objects by astronomical observations only, observing that such determinations are liable to great inaccuracies —"three, four, or perhaps ten minutes"—unless the observations are very numerous at every station. He then proposes to execute a triangulation emanating from a measured base-line, and verified from time to time by other such base-lines; all the most conspicuous geographical marks in the Peninsula were to be referred to the Astronomical Observatory at Madras, by a net of triangles which was to be thrown over the entire surface of the country; the lengths of the sides of all the triangles were to be computed from the base-lines, and the azimuths of certain sides to be determined by astronomical observations; thus data would be forthcoming for calculating the latitudes and longitudes of the trigonometrical stations with reference to the corresponding elements of the Madras Observatory.

But in order that the results of the triangulation might be correctly employed in determining the spheroidal co-ordinates of the trigonometrical stations, it was necessary that the figure of the earth, and the length of the polar or of the equatorial axis, should be accurately known. Major Lambton was fully aware that at that time these elements were not known with sufficient accuracy for operations of such extent and magnitude as those which he was about to undertake, and that it would be incumbent on him to execute a geodetic survey *pari passu* with his geographical survey, as a necessary preliminary to the determination of the elements of the trigonometrical stations and other geographical marks. He appears moreover to have acquired an impression, from the results of certain pendulum observations (by whom taken is not stated) in inter-tropical latitudes, that there is a sudden abnormal diminution of the force of gravity in the parallel of 10° north of the equator, and consequently that "a degree on the meridian "from that parallel to the equator must be very short compared with a degree immediately to "the northward of 10°". Hence he observes that it will be necessary to "attend to this cir-"cumstance", not only as influencing the operations of the geographical survey, but as an object of interest with regard to the determination of the figure of the earth; he remarks that as the operations of geodesists had hitherto been restricted to regions which were upwards of 33° from the equator, there was yet "something left as a desideratum" which his operations might supply; and he adds "I shall rejoice indeed if it should come within my province to make "observations tending to elucidate so sublime a subject."

His report closes with the following observations; "I have now adduced what I con-"ceive to be sufficient as being illustrative of the principles of my intended survey, which, on "the scale of general science, will I perceive involve many more objects than what immediately "appertain to geography. But as that is the principal end in view, and more particularly a "knowledge of the extensive acquisitions in Mysore, it will be my aim to anticipate every wish "the Right Honorable the Governor in Council may have, towards forwarding a work so useful "and so desirable to the nation."

These were the objects which Major Lambton proposed to accomplish by his 'Geographical Survey of the Peninsula,' and the principal objects of the varied operations of what is now known as the 'Great Trigonometrical Survey of India', are still to furnish leading points, as a basis for the operations of topographical, cadastral and fiscal surveys, in all India, and at the same time to contribute materials for further geodetic investigations. Commenced by Major Lambton in the year 1800, they have never been entirely suspended, though they have frequently been greatly retarded by the paucity of officers available for their prosecution. The exigencies of the State have often necessitated the removal of certain officers to other duties, and the places of other officers, whose failing health had compelled them to seek the advantages of a change of climate to Europe or some other quarter of the globe, have frequently remained unfilled. But, whatever may have been the exigencies of the public service, the objects proposed by Major Lambton have never been wholly lost sight of, and the operations have invariably been supported, as adequately as circumstances would permit, first by the Madras Government under whose auspices they were commenced, and afterwards by the Government of India, with the steadfast support and cordial approval of the Hon'ble Court of Directors of the East India Company.

2.

Commencement of Operations.

The earliest operation of the survey was the measurement of a base-line in the vicinity of Bangalore, which was effected towards the close of the year 1800. The instructions communicated to Major Lambton by the Madras Government on receiving the report of this operation may be here quoted, as indicating the lively and intelligent interest with which his proceedings were regarded, and the early recognition of the necessity for aiming at the utmost possible accuracy. In a letter dated 24th September 1801 the Chief Secretary says

"I am directed to acknowledge the receipt of your letter of the 24th June last and of the sketch of your "survey which accompained it, and to inform you that the Right Hon'ble the Governor in Council is entirely satisfied "with this further proof of your assiduity, zeal and talents.

"It being of importance that the fundamental principles of your survey should be established with the greatest "practicable degree of precision, the Governor in Council is desirous that the measurement of the base-line, transmit- "ted with your letter of the 22nd December last, should be supported by the observations for ascertaining the latitude "and direction of the meridian, and that all the operations shall be detailed exactly as they were taken, with such "remarks as occurred at the time, and also that the method observed in your computations should be briefly explained. "I am therefore directed to desire that the explanations and documents may be transmitted to me for the information "of His Lordship in Council, so soon as you shall be enabled to complete them.

"As it appears from the plan of the base, that some interruptions occurred in the measurement of it, it may "perhaps be of importance to repeat that measurement, or at any rate it will be expedient that a base of verification "should be measured, which may afford you the means of judging of the accuracy of the original base."

Major Lambton eventually rejected this base-line, and measured another on more favorable ground in the neighborhood, in the year 1804.

At the commencement of the operations the only instruments with which the Government appears to have been able to supply him, were a steel measuring chain and a five-feet Zenith Sector, both by Ramsden; no satisfactory instruments for measuring the angles of the proposed triangulation appear to have been forthcoming in any part of India, and it was necessary to send to England for instruments, which were received two years afterwards. Meanwhile Major Lambton determined the latitude of certain stations with the Zenith Sector, and set to work on the preliminary operation of laying out the triangulation and selecting stations at which observations were to be taken, when suitable instruments were received. These instruments arrived towards the end of 1802, by which time the preliminary operations had been carried over the newly acquired Province of Mysore, and extended eastwards to Madras.

3.

The instruments and the methods of observation and reduction.

The new instruments were a three-feet theodolite by Cary; an eighteen-inch repeating theodolite by the same maker; two steel measuring chains by Ramsden, a standard brass scale by Cary, and several small theodolites, by different makers, for minor purposes.

Of the three-feet or 'great' theodolite, by Cary, a brief description may be here given, as it was employed in the measurement of the principal angles. "It was a fac-simile of the one made by Ramsden for the Board of Ordnance in England, and was originally a very noble piece of workmanship and seems to have been divided with great accuracy".* The azimuthal circle was 36 inches in diameter, but it was read by two microscopes only, which were placed at 180° apart; the vertical circle appears to have had a diameter of 18 inches, and two microscopes; the focal length of the telescope was 37 inches, aperture 2·5 inches, and the magnifying powers were 36,45 and 66; a micrometer, adapted for vertical measurements, was fitted to the eye-piece.

Major Lambton has given the following description of the system which he pursued in measuring the horizontal angles† and in apportioning their errors.

"As to the angles in general they have been taken three and four times, and every time "that the object was observed, both microscopes were read off thrice, and two separate field-books "kept for making out the angles. What are here made use of are the means taken from two "books. In case a difference of those angles, noticed at the time, left any reason to suspect an "error in the instrument, the division between the dots was carefully examined, as well as those "to the right and left, and if any error was discovered, allowance was made accordingly. "Difficulty however very frequently arose from the haziness of the weather, which rendered the "objects at the very distant points extremely dull, and occasioned some irregularity in the "angles. Whenever that happened the observations were often repeated, and in case any one "in particular was different from the other so much as ten seconds, it was rejected till the three "angles of the triangle had been observed. If the sum of these angles was near what it ought "to be,‡ no further notice was taken of it, but should the sum of the three angles be nearer "the truth by taking it into the account, and that there appeared an irregularity in the other "two observed angles, I have made it a rule to take each observed angle as a correct one, and "divide the excess or defect between the other two, and then compute from the given side the "other two sides; and after doing the same thing with each of the angles successively, a mean "of the sides thus brought out was taken, which to certain limits will always be near the truth. "I then varied the selection of the observed angles, rejecting such as I had reason to doubt, and "by correcting them and computing the two required sides of the triangle, those which gave "the sides nearest to what had been brought out by the other method, were adopted, let the "error be what it would. This however has rarely happened, and when it did, great precaution "was used, and no angle was rejected without some reason appeared to render it doubtful".

* See Colonel Everest's *Account of the Measurement of an Arc of the Meridian*, 1830.
† Page 63 of Vol. I of the General Report of the Trigonometrical Survey, in manuscript.
‡ In such cases the error of the triangle was so divided that each angle received a correction proportioned to it's magnitude.

Such a system of operation is not calculated to elicit results of the full accuracy which an instrument can be made to give, and the method of treating the results was somewhat arbitrary and would not now-a-days be considered justifiable; but the processes were quite on a par with the contemporary operations of European geodesists, and it would be unreasonable to expect a higher order of accuracy, or more scientific methods of analysis and reduction, in a work which from the outset was beset with many difficulties, and was carried on at so great a distance from the centres of civilization and science.

The difficulties which Major Lambton alludes to as arising from the haziness of the weather might have been materially diminished had he been supplied with luminous signals, such as heliotropes and lamps, to erect on the stations which he was observing; but such signals were not employed in the operations of the survey until after the year 1832, when they were introduced by Colonel Everest. For very many years the signals were "masts, flagstaves, and other opaque objects, and then days and days often passed away without a glimpse of the distant object." As the atmosphere in India is usually most favorable during the rainy season, for viewing such objects, it became the practice to wait for the first heavy fall of rain and then take the field, and, so long as the operations were restricted to the southern portions of the Peninsula, the practice does not appear to have been attended with any other detriment than the great personal inconvenience of the Surveyors. But on proceeding to the north, into the basins of the Kistna and the Godavery rivers, though at this season the atmosphere was still most favorable for the operations, the climate was found to be very deadly, and Colonel Everest, who had then been recently appointed to the survey, and was commencing, in those regions, the operations which have won for him such honor as a geodesist, was one of the many sufferers; he has left on record the following remarks on this subject,—

"It is easy to conceive what a reckless waste of life and health was caused by this exposure to the pitiless pelting of the tropical rains, in forest tracts teeming with miasma: no constitution, European or Asiatic, could bear up for any length of time against such a complication of hardships as thence arose,—eternal watchings by day to the prevention of all regular exercise—tents decomposing into their original elements—servants—cattle—baggage —clothes—bedding—all daily dripping with rain—every comfort which the indwellers of cities and leaders of regular lives deem essential to happiness and even to existence, remorsely sacrificed."

"The introduction of lamps and heliotropes has totally changed the face of things, and by rendering the rainy season the least fitting period for observing luminous objects, especially those dependent on cloudless skies, has afforded an opportunity of which I eagerly availed myself to spare the health of my valuable subordinates, by ordering them to desist from field operations at the very period which, in the early part of my career and my four years' heavy apprenticeship, used to be chosen *par excellence* for their commencement."

4.

Geodotic investigations a necessary part of the operations.

It has already been stated that one of the objects which Colonel Lambton had in view was the determination of the elements of the figure of the Earth, as a preliminary to the calculations of the latitudes and longitudes of the trigonometrical stations. The necessity for so doing is indicated by the erroneous values of the best determinations of those elements which were known to him when he was commencing his operations, and which he was obliged to employ in the calculations of the spherical excesses of the triangles, until he had himself succeeded in making better determinations. The adopted value of the compression—or ellipticity—was $\frac{1}{150}$, or about twice the true amount, and the adopted lengths of meridional arcs in latitude 13° were too small by about 4·85 parts in 1000, while the lengths of the arcs of parallel in that latitude were too great by about 1·43 parts in 1000.*

Colonel Lambton decided on determining the figure of that portion of the earth's surface to which his operations would be restricted, by measuring the lengths of meridional arcs in successive parallels of latitude, from Cape Comorin northwards, and the lengths of arcs of great-circles perpendicular to the meridians, on the parallels of Madras and Bombay. He intended to apply the results to the triangulation, with the expectation that the latitudes and longitudes of the trigonometrical stations would thus be determined "to a certain extent from actual measurement, and in a great measure independently of any hypothesis of the earth's figure."

5.

Determination of the lengths of arcs of great circles perpendicular to a meridian.

One of the first objects to which Colonel Lambton devoted himself after obtaining the great theodolite from England, was the determination of the lengths of arcs of great circles perpendicular to the meridians of certain of the principal stations. Stations for the triangulation westwards from Madras to Bangalore and thence to Mangalore had been previously so selected as to present several pairs of reciprocating stations in nearly the same latitudes and at distances of 52 to 64 miles apart. The exact distances were determined by triangulation from the nearest base-lines, which also furnished data for the calculation of the latitudes from the nearest astronomical stations; the mutual azimuths were determined by observations of the pole-star; and with these data the great-circle arcs corresponding to the distances were determined by spherical astronomy, and then the lengths of degrees of great-circles perpendicular to the meridians were computed.

The results of these operations were as follows,†

length of the perpendicular degree in Lat.	12° 32′ 12″	61061·0	fathoms
„ „	12 55 10	60743·8	„
„ „	„	60751·8	„

Of these operations, which were carried out in the years 1802-5, Colonel Lambton remarks that "the more we investigate this interesting subject, and the more ample means we "employ to ascertain the exact figure of the earth, the more seems to be wanting to satisfy "our research; and if we feel reluctant in giving up the elliptic hypothesis, because it is

* See page 65 of Vol. I of the General Report of the Trigonometrical Survey, in manuscript.

† See *Asiatic Researches*, vol. VIII, page 193, and vol. X, page 366.

"consonant to that harmony and order with which we are familiar, the discord which these "results indicate affords by no means sufficient evidence to induce us to abandon that theory. "The great nicety in making the pole-star observations is well understood, and it will be made "more manifest in the case before us by increasing or diminishing the half sum of the angles "with the meridians, reciprocally taken at *Mullapunnabetta* and *Savendroog*, by one second only, "when it will appear that a difference of nearly *one hundred and fifty fathoms*, in the perpendi-"cular degree, will be occasioned thereby. I am fully aware of the delicacy necessary in "taking these angles, and I am also aware that some eminent Mathematicians consider the "method of determining the difference of longitude by the convergency of meridians as in-"sufficient in these low latitudes; yet I am of opinion that by repeating these observations, "whenever stations can be found either in the same or in different latitudes, the truth may "ultimately be very nearly attained." *

For several years Colonel Lambton computed the latitudes and longitudes of the stations of the survey with the elements of the figure of the earth which were afforded by a short meridional arc in the neighborhood of Madras, and by the mean of the two values of the perpendicular degree in latitude 12° 55′ 10″ above indicated. But about the year 1812, by which time he had carried the great meridional arc from Cape Comorin northwards to Gooty—a distance of about 7°—and had received the results of recent geodetic operations in Europe, he ascertained that—assuming the earth to be a regular spheroid—his adopted value of the perpendicular degree was about 120 fathoms too small, for the most probable value afforded by the new data was 60867 fathoms. Colonel Lambton accepted the new value, and employed it—with an ellipticity =† $\frac{1}{304}$ nearly, and for the meridional degree in latitude 13° 34′ 44″ the value 60491·4 fathoms,—in recomputing the latitudes and longitudes previously determined,‡ and in all computations of the elements of the stations which were fixed in the course of the operations of the subsequent decade.

No record is forthcoming of any further operations to determine the lengths of arcs perpendicular to the meridian, but Colonel Lambton was for many years favorably disposed to such investigations, as is apparent from the instructions which he gave to Captain Everest in the year 1822, when that officer was commencing the triangulation, on the parallel of 18°, which was to be extended from the Great Arc to the island of Bombay. Captain Everest was enjoined to lay out the triangulation in such a manner as to give distances "between sixty and "seventy miles in length, and as nearly from east to west in their direction as possible, so that "the difference of longitude between the two extremities of such distances may be determined "by pole-star observations." The triangulation was duly completed, and several azimuths were observed, but the proposed determinations of differences of longitude do not appear to have been carried out.

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* See *Asiatic Researches Vol. X page* 366.

† See pages 7 and 22 of Vol. III of the General Report of the Trigonometrical Survey (in manuscript) of which there is a copy in the India office.

‡ All the values of difference of longitude between the Madras observatory and the stations of the triangulation, which are given in volumes X and XII of *the Asiatic Researches*, are too great, by about 7″ for 1° of longitude, as the adopted values of the corresponding perpendicular degree were too small.

6.

Determinations of the lengths of meridional arcs.

Of all Colonel Lambton's contributions to geodesy, the most important are his measurements of meridional arcs, the results of which have been employed up to the present time, in combination with those of analogous operations in other parts of the globe, in all investigations of the figure of the earth.

As the instruments with which he was supplied when he commenced his labors were merely a measuring chain and a zenith sector, his first operations were necessarily restricted to the measurement of base-lines, and to taking astronomical observations for the determination of the latitudes of certain stations on the proposed meridional arcs. The zenith sector* was constructed by Ramsden, and is stated by Colonel Everest to have been "a beautiful instrument *for that time*;" it had an arc of 18° to a radius of 5 feet, and is described by Colonel Lambton in the Asiatic Researches (Vol. VIII p. 180), and is similar to the zenith sector described by General Roy in the Philosophical Transactions for 1790.

The first meridional arc which was measured was 1° 35′ in length, between the stations of Trivandeporum and Paudree, and lies at a distance of about 35 miles to the west of the meridian of the Madras observatory. It made the length of the degree = 60494 fathoms in latitude 12° 32′.†

The arcs subsequently measured were all portions of what is now known as the great Indian Arc. In the first instance an arc of about 2° in length was measured from the station of Dodagoontah—near Bangalore—southwards to Patchapolliam; it made the length of the degree = 60530 fathoms in latitude 11° 59′ 55″. This arc was then extended northwards to Paughur, making the length of the degree = 60466 fathoms in latitude 12° 33′ 9″.‡

Thus it was evident either that the elliptical hypothesis of the earth's figure was erroneous—for the lengths of the degrees were apparently decreasing instead of increasing with the latitude—or that the operations were not reliable, being erroneous either intrinsically or from circumstances beyond control. Similar anomalies had perplexed most of the geodesists of that time, and have given rise to much discussion; it is now well known that they are due, for the most part, to deflections of the plumb line, by local attraction, at the astronomical stations; but at that time many persons supposed that they arose from errors in the observations, and it was not until the operations had been repeated in several instances, with more perfect instruments and better modes of observation and reduction, and exhibited the unmistakeable reality of the discrepancies,§ that the cause became generally recognized.

But Colonel Lambton appears from the outset to have conjectured that the discrepancies in his operations arose from local attraction; and thus, instead of revising his triangulation or his astronomical observations, he immediately proceeded to select new stations, which were less

* See *Asiatic Researches Vol. X*, for a discussion of numerous observations which were taken with this instrument by Captain Warren at the Madras observatory.

† See *Asiatic Researches Vol. VIII page* 185.

‡ See page 274 of Vol. I of the General Report of the Trigonometrical Survey, in manuscript.

§ See Principal Triangulation of Ordnance Survey, page 560.

liable to the influence of the attraction of hills and superficial irregularities, and he observed their latitudes. Thus Paughur being on the "northern extremity of a range of rocky hills running north and south" was rejected, and the station of Bomasundrum, in an open plain about 10 miles to the S.E., was adopted instead; the arc from thence to Patchapolliam made the mean length of the degree = 60451 fathoms, in latitude 12° 29′ 51″. Colonel Lambton remarks on this result that "when, after a very excellent set of observations, the degree due "to the middle point of the arc between Bomasundrum and Patchapolliam was found to be less "than what was deduced from the arc terminated by the parallel of Paughur, I own I felt both "surprise and disappointment."

He still however had an intuitive conviction that the discrepancies were due to local attraction, and he attributed them partly to the influence of the great table land to the south of Bomasundrum on which Dodagoontah is situated, and partly to "a vein of dense ore lying between the two stations". He concluded that it would be impossible to arrive at more accurate values of the measures of meridional degrees, until the operations, both in Europe and in India, had been further extended, but that what had been done up to that time "had discovered to us "an agent unthought of in former days, viz., a disturbing force occasioned by the attraction "of mountains, and by *diversity in the density of strata under the surface*, all which will more or "less cause some deflection of the plumb-line". The words here italicized, and other passages in his writings to the same effect—as for instance where he hesitatingly expresses a hope that the sandy plains of the Carnatic may be "free from those inconveniences which are found in "mountainous regions"—show that Colonel Lambton was prepared to recognize the influence not only of mountain ranges and other self-evident irregularities of the earth's crust, but of variations in density under the surface, such as half a century afterwards were proved to exist below the plains on which Moscow is situated, and which are very possibly of more importance than the superficial irregularities to which the attention of geodesists has hitherto been chiefly devoted.

The next meridional arc which was measured lies between Patchapolliam and Punnœ, and is an extension of the former operations southwards to the vicinity of Cape Comorin. The amplitude of this arc was 2° 50′, and it made the length of the degree = 60472·83 in latitude 9° 34′ 44″. Operations were subsequently carried northwards to Namthabad, in latitude 15° 6′, completing an arc of 4° 6′ in amplitude from Patchapolliam, which made the length of the degree = 60487·56 fathoms in latitude 13° 2′ 55″.*

As the results afforded by the arcs Punnœ-Patchapolliam-Namthabad were very fairly accordant *inter se* and with those of recent European arcs, on the elliptic hypothesis, and as the three astronomical stations were to all appearance much less liable to be affected by local attraction than the stations of Dodagoontah, Paughur and Bomasundrum, Colonel Lambton decided on rejecting the last mentioned stations, and retaining the others only.

Bessel, in his investigation of the figure of the earth, has employed Colonel Lambton's observations at Dodagoontah, but he has rejected the observations at Paughur and Bomasundrum, and in this he has been followed by Captain Clarke; but all, if any, of the stations

* See page 5 of vol. III of the General Report of the Trigonometrical Survey, in manuscript.

should be used, if Colonel Lambton's hypothesis that the plumb-line is deflected in opposite directions by intermediate masses between the northern and the southern stations is correct. That the deflection to the north at Dodagoontah is probably very considerable has been recently shown, on the completion of the *modern* principal triangulation between Madras and Bangalore; the geodetic latitude of Dodagoontah, as referred to the astronomical latitude of Madras, is found to be 8″·4 in excess of the value which was deduced by Bessel from a discussion of Colonel Lambton's zenith distances, and which has been closely corroborated by Captain Herschel's recent zenith distances.

It is unnecessary to enter into the details of the operations for extending the Great Arc northwards; by the year 1815 they had been carried up to Daumergida, in latitude 18° 3′, under Colonel Lambton's superintendence, and afterwards they were advanced to Takal Khera, in latitude 21° 6′, with Captain Everest's assistance; and by the year 1825 they had been extended by Captain Everest up to Kalianpur, in latitude 24° 7′.

The sections from Daumergida northwards to Kalianpur were re-measured by Captain —then Lieutenant Colonel—Everest, after his return from Europe in 1830, with the aid of the best modern instruments and appliances, which he had been most liberally supplied with by the Court of Directors of the Hon'ble East India Company. The comparative results of the ancient and the modern operations are set forth in Colonel Everest's *Account of the measurement of two sections of the meridional arc of India*, 1847. The angles which had been measured with the old theodolites, before the introduction of the systematic method of eliminating errors of graduation, were found to differ by 3″ to 6″ and even as much as 10″ from the values by the new theodolites, while those which had been subsequently measured usually agreed within 1″ and rarely differed by more than 2″ to 3″ from the new values.* By the old triangulation and base-lines, the difference between the computed and the measured value of the Beder base was 6·58 feet,† or rather more than the five-thousandth part, by the new it was only 0·36 of a foot‡. The unit of length of the old operations was not known with any certainty, and the base-lines, having been merely measured with chains, were unreliable§. Nevertheless these errors had fortuitously tended to cancel each other, in the meridional arc from Daumergida to Kalianpur, and the total length, 2202926·2 feet|| by the revised operations, differed (in excess) from the original value by 106·7 feet only.

A still more remarkable instance of fortuitous cancelment of error is presented by the old value of the corresponding astronomical arc of amplitude, which differs from the new by only 0″·29.¶ The original observations had been made with a zenith sector, the arc of which was too small to permit of any of the stars which had been observed up to that time at the southern stations of the Great Arc being satisfactorily observed higher north, most of them falling quite beyond the range of the sector; thus it was necessary to resort to the method of

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* *See Everest's Arc Book of* 1847—*page* XL
† „ „ „ „ XLI
‡ „ „ „ „ 42
§ *See section* 7 *of Chapter* V *of the present volume.*
|| *See Everest's Arc Book of* 1847 *page* XLIV, *and his Arc Book of* 1830 *page* 112.
¶ Amplitude by original operations, 6° 3′ 55″·78. *See Arc Book of* 1830 *page* 112.
„ revised „ 6 3 55 ·97. „ 1847 191.

absolute latitudes instead of differential arcs, which introduced the—in those days very large—errors of star's places; moreover the observations were comparatively few, and they were without barometric readings for the determination of the refractions. On the other hand, in the subsequent operations, the observations at Daumergida and Kalianpur were very numerous and strictly differential, the same stars being observed at the same times with two colossal astronomical circles, one at each station.

The sections of the Great Arc from Daumergida southwards to Punnœ are being re-measured at the present time, at the recommendation of the President and Council of the Royal Society,* but the undertaking is not yet sufficiently advanced to permit of the results being closely compared with those of the early operations, excepting at the Bangalore base, the error of which has been found to be about the $\frac{1}{12,000}$th part of it's length. There is however every reason to expect that the discrepancies in these sections will be of greater importance than in those which were re-measured by Colonel Everest, and which being the latest were probably the most accurate. It is known that in the early operations the observations were very few and not so systematic as afterwards; in several cases only two of the angles of the principal triangles were measured, whereas subsequently all three angles were measured, and the triangulation was further strengthened by adopting the form of a chain of polygonal figures in the place of single triangles.

7.

Injury to the Great Theodolite.

During the year 1808, Colonel Lambton's great theodolite met with a very serious misfortune; in being hoisted, in it's case, to the summit of a lofty pagoda on the plains of Tanjore, the bearing rope, which kept the weight from striking against the side of the building, snapped, and the instrument, case and all, struck with a violent crash on the wall, breaking the case and so distorting the azimuthal circle as to render it to all appearance worthless.† Colonel Lambton took the instrument to pieces, and after six weeks of anxious and unceasing exertion, he succeeded in drawing out the injured circle to it's original shape, by means of wedges, screws and pullies. To what extent the graduation was injured does not appear to have ever been definitely ascertained; but the accident led to the eventual introduction of a systematic method of observation, giving readings of the azimuthal circles at numerous equidistant graduations and thus eliminating the effects of errors of graduation to a very considerable extent. This method of observation has been attended with very great success, and since it's introduction the principal angles of this survey have been measured with a degree of accuracy which is probably not surpassed by the best European surveys, and is approached by them only; but it was originated by Colonel Everest, and during the operations before the year 1818—when that officer was appointed an assistant to Colonel Lambton—there was no systematic 'change of zero', and frequently no change at all.

* See Report of the Committee, composed of Professors Airy, Miller and Stokes, which was assembled in 1861 at the request of the President and Council of the Royal Society, to report on Colonel Lambton's surveys.

† *See Everest's Arc Book of* 1830 *page* 46.

8.

The General Triangulation of the southern Peninsula, up to the parallel of 16°.

The geodetic operations which have already been reviewed, formed but a small portion of the labors of Colonel Lambton. Though executed with greater care and attention to accuracy of detail than other portions of the operations—in order to furnish the elements of the figure of the earth which were required for the calculations of the latitudes and longitudes of the trigonometrical stations—they were merely the basis of a vast net-work of principal and secondary triangulation, which was thrown over all the accessible portions of the Peninsula, from Cape Comorin to the parallel of 16°, covering an area of which the length is about 8° in latitude, and the average breadth 5° in longitude. This region is, for the most part, exceedingly favorable for the rapid execution of a net-work of triangulation; it presents numerous hills, either isolated or clustered in ranges with broad vallies between, and as the summits of these hills are generally bare and free from forest, the surrounding country can be viewed to great distances from them; thus they were admirably adapted, not only for the stations of the principal triangulation, but for enabling observations to be taken to fix the positions of pagodas, minarets and other permanent objects of reference, in the subjacent plains and on the lower hills, for the use of topographical surveyors. Wherever the ground permitted the formation of triangles with long sides—*e. g*, twenty miles and upwards—the angular measurements were invariably made either with the great theodolite or with an 18-inch repeating theodolite, the second best instrument with which Colonel Lambton had been supplied; these were considered as the principal triangles, and they are shown on the Index Chart facing the title page of this volume. Smaller triangles, emanating from sides of the former as bases, were generally measured with inferior instruments, and are not shown in the Chart. The triangulation was verified and controlled by base-lines measured at distances of 90 to 250 miles, full details of which are given in chapter V of this Volume.*

Wherever hills were numerous, the operations were carried on with great rapidity; but in the plains of Tanjore, and generally in the low lands which trend inwards from the east coast, south of Pondicherry, they were greatly impeded; and it was while the great theodolite was being hoisted to the summit of a pagoda in Tanjore that it met with the accident which has already been described. In these tracts there are considerable gaps in the principal and also in the secondary triangulation; the surface of the country was very flat and destitute of commanding positions, it was also densely wooded, and these difficulties were found to be insurmountable. Thirty-five years afterwards the principal triangulation of this survey was being successfully carried—under the superintendence of Colonel Waugh—through a far more difficult country, the well known Terai, bordering the southern slopes of the Himalayas from the meridian of 79° eastwards to the Assam Valley, which is as flat as Tanjore and is moreover covered with dense and deadly forests and jungle. But then the means and appliances of the survey, and it's command of skilled labor, were far greater than they ever had been in Colonel Lambton's time.

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* The whole of the triangulation below the parallel of 16°, is shown in a chart on the scale of 8 miles = 1 inch,—in 8 sections—entitled, "*Plan of the Trigonometrical Operations carried on in the Peninsula of India, from the year* 1802 *to* 1814 *inclusive, under the superintendence of Lieut.-Colonel W. Lambton.*" Pulished by J. Horsburgh, 1827.

9.

Objections raised to the system of operations; proposals for an astronomical instead of a geodetic basis for the Survey of India.

"Shortly after the commencement of his labors, Colonel Lambton was called on to "demonstrate the utility of his work. It was assorted that surveys on an astronomical basis "would be equally accurate, and more economical than geodetical operations. The futility of "these views was ably exposed by the Colonel, and being supported by the Astronomer Royal "of the day, the Reverend K. Maskelyne, all open opposition was withdrawn, and Major "Rennell, who was the chief advocate of the astronomical basis, afterward concurred in the "trigonometrical system. As this view of the subject has been confirmed by the practical "testimony of every nation in Europe, and the importance of trigonometrical operations is now "universally admitted, by all practical scientific men, as the only trustworthy basis for exten-"sive national surveys, it is unnecessary to discuss the first principles any further in this place, "and they are only adverted to in illustration of the formidable prejudices the trigonometrical "survey in India has all along had to contend with. Colonel Lambton's operations detected "an error of no less a quantity than 40 miles in the breadth of the Peninsula, as previously "laid down astronomically in the way Major Rennell proposed. All the principal places "on the old maps, which had been fixed astronomically, were found considerably out of posi-"tion. For example, Arcot was out 10 miles, and Hyderabad no less than 11′ in latitude "and 32′ in longitude. In fact for the survey of an enormous empire, the trigonometrical "system is not only the most rigorous, but the cheapest in the end.*

10.

Geographical Operations.

About three years after the commencement of his operations, Colonel Lambton was called on by the Government of Madras to furnish all possible information regarding "the appearance "and resources of the country, it's roads, it's supply of water, and whether favorable for military "movements; also to represent it's general features, such as rivers, vallies, passes, mountains, "the state of fortified places &c; and in short to notice every circumstance that may afford useful "information in time of war." Eventually four officers, who had been trained in the Madras Military Institution, were appointed to assist Colonel Lambton in these operations; they were employed in delineating the principal geographical features of the country, on the basis of the triangulation, in such a manner as to indicate every thing that was considered to be of importance for military operations. The runs of the mountain ranges, the courses of the principal rivers, and the lines of the great military roads, were laid down in a general manner, by determining the positions of the principal points and places on them, and more particularly the positions

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* Very little information on the subject of these proposals is to be found in the records of the Department, and the above details are taken from a *Report on the Progress and Expense of the Great Trigonometrical Survey of India* which was prepared by Colonel A. Scott Waugh—then Surveyor General and Superintendent of the Great Trigonometrical Survey—for the information of the Houses of Parliament, and was printed on the 15th April 1851, by order of the House of Commons.

which were or might be halting places for troops. In fact, whenever the triangulation entered a district of which no regular survey had been or was being made, and political reasons, or the physical difficulties of the country, rendered it improbable that such a survey would soon be made, Colonel Lambton and his few assistants were required to make a generalized preliminary survey, and report on the condition and capabilities of the country; also to furnish sketches of forts, and supply all other information which would be useful for military purposes. Thus by the year 1814 he was able to furnish the Government with a series of Maps exhibiting all the most prominent geographical features of the Peninsula, as far north as Goa on the west and Musulipatam on the east coast.

These operations were frequently suspended for a while; the assistants were removed, and Colonel Lambton was on one occasion instructed to restrict his operations to the principle triangulation only, and to stop all secondary triangulation and all measures for acquiring geographical details. Some alarm appears to have been felt of evils which might result from multiplying copies of maps or other materials connected with the survey of the country; in 1810 Colonel Lambton was directed to transfer all the geographical and topographical materials in his office to the Quarter Master General; he was even prohibited from retaining any copies of those documents, but he was graciously informed that the Governor in Council did not require him to render any account of the materials which he had collected at his private expense, during the progress of the general survey. Eventually however these objections were overruled, and Colonel Lambton was requested to combine his materials with those of other surveys into a series of geographical maps.

The operations were also frequently interrupted by the disturbed political condition of the country; in some of the Native States, though the Rulers were anxious to render all necessary assistance to the surveyors, there was no sufficient authority to prevent opposition, which was manifested sometimes actively by hindering the surveyors from erecting stations on the most commanding points in the country, sometimes passively by refusing to allow them to purchase food and endeavouring to starve them away. The Travancore war brought matters for a while to a stand-still, and Colonel Lambton took a share in the military operations; he served at the capture of the Arumbulli lines, the fortifications which protect the neck of the promontory on the extremity of which Cape Comorin is situated.

11.

The Survey transferred from the control of the Madras Government to that of the Government of India.

The success which had attended Colonel Lambton's early labors had naturally induced the Hon'ble Court of Directors of the East India Company to desire that the Survey should be gradually expanded, so as to embrace the whole south of India, and then be advanced progressively to the north. Thus by the year 1817 the Great Arc had been carried northwards as far as the Beder base, in latitude 18° 3′, while the general triangulation had reached the parallel of 16°; the operations had passed beyond the limits of the Madras Presidency and entered into Provinces which were politically connected with the Bengal Presidency, and the British Authorities in which were under the sole orders of the Governor General in Council

—the Supreme Government of India. These circumstances appeared to the Marquis of Hastings, who was then Governor General, to indicate that the time had arrived when expediency required that the Trigonometrical Survey should be taken under the direct and immediate control of the Supreme Government, and this measure was carried out on the 1st January 1818*. The Governor General moreover directed "that the Survey be denominated the Great "Trigonometrical Survey of India, and Lieutenant-Colonel Lambton the Superintendent thereof; "that a duly qualified officer be appointed Chief Assistant to the Superintendent; and that a "person skilled in natural science, and capable of affording medical and surgical aid to the "survey establishment, be permanently attached to it as Geologist and Surgeon."

As regards the appointment of a Chief Assistant, the Governor General observed that "the intense mental and bodily labour of conducting the Trigonometrical Survey has been performed heretofore by "Colonel Lambton alone, and the rank and the advancing age of that zealous and distinguished person now demands "some relief from such severe fatigue. But independently of the consideration so eminently due to the individual, the "Governor General is decidedly of opinion that the strongest reasons of public expediency exist for associating an assis- "tant in this great employment. The mathematical qualifications for conducting such labours are of a very high order, "and possessed by few in India; they require to have been kept up by habitual exercise; and moreover the extreme "accuracy indispensable in trigonometrical calculations on the scale of Colonel Lambton's undertaking, demands a "dexterity in the use of the instruments, and a scrupulous degree of attention in what may be termed the practical part "of the labor, which can scarcely be conceived by persons unaccustomed to it, and which is to be learnt only by a "rigorous apprenticeship. The regretted time must one day arrive when Lieutenant Colonel Lambton's task is to de- "volve on a successor. It would not be wise to trust to chance for producing one fully equal to the duty at the "moment when he is wanted; neither is it right that this important Survey should thus hang on the life of a single in- "dividual. Lieutenant Colonel Lambton himself has urged this point to the Governor General and has pressed on his "Lordship the propriety of giving him an associate. The Governor General therefore has selected for this Office, Cap- "tain Everest, of the Artillery, of whose eminent degree of science as a mathematician he is assured, and whose talents "are known to the Vice-President in Council, both by his surveys in Java, under the Quarter Master General's Depart- "ment, and by his successful exertions as an Engineer, in recently clearing the navigation of the Matabanga and other "rivers."

In May 1818 Dr. Voysey was appointed to be Surgeon and Geologist to the survey.

Hitherto Colonel Lambton had been carrying on the principal triangulation and the geodetic operations almost single handed†, for the officers of the Military Institution, who had served under his orders for some years, had been solely employed in secondary triangulation and in the geographical operations. His normal establishment consisted of a sufficient number of the natives of the country to carry the instruments about, and a few chain-men and signallers; also three European or East Indian subordinates, who were originally employed as computers in carrying on the several calculations of the triangulation, but eventually were trained to render assistance in the field also. All the principal operations hitherto, whether in the field or in recess quarters, whether in the actual observations and measurements, or in the

* The instructions were conveyed in a letter No. 111, dated 25th October 1817 from the Governor General to the Madras Government, from which the above extracts are taken.

† "In his early operations Colonel Lambton was assisted by Lieutenant Warren of his Majesty's 33rd, and Captain Kater, of his "Majesty's 12th Foot. The first named officer belonged to the ancient noblesse of France, to which country he returned after the peace. "His stay with Colonel Lambton was of short duration, as he was, at a very early period of the work, appointed to the charge of the "Madras observatory. Captain Kater's health having failed, obliged him to quit the department. This officer afterwards acquired an "European reputation as a scientific man, having become a member of almost every academy in Europe, been employed on every business "of national research, appointed a member of the Board of Longitude, and finally elected Vice-President of the Royal Society. Thus it "appears that, during the greater portion of his career, Colonel Lambton worked nearly single handed in the extensive and arduous opera- "tions which he carried on, amidst the formidable trials and obstacles that the baneful nature of the climate and the want of resources in "the country everywhere presented." *Extracted from Colonel Waugh's Parliamentary Report on the Progress and Expense of the Great Trigonometrical Survey of India.*

calculations connected therewith, had been performed by Colonel Lambton and his three subordinates. Thus simultaneously with the transfer of the survey to the direct control of the Supreme Government, the strength of the establishment was materially increased, and the Marquis of Hastings, so deservedly celebrated for his happy selections of able men for public business, made a fortunate choice in his selection of Captain Everest as Colonel Lambton's chief assistant.

12.

Continuation of the narrative to the death of Colonel Lambton in 1823; *the operations embracing the country between the parallels of* 16° *and* 19°, *and the meridians of* 77° *and* 80°.

When the survey had been carried to the north of the parallel of 16°, and had reached the basins of the Kistna and the Godavery Rivers, it's further progress was much impeded, and for several years the advance was very slow in comparison with the rapid strides which had been made in the southern portion of the Peninsula. The scene of the operations was now the country of the Deccan, the Dominions of a Native Prince—the Nizam of Hydrabad—whose authority was at all times very feebly exerted over his subjects; many of the petty Chieftans were in open rebellion against the native government, and all were more or less suspicious of the operations of the surveyors, viewing the planting of flags and signals with much jealousy and apprehension, as mere preliminaries to taking possession of the country.

Thus it was a matter of some delicacy on the part of the British Resident at the Nizam's Court to support the surveyors, and on that of Colonel Lambton of some hazard to venture into these regions, which did not settle down into repose until the Marquis of Hastings had destroyed the Pindara confederacies in 1818; and even after that event the survey parties had to be strongly guarded, and it was frequently necessary to send soldiers of the Nizam's army with the native subordinates as well as with the European officers, for their protection.

But the chief causes of delay arose from the physical difficulties and the comparatively meagre resources of the country, and from the deadly nature of the climate at the season of the year when—for the reasons already explained at page XIX—it was considered necessary to carry on the principal triangulation.

The face of the country was covered with extensive forests which had spread over the sides and the summits of the hills, so that several days and sometimes weeks had to be spent in clearing the hill tops and preparing them for stations of observation; the commanding positions which were most favorable for the operations were frequently situated at great distances from the nearest inhabited localities; and, worse than all, the heavy rains which cleared the atmosphere sufficiently to permit of observations being taken to distant signals, were invariably followed by a deadly season of some months duration, caused by the influence of a powerful sun on a moist soil and rank vegetation teeming with the germs of malaria.

Captain Everest joined Colonel Lambton late in the year 1818, and was deputed in June of the following year, at the commencement of the rainy season, to extend the general triangulation eastwards, from the sides of the Great Arc near Hyderabad to the meridian of 80°. He has given vivid descriptions of his operations in the Introduction to the Arc-Book of 1830, and in his reports to Government. One of his first duties was to quell a mutiny of the detachment of Nizam's troops which formed his escort; he had to carry the operations through a country which he describes as a "dreadful wilderness," a region than which "no part of the earth was more dreary, desolate and fatal"; he had to improvise means for crossing numerous streams which had been swollen to rivers by the heavy rains; at some of the hill stations nearly a square mile of forest had to be cleared away before observations could be commenced; and when all these difficulties were successfully surmounted and he was hoping to complete the observations in course of a few days—and thus, in Colonel Lambton's words, "have performed a very magnificent work indeed to start with"—he and his assistants and the entire native establishment were struck down by a malignant fever, many perished miserably by the road side, and the survivors had to be carried into Hydrabad, whence the whole of the public elephants, litters and vehicles of all descriptions had been despatched to their succour, on the receipt of the first intelligence of the calamity.

Captain Everest's constitution suffered so much that he was obliged to go to the Cape of Good Hope for a year, to seek the advantages of a change of climate. There he employed himself in investigating La Caille's meridional arc, which had presented an unaccountable anomaly when compared with similar measurements executed on the opposite side of the equator, giving rise to the hypothesis that the opposite hemispheres of the globe were of different forms. Captain Everest showed* that the discordance most probably arose from the disturbing influence occasioned by the attraction of the mountains in the neighborhood of the two terminal stations of the arc; and twenty years afterwards his views were fully corroborated by Sir Thomas Maclear's operations for the verification and extension of this arc.

Doctor Voysey, who had joined the survey a few months before Captain Everest, shared all the perils and privations of that officer's first campaign as a surveyor, but fortunately with less harm to himself. He remained with Colonel Lambton, and was of great assistance to him, aiding in the measurement of the Takal Khera base-line, in the year 1822, and completing the surrounding principal triangulation, while his chief was engaged in observing zenith distances. Colonel Lambton earnestly recommended that Doctor Voysey should be formally appointed to the Survey as his assistant, but the Governor General "doubting the expediency of combining in one individual the functions of Surgeon, Geologist and Surveyor" withheld his consent from the measure.

After the year 1819 Colonel Lambton ceased to take an active part in the triangulation, which was then chiefly carried on by his principal sub-assistant Mr. J. De Penning; and the operations at Takal Khera, in the year 1822, were the last in which he took any personal share. He was proceeding from Hydrabad to Nagpore, to make arrangements for extending the operations of the Great Arc northwards, across the Mahadeo and the Vindhya ranges and into the plains of Central India, when, on the 20th January 1823, he died at Hingunghat, a now well known commercial town which is situated about 50 miles to the south of the city of Nagpore.

* See Grant's History of Physical Astronomy, page 147.

Colonel Lambton was 47 years old when he commenced the operations which have now been reviewed; he had thus already reached an age when, in India, men are mostly thought old, or at least are considered to have passed the prime of life, and are within eight years of the age at which the servants of Government are liable to be superannuated; but he was still in the prime of his life, and the full vigor of an unusually robust and energetic manhood. Until within a few years of his death, at the age of 70, he seems to have scarcely known what it was to have had a day's ill-health, though he never spared himself, nor shrank from accepting his full share of the privations to which all the members of the survey were exposed, and which even Captain Everest thought reckless and almost unjustifiable; he accepted these as a matter of course, and seems to have thought little, and said less, about them, rarely alluding to them excepting when he was endeavouring to obtain promotion for his subordinates who had shared them with him. His life was an entire devotion of self to the interests of the public service and the advancement of science, without a thought of ever ceasing from his labors while life lasted; and, as he had ever looked forward to dying, so he died, at his post.

By far the greater portion of the operations hitherto had been performed by Colonel Lambton with his own hands, and it is much to be marvelled at that he should have succeeded in doing all that he did, with the limited means at his disposal. He had however contemplated extending his researches to other subjects than those to which his energies were so unsparingly devoted; he had formed a project for the investigation of the laws of terrestrial refraction, and was making arrangements for the determination, by pendulum observations, of the relative force of gravity at the several stations of the Great Arc, and at "corresponding stations in the same latitudes on the sea coast." But it was only permitted to him to complete a part of the programme of achievement which he had set before himself; the rest he was compelled to bequeath to his successors. The investigations into the laws of terrestrial refraction were made a few years after his death by Colonel Everest and Captain Waugh. The project for investigations of the force of gravity was set aside for several years and eventually forgotten; but in 1864, General Sabine, then President of the Royal Society, recommended that pendulum observations should be taken at the stations of the Indian Arc, in conjunction with the operations of the survey, and the measure having been approved of by the Government, has been subsequently carried on by Captain Basevi, and is now all but completed; the principle, which was originally enunciated by Colonel Lambton, of comparing inland with coast stations, has been strictly followed; and the results promise to throw much light on the laws of the local variations of gravity which are superposed on the normal variation from the poles to the equator.

These are not the pages of a biography, nor is this the place to enter into further details of the career of the first chief of the Trigonometrical Survey of India; but even here it may be added—in the words of his pupil Captain Everest—that "Colonel Lambton was ever the kindest of masters, and used his authority with so gentle a hand as hardly to leave a consciousness of it's existence."*

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* The whole of the triangulation executed in the period reviewed in this Section 1 is shown in two "*Plans of the Triangulation in the Nizam's Dominions, extending from Kurnool to the Godavery, and lying to the eastward of Nirmul and Kurnool*", published by James Horsburgh in 1827.

13.

The Operations during the period 1823-30.

Captain Everest returned from the Cape of Good Hope in 1822, and was employed in carrying a series of principal triangles from the Great Arc westwards towards Bombay, when the news reached him of Colonel Lambton's death. Shortly afterwards, on being appointed by the Government of India to succeed Colonel Lambton, he postponed all further operations in the direction of Bombay, and proceeded to extend the Great Arc northwards, in fulfilment of his late chief's intentions.

Hitherto these operations had not advanced beyond the neighborhood of Ellichpoor, in the valley of Berar, between which and the plains of Central India on the north, three nearly parallel chains of mountains are situated, trending in an east-and-westerly direction; the two southern chains are known indifferently as the Sautpoora or the Mahadeo Ranges, the northern is the Vindhya Range, and they form the basins of the Taptee and the Nurbudda Rivers, which flow between them, on either side of the central range, from east to west.

Considerable difficulties having been anticipated in carrying the operations across this region, Dr. Voysey had been deputed in the previous year to march through it and explore the country northwards as far as Agra, with the expectation that it might be found necessary to make a considerable detour to the east in order to avoid the direct passage of the mountain ranges; but he reported that though the mountains were wild and desolate, and covered with forests which would be deadly in the rainy season, he had seen no difficulties at all equal to those which the survey had already encountered and successfully surmounted between the Godavery and Ellichpoor.

In two years Captain Everest carried the Great Arc over the mountains and into the plains of Central India, advancing as far north as the town of Sironj, in the parallel of 24° 7′. Every effort having been made to guard against a repetition of the catastrophy which had previously arrested the operations, and great assistance being rendered by the Political Officers who represented the British Government at the Courts of the Native States, what had once been conceived to form an impenetrable barrier was surmouuted with a rapidity which surpassed the most sanguine expectations, and without any loss of life.

But Captain Everest experienced a return of the typhus fever which he had originally contracted in the forest-clad basin of the Godavery River, and which now attacked him with still greater virulence; he was in a great measure deprived of the use of his limbs, and was liable to convulsive paroxysms, attended with agonizing pain; yet, with a courage and endurance worthy of his late chief, he persisted in the undertaking, though constantly warned that he must fall a sacrifice; during the whole of his observations with the zenith sector, he had to be lifted into and out of the observer's chair; at the great theodolite his arm had to be supported when extended to reach a tangent screw, and on some occasions his state of weakness and exhaustion was such that without being held up he could not have stood to the instrument.* Nevertheless he persevered, and succeeded. He carried the operations northwards until the entire length of the Arc, including the several southern sections which had been measured by Colonel Lambton, exceeded that of the longest European Arc. He then suspended all further operations, and at the end of the year 1825 he proceeded to Europe; there he brought up the calculations of the operations in which he had been engaged, and published a description of them in the work entitled "*An Account of the Measurement of an Arc of the Meridian between the parallels of* 18° 3′ *and* 24° 7′" *London* 1830, to which reference has been frequently made in these pages.

Mention has already been made of Doctor Voysey's services to Colonel Lambton, in the actual operations of the survey, and to Captain Everest, in the exploration of the country between Ellichpoor and Agra with a view to ascertaining it's suitability for future operations. While thus employed Doctor Voysey was also collecting materials for a report on the Geology of India, and, during the period of five years, 1819-23, of his association with the Trigonometrical Survey, he completed "two principal barometrical and geological sections, one extend-"ing from Bombay to the north of the Godavery and one from Agra to Madras; in addition "he had completed several minor sections of 3, 4 and 500 miles each, and a geological section "of the country between Calcutta and Agra." He had been under tents or marching the whole of that time, with the exception of a period of a few months, and had travelled by land upwards of eight thousand miles; he was constantly on duty notwithstanding that he had been twice subjected to fever contracted in the jungles on the banks of the Godavery. He died in 1824, on his way to Calcutta, unfortunately before the value of his indefatigable services and assiduous devotion to his duties had been recognized by the Supreme Government.

Colonel Everest did not return to India until the year 1830. During his absence the geodetic operations were suspended, and the situation of Superintendent was held open until his return. The subordinates were employed, under the principal Sub-Assistant Mr. Joseph Olliver, in carrying a triangulation from the terminal stations of the Great Arc near Sironj, eastwards, to Calcutta, a distance of 671 miles; "notwithstanding the frequent ravages of jungle fever, which has all along been the most baneful enemy of the trigonometrical survey, as well as one of the chief retarding causes,"† this operation was accomplished in about six years, at the rate of 112 miles per annum, with branching series of secondary triangles.

14.

Concluding observations.

The operations of the three first decades of the Trigonometrical Survey of India, which have now been reviewed, form a group by themselves, and have little in common with the subsequent operations. They were executed at a time when the science of geodesy was in it's

* See the Arc Book of 1830, pages 36 and 37. Colonel Everest seems to have suffered much from a want of sleep; in a letter, dated 5th October 1825, he inveighs against the "indecent conduct" of one of his assistants, who had brought neighing horses into his camp, notwithstanding that a positive order had been passed "the necessity of which was obvious to the most common understanding, that no noises were to be made by man *or beast* which might be likely to disturb his rest."

† Colonel Waugh's Report to the House of Commons, para. 22.

infancy, when the several instruments which are necessary for the linear and the angular measurements of a survey were still far from their present state of—practically—almost absolute perfection, and when the methods of reduction and analysis were still rude and imperfect.

Thus the geodetic measurements have shared the fate of all similar operations which were contemporaneously executed in Europe and other parts of the globe, in that they have been or are being superseded by revisionary operations with modern instruments of superior accuracy and value; they have answered the purposes for which they were immediately required, and have furnished data for a fairly approximate determination of the figure of the earth.

But for geographical purposes, for providing points on which to base topographical, cadastral or fiscal surveys, the whole of the operations are still most valuable, and they must continue to be so as long as the trigonometrical stations and the points laid down from them remain in existence. Little is now required for their completion in this respect beyond the extension of the modern triangulation southwards, from Madras to the points at which a suitable junction may be made with the triangulation of the Island of Ceylon, which has not yet been connected with that of India. When this operation and the revision of the southern sections of the Great Arc have been completed, the results of the old triangulation may be reproduced on the basis of the modern, which should leave nothing to be desired to satisfy the most fastidious requirements of topographical surveyors. But such a measure cannot be carried out until the triangulation which is now in progress shall have been completed. Thus the final reduction and publication of the results of the early operations will probably form the last stage of the work of the Trigonometrical Survey; the operations subsequent to the year 1830 must first be finally reduced, and afterwards those of the preceding years.

The only parts of the early operations which might have been employed in the first stage of the final reductions are the linear measurements; but it will be found, from the critical examination of the base-lines of that period, which forms Chapter V of the present volume, that these linear operations are worthless for the purpose of controlling any portion of the principal triangulation of this survey, and that they would certainly introduce larger errors than are liable to be generated in the course of the modern angular measurements.

SECTION I.

THE STANDARDS

OF

MEASURE.

SECTION I.

THE STANDARDS OF MEASURE OF THE GREAT TRIGONOMETRICAL SURVEY OF INDIA.

CHAPTER I.

Description of the Standards.

Several standards, of various dimensions and different metals, have been used in the course of the operations of the Trigonometrical Survey; these will now be described in the order in which they were obtained.

1.

Cary's three feet brass scale.

This scale is 3·15 feet in length, 1·51 inches in breadth and ·14 inch in depth; it was laid off by Cary from the scale of Alexander Aubert Esq., and is referred to by Captain Kater in the Philosophical Transactions for 1821. It was received in India in May 1802, and from that time until the year 1825 it was employed in defining the lengths of the steel chains by Ramsden which were used by Colonels Lambton and Everest in the measurements of various base-lines. The processes followed on these occasions have been described by Colonel Everest at pages 51 and 52 of his first account of the measurement of an arc in India (*London* 1830). This scale does not appear to have ever been directly compared with any of the standards which were subsequently constructed for the Indian Survey; an indirect comparison might however be obtained if necessary, for the steel chains by Ramsden were compared with standard **A** by Colonel Everest in 1832, see pages CI to CIII of his Arc Book of 1847. The scale however has long ceased to serve the purpose for which it was originally employed. It was used at the 8 base lines which were measured between the years 1830 and 1864, with the Colby apparatus of compensating bars and microscopes, but simply for the purpose of measuring the distance—never exceeding 5 feet—between the end of a last set of bars, and a section station or the closing extremity of a base line, and also for determining the values of the runs of the micrometers for comparing the lengths of the compensated bars with standard **A**.

These runs were invariably determined from inch 7 to 8 of the scale, which was assumed to be exactly equal to the $\frac{1}{120}$ part of the Standard; it has recently been found to differ from that quantity, but—as will be subsequently shown—by so small an amount as to have no appreciable effect on the reductions.

2.

The 10-feet iron standard bars **A** *and* **B**, *and the 6-inch brass scales A and B.*

These were constructed in England under Colonel Everest's Superintendence, and were brought out to India about the year 1832.

The 10-feet standards are of wrought iron, 122 inches in length, ·9 in breadth and 2 in depth. Each bar is supported on two rollers, at one fourth and three fourths of its length, secured to the bottom of the wooden box by which the bar is encased; the ends of the bar are cut away to half its depth, so that the dots, marking on platinum pins the measure of 10 feet, are in the neutral axis of the bar. On the upper surface, 30·5 inches from the middle of the bar towards either extremity, are two wells for thermometers.

The brass scales are 10·25 inches long, 2 in breadth and ·5 inch in depth, the standard measure being defined by dots engraved on silver pins let into the brass at 6 inches apart. Each is fitted with a thermometer resting flat on the scale and having a round bulb for which there is a slight indentation on the surface of the scale. Each is also provided with a micrometer, for measuring the difference between the 6-inch space on the scale, and the distance between the visual axes of the compensated microscopes.

The iron standard **B** was compared with the Ordnance Survey 10-feet standard $\mathbf{O}_2$ in London in 1831, by Lieutenant Murphy R.E., *(Account of Lough Foyle Base Appx. V)*. It was twice compared with the iron standard **A** at Dehra Doon in India, in November 1834, and February 1835, by Colonel Everest. The 6-inch brass scales *A* and *B* were also compared by Colonel Everest in India in June 1835. **A** and *A* have remained in India ever since, and been employed, the former at all, the latter at all but the two last, of the ten base lines which have been measured with the Colby apparatus of compensated bars and microscopes, between the years 1832 and 1869. **B** and *B* were sent to England in 1843-4, and were conveyed by Colonel Everest to Southampton, and made over to the office of the Ordnance Survey. In 1846, **B** was compared with the 10-feet Ordnance Standard $\mathbf{O}_1$, and *B* with the Ordnance 6-inch scale. **B** was subsequently taken to Russia, where it was compared by M. Struve with several continental standards. In 1865 it was compared in the Ordnance Office at Southampton, by Captain Clarke, with the new 10-feet Indian Standards which will now be described.

3.

The 10-feet steel standard $\mathbf{I}_S$, *the 10-feet bronze standard* $\mathbf{I}_B$, *and the standard steel foot,* **IF.**

Questions had been raised as to the possible variation in length of the 10-feet standard **A**; and certainly it was not inconceivable that the length might have varied in the course of the many journeys which this bar had been made to perform, each of several hundred miles in length, by land and sea, from the Head Quarters of the Survey to the eight base-lines to which it was conveyed between the years 1832 and 1863, viz. those at Calcutta, Dehra Doon, Sironj, Beder, Sonakhoda, Attok, Karachi, and Vizagapatam.

To remove all doubts on this subject, two new standards, of 10 feet in length, were constructed for this Survey by Messrs. Troughton and Simms, in 1864; one, known as I_S, of cast steel, hammered; the other, known as I_B, of bronze, or more correctly Baily's metal, an alloy formed in the proportions copper 16, tin 2½, zinc 1.

These bars are similar in section and dimensions. The section is in the form of a girder with equal flanges above and below; breadth of flanges 1·57 inches, breadth between flanges ·74 inch, depth between flanges 1·55 inches. total depth 2·55 inches; total length 122·9 inches. Each is divided, on its upper surface, into six spaces, by seven gold pins about a tenth of an inch in diameter, drilled, one at the centre of the bar and three on each side of the centre, at one foot, two feet, and five feet from the centre; this arrangement affords two spaces of a yard each, on the right and left, and four contiguous spaces of one foot each in the centre. The small circular surfaces around the gold pins are slightly depressed below the general surface of the bar. The divisions are indicated by lines drawn on the gold pins perpendicularly to the length of the bar.

In the upper surface of each bar there are three contiguous pairs of thermometer wells, one pair in the centre of the right yard, another in that of the left yard, the third in the centre of the bar; each of these pairs of wells is intended to receive two thermometers,—with the bulbs close together and scales lying outwards—one ranging from 45° to 65°, the other from 65° to 85°, and having degrees of about ·40 inch long, divided into tenths; with this arrangement the temperature of the bars between 45° and 85° is indicated by three thermometers, which can be read to the thousandth part of a degree, with the aid of a microscope having a sliding system of converging lines in the eye piece. There are also two more thermometer wells, at one-fourth and three-fourths of the bar's length, intended for thermometers ranging from 30° to 105°, the degrees being subdivided into halves only; this arrangement is adapted for the measurement of occasional extreme temperatures.

Each of the bars rests upon eight rollers which are framed in two systems of levers, care being taken in the construction that the levers balance accurately on their axles, and that the rollers revolve freely. By this system of levers the pressure upwards of each roller upon the bar is the same, and the bar is thus supported by eight equal pressures applied at equal intervals. The distance apart of the rollers is 15·5 inches, as given by Mr. Airy's formula

$$\frac{a}{\sqrt{n^2 - 1}}$$

where a is the length of the bar and n the number of rollers. (See *Memoirs of the Royal Astronomical Society Vol. XV.*)

Of the eight rollers supporting the bar, one is a true cylinder, the others are slightly convex or barrel shaped, by which means a proper bearing is secured.

THE STANDARDS OF MEASURE.

The standard foot **I F**, is a bar of steel, an inch square and 13 inches in length. There are two wells for thermometers, 3·5 inches on either side of the centre of the bar. Lines marking the inches and smaller sub-divisions are drawn on gold pins let into the bar; the extreme inches are sub-divided into twentieths.

The standard 10-feet steel and bronze bars and the cradels for their support, were copied —with very slight modifications—from the Ordnance Intermediate Bar $\mathbf{O\,I_1}$, and it's system of cradels. The standard foot, was also copied from the Ordnance Foot **O F**. See *Captain Clarke's Comparisons of Standards of length, Chapters XVI to XX. London* 1866.

As the 10-feet standards are sub-divided into yards and feet, and the foot standard into inches and twentieths of an inch, it is possible to ascertain the relative lengths of the small spaces on which the micrometer runs depend, and of the six inch standard scales, to the 10-feet standards and the Standard Yard, and thus to refer all the measurements to a common unit.

CHAPTER II.

The Thermal Expansions of the Standards.

1.

An accurate knowledge of the variation in the length of a standard bar, corresponding to a given change in the temperature of the bar, is essentially necessary for a correct determination of the comparative lengths, at a given normal temperature,—as 62° Fahrenheit—of standards which have been actually compared at temperatures differing by more than a very few degrees from the normal temperature; it is also necessary for the reduction of the lengths of base-lines which are measured with metal bars of various temperatures, to the lengths at the normal temperature.

But the determination of the absolute thermal expansion of a metal bar is a problem of very great delicacy and difficulty, as will be readily seen on comparing the discrepancies which are so frequently met with when the expansion of the same bar has been determined on several occasions. Such discrepancies have given rise to the hypothesis that the expansion is not constant, but is liable in course of time to vary. Thus the expansion of the 10-feet Ordnance Standard $\mathbf{O}_1$ has been determined no less than six times, with the following results, for a variation of temperature equal to 1° Fahrenheit. (See *Principal Triangulation of the Ordnance Survey. London* 1858; *pages* 205 *and* 221.)

Year.	Co-efficient of expansion.	Expansion in millionths of a yard.
1827	·00000652	21·74
1844	·00000613	20·33
1844	·00000607	20·23
1845	·00000620	20·65
1846	·00000592	19·74
1849	·00000637	21·23

With reference to the last of these determinations Captain Clarke observes that "it seems that the expansion of the standard $\mathbf{O}_1$, must have increased since 1846, and is again approaching its former value, namely ·0000065."

It remains to be seen how far such differences between numerical values as are here exhibited are due to actual changes of expansibility, in course of time, and how far to errors in the determination of the expansion. As regards the possibility of changes, sufficient information does not appear to be at present forthcoming to enable any valid conclusions to be formed; it is therefore only practicable at present to investigate the influence of errors in the observations.

THE STANDARDS OF MEASURE.

The examination of any group of good observations of the expansion of metal bars will at once show that whatever errors exist, of a nature to exercise a sensible influence on the results, must be *constant errors*, due to defects in the apparatus, or the modus operandi, or possibly to both causes, for the theoretical probable errors of the results are almost invariably far smaller than the differences between the results of independent groups of observations.

Two methods appear to have been most commonly followed hitherto, in investigations of this nature.

In one of these methods the bar has been placed under a pair of microscopes, and it's length (relatively to the distance between the microscopes) been determined by observations at a natural temperature; it has then been heated by steam to a temperature approaching 212°, and it's length again determined. But the violence to which the bar is subjected has brought this method into disfavor, as it appears liable to alter the normal length of the bar, temporarily, if not permanently.* Moreover there is much reason to doubt whether the factors of expansion thus derived for such high temperatures are strictly applicable to measures at lower temperatures.

The other method is to remove the bar from the comparing room into a chamber artificially heated to a temperature of about 100°—which is slightly greater than the maximum occurring in practical operations—and allowing it to remain there until it has acquired a steady temperature; then bringing it back into the comparing room, carefully enveloped in blankets, and adjusting it quickly under the microscopes. In Russia a converse method has been followed, and the bars have been cooled down in sheds pervaded by the extreme cold of the winter, and then brought into a warm comparing room.

Frequently the microscopes have been assumed to hold an invariable position throughout the comparisons—an assumption which is very questionable—but occasionally the experiments have been conducted so as to be independent of the stability of the microscopes, by comparing the bar under treatment with another bar of which the temperature remains nearly constant, the expansion being known with sufficient accuracy to indicate the variations in length for slight changes in temperature.

It is manifest that the accuracy of the results of all such experimental observations must depend very materially on the accuracy with which the temperatures of the bars are indicated by the thermometers. But when the temperatures of the bars are changing, the temperatures of the thermometers, whose bulbs are fixed in the wells of the bars and are protected from external influences, necessarily *lag* behind those of the bars, and consequently the indications of the thermometers must be to some extent erroneous.

In order to guard against errors of this nature, Captain Clarke—before determining the expansions of the new Steel and Bronze Standards described in the preceding chapter—devised

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* NOTE.—Captain Clarke remarks that "if a bar of iron be heated from 62° to 212°, it is so extended 150 × 6 = 900 millionths of its length; and if the modulus of elasticity be, say, 30,000,000 and the section two square inches, the force required to produce the above extension is 60 × 900 = 54,000 lbs., or 24 tons. As a standard of length can seldom be used at a temperature exceeding 90°, it seems unnecessary that it should be heated in expansion experiments above 100° at the outside."

an apparatus for artificially raising the temperature of a bar to any desirable point, and retaining the temperature at that point as long as might be wished. The apparatus is minutely described in Chapter XVI of his *Comparisons of Standards*, and several illustrative plates are attached in explanation. In this place therefore it is only necessary to state that the bar rests on a carriage between two copper boxes of slightly greater length than the bar, and 5 inches in height by 3 in breadth; these boxes serve as tanks for holding the water by which the bar is heated. By means of supply and discharge pipes, an unintermittent flow of water, brought from a reservoir in which its temperature is maintained at any desired point, is passed through the tanks, and the variations of temperature in the tanks are very slow and very small and in their influence on the bar generally insensible.

Captain Clarke observes that

"even with the existence of small sensible oscillations about a mean temperature, there is this advantage above "the method of observing a bar steadily cooling, that sometimes we observe the bar in the state of expanding, and some- "times in the state of contracting, the one as often as the other, and thus a constant error is avoided."

Captain Clarke has investigated the influence of an *unsustained* temparature on a bar under comparison. After closing his observations of the expansions of the Steel Bar, he cut off the supply of warm water, which was than at a temperature of 63°, the temperature of the room being 43°; six comparisons were made at various intervals within the following thirty hours, at the end of which the temperature of the bar had fallen to about 51°; it was then again heated to above 65° and allowed to cool, and, when cooling, two more comparisons were made. The resulting values of the expansion are very satisfactorily accordant *inter se*, but they are smaller than those previously deduced with *sustained* temperatures, in the proportion of 20·740 to 21·194; this indicates that the temperature of the thermometers was on an average about 0·3° Fahrenheit greater than that of the bar, and was consequently lagging behind the bar, though the latter was cooling at the slow rate of only about 0·4° in an hour.

Similar results were obtained by Captain Clarke in experiments on the Ordnance iron Standard **O** I_2 while cooling. Moreover, on determining the expansions of this bar and the sister bar **O** I_1, with his heat sustaining apparatus, he obtained larger values than had been obtained from previous determinations which had been made under falling temperatures. The resulting expansions, expressed in millionths of a yard, for 1° of Fahrenheit, were respectively as follows, (See *Comparisons of Standards Chap. VI and XVII.*)

With a falling temperature, expansion of **O** $I_1 = 21{\cdot}055 \pm {\cdot}089$
With a sustained temperature, expansion of **O** $I_1 = 21{\cdot}576 \pm {\cdot}010$

With a falling temperature, expansion of **O** $I_2 = 21{\cdot}400 \pm {\cdot}050$
With a sustained temperature, expansion of **O** $I_2 = 21{\cdot}591 \pm {\cdot}011$

In the case of O I_1 the difference is material, the magnitude thereof being about six times the amount of the probable error of the first determination, and fifty times that of the second, thus illustrating the imperative necessity of guarding against the presence of constant errors in investigations of this nature.

THE STANDARDS OF MEASURE.

Certain comparisons which were made at Dehra Doon in May 1869, to determine the difference between the expansions of the iron standard bar **A**, and the steel standard $\mathbf{I}_S$, tell the same tale. The observations were made in a base line tent, in order to secure the greatest range obtainable from the natural variations of daily temperature. They were taken early in the morning and late in the afternoon—at the hours of maximum and minimum temperatures—commencing a little before and ending a little after the highest and lowest points had been reached, in order that the momentary variations of temperature might be a minimum and that the errors arising therefrom might be practically cancelled. The comparisons furnish—*inter alia*—two groups of observations, each containing seven determinations of the value of $\mathbf{I}_S - \mathbf{A}$, one group under a decidedly rising, the other under a decidedly falling temperature; the mean temperatures of the two groups differ by less than 3°, so that no possible error in the adopted value of expansion of either bar can affect the reduction of the observations of one group to the temperature of the other. The results are as follows,

$$\left.\begin{array}{l}\text{Under a falling temperature } \mathbf{I}_s - \mathbf{A} = 72.0 \\ \text{Under a rising temperature } \mathbf{I}_s - \mathbf{A} = 57.4\end{array}\right\} \textit{millionths of a yard at } 89^\circ.48^*$$

The difference far exceeds any possible errors of observation, and clearly arises from the circumstance that the variation of temperature of the iron bar **A** was much more rapid than that of the steel bar $\mathbf{I}_s$; the mass of the steel bar is about half as much again as that of the iron, and its diurnal range of temperature was only two-thirds of that of the iron; in neither bar could the thermometers have exactly indicated the temperature of the bar, but the lagging of the thermometers in the iron bar, which expanded most rapidly, must have been greater than the lagging of the thermometers in the steel bar; probably by about 0·3°, for the error of either determination as compared with the mean, is 7·3, and the expansion for 1° about 21; the mean of the two values is almost identical with the mean which is derived from the whole of the comparisons—about sixty in number—and with the value which has been independently deduced from other observations.

From a consideration of the preceding facts it must be clear that determinations of the thermal expansion of metal bars are only to be relied on when taken with the utmost care to exclude constant errors, and consequently that apparent variations of expansibility, in course of time, may in reality have been caused by errors in the respective determinations of the expansion by different methods and different observers.

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* The millionth part of the yard has been adopted by Captain Clarke, in his Comparisons of Standards of Length, as a unit of reference for small quantities. It is a convenient unit, being uncumbered with the large number of decimal places which are required when the inch is adopted as the unit. It will be frequently used in this volume, and always whenever the results of the operations of this survey have to be combined with the results of Captain Clarke's comparisons, and his investigations of the expansions, of the standards.

2.

The Expansion of the 10-*feet Standard* **A**.

The factor of expansion of this bar was first determined in 1832, in Calcutta, by Mr. James Prinsep and Captain Wilcox. The observations are given in detail in No. XV of the Asiatic Journal (*March* 1833) in an article by Mr. Prinsep; and Colonel Everest has given a synopsis of the results which he has deduced from them, at page XCVII of his Arc Book of 1847.

The method of operation was briefly as follows; the bar was placed inside a double case formed of two concentric tin tubes, soldered together at the extremities, but separated by a space into which steam might be admitted. The bar was then brought under two microscopes which were fixed on isolated piers of stone. The microscopes were first read when the bar was at the natural temperature of the comparing room, which appears to have ranged from 71° to 79°. Then "the stop cock of a pipe which communicated with the boiler of a small steam engine was turned, and a stream of steam, entering at one end, was made to pass longitudinally along the whole space between the tin tubes. and discharge itself at the opposite end. When the steam had been applied for a sufficient period, and both thermometers and micrometers continued to agree in indicating no change, the readings of both were again noted, and the communication with the boiler being cut off by turning the stop cock, the whole was allowed to cool down to the ordinary temperature of the room, in which state the readings were made for a third time."

The factor of expansion thus deduced was ·000,006,801 for 1° Fahrenheit, and the corresponding linear expansion is 22·67 *millionths of a yard.*

Up to the present time this value has been employed for the reduction of all measures of the standard at various temperatures, to the normal length at the temperature of 62°.

But an analysis of the numerous comparisons which have been made at each base-line, between this standard, and the compensated bars used in measuring the lengths of the base-lines, has shown that the discrepancies between the several comparisons on each occasion would be materially reduced were a smaller value of the expansion of the standard to be employed. Such comparisons in themselves afford a means of determining the expansion of the standard, with very tolerable accuracy, and they have been used for this purpose by Captain Clarke, in determining the expansion of the Ordnance Standard $\mathbf{O}_1$, for the reduction of the measurement of the base-line on Salisbury Plain. (*Principal Triangulation of the Ordnance Survey, page* 220.)

The following values of the expansion of the standard bar **A** have been thus obtained for eight out of the ten base-lines, no such investigations having been made for the bases at Beder and Cape Comorin :—

Base-Line.	Year of measurement.	Mean temperature of standard during comparisons.	Expansion in millionths of a yard for 1° Fahrenheit.
Calcutta, ...	1832	67°	20·92 ± ·21
Dehra Doon, ...	1835	66	21·13 ± ·06
Seronj, ...	1838	63	20·46 ± ·09
Sonakhoda, ...	1848	64	21·21 ± ·09
Attok, ...	1854	53	20·92 ± ·09
Karachi, ...	1855	68	20·80 ± ·11
Vizagapatam, ...	1863	73	21·39 } *p. e.* not computed.
Bangalore, ...	1868	71	22·01 } *p. e.* not computed.

These expansions are all considerably in defect of the value obtained by direct observation at Calcutta; it is noticeable that one of the largest differences occurs at the Calcutta base-line, which was measured in the year in which the direct determination was made; the difference therefore is clearly due rather to the observations themselves, than to an actual change in the expansion.

Colonel Everest observes that his factor agrees very closely with the one given in Mr. Ure's tables, of ·000,006,779, derivable from an increment between 32° and 212°. On the other hand it considerably exceeds the factors determined for the wrought iron standards of the Ordnance Survey, from temperatures not exceeding 100°, by the two processes already described; the excess is least when the comparison is made with observations at sustained temperatures, but even then it is considerable, being more than 5 *per cent* of the total amount. As compared with the expansions of the wrought iron standards of the Russian Arc, Colonel Everest's factor is 7 *per cent* greater, (see *Struve's Arc du Meridien, pages* 49 *to* 51). Thus a re-determination of the expansion of this standard was evidently called for.

3.

Re-determination of the Expansion of Standard **A**.

The expansion of the steel standard I_S having been very accurately determined by Captain Clarke, under temperatures which were carefully sustained, at points not rising above 100°, by means of the apparatus which has been already described, (see also *Comparisons of Standards. Chapter XVI*) an attempt was made at Dehra Doon, in May 1869, to deduce the *difference* between the expansions of I_S and of **A**, by means of comparisons at the highest and lowest natural daily temperatures. The comparisons were made in a base-line tent, the microscopes being set up on isolated masonry pillars. The range of temperature was about 20°, the mean temperature being 89°. Adopting for I_S the value of 21·159, as determined by Captain Clarke, the result was

$$\textit{Expansion of } \mathbf{A}, \textit{ for } 1^\circ \textit{ Fahrenheit} = \overset{m.y}{21{\cdot}760}.$$

These are the experiments which have been already described at page 8, and it has been shown that they indicate large differences between the observed measures of $\mathsf{I}_S - \mathbf{A}$ when taken under rising temperatures, as compared with those which were obtained when the temperatures were falling. For this reason the results could not be considered conclusive, and it was decided to make a new determination, with the aid of a heat sustaining apparatus, similar to that devised by Captain Clarke.

In order to secure as low natural temperatures as possible, the final experiments were carried on in the winter, on the hill station of Masuri, in a room attached to the summer offices of the Trigonometrical Survey. They were conducted by Mr. Hennessey, who also supervised the entire details of the construction of the apparatus, and the measures for retaining the comparing room at a temperature as nearly constant as possible. Mr. Hennessey's account of his procedure will be given at length in the Appendix; in this place it is only necessary to give a brief sketch of the operations and to epitomize the results.

The steel standard I_S was again employed on this occasion. The observations were divided into 4 groups, each containing 30 comparisons of I_S with **A**.

In group No. 1, both bars were heated.

In group No. 2, both bars were cold, *i. e.* at the natural temperature of the comparing room, which was about 52°.

In group No. 3, I_S was hot and **A** was cold.

In group No. 4, I_S was cold and **A** was hot.

The hot temperatures were altered at pleasure from 88° to 98°, and so thoroughly were they controlled that the bars never varied in temperature by more than 0°.1 during the whole of the observations on any day, and the average range of temperature in the same time was not more than $0^\circ 03$; whenever the temperature was raised or lowered, a long interval was always allowed to elapse before resuming observations, and the changes of temperature were invariably made very gently and slowly.

Combining groups 1 and 2, a value of the difference between the expansions of I_S and **A** is obtained. Combining groups 2, 3, and 4, absolute values of the expansions of both bars are obtained.*

Employing the symbol E to denote the expansion of a bar, *in millionths of a yard*, for an increase of temperature of 1° Fahrenheit, and the symbol F to denote the corresponding factor of expansion, the following symbols will indicate these quantities for each of the 10-feet standards of the Indian Survey.

E_a	the expansion,	F_a	the factor,	of the wrought iron	standard **A**
E_b	"	F_b	"	"	" **B**
E_S	"	F_S	"		steel standard I_S
E_B	"	F_B	"		bronze standard I_B

Combining groups 1 and 2, by the method of least squares,

$$E_a - E_S = \overset{m.y}{0{\cdot}557}$$

combining groups 2, 3, and 4,

$$E_a = 21{\cdot}747 \pm {\cdot}0078$$

$$E_S = 21{\cdot}337 \pm {\cdot}0077$$

$$\therefore\ E_a - E_S = 0{\cdot}410$$

combining all four groups,

$$E_a = 21{\cdot}797 \pm {\cdot}0079$$

$$E_S = 21{\cdot}290 \pm {\cdot}0080$$

$$\therefore\ E_a - E_S = 0{\cdot}506$$

The expansions of I_S and I_B have been twice determined by Captain Clarke, (See *Comparisons of Standards, Chapter XVI*). The first set of observations was taken in February and March 1865, the second in April and May of the same year.

* Though group 2 is thus employed in both combinations, the results are practically independent, for the errors of the observations of this group are insignificant in comparison with these of either of the other groups.

THE THERMAL EXPANSIONS OF THE STANDARDS.

The first series consists of 50 comparisons, at temperatures ranging from 39° to 99°; the second of 27 comparisons at temperatures ranging from 56° to 96°; the results are as follows,—

by the first series $E_B = \overset{m.y}{32.957} \pm .013$
$E_S = 21.194 \pm .014$

by the second series $E_B = 32.759 \pm .019$
$E_S = 21.159 \pm .019$

Captain Clarke accepts the results of the second series only, apparently for the reason that in the first series the bars were suspended from above, while in the latter they rested on rollers—"under circumstances more similar to those in which they will be actually used"—and because in the first series there were irregularities in the distance, about $\frac{3}{16}$ of an inch, of the hot water tanks from the bar, at different parts of it's length, whereas in the second, the tanks were somewhat improved as to straightness, and were placed at a greater distance from the bar than before, namely about $\frac{7}{16}$ inch.

The discrepancies between the results of the preceding investigations are much smaller than those which are frequently met with in similar investigations, and are thus a satisfactory proof the advantages which are secured by the employment of a heat sustaining apparatus. Still however they are materially larger than the probable errors would lead one to expect, the difference between the lowest and highest values of the expansion of the steel standard amounting to nearly 1 *per cent.* of the total expansion. Clearly the differences between the results by the same observer cannot be due to any change in the expansibility of the bars in the intervals of only a few weeks duration between the successive series of observations. The difference between Captain Clarke's value of the expansion of the steel standard and that obtained by Mr. Hennessey, may be due to a change in the expansibility of the bar in the intervening period of 4½ years; but it is most probably due to constant and inconstant errors in the temperatures indicated by the thermometers during the investigations, such as may arise either from the intrinsic errors of the thermometers or from actual differences between the temperatures of the bars and those of the thermometers; in both investigations however the thermometers were carefully tested in ice and compared with very accurately calibrated standards, and the operations for sustaining the temperatures must have materially tended to equalize the thermal conditions of the bars and the thermometers, but for which circumstances larger discrepancies might have been met with.

The differences between the results obtained by the same observer, must evidently be assumed to be due to the intrinsic errors of the operations, and it may also be assumed that the differences between Mr. Hennessey's results and Captain Clarke's are due to this cause and not to any appreciable physical influence. These assumptions are equivalent to admitting that the most elaborate and exact observations for determining the expansion of a metal bar which it appears possible to make are liable to errors not materially less than 1 *per cent.* of the amount of the expansion.

Adopting mean results, the value of the expansion of **A** must be that obtained by combining the whole of Mr. Hennessey's observations, whence

$$E_a = \overset{m.y}{21\cdot797}, \qquad F_a = \cdot000{,}006{,}539$$

For $\mathbf{I}_S$, I adopt the mean of the result from all Mr. Hennessey's observations and the result from Captain Clarke's second series of observations, as he himself rejects his first series; thus

$$E_S = 21\cdot225, \qquad F_S = \cdot000{,}006{,}368$$

For $\mathbf{I}_B$, I have simply to follow Captain Clarke, and accept the value of expansion which he has accepted, or

$$E_B = 32\cdot759, \qquad F_B = \cdot000{,}009{,}827$$

4.

Adoption of a rate of expansion varying with the temperature for the 10-*feet standard* **A**.

The value of the expansion of **A** which has been finally arrived at in the last section has been determined from measurements of the increments of the bar between temperatures of about 52° and 96°; on the other hand the value of the expansion of this bar which was obtained in Calcutta in 1832—*viz.* 22·669 *m.y*—was determined from measurements of the increments between temperatures of 76° and 212°. Thus the difference between the two results—which is as much as 0·872 *m.y*, or precisely 4 *per cent.* of the whole expansion—is not necessarily due to errors in the first determination; and the results obtained from the comparisons of the standard with the compensated bars at the several base-lines—which have been given in the table in the preceding section of this Chapter—indicate that there is a considerable probability that it cannot be due to absolute changes in the expansibility of the bar.

I shall assume therefore that it is mainly due to the circumstance that the average increment of the bar, for a change of 1° of temperature, is greater at the high temperatures which were employed in 1832, than at the comparatively low temperatures which were employed in 1870. That the co-efficients of dilatation increase with the temperature, when the temperature is between the boiling point of water and the melting points of metals, has been sufficiently shown by the investigations of Dulong and Petit. That the increase is appreciable between the temperatures of the freezing and boiling points of water, does not appear as yet to have been generally established. But investigations of the factors of expansion of the wrought iron standards which were employed in the verification of La Caille's Arc of the Meridian at the Cape of Good Hope, have lead the Astronomer Royal to the conclusion that, between 40° and 140°, "the expansion increases rapidly with the rising temperatures"; the reductions of the measures of the standards, to the normal temperature of 62°, during the operations at the Cape, were consequently made with factors varying with the temperature. (See *Sir Thomas Maclear's Verification and Extension of La Caille's Arc, pages* 350,351).

The law of the expansion of standard **A** has been empirically determined in the following manner. Putting l_τ for the length of the bar at τ, the lowest temperature of the observations, and l_t for the length at t, any other temperature, it is assumed that

$$l_t = l_\tau + (t - \tau)\, x + (t - \tau)^2\, y \quad \ldots\ldots\ldots \qquad (1)$$

then l_τ and τ being constant, the expansion for 1° at any temperature t will be

$$d\, l_t = x + 2\,(t - \tau)\, y \quad \ldots\ldots\ldots \qquad (2)$$

The lowest temperature of observations being 52°, and the other temperatures being 76°, 96°, and 212°, we have the following equations

$$\begin{aligned} l_{76} &= l_{52} + 24\,x + (24)^2\, y \\ l_{96} &= l_{52} + 44\,x + (44)^2\, y \\ l_{212} &= l_{52} + 160\,x + (160)^2\, y \end{aligned}$$

The observed increment during the experiments in 1832 was $= (212 - 76) \times 22{\cdot}669$; during the experiments in 1870 it was $= (96 - 52) \times 21{\cdot}797$

$$\therefore\ l_{96} - l_{52} = 44\,x + (44)^2 y = 44 \times 21{\cdot}797$$
$$\text{and } l_{212} - l_{76} = 136\,x + (160^2 - 24^2)\, y = 136 \times 22{\cdot}669$$

$$\text{Thus} \qquad \begin{aligned} x + 44\,y &= 21{\cdot}797 \\ x + 184\,y &= 22{\cdot}669 \end{aligned}$$

$$\text{whence} \qquad \begin{aligned} x &= 21{\cdot}523 \\ y &= {\cdot}00623 \end{aligned}$$

It is necessary to find the mean expansion for 1° between the normal temperature 62°, and any temperature t. The entire increment of the bar, between the temperatures $t = a$ and $t = b$, is

$$\begin{aligned} l_b - l_a &= \int_a^b d\, l_t \\ &= (b - a)\, \{x + (b + a - 2\,\tau)\, y\} \end{aligned}$$

Thus, τ being = 52°, the mean expansion for 1° between 62° and any temperature t is

$$\frac{l_t - l_{62}}{t - 62} = x + (t - 42°)\, y$$

$$\text{or } {}_tE_a = 21{\cdot}523 + (t - 42°) \times {\cdot}00623$$

The corresponding numerical values for certain given temperatures will be found in the last section of this chapter.

5.

The Expansion of the 10-*feet Standard* **B**.

No direct experiments have ever been made for determining the expansion of this bar. Colonel Everest assumed it to be equal to that of standard **A**; both bars were constructed at the same time, and, as was supposed, of the same metal, and they are similar to each other in every respect.

Colonel Everest compared **A** with **B** in 1834 and again in 1835; the observations having been taken over a large range of temperature—18° in the first instance, and 30° in the second—can be treated so as to furnish values of the difference of the expansions of the standards as well as of the difference of length. This has been done, and the method which was followed will be found described in detail in the Appendix, in the section on the comparisons of the lengths and of the expansions of standards **A** and **B**. The results will be shown in this place.

Adopting the symbols at page 12, and putting

$$E_b = E_a + y$$
$$\text{and } E_a = e - de$$

where $e = \overset{m.y}{22{\cdot}669}$, Colonel Everest's value of the expansion of **A**, and de denotes the error of that value, the following values of y have been obtained by the method of least squares;

from the first group of observations,		$y = -\ 0{\cdot}575 + {\cdot}008\ de$
from the second group	„	$y = -\ 0{\cdot}109 - {\cdot}015\ de$
from both groups	„	$y = -\ 0{\cdot}145 - {\cdot}009\ de$

Assuming de to be equal to $+\ 0{\cdot}872$, the amount by which Colonel Everest's value of the expansion exceeds Mr. Hennessey's, we get from the mean of both groups

$$y = -\ 0{\cdot}153$$
$$\text{whence} \quad E_b = 21{\cdot}644$$

The value of y being so small, it is clear that Colouel Everest's assumption that the expansion of **B** is the same as that of **A**, is sufficiently exact for the reduction of observations at temperatures not differing very materially from 62°.

6.

The Expansions of the 6-inch brass scales A and B, and of the steel foot **IF.**

No determinations of the expansions of these small bars have been made.

The co-efficient of expansion of the brass scales has been uniformly assumed to be ·000,010,417, which is probably too large, having been deduced from experiments over a great range of temperature;—a more probable value is, ·000,009,855; (see *Account of the Lough Foyle Base, Appendix, Page* 12.)

The expansion of the steel foot has been assumed to be the same as that of the 10-feet steel standard I_S.

7.

On the possible increments of expansion of the steel and bronze Standards I_S and I_B, for an ordinary increase of temperature.

The expansions of these bars have been twice determined by Captain Clarke, and that of I_S has been re-determined by Mr. Hennessey, with the results which have already been stated in section 4 of this Chapter. In both instances the observations were restricted to temperatures not exceeding 100°, and thus they do not furnish sufficient data for determining the variation of expansion with temperature. Captain Clarke however, having noticed that there was an inclination to a predominance of + errors at the lower temperatures and — errors at the higher temperatures, in his observations, has given tables of the result of each comparison, and the temperature at which it was made. From these tables the following one has been prepared, by grouping together the expansions at the highest and lowest temperatures.

Bar.	Number of measures.	Temperatures.		Expansion.	Series of experiments.
		Range.	Means.	m.y	
Steel, ...	4	42° to 88°	65°	21·130	First.
	5	42 to 97	69·5	21·220	
Do., ...	4	56 to 75	65·5	21·103	Second.
	4	56 to 96	76	21·177	
Bronze, ...	5	44 to 74	59	32·747	First.
	6	44 to 98	71	33·023	
Do., ...	4	57 to 76	66·5	32·607	Second.
	4	57 to 96	76·5	32·827	

There is an apparent increase of expansion with the temperature in the four comparisons between the observations of each group; it is greatest for the bronze bar, but is sufficiently marked for the steel, and indicates the probability that the expansions of both bars increase with the temperature, by appreciable amounts, even at temperatures between 60° and 80°.

8.

Recapitulation of the adopted Expansions.

I have assumed that the expansion of the 10-feet Standard **A** has not varied during the interval between 1832, when it was determined at high temperatures, and 1870, when it was determined at ordinary temperatures; also that the values obtained on the two occasions indicate—with all practicable accuracy—the expansions at the respective temperatures of the observations, and that the difference between the results is due to an increase of expansibility for an increase of temperature.

I have shown that there is much reason to believe that the expansions of the steel and bronze standards, I_S and I_B, increase with the temperature; but that whereas there are sufficient data for indicating, with fair probability, the precise amount of the expansion of **A** at various temperatures, no such data are forthcoming for I_S and I_B, or **B**, the bars with which **A** has been compared for the determination of it's relations to the European Standards of length. In reducing the comparative lengths of these bars, at the temperatures of observation, to the corresponding lengths at the normal temperature, it would be manifestly incorrect to recognize the expansion of **A**, and to ignore that of the other bars. For supposing **A** to be compared with I_S, and that at a temperature t, which is practically identical for both bars,

$$I_S - A = m,$$

then, putting e_a and e_s for the expansions of the bars, it follows that at the temperature of 62°

$$I_S - A = m - (e_s - e_a)(t - 62°)$$

thus the reduction depends on the *difference* of the expansions and is scarcely affected by the small changes in this difference which may occur within the ordinary ranges of temperature. On the other hand, in reducing the comparative lengths of the standard **A** and the *compensated* bars—which have been employed in the measurement of the base-lines, and which do not vary materially with the temperature but are nearly of a constant length—it is necessary to employ the value of the expansion of **A** which corresponds to the temperature of the observations. Hence therefore one value of expansions will be employed in the final reductions of the comparisons of standards, and other values in the final reductions of the base-lines; as are shown in the following tables.

THE THERMAL EXPANSIONS OF THE STANDARDS.

Expansions, for 1°· Fahrenheit, used in reductions of comparisons of standards.

Bar.	Expansion in millionths of a yard.	Co-efficient of expansion.
10-feet Stand **A**, (wrought iron)	21·797	·000,006,539
„ **B** („)	21·644	·000,006,493
„ $\mathbf{I}_S$ (steel)	21·225	·000,006,367
„ $\mathbf{I}_B$ (bronze)	32·759	·000,009,828
Standard Foot **IF** (steel)	2·122	·000,006,367
6-inch Standards *A* & *B* (brass)	1·736	·000,010,417

Expansions, for 1°· Fahrenheit, of Standard **A**, *at various temperatures, for reductions of comparisons with compensated bars.*

Temperatures.	Expansion.	Co-efficient.
42°	m.y 21·523	·000,006,457
52	21·585	·000,006,476
62	21·648	·000,006,494
72	21·710	·000,006,513
82	21·772	·000,006,532
92	21·835	·000,006,551

This table has been computed with the formula at the end of the 4th section of this Chapter.

It should be here repeated that the propriety of employing the value of the expansion of **A** which was determined at Calcutta in 1832 has only recently been questioned; that value had been already used in all the reductions of the comparisons, both with the other Standard Bars and with the Compensated Bars. Differential expressions have therefore been added to the several reductions to show the extent to which the comparisons of length between the standard bars will be affected by changes in the adopted values of the expansions of either of the bars.

For the base-lines, the mean temperatures of **A**, during the comparisons with the compensated bars, will be shown, and corrections for the difference between the adopted value of the expansion, and that given in the second table, for the corresponding temperature, will be applied to the lengths of the base-lines.

CHAPTER III.

Comparisons of the Standards.

1.

The influence of Personal Equations.

The extremities of the old 10-feet and the 6-inch standards are defined by dots on platinum or silver pins, which are drilled into the bars.

The extremities, and the several sub-divisions, of the new 10-feet steel and bronze bars, and of the steel foot, are defined by lines which are drawn—perpendicularly to the length of the bar—on gold pins, drilled into the bars.

The dots on the old standards vary from 50 to 100 millionths of a yard in diameter, or from about 40 to 80 divisions of the micrometers which have been generally used for the comparisons.

A perfectly symmetrical dot of these dimensions may either be intersected by a single wire of the micrometer, or it may be brought between a pair of wires, with a probable error less than one micrometer division for a single reading, and materially less for the mean of a number of readings. But comparisons of standards by different observers frequently exhibit far larger discrepancies than can be explained by the differences between the several measures made by any individual observer; such differences are generally due to accidental errors of observation only, and the magnitudes of the corresponding probable errors will not vary materially for different persons who, from long practise, are well skilled in the operations; but the discrepancies between the results of the observations of several persons will usually be far larger than the probable errors of *observation only*, and they may be frequently traced to the personal equations of the observers.

When the dots are unsymmetrical, the errors of observation are much increased; large discrepancies may be expected whenever the intensity of the light by which the dots are illuminated is varied, as when the light of a lamp is substituted for sunlight reflected from a heliotrope. A true dot is of the form of an inverted cone with its axis at right angles to the surface of the bar; a jagged dot is irregular in outline and depth; thus while changes of illumination will not affect the appearance of the former or disturb the estimate of the position of the central point, they may considerably affect the appearance of the latter, and indicate new centres with every change of illumination. Here then there will be a still greater tendency to differences between results obtained by different observers.

The influence of the personal equation will now be investigated in two groups of comparisons of small lengths, not exceeding 6 inches, in which the micrometer microscopes at both extremities were read by the same person. Such observations are evidently better suited for the purposes of the present investigation than the comparisons of the 10-feet bars, for two observers are always required for the latter, and the results are liable to be materially affected by errors in the apparent temperatures, and in the adopted values of the expansions.

Comparisons of the 6-*inch Standard A, and the* 6-*inch scales used in the base line operations, with the central* 6-*inch space* [*d.l*] *of the foot* **IF**.

The scales are respectively known by the letters *M, N, R, S, T, U, V,* and *W,* and are similar in all respects to standard *A.* Each was compared four times with **IF** by five of the Officers of this Survey, with the following mean results by each observer, which are expressed in millionths of a yard, as reduced to the temperature of 62°, the temperatures of observation ranging from 66° to 70°.

Observer's initials.	[*d.l*] − *A*	[*d.l*] − *M*	[*d.l*] − *N*	[*d.l*] − *R*	[*d.l*] − *S*	[*d.l*] − *T*	[*d.l*] − *U*	[*d.l*] − *V*	[*d.l*] − *W*
M. W. R.	+ 1·02	− 2·67	−10·08	− 6·59	+ 0·98	+ 1·90	− 8·55	+ 5·94	+ 3·38
W. J. H.	8·96	4·69	12·50	7·64	2·84	3·11	9·74	4·60	2·11
T. G. M.	4·91	5·25	14·72	7·17	1·67	3·16	7·97	1·67	− 0·90
J. B. N. H.	7·36	3·93	13·28	10·92	0·07	− 0·13	12·30	3·77	+ 1·54
H. R. T.	5·48	1·17	9·30	9·86	2·40	+ 2·27	11·60	5·89	3·41
Mean	+ 5·55	− 3·54	−11·98	− 8·44	+ 1·59	+ 2·06	−10·03	+ 4·37	+ 1·91

Computing the value of the probable error of the result obtained by a single observer from the squares of the differences between the individual results and the mean of each group, and calling this probable error *e*, we get

$$e = \pm \cdot 67 \sqrt{\frac{131 \cdot 88}{45 - 9}} = \pm \overset{m.y}{1 \cdot 28}$$

The value of *e* thus determined may be considered to be the *entire* probable error of the result obtained by a single observer, and to include both the personal errors, and the accidental errors of observation; so that if *p* be the probable personal error, and *o* the probable error of observation, we may put

$$e^2 = p^2 + o^2$$

the other errors being, from the circumstances of the observations, presumably constant for all the comparisons. The several observations by each observer are given in the appendix; the differences between single comparisons and the mean of the group to which they appertain indicate that, in a single comparison, the probable error of observation only is $= \pm \cdot 81$, and as four comparisons were made by each observer

$$o = \pm \frac{\cdot 81}{\sqrt{4}} = \pm \overset{m.y}{\cdot 40}$$

Thus

$$p^2 = e^2 - o^2 = (1 \cdot 28)^2 - (\cdot 40)^2 = 1 \cdot 48$$

$$p = \pm \overset{m.y}{1 \cdot 22}$$

Thus the entire error appears to be almost wholly due to the *personal equations* of the observers.

Comparisons of 5-*inch and* 6-*inch spaces on the standard steel foot, with corresponding spaces on Cary's brass scale.*

These comparisons were made in order to determine the relation to Standard **A** of inch 7 to 8 of Cary's brass scale, on which the runs of the micrometers had been taken, at every occasion of comparative measurements between the years 1832 and 1867. The space 7 to 13 of Cary's scale was compared with the space *a* to *g* of the standard foot, and 8 to 13 with *b* to *g*, whence the value of inch 7 to 8 of Cary's scale is determined relatively to inch *a* to *b* of the standard foot, the relative value of which to standard **A** is known.

Each space was compared five times by six of the Officers of this Survey, with the following results, which are expressed in millionths of a yard, as reduced to the temperature of 62°, the temperatures of observation ranging from 64° to 68°.

Observer's initials.	*a* to *g* — 7 to 13	*b* to *g* — 8 to 13	*a* to *b* — 7 to 8
T. G. M.	− 1·7	− 20·5	+ 18·8
J. B. N. H.	4·1	16·1	12·0
H. R. T.	9·8	21·6	11·8
C. L.	4·3	18·2	13·9
H. K.	5·5	13·9	8·4
T. T. C.	3·2	19·1	15·9
Mean	− 4·8	− 18·2	+ 13·4

Computing the entire probable error, as above, from the squares of the differences between the results by each observer and the mean for the corresponding group of the *direct* comparisons, we obtain

$$e = \pm \cdot 67 \sqrt{\frac{78 \cdot 96}{12-2}} = \pm \overset{m.y}{1 \cdot 88}^{*}$$

From the details of the observations which are given in the appendix it can be shown that, in a single comparison, the probable error of observation only is $= \pm \cdot 72$, and as five comparisons were made by each observer

$$o = \pm \frac{\cdot 72}{\sqrt{5}} = \pm \cdot 33$$

whence

$$p^2 = e^2 - o^2 = (1 \cdot 88)^2 - (\cdot 33)^2 = 3 \cdot 43$$

$$\therefore p = \pm 1 \cdot 85$$

Comparing p and e the entire error is again seen to be almost wholly due to the *personal equations* of the observers.

In the observations of the foot and the 6-inch scales, the comparisons were made between good lines and dots which—with a very few exceptions—were fairly symmetrical. In the observations of the foot and Cary's scale, the comparisons were made between good lines on the former and coarse lines on the latter, for Cary's scale was constructed some time before the year 1802, when the art of dividing had not reached its present perfection. Thus p is much larger in the second case than in the first.

For the probable personal errors of comparisons of small bars which can be made by a single observer, it may be assumed that, with fairly good lines or dots,

$$p = \pm \overset{m.y}{1 \cdot 2}$$

while for long bars, in which the comparisons must be made by two observers, the probable personal error will be

$$p = \pm 1 \cdot 2 \sqrt{2} = \pm \overset{m.y}{1 \cdot 7}$$

It is clear from these results that personal errors are liable to be of considerable magnitude as compared with the ordinary accidental errors of observation, and consequently that

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* The probable error of a single determination of a to $b - 7$ to 8, deduced from the differences of the *direct* comparisons and their mean, is

$$= \pm \cdot 67 \sqrt{\frac{65 \cdot 18}{6-1}} = \pm \overset{m.y}{2 \cdot 42}$$

which is, as it should be, somewhat less than $e\sqrt{2}$.

when great accuracy is required, standards should be compared by as many skilled observers as possible ;—it is further evident that the differences between comparisons of standards at different periods may be due to the personal equations of the observers, rather than to any actual change in the length of either standard, in the interval between the comparisons.

2.

Comparisons of the 10-feet Standards **A** *and* **B**, *in* 1834-35.

Comparisons were twice made at Dehra Doon under the superintendence of Colonel Everest, the first time in a house, the second time under tents, after the measurement of the Dehra Doon base-line. Full details of the comparisons, and their reduction by the method of least squares, are given in the Appendix. The resulting values, at the temperature of 62°, are as follows :—

In 1834	B − A =	m.y 3·75 the mean temperature of observation being	66·4
in 1835	B − A =	− 0·42 „ „	59·0

Combining both groups of observations by the method of least squares, it follows that

in 1834-35 B − A = 0·64 the mean temperature of the observations being 62·7

3.

Comparisons of the 10-feet Standards **B**, I_S, I_B, *and Ordnance Survey* O_1.

On reference to Chapters XX and XXII of Captain Clarke's *Comparisons of Standards of Length*, it will be seen that the Indian Standard **B** — therein called I_b — was compared in England with O_2 in 1831, with O_1 in 1846, and with I_B, I_S and O_1 in 1865.

Taking into account the difference of O_1 and O_2, the results given by Captain Clarke are as follows, as reduced to the normal temperature of 62° ;

In 1831,	$B - O_1 =$	m.y − 22·25,	the mean temperature of observation being	° 51·0
in 1846,	$B - O_1 =$	− 24·03	„ „	73·5
in 1865,	$I_S - B =$	86·50	„ „	61·3
„	$I_B - B =$	218·58	„ „	63·2
„	$I_S - O_1 =$	63·28	„ „	63·6
„	$I_B - O_1 =$	195·36	„ „	62·7

and from the last four comparisons it follows that

in 1865 $B - O_1 =$ − 23·22, the mean temperature of observation being 62°·7

The first four comparisons in 1865 have however been combined with comparisons of I_S and the Ordnance Standards O_1, OI_1, and Y_{55}, by Captain Clarke, who has thus obtained the following Final Results; see *Chapter XXII.*

$$I_S - B = 86{\cdot}81$$
$$I_B - B = 218{\cdot}27$$
$$I_S - O_1 = 64{\cdot}21$$
$$I_B - O_1 = 195{\cdot}67$$
$$B - O_1 = -\ 22{\cdot}60$$

4.

Comparisons of the 10-feet Standards **A**, I_S *and* I_B, *in* 1867—70.

These bars were compared at Dehra Doon in 1867, shortly after the arrival of I_S and I_B from England. Full details of the comparisons will be found in the Appendix; the results, reduced to the temperature of 62° with the latest and most probable values of the factors of expansion, are as follows;

$I_S - A = \overset{m.y}{80{\cdot}84}$, the mean temperature of observation being $71{\cdot}7^\circ$
$I_B - A = 212{\cdot}64$ „ „ 71·9
$I_B - I_S = 132{\cdot}06$ „ „ 72·0

Adopting Captain Clarke's final value of $I_B - I_S$ ($= 131{\cdot}46$), we get,

$I_S - A = 81{\cdot}18$, through I_B,

and combining with the direct value, as above, we get

$I_S - A = 81{\cdot}01$, the mean temperature of observation being 71°·9

But the comparative length of I_S and **A** was re-determined by Mr. Hennessey, in 1870, in the course of his operations for investigating the factor of expansion of **A**; the result, as reduced to the temperature of 62° with the latest and most probable values of the expansions, was,

$I_S - A = 84{\cdot}03$, the mean temperature of observation being 51°·8.

The mean of the two series of comparisons in 1867 and 1870 gives

$I_S - A = 82{\cdot}52$, the mean temperature of observation being 61°·9.

5.

Examination of the comparative lengths of the 10-*feet Standards* **A** *and* **B**, *as deduced from the observations of* 1834-35 *and* 1865-70.

By the comparisons of 1834-35

$$\mathbf{B} - \mathbf{A} = + \overset{m.y}{0{\cdot}64}$$

Combining the value of $\mathbf{I}_S - \mathbf{A} = 82{\cdot}52$, for 1867-70, with Captain Clarke's value of $\mathbf{I}_S - \mathbf{B} = 86{\cdot}81$, for 1865, we get,

$$\mathbf{B} - \mathbf{A} = - 4{\cdot}29$$

As the mean temperatures of the comparisons in both instances almost exactly coincide with the normal temperature of 62°, the results are unaffected by any errors in the adopted values of the expansions of the bars. Thus the difference between the two results might be supposed to arise from a change in the relative lengths of the bars, during the intermediate interval of upwards of 30 years, when the bars remained, one in the warm climate of India, the other in northern Europe. Unfortunately however when the first comparisons were made, as much care was not taken in determining the calibration and index errors of thermometers as is done in modern observations; the thermometers appear to have been compared with a standard belonging to the Royal Society, but for index error only; recent examinations have shown that the calibration errors are large, but corrections cannot now be applied, for the thermometers were divided, not on their own stems, but on metal plates, and there is considerable play in the attachments. Hence there is an uncertainty of at least $\pm\, 0{\overset{\circ}{\cdot}}2$ in the temperatures of either bar during the first comparisons, which of itself is sufficient to be the cause of the difference between the two results. See *Descriptions and Comparisons of Thermometers, in the Appendix.*

For these reasons I have decided to assume that the relative length of the 10-feet Standards **A** and **B** has not altered appreciably, and that the true difference in length is most probably indicated by the latest comparisons, whence

$$\mathbf{A} = \mathbf{B} + \overset{m.y}{4{\cdot}29}$$

6.

Final Results. The relations of the Indian 10-*feet Standards to each other and to the Principal European Standards of Length.*

The comparisons lately made in India furnish additional equations of condition, for the relations between the Indian and the Ordnance Survey Standards, which might be combined with the equations resulting from Captain Clarke's comparisons in England, so as to furnish a simultaneous solution of the relations of all the Standards. This would however disturb the results already obtained by Captain Clarke, but so slightly that the differences would be far within the probable errors of the respective determinations. I have therefore adopted Captain Clarke's results as final.

Thus the lengths in terms of the Ordnance Standard yard $\mathbf{Y}_{55}$ are

$$\mathbf{B}^{*} = (3{\cdot}333{,}315{,}90)\ \mathbf{Y}_{55}$$
$$\mathbf{A} = (3{\cdot}333{,}320{,}19)\ \mathbf{Y}_{55}$$

On the following page a table of the relative length of the Standards will be found which is taken from page 280 of Captain Clarke's *Comparisons of Standards of Length*, with the addition of the length of the Indian 10-feet Standard **A**, which is the unit of the operations of this Survey. The Yard, the Toise, and the Metre, the lengths of which are given in the three last lines of the table, may be here briefly defined, with the aid of the information given by Captain Clarke.

The Yard is the mean length, in the year 1864, of five copies, No. 29, 55, 65, 66, & 67, of the National Standard Yard. Captain Clarke states, on the authority of the Official *Account of the Construction of the new National Standard of Length, and its Principal Copies*, that if $\mathfrak{Y}$ represents the length of the yard in abstract idea, the mean length of the five yards was originally, in 1853,

$$\mathfrak{Y} + \overset{m.y}{0{\cdot}08}$$

ou re-comparing the bars in 1864, he assumed that the mean length had not altered, and thus determined the length of the Ordnance copy of the Standard Yard to be

$$\mathbf{Y}_{55} = \mathfrak{Y} - 0{\cdot}40$$

The Toise is the *Toise of Peru*, at the temperature of
$13^{\circ}{\cdot}00$ *Reaumur* = $16^{\circ}{\cdot}25$ *Centigrade* = $61^{\circ}{\cdot}25$ *Fahrenheit.*

The original Toise was constructed in 1735 for the measurement of the Arc of Peru; in 1823 it was compared with Bessel's Toise, and in 1852 with the Prussian Toise No. 10, and with the Belgian Toise No. 11, which were compared by Captain Clarke with the English and other standards in 1864.

The Metre is by definition 443·296 "lignes" of the *Toise of Peru*, and it would appear "that the platinum bars which were to represent the metre at the temperature of melting ice, "($0^{\circ}{\cdot}00\ C = 0{\cdot}00\ R = 32^{\circ}{\cdot}00\ F$) were laid off from the *Toise of Peru* at 13°· Reaumur, allow-"ance being made for the contraction of the bars, according to the rate of expansion of plati-"num, as ascertained by Borda."

* See Captain Clarke's *Comparisons of Standards of Length*, page 270.

RELATIVE LENGTHS OF STANDARDS.

Standards.		Expressed in Terms of the standard yard. — Y.	Expressed in Inches. — Inc. = $\frac{1}{36}$ Y.	Expressed in Lines of the Toise. — Line = $\frac{1}{864}$ T.	Expressed in Millimeters. — Millimeter = $\frac{1}{100}$ M.
Indian 10-feet bar A at temperature,	62°·00 F	3·333 318 86	119·999 479	1351·148 21	3047·959 42
Indian 10-feet bar **B** ,,	62 ·00	3·333 314 57	119·999 324	1351·146 47	3047·955 50
,, ,, $\mathbf{I}_S$,,	62 ·00	3·333 401 38	120·002 450	1351·181 66	3048·034 88
,, ,, $\mathbf{I}_B$,,	62 ·00	3·333 532 84	120·007 182	1351·234 95	3048·155 08
Ordnance 10-feet bar $\mathbf{O}_1$,,	62 ·00	3·333 337 17	120·000 138	1351·155 63	3047·976 16
Russian double Toise **P** ,,	61 ·25	4·263 007 98	153·468 287	1727·994 19	3898·059 52
Ordnance copy of standard yard, $\mathbf{Y}_{55}$,,	62 ·00	0·999 999 60	35·999 986	405·346 06	914·391 43
The Yard		1·000 000 00	36·000 000	405·346 22	914·391 80
The Toise		2·131 511 16	76·734 402	864·000 00	1949·036 32
The Metre		1·093 623 11	39·370 432	443·296 00	1000·000 00

7.

The relations of the Foot **IF**, *and it's sub-divisions, to the* 10-*feet Standard* **A**.

The lengths of this bar and it's sub-divisions, relatively to the standard yard Y_{55} have been very carefully determined by Captain Clarke, See *Comparisons of Standards, Chapter XIX.* The 13 inch lines are marked *a, b, c, d, e, f, g, h, k, l, m, n,* and *p*. The definite values of the entire length and of the different spaces are as follows:—

$$\begin{aligned}
& && m.y \\
[a{\cdot}p] &= \tfrac{1}{3}\, Y_{55} &+& 2{\cdot}91 \pm 0{\cdot}134 \\
[a{\cdot}b] &= \tfrac{1}{36}\, Y_{55} &-& 1{\cdot}41 \pm {\cdot}076 \\
[a{\cdot}c] &= \tfrac{2}{36}\, Y_{55} &+& 0{\cdot}14 \pm {\cdot}098 \\
[a{\cdot}d] &= \tfrac{3}{36}\, Y_{55} &+& 0{\cdot}91 \pm {\cdot}083 \\
[a{\cdot}e] &= \tfrac{4}{36}\, Y_{55} &-& 0{\cdot}11 \pm {\cdot}112 \\
[a{\cdot}f] &= \tfrac{5}{36}\, Y_{55} &+& 0{\cdot}01 \pm {\cdot}108 \\
[a{\cdot}g] &= \tfrac{6}{36}\, Y_{55} &-& 0{\cdot}19 \pm {\cdot}095 \\
[d{\cdot}l] &= \tfrac{6}{36}\, Y_{55} &-& 0{\cdot}01 \pm {\cdot}134
\end{aligned}$$

The corresponding values in terms of the 10-feet Standard **A** will be as follows :—

$$\begin{aligned}
& && m.y \\
[a{\cdot}p] &= \tfrac{1}{10}\, A &+& 4{\cdot}22 \\
[a{\cdot}b] &= \tfrac{1}{120}\, A &-& 1{\cdot}30 \\
[a{\cdot}c] &= \tfrac{2}{120}\, A &+& 0{\cdot}36 \\
[a{\cdot}d] &= \tfrac{3}{120}\, A &+& 1{\cdot}24 \\
[a{\cdot}e] &= \tfrac{4}{120}\, A &+& 0{\cdot}33 \\
[a{\cdot}f] &= \tfrac{5}{120}\, A &+& 0{\cdot}56 \\
[a{\cdot}g] &= \tfrac{6}{120}\, A &+& 0{\cdot}47 \\
[d{\cdot}l] &= \tfrac{6}{120}\, A &+& 0{\cdot}65
\end{aligned}$$

8.

The relations of the 6-inch brass scale A, and of the corresponding scales which are employed in the measurements of the base-lines, to the 10-feet Standard **A**.

The method by which it was orginally intended to determine the relation of the 6-inch to the 10-feet standards, appears to have been as follows. The two 6-inch scales *A* and *B* and the two 10-feet bars **A** and **B** were compared in India in 1834-35; *B* and **B** were taken to England in 1843 by Colonel Everest, and were compared, the former with the Ordnance scale of 60 inches by Troughton and Simms, the latter with the Ordnance 10-feet bar O_1, with which the scale of 60 inches was also compared; thus the relations of *A* to **A** might have been determined. The comparisons in England are given at page 100 of the *Account of the Measurement of the Lough Foyle Base*, but they are not satisfactory, and have never been used; and until the year 1867 the short standard was assumed to be exactly equal to the twentieth part of the long standard. It was then compared with the central 6-inch space of the new standard Foot **IF**, the relation of which to the 10-feet standard **A** has been given in the preceding section of this chapter.

Before indicating the result of this comparison, it is necessary to state that the standard 6-inch scale was originally constructed for the purpose of determining the exact lengths of the compensated 6-inch microscopes which are employed in the measurements of base lines with the Colby Apparatus. The inconvenience of having only one scale of reference for several microscopes was found to be so great, at the measurement of the first base-line, that Colonel Everest caused seven new scales to be constructed, which were precisely similar in all respects to the standard, and were carefully compared therewith, in 1835, see *page* 284 *of Colonel Everest's Arc Book of* 1847.

In 1867 the microscope scales, as well as the standard, were compared with the central 6-inch space of the foot **IF**, and it was found that the relations of the former to the standard had altered very materially. This will be seen from the following table of the results on the two occasions, further details of which will be found in the Appendix.

	1835.	1867.	1835—1867.
	m.y	m.y	m.y
A − *M*	+ ·57	− 9·09	+ 9·66
A − *N*	− 10·08	− 17·53	+ 7·45
A − *R*	− 2·58	− 13·99	+ 11·41
A − *S*	+ 2·08	− 3·96	+ 6·04
A − *T*	+ 2·71	− 3·49	+ 6·20
A − *U*	− 7·86	− 15·58	+ 7·72
		Mean	+ 8·08

On the other hand the following table shows, that the mutual relations of the microscope scales, as determined by comparing each scale with the mean of all, on the two occasions, had not altered materially, as the differences do not exceed what is possibly due to errors of observation, and to personal equation.

	1835	1867	1835—1867
	m.y	m.y	m.y
M — mean of scales,	− 3·10	− 1·52	− 1·58
N — ,,	+ 7·55	+ 6·92	+ 0·63
R — ,,	+ 0·05	+ 3·38	− 3·33
S — ,,	− 4·61	− 6·65	+ 2·04
T — ,,	− 5·24	− 7·12	+ 1·88
U — ,,	+ 5·33	+ 4·97	+ 0·36

The alteration in the length of the Standard scale is believed to be due to the displacement of the centre of one of the two terminal dots which is known to have been inadvertently burnished, instead of being dusted only, when the scale was employed in certain comparisons in 1862.

Assuming the mean length of the microscope scales to have been the same on both occasions, but the Standard to have been 8·1 *m.y* longer on the first than on the second occasion the relations to **A** will be as follows:

$$A = \frac{1}{20}\mathbf{A} + 3{\cdot}2 \text{ m.y, in } 1835$$

$$A = \frac{1}{20}\mathbf{A} - 4{\cdot}9\text{, in } 1867$$

Having the microscope scales, we are able to dispense with the standard 6-inch scale in the reduction of the microscope lengths to the unit of the 10-feet standard **A**, at all the base-lines, with the exception of the one at Calcutta, which was measured before the microscope scales were constructed.

In the corrections for unit the mean length of the microscope scales will be assumed to be unaltered, but the relative length of each to the mean of all will be given two values; the first value will be that which was determined in 1835, and has already been used in the calculations of the lengths of all base-lines measured before 1867, calculations which it is not desirable to disturb; the second value will be the mean of the two determinations in 1835 and in 1867, and it will be employed in the calculations of the base-lines measured after 1867.

Table of the adopted relations of the microscope scales to the 10-*feet Standard* **A**.

Scale	Before 1867	After 1867
	m.y	m.y
M	$\frac{1}{20}$ **A** + 2·6	$\frac{1}{20}$ **A** + 3·4
N	" + 13·3	" + 13·0
P	" + 12·9	" + 12·9
R	" + 5·8	" + 7·5
S	" + 1·1	" + 0·1
T	" + 0·5	" − 0·5
U	" + 11·1	" + 10·9
V		" − 3·7
W		" − 1·3

Microscope *P* was in England for repair in 1867; *V* and *W* are new microscopes which were first employed at the base-lines measured after 1867.

9.

The relation of inch [7·8] *of Cary's* 3-*feet brass scale to the* 10-*feet Standard* **A**.

In 1869 this inch was compared with inch [*a*.*b*] of the Standard Foot **IF**, and the result was as follows (see *Appendix to this volume.*)

$$[7.8] = [a.b] - \overset{m.y}{13·4}$$

but by section 7 of this Chapter

$$[a.b] = \frac{1}{120}\mathbf{A} - 1·3$$

therefore

$$[7.8] = \frac{1}{120}\mathbf{A} - 14·7$$

SECTION II.

THE MEASUREMENT

OF THE

BASE LINES.

THE MEASUREMENT OF THE BASE-LINES.

CHAPTER IV.

Preliminary Observations.

The immense extent of the triangulation of India has necessitated the measurement of several base-lines, in order to verify and controul the results of the angular measures.

The net-work of triangulation which was thrown over southern India, between the parallels of 8° and 19° of latitude, by Colonel Lambton, covers an area of 146,000 square miles, in which nine base-lines were employed, the distances apart, of contiguous base-lines, varying from 90 to 250 miles.

The meridional and longitudinal series of principal triangles, which were initiated by Colonel Everest in place of the previous net-work system of triangulation, are already equivalent to a chain of triangles somewhat more than 15,000 miles in length, and they will attain a length of 17,500 miles when the operations, from the Coasts of the Peninsula northwards to the Himalayan Mountains, and from the Soolimani and Beloochistan Ranges eastwards to the Frontier of Bengal, will be completed. The whole of these chains of triangulation will be controlled by ten base-lines, five of which are situated on the central meridional arc—the axis of Indian Geodesy—at the points where it is crossed by the longitudinal chains of triangles, the remainder are situated at the angles of junction of the external chains with each other, and with the most important of the meridional and longitudinal chains. The distances from base to base, along the chains of triangles by which they are directly connected, vary from 275 to 750 miles;—thus in this portion of the triangulation, the base-lines are much farther apart, and far less numerous, relatively to the extent of the operations, than in the preceding portion.

The change, in the method of procedure, from throwing a net-work of triangulation over the entire country, to constructing chains of triangles, at convenient intervals apart, on certain obligatory meridians and parallels, was contemporaneous with the supercession of the old instruments by new and improved instruments—constructed with all the accuracy and refinement of modern science—with the application of more delicate and systematic methods of observation, and with the introduction of more rigorous formulæ of calculation and reduction.

These important changes took place about the year 1832, shortly after Colonel Everest's return from a visit of several years duration to Europe, which he had turned to good account in obtaining new instruments for the prosecution of the operations of the Trigonometrical Survey of India.

Of the new instruments, the most important, in it's superiority over the corresponding appliances of former times, was probably the Colby apparatus of compensation bars and microscopes, for the measurement of base-lines. All Colonel Lambton's base-lines, as well as Colonel Everest's up to the year 1826, had been measured with a steel chain by Ramsden, whereas all subsequent base-lines have been measured with a far superior apparatus, which was constructed on the pattern of the one designed by Colonel Colby for the use of the Ordnance Survey of Great Britain; some of the chain base-lines have also been re-measured with this apparatus.

Thus the linear operations may be divided into two groups, which must be noticed separately, one comprising the base-lines which were measured with chains, the other comprising those which were measured with the apparatus of compensation bars and microscopes. It is desirable that these should be described in succession, and this will now be done, commencing with the group of base-lines which were first measured.

CHAPTER V.

The Base-Lines which were measured with Chains.

1.

Description of the Chains.

At page 50 of his *Account of the Measurement of an Arc of the Meridian between the parallels of* 18° 3′ *and* 24° 7′, *London,* 1830, Colonel Everest observes that

"in the commencement of the Great Trigonometrical Survey under my predecessor, in 1799, one steel chain by "Ramsden was the only measuring apparatus. The history of this was rather singular. It had been sent, with Lord "Macartney's embassy, as a present to the Emperor of China, and, having been refused by that potentate, it was made "over by his Lordship to the Astronomer Dr. Dinwiddie, who brought it to Calcutta for sale, together with the zenith "sector (a beautiful instrument *for that time*) by Ramsden. The purchase of both was made by Lord Clive, [afterwards "Earl Powis,] the Governor of Madras, at the instance of the Earl of Mornington, Governor General of India."

"About this chain nothing was known but from the verbal account of Dr. Dinwiddie, who stated that it was "set off from Ramsden's bar at 62° of Fahrenheit. It was constantly used as a measuring chain, and no means were "known of discovering the quantity to be allowed for wear and tear until May 1802, when another steel chain was "received from the late Mr. Ramsden, which had been set off at the temperature of 50° Fahrenheit from his bar. The "last chain was never used in the field, but reserved as a standard with which the old chain was compared, both before "and after the measurement of a base-line; a plan which answered extremely well, as long as it was merely subjected "to the slight effects of friction which resulted from such short trials; but in the course of the operations it was found "that the joints of the standard chain had become oxidated, and, in cleaning these, the length became altered, so "that it could no longer be relied on as an invariable standard.

"At the time of the receipt of the new chain, the standard brass scale, three feet in length, referred to by "Captain Kater in the Philosophical Transactions for 1821,* arrived also in India, and the late Lieutenant-Colonel "resolved to use this in his future comparisons."

The chain, of curious history, with which the operations of this Survey were commenced, is thus described by Colonel Lambton; †

"The chain is of blistered steel, constructed by Mr. Ramsden, and is precisely alike, in every respect, with that "used by General Roy in measuring his base of verification on *Rumney Marsh.* It consists of 40 links of 2½ feet each, "measuring, in the whole, 100 feet. It has two brass register heads, with a scale of six inches to each; these scales "slide in the brass heads, and are moved by a finger screw, for the purpose of adjusting exactly the two extremities of "the chain when extended. In short every part of it is the same as the one above mentioned, which has been fully "described in the Philosophical Transactions of 1790."

The second chain, which was received in the year 1802, was also constructed by Mr. Ramsden, and was probably similar in all respects to the first; it was stated to have been measured off from "the standard in London," at the temperature of 50° Fahrenheit, and as there was no positive information regarding the unit of length of the first chain, the second was employed as a standard of reference only, and was not used in measuring any of the base-lines;

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* For further details regarding this scale see Section 1 of Chapter I, of this volume.

† See page 321 of volume 7 of Asiatic Researches, Calcutta, 1801.

thus it served the two-fold purpose of affording a unit of measure—which at the time was supposed to be invariable—and of determining the correction for the elongation, by wear and tension, of the old chain with which the measurements were made, and which was invariably compared with the standard chain, before and after each measurement.

2.

The method of using the Chains.

Several strong wooden pickets were prepared, of three inches in diameter, and from three to four feet in leugth, hooped and shod with iron; each picket was capped by a piece of hard wood, eight inches in length and four in breadth, for the purpose of receiving and supporting the ends of the 'coffers'. The coffers, in which the chains were supported during the measurement, were a few inches less than twenty feet in length, and were six inches wide in the middle, three at the extremities, and about four inches deep; they were constructed of planks, the sides being seven inches in depth, and passing two inches below the bottom plank, in order to increase the rigidity. The brass register heads, carrying a graduated slider which was moved by a slow motion screw, were each mounted on a strong picket, and were set up at the end of every successive length of 100 feet. In stony ground, tripods were used instead of pickets, the heads of the tripods being fitted on a 'common wooden press screw', to permit of their being raised or lowered.

The measurement was made in hypothenusal lengths; the pickets or tripods were first aligned in the direction of the base, their tops were then made parellel to the hypothenuse, and the coffers were put on them; the coffers were all of the same thickness, and formed the plane in which the chain was to be extended. The rear end of the chain was attached to a drawing post beyond the rear register, to which it could be drawn, by a screw, until the extremity of the chain coincided with any required line on the register; the chain was drawn out in the coffers by the weight of an 8½ inch shell suspended from its advanced extremity; the rear end was then adjusted over the corresponding register, after which a register was adjusted under the advanced end.

Five thermometers were put into the coffers, one into each, and allowed to remain there "for some minutes, a cloth at the same time covering them". They were then taken out and the mean temperature was recorded.

Colonel Lambton states that, in the measurement of the first base-line at Bangalore, in 1800,

"when any hypothenuse was terminated, a line, with a plummet, was let fall from the arrow upon the feather "edge of the chain; and the point, on the ground, was marked, which was defined by the point of the plummet (for a "brass register head was there unnecessary) and the height of that extremity of the chain, from the ground, was "carefully taken. The new hypothenuse, therefore, commenced from that same point, and the arrow at the beginning "of the next chain was made to coincide with a plumb line falling to the said point."

At the subsequent base-lines, a special apparatus was made for marking the points at which it was necessary to carry on the measurement at a higher or lower level than that of the termination of the last length measured; but the transfer of the terminal extremity of a length to the register, and from the register to the initial extremity of the subsequent length, was always done by means of "a plumb line freely suspended."

In some instances Colonel Lambton dispensed with the use of the coffers, and put the chains on the ground, which was first carefully prepared by having all impediments removed and all hollows filled up. The registers were inserted into leaden slabs, sunk into the ground, and the extremities of the chain were drawn out by a pair of small capstans, acting on pulleys, one at each end of the chain, but without any apparatus for regulating the tension, such as the weight of the 8½ inch shell which was used at the forward end when coffers were employed. Colonel Lambton was under the impression that there would be no sensible difference between the length of a base-line thus measured on the ground, or, as formerly, on coffers; and he states that "as much may be measured in one day in this manner, as can be done in "six by the coffers."

3.

The Localities of the Base-Lines.

The first operation of the Trigonometrical Survey of India was the measurement of a base-line in the vicinity of Bangalore, by Colonel—then 'Major of Brigade'—Lambton, in the year 1800. Certain particulars regarding this operation are given in Vol. VII of the Asiatic Researches, but I have been unable to find any information regarding the positions of the extremities, or to ascertain whether this base was ever connected by triangulation with the base which was measured in the neighbourhood, in 1804, by Lieutenant Warren, under Colonel Lambton's instructions. The steps which were taken for leaving permanent marks at the extremities of subsequent base-lines are so minutely described, that the absence of any such information in the present instance indicates that permanent marks were probably not constructed. This base-line appears to have been set aside, when it was found that a new line might be measured in the vicinity, on very much more favorable ground. It need not be further noticed.

The next measurement of a base-line was made in the year 1802, in the vicinity of Madras, shortly after the arrival of the second steel chain from England, which was then, and on all subsequent occasions, employed as a standard for the old chain to be compared with, before and after the measurement of any base-line.

The latitudes and longitudes of the middle points of the several chain base-lines, and the year of measurement, are given in the following table:—

MEASUREMENT OF BASE-LINES.

Year of measurement.	Chain Base-Lines.	Latitude.	Longitude.	By whom supervised.	Whether on the ground, or on Coffers.
		° ′	° ′		
1802	Madras,	12 57	80 16	Colonel Lambton.	Coffers.
1804	Bangalore,	12 57	77 42	Lieut. Warren.	"
1806	Coimbetoor,	10 58	77 43	Colonel Lambton.	"
1808	Tanjore,	10 44	79 8	"	Ground.
1809	Palamcotta,	8 47	77 43	"	Uncertain.
1811	Gooty,	15 3	77 40	"	"
1812	Guntoor,	16 17	80 31	"	Ground.
1814	Coomptee,	14 28	74 25	"	"
1815	Beder,	18 3	77 41	"	Uncertain.
1822	Takal K'hera,	21 7	77 42	"	"
1825	Sironj,	24 7	77 52	Captain Everest.	"

It is highly probable that all the base-lines in longitude 77° to 78° were measured with the aid of the coffers, as they were required for the triangulation of the 'Great Arc', where the utmost possible accuracy was aimed at; on the other hand the base-lines at Tanjore, Guntoor and Coomptee, which were measured on the ground, were considered of secondary importance.

4.

The Thermal Expansions of the Chains.

The thermal expansions were determined by Colonel Lambton, at Madras, by extending a chain in the coffers, and adjusting each of it's extremities over a register, in a manner precisely similar to the ordinary procedure of the measurement; the chain was held in this position for some days, and it's extremities were compared with the registers at sunrise, and at 2 P. M., the coolest and hottest times of the day.

Seven comparisons were thus made with each chain the diurnal ranges of temperature varying from 25° to 42°, between the minimum of 80° *(Fahrenheit)* and the maximum of 124°. The resulting linear expansions, on the entire length of 100 feet, and the co-efficients, for 1° of temperature, were as follows:—

		inch		
Old chain	*Expansion*	·00737	*Co-efficient*	·000,006,14
New, or standard chain	"	·00742	"	·000,006,18

These results are remarkable for their close approximation to the expansions of steel bars, which have been obtained by very much more delicate and laborious processes; thus the co-efficient of expansion of the Steel Standard I_S is ·000,006,37; see *page* 19 *of this volume.*

5.

Comparative lengths of the old chain and the new or standard chain.

The comparisons appear to have been made by placing the chains successively in the coffers, and, when extended by the weight of the 8½ inch shell, adjusting one extremity over a register, and bringing a register under the other extremity, by means of the slow motion screws, as in the ordinary operations of the measurement. The results are as follows, the old chain being invariably the longer of the two.

Year.	Base-Line or Locality.	Excess of old chain in inches. Before the base-lines.	After the base-lines.	Mean.	Lengthening of old chain during measurement of a base line.
1802	Madras Base,	·04346	·05306	·04826	·00960
1804	Bangalore ,,	·07428	·08592	·08010	·01164
1806	Coimbatoor ,,	·08736	·12012	·10374	·03276
1809	Palamcotta ,,	·14256	·18767	·16513	·04511
1811	Gooty ,,	·14616	·17376	·15996	·02760
1813	Bellary			·19560	
1814	Hyderabad			·21072	
1815	Bider Base,	·21072	·21936	·21504	·00864
1822	Takal K'hera ,,	·20904	·22476	·21690	·01572
1825	Sironj ,,	·22981	·23833	·23407	·00852

No comparisons were made at the Tanjore, Guntoor, or Coomptee base-lines.

6.

Investigations of supposed variations in the length of the standard chain.

It will be noticed that the old chain was steadily gaining in length over the standard until the year 1811, when the excess was found to be less than it had been in 1809. This circumstance led Colonel Lambton to suspect the hitherto assumed invariability of the standard chain, and he determined to test the standard by comparing it with his only other standard of length, viz., the 3 feet brass scale by Cary. At Bellary, in 1813, Colonel Lambton caused a wall to be built, 2½ feet high, 2 feet thick, and 106 feet long, of brick and mortar, well leveled and plastered with the finest 'chunam'. A series of brass 'buttons' was inserted into the surface of the wall, in a straight line, the first five at 2½ feet, the remainder at 10 feet asunder. A space of 2½ feet was than taken off the scale with a beam compass, and transferred to the wall until the first 10 feet were marked off on the buttons; this 10 feet was then set off, in successive spaces, by a large beam compass, until the whole hundred feet had been attained. Tents had been previously pitched over the entire length of the wall, and the chain and the five thermometers had been kept by the side of the wall for several hours previously.

Immediately after the length of one hundred feet had been laid off, the chain was extended, at full length, on the wall, in the usual manner, one end being fixed firmly, and the weight being applied to the other end. The chain was found to exceed the length marked off on the wall, by ·0341 inches, the mean temperature indicated by the thermometers being 72°.

Colonel Lambton was under the impression that Cary's (brass) scale was of the exact length of a brass standard in London, and that the chain, when originally constructed, measured exactly 100 feet of the London standard, at the temperature of 50°. On these assumptions, he reduced the result of the above comparison to the temperature of 50°,* and thus found the length of the chain to be ·1430 inch in excess of 100 feet of the London standard, at that temperature.

At Hyderabad, in 1814, Colonel Lambton again compared the chain with Cary's scale, in much the same manner as he has done at Bellary, but the comparisons of the chain with the space laid off on the wall were made three times, on successive days, instead of once only, the wall being assumed to be unaffected by changes of temperature.

Similar comparisons were again made at Hyderabad, in 1821, under Colonel Lambton's superintendence.

At Sironj, in 1825, the chain was again compared with Cary's scale, in much the same manner as on the former occasions, but by Captain Everest, whose account of the operation and the results are given at pages 51, 52, and 124 of his Arc Book of 1830; instead of a wall, Captain Everest employed "large slabs of sand-stone, ten feet long, supported on stone pillars, "under the idea that they might be less liable than the masonry to be affected by the changes "of temperature which took place during the measurement".

The excess of the chain over one hundred feet of the standard scale, as reduced to the temperature of 50° Fahrenheit, on these several occasions, was as follows :—

at Bellary,	in 1813,	excess	=	·1428	inch,
at Hyderabad,	in 1814,	„	=	·1889	„
at „	in 1821,	„	=	·2480	„
at Sironj,	in 1825,	„	=	·1593	„

While the length of the chain appeared to be increasing, relatively to that of the scale, this was supposed to be due to the removal of rust from the joints of the former; but the apparent decrement in length, at the last comparison, raised a suspicion that the accuracy of the whole of the comparisons was exceedingly questionable. Nothing better was practicable at the time and with the available appliances. But it is clear that any measuring chain, however perfectly constructed, must necessarily be a most uncertain standard of reference for delicate

* Employing the following co-efficients of expansion, ·000,006,18 for the chain, and ·000,010,31 for the scale, for 1°· of Fahrenheit.

measures; the joints may rust, or became clogged with dust, the friction of the chain on the surface on which it is supported may prevent it's being always drawn out to the same length by the drawing weight, the action of the weight has a tendency to increase the length of the chain, and the temperature of the chain cannot be very exactly ascertained.

Moreover the transfer of the length of a fractional portion of a small scale, by successive operations, until a length of one hundred feet has been laid off, and that with the aid of beam-compasses only, is a process which cannot be expected to lead to results of the precision that is required for operations of this nature.

If we might assume that the comparative length of the standard chain and Cary's scale had been accurately determined by these operations, there would still be no evidence forthcoming, as to whether the chain had increased in length, in the interval of eleven years, between it's arrival in India, and the time when it was first compared with the scale, for the unit of length of the scale was merely *assumed* to be equal to that of "the London standard," from which the chain had been laid off by Mr. Ramsden, and the relative lengths of these two scales does not appear to have ever been directly determined.

The chain was eventually compared, by Colonel Everest, in 1832, with the 10-feet iron Standard Bar **A**, which was sent out to India in 1830, and has ever since been the unit of measure of the Trigonometrical Survey. The comparisons are described in detail at pages CI to CIII of Colonel Everest's Arc Book of 1847. The excess of the chain over ten lengths of this standard, at the temperature of 62°, was found to be = ·1011 of an inch.

7.

The impossibility of ascertaining the unit of length of the chain base-lines, otherwise than by re-measurement.

The uncertainty which exists regarding the invariability of length of the standard chain, and the impossibility of ascertaining the length of that chain in terms of the only other standard—Cary's 3-feet scale—with much exactness, have already been set forth in the preceding section; and these facts are sufficient to show that the unit of length of the chain base-lines cannot possibly be obtained otherwise than by re-measuring the lines with better instruments. But, in order to complete the history of this subject, it is necessary to state that, on the publication of Captain Kater's paper in the Philosophical Transactions of 1821, Colonel Lambton ascertained, for the first time, that the unit of length of "the London Standard", from which the chain was laid off, was not the same as that of Cary's scale. Captain Kater had arrived at the conclusion that the former was to the latter in the proportion of ·999930 to 1·000018, all measurements by the former requiring a multiplier of 1·00007, and by the latter a multiplier of ·999982, to reduce them to units of "Mr Bird's scale of 1760," which had been adopted as the Parliamentary or Imperial Standard, by Act 5 of George IV, Chapter LXXIV.

Captain Kater, however, had not compared either of these standards with the Parliamentary Standard, but instead thereof* he had employed "a standard *supposed to represent* Colonel Lambton's, and a 40-inch bar *supposed to represent* Ramsden's". Thus the comparisons are wholly inconclusive.

Another point of still greater importance is the uncertainty which exists as to whether the standard chain was laid off from Ramsden's brass scale, as Colonel Lambton believed or from Ramsden's Prismatic cast-iron bar—which was laid off from his brass scale expressly for laying off the chains which were used in the Ordnance Survey base-lines—as Captain Clarke thinks most probable.† Colonel Lambton, in one of his papers, alludes to the scale and the bar indifferently as if they were one and the same thing; and in a memorandum on the subject of certain corrections which he applied to the Arc between 8° 9′ 38″ and 10° 3′ 24″, to reduce it to the Parliamentary Standard, by means of Captain Kater's determinations, he states‡ that the standard chain had been "laid off from Ramsden's *Bar*, at the temperature of 50°". §Colonel Everest also, in the paragraph quoted in the first section of this chapter, specifies the bar, and not the scale, but, on the other hand, he has corrected his chain base-lines as if the scale had been employed. It seems probable that Colonels Lambton and Everest were neither of them aware that the bar and the scale were two different things. As the measurements were finally reduced to the normal temperature of 62°, and the *bar* was of cast-iron, while the *scale* was of brass, the uncertainty from this cause is equivalent to a doubt of about 7° in the mean temperature of the measurement.

It is thus clear that the only means of determining the unit of length of the chain base-lines was by re-measuring them, with the admirable apparatus which Colonel Everest brought out to India in 1830, in supercession of the chains and standards which had been employed up to that time.

It may also be shewn that, even when the unit of length of the standard chain was best determined—*viz.*, by Colonel Everest's comparisons at Sironj, in 1832, with the new 10-feet standard bar **A**, when micrometer microscopes were first employed in the comparisons —the results were unsatisfactory, evidently because of the intrinsic defects of the chains. The comparisons between the measuring and the standard chains, before and after the base-line measurements—the results of which have been given in a preceding section of this Chapter—indicate that the lengthening of the former was by no means as uniform as might be expected, being very much greater for the operations in 1806 to 1811 than it was either before or afterwards. Thus a doubt is thrown on the accuracy of the comparisons.

And it would also appear that the measuring chain was stretched out to a greater length during the comparisons than it was during the measurements, for the length of the Sironj Base,

* See page 5 of Mr. Airy's *Account of the Construction of the new National Standard of Length and it's Principal Copies*, 1858.

† See pages 753 and 754 of the *Account of the Principal Triangulation of the Ordnance Survey*, 1858, and pages 209 to 212 for the account of the Prismatic Bar and it's thermal expansion.

‡ See page 18 of the 6th volume, in manuscript, of the operations of the Trigonometrical Survey, a copy of which is lodged in the India Office.

§ See pages 126, 129, and 132 of his Account of the Indian Arc, 1830 as determined by the chaining, is 2·8 feet less* than the length subsequently determined by the apparatus of compensation bars and microscopes, both lengths being expressed in terms of the same unit, viz., the newly obtained 10-feet standard bar.

Taking all these circumstances into consideration, the conclusion is inevitable and irresistible that the chain base-lines are worthless for the purpose of controlling the Principal Triangulation of this Survey, and more particularly that great portion of it which has been completed since the year 1830, with the best modern instruments. They have served the purpose for which they were more immediately required, but they have been superceded by the base-lines which were subsequently measured with the Colby apparatus of compensation bars and microscopes; thus they need not now be further noticed†.

* See Colonel Everest's Arc Book of 1847, pages CIV and 280.

† All extant details regarding these base-lines will be found in the first 6 volumes of the General Report of the Trigonometrical Survey, which are deposited at the India Office in manuscript; in volumes VII, VIII, X, XII, XIII of the Asiatick Researches, in the Philosophical transactions for 1818 and 1823, and in Colonel Everest's Accounts of the measurement of the Indian Arc, 1830 and 1847.

CHAPTER VI.

The Colby Apparatus of Compensation Bars and Microscopes.

1.

Description of the Apparatus.

The apparatus of compensation bars and misroscopes which was brought out to India by Colonel Everest, and has been employed at all the base-lines which have been measured in the course of the operations of this survey since the year 1830, is precisely similar, in almost all respects, to the apparatus which was invented by Major General Colby for the measurement of the base-lines of the Ordnance Survey; both apparatuses are believed to have been constructed by the same makers, viz., Messrs. Troughton and Simms. Elaborate descriptions thereof, with numerous illustrations and full details of the method of operation, have already been published in Captain Yolland's *Account of the measurement of the Lough Foyle Base*, 1847, in Colonel Everest's *Account of the measurcment of the Meridional Arc of India*, 1847, in Captain Clarke's *Account of the Principal Triangulation of the Ordnance Survey*, 1858, and in Sir Thomas Maclear's *Verification and Extension of La Caille's Arc of Meridian*, 1866. A minute description of the several parts of the apparatus and of the method of operation is therefore unnecessary in this place, where such particulars only need be given as are required for the understanding of the investigation of the probable errors of base-lines measured with this apparatus, which will be the subject of the following Chapters.

Each compensation bar consists of two bars, one of iron the other of brass, each 10·1 feet in length, ·55 inch broad, 1·5 inch deep, and placed 1·3 inch apart; rigidly connected at their centres by a pair of small transverse steel cylinders, these bars are free to expand from or contract towards their centres, independently of each other; at each extremity they are connected together by a flat iron tongue—6·3 inches in length, ·25 inch thick, and of a breadth tapering from 1·1 to ·6 inch—which is attached by pivots, in such a manner as to permit the bars to expand freely while the tongue oscillates on the pivots; the attachment to the brass bar is made near the broad end of the tongue, while the narrow end projects to a distance of 3·4 inches beyond the iron bar.

The compensation point is marked on a silver pin near the extremity of each tongue; the distances of this point from the axes of the pivots of attachment to the brass and iron bars, should be exactly in the same proportion as the co-efficient of expansion of the brass bar is to that of the iron bar. Were this condition fulfilled, the length of the compound bar—viz., the distance between the compensation points on the two tongues—would be constant, whatever might be the temperature of the bar, provided that both the components were of precisely the same temperature; the length is, by construction, slightly greater than that of the 10-feet standard, at 62°F.

The compound bar is boxed into a deal case, and each of the components rests—at one fourth and three fourths of it's length—on brass rollers which are fixed to the bottom of the box, and have raised flanges to prevent lateral motion; longitudinal motion is prevented by means of a brass stay, fixed firmly to the bottom of the box at its centre, and projecting upwards between the two steel cylinders by which the bars are rigidly connected at their centres. Here a spirit level is attached, parallel to the direction of the bars, and is read through a glass window in the lid of the box; a pair of cross levels is mounted on the top of the box. The tongues project about two inches beyond the side of the box which is next to the iron bar, and are protected by brass caps or 'nozzles', with sliders which can be opened whenever the compensation points have to be viewed.

There are six compound bars, which are respectively distinguished by the letters A, B, C, D, E, and H. When in use, the box containing a compensation bar is supported, at one fourth and three fourths of its length, on strong brass tripods, or 'camels', which are capable of communicating motion in a longitudinal, transversal, or vertical direction; for a description of these camels see *Appendix No.* 1; they rest on strong diagonally-braced wooden trestles, the heights of which are regulated by the slope of the ground.

The compensation microscope consists of a pair of microscopes which are attached—with the visual axes nearly parallel to each other and at a distance of about six inches apart—to two parallel bars, the planes of which are perpendicular to the axes of the microscopes, the bar near the eye end being of brass, and that near the object end of iron, and both being free to expand from or contract towards their centres; the adjustments are so made that the outer foci of the object glasses are compensation points at exactly six inches apart. The bars are united, at their centres, by a cylindrical tube, which is fixed at right angles to their direction, and is prolonged—beyond the iron bar—to a length of 3 inches, which fits into and is made to revolve, as an axis, in the socket of the tribrach at the base of the instrument. At the extremities of the arms of the tribrach there are foot screws, by which, and the attached level, the axis, revolving in it's bearings, can be made vertical. In some of the compensation microscopes, the axial tube is converted into a look-down telescope, by the addition of an eye piece, at one end, and an internal sliding tube—adapted to receive object glasses of various focal lengths—at the other end. The axis is capable of being moved, over the centre of the tribrach, both in a longitudinal and in a transverse direction, by slow motion screws, acting on horizontal plates in grooves on the head of the tribrach. Thus the instrument may be centered in the normal of an obligatory point below, with the aid of the look-down telescope. The axis of rotation is indicated to the alignment officer by a 'director', a thin bar—about 2·5 inches in length and ·3 inch in breadth, with a fine silver line down the middle—which is fixed, at right angles, to a circular plate of the same diameter as the cap of the eye piece of the look-down telescope, and, projecting through it, fits into the aperture of the eye piece; the silver line on the director is in the prolongation of the axis of rotation of the instrument.

The visual axes of the component microscopes are so adjusted that a line joining their external foci, or compensation points, would pass through the axis of rotation at right angles; a 'side telescope', moving in a plane, parallel to that which passes through the foci and the axis of rotation, is attached to the instrument on one side, and when it is made parallel to the line—by a process which will be subsequently explained—and the axis is in the line, both the microscopes will also be in the line; and when the axis is vertical, the focal points will be in the same horizontal plane.

In the arrangements for comparing the microscopes with their scales, or with the standard 6-inch scale,* an important improvement was introduced by Colonel Everest,† which may be described in this place. The microscopes of the Ordnance Survey do not contain any micrometers for measuring the difference between the length of the microscope and that of the scale of reference; it is therefore necessary, in making comparisons of verification *after* a measurement, either to watch for the temperature at which the length of the scale becomes equal to that of the microscope, or to attempt to estimate the small differences in length by comparing them with the known diameters of the dots or of the wires. But at the measurement of the first base line in India—the one at Calcutta—so much inconvenience was found to arise from this imperfection of the apparatus, that Colonel Everest caused micrometers to be attached to the scales, for the purpose of measuring the distance between the dot on a scale and the wire of a microscope. The micrometer screw acts on a thin narrow brass plate, carrying a diaphragm into which a piece of transparent talc is inserted; thus the dot can be seen under the microscope through the talc; two cross lines are cut on the talc, the intersection of which is brought by the micrometer screw either over the cut on the scale, or under the wire of the microscope, the distance between which is thus measured with a degree of accuracy unattainable by mere estimation.

Two new compensation microscopes, which were received in India in 1866, are each provided with micrometers in the eye piece of one of the components, for the purpose of making these small measurements.

2.

The method of using the apparatus which has been followed in the operations of this Survey.

The apparatus is adapted to measure a length, at one time, of 63 feet, of which 60 feet

* The relative length of all these scales to the 10-feet standard have been given in Section 8 of Chapter III of this volume.

† In his *Verification and Extension of La Caille's Arc*, Sir Thomas Maclear alludes to this defect in the Ordnance Survey Microscopes as causing the comparisons to "fall short of the precision attainable by means of micrometer microscopes."

is obtained from the six bars, 2·5 feet from the five microscopes connecting the bars, and ·5 foot from the half lengths of the two end microscopes.

The measurements being invariably horizontal, and not hypothenusal, considerable care is taken to select a strip of ground, which is either quite level or is gently undulating, for the operations. The measurements are performed most rapidly and satisfactorily when the slopes permit of their being carried on with the complete set of six bars and seven microscopes, and when the differences of level between contiguous lengths are not more than a few inches. The ground is roughly leveled over, in the first instance, in order to determine the angles of inclination, that trestles, of various heights to suit the slopes, may be prepared for supporting the bars. When a slope exceeds 1 in 20, the measurement is carried on in sets of three or of two bars, with a proportional number of microscopes, in order that the stability of the apparatus may not be impaired by mounting any portion of it to a considerable height above the ground, and also that the distances of the end microscopes from the subjacent 'registers' may not be too great for the exact centering of the axis of a look-down telescope over an obligatory point below, or, conversely, for centering such a point exactly under the telescope.

The alignment is marked out, in the first instance, by points on pins at intervals of a few hundred yards apart, over which vanes are erected or heliotropes are exhibited, for the guidance of the alignment officer. This officer employs for his operations a 'boning instrument' which may be described as a transit telescope riding, on Y's, on a frame to which motion can be communicated in a direction transverse to that of the telescope, in order to enable the telescope to be brought into the alignment which is indicated by the forward signals. The boning instrument is put up near the the rear end of the measuring apparatus, and is moved forwards with the apparatus after each length or every alternate length is measured; it's greatest distance from any point of the apparatus is not allowed to exceed 2½ sets or 157·5 feet, the shortest distance usually being a half set, or 31·5 feet.

The operations are invariably conducted under tents, in order that the apparatus may be sheltered from wind and—what is of more importance in India—from the direct rays of the sun. Two sets of tents are provided, that one set may always be ready in advance to shelter the bars by the time they are moved forwards; a small tent is also provided for the boning instrument. Eight officers are required to manipulate the apparatus when the whole of the bars are used, one at the boning instrument, and one at each of the seven microscopes: an assistant is employed in advance, in laying the trestles.

The first stage in the operations is the laying of the trestles, as approximately as possible, in the line—with the aid of a small theodolite—and raising or lowering them until their heads are nearly in the same horizontal plane. This done, the camels are placed on the trestles, the bars on the camels, and the microscopes on tribrachs which are attached to the ends of the bars, and contain grooves for the feet of the microscopes to rest in without shake. The first or rear bar carries a microscope at each end, the other bars carry one at the forward end only.

The first bar of a set having been leveled, the microscopes at its extremities are leveled and each is adjusted to focus on the compensation point on the contiguous tongue of the bar;

the rear end microscope is centered in the normal of the point on the register head which marks the termination of the measurement of the preceding set of bars, the director is then placed on the eye piece of the look-down telescope, and the boning instrument is brought exactly into the line, by observations of the director and of one of the forward signals. The director is then carried forward and placed on the axial tube of the microscope at the advanced end of the bar, which is brought into the line—by the officer in charge guided by signals from the officer at the boning instrument—by means of the transverse screw at the head of the camel which supports that end of the bar. Watching the number of turns of the screw which are made for this purpose, and giving one third of that number of turns to the transverse screw of the camel under the rear end of the bar, the officer at that end is able to keep his microscope so nearly in the alignment, that, when it is subsequently brought back to it's exact position over the register, by moving the bar, the second microscope will probably not be sensibly displaced: otherwise the operation must be repeated, until the axes of rotation of both microscopes are brought into the line.

The compensation points of the bars have now to be aligned, by a process which introduces us to the 'horns' of the boning instrument. These horns are a pair of parallel bars cut out of a plate of thin metal, and firmly secured, in a vertical position, to the front of the boning instrument, one on either side of, but not touching, the telescope, which moves freely up and down between them; the distance between parallel planes passing through the inner edge of each horn and the visual axis of this telescope, is made equal to the average distance between the parallel planes passing through the visual axis of the side telescopes and the compensation points of the several microscopes. Thus when the axis of rotation of a microscope has been aligned by the boning instrument, the compensation points of the two components are brought on the line, by setting the side telescope on the corresponding horn of the boning instrument. If, when this is done, the point on the contiguous tongue of the bar is truly centered under the corresponding microscope component, the alignment of that point is correct; if not, the microscope must be brought over the point by a motion of the whole instrument, parallel to the alignment, which is communicated by means of it's transverse screw. The microscope is then brought back to the line by the transverse screw of the camel at that end of the bar. Similar operations are performed on the microscope at the other end of the bar, with this exception that it is directed into the line by the boning instrument, instead of being brought into the line by reference to a point below. These operations are repeated until, by successive approximations, the axis of rotation of each microscope, the visual axes of it's components, and the compensation points of the bar, have all been brought exactly into the line.

Then the second bar is adjusted to the height of the first and aligned, by bringing the compensation point at it's rear end into the focus, and under the centre, of the contiguous component of the microscope on the adjacent end of the first bar; the microscope and compensation point at the further end of this bar are then aligned, in the same manner as at the advanced end of the first bar. By similar processes the whole of the bars are brought successively into the line.

The measurement of the length is the last part of the process; it is complete when the look-down telescope of the rear end microscope is centered in the normal of the point on the register below, and when the compensation points of all the bars are exactly bisected by the central wires of their microscopes; a register is then centered under the look-down telescope of the microscope at the forward end of the bars, in order to mark the termination of the length of this set of bars and microscopes.

Thus the method of operation is one of successive approximations, each of which disturbs a preceding adjustment, but to an extent which diminishes with every succeeding approximation, until, finally, the residual errors should be far too small to exercise any appreciable influence on the result.

The registers are of three descriptions, viz., solid equilateral slabs of cast-iron, which are used when the ends of the apparatus are very slightly raised above the ground; cast-iron triangular frames, carrying a brass sliding tube that can be raised or lowered at pleasure, which are ordinarily employed; and stout wrought iron pins, from 18-inches to 4 feet long, which are used whenever the measurement is likely to be suspended for more than a few minutes, as at night and when the ground is soft and unsatisfactory. The heads of the two first descriptions of registers contain a single point of reference, on a brass plate to which lateral or longitudinal motion can be communicated by slow motion screws; the heads of the pin registers are larger and contain several points, in rows, each point having a number engraved beside it, to ensure it's identification, an arrangement necessitated by the difficulty of driving the pins accurately into the ground.

The differences of level between the successive sets of bars are determined by measuring the heights of the end bars above the surfaces of the registers.

3.

Comparisons of the Compensation Bars and Microscopes with the 10-*feet and the* 6-*inch standards.*

As the compensation bars and microscopes are necessarily more liable to be altered in length, by accidents and misadventures, than is a simple bar of iron or brass, they are never relied on as retaining an invariable length, but are frequently compared, the former with the 10-feet standard bar **A**, the latter with their respective 6-inch scales, in the process of the measurement of each base-line. And this is the more necessary in order to guard against the errors which may have been made in fixing the compensation points, as well as those which may arise from the brass or the iron component acquiring a different temperature to that of the other component, in the course of the ordinary diurnal variations of temperature under which the operations are carried on; it is evident that the effects of these errors will be eliminated if the comparisons with the standards are made under precisely similar circumstances to those which obtain during the measurement.

In the comparisons at the Calcutta base, which was the one first measured in India with this apparatus, and in those previous to the measurement of the second base—that at Dehra Doon—the first of the above objects was alone contemplated; the comparisons were made, not in the base-line tents, but in buildings attached to the Surveyor General's Offices at those places, and, at Calcutta, they were made during the night. But the comparisons after the two measurements of the Dehra Doon Base, and on all subsequent occasions, were made in the base-line tents, under circumstances very similar to those of the measurement,—that is to say they were commenced early in the morning, suspended for a short time and resumed before noon, and concluded in the evening, at the same times as the corresponding operations of the measurement. They have invariably been made for at least three or four days before and after each measurement, and, at the fifth base (Sonakhoda) Colonel Waugh introduced the system—which has been followed on all subsequent occasions—of making comparisons at the centre of the base, in addition to those before and after the measurement.

An equal amount of attention has not been devoted to the compensation microscopes, as the length of only the $\frac{1}{21}$st part of the base is dependent on them; each microscope has however been generally compared with its scale several times, during the course of the measurement.

The following remarks on this subject are extracted from Colonel Waugh's report (in manuscript) on the Chuch base, near Attock.

"Colonel Everest, in his work on the Indian Arc, has stated, that no dependence can be placed on the permanent length of the compensation bars. It is this uncertainty, in fact, which renders it necessary at every base-line, after every march, or any change of circumstances, to compare them with the standard. An attentive consideration of a day's comparisons will shew that their length is not constant during a single hour of the day. From sunrise their length first increases a little, and then diminishes for a time, although the temperature is increasing rapidly. After which they again expand, the heat still increasing. These alterations may be explained, almost entirely, by the effects of dissimilar radiating power in the brass and iron bars. There is a great difference between the heating and cooling capacities of brass and iron, and this difference prevents the two bars having the same temperature for any length of time. The want of identity in temperature between the metals, will apparently produce, under some circumstances, the effects of over-compensation, while in other circumstances the bars will appear under-compensated. The cause of the observed change in length appears to be the difference of temperature between the two metals in the compound bar, independent altogether of absolute temperature. The alterations in length, in fact, varying according to the rate or velocity at which the temperature of the air is undergoing change.

"A rapid change of temperature will produce a great alteration in the length of the compound bar and *vice versa*. At sunrise, under tents, the bars go on cooling for a short time, and their apparent length increases in a corresponding ratio. Then as they begin to acquire caloric, their length decreases, until both bars are uniformly heated, when the length of the compound bar increases until the hottest period of the day is attained, when the bars again begin to measure shorter as the temperature decreases. These phenomenæ are obvious from an inspection of a day's comparison at any base line. It is clear also that the fluctuations in length are independent of absolute temperature, as far as it is possible to judge. The only remedy available to us for this inconstancy in the length of the compensation bars, is to compare them with the standard under circumstances exactly indentical with those prevailing during the measurement. It is from a consideration of the vast importance of this rule, that the bars were compared at Sonakhoda and Chuch bases, at the centre of the line. For the same reason also, at this latter base, the measurement and comparisons have been divided into morning and evening sets for the purpose of computations.

4.

The lengths of the base-lines, the time occupied in their measuremeut, and the verificatory triangulation.

It will be readily understood, from the foregoing descriptions, that the operations for the measurement of a base-line, with the compensation bars and microscopes, are exceedingly tedious and laborious. This is more particularly the case at the commencement of a measurement, when the several persons employed are imperfectly familiar with the manipulation of the apparatus and each has still to learn how to execute his own share of the operations with the least possible obstruction to his coadjutors. During the first week, it rarely happens that more than six or seven sets—equivalent to about $\frac{1}{12}$th of a mile—are measured in one day. But after three or four miles have been finished, the measurement advances at the daily rate of twenty to twenty-five sets, or rather more than $\frac{1}{4}$ of a mile.

That this circumstance has exercised considerable influence in determining the lengths of the base-lines, will be seen from the following extract from Colonel Waugh's "Instructions for selecting Base-Lines."

"Scientific men entertain various opinions regarding the proper length for bases. Continental geodesists of "the greatest celebrity are in favor of short lines from 1 $\frac{1}{2}$ to 3 miles in length, and have practically carried out this "principle in modern operations. English base-lines, on the other hand have always been of considerable length, "varying in fact from 5 to 10 miles. Nothing seems to be gained by very short lines, except a trifling saving of time "and labor. It is clear that the short bases in fashion on the continent, cannot be connected with great triangles, "without several supplemental stations, which is an evil because the stations of a series should be as few as possible, "and the length of the sides of triangles ought only to be limited, by considerations connected with distinct vision of "the signals. The chief part of the expense, difficulty, and delay attending the measurement of bases, consists of "preparatory arrangements, common to short as well as long bases; such as transport of apparatus to the spot, as- "sembly of establishment from distant parts of the country, and training them to the duties. The measurement of "the first mile always occupies a considerable time, but after facility has been acquired by practice, the work proceeds "rapidly at an accelerating rate. After the first 2 or 3 miles, the measurement usually proceeds at the rate of 4 days "per mile, or even less, according to the length of day light available. Two or three additional miles seem therefore "to be a matter of small importance, as the time occupied in measurement will not be extended thereby beyond 8 to "12 days.

"In India, 7 miles is considered an average length of line, and as nothing can be gained by departing from the "example of our English predecessors and running after modern continental fashions, it appears desirable that a base "should not fall short of 6 miles, nor exceed 8 miles. The character of the ground will generally give limits to the "length of the base, for it is always difficult to obtain unexceptionable ground averaging 7 miles in length."

Of the ten base-lines which have now been measured with the apparatus of compensation bars and microscopes, all but the last are of lengths varying from 6·43 to 7·87 miles;—the last was restricted to about one-fourth only of the average length, but it was measured four times over, in order to furnish data for the determination of the probable errors of measurements with this apparatus.

The following table gives the position of each base, the length in miles and in sets, the number of working days and the average and the maximum daily progress of the measurement;

but it does not include the time occupied by the comparisons of the compensation bars with the standard.

Year of measurement.	Co-ordinates of centre.		Base-Line.	Length in.		Number of days.	Daily progress in sets.	
	Latitude.	Longitude.		Miles.	Sets.		Average.	Maximum.
	° ′	° ′						
1831-32	22 40	88 25	Calcutta,	6·43	539	45	12·0	23
1834-35	30 18	77 58	Dehra Doon, first measure,	7·42	622	50	12·4	23
1835	..	..	„ second „	..	..	31	20·1	35
1837-38	24 7	77 51	Sironj,	7·28	609	38	16·0	24
1841	17 56	77 37	Bider,	7·87	660	39	16·9	23
1847-48	26 17	88 17	Sonakhoda,	6·95	583	34	17·1	25
1853-54	33 55	72 29	Chuch, or Attok,	7·83	656	44	14·9	26
1854-55	24 56	67 13	Karachi,	7·32	613	30	20·4	32
1862-63	17 58	83 15	Vizagapatam,	6·59	552	32	17·2	22
1868	13 3	77 40	Bangalore,	6·83	574	40	14·4	23
1869	8 15	77 45	Cape Comorin, first measure,	1·68	142	10	14·2	21
			„ second „	..	..	9	15·8	22
			„ third „	..	..	7	20·3	26
			„ fourth „	..	..	7	20·3	27

All the base-lines, with three exceptions, have been divided into three or four sections, the relative lengths of which have been compared by triangulation along one or both flanks, for the purpose of verification. The exceptions are the Calcutta base, the Sironj base—which had been previously measured with the old standard chain—and the Cape Comorin base, which was measured four times with the Colby apparatus.

CHAPTER VII.

On the errors of the compensation bars and microscopes.

1.

Preliminary Observations.

Compared with the measuring chains, which were used in the early operations of this Survey, the apparatus of compensation bars and microscopes may be considered to be perfect, being as superior to the former as a first class chronometer to a village clock. Instead of a chain of short bars linked together, which is liable to alterations in length—by changes in temperature that cannot be precisely determined, by the strains to which it is necessarily subjected, and by the wear and rust of the joints—it furnishes a number of unconnected bars, the lengths of which are, comparatively, invariable, and these bars are never brought into contact with each other, but are placed at short distances apart which are measured optically; instead of plummets, it furnishes look-down telescopes, rotating with levels on their axes; and instead of verniers, unsusceptible of recognizing smaller quantities than the one-thousandth part of an inch, it furnishes powerful micrometer microscopes, in which quantities even less than the twenty-thousandth part of an inch are sensible and susceptible of measurement.

But while the power of measuring such minute quantities is the strong point and special characteristic of this apparatus—by which not only is it widely separated from such rude appliances as measuring chains, but is placed on a par with all the more modern apparatuses which have been constructed for similar purposes—this very capability has brought it's intrinsic defects into prominent display, and revealed errors which, though very minute, are systematic and force themselves into notice.

Thus a sensation of dissatisfaction with the performances of the apparatus has been experienced, to a greater or less degree, by all the officers of this survey who have been brought into contact with it, and there has always been a feeling of disappointment that the accuracy of the operations was not in keeping with the powers of micrometric measurement; * for the compensation bars and microscopes, instead of retaining a constant length under all temperatures and circumstances, are found to vary in length by amounts which, when expressed in terms of the divisions of the comparing micrometers, are frequently very considerable.

Thus Colonel Everest, at page XCIX of his Arc Book of 1847, avows it as his conviction that

> "Whereas in former years, by the use of simple glass or metallic rods, considerable deviations existed, of which "the law was known, so now by the principle of compensation, those deviations, though decimated or still further sub-"divided, seem to follow a law of which we are ignorant."

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* Colonel—now Major General Sir Andrew—Waugh, in his report (in manuscript) on the Chuch Base Line, remarks that "a "feeling of scrupulous refinement and extreme accuracy has always been cultivated in this Department, and so important has the sense of "extreme accuracy been considered, that a straining after inappreciable niceties has never been discouraged, lest in abandoning the inap-"preciable, the sense of refinement should itself be blunted."

The errors arising from these deviations have been guarded against, as much as possible, by endeavoring that the comparisons of the bars with the standard should be made under similar circumstances and conditions to those of the measurement, as has already been set forth. The verificatory triangulation, by which each section of a base-line is compared with the others, has rarely indicated discrepancies of a larger magnitude than ¼ of an inch for each mile—or the $\frac{1}{250,000}$th part— of the measurement, and this circumstance has materially tended to allay the alarm which the erratic behaviour of bars and microscopes had occasioned.

2.

On the construction of the compensation bars, and the measures taken for equalizing the thermal capacities of the components.

The variations in the length of a truly compensated bar are well known to arise from the differences of temperature of the brass and iron components of the bar. If the ratio of the expansion of the brass to that of the iron component is as 3 to 2, then the change in the distance between the compensation points, for a difference of 1° of temperature between the two components, will be three times the change in the length of the iron component for a variation of 1° of temperature; thus the compound bar may be regarded as a very accurate differential thermometer, which measures the difference of temperature of it's two components with greater precision than could be attained by any but the most delicate thermometers.

Now a brass bar has a greater capacity for heat—greater powers of radiation and absorption—than an iron bar of the same dimensions; thus the brass component of a compensation bar has a tendency to acquire the ordinary diurnal variations of temperature more rapidly than the iron component, and consequently the length of the bar is liable to corresponding variations.

These circumstances were all well known to Colonel Colby—who was the first person to apply the principle of compensation to the construction of bars for the measurement of base lines—and to his assistant, Lieutenant Drummond, who supervised the construction of the bars for the Ordnance Survey. They ascertained that, in order to produce the desired equality of temperature, it was necessary* "either to make the bars of different dimensions, or to vary their surfaces till, by means of increased or diminished radiation or absorption, the desired equality was produced." The second method was chosen, and experiments were made on the heating and cooling of brass and iron cylinders, with a view of ascertaining the best means of so coating their surfaces, "as to induce them to acquire or part with equal increments of temperature (when similarly exposed) in the same periods of time." These experiments showed that, without altering the relative dimensions of the bars, it was possible, by appropriate coatings, to reverse their normal capacities for heat, and therefore to equalize their rates of changing temperature. For this purpose the brass bars were bronzed and varnished; the iron bars were browned and lacquered, and smoked until a sufficient surface of lamp-black was obtained to produce the requisite effect, they were then varnished.

* See *Account of the Measurement of the Lough Foyle Base, pages* 9 *and* 10.

WITH THE COMPENSATION APPARATUS.

No very detailed information is forthcoming regarding the processes by which the compensation points of the bars for the Indian Survey were laid off, and the thermal capacities of the brass and the iron components were equalized. From a memorandum by Colonel Everest it appears that the bars were heated "to 180° Fahrenheit and upwards", in an oven, and then placed under a pair of microscopes, the distance between which was equal to the length of the standard bar at 62°, and

"The points were then noted which, in the course of cooling, retained the same relative positions; this operation was repeated several times on each compensation bar, and the points so determined were ultimately marked by dots on their silver disks, as neutral points."

"Coatings of varnish were partially applied, the due adhibition of which rests on trial, and is another point of difficulty in determining the nodal points."

The apparatus was completed by Messrs. Troughton and Simms in the year 1830, and was tested by a short measurement, on Lord's Cricket Ground, at which Lieutenant Drummond assisted; it appears probable that the makers availed themselves of the experience which had been acquired in the construction of the Ordnance Survey bars, to satisfy all the requisite conditions, as closely as was possible, in the construction of the bars for India.

Nevertheless the fluctuations in the lengths of the bars clearly indicate that the brass and the iron components are liable to acquire different temperatures; thus very material errors may arise when the circumstances of the comparisons of the bars with the standard are not similar to the circumstances which prevailed during the measurement. It is essentially necessary therefore to ascertain the amount of error to which a base-line measured by this apparatus is liable.

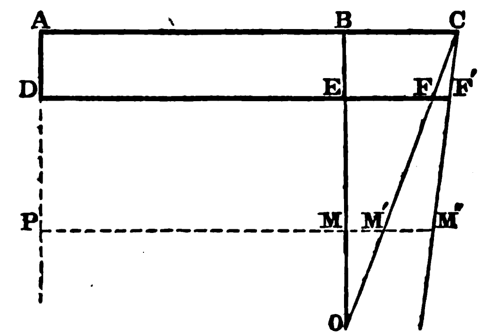
This may be done either by comparing the sections of the line by triangulation executed for that purpose, or by investigating the probable errors of every successive operation in the process of the measurement, and combining these to obtain the entire probable error, or by an examination of the discrepancies between two or more measurements of the same distance, which may have been made for the purpose of deciding this question. The two last methods are preferable, as they are independent of extraneous errors, such as are introduced in the first method, by the measurement of angles.

Colonel Everest measured his second base-line—the one in Dehra Doon—twice over; and he has given the results at pages 288 to 292 of his Arc Book of 1847; unfortunately the value of this operation is materially diminished because the comparisons of the bars with the standard, before the first measurement, were made "under a thatched building", and not in the bar tents, under circumstances as similar as possible to those of the measurement, as was done during the after comparisons at this base-line, and on all subsequent occasions.

At the Cape Comorin base—the tenth and last which has been measured with the apparatus—the probable errors of every successive operation in the process of the measurement were independently ascertained; the line was measured four times, thus furnishing additional means of ascertaining the probable error of the entire operation, but it's length was restricted to about one-fourth of the ordinary length. The results of these investigations will be indicated further on, but first it will be necessary to enter on a theoretical examination of the variations of compensation bars.

3.

Theory of the changes in the length of a compensation bar, relatively to the normal length of a standard bar.



Let A B C, D E F F' be the halves of the two components of a compensation bar, firmly fixed in the plane A D P, but free to expand or contract in length, A B C being the brass component.

Let B E M O be the axis of the tongue, O being the the true point of compensation, while M is the point marked by the maker, at a distance O M from O which is to be ascertained from the performances of the bar.

Let P M M' M'' be drawn through M parallel* to A B or D E, and let the distance P M be considered as equal to half the normal length of the compound bar, viz. the distance between the compensation points, when the temperature of both the components is 62° *Fahrenheit.*

Let the linear expansion of the brass component, for 1°*F*, be e_b

and „ iron „ „ e_i

and let M B = m, M E = n.

Then, when both components are at the temperature of T + 62°, the half length of the bar will be P M', exceeding P M by M M', and the increase of the whole bar over it's normal length will be

$$2\,\mathrm{MM'} = 2\,\mathrm{OM}.\frac{\mathrm{EF}}{\mathrm{OE}} = 2\,\mathrm{OM}.\frac{e_i}{n+\mathrm{OM}}.\ \mathrm{T} \qquad (1)$$

Thus 2 M M' is the measure of the change in the length of the compound bar for a temperature T° above the normal temperature, alike for both the components; representing this quantity, which may be called the error of compensation, by η,

$$\eta = 2\,\mathrm{OM}\ \frac{e_i}{n+\mathrm{OM}} \qquad (2)$$

Now suppose the two components to be of unequal temperatures, that of the brass bar being T_b + 62°, and that of the iron being T_i + 62°, also let

$$T_i = T_b + t \qquad (3)$$

* Strictly speaking, if the bars are parallel to each other at the normal temperature, they cannot be parallel at any other temperature; they are made to diverge by the expansion of the included portion of the tongue, and to converge by it's contraction and deflection from the perpendicular, but by amounts which cannot have any sensible effect on the results; thus at temperatures as much as 40° above or below the normal temperature, the deflection of the tongue from the perpendicular is less than 16′, while at the higher limit the angle of divergence is 1″·6 and at the lower the angle of convergence is 1″·7. The effect on the length of a bar due to the contraction or expansion of the included portion of the tongue in it's deflected positions at those temperatures would be 0·8 *m.y.*

so that the half length of the compound bar is now

$$PM'' = PM + MM' + M'M''$$

in which equation

$$M'M'' = FF' . \frac{CM'}{CF} = \tfrac{1}{2} e_i t \frac{m}{m - n} \quad \ldots\ldots \quad (4)$$

and

$$MM' = \tfrac{1}{2} \eta T_b \quad \ldots\ldots \quad (5)$$

Putting B for the normal length of the compound bar, and B′ for its actual length then,

$$B' - B = e_i t . \frac{m}{m - n} + \eta T_b \quad \ldots\ldots \quad (6)$$

Now the changes in length can only be ascertained by comparing the compound bar with a standard bar; and when the standard is at some other temperature than the normal temperature, the result will be affected by the error in the adopted value of the expansion of the standard; this error must therefore be recognized.

Let A be the length of the standard at 62° *F*, A′ its length at the temperature T + 62°, E_a its actual expansion for 1° of temperature, while the adopted value thereof is E'_a, having an error dE'_a, so that

$$E_a = E'_a - dE'_a \quad \ldots\ldots \quad (7)$$

then

$$A' - A = T_a (E'_a - dE'_a) \quad \ldots\ldots \quad (8)$$

Finally putting X = B − A, or the excess of the normal length of the compensation bar over the normal length of the standard, and putting e'_i for the adopted value of the expansion of the iron component, and de'_i for the error of that value, we get from equations (6) and (8)

$$X = B' - A' - (e'_i - de'_i) t \frac{m}{m - n} - \eta T_b + (E'_a - dE'_a) T_a \quad \ldots\ldots \quad (9)$$

Thus it is evident that in order to determine the normal relations of the compensation bar and the standard, from comparisons made at any (known) temperatures other than the normal temperature, it is necessary to know the expansion not only of the standard but of one of the two components of the bar, also the error of compensation, and the distances of the compensation points from the two components; and it appears to be more particularly necessary that the difference of temperature of the components should be accurately known, because it alters the length of the compound bar by about three times the amount that a simple bar of iron would be altered by an equal change of temperature.

4.

The data for the investigation of the changes in length of the Indian compensation bars, relatively to the length of the 10-*feet standard* **A.**

The operations which have been performed for the determination of the thermal expansion of the 10-feet standard **A**, have been fully described in sections 2, 3, and 4 of Chapter II, and the results thereof are set forth in section 8 of the same chapter. It will seen that the original value of the expansion, or E'_a, was $= 22{\cdot}67\ m.y$ for an increment of temperature of 1° Fahrenheit, this value being determined from the measured increment between the temperatures of 76° and 212°, at Calcutta, in 1832.

It will also be seen that the most probable value of dE'_a, the error of E'_a, must be ascertained by subtracting from 22·67 the value of the expansion of the standard for the mean temperature of the observations, which is given in the second table of section 8.

The distances of the dots on the tongues of the compound bars, from the axes of the pins by which the tongues are fixed to the brass and the iron components, have been recently measured very carefully, with the following results; it is necessary however to premise that whenever the bars have to be manipulated, whether in the measurement of a base-line, or in the comparisons with the standard, the observers invariably occupy a position behind the brass component, or on the side of the bar opposite to that from which the tongues project, and thus the compensation point which is on the right hand, when the observer is facing in the direction that the tongues are pointing, is usually called the 'right dot', and the other the 'left dot'.

Distances, in inches, of the dots on the tongues from the axes of the brass and the iron components.

Bar.	Brass Components.			Iron Components.		
	Right.	Left.	Mean.	Right.	Left.	Mean.
A	5·176	5·165	5·171	3·369	3·364	3·367
B	5·179	5·172	5·176	3·370	3·371	3·371
C	5·178	5·180	5·179	3·370	3·366	3·368
D	5·178	5·162	5·170	3·377	3·354	3·366
E	5·180	5·167	5·174	3·374	3·365	3·370
H	5·173	5·179	5·176	3·374	3·370	3·372
Mean of bars.			5·174			3·369

WITH THE COMPENSATION APPARATUS.

The close agreement between the corresponding distances for each of the bars, would indicate that the compensation points of one bar were first fixed by repeated trials, and that then those of the other bars were laid off at the same distances from the respective components; but in the passage quoted at page 57, Colonel Everest expressly states that the operation of determining the positions of the points "was repeated several times on *each* compensation bar". It is therefore highly probable that the materials of which the respective components of the bars were constructed must have been very similar; and this is corroborated by the circumstance that the hourly variations between the lengths of the compensation bars and the standard, during the course of the daily comparisons, have invariably been found to be much the same for each of the bars, as will be seen to be the case in the curves of the excess of each of the bars over the standard, at the Cape Comorin base-line, which are indicated in plates I to XVI.

The expansion of the wrought iron components has never been determined, but as these bars were constructed at the same time as the standard bar—which is also of wrought iron—and by the same makers, it is probable that they were made of very similar metal, and consequently we may assume that their expansion is, practically, identical with that of the standard, and may therefore be considered $= E'_a - dE'_a$

There were no means of ascertaining the actual temperatures of the components of the compensation bars at either of the nine base-lines which were first measured; but before the measurement of the last base—the one at Cape Comorin—two wells were sunk, to a depth of ⅜ths of an inch, into each of the components of the bar B, at a distance of two inches outside the points of support, in order to receive the bulbs of the thermometers which were required to indicate the temperatures. As very delicate thermometers were needed for this purpose, and the available number of such thermometers was limited, no arrangements were made for determining the temperatures of the components of the five remaining bars, which were assumed to be identical with those of the bar B. From what has been already stated regarding the similarity of the hourly curves of the excess of each of the bars over the standard, it is obvious that any one of them may be taken as a fair representative of the others, and the bar B was selected for this purpose.

These are the data which are forthcoming for the solution of equation (9); but it is still necessary to determine the error of compensation, η, for which no special investigations have been made; the value of this error must therefore be deduced from the equations of condition which are furnished by the numerous comparisons of bar B with the standard, at the Cape Comorin base-line.

CHAPTER VIII.

Investigation of the probable errors of the Cape Comorin base-line.

1.

The fluctuations of the compensation bars found to be due to the relative positions—with regard to external thermal influences—rather than to the respective thermal capacities, of the brass and the iron components.

Thermometers were attached to the compensation bar B, for the reasons already stated at Bangalore, during the interval between the measurements of the base-lines at that place, and at Cape Comorin. After the arrangements were completed, the bar was placed in an open verandah, on the north side of a house—where it was sheltered from the direct rays of the sun—and hourly readings of the thermometers were made throughout the day and night, in order to ascertain the differences of temperature of the brass and the iron components.

Happily it occurred to Captain Herschel, who was conducting these investigations, to reverse the bar, on the second day, so that the component which had been on the inner side of the verandah, or that nearest to the wall, became transferred to the opposite side, the bar remaining at much the same distance as formerly—about three feet—from the wall. It was then found that the relative temperature of the components was reversed, the one which had been hottest at a certain hour of the first day, being coldest at the same hour of the next day; evidently one of the components was acquiring or parting with heat more rapidly than the other, not so much in consequence of it's thermal capacity, as in consequence of it's position relatively to the wall and to the open air. So far as could be gathered from the evidence of two days observations, the influence of the thermal capacities of the two components, in causing differences of temperature, appeared to be insignificant in comparisou with that of the positions of the components relatively to external objects; in fact it now appears that the operations performed by the makers of the apparatus, with a view to equalizing the thermal capacities of the two components of this bar, which have been described in the preceding chapter, have been very fairly successful, and that the observed thermal inequalities are due—for the most part—to external circumstances.

This discovery of Captain Herschel's is of much significance, and has helped to unravel some of the perplexities which the fluctuations in the lengths of the bars had previously presented. It indicates that these fluctuations must be contingent on the positions of the bars relatively to the sun, and to prevailing winds, during the comparisons, and consequently that they are functions of the azimuths of the base-lines, for the bars and standards are, as a rule, placed parallel to the line during the comparisons. Thus maxima and minima values will be obtained at base-lines when the direction is east and west—maxima when the tongues are pointing to the south, minima when pointing to the north—and intermediate values will be obtained at base lines of which the direction is meridional, whether the tongues are pointing to the east or to the west.

Of all the external influences which are liable to affect the lengths of the bars, that of the sun is, in India, the most important; every precaution is therefore taken to prevent the rays of the sun from falling directly on the bars, during the measurements, and the comparisons. It is necessary to roll up the cloths of the tents on the side towards which the tongues of the compensation bars are pointing, in order to obtain sufficient light for the operations; thus the base-lines have usually been given an east-and-westerly direction, and have been measured with the tongues of the bars pointing to the north; for then, by closing the tent cloths towards the sun and opening those in the opposite direction, operations may be commenced at sunrise, whereas otherwise they cannot be begun until an hour or two later.

2.

Preliminary arrangements; programme of operations.

In the vicinity of Cape Comorin it was found impossible to obtain suitable ground for a base-line in any direction approaching that of east and west; the configuration of the coast-line, the off-shoots of the great range of hills which, trending southwards from the parallel of 21°, terminate at the Cape, and the numerous groves of valuable palmyra trees by which the surface of the country is covered, combined to render the selection of a suitable line a very difficult matter, and eventually necessitated the adoption of one running almost exactly north and south. The line was to be divided into three sections of which the central section only was to be measured, while the length of the whole was to be determined by triangulation, on both flanks, from the measured section; in order therefore that the accuracy of the whole should not be inferior to what would have been obtained had the entire length been measured, it was necessary that the ground should be generally as favorable as if the entire length were to be measured. The actual arrangements were in fact very similar to those of all the other base-lines, but with this difference, that whereas formerly the triangulation served the purpose of verifying the linear measurements, by affording comparisons of the relative lengths of the sections, it was now needed to determine the length of the entire line, while the linear measurements would be verified by repetitions.

The object which was contemplated was not so much the measuring the base with very great accuracy, as ascertaining the errors to which base-lines measured with the apparatus are liable; this was to be effected by two methods of investigation, *viz.*, by comparing the results of four independent measurements of the base, and by determining the magnitudes of the errors which may possibly occur in each of the several processes of the operations.

The facts which had been recently ascertained regarding the thermal inequalities of the brass and the iron components of the compensation bars, indicated the propriety of reversing the positions of the components, after each measurement, in order to obtain a measure of the differences due to position. Thus, the direction of the line being almost exactly north and south, two measurements were made with the brass component occupying a position to the east of the iron, and the two other measurements with the brass component to the west. In order that the four measures might be strictly independent, the compensation bars were compared with the standard throughout the two days immediately preceding and following each measurement, with the components holding the same relative position to each other that they were to hold or had held during the measurement. Thus each measurement may be reduced singly, in terms of the lengths of the bars which were obtained from the comparisons immediately before and after it, and, as at all previous base-lines, without taking any cognizance of the differences between the circumstances of the comparisons and those of the measurement; and the several measurements may be reduced collectively, in terms of the mean lengths of the bars as determined from the whole of the comparisons, and with due recognition of the effects of the thermal inequalities and the imperfect compensation of the components, as indicated by the representative bar B.

The order of procedure will be clearly gathered from the following table, in which the numerals I, II, III, IV, distinguish the respective measurements, and the numerals 1, 2, 3, 4 indicate the days of comparison before and after each measurement.

Brass Components West.		Brass Components East.	
Day of 1869.	Operation.	Day of 1869.	Operation.
January 9	Comparisons I, 1.	January 28.	Comparisons II, 1.
„ 11	„ I, 2.	„ 29.	„ II, 2.
„ 12 to 24	Measurement I.	Jan. 30 to Feb. 9.	Measurement II.
„ 25	Comparisons I, 3.	February 10.	Comparisons II, 3.
„ 26	„ I, 4.	„ 11.	„ II, 4.
February 12	Comparisons III, 1.	February 26.	Comparisons IV, 1.
„ 13	„ III, 2.	„ 27.	„ IV, 2.
„ 14 to 23	Measurement III.	Feb. 28 to March 8.	Measurement IV.
„ 24	Comparisons III, 3.	March 9.	Comparisons IV, 3.
„ 25	„ III, 4.	„ 10.	„ IV, 4.

WITH THE COMPENSATION APPARATUS.

The length of the base was 141 entire sets of six bars and seven microscopes, *plus* a set of three bars and four microscopes, *minus* a distance of about 31 inches which was measured with a beam compass. Stones were sunk at the end of the 35th, 70th, and 105th entire sets of bars and microscopes, from the north end of the line, carrying brass plates on which marks were engraved under the extremities of the sets, as each successive measurement passed over the stones; the distances of these marks—in the direction of the measurement and at right angles to that direction—from an arbitrary point of reference on each plate, which was used as an origin of co-ordinates, were subsequently measured.

These points are designated **X**, **Y**, and **Z** in the following record, in which the values of the four measurements of the parts North-end to **X**, **X** to **Y**, **Y** to **Z**, and **Z** to South-end, are given as an additional indication of the errors of the operations to that which is afforded by the measurements of the whole length. The partial measures are designated as follows, the, numerals corresponding to the number of the measurement;

I **NX**	I **XY**	I **YZ**	I **ZS**
II ,,	II ,,	II ,,	II ,,
III ,,	III ,,	III ,,	III ,,
IV ,,	IV ,,	IV ,,	IV ,,

3.

Formation of the equations of conditions for determining the relative length of the compensation bar B to the Standard.

Equation (9) of the preceding chapter, indicates the form in which the equations of condition presented by the comparisons of the compensation bars with the standard may be generally expressed. In order to guard against accidental gross errors in reading the heads of the comparing microscopes, and in recording the results, it is customary to employ three assistants to register all the observations independently, and to require them to make a preliminary calculation of the reduction of the relative lengths of the bars and the standard, at the temperatures of observation, to the corresponding normal lengths at the temperature of 62° *F*. At the Cape Comorin base these provisional calculations were made subservient to the final reductions, in the following manner.

Equation (9) may be written thus

$$x = (\mathrm{B}' - \mathbf{A}' + \mathrm{E}'_a \,.\, \mathrm{T}_a) - (e'_i - de'_i)\, t.\, \frac{m}{m-n} - \eta.\, \mathrm{T}_b - d\mathrm{E}'_a.\, \mathrm{T}_a$$

Now $\mathrm{B}' - \mathbf{A}'$ is directly obtained from the comparisons in terms of the divisions of the comparing micrometers; and as the runs of these micrometers are known, E'_a, or the adopted value of the linear expansion of the standard,—the value originally determined in Calcutta in 1832—may be expressed in micrometer divisions. If this is done, and we put

$$x'' = \mathrm{B}' - (\mathbf{A}' - \mathrm{E}'_a \,.\, \mathrm{T}_a) \quad \ldots\ldots\ldots\ldots\ldots \quad (10)$$

x'' will be a *preliminary* value of the excess of the bar over the normal length of the standard—expressed in micrometer divisions—which is uncorrected for the difference of temperature of the brass and iron components, and for the error of compensation, and the errors of the adopted co-efficients of expansion of the standard and of the iron component.

The values of x'' for every comparison of each bar with the standard, will be found in the detailed description of the operations of this base-line; they are also graphically exhibited by curves in plates I to XVI at the end of this volume, each plate representing one day's results, on scales of micrometer divisions and millionths of a yard.

Thus we obtain the equation

$$x = x'' - (e'_i - de'_i)\, t . \frac{m}{m-n} - \eta . \mathrm{T}_b - d\mathrm{E}'_a . \mathrm{T}_a \quad \ldots \ldots \quad (11)$$

We are obliged to assume e_i, the linear expansion of the iron component, to be equal to that of the standard bar **A**; though the equations of condition afforded by the comparisons are upwards of three hundred in number, the co-efficients of e_i are invariably so small that a reliable value of this *quæsitum* cannot be obtained by treating it as an unknown quantity to be deduced from these equations; moreover the assumed value has been ascertained to be probably much nearer the truth than the value which would be given by the equations. Putting $e'_i = E'_a$ and $de'_i = dE'_a$, expressing E'_a in micrometer divisions, and substituting for m and n their corresponding numerical values, equation (11) becomes

$$x = x'' - 51{\cdot}4\, t - \eta . \mathrm{T}_b - (\mathrm{T}_a - 2{\cdot}9\, t)\, d\mathrm{E}'_a$$

If now we put

$$x' = x'' - 51{\cdot}4\, t \quad \ldots \ldots \quad (12)$$

x' will be a *second* preliminary value—expressed in micrometer divisions—of the excess of the bar over the normal length of the standard, corrected for the difference of temperature of the brass and iron components, but uncorrected for the errors of compensation and of the adopted co-efficient of expansion of the standard. This second approximation to the true value of x was made in order that the fluctuations in the lengths of the compensation bars which were due to the differences of temperature of their components, might be clearly indicated. Thus we arrive finally at the following equation,

$$x = x' - \eta . \mathrm{T}_b - (\mathrm{T}_a - 2{\cdot}9\, t)\, d\mathrm{E}'_a \quad \ldots \ldots \quad (13)$$

in which the symbol $d\mathrm{E}'_a$, which expresses the error of the old value of the expansion of the standard, has been retained, partly because the operations for re-determining the value of the expansion had not been commenced when the calculations for the reduction of the observations at this base-line were being carried on, and partly in order that any person who may object to the grounds on which the values in the tables at page (19) have been adopted, may have the means of readily substituting any other value which may be deemed preferable.

4.

Determination of the error of compensation of bar B.

By taking the mean of n equations of the form of (13), and subtracting it in succession from each of the n equations, x is eliminated, and n equations are obtained of the following form

$$\delta T_b . \eta = \delta x' - \delta (T_a - 2{\cdot}9\, t) . dE'_a \quad \ldots \quad (14)$$

The equations thus formed for the determination of η have been considered as of equal weight, and solved by the method of minimum squares. In order to indicate the errors to which the results are liable, the equations have been divided into eight distinct and independent groups, each containing the comparisons of the two days immediately preceding or following the successive measurements of the base;—the normal equations thus obtained have been solved independently, and then added together to give the equation from which the most probable value of η is obtained. The results are as follows,

COMPARISONS.		Normal equations in η, in micrometer divisions.	Values of η in divisions, dE' being $= 0{\cdot}68$ division.
Distinguishing numerals.	Number.		
I, 1 and I, 2	33	$623\,\eta = 595 - 519\, dE'_a$	$\eta = 1{\cdot}0 - 0{\cdot}8\, dE'_a \overset{d}{=} 0{\cdot}5$
I, 3 „ I, 4	39	734 „ = 470 − 596 „	„ = 0·6 − 0·8 „ = 0·1
II, 1 „ II, 2	39	646 „ = 664 − 576 „	„ = 1·0 − 0·9 „ = 0·4
II, 3 „ II, 4	40	936 „ = 1443 − 878 „	„ = 1·5 − 0·9 „ = 0·9
III, 1 „ III, 2	40	640 „ = 1196 − 672 „	„ = 1·9 − 1·0 „ = 1·2
III, 3 „ III, 4	40	840 „ = 1833 − 840 „	„ = 2·2 − 1·0 „ = 1·5
IV, 1 „ IV, 2	40	731 „ = 969 − 634 „	„ = 1·3 − 0·9 „ = 0·7
IV, 3 „ IV, 4	40	719 „ = 843 − 627 „	„ = 1·2 − 0·9 „ = 0·6
All	311	$5869\,\eta = 8013 - 5342$ „	$\eta = 1{\cdot}37 - 0{\cdot}91$ „ $= 0{\cdot}75$

Considering the difficulties which attend investigations of this nature, when the observations are necessarily taken under changing temperatures, and the exact temperatures are probably never indicated by the thermometers, excepting at the maxima and minima, these determinations are as satisfactory as can be expected, and the final result is worthy of confidence; expressing this result in inches and in millionths of a yard,

$$\eta = \cdot000{,}034{,}4 \text{ inch} = 0\cdot96 \text{ millionths of a yard};$$

this value of η was used in the reductions of the Cape Comorin base-line.

An independent value was subsequently obtained from comparisons of bar B with the 10-feet (steel) Standard I_s, which were made in Dehra Doon in May 1869, after the return of the base-line apparatus from Cape Comorin; the comparisons were taken early in the morning and late in the afternoon, at maxima and minima temperatures, on four days, four comparisons being made on each occasion, and thermometers being used to determine the temperatures of the two components of bar B, as at the Cape base.

The results are as follows:—

$$24\cdot54\,\eta = \overset{m.y}{38\cdot5} \text{ whence } \eta = \overset{m.y}{1\cdot6}$$
$$24\cdot25\,\eta = 28\cdot5 \quad ,, \quad \eta = 1\cdot2$$
$$21\cdot73\,\eta = 15\cdot8 \quad ,, \quad \eta = 0\cdot7$$
$$18\cdot25\,\eta = 17\cdot4 \quad ,, \quad \eta = 1\cdot0$$

thus finally

$$88\cdot77\,\eta = 100\cdot2 \quad ,, \quad \eta = 1\cdot13$$

This result corroborates the one which was obtained at the Cape base-line very satisfactorily; probably a more accurate determination of η could not be arrived at excepting by investigations under artificially sustained temperatures, with an apparatus similar to those employed in determining the expansions of the standards of length of the Ordnance and the Indian Surveys, which have been described in Chapter II.

It is evident that since the sign of η is positive, the bar has been *under* compensated, or in other words, that it's length increases with the temperature.

The above results are further confirmed by the provisional determinations of the expansion of the standard from the comparisons with the compensation bars at eight base-lines, which are given on page (10). Those determinations were made on the assumption that the bars were truly compensated—an assumption which is now shown to be erroneous—and they exhibit the expansion of the standard *minus* that of the bars, since the latter are found to be under compensated, and to increase in length as the temperature increases. If to the average value of the eight determinations, *viz.*, 21·10 *m.y*, the compensation error $\eta = 1\cdot05$ — assumed to be the same for all the bars—is added, we get for the expansion of the standard the value 22·15, which exceeds the probable value, 21·67, corresponding to the mean temperature (66°) of the base-lines, by 0·48 *m.y*, or only 2·2 *per cent* of the actual expansion; see page (19). Considering that there were no means of ascertaining the temperatures of the brass and iron components of the compensation bars at the said base-lines, and that the errors in elaborate determinations of the expansions of simple bars of metal are liable to exceed this percentage, when the temperatures cannot be controlled artificially, this result must be admitted to be very fairly corroborative of the others.*

Referring to equation (2) and the figure at page (58), it will be seen that the position of M, the mark on the tongue, falls between the true point of compensation and the bars, at a distance

$$OM = \frac{n}{2e_i - \eta}\,\eta$$

Whence, since $n = 3\cdot4$ inches, $e_i = 21\cdot8$ *m.y*, and $\eta = 1\cdot0$ *m.y*,

$$OM = \cdot08 \text{ inch.}$$

5.

Determination of the normal excess of the mean of all the compensation bars over the standard at 62°F; probable errors; thermometric errors.

For the reasons which have been already set forth in section 4 of the preceding chapter, the compensation bar B is assumed to be, in all respects but length, a representative of the other bars; or in other words, the recorded temperatures of it's components are considered to be the same—under like conditions and at the same times—as the mean temperatures of the corresponding components of the whole of the bars, the materials of which the respective components are composed are supposed to be similar, and the mean compensation error is assumed to be the same as that which has been determined for B.

With these assumptions, if we employ the symbols X, X′ and X″ to represent, for the mean of the bars, the excesses over the normal length of the standard which have hitherto been represented by the symbols x, x', aud x'', for the bar B, we get by equations (10) to (13) the following equations, in which the numerals are expressed in micrometer divisions.

$$X'' = \left\{ \begin{array}{l} \text{Mean of the actual length of the} \\ \text{six bars at the time of observation} \end{array} \right\} - A' + E'_a \, . \, T_a \quad \ldots \quad (15)$$

$$X' = X'' - 51\cdot4\,t \quad \ldots \quad (16)$$

$$X = X'' - 51\cdot4\,t - \eta T_b - T_a\, dE'_a + 2\cdot9\, t\, de'_i \quad \ldots \quad (17)$$

Thus X″ corresponds to the excess of the mean of the bars over the standard which, at all previous base-lines, was computed with the old co-efficient of expansion of the standard—determined in Calcutta in 1832—and was adopted as final, the thermal inequalities of the component bars and the errors of compensation being assumed to be eliminated by the similarity of circumstances during the comparisons and the measurements. The equations which

* The operations at Calcutta, Attock and Karachi most closely corroborate the recent results, and they happen, in point of fact, to be the most reliable for the investigation; for at Calcutta the comparisons were made in a building, where the bars would be less exposed to the sun's influence than in tents, at Karachi the direction of the line was nearly meridional, and at Attock the positions of the bars were reversed during the operations.

give the numerical values of X″ will be found in the detailed description of each base-line, and, for the Cape Comorin base, these values, as well as those of the corresponding excesses of each of the bars over the standard, are graphically delineated also on plates I to XVI. On the following plates, XVII to XXXII, the mean excess X″ is repeated, and X′, the mean excess corrected for temperature only, and X, the mean excess finally corrected, are shown.

These curves indicate that the positions of the components relatively to the sun, materially influences the length of the compensation bar; thus as a rule when the brass component was to the west, the length of the bar increased from 7 A.M. to 9½ A.M., and then decreased until noon—at which time the sun arrived in the azimuth of the line—and the converse happened during the same hours when the brass component was to the east. There are occasional exceptions to the rule, and days on which the bars maintained a nearly constant length for several hours after sun-rise; but these exceptions tend to confirm the rule, as it can almost always be shown that, when they occured, the sky was more or less laden with clouds, which must have had the effect of diffusing the heat of the sun, and preventing it from striking more on one of the components than on the other. The influence of the sun and of winds on the temperatures of the bars will be examined hereafter and therefore need not be further alluded to in this place.

The curves in plates XVII to XXXII indicate that the several corrections which have been applied have considerably diminished the magnitude of the discordances between observations taken at different hours of the day; the mean of the extreme daily ranges of the values of X″ and of X, for the comparisons before and after each measurement, are as follows:

	I	II	III	IV	Mean
	m.y	m.y	m.y	m.y	m.y
X″	40·9	60·1	21·6	66·8	47·4
X	16·4	14·9	20·5	13·8	16·4

The results of 14 days comparisons are materially improved, but those of two days (comp. III. 3 and III. 4) are slightly deteriorated.

The probable error of the comparisons of the mean of the bars with the standard, as deduced from the squares of the differences between single values and the mean of all, are as follows:

			m.y
for X″, probable error of	a single value	= ±	13·5
„ „	mean of 311 values	= ±	0·77
for X „	a single value	= ±	4·7
„ „	mean of 311 values	= ±	0·27

It may be observed that the probable error of a single determination of the relative length of the bar B to the mean of all the compensation bars—under like conditions—is only ± 2·4 *m.y*, a quantity of which the magnitude is much the same as that of the probable error of a single determination of the relative lengths of the 10-feet standards, the details of which are given in appendix No. 3; as the bars were compared in tents during varying temperatures, and under far less favorable circumstances than the standards—which were compared in a substantial building, and when the temperatures were steady—the smallness of this probable error tends to corroborate what has been previously stated regarding the similarity of the bars to each other in all essential respects.

These probable errors, it should be stated, in all instances include the personal equations of several observers; for the observations were invariably taken by a number of persons, in order that the constant errors which arise from personality might be neutralized as far as possible. Referring to page (23) it will be seen that the probable personal error in the comparisons of long bars, when two observers are employed—one at each of the microscopes—is as much as $\pm 1 \cdot 7$ *m.y.*

The mean values of X, the normal excess of the mean of the compensation bars over the standard, at the temperature of 62°*F*, as deduced from the comparisons before and after each measurement, and from the whole of the comparisons, are as follows, the adopted value of η being 0·75 *micr. div.* and of dE'_a 0·684 *div.* and 1 *div.* being = 1·277 *m.y.*

$$X = X'' - 51{\cdot}4\,t - T_b\,.\,\eta - T_a\,dE'_a + 2{\cdot}9\,t\,de'_i$$

$$\begin{array}{llcl}
 & & & \quad\quad\quad\quad\quad\quad\quad\quad\quad\quad\quad\quad\quad\quad\quad\quad\quad\quad\quad\quad\quad\quad\quad\quad\quad\quad d \quad\quad\;\; m.y \\
\text{I} & X_1 & = & 206{\cdot}3 - 18{\cdot}0 - 19{\cdot}8\,\eta - 18{\cdot}8\,dE'_a + 1{\cdot}0\,de'_i = 161{\cdot}3 = 206{\cdot}0 \\
\text{II} & X_2 & = & 188{\cdot}5 + 6{\cdot}0 - 22{\cdot}8\;,, - 21{\cdot}5\;,, - 0{\cdot}3\;,, = 162{\cdot}5 = 207{\cdot}5 \\
\text{III} & X_3 & = & 189{\cdot}2 + 12{\cdot}3 - 23{\cdot}0\;,, - 21{\cdot}7\;,, - 0{\cdot}7\;,, = 169{\cdot}0 = 215{\cdot}8 \\
\text{IV} & X_4 & = & 195{\cdot}8 + 4{\cdot}3 - 25{\cdot}0\;,, - 23{\cdot}4\;,, - 0{\cdot}2\;,, = 165{\cdot}3 = 211{\cdot}1 \\
\text{Mean, or} & X & = & 195{\cdot}0 + 1{\cdot}1 - 22{\cdot}6\;,, - 21{\cdot}3\;,, - 0{\cdot}1\;,, = 164{\cdot}5 = 210{\cdot}1
\end{array}$$

If the probable error of the final result, viz. the general mean, is computed from the squares of the differences between the mean of all and the values respectively corresponding to the different measurements, it is found to be

$$p.e \text{ of mean value of } X = \pm \overset{m.y}{1{\cdot}47}$$

The magnitude of this value of the probable error is nearly six times that of the value ($\pm$ 0·27 *m.y*) which was obtained from the differences between single values of X and the mean of all, thus indicating the presence of certain uneliminated errors, constant in each group of comparisons, but varying in different groups. These errors probably arise from the state of the weather, the alternations between cloud and sunshine, and the direction of the prevailing winds, on the days when the comparisons were made; there is evidence to show that during the comparisons appertaining to measurement No. III—the result of which differs most materially, and exceeds the mean of the three others by 7·6 *m.y*—the weather differed materially from what it was during the other comparisons, as will be noticed further on in the section on the thermal inequalities of the compensation bars during the operations. Now the degree of accuracy with which the thermometers indicate the temperatures of the bars and the standard is considerably influenced by the diurnal changes of temperature, which again depend on the state of the weather; when the diurnal temperature is uniformly progressive from a minimum to a maximum, as during a day of continuous sunshine, the temperatures of the thermometers lag behind and are always less than those of the bars; but when the diurnal temperatures fluctuate, and have several maxima and minima, as during a day of alternate cloud and sunshine, the thermometers are sometimes in defect and sometimes in excess of the temperatures of the bars, and thus there is less constancy of error.

It is not improbable that the observations of the standard are more influenced by this circumstance than those of the compensation bar B, for if the thermometers on both the components of this bar lag equally behind the true temperatures, the difference of temperature will be correctly indicated, which is the chief desideratum, as the absolute temperature of the compensation bar is unimportant, and does not require to be known with great accuracy.

But the absolute temperature of the standard is most important; at pages (7) and (8) instances are cited in which thermometers attached to standard bars are shown to have been lagging to an extent of about $0^\circ{\cdot}3$ *F* behind the temperatures of the bars and that under most favorable circumstances, when the temperatures, were changing very slowly; a similar amount of lagging during comparisons I, II, and IV, in excess of what obtained at III, would suffice to explain the differences between the results on those occasions, and there is thus some probability that the exceptionally large value for III is in reality more correct than the other values.

6.

Determination of the actual lengths of the compensation bars during the measurements.

If we put ${}_oL$ for the actual length of the (mean of all the) compensation bars at the time of any observation, ${}_oT_b$ for the corresponding temperature of the brass component and ${}_ot$ for the difference of temperature of the two components at that time, we get, as in equation (6)

$$ {}_oL - (\mathbf{A} + X) = (e'_i - de'_i)\ {}_ot . \frac{m}{m-n} + {}_oT_b . \eta $$

$$ \text{or } {}_oL - \mathbf{A} = X + 51{\cdot}4\ {}_ot + {}_oT_b\ \eta - 2{\cdot}9\ {}_ot\ de'_i \quad \ldots \ldots \ldots \quad (18) $$

Now the temperatures of both the components of the compensation bar B were observed when each 'set' was measured, and we have thus as many values of ${}_ot$ and of ${}_oT_b$ as the number of sets; putting r for this number, then the corresponding mean actual length of the (mean of all the) bars during the measurement of r sets will be

$$ \frac{[{}_oL]}{r} - \mathbf{A} = X + 51{\cdot}4 \frac{[{}_ot]}{r} + \frac{[{}_oT_b]}{r} \eta - 2{\cdot}9 \frac{[{}_ot]}{r} de'_i \quad \ldots \ldots \ldots \quad (19) $$

The symbolical and the concluded numerical values of X have already been given on the preceding page, and it will be desirable to operate with the former, in order to obtain a measure of the effects which any differences between the temperatures and other circumstances of the measurements, and those which prevailed during the comparisons, are liable to produce;

thus, substituting accordingly for X, and putting $L = \frac{[_oL]}{r}$ we get

$$L - \mathbf{A} = X'' + 51{\cdot}4\left(\frac{[_ot]}{r} + 1{\cdot}1\right) + \left(\frac{[_oT_b]}{r} - 22{\cdot}6\right)\eta - 21{\cdot}3\ dE'_a - \left(2{\cdot}9\frac{[_ot]}{r} - 0{\cdot}1\right) de'_i \quad (20)$$

Thus the following values of the mean length of the brass are obtained for the several measurements of each section of the base-line, the sections being indicated as set forth on page (65)

Section.	Position of brass component.	X″	51·4 t	Co-efficients of η = ·75d	Co-efficients of dE′ₐ = ·68d	Co-efficients of de′ᵢ = ·68d	L − A Micrometer divisions.	L − A Millionths of a yard.	Actual mean length of all the bars in feet of standard A.
		d	d						
I NX	West	+ 195·0	+ 10·9	− 4·8	− 21·3	− 0·7	187·2	239·0	10·000,717,0
„ XY	„	„	+ 13·7	− 4·2	„	− 0·8	190·5	243·2	„ 729,6
„ YZ	„	„	+ 16·2	− 3·4	„	− 0·9	193·4	246·9	„ 740,7
„ ZS	„	„	+ 10·5	− 3·5	„	− 0·6	187·9	239·9	„ 719,7
II NX	East	„	+ 0·5	+ 2·3	„	− 0·1	182·5	233·0	„ 699,0
„ XY	„	„	− 0·8	− 1·1	„	0·0	178·8	228·3	„ 684,9
„ YZ	„	„	− 3·6	− 1·5	„	+ 0·2	175·8	224·4	„ 673,2
„ ZS	„	„	+ 3·2	− 0·2	„	− 0·2	183·3	234·0	„ 702,0
III NX	West	„	+ 0·9	− 0·5	„	− 0·1	180·8	230·8	„ 692,4
„ XY	„	„	+ 2·9	− 1·8	„	− 0·2	181·9	232·2	„ 696,6
„ YZ	„	„	+ 4·6	− 2·5	„	− 0·3	182·9	233·5	„ 700,5
„ ZS	„	„	− 2·2	+ 0·3	„	+ 0·1	178·5	227·9	„ 683,7
IV NX	East	„	+ 11·6	+ 2·6	„	− 0·7	193·4	246·9	„ 740,7
„ XY	„	„	− 1·8	+ 0·9	„	+ 0·1	179·4	229·0	„ 687,0
„ YZ	„	„	+ 0·5	+ 2·9	„	− 0·1	183·0	233·6	„ 700,8
„ ZS	„	„	+ 8·6	+ 1·4	„	− 0·5	189·7	242·2	„ 726,6

Thus the fluctuations in the actual lengths of the (mean of all the) compensation bars have an extreme range of 22·5 *m.y*; they represent the effects of the differences between the circumstances of the measurements and those of the comparisons with the standard, and it will be seen that the most important of these effects is traceable to the thermal inequalities of the bars, the influence of the compensation error being comparatively small, while that of the uncertainty in the adopted value of the expansion of the iron components is still less and is quite insignificant. It will also be noticed that the fluctuations of the mean bar-length are less influenced by the relative positions of the brass and the iron components than by the differences between the circumstances of the comparisons and the measurements, as might be expected from the meridional direction of the line.

At all the other base-lines which have been measured with this apparatus, the influence of the error of compensation would probably be less than at this base, for it depends on the difference between the actual and the normal temperature, which was about 12° greater on an average at this than at any other base; on the other hand the differences between the thermal inequalities of the components of the bars, during the measurements and the comparisons, may have been greater at other base-lines, for the diurnal ranges of temperature and the vicissitudes of climate have occasionally been greater than they were at this base.

7.

Determination of the lengths of the compensation microscopes during the measurement; probable errors

The lengths have been derived from comparisons of the microscopes with their scales at various stages of the operations, generally before, after and at the middle of each measurement. The comparisons will be found in the detailed account of the operations, and their results will be given in the next section: thus in this place it is only necessary to indicate the manner in which the microscope lengths are determined, and their probable errors ascertained.

The compensation microscopes are the least satisfactory portion of the apparatus, and are far more liable than the compensation bars to accidental changes in length. It is scarcely possible to adjust a side telescope to parallelism with the microscope components, without altering the distance between the external foci of the latter, and thus disturbing what is called the length of the microscope; consequently after every such adjustment the instrument has to be compared with a 6-inch scale, and comparisons must be made at the successive stages of the operations before correcting this adjustment, should it be necessary to do so, which sometimes happens.

The mean value of the length of a microscope, as determined from the comparisons before and after the measurement of any portion of the line, during which the microscope has not been adjusted or intentionally altered in length, is considered to be the length of the microscope for that portion of the measurement.

The probable errors of these lengths are deduced from the differences of the values obtained at successive comparisons—between which there has not been any adjustment or intentional alteration—by the usual formula

$$p.\,e \text{ of a single determination}^{*} = \sqrt{\frac{[d^2]}{n-m}}$$

* These so called 'single' determinations, are, in each instance, the mean of three or more comparisons of a microscope with it's scale.

n being the number of single determinations, and m the number of groups of such determinations. Assuming the probable error to be the same for all the microscopes, at this base-line,

$$\text{the } p.\,e \text{ of a single determination} = \pm\, 4{\cdot}8\; m.y$$

thus, with three determinations at equal intervals, the probable error of the length measured by the microscopes, in N sets of measures—each containing five entire and two half microscope lengths, as is usual—will be

$$\pm\, 4{\cdot}8\, N\sqrt{\frac{5{\cdot}5}{3}} = \pm\, 6{\cdot}5\, N\; m.y$$

8.

Determination of the length of the base-line, allowing for the effects of the thermal inequalities and the imperfect compensation of the bars; probable errors.

The length of a base-line measured with this apparatus is the sum of the bar lengths and the microscope lengths, ± a short terminal length which has to be measured with a beam compass.

Combining all these lengths together, the results of the operations are as follows;

Measurement.	Position of brass components.	Measured lengths expressed in feet of standard A				
		With the compensation bars.	With the compensation microscopes.	With the beam compass.	Total.	Mean.
N X I	West	2100·1506	105·0162	+ 0·0142	2205·1810	
„ II	East	·1468	·0193	+ 0·0209	·1870	
„ III	West	·1454	·0187	+ 0·0159	·1800	
„ IV	East	·1555	·0244	+ 0·0069	·1868	2205·1837
X Y I	West	2100·1532	105·0166	− 0·0056	2205·1642	
„ II	East	·1438	·0193	− 0·0027	·1604	
„ III	West	·1463	·0187	− 0·0031	·1619	
„ IV	East	·1443	·0236	− 0·0060	·1619	2205·1621
Y Z I	West	2100·1555	105·0170	− 0·0033	2205·1692	
„ II	East	·1414	·0193	+ 0·0042	·1649	
„ III	West	·1471	·0187	+ 0·0028	·1686	
„ IV	East	·1472	·0232	− 0·0042	·1662	2205·1672
Z S I	West	2190·1573	109·5178	− 2·5969	2297·0782	
„ II	East	·1534	·5202	− 2·6003	·0733	
„ III	West	·1494	·5182	− 2·5889	·0787	
„ IV	East	·1588	·5242	− 2·6036	·0794	2297·0774
N S I	West	8490·6166	424·5676	− 2·5916	8912·5926	
„ II	East	·5854	·5781	− 2·5779	·5856	
„ III	West	·5882	·5743	− 2·5733	·5892	
„ IV	East	·6058	·5954	− 2·6069	·5943	8912·5904

In the three Sections **NX**, **XY** and **YZ** the distances which were measured with the compensation bars are equivalent to the actual lengths of 35 entire sets of the six bars, and will be found by multiplying the mean lengths given in the table in section (6) by 210; the corresponding distances in the section **ZS**, are equivalent to the actual lengths of 36 entire sets and of 1 half set of bars, and will be found by multiplying the mean lengths in that table by $6 \times 36 + 3 = 219$, and applying a correction of $-\cdot 0003$ of a foot to the results, to allow for the difference of the mean length of the three bars of the half set from that of the entire set of bars.

The reductions of the distances which were measured with the compensation microscopes, and the short terminal lengths measured with a beam compass, are given in the detailed account of the operations.

If the probable errors of the preceding results are determined from the squares of the differences between each result and the mean of the group to which it appertains, they will be as follows—

$$p.\,e \text{ of a single measurement of any section} = \pm \cdot 67 \sqrt{\frac{\cdot 00008425}{16-4}}$$

$$= \pm \cdot 0018 \; (\textit{of a foot})$$

$$p.\,e \text{ of a single measurement of the entire length} = \pm \cdot 67 \sqrt{\frac{\cdot 00004453}{4-1}}$$

$$= \pm \cdot 0026$$

whence, expressing the probable error in millionth-parts, μ, of the distance measured, we obtain

from the sections, *p. e* of a single measure $= \pm\, 0\cdot 8\, \mu$
from the entire length, ,, ,, $= \pm\, 0\cdot 3\, \mu$

9.

Determination of the length of the base-line by the usual method; probable errors.

The values of $X_1 \ldots\ldots X_4$, or the several determinations of the normal excess of the mean of the compensation bars over the standard, from the comparisons before and after each measurement of the line, are expressed at page 71, by equations which indicate the influences of the thermal inequalities of the bar-components, the influences of the compensation errors, and those of the errors in the adopted values of expansion for the standard and the iron components. There are no means of determining the effects of any of these influences, with the exception of that of the error of the expansion of the standard, for the base-lines which have been previously measured with this apparatus. If therefore the products of t, η and de'_i in those equations are rejected, values of $X_1 \ldots X_4$ will be obtained which will be analogous to those employed in the reduction of all the previous base-lines. By using these values, the lengths of the several measurements of this base-line may be determined in the usual way, and thus some estimate of the average probable error of the other base-lines may be formed.

Excess of mean of bars over Standard.	Mean length of all the bars in feet of **A**
$X_1 = 206{\cdot}3^{d} - 18{\cdot}8\, dE'_a = 193{\cdot}4^{d} = 247{\cdot}0^{m.y}$	10·000,740,7
$X_2 = 188{\cdot}5 - 21{\cdot}5$,, $= 173{\cdot}8 = 221{\cdot}9$	10·000,665,7
$X_3 = 189{\cdot}2 - 21{\cdot}7$,, $= 174{\cdot}4 = 222{\cdot}7$	10·000,668,0
$X_4 = 195{\cdot}8 - 23{\cdot}4$,, $= 179{\cdot}8 = 229{\cdot}6$	10·000,688,6

whence, and with the microscope and the beam compass lengths given in the preceding section, we get the following results;

Measurement.	Measured lengths expressed in feet of standard **A**			
	With the compensation bars.	With the microscopes and beam compass.	Total.	Mean.
N X I	2100·1555	105·0304	2205·1859	
,, II	·1398	·0402	·1800	
,, III	·1403	·0346	·1749	
,, IV	·1446	·0313	·1759	2205·1792
X V I	2100·1555	105·0110	2205·1665	
,, II	·1398	·0166	·1564	
,, III	·1403	·0156	·1559	
,, IV	·1446	·0176	·1622	2205·1603
V Z I	2100·1555	105·0137	2205·1692	
,, II	·1398	·0235	·1633	
,, III	·1403	·0215	·1618	
,, IV	·1446	·0190	·1636	2205·1645
Z S I	2190·1619	106·9209	2297·0828	
,, II	·1455	·9199	·0654	
,, III	·1460	·9293	·0753	
,, IV	·1505	·9206	·0711	2297·0737
N S I	8490·6284	421·9760	8912·6044	
,, II	·5649	2·0002	·5651	
,, III	·5669	2·0010	·5679	
,, IV	·5843	1·9885	·5728	8912·5776

Determining the probable errors in the same way as in the preceding section,

$$\left.\begin{array}{r} p.e \text{ of a single measurement} \\ \text{of any section} \end{array}\right\} = \pm \cdot 67 \sqrt{\frac{\cdot 00034418}{12}}$$

$$= \pm \cdot 0036 \text{ (of a foot)}$$

$$\left.\begin{array}{r} p.e \text{ of a single measurement} \\ \text{of the entire length} \end{array}\right\} = \pm \cdot 67 \sqrt{\frac{\cdot 00099162}{3}}$$

$$= \pm \cdot 0122$$

and, expressing these quantities in millionth-parts of the distance measured, we obtain

from the sections, *p. e* of a single measure $= \pm 1 \cdot 6\ \mu$

from the entire length, „ „ $= \pm 1 \cdot 4\ \mu$

The difference between the mean values of the entire length by the two processes of deduction is ·0128 of a foot $= 1 \cdot 4\ \mu$.

10.

Determination of the probable errors of each of the several operations of the base-line, and thence the probable error of the measurement.

At the end of this volume will be found a report, by Captain Basevi, on the Practical Errors of the measurement of this base-line. The errors therein discussed are those which arise from imperfect alignment and leveling of the compensation bars and microscopes, and those also which are liable to occur in intersecting the dots on the bars and the registers. It will be found on reference to Captain Basevi's careful and elaborate investigations, that the combined effect of these errors, in a single measurement of the base-line, is probably $= \cdot 00014 \pm \cdot 00117$ of a foot, where the first term expresses the probable magnitude of the errors which are always positive, arising from inaccurate alignment and leveling, and the second term expresses the probable amount of all the several errors which may be either positive or negative.

To this quantity it is necessary to add the probable errors which are due to the errors in the adopted values of the lengths of the compensation bars and microscopes.

For the *p.e* of the mean length of the bars, we may accept the value $\pm 1 \cdot 47$ *m.y*, at page 71; and since the number of bar-lengths in the entire measurement was 849,

$$\text{the } p.e \text{ of the length by the bars} = \pm \overset{m.y}{1 \cdot 47} \times 849$$

$$= \pm \cdot 00374 \text{ (of a foot);}$$

also since the number of sets of microscopes was 141·5, we get, from section 7,

$$\left.\begin{array}{r} \text{the } p.e \text{ of the length measured} \\ \text{by the microscopes} \end{array}\right\} = \pm \overset{m.y}{6 \cdot 50} \times 141 \cdot 5$$

$$= \pm \cdot 00276 \text{ (of a foot)}$$

Thus the entire probable error of a single measurement of the base is

$$= \cdot 00014 \pm \sqrt{(\cdot 00117)^2 + (\cdot 00374)^2 + (\cdot 00276)^2}$$
$$= \cdot 00014 \pm \cdot 00479 \textit{ of a foot}$$

which, when expressed in millionth-parts of the distance measured, is

$$= 0\cdot 02\,\mu \pm 0\cdot 5\,\mu$$

11.

On the observed thermal inequalities of the components of compensation bar B, during the comparisons with the standard and during the measurement of the base-line.

The differences between the temperatures of the two components of compensation bar B, at the hours of 7 A.M. 10 A.M. 1 P.M. and 4 P.M. as obtained by interpolation from the thermometer readings near those times, during the entire course of the operations, are given in the following table, for each day of the comparisons with the standard and of the measurements; they are expressed as excesses, ±, of the temperature of the iron component over that of the brass, or $t = T_i - T_b$, see equation (3), the *plus* sign showing that the iron bar was hottest, the *minus* sign that the brass bar was hottest.

Brass Component West.

FIRST COMPARISONS AND MEASUREMENT.					THIRD COMPARISONS AND MEASUREMENT.				
Day.	Values of t at				Day.	Values of t at			
	7 A.M.	10 A.M.	1 P.M.	4 P.M.		7 A.M.	10 A.M.	1 P.M.	4 P.M.
Jan. 9	+ °·02	+ °·19	+ °·39	+ °·32	Feb. 12	+ °·12	+ °·21	− °·32	− °·40
11	+ ·08	·35	·40	·05	13	·21	·04	·37	·23
13	− ·02	·25	·43	·02	15	·17	·28	·08	·52
14	− ·02	·36	·44	·23	16	·16	·32	·09	·41
15	....	....	·19	·21	17	·14	·34	·08	·38
16	− ·10	·22	·24	·20	18	·11	·30	·23	....
18	+ ·01	·26	·49	·39	19	·08	·36	·04	·32
19	+ ·01	·18	·30	·07	20	·11	·21	·20	·25
20	+ ·08	·24	·56	·29	22	·04	+ ·27	·23	·08
21	+ ·03	·32	·48	·36	24	·04	− ·34	·65	·70
22	+ ·01	·12	·25	·33	25	·05	− ·16	·67	·78
23	− ·01	·25	·23	....					
25	+ ·10	·53	·55	·43					
26	+ ·10	·52	·60	·35					
Means	+ ·02	+ ·29	+ ·40	+ ·25	Means	+ ·11	+ ·17	− ·27	− ·41

Brass component East.

Second comparisons and measurement.					Fourth comparisons and measurement.				
Day.	Values of *t* at				Day.	Values of *t* at			
	7 A.M.	10 A.M.	1 P.M.	4 P.M.		7 A.M.	10 A.M.	1 P.M.	4 P.M.
	°	°	°	°		°	°	°	°
Jan. 28	+ ·01	− ·10	− ·25	+ ·43	Feb. 26	+ ·01	− ·23	− ·10	+ ·29
29	+ ·10	·23	− ·23	·40	27	+ ·01	− ·16	+ ·04	·37
30	....	·38	+ ·15	....	Mar. 1	·00	− ·34	+ ·16	·82
Feb. 1	− ·06	·32	+ ·14	·86	2	+ ·04	+ ·01	+ ·29	·50
2	− ·04	·30	+ ·13	·52	3	− ·02	− ·48	+ ·02	·81
3	− ·02	·30	+ ·12	·63	4	+ ·04	− ·54	+ ·08	....
4	− ·02	·61	− ·12	....	5	+ ·06	− ·76	+ ·06	·72
5	− ·01	·53	+ ·01	·60	6	+ ·04	+ ·07	+ ·42	·50
6	− ·02	·08	− ·10	·55	8	− ·02	− ·08	+ ·28	....
8	− ·01	·63	− ·19	·60	9	− ·02	− ·65	− ·10	·54
9	·00	....	....	....	10	+ ·07	− ·87	+ ·02	·60
10	+ ·04	·64	− ·31	·32					
11	+ ·07	·46	− ·29	·29					
Means	·00	− ·38	− ·06	+ ·52	Means	+ ·02	− ·37	+ ·11	+ ·57

First comparisons and measurement. At 7 A.M. the temperatures of the bars were nearly identical; by 10 A.M. that of the iron bar, which was to the east of the brass bar, and therefore most exposed to the influence of the morning sun, was in excess; at 1 P.M. it was still more in excess, and it continued greater throughout the day, but after that hour it was gradually being overtaken by the brass bar which was most influenced by the afternoon sun.

Second, third and fourth comparisons and measurement. At 10 A.M. the temperature of whichever of the two bars was towards the morning sun was greater than that of the other bar; at 1 P.M. the temperatures were either nearly equal or were reversed, and from that time the bar nearest the afternoon sun was acquiring a higher temperature than the other, until at 4 P.M., when the operations terminated, the difference of temperature was generally greater than at any other hour of the day.

The several groups of observations show that the influence of the thermal capacities of the brass and the iron components of this compensation bar—or rather the residual influence arising from any failure on the part of the makers to equalize the capacities of the components, (as indicated at pages 56 and 57,)—is wholly inappreciable, as compared with external influences, in producing the actual thermal inequalities of the bars. It is quite clear that whichever bar happened from it's position to have been most exposed to the sun's influence, acquired most heat, irrespectively of the material of which it is composed. The actual difference of temperature at any hour of the day must necessarily be dependent, to some extent, on the relative amounts of heat which had been previously, as well as on what is then being, acquired or lost by the bars; thus in the first group of observations, the temperature of the west bar was throughout the entire day—the afternoon as well as the forenoon—invariably less than that of the east bar, though in the three other groups the east bar was generally hottest in the forenoon and the west bar in the afternoon.

In plate XXXIII, curves are given which show the excess of the mean of the compensation bars over the standard—during the comparisons before and after each measurement—corrected for the compensation error of the bars, and the error in the adopted values of expansion for the standard and the iron component, but uncorrected for the observed differences of temperature of the two components. These curves corroborate the evidence of the thermometers, by showing that the fluctuations in the lengths of the compound bars depend on the relative positions with regard to external influences, rather than on the thermal capacities of the components.

During the progress of the operations, occasional notes were made of the state of the weather, the aspect of the sky, and the direction of the wind. They will be found in the detailed account of the operations. It is to be regretted that they are so few and unsystematic; a more exact record would probably have shown conclusively—what the existing record merely suggests—that the thermal inequalities and the fluctuations in the lengths of the compensation bars are very closely connected with the aspect of the sky, the amount of cloud and aqueous vapour tending either to obstruct or to diffuse the sun's heat, and the direction of the prevailing winds. In fact, if it may be assumed that the thermal capacities of the components have been equalized, as seems very probable, the thermal inequalities and the fluctuations in length afford more evidence of the relative amounts of cloud and sunshine, than is to be obtained from the records of the weather, and this more particularly during the forenoons and afternoons, when the bars would be most affected by alternations of cloud and sunshine, whereas at noon they would only be affected by changes of wind. Thus in the first comparisons and measurement, when the west bar remained throughout the day at a lower temperature than the east bar, the mornings must have been clear and bright, and the afternoons cloudy; the reverse must have happened during the third comparisons and measurement, when both bars had nearly the same temperature for several hours in the morning, while in the afternoon the west bar was considerably the hottest. And if the curves in plate XXXIII are examined, and compared with those in plates I to XVI, it will be seen that there are occasional jumps from peaks to hollows in the forenoons and afternoons, in which all the six compound bars behave in a similar manner, and which, as they are certainly not due to accidental errors in the comparisons with the standard, indicate a sudden change from cloud to sunshine or *vice versâ*. The temperature curves in plates XVII to XXXII show that these fluctuations are independent of the absolute temperature.

During the first and third measurements and comparisons, strong land winds, from the north, prevailed all day and more particularly about noon; but in the second and fourth, the mornings were generally calm, and sea breezes from the east and south set in about noon. This seems to have caused inequalities of temperature in the opposite halves of the bars, as will be seen by the following table of the differences of temperature of the north and south thermometers.

Operation.	Mean values of N − S at			
	7 A.M.	10 A.M.	1 P.M.	4 P.M.
First comparisons and measurement,	− °·08	− °·24	− °·31	− °·22
Second ,, ,,	+ ·05	+ ·16	− ·01	− ·05
Third ,, ,,	− ·05	− ·23	− ·36	− ·31
Fourth ,, ,,	+ ·04	+ ·12	+ ·07	− ·02

It should be here observed that every precaution was taken to equalize the temperatures of the bar-components as much as possible; the bars were never placed in the open air nor exposed to the direct rays of the sun, though they were necessarily more or less exposed to winds, through the tent openings for admitting light; all the interstices between the components and the sides, ends, tops and bottoms of the boxes in which they are contained, were carefully stuffed with cotton; the operations were invariably carried on under tents, of which there was a sufficient supply to permit of the bars being moved forwards under shelter, in the course of the successive stages of the operations; the tents were made of three or four folds of cloth, white on the outside, blue in the middle, and yellow on the inside.

The wells for the bulbs of the thermometers in the compensation bar B, as well as in the standard bar, were kept full of oil, to facilitate the conduction of the temperature of the bars to the thermometers.

CHAPTER IX.

Determination of the probable error of a base-line, by comparing the sections of the line by triangulation.

1.

Preliminary observations.

When a base-line is divided into two or more sections and these sections are connected by triangulation, the ratio of any two sections, or of any combinations of sections, to each other, may be computed from the triangulation, and may then be compared with the corresponding ratio which is given by the linear measurements. The value of these comparisons, as a test on the accuracy of the linear measurements, will however depend on the probable errors of the triangulation, which must therefore be investigated in the first instance.

For this purpose it will be necessary to give a brief outline of the systems which are followed in this Survey in the measurement of the angles, in the calculations of the probable errors of the angles, and in the reduction of the triangulation in such a manner as to obtain the most probable results. Full details of these subjects will be given in a subsequent volume.

2.

The probable errors of the Principal Angles.

The angles of the triangulations which have been executed for the purpose of comparing the sections of the several base-lines *inter se* have invariably been measured with the best theodolites in the Department; these instruments have large azimuthal circles, some three feet and none less than two feet in diameter, which are read by five equidistant microscopes; as the observations at each station are proceeded with, the setting of the zero to the referring mark is systematically altered from time to time, in order to eliminate the graduation errors as far as is practicable; every angle is measured not less than twice in each position of the zero, of which there are never less than eight, and more frequently ten; the entire number of measures of an angle is never less than twenty; and the number of equidistant graduations on the circle which are read during the observations of each signal, is never less than forty, and is more frequently fifty, *i.e*, the arcs between the readings are 9° or 7° 12'.

The probable errors of the angles have been determined in three ways; from the evidence of the observations of each angle, from that of the errors of the triangles—or the differences between the sum of the observed angles and 180° + the spheroidal excess—and from the most probable values of the errors of the angles of the polygonal figures; and the results by the last method—which generally gives errors of largest magnitude—have been adopted. Thus the angles of the Indus, Karachi, Jogi Tila, Rahun, and N. W. Himalaya chains of triangles—numbering altogether 1407 angles—have been shown to have an average probable error of $\pm$ 0″·28, large groups of angles, which have been measured under more favorable circumstances than the average, having probable errors less than $\pm$ 0″·20. The three angles of every principal triangle are invariably observed.

3.

Investigation of the probable errors of the trigonometrical ratios.

These probable errors are functions of the geometrical conditions of the triangulation and of the errors of the angles, the values of which are very easily determined when the triangulation is carried along one flank only of the base-line, for then the only geometrical condition to be satisfied is that the sum of the angles of each triangle shall be equal to 180° + the spheroidal excess. When the triangulation is carried along both flanks of the line, so as to form a polygonal figure, with one or more central points, the problem is more intricate, for additional geometrical conditions are introduced, viz., that the sum of the angles at the central stations must be exactly equal to 360°, and that no side of the triangulation can have two values, or in other words, that the length of any side, as determined by processes of calculation from any other side of the figure, must be identical.

The 'triangular', 'central', and 'side' equations of condition must be satisfied in such a manner that the probable errors of the corrected angles will be a minimum.

Let $x_1, x_2 \ldots . x_t$ be the most probable values of the errors of t observed angles, connected by n geometrical equations of condition which are as follows

$$\left.\begin{array}{l} a_1 x_1 + a_2 x_2 + \ldots \ldots + a_t\, x_t = e_a \\ b_1 x_1 + b_2 x_2 + \ldots \ldots + b_t\, x_t = e_b \\ \ldots \ldots \ldots \ldots \ldots \ldots \\ n_1 x_1 + n_2 x_2 + \ldots \ldots + n_t\, x_t = e_n \end{array}\right\} \quad \ldots \ldots \quad (20)$$

Let $u_1, u_2 \ldots u_t$ be the reciprocals of the weights of the observed angles, then the quantity

$$U = \frac{x_1^2}{u_1} + \frac{x_2^2}{u_2} + \quad \ldots \ldots \ldots + \frac{x_t^2}{u_t} \quad \ldots \ldots \quad (21)$$

must be made a minimum; and, by introducing indeterminate multipliers, $\lambda_a, \lambda_b \ldots . \lambda_n$, whose values are obtained from the following equations

$$\left.\begin{array}{l} [aa.u]\,\lambda_a + [ab.u]\,\lambda_b + \ldots \ldots + [an.u]\,\lambda_n = e_a \\ [ab.u]\,\lambda_a + [bb.u]\,\lambda_b + \ldots \ldots + [bn.u]\,\lambda_n = e_b \\ \ldots \ldots \ldots \ldots \ldots \ldots \ldots \ldots \\ [an.a]\,\lambda_a + [bn.u]\,\lambda_b + \ldots \ldots + [nn.u]\,\lambda_n = e_n \end{array}\right\} \quad \ldots \ldots \quad (22)$$

the values of $x_1, x_2 \ldots x_t$ will be expressed by the following equations

$$\left.\begin{array}{l} x_1 = u_1 (a_1 \lambda_a + b_1 \lambda_b + \ldots\ldots + n_1 \lambda_n) \\ x_2 = u_2 (a_2 \lambda_a + b_2 \lambda_b + \ldots\ldots + n_2 \lambda_n) \\ \ldots\ldots\ldots\ldots\ldots\ldots\ldots\ldots \\ x_t = u_t (a_t \lambda_a + b_t \lambda_b + \ldots\ldots + n_t \lambda_n) \end{array}\right\} \quad \ldots\ldots\ldots \quad (23)$$

corresponding corrections being applied to the observed angles of the triangulation, all the requisite conditions will be satisfied, and the ratios of any of the sections of the base-line, or of any combinations of sections, to each other, may be determined.

We have then to find the probable errors of these functions of the corrected angles. Proceeding to actual errors and putting $\bar{x}_1, \bar{x}_2 \ldots \bar{x}_t$ for the actual errors of the observed angles, then the actual error of F, any function of the corrected angles, may be expressed by the equation

$$a.e \text{ of } F = F \left\{ f_1 (\bar{x}_1 - x_1) + f_2 (\bar{x}_2 - x_2) + \ldots + f_t (\bar{x}_t - x_t) \right\} \ldots \quad (24)$$

in which $f_1, f_2, \ldots f_t$ are coefficients depending on the function under investigation.

The probable error of F may then be obtained from the following equation

$$\left.\begin{array}{r} \frac{\rho^2}{F^2} \times e.m.s.^2 \text{ of } F = [f^2 u] - \left\{ [fua]^2 A_a + 2[fua][fub] A_b + \ldots + 2[fua][fun] A_n \right\} \\ - \left\{ [fub]^2 B_b + \ldots + 2[fub][fun] B_n \right\} \\ - \ldots\ldots\ldots\ldots\ldots\ldots \\ -[fun]^2 N_n \end{array}\right\} (25)$$

in which the factors $A_a, A_b, \ldots, B_b, B_c \ldots, N_n$, are the coefficients of $e_a, e_b, \ldots e_n$ (the right hand terms of the geometrical equations of condition) in the following equations, which are obtained by solving equations (22)

$$\left.\begin{array}{l} \lambda_a = A_a e_a + A_b e_b + \ldots\ldots + A_n e_n \\ \lambda_b = A_b e_a + B_b e_b + \ldots\ldots + B_n e_n \\ \ldots\ldots\ldots\ldots\ldots\ldots\ldots\ldots \\ \lambda_n = A_n e_a + B_n e_b + \ldots\ldots + N_n e_n \end{array}\right\} \quad (26)$$

In equation (25), ρ is a factor for converting the weights of the observed angles into the probable errors of those angles, which has to be specially determined; it is a constant for all angles measured with the same instrument, with the same system of observation and under similar circumstances, but a variable for observations with different instruments, or with the same instrument under different circumstances; for the triangulation of any one base-line it may be taken as a constant, and if we put the *p.e* of an observed angle $= \theta$, in terms of radius, we shall have

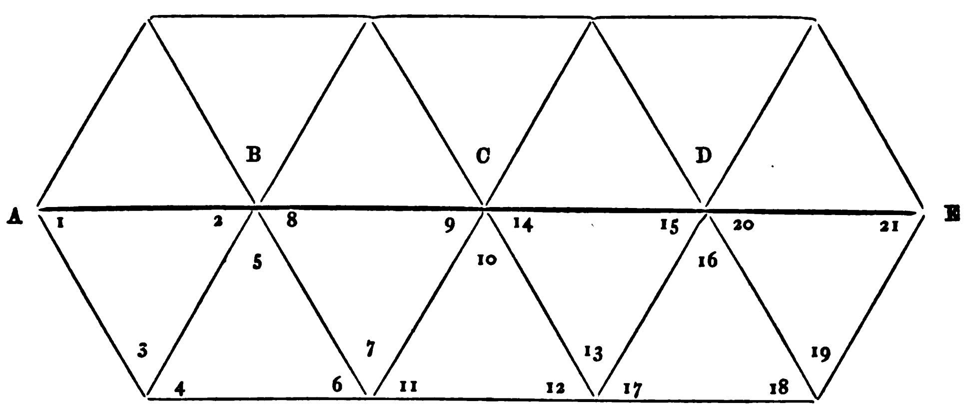
$$\theta^2 = \frac{u}{\rho^2} \ldots\ldots\ldots\ldots\ldots\ldots (27)$$

When the triangulation is carried along one flank only, there will be no other geometrical equations of condition than the triangular, the coefficients A_a, A_b . . . , B_b B_c . . . in equation (25) will vanish, and

$$\text{the } p.e^2 \text{ of } F = \frac{F^2}{\rho^2}\,[f.^2u]^* \ldots\ldots\ldots\ldots\ldots (28)$$

4.

Application of the preceding investigation.



The annexed diagram denotes a base-line divided into sections, the ratios of which have been determined by triangulation on both flanks of the base. When the triangulation has been made consistent by applying the most probable corrections to the observed angles, as indicated in the preceding section, it is immaterial whether the ratios are computed through the triangles on one flank or on the other, as identical results will be obtained in either case. Following the lower flank of the diagram, the angles 3, 7, 13, 19, opposite the sections of the base, and the angles 1, 4, 6, 8, 9, . . . opposite the sides of continuation of the triangles, will be required.

Putting $(\bar{x} - x) = \mathrm{x}$, (see equation 24) and c for the cotangent of any angle

$$\begin{aligned} \text{and } p &= c_1 x_1 - c_3 x_3 + c_4 x_4 - c_6 x_6 + c_7 x_7 - c_9 x_9 \\ q &= - c_7 x_7 + c_8 x_8 + c_{11} x_{11} - c_{12} x_{12} + c_{13} x_{13} - c_{15} x_{15} \\ r &= - c_{13} x_{13} + c_{14} x_{14} + c_{17} x_{17} - c_{18} x_{18} + c_{19} x_{19} - c_{21} x_{21} \end{aligned}$$

* The brackets in this and the preceding equations denote summations, thus

$$[f^2.u] = f_1^2.u_1 + f_2^2.u_2 + \ldots\ldots + f_t^2.u_t$$

$$\text{then the } a.e \text{ of } \frac{BC}{AB} = p \cdot \frac{BC}{AB}$$

$$a.e \text{ of } \frac{CD}{AB} = (p+q)\frac{CD}{AB}$$

$$a.e \text{ of } \frac{DE}{AB} = (p+q+r)\frac{DE}{AB}$$

$$a.e \text{ of } \frac{AC}{AB} = a.e \text{ of } \frac{BC}{AB}$$

$$a.e \text{ of } \frac{AD^*}{AB} = (2p+q)\frac{AD}{AB}$$

$$a.e \text{ of } \frac{AE}{AB} = (3p+2q+r)\frac{AE}{AB}$$

substituting for p, q and r their values as above given, the co-efficients of $x_1, x_2, x_3 \ldots$ will, in each instance, correspond to the co-efficients $f_1, f_2, f_3 \ldots$ in equations (24) and (25).

Thus the probable errors of the ratios under consideration, and in like manner those of any other functions of the angles of the triangulation, may be determined.

In order to compare the probable errors of the several ratios, we must assume that the weights of the angles are equal and that the triangles are equilateral. On these suppositions, the following table gives the co-efficients of θ in the expressions for the probable error of the ratios, for base-lines divided into 2, 3, or 4 sections as the case may be, and it is drawn up so as to be applicable also to cases in which the triangulation does not form polygonal figures, as in the diagram at page 86, but is restricted to a single flank of the base. For when the weights of the angles are equal, equation (25) may be written thus, for any polygonal figure, whether symmetrical or not,

$$p.e \text{ of } F = \theta \left\{ [f^2] - \Sigma \right\}^{\frac{1}{2}}$$

and when the triangulation is on one flank only Σ vanishes, and then

$$p.e \text{ of } F = \theta \left\{ [f^2] \right\}^{\frac{1}{2}}$$

---

* Supposing a base to be divided into three sections, as ABCD, the $a.e$ of the ratio of the entire length to the central section will be as follows,

$$a.e \text{ of } \frac{AD}{BC} = (-p+q)\frac{AD}{BC}$$

TABLE of the co-efficients of θ in the expressions for the probable errors of certain ratios, when the weights of the angles are equal and the triangles are equilateral.

Ratios	$[f^2]$	Σ	Co-efficients of θ for triangulation on: one flank only.	both flanks.
Base of two Sections A B C				
$\frac{BC}{AB}$ and $\frac{AC}{AB}$	2	1	1·41	1·00
Base of three Sections A B C D				
$\frac{BC}{AB}$	2	$\frac{38}{35}$	1·41	0·96
$\frac{CD}{AB}$	$\frac{10}{3}$	$\frac{38}{21}$	1·83	1·23
$\frac{AD}{AB}$*	$\frac{26}{3}$	$\frac{494}{105}$	2·94	1·99
Base of four Sections A B C D E				
$\frac{BC}{AB}$	2	$\frac{37}{34}$	1·41	0·95
$\frac{CD}{AB}$	$\frac{10}{3}$	$\frac{98}{51}$	1·83	1·19
$\frac{DE}{AB}$	$\frac{14}{3}$	$\frac{5}{2}$	2·16	1·47
$\frac{AE}{AB}$	$\frac{68}{3}$	$\frac{210}{17}$	4·76	3·21

* When the length of a base-line is determined partly by measurement and partly by triangulation, the probable error of the final result is much less, *cæteris paribus*, if a central section is measured as was done at the Cape Comorin base, than if either of end sections are measured. For with the same assumptions as above, the terms in the expression for

$$\text{the } p.\,e \text{ of } \frac{AD}{BC} \text{ are } [f^2] = \frac{14}{3} \text{ and } \Sigma = \frac{38}{15}$$

whence the co-efficients of θ are respectively 2·16 and 1·46.

5.

The probable errors of the ratios of the linear measurements.

If we assume that the probable errors of the measurements are proportional to the lengths measured, and if we put l for the ratio of the probable error of any measurement to the length measured, then

$$\text{the } p.e \text{ of } \frac{BC}{AB} = \frac{BC}{AB} l \sqrt{2}, = l\sqrt{2} \text{ when the lengths are equal;}$$

the probable error of the ratio of any two sections may be similarly expressed.

For combinations of sections we have

$$p.e \text{ of } \frac{AD}{AB} = l\sqrt{\frac{BD^2 + BC^2 + CD^2}{AB^2}}, = l\sqrt{6} \text{ when the lengths are equal.}$$
$$p.e \text{ of } \frac{AE}{AB} = l\sqrt{\frac{BE^2 + BC^2 + CD^2 + DE^2}{AB^2}}, = l\sqrt{12} \quad \text{,,} \qquad \text{,,}$$

6.

Determination of the average probable error of the differences between the ratios given by the triangulation and those by the linear measurements, and thence the average probable error of the linear measurements.

If we take any *one* of the ratios of which the probable errors have been investigated in the two last sections, as BC : AB, and compare the trigonometrical value with that obtained from the base-line measurements, and putting

$$T = \text{the value of } \frac{BC}{AB} \text{ by the triangulation}$$
$$M = \quad \text{,,} \quad \text{,,} \quad \text{linear measurement,}$$

find the value of

$$D = T - M$$

and if, from the evidence of several base-lines, we obtain n independent values of D, which are of equal weight—the probable errors of the triangulation being the same in every instance, and likewise those of the linear measurements,—then we may find the probable error of D from the formula

$$p.e\, D = \cdot 67 \sqrt{\frac{[D^2]}{n}} \quad \ldots\ldots\ldots\ldots\ldots\ldots \quad (29)$$

Now it has been shown that when the probable errors of the angles are equal, and the triangles are equilateral, and have been carried along one flank only of the base-line, the probable errors of the triangulation and of the measurement are respectively as follows,

$$\text{for the ratio } \frac{BC}{AB}, \quad p.e\, T = \theta \sqrt{2}$$

$$\text{,,} \qquad p.e\, M = l \sqrt{2}$$

and since

$$p.e^2\, D = p.e^2\, T + p.e^2\, M \quad \ldots\ldots\ldots\ldots\ldots \quad (30)$$

l, the ratio of the probable error of any linear measurement to the length measured, would, in this instance, be obtained from the equation

$$l^2 = \tfrac{1}{2}\, p.e^2\, D - \theta^2.$$

But it is evident that, when the probable errors of the angular and likewise of the linear measurements are constant, the modulus of error of the value of D, for the ratio of the first and third section, must be greater than that for the ratio of the first and second section which has just been considered; and generally that for the ratios of distant sections or of combinations of sections, the modulus of error of D must be greater than for the ratios of contiguous or of single sections. Strictly speaking therefore the values of D from which a *p.e* D is determined should be obtained for each of the ratios *per se.* The seven base-lines of this survey at which these comparisons of ratios have been made, do not however afford a sufficient number of comparisons to permit of a satisfactory determination of the *p.e* D for each ratio. Moreover though the probable errors of the angles, and likewise of the linear measurements, may be assumed to be much the same at all the base-lines, the geometrical conditions have not been indentical, the lengths of the sections, though generally nearly equal, occasionally varying in the proportion of 2 to 3, with a corresponding deviation from the equilateral form of triangles. Thus an exact determination of the *p.e* D is not possible, but a very fair approximation may be arrived at by treating the data which are available as if all the triangles had been equilateral.

The whole of the values of D, which have been obtained from the comparisons of the ratios of single sections at the seven base-lines, are given in the following table:—

BASE-LINES.	RATIOS.					
	$\frac{BC}{AB}$	$\frac{CD}{AB}$	$\frac{DE}{AB}$	$\frac{CD}{BC}$	$\frac{DE}{BC}$	$\frac{DE}{CD}$
Triangulation on one flank.						
Dehra Doon	− 3·55 μ	− 4·02 μ		− 0·31 μ		
Beder	6·31 ,,	+ 1·18 ,,		+ 3·99 ,,		
Sonakhoda	+ 1·23 ,,	1·36 ,,	+ 1·02 μ	0·07 ,,	− 0·13 μ	− 0·18 μ
Chuch	3·36 ,,	3·65 ,,	2·22 ,,	0·67 ,,	0·88 ,,	1·79 ,,
Karachi	− 2·65 ,,	− 5·34 ,,	− 6·64 ,,	− 2·78 ,,	4·04 ,,	1·16 ,,
Triangulation on both flanks.						
Vizagapatam	− 3·26 ,,	+ 4·95 ,,		+ 7·75 ,,		
Bangalore	2·26 ,,	−10·48 ,,		− 9·53 ,,		

Combining the whole of these values as if they were independent and had a common modulus of error,

$$p.e\,D = \pm \cdot 67\,\mu \sqrt{\frac{529\cdot 39}{30}} = \pm\, 2\cdot 81\,\mu.$$

The values of the *p.e* M may be taken as the same for the whole of the above ratios; not so the values of the *p.e* T, but of them a fair average value may be obtained by combining the respective values for the several ratios, which have been given in section 4*, with weights proportional to the number of determinations of D for that ratio in the preceding table; thus

$$p.e\,T = \frac{\theta}{30}\left\{ 13 \times 1\cdot 41 + 8 \times 1\cdot 83 + 3 \times 2\cdot 16 + 4 \times 0\cdot 96 + 2 \times 1\cdot 23 \right\} = 1\cdot 52\,\theta,$$

and since the *p.e* M may be taken $= l\sqrt{2}$, by substituting in equation (30) we get

$$l = \pm \frac{1}{1\cdot 41}\left\{ (2\cdot 81\,\mu)^2 - (1\cdot 52\,\theta)^2 \right\}^{\frac{1}{2}} \; \ldots\ldots\ldots\ldots\ldots (31)$$

The probable error of the angles measured with the great theodolites of this survey is $\pm\, 0''\cdot 28$ on an average and is frequently not more than $\pm\, 0''\cdot 20$, (see section 2 of this Chapter); with the larger value, we have $\theta = \theta''.\sin 1'' = 4\cdot 85\,\mu\,\theta'' = \pm\, 1\cdot 36\,\mu$,

$$\therefore\; l = \pm\, 1\cdot 35\,\mu$$

with the smaller value, we have $\theta = \pm\, 0\cdot 97\,\mu$

$$\therefore\; l = \pm\, 1\cdot 70\,\mu$$

and since θ cannot vanish the limits of l will be $\pm\, 1\cdot 99\,\mu$

It may be here noticed that equation (31) corroborates the values of θ'' which have just been adopted; for since l cannot vanish the limits of θ'' will be $\pm\, 0''\cdot 38$; and as in the triangulation of the seven base-lines the number of measured angles is very considerable, being $2 \times 15 + 3 \times 21 + 2 \times 30 = 153$, and the modulus of error is much the same for each of the angles, as they were all measured with the best of the great 3 feet and 2 feet theodolites, this limiting value of θ'' is worthy of every confidence.

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* The *p.e* T for the ratios $\frac{CD}{BC}$ and $\frac{DE}{CD}$ may be here taken as = the *p.e* T for the ratio $\frac{BC}{AB}$

and " ratio $\frac{DE}{BC}$ " = " $\frac{CD}{AB}$

CHAPTER X.

General conclusions on the probable errors of base-lines measured with the compensation apparatus.

1.

The Dehra Doon base-line.

This base was measured twice over by Colonel Everest, and the comparative results of the two measurements, for each of the several sections, are given at page II_{44}.

The comparisons of the compensation bars with the standard before the measurements, were made in a house, instead of being made in tents under circumstances precisely similar to those of the measurements, as was done at the subsequent comparisons at this base-line, and afterwards at all the others bases. The necessity for this precaution has already been abundantly shown; and, from what has been stated in section 1 of Chapter VIII, it is evident that the precaution is least necessary for a base-line of which the direction is meridional, but most necessary for one of which the direction is nearly east and west, as this base the azimuth of which, at it's eastern extremity, is 113° 44′.

On comparing the results of the two measurements of each of the six sections, it will be seen that, in every instance, the length by the first exceeds that by the second measurement, the excess ranging from 3·4 μ to 8·0 μ, and averaging 6·3 μ, μ being as formerly the millionth part of the length measured. The value of the probable error from this base-line might be taken as

$$p.e \text{ of a single measurement} = \pm \frac{\cdot 67}{\sqrt{2}} 6{\cdot}3\,\mu = \pm\, 3\,\mu$$

but under existing circumstances this value is probably too large, and it cannot be considered to be as reliable as those which have been deduced in the two last chapters.

2.

Recapitulation of the results of Chapters VIII and IX; conclusions regarding the probable errors of the measurements with the compensation apparatus, excluding the errors of the standards.

In Chapter VIII the probable error of a single measurement of the Cape Comorin base-line, has been determined from the evidence of the differences of the successive measurements, *first*, with such recognition of the thermal inequalities of the components and the compensation errors of the compound bars as is afforded by the observations of the temperatures and the determination of the compensation error of the representative bar B, and, *secondly*, on the usual assumption that the mean lengths of the bars were the same during the measurements as during the comparisons; a *third* determination was made from an investigation of the probable errors of each of the several operations of the measurement. In Chapter IX a *fourth* determination has been made from the differences between the ratios of the sections as given by the triangulation and by the linear measurements, for the seven base-lines at which verificatory triangulation has been executed.

From these investigations the probable error of a single measurement of a base-line by the compensation apparatus, *excluding* all constant errors, is as follows:—

from the first, $l =$	say $\pm$ 0·6 μ	*see page*	76
„ second, $l =$	„	1·5 μ	„	78
„ third, $l =$	„	0·5 μ	„	79
„ fourth, $l =$	„	1·5 μ	„	91

In all but the third investigation the results have been derived from comparisons of values which would be equally affected by any constant errors in the determinations of the units, temperatures and co-efficients of expansion of the standards of length; in the third only could the influence of such errors have been recognized, but there it was purposely disregarded in order that the results might be comparable with those of the other investigations. Such errors will be considered in the next section, but they may be disregarded for the present, as they are common to every apparatus for the measurement of base-lines; and we may conclude, from the above figures, that the average probable error of any single measurement of length by the compensation apparatus—expressed in millionth parts of the length measured—does not exceed

$$\pm 1{\cdot}5\ \mu$$

At page 270 of his *Comparisons of Standards of Length*, Captain Clarke shows that the probable errors of the relations of five of the 10-feet standards of the Ordnance and the Indian Survey to the Standard Yard Y_{55} range from $\pm$ 0·98 *m.y* to $\pm$ 1·35 *m.y*, or from 0·3 μ to 0·4 μ (in parts of their own length). Now the relations of these standards were determined with the utmost possible nicety and exactitude, in a comparing room, specially constructed for the purpose, of which the temperature rarely changed by more than 1° F. in the twenty-four hours; and the comparisons were made at a temperature so nearly coinciding with the normal temperature of 62°, that the results are quite unaffected by any errors in the adopted values of the expansions of either of the standards. The utmost accuracy humanly possible appears to have been well nigh reached. But in the operations with the compensation apparatus the conditions were by no means so favorable for exactitude; the measurements were carried on under considerable vicissitudes of climate, under more or less exposure to the open air, and with no better shelter from a tropical sun than is afforded by tents; the fact therefore that the probable errors of the results may be taken as only about five times those of Captain Clarke's determinations of the lengths of the standards, is a very satisfactory evidence of the accuracy of the compensation apparatus as an instrument of measurement.

3.

Influence of the probable errors of unit, temperature and co-efficient of expansion, of the standards of measure, on the lengths of the base-lines.

I. Influence of errors of unit.

First, for the 10-feet standard **A**. The mean of the two determinations of the relation of this standard to the standard I_S, which are given in Section 4 of Chapter III, has been adopted as final; the probable error of the result may be taken as

$$\pm \cdot 67 \frac{3 \cdot 02}{2} = \pm 1 \cdot 0 \ (m.y.)$$

which is much the same as the probable error of Captain Clarke's determination of the relation of I_S to the standard yard Y_{55}, (*Comparisons of Standards of Length, page* 270.) Thus the relation of **A** to the yard has a probable error $= \pm 1 \cdot 4$ *m.y*, and therefore

$$\text{the } p.e \text{ of unit of } \mathbf{A} = \pm 0 \cdot 42 \ \mu$$

Secondly, for the 6-inch scales. The average probable error of the relation of any microscope scale to $\frac{1}{20}$ **A** is $= \pm \cdot 58$ *m.y.** ; thus the probable error of unit in the length measured by a complete set of bars and microscopes is $\pm \cdot 58 \sqrt{5 \cdot 5}$ $(= 1 \cdot 36)$ *m.y*; and as this length is 63 feet,

$$\text{the } p.e \text{ of unit} = \pm \cdot 06 \ \mu$$

II. Influence of errors of temperature.

First, the errors arising from the inaccuracies of the thermometers. All the thermometers which have been used at the several base-lines and during the comparisons of standards are described in Appendix 8, on reference to which it will be seen that the thermometers which were originally sent out to India with the base-line apparatus have never been calibrated, and that for a period of about 25 years after their construction, in or about the year 1830, nothing is known regarding their index errors. They were not graduated on their stems, but were fastened to metal scales, their attachments to which were not rigid but permitted of a play

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* The relations of the 6-inch scales to the central 6-inch space [*d.l*] of the standard foot **IF** are given at page 19 of the Appendices; the *p.e* of ([*d.l*] − R) being of the same magnitude as the average of all the others may be used as a fair indication of the *p.e* of these relations: then since

$$
\begin{array}{lll}
 & & \quad m.y \quad\; m.y \\
[d.l] - R & = & -\,8 \cdot 44 \pm \cdot 56 \\
[d.l] - \frac{1}{6}\,\mathsf{Y}_{55} & = & -\,0 \cdot 01 \pm \cdot 13 \text{ Captain Clarke's Comparisons of Standards page 249} \\
\quad - \frac{10}{3}\,\mathsf{Y}_{55} & = & 69 \cdot 38 \pm \cdot 98 \quad \text{,, \quad ,, \quad ,, \quad 270} \\
\mathsf{I}_S - \mathbf{A} & = & 82 \cdot 52 \pm 1 \cdot 0
\end{array}
$$

$$\text{Hence } R - \frac{1}{20}\,\mathbf{A} = 9 \cdot 1 \pm \cdot 58$$

equivalent to about 0°·2. There are sufficient reasons for concluding that the thermometers α and β, which were employed on standard **A** at the first eight base-lines, must have had, at the commencement of the Karachi base-line in the year 1854, a mean index and calibration error of about + 0°·51 F which they were found to have in 1867, on being tested in melting ice and compared with the modern standard thermometers which were obtained in that year. Possibly the zero points of all the thermometers were correct originally, and were subsequently disturbed by the contraction of the bulb to which all newly made thermometers are liable; but the play in the attachments is fatal to any exact conclusions on this subject.

It will be assumed that the combined index and calibration errors of all the working thermometers give rise to an average probable error of temperature = ± 0°·3 at the first six base-lines, and = ±0°·1 at the Karachi and Vizagapatam base-lines, to which a correction for index error has been applied. Now twenty parts in twenty-one of every base are expressed directly in terms of the iron standard **A**, of which the co-efficient of expansion for 1° F is 6·5 μ; but the remainder is expressed primarily in terms of the brass scales, of which the expansion has been taken as 9·9 μ; thus an error of 1° of temperature is equivalent to an error of 6·7 μ in length.

Hence the *p.e* arising from the assumed inaccuracies of the thermometers is,

= ± 2·0 μ for the first six base-lines

and = ± 0·7 μ for Karachi and Vizagapatam.

Carefully calibrated thermometers, of which the index errors have been determined from time to time, were employed at the Bangalore and the Cape Comorin base-lines, which should therefore have no errors of this nature.

Secondly, errors arising from differences between the actual temperatures of the standards and those indicated by the thermometers. When the temperature of a metal bar is rapidly rising or falling, the temperatures indicated by thermometers whose bulbs are in wells in the bar and are protected from any other thermal influence than that of the bar, have a tendency to lag behind the temperature of the bar, even when the wells are filled with oil to facilitate the conduction of heat to or from the bulbs of the thermometers. At pages (7) and (8) of this volume instances are given in which the lagging amounted to about 0°·3 F during changes of temperature which were not nearly so rapid as those that are daily experienced in the measurements of base-lines. As a rule the temperature of standard **A** is rising for about four-fifths of the daily working hours, which are generally from 7 A.M. to 4 P.M.; at first it usually falls for about half an hour, then rises for several hours, to fall again only a little before the close of the day's work, following the diurnal variations of temperature by an interval of about two hours.

There are no means of ascertaining what the average actual amount of thermometric lagging has been at any of the base-lines which have been measured hitherto. An investigation of this subject would have been very laborious and difficult, necessitating the employment of an apparatus for artificially sustaining the temperature of one bar at a constant point, while the bar was being compared with another bar of which the temperature was following the ordinary daily rise and nightly fall.

Supposing the resultant average amount of lagging during the operations of the base-lines to be − 0°·3 F, for the thermometers attached to standard **A**—which for the climate of

India appears to be a very moderate assumption—and assuming that the errors of this nature in determining the temperatures of the scales cancel each other, because the bulbs of the thermometers are not inserted into these small bars, the error in the length of a base from this cause would be

$$= -0{\cdot}3 \times \frac{20}{21} \times 6{\cdot}5\,\mu = -2\,\mu \text{ nearly.}$$

III. Influence of the errors of the co-efficients of expansion of the standards.

For the reasons stated at pages (12) and (13) it may be assumed that the probable errors of the values of the factors of expansion which have been finally adopted in the reductions of the base-lines are = 1 *per cent* of the magnitude of the respective factors. It has just been shown that a change of 1° F in the temperatures of the iron and the brass standards is equivalent to an alteration of 6·7 μ in any length measured by the compensation apparatus; thus the probable error arising from the adopted values of the factors of expansion would be = $\pm\,0{\cdot}067\,\mu$ for 1° F. Putting T for the mean temperature of standard **A** during the measurement of any base-line, and assuming that the mean temperatures of the brass scales are much the same,

the *p.e* from errors of co-efficients of expansion = $\pm\,{\cdot}067\,(T - 62°)\,\mu$
which for the first nine base-lines is on an average = $\pm\,0{\cdot}5\,\mu$
but for the Cape Comorin base is = $\pm\,1{\cdot}4\,\mu$

4.

Final conclusions. Equal weights given to all the base-lines.

We have seen that, excluding the constant errors of the standards of measure, the probable error of any length measured by the compensation apparatus may be taken as $\pm\,1{\cdot}5\,\mu$, μ being the millionth part of the length measured. We have also seen that the constant and inconstant errors of the standards may be generally taken as of the following magnitudes,

error of unit, $\pm\,0{\cdot}4\,\mu$
error of temperature, $-\,2\,\mu \pm 2\,\mu$
error of factor of expansion, $\pm\,0{\cdot}5\,\mu$
whence the combined error is, $-\,2\,\mu \pm 2{\cdot}1\,\mu$

Thus the total error arising from the compensation apparatus and the standards of length may be taken as

$$= -\,2\,\mu \pm 2{\cdot}6\,\mu$$

for a single measurement of length; and it is evident that as the errors connected with the standards are larger than those arising from the compensation apparatus, very little gain in accuracy is obtained when the measurements with the compensation apparatus are repeated.

It should be here reiterated that the negative error, $-\,2\,\mu$, in the above expressions of error, is an arbitrary estimate of the probable influence of the difference between the temperatures of the 10-foot standard and those indicated by the thermometers attached to the standard during the course of the daily working hours, which results from the phenomenon of lagging. Believing that more error *may* arise from this circumstance than from the combined influence of every other cause of error, more particularly in India—where the diurnal vicissitudes of climate during certain seasons of the year are very slight, and the weather repeats itself, days of bright and almost unbroken sunshine following each other sometimes for weeks together—I have thought it better to introduce an arbitrary estimate of the possible effect of the error than to omit it altogether. But it should be omitted in making comparisons of the probable errors of the base-lines of this survey with those of other surveys in which it may have been disregarded.

And since this error is almost beyond human control, the probable error for which the compensation apparatus, the standards of length and the persons using them are responsible, may be taken as $= \pm 2{\cdot}6$ millionth parts of the length measured; a quantity which must be considered small when expressed in terms of any terrestrial magnitude, being equivalent to only 108 feet in the length of the polar axis of the earth. But the final results of the operations, the lengths of the arcs, the coordinates of the fixed points &c., are dependent both on the linear and on the angular measurements, and no advantages would be gained if the accuracy of one class of operations were materially greater than that of the other; the linear errors of any geodetic operation are thus not so much a matter of interest as is their relation to the angular errors.

Now in order to find this relation we must compare the probable errors of the ratios by the linear measurements with those by the trigonometrical operations. From what has been already stated above and at page (89) it appears that

the *p.e* of the ratio of two base-lines of equal length is $= \pm 2{\cdot}6 \sqrt{2}\,\mu = \pm 3{\cdot}7\,\mu$.

The probable error of the ratio of any side in an equilateral triangle to the base is $= \theta \sqrt{\frac{2}{3}}$, when that of each of the three angles is θ. In the best operations of this survey $\theta'' = \pm 0''{\cdot}2$, and $\theta = \pm 0{\cdot}97\,\mu$; thus in the best equilateral triangles or those which are measured with the most accurate and powerful instruments under the most favorable circumstances,

the *p.e* of the ratio of the second side to the first may be taken as $\pm 0{\cdot}8\,\mu$,

which is about one fifth that of the linear measurements. But the distances between the base-lines of this survey range from 275 to 750 miles, and the probable errors of the four chains of triangles directly connecting the base-lines at Dehra Doon, Sironj, Karachi and Attok, the average length of which is 575 miles, have been recently determined very approximately, and show that

the *p.e* of the ratio of the last side to the first averages $\pm 10\,\mu$,

which is not quite three times that of the linear measurements. Thus the relations of the probable errors of the linear and the angular measurements may be considered to be sufficiently harmonious and consistent.

It only remains to add that after a careful consideration of all the available data for determining the relative weights of the several base-lines, I have arrived at the conclusion that there is no sufficient evidence for assigning different weights to different bases which would be generally accepted as conclusive. In the bases which were last measured the errors of the thermometers were unquestionably much less than was previously the case, though perhaps at the first one of all they may have been small; on the other hand the differences between the trigonometrical and the linear ratios at Vizagapatam and Bangalore are larger than those which occurred previously, (see the table in page 90). At Calcutta the compesation bars were compared with the standard in a house, and not in tents on the base-line; but fortunately the direction of the line was meridional. At Dehra Doon the first set of comparisons was made in a house, but the others were made in tents, and the line was twice measured. The Cape Comorin base was measured four times, but it's mean temperature was 7° higher than that of any other base, and therefore it would be most affected by an error in the co-efficient of expansion of the standard. It is very clear however, from the investigations which have been gone into, that the actual errors of the results must, in all cases, be very minute, and therefore there can be no valid objection to assuming that the respective results are, to all intents and purposes, of equal value. This assumption will therefore be made, and it will much simplify the general reduction of the triangulation which is now being carried on.

5.

Progressive and accidental changes in the lengths of the compensation bars.

The determinations of the relations of the compensation bars to the standard, at the several comparisons at each base-line, are given in the following table, which shows the excess of the actual length of the mean of the bars over the standard, or L—**A**, and that of each of the bars over the mean, or A—L, B—L, . . . The quantities L—**A** are primarily expressed by two terms, the first of which is numerical, and gives the excess as computed with the old value of the factor of expansion of the standard, and corresponds with the X″ of equation (15), page (69); the second contains a symbol, dE'_a, for the error of that factor and a numerical coefficient $= -(T_a - 62°)$ or the sign-changed excess of the mean actual temperature of the standard over the normal temperature of 62°; now dE'_a may be taken as $= 1{\cdot}0\ m.y = 0{\cdot}3\ \mu$, on an average, for the mean actual temperatures of the whole of the base-lines,* and this value has been used to obtain the concluded actual relations of the mean of the bars to the standard.

Approximate values of the normal relations of the mean of the bars to the standard are also given, by allowing for the effect of the errors of compensation, and assuming that the temperatures of the bars were the same as those of the standard. For an exact determination of the normal length of the bars it is necessary that the respective temperatures of the brass and the iron components should be known, but no data are available for ascertaining what these temperatures were at any but the last base-line.

If in equation (17) page (69) we put $t = 0$, and assume $T_b = T_a$, then

$$X = X'' - T_a(\eta + dE_a') \text{ approximately;}$$

but $\eta = 1{\cdot}0\ m.y$ very nearly, thus $\eta + dE'_a = 0{\cdot}6\mu$ in parts of the bars or the standard;

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* See the table of thermal expansions of standard **A** at various temperatures, page 19.

the approximate normal lengths have therefore been determined, in each instance, by multiplying the co-efficients of dE'_a in the table by 0·6 μ, and applying the quantity thus found to the preliminary numerical relation of the mean of the compensation bars to the standard.

Base-line and year of measurement	Values of L—A				Relations of each bar to mean of all					
	Actual			Approx normal	A—L	B—L	C—L	D—L	E—L	H—L
1831-32 Calcutta ...	33·9 μ	− 6·8 dE'_a	= 31·9 μ	29·8 μ	+ 0·9 μ	− 5·4 μ	+ 0·3 μ	+ 6·5 μ	+ 5·6 μ	− 7·9 μ
	33·5	1·5	33·0	32·6	2·3	5·6	0·4	7·9	4·3	9·3
1834-35 Dehra Doon	42·0	4·6	40·6	39·2	0·1	8·5	0·3	13·6	− 2·9	2·6
	37·2	+ 2·2	37·9	38·5	0·0	8·6	− 0·8	13·2	2·9	0·9
	42·8	− 10·5	39·6	36·5	− 1·0	7·2	1·1	14·3	3·0	2·1
1837-38 Sironj ...	45·2	6·0	43·4	41·6	+ 2·3	9·5	0·2	17·6	5·1	5·1
	41·2	+ 2·2	41·9	42·5	3·3	10·3	0·1	17·9	4·3	6·5
1841 Bider ...	56·1	− 18·7	50·5	44·9	− 0·2	6·5	+ 3·3	10·1	1·6	5·2
	53·7	10·3	50·6	47·5	+ 1·3	7·5	2·9	8·7	1·8	3·5
1847-48 Sonakhoda	59·9	8·1	57·5	55·0	− 1·4	7·9	2·4	10·9	1·1	3·0
	52·0	0·7	51·8	51·6	0·5	9·7	1·8	10·2	0·0	1·9
	50·7	+ 0·9	51·0	51·2	1·0	10·1	2·3	10·6	0·1	1·7
1853-54 Chuch ...	53·5	11·5	57·0	60·4	1·4	11·6	2·8	12·5	2·4	0·0
	55·1	8·2	57·6	60·0	0·7	10·8	2·0	13·1	2·3	1·2
	56·4	10·1	59·4	62·5	+ 0·1	10·7	1·6	12·4	2·7	0·7
1854-55 Karachi ...	62·2	− 8·4	59·7	57·2	− 0·6	10·1	3·3	12·8	1·9	3·5
	58·5	3·9	57·3	56·2	2·4	9·5	2·6	12·1	1·4	1·5
	56·8	6·3	54·9	53·0	4·9	9·7	5·0	12·4	0·4	2·3
1862-63 Vizagapatam	61·1	8·8	58·5	55·8	4·7	10·0	3·0	10·5	+ 0·7	+ 0·5
	63·6	13·7	59·5	55·4	3·6	9·8	4·4	9·0	1·4	− 1·4
	63·9	14·7	59·5	55·1	5·3	9·7	2·6	10·7	1·3	+ 0·3
1868 Bangalore ...	62·0	6·2	60·1	58·3	11·0	15·4	4·0	23·0	1·1	− 1·6
	62·6	9·5	59·7	56·9	9·7	16·3	4·6	21·6	− 0·4	+ 0·2
	69·2	14·5	64·8	60·5	10·9	17·0	4·8	22·8	+ 0·5	− 0·2
1869 Cape Comorin	79·0	18·8	73·4	67·7	16·7	10·0	5·8	23·1	1·6	2·3
	72·2	21·5	65·7	59·3	15·5	9·9	5·1	21·0	0·3	1·1
	72·5	21·7	66·0	59·5	16·8	10·7	4·9	22·6	1·4	1·4
	75·0	23·4	68·0	61·0	15·9	10·6	5·0	22·1	1·4	1·6

The table shows that the lengths of the compensation bars were increasing progressively, from the time these bars were first used in India, in 1831-32, up to the measurement of the Chuch Base-line, in 1853-54; since then the lengths have fluctuated, sometimes increasing, sometimes decreasing. The table also shows that there have been other changes in length, which may be termed accidental to distinguish them from the progressive alterations. It is believed that up to the year 1867, nothing was purposely done to the bars which could have altered their lengths, excepting that they were carried distances of many hundred miles between the respective base-lines, and always by land; but they were always transported on men's shoulders, two men for each bar, and at every halt they were rested on pairs of trestles, and were never placed on the ground; in fact they could scarcely have been more tenderly handled or better cared for than they have been. For many years it was supposed that the progressive alteration in the relations of the bars to the standard, might be due to a change in the standard, and the bars were therefore all the more jealously guarded. The constancy of the standard was not established beyond doubt until the year 1867, (see sections 4 and 5 of Chapter III); afterwards no further hesitation was felt as to doing anything which might disturb the lengths of the bars; they were all taken to pieces and well cleaned before the measurement of the Bangalore base-line, and in the following year thermometer wells were bored into bar B. These operations have had the effect of disturbing the lengths of some of the bars, but the mean length of all is much the same as it was a few years previously.

CHAPTER XI.

On the calculations for the reduction of the base-lines.

1.

General details.

The greater portion of the calculations will be readily understood from the actual procedure in each case, and from the full explanations which have already been entered into regarding the treatment of the Cape Comorin base-line. It has been seen that the determination of the lengths of the compensation bars is the most important part of the process, as twenty parts in twenty-one of the base are measured by these bars. It has been shown in Section 3 of Chapter VII that for the exact determination of the normal length of a compensation bar as compared with a standard bar, the error of compensation and the thermal inequalities of the components of the compensation bar should be known; the exact expression for the length is given by equation 9; whence it follows that for the first nine base-lines, at which no steps were taken to measure the temperatures of the components, the terms in that equation into which t and T_b enter must be neglected, and we must put

$$X = B' - \mathbf{A}' + (E'_a - dE'_a)\, T_a \text{ approximately.}$$

The values of X have been thus computed for all the first nine base-lines, and though in no case do they indicate the normal bar-length, they always give the actual bar-length at the time of the comparisons, and thus in every case the determination of the length measured by the bars will be correct, if the average temperatures and thermal inequalities, and consequently the average lengths of the bars, were the same during the comparisons as during the measurements.

The reduction of the lengths measured by the microscopes is described in Section 7 of Chapter VIII, and the method of grouping the results is sufficiently obvious, and may be readily followed.

All the linear measurements are finally expressed in feet of the 10-feet standard **A**; in Colonel Everest's Arc Book of 1847 the microscope lengths were expressed in terms of a standard 6-inch scale, the relative length of which to the 10-feet standard had not then been determined. The relations of length which have been employed in the present reductions are those which are given in Sections 7 to 9 of Chapter III.

The factors of expansion for 1° *Fahrenheit*, which have been used, are the old values which were employed by Colonel Everest, *viz.*, ·000,006,801 for the iron standard **A**, and 000,010,417 for the brass scales; subsequently corrections have been applied for the differences between these values and those indicated in Sections 6 and 8 of Chapter II, which have been obtained from the latest and most exact investigations.

2.

Reduction of the measured length of a base to the length at the mean sea level.

The formulæ which have been employed in these reductions are demonstrated at the end of the details of the reduction of the first—the Calcutta—base-line. The process is divided into two parts, first a reduction from the levels of the measurement to the level of the origin, and secondly from that of the origin to the mean sea level; it will be easy at any future time to apply a correction to the length of any base-line, corresponding to any correction which may be required for the adopted height of the origin above the mean sea.

The heights of the origins have been derived in some instances from spirit leveling operations in others from the vertical angles of the triangulation. From the commencement of the survey until the year 1856 all the heights were invariably determined from observations of reciprocal vertical angles between the principal stations of the triangulation. But this method, though susceptible of a high degree of accuracy in a hill region, is beset with many difficulties in a level country; the rays of light, grazing the surface of the ground, pass through various gradations of refraction, from a low negative to a high positive value, during the course of the day and night; the success of the method depends on the reciprocal angles being equally refracted, which probably would not be the case even if the observations were simultaneous; whereas from the circumstance of there being only one large theodolite with each survey party, there is always an interval of several days between the reciprocating observations, and thus there is all the more reason to mistrust the assumed equality of refraction.

The principal chains of triangles have frequently been carried across plains of a breadth of several hundred miles, for the Peninsula of India is separated from the Himalayan and the Soolimani ranges of mountains by the vast plains of Sind, the Punjab, Rajpootana and Central India, and by the valley of the Ganges which is no-where less than 150 miles in breadth, all which have been repeatedly crossed by the triangulation. And as these plains were very unfavorable for the vertical operations, and the chains of triangles were of great length—occasionally as much as 2000 miles from sea to sea, without external check or verification—lines of spirit levels were commenced, in the year 1856, to controul the results of the trigonometrical determinations.

During the immediately preceding period of about twenty years the rule had been followed of restricting the observations of vertical angles as closely as possible to the time of minimum refraction, which occurs daily between the hours of 1 and 3 P.M. *apparent time;* the back angle was also measured at nearly the same interval from apparent noon as the forward angle. But during the operations of the period between 1800 and 1836 the observations were taken at any hour of the day and often during the night.

On comparing the results of the spirit levels with trigonometrical heights which had been determined by observations at the time of minimum refraction, the accordance is found to be very satisfactory; the errors of the trigonometrical determinations between base-lines being as follows:

WITH THE COMPENSATION APPARATUS.

From	Karachi to Attok,	706	miles,	error	— 3·2 feet
„	Attok to Dehra Doon,	416	„	„	+ 5·1 „
„	Dehra Doon to Sironj,	429	„	„	+ 1·8 „
„	Karachi to Sironj,	669	„	„	+ 2·1 „
„	Sironj to Calcutta,	680	„	„	— 4·6 „

On the other hand the errors of the trigonometrical determinations in the early operations of the survey are occasionally very large; for example the value of the height of the Sironj base which is given as 1644·5 feet at page 83 of Colonel Everest's Arc Book of 1847 is 113·1 feet in excess of the value obtained by the leveling operations, with which the results of the modern triangulation agree so well.

The datum of the spirit leveling operations is the mean sea level of Karachi harbour; from thence the main line of levels has been carried up the right bank of the Indus to Mittunkote, Ferozepore, thence to Allahabad, and down to Calcutta, over a distance of upwards of 2000 miles, closing on the datum of the long established tide guage at the Kidderpore Dock, on the left bank of the Hoogly river. The mean level of this tidal river, in the dry season, was determined by the operations to be 2·33 feet above the mean sea level at Karachi; in the rainy season it is considerably higher. The line of levels has not yet been carried to any point on the coast of the Bay of Bengal near Calcutta which is in free communication with the sea.

The heights of the base-lines at Karachi, Attok (or Chuch) Dehra Doon, Sironj, and Calcutta are referred to the mean sea level of Karachi harbour by the leveling operations. The height of the Sonakoda base is dependent on the triangulation from Calcutta; that of the Bider base is the mean of independent trigonometrical determinations from the tidal stations at Bombay on the west coast, Vizagapatam on the east coast, and from the Sironj base. The height of the Vizagapatam base depends on a contiguous tidal station. with which it is connected by a short line of levels; that of the Cape Comorin base is similarly dependent on a tidal station at Tuticorin, where however final results have not yet been obtained; and that of the Bangalore base-line on the levels of the line of railway form Madras, which agree within 4 feet with the corresponding values by the triangulation.

3.

Verification of the linear measurements by triangulation between the sections of the base-lines.

The comparisons of the measured lengths of certain sections of the base with other sections, by triangulation, have always been made by determining the excess (±) of the length of each section—as computed from some other section or the entire base—over the measured length. One of the sections—usually that nearest the origin—is adopted as the base of the triangulation, and the lengths of the other sections are computed therefrom.

MEASUREMENT OF BASE-LINES

Supposing the measured lengths of the sections to be AB, BC, CD . . . . , and that of the entire base to be AD . . . . , while the corresponding lengths by the triangulation are ab, bc, cd . . . . and ad . . . . , where ab = AB; then

$$\left.\begin{array}{l}\frac{AD}{ad} \cdot ab - AB \\ \frac{AD}{ad} \cdot bc - BC \\ \cdots\cdots\end{array}\right\}$$ are the excesses of the lengths computed from the entire base, for each section, over the measured lengths.

$$\left.\begin{array}{l}bc - BC \\ cd - CD \\ \cdots\cdots\end{array}\right\}$$ are the excesses of the lengths computed from the first, for the following sections, over the measured lengths.

and so on.

The natural numbers corresponding to the differences between the logarithms of the measured and computed values were obtained from the following formula.

$$\text{Since } \log_e (x + dx) = \log_e x + \frac{(dx)}{x} - \frac{(dx)^2}{2x^2} + \cdots\cdots$$

$$\therefore \ dx = \left\{\log_{10} (x + dx) - \log_{10} x\right\} \frac{x}{\text{Modulus}} \text{ nearly.}$$

CALCUTTA BASE-LINE.

The middle point of the base-line is in Latitude N. 22° 40′, Longitude E. 88° 25′. Azimuth of N. end at S. end=177° 11′. The line is 6·432 miles in length. It was measured under the directions of Captain G. Everest R.A., with the assistance of Captain Wilcox, Lieutenant Western, Mr. Logan, Mr. Taylor, Mr. Ollivver and Mr. DePenning. The names of the remaining assistants who took a share in the operations cannot be traced from the Field books. The measurement was commenced at the S. end and carried on continuously to the N. end. No verificatory triangulation of the line was executed.

INTRODUCTION.

"The base-line in the vicinity of Calcutta was measured with the new Compensation "bars in 1831-32, that being the first occasion of their being practically tried in India, it was "commenced on 5th November 1831 and finished on 28th January 1832.

"The line chosen was on a straight part of the Barrackpore road near Chitpore about "6½ miles long, where two towers of 75 feet height were erected one at each limit so as to "overtop the high trees and buildings in the suburbs, with a view to its subsequent connection "with the triangulation.

"As the alluvial soil of the delta of the Ganges induced the supposition that these towers "might sink, the precaution was taken of embedding a large stone at the distance of one complete "set of bars from the point within the tower which marked the limit, both which stones were "subsequently vaulted over, so as to admit of future reference.

"In the measurement, a stone was also embedded at the end of the 12th set of bars (1) "with the view of trying the same length by remeasurement after the whole work was finished. "The reference in this instance (2) was made to the mark at the end of the first set and not to "that within the tower, because the stability of the latter was suspected.

"The bars were compared with the standard **A**, 67 times before the measurement and 80 "times after the measurement.

"The comparisons in both these instances were made in a thatched building erected in "the grounds attached to the Surveyor General's Office, Chaoringhi, and at night, by lamp light, "one of the reverberatory lamps with an Argand's burner being placed at as great a distance as ad-"mitted of its properly illuminating the microscopes; but this plan is liable to the objection "that the comparisons were made under different circumstances from those under which the "measurement was conducted so that any defect or excess in the compensation would tend to "vitiate the numerical value given by the measurement.

"The comparison of the microscopes was made on seven different occasions during the "measurement, including those prior and subsequent. It is to be noticed that at this time the "micrometric apparatus appended to the six-inch scales was not in existence (3) and the only "mode of obtaining a value of these minute errors was by estimating them in terms of the "images of the wires in the eye pieces of the microscopes" (4).

(Taken from the General Report on the Calcutta Longitudinal Series by Lieutenant-Colonel G. Everest, R.A.)

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(1) Reckoning from the South end.

(2) *i.e.* on re-measurement.

(3) The seven scales with micrometers attached were constructed subsequently to the measurement of the Calcutta base.

(4) The value of the apparent image of the wire was found equal to ·0007 of an inch. For particulars see page lxxxvii of introduction to Colonel Everest's account of the Meridional Arc of India, 1847.

Comparisons between the Standard Bar **A** *and the Compensated Bars* **A, B, C, D, E, H,** *made at the Surveyor General's Office Calcutta, before the measurement.*

1831 Novr.	Mean of the times of observing A	No. of comparison	Corrected mean temperature of A	Micrometer Readings in Divisions. 1 Division = $\frac{1}{20090}$ Cary's Inch [7·8], = 1·3819 m.y of A — Mean A	A	B	C	D	E	H	Mean of the compensated bars.	Remarks.
	h. m.		°	—	—	—	—	—	—	—	—	
5th	9 1 P.M.	1	73·50	108·5	203·9	211·0	209·5	186·8	193·7	232·4	206·2	Capt. Everest
	10 6	2	72·67	118·5	200·2	227·0	203·6	190·6	195·5	235·7	208·8	at the micro-
	10 57	3	72·40	122·9	200·7	222·1	200·9	189·6	193·6	230·0	206·1	meter micro-
	11 45	4	72·07	127·0	197·8	213·4	198·3	190·3	188·6	224·7	202·2	scope.
6th	0 33 A.M.	5	71·62	131·8	198·6	213·0	199·1	185·0	192·2	225·1	202·2	
	1 21	6	71·22	137·4	198·8	213·0	206·3	189·5	186·9	224·0	203·1	
7th	6 41 P.M.	7	70·00	119·5	157·5	171·1	164·5	147·4	151·4	189·0	163·5	
	7 32	8	69·77	122·3	157·3	175·1	159·7	148·1	154·0	188·5	163·8	
	8 57	9	69·07	130·3	158·1	175·5	162·0	153·3	155·4	189·0	165·5	
	10 22	10	68·17	139·6	153·7	169·5	157·3	144·0	150·2	184·8	159·9	
	11 6	11	67·65	147·6	155·2	173·2	160·5	148·0	150·6	184·8	162·0	
	11 46	12	67·25	154·8	151·7	170·6	160·4	148·5	146·5	184·1	160·3	
8th	11 27 P.M.	13	66·40	152·1	135·8	163·5	140·9	139·3	130·2	164·2	145·6	Capt. Everest
9th	0 10 A.M.	14	67·40	138·2	148·4	169·9	155·0	136·8	135·9	165·8	152·0	and Lieut.
	0 56	15	68·45	124·9	152·8	176·1	159·1	146·4	142·6	172·8	158·3	Wilcox at the
	1 46	16	69·55	113·7	158·9	175·7	166·1	152·6	147·7	174·6	162·6	microscopes.
	2 36	17	70·47	101·1	159·8	182·6	165·0	152·2	148·8	176·3	164·1	
	7 27 P.M.	18	69·60	111·9	155·0	164·6	154·6	144·2	142·2	175·8	156·1	Mr. Taylor at
	8 8	19	69·17	116·5	156·2	165·0	155·4	143·0	138·4	173·5	155·2	the microme-
	8 47	20	68·87	123·1	157·1	163·6	151·0	143·2	139·0	176·0	155·0	ter micro-
	9 36	21	68·72	129·8	154·5	162·3	148·8	140·5	139·5	176·2	153·6	scope.
	10 20	22	68·55	132·7	144·0	164·0	145·0	126·2	140·0	165·0	147·4	
	10 49	23	68·25	135·5	149·0	165·8	150·0	136·2	141·7	171·2	152·3	
	11 14	24	67·80	136·6	147·[illegible]	160·6	149·4	138·7	134·2	167·8	149·6	
	11 47	25	68·20	121·1	151·8	172·1	153·0	146·4	135·2	165·3	154·0	Mr. Olliver at
10th	0 28 A.M.	26	69·40	103·8	165·0	172·7	163·4	136·3	143·1	168·1	158·1	do.
	1 10	27	70·27	93·5	152·7	175·2	163·0	144·2	135·0	170·4	156·7	
	1 49	28	71·10	86·6	157·6	177·3	163·5	146·4	144·0	171·6	160·1	
	7 1 P.M.	29	71·07	89·3	154·6	167·6	153·4	142·0	136·0	176·0	154·9	Lieut. Western
	7 42	30	70·57	96·9	153·5	165·0	148·0	136·0	141·5	176·3	153·4	at do.
	8 21	31	70·05	105·2	150·8	166·0	146·2	138·0	142·5	175·7	153·2	
	9 49	32	69·27	120·5	149·5	168·0	146·0	140·0	142·0	174·2	153·3	
	10 20	33	68·97	125·5	145·9	162·8	149·0	134·5	139·5	168·5	150·0	
	10 50	34	68·57	131·0	149·5	164·8	151·0	134·0	139·6	171·0	151·6	

Before the measurement—(Continued.)

1831 Novr.	Mean of the times of observing A	No. of comparison	Corrected mean temperature of A	Micrometer Readings in Divisions. 1 Division = $\frac{1}{20090}$ Cary's Inch [7·8], = 1·8819 m.y of A — Mean A	A	B	C	D	E	H	Mean of the compensated bars	Remarks.
	h. m.		°	—	—	—	—	—	—	—	—	
11th	0 29 A.M.	35	67·97	142·2	152·7	168·0	149·2	137·8	137·6	168·6	152·3	Mr. Taylor at the micrometer microscope.
	1 9	36	67·72	142·9	155·8	161·8	154·2	135·0	138·8	176·7	153·7	
	1 32	37	67·45	141·3	161·0	163·7	146·2	133·4	138·0	171·2	152·2	
	1 54	38	67·12	142·0	153·5	159·6	154·0	120·0	126·6	171·1	147·5	
	2 21	39	66·87	138·0	138·0	138·0	129·0	116·2	122·0	150·5	132·3	
	3 4	40	66·70	135·5	131·0	144·5	135·0	113·8	117·0	151·5	132·1	
	4 11	41	66·25	90·4	77·5	92·2	85·2	64·0	66·4	101·5	81·1	
	4 31	42	66·17	93·1	75·4	99·2	80·4	68·6	73·0	93·0	81·6	
	4 51	43	66·12	96·0	78·2	96·4	80·6	64·3	69·8	102·2	81·9	
	6 29 P.M.	44	70·97	28·8	85·8	104·7	91·3	71·6	79·1	108·3	90·1	Mr. Olliver at ditto.
	7 5	45	70·97	27·9	90·9	104·6	90·2	77·3	75·0	111·0	91·5	
	7 33	46	70·92	29·0	92·5	108·6	94·1	78·2	82·2	110·2	94·3	
	8 2	47	70·82	31·5	92·5	105·4	88·8	76·7	79·4	110·7	92·2	
	8 33	48	70.60	32·8	92·7	103·6	84·8	76·2	75·0	111·9	90·7	
	9 4	49	70·32	37·0	87·2	103·7	85·4	70·6	80·2	106·8	89·0	
	9 36	50	69·97	43·1	88·1	102·3	90·4	71·2	77·9	105·6	89·2	
	10 10	51	69·57	48·0	84·0	101·2	88·8	70·6	71·2	103·8	86·6	
	10 44	52	69·00	55·0	86·0	95·1	89·1	65·0	71·7	101·8	84·8	
	11 19	53	68·47	63·8	82·0	97·2	82·0	62·2	71·0	101·7	82·7	
12th	0 54 A.M.	54	67·17	76·5	75·8	94·5	82·2	59·7	64·2	101·2	79·6	Lieut. Wilcox at ditto.
	1 41	55	66·65	82·5	71·4	95·2	84·0	60·9	67·3	97·7	79·4	
	2 26	56	66·27	85·3	78·6	93·3	82·1	64·6	70·7	97·0	81·0	
	3 9	57	65·92	91·1	80·3	93·2	84·3	65·5	63·3	94·7	80·2	
	3 54	58	65·55	97·2	72·8	94·1	78·1	61·7	61·7	95·0	77·2	
	4 39	59	65·12	100·9	74·0	89·7	77·8	56·0	60·4	90·2	74·7	
	7 11 P.M.	60	68·72	140·1	169·0	180·0	165·5	154·0	155·5	183·5	167·9	Lieut. Western at ditto.
	7 41	61	68·60	141·9	165·0	183·0	163·5	148·9	156·0	188·0	167·4	
	8 20	62	68·35	146·0	170·0	182·3	171·0	157·2	152·0	188·0	170·1	
	8 55	63	68·07	150·3	163·0	178·0	163·0	148·0	155·0	186·4	165·6	
	9 23	64	67·82	154·0	169·4	183·0	167·0	146·5	155·0	184·5	167·6	
	9 53	65	67·50	158·7	166·5	177·0	161·7	145·5	151·3	186·7	164·8	
	10 24	66	67·20	161·4	164·7	180·0	159·7	151·5	155·0	182·0	165·5	
	10 53	67	66·92	164·1	164·0	177·5	161·0	145·0	151·0	184·5	163·8	
	Means, ...		68·80	110·72	138·39	153·59	139·68	124·71	126·98	159·49	140·47	

Before the measurement—(Continued.)

Let the mean length of the compensated bars minus the Standard **A** at 62 *F.* be denoted by x, and the observed excess of the compensated bars by δ when the temperature of **A** is $t°$. Then, the expansion of **A** for 1° being $(E_a - dE_a)$, we have

$$x - (t° - 62°)(E_a - dE_a) - \delta = 0$$

Treating the preceding bar comparisons as shewn in this equation, we obtain the following series of results:—

$x - 11{\cdot}50$	$(E_a - dE_a)$	$+97{\cdot}7 = 0$	$x - 7{\cdot}40$	$(E_a - dE_a)$	$+54{\cdot}3 = 0$
$x - 10{\cdot}67$	,,	$+90{\cdot}3 = 0$	$x - 8{\cdot}27$	,,	$+63{\cdot}2 = 0$
$x - 10{\cdot}40$	,,	$+83{\cdot}2 = 0$	$x - 9{\cdot}10$	,,	$+73{\cdot}5 = 0$
$x - 10{\cdot}07$	,,	$+75{\cdot}2 = 0$	$x - 9{\cdot}07$	,,	$+65{\cdot}6 = 0$
$x - 9{\cdot}62$	,,	$+70{\cdot}4 = 0$	$x - 8{\cdot}57$	,,	$+56{\cdot}5 = 0$
$x - 9{\cdot}22$	,,	$+65{\cdot}7 = 0$	$x - 8{\cdot}05$	,,	$+48{\cdot}0 = 0$
$x - 8{\cdot}00$	,,	$+44{\cdot}0 = 0$	$x - 7{\cdot}27$	,,	$+32{\cdot}8 = 0$
$x - 7{\cdot}77$	,,	$+41{\cdot}5 = 0$	$x - 6{\cdot}97$	,,	$+24{\cdot}5 = 0$
$x - 7{\cdot}07$	,,	$+35{\cdot}2 = 0$	$x - 6{\cdot}57$	,,	$+20{\cdot}6 = 0$
$x - 6{\cdot}17$	,,	$+20{\cdot}3 = 0$	$x - 5{\cdot}97$	,,	$+10{\cdot}1 = 0$
$x - 5{\cdot}65$	,,	$+14{\cdot}4 = 0$	$x - 5{\cdot}72$	,,	$+10{\cdot}8 = 0$
$x - 5{\cdot}25$	,,	$+5{\cdot}5 = 0$	$x - 5{\cdot}45$	,,	$+10{\cdot}9 = 0$
$x - 4{\cdot}40$	,,	$-6{\cdot}5 = 0$	$x - 5{\cdot}12$	,,	$+5{\cdot}5 = 0$
$x - 5{\cdot}40$	,,	$+13{\cdot}8 = 0$	$x - 4{\cdot}87$	,,	$-5{\cdot}7 = 0$
$x - 6{\cdot}45$	,,	$+33{\cdot}4 = 0$	$x - 4{\cdot}70$	,,	$-3{\cdot}4 = 0$
$x - 7{\cdot}55$	,,	$+48{\cdot}9 = 0$	$x - 4{\cdot}25$	,,	$-9{\cdot}3 = 0$
$x - 8{\cdot}47$	,,	$+63{\cdot}0 = 0$	$x - 4{\cdot}17$	,,	$-11{\cdot}5 = 0$
$x - 7{\cdot}60$	,,	$+44{\cdot}2 = 0$	$x - 4{\cdot}12$	,,	$-14{\cdot}1 = 0$
$x - 7{\cdot}17$	,,	$+38{\cdot}7 = 0$	$x - 8{\cdot}97$	,,	$+61{\cdot}3 = 0$
$x - 6{\cdot}87$	,,	$+31{\cdot}9 = 0$	$x - 8{\cdot}97$	,,	$+63{\cdot}6 = 0$
$x - 6{\cdot}72$	,,	$+23{\cdot}8 = 0$	$x - 8{\cdot}92$	,,	$+65{\cdot}3 = 0$
$x - 6{\cdot}55$	,,	$+14{\cdot}7 = 0$	$x - 8{\cdot}82$	,,	$+60{\cdot}7 = 0$
$x - 6{\cdot}25$	,,	$+16{\cdot}8 = 0$	$x - 8{\cdot}60$	,,	$+57{\cdot}9 = 0$
$x - 5{\cdot}80$	,,	$+13{\cdot}0 = 0$	$x - 8{\cdot}32$	,,	$+52{\cdot}0 = 0$
$x - 6{\cdot}20$	,,	$+32{\cdot}9 = 0$	$x - 7{\cdot}97$	,,	$+46{\cdot}1 = 0$

Before the measurement—(Continued.)

$$x - 7{\cdot}57\,(E_a - dE_a) + 38{\cdot}6 = 0$$
$$x - 7{\cdot}00 \quad ,, \quad + 29{\cdot}8 = 0$$
$$x - 6{\cdot}47 \quad ,, \quad + 18{\cdot}9 = 0$$
$$x - 5{\cdot}17 \quad ,, \quad + 3{\cdot}1 = 0$$
$$x - 4{\cdot}65 \quad ,, \quad - 3{\cdot}1 = 0$$
$$x - 4{\cdot}27 \quad ,, \quad - 4{\cdot}3 = 0$$
$$x - 3{\cdot}92 \quad ,, \quad - 10{\cdot}9 = 0$$
$$x - 3{\cdot}55 \quad ,, \quad - 20{\cdot}0 = 0$$
$$x - 3{\cdot}12 \quad ,, \quad - 26{\cdot}2 = 0$$

$$x - 6{\cdot}72\,(E_a - dE_a) + 27{\cdot}8 = 0$$
$$x - 6{\cdot}60 \quad ,, \quad + 25{\cdot}5 = 0$$
$$x - 6{\cdot}35 \quad ,, \quad + 24{\cdot}1 = 0$$
$$x - 6{\cdot}07 \quad ,, \quad + 15{\cdot}3 = 0$$
$$x - 5{\cdot}82 \quad ,, \quad + 13{\cdot}6 = 0$$
$$x - 5{\cdot}50 \quad ,, \quad + 6{\cdot}1 = 0$$
$$x - 5{\cdot}20 \quad ,, \quad + 4{\cdot}1 = 0$$
$$x - 4{\cdot}92 \quad ,, \quad - 0{\cdot}3 = 0$$

And from the mean of these results,

$$x = -\overset{d}{29{\cdot}75} + 6{\cdot}80\,(E_a - dE_a):$$

adopting the original value of the expansion of **A** given at page (9),

$$E_a = \overset{m.y}{22{\cdot}67} = \overset{d}{16{\cdot}405},$$

$$\text{and } x = \overset{d}{81{\cdot}80} - 6{\cdot}80\,dE_a = \overset{m.y}{113{\cdot}04} - 6{\cdot}80\,dE_a = \text{L} - \mathbf{A};$$

where L denotes the mean length of the compensated bars obtained from *all* the comparisons, as represented by the mean micrometer reading $-$ 140·47, page L—5.

Comparing this reading with the mean reading of each compensated bar given on the same page we obtain the following:—

In terms of	A − L	B − L	C − L	D − L	E − L	H − L
Micrometer divisions.	+ 2·08	−13·12	+0·79	+15·76	+13·49	−19·02
Millionths of a yard.	+ 2·87	−18·13	+1·09	+21·78	+18·64	−26·28

Also combining the values in this table with the equivalent of L—**A** above determined there result,

$$\text{A} - \mathbf{A} = \overset{d}{83{\cdot}88} - 6{\cdot}80\,dE_a = \overset{m.y}{115{\cdot}91} - 6{\cdot}80\,dE_a$$
$$\text{B} - \mathbf{A} = 68{\cdot}68 - \quad ,, \quad = 94{\cdot}91 - \quad ,,$$
$$\text{C} - \mathbf{A} = 82{\cdot}59 - \quad ,, \quad = 114{\cdot}13 - \quad ,,$$
$$\text{D} - \mathbf{A} = \overset{d}{97{\cdot}56} - 6{\cdot}80\,dE_a = \overset{m.y}{134{\cdot}82} - 6{\cdot}80\,dE_a$$
$$\text{E} - \mathbf{A} = 95{\cdot}29 - \quad ,, \quad = 131{\cdot}68 - \quad ,,$$
$$\text{H} - \mathbf{A} = 62{\cdot}78 - \quad ,, \quad = 86{\cdot}76 - \quad ,,$$

$$\text{and } 6x = \overset{m.y}{678{\cdot}2} - 40{\cdot}8\,dE_a$$

Comparisons between Standard Bar **A** *and the Compensated Bars* A, B, C, D, E, H, *made at the Surveyor General's Office Calcutta, after the measurement.*

1832. Jan.	Mean of the times of observing **A**	No. of comparison	Corrected mean temperature of **A**	Micrometer Readings in Divisions. 1 Division = $\frac{1}{20090}$ Cary's Inch [7·8], = 1·3819 m.y of **A**								Remarks.
				Mean **A**	A	B	C	D	E	H	Mean of the compensated bars.	
	h m		°	—	—	—	—	—	—	—	—	
24th	7 34 P.M.	1	64·80	180·0	140·5	155·0	138·0	125·5	125·5	155·0	139·9	Capt. Everest at the micrometer microscope.
	8 19	2	64·32	186·8	146·0	155·5	144·5	120·5	138·0	162·0	144·4	
	8 56	3	63·75	192·5	140·0	158·0	138·0	124·5	136·0	169·5	144·3	
	9 51	4	62·72	212·0	133·0	152·5	150·0	126·5	134·5	161·0	142·9	
	10 19	5	62·27	220·8	134·5	161·5	151·0	124·0	133·5	162·5	144·5	
	10 46	6	61·77	227·3	135·0	149·0	142·5	119·5	132·0	163·5	140·3	
	11 13	7	61·27	230·5	126·0	166·0	135·0	120·5	131·5	158·5	139·6	
	11 49	8	60·85	235·0	137·0	156·5	140·0	128·0	123·5	160·0	140·8	
25th	0 36 A.M.	9	60·25	251·0	133·0	154·5	144·5	134·0	124·0	172·0	143·7	Lieut. Western at do.
	1 6	10	59·97	252·0	133·0	163·0	137·0	117·0	129·5	157·0	139·4	
	1 41	11	59·70	255·3	130·0	152·0	148·0	120·0	132·5	162·0	140·8	
	2 17	12	59·37	261·8	133·0	164·0	142·0	120·5	130·0	158·0	141·3	
	2 46	13	59·12	264·0	136·5	155·0	137·5	123·0	143·0	160·0	142·5	
	3 47	14	58·75	201·3	69·0	91·5	76·0	48·0	75·0	91·0	75·1	
	4 18	15	58·55	205·3	71·5	96·0	68·0	55·5	55·0	99·0	74·2	
	4 53	16	58·20	210·0	57·0	97·5	75·0	53·0	64·0	99·0	74·3	
	7 20 P.M.	17	67·02	77·0	60·0	73·0	66·0	54·0	51·5	103·5	68·0	Mr. Taylor & Mr. Logan at the microscopes.
	7 46	18	66·80	78·8	67·0	76·5	74·0	53·0	66·0	92·0	71·4	
	8 17	19	66·32	88·5	68·0	86·0	76·0	65·5	66·5	104·5	77·8	
	8 45	20	65·90	95·0	67·0	70·5	78·5	57·0	61·0	97·0	71·8	
	9 1	21	65·57	104·3	72·0	73·5	75·0	48·5	70·5	102·5	73·7	
	9 20	22	65·22	114·0	69·5	78·5	77·0	51·5	60·5	97·5	72·4	
	9 39	23	64·80	116·2	71·4	83·5	84·4	57·0	60·0	104·4	76·8	
	10 6	24	64·07	129·5	74·5	68·5	66·0	56·0	51·0	102·5	69·8	
	10 35	25	63·55	133·5	64·0	72·5	63·0	52·5	63·0	100·0	69·2	
	11 1	26	62·95	137·0	63·0	85·5	63·0	58·5	54·0	101·5	70·9	
	11 26	27	62·32	148·3	62·0	78·0	80·5	58·0	68·5	106·5	75·6	
	11 44	28	62·05	152·8	65·5	75·5	75·0	50·5	58·5	93·0	69·7	
26th	0 50 A.M.	29	60·80	167·4	68·6	91·8	71·8	56·3	66·7	100·8	76·0	Capt. Wilcox at the micrometer microscope.
	1 41	30	60·30	172·4	74·8	94·2	66·8	57·2	58·6	95·0	74·4	
	2 27	31	59·87	181·0	66·0	85·0	66·2	51·5	66·0	92·0	71·1	
	3 7	32	59·42	190·8	67·4	84·0	65·8	51·0	57·5	90·7	69·4	
	3 51	33	59·00	196·7	67·8	90·6	69·2	52·0	52·2	96·0	71·3	
	4 38	34	58·52	203·5	60·0	84·3	66·8	49·0	54·0	87·4	66·9	
	7 31 P.M.	35	67·35	190·5	190·0	214·0	187·0	178·0	179·5	213·5	193·7	
	7 59	36	67·00	194·5	186·0	207·5	193·5	174·0	173·0	220·0	192·3	
	8 25	37	66·57	202·3	187·0	206·5	189·0	181·0	179·0	222·0	194·1	
	9 26	38	65·55	217·5	184·5	213·5	201·0	171·0	179·0	212·0	193·5	
	9 49	39	65·05	225·5	191·5	215·0	200·5	178·0	182·0	215·5	197·1	
	10 12	40	64·62	233·8	194·0	206·5	183·0	178·0	181·0	222·0	194·1	
	10 33	41	64·25	238·8	189·0	210·0	187·0	178·0	184·5	216·0	194·1	

After the measurement—(Continued.)

1832. Jan.	Mean of the times of observing A	No. of comparisons	Corrected mean temperature of A	Micrometer readings in divisions. 1 Division = $\frac{1}{20090}$ Cary's Inch [7·8], = 1·3819 *m.y.* of A — Mean A	A	B	C	D	E	H	Mean of the compensated bars.	Remarks.
	h m		°	—	—	—	—	—	—	—	—	
26th	10 53 P.M.	42	63·85	244·5	189·5	205·5	194·0	173·5	187·5	214·0	194·0	Capt. Wilcox at the micrometer mic: Lieut. Western at do.
	11 14	43	63·40	250·0	183·5	208·0	184·0	175·0	184·0	217·5	192·0	
	11 35	44	63·00	258·5	186·5	211·0	195·5	174·0	183·0	211·0	193·5	
27th	0 16 A.M.	45	62·12	279·5	198·5	205·5	185·5	173·0	183·5	215·0	193·5	
	0 39	46	61·67	276·0	188·0	212·0	186·0	177·0	195·0	218·0	196·0	
	1 5	47	61·22	277·5	184·0	214·0	191·0	172·0	184·0	213·0	193·0	
	1 37	48	60·57	290·0	184·0	217·0	188·0	176·0	190·0	210·0	194·2	
	2 9	49	60·02	296·0	189·0	211·0	201·5	175·0	187·0	222·0	197·6	
	2 33	50	59·80	301·5	190·0	217·0	191·5	174·0	182·5	216·0	195·2	
	3 7	51	59·40	309·0	195·0	213·0	201·5	172·5	180·0	214·5	196·1	
	3 39	52	59·02	311·8	179·0	214·0	199·0	171·5	182·5	210·0	192·7	
	4 5	53	58·77	314·8	187·0	205·0	189·0	174·0	188·0	212·0	192·5	
	4 33	54	58·57	320·5	191·0	217·0	197·0	172·0	193·0	209·0	196·5	
	7 23 P.M.	55	68·87	169·8	183·5	205·5	190·5	178·0	177·5	222·5	192·9	Mr. DePenning and Mr. Logan at the microscopes.
	7 50	56	68·27	176·5	181·4	195·4	186·0	165·0	183·7	222·8	189·1	
	8 12	57	68·02	177·6	185·0	206·2	187·5	172·2	177·0	217·2	190·9	
	8 54	58	67·22	183·2	188·7	204·0	184·3	173·7	185·4	215·3	191·9	
	9 14	59	67·07	191·2	187·0	203·4	191·5	171·5	189·4	218·5	193·6	
	9 34	60	66·80	199·5	187·2	202·5	187·9	173·2	182·0	215·6	191·4	
	9 59	61	66·40	204·0	191·5	200·4	194·8	173·4	184·0	217·5	193·6	
	10 23	62	66·02	212·2	186·5	205·3	190·5	168·4	187·5	216·7	192·5	
	10 57	63	65·47	216·6	191·2	201·0	190·0	165·0	178·5	218·2	190·7	
	11 20	64	65·17	219·7	189·0	203·0	185·3	172·6	180·0	214·9	190·8	
28th	0 34 A.M.	65	64·27	241·3	190·8	212·7	196·8	174·3	180·3	214·3	194·9	Capt. Wilcox at the micrometer microscope.
	1 12	66	63·80	249·9	187·8	210·8	195·0	176·3	182·5	217·6	195·0	
	1 49	67	63·37	255·5	194·7	212·3	194·0	180·4	187·6	214·5	197·3	
	2 27	68	63·10	259·2	193·8	207·0	194·3	175·9	186·2	210·9	194·7	
	3 6	69	62·77	264·8	192·8	214·3	196·0	173·0	187·1	218·0	196·9	
	3 42	70	62·47	265·2	196·4	217·2	199·5	179·0	185·1	216·7	199·0	
	4 20	71	62·35	266·3	194·5	210·0	194·8	178·6	186·9	214·2	196·5	
	4 59	72	62·22	270·0	191·9	218·1	198·0	180·2	188·8	219·2	199·4	
	7 22 P.M.	73	69·50	165·3	194·5	203·0	195·0	184·5	183·5	221·5	197·0	Mr. Taylor at do.
	7 39	74	69·30	168·5	196·5	206·5	198·5	181·0	193·5	225·0	200·2	
	7 57	75	68·97	167·5	198·0	212·0	205·5	179·5	192·0	220·0	201·2	
	8 37	76	68·12	184·5	186·0	214·5	197·5	183·0	191·0	218·5	198·4	
	8 53	77	67·97	190·3	205·5	213·5	212·0	188·0	199·5	218·0	206·1	
	9 9	78	67·70	193·0	188·5	221·5	192·5	184·0	196·5	221·5	200·8	
	9 28	79	67·27	201·3	190·0	207·5	205·0	175·0	192·0	224·5	199·0	
	9 45	80	66·87	206·5	205·0	218·5	201·5	178·5	181·5	220·0	200·8	
	Means	...	63·52	210·05	148·85	167·85	153·26	135·26	143·88	176·67	154·30	

After the measurement—(Continued.)

As on page I—6 we have

$$x - (t^\circ - 62^\circ)\,(E_a - d\,E_a) - \delta = 0;$$

and from the preceding bar comparisons, we obtain the following series of results:

$x - 2.80$	$(E_a - d\,E_a)$	$- 40.1 = 0$	$x - 2.25$	$(E_a - d\,E_a)$	$- 44.7 = 0$
$x - 2.32$	„	$- 42.4 = 0$	$x - 1.85$	„	$- 50.5 = 0$
$x - 1.75$	„	$- 48.2 = 0$	$x - 1.40$	„	$- 58.0 = 0$
$x - 0.72$	„	$- 69.1 = 0$	$x - 1.00$	„	$- 65.0 = 0$
$x - 0.27$	„	$- 76.3 = 0$	$x - 0.12$	„	$- 86.0 = 0$
$x + 0.23$	„	$- 87.0 = 0$	$x + 0.33$	„	$- 80.0 = 0$
$x + 0.73$	„	$- 90.9 = 0$	$x + 0.78$	„	$- 84.5 = 0$
$x + 1.15$	„	$- 94.2 = 0$	$x + 1.43$	„	$- 95.8 = 0$
$x + 1.75$	„	$- 107.3 = 0$	$x + 1.98$	„	$- 98.4 = 0$
$x + 2.03$	„	$- 112.6 = 0$	$x + 2.20$	„	$- 106.3 = 0$
$x + 2.30$	„	$- 114.5 = 0$	$x + 2.60$	„	$- 112.9 = 0$
$x + 2.63$	„	$- 120.5 = 0$	$x + 2.98$	„	$- 119.1 = 0$
$x + 2.88$	„	$- 121.5 = 0$	$x + 3.23$	„	$- 122.3 = 0$
$x + 3.25$	„	$- 126.2 = 0$	$x + 3.43$	„	$- 124.0 = 0$
$x + 3.45$	„	$- 131.1 = 0$	$x - 6.87$	„	$+ 23.1 = 0$
$x + 3.80$	„	$- 135.7 = 0$	$x - 6.27$	„	$+ 12.6 = 0$
$x - 5.02$	„	$- 9.0 = 0$	$x - 6.02$	„	$+ 13.3 = 0$
$x - 4.80$	„	$- 7.4 = 0$	$x - 5.22$	„	$+ 8.7 = 0$
$x - 4.32$	„	$- 10.7 = 0$	$x - 5.07$	„	$+ 2.4 = 0$
$x - 3.90$	„	$- 23.2 = 0$	$x - 4.80$	„	$- 8.1 = 0$
$x - 3.57$	„	$- 30.6 = 0$	$x - 4.40$	„	$- 10.4 = 0$
$x - 3.22$	„	$- 41.6 = 0$	$x - 4.02$	„	$- 19.7 = 0$
$x - 2.80$	„	$- 39.4 = 0$	$x - 3.47$	„	$- 25.9 = 0$
$x - 2.07$	„	$- 59.7 = 0$	$x - 3.17$	„	$- 28.9 = 0$
$x - 1.55$	„	$- 64.3 = 0$	$x - 2.27$	„	$- 46.4 = 0$
$x - 0.95$	„	$- 66.1 = 0$	$x - 1.80$	„	$- 54.9 = 0$
$x - 0.32$	„	$- 72.7 = 0$	$x - 1.37$	„	$- 58.2 = 0$
$x - 0.05$	„	$- 83.1 = 0$	$x - 1.10$	„	$- 64.5 = 0$
$x + 1.20$	„	$- 91.4 = 0$	$x - 0.77$	„	$- 67.9 = 0$
$x + 1.70$	„	$- 98.0 = 0$	$x - 0.47$	„	$- 66.2 = 0$
$x + 2.13$	„	$- 109.9 = 0$	$x - 0.35$	„	$- 69.8 = 0$
$x + 2.58$	„	$- 121.4 = 0$	$x - 0.22$	„	$- 70.6 = 0$
$x + 3.00$	„	$- 125.4 = 0$	$x - 7.50$	„	$+ 31.7 = 0$
$x + 3.48$	„	$- 136.6 = 0$	$x - 7.30$	„	$+ 31.7 = 0$
$x - 5.35$	„	$+ 3.2 = 0$	$x - 6.97$	„	$+ 33.7 = 0$
$x - 5.00$	„	$- 2.2 = 0$	$x - 6.12$	„	$+ 13.9 = 0$
$x - 4.57$	„	$- 8.2 = 0$	$x - 5.97$	„	$+ 15.8 = 0$
$x - 3.55$	„	$- 24.0 = 0$	$x - 5.70$	„	$+ 7.8 = 0$
$x - 3.05$	„	$- 28.4 = 0$	$x - 5.27$	„	$- 2.3 = 0$
$x - 2.62$	„	$- 39.7 = 0$	$x - 4.87$	„	$- 5.7 = 0.$—

After the measurement—(Continued.)

The mean of these results gives,

$$x \overset{d}{=} 55{\cdot}75 + 1{\cdot}52\,(E_a - dE_a).$$

Adopting the original value of the expansion of **A** given at page (9)

$$E_a \overset{m.y}{=} 22{\cdot}67 \overset{d}{=} 16{\cdot}405,$$

$$\text{and } x \overset{d}{=} 80{\cdot}69 - 1{\cdot}52\,dE_a \overset{m.y}{=} 111{\cdot}51 - 1{\cdot}52\,dE_a = \mathrm{L} - \mathbf{A}.$$

Proceeding as on page I—7 we obtain:—

In terms of	A—L	B—L	C—L	D—L	E—L	H—L
Micrometer divisions.	+5·45	−13·55	+1·04	+19·04	+10·42	−22·37
Millionths of a yard.	+7·53	−18·72	+1·44	+26·31	+14·40	−30·91

Also the following,

$$\mathrm{A} - \mathbf{A} \overset{d}{=} 86{\cdot}14 - 1{\cdot}52\,dE_a \overset{m.y}{=} 119{\cdot}04 - 1{\cdot}52\,dE_a$$
$$\mathrm{B} - \mathbf{A} = 67{\cdot}14 - \text{,,} \quad = 92{\cdot}79 - \text{,,}$$
$$\mathrm{C} - \mathbf{A} = 81{\cdot}73 - \text{,,} \quad = 112{\cdot}95 - \text{,,}$$
$$\mathrm{D} - \mathbf{A} \overset{d}{=} 99{\cdot}73 - 1{\cdot}52\,dE_a \overset{m.y}{=} 137{\cdot}82 - 1{\cdot}52\,dE_a$$
$$\mathrm{E} - \mathbf{A} = 91{\cdot}11 - \text{,,} \quad = 125{\cdot}91 - \text{,,}$$
$$\mathrm{H} - \mathbf{A} = 58{\cdot}32 - \text{,,} \quad = 80{\cdot}60 - \text{,,}$$

$$\text{and } 6x \overset{m.y}{=} 669{\cdot}1 - 9{\cdot}1\,dE_a.$$

Deduction of the total length measured by the compensated bars.

From page I—7 the excess of the 6 compensated bars above 6 times **A** *before* the meast. $\overset{m.y}{=} 678{\cdot}2 - 40{\cdot}8\,dE_a$

And as above ,, ,, *after* ,, $= 669{\cdot}1 - 9{\cdot}1\,dE_a$

Therefore the mean excess of ,, applicable to the base-line $= 673{\cdot}7 - 25{\cdot}0\,dE_a$

Also the mean length of a set of 6 compensated bars in feet of the standard $= 60{\cdot}0020211\,\frac{\mathbf{A}}{10} - 25{\cdot}0\,dE_a$

And the total length of the 539 sets measured by the compensated bars $= 32341{\cdot}0894\,\frac{\mathbf{A}}{10} - 13475\,dE_a$

Now the mean temperature of **A** during the bar comparisons was $62° + \frac{25°{\cdot}0}{6} = 66°{\cdot}2$, for which temperature the corresponding expansion of **A** from page (19) is 21·674 *m.y.* Comparing this value of expansion with the original value = 22·67 *m.y.*, used in the foregoing, it is found, that $dE_a = +\,0{\cdot}996$ *m.y.*; and substituting for dE_a this numerical value, there results,

The total length of the 539 sets measured by the compensated bars $= (32341{\cdot}0894 - 0{\cdot}0403)\,\frac{\mathbf{A}}{10}$

$= 32341{\cdot}0491\,\frac{\mathbf{A}}{10}$

Comparisons between the Compensated Microscopes and the 6-inch brass scale A, and provisional determination of microscope errors, during the measurement, expressed in millionths of an inch (m.i.).

When compared 1831.		Microscope.	Observed temperature.	Reduction to 62° Faht. Expansion of 6″ scale for 1° = E = 62·5 m. i.	Microscope—A. Observed value in terms of Wire = 69·7 m. i.	Microscope—A. Observed value in terms of m. i.	Microscope—A. At 62° m. i.	Reference number.
			°	+				
22nd & 23rd Nov.	Before measurement.	*M*	67·5	344	·0	0	+ 344	1
		O	77·6	975	·0	0	975	2
		P	77·6	975	·0	0	975	3
		R	77·8	988	·0	0	988	4
		S	75·6	850	·0	0	850	5
		T	76·0	875	·0	0	875	6
		U	66·7	294	·0	0	294	7
13th Dec.	Between sets No. 149 and 150.	*M*	78·3	1019	−1·6	−1116	− 97	8
		O	67·3	331	·0	0	+ 331	9
		P	68·3	394	−1·3	− 907	− 513	10
		R	78·3	1019	−1·2	− 837	+ 182	11
		S	70·6	538	−0·6	− 418	+ 120	12
		T	64·6	163	+1·6	+1116	+1279	13
		U	72·4	650	−0·6	− 418	+ 232	14
17th Dec.	Between sets No. 192 and 193.	*M*	75·1	819	−3·2	−2232	−1413	15
		*M**	74·9	806	·0	0	+ 806	16
		O	75·5	844	·5	349	+ 495	17
		P	75·3	831	2·0	1395	− 564	18
		R	74·3	769	1·3	907	− 138	19
		S	74·8	800	·9	628	+ 172	20
		T	76·3	894	0·1	70	+ 824	21
		U	73·6	725	0·6	418	+ 307	22
24th Dec.	Between sets No. 287 and 288.	*M*	74·8	800	+1·5	+1046	+1846	23
		O	75·0	813	1·7	1186	1999	24
		P	74·7	794	1·6	1116	1910	25
		R	75·8	863	2·3	1604	2467	26
		S	76·3	894	1·0	697	1591	27
		T	74·5	781	0·4	279	1060	28
		U	75·4	838	0·7	488	1326	29

When compared 1832. Jan.		Microscope.	Observed temperature.	Reduction to 62° Faht. Expansion of 6′ scale for 1° = E = 62·5 m. i.	Microscope—A. Observed value in terms of Wire = 69·7 m. i.	Microscope—A. Observed value in terms of m. i.	Microscope—A. At 62° m. i.	Reference number.
			°	+				
6th.	Between sets No. 404 and 405.	*M*	68·3	394	+1·8	+1255	+1649	30
		O	68·9	431	−1·5	−1046	− 615	31
		P	68·6	413	−0·5	− 349	+ 64	32
		R	68·9	431	−1·2	− 837	− 406	33
		S	68·6	413	−0·4	− 279	+ 134	34
		T	68·3	394	+1·0	+ 697	+1091	35
		U	68·9	431	·0	0	+ 431	36
14th.	Between sets No. 499 and 500.	*M*	69·2	450	+1·6	+1116	+1566	37
		N	68·6	413	− ·2	− 140	+ 273	38
		O	71·2	575	1·4	976	− 401	39
		P	71·6	600	0·7	488	+ 112	40
		R	71·4	588	1·0	697	− 109	41
		T	71·2	575	0·5	349	+ 226	42
		U	68·1	381	·0	0	+ 381	43
20th.	After measurement, or set No. 539.	*M*	71·5	594	+ ·8	+ 558	+1152	44
		*M**	71·5	594	+ ·4	+ 279	+ 873	45
		N	71·6	600	− ·3	− 209	+ 391	46
		O	70·6	538	−1·3	− 907	− 369	47
		*O**	70·6	538	+0·2	+ 140	+ 678	48
		P	71·0	563	− ·3	− 209	+ 354	49
		R	71·7	606	−1·1	− 767	− 161	50
		*R**	71·9	619	+0·2	+ 140	+ 759	51
		S	70·4	525	−0·1	− 70	+ 455	52
		U	71·9	619	−0·5	− 349	+ 270	53

* These microscopes were compared a second time, because they were adjusted after the first comparison.

Microscope Comparisons—(Continued.)

The required combinations of individual microscope errors taken from the preceding page, are expressed as follows;

	Reference numbers.		m.i.	*mean temp:*	
$e_1 =$	$1 + 2 + 3 + 4 + 5 + \frac{6+7}{2}$	$= +$	4717	at (62° + 12°6)	before the measurement
$e_2 =$	$8 + 9 + 10 + 11 + 12 + \frac{13+14}{2}$	$= +$	779	at (62° + 9·9)	between sets 149 & 150
$e_3 =$	$15 + 17 + 18 + 19 + 20 + \frac{21+22}{2}$	$= -$	882	at (62° + 13.0)	„ 192 & 193
$e_4 =$	$16 + 17 + 18 + 19 + 20 + \frac{21+22}{2}$	$= +$	1337	at (62° + 13·0)	„ „
$e_5 =$	$23 + 24 + 25 + 26 + 27 + \frac{28+29}{2}$	$= +$	11006	at (62° + 13·3)	„ 287 & 288
$e_6 =$	$30 + 31 + 32 + 33 + 34 + \frac{35+36}{2}$	$= +$	1587	at (62° + 6·7)	„ 404 & 405
$e_7 =$	$37 + 38 + 39 + 40 + 41 + \frac{42+43}{2}$	$= +$	1745	at (62° + 8·3)	„ 499 & 500
$e_8 =$	$44 + 46 + 47 + 49 + 50 + \frac{52+53}{2}$	$= +$	1730	at (62° + 9·3)	after the measurement
$e_9 =$	$45 + 46 + 48 + 49 + 51 + \frac{52+53}{2}$	$= +$	3418	at (62° + 9·3)	„

And from the foregoing, we obtain the following equations for the microscope errors per set (or *m.e*); where *dE* expresses the error in the adopted value of the expansion for the 6 inch scales.

		m.i.		
$(m.e.)_1 = \frac{e_1+e_2}{2}$	$= +$ 2748	$- 6 \times 11.3\, dE$	applicable to sets Nos.	1 to 149.
$(m.e.)_2 = \frac{e_2+e_3}{2}$	$= -$ 52	$- 6 \times 11{\cdot}5\, dE$	„ „	150 to 192.
$(m.e.)_3 = \frac{e_4+e_5}{2}$	$= +$ 6172	$- 6 \times 13{\cdot}2\, dE$	„ „	193 to 287.
$(m.e.)_4 = \frac{e_5+e_6}{2}$	$= +$ 6297	$- 6 \times 10{\cdot}0\, dE$	„ „	288 to 404.
$(m.e.)_5 = \frac{e_6+e_7}{2}$	$= +$ 1666	$- 6 \times 7{\cdot}5\, dE$	„ „	405 to 499.
$(m.e.)_6 = \frac{e_7+e_8}{2}$	$= +$ 1738	$- 6 \times 8{\cdot}8\, dE$	„ „	500 to 539.
$(m.e.)_7 = e_9$	$= +$ 3418	$- 6 \times 9{\cdot}3\, dE$	applicable to the 11 sets re-measured.	

Microscope Comparisons—(Continued.)

Hence the total microscope errors are as follows,

			$m.i$		feet of A	
In sets Nos. 1 to 149	$= 149\,(m.e.)_1$	$=+$	409452	$-\ 10102\ dE$	$=+\ 0{\cdot}0341$	$-\ 10102\ dE$
150 to 192	$= 43\,(m.e.)_2$	$=-$	2236	$-\ 2967\ dE$	$=-\ 0{\cdot}0002$	$-\ 2967\ dE$
193 to 287	$= 95\,(m.e.)_3$	$=+$	586340	$-\ 7524\ dE$	$=+\ 0{\cdot}0489$	$-\ 7524\ dE$
288 to 404	$= 117\,(m.e.)_4$	$=+$	736749	$-\ 7020\ dE$	$=+\ 0{\cdot}0614$	$-\ 7020\ dE$
405 to 499	$= 95\,(m.e.)_5$	$=+$	158270	$-\ 4275\ dE$	$=+\ 0{\cdot}0132$	$-\ 4275\ dE$
500 to 539	$= 40\,(m.e.)_6$	$=+$	69520	$-\ 2112\ dE$	$=+\ 0{\cdot}0058$	$-\ 2112\ dE$
And the total microscope error in the base-line, ...					$+\ 0{\cdot}1632$	$-\ 34000\ dE$

Final deduction of the total length measured by the compensated microscopes.

Hitherto the microscope errors have been determined only provisionally; *i.e.* in terms of the 6-inch standard scale A. But from page (31), $2\,A = 1{\cdot}0000192\ \frac{\mathsf{A}}{10}$ value in 1835. Also, the co-efficient of expansion for brass, has been taken at ·000,010,417 in the foregoing reductions, whereas it appears from page (17) that a more probable value is ·000,009,855. Accepting the latter, it may be found that $dE = 3{\cdot}372^{\cdot}\ (m.i)$. Hence, remembering that a set of microscopes, apart from all corrections, represents 3 feet in length, we have

$$\left.\begin{array}{r}\text{The total length of the 539 sets}\\ \text{measured by the compensated microscopes}\end{array}\right\} = \{539 \times 3 + \overset{\textit{feet of } A}{0{\cdot}1632}\} - 34000\ dE$$

$$= (1617{\cdot}1943 - 0{\cdot}0096)\ \frac{\mathsf{A}}{10}$$

$$= 1617{\cdot}1847\ \frac{\mathsf{A}}{10}$$

Disposition of the bars and microscopes during the measurement.

The field books contain no information as to the order of succession in which the bars were laid, or as respects the places assigned to the microscopes during the measurement. It is however perfectly clear that every set comprised 6 bars and 7 microscopes; only one-half of the rear-end and advanced microscopes, as usual, being operative. It will be remembered that this was the first base-line measured in India with Colby's compensation apparatus, and some of the information with which subsequent measurements are complete, is here absent, no doubt from the want of experience which was acquired in after operations of the same kind.

DETAILS OF THE MEASUREMENT.

Extracts from the Field Book of the Measurement, and calculated Heights of sets above the origin.

Adopted heights above mean sea level.

South End (origin) = 13·0 feet.

North End (terminus) = 16·3 feet.

1831	No. of the set	Mean time of ending	No. of bars used	Height of Set above origin
		h. m.		feet
Novr. 23rd	1		6	+ 1·3
	2	4 45 P.M.	6	1·4
24th	3	9 30 A.M.	6	1·1
	4	11 0	6	·5
	5	2 40 P.M.	6	·4
	6	3 45	6	·5
25th	7	8 30 A.M.	6	·4
	8	10 0	6	·6
	9	10 58	6	·8
	10	2 55 P.M.	6	·8
	11	3 56	6	·9
26th	12	9 25 A.M.	6	1·0
	13	10 45	6	1·1
	14	2 50 P.M.	6	1·3
	15	3 40	6	1·8
	16	5 5	6	1·4
28th	17	7 55 A.M.	6	1·6
	18	8 45	6	1·6
	19	9 35	6	1·5
	20	10 42	6	1·5
	21	3 5 P.M.	6	1·6
	22	4 5	6	2·2
	23	5 15	6	2·2
29th	24	7 25 A.M.	6	1·7
	25	8 9	6	1·7
	26	8 46	6	2·0
	27	9 24	6	2·2
	28	10 20	6	2·3
	29	11 12	6	2·3
	30	2 16 P.M.	6	2·5
	31	3 9	6	3·0
	32	4 1	6	2·6
	33	4 34	6	2·6
	34	5 9	6	2·8
30th	35	7 3 A.M.	6	3·0
	36	7 53	6	3·0
	37	8 40	6	3·3
	38	9 17	6	3·2
	39	9 51	6	3·6
	40	1 19 P.M.	6	3·8
	41	2 1	6	3·6

1831	No. of the set	Mean time of ending	No. of bars used	Height of Set above origin
		h. m.		feet
Novr. 30th	42	2 41 P.M.	6	+ 3·3
	43	3 33	6	3·9
	44	4 29	6	4·2
Dec. 1st	45	7 4 A.M.	6	4·2
	46	7 46	6	4·1
	47	8 44	6	4·2
	48	9 29	6	4·3
	49	10 34	6	4·4
	50	2 22 P.M.	6	4·6
	51	3 53	6	4·5
	52	4 37	6	4·5
	53	5 13	6	4·7
2nd	54	8 0 A.M.	6	4·5
	55	8 58	6	4·5
	56	9 40	6	4·4
	57	10 17	6	4·3
	58	1 24 P.M.	6	3·8
	59	2 5	6	3·9
	60	2 48	6	4·2
	61	3 43	6	4·3
	62	4 32	6	4·3
	63	5 17	6	4·3
3rd	64	7 36 A.M.	6	4·4
	65	8 7	6	4·6
	66	8 43	6	5·2
	67	9 30	6	5·2
	68	10 0	6	5·1
	69	1 30 P.M.	6	5·2
	70	2 4	6	5·1
	71	2 50	6	5·3
	72	3 34	6	5·5
	73	5 10	6	6·0
5th	74	7 30 A.M.	6	6·0
	75	8 15	6	6·0
	76	8 56	6	6·1
	77	9 38	6	6·5
	78	10 18	6	6·7
	79	1 30 P.M.	6	6·8
	80	2 10	6	6·9
	81	2 36	6	7·2
	82	3 14	6	7·5

NOTE.—The rear end of set No. 1 stood over the dot at the South End.

Extracts from the Field Book—(Continued.)

1831	No. of the set	Mean time of ending	No. of bars used	Height of Set above origin	1831	No. of the set	Mean time of ending	No. of bars used	Height of Set above origin
		h. m.		*feet*			*h. m.*		*feet*
Dec. 5th	83	4 15 P.M.	6	+ 7·3	Dec. 10th	133	2 56 P.M.	6	+ 3·9
	84	5 11	6	7·2		134	3 34	6	4·0
6th	85	7 52 A.M.	6	7·2		135	4 7	6	3·8
	86	8 43	6	7·2		136	4 47	6	3·7
	87	9 37	6	7·0	12th	137	7 31 A.M.	6	3·6
	88	10 22	6	6·8		138	8 0	6	3·6
	89	1 40 P.M.	6	6·8		139	8 25	6	3·4
	90	2 19	6	6·7		140	8 49	6	3·3
	91	3 8	6	6·6		141	9 24	6	3·2
	92	3 50	6	6·6		142	9 56	6	3·2
	93	4 38	6	6·4		143	1 23 P.M.	6	2·9
7th	94	7 15 A.M.	6	6·2		144	1 55	6	2·9
	95	8 0	6	6·3		145	2 28	6	2·7
	96	8 40	6	6·4		146	3 1	6	2·7
	97	9 37	6	6·2		147	3 38	6	2·6
	98	10 28	6	6·0		148	4 20	6	2·5
	99	1 30 P.M.	6	6·1		149	5 5	6	2·4
	100	2 7	6	6·0	14th	150	8 3 A.M.	6	2·3
	101	2 58	6	6·0		151	8 34	6	2·3
	102	3 36	6	5·7		152	9 2	6	2·3
	103	4 17	6	5·8		153	9 30	6	2·3
	104	5 3	6	5·5		154	10 10	6	2·5
8th	105	7 22 A.M.	6	5·3		155	1 25 P.M.	6	2·5
	106	8 3	6	5·2		156	1 57	6	2·5
	107	8 43	6	5·1		157	2 30	6	2·4
	108	9 20	6	5·0		158	3 3	6	2·4
	109	9 57	6	5·1		159	3 32	6	2·6
	110	1 29 P.M.	6	5·2		160	4 0	6	2·7
	111	2 15	6	5·1		161	4 30	6	2·7
	112	3 0	6	5·1		162	4 54	6	2·9
	113	3 42	6	5·0	15th	163	9 37 A.M.	6	2·8
	114	4 22	6	5·0		164	10 17	6	2·8
	115	4 55	6	4·8		165	1 33 P.M.	6	2·9
9th	116	8 0 A.M.	6	4·7		166	2 6	6	3·0
	117	8 40	6	4·7		167	2 32	6	3·1
	118	10 12	6	4·8		168	3 5	6	3·3
	119	1 42 P.M.	6	4·5		169	3 40	6	3·3
	120	2 30	6	4·2		170	4 15	6	3·1
	121	3 17	6	4·0		171	4 52	6	3·3
	122	3 54	6	4·2	16th	172	7 16 A.M.	6	3·4
	123	4 23	6	4·1		173	7 47	6	3·6
	124	4 55	6	4·2		174	8 14	6	3·6
10th	125	7 28 A.M.	6	4·3		175	8 45	6	3·8
	126	8 12	6	4·4		176	9 19	6	3·9
	127	8 50	6	4·2		177	9 53	6	4·0
	128	9 30	6	4·2		178	1 24 P.M.	6	4·5
	129	10 2	6	4·2		179	1 52	6	4·6
	130	1 18 P.M.	6	4·2		180	2 15	6	4·7
	131	1 50	6	4·2		181	2 47	6	4·8
	132	2 24	6	4·1		182	3 8	6	4·9

Extracts from the Field Book—(Continued.)

1831.	No. of the Set.	Mean time of ending.	No. of bars used.	Height of Set above origin.	1831.	No. of the Set.	Mean time of ending.	No. of bars used.	Height of Set above origin.
		h. m.		feet			h. m.		feet
Dec. 16th	183	3 30 P.M.	6	+ 4·8	Dec. 21st	233	1 15 P.M.	6	+ 3·2
	184	3 53	6	5·0		234	1 33	6	3·1
	185	4 20	6	5·1		235	1 50	6	2·9
17th	186	7 15 A.M.	6	4·9		236	2 19	6	3·2
	187	7 42	6	5·1		237	2 47	6	2·9
	188	8 10	6	5·3		238	3 10	6	3·2
	189	8 41	6	5·4		239	3 26	6	3·1
	190	9 5	6	5·3		240	3 51	6	3·1
	191	9 40	6	5·5		241	4 19	6	2·9
	192	10 11	6	5·5		242	4 39	6	2·8
19th	193	7 31 A.M.	6	5·3	22nd	243	7 15 A.M.	6	2·8
	194	8 1	6	5·2		244	7 33	6	2·7
	195	8 31	6	5·6		245	8 4	6	2·5
	196	9 0	6	5·7		246	8 29	6	2·7
	197	9 25	6	5·6		247	8 46	6	2·9
	198	9 48	6	5·9		248	9 10	6	3·3
	199	1 0 P.M.	6	5·8		249	9 38	6	3·3
	200	1 29	6	5·9		250	9 57	6	3·3
	201	2 5	6	6·0		251	1 19 P.M.	6	3·3
	202	2 26	6	6·3		252	1 43	6	3·3
	203	2 51	6	6·3		253	2 21	6	3·3
	204	3 12	6	6·4		254	2 42	6	3·2
	205	3 36	6	6·5		255	3 4	6	3·2
	206	3 56	6	6·5		256	3 25	6	3·2
	207	4 20	6	6·6		257	3 55	6	3·2
	208	4 44	6	6·8		258	4 28	6	3·5
20th	209	7 28 A.M.	6	6·9		259	4 55	6	3·4
	210	8 0	6	6·9	23rd	260	7 21 A.M.	6	3·1
	211	8 26	6	6·7		261	7 48	6	3·3
	212	8 52	6	6·5		262	8 9	6	3·3
	213	9 26	6	6·3		263	8 30	6	3·2
	214	9 55	6	6·3		264	8 51	6	3·1
	215	10 24	6	5·9		265	9 15	6	3·1
	216	1 3 P.M.	6	5·4		266	9 33	6	3·2
	217	1 30	6	5·4		267	9 52	6	3·2
	218	1 58	6	4·7		268	1 1 P.M.	6	3·3
	219	2 25	6	4·5		269	1 24	6	3·3
	220	2 56	6	4·5		270	1 50	6	3·3
	221	3 24	6	4·3		271	2 9	6	3·1
	222	3 53	6	4·1		272	2 27	6	3·4
	223	4 25	6	4·1		273	2 54	6	3·4
	224	4 55	6	3·8		274	3 14	6	3·4
21st	225	7 25 A.M.	6	3·6		275	3 32	6	3·5
	226	7 55	6	3·6		276	3 50	6	3·4
	227	8 19	6	3·3		277	4 15	6	3·3
	228	8 40	6	3·4		278	4 33	6	3·4
	229	9 7	6	3·3		279	4 52	6	3·5
	230	9 28	6	3·2	24th	280	7 10 A.M.	6	3·6
	231	9 48	6	3·0		281	7 45	6	3·6
	232	10 11	6	3·2		282	8 10	6	3·5

Extracts from the Field Book—(Continued.)

1831.	No. of the Set.	Mean time of ending.	No. of bars used.	Height of Set above origin.	1831-32.	No. of the Set.	Mean time of ending.	No. of bars used.	Height of Set above origin.
		h. m.		feet			h. m.		feet
Dec. 24th	283	8 32 A.M.	6	+ 3·5	Dec. 31st	333	2 50 P.M.	6	+ 4·6
	284	8 52	6	3·5		334	3 20	6	4·7
	285	9 18	6	3·6		335	3 44	6	4·7
	286	9 37	6	3·9		336	4 9	6	4·8
	287	10 0	6	3·7	Jan. 2nd	337	7 25 A.M.	6	4·9
27th	288	7 39 A.M.	6	3·3		338	7 59	6	5·0
	289	8 14	6	3·2		339	8 29	6	5·1
	290	8 40	6	3·3		340	8 58	6	5·0
	291	9 9	6	3·3		341	9 25	6	5·0
	292	9 34	6	3·4		342	9 45	6	5·1
	293	10 22	6	3·4		343	10 3	6	5·4
	294	2 3 P.M.	6	3·3		344	0 58 P.M.	6	5·4
	295	3 10	6	3·5		345	1 30	6	5·5
	296	4 5	6	3·6		346	1 51	6	5·7
	297	4 50	6	4·0		347	2 15	6	5·8
28th	298	7 30 A.M.	6	3·9		348	2 38	6	5·9
	299	8 0	6	3·9		349	3 6	6	5·8
	300	8 26	6	4·0		350	3 32	6	6·0
	301	8 54	6	4·2		351	3 47	6	6·0
	302	9 24	6	4·2		352	4 12	6	6·2
	303	9 50	6	4·0		353	4 40	6	6·3
	304	10 20	6	4·2		354	5 1	6	6·3
30th	305	7 5 A.M.	6	3·9	3rd	355	7 5 A.M.	6	6·3
	306	7 28	6	3·9		356	7 29	6	6·4
	307	8 0	6	4·1		357	7 59	6	6·2
	308	8 34	6	4·1		358	8 22	6	6·2
	309	9 18	6	4·0		359	8 38	6	6·3
	310	9 47	6	3·8		360	9 1	6	6·3
	311	10 14	6	3·6		361	9 33	6	6·3
	312	1 6 P.M.	6	3·4		362	9 53	6	6·3
	313	1 52	6	3·2		363	0 54 P.M.	6	6·5
	314	2 20	6	3·3		364	1 8	6	6·6
	315	2 45	6	3·4		365	1 38	6	6·7
	316	3 14	6	3·4		366	1 55	6	6·8
	317	3 42	6	3·7		367	2 17	6	6·8
	318	4 4	6	4·0		368	2 48	6	6·9
	319	4 32	6	4·1		369	3 12	6	7·1
	320	4 54	6	4·4		370	3 36	6	7·1
31st	321	7 16 A.M.	6	4·3		371	3 59	6	7·4
	322	7 39	6	4·4		372	4 18	6	7·4
	323	8 4	6	4·4		373	4 50	6	7·4
	324	8 27	6	4·3	4th	374	7 25 A.M.	6	7·5
	325	8 55	6	4·[illegible]		375	8 25	6	7·5
	326	9 12	6	4·7		376	8 54	6	7·4
	327	9 35	6	4·7		377	9 23	6	7·3
	328	9 55	6	4·7		378	9 49	6	7·4
	329	1 7 P.M.	6	4·6		379	10 13	6	7·5
	330	1 27	6	4·6		380	1 16 P.M.	6	7·6
	331	1 55	6	4·6		381	1 46	6	7·7
	332	2 17	6	4·6		382	2 10	6	7·7

Extracts from the Field Book—(Continued.)

1832.	No. of the Set.	Mean time of ending.	No. of bars used.	Height of Set above origin.	1832.	No. of the Set.	Mean time of ending.	No. of bars used.	Height of Set above origin.
		h. m.		feet			h. m.		feet
Jan. 4th	383	2 34 P.M.	6	+ 7·9	Jan. 10th	433	4 3 P.M.	6	+ 8·2
	384	2 56	6	8·0		434	4 21	6	8·1
	385	3 25	6	8·0		435	4 42	6	8·0
	386	3 50	6	8·0		436	5 10	6	8·0
	387	4 13	6	8·0	11th	437	7 40 A.M.	6	8·0
	388	4 35	6	7·8		438	8 2	6	7·8
5th	389	7 32 A.M.	6	7·7		439	8 26	6	7·8
	390	7 58	6	7·8		440	8 51	6	7·8
	391	8 24	6	7·9		441	9 19	6	7·6
	392	8 40	6	8·0		442	9 36	6	7·6
	393	9 15	6	8·5		443	9 52	6	7·5
	394	2 4 P.M.	6	8·4		444	10 11	6	7·5
	395	2 39	6	8·6		445	1 7 P.M.	6	7·4
	396	3 37	6	8·7		446	1 22	6	7·3
	397	4 21	6	8·6		447	1 41	6	7·4
	398	4 50	6	8·7		448	2 0	6	7·3
6th	399	7 41 A.M.	6	8·6		449	2 41	6	7·2
	400	7 59	6	8·8		450	2 59	6	7·1
	401	8 33	6	8·6		451	3 15	6	7·1
	402	9 4	6	8·7		452	3 32	6	7·2
	403	9 31	6	8·8		453	4 7	6	7·2
	404	10 2	6	8·7		454	4 24	6	7·2
9th	405	7 54 A.M.	6	8·6		455	4 40	6	7·2
	406	8 30	6	8·7		456	5 0	6	7·1
	407	8 48	6	8·7	12th	457	7 30 A.M.	6	7·1
	408	9 10	6	8·9		458	7 47	6	7·1
	409	9 39	6	8·8		459	8 1	6	7·0
	410	9 58	6	8·8		460	8 20	6	6·9
	411	1 14 P.M.	6	8·6		461	8 49	6	6·8
	412	1 38	6	8·5		462	9 31	6	6·7
	413	2 10	6	8·5		463	9 50	6	6·6
	414	2 28	6	8·5		464	10 6	6	6·5
	415	2 47	6	8·4		465	1 12 P.M.	6	6·3
	416	3 6	6	8·5		466	1 30	6	6·4
	417	3 30	6	8·5		467	1 49	6	6·4
	418	3 50	6	8·5		468	2 6	6	6·5
	419	4 8	6	8·2		469	2 46	6	6·7
	420	4 30	6	8·3		470	3 5	6	6·6
10th	421	8 4 A.M.	6	8·2		471	3 46	6	6·9
	422	8 26	6	8·1		472	4 1	6	7·0
	423	8 48	6	8·0		473	4 27	6	7·1
	424	9 5	6	7·9		474	4 44	6	7·0
	425	9 29	6	8·1		475	5 0	6	6·9
	426	9 46	6	8·0		476	5 17	6	7·1
	427	10 8	6	8·0	13th	477	7 20 A.M.	6	7·1
	428	1 42 P.M.	6	8·1		478	7 44	6	7·1
	429	2 21	6	8·1		479	8 1	6	6·9
	430	2 41	6	8·2		480	8 22	6	6·8
	431	3 1	6	8·2		481	9 18	6	6·9
	432	3 22	6	8·2		482	9 47	6	6·6

DETAILS OF THE MEASUREMENT.

Extracts from the Field Book—(Continued.)

1832.	No. of the Set.	Mean time of ending.	No. of bars used.	Height of Set above origin.	1832.	No. of the Set.	Mean time of ending.	No. of bars used.	Height of Set above origin.
		h. m.		feet			h. m.		feet
Jan. 13th	483	10 10 A.M.	6	+ 6·4	Jan. 16th	512	9 34 A.M.	6	+ 5·2
	484	1 40 P.M.	6	6·3		513	9 58	6	5·3
	485	2 16	6	6·3		514	0 41 P.M.	6	5·1
	486	2 39	6	6·0		515	0 58	6	5·2
	487	2 57	6	5·9		516	1 17	6	5·1
	488	3 15	6	6·0		517	1 47	6	5·1
	489	3 41	6	6·2		518	2 7	6	5·0
	490	4 5	6	6·0		519	2 28	6	5·1
	491	4 28	6	5·9		520	2 46	6	5·3
	492	5 10	6	6·0		521	3 6	6	5·2
14th	493	7 30 A.M.	6	5·8		522	3 24	6	5·0
	494	8 3	6	5·9		523	3 42	6	4·7
	495	8 30	6	5·8		524	4 0	6	4·5
	496	8 55	6	5·7		525	4 26	6	4·5
	497	9 21	6	5·7		526	4 43	6	4·8
	498	9 47	6	5·7		527	5 10	6	4·9
	499	10 10	6	5·8	17th	528	7 32 A.M.	6	4·7
	500	3 50 P.M.	6	5·7		529	7 58	6	4·4
	501	4 10	6	5·7		530	8 22	6	4·0
	502	4 32	6	5·5		531	8 41	6	3·6
	503	4 50	6	5·6		532	9 3	6	3·5
	504	5 5	6	5·5		533	9 30	6	3·3
16th	505	7 10 A.M.	6	5·3		534	9 56	6	3·4
	506	7 36	6	5·4		535	10 16	6	3·9
	507	7 56	6	5·3		536	1 13 P.M.	6	4·1
	508	8 14	6	5·3		537	4 20	6	4·0
	509	8 36	6	5·4		538	5 9	6	3·8
	510	8 55	6	5·3	18th	539	8 38 A.M	6	2·8
	511	9 12	6	5·3					

The advanced end of set No. 539 fell in defect (*i.e.* south,) of the dot at North End 1·7144 feet, as measured on Cary's brass scale with a beam compass.

Height of set No. 539 above North End = 1·2 feet.

Reduction to Mean Sea Level.

The formula employed for this computation is obtained as follows :—
Let ϕ denote the radius of curvature for the azimuth of the base-line at the mean latitude of the extremities, H and H_1 the adopted heights above sea level respectively of the origin and terminus, $(H_1 - H) = h$, $h_m =$ the value of h obtained from the measurement, and δh a correction to h_m which may be afforded either by the triangulation or by spirit levelling; also let $R = \phi + H$.

If $h_1\ h_2 \ldots h_p$ denote the heights above the origin of the successive sets of bars, or lengths actually measured, where any set may consist of a smaller integral number than 6 of bars and microscopes, and if l stands for a complete set of 6 bars and 6 microscopes, or 63 feet, then the correction to the measured length to find the corresponding length at the level of the *origin*, or

$C_2 = -\frac{l}{R}(h_1 + h_2 + \ldots\ldots + h_p) = -\frac{l}{R}[h]_1^p$ provided the p sets are each equal to l in length. If however the sth, rth and tth sets are incomplete and consist respectively of only s, r and t bars and microscopes, then the correction becomes

$$C_2 = -\frac{l}{R}\left\{[h]_1^p - [(6-s)h_s + (6-r)h_r + (6-t)h_t]\right\}\text{; or abbreviating}$$

$$= -\frac{l}{R}\left\{[h]_1^p + a\right\}$$

a being thus a correction in consequence of incomplete sets.

Again if δh is not zero, and we disperse this quantity amongst the heights $h_1\ h_2 \ldots h_p$ on the assumption that

$$h_1 \text{ shall become } h_1 + \frac{\delta h}{p}$$
$$h_2 \ldots\ldots\ldots h_2 + \frac{2\,\delta h}{p}$$
$$\ldots\ldots\ldots\ldots \qquad (1)$$

then the correction will be

$$C_2 = -\frac{l}{R}\left\{[h]_1^p + a + \frac{p+1}{2}\delta h\right\} \qquad (2)$$

where it is sufficiently accurate to adopt h_s for $\left(h_s + \frac{s\,\delta h}{p}\right)$, h_r for $\left(h_r + \frac{r\,\delta h}{p}\right)$, &c. in finding a.

It remains to remark, that it is convenient for arithmetical purposes, when deducing the total lengths measured with the bars, those measured with the microscopes, and in general, to reckon the line as made up of n *complete* sets of bars and microscopes, n being the nearest integer not greater than $\frac{\lambda}{63}$. If we write n for p in the term $\frac{p+1}{2}\delta h$, the error committed is $\frac{l \times \delta h}{2R}(p - n)$, which in the extreme case of the Dehra Doon base-line amounts to less than ·0001 feet. Availing ourselves of this convenience, the correction to origin finally becomes

$$C_2 = -\frac{l}{R}\left\{[h]_1^p + a + \frac{n+1}{2}\delta h\right\} \qquad (3)$$

Similarly, if λ be the length of the line at the level of the origin, then the reduction from origin to sea level or

$$C_1 = -\lambda\frac{H}{R} \qquad (4)$$

and from (3) and (4)

$$C_1 + C_2 = -\lambda\frac{H}{R} - \frac{63}{R}\left\{[h]_1^p + a + \frac{(n+1)}{2}\delta h\right\} \qquad (5)$$

Reduction to Mean Sea Level—(Continued.)

which for shortness may be written

$$C = C_1 + C_2 = -\lambda\frac{H}{R} - \frac{63}{R}F \quad . \; . \; . \; . \; . \; . \; . \; . \; . \; . \; . \; . \; . \; . \quad (6)$$

It must be added that in applying (5) to the reduction of a base-line in parts, *i.e.* reducing each section to sea level by itself, the following modification is necessary. Suppose the base-line divided into sections I, II, III and IV : if we retain the symbols of (5) for the elements of the *entire* line and distinguish the similar quantities for *each section* by means of corresponding subscripts, there result by writing ${}_1dh$ for ${}_1n\frac{\delta h}{n}$; ${}_2dh$ for ${}_2n\frac{\delta h}{n}$ &c.

$$\left.\begin{array}{lll}
\text{For section I} & {}_1C={}_1C_1+{}_1C_2=-{}_1\lambda\frac{H}{R}-\frac{63}{R}\left\{[h]_1^{{}_1p}+{}_1a+\frac{({}_1n+1)}{2}{}_1dh\right\} \ldots\ldots & =-{}_1\lambda\frac{H}{R}-\frac{63}{R}{}_1F \\
\text{,, II} & {}_2C={}_2C_1+{}_2C_2=-{}_2\lambda\frac{H}{R}-\frac{63}{R}\left\{[h]_{{}_1p+1}^{{}_2p}+{}_2a+{}_2n\,{}_1dh+\frac{({}_2n+1)}{2}{}_2dh\right\} \ldots\ldots & =-{}_2\lambda\frac{H}{R}-\frac{63}{R}{}_2F \\
\text{,, III} & {}_3C={}_3C_1+{}_3C_2=-{}_3\lambda\frac{H}{R}-\frac{63}{R}\left\{[h]_{{}_2p+1}^{{}_3p}+{}_3a+{}_3n\,({}_1dh+{}_2dh)+\frac{({}_3n+1)}{2}{}_3dh\right\} \ldots & =-{}_3\lambda\frac{H}{R}-\frac{63}{R}{}_3F \\
\text{,, IV} & {}_4C={}_4C_1+{}_4C_2=-{}_4\lambda\frac{H}{R}-\frac{63}{R}\left\{[h]_{{}_3p+1}^{p}+{}_4a+{}_4n\,({}_1dh+{}_2dh+{}_3dh)+\frac{({}_4n+1)}{2}{}_4dh\right\} & =-{}_4\lambda\frac{H}{R}-\frac{63}{R}{}_4F
\end{array}\right\}(7)$$

the foregoing expressions have been employed in the reduction of all the base-lines given in this volume.

For the base-line under reduction $\lambda = 33960$; Log $R = 7\cdot31838$; $[h]_1^p = 2710$; $a = 0$; $\delta h = 1\cdot7$, all in feet; and $n = 539$. Hence we obtain by (5) in feet,

$$C_1 = -0\cdot0212: \quad C_2 = -0\cdot0096: \text{ and } \therefore C = -0\cdot0308$$

Final length of the base-line in feet of Standard A.

Measured with the compensated bars,	page I—11	=	32341·0491
,, ,, microscopes,	page I—14	=	1617·1847
,, beam compass,	page I—20	= +	1·7144
Reduction to sea level as above		= −	0·0308
Length S. end to N. end at mean sea level		=	33959·9174
,, ,,	Log.	=	4·53096663

Distance from rear-end of set No. 2 to advanced-end of set No. 12 by 1st and 2nd measurements contrasted.

By 1st measurement.

		feet of A
Measured with the compensated bars	= 11 × 60·001915	= 660·0211
" " microscopes	= 11 × 3·001616	= 33·0178
Length of the 11 sets		= 693·0389

By 2nd measurement.

Measured with the compensated bars	= 11 × 60·001980	= 660·0218
" " microscopes	= 11 × 3·001187	= 33·0131
" beam compass		= − 0·0022
Length of the 11 sets		= 693·0327

DESCRIPTION OF STATIONS.

SOUTH END OF CALCUTTA BASE, Latitude N. 22° 37′, Longitude E. 88° 25′, is situated at the junction of the Barackpore and Chitpore roads and directly opposite to a garden house owned by Rajah Baboo. It is in the district of the 24 Pergannahs, pergannnh Calcutta.

The station is marked by a square hollow tower 73·6 feet in height and some 13 feet square at top; the isolated pillar for the theodolite being bulit on beams, which are let into the wall about 4 feet below the upper surface of the tower. The usual circle and dot are engraved on a block of stone fixed in the ground floor of the building.

NORTH END OF CALCUTTA BASE, Latitude N. 22° 43′, Longitude E. 88° 25′, is situated east of Sukchár village, at the junction of the road from Sukchár to Baraset with the Barackpore road, and opposite to the 11th mile stone from the Government House in Calcutta. It is in the district of the 24 Pergannahs, pergannah Calcutta.

The tower is 74·5 feet high. In other respects, the station is similar to the S. End of the base.

J. B. N. HENNESSEY.

DEHRA DOON BASE-LINE.

The middle point of the base-line is in Latitude N. 30° 18′, Longitude E. 77° 58′. Azimuth of W. end at E. end = 113° 44′. Length 7·42 miles.

The line was measured over twice. The 1st measurement was made under the directions of Major G. Everest, R.A., and Lieutenant A. S. Waugh, R.E., supervised the 2nd measurement. The assistants employed in the operations, as well as the duties assigned to each person, are shown in the following lists.

During 1st measurement.

Major G. Everest, R.A.—*At the Boning Instrument.*

In charge of Microscopes.

Lieut. A. S. Waugh, R.E.—*At rear end of Bar* A.
Lieut. T. Renny, R.E.
Mr. J. Olliver.
Mr. G. Logan.
Mr. J. Peyton.
Mr. C. Murphy.
Capt. R. Wilcox.—*At advanced end of Bar* H.

Mr. H. Keelan.—*Laying the trestles.*
Mr. N. Kallonas.—— } *Recorders.*
Baboo Radhanath Sikdhar. }

During 2nd measurement.

Mr. G. Logan.—*At the Boning Instrument.*

In charge of Microscopes.

Lieut. A. S. Waugh, R.E.—*At rear end of Bar* A.
Mr. H. Keelan.
Mr. J. Peyton.
Mr. N. Kallonas.
Mr. J. Olliver.
Mr. C. Murphy.
Lieut. T. Renny, R.E.—*At advanced end of Bar* H.

Mr. J. Mulheran.—*Laying the trestles.*
Mr. N. Kallonas.—— } *Recorders.*
Baboo Radhanath Sikdhar. }

INTRODUCTION.

This base-line was measured in the Dehra Doon along the southern bank of the Asan Nuddee. Its eastern extremity is situated about 1·1 miles nearly due west of Bhimtál, which is by the road from Dehra to the Mohan pass.

The line was measured over twice. On the 1st occasion in the direction from West to East, when the tongues of the bars pointed North. The 2nd measurement was made in the contrary direction, the bar-tongues however still pointing North. The measurement was always continuous, *i.e.*, every succeeding set originated at the point marking the terminus of its predecessor.

In the 1st measurement, an iron pin with a flat register head, was fixed at each of five convenient points in the alignment. The dot on the register head of pin No. 1 was made at the termination of set No. 66, and similarly, dots on pins Nos. 2, 3, 4, and 5 and at E. End were made successively at the termini of sets Nos. 157, 219, 389, 520, and 622. In the 2nd measurement, other dots marking the terminations of sets were made on the same register heads and at the W. End, and the distance between the two dots at each point of reference was carefully measured. In this manner the entire length W. End to E. End was divided into six parts and each part measured over twice.

Fifty comparisons, between the compensated bars and the standard **A**, were made before the 1st measurement in a thatched building set up for the purpose in the grounds of the Surveyor General's Office Dehra. Sixty-one similar comparisons were made after the 1st measurement, and 66 after the 2nd measurement, at Camp Barwala, "under circumstances precisely the same with those under which the bars were used in practice, that is under the same tents and at the same hours of the day."*

The microscopes were compared with their scales on 13 occasions during the 1st measurement and on 5 occasions during the 2nd measurement.

In respect to time, the first set of bar comparisons was made on 12th November 1834, the last on 2nd April 1835.

The stations of the verificatory triangulation were 7 in number, forming a single series of triangles. Of these stations, 4 were in the alignment, *viz.*, W. End, A or Heliotropewala (identical with pin No. 2), B or Barwala (identical with pin No. 4), and E. End. The three auxiliary stations α, β and γ were selected on spurs of the Sewalik range of hills. The angles were measured with a 3-foot Theodolite (by either Troughton or Barrow.) read by 5 microscopes. At stations A, γ and E. End, 2 measures were taken on each of 12 zeros. At the remaining 4 stations, 3 measures were made on each of 8 zeros.

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* Page xxiv Everest's Meridional Arc of India, 1847.

Comparisons between the Standard Bar **A** *and the Compensated Bars* A, B, C, D, E, H, *made at the Surveyor General's Office, Dehra Doon, before the first measurement.*

1834 Nov.	Mean of the times of observing A	No. of comparison	Corrected mean temperature of A	Micrometer Readings in Divisions. 1 Division = $\frac{1}{20138 \cdot 2}$ Cary's Inch [7.8], = 1·3786 m.y of A								Remarks
				Mean A	A	B	C	D	E	H	Mean of the compensated bars.	
	h m		°	+	+	+	+	+	+	+	+	
12th	11 57 A.M.	1	66·42	226·3	253·5	230·5	244·0	279·5	243·5	238·0	248·2	Major Everest at the micrometer microscope.
	0 39 P.M.	2	67·90	242·8	244·5	225·5	246·0	271·5	234·5	237·0	243·2	
	1 13	3	69·05	265·5	248·0	231·0	248·0	278·5	243·0	244·5	248·8	
	1 45	4	70·15	283·0	246·5	227·0	247·5	277·5	244·5	248·0	248·5	
	2 22	5	71·20	298·0	248·5	230·5	253·0	284·0	248·5	243·5	251·3	
	2 55	6	72·05	311·1	252·0	230·3	256·5	287·0	247·0	243·0	252·6	
		7	72·67	324·9	252·5	232·5	260·5	283·0	244·5	245·5	253·1	
13th	8 29 A.M.	8	56·88	42·6	220·5	202·0	225·5	253·5	210·6	213·7	221·0	
	8 59	9	57·61	54·4	220·5	200·0	225·5	252·5	212·0	215·5	221·0	
	9 48	10	59·65	61·8	197·6	172·4	194·0	228·7	187·8	192·0	195·4	
	0 11 P.M.	11	66·27	163·2	195·8	176·3	201·6	229·0	198·0	198·5	199·9	
	2 29	12	70·57	244·1	204·0	189·5	215·4	241·3	211·5	205·3	211·2	
	2 57	13	71·30	256·0	211·6	190·3	211·0	242·0	206·0	205·5	211·1	
	3 18	14	71·75	265·5	211·0	190·5	214·0	240·3	205·7	204·4	211·0	
	3 38	15	72·17	273·7	211·5	193·1	210·0	243·0	205·5	203·8	211·2	
		16	72·60	279·5	212·0	190·5	210·7	245·1	206·7	201·8	211·1	
		17	72·85	283·3	212·5	189·9	211·9	244·8	209·8	200·5	211·6	
14th	7 18 A.M.	18	57·12	52·8	237·1	212·5	242·0	272·7	224·0	225·0	235·6	
	7 42	19	56·80	49·7	241·4	216·7	240·3	266·4	221·0	223·0	234·8	
	8 9	20	56·76	49·6	235·5	214·1	239·0	265·0	225·0	222·0	233·4	
	8 39	21	57·23	58·5	236·5	211·7	234·5	265·5	218·3	222·1	231·4	
	9 6	22	58·02	72·8	233·7	212·0	231·8	262·5	219·3	220·5	230·0	
	9 31	23	58·90	87·6	230·8	207·6	227·1	259·5	219·3	222·6	227·8	
	11 58	24	66·56	203·8	235·8	210·5	230·0	267·8	222·6	229·5	232·7	
	0 23 P.M.	25	67·83	223·9	229·8	206·5	235·3	268·6	228·4	228·9	232·9	
	0 47	26	68·85	239·7	232·4	212·5	231·5	267·9	228·1	226·9	233·2	
	1 11	27	69·83	253·1	231·8	210·0	225·5	265·2	225·0	227·1	230·8	
	1 35	28	70·86	267·5	228·3	209·5	228·3	261·3	225·0	224·2	229·4	
	1 58	29	71·67	283·5	231·0	210·0	231·3	262·8	223·7	228·4	231·2	
	2 19	30	72·32	295·8	233·4	210·8	233·1	264·5	225·5	226·7	232·3	
	2 41	31	73·05	304·1	230·6	209·0	231·0	266·7	224·0	227·5	231·5	
	3 3	32	73·65	312·9	229·8	211·4	232·4	264·1	223·9	227·4	231·5	
	3 28	33	74·12	322·0	230·0	213·5	234·8	266·2	226·1	226·9	232·9	
15th	7 35 A.M.	34	57·67	75·0	249·8	220·5	252·0	279·0	229·1	236·5	244·5	
	8 4	35	57·32	73·2	248·4	221·5	249·9	278·0	232·8	235·0	244·3	
	8 34	36	57·55	76·3	247·1	220·0	250·5	277·5	234·0	237·6	244·5	
	8 59	37	58·05	84·4	243·2	223·7	242·5	273·9	230·6	233·5	241·2	
	9 19	38	58·67	93·8	239·3	216·8	240·7	277·8	233·6	236·4	240·8	
	9 40	39	59·42	104·3	244·8	219·6	240·9	275·0	232·6	238·0	241·8	
	10 0	40	60·30	117·3	240·7	218·0	237·2	274·0	230·3	237·1	239·6	

Before the first measurement—(Continued.)

1834 Nov.	Mean of the times of observing A	No. of comparison	Corrected mean temperature of A	Micrometer Readings in Divisions 1 Division = $\frac{1}{20138{\cdot}2}$ Cary's Inch [7.8], = 1·3786 m.y. of A — Mean A	A	B	C	D	E	H	Mean of the compensated bars	Remarks
	h m		°	+	+	+	+	+	+	+	+	
15th	0 34 P.M.	41	66·70	223·6	246·1	229·0	244·1	277·5	241·3	242·0	246·7	Major Everest at the micrometer microscope.
	0 54	42	67·55	239·1	249·0	229·9	245·0	279·0	241·8	244·0	248·1	
	1 13	43	68·40	255·2	245·5	228·5	249·6	283·9	241·8	243·1	248·7	
	1 35	44	69·32	267·6	247·4	230·5	247·0	284·5	244·1	241·4	249·2	
	1 57	45	70·23	279·6	244·0	226·0	248·0	282·0	244·5	242·3	247·8	
	2 22	46	71·11	294·8	244·8	226·1	244·0	279·0	245·1	241·1	246·7	
	2 44	47	71·90	306·5	248·0	233·8	245·8	283·3	242·5	232·5	247·7	
	3 5	48	72·50	312·8	247·6	227·0	246·3	284·2	243·5	247·8	249·4	
	3 25	49	72·85	319·3	249·7	229·5	243·1	283·4	244·5	242·0	248·7	
	3 46	50	73·17	328·5	249·1	234·8	250·3	287·5	247·0	247·0	252·6	
	Means, ...		66·55	208·09	235·10	214·31	235·60	267·75	227·95	228·53	234·87	

Let the mean length of the compensated bars minus the Standard **A** at 62° *F.* be denoted by x, and the observed excess of the compensated bars by δ when the temperature of **A** is $t°$. Then, the expansion of **A** for 1° being $(E_a - dE_a)$, we have

$$x - (t° - 62°)\,(E_a - dE_a) - \delta = 0$$

Treating the preceding bar comparisons as shewn in this equation, we obtain the following series of results:—

$x - 4{\cdot}42\,(E_a - dE_a) - 21{\cdot}9 = 0$
$x - 5{\cdot}90$ „ $- 0{\cdot}4 = 0$
$x - 7{\cdot}05$ „ $+ 16{\cdot}7 = 0$
$x - 8{\cdot}15$ „ $+ 34{\cdot}5 = 0$
$x - 9{\cdot}20$ „ $+ 46{\cdot}7 = 0$
$x - 10{\cdot}05$ „ $+ 58{\cdot}5 = 0$
$x - 10{\cdot}67$ „ $+ 71{\cdot}8 = 0$
$x + 5{\cdot}12$ „ $- 178{\cdot}4 = 0$
$x + 4{\cdot}39$ „ $- 166{\cdot}6 = 0$
$x + 2{\cdot}35$ „ $- 133{\cdot}6 = 0$
$x - 4{\cdot}27$ „ $- 36{\cdot}7 = 0$
$x - 8{\cdot}57$ „ $+ 32{\cdot}9 = 0$
$x - 9{\cdot}30$ „ $+ 44{\cdot}9 = 0$
$x - 9{\cdot}75$ „ $+ 54{\cdot}5 = 0$

$x - 10{\cdot}17\,(E_a - dE_a) + 62{\cdot}5 = 0$
$x - 10{\cdot}60$ „ $+ 68{\cdot}4 = 0$
$x - 10{\cdot}85$ „ $+ 71{\cdot}7 = 0$
$x + 4{\cdot}88$ „ $- 182{\cdot}8 = 0$
$x + 5{\cdot}20$ „ $- 185{\cdot}1 = 0$
$x + 5{\cdot}24$ „ $- 183{\cdot}8 = 0$
$x + 4{\cdot}77$ „ $- 172{\cdot}9 = 0$
$x + 3{\cdot}98$ „ $- 157{\cdot}2 = 0$
$x + 3{\cdot}10$ „ $- 140{\cdot}2 = 0$
$x - 4{\cdot}56$ „ $- 28{\cdot}9 = 0$
$x - 5{\cdot}83$ „ $- 9{\cdot}0 = 0$
$x - 6{\cdot}85$ „ $+ 6{\cdot}5 = 0$
$x - 7{\cdot}83$ „ $+ 22{\cdot}3 = 0$
$x - 8{\cdot}86$ „ $+ 38{\cdot}1 = 0$

Before the first measurement—(Continued.)

$x - 9{\cdot}67\,(E_a - dE_a) + 52{\cdot}3 = 0$	$x + 1{\cdot}70\,(E_a - dE_a) - 122{\cdot}3 = 0$
$x - 10{\cdot}32$ „ $+ 63{\cdot}5 = 0$	$x - 4{\cdot}70$ „ $- 23{\cdot}1 = 0$
$x - 11{\cdot}05$ „ $+ 72{\cdot}6 = 0$	$x - 5{\cdot}55$ „ $- 9{\cdot}0 = 0$
$x - 11{\cdot}65$ „ $+ 81{\cdot}4 = 0$	$x - 6{\cdot}40$ „ $+ 6{\cdot}5 = 0$
$x - 12{\cdot}12$ „ $+ 89{\cdot}1 = 0$	$x - 7{\cdot}32$ „ $+ 18{\cdot}4 = 0$
$x + 4{\cdot}33$ „ $- 169{\cdot}5 = 0$	$x - 8{\cdot}23$ „ $+ 31{\cdot}8 = 0$
$x + 4{\cdot}68$ „ $- 171{\cdot}1 = 0$	$x - 9{\cdot}11$ „ $+ 48{\cdot}1 = 0$
$x + 4{\cdot}45$ „ $- 168{\cdot}2 = 0$	$x - 9{\cdot}90$ „ $+ 58{\cdot}8 = 0$
$x + 3{\cdot}95$ „ $- 156{\cdot}8 = 0$	$x - 10{\cdot}50$ „ $+ 63{\cdot}4 = 0$
$x + 3{\cdot}33$ „ $- 147{\cdot}0 = 0$	$x - 10{\cdot}85$ „ $+ 70{\cdot}6 = 0$
$x + 2{\cdot}58$ „ $- 137{\cdot}5 = 0$	$x - 11{\cdot}17$ „ $+ 75{\cdot}9 = 0$

And from the mean of these results,

$$x = \overset{d}{26{\cdot}78} + 4{\cdot}55\,(E_a - dE_a):$$

adopting the original value of the expansion of **A** given at page (9),

$$E_a = \overset{m.y}{22{\cdot}67} = \overset{d}{16{\cdot}444},$$

$$\text{and } x = \overset{d}{101{\cdot}60} - 4{\cdot}55\,dE_a = \overset{m.y}{140{\cdot}07} - 4{\cdot}55\,dE_a = \mathrm{L} - \mathbf{A};$$

where L denotes the mean length of the compensated bars obtained from *all* the comparisons, as represented by the mean micrometer reading $\overset{d}{234{\cdot}87}$, page II—5.

Comparing this reading with the mean reading of each compensated bar given on the same page we obtain the following:—

In terms of	A − L	B − L	C − L	D − L	E − L	H − L
Micrometer divisions.	+ 0·23	−20·56	+0·73	+32·88	−6·92	−6·34
Millionths of a yard.	+ 0·32	−28·34	+1·01	+45·33	−9·54	−8·74

Also combining the values in this table with the equivalent of L—**A** above determined there result,

$\mathrm{A} - \mathbf{A} = \overset{d}{101{\cdot}83} - 4{\cdot}55\,dE_a = \overset{m.y}{140{\cdot}39} - 4{\cdot}55\,dE_a$	$\mathrm{D} - \mathbf{A} = \overset{d}{134{\cdot}48} - 4{\cdot}55\,dE_a = \overset{m.y}{185{\cdot}40} - 4{\cdot}55\,dE_a$
$\mathrm{B} - \mathbf{A} = 81{\cdot}04 -$ „ $= 111{\cdot}73 -$ „	$\mathrm{E} - \mathbf{A} = 94{\cdot}68 -$ „ $= 130{\cdot}53 -$ „
$\mathrm{C} - \mathbf{A} = 102{\cdot}33 -$ „ $= 141{\cdot}08 -$ „	$\mathrm{H} - \mathbf{A} = 95{\cdot}26 -$ „ $= 131{\cdot}33 -$ „

$$\text{and } 6x = \overset{m.y}{840{\cdot}4} - 27{\cdot}3\,dE_a.$$

Comparisons between the Standard Bar **A** *and the Compensated Bars* A, B, C, D, E, H, *made at Barwala Camp, Dehra Doon, between the two measurements.*

1835 Feb.	Mean of the times of observing A		No. of comparison	Corrected mean temperature of A	Micrometer Readings in Divisions (1 Division = $\frac{1}{20168 \cdot 7}$ Cary's Inch [7.8], = 1·3765 m.y. of A) Mean A	A	B	C	D	E	H	Mean of the compensated bars	Remarks
	h m			°		+	+	+	+	+	+	+	
11th	7 36	A.M.	1	41·72	−77·5	343·5	312·2	334·0	367·1	322·0	325·5	334·1	Major Everest at the micrometer microscope.
	8 8		2	42·32	65·1	341·5	311·0	330·0	365·5	324·0	330·4	333·7	
	8 37		3	43·52	41·9	335·1	309·5	328·5	362·0	323·0	333·5	331·9	
	9 4		4	45·27	14·3	332·5	307·0	322·8	360·8	324·0	331·0	329·7	
	9 32		5	47·50	+15·6	329·0	304·0	318·5	358·0	320·0	330·2	326·6	
	10 7		6	50·55	61·1	324·1	303·0	313·5	354·5	321·0	334·0	325·0	
	10 41		7	53·65	108·3	318·0	301·0	311·0	351·0	320·4	331·8	322·2	
	1 34	P.M.	8	68·85	336·8	308·5	288·9	300·3	350·0	318·0	329·0	315·8	
	2 1		9	69·87	351·2	311·0	291·0	309·5	354·0	314·5	329·0	318·2	
	2 31		10	70·90	363·7	315·5	296·4	311·1	356·0	318·0	325·9	320·5	
	3 12		11	71·47	369·5	308·3	289·6	312·5	349·0	310·5	311·5	313·6	
	3 52		12	71·65	371·1	313·5	295·5	316·0	347·0	312·0	314·6	316·5	
	4 22		13	71·32	364·1	316·5	300·3	321·2	352·0	309·5	310·0	318·3	
	4 50		14	70·37	343·0	318·0	298·0	317·2	347·8	304·0	300·0	314·2	
12th	7 19	A.M.	15	48·17	− 7·2	313·5	287·3	310·6	333·0	296·0	296·0	306·1	
	7 52		16	48·50	+ 2·9	313·0	289·0	307·0	355·5	297·0	390·0	310·3	
	8 28		17	49·42	19·1	311·6	287·9	304·0	340·0	297·1	305·5	307·7	
	9 2		18	51·00	43·5	301·0	280·8	298·3	333·5	293·5	303·0	301·7	
	9 32		19	53·05	76·3	299·5	276·5	296·0	334·0	295·0	301·1	300·4	
	10 0		20	55·17	110·8	301·2	276·0	293·0	333·9	296·8	303·0	300·7	
	10 30		21	57·40	144·5	294·4	274·0	290·2	324·1	292·0	301·0	296·0	
	1 14	P.M.	22	67·87	294·1	296·0	276·7	284·8	339·0	290·5	293·5	296·8	
	1 49		23	69·40	318·0	292·1	279·5	291·1	329·5	286·6	293·0	295·3	
	2 24		24	70·52	332·3	288·5	273·5	289·8	324·5	285·9	290·4	292·1	
	3 5		25	71·20	345·2	291·0	272·6	292·5	328·5	282·4	289·3	292·7	
	3 35		26	71·47	349·5	291·5	276·0	304·0	329·0	288·1	291·0	296·6	
	4 6		27	71·62	350·6	294·0	277·0	304·5	333·5	286·7	286·5	297·0	
	4 37		28	71·40	345·0	300·0	278·5	299·5	332·0	284·5	287·0	296·9	
	5 8		29	70·82	336·2	301·9	279·5	303·9	337·3	286·4	290·7	300·0	
13th	7 30	A.M.	30	48·80	9·3	312·7	289·4	313·5	342·9	298·5	305·6	310·4	
	8 7		31	49·30	18·6	314·2	292·5	313·7	339·0	299·0	305·0	310·6	
	8 39		32	50·50	39·3	307·0	286·9	305·0	336·5	296·8	303·0	305·9	
	9 13		33	52·25	66·5	304·8	283·0	297·1	334·0	299·0	303·0	303·5	
	9 47		34	54·37	98·8	296·0	275·9	289·0	326·0	294·0	299·5	296·7	
	10 21		35	56·57	130·8	295·0	276·0	297·6	321·0	289·0	298·5	296·2	
	10 51		36	58·67	160·7	290·7	272·6	284·0	324·0	286·0	297·7	292·5	
	1 37	P.M.	37	69·97	329·9	291·6	275·6	296·7	320·1	290·0	279·0	292·2	
	2 15		38	71·95	359·3	286·5	273·0	291·9	327·1	287·0	293·0	293·1	
	2 59		39	73·77	392·3	293·0	281·2	301·9	333·0	295·1	294·0	299·7	

Between the two measurements—(Continued.)

1832 Feb.	Mean of the times of observing A		No. of comparison	Corrected mean temperature of A	Micrometer readings in divisions. 1 Division = $\frac{1}{20168 \cdot 7}$ Cary's Inch [7.8], = 1·8765 m.y. of A — Mean A	A	B	C	D	E	H	Mean of the compensated bars.	Remarks
	h m			°		+	+	+	+	+	+	+	
13th	3 37	P.M.	40	74·85	+413·8	303·5	288·0	313·0	337·8	303·1	298·8	307·4	Major Everest at the micrometer microscope.
	4 7		41	75·15	414·6	306·5	287·0	313·9	340·5	297·9	296·7	307·1	
	4 35		42	75·02	412·5	300·8	287·0	312·0	334·0	298·0	297·4	304·9	
	5 3		43	74·55	405·5	303·0	287·0	316·8	341·5	296·4	292·3	306·2	
16th	7 33	A.M.	44	42·77	−139·8	267·8	240·5	258·1	289·2	245·0	250·5	258·5	
	8 4		45	43·37	129·3	267·9	237·8	257·8	287·4	246·0	254·0	258·5	
	8 35		46	44·35	111·2	263·1	234·9	251·0	284·0	248·1	254·1	255·9	
	9 8		47	45·87	85·6	260·7	229·3	252·0	283·0	251·0	255·4	255·2	
	9 39		48	47·57	55·7	259·0	234·4	254·5	286·9	252·0	260·1	257·8	
	10 6		49	49·22	28·6	255·0	234·0	251·0	282·5	249·5	255·0	254·5	
	10 30		50	50·65	13·5	251·1	230·0	246·7	282·5	250·0	255·0	252·6	
	10 50		51	51·90	+ 2·8	251·0	231·3	248·4	283·1	249·0	255·9	253·1	
	1 16	P.M.	52	59·32	115·0	261·1	235·0	259·3	291·2	254·0	260·5	260·2	
	1 36		53	60·57	133·0	260·0	237·7	261·5	290·0	251·3	261·9	260·4	
	1 59		54	61·77	152·0	256·0	238·9	252·0	289·5	256·0	260·0	258·7	
	2 25		55	62·97	169·6	255·0	235·4	257·8	286·0	251·0	256·5	257·0	
	3 3		56	64·65	202·3	251·9	235·0	248·9	286·0	245·5	251·2	253·1	
	3 28		57	65·50	214·7	251·5	233·3	250·9	284·9	247·9	248·5	252·8	
	3 51		58	66·10	220·7	247·2	228·5	241·5	280·2	247·0	245·5	248·3	
	4 13		59	66·40	224·3	250·9	231·3	247·5	280·9	244·9	245·0	250·1	
	4 38		60	66·37	223·2	248·5	231·0	252·2	281·0	242·1	242·0	249·5	
	5 4		61	66·00	215·9	253·0	225·5	246·5	282·6	240·9	241·8	248·4	
	Means		...	59·79	165·71	292·13	271·33	290·15	324·11	285·25	289·89	292·14	

As on page II—5 we have

$$x - (t^\circ - 62^\circ)(E_a - dE_a) - \delta = 0;$$

and from the preceding bar comparisons, we obtain the following series of results :—

$x + 20{\cdot}28\,(E_a - dE_a) - 411{\cdot}6 = 0$	$x - 6{\cdot}85\,(E_a - dE_a) + 21{\cdot}0 = 0$
$x + 19{\cdot}68$ „ $- 398{\cdot}8 = 0$	$x - 7{\cdot}87$ „ $+ 33{\cdot}0 = 0$
$x + 18{\cdot}48$ „ $- 373{\cdot}8 = 0$	$x - 8{\cdot}90$ „ $+ 43{\cdot}2 = 0$
$x + 16{\cdot}73$ „ $- 344{\cdot}0 = 0$	$x - 9{\cdot}47$ „ $+ 55{\cdot}9 = 0$
$x + 14{\cdot}50$ „ $- 311{\cdot}0 = 0$	$x - 9{\cdot}65$ „ $+ 54{\cdot}6 = 0$
$x + 11{\cdot}45$ „ $- 263{\cdot}9 = 0$	$x - 9{\cdot}32$ „ $+ 45{\cdot}8 = 0$
$x + 8{\cdot}35$ „ $- 213{\cdot}9 = 0$	$x - 8{\cdot}37$ „ $+ 28{\cdot}8 = 0$

Between the two measurements—(Continued.)

$x+13{\cdot}83\ (E_a-dE_a)\ -313{\cdot}3=0$
$x+13{\cdot}50$ „ $-307{\cdot}4=0$
$x+12{\cdot}58$ „ $-288{\cdot}6=0$
$x+11{\cdot}00$ „ $-258{\cdot}2=0$
$x+8{\cdot}95$ „ $-224{\cdot}1=0$
$x+6{\cdot}83$ „ $-189{\cdot}9=0$
$x+4{\cdot}60$ „ $-151{\cdot}5=0$
$x-5{\cdot}87$ „ $-2{\cdot}7=0$
$x-7{\cdot}40$ „ $+22{\cdot}7=0$
$x-8{\cdot}52$ „ $+40{\cdot}2=0$
$x-9{\cdot}20$ „ $+52{\cdot}5=0$
$x-9{\cdot}47$ „ $+52{\cdot}9=0$
$x-9{\cdot}62$ „ $+53{\cdot}6=0$
$x-9{\cdot}40$ „ $+48{\cdot}1=0$
$x-8{\cdot}82$ „ $+36{\cdot}2=0$
$x+13{\cdot}20$ „ $-301{\cdot}1=0$
$x+12{\cdot}70$ „ $-292{\cdot}0=0$
$x+11{\cdot}50$ „ $-266{\cdot}6=0$
$x+9{\cdot}75$ „ $-237{\cdot}0=0$
$x+7{\cdot}63$ „ $-197{\cdot}9=0$
$x+5{\cdot}43$ „ $-165{\cdot}4=0$
$x+3{\cdot}33$ „ $-131{\cdot}8=0$
$x-7{\cdot}97$ „ $+37{\cdot}7=0$
$x-9{\cdot}95$ „ $+66{\cdot}2=0$

$x-11{\cdot}77\ (E_a-dE_a)\ +92{\cdot}6=0$
$x-12{\cdot}85$ „ $+106{\cdot}4=0$
$x-13{\cdot}15$ „ $+107{\cdot}5=0$
$x-13{\cdot}02$ „ $+107{\cdot}6=0$
$x-12{\cdot}55$ „ $+99{\cdot}3=0$
$x+19{\cdot}23$ „ $-398{\cdot}3=0$
$x+18{\cdot}63$ „ $-387{\cdot}8=0$
$x+17{\cdot}65$ „ $-367{\cdot}1=0$
$x+16{\cdot}13$ „ $-340{\cdot}8=0$
$x+14{\cdot}43$ „ $-313{\cdot}5=0$
$x+12{\cdot}78$ „ $-283{\cdot}1=0$
$x+11{\cdot}35$ „ $-266{\cdot}1=0$
$x+10{\cdot}10$ „ $-250{\cdot}3=0$
$x+2{\cdot}68$ „ $-145{\cdot}2=0$
$x+1{\cdot}43$ „ $-127{\cdot}4=0$
$x+0{\cdot}23$ „ $-106{\cdot}7=0$
$x-0{\cdot}97$ „ $-87{\cdot}4=0$
$x-2{\cdot}65$ „ $-50{\cdot}8=0$
$x-3{\cdot}50$ „ $-38{\cdot}1=0$
$x-4{\cdot}10$ „ $-27{\cdot}6=0$
$x-4{\cdot}40$ „ $-25{\cdot}8=0$
$x-4{\cdot}37$ „ $-26{\cdot}3=0$
$x-4{\cdot}00$ „ $-32{\cdot}5=0$

And from the mean of these results,

$$x \overset{d}{=} 126{\cdot}43 - 2{\cdot}21\,(E_a - dE_a).$$

Adopting the original value of the expansion of **A** given at page (9)

$$E_a \overset{m.y}{=} 22{\cdot}67 \overset{d}{=} 16{\cdot}469,$$

$$\text{and } x \overset{d}{=} 90{\cdot}03 + 2{\cdot}21\,dE_a \overset{m.y}{=} 123{\cdot}93 + 2{\cdot}21\,dE_a = \text{L} - \mathbf{A}.$$

Proceeding as on page II—6 we obtain;

In terms of	A—L	B—L	C—L	D—L	E—L	H—L
Micrometer divisions.	−0·01	−20·81	−1·99	+31·97	−6·89	−2·25
Millionths of a yard.	−0·01	−28·64	−2·74	+44·01	−9·48	−3·10

Also the following;

$\text{A} - \mathbf{A} \overset{d}{=} 90{\cdot}02 + 2{\cdot}21\,dE_a \overset{m.y}{=} 123{\cdot}92 + 2{\cdot}21\,dE_a$
$\text{B} - \mathbf{A} = 69{\cdot}22 +$ „ $= 95{\cdot}29 +$ „
$\text{C} - \mathbf{A} = 88{\cdot}04 +$ „ $= 121{\cdot}19 +$ „

$\text{D} - \mathbf{A} \overset{d}{=} 122{\cdot}00 + 2{\cdot}21\,dE_a \overset{m.y}{=} 167{\cdot}94 + 2{\cdot}21\,dE_a$
$\text{E} - \mathbf{A} = 83{\cdot}14 +$ „ $= 114{\cdot}45 +$ „
$\text{H} - \mathbf{A} = 87{\cdot}78 +$ „ $= 120{\cdot}83 +$ „

$$\text{and } 6x \overset{m.y}{=} 743{\cdot}6 + 13{\cdot}3\,dE_a$$

Final deduction of the total length measured with the compensated bars in the 1st measurement.

From page II—6 the excess of the 6 compensated bars above 6 times **A** *before* the 1st meast:				$= \overset{m.y}{840.4} - 27.3\, dE_a$
,, II—9	,,	*between* the two	,,	$= 743.6 + 13.3\, dE_a$
Therefore the mean excess of	,,	applicable to the 1st	,,	$= 792.0 - 7.0\, dE_a$
And the mean length of a set of 6 compensated bars in feet of the standard				$= 60.002376 \frac{\mathbf{A}}{10} - 7.0\, dE_a$

Hence the total lengths measured with the compensated bars

			feet of **A**	
in sets Nos.	1 to 66	=	3960·1568 —	462 dE_a
,,	67 to 157	=	5460·2162 —	637 dE_a
,,	158 to 219	=	3720·1473 —	434 dE_a
,,	220 to 389	=	10200·4039 —	1190 dE_a
,,	390 to 520	=	7860·3113 —	917 dE_a
,,	521 to 622	=	6120·2424 —	714 dE_a
,,	1 to 622	=	37321·4779 —	4354 dE_a

Now the mean temperature of **A** during the above bar comparisons was $62° + \frac{7°.0}{6} = 63°.2$, for which temperature the corresponding expansion of **A** from page (19) is 21·655 *m.y.* Comparing this value of expansion with the original value = 22·67 *m.y.*, used in the foregoing, it is found, that $dE_a = + 1.015$ *m.y.*; and substituting for dE_a this numerical value, there result;—

Total lengths measured with the compensated bars

			feet	of	**A**
in sets Nos.	1 to 66 or W. End,	to Pin No. 1	=(3960·1568	— 0·0014) =	3960·1554
,,	67 to 157 or Pin No. 1,	to Pin No. 2 (Stn. A)	=(5460·2162	— 0·0019) =	5460·2143
,,	158 to 219 or Pin No. 2 (Stn. A),	to Pin No. 3	=(3720·1473	— 0·0013) =	3720·1460
,,	220 to 389 or Pin No. 3,	to Pin No. 4 (Stn. B)	=(10200·4039	— 0·0036) =	10200·4003
,,	390 to 520 or Pin No. 4 (Stn. B),	to Pin No. 5	=(7860·3113	— 0·0028) =	7860·3085
,,	521 to 622 or Pin No. 5,	to E. End	=(6120·2424	— 0·0022) =	6120·2402
,,	1 to 622 or W. End,	to E. End	= 37321·4779	— 0·0132 =	37321·4647

Comparisons between the Standard Bar **A** *and the Compensated Bars* A, B, C, D, E, H, *made at Barwala Camp, Dehra Doon, after the 2nd measurement.*

1835 March and April	Mean of the times of observing **A**		No. of comparison	Corrected mean temperature of **A**	Mean **A**	A	B	C	D	E	H	Mean of the compensated bars.	Remarks
					MICROMETER READINGS IN DIVISIONS. 1 Division = $\frac{1}{20218\cdot9}$ Cary's Inch [7.8], = 1·3731 m.y. of **A**								
	h m			°	+	+	+	+	+	+	+	+	
31st	6 47	A.M.	1	50·07	288·4	580·9	547·0	564·7	596·9	568·5	559·1	569·5	
	7 15		2	50·35	294·2	573·3	547·9	568·4	599·2	557·3	562·2	568·1	
	7 38		3	51·07	306·4	574·1	543·9	561·1	597·1	553·3	561·9	565·2	
	8 4		4	52·30	326·5	569·1	542·3	556·7	592·0	552·0	557·1	561·5	
	8 30		5	53·87	351·0	564·8	542·1	550·5	588·8	551·9	559·9	559·7	
	8 53		6	55·57	375·7	556·9	543·7	552·0	593·4	551·7	561·0	559·8	
	9 16		7	57·45	403·5	556·9	536·6	550·4	588·3	549·7	556·9	556·5	
	9 49		8	60·62	451·8	547·9	535·1	540·1	582·4	547·2	557·0	551·6	
	10 20		9	63·85	502·3	552·0	531·3	545·6	583·9	551·0	559·1	553·8	
	10 41		10	66·12	539·3	549·0	533·4	539·1	588·0	550·9	559·9	553·4	
	11 2		11	68·42	575·0	548·2	536·0	546·8	588·8	547·0	557·7	554·1	
	1 30	P.M.	12	81·60	781·2	563·2	568·0	579·0	615·2	570·6	579·9	579·3	
	1 56		13	82·87	803·9	576·9	568·3	579·8	619·8	575·5	578·9	583·2	
	2 21		14	83·77	824·2	573·9	566·0	582·9	617·2	571·4	580·9	582·1	
	2 44		15	84·52	835·6	577·7	570·0	582·5	615·9	576·3	579·8	583·7	
	3 6		16	85·20	841·8	581·7	567·5	580·2	614·0	575·1	576·8	582·6	
	3 32		17	85·67	845·8	575·7	572·0	583·7	618·4	576·0	575·5	583·6	
	3 58		18	85·92	850·5	582·4	565·8	586·1	619·2	581·1	570·2	584·1	
	4 20		19	85·92	847·9	587·1	573·0	587·8	620·2	574·2	573·4	586·0	
	4 41		20	85·80	847·2	582·8	567·0	586·9	620·9	571·4	572·8	583·6	
	5 2		21	85·42	844·9	581·2	567·0	583·0	622·0	568·8	565·8	581·3	
	5 30		22	84·67	826·5	579·8	565·9	575·9	606·0	563·9	564·2	576·0	
1st	6 49	A.M.	23	51·60	323·7	587·1	556·1	576·2	609·0	567·0	575·4	578·5	
	7 15		24	52·02	331·8	587·0	557·4	573·3	609·3	564·0	565·9	576·2	
	7 39		25	52·82	345·1	585·0	550·9	576·8	606·1	561·3	572·4	575·4	
	8 4		26	54·20	364·6	579·1	555·9	572·1	606·9	557·1	575·4	574·4	
	8 28		27	55·72	387·1	572·9	541·1	565·1	597·5	558·8	568·8	567·4	
	8 46		28	57·07	410·6	568·2	545·8	561·7	596·0	561·2	566·8	566·6	
	9 3		29	58·52	432·0	562·9	549·0	555·6	600·9	559·6	566·8	565·8	
	9 29		30	60·72	464·9	555·8	535·1	557·1	599·1	562·0	568·0	562·9	
	9 55		31	63·07	502·1	561·9	545·0	552·9	598·3	560·0	565·3	563·9	
	10 12		32	64·85	530·7	553·9	546·8	552·1	599·4	563·3	565·2	563·5	
	10 32		33	66·82	561·0	558·7	545·8	553·0	595·8	561·9	569·6	564·1	
	1 30	P.M.	34	82·17	789·4	564·4	563·2	579·9	616·1	568·9	570·3	577·1	
	1 53		35	83·30	808·5	566·1	566·1	580·2	621·8	564·7	574·8	579·0	
	2 15		36	84·20	825·0	573·9	565·9	584·9	620·6	577·7	577·7	583·5	
	2 38		37	84·85	836·9	574·9	568·0	577·0	626·1	578·0	576·8	583·5	
	2 59		38	85·42	844·0	575·9	569·8	580·5	617·3	579·1	578·0	583·4	
	3 16		39	85·82	850·4	574·8	567·7	582·2	616·3	575·3	574·0	581·7	
	3 38		40	86·10	856·0	574·6	566·5	573·1	615·9	574·0	570·9	579·2	

Comparisons between the Standard Bar **A** *and the Compensated Bars* A, B, C, D, E, H, *made at Barwala Camp, Dehra Doon, after the 2nd measurement.*

1835 April.	Mean of the times of observing **A**	No. of comparison	Corrected mean temperature of **A**	MICROMETER READINGS IN DIVISIONS 1 Division = $\frac{1}{20218 \cdot 9}$ Cary's Inch [7.8], = 1·3731 m.y. of **A** — Mean **A**	A	B	C	D	E	H	Mean of the compensated bars	REMARKS
	h m		°	+	+	+	+	+	+	+	+	
1st	3 59 P.M.	41	86·25	859·5	576·0	566·8	583·5	619·9	576·8	569·2	582·0	
	4 17	42	86·27	859·0	577·8	565·9	583·1	623·9	573·3	573·3	582·9	
	4 35	43	86·25	856·4	578·8	565·7	576·9	621·0	574·9	572·6	581·7	
	4 58	44	86·05	849·9	577·9	568·1	583·2	617·5	574·2	563·7	580·8	
	5 23	45	85·60	837·0	580·7	559·1	581·2	612·7	564·5	564·5	577·1	
2nd	7 6 A.M.	46	53·95	374·3	596·4	572·3	591·3	623·0	582·0	581·9	591·2	
	7 28	47	54·55	380·8	595·0	576·1	589·4	623·9	582·8	586·9	592·4	
	7 49	48	55·42	392·9	590·8	570·5	586·9	622·5	576·9	580·7	588·1	
	8 9	49	56·50	412·3	581·9	568·9	585·0	621·0	578·6	581·9	586·2	
	8 33	50	58·25	442·2	588·1	567·2	578·9	617·4	579·8	584·4	586·0	
	8 57	51	60·20	471·8	584·0	564·8	573·0	612·9	579·7	583·8	583·0	
	9 16	52	61·92	496·9	584·2	560·3	577·3	615·1	582·1	581·8	583·5	
	9 36	53	63·52	526·0	574·3	560·8	567·3	616·0	579·3	582·8	580·1	
	9 55	54	65·15	553·5	576·4	561·8	569·9	618·1	572·7	585·0	580·7	
	10 14	55	66·92	580·6	571·9	559·0	565·9	615·5	577·6	584·0	579·0	
	2 0 P.M.	56	86·35	864·5	577·1	571·0	590·5	629·0	584·3	587·1	589·8	
	2 18	57	87·02	879·7	582·0	572·0	595·0	633·1	591·0	583·1	592·7	
	2 35	58	87·50	887·1	583·3	575·2	602·1	634·9	586·4	585·6	594·6	
	2 54	59	87·92	893·4	584·1	574·0	595·0	631·5	588·8	587·0	593·4	
	3 13	60	88·15	898·6	583·9	587·1	590·3	631·0	589·6	583·0	594·2	
	3 48	61	88·45	900·6	588·9	575·9	596·0	631·0	585·9	580·2	593·0	
	4 3	62	88·55	902·7	588·7	574·7	594·9	627·0	586·8	579·0	591·9	
	4 17	63	88·50	900·0	592·9	578·0	599·9	629·6	583·4	579·6	593·9	
	4 31	64	88·37	896·6	588·1	576·4	600·9	619·4	586·9	573·9	590·9	
	4 47	65	88·20	892·3	590·5	574·1	586·7	627·8	577·3	576·4	588·8	
	5 11	66	87·80	883·2	586·0	569·9	592·8	625·8	579·0	576·3	588·3	
Means, ...			72·48	647·26	575·64	560·63	575·36	612·73	570·81	573·03	578·03	

After the 2nd measurement—(Continued.)

As on page II—5 we have

$$x - (t^\circ - 62^\circ)(E_a - dE_a) - \delta = 0;$$

and from the preceding bar comparisons, we obtain the following series of results :—

$x+11.93$	(E_a-dE_a)	$-281.1=0$	$x-20.17$	(E_a-dE_a)	$+212.3=0$
$x+11.65$	"	$-273.9=0$	$x-21.30$	"	$+229.5=0$
$x+10.93$	"	$-258.8=0$	$x-22.20$	"	$+241.5=0$
$x+9.70$	"	$-235.0=0$	$x-22.85$	"	$+253.4=0$
$x+8.13$	"	$-208.7=0$	$x-23.42$	"	$+260.6=0$
$x+6.43$	"	$-184.1=0$	$x-23.82$	"	$+268.7=0$
$x+4.55$	"	$-153.0=0$	$x-24.10$	"	$+276.8=0$
$x+1.38$	"	$-99.8=0$	$x-24.25$	"	$+277.5=0$
$x-1.85$	"	$-51.5=0$	$x-24.27$	"	$+276.1=0$
$x-4.12$	"	$-14.1=0$	$x-24.25$	"	$+274.7=0$
$x-6.42$	"	$+20.9=0$	$x-24.05$	"	$+269.1=0$
$x-19.60$	"	$+201.9=0$	$x-23.60$	"	$+259.9=0$
$x-20.87$	"	$+220.7=0$	$x+8.05$	"	$-216.9=0$
$x-21.77$	"	$+242.1=0$	$x+7.45$	"	$-211.6=0$
$x-22.52$	"	$+251.9=0$	$x+6.58$	"	$-195.2=0$
$x-23.20$	"	$+259.2=0$	$x+5.50$	"	$-173.9=0$
$x-23.67$	"	$+262.2=0$	$x+3.75$	"	$-143.8=0$
$x-23.92$	"	$+266.4=0$	$x+1.80$	"	$-111.2=0$
$x-23.92$	"	$+261.9=0$	$x+0.08$	"	$-86.6=0$
$x-23.80$	"	$+263.6=0$	$x-1.52$	"	$-54.1=0$
$x-23.42$	"	$+263.6=0$	$x-3.15$	"	$-27.2=0$
$x-22.67$	"	$+250.5=0$	$x-4.92$	"	$+1.6=0$
$x+10.40$	"	$-254.8=0$	$x-24.35$	"	$+274.7=0$
$x+9.98$	"	$-244.4=0$	$x-25.02$	"	$+287.0=0$
$x+9.18$	"	$-230.3=0$	$x-25.50$	"	$+292.5=0$
$x+7.80$	"	$-209.8=0$	$x-25.92$	"	$+300.0=0$
$x+6.28$	"	$-180.3=0$	$x-26.15$	"	$+304.4=0$
$x+4.93$	"	$-156.0=0$	$x-26.45$	"	$+307.6=0$
$x+3.48$	"	$-133.8=0$	$x-26.55$	"	$+310.8=0$
$x+1.28$	"	$-98.0=0$	$x-26.50$	"	$+306.1=0$
$x-1.07$	"	$-61.8=0$	$x-26.37$	"	$+305.7=0$
$x-2.85$	"	$-32.8=0$	$x-26.20$	"	$+303.5=0$
$x-4.82$	"	$-3.1=0$	$x-25.80$	"	$+294.9=0$

After the 2nd measurement—(Continued.)

And from the mean of these results,

$$x = -\overset{d}{69\cdot23} + 10\cdot48\,(E_a - dE_a).$$

Adopting the original value of the expansion of **A** given at page (9),

$$E_a = \overset{m.y}{22\cdot67} = \overset{d}{16\cdot510},$$

$$\text{and } x = \overset{d}{103\cdot79} - 10\cdot48\,dE_a = \overset{m.y}{142\cdot51} - 10\cdot48\,dE_a = \text{L} - \mathbf{A}.$$

Proceeding as on page II—6 we obtain :—

In terms of	A − L	B − L	C − L	D − L	E − L	H − L
Micrometer divisions.	− 2·39	−17·40	−2·67	+34·70	−7·22	−5·00
Millionths of a yard.	− 3·28	−23·89	−3·67	+47·65	−9·91	−6·87

Also the following,

$$
\begin{aligned}
\text{A} - \mathbf{A} &= \overset{d}{101\cdot40} - 10\cdot48\,dE_a = \overset{m.y}{139\cdot23} - 10\cdot48\,dE_a \\
\text{B} - \mathbf{A} &= 86\cdot39 - \quad ,, \quad = 118\cdot62 - \quad ,, \\
\text{C} - \mathbf{A} &= 101\cdot12 - \quad ,, \quad = 138\cdot84 - \quad ,, \\
\text{D} - \mathbf{A} &= 138\cdot49 - \quad ,, \quad = 190\cdot16 - \quad ,, \\
\text{E} - \mathbf{A} &= 96\cdot57 - \quad ,, \quad = 132\cdot60 - \quad ,, \\
\text{H} - \mathbf{A} &= 98\cdot79 - \quad ,, \quad = 135\cdot64 - \quad ,,
\end{aligned}
$$

$$\text{and } 6x = \overset{m.y}{855\cdot1} - 62\cdot9\,dE_a.$$

Final deduction of the total length measured with the compensated bars in the 2nd measurement

From page II—9 the excess of the 6 compensated bars above 6 times **A** *between* the two measurements		$= 743.6 + 13.3\, dE_a$ m.y
„ II—14	„ *after* the 2nd „	$= 855.1 - 62.9\, dE_a$
Therefore the mean excess of	„ applicable to the 2nd „	$= 799.4 - 24.8\, dE_a$
And the mean length of a set of 6 compensated bars in feet of the standard		$= 60.0023982\, \frac{\mathbf{A}}{10} - 24.8\, dE_a$

Hence the total lengths measured with the compensated bars

		feet of **A**
in sets Nos.	1 to 102	$= 6120.2446 - 2530\, dE_a$
„	103 to 233	$= 7860.3142 - 3249\, dE_a$
„	234 to 403	$= 10200.4077 - 4216\, dE_a$
„	404 to 465	$= 3720.1487 - 1538\, dE_a$
„	466 to 556	$= 5460.2182 - 2257\, dE_a$
„	557 to 622	$= 3960.1583 - 1637\, dE_a$
„	1 to 622	$= 37321.4917 - 15427\, dE_a$

Now the mean temperature of **A** during the above bar comparisons was $62° + \frac{24°.8}{6} = 66°.1$, for which temperature the corresponding expansion of **A** from page (19) is 21·673 *m.y.* Comparing this value of expansion with the original value = 22·67 *m.y.*, used in the foregoing; it is found, that $dE_a = + 0.997$ *m.y.*; and substituting for dE_a this numerical value, there result,

Total lengths measured with the compensated bars

			feet of **A**
in sets Nos.	1 to 102 or E. End,	to Pin No. 5	= 6120·2446 − 0·0076 = 6120·2370
„	103 to 233 or Pin No. 5,	to Pin No. 4 (Stn. B)	= 7860·3142 − 0·0097 = 7860·3045
„	234 to 403 or Pin No. 4 (Stn. B),	to Pin No. 3	= 10200·4077 − 0·0126 = 10200·3951
„	404 to 465 or Pin No. 3,	to Pin No. 2 (Stn. A)	= 3720·1487 − 0·0046 = 3720·1441
„	466 to 556 or Pin No. 2 (Stn. A),	to Pin No. 1	= 5460·2182 − 0·0068 = 5460·2114
„	557 to 622 or Pin No. 1,	to W. End	= 3960·1583 − 0·0049 = 3960·1534
„	1 to 622 or E. End,	to W. End	37321·4917 − 0·0462 = 37321·4455

***Comparisons between the Compensated Microscopes and their 6-inch brass scales during the 1st measurement, and provisional determination of Microscope errors with respect to the 6-inch brass scale A, expressed in millionths of an inch* (m. i.)**

When compared — 1834		Microscope.	Scale compared with.	Corrected temperature.	Reduction to 62° Fah. Expansion of 6″ scale for 1° = *E* = 62·5 *m.i.*	Microscope — Microscope Scale. Observed value in terms of: Divisions 10000 = 1″.	*m. i.*	Micros: Scale − *A*, at 62° Fah.	Micros: − Scale *A*, at 62° Fah. *m. i.*	Reference number.
December 1st	Before the 1st measurement.	*U*	*U*	65°·15	+ 197	·00	0	+ 283	+ 480	1
		O	*R*	59·31	− 168	+ 3·75	+ 375	93	300	2
		P	*P*	64·46	+ 154	− 4·20	− 420	350	84	3
		M	*M*	61·25	− 47	+ 2·25	+ 225	− 21	157	4
		N	*N*	59·02	187	2·00	200	+ 363	376	5
		T	*T*	63·85	+ 115	8·70	870	− 97	888	6
		S	*S*	61·94	− 4	5·30	530	75	451	7
" 4th	Between sets No. 22 and 23.	*U*	*U*	68·05	+ 378	·00	0	+ 283	+ 661	8
		O	*R*	69·91	494	− 0·70	− 70	93	517	9
		P	*P*	68·95	435	6·50	650	350	135	10
		M	*M*	69·85	491	3·20	320	− 21	150	11
		N	*N*	68·12	382	+ 1·00	+ 100	+ 363	845	12
		T	*T*	69·35	459	·00	0	− 97	362	13
		S	*S*	67·64	352	+ 3·05	+ 305	75	582	14
" 8th	Between sets No. 49 and 50.	*U*	*U*	69·05	+ 441	·00	0	+ 283	+ 724	15
		O	*R*	65·81	238	·00	0	93	331	16
		P	*P*	65·66	229	− 7·83	− 783	350	− 204	17
		M	*M*	68·05	378	·30	30	− 21	+ 327	18
		N	*N*	68·12	382	2·15	215	+ 363	530	19
		T	*T*	66·65	290	+ 2·20	+ 220	− 97	413	20
		S	*S*	63·64	102	6·43	643	75	670	21
		R	*R*	66·81	301	·00	0	+ 93	394	22
" 11th	Between sets No. 71 and 72.	*U*	*U*	65·15	+ 197	·00	0	+ 283	+ 480	23
		O	*R*	64·51	157	+ 2·20	+ 220	93	470	24
		*O**	*R*	68·01	376	− 3·33	− 333	93	136	25
		P	*P*	65·96	248	9·37	937	350	− 339	26
		M	*M*	70·55	535	4·00	400	− 21	+ 114	27
		N	*N*	69·12	445	2·26	226	+ 363	582	28
		T	*T*	69·05	440	6·75	675	− 97	− 332	29
		R	*R*	69·61	476	·33	33	+ 93	+ 536	30
" 17th	Between sets No. 129 and 130.	*U*	*U*	68·15	+ 384	+ 1·17	+ 117	+ 283	+ 784	31
		O	*R*	67·81	363	− 1·00	− 100	93	356	32
		P	*P*	68·06	379	9·87	987	350	− 258	33
		M	*M*	67·45	341	·00	0	− 21	+ 320	34
		N	*N*	67·42	339	·00	0	+ 363	702	35
		T	*T*	66·85	303	− 7·99	− 799	− 97	− 593	36
		R	*R*	65·11	195	+ 2·00	+ 200	+ 93	+ 488	37

* These microscopes were compared a second time, because they were adjusted after the first comparison.

During the 1st measurement—(Continued.)

When compared — 1834-35		Microscope.	Scale compared with.	Corrected temperature.	Reduction to 62° Fah. Expansion of 6″ scale for 1° = E = 62·5 m.i.	Microscope — Microscope Scale. Observed value in terms of Divisions 10000=1″	Microscope — Microscope Scale. Observed value in terms of m.i.	Micros : Scale — A, at 62° Fah.	Micros : — Scale A, at 62° Fah. m.i.	Reference number.
December 21st	Between sets No. 166 and 167.	*U*	*U*	56°·15	− 366	+ 5·50	+ 550	+ 283	+ 467	38
		O	*R*	66·81	+ 301	− 4·00	− 400	93	− 6	39
		P	*P*	66·76	298	7·50	750	350	− 102	40
		M	*M*	60·25	− 109	+ 3·93	+ 393	− 21	+ 263	41
		N	*N*	61·42	37	2·33	233	+ 363	559	42
		T	*T*	65·85	+ 240	− 6·50	− 650	− 97	− 507	43
		R	*R*	63·61	101	+ 1·83	+ 183	+ 93	+ 377	44
„ 27th	Between sets No. 209 and 210.	*U*	*U*	65·35	+ 209	+ 2·67	+ 267	+ 283	+ 759	45
		O	*R*	68·31	395	− 1·70	− 170	93	318	46
		P	*P*	68·06	379	7·23	723	350	6	47
		*P**	*P*	67·76	360	7·62	762	350	− 52	48
		M	*M*	66·25	266	+ 3·00	+ 300	− 21	+ 545	49
		N	*N*	65·72	232	− ·73	− 73	+ 363	522	50
		T	*T*	61·05	− 60	4·80	480	− 97	− 637	51
		R	*R*	65·11	+ 195	+ 1·60	+ 160	+ 93	+ 448	52
January 3rd	Between sets No. 283 and 284.	*U*	*U*	63·85	+ 116	+ 2·77	+ 277	+ 283	+ 676	53
		O	*R*	65·01	188	·00	0	93	281	54
		P	*P*	65·96	248	− 7·67	− 767	350	− 169	55
		M	*M*	66·25	266	+ ·28	+ 28	− 21	+ 273	56
		N	*N*	68·42	401	− 2·13	− 213	+ 363	551	57
		T	*T*	68·15	384	7·73	773	− 97	− 486	58
		R	*R*	69·61	476	·00	0	+ 93	+ 569	59
„ 5th	Between sets No. 297 and 298.	*U*	*U*	58·95	− 191	− 3·90	− 390	+ 283	− 298	60
		O	*R*	63·31	+ 82	+ ·70	+ 70	93	+ 245	61
		P	*P*	60·46	− 96	− 2·50	− 250	350	4	62
		M	*M*	63·45	+ 91	+ 2·90	+ 290	− 21	360	63
		N	*N*	63·92	120	2·27	227	+ 363	710	64
		T	*T*	65·65	228	− 3·80	− 380	− 97	− 249	65
		R	*R*	60·31	− 106	+ 6·00	+ 600	93	+ 587	66
„ 11th	Between sets No. 388 and 389.	*U*	*U*	63·25	+ 78	+ 4·32	+ 432	+ 283	+ 793	67
		O	*R*	63·31	82	·60	60	93	235	68
		P	*P*	59·46	− 159	− 1·50	− 150	350	41	69
		M	*M*	59·75	141	+ 6·00	+ 600	− 21	438	70
		N	*N*	62·42	+ 26	2·70	270	+ 363	659	71
		T	*T*	64·55	159	− 4·00	− 400	− 97	− 338	72
		R	*R*	61·31	− 43	+ 5·00	+ 500	+ 93	+ 550	73
January 12th	Between sets No. 395 and 396.	*S*	*S*	63·94	+ 121	+ 4·10	+ 410	− 75	+ 456	74
„ 18th	Between sets No. 471 and 472.	*U*	*U*	65·55	+ 222	+ 3·03	+ 303	+ 283	+ 808	75
		O	*R*	68·71	420	− 1·40	− 140	93	373	76
		P	*P*	65·93	246	8·83	883	350	− 287	77
		M	*M*	65·05	191	+ 6·50	+ 650	− 21	+ 820	78
		N	*N*	66·62	289	·00	0	+ 363	652	79
		T	*T*	63·35	84	− 1·20	− 120	− 97	− 133	80
		S	*S*	67·04	315	+ 2·40	+ 240	75	+ 480	81

* These microscopes were compared a second time, because they were adjusted after the first comparison.

During the 1*st measurement*—(Continued).

When compared — 1835		Microscope.	Scale compared with.	Corrected temperature.	Reduction to 62° Fah. Expansion of 6″ scale for 1° = E = 62·5 m. i.	Microscope — Microscope Scale. Observed value in terms of		Micros : Scale — A at 62° Fah.	Micros : — Scale A, at 62° Fah.	
						Divisions 10000 = 1″	m. i.		m. i.	Reference number.
24th January	Between sets No. 517 and 518.	U	U	60°·85	− 72	+ 7·30	+ 730	+ 283	+ 941	82
		O	R	62·61	+ 38	4·50	450	93	581	83
		O*	R	67·61	351	− 1·50	− 150	93	294	84
		P	P	61·12	− 55	2·37	237	350	58	85
		M	M	61·25	47	+ 6·80	+ 680	− 21	612	86
		N	N	66·32	+ 270	0·40	40	+ 363	673	87
		T	T	58·55	− 216	2·50	250	− 97	− 63	88
		S	S	58·64	210	8·33	833	75	+ 548	89
31st „	Between sets No. 622_1 and 622_2.	U	U	62·35	+ 22	+ 2·83	+ 283	+ 283	+ 588	90
		O	R	60·01	− 124	1·32	132	93	101	91
		P	P	59·86	134	− 4·76	− 476	350	− 260	92
		T	T	63·35	+ 84	2·57	257	− 97	270	93
		N	N	62·02	1	·00	0	+ 363	+ 364	94
		M	M	62·65	41	+ 8·33	+ 833	− 21	853	95
		S	S	60·94	− 66	5·90	590	75	449	96
5th February	„	R	R	62·31	+ 20	5·20	520	+ 93	633	97

The required combinations of individual microscope errors taken from pages II—16 to II—18, are expressed as follows;

	Reference numbers.	m.i.	*mean temp :*		
$e_1 =$	$2 + 3 + 4 + 5 + 6 + \frac{1+7}{2}$	$= + 2271$	at $(62° - 0°09)$		before the measurement
$e_2 =$	$9 + 10 + 11 + 12 + 13 + \frac{8+14}{2}$	$= + 2631$	at $(62 + 7·01)$		between sets 22 & 23
$e_3 =$	$16 + 17 + 18 + 19 + 20 + \frac{8+21}{2}$	$= + 2063$	at $(62 + 4·69)$	From comparisons made	„ 49 & 50
$e_4 =$	$16 + 17 + 18 + 19 + 20 + \frac{15+22}{2}$	$= + 1956$	at $(62 + 5·04)$		„ do.
$e_5 =$	$24 + 26 + 27 + 28 + 29 + \frac{23+30}{2}$	$= + 1003$	at $(62 + 5·76)$		„ 71 & 72
$e_6 =$	$25 + 26 + 27 + 28 + 29 + \frac{23+30}{2}$	$= + 669$	at $(62 + 6·35)$		„ do.
$e_7 =$	$32 + 33 + 34 + 35 + 36 + \frac{31+37}{2}$	$= + 1163$	at $(62 + 5·37)$		„ 129 & 130
$e_8 =$	$39 + 40 + 41 + 42 + 43 + \frac{38+44}{2}$	$= + 629$	at $(62 + 1·50)$		„ 166 & 167
$e_9 =$	$46 + 47 + 49 + 50 + 51 + \frac{45+52}{2}$	$= + 1358$	at $(62 + 3·77)$		„ 209 & 210
$e_{10} =$	$46 + 48 + 49 + 50 + 51 + \frac{45+52}{2}$	$= + 1300$	at $(62 + 3·72)$		„ do.

During the 1*st measurement*—(Continued.)

Reference numbers.	m.i.	*mean temp:*	From comparisons made	
$e_{11} = 54 + 55 + 56 + 57 + 58 + \frac{53+59}{2}$	$= + 1073$	at $(62^\circ + 4^\circ.75)$	between sets	283 & 284
$e_{12} = 61 + 62 + 63 + 64 + 65 + \frac{60+66}{2}$	$= + 1215$	at $(62 + 0.74)$	"	297 & 298
$e_{13} = 68 + 69 + 70 + 71 + 72 + \frac{67+73}{2}$	$= + 1707$	at $(62 - 0.04)$	"	388 & 389
$e_{14} = 68 + 69 + 70 + 71 + 73 + \frac{67+72}{2}$	$= + 2151$	at $(62 - 0.31)$	"	do.
$e_{15} = 68 + 69 + 70 + 71 + 72 + \frac{67+74}{2}$	$= + 1660$	at $(62 + 0.18)$	"	do. and 395 & 396
$e_{16} = 76 + 77 + 78 + 79 + 80 + \frac{75+81}{2}$	$= + 2069$	at $(62 + 3.99)$	"	471 & 472
$e_{17} = 83 + 85 + 86 + 87 + 88 + \frac{82+89}{2}$	$= + 2606$	at $(62 - 0.40)$	"	517 & 518
$e_{18} = 84 + 85 + 86 + 87 + 88 + \frac{82+89}{2}$	$= + 2319$	at $(62 + 0.43)$	"	do.
$e_{19} = 91 + 92 + 93 + 94 + 95 + \frac{90+96}{2}$	$= + 1307$	at $(62 - 0.41)$	"	622_1 & 622_2
$e_{20} = 91 + 92 + 93 + 94 + 97 + \frac{90+96}{2}$	$= + 1087$	at $(62 - 0.47)$	"	do.

And from the foregoing, we obtain the following equations for the microscope errors per set (or *m.e*); where dE expresses the error in the adopted value of the expansion for the 6-inch scales.

	m.i.			
$(m.e.)_1 = \frac{e_1+e_2}{2}$	$= + 2451 - 6 \times 3.46\, dE$	applicable to sets Nos.		1 to 22
$(m.e.)_2 = \frac{e_2+e_3}{2}$	$= + 2347 - 6 \times 5.85\, dE$	"	"	23 to 49
$(m.e.)_3 = \frac{e_4+e_5}{2}$	$= + 1480 - 6 \times 5.40\, dE$	"	"	50 to 71
$(m.e.)_4 = \frac{e_6+e_7}{2}$	$= + 916 - 6 \times 5.86\, dE$	"	"	72 to 129
$(m.e.)_5 = \frac{e_7+e_8}{2}$	$= + 896 - 6 \times 3.44\, dE$	"	"	130 to 166
$(m.e.)_6 = \frac{e_8+e_9}{2}$	$= + 994 - 6 \times 2.64\, dE$	"	"	167 to 209
$(m.e.)_7 = \frac{e_{10}+e_{11}}{2}$	$= + 1186 - 6 \times 4.24\, dE$	"	"	210 to 283
$(m.e.)_8 = \frac{e_{11}+e_{12}}{2}$	$= + 1144 - 6 \times 2.75\, dE$	"	"	284 to 297
$(m.e.)_9 = \frac{e_{12}+e_{13}}{2}$	$= + 1461 - 6 \times 0.35\, dE$	"	"	298 to 388
$(m.e.)_{10} = e_{14}$	$= + 2151 + 6 \times 0.31\, dE$	"	"	389 to 395
$(m.e.)_{11} = \frac{e_{15}+e_{16}}{2}$	$= + 1865 - 6 \times 2.09\, dE$	"	"	396 to 471
$(m.e.)_{12} = \frac{e_{16}+e_{17}}{2}$	$= + 2338 - 6 \times 1.80\, dE$	"	"	472 to 517
$(m.e.)_{13} = \frac{e_{18}+e_{19}}{2}$	$= + 1813 - 6 \times 0.01\, dE$	"	"	518 to 621
$(m.e.)_{14} = e_{20}$	$= + 1087 + 6 \times 0.47\, dE$	"	"	622

During the 1st measurement—(Continued.)

Hence the total microscope errors are as follows,

		m.i.		feet of A
In sets Nos. 1 to 66	$22(m.e)_1$ =	53922 − 457 dE	=	0·0045 − 457 dE
	$27(m.e)_2$ =	63369 − 948 dE	=	0·0053 − 948 dE
	$17(m.e)_3$ =	25160 − 551 dE	=	0·0021 − 551 dE
			sum =	0·0119 − 1956 dE
In sets Nos. 67 to 157	$5(m.e)_3$ =	7400 − 162 dE	=	0·0006 − 162 dE
	$58(m.e)_4$ =	53128 − 2039 dE	=	0·0044 − 2039 dE
	$28(m.e)_5$ =	25088 − 578 dE	=	0·0021 − 578 dE
			sum =	0·0071 − 2779 dE
In sets Nos. 158 to 219	$9(m.e)_5$ =	8064 − 186 dE	=	0·0007 − 186 dE
	$43(m.e)_6$ =	42742 − 681 dE	=	0·0036 − 681 dE
	$10(m.e)_7$ =	11860 − 254 dE	=	0·0010 − 254 dE
			sum =	0·0053 − 1121 dE
In sets Nos. 220 to 389	$64(m.e)_7$ =	75904 − 1628 dE	=	0·0063 − 1628 dE
	$14(m.e)_8$ =	16016 − 231 dE	=	0·0013 − 231 dE
	$91(m.e)_9$ =	132951 − 191 dE	=	0·0111 − 191 dE
	$1(m.e)_{10}$ =	2151 + 2 dE	=	0·0002 + 2 dE
			sum =	0·0189 − 2048 dE
In sets Nos. 390 to 520	$6(m.e)_{10}$ =	12906 + 11 dE	=	0·0011 + 11 dE
	$76(m.e)_{11}$ =	141740 − 953 dE	=	0·0118 − 953 dE
	$46(m.e)_{12}$ =	107548 − 497 dE	=	0·0090 − 497 dE
	$3(m.e)_{13}$ =	5439 − 0 dE	=	0·0005 − 0 dE
			sum =	0·0224 − 1439 dE
In sets Nos. 521 to 622	$101(m.e)_{13}$ =	183113 − 6 dE	=	0·0153 − 6 dE
	$1(m.e)_{14}$ =	1087 + 3 dE	=	0·0001 + 3 dE
			sum =	0·0154 − 3 dE

During the 1*st Measurement*—(Continued.)

Final deduction of the total lengths measured with the compensated microscopes.

Hitherto the microscope errors have been determined only provisionally; *i.e.* in terms of the 6-inch brass scale *A*. But from page (31), we have $2A = 1{\cdot}0000192 \frac{\mathbf{A}}{10}$, value in 1835. Also the coefficient of expansion for brass, has been taken at ·000,010,417 in the foregoing reductions, whereas it appears from page (17) that ·000,009,855 is a more probable value. Accepting the latter, it may be found that $dE = 3{\cdot}372$ (*m.i*). Hence, remembering that the length measured with a set of microscopes is equal to 3 feet of *A* + the corresponding (*m.e*), we have,

Total length measured with the compensated microscopes

		feet of *A*		feet of **A**
In sets Nos. 1 to 66 or W. End, to Pin No. 1	.... =	{66 × 3 + ·0119}	− 1956 *dE* = (198·0157 − ·0005) =	198·0152
" Nos. 67 to 157 or Pin No. 1, to Pin No. 2 (Stn. A)	.... =	{91 × 3 + ·0071}	− 2779 *dE* = (273·0123 − ·0008) =	273·0115
" Nos. 158 to 219 or Pin No. 2 (Stn. A), to Pin No. 3	.... =	{62 × 3 + ·0053}	− 1121 *dE* = (186·0089 − ·0003) =	186·0086
" Nos. 220 to 389 or Pin No. 3, to Pin No. 4 (Stn. B)	.... =	{170 × 3 + ·0189}	− 2048 *dE* = (510·0287 − ·0006) =	510·0281
" Nos. 390 to 520 or Pin No. 4 (Stn. B), to Pin No. 5	.... =	{131 × 3 + ·0224}	− 1439 *dE* = (393·0299 − ·0004) =	393·0295
" Nos. 521 to 622 or Pin No. 5, to E. End	.... =	{102 × 3 + ·0154}	− 3 *dE* = (306·0213 − ·0000) =	306·0213
" Nos. 1 to 622 or W. End, to E. End	....		= (1866·1168 − ·0026) =	1866·1142

Comparisons between the Compensated Microscopes and their 6-inch brass scales during the 2nd measurement, and provisional determination of microscope errors with respect to the 6-inch brass scale A, expressed in millionths of an inch (m. i.).

When compared — 1835		Microscope.	Scale compared with.	Corrected temperature.	Reduction to 62° Fah. Expansion of 6″ scale for 1° = E = 62·5 *m. i.*	Microscope — Microscope Scale. Observed value in terms of Divisions 10000 = 1″	Microscope — Microscope Scale. Observed value in terms of *m. i.*	Micros: Scale — A at 62° Fah.	Micros: — Scale A, at 62° Fah. *m. i.*	Reference number
February 17th	Before the 2nd measurement	*U*	*U*	68°·65	+ 416	+ 1·30	+ 130	+ 283	+ 829	1
„ 19th		*O*	*R*	50·71	− 706	4·13	413	93	− 200	2
„ 17th		*P*	*P*	61·86	9	− 1·67	− 167	350	+ 174	3
		M	*M*	65·05	+ 191	+ 5·08	+ 508	− 21	678	4
		N	*N*	68·02	376	− 1·04	− 104	+ 363	635	5
		T	*T*	66·65	290	4·30	430	− 97	− 237	6
		S	*S*	63·94	121	+ 6·80	+ 680	75	+ 726	7
		R	*R*	69·01	438	2·23	223	+ 93	754	8
„ 27th	Between sets No. 115 and 116	*U*	*U*	73·25	+ 703	− 2·23	− 223	+ 283	+ 763	9
		O	*R*	71·31	582	5·30	530	93	145	10
		*O**	*R*	76·81	926	14·70	1470	93	− 451	11
		P	*P*	72·96	685	14·00	1400	350	365	12
		M	*M*	73·25	703	2·03	203	− 21	+ 479	13
		*M**	*M*	74·75	797	6·53	653	21	123	14
		N	*N*	73·37	710	4·95	495	+ 363	578	15
		T	*T*	71·98	624	7·33	733	− 97	− 206	16
		S	*S*	73·19	699	+ 2·03	+ 203	75	+ 827	17
		R	*R*	73·91	745	− 7·10	− 710	+ 93	128	18
March 7th	Between sets No. 233 and 234	*R*	*R*	64·61	+ 163	·00	0	+ 93	+ 256	19
		O	*R*	54·31	− 481	− 7·27	− 727	93	− 1115	20
		P	*P*	57·26	296	·43	43	350	+ 11	21
		M	*M*	59·25	172	+ ·50	+ 50	− 21	− 143	22
		N	*N*	71·52	+ 595	− 5·40	− 540	+ 363	+ 418	23
		T	*T*	63·65	103	3·37	337	− 97	− 331	24
		S	*S*	62·24	15	+ 5·80	+ 580	75	+ 520	25
„ 23rd	Between sets No. 465 and 466	*R*	*R*	53·89	− 507	+ 4·40	+ 440	+ 93	+ 26	26
		O	*R*	58·61	212	− 4·77	− 477	93	− 596	27
		P	*P*	64·56	+ 160	5·97	597	350	87	28
		M	*M*	57·05	− 309	+ 2·60	+ 260	− 21	70	29
		N	*N*	67·12	+ 320	− 3·47	− 347	+ 363	+ 336	30
		T	*T*	60·62	− 86	2·07	207	− 97	− 390	31
		S	*S*	59·24	173	+ 8·03	+ 803	75	+ 555	32
„ 24th	Between sets No. 490 and 491	*S*	*S*	83·24	+ 1327	·00	0	75	1252	33
„ 28th	After the 2nd measurement	*R*	*R*	59·14	− 179	+ 2·37	+ 237	+ 93	+ 151	34
		O	*R*	65·49	+ 218	− 11·78	− 1178	93	− 867	35
		P	*P*	68·56	410	7·75	775	350	15	36
		M	*M*	65·85	241	1·10	110	− 21	+ 110	37
		N	*N*	55·87	− 383	+ 3·66	+ 366	+ 363	346	38
		T	*T*	66·95	+ 309	− 6·23	− 623	− 97	− 411	39
		S	*S*	58·44	− 223	+ 12·13	+ 1213	75	+ 915	40

* These microscopes were compared a second time, because they were adjusted after the first comparison.

During the 2nd measurement—(Continued.)

The required combinations of individual microscope errors taken from the preceding page, are expressed as follows ;

	Reference numbers		*m.i*		From comparisons made
e_1	$= 2 + 3 + 5 + 6 + 8 + \frac{1+7}{2}$	$=$	$+ 1904$	at $(62^\circ + 1^\circ{\cdot}76)$	before the measurement.
e_2	$= 2 + 3 + 4 + 5 + 6 + \frac{1+7}{2}$	$=$	$+ 1828$	at $(62 + 1{\cdot}10)$	"
e_3	$= 10 + 12 + 13 + 15 + 16 + \frac{9+17}{2}$	$=$	$+ 1426$	at $(62 + 10{\cdot}68)$	between sets 115 and 116
e_4	$= 11 + 12 + 14 + 15 + 16 + \frac{17+18}{2}$	$=$	$+ 157$	at $(62 + 11{\cdot}90)$	" "
e_5	$= 20 + 21 + 22 + 23 + 24 + \frac{19+25}{2}$	$=$	$- 772$	at $(62 - 0{\cdot}43)$	" 233 " 234
e_6	$= 27 + 28 + 29 + 30 + 31 + \frac{26+32}{2}$	$=$	$- 516$	at $(62 - 1{\cdot}25)$	" 465 " 466
e_7	$= 27 + 28 + 29 + 30 + 31 + \frac{26+33}{2}$	$=$	$- 168$	at $(62 + 0{\cdot}75)$	" 490 " 491
e_8	$= 35 + 36 + 37 + 38 + 39 + \frac{34+40}{2}$	$=$	$- 304$	at $(62 + 1{\cdot}59)$	after the measurement.

And from the foregoing, we obtain the following equations for the microscope errors per set (or *m.e*); where dE expresses the error in the adopted value of the expansion of the 6-inch scales.

		m.i		
$(m.e)_1 = e_1$	$=$	$+ 1904 - 6 \times 1{\cdot}76\ dE$	applicable to set No.	1
$(m.e)_2 = \frac{e_2+e_3}{2}$	$=$	$+ 1627 - 6 \times 5{\cdot}89\ dE$	"	2 to 115
$(m.e)_3 = \frac{e_4+e_5}{2}$	$=$	$- 308 - 6 \times 5{\cdot}74\ dE$	"	116 to 233
$(m.e)_4 = \frac{e_5+e_6}{2}$	$=$	$- 644 + 6 \times 0{\cdot}84\ dE$	"	234 to 465
$(m.e)_5 = e_6$	$=$	$- 516 + 6 \times 1{\cdot}25\ dE$	"	466 to 490
$(m.e)_6 = \frac{e_7+e_8}{2}$	$=$	$- 236 - 6 \times 1{\cdot}17\ dE$	"	491 to 622

Hence the total microscope errors are as follows :—

		m.i.	*feet of A*
In sets Nos. 1 to 102 =	$1(m.e)_1 =$	$1904 - 11\ dE =$	$0{\cdot}0002 - 11\ dE$
	$101(m.e)_2 =$	$164327 - 3569\ dE =$	$0{\cdot}0137 - 3569\ dE$
		sum =	$0{\cdot}0139 - 3580\ dE$
In sets Nos. 103 to 233 =	$13(m.e)_2 =$	$21151 - 459\ dE =$	$0{\cdot}0018 - 459\ dE$
	$118(m.e)_3 =$	$- 36344 - 4064\ dE =$	$- 0{\cdot}0030 - 4064\ dE$
		sum	$- 0{\cdot}0012 - 4523\ dE$
In sets Nos. 234 to 403 =	$170(m.e)_4 =$	$- 109480 + 857\ dE =$	$- 0{\cdot}0091 + 857\ dE$

(Total microscope errors continued on next page.)

During the 2nd measurement—(Continued.)

Total Microscope errors (continued from preceding page)

In sets Nos. 404 to 465 = 62 $(m.e)_4$ = − 39928 + 312 dE = − 0·0033 + 312 dE

In sets Nos. 466 to 556 = { 25 $(m.e)_5$ = − 12900 + 188 dE = − 0·0011 + 188 dE
{ 66 $(m.e)_6$ = − 15576 − 463 dE = − 0·0013 − 463 dE

sum = − 0·0024 − 275 dE

In sets Nos. 557 to 622 = 66 $(m.e)_6$ = − 15576 − 463 dE = − 0·0013 − 463 dE

Final deduction of the total lengths measured with the compensated microscopes.

Hitherto the microscope errors have been determined only provisionally; *i.e.* in terms of the 6-inch brass scale A. But from page (31), we have $2\,A = 1{\cdot}0000192\,\frac{A}{10}$, value in 1835. Also, the coefficient of expansion for brass, has been taken at ·000,010,417 in the foregoing reductions, whereas it appears from page (17) that ·000,009,855 is a more probable value. Accepting the latter, it may be found that $dE = 3{\cdot}372\ (m.i)$. Hence, remembering that the length measured with a set of microscopes is equal to 3 feet of A + the corresponding $(m.e)$, we have,

Total lengths measured with the compensated microscopes

			feet of A
In sets Nos. 1 to 102 or E. End, to Pin No. 5	= {102 × 3 + ·0139} − 3580 dE	= (306·0198 − ·0010) =	306·0188
" Nos. 103 to 233 or Pin No. 5, to Pin No. 4 (Stn. B)	= {131 × 3 − ·0012} − 4523 dE	= (393·0063 − ·0013) =	393·0050
" Nos. 234 to 403 or Pin. No. 4, (Stn. B), to Pin No. 3	= {170 × 3 − ·0091} + 857 dE	= (510·0007 + ·0002) =	510·0009
" Nos. 404 to 465 or Pin No. 3, to Pin No. 2 (Stn. A)	= {62 × 3 − ·0033} + 312 dE	= (186·0003 + ·0001) =	186·0004
" Nos. 466 to 556 or Pin No. 2, (Stn. A), to Pin No. 1	= {91 × 3 − ·0024} − 275 dE	= (273·0028 − ·0001) =	273·0027
" Nos. 557 to 622 or Pin No. 1, to W. End	= {66 × 3 − ·0013} − 463 dE	= (198·0025 − ·0001) =	198·0024
" Nos. 1 to 622 or E. End, to W. End		= (1866·0324 − ·0022) =	1866·0302

DETAILS OF THE 1ST MEASUREMENT.

Disposition of the bars and microscopes.

Typical illustrations shewing the permutations and combinations of the bars and microscopes during the 1st measurement. The instruments are here named in the succession that actually occurred, commencing from the rear-end of a set; and the numbers assigned to the illustrations, will be found employed in the tables of "Extracts from the Field Book &c."

Bar Illustration.

No. 1	No. 2	No. 3	No. 4	No. 5	No. 6
A	A	H	A	D	D
B	B		B	E	E
C	C		C	H	
D	D				
E	E				
H					

Statement.

No. 1 occurs in sets Nos. 1 to 301, in set No. 303 and in sets Nos. 304 to 617.
No. 2 " set No. 302_1.
No. 3 " sets Nos. 302_2 and 622_3.
No. 4 " Nos. 618_1, 619_1, 620_1, 621_1 & 622_1.
No. 5 " Nos. 618_2, 619_2, 620_2, 621_2.
No. 6 " set No. 622_2.

Microscope Illustration.

No. 1	No. 2	No. 3	No. 4	No. 5	No. 6	No. 7	No. 8	No. 9
½U	½U	½U	½T	½U	½U	½T	½T	½R
O	O	O	½R	O	O	N	N	½S
P	P	P		P	P	M	½R	
M	M	M		M	½T	½S		
N	N	N		N				
T	T	½T		R				
½S	½R			½T				

Statement.

No. 1 occurs in sets Nos. 1 to 49, and in sets Nos. 396 to 617.
No. 2 " sets Nos. 50 to 301, in set No. 303, and in sets Nos. 304 to 388.
No. 3 " set No. 302_1.
No. 4 " No. 302_2.
No. 5 " sets Nos. 389 to 395.
No. 6 " Nos. 618_1, 619_1, 620_1, 621_1 and 622_1.
No. 7 " Nos. 618_2, 619_2, 620_2, 621_2.
No. 8 " set No. 622_2.
No. 9 " No. 622_3.

Extracts from the Field Book of the measurement, and calculated heights of sets above the origin.

Adopted heights above mean sea level.
West End (origin) = 1770·1 feet.
East End (terminus) = 1957·7 feet.

When compared — 1834	No. of the Set.	Temperature of Air.	Mean time of ending.	No. of bars used.	Height of set above origin.	Numeral shewing arrangement of Bars.	Micros:	When compared — 1834	No. of the Set.	Temperature of Air.	Mean time of ending.	No. of bars used.	Height of set above origin.	Numeral shewing arrangement of Bars.	Micros:
		°	h. m.		feet.					°	h. m.		feet.		
1st Dec.	1	71·5	2 3 P.M.	6	+ 2·3	1	1	2nd Dec.	7	73·8	2 56 P.M.	6	− ·0	1	1
	2	72·3	3 15	6	2.3	1	1		8	73·0	3 49	6	+ ·1	1	1
	3	69·0	4 20	6	·9	1	1		9	69·5	4 44	6	·0	1	1
2nd "	4	53·0	9 31 A.M.	6	− ·2	1	1	3rd "	10	46·0	8 3 A.M.	6	·9	1	1
	5	60·3	10 40	6	·3	1	1		11	51·5	9 6	6	1·6	1	1
	6	72·0	1 54 P.M.	6	·2	1	1		12	58·8	10 12	6	2·0	1	1

Note.—The rear-end of set No. 1 stood exactly over the dot at West-End.

Extracts from the Field Book—(Continued.)

When compared 1834	No. of the Set.	Temperature of Air.	Mean time of ending.	No. of bars used.	Height of Set above origin.	Numeral shewing arrangement of Bars.	Numeral shewing arrangement of Micros:	When compared 1834	No. of the Set.	Temperature of Air.	Mean time of ending.	No. of bars used.	Height of Set above origin.	Numeral shewing arrangement of Bars.	Numeral shewing arrangement of Micros:
		°	h. m.		feet.					°	h. m.		feet.		
3rd Dec.	13	62·0	11 0 A.M.	6	+ 1·6	1	1	6th Dec.	40	76·8	2 18 P.M.	6	− ·8	1	1
	14	69·9	2 0 P.M.	6	·8	1	1		41	77·2	3 12	6	1·2	1	1
	15	70·0	3 3	6	·5	1	1		42	66·9	3 50	6	1·3	1	1
	16	68·0	3 55	6	− ·6	1	1		43	62·6	4 30	6	1·7	1	1
	17	58·7	4 39	6	·9	1	1		44	53·3	5 9	6	+ 0·1	1	1
	18	53·3	5 20	6	+ ·2	1	1	8th "	45	43·3	8 14 A.M.	6	0·5	1	1
4th "	19	48·0	8 0 A.M.	6	1·4	1	1		46	50·0	9 0	6	1·5	1	1
	20	54·8	8 51	6	1·7	1	1		47	55·8	10 1	6	1·9	1	1
	21	58·8	9 47	6	1·2	1	1		48	59·8	10 33	6	1·8	1	1
	22	63·0	10 35	6	·7	1	1		49	64·3	11 13	6	2·0	1	1
	23	72·8	2 11 P.M.	6	·8	1	1		50	73·8	3 51 P.M.	6	2·5	1	2
	24	72·0	3 9	6	·2	1	1		51	61·3	4 31	6	3·1	1	2
	25	67·7	4 6	6	− 1·6	1	1		52	51·8	5 11	6	3·4	1	2
	26	56·1	5 6	6	1·5	1	1	9th "	53	40·9	8 4 A.M.	6	3·1	1	2
5th "	27	46·0	8 3 A.M.	6	2·5	1	1		54	46·6	8 48	6	2·8	1	2
	28	54·6	9 11	6	·5	1	1		55	52·8	9 36	6	3·6	1	2
	29	60·3	10 17	6	+ ·1	1	1		56	57·3	10 13	6	3·3	1	2
	30	64·3	10 58	6	·3	1	1		57	62·2	10 51	6	3·0	1	2
	31	73·9	2 58 P.M.	6	·4	1	1		58	75·5	2 0 P.M.	6	3·1	1	2
	32	73·0	3 38	6	− 1·2	1	1		59	76·0	3 7	6	3·0	1	2
	33	60·5	4 29	6	1·3	1	1		60	76·1	3 58	6	3·4	1	2
	34	50·5	5 17	6	1·2	1	1		61	54·6	5 15	6	4·6	1	2
6th "	35	42·6	8 2 A.M.	6	·6	1	1	10th "	62	49·8	9 0 A.M.	6	5·9	1	2
	36	49·3	8 47	6	·2	1	1		63	58·8	10 10	6	7·5	1	2
	37	54·9	9 38	6	·2	1	1		64	65·5	11 15	6	8·9	1	2
	38	59·4	10 19	6	·1	1	1		65	74·0	2 10 P.M.	6	10·7	1	2
	39	74·5	1 29 P.M.	6	·6	1	1		66	73·0	3 54	6	11·0	1	2

The dot on Pin No. 1 was fixed exactly in the normal at the advanced end of set No. 66. Height of Set No. 66 above Pin No. 1 = 2·1 feet.

11th Dec.	67	39·0	7 40 A.M.	6	+ 11·6	1	2	13th Dec.	83	50·8	7 59 A.M.	6	+ 6·9	1	2
	68	47·5	8 44	6	11·8	1	2		84	54·0	8 49	6	8·2	1	2
	69	54·0	9 34	6	11·0	1	2		85	56·5	9 32	6	7·5	1	2
	70	57·5	10 24	6	10·6	1	2		86	60·5	10 24	6	7·2	1	2
	71	64·4	11 7	6	10·7	1	2		87	64·0	11 8	6	6·5	1	2
	72	74·0	2 43 P.M.	6	10·5	1	2		88	70·0	3 5 P.M.	6	6·6	1	2
	73	72·5	3 52	6	10·3	1	2		89	66·2	3 58	6	7·6	1	2
	74	56·6	4 52	6	8·7	1	2		90	56·6	4 44	6	7·6	1	2
12th "	75	43·9	8 0 A.M.	6	6·8	1	2	15th "	91	42·8	7 46 A.M.	6	8·1	1	2
	76	51·8	8 55	6	7·8	1	2		92	45·3	8 16	6	8·8	1	2
	77	53·5	9 40	6	8·6	1	2		93	46·4	8 47	6	9·0	1	2
	78	55·9	10 33	6	8·2	1	2		94	48·6	9 16	6	8·2	1	2
	79	58·6	11 21	6	7·3	1	2		95	51·4	9 53	6	8·9	1	2
	80	58·4	2 17 P.M.	6	6·7	1	2		96	53·5	10 34	6	9·4	1	2
	81	56·4	3 30	6	7·5	1	2		97	57·8	11 13	6	8·9	1	2
	82	55·0	4 32	6	8·2	1	2		98	65·8	1 40 P.M.	6	8·5	1	2

Extracts from the Field Book—(Continued.)

When compared — 1834	No. of the Set.	Temperature of Air.	Mean time of ending.	No. of bars used.	Height of Set above origin.	Numeral shewing arrangement of Bars.	Numeral shewing arrangement of Micros:
		°	h. m.		feet.		
15th Dec.	99	67·9	2 16 P.M.	6	+ 8·1	1	2
	100	66·3	2 54	6	8·3	1	2
	101	67·8	3 25	6	9·0	1	2
	102	62·3	3 56	6	9·3	1	2
	103	58·8	4 29	6	10·0	1	2
	104	50·9	5 14	6	12·6	1	2
16th „	105	40·9	7 45 A.M.	6	13·2	1	2
	106	45·0	8 23	6	13·3	1	2
	107	49·0	9 7	6	14·7	1	2
	108	52·8	9 38	6	15·1	1	2
	109	55·5	10 11	6	16·4	1	2
	110	58·9	10 47	6	17·4	1	2
	111	63·0	11 21	6	17·6	1	2
	112	66·3	11 49	6	17·8	1	2
	113	73·3	2 6 P.M.	6	19·3	1	2
	114	73·3	2 45	6	19·6	1	2
	115	71·6	3 31	6	19·6	1	2
	116	68·0	4 0	6	20·1	1	2
	117	63·3	4 35	6	19·7	1	2
	118	57·0	5 4	6	19·9	1	2
17th „	119	40·0	7 40 A.M.	6	18·9	1	2
	120	43·8	8 19	6	17·2	1	2
	121	47·8	9 11	6	17·5	1	2
	122	53·0	9 51	6	19·7	1	2
	123	58·8	10 31	6	20·2	1	2
	124	61·3	11 2	6	20·8	1	2
	125	65·3	11 47	6	21·6	1	2
	126	67·3	0 23 P.M.	6	22·2	1	2
	127	72·8	1 7	6	23·7	1	2
	128	73·3	1 47	6	24·8	1	2

When compared — 1834	No. of the Set.	Temperature of Air.	Mean time of ending.	No. of bars used.	Height of Set above origin.	Numeral shewing arrangement of Bars.	Numeral shewing arrangement of Micros:
		°	h. m.		feet.		
17th Dec.	129	75·5	2 37 P.M.	6	+ 25·1	1	2
18th „	130	50·3	7 42 A.M.	6	24·9	1	2
	131	51·9	8 11	6	24·2	1	2
	132	53·5	8 46	6	24·6	1	2
	133	54·6	9 18	6	24·5	1	2
	134	55·6	9 53	6	25·2	1	2
	135	58·3	10 23	6	25·5	1	2
	136	61·5	11 7	6	26·0	1	2
	137	64·3	11 41	6	25·8	1	2
	138	69·3	2 13 P.M.	6	24·6	1	2
	139	68·1	2 49	6	23·9	1	2
	140	66·3	3 21	6	23·5	1	2
	141	66·2	3 52	6	23·4	1	2
	142	64·5	4 39	6	23·5	1	2
	143	57·3	5 12	6	23·2	1	2
19th „	144	43·9	7 49 A.M.	6	22·6	1	2
	145	48·3	8 27	6	22·7	1	2
	146	52·8	9 35	6	22·7	1	2
	147	55·0	10 2	6	23·9	1	2
	148	56·6	10 44	6	25·1	1	2
	149	57·9	11 13	6	25·1	1	2
	150	63·0	1 29 P.M.	6	25·2	1	2
	151	62·4	2 1	6	25·5	1	2
	152	62·5	2 31	6	26·3	1	2
	153	67·0	3 5	6	26·5	1	2
	154	65·8	3 36	6	26·5	1	2
	155	64·3	4 6	6	27·1	1	2
	156	62·1	4 36	6	27·8	1	2
	157	56·2	5 7	6	28·2	1	2

The dot on Pin No. 2, *i.e.* Station A was fixed exactly in the normal at the advanced end of set No. 157. Height of set No. 157 above Station A = 2·5 feet.

When compared — 1834	No. of the Set.	Temperature of Air.	Mean time of ending.	No. of bars used.	Height of Set above origin.	Numeral shewing arrangement of Bars.	Numeral shewing arrangement of Micros:
20th Dec.	158	51·5	8 5 A.M.	6	+ 28·4	1	2
	159	52·9	8 34	6	28·2	1	2
	160	55·0	9 11	6	27·4	1	2
	161	57·1	9 43	6	27·1	1	2
	162	58·5	10 20	6	27·0	1	2
	163	60·1	10 59	6	28·0	1	2
	164	62·9	2 17 P.M.	6	28·1	1	2
	165	62·0	2 45	6	28·1	1	2
	166	59·9	3 32	6	27·9	1	2
22nd „	167	42·4	8 16 A.M.	6	27·7	1	2
	168	47·0	8 52	6	28·0	1	2
	169	51·8	9 33	6	28·2	1	2
	170	54·6	10 3	6	27·8	1	2

When compared — 1834	No. of the Set.	Temperature of Air.	Mean time of ending.	No. of bars used.	Height of Set above origin.	Numeral shewing arrangement of Bars.	Numeral shewing arrangement of Micros:
22nd Dec.	171	57·4	10 37 A.M.	6	+ 27·3	1	2
	172	60·0	11 9	6	26·4	1	2
	173	70·1	1 32 P.M.	6	25·3	1	2
	174	70·8	2 1	6	24·1	1	2
	175	70·0	2 37	6	22·6	1	2
	176	63·3	3 5	6	22·1	1	2
	177	61·2	3 40	6	23·0	1	2
	178	60·0	4 13	6	23·0	1	2
	179	58·9	4 42	6	22·5	1	2
	180	53·9	5 13	6	22·0	1	2
23rd „	181	35·3	7 23 A.M.	6	22·2	1	2
	182	39·9	8 5	6	22·3	1	2
	183	45·5	8 51	6	22·5	1	2

Extracts from the Field Book—(Continued.)

When compared — 1834	No. of the Set.	Temperature of Air.	Mean time of ending. h.	m.		No. of bars used.	Height of Set above origin.	Numeral shewing arrangement of Bars.	Micros:	When compared — 1834-35	No. of the Set.	Temperature of Air.	Mean time of ending. h.	m.		No. of bars used.	Height of Set above origin.	Numeral shewing arrangement of Bars.	Micros:
		°	h.	m.			feet.					°	h.	m.			feet.		
23rd Dec.	184	50·3	9	29	A.M.	6 +	22·5	1	2	24th Dec.	202	71·2	1	58	P.M.	6 +	21·9	1	2
	185	52·8	10	6		6	22·0	1	2		203	71·8	2	24		6	21·8	1	2
	186	55·8	10	36		6	21·7	1	2		204	68·1	2	47		6	22·1	1	2
	187	69·4	1	42	P.M.	6	22·0	1	2		205	67·2	3	14		6	21·7	1	2
	188	69·8	2	17		6	21·5	1	2		206	63·2	3	34		6	22·6	1	2
	189	69·9	2	55		6	20·1	1	2		207	60·8	4	2		6	23·1	1	2
	190	62·6	3	25		6	19·8	1	2		208	57·5	4	23		6	24·5	1	2
	191	60·0	4	9		6	20·0	1	2		209	54·6	4	47		6	25·4	1	2
	192	54·5	4	40		6	19·4	1	2	29th „	210	39·5	7	57	A.M.	6	25·1	1	2
24th „	193	38·1	7	22	A.M.	6	19·8	1	2		211	43·8	8	34		6	24·9	1	2
	194	40·6	8	3		6	20·7	1	2		212	47·9	9	6		6	24·8	1	2
	195	45·8	8	47		6	20·6	1	2		213	51·6	9	41		6	25·0	1	2
	196	49·0	9	18		6	21·1	1	2		214	55·5	10	20		6	25·1	1	2
	197	53·0	9	52		6	21·8	1	2		215	58·0	10	46		6	24·3	1	2
	198	55·5	10	18		6	22·2	1	2		216	67·9	1	32	P.M.	6	24·4	1	2
	199	60·5	10	57		6	22·2	1	2		217	68·3	2	4		6	25·5	1	2
	200	62·5	11	21		6	22·3	1	2		218	67·7	2	36		6	25·4	1	2
	201	71·5	1	33	P.M.	6	22·0	1	2		219	66·0	3	56		6	25·5	1	2

The dot on Pin No. 3, was fixed exactly in the normal at the advanced end of set No. 219.
Height of set No. 219 above Pin No. 3 = 2·5 feet.

When compared	No. of the Set.	Temperature of Air.	h.	m.		No. of bars used.	Height of Set above origin.	Bars.	Micros:	When compared	No. of the Set.	Temperature of Air.	h.	m.		No. of bars used.	Height of Set above origin.	Bars.	Micros:
29th Dec.	220	60·7	4	21	P.M.	6 +	25·5	1	2	31st Dec.	245	71·3	1	37	P.M.	6 +	13·0	1	2
	221	59·0	4	46		6	24·6	1	2		246	70·9	2	2		6	11·7	1	2
	222	52·9	5	10		6	23·5	1	2		247	69·4	2	27		6	11·9	1	2
30th „	223	35·5	7	41	A.M.	6	22·2	1	2		248	66·3	2	53		6	12·0	1	2
	224	39·6	8	21		6	20·9	1	2		249	64·8	3	18		6	11·1	1	2
	225	45·0	8	56		6	20·2	1	2		250	63·2	3	37		6	10·1	1	2
	226	50·0	9	41		6	18·3	1	2		251	61·7	4	0		6	10·0	1	2
	227	55·0	10	30		6	15·7	1	2		252	59·8	4	20		6	10·3	1	2
	228	60·5	11	18		6	12·5	1	2		253	57·0	4	43		6	9·6	1	2
	229	62·1	11	44		6	11·0	1	2		254	52·7	5	6		6	9·4	1	2
	230	66·6	0	42	P.M.	6	13·3	1	2		255	47·1	5	36		6	9·2	1	2
	231	68·6	1	22		6	14·6	1	2	2nd Jan.	256	45·0	7	45	A.M.	6	7·6	1	2
	232	69·8	3	19		6	14·7	1	2		257	46·5	8	15		6	8·3	1	2
	233	69·5	3	50		6	14·8	1	2		258	48·5	8	45		6	9·1	1	2
	234	59·5	4	22		6	15·5	1	2		259	50·0	9	10		6	9·1	1	2
	235	51·8	4	54		6	16·1	1	2		260	53·3	9	42		6	9·1	1	2
	236	46·2	5	21		6	15·7	1	2		261	54·5	10	5		6	9·9	1	2
31st „	237	36·5	7	41	A.M.	6	15·3	1	2		262	56·0	10	39		6	11·9	1	2
	238	39·3	8	11		6	15·4	1	2		263	58·1	11	13		6	12·1	1	2
	239	44·5	8	46		6	15·7	1	2		264	63·4	1	11	P.M.	6	13·1	1	2
	240	48·4	9	9		6	15·9	1	2		265	65·0	1	36		6	13·5	1	2
	241	51·9	9	44		6	16·4	1	2		266	66·9	2	3		6	13·4	1	2
	242	54·0	10	9		6	15·9	1	2		267	68·5	2	32		6	12·4	1	2
	243	56·9	10	40		6	15·3	1	2		268	70·5	3	2		6	11·4	1	2
	244	60·2	11	9		6	14·5	1	2		269	71·4	3	25		6	11·3	1	2

Extracts from the Field Book—(Continued.)

When compared 1835	No. of the Set.	Temperature of Air.	Mean time of ending. h.	m.	No. of bars used.	Height of Set above origin.	Numeral shewing arrangement of Bars.	Micros:	When compared 1835	No. of the Set.	Temperature of Air.	Mean time of ending. h.	m.	No. of bars used.	Height of Set above origin.	Numeral shewing arrangement of Bars.	Micros:
		°	h.	m.		feet.					°	h.	m.		feet.		
2nd Jan.	270	70·1	3	52 P.M.	6 +	10·3	1	2	6th Jan.	316	55·0	4	23 P.M.	6 +	23·1	1	2
	271	66·8	4	15	6	10·8	1	2		317	51·0	4	51	6	24·3	1	2
	272	62·8	4	47	6	11·4	1	2		318	46·0	5	17	6	25·3	1	2
	273	58·0	5	17	6	12·8	1	2	7th "	319	29·1	7	50 A.M.	6	26·4	1	2
3rd "	274	40·5	7	40 A.M.	6	12·6	1	2		320	31·5	8	20	6	27·0	1	2
	275	42·5	8	8	6	12·2	1	2		321	36·5	8	58	6	27·6	1	2
	276	45·0	8	39	6	12·2	1	2		322	40·9	9	23	6	28·8	1	2
	277	48·8	9	7	6	13·0	1	2		323	46·7	9	58	6	30·1	1	2
	278	53·5	9	39	6	13·4	1	2		324	49·8	10	27	6	30·8	1	2
	279	56·4	10	7	6	13·1	1	2		325	54·8	10	55	6	31·3	1	2
	280	60·8	10	43	6	12·8	1	2		326	57·0	11	18	6	31·6	1	2
	281	64·9	11	13	6	12·0	1	2		327	69·3	1	25 P.M.	6	32·0	1	2
	282	68·0	11	47	6	13·0	1	2		328	70·1	1	49	6	33·6	1	2
	283	69·6	0	27 P.M.	6	12·8	1	2		329	70·8	2	19	6	35·5	1	2
	284	74·2	2	37	6	12·3	1	2		330	62·0	2	49	6	35·9	1	2
	285	74·0	3	0	6	12·2	1	2		331	59·0	3	18	6	36·3	1	2
	286	73·1	3	38	6	12·6	1	2		332	58·0	3	43	6	36·5	1	2
	287	62·0	4	23	6	12·8	1	2		333	56·1	4	9	6	36·4	1	2
	288	58·8	4	47	6	13·4	1	2		334	53·5	4	33	6	35·0	1	2
	289	54·5	5	13	6	13·6	1	2		335	50·8	4	58	6	37·0	1	2
	290	51·0	5	32	6	14·3	1	2		336	48·0	5	19	6	37·3	1	2
5th "	291	37·2	7	54 A.M.	6	14·7	1	2	8th "	337	29·8	7	43 A.M.	6	37·1	1	2
	292	41·2	8	27	6	15·3	1	2		338	31·9	8	7	6	37·1	1	2
	293	45·0	9	1	6	15·2	1	2		339	36·5	8	52	6	37·7	1	2
	294	48·5	9	28	6	15·3	1	2		340	43·1	9	24	6	40·2	1	2
	295	52·1	10	1	6	15·2	1	2		341	47·2	9	54	6	41·7	1	2
	296	54·9	10	31	6	15·5	1	2		342	49·8	10	20	6	41·4	1	2
	297	58·0	11	4	6	16·5	1	2		343	53·5	10	48	6	41·2	1	2
	298	67·2	1	47 P.M.	6	17·0	1	2		344	56·4	11	13	6	41·7	1	2
	299	66·9	2	14	6	16·5	1	2		345	64·2	1	38 P.M.	6	40·7	1	2
	300	65·2	2	48	6	16·0	1	2		346	65·5	2	0	6	41·7	1	2
	301	59·0	3	14	6	16·2	1	2		347	59·1	2	35	6	43·3	1	2
	302_1	51·9	4	44	5	15·1	2	3		348	58·9	2	58	6	44·2	1	2
	303	48·5	5	10	6	15·2	1	2		349	57·8	3	30	6	45·3	1	2
	302_2	43·0	5	39	1	15·2	3	4		350	57·0	4	2	6	45·5	1	2
6th "	304	32·2	8	0 A.M.	6	16·1	1	2		351	54·3	4	30	6	47·2	1	2
	305	35·0	8	36	6	17·0	1	2		352	51·9	4	58	6	46·1	1	2
	306	39·9	9	12	6	17·1	1	2		353	44·8	5	29	6	45·0	1	2
	307	45·0	9	51	6	16·7	1	2	9th "	354	28·9	7	38 A.M.	6	47·8	1	2
	308	49·5	10	35	6	17·4	1	2		355	30·9	8	14	6	49·9	1	2
	309	54·0	11	9	6	18·1	1	2		356	33·9	8	41	6	49·6	1	2
	310	57·3	11	43	6	19·5	1	2		357	40·9	9	15	6	50·7	1	2
	311	62·5	1	38 P.M.	6	19·6	1	2		358	45·0	9	43	6	51·3	1	2
	312	63·1	2	5	6	19·5	1	2		359	48·5	10	18	6	52·0	1	2
	313	65·3	3	0	6	20·1	1	2		360	51·8	10	40	6	52·6	1	2
	314	57·6	3	28	6	21·8	1	2		361	55·4	11	7	6	53·1	1	2
	315	57·2	3	59	6	22·2	1	2		362	67·1	1	7 P.M.	6	54·5	1	2

Extracts from the Field Book—(Continued.)

When compared — 1835	No. of the Set.	Temperature of Air.	Mean time of ending.	No. of bars used.	Height of Set above origin.	Numeral shewing arrangement of Bars.	Numeral shewing arrangement of Micros:	When compared — 1835	No. of the Set.	Temperature of Air.	Mean time of ending.	No. of bars used.	Height of Set above origin.	Numeral shewing arrangement of Bars.	Numeral shewing arrangement of Micros:
		°	h. m.		feet.					°	h. m.		feet.		
9th Jan.	363	65·5	1 37 P.M.	6 +	55·5	1	2	10th Jan.	377	39·9	9 22 A.M.	6 +	74·2	1	2
	364	67·1	2 3	6	56·6	1	2		378	44·4	9 50	6	75·3	1	2
	365	67·0	2 26	6	57·9	1	2		379	49·5	10 27	6	75·9	1	2
	366	60·6	2 56	6	59·2	1	2		380	53·0	10 54	6	77·7	1	2
	367	59·5	3 20	6	60·3	1	2		381	55·9	11 29	6	78·1	1	2
	368	58·4	3 44	6	61·5	1	2		382	57·9	11 54	6	78·3	1	2
	369	57·5	4 6	6	62·7	1	2		383	64·2	1 52 P.M.	6	77·7	1	2
	370	55·3	4 30	6	63·4	1	2		384	65·8	2 17	6	79·0	1	2
	371	52·5	4 50	6	64·7	1	2		385	65·5	2 47	6	80·3	1	2
	372	47·8	5 18	6	65·5	1	2		386	58·0	3 30	6	81·3	1	2
	373	45·2	5 41	6	67·1	1	2		387	57·5	4 12	6	84·0	1	2
10th „	374	28·5	7 44 A.M.	6	69·2	1	2		388	54·8	4 42	6	86·2	1	2
	375	30·0	8 19	6	70·9	1	2	12th „	389	34·2	8 16 A.M.	6	86·7	1	5
	376	33·6	8 49	6	72·3	1	2								

The dot on Pin No. 4, *i.e.* Station B was fixed exactly in the normal at the advanced end of set No. 389. Height of set No. 389 above Station B = 2·0 feet.

When compared — 1835	No. of the Set.	Temperature of Air.	Mean time of ending.	No. of bars used.	Height of Set above origin.	Bars.	Micros:	When compared — 1835	No. of the Set.	Temperature of Air.	Mean time of ending.	No. of bars used.	Height of Set above origin.	Bars.	Micros:
12th Jan.	390	39·9	8 51 A.M.	6 +	86·5	1	5	14th Jan.	419	69·5	2 41 P.M.	6 +	98·2	1	1
	391	46·4	9 30	6	83·7	1	5		420	62·0	3 13	6	99·0	1	1
	392	49·3	9 56	6	82·5	1	5		421	60·3	3 39	6	99·4	1	1
	393	53·2	10 26	6	82·3	1	5		422	57·0	4 17	6	99·7	1	1
	394	55·5	10 55	6	81·7	1	5		423	53·6	4 50	6	101·8	1	1
	395	58·5	11 26	6	81·5	1	5	15th „	424	30·3	7 52 A.M.	6	103·2	1	1
13th „	396	33·5	8 11	6	82·1	1	1		425	33·8	8 25	6	103·9	1	1
	397	42·8	9 11	6	80·5	1	1		426	38·9	8 59	6	104·2	1	1
	398	50·6	10 19	6	78·9	1	1		427	44·4	9 28	6	105·4	1	1
	399	54·9	10 54	6	79·0	1	1		428	48·5	9 59	6	105·3	1	1
	400	62·0	11 52	6	83·3	1	1		429	52·8	10 30	6	106·1	1	1
	401	64·5	0 30 P.M.	6	85·8	1	1		430	57·5	11 3	6	105·9	1	1
	402	68·8	2 35	6	88·4	1	1		431	62·0	11 35	6	106·4	1	1
	403	67·9	3 5	6	88·0	1	1		432	68·9	1 54 P.M.	6	105·7	1	1
	404	60·1	3 32	6	87·8	1	1		433	69·8	2 24	6	105·3	1	1
	405	59·0	4 0	6	88·0	1	1		434	69·9	3 0	6	104·3	1	1
	406	56·1	4 30	6	89·0	1	1		435	62·9	3 27	6	104·0	1	1
	407	53·2	5 0	6	90·8	1	1		436	60·8	4 0	6	104·3	1	1
	408	43·4	5 33	6	92·6	1	1		437	60·6	4 25	6	105·3	1	1
14th „	409	28·6	7 40 A.M.	6	93·2	1	1		438	56·8	5 5	6	104·9	1	1
	410	31·8	8 13	6	93·1	1	1		439	51·5	5 38	6	105·1	1	1
	411	35·0	8 40	6	93·7	1	1	16th „	440	34·0	7 55 A.M.	6	104·7	1	1
	412	40·8	9 13	6	94·3	1	1		441	37·9	8 36	6	103·0	1	1
	413	44·6	9 40	6	94·7	1	1		442	45·2	9 15	6	99·4	1	1
	414	48·8	10 14	6	95·2	1	1		443	49·9	9 48	6	99·1	1	1
	415	51·9	10 41	6	96·1	1	1		444	53·9	10 20	6	98·7	1	1
	416	56·4	11 17	6	97·3	1	1		445	58·0	10 52	6	98·5	1	1
	417	60·5	11 46	6	97·6	1	1		446	62·3	11 24	6	98·7	1	1
	418	70·3	2 13 P.M.	6	98·0	1	1		447	65·3	11 57	6	97·9	1	1

Extracts from the Field Book—(Continued.)

When compared — 1835	No. of the Set.	Temperature of Air.	Mean time of ending. h.	m.	No. of bars used.	Height of Set above origin.	Numeral shewing arrangement of Bars.	Micros:
		°	h.	m.		feet.		
16th Jan.	448	71·5	2	4 P.M.	6 +	97·0	1	1
	449	71·9	2	32	6	98·0	1	1
	450	63·8	3	16	6	99·4	1	1
	451	62·0	3	56	6	101·1	1	1
	452	59·5	4	32	6	101·0	1	1
	453	56·8	4	59	6	99·2	1	1
	454	51·8	5	27	6	99·4	1	1
	455	47·5	5	49	6	99·4	1	1
17th „	456	31·9	7	43 A.M.	6	99·7	1	1
	457	34·9	8	20	6	99·5	1	1
	458	40·2	8	58	6	100·0	1	1
	459	46·1	9	30	6	101·8	1	1
	460	52·0	10	13	6	103·1	1	1
	461	56·4	10	44	6	103·7	1	1
	462	62·1	11	20	6	104·4	1	1
	463	73·6	1	43 P.M.	6	104·2	1	1
	464	73·3	2	14	6	100·8	1	1
	465	66·0	2	45	6	100·1	1	1
	466	64·4	3	13	6	98·9	1	1
	467	61·8	3	42	6	98·8	1	1
	468	60·2	4	9	6	100·1	1	1
	469	57·6	4	33	6	99·7	1	1
	470	53·5	4	57	6	100·2	1	1
	471	47·8	5	23	6	101·0	1	1
19th „	472	36·5	7	35 A.M.	6	102·0	1	1
	473	40·6	8	6	6	104·1	1	1
	474	44·9	8	38	6	104·6	1	1
	475	49·1	9	3	6	105·0	1	1
	476	53·0	9	34	6	105·7	1	1
	477	56·9	10	2	6	106·5	1	1
	478	61·8	10	34	6	106·4	1	1
	479	65·8	11	3	6	106·9	1	1
	480	70·3	1	11 P.M.	6	107·3	1	1
	481	72·5	1	46	6	108·2	1	1
	482	71·4	2	21	6	108·2	1	1
	483	64·5	2	51	6	107·7	1	1
	484	63·5	3	23	6	107·8	1	1
19th Jan.	485	60·5	4	4 P.M.	6 +	108·4	1	1
	486	55·2	4	40	6	108·5	1	1
	487	53·0	5	8	6	107·7	1	1
20th „	488	37·3	8	1 A.M.	6	106·5	1	1
	489	41·4	8	31	6	104·8	1	1
	490	49·5	9	23	6	103·0	1	1
	491	52·9	9	51	6	103·2	1	1
	492	57·9	10	31	6	104·4	1	1
	493	61·2	10	56	6	104·5	1	1
	494	60·5	1	54 P.M.	6	105·0	1	1
	495	59·8	2	24	6	105·3	1	1
	496	55·5	3	0	6	105·5	1	1
	497	56·7	3	31	6	105·8	1	1
	498	55·8	4	9	6	106·8	1	1
	499	55·6	4	45	6	107·1	1	1
	500	50·2	5	15	6	107·2	1	1
21st „	501	34·8	7	45 A.M.	6	107·6	1	1
	502	44·4	9	11	6	107·0	1	1
	503	50·3	9	56	6	105·4	1	1
	504	53·5	10	39	6	106·4	1	1
	505	55·8	11	35	6	105·6	1	1
23rd „	506	39·3	9	11	6	106·5	1	1
	507	44·5	9	43	6	108·6	1	1
	508	49·4	10	25	6	108·4	1	1
	509	55·0	11	12	6	107·1	1	1
	510	61·5	0	2 P.M.	6	107·5	1	1
	511	64·8	0	42	6	111·1	1	1
	512	71·7	2	57	6	113·0	1	1
	513	69·4	3	45	6	113·5	1	1
	514	66·5	4	26	6	111·3	1	1
24th „	515	33·0	7	45 A.M.	6	111·6	1	1
	516	44·3	9	2	6	114·8	1	1
	517	61·4	11	8	6	119·9	1	1
	518	72·5	1	58 P.M.	6	122·4	1	1
	519	71·2	2	26	6	123·1	1	1
	520	69·5	3	19	6	123·9	1	1

The dot on Pin No. 5, was fixed exactly in the normal at the advanced end of set No. 520.
Height of set No. 520 above Pin No. 5, = 2·0 feet.

When compared — 1835	No. of the Set.	Temperature of Air.	Mean time of ending. h.	m.	No. of bars used.	Height of Set above origin.	Numeral shewing arrangement of Bars.	Micros:
24th Jan.	521	65·9	3	46 P.M.	6 +	124·5	1	1
	522	61·3	4	26	6	124·2	1	1
	523	56·5	4	56	6	123·0	1	1
	524	47·6	5	30	6	120·8	1	1
26th „	525	31·9	7	51 A.M.	6	122·4	1	1
	526	38·8	8	30	6	122·7	1	1
26th Jan.	527	44·3	8	57 A.M.	6 +	122·5	1	1
	528	49·9	9	31	6	122·1	1	1
	529	54·5	10	3	6	121·6	1	1
	530	60·3	10	41	6	120·7	1	1
	531	65·5	11	21	6	121·7	1	1
	532	74·5	1	44 P.M.	6	122·6	1	1

Extracts from the Field Book—(Continued.)

When compared — 1835	No. of the Set.	Temperature of Air.	Mean time of ending.	No. of bars used.	Height of Set above origin.	Numeral shewing arrangement of Bars.	Micros:
		°	h. m.		feet.		
26th Jan.	533	75·6	2 16 P.M.	6 +	123·3	1	1
	534	77·3	2 53	6	124·2	1	1
	535	77·5	3 24	6	125·4	1	1
	536	76·0	3 55	6	126·3	1	1
	537	68·5	4 18	6	127·4	1	1
	538	66·3	4 41	6	127·9	1	1
	539	63·5	5 9	6	128·6	1	1
	540	54·5	5 39	6	128·9	1	1
27th „	541	33·9	7 55 A.M.	6	129·6	1	1
	542	37·8	8 23	6	129·6	1	1
	543	42·5	8 50	6	129·8	1	1
	544	48·8	9 24	6	130·7	1	1
	545	53·5	9 50	6	130·8	1	1
	546	56·9	10 19	6	130·7	1	1
	547	59·8	10 44	6	130·7	1	1
	548	63·5	11 16	6	130·8	1	1
	549	74·0	1 34 P.M.	6	130·9	1	1
	550	75·8	1 59	6	131·6	1	1
	551	76·9	2 21	6	131·8	1	1
	552	76·6	2 45	6	132·0	1	1
	553	71·5	3 5	6	131·7	1	1
	554	69·7	3 54	6	129·4	1	1
	555	69·3	4 20	6	125·3	1	1
	556	66·6	4 47	6	125·5	1	1
	557	65·4	5 11	6	126·2	1	1
	558	55·5	5 39	6	126·0	1	1
28th „	559	33·4	8 6 A.M.	6	126·6	1	1
	560	37·5	8 33	6	127·4	1	1
	561	41·8	8 57	6	128·3	1	1
	562	46·5	9 24	6	128·9	1	1
	563	52·3	9 53	6	129·4	1	1
	564	55·5	10 22	6	130·6	1	1
	565	60·0	10 54	6	130·8	1	1
	566	65·8	11 34	6	129·0	1	1
	567	71·7	1 40 P.M.	6	128·1	1	1
	568	73·8	2 18	6	127·7	1	1
	569	66·5	2 47	6	129·3	1	1
	570	64·5	3 27	6	131·3	1	1
	571	62·3	4 8	6	133·8	1	1
	572	58·3	4 44	6	136·2	1	1
	573	58·0	5 2	6	137·9	1	1
	574	52·8	5 25	6	138·4	1	1
29th „	575	30·5	7 35 A.M.	6	138·9	1	1
	576	34·5	8 4	6	139·9	1	1
	577	39·3	8 31	6	140·4	1	1
	578	44·0	8 57	6	140·5	1	1
	579	48·0	9 16	6	140·9	1	1
	580	51·5	9 43	6	139·8	1	1
		°	h. m.		feet.		
29th Jan.	581	54·6	10 4 A.M.	6 +	137·3	1	1
	582	57·5	10 28	6	137·2	1	1
	583	59·5	10 50	6	137·1	1	1
	584	63·8	11 19	6	139·0	1	1
	585	70·3	1 4 P.M.	6	139·0	1	1
	586	72·6	1 29	6	137·6	1	1
	587	73·5	1 55	6	139·3	1	1
	588	73·9	2 20	6	140·3	1	1
	589	67·3	2 43	6	140·8	1	1
	590	65·5	3 10	6	142·1	1	1
	591	64·8	3 33	6	142·9	1	1
	592	63·7	3 52	6	143·8	1	1
	593	62·8	4 12	6	144·4	1	1
	594	61·3	4 33	6	144·4	1	1
	595	59·5	4 55	6	144·5	1	1
	596	53·0	5 13	6	144·1	1	1
	597	47·4	5 32	6	141·9	1	1
30th „	598	33·5	8 11 A.M.	6	144·0	1	1
	599	39·0	8 40	6	146·0	1	1
	600	44·0	9 4	6	146·8	1	1
	601	48·5	9 25	6	148·0	1	1
	602	51·5	9 47	6	148·6	1	1
	603	54·0	10 8	6	149·5	1	1
	604	57·1	10 30	6	150·3	1	1
	605	59·8	10 50	6	151·1	1	1
	606	67·1	0 40 P.M.	6	151·3	1	1
	607	69·5	1 11	6	150·3	1	1
	608	71·1	1 44	6	148·3	1	1
	609	66·9	2 4	6	148·6	1	1
	610	65·5	2 29	6	148·5	1	1
	611	65·5	2 49	6	148·1	1	1
	612	64·5	3 20	6	148·3	1	1
	613	63·5	3 46	6	149·9	1	1
	614	62·3	4 11	6	150·5	1	1
	615	60·5	4 33	6	152·0	1	1
	616	55·6	5 3	6	153·9	1	1
	617	48·8	5 32	6	155·6	1	1
31st „	618_1	36·3	7 43 A.M.	3	157·6	4	6
	618_2	41·4	8 18	3	159·6	5	7
	619_1	48·0	9 1	3	161·9	4	6
	619_2	53·3	9 26	3	164·1	5	7
	620_1	57·5	10 9	3	167·9	4	6
	620_2	61·4	10 51	3	171·6	5	7
	621_1	65·2	11 34	3	174·3	4	6
	621_2	67·5	0 6 P.M.	3	177·5	5	7
	622_1	67·4	1 28	3	178·8	4	6
5th Feb.	622_2	59·5	3 33	2	179·1	6	8
17th „	622_3	67·0	11 30 A.M.	1	179·2	3	9

The dot at East-End was fixed exactly in the normal at the advanced end of set No. 622_3.
Height of set No. 622_3 above dot at East-End = 1·6 feet.

DETAILS OF THE 2ND MEASUREMENT.

Disposition of the bars and microscopes.

Typical illustrations shewing the permutations and combinations of the bars and microscopes during the 2nd measurement. The instruments are here named in the succession that actually occurred, commencing from the rear-end of a set; and the numbers assigned to the illustrations, will be found employed in the tables of "Extracts from the Field Book &c." as a means of reference.

Bar Illustration.

No. 1	No. 2	No. 3
A	A	D
B	B	E
C	C	H
D		
E		
H		

Statement.

No. 1 occurs in set No. 1, in sets Nos. 5 to 340, in sets Nos. 342 and 343, and in sets Nos. 344 to 622.

No. 2 " Nos. 2_1, 3_1, 4_1, and 341_1.

No. 3 " Nos. 2_2, 3_2, 4_2, and 341_2.

Microscope Illustration.

No. 1	No. 2	No. 3	No. 4	No. 5	No. 6	No. 7
½U	½U	½T	½U	½R	½R	½M
O	O	N	O	O	O	N
P	P	M	P	P	P	T
T	½T	½S	M	M	½M	½S
N			N	N		
R			T	T		
½S			½S	½S		

Statement.

No. 1 occurs in set No. 1 only.
No. 2 " sets Nos. 2_1, 3_1, and 4_1.
No. 3 " Nos. 2_2, 3_2, and 4_2.
No. 4 " Nos. 5 to 115.
No. 5 " Nos. 116 to 340, in sets Nos. 342 and 343, and in sets Nos. 344 to 622.
No. 6 " set No. 341_1,
No. 7 " No. 341_2,

Extracts from the Field Book of the remeasurement, and calculated heights of sets above the origin.

Adopted heights above mean sea level.
East End (origin) = 1957·7 feet.
West End (terminus) = 1770·1 feet.

When compared — 1835	No. of the Set.	Temperature of Air.	Mean time of ending.	No. of bars used.	Height of set above origin.	Numeral shewing arrangement of Bars.	Micros:	When compared — 1835	No. of the Set.	Temperature of Air.	Mean time of ending.	No. of bars used.	Height of set above origin.	Numeral shewing arrangement of Bars.	Micros:
		°	h. m.		feet.					°	h. m.		feet.		
19th Feb.	1	62·3	9 32 A.M.	6	+ 2·2	1	1	20th Feb.	6	48·4	7 22 A.M.	6	− 21·9	1	4
	2_1	66·3	10 12	3	0·6	2	2		7	57·0	8 23	6	23·7	1	4
	2_2	69·9	11 4	3	− 3·0	3	3		8	59·9	9 1	6	25·4	1	4
	3_1	72·5	11 39	3	5·8	2	2		9	62·2	9 26	6	26·8	1	4
	3_2	76·8	2 31 P.M.	3	10·5	3	3		10	63·7	10 1	6	27·4	1	4
	4_1	76·9	3 12	3	13·8	2	2		11	68·6	10 36	6	29·2	1	4
	4_2	71·0	3 50	3	16·4	3	3		12	71·9	11 12	6	29·3	1	4
	5	66·4	4 32	6	18·8	1	4		13	76·3	1 19 P.M.	6	29·3	1	4

NOTE.—The rear-end of set No. 1 stood exactly over the dot at East-End.

Extracts from the Field Book—(Continued.)

When compared 1835	No. of the Set.	Temperature of Air.	Mean time of ending.			No. of bars used.	Height of Set above origin.	Numeral shewing arrangement of Bars.	Micros:
		°	h.	m.			feet.		
20th Feb.	14	74·8	1	56	P.M.	6	— 28·8	1	4
	15	72·5	2	33		6	29·0	1	4
	16	72·4	3	10		6	27·0	1	4
	17	69·5	4	2		6	26·7	1	4
	18	66·5	4	38		6	26·4	1	4
	19	63·3	5	5		6	27·3	1	4
21st „	20	49·2	7	32	A.M.	6	28·4	1	4
	21	53·9	7	56		6	29·2	1	4
	22	57·4	8	25		6	29·8	1	4
	23	60·7	8	51		6	30·9	1	4
	24	63·6	9	25		6	32·0	1	4
	25	67·0	9	54		6	34·1	1	4
	26	69·3	10	26		6	35·4	1	4
	27	72·1	10	55		6	33·9	1	4
	28	77·8	1	7	P.M.	6	32·9	1	4
	29	79·5	1	32		6	33·4	1	4
	30	82·2	2	3		6	33·6	1	4
	31	80·9	2	27		6	34·3	1	4
	32	78·9	2	55		6	35·0	1	4
	33	78·6	3	21		6	35·8	1	4
	34	72·8	3	47		6	36·6	1	4
	35	70·1	4	11		6	37·5	1	4
	36	65·5	4	40		6	38·3	1	4
	37	58·6	5	12		6	39·0	1	4
23rd „	38	58·7	7	25	A.M.	6	38·0	1	4
	39	61·7	7	57		6	38·1	1	4
	40	65·5	8	30		6	39·9	1	4
	41	67·1	8	53		6	39·9	1	4
	42	67·7	9	25		6	39·9	1	4
	43	68·6	9	55		6	37·9	1	4
	44	70·5	10	24		6	36·9	1	4
	45	71·0	10	52		6	37·0	1	4
	46	74·0	1	0	P.M.	6	37·2	1	4
	47	75·8	1	29		6	37·9	1	4
	48	74·3	2	12		6	38·7	1	4
	49	73·9	2	35		6	39·5	1	4
	50	71·0	3	6		6	39·9	1	4
	51	69·9	3	32		6	41·2	1	4
	52	63·2	5	15		6	43·6	1	4
24th „	53	54·1	7	39	A.M.	6	47·0	1	4
	54	58·0	8	10		6	48·7	1	4
	55	61·5	8	44		6	50·4	1	4
	56	63·3	9	6		6	50·0	1	4
	57	66·9	9	35		6	49·4	1	4
	58	71·0	10	16		6	47·4	1	4
24th Feb.	59	74·0	10	42	A.M.	6	— 47·5	1	4
	60	76·9	11	10		6	48·6	1	4
	61	79·4	1	10	P.M.	6	49·4	1	4
	62	77·7	1	44		6	50·1	1	4
	63	78·8	2	14		6	50·9	1	4
	64	78·9	2	42		6	51·7	1	4
	65	78·5	3	5		6	52·1	1	4
	66	79·0	3	36		6	52·5	1	4
	67	77·3	4	6		6	52·3	1	4
	68	74·8	4	37		6	51·6	1	4
	69	69·5	4	59		6	49·8	1	4
	70	66·8	5	34		6	47·7	1	4
25th „	71	56·0	7	22	A.M.	6	46·5	1	4
	72	57·7	7	47		6	46·7	1	4
	73	60·0	8	16		6	46·6	1	4
	74	63·6	8	38		6	47·6	1	4
	75	65·9	9	8		6	47·6	1	4
	76	67·0	9	33		6	47·7	1	4
	77	70·1	10	0		6	47·7	1	4
	78	70·3	10	18		6	47·5	1	4
	79	72·1	10	41		6	48·2	1	4
	80	76·3	0	44	P.M.	6	48·5	1	4
	81	76·9	1	15		6	48·6	1	4
	82	78·0	1	39		6	48·8	1	4
	83	73·4	2	5		6	48·9	1	4
	84	75·6	2	26		6	49·6	1	4
	85	76·5	2	50		6	50·4	1	4
	86	72·5	3	6		6	51·0	1	4
	87	71·5	3	28		6	51·5	1	4
	88	69·9	3	50		6	52·4	1	4
	89	67·0	4	10		6	53·5	1	4
	90	65·8	4	38		6	54·3	1	4
26th „	91	43·7	7	33	A.M.	6	55·2	1	4
	92	49·0	8	5		6	56·2	1	4
	93	51·3	8	35		6	57·3	1	4
	94	53·9	8	59		6	56·3	1	4
	95	56·2	9	26		6	55·8	1	4
	96	58·3	9	48		6	55·4	1	4
	97	60·1	10	14		6	55·2	1	4
	98	61·3	10	39		6	55·3	1	4
	99	63·0	11	6		6	57·0	1	4
	100	67·8	1	12	P.M.	6	55·4	1	4
	101	68·8	1	40		6	54·1	1	4
	102	69·0	2	55		6	53·3	1	4

The advanced end of set No. 102 fell in excess, (i.e., west) of dot by 1st measurement on Pin No. 5, 0·0425 feet, as measured on Cary's brass scale with a pair of compasses.

Height of set No. 102 above Pin No. 5 = 2·7 feet.

***Extracts from the Field Book*—(Continued.)**

When compared 1835	No. of the Set.	Temperature of Air.	Mean time of ending.		No. of bars used.	Height of Set above origin.	Numeral shewing arrangement of: Bars.	Micros:
		°	h.	m.		feet.		
26th Feb.	103	70·6	3	31 P.M.	6	— 53·7	1	4
	104	69·1	3	57	6	54·4	1	4
	105	63·6	4	38	6	56·0	1	4
	106	60·0	5	9	6	58·4	1	4
	107	55·0	5	38	6	61·9	1	4
27th „	108	44·0	7	28 A.M.	6	65·0	1	4
	109	50·2	8	3	6	65·4	1	4
	110	54·1	8	35	6	65·7	1	4
	111	57·0	9	7	6	66·4	1	4
	112	59·0	9	43	6	67·1	1	4
	113	62·5	10	9	6	70·2	1	4
	114	65·2	10	34	6	71·0	1	4
	115	69·0	11	5	6	69·9	1	4
	116	76·0	3	33 P.M.	6	69·6	1	5
	117	74·0	4	20	6	70·0	1	5
	118	70·9	4	41	6	71·9	1	5
	119	68·2	5	6	6	72·5	1	5
	120	65·9	5	31	6	72·9	1	5
28th „	121	48·0	7	30 A.M.	6	71·7	1	5
	122	54·0	8	4	6	70·9	1	5
	123	57·5	8	30	6	70·9	1	5
	124	60·7	8	59	6	70·9	1	5
	125	63·2	9	24	6	71·1	1	5
	126	66·8	9	53	6	72·3	1	5
	127	69·7	10	16	6	72·3	1	5
	128	72·0	10	44	6	72·3	1	5
	129	74·0	11	5	6	72·6	1	5
	130	80·4	1	51 P.M.	6	73·1	1	5
	131	78·7	2	34	6	73·7	1	5
	132	78·4	3	10	6	74·0	1	5
	133	77·0	3	55	6	75·5	1	5
	134	71·0	4	19	6	73·7	1	5
	135	69·9	4	43	6	72·1	1	5
	136	67·0	5	9	6	70·4	1	5
	137	62·0	5	36	6	69·3	1	5
2nd Mar.	138	45·2	7	19 A.M.	6	69·8	1	5
	139	49·1	7	52	6	69·9	1	5
	140	53·7	8	26	6	70·1	1	5
	141	58·0	8	52	6	69·8	1	5
	142	61·9	9	17	6	69·4	1	5
	143	64·8	9	46	6	70·2	1	5
	144	68·8	10	14	6	70·9	1	5
	145	71·0	10	37	6	71·3	1	5
	146	73·0	11	1	6	71·4	1	5
	147	78·9	1	30 P.M.	6	72·0	1	5
	148	79·8	1	55	6	72·3	1	5
	149	80·2	2	21	6	73·0	1	5
2nd Mar.	150	79·6	2	45 P.M.	6	— 74·2	1	5
	151	78·3	3	12	6	76·1	1	5
	152	76·0	3	36	6	77·1	1	5
	153	70·0	3	59	6	77·8	1	5
	154	67·5	4	20	6	78·5	1	5
	155	65·7	4	43	6	79·1	1	5
	156	62·2	5	5	6	79·2	1	5
	157	57·0	5	29	6	78·9	1	5
3rd „	158	41·8	7	11 A.M.	6	77·7	1	5
	159	46·1	7	38	6	77·1	1	5
	160	53·5	8	26	6	74·2	1	5
	161	57·3	8	57	6	73·5	1	5
	162	61·5	9	24	6	73·7	1	5
	163	65·4	9	50	6	74·8	1	5
	164	67·9	10	12	6	75·9	1	5
	165	71·7	10	37	6	77·7	1	5
	166	73·3	11	2	6	78·2	1	5
	167	78·6	1	52 P.M.	6	78·7	1	5
	168	81·0	2	26	6	78·8	1	5
	169	81·1	2	47	6	78·6	1	5
	170	80·0	3	9	6	79·1	1	5
	171	79·1	3	35	6	78·0	1	5
	172	72·8	3	57	6	77·6	1	5
	173	69·9	4	23	6	79·0	1	5
	174	68·0	4	45	6	80·7	1	5
	175	65·1	5	7	6	81·4	1	5
	176	60·5	5	30	6	80·9	1	5
4th „	177	46·1	7	30 A.M.	6	79·9	1	5
	178	51·0	7	58	6	79·9	1	5
	179	55·3	8	28	6	79·8	1	5
	180	60·1	8	59	6	79·7	1	5
	181	65·0	9	34	6	78·9	1	5
	182	69·9	10	3	6	76·4	1	5
	183	73·2	10	37	6	74·4	1	5
	184	75·0	11	3	6	73·8	1	5
	185	81·6	2	15 P.M.	6	73·3	1	5
	186	82·1	2	44	6	73·1	1	5
	187	80·5	3	15	6	73·9	1	5
	188	75·5	3	46	6	75·3	1	5
	189	72·0	4	29	6	74·5	1	5
	190	70·2	4	53	6	73·6	1	5
	191	66·6	5	18	6	72·9	1	5
	192	60·5	5	52	6	72·5	1	5
5th „	193	42·6	7	22 A.M.	6	72·6	1	5
	194	48·7	7	54	6	72·8	1	5
	195	55·0	8	30	6	73·0	1	5
	196	59·0	8	56	6	73·5	1	5

Extracts from the Field Book—(Continued.)

When compared — 1835	No. of the Set.	Temperature of Air.	Mean time of ending.			No. of bars used.	Height of Set above origin.	Numeral shewing arrangement of Bars.	Numeral shewing arrangement of Micros:	When compared — 1835	No. of the Set.	Temperature of Air.	Mean time of ending.			No. of bars used.	Height of Set above origin.	Numeral shewing arrangement of Bars.	Numeral shewing arrangement of Micros:
		°	h.	m.			feet.					°	h.	m.			feet.		
5th Mar.	197	64·8	9	36	A.M.	6	— 74·1	1	5	6th Mar.	216	61·7	8	54	A.M.	6	— 88·7	1	5
	198	69·6	10	2		6	74·9	1	5		217	64·4	9	20		6	89·9	1	5
	199	72·1	10	28		6	75·5	1	5		218	67·0	9	42		6	91·2	1	5
	200	74·6	10	58		6	76·7	1	5		219	68·2	10	0		6	91·7	1	5
	201	80·6	1	30	P.M.	6	78·5	1	5		220	71·9	10	25		6	91·7	1	5
	202	79·6	1	54		6	79·3	1	5		221	73·8	10	43		6	92·5	1	5
	203	79·4	2	19		6	79·9	1	5		222	75·0	11	8		6	94·2	1	5
	204	81·1	2	41		6	80·3	1	5		223	79·0	1	14	P.M.	6	96·6	1	5
	205	80·1	3	9		6	81·1	1	5		224	79·0	1	36		6	98·8	1	5
	206	80·0	3	30		6	81·0	1	5		225	83·2	2	1		6	98·9	1	5
	207	78·5	3	55		6	81·4	1	5		226	81·9	2	24		6	99·0	1	5
	208	76·0	4	17		6	82·6	1	5		227	82·0	2	50		6	97·1	1	5
	209	71·2	4	46		6	83·7	1	5		228	82·3	3	13		6	97·2	1	5
	210	70·5	5	7		6	84·6	1	5		229	81·0	3	37		6	97·1	1	5
	211	63·2	5	35		6	85·1	1	5		230	77·0	3	57		6	96·1	1	5
6th „	212	46·0	7	7	A.M.	6	85·7	1	5		231	75·3	4	20		6	95·7	1	5
	213	50·5	7	34		6	85·9	1	5		232	72·8	4	45		6	95·0	1	5
	214	54·7	7	58		6	86·2	1	5		233	66·1	5	35		6	92·0	1	5
	215	58·0	8	24		6	86·6	1	5										

The advanced-end of set No. 233 fell in excess, (*i. e.* west) of the dot by 1st measurement on Pin No. 4 or Station B, 0·0493 feet, as measured on Cary's brass scale with a pair of compasses.

Height of set No. 233 above Station B = 1·8 feet.

When compared — 1835	No. of the Set.	Temperature of Air.	Mean time of ending.			No. of bars used.	Height of Set above origin.	Bars.	Micros:	When compared — 1835	No. of the Set.	Temperature of Air.	Mean time of ending.			No. of bars used.	Height of Set above origin.	Bars.	Micros:
7th Mar.	234	78·2	0	59	P.M.	6	— 90·8	1	5	9th Mar.	256	76·2	1	7	P.M.	6	— 118·1	1	5
	235	78·6	1	29		6	92·2	1	5		257	76·9	1	29		6	119·0	1	5
	236	78·0	1	52		6	94·5	1	5		258	78·0	1	51		6	120·3	1	5
	237	78·6	2	14		6	96·8	1	5		259	77·6	2	11		6	121·5	1	5
	238	78·6	2	37		6	98·7	1	5		260	78·6	2	32		6	122·9	1	5
	239	76·4	3	9		6	99·6	1	5		261	78·7	2	53		6	124·2	1	5
	240	76·0	3	32		6	100·5	1	5		262	77·9	3	13		6	125·2	1	5
	241	75·3	3	55		6	100·2	1	5		263	74·8	3	35		6	126·1	1	5
	242	76·0	4	21		6	100·2	1	5		264	72·2	3	57		6	126·5	1	5
	243	72·8	4	44		6	100·9	1	5		265	67·1	4	23		6	127·2	1	5
	244	69·0	5	20		6	101·9	1	5		266	64·0	4	49		6	127·9	1	5
9th „	245	53·8	7	20	A.M.	6	103·2	1	5		267	61·0	5	10		6	129·0	1	5
	246	54·6	7	44		6	104·3	1	5		268	58·5	5	35		6	129·7	1	5
	247	55·7	8	6		6	106·0	1	5	10th „	269	49·3	7	7	A.M.	6	130·1	1	5
	248	59·6	8	30		6	107·9	1	5		270	53·3	7	38		6	132·9	1	5
	249	62·3	8	54		6	109·4	1	5		271	56·7	8	2		6	131·3	1	5
	250	63·3	9	13		6	111·0	1	5		272	59·0	8	25		6	131·8	1	5
	251	63·6	9	35		6	112·9	1	5		273	61·0	8	47		6	132·9	1	5
	252	65·1	9	53		6	114·3	1	5		274	63·0	9	8		6	133·6	1	5
	253	66·0	10	17		6	115·3	1	5		275	64·3	9	26		6	134·3	1	5
	254	67·3	10	40		6	116·3	1	5		276	66·6	9	48		6	135·1	1	5
	255	68·3	11	0		6	117·2	1	5		277	69·2	10	11		6	137·0	1	5

Extracts from the Field Book—(Continued.)

When compared — 1835	No. of the Set.	Temperature of Air.	Mean time of ending.		No. of bars used.	Height of Set above origin.	Numeral shewing arrangement of	
							Bars.	Micros:
		°	h.	m.		feet.		
10th Mar.	278	71·0	10	36 A.M.	6 —	137·4	1	5
	279	73·0	11	7	6	136·6	1	5
	280	77·5	1	9 P.M.	6	136·9	1	5
	281	80·8	1	30	6	137·2	1	5
	282	79·7	1	50	6	137·2	1	5
	283	80·0	2	16	6	137·9	1	5
	284	81·0	2	43	6	140·2	1	5
	285	81·0	3	3	6	140·9	1	5
	286	80·8	3	23	6	141·2	1	5
	287	79·3	3	44	6	141·2	1	5
	288	75·3	4	5	6	141·6	1	5
	289	72·0	4	25	6	143·6	1	5
	290	69·1	4	47	6	142·3	1	5
	291	67·0	5	8	6	141·9	1	5
	292	63·5	5	30	6	142·3	1	5
11th „	293	50·5	6	44 A.M.	6	142·3	1	5
	294	52·6	7	5	6	143·1	1	5
	295	54·8	7	31	6	145·3	1	5
	296	57·0	7	51	6	146·6	1	5
	297	59·9	8	11	6	147·1	1	5
	298	61·6	8	33	6	147·5	1	5
	299	63·1	8	52	6	148·1	1	5
	300	64·8	9	13	6	148·8	1	5
	301	66·6	9	30	6	149·9	1	5
	302	68·0	9	48	6	151·0	1	5
	303	71·0	10	9	6	151·8	1	5
	304	73·0	10	30	6	152·2	1	5
	305	75·9	10	49	6	153·5	1	5
	306	76·6	11	10	6	154·7	1	5
	307	80·9	1	9 P.M.	6	155·9	1	5
	308	81·2	1	27	6	156·7	1	5
	309	83·1	1	48	6	157·5	1	5
	310	83·8	2	10	6	159·1	1	5
	311	82·2	2	57	6	159·8	1	5
	312	81·0	3	18	6	159·2	1	5
	313	80·3	3	37	6	159·7	1	5
	314	80·0	3	56	6	161·3	1	5
	315	78·0	4	15	6	162·0	1	5
	316	75·8	4	32	6	162·8	1	5
	317	73·9	4	48	6	162·7	1	5
	318	71·7	5	11	6	162·9	1	5
	319	68·7	5	28	6	163·8	1	5
12th „	320	53·0	6	30 A.M.	6	164·7	1	5
	321	55·0	6	54	6	164·7	1	5
	322	57·7	7	13	6	164·0	1	5
	323	60·4	7	33	6	164·1	1	5
	324	63·5	7	56	6	163·3	1	5
12th Mar.	325	65·1	8	17 A.M.	6 —	162·9	1	5
	326	67·0	8	38	6	164·0	1	5
	327	68·6	8	58	6	164·7	1	5
	328	71·5	9	21	6	164·7	1	5
	329	74·9	9	44	6	164·7	1	5
	330	76·1	10	0	6	164·9	1	5
	331	76·1	10	19	6	165·3	1	5
	332	78·3	10	38	6	165·3	1	5
	333	78·3	10	59	6	165·4	1	5
	334	81·7	0	55 P.M.	6	166·4	1	5
	335	82·1	1	16	6	167·1	1	5
	336	83·5	1	39	6	166·5	1	5
	337	81·8	2	0	6	167·2	1	5
	338	80·9	2	21	6	167·7	1	5
	339	80·3	2	41	6	167·7	1	5
	340	80·9	3	7	6	167·5	1	5
	341_1	80·4	3	35	3	167·4	2	6
	342	79·0	3	55	6	168·1	1	5
	343	77·6	4	19	6	168·3	1	5
	341_2	71·2	4	48	3	167·9	[illegible]	7
	344	68·7	5	7	6	167·3	1	5
	345	67·7	5	29	6	167·5	1	5
13th „	346	58·0	8	9 A.M.	6	168·4	1	5
	347	59·0	8	31	6	168·6	1	5
	348	60·2	8	55	6	168·2	1	5
	349	61·4	9	15	6	167·4	1	5
	350	61·3	9	40	6	167·7	1	5
	351	62·1	10	2	6	169·1	1	5
	352	64·4	10	22	6	169·8	1	5
	353	64·8	10	45	6	170·3	1	5
	354	64·6	11	12	6	169·4	1	5
	355	66·7	1	40 P.M.	6	169·0	1	5
	356	67·6	2	6	6	168·1	1	5
	357	67·8	2	30	6	167·1	1	5
	358	67·9	2	56	6	167·0	1	5
	359	67·3	3	16	6	167·3	1	5
	360	68·3	3	34	6	168·0	1	5
	361	66·4	3	53	6	169·2	1	5
	362	65·3	4	15	6	170·2	1	5
	363	63·5	4	40	6	171·3	1	5
14th „	364	45·4	6	56 A.M.	6	171·3	1	5
	365	46·7	7	21	6	171·2	1	5
	366	49·8	7	45	6	172·4	1	5
	367	51·7	8	11	6	172·4	1	5
	368	54·1	8	39	6	171·4	1	5
	369	56·2	9	5	6	170·8	1	5
	370	57·9	9	26	6	170·7	1	5

Extracts from the Field Book—(Continued.)

When compared — 1835	No. of the Set.	Temperature of Air.	Mean time of ending. h.	m.		No. of bars used.	Height of Set above origin.	Numeral shewing arrangement of Bars.	Micros:
		°	h.	m.			feet.		
14th Mar.	371	59·2	9	46	A.M.	6 —	170·0	1	5
	372	60·3	10	7		6	170·2	1	5
	373	61·1	10	31		6	170·0	1	5
	374	62·0	10	53		6	169·1	1	5
	375	63·9	11	20		6	168·1	1	5
	376	73·0	4	14	P.M.	6	168·4	1	5
	377	72·4	4	35		6	169·0	1	5
	378	72·1	4	59		6	167·7	1	5
	379	64·0	5	23		6	166·1	1	5
	380	59·8	5	45		6	165·0	1	5
	381	56·3	6	4		6	164·1	1	5
17th „	382	47·2	7	22	A.M.	6	163·9	1	5
	383	50·3	7	44		6	164·2	1	5
	384	54·3	8	7		6	164·4	1	5
	385	57·3	8	30		6	164·5	1	5
	386	59·8	8	52		6	164·5	1	5
	387	62·2	9	14		6	164·2	1	5
17th Mar.	388	64·0	9	36	A.M.	6 —	164·2	1	5
	389	65·8	9	56		6	164·2	1	5
	390	68·2	10	20		6	164·5	1	5
	391	69·7	10	39		6	165·0	1	5
	392	72·4	11	6		6	165·5	1	5
	393	80·1	1	50	P.M.	6	167·4	1	5
	394	78·8	2	16		6	168·8	1	5
	395	80·0	2	44		6	167·7	1	5
	396	77·7	3	25		6	165·3	1	5
	397	75·0	3	54		6	162·2	1	5
	398	73·6	4	22		6	160·3	1	5
	399	72·9	4	52		6	159·2	1	5
	400	70·6	5	10		6	158·2	1	5
	401	68·3	5	32		6	157·2	1	5
	402	65·5	5	53		6	156·1	1	5
18th „	403	57·0	7	49	A.M.	6	155·1	1	5

The advanced-end of set No. 403 fell in excess, (*i.e.* west) of the dot by 1st measurement on Pin No. 3 [illegible] 0·0939 feet, as measured on Cary's brass scale with a pair of compasses.

Height of set No. 403 above Pin No. 3 = 2·4 feet.

When compared — 1835	No. of the Set.	Temperature of Air.	Mean time of ending. h.	m.		No. of bars used.	Height of Set above origin.	Numeral shewing arrangement of Bars.	Micros:
18th Mar.	404	57·8	8	20	A.M.	6 —	155·1	1	5
	405	59·3	8	47		6	155·1	1	5
	406	60·3	9	7		6	155·8	1	5
	407	60·3	9	28		6	156·5	1	5
	408	59·8	9	49		6	156·4	1	5
	409	59·6	10	11		6	155·9	1	5
	410	60·0	10	36		6	155·7	1	5
	411	60·5	10	52		6	155·0	1	5
	412	61·1	11	11		6	155·4	1	5
	413	66·2	1	14	P.M.	6	155·4	1	5
	414	67·6	1	34		6	155·4	1	5
	415	68·5	1	57		6	155·9	1	5
	416	69·9	2	16		6	157·2	1	5
	417	71·1	2	36		6	158·1	1	5
	418	72·0	2	58		6	158·8	1	5
	419	71·5	3	17		6	158·9	1	5
	420	71·0	3	36		6	158·8	1	5
	421	70·4	3	59		6	158·4	1	5
	422	69·8	4	17		6	158·6	1	5
	423	69·7	4	36		6	159·0	1	5
	424	67·5	4	57		6	158·8	1	5
	425	65·4	5	16		6	158·6	1	5
	426	65·0	5	35		6	158·9	1	5
19th „	427	56·8	8	10	A.M.	6	159·1	1	5
19th Mar.	428	57·0	8	35	A.M.	6 —	159·9	1	5
	429	58·3	9	3		6	161·2	1	5
	430	61·5	9	25		6	161·5	1	5
	431	64·0	9	49		6	161·5	1	5
	432	66·1	10	10		6	160·9	1	5
	433	68·6	10	32		6	160·8	1	5
	434	68·7	10	58		6	160·5	1	5
	435	73·0	1	27	P.M.	6	159·4	1	5
	436	73·5	1	52		6	158·8	1	5
	437	75·6	2	14		6	158·9	1	5
	438	75·5	2	32		6	158·3	1	5
	439	76·0	2	55		6	157·5	1	5
	440	74·7	3	13		6	158·0	1	5
	441	72·0	3	37		6	158·4	1	5
	442	71·6	4	1		6	158·2	1	5
	443	72·0	4	25		6	158·1	1	5
	444	71·5	4	46		6	157·8	1	5
	445	71·3	5	12		6	157·0	1	5
	446	69·2	5	33		6	157·3	1	5
	447	65·0	5	53		6	158·3	1	5
21st „	448	64·3	9	32	A.M.	6	157·9	1	5
	449	67·1	9	58		6	156·5	1	5
	450	69·5	10	21		6	155·4	1	5
	451	71·4	10	40		6	154·0	1	5

Extracts from the Field Book—(Continued.)

When compared — 1835	No. of the Set.	Temperature of Air.	Mean time of ending.	No. of bars used.	Height of Set above origin.	Numeral shewing arrangement of Bars.	Numeral shewing arrangement of Micros:	When compared — 1835	No. of the Set.	Temperature of Air.	Mean time of ending.	No. of bars used.	Height of Set above origin.	Numeral shewing arrangement of Bars.	Numeral shewing arrangement of Micros:
		°	h. m.		feet.					°	h. m.		feet.		
21st Mar.	452	72·2	11 0 A.M.	6	— 153·5	1	5	21st Mar.	459	80·3	1 23 P.M.	6	— 152·0	1	5
	453	74·9	11 22	6	152·4	1	5		460	82·0	1 44	6	152·4	1	5
	454	75·8	11 44	6	151·9	1	5		461	83·3	2 3	6	152·3	1	5
	455	76·7	0 2 P.M.	6	151·9	1	5		462	83·7	2 25	6	152·5	1	5
	456	77·8	0 22	6	151·8	1	5		463	81·2	2 47	6	152·3	1	5
	457	78·7	0 40	6	151·4	1	5		464	80·0	3 12	6	151·2	1	5
	458	79·0	1 1	6	151·6	1	5	23rd „	465	66·0	10 0 A.M.	6	151·3	1	5

The advanced-end of set No. 465 fell in excess, (*i. e.* west) of the dot by 1st measurement on Pin No. 2 or Station A, 0·1131 feet, as measured on Cary's brass scale with a pair of compasses.

Height of Set No. 465 above Station A = 2·4 feet.

When compared — 1835	No. of the Set.	Temperature of Air.	Mean time of ending.	No. of bars used.	Height of Set above origin.	Bars.	Micros:	When compared — 1835	No. of the Set.	Temperature of Air.	Mean time of ending.	No. of bars used.	Height of Set above origin.	Bars.	Micros:
23rd Mar.	466	70·2	10 25 A.M.	6	— 151·4	1	5	24th Mar.	500	81·7	2 13 P.M.	6	— 158·9	1	5
	467	72·3	10 49	6	152·0	1	5		501	84·6	2 36	6	159·6	1	5
	468	74·2	11 10	6	152·3	1	5		502	86·4	2 57	6	161·4	1	5
	469	79·7	1 8 P.M.	6	152·7	1	5		503	85·8	3 21	6	162·1	1	5
	470	80·5	1 28	6	152·8	1	5		504	85·2	3 45	6	160·5	1	5
	471	80·0	1 49	6	153·1	1	5		505	84·0	4 5	6	159·3	1	5
	472	80·3	2 10	6	153·8	1	5		506	79·0	4 25	6	159·4	1	5
	473	81·0	2 32	6	154·0	1	5		507	76·4	4 46	6	159·4	1	5
	474	81·0	2 52	6	154·4	1	5		508	74·1	5 7	6	159·1	1	5
	475	82·4	3 14	6	154·6	1	5		509	71·3	5 26	6	159·3	1	5
	476	82·0	3 31	6	155·5	1	5		510	68·3	5 45	6	160·0	1	5
	477	82·0	3 54	6	156·3	1	5		511	64·4	6 8	6	161·0	1	5
	478	80·5	4 12	6	156·9	1	5	25th „	512	48·4	6 45 A.M.	6	161·0	1	5
	479	75·8	4 34	6	156·9	1	5		513	50·3	7 10	6	161·5	1	5
	480	74·2	4 54	6	156·7	1	5		514	53·3	7 30	6	162·4	1	5
	481	71·8	5 14	6	156·2	1	5		515	57·0	7 49	6	163·8	1	5
	482	69·3	5 34	6	155·8	1	5		516	59·0	8 11	6	164·5	1	5
	483	66·9	5 57	6	155·8	1	5		517	60·7	8 30	6	166·0	1	5
24th „	484	49·7	6 56 A.M.	6	155·0	1	5		518	63·4	8 54	6	165·6	1	5
	485	53·0	7 19	6	154·5	1	5		519	66·3	9 15	6	167·0	1	5
	486	54·5	7 41	6	153·5	1	5		520	68·1	9 35	6	168·9	1	5
	487	56·0	8 0	6	153·6	1	5		521	70·9	9 56	6	169·6	1	5
	488	58·0	8 22	6	154·1	1	5		522	72·2	10 14	6	170·2	1	5
	489	60·4	8 42	6	154·1	1	5		523	74·4	10 33	6	171·2	1	5
	490	63·0	9 1	6	154·6	1	5		524	75·7	10 54	6	170·8	1	5
	491	65·7	9 20	6	155·2	1	5		525	78·3	11 18	6	170·5	1	5
	492	68·3	9 40	6	155·3	1	5		526	81·4	1 11 P.M.	6	170·4	1	5
	493	70·4	9 57	6	154·6	1	5		527	82·6	1 32	6	169·7	1	5
	494	72·4	10 20	6	154·6	1	5		528	83·6	1 56	6	170·2	1	5
	495	74·6	10 40	6	155·0	1	5		529	85·7	2 13	6	170·7	1	5
	496	76·8	11 3	6	156·5	1	5		530	86·7	2 32	6	170·2	1	5
	497	80·8	1 8 P.M.	6	157·9	1	5		531	87·5	2 52	6	170·2	1	5
	498	81·1	1 27	6	158·2	1	5		532	86·8	3 11	6	171·0	1	5
	499	81·4	1 52	6	158·8	1	5		533	86·7	3 30	6	171·5	1	5

Extracts from the Field Book—(Continued.)

When compared — 1835	No. of the Set.	Temperature of Air.	Mean time of ending. h. m.	No. of bars used.	Height of Set above origin. feet.	Numeral shewing arrangement of Bars.	Micros:
25th Mar.	534	86·2	3 48 P.M.	6	— 171·7	1	5
	535	85·8	4 6	6	172·5	1	5
	536	84·9	4 25	6	172·6	1	5
	537	84·0	4 42	6	172·2	1	5
	538	82·5	4 59	6	171·6	1	5
	539	76·2	5 17	6	171·2	1	5
	540	72·5	5 38	6	171·2	1	5
	541	69·5	5 58	6	171·2	1	5
26th „	542	46·3	6 48 A.M.	6	172·0	1	5
	543	50·0	7 11	6	172·6	1	5
	544	53·7	7 31	6	172·2	1	5
	545	56·3	7 50	6	171·3	1	5

When compared — 1835	No. of the Set.	Temperature of Air.	Mean time of ending. h. m.	No. of bars used.	Height of Set above origin. feet.	Numeral shewing arrangement of Bars.	Micros:
26th Mar.	546	59·4	8 11 A.M.	6	— 171·1	1	5
	547	61·3	8 26	6	171·6	1	5
	548	64·0	8 53	6	172·8	1	5
	549	66·5	9 13	6	170·3	1	5
	550	70·0	9 38	6	169·3	1	5
	551	72·7	10 2	6	168·9	1	5
	552	74·1	10 18	6	169·2	1	5
	553	76·0	10 35	6	168·7	1	5
	554	77·5	10 53	6	168·4	1	5
	555	79·2	11 12	6	167·5	1	5
	556	85·0	2 1 P.M.	6	167·3	1	5

The advanced-end of set No. 556 fell in excess, (*i.e.* west) of the dot by 1st measurement on Pin No. 1, 0·1189 feet, as measured on Cary's brass scale with a pair of compasses.

Height of set No. 556 above Pin No. 1 = 2·9 feet.

When compared — 1835	No. of the Set.	Temperature of Air.	Mean time of ending. h. m.	No. of bars used.	Height of Set above origin. feet.	Numeral shewing arrangement of Bars.	Micros:
26th Mar.	557	87·2	2 24 P.M.	6	— 167·9	1	5
	558	88·0	2 46	6	169·1	1	5
	559	85·0	3 5	6	170·1	1	5
	560	85·4	3 25	6	171·6	1	5
	561	84·8	3 47	6	172·9	1	5
	562	84·7	4 4	6	174·8	1	5
	563	84·0	4 23	6	175·2	1	5
	564	83·7	4 43	6	176·1	1	5
	565	83·0	5 0	6	175·8	1	5
	566	75·7	5 19	6	176·4	1	5
	567	72·5	5 35	6	175·9	1	5
	568	69·0	5 52	6	175·5	1	5
	569	66·3	6 10	6	176·2	1	5
27th „	570	48·2	6 49 A.M.	6	175·7	1	5
	571	50·9	7 6	6	175·8	1	5
	572	52·0	7 23	6	176·3	1	5
	573	53·7	7 38	6	176·7	1	5
	574	55·3	7 55	6	177·1	1	5
	575	57·0	8 13	6	177·5	1	5
	576	59·5	8 30	6	177·1	1	5
	577	60·7	8 45	6	177·6	1	5
	578	63·3	9 0	6	178·6	1	5
	579	65·4	9 14	6	179·2	1	5
	580	67·8	9 29	6	180·8	1	5
	581	70·6	9 42	6	180·5	1	5
	582	73·3	9 59	6	180·6	1	5
	583	75·0	10 13	6	180·2	1	5
	584	76·6	10 30	6	179·8	1	5
	585	78·2	10 43	6	179·5	1	5

When compared — 1835	No. of the Set.	Temperature of Air.	Mean time of ending. h. m.	No. of bars used.	Height of Set above origin. feet.	Numeral shewing arrangement of Bars.	Micros:
27th Mar.	586	79·0	11 0 A.M.	6	— 179·2	1	5
	587	85·0	0 50 P.M.	6	179·3	1	5
	588	86·3	1 9	6	179·9	1	5
	589	88·1	1 24	6	180·5	1	5
	590	88·9	1 42	6	180·6	1	5
	591	88·2	1 59	6	180·0	1	5
	592	89·0	2 15	6	178·5	1	5
	593	88·5	2 34	6	178·4	1	5
	594	88·0	2 52	6	178·8	1	5
	595	88·0	3 10	6	179·6	1	5
	596	86·9	3 28	6	181·7	1	5
	597	84·8	3 45	6	180·8	1	5
	598	81·6	4 5	6	180·5	1	5
	599	80·3	4 26	6	179·0	1	5
	600	78·8	4 50	6	178·1	1	5
	601	76·8	5 11	6	178·1	1	5
	602	75·2	5 26	6	177·7	1	5
	603	73·2	5 44	6	177·1	1	5
	604	72·5	6 2	6	177·4	1	5
28th „	605	70·6	9 22 A.M.	6	178·4	1	5
	606	73·0	9 38	6	179·8	1	5
	607	74·7	9 52	6	179·4	1	5
	608	76·1	10 10	6	178·9	1	5
	609	77·0	10 27	6	178·2	1	5
	610	78·2	10 41	6	177·4	1	5
	611	79·0	10 56	6	177·3	1	5
	612	80·9	11 11	6	177·8	1	5
	613	81·3	11 25	6	178·7	1	5
	614	82·6	11 40	6	179·3	1	5

Extracts from the Field Book—(Continued.)

When compared — 1835	No. of the Set.	Temperature of Air	Mean time of ending	No. of bars used	Height of Set above origin	Numeral shewing arrangement of Bars.	Micros:	When compared — 1835	No. of the Set.	Temperature of Air	Mean time of ending	No. of bars used	Height of Set above origin	Numeral shewing arrangement of Bars.	Micros:
		°	h. m.		feet.					°	h. m.		feet.		
28th Mar.	615	82·2	11 54 A.M.	6	—179·6	1	5	28th Mar.	619	86·4	1 0 P.M.	6	—179·4	1	5
	616	84·4	0 11 P.M.	6	179·2	1	5		620	88·5	1 18	6	178·7	1	5
	617	85·5	0 26	6	179·1	1	5		621	87·0	1 36	6	177·4	1	5
	618	85·3	0 43	6	179·6	1	5		622	84·7	2 55	6	177·4	1	5

The advanced-end of set No. 622 fell in excess, (*i. e.* west) of the dot at West-End, 0·1296 feet, as measured on Cary's brass scale with a pair of compasses.

Height of set No. 622 above West-End = 2·3 feet.

Reduction to Mean Sea Level.

Let the sections into which this line is divided be denoted as follows:

West-End to Pin No. 1 by	Section I
Pin No. 1 to Pin No. 2 by	„ II
Pin No. 2 to Pin No. 3 by	„ III
Pin No. 3 to Pin No. 4 by	„ IV
Pin No. 4 to Pin No. 5 by	„ V
Pin No. 5 to East-End by	„ VI

Then in the notation of (7) page I_{22} we have

For the 1st measurement—(in feet.)

$H = 1770$; $h = 187{\cdot}6$; $\delta h = 10{\cdot}0$; Log $R = 7{\cdot}32068$; and $n = 622$.

	$[h]_1^p$ +	a −	n	dh +	F +	λ +	C_2 −	C_1 −	C −
Section I	92	0	66	1·1	129	4158	·0004	·3517	·3521
„ II	1505	0	91	1·5	1674	5733	·0050	·4849	·4899
„ III	1482	0	62	1·0	1675	3906	·0050	·3304	·3354
„ IV	5163	15	170	2·7	5991	10710	·0180	·9059	·9239
„ V	13262	0	131	2·1	14226	8253	·0428	·6981	·7409
„ VI	14827	1026	102	1·6	14740	6426	·0444	·5435	·5879

Reduction to Mean Sea Level—(Continued.)

For the 2nd measurement—we have in feet.

$H = 1958$; $h = -187{\cdot}6$; $\delta h = -7{\cdot}9$; Log $R = 7{\cdot}32068$; and $n = 622$.

	$[h]_1^p$	a	n	dh	F	λ	C_2	C_1	C
	−	+		−	−		+	−	−
Section I	11731	0	66	0·8	12227	4158	·0368	·3891	·3523
„ II	14811	0	91	1·1	15408	5733	·0464	·5364	·4900
„ III	9705	0	62	0·8	10052	3906	·0303	·3655	·3352
„ IV	25524	168	170	2·2	26054	10710	·0784	1·0021	·9237
„ V	10106	0	131	1·7	10388	8253	·0313	·7722	·7409
„ VI	4177	25	102	1·3	4219	6426	·0127	·6013	·5886

Final length of the Base-Line and of its Parts in feet of Standard A.

Statement	*Measured with* Compensated bars pages II—10 and II—15	Compensated microscopes pages II—21 and II—24	Beam compass pages II—34 to II—41	Reduction to sea level pages II—42 and II—43	Length by each measurement	Mean length by the two measurements
		West-End to Pin No. 1.				
By 1*st measurement*, „ 2*nd* „	3960·1554 ·1534	198·0152 ·0024	0·0 − 0·0107	− 0·3521 − 0·3523	4157·8185 ·7928	4157·8057
		Pin No. 1 to Pin No. 2 (or Station A.)				
By 1*st measurement*, „ 2*nd* „	5460·2143 ·2114	273·0115 ·0027	0·0 − 0·0058	− 0·4899 − 0·4900	5732·7359 ·7183	5732·7271
		Pin No. 2 (or Station A) to Pin No. 3.				
By 1*st measurement*, „ 2*nd* „	3720·1460 ·1441	186·0086 ·0004	0·0 − 0·0192	− 0·3354 − 0·3352	3905·8192 ·7901	3905·8046
		Pin No. 3 to Pin No. 4 (or Station B.)				
By 1*st measurement*, „ 2*nd* „	10200·4003 ·3951	510·0281 ·0009	0·0 − 0·0446	− 0·9239 − 0·9237	10709·5045 ·4277	10709·4661
		Pin No. 4 (or Station B.) to Pin No. 5.				
By 1*st measurement*, „ 2*nd* „	7860·3085 ·3045	393·0295 ·0050	0·0 − 0·0068	− 0·7409 − 0·7409	8252·5971 ·5618	8252·5795
		Pin No. 5 to East-End.				
By 1*st measurement*, „ 2*nd* „	6120·2402 ·2370	306·0213 ·0188	0·0 − 0·0425	− 0·5879 − 0·5886	6425·6736 ·6247	6425·6491
		West-End to East-End.				
By 1*st measurement*, „ 2*nd* „	37321·4647 ·4455	1866·1142 ·0302	0·0 − 0·1296	− 3·4301 − 3·4307	39184·1488 39183·9154	39184·0321

And from the foregoing,

		feet
West-End to Pin No. 2 (or Station A)	=	9890·5328, Log. 3·995219688
Pin No. 2 (or Station A) to Pin No. 4 (or Station B)	=	14615·2707, Log. 4·164806863
Pin No. 4 (or Station B) to East-End	=	14678·2286, Log. 4·166673647
West-End to East-End	=	39184·0321, Log. 4·593109124

Verificatory Minor Triangulation.

No. of Triangle	Name of Station	Corrected Angle	Log. Sine	Log. Distance	Distance in Feet	Distance in Miles	Error of Triangle
		° ′ ″					″
1	West-End of Base, ...	71 11 41·526	9·976175848	4·189642081			
	Station A, ...	71 34 35·359	9·977150135	4·190616368			−2·291
	„ α	37 13 43·149	9·781753455	3·995219688	9890·5328	1.873	
		180 0 0·034					
2	Station α	78 11 26·844	9·990709265	4·213929586			
	„ A, ...	34 3 2·605	9·748131086	3·971351407			+1·804
	„ β	67 45 30·585	9·966421760	4·189642081			
		180 0 0·034					
3	Station A, ...	74 22 21·452	9·983641598	4·273623486			
	„ β	48 33 17·647	9·874823932	4·164805820	14615·2356	2·768	−0·375
	„ B, ...	57 4 20·955	9·923947698	4·213929586			
		180 0 0·054					
4	Station β	56 28 14·570	9·920959539	4·315924793			
	„ B, ...	74 23 44·453	9·983690437	4·378655691			−1·408
	„ γ	49 8 1·065	9·878658232	4·273623486			
		180 0 0·088					
5	Station B, ...	48 31 54·200	9·874668723	4·191444706			
	„ γ	45 3 15·634	9·849896485	4·166672468	14678·1888	2·780	−0·266
	East-End of Base, ...	86 24 50·220	9·999148810	4·315924793			
		180 0 0·054		Sums	39183·9572	7·421	

NOTE.—Each side of a triangle is given in the same horizontal line with the angle which it subtends.

The angles of the verificatory triangulation were measured with a 3-foot Theodolite (either the one by Troughton or that by Barrow) read by 5 micrometer-microscopes. At stations A, γ and E. End, 2 measures were taken on each of 12 zeros. At the remaining 4 stations, 3 measures were made on each of 12 zeros. The stations on the line are W. End, A, B, and E. End.—The auxiliary stations are α, β and γ.

Comparison in feet between the values computed by means of the verificatory triangulation and the measured value.

Of the entire line.

		Log.
West-End to East-End by the mean of the two measurements page II—44	39184·0321	4·593 1091 24
" " computed in terms of West-End to Station A page II—45	39183·9572	4·593 1082 93
Log. computed value — Log. measured value —		0·000 0008 31

In terms of the entire line by measurement.

	Computed	Computed − Measured*
West-End to Station A	9890·5517	+0·0189
Station A to Station B	14615·2636	−0·0071
Station B to East-End	14678·2168	−0·0118

Of each section in terms of the others.

	W. End to Station A	Station A to Station B	Computed − Measured	Station B to E. End	Computed − Measured
Measured lengths* ...	9890·5328	14615·2707	... ...	14678·2286	
Computed on base West-End to Station A	... ...	14615·2356	−·0351	14678·1888	−·0398
Computed on base Station A to Station B	... ...	... ...	... ...	14678·2241	−·0045

NOTE.—Since $\text{Log}_e (x + dx) = \text{Log}_e x + \frac{(dx)}{x} - \frac{(dx)^2}{2x^2} + \&c.$

$dx = \left\{ \text{Log}_{10} (x + dx) - \text{Log}_{10} x \right\} \frac{x}{\text{Modulus}}$ nearly, by which expression the required variations in the foregoing natural numbers have been calculated.

Description of Stations.

WEST-END OF DEHRA DOON BASE, Lat. 30° 20′, Long. 77° 54′, is situated in the district of Dehra Doon, about 2 miles to the E. of the small village of Sherpúr, and about 1 mile S. from the Asan river.

The following description of the station is taken from the original record by Colonel Everest:—

"A stone 5 feet in length and 1 foot square base was sunk to the surface of the ground and lodged in a "pile of masonry 14 feet square with a circular pillar of masonry in the middle of 4 feet diameter, the pillar being built "disjointed from the rest of the pile in order that the instrument might remain isolated. Into the exposed surface of "the central stone a piece of brass was soldered on which was inserted a fine silver wire to receive the small dot which "marked the limit of the base-line. This was covered over by a circular brass plate 2 inches diameter fixed by 3 screws, "the female screws of which were cut in pieces of brass soldered into the stone. The upper surface of the brass plate "was left even with that of the stone, a circular space being hollowed out to admit it. A parapet wall of 12 inches high "was erected round the platform and ultimately when the base was concluded the whole was built up to a level with this "parapet, a supplemental stone of 1 foot square and 3 inches thick with a piece of brass and dot soldered into it being "accurately placed over the dot in the lower stone by means of the centering telescope of the large theodolite. For "protection against cattle and other intruders a thick hedge of prickly pear was planted round the platform."

The station was constructed in 1834-35, but when visited in 1867, was found with great difficulty; the prickly pear hedge had disappeared, and there was nothing to distinguish the station from the numerous mounds which were scattered around. For its future better protection and to facilitate identification, a tower was built over the masonry platform above described, with sides parrallel or perpendicular to the line of the base, and an arched passage 5 feet wide and 6 feet high, to allow of access to the mark-stones, should the base be remeasured at any future time. The tower is about 10 feet square and 8 feet high; it has an external masonry staircase leading to the summit, which is horizontal, to serve as a platform for future observations. A central pillar 4 feet in diameter rests on the vault, and rises to the level of the platform, but is separated therefrom by an annulus; it is perforated for reference to the marks below, the perforation being closed above by a mark-stone containing the usual circle, and a fine hole bored through the stone instead of the usual central dot; the mark on this stone is truly in the normal of those below, and is 10·23 feet above Colonel Everest's upper mark.

As the mark on the top of the new tower will suffice for ordinary use, the entrances to the vault have been bricked up with masonry, for the better protection of the original marks.

EAST-END OF DEHRA DOON BASE, Lat. 30° 17′, Long. 78° 1′, is situated on the extremity of one of the spurs of the Gháti or Siwalik range of hills, in the district of Dehra Doon. The nearest village is Mohabáwála, about a mile to the South-East. The Asan river winds round the foot of the spur, and one branch of it takes its rise in a ravine about 100 yards to the westward of the station.

This station is described by Colonel Everest as having been "marked in the same manner as the western limit, so that a description of one will answer for the other."

It was visited by Captain Branfill in January 1862, to be connected with the line of spirit levels which had been brought up from Karáchí harbour, as a part of the operations of this department. As no record was forthcoming of the height of Colonel Everest's upper mark above the mark on the stone pyramid, to which the base-line measurement was referred, it was necessary to remove the upper mark-stone; then the level of the summit of the pyramid was determined as 1957·65 feet above the mean sea level of Karáchí harbour; Colonel Everest's upper mark was found to have been 17 inches, or 1·42 feet above the mark on the pyramid; the stone slab containing the said upper mark was replaced in the normal of and at its original height above the mark on the pyramid.

In 1867 a tower was built over the station similar to the one that was constructed in the same year over the west end of the base, the description of which may be referred to for further details. The mark in the stone on the summit of the tower is 8·71 feet above Colonel Everest's upper mark, and consequently 1967·78 feet above the mean sea level of Karáchí harbour, as determined by the spirit levelling operations.

Description of Stations—(Continued.)

STATION A OR HELIOTROPE-WALA.* This station is 157 sets of bars from the West-End. It is marked by a stone 2 feet long sunk into the ground, on the upper surface of which is a piece of brass with a dot engraved on it; a hedge of cactus was planted round it to prevent intrusion.

STATION B OR BAR-WALA.* This station is at the distance of 389 sets of bars from the West-End, or 232 sets from station A, and as the whole base is 622 sets long, the distancee ofstation B from the East-End is 233 sets. It was marked and protected exactly in the same manner as station A.

STATIONS α, β, γ.* These stations are situated on the northern face of the Ghati or Siwalik range of hills, which affords spurs and eminences sufficiently favorable for stations. They are in the midst of Sal jungle, and have no village near them or any other token by which they can be described. Each is marked with a stone 2 feet long sunk into the ground into the upper surface of which a piece of brass with a dot engraved on it is soldered.

J. B. N. HENNESSEY.

* See page 266 Everest's Meridional Arc of India, 1847.

SIRONJ BASE-LINE.

The middle point of the base-line is in Latitude N. 24° 7′, Longitude E. 77° 51′; the Azimuth of North-East End at South-West End is 49° 26′ and the line is 7·28 Miles in length.

The measurement was effected under the directions of *Major G. Everest R.A., with the assistance of the following:

Lieutenant A. S. Waugh R.E.
,, T. Renny, R.E.
,, W. Jones, R.E.
Mr. G. Logan.
,, J. Peyton.
,, W. N. James
,, H. Keelan
Baboo Radhanath Sickdhar.
Mr. G. Terry.
,, N. Parsick.

* Afterwards Colonel Sir G. Everest, C.B.

INTRODUCTION.

This base-line was selected and originally measured with a steel chain in 1825 by Captain G. Everest. He subsequently remeasured it, in 1837-38, with the compensated apparatus, and the details hereafter given appertain to the latter operations. The terminal points were practically identical on the two occasions of measurement: they are situated in Malwa or Central India, generally to the east of Sironj, the South-West-End being some 5 miles distant and nearly due East from that town.

The measurement was commenced at the South-West-End, bar-tongues pointing North-West, and was carried on *continuously* to the North-East-End, so that every succeeding set originated at the terminus of its predecessor.

The compensated bars were compared with the standard A. both before and after the measurement, at Rasuli, a village near the base-line and about 2 miles from the South-West-End. Seventy-nine comparisons were made on the first occasion and sixty-one on the second, and this "process was gone through in the usual manner, both before and after the measurement, under the same tents as those used during that operation."* It is not stated in the field records whether the bar-tongues during comparisons pointed in the same direction as during the measurement.

Of the two comparing microscopes employed in the preceding bar comparisons, one was fitted with a micrometer while the other had its wires (or lines) fixed.

The compensated microscopes were compared with their scales on 11 occasions, including the comparisons taken prior and subsequent to the measurement.

In respect to time, the first set of bar comparisons was made on the 23rd November 1837, the last on the 22nd of the following January.

The base-line was not verified by means of minor triangulation.

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* Page xxxiv Everest's Meridional Arc of India (1847).

Comparisons between the Standard Bar **A** *and the Compensated Bars* A, B, C, D, E, H, *made at Rasuli village, before the measurement.*

1837. Novr.	Mean of the times of observing **A**	No. of comparison	Temperature of Air	Corrected mean temperature of **A**	Mean **A**	A	B	C	D	E	H	Mean of the compensated bars	Remarks.
	Micrometer Readings in Divisions. 1 Division = $\frac{1}{20088·6}$ Cary's Inch [7.8], = 1·3820 m.y. of **A**												
	h. m.		°	°	+	+	+	+	+	+	+	+	
23rd	6 51 A.M.	1		56·17	340·1	545·4	516·8	531·3	571·5	514·9	521·7	533·6	Lts. Waugh and Renny at the microscopes.
	7 31	2		56·97	349·1	535·5	509·1	521·9	563·9	514·2	515·9	526·8	
	8 6	3		58·75	379·9	534·1	502·6	525·9	565·9	516·4	513·9	526·5	
	8 41	4		61·47	427·0	533·9	507·6	520·9	565·9	514·1	513·7	526·0	
	9 20	5		65·30	494·7	526·9	500·0	531·1	569·2	521·9	525·9	529·2	
	9 57	6		69·25	560·0	536·9	508·1	536·9	577·3	526·8	528·9	535·8	
	10 29	7		72·57	613·1	538·9	513·0	538·9	584·0	532·5	536·2	540·6	
	1 22 P.M.	8		80·22	726·6	552·9	531·2	546·9	598·1	537·8	536·0	550·5	
	1 53	9		81·07	740·1	553·1	528·1	551·3	592·4	538·9	535·7	549·9	
	2 26	10		81·67	736·9	542·6	526·0	551·2	586·9	532·9	528·0	544·6	
	2 57	11		81·92	745·7	549·9	524·2	554·4	592·6	531·1	530·1	547·1	
	3 33	12		82·02	740·5	548·4	529·9	550·9	590·0	529·1	529·2	546·3	
	4 4	13		81·82	738·4	554·9	531·2	555·4	594·9	539·0	533·2	551·4	
24th	6 42 A.M.	14		53·75	326·6	572·9	545·0	561·9	602·9	545·4	553·1	563·5	Cirro-strati in horizon.
	7 11	15		53·92	329·7	571·6	543·8	558·8	602·9	545·0	550·1	562·0	
	7 39	16		54·47	337·5	571·7	538·7	558·1	599·9	542·9	558·9	560·0	
	8 3	17		55·25	351·6	564·9	540·1	554·0	597·1	542·1	546·9	557·5	
	8 28	18		56·50	376·4	573·1	532·5	553·2	600·1	548·1	549·9	559·5	
	8 51	19		58·10	400·4	569·9	538·8	558·9	598·5	548·4	551·0	560·9	
	9 15	20		60·27	433·6	565·9	533·1	552·2	598·1	547·1	553·0	558·2	
	9 40	21		62·62	471·5	564·9	531·3	549·3	593·0	538·0	543·0	553·3	
	10 29	22		67·72	549·0	563·6	530·3	562·2	599·9	546·0	547·0	558·2	
	1 16 P.M.	23		76·30	681·2	570·9	546·1	577·2	614·1	554·2	552·0	569·1	
	1 39	24		77·12	697·6	572·1	550·1	573·1	615·9	556·9	555·9	570·7	
	2 2	25		77·92	709·0	574·9	550·2	574·0	619·2	559·1	555·1	572·1	
	2 27	26		78·77	720·5	575·9	550·1	573·9	617·9	557·9	556·1	572·0	
	2 50	27		79·47	732·2	584·9	557·0	579·0	622·4	563·9	563·1	578·4	
	3 18	28		79·85	742·5	585·9	558·9	586·9	626·0	572·3	568·4	583·1	
	3 43	29		80·05	746·6	589·9	563·9	585·0	628·1	570·9	566·2	584·0	
	4 7	30		79·95	743·5	587·0	565·9	587·1	629·9	572·4	566·9	584·9	
25th	6 5 A.M.	31		52·30	335·0	595·9	573·9	592·1	633·9	580·3	585·2	593·6	Sky clear.
	6 32	32		52·25	332·4	604·9	571·1	588·0	632·1	579·6	583·7	593·2	
	6 56	33		52·52	339·5	602·1	568·9	587·1	630·9	574·9	582·2	591·0	
	7 20	34		53·42	354·5	601·0	565·0	580·0	628·4	573·1	577·0	587·4	
	7 45	35		54·92	379·4	589·1	559·9	576·1	622·2	569·1	575·0	581·9	
	8 9	36		56·77	410·9	588·0	551·8	576·0	622·4	565·7	571·2	579·2	
	8 34	37		58·95	442·6	585·8	553·1	574·2	613·3	564·9	567·0	576·4	
	8 58	38		61·30	477·5	579·0	545·9	568·1	612·8	563·1	565·9	572·5	
	9 23	39		63·75	515·5	579·0	545·9	568·8	615·1	562·9	565·3	572·8	
	9 49	40		66·27	553·9	578·7	546·3	567·2	614·8	567·2	567·2	573·6	Error of chro. this morning 43′ slow.

Before the measurement—(Continued.)

1837 Novr.	Mean of the times of observing A		No. of comparison.	Temperature of Air.	Corrected mean temperature of A	Micrometer Readings in Divisions — 1 Division = $\frac{1}{20088 \cdot 6}$ Cary's Inch [7.8] = 1·3820 *m.y* of A — Mean A	A	B	C	D	E	H	Mean of the compensated bars	Remarks
	h. m.			°	°	+	+	+	+	+	+	+	+	
25th	1 35	P.M.	41		77·60	729·6	604·8	579·9	601·2	648·1	586·8	579·8	600·1	Sky clear.
	1 58		42		78·40	745·0	602·9	584·9	603·9	651·3	590·9	582·9	602·8	
	2 20		43		79·10	758·4	607·1	582·4	611·3	652·9	591·7	586·2	605·3	
	2 44		44		79·67	767·0	609·1	584·9	614·0	650·1	591·0	590·0	606·5	
	3 6		45		80·12	773·6	609·9	584·1	611·0	656·0	595·9	591·9	608·1	
	3 27		46		80·45	778·7	613·4	586·0	613·7	650·9	596·0	593·9	609·0	
	3 48		47		80·55	781·5	614·0	589·9	612·3	651·0	593·6	590·1	608·5	
	4 8		48		80·57	781·0	618·0	594·1	609·9	655·0	598·0	594·9	611·7	
	4 29		49		80·50	777·0	619·0	591·1	617·1	656·0	596·7	592·2	612·0	
27th	6 48	A.M.	50		49·85	344·2	650·1	622·0	633·0	685·4	624·0	635·8	641·7	Sky clear. Haze.
	7 19		51		50·00	347·4	648·9	620·3	637·2	676·9	621·3	626·9	638·6	
	7 48		52		50·87	362·1	646·1	614·9	628·0	677·0	620·1	625·2	635·2	
	8 16		53		52·67	392·5	637·3	608·8	626·0	670·2	617·4	621·0	630·1	
	8 44		54		55·20	431·3	634·0	601·3	619·1	664·2	612·3	618·0	624·8	
	9 13		55		58·22	475·4	628·0	599·0	624·9	660·0	612·0	612·0	622·7	
	9 48		56		61·95	533·7	623·2	593·2	618·1	660·5	607·9	610·0	618·8	
	10 19		57		65·40	585·5	624·3	588·1	615·9	659·1	610·0	611·1	618·1	Sky clear.
	10 45		58		68·32	628·9	625·4	593·0	615·9	660·8	613·1	614·9	620·5	
	1 32	P.M.	59		80·90	828·1	643·3	621·1	642·3	690·1	630·9	625·9	642·3	Do.
	2 0		60		82·07	847·9	646·1	619·2	648·0	693·4	638·0	631·0	646·0	
	2 31		61		83·10	862·6	651·2	625·0	651·1	696·0	640·7	632·1	649·4	
	3 3		62		83·72	872·6	650·0	628·0	651·3	699·0	642·9	637·9	651·5	
	3 56		63		83·87	876·6	659·0	637·0	659·1	702·6	645·3	638·5	656·9	
	4 22		64		83·65	873·0	657·1	637·9	662·9	704·0	648·1	640·1	658·4	
28th	6 39	A.M.	65	47·0	49·55	356·6	670·5	635·0	648·3	695·2	646·6	649·2	657·5	
	7 6		66	49·6	49·40	355·3	669·4	635·0	654·4	694·9	642·9	649·0	657·6	
	7 33		67	54·5	49·97	364·5	664·9	632·6	646·9	687·8	636·4	642·0	651·8	
	8 5		68	60·3	51·72	392·9	655·9	620·9	634·2	685·9	628·2	631·2	642·7	
	8 38		69	65·9	54·37	432·0	648·9	614·9	636·9	674·9	624·3	627·4	637·9	
	9 8		70	70·5	57·45	477·3	640·3	607·6	629·9	670·9	621·1	625·4	632·5	
	9 36		71	74·1	60·50	525·4	632·9	600·1	625·0	671·1	619·4	622·3	628·5	
	10 3		72	76·8	63·65	573·0	633·2	596·5	624·2	669·2	622·1	622·1	627·9	
	10 32		73	78·9	66·87	622·7	636·0	599·9	630·9	668·0	624·1	620·1	629·8	
	1 39	P.M.	74	83·8	79·47	809·9	655·1	625·9	653·2	697·4	640·0	633·3	650·8	
	2 9		75	84·1	80·65	827·9	655·2	628·3	659·0	703·9	645·1	635·0	654·4	
	2 39		76	84·0	81·50	842·0	658·0	632·4	658·8	707·5	648·2	644·9	658·3	
	3 10		77	83·8	82·17	853·7	663·8	635·0	671·1	706·9	653·0	646·9	662·8	
	3 37		78	83·2	82·55	859·8	671·8	643·1	668·0	709·0	653·8	647·1	665·5	
	4 4		79	82·2	82·62	861·7	669·0	643·1	671·8	709·1	652·9	648·9	665·8	
			Means		68·01	587·23	603·34	574·96	597·21	640·08	585·36	585·34	597·72	

Before the measurement—(Continued.)

Let the mean length of the compensated bars minus the Standard **A** at 62° *F.* be denoted by x, and the observed excess of the compensated bars by δ when the temperature of **A** is $t°$. Then, the expansion of **A** for 1° being $(E_a - dE_a)$, we have

$$x - (t° - 62°)\,(E_a - dE_a) - \delta = 0$$

Treating the preceding bar comparisons as shewn in this equation, we obtain the following series of results :—

		d				*d*	
$x+$ 5·83	$(E_a - dE_a)$	−193·5	= o	$x+$ 7·08	$(E_a - dE_a)$	−202·5	= o
$x+$ 5·03	"	−177·7	= o	$x+$ 5·23	"	−168·3	= o
$x+$ 3·25	"	−146·6	= o	$x+$ 3·05	"	−133·8	= o
$x+$ 0·53	"	− 99·0	= o	$x+$ 0·70	"	− 95·0	= o
$x-$ 3·30	"	− 34·5	= o	$x-$ 1·75	"	− 57·3	= o
$x-$ 7·25	"	+ 24·2	= o	$x-$ 4·27	"	− 19·7	= o
$x-$10·57	"	+ 72·5	= o	$x-$15·60	"	+129·5	= o
$x-$18·22	"	+176·1	= o	$x-$16·40	"	+142·2	= o
$x-$19·07	"	+190·2	= o	$x-$17·10	"	+153·1	= o
$x-$19·67	"	+192·3	= o	$x-$17·67	"	+160·5	= o
$x-$19·92	"	+198·6	= o	$x-$18·12	"	+165·5	= o
$x-$20·02	"	+194·2	= o	$x-$18·45	"	+169·7	= o
$x-$19·82	"	+187·0	= o	$x-$18·55	"	+173·0	= o
$x+$ 8·25	"	−236·9	= o	$x-$18·57	"	+169·3	= o
$x+$ 8·08	"	−232·3	= o	$x-$18·50	"	+165·0	= o
$x+$ 7·53	"	−222·5	= o	$x+$12·15	"	−297·5	= o
$x+$ 6·75	"	−205·9	= o	$x+$12·00	"	−291·2	= o
$x+$ 5·50	"	−183·1	= o	$x+$11·13	"	−273·1	= o
$x+$ 3·90	"	−160·5	= o	$x+$ 9·33	"	−237·6	= o
$x+$ 1·73	"	−124·6	= o	$x+$ 6·80	"	−193·5	= o
$x-$ 0·62	"	− 81·8	= o	$x+$ 3·78	"	−147·3	= o
$x-$ 5·72	"	− 9·2	= o	$x+$ 0·05	"	− 85·1	= o
$x-$14·30	"	+112·1	= o	$x-$ 3·40	"	− 32·6	= o
$x-$15·12	"	+126·9	= o	$x-$ 6·32	"	+ 8·4	= o
$x-$15·92	"	+136·9	= o	$x-$18·90	"	+185·8	= o
$x-$16·77	"	+148·5	= o	$x-$20·07	"	+201·9	= o
$x-$17·47	"	+153·8	= o	$x-$21·10	"	+213·2	= o
$x-$17·85	"	+159·4	= o	$x-$21·72	"	+221·1	= o
$x-$18·05	"	+162·6	= o	$x-$21·87	"	+219·7	= o
$x-$17·95	"	+158·6	= o	$x-$21·65	"	+214·6	= o
$x+$ 9·70	"	−258·6	= o	$x+$12·45	"	−300·9	= o
$x+$ 9·75	"	−260·8	= o	$x+$12·60	"	−302·3	= o
$x+$ 9·48	"	−251·5	= o	$x+$12·03	"	−287·3	= o
$x+$ 8·58	"	−232·9	= o				

Before the measurement—(Continued.)

$$\begin{array}{llll}
x+10{\cdot}28\,(E_a-dE_a)-249{\cdot}8=0 & & x-17{\cdot}47\,(E_a-dE_a)+159{\cdot}1=0 \\
x+\ 7{\cdot}63 \quad ,, \quad -205{\cdot}9=0 & & x-18{\cdot}65 \quad ,, \quad +173{\cdot}5=0 \\
x+\ 4{\cdot}55 \quad ,, \quad -155{\cdot}2=0 & & x-19{\cdot}50 \quad ,, \quad +183{\cdot}7=0 \\
x+\ 1{\cdot}50 \quad ,, \quad -103{\cdot}1=0 & & x-20{\cdot}17 \quad ,, \quad +190{\cdot}9=0 \\
x-\ 1{\cdot}65 \quad ,, \quad -\ 54{\cdot}9=0 & & x-20{\cdot}55 \quad ,, \quad +194{\cdot}3=0 \\
x-\ 4{\cdot}87 \quad ,, \quad -\ \ 7{\cdot}1=0 & & x-20{\cdot}62 \quad ,, \quad +195{\cdot}9=0
\end{array}$$

And from the mean of these results,

$$x=\overset{d}{10{\cdot}49}+6{\cdot}01\,(E_a-dE_a):$$

adopting the original value of the expansion of **A** given at page (9),

$$E_a=\overset{m.y}{22{\cdot}67}=\overset{d}{16{\cdot}404},$$

$$\text{and } x=\overset{d}{109{\cdot}08}-6{\cdot}01\,dE_a=\overset{m.y}{150{\cdot}75}-6{\cdot}01\,dE_a=\mathrm{L}-\underline{\mathbf{A}};$$

where L denotes the mean length of the compensated bars obtained from *all* the comparisons, as represented by the mean micrometer reading $\overset{d}{597{\cdot}72}$, page III—5.

Comparing this reading with the mean reading of each compensated bar given on the same page we obtain the following:—

In terms of	A – L	B – L	C – L	D – L	E – L	H – L
Micrometer divisions	+5·62	−22·76	−0·51	+42·36	−12·36	−12·38
Millionths of a yard.	+7·77	−31·45	−0·70	+58·54	−17·08	−17·11

Also combining the values in this table with the equivalent of L—**A** above determined, there result,

$$\begin{array}{l}
\mathrm{A}-\mathbf{A}=\overset{d}{114{\cdot}70}-6{\cdot}01\,dE_a=\overset{m.y}{158{\cdot}52}-6{\cdot}01\,dE_a \\
\mathrm{B}-\mathbf{A}=\ \ 86{\cdot}32-\quad ,, \quad =119{\cdot}30-\quad ,, \\
\mathrm{C}-\mathbf{A}=108{\cdot}57-\quad ,, \quad =150{\cdot}05-\quad ,, \\
\mathrm{D}-\mathbf{A}=151{\cdot}44-\quad ,, \quad =209{\cdot}29-\quad ,, \\
\mathrm{E}-\mathbf{A}=\ \ 96{\cdot}72-\quad ,, \quad =133{\cdot}67-\quad ,, \\
\mathrm{H}-\mathbf{A}=\ \ 96{\cdot}70-\quad ,, \quad =133{\cdot}64-\quad ,,
\end{array}$$

$$\text{and } 6\,x=\overset{m.y}{904{\cdot}5}-36{\cdot}1\,dE_a.$$

Comparisons between the Standard Bar **A** *and the Compensated Bars* A, B, C, D, E, H, *made after the measurement.*

1838 Jany.	Mean of the times of observing **A**	No. of comparison	Temperature of Air	Corrected mean temperature of **A**	Micrometer Readings in Divisions: 1 Division = $\frac{1}{20076 \cdot 77}$ Cary's Inch [7.8], = 1·3828 m.y of **A** — Mean **A**	A	B	C	D	E	H	Mean of the compensated bars	Remarks
	h. m.		°	°	+	+	+	+	+	+	+	+	
19th	7 41 A.M.	1	43·3	39·82	184·7	644·1	606·9	616·9	664·2	612·0	620·8	627·5	Sky clear.
	8 16	2	50·4	41·45	209·5	632·1	597·0	613·9	659·1	607·3	610·3	620·0	
	8 52	3	57·0	44·75	257·6	625·1	590·1	607·9	656·2	604·1	604·6	614·7	
	9 20	4	60·9	47·65	303·1	618·1	585·9	599·9	652·1	597·1	598·3	608·6	
	9 49	5	64·4	51·00	353·8	614·9	578·1	594·0	640·1	597·9	589·1	602·4	
	10 14	6	67·2	54·20	399·3	607·2	572·0	597·0	640·8	590·1	589·1	599·4	
	10 38	7	68·9	57·12	441·8	605·0	576·1	595·1	641·9	596·0	589·0	600·5	
	1 28 P.M.	8	74·4	68·97	614·2	618·0	591·0	620·1	665·3	608·1	593·4	616·0	
	1 53	9	75·5	70·20	633·0	619·9	595·4	619·2	662·9	605·0	597·1	616·6	
	2 18	10	76·2	71·35	649·5	625·0	588·2	620·0	665·2	611·1	600·4	618·3	
	2 42	11	75·9	72·25	664·5	624·9	601·2	623·8	663·9	612·9	603·4	621·7	
	3 10	12	75·7	73·10	677·5	628·2	601·0	624·9	670·6	614·8	604·2	624·0	
	3 40	13	75·8	73·70	687·5	629·1	600·1	629·0	668·9	618·2	603·9	624·9	
	4 5	14	75·0	74·00	692·6	633·0	606·1	629·9	670·1	617·9	608·8	627·6	
20th	6 51 A.M.	15	36·7	38·77	165·2	643·9	604·1	619·9	661·9	609·1	619·9	626·5	
	7 18	16	40·4	38·82	164·0	639·9	598·0	620·1	661·1	607·7	615·9	623·8	
	7 58	17	47·4	40·20	183·0	635·0	596·6	613·1	660·2	604·3	608·2	619·6	
	8 22	18	51·9	41·92	209·1	626·9	589·7	605·9	653·9	598·1	603·0	612·9	
	8 54	19	57·1	44·82	253·8	618·5	579·9	598·9	639·9	589·0	591·3	602·9	
	9 27	20	62·1	48·25	303·3	607·1	572·8	592·4	633·5	587·9	584·8	596·4	
	9 53	21	65·9	51·42	350·5	603·8	564·4	585·4	633·9	585·1	580·0	592·1	
	10 20	22	68·4	54·57	398·6	596·4	562·9	583·9	635·0	584·1	578·1	590·1	
	10 42	23	70·0	57·22	436·7	599·0	558·9	587·1	632·1	585·0	579·0	590·2	
	1 28 P.M.	24	76·1	70·37	619·8	601·4	578·0	612·1	645·9	589·0	576·0	600·4	
	2 4	25	76·3	72·27	648·8	603·9	579·0	612·5	649·1	593·2	582·4	603·4	
	2 27	26	76·4	73·22	663·9	605·0	583·2	610·1	653·6	597·0	585·0	605·7	
	2 52	27	76·6	74·02	677·0	612·0	584·4	612·9	655·3	597·9	586·9	608·2	
	3 16	28	76·7	74·62	685·6	611·9	586·7	611·8	654·9	590·0	587·7	607·2	
	3 39	29	76·3	75·02	692·2	616·9	588·8	616·1	656·0	603·1	590·2	611·9	
	4 0	30	75·8	75·32	696·6	618·6	592·9	616·2	655·0	603·9	588·1	612·5	
	4 21	31	74·9	74·55	699·0	620·0	593·0	618·9	659·0	607·0	591·1	614·8	
21st	7 1 A.M.	32	37·1	38·25	134·3	620·3	585·8	600·9	643·2	590·8	603·1	607·4	
	7 30	33	42·1	38·67	136·3	619·0	577·4	603·1	636·9	587·4	595·8	603·3	
	8 11	34	50·7	40·87	170·0	611·0	571·0	590·9	637·9	579·2	582·6	595·4	
	8 41	35	56·2	43·67	212·1	600·1	559·1	582·1	626·9	572·0	573·0	585·5	
	9 11	36	61·7	47·05	265·6	589·8	544·3	570·9	618·0	569·9	566·1	576·5	
	9 37	37	65·4	50·17	312·0	581·8	548·9	571·0	614·0	566·1	561·9	574·0	
	9 58	38	67·9	53·02	352·6	576·0	542·1	565·9	610·9	563·1	558·7	569·5	
	10 19	39	70·0	55·70	393·3	579·2	500·1	565·2	610·0	564·1	560·1	563·1	

After the measurement—(Continued.)

1838 Jany.	Mean of the times of observing A	No. of comparison	Temperature of Air	Corrected mean temperature of A	Micrometer Readings in Divisions (1 Division = $\frac{1}{20076\cdot77}$ Cary's Inch [7.8], = 1·3828 m.y. of A) Mean A	A	B	C	D	E	H	Mean of the compensated bars	Remarks
	h. m.		°	°	+	+	+	+	+	+	+	+	
21st	2 37 P.M.	40	78·8	75·45	674·9	588·8	560·0	603·0	650·0	576·4	560·1	589·7	
	3 0	41	78·4	76·07	684·5	583·0	557·9	592·1	641·8	574·4	561·3	585·1	
	3 22	42	78·1	76·55	691·9	586·1	561·4	592·0	635·4	574·0	562·5	585·2	
	3 45	43	77·6	76·80	696·7	589·2	564·7	593·8	635·1	578·9	565·0	587·8	
	4 6	44	76·9	76·95	700·7	593·1	564·9	595·1	638·1	578·5	567·5	589·5	
	4 24	45	75·6	77·00	699·0	595·1	563·8	590·2	632·2	577·9	567·4	587·8	
	4 43	46	73·7	76·90	696·5	598·1	568·3	592·9	632·0	580·1	568·9	590·1	
22nd	6 57 A.M.	47	38·9	40·45	158·2	613·0	575·2	593·1	629·9	580·9	582·2	595·7	
	7 20	48	42·6	40·62	161·4	608·8	574·9	591·1	632·1	582·0	587·9	596·1	
	7 51	49	48·1	41·77	179·0	605·9	564·1	585·3	622·2	570·1	580·9	588·1	
	8 15	50	52·6	43·32	202·2	595·9	554·9	579·0	619·9	566·1	573·0	581·5	
	8 48	51	58·4	46·32	245·4	583·2	547·2	565·9	611·1	561·2	559·1	571·3	
	9 11	52	62·1	48·57	278·9	580·6	542·1	563·3	610·9	560·1	556·1	568·9	
	9 33	53	65·4	51·12	317·1	573·9	537·4	558·3	603·0	554·0	553·9	563·4	
	9 59	54	68·4	54·20	363·6	567·0	535·1	558·0	604·0	552·0	549·0	560·9	
	1 40 P.M.	55	77·8	73·72	648·1	575·1	553·2	580·9	627·0	565·2	552·3	575·6	
	1 59	56	80·6	74·70	665·1	578·0	553·8	578·2	625·4	569·8	554·9	576·7	
	2 20	57	81·2	75·70	681·0	579·9	559·2	584·0	626·4	571·2	557·9	579·8	
	2 42	58	81·3	76·67	696·5	584·4	558·0	585·0	631·2	572·1	558·9	581·6	
	3 3	59	81·6	77·52	711·0	588·8	561·8	586·9	629·9	577·6	564·1	584·9	
	3 24	60	81·7	78·25	721·0	589·9	559·9	586·8	625·2	572·9	563·0	583·0	
	3 45	61	81·2	78·80	727·7	589·9	563·1	590·0	630·0	575·3	567·2	585·9	
			Means	59·83	462·17	605·08	572·33	596·78	640·20	586·68	581·55	597·10	

After the measurement—(Continued)

As on page III—6 we have

$$x - (t^\circ - 62^\circ)\,(E_a - dE_a) - \delta = 0;$$

and from the preceding bar comparisons, we obtain the following series of results :—

		d			d
$x+22·18$	$(E_a - dE_a)$	$-442·8 = 0$	$x+23·75$	$(E_a - dE_a)$	$-473·1 = 0$
$x+20·55$	„	$-410·5 = 0$	$x+23·33$	„	$-467·0 = 0$
$x+17·25$	„	$-357·1 = 0$	$x+21·13$	„	$-425·4 = 0$
$x+14·35$	„	$-305·5 = 0$	$x+18·33$	„	$-373·4 = 0$
$x+11·00$	„	$-248·6 = 0$	$x+14·95$	„	$-310·9 = 0$
$x+\ 7·80$	„	$-200·1 = 0$	$x+11·83$	„	$-262·0 = 0$
$x+\ 4·88$	„	$-158·7 = 0$	$x+\ 8·98$	„	$-216·9 = 0$
$x-\ 6·97$	„	$-\ \ 1·8 = 0$	$x+\ 6·30$	„	$-169·8 = 0$
$x-\ 8·20$	„	$+\ 16·4 = 0$	$x-13·45$	„	$+\ 85·2 = 0$
$x-\ 9·35$	„	$+\ 31·2 = 0$	$x-14·07$	„	$+\ 99·4 = 0$
$x-10·25$	„	$+\ 42·8 = 0$	$x-14·55$	„	$+106·7 = 0$
$x-11·10$	„	$+\ 53·5 = 0$	$x-14·80$	„	$+108·9 = 0$
$x-11·70$	„	$+\ 62·6 = 0$	$x-14·95$	„	$+111·2 = 0$
$x-12·00$	„	$+\ 65·0 = 0$	$x-15·00$	„	$+111·2 = 0$
$x+23·23$	„	$-461·3 = 0$	$x-14·90$	„	$+106·4 = 0$
$x+23·18$	„	$-459·8 = 0$	$x+21·55$	„	$-437·5 = 0$
$x+21·80$	„	$-436·6 = 0$	$x+21·38$	„	$-434·7 = 0$
$x+20·08$	„	$-403·8 = 0$	$x+20·23$	„	$-409·1 = 0$
$x+17·18$	„	$-349·1 = 0$	$x+18·68$	„	$-379·3 = 0$
$x+13·75$	„	$-293·1 = 0$	$x+15·68$	„	$-325·9 = 0$
$x+10·58$	„	$-241·6 = 0$	$x+13·43$	„	$-290·0 = 0$
$x+\ 7·43$	„	$-191·5 = 0$	$x+10·88$	„	$-246·3 = 0$
$x+\ 4·78$	„	$-153·5 = 0$	$x+\ 7·80$	„	$-197·3 = 0$
$x-\ 8·37$	„	$+\ 19·4 = 0$	$x-11·72$	„	$+\ 72·5 = 0$
$x-10·27$	„	$+\ 45·4 = 0$	$x-12·70$	„	$+\ 88·4 = 0$
$x-11·22$	„	$+\ 58·2 = 0$	$x-13·70$	„	$+101·2 = 0$
$x-12·02$	„	$+\ 68·8 = 0$	$x-14·67$	„	$+114·9 = 0$
$x-12·62$	„	$+\ 78·4 = 0$	$x-15·52$	„	$+126·1 = 0$
$x-13·02$	„	$+\ 80·3 = 0$	$x-16·25$	„	$+138·0 = 0$
$x-13·32$	„	$+\ 84·1 = 0$	$x-16·80$	„	$+141·8 = 0$
$x-12·55$	„	$+\ 84·2 = 0$			

After the measurement—(Continued.)

And from the mean of these results,

$$x = \overset{d}{134{\cdot}93} - 2{\cdot}17\,(E_a - dE_a):$$

adopting the original value of the expansion of **A** given at page (9),

$$E_a = \overset{m.y}{22{\cdot}67} = \overset{d}{16{\cdot}394},$$

$$\text{and } x = \overset{d}{99{\cdot}36} + 2{\cdot}17\,dE_a = \overset{m.y}{137{\cdot}40} + 2{\cdot}17\,dE_a = \text{L} - \mathbf{A};$$

where L denotes the mean length of the compensated bars obtained from *all* the comparisons, as represented by the mean micrometer reading $\overset{d}{597{\cdot}10}$, page III—9.

Comparing this reading with the mean reading of each compensated bar given on the same page we obtain the following:—

In terms of	A − L	B − L	C − L	D − L	E − L	H − L
Micrometer divisions.	+ 7·98	−24·77	−0·32	+43·10	−10·42	−15·55
Millionths of a yard.	+11·03	−34·25	−0·44	+59·60	−14·41	−21·50

Also combining the values in this table with the equivalent of L—**A** above determined, there result,

$$\begin{aligned}
\text{A} - \mathbf{A} &= \overset{d}{107{\cdot}34} + 2{\cdot}17\,dE_a = \overset{m.y}{148{\cdot}43} + 2{\cdot}17\,dE_a\\
\text{B} - \mathbf{A} &= 74{\cdot}59 + \quad ,, \quad = 103{\cdot}15 + \quad ,,\\
\text{C} - \mathbf{A} &= 99{\cdot}04 + \quad ,, \quad = 136{\cdot}96 + \quad ,,\\
\text{D} - \mathbf{A} &= 142{\cdot}46 + \quad ,, \quad = 197{\cdot}00 + \quad ,,\\
\text{E} - \mathbf{A} &= 88{\cdot}94 + \quad ,, \quad = 122{\cdot}99 + \quad ,,\\
\text{H} - \mathbf{A} &= 83{\cdot}81 + \quad ,, \quad = 115{\cdot}90 + \quad ,,
\end{aligned}$$

$$\text{and } 6\,x = \overset{m.y}{824{\cdot}4} + 13{\cdot}0\,dE_a.$$

Final deduction of the total length measured with the compensated bars.

From page III—7 the excess of the 6 compensated bars above 6 times **A** *before* the meast: = $\overset{m.y}{904{\cdot}5} - 36{\cdot}1\,dE_a$

" III—11 " *after* " = $824{\cdot}4 + 13{\cdot}0\,dE_a$

Therefore the mean excess of " applicable to the base-line = $864{\cdot}5 - 11{\cdot}6\,dE_a$

Also the mean length of a set of 6 compensated bars in feet of the standard = $60{\cdot}0025935\,\frac{A}{10} - 11{\cdot}6\,dE_a$

Similarly, from pages III—7 and III—11, the mean excess of the 4 compensated bars A, B, C, D above 4 times **A** } = $611{\cdot}4 \quad - 7{\cdot}7\,dE_a$

And the mean length of the set of compensated bars A, B, C, D in feet of the standard } = $40{\cdot}0018342\,\frac{A}{10} - 7{\cdot}7\,dE_a$

Hence the total lengths measured with the compensated bars

		feet of A
in sets Nos. 1 to 609	=	$36541{\cdot}5794 - 7064\,dE_a$
in set No. 609_1	=	$40{\cdot}0018 - 8\,dE_a$
in sets Nos. 1 to 609_1	=	$36581{\cdot}5812 - 7072\,dE_a$

Now the mean temperature of **A** during the above bar comparisons was $62° + \frac{11°{\cdot}6}{6}$ (or $62° + \frac{7°{\cdot}7}{4}$) $= 63°{\cdot}9$, for which temperature the corresponding expansion of **A** from page (19) is $21{\cdot}660$ *m.y*. Comparing this value of expansion with the original value = $22{\cdot}67$ *m.y* used in the foregoing; it is found, that $dE_a = +\,1{\cdot}01$ *m.y*; and substituting for dE_a this numerical value there results;—

The total length measured with the compensated bars in sets Nos. 1 to 609_1 = $(36581{\cdot}5812 - {\cdot}0214)\,\frac{A}{10}$

$$= 36581{\cdot}5598\,\frac{A}{10}$$

Comparisons between the Compensated Microscopes and their 6-inch brass scales during the measurement, and provisional determination of Microscope errors with respect to the 6-inch brass scale A, expressed in millionths of an inch (m.i.)

When compared — 1837		Microscope.	Scale compared with.	Corrected temperature.	Reduction to 62° Fah. Expansion of 6″ scale for 1° = E = 62·5 m.i.	Microscope − Microscope Scale. Observed value in terms of Divisions 10000 = 1″.	Microscope − Microscope Scale. Observed value in terms of m.i.	Micros : Scale − A, at 62° Fah.	Micros : − Scale A, at 62° Fah. m.i.	Reference number.
November 29th	Before the measurement.	*U*	*U*	82·65°	+1291	− 2·35	− 235	+ 283	+1339	1
		M	*M*	83·05	1316	·00	0	− 21	1295	2
		O	*R*	83·01	1313	·00	0	+ 93	1406	3
		P	*P*	82·76	1298	−10·10	−1010	350	638	4
		N	*N*	83·42	1339	·00	0	363	1702	5
		R	*R*	74·51	782	·00	0	93	875	6
		S	*S*	83·24	1327	·00	0	− 75	1252	7
December 6th	Between sets No. 62 and 63.	*U*	*U*	77·85	+ 991	+ 3·03	+ 303	+ 283	+1577	8
		M	*M*	78·45	1028	− 4·93	− 493	− 21	514	9
		*M**	*M*	77·05	941	+ 6·90	+ 690	21	1610	10
		O	*R*	78·71	1045	·63	+ 63	+ 93	1201	11
		P	*P*	79·26	1079	− 3·26	− 326	350	1103	12
		N	*N*	78·42	1026	+ 6·37	+ 637	363	2026	13
		R	*R*	79·31	1082	− 8·67	− 867	93	308	14
		S	*S*	77·74	984	+ 4·67	+ 467	− 75	1376	15
„ 12th	Between sets No. 133 and 134.	*U*	*U*	55·45	− 409	+16·53	+1653	+ 283	+1527	16
		*U**	*U*	63·68	+ 105	12·33	1233	283	1621	17
		M	*M*	57·45	− 284	9·83	983	− 21	678	18
		O	*R*	56·31	356	17·70	1770	+ 93	1507	19
		P	*P*	55·36	415	7·03	703	350	638	20
		N	*N*	52·92	568	16·77	1677	363	1472	21
		*N**	*N*	61·42	37	14·03	1403	363	1729	22
		R	*R*	60·31	106	·00	0	93	− 13	23
		*R**	*R*	69·11	+ 445	− 5·23	− 523	93	+ 15	24
		S	*S*	55·24	− 423	+17·33	+1733	− 75	1235	25
„ 15th	Between sets No. 181 and 182.	*U*	*U*	62·02	+ 1	+10·47	+1047	+ 283	+1331	26
		M	*M*	68·55	410	5·17	517	− 21	906	27
		O	*R*	64·76	173	10·70	1070	+ 93	1336	28
		P	*P*	62·51	32	4·12	412	350	794	29
		N	*N*	61·74	− 16	12·83	1283	363	1630	30
		R	*R*	63·11	+ 70	− 1·53	− 153	93	10	31
		S	*S*	60·24	− 110	+14·33	+1433	− 75	1248	32
„ 19th	Between sets No. 194 and 195.	*T*	*T*	46·28	− 983	+ 7·73	+ 773	− 97	− 307	33
„ 22nd	Between sets No. 252 and 253.	*U*	*U*	66·65	+ 291	+ 9·67	+ 967	+ 283	+1541	34
		M	*M*	68·45	403	6·63	663	− 21	1045	35
		O	*R*	68·08	380	7·37	737	+ 93	1210	36
		T	*T*	67·90	369	− 2·63	− 263	− 97	9	37
		N	*N*	66·42	276	+11·10	+1110	+ 363	1749	38
		R	*R*	69·71	482	− 6·60	− 660	93	− 85	39
		S	*S*	66·74	296	+11·67	+1167	− 75	+1388	40

* These microscopes were compared a second time, because they were adjusted after the first comparison.

Microscope Comparisons—(Continued.)

When compared — 1837-38		Microscope.	Scale compared with.	Corrected temperature.	Reduction to 62° Fah. Expansion of 6″ scale for 1° = E = 62·5 *m.i.*	Microscope — Microscope Scale. Observed value in terms of Divisions 10000 = 1″	*m.i.*	Micros : Scale − A, at 62° Fah.	Micros : Scale − A, at 62° Fah. *m.i.*	Reference number.
December 28th	Between sets No. 331 and 332.	*U*	*U*	° 74·92	+ 807	+ 4·03	+ 403	+ 283	+1493	41
		M	*M*	76·05	878	− 1·93	− 193	− 21	664	42
		O	*R*	75·08	817	+ 4·10	+ 410	+ 93	1320	43
		T	*T*	75·70	856	− 5·63	− 563	− 97	196	44
		N	*N*	74·62	789	+ 9·10	+ 910	+ 363	2062	45
		R	*R*	77·21	951	− 9·30	− 930	93	114	46
		S	*S*	74·24	765	+ 4·00	+ 400	− 75	1090	47
" 30th	Between sets No. 368 aud 369.	*U*	*U*	74·92	+ 807	+ 4·40	+ 440	+ 283	+1530	48
		M	*M*	75·65	853	− 2·59	− 259	− 21	573	49
		O	*R*	72·71	670	+ 4·80	+ 480	+ 93	1243	50
		T	*T*	75·35	834	− 5·63	− 563	− 97	174	51
		N	*N*	75·62	851	+ 8·90	+ 890	+ 363	2104	52
		R	*R*	76·26	891	−12·70	−1270	93	− 286	53
		S	*S*	74·74	796	+ 5·17	+ 517	− 75	+1238	54
January 3rd	"	*U*	*U*	70·31	+ 519	+ 7·17	+ 717	+ 283	+1519	55
		M	*M*	70·65	541	6·13	613	− 21	1133	56
		O	*R*	74·85	803	4·10	410	+ 93	1306	57
		T	*T*	74·00	750	− 4·10	− 410	− 97	243	58
		N	*N*	69·45	466	+11·60	+1160	+ 363	1989	59
		R	*R*	72·25	640	− 5·73	− 573	93	160	60
		S	*S*	70·24	515	+10·50	+1050	− 75	1490	61
" 9th	Between sets No. 455 and 456.	*U*	*U*	77·12	+ 945	+ 3·63	+ 363	+ 283	+1591	62
		M	*M*	77·55	972	·23	23	− 21	974	63
		O	*R*	79·11	1070	3·33	333	+ 93	1496	64
		T	*S*	79·44	1090	− 6·17	− 617	− 75	398	65
		N	*N*	75·62	851	+ 8·60	+ 860	+ 363	2074	66
		*N**	*N*	79·42	1089	5·27	527	363	1979	67
		R	*R*	78·71	1045	−11·30	−1130	93	8	68
		S	*S*	77·74	984	+ 4·50	+ 450	− 75	1359	69
" 13th	Between sets No. 539 and 540.	*U*	*U*	76·45	+ 903	+ 3·27	+ 327	+ 283	+1513	70
		M	*M*	74·15	760	2·23	223	− 21	962	71
		O	*R*	77·31	957	1·70	170	+ 93	1220	72
		T	*T*	76·80	925	− 6·40	− 640	− 97	188	73
		N	*N*	74·32	770	+ 9·05	+ 905	+ 363	2038	74
		R	*R*	74·76	798	− 7·33	− 733	93	158	75
		S	*S*	75·74	859	+ 5·50	+ 550	− 75	1334	76
" 18th	After the measurement.	*U*	*U*	67·52	+ 345	+ 7·53	+ 753	+ 283	+1381	77
		M	*M*	66·05	253	5·20	520	− 21	752	78
		O	*R*	69·31	457	8·07	807	+ 93	1357	79
		T	*T*	69·65	478	− 1·20	− 120	− 97	261	80
		N	*N*	67·42	339	+11·43	+1143	+ 363	1845	81
		R	*R*	68·21	388	− 5·93	− 593	93	− 112	82
		S	*M*	68·75	422	+ 8·07	+ 807	− 21	+1208	83

* These microscopes were compared a second time, because they were adjusted after the first comparison.

Microscope Comparisons—(Continued.)

The required combinations of individual microscope errors taken from pages III—13 and III—14, are expressed as follows;

	Reference numbers.	*m.i*	*mean temp:*	From comparisons made
$e_1 =$	$2 + 3 + 4 + 5 + 6 + \frac{1+7}{2}$	$= +\ 7212$	at (62° + 19°·62)	before the measurement.
$e_2 =$	$9 + 11 + 12 + 13 + 14 + \frac{8+15}{2}$	$= +\ 6629$	at (62 + 16·66)	between sets 62 & 63
$e_3 =$	$10 + 11 + 12 + 13 + 14 + \frac{8+15}{2}$	$= +\ 7725$	at (62 + 16·43)	„ do.
$e_4 =$	$18 + 19 + 20 + 21 + 23 + \frac{16+25}{2}$	$= +\ 5663$	at (62 − 5·72)	„ 133 & 134
$e_5 =$	$18 + 19 + 20 + 22 + 24 + \frac{17+25}{2}$	$= +\ 5995$	at (62 − 2·15)	„ do.
$e_6 =$	$27 + 28 + 29 + 30 + 31 + \frac{26+32}{2}$	$= +\ 5966$	at (62 + 1·63)	„ 181 & 182
$e_7 =$	$27 + 28 + 30 + 31 + 33 + \frac{26+32}{2}$	$= +\ 4865$	at (62 − 1·07)	„ 194 & 195
$e_8 =$	$29 + 35 + 36 + 38 + 39 + \frac{34+40}{2}$	$= +\ 6178$	at (62 + 4·98)	„ 252 & 253
$e_9 =$	$35 + 36 + 37 + 38 + 39 + \frac{34+40}{2}$	$= +\ 5393$	at (62 + 5·88)	„ do.
$e_{10} =$	$42 + 43 + 44 + 45 + 46 + \frac{41+47}{2}$	$= +\ 5648$	at (62 + 13·54)	„ 331 & 332
$e_{11} =$	$49 + 50 + 51 + 52 + 53 + \frac{48+54}{2}$	$= +\ 5192$	at (62 + 13·07)	„ 368 & 369
$e_{12} =$	$56 + 57 + 58 + 59 + 60 + \frac{55+61}{2}$	$= +\ 6336$	at (62 + 9·91)	„ do.
$e_{13} =$	$63 + 64 + 65 + 66 + 68 + \frac{62+69}{2}$	$= +\ 6425$	at (62 + 15·98)	„ 455 & 456
$e_{14} =$	$63 + 64 + 65 + 67 + 68 + \frac{62+69}{2}$	$= +\ 6330$	at (62 + 16·61)	„ do.
$e_{15} =$	$71 + 72 + 73 + 74 + 75 + \frac{70+76}{2}$	$= +\ 5990$	at (62 + 13·57)	„ 539 & 540
$e_{16} =$	$71 + 72 + 74 + \frac{70+73}{2}$	$= +\ 5071$	at (62 + 13·60)	„ do.
$e_{17} =$	$78 + 79 + 80 + 81 + 82 + \frac{77+83}{2}$	$= +\ 5398$	at (62 + 6·13)	after the measurement.
$e_{18} =$	$78 + 79 + 81 + \frac{77+80}{2}$	$= +\ 4775$	at (62 + 5·84)	„ do.

And from the foregoing, we obtain the following equations for the microscope errors per set (or *m.e.*); where dE expresses the error in the adopted value of the expansion of the 6-inch scales.

		m.i.		
$(m.e.)_1 = \frac{e_1 + e_2}{2}$	$= +\ 6921 - 6 \times 18{\cdot}14\ dE$	applicable to sets Nos.		1 to 62
$(m.e.)_2 = \frac{e_3 + e_4}{2}$	$= +\ 6694 - 6 \times 5{\cdot}36\ dE$	„	„	63 to 133
$(m.e.)_3 = \frac{e_5 + e_6}{2}$	$= +\ 5981 + 6 \times 0{\cdot}26\ dE$	„	„	134 to 181
$(m.e.)_4 = \frac{e_6 + e_8}{2}$	$= +\ 6072 - 6 \times 3{\cdot}31\ dE$	„	„	182 to 194

(Microscope errors per set (or *m.e.*) continued on next page.)

Microscope Comparisons—(Continued.)

Microscope errors per set (or *m.e.*) continued from preceding page.

$(m.e.)_5 = \frac{e_7 + e_9}{2} = + \overset{m.i.}{5129} - 6 \times 2{\cdot}41\ dE$	applicable to sets Nos.		195 to 252
$(m.e.)_6 = \frac{e_9 + e_{10}}{2} = + 5521 - 6 \times 9{\cdot}71\ dE$	„	„	253 to 331
$(m.e.)_7 = \frac{e_{10} + e_{11}}{2} = + 5420 - 6 \times 13{\cdot}31\ dE$	„	„	332 to 368
$(m.e.)_8 = \frac{e_{12} + e_{13}}{2} = + 6381 - 6 \times 12{\cdot}95\ dE$	„	„	369 to 455
$(m.e.)_9 = \frac{e_{14} + e_{15}}{2} = + 6160 - 6 \times 15{\cdot}09\ dE$	„	„	456 to 539
$(m.e.)_{10} = \frac{e_{15} + e_{17}}{2} = + 5694 - 6 \times 9{\cdot}85\ dE$	„	„	540 to 609
$(m.e.)_{11} = \frac{e_{16} + e_{18}}{2} = + 4923 - 4 \times 9{\cdot}72\ dE$	applicable to set No.		609_1

Hence the total microscope errors are as follows:—

			m.i.		feet of A
in sets Nos.	1 to 62 = 62	$(m.e.)_1$	= 429102 − 6748 dE	=	·0358 − 6748 dE
	63 to 133 = 71	$(m.e.)_2$	= 475274 − 2283 dE	=	·0396 − 2283 dE
	134 to 181 = 48	$(m.e.)_3$	= 287088 + 75 dE	=	·0239 + 75 dE
	182 to 194 = 13	$(m.e.)_4$	= 78936 − 258 dE	=	·0066 − 258 dE
	195 to 252 = 58	$(m.e.)_5$	= 297482 − 839 dE	=	·0248 − 839 dE
	253 to 331 = 79	$(m.e.)_6$	= 436159 − 4603 dE	=	·0363 − 4603 dE
	332 to 368 = 37	$(m.e.)_7$	= 200540 − 2955 dE	=	·0167 − 2955 dE
	369 to 455 = 87	$(m.e.)_8$	= 555147 − 6760 dE	=	·0463 − 6760 dE
	456 to 539 = 84	$(m.e.)_9$	= 517440 − 7605 dE	=	·0431 − 7605 dE
	540 to 609 = 70	$(m.e.)_{10}$	= 398580 − 4137 dE	=	·0332 − 4137 dE
in set No. 609_1	= 1	$(m.e.)_{11}$	= 4923 − 39 dE	=	·0004 − 39 dE

And the total microscope errors in the base-line = ·3067 −36152 dE

Microscope Comparisons—(Continued.)

Final deduction of the total lengths measured with the compensated microscopes.

Hitherto the microscope errors have been determined only provisionally: *i.e.* in terms of the 6-inch brass scale *A*. But from page (31), we have $2\ A = 1{\cdot}0000192\ \frac{\mathbf{A}}{10}$, value in 1835. Also, the co-efficient of expansion for brass, has been taken at ·000,010,417 in the foregoing reductions, whereas it appears from page (17) that ·000,009,855 is a more probable value. Accepting the latter, it may be found that $dE = 3{\cdot}372$ (*m.i*). Hence, remembering that the length measured with a set of microscopes is equal to 3 feet of *A* + the corresponding (*m.e*), we have,

Total lengths measured with the compensated microscopes

		feet of *A*		feet of **A**	
In sets Nos. 1 to 609	=	{609 × 3 + ·3063}	− 36113 *dE* =	(1827·3414 − ·0101)	= 1827·3313
In set No. 609_1	=	{1 × 2 + ·0004}	− 39 *dE* =	(2·0004 − ·0000)	= 2·0004
In sets Nos. 1 to 609_1 or South-West-End to North-East-End			=	(1829·3418 − ·0101)	= 1829·3317

Disposition of the bars and microscopes during the measurement.

The following typical illustrations show the permutations and combinations of the bars and microscopes during the measurement. The instruments are here named in the succession that actually occurred, commencing from the rear-end of a set; and the numbers assigned to the illustrations, will be found employed in the tables of "Extracts from the Field Book &c."

Bar Illustration.

No. 1	No. 2
A	A
B	B
C	C
D	D
E	
H	

Statement.

No. 1 occurs in sets Nos. 1 to 609.
No. 2 „ set No. 609_1.

Microscope Illustration.

No. 1	No. 2	No. 3
½U	½U	½U
M	M	M
O	O	O
P	T	N
N	N	½T
R	R	
½S	½S	

Statement.

No. 1 occurs in sets Nos. 1 to 194.
No. 2 „ Nos. 195 to 609.
No. 3 „ set No. 609_1

Extracts from the Field Book of the measurement, and calculated heights of sets above the origin.

Adopted heights above mean sea level.
South-West-End (origin) = 1529·4 feet.
North-East-End (terminus) = 1479·0 feet.

When compared — 1837	No. of the Set.	Temperature of Air	Mean time of ending	No. of bars used	Height of Set above origin	Numeral shewing arrangement of Bars.	Numeral shewing arrangement of Micros:	When compared — 1837	No. of the Set.	Temperature of Air	Mean time of ending	No. of bars used	Height of Set above origin	Numeral shewing arrangement of Bars.	Numeral shewing arrangement of Micros:
		°	h. m.		feet.					°	h. m.		feet.		
1st Dec.	1	53·3	6 55 A.M.	6	+ 2·2	1	1	5th Dec.	43	66·3	8 28 A.M.	6	− 17·2	1	1
	2	64·0	8 0	6	1·1	1	1		44	71·0	9 2	6	17·3	1	1
	3	71·1	8 59	6	·0	1	1		45	73·8	9 26	6	17·7	1	1
	4	75·7	9 37	6	− ·7	1	1		46	75·9	10 2	6	17·7	1	1
	5	79·3	10 25	6	1·2	1	1		47	78·2	10 30	6	18·4	1	1
	6	81·7	11 2	6	1·8	1	1		48	78·7	11 6	6	18·7	1	1
	7	82·0	1 44 P.M.	6	2·6	1	1		49	81·0	1 46 P.M.	6	19·3	1	1
	8	82·1	2 27	6	3·1	1	1		50	81·0	2 14	6	19·5	1	1
	9	82·2	3 21	6	3·2	1	1		51	81·3	2 52	6	19·9	1	1
	10	80·3	4 9	6	3·3	1	1		52	80·8	3 22	6	19·9	1	1
2nd „	11	52·0	6 54 A.M.	6	3·6	1	1		53	80·2	3 51	6	20·2	1	1
	12	58·7	7 37	6	4·3	1	1		54	79·0	4 18	6	20·4	1	1
	13	65·0	8 12	6	4·5	1	1	6th „	55	48·0	6 58	6	20·4	1	1
	14	70·7	8 42	6	5·0	1	1		56	53·7	7 34 A.M.	6	20·9	1	1
	15	75·4	9 17	6	5·3	1	1		57	60·0	8 1	6	21·1	1	1
	16	79·0	9 50	6	5·9	1	1		58	65·1	8 40	6	21·6	1	1
	17	82·7	10 31	6	6·7	1	1		59	71·3	9 16	6	21·8	1	1
	18	84·0	11 3	6	7·6	1	1		60	72·8	9 46	6	22·7	1	1
	19	84·2	1 46 P.M.	6	8·4	1	1		61	76·6	10 22	6	22·6	1	1
	20	83·6	2 18	6	8·5	1	1		62	80·5	10 59	6	22·7	1	1
	21	82·7	3 6	6	9·0	1	1	7th „	63	48·5	7 3	6	23·2	1	1
	22	82·0	3 36	6	9·5	1	1		64	54·0	7 30	6	23·6	1	1
	23	81·0	4 11	6	10·3	1	1		65	59·2	7 59	6	23·9	1	1
	24	78·2	4 39	6	10·5	1	1		66	63·7	8 30	6	24·3	1	1
4th „	25	48·1	6 47 A.M.	6	10·7	1	1		67	69·0	9 1	6	24·6	1	1
	26	52·8	7 18	6	11·0	1	1		68	73·0	9 29	6	24·8	1	1
	27	60·3	7 58	6	11·2	1	1		69	75·8	10 1	6	25·2	1	1
	28	65·7	8 22	6	11·3	1	1		70	78·1	10 26	6	25·6	1	1
	29	69·7	8 56	6	11·6	1	1		71	81·0	10 57	6	25·9	1	1
	30	73·2	9 21	6	11·9	1	1		72	81·5	1 32 P.M.	6	26·2	1	1
	31	75·2	9 52	6	12·5	1	1		73	82·0	2 1	6	26·6	1	1
	32	78·3	10 20	6	12·9	1	1		74	81·4	2 35	6	26·8	1	1
	33	80·3	10 54	6	13·1	1	1		75	80·5	2 58	6	27·0	1	1
	34	81·0	11 21	6	13·5	1	1		76	79·5	3 28	6	27·2	1	1
	35	81·8	2 0 P.M.	6	14·1	1	1		77	78·7	3 56	6	27·1	1	1
	36	81·8	2 25	6	14·4	1	1		78	77·2	4 23	6	27·1	1	1
	37	80·8	3 23	6	15·0	1	1		79	74·2	4 47	6	26·7	1	1
	38	80·0	3 59	6	14·9	1	1	8th „	80	44·5	6 45 A.M.	6	27·3	1	1
	39	78·0	4 40	6	15·2	1	1		81	48·8	7 12	6	27·6	1	1
5th „	40	48·3	6 37 A.M.	6	15·6	1	1		82	54·8	7 43	6	28·3	1	1
	41	51·4	7 13	6	16·5	1	1		83	59·1	8 7	6	28·9	1	1
	42	60·2	7 57	6	16·9	1	1		84	63·8	8 38	6	29·3	1	1

Note.—The rear-end of set No. 1 stood exactly over the dot at South-West-End.

Extracts from the Field Book—(Continued.)

When compared — 1837	No. of the Set.	Temperature of Air	Mean time of ending	No. of bars used	Height of Set above origin	Numeral shewing arrangement of: Bars.	Micros:
		°	h. m.		feet.		
8th Dec.	85	68·0	9 0 A.M.	6	— 29·5	1	1
	86	72·5	9 34	6	28·7	1	1
	87	76·0	10 2	6	27·1	1	1
	88	78·0	10 30	6	27·1	1	1
	89	80·0	10 56	6	27·0	1	1
	90	80·0	1 32 P.M.	6	27·0	1	1
	91	81·5	1 58	6	27·0	1	1
	92	82·1	2 27	6	27·2	1	1
	93	80·8	2 53	6	27·3	1	1
	94	80·7	3 19	6	27·0	1	1
	95	79·0	3 41	6	27·6	1	1
	96	77·4	4 4	6	27·8	1	1
	97	75·3	4 30	6	28·1	1	1
9th „	98	44·0	6 41 A.M.	6	28·2	1	1
	99	48·0	7 10	6	28·4	1	1
	100	54·1	7 40	6	28·3	1	1
	101	59·1	8 2	6	29·4	1	1
	102	65·0	8 35	6	29·8	1	1
	103	67·8	8 57	6	30·4	1	1
	104	72·0	9 23	6	31·1	1	1
	105	74·0	9 44	6	31·0	1	1
	106	77·3	10 22	6	29·8	1	1
	107	79·2	10 56	6	29·6	1	1
	108	81·3	1 20 P.M.	6	30·0	1	1
	109	81·4	1 44	6	30·0	1	1
	110	81·0	2 15	6	29·9	1	1
	111	80·2	2 39	6	30·2	1	1
	112	79·2	3 2	6	30·5	1	1
	113	78·1	3 22	6	30·8	1	1
	114	77·2	3 45	6	30·5	1	1
	115	76·0	4 6	6	30·5	1	1
	116	74·1	4 34	6	31·1	1	1
11th „	117	42·7	6 42 A.M.	6	31·0	1	1
	118	47·0	7 10	6	31·0	1	1
	119	53·1	7 43	6	30·3	1	1
	120	57·0	8 10	6	30·4	1	1
	121	63·0	8 43	6	29·9	1	1
	122	67·2	9 8	6	30·1	1	1
	123	71·5	9 31	6	29·6	1	1
	124	73·0	9 53	6	30·0	1	1
	125	73·3	10 24	6	30·2	1	1
	126	74·5	10 50	6	30·7	1	1
	127	76·7	1 34 P.M.	6	30·3	1	1
	128	78·0	1 58	6	30·3	1	1
	129	77·8	2 30	6	29·8	1	1
	130	76·5	2 52	6	29·6	1	1
	131	75·3	3 22	6	30·0	1	1
	132	74·0	3 52	6	30·2	1	1
11th Dec.	133	71·8	4 16 P.M.	6	— 30·7	1	1
12th „	134	76·4	1 19	6	30·6	1	1
	135	76·0	1 43	6	30·5	1	1
	136	76·3	2 14	6	31·1	1	1
	137	77·0	2 38	6	31·3	1	1
	138	76·0	3 9	6	31·7	1	1
	139	75·4	3 30	6	31·9	1	1
	140	74·0	3 56	6	32·2	1	1
	141	71·0	4 20	6	32·0	1	1
13th „	142	43·8	6 42 A.M.	6	32·4	1	1
	143	46·2	7 5	6	32·6	1	1
	144	50·0	7 36	6	33·1	1	1
	145	54·0	7 57	6	33·3	1	1
	146	58·8	8 25	6	33·6	1	1
	147	62·7	8 49	6	34·0	1	1
	148	66·8	9 18	6	34·4	1	1
	149	69·6	9 42	6	34·9	1	1
	150	71·0	10 13	6	35·1	1	1
	151	73·0	10 25	6	35·5	1	1
	152	73·5	10 52	6	35·9	1	1
	153	80·0	1 23 P.M.	6	36·4	1	1
	154	81·5	1 47	6	37·0	1	1
	155	81·2	2 14	6	37·6	1	1
	156	79·8	2 50	6	37·8	1	1
	157	78·0	3 12	6	37·9	1	1
	158	77·6	3 40	6	38·5	1	1
	159	77·5	4 7	6	38·9	1	1
	160	76·0	4 27	6	39·3	1	1
14th „	161	45·2	6 33 A.M.	6	39·9	1	1
	162	49·0	7 4	6	40·3	1	1
	163	54·0	7 35	6	40·6	1	1
	164	59·3	8 1	6	41·1	1	1
	165	64·8	8 34	6	41·6	1	1
	166	67·1	8 57	6	41·9	1	1
	167	71·0	9 25	6	42·4	1	1
	168	73·5	9 44	6	42·9	1	1
	169	75·8	10 10	6	43·4	1	1
	170	76·1	10 38	6	43·7	1	1
	171	79·0	11 4	6	43·7	1	1
	172	82·8	1 31 P.M.	6	43·9	1	1
	173	82·3	1 57	6	44·2	1	1
	174	79·1	2 24	6	44·7	1	1
	175	80·1	2 46	6	44·8	1	1
	176	80·7	3 15	6	45·0	1	1
	177	80·0	3 38	6	45·0	1	1
	178	79·0	4 5	6	45·1	1	1
	179	76·0	4 36	6	45·5	1	1
15th „	180	54·0	6 46 A.M.	6	45·8	1	1

December 14th. (161) Clouds in the East.

Extracts from the Field Book—(Continued.)

When compared — 1837	No. of the Set.	Temperature of Air	Mean time of ending	No. of bars used	Height of Set above origin	Numeral shewing arrangement of Bars.	Micros :
		°	h. m.		feet.		
15th Dec.	181	58·0	7 30 A.M.	6	— 46·2	1	1
	182	76·0	9 58	6	46·7	1	1
	183	79·2	10 36	6	47·2	1	1
	184	81·0	11 5	6	47·7	1	1
18th „	185	43·6	6 56	6	48·1	1	1
	186	56·8	8 31	6	48·8	1	1
	187	64·0	9 16	6	48·6	1	1
	188	69·5	10 3	6	48·2	1	1
	189	72·6	10 45	6	48·3	1	1
	190	77·0	1 52 P.M.	6	48·5	1	1
	191	77·0	2 35	6	48·8	1	1
	192	77·0	3 18	6	49·6	1	1
	193	75·0	4 1	6	50·2	1	1
	194	73·0	4 35	6	50·4	1	1
19th „	195	47·6	7 35 A.M.	6	49·6	1	2
	196	54·8	8 36	6	49·7	1	2
	197	63·3	9 12	6	49·9	1	2
	198	67·2	9 43	6	50·0	1	2
	199	71·0	10 16	6	50·0	1	2
	200	74·0	10 38	6	50·2	1	2
	201	76·0	11 10	6	50·4	1	2
	202	75·0	1 35 P.M.	6	50·5	1	2
	203	75·6	2 4	6	50·7	1	2
	204	76·2	2 31	6	51·1	1	2
	205	75·3	2 56	6	51·2	1	2
	206	75·0	3 25	6	51·3	1	2
	207	74·1	3 48	6	51·5	1	2
	208	73·0	4 20	6	51·7	1	2
20th „	209	40·0	6 53 A.M.	6	51·9	1	2
	210	43·3	7 20	6	52·2	1	2
	211	49·2	7 53	6	52·3	1	2
	212	53·4	8 16	6	52·6	1	2
	213	57·8	8 42	6	52·8	1	2
	214	61·2	9 4	6	52·8	1	2
	215	65·0	9 30	6	53·1	1	2
	216	66·5	9 50	6	53·4	1	2
	217	68·6	10 15	6	53·4	1	2
	218	70·3	10 40	6	53·6	1	2
	219	71·0	11 3	6	53·9	1	2
	220	72·2	1 52 P.M.	6	53·9	1	2
	221	72·1	2 13	6	54·6	1	2
	222	73·1	2 45	6	54·7	1	2
	223	73·1	3 12	6	55·2	1	2
	224	72·0	3 48	6	55·6	1	2
	225	69·8	4 14	6	56·1	1	2
	226	67·5	4 43	6	56·0	1	2
21st „	227	38·1	6 50 A.M.	6	56·4	1	2
	228	42·5	7 20	6	56·4	1	2
21st Dec.	229	47·5	7 52 A.M.	6	— 56·4	1	2
	230	52·2	8 18	6	56·6	1	2
	231	58·1	8 48	6	56·8	1	2
	232	62·3	9 12	6	56·7	1	2
	233	66·2	9 41	6	57·5	1	2
	234	68·1	10 5	6	58·0	1	2
	235	71·0	10 32	6	58·2	1	2
	236	71·5	10 54	6	58·3	1	2
	237	72·7	1 26 P.M.	6	58·5	1	2
	238	73·7	1 49	6	58·7	1	2
	239	73·3	2 18	6	59·0	1	2
	240	74·3	2 42	6	59·1	1	2
	241	73·1	3 9	6	59·1	1	2
	242	72·0	3 30	6	59·1	1	2
	243	71·4	4 6	6	58·9	1	2
	244	70·2	4 28	6	58·3	1	2
22nd „	245	37·0	6 50 A.M.	6	58·5	1	2
	246	42·8	7 25	6	58·6	1	2
	247	47·3	7 49	6	59·1	1	2
	248	52·3	8 18	6	59·9	1	2
	249	58·0	8 49	6	61·4	1	2
	250	64·7	9 27	6	62·9	1	2
	251	68·3	9 56	6	64·4	1	2
	252	71·0	10 29	6	65·4	1	2
	253	72·5	1 54 P.M.	6	66·6	1	2
	254	74·0	2 24	6	66·9	1	2
	255	74·8	2 53	6	66·8	1	2
	256	73·2	3 28	6	66·4	1	2
	257	71·8	3 54	6	66·6	1	2
	258	69·6	4 21	6	66·6	1	2
23rd „	259	36·0	6 47	6	65·7	1	2
	260	42·8	7 36	6	64·7	1	2
	261	49·8	8 13	6	62·7	1	2
	262	59·0	9 11	6	61·7	1	2
	263	64·4	9 43	6	60·4	1	2
	264	68·0	10 11	6	59·5	1	2
	265	71·3	10 43	6	59·0	1	2
	266	75·7	1 58 P.M.	6	58·8	1	2
	267	77·0	2 32	6	58·7	1	2
	268	76·5	3 2	6	58·7	1	2
	269	76·1	3 28	6	58·3	1	2
	270	75·2	3 54	6	58·3	1	2
	271	72·8	4 20	6	56·7	1	2
25th „	272	50·3	7 1 A.M.	6	55·9	1	2
	273	51·1	7 36	6	57·0	1	2
	274	55·1	8 7	6	58·0	1	2
	275	58·9	8 39	6	58·8	1	2
	276	63·7	9 9	6	59·6	1	2

December 23rd. (259) Clouds in the East.

Extracts from the Field Book—(Continued.)

When compared 1837	No. of the Set	Temperature of Air	Mean time of ending	No. of bars used	Height of Set above origin	Numeral shewing arrangement of Bars.	Micros:
		°	h. m.		feet.		
25th Dec.	277	65·8	9 35 A.M.	6	− 59·1	1	2
	278	70·9	10 8	6	58·7	1	2
	279	71·3	10 32	6	58·0	1	2
	280	73·8	10 55	6	57·7	1	2
	281	75·2	1 27 P.M.	6	57·2	1	2
	282	76·9	1 55	6	57·0	1	2
	283	74·3	2 20	6	56·6	1	2
	284	75·7	2 41	6	56·8	1	2
	285	72·0	3 12	6	56·7	1	2
	286	72·4	3 30	6	56·5	1	2
	287	72·3	3 53	6	55·8	1	2
	288	71·0	4 19	6	55·2	1	2
26th „	289	42·1	6 51 A.M.	6	54·5	1	2
	290	46·2	7 17	6	54·5	1	2
	291	50·6	7 46	6	53·9	1	2
	292	55·0	8 12	6	53·8	1	2
	293	59·6	8 45	6	53·6	1	2
	294	65·6	9 14	6	53·2	1	2
	295	70·0	9 43	6	52·9	1	2
	296	71·3	10 10	6	53·0	1	2
	297	72·3	10 31	6	52·4	1	2
	298	72·7	10 56	6	52·2	1	2
	299	73·7	1 31 P.M.	6	51·8	1	2
	300	74·3	1 59	6	51·7	1	2
	301	75·0	2 36	6	51·6	1	2
	302	74·0	3 3	6	51·0	1	2
	303	73·5	3 29	6	51·0	1	2
	304	73·2	3 49	6	51·2	1	2
	305	71·7	4 18	6	51·1	1	2
27th „	306	38·9	6 45 A.M.	6	51·3	1	2
	307	42·4	7 13	6	51·1	1	2
	308	47·1	7 44	6	50·9	1	2
	309	54·2	8 18	6	50·6	1	2
	310	60·0	8 46	6	50·5	1	2
	311	65·0	9 14	6	50·0	1	2
	312	68·3	9 38	6	50·2	1	2
	313	70·9	10 12	6	49·9	1	2
	314	73·0	10 38	6	50·1	1	2
	315	74·0	11 1	6	50·1	1	2
	316	75·0	1 34 P.M.	6	49·9	1	2
	317	76·0	1 58	6	49·9	1	2
	318	76·8	2 23	6	50·0	1	2
	319	76·1	2 53	6	50·5	1	2
	320	76·2	3 22	6	51·1	1	2
	321	75·1	3 50	6	50·7	1	2
	322	73·8	4 21	6	49·9	1	2
28th „	323	42·0	6 56 A.M.	6	49·7	1	2
	324	46·1	7 27	6	49·3	1	2

When compared 1837-38	No. of the Set.	Temperature of Air	Mean time of ending	No. of bars used	Height of Set above origin	Numeral shewing arrangement of Bars.	Micros:
		°	h. m.		feet		
28th Dec.	325	53·0	7 56 A.M.	6	− 49·5	1	2
	326	60·8	8 26	6	49·5	1	2
	327	66·1	9 0	6	49·7	1	2
	328	70·0	9 26	6	49·6	1	2
	329	73·9	9 58	6	49·5	1	2
	330	75·3	10 24	6	49·7	1	2
	331	76·0	10 56	6	49·7	1	2
	332	80·0	1 58 P.M.	6	49·6	1	2
	333	81·0	2 24	6	50·0	1	2
	334	81·0	2 50	6	50·1	1	2
	335	79·8	3 19	6	50·4	1	2
	336	78·5	3 47	6	49·7	1	2
	337	77·0	4 12	6	49·4	1	2
	338	73·8	4 37	6	49·0	1	2
29th „	339	41·7	6 44 A.M.	6	49·0	1	2
	340	44·0	7 12	6	48·9	1	2
	341	49·5	7 41	6	48·2	1	2
	342	55·3	8 7	6	47·8	1	2
	343	61·3	8 30	6	47·5	1	2
	344	66·3	8 54	6	46·7	1	2
	345	70·2	9 22	6	45·6	1	2
	346	73·3	9 49	6	45·3	1	2
	347	75·2	10 19	6	45·9	1	2
	348	75·5	10 45	6	46·3	1	2
	349	80·0	1 30 P.M.	6	45·6	1	2
	350	80·3	2 3	6	44·7	1	2
	351	80·0	2 30	6	44·2	1	2
	352	79·3	2 50	6	43·9	1	2
	353	77·1	3 46	6	43·5	1	2
	354	74·8	4 29	6	43·1	1	2
30th „	355	48·5	6 54 A.M.	6	42·6	1	2
	356	52·8	7 22	6	42·2	1	2
	357	57·8	7 53	6	41·9	1	2
	358	61·1	8 16	6	41·7	1	2
	359	65·3	8 45	6	41·2	1	2
	360	68·8	9 9	6	40·9	1	2
	361	71·0	9 38	6	41·1	1	2
	362	73·5	10 0	6	41·0	1	2
	363	75·4	10 30	6	41·1	1	2
	364	76·9	11 4	6	41·3	1	2
	365	79·7	1 38 P.M.	6	41·3	1	2
	366	79·8	2 6	6	41·5	1	2
	367	79·7	2 35	6	42·0	1	2
	368	79·3	3 13	6	42·8	1	2
3rd Jan.	369	76·0	2 20	6	43·7	1	2
	370	76·3	2 51	6	44·5	1	2
	371	75·9	3 12	6	45·2	1	2
	372	75·0	3 45	6	46·1	1	2

Extracts from the Field Book—(Continued.)

When compared — 1838	No. of the Set	Temperature of Air	Mean time of ending	No. of bars used	Height of Set above origin	Numeral shewing arrangement of Bars.	Numeral shewing arrangement of Micros:
		°	h. m.		feet		
3rd Jan.	373	73·9	4 13 P.M.	6	— 46·6	1	2
	374	71·2	4 42	6	47·2	1	2
4th "	375	40·2	6 57 A.M.	6	47·7	1	2
	376	43·0	7 24	6	48·3	1	2
	377	47·5	7 52	6	48·6	1	2
	378	53·0	8 19	6	48·9	1	2
	379	58·9	8 45	6	49·4	1	2
	380	64·0	9 9	6	50·0	1	2
	381	69·2	9 40	6	50·5	1	2
	382	72·0	10 10	6	51·2	1	2
	383	73·0	10 32	6	51·9	1	2
	384	74·5	11 2	6	52·4	1	2
	385	78·8	1 54 P.M.	6	52·6	1	2
	386	79·0	2 21	6	53·0	1	2
	387	80·0	2 51	6	53·1	1	2
	388	80·5	3 15	6	53·4	1	2
	389	78·4	3 48	6	53·8	1	2
	390	77·2	4 12	6	54·1	1	2
	391	74·3	4 42	6	54·2	1	2
5th "	392	39·5	6 54 A.M.	6	54·8	1	2
	393	43·5	7 24	6	54·9	1	2
	394	50·0	7 56	6	55·4	1	2
	395	55·2	8 25	6	55·6	1	2
	396	61·2	8 51	6	55·7	1	2
	397	67·0	9 21	6	56·0	1	2
	398	70·3	9 57	6	56·6	1	2
	399	73·6	10 20	6	56·8	1	2
	400	77·2	10 50	6	56·6	1	2
	401	79·3	1 48 P.M.	6	56·8	1	2
	402	79·4	2 16	6	57·0	1	2
	403	80·2	2 41	6	57·5	1	2
	404	80·0	3 4	6	57·2	1	2
	405	79·7	3 32	6	57·4	1	2
	406	79·3	3 53	6	57·6	1	2
	407	77·3	4 15	6	57·8	1	2
	408	75·5	4 38	6	57·8	1	2
6th "	409	39·3	6 55 A.M.	6	57·8	1	2
	410	44·5	7 25	6	57·7	1	2
	411	50·3	7 56	6	58·1	1	2
	412	56·1	8 20	6	58·2	1	2
	413	61·7	8 49	6	58·1	1	2
	414	66·3	9 17	6	57·6	1	2
	415	71·2	9 47	6	57·3	1	2
	416	73·7	10 10	6	57·5	1	2
	417	75·3	10 36	6	57·9	1	2
	418	76·8	10 59	6	58·0	1	2
	419	81·1	1 32 P.M.	6	58·0	1	2
	420	82·0	1 58	6	57·3	1	2

When compared — 1838	No. of the Set	Temperature of Air	Mean time of ending	No. of bars used	Height of Set above origin	Numeral shewing arrangement of Bars.	Numeral shewing arrangement of Micros:
		°	h. m.		feet		
6th Jan.	421	81·8	2 25 P.M.	6	— 57·0	1	2
	422	81·3	2 50	6	57·4	1	2
	423	81·0	3 19	6	57·5	1	2
	424	80·5	3 42	6	57·3	1	2
	425	78·3	4 11	6	57·4	1	2
	426	77·0	4 36	6	57·2	1	2
	427	73·0	5 4	6	57·4	1	2
8th "	428	45·0	6 49 A.M.	6	57·6	1	2
	429	48·5	7 35	6	57·3	1	2
	430	55·0	8 6	6	57·3	1	2
	431	60·1	8 28	6	57·6	1	2
	432	64·5	8 54	6	57·6	1	2
	433	68·1	9 24	6	57·8	1	2
	434	71·2	9 48	6	58·2	1	2
	435	72·2	10 8	6	58·5	1	2
	436	75·0	10 31	6	58·8	1	2
	437	76·2	10 54	6	58·9	1	2
	438	81·4	1 45 P.M.	6	59·1	1	2
	439	82·5	2 9	6	59·4	1	2
	440	82·3	2 40	6	59·4	1	2
	441	82·5	3 3	6	59·5	1	2
	442	82·3	3 28	6	59·7	1	2
	443	81·2	3 50	6	60·0	1	2
	444	79·2	4 16	6	60·2	1	2
	445	76·3	4 44	6	60·3	1	2
9th "	446	45·4	6 56 A.M.	6	59·8	1	2
	447	47·8	7 21	6	60·1	1	2
	448	54·0	7 58	6	60·2	1	2
	449	58·3	8 23	6	60·4	1	2
	450	62·2	8 48	6	60·4	1	2
	451	66·0	9 9	6	60·2	1	2
	452	69·0	9 38	6	60·5	1	2
	453	71·0	10 0	6	60·4	1	2
	454	73·8	10 30	6	60·3	1	2
	455	75·4	10 52	6	60·1	1	2
	456	80·5	2 21 P.M.	6	60·1	1	2
	457	81·0	2 52	6	59·8	1	2
	458	80·3	3 24	6	60·3	1	2
	459	79·8	3 46	6	60·3	1	2
	460	78·2	4 12	6	60·2	1	2
	461	76·0	4 31	6	59·7	1	2
	462	72·6	4 55	6	59·1	1	2
10th "	463	36·6	6 54 A.M.	6	58·9	1	2
	464	40·3	7 19	6	59·2	1	2
	465	45·8	7 48	6	59·2	1	2
	466	50·8	8 12	6	58·6	1	2
	467	55·0	8 36	6	58·2	1	2
	468	59·2	8 56	6	57·5	1	2

Extracts from the Field Book—(Continued.)

When compared — 1838	No. of the Set.	Temperature of Air	Mean time of ending	No. of bars used	Height of Set above origin	Numeral shewing arrangement of Bars.	Numeral shewing arrangement of Micros:	When compared — 1838	No. of the Set.	Temperature of Air	Mean time of ending	No. of bars used	Height of Set above origin	Numeral shewing arrangement of Bars.	Numeral shewing arrangement of Micros:
		°	h. m.		feet.					°	h. m.		feet.		
10th Jan.	469	63·5	9 22 A.M.	6	− 56·8	1	2	12th Jan.	517	78·7	1 32 P.M.	6	− 47·7	1	2
	470	65·0	9 41	6	56·4	1	2		518	81·0	1 53	6	47·5	1	2
	471	67·6	10 3	6	56·4	1	2		519	82·0	2 15	6	47·2	1	2
	472	70·2	10 27	6	55·6	1	2		520	82·9	2 33	6	47·3	1	2
	473	71·2	10 51	6	55·3	1	2		521	82·2	2 54	6	47·2	1	2
	474	77·5	1 53 P.M.	6	54·3	1	2		522	80·2	3 14	6	47·6	1	2
	475	78·2	2 17	6	53·2	1	2		523	80·3	3 38	6	47·7	1	2
	476	78·8	2 44	6	52·5	1	2		524	79·1	3 57	6	47·4	1	2
	477	78·8	3 8	6	52·3	1	2		525	77·5	4 19	6	47·6	1	2
	478	78·0	3 34	6	52·2	1	2		526	76·0	4 39	6	47·3	1	2
	479	77·5	3 56	6	52·7	1	2		527	73·6	5 0	6	47·5	1	2
	480	74·4	4 20	6	53·2	1	2	13th „	528	38·5	6 55 A.M.	6	47·6	1	2
	481	72·0	4 40	6	52·7	1	2		529	40·6	7 18	6	47·7	1	2
	482	70·0	5 4	6	51·9	1	2		530	45·2	7 43	6	48·2	1	2
11th „	483	37·7	6 52 A.M.	6	52·0	1	2		531	50·1	8 4	6	48·7	1	2
	484	40·5	7 13	6	51·8	1	2		532	55·1	8 27	6	49·5	1	2
	485	45·2	7 39	6	51·6	1	2		533	60·2	8 49	6	49·7	1	2
	486	49·6	8 0	6	51·7	1	2		534	64·2	9 14	6	49·5	1	2
	487	54·8	8 25	6	52·2	1	2		535	68·2	9 35	6	48·7	1	2
	488	59·4	8 47	6	52·6	1	2		536	72·0	9 58	6	47·3	1	2
	489	64·0	9 9	6	51·9	1	2		537	74·5	10 19	6	46·5	1	2
	490	68·3	9 36	6	50·9	1	2		538	76·7	10 39	6	46·0	1	2
	491	71·0	10 0	6	50·5	1	2		539	79·0	11 0	6	45·2	1	2
	492	72·0	10 18	6	50·8	1	2		540	81·0	2 7 P.M.	6	44·6	1	2
	493	74·0	10 44	6	51·4	1	2		541	81·7	2 31	6	44·1	1	2
	494	75·3	11 2	6	51·7	1	2		542	82·1	2 56	6	43·6	1	2
	495	78·2	1 30 P.M.	6	51·1	1	2		543	81·3	3 16	6	43·2	1	2
	496	80·0	2 3	6	50·7	1	2		544	80·0	3 38	6	43·0	1	2
	497	80·6	2 27	6	50·4	1	2		545	79·0	4 2	6	42·2	1	2
	498	80·0	2 48	6	50·8	1	2		546	77·8	4 24	6	41·7	1	2
	499	80·0	3 9	6	50·8	1	2		547	76·0	4 48	6	41·5	1	2
	500	79·5	3 31	6	50·4	1	2	15th „	548	39·6	7 1 A.M.	6	41·1	1	2
	501	77·2	3 58	6	49·9	1	2		549	41·3	7 25	6	40·6	1	2
	502	76·2	4 17	6	49·5	1	2		550	46·0	7 52	6	40·7	1	2
	503	73·2	4 41	6	49·5	1	2		551	51·3	8 16	6	40·7	1	2
	504	70·2	5 2	6	49·7	1	2		552	58·1	8 42	6	40·8	1	2
12th „	505	37·1	6 56 A.M.	6	49·5	1	2		553	63·3	9 3	6	41·0	1	2
	506	41·1	7 25	6	49·2	1	2		554	68·0	9 28	6	41·5	1	2
	507	47·0	7 50	6	48·9	1	2		555	71·0	9 50	6	41·1	1	2
	508	54·2	8 20	6	48·7	1	2		556	74·6	10 13	6	41·6	1	2
	509	58·8	8 46	6	48·3	1	2		557	77·0	10 33	6	41·9	1	2
	510	63·0	9 11	6	48·0	1	2		558	79·4	11 3	6	42·2	1	2
	511	66·4	9 26	6	47·5	1	2		559	83·7	1 31 P.M.	6	42·7	1	2
	512	69·2	9 45	6	47·3	1	2		560	83·3	1 55	6	42·9	1	2
	513	71·3	10 3	6	46·9	1	2		561	84·2	2 31	6	43·0	1	2
	514	73·6	10 24	6	47·1	1	2		562	84·0	2 55	6	42·4	1	2
	515	74·7	10 47	6	47·3	1	2		563	82·3	3 20	6	41·8	1	2
	516	76·8	11 8	6	47·5	1	2		564	81·0	3 41	6	41·5	1	2

Extracts from the Field Book—(Continued.)

When compared 1838	No. of the Set.	Temperature of Air	Mean time of ending	No. of bars used	Height of Set above origin	Numeral shewing arrangement of Bars.	Numeral shewing arrangement of Micros:
		°	h. m.		feet.		
15th Jan.	565	80·5	4 8 P.M.	6	— 40·8	1	2
	566	80·0	4 31	6	40·3	1	2
	567	74·0	4 59	6	40·3	1	2
16th „	568	42·7	6 51 A.M.	6	40·6	1	2
	569	45·2	7 16	6	40·8	1	2
	570	47·0	7 39	6	41·3	1	2
	571	52·3	8 3	6	41·5	1	2
	572	58·0	8 25	6	41·5	1	2
	573	64·0	8 52	6	41·4	1	2
	574	68·2	9 13	6	41·5	1	2
	575	71·0	9 38	6	41·3	1	2
	576	73·8	10 0	6	41·1	1	2
	577	77·3	10 31	6	40·7	1	2
	578	79·0	10 54	6	41·1	1	2
	579	82·2	11 24	6	40·8	1	2
	580	86·8	2 41 P.M.	6	40·6	1	2
	581	86·0	3 4	6	40·7	1	2
	582	85·0	3 32	6	41·1	1	2
	583	83·3	3 57	6	40·5	1	2
	584	81·6	4 25	6	40·2	1	2
	585	78·8	4 50	6	40·0	1	2
17th „	586	45·7	6 55 A.M.	6	40·5	1	2
	587	48·0	7 20	6	40·1	1	2
	588	51·0	7 46	6	40·0	1	2
17th Jan.	589	55·0	8 8 A.M.	6	— 40·3	1	2
	590	60·2	8 31	6	40·6	1	2
	591	65·1	8 56	6	39·8	1	2
	592	68·2	9 20	6	39·9	1	2
	593	71·2	9 45	6	39·9	1	2
	594	74·2	10 9	6	40·0	1	2
	595	76·2	10 35	6	39·9	1	2
	596	78·0	10 58	6	38·8	1	2
	597	82·0	1 13 P.M.	6	37·8	1	2
	598	82·1	1 34	6	37·5	1	2
	599	82·4	1 55	6	36·8	1	2
	600	82·1	2 15	6	36·4	1	2
	601	82·0	2 33	6	35·9	1	2
	602	81·6	2 50	6	35·6	1	2
	603	81·3	3 9	6	35·2	1	2
	604	81·0	3 25	6	35·2	1	2
	605	80·0	3 45	6	34·5	1	2
	606	79·2	4 0	6	34·3	1	2
	607	78·0	4 20	6	34·1	1	2
	608	76·6	4 35	6	34·4	1	2
	609	73·5	5 0	6	33·9	1	2
18th „	609_1	64·0	9 5 A.M.	4	31·8	2	3
				Total	— 26500·8		

The advanced-end of set No. 609_1 fell in defect, (*i. e.* south) of the dot at North-East-End, 5·3567 feet, as measured on Cary's brass scale with a beam compass.

Height of set No. 609_1 above North-East-End = 2·1 feet.

Reduction to Mean Sea Level.

In the notation of page I—22 we have

$\lambda = 38416$; Log $R = 7{\cdot}31987$; $H = 1529$; $[h]_1^p = -26500{\cdot}8$; $a = 10{\cdot}6$; $\delta h = -16{\cdot}5$, all in feet; and $n = 609$.

Hence from the equation $C_1 + C_2 = -\lambda\frac{H}{R} - \frac{63}{R}\left\{[h]_1^p + a + \frac{(n+1)}{2}\delta h\right\}$, see page I—21, we obtain in feet,

$$C_1 = -2{\cdot}8122;\ C_2 = +0{\cdot}0951;\ \text{and} \therefore\ C = C_1 + C_2 = -2{\cdot}7171.$$

Final length of the base-line in feet of Standard A.

Measured with the compensated bars,	page III—12	=	36581·5598
„ „ microscopes,	page III—17	=	1829·3317
„ beam compass,	page III—24	=	5·3567
Reduction to sea level as above		= −	2·7171
Length South-West-End to North-East-End at mean sea level		=	38413·5311
	Log.	=	4·58448423

NOTE.—(1) A correction of + 0·005 feet was accidentally lost sight of at the time of deducing this length. Referring to this quantity, Colonel Everest remarks at page 277 of his Meridional Arc of India 1847, that "the small correction of 0·005 of a foot which is "applied to this measurement, is due to the circumstance that the angles about the base were observed in the years 1836-37 with the upper "marks of the platform in their existing positions, which upper marks, on subsequent reference to the lower ones embedded in the earth, "shewed small discrepancies, and it was found to involve less computation to reduce the measured base to the positions used in 1836-37 "than to correct the angles about the base."

As the omission was not recollected until a considerable amount of calculations based on the length here adopted had been completed; it was considered unnecessary to incur the numerous arithmetical alterations involved, especially since the correction is only $\frac{\cdot 005}{38414}$ or 0·1 millionth part of the base-line. The length of the base-line is therefore accepted at the value given above.

(2) The limiting points of the base-line adopted in the foregoing measurement (of 1837) are practically identical with those laid down by Captain Everest in 1825 when he obtained the length of this line by measuring with a chain. The value obtained on the latter occasion when expressed in terms of Standard A is 38410·543 feet (see Everest's *Arc Book of* 1847, foot note p. xxxiii) being 2·988 feet in defect of the final value above deduced.

Description of Stations.

SOUTH-WEST-END OF SIRONJ BASE, Lat. 24° 5′, Long. 77° 48′, is situated on the lands of the village of Parsora, in pargana Sironj of the territories of the Nawab of Tonk. The circumjacent villages, with their distances and bearings, are as follows:—Parsora, 1·1 miles E.; Rasali, 3·5 miles N.N.W.; Eklaod and Kachpura, 3·0 miles N.E.; Bania Dhana and Ekodia, 1·3 miles S.E.

The station is marked by a prismatic stone, having a circle and dot engraved on the upper surface, sunk endwise to a level with the surface of the ground. Over this stands a pillar of masonry 2 feet high, and 4 feet in diameter, having a mark-stone in its upper surface with the usual circle and dot engraved on it adjusted normally over the lower mark. The whole is enclosed by a square pile of earth. The lowest dot is the one that was used in the measurement of this base-line.

The South-West-End was connected in 1861, by a double line of spirit levels, with the mean sea level at Karachi, when it was found that the height of the upper markstone was 1531·36 feet above this datum.

NORTH-EAST-END OF SIRONJ BASE, Lat. 24° 9′, Long. 77° 53′, stands on the lands of the village of Rájpúr, in pargana Sironj of the territories of the Nawab of Tonk. The circumjacent villages, with their distances and bearings, are,—Rájpúr, 0·7 miles E.; Tal Barodia, 1·5 miles N.E.; Thanarpúr Binchakeri, 1·2 miles E.S.E.; and Sialpúr, 1·7 miles S.

The station is marked precisely after the method adopted for the South-West-End Station.

J. B. N. HENNESSEY.

BIDER BASE-LINE.

The middle point of the base-line is in Latitude N. 17° 56′ Longitude E. 77° 37′ Azimuth of East-End at West-End 305° 51′. Length 7·87 miles.

The measurement was effected under the directions of Lieutenant A. S. Waugh, R.E., with the aid of the following Officers and Assistants.

Lieutenant T. Renny, R.E.
" W. S. Jacob, R.E.
Mr. G. Logan.
" J. Olliver.
" T. Olliver.
" G. Terry.
" N. Parsick.
" J. Rossenrode.
" — DaCosta.
Mir Siud Mohsin.

INTRODUCTION.

This base-line was measured in the valley of the Manjra River near the town and fortress of Bider, from which the West-End is distant about 2 miles to the North. The line was selected and prepared for measurement by Lieutenant A. S. Waugh, R.E., who in the first instance endeavoured to search out the extremities of the base-line measured with a chain in this vicinity by Colonel Lambton in the year 1815; but as no traces of the old line could be discovered, the intention of including it in the new line and determining its length with the compensated apparatus was necessarily relinquished.

The measurement was commenced at the West-End, bar-tongues pointing North, and carried on *continuously* to the East-End, so that every succeeding set originated at the point marking the terminus of its predecessor. The line was divided into 3 sections by the subdividing points A and B, to admit of verification by Minor Triangulation.

Fifty-seven comparisons were made between the compensated bars and the standard **A** before the measurement was commenced and as many more after it was completed. On the first occasion the site selected was very near the West-End of the base, the comparing piers of granite were set up *parallel* to the line, and the bar-tongues pointed *North*, as they did during measurement. The spot chosen for the after comparisons was in the low-grounds bordering the little streamlet near the village of Malgi; the piers were set up as before *parallel* to the line, but in order to obtain a more favorable light the ends of the bars were reversed so that their tongues now pointed *South*.

Of the two comparing microscopes employed in the preceding bar comparisons, one was fitted with a micrometer while the other had its wires (or lines) fixed.

The compensated microscopes were compared with their scales on 7 occasions, including the comparisons taken prior and subsequent to the measurement.

In respect to time, the first set of bar comparisons was made on the 12th October 1841, the last on the 8th of the following December.

The stations of the verificatory triangulation were 7 in number, forming a single series of triangles. Of these stations 4 were in the alignment, *viz.*, W. End, A, B and E. End; while the auxiliary stations α, β and γ were selected on suitable prominences south of the line. The angles were observed with Troughton's 3-foot theodolite, the mean being derived from 24 measures taken in equal numbers at 8 equidistant zeros.

Comparisons between the Standard Bar **A** *and the Compensated Bars* A, B, C, D, E, H, *made at Bapur, or West-End of the base-line, before the measurement.*

Micrometer Readings in Divisions: 1 Division = $\frac{1}{20069{\cdot}67}$ Cary's Inch [7.8] = 1·3833 m.y of **A**

1841 Octr.	Mean of the times of observing **A**	No. of comparison.	Temperature of Air.	Corrected mean temperature of **A**	Mean **A**	A	B	C	D	E	H	Mean of the compensated bars	Remarks.
	h. m.		°	°	+	+	+	+	+	+	+	+	
12th	7 36 A.M.	1	75·9	69·97	118·0	119·2	100·9	118·3	136·4	110·6	106·1	115·3	Sky clear, with a few cirri here and there.
	8 12	2	78·7	71·65	145·5	116·9	96·4	115·8	134·6	112·9	102·6	113·2	
	8 44	3	80·8	73·65	177·6	116·0	96·3	114·3	134·8	114·1	102·9	113·1	
	9 14	4	82·4	75·75	210·0	113·2	93·7	117·0	136·9	113·8	104·1	113·1	
	9 42	5	84·2	77·47	239·0	111·2	92·1	114·0	134·9	113·4	102·2	111·3	Lt. Waugh, at the micrometer microscope; Lt. Renny at the plain microscope.
	10 8	6	85·5	79·12	264·7	107·7	89·1	113·4	133·3	113·4	101·0	109·7	
	10 35	7	86·2	80·75	289·7	107·3	89·2	110·9	132·1	111·9	100·0	108·6	
	11 2	8	87·1	82·27	312·7	106·8	89·7	110·9	131·0	112·1	97·9	108·1	
	1 40 P.M.	9	89·1	87·35	384·3	105·0	91·8	115·4	128·8	104·6	93·9	106·6	
	2 7	10	89·0	87·82	389·8	102·8	89·0	114·1	128·3	106·3	93·1	105·6	
	2 34	11	89·1	88·07	394·6	104·1	90·4	114·9	131·9	104·7	91·7	106·3	
	3 2	12	88·9	88·32	398·0	104·3	91·9	117·5	128·4	101·6	89·0	105·5	
	3 28	13	88·6	88·55	397·5	102·8	89·6	116·2	129·3	100·1	88·0	104·3	Afternoon warm, strong gusts of wind occasionally; a few clouds.
	3 56	14	87·8	88·60	394·6	102·2	89·0	114·9	129·3	99·9	87·3	103·8	
	4 24	15	86·9	88·35	390·9	101·9	88·6	116·8	130·0	101·1	89·0	104·6	
	4 51	16	85·8	87·95	383·9	106·9	91·1	117·8	127·1	96·9	87·0	104·5	
	5 19	17	84·3	87·35	371·1	102·7	92·7	116·9	128·3	98·9	87·0	104·4	
13th	6 31 A.M.	18	70·3	69·62	68·8	75·1	65·2	86·6	99·4	66·1	64·9	76·2	A few clouds towards the E. & S. horizon, the rest of the sky clear. Sky overcast with clouds.
	7 0	19	72·8	69·75	72·0	80·2	62·3	90·8	97·8	69·0	64·2	77·4	
	7 27	20	75·1	70·40	83·0	79·0	57·7	85·0	96·6	65·1	63·5	74·5	
	7 53	21	76·4	71·22	97·7	79·9	58·3	83·1	96·8	66·9	61·8	74·5	
	8 16	22	77·5	72·10	111·6	78·0	56·0	80·4	95·3	67·1	61·6	73·1	
	8 41	23	78·6	73·15	128·0	73·2	51·3	82·1	92·8	64·0	60·1	70·6	
	9 4	24	79·8	74·20	145·1	69·8	51·6	74·9	91·1	65·0	59·2	68·7	
	9 26	25	81·4	75·30	163·4	68·9	49·0	74·1	91·9	63·0	58·2	67·5	
	9 50	26	82·9	76·60	185·6	66·2	50·2	74·0	91·8	67·1	57·1	67·7	
	10 15	27	83·4	78·07	207·6	65·3	50·2	70·6	93·2	65·0	56·8	66·9	
	10 38	28	84·8	79·40	227·1	62·2	47·0	69·2	90·0	62·3	55·1	64·3	
	1 24 P.M.	29	87·5	85·65	333·4	76·3	66·4	94·4	111·0	83·1	70·8	83·7	
	1 56	30	87·0	86·07	340·1	81·2	68·1	91·2	109·7	80·0	69·1	83·2	
	2 23	31	86·6	86·27	341·2	80·7	72·5	96·0	108·1	79·0	68·0	84·1	
	2 48	32	86·3	86·35	341·0	80·1	68·1	89·8	110·5	78·8	65·7	82·2	
	3 12	33	85·9	86·35	340·2	79·3	64·0	95·0	107·9	80·6	66·0	82·1	
	3 37	34	85·8	86·30	338·8	77·0	70·2	94·8	109·0	77·7	66·0	82·5	
	4 4	35	85·8	86·17	336·9	81·5	71·7	96·3	110·1	76·7	68·0	84·1	
	4 32	36	85·5	86·02	332·2	80·0	69·1	95·4	106·8	72·7	67·0	81·8	
	5 2	37	84·2	85·82	326·2	79·2	71·0	91·2	107·7	77·0	65·8	82·0	

Before the measurement—(Continued.)

1841 Octr.	Mean of the times of observing A		No. of comparison.	Temperature of Air.	Corrected mean temperature of A	Micrometer Readings in Divisions 1 Division = $\frac{1}{20069 \cdot 67}$ Car'y Inch [7.8] = 1·3833 m.y of A — Mean A	A	B	C	D	E	H	Mean of the compensated bars	Remarks.
	h. m.			°	°	+	+	+	+	+	+	+	+	
14th	6 25	A.M.	38	71·5	70·97	67·6	55·2	39·0	59·6	77·1	43·1	43·9	53·0	
	6 52		39	73·0	71·17	70·5	56·1	39·2	58·1	77·4	43·0	42·6	52·7	
	7 18		40	74·9	71·60	78·4	52·8	34·1	60·3	75·0	45·0	41·5	51·5	
	7 42		41	77·1	72·27	90·0	53·8	34·0	54·4	72·3	46·0	41·3	50·3	
	8 ·4		42	79·1	73·15	104·6	53·3	33·5	56·9	76·1	44·6	40·8	50·9	
	8 27		43	80·4	74·25	122·8	48·7	34·8	53·7	76·7	44·8	40·1	49·8	
	8 51		44	81·5	75·52	143·4	51·5	32·8	59·1	75·1	44·8	41·8	50·9	
	9 15		45	82·8	76·90	163·8	47·0	32·0	53·8	73·3	46·1	38·8	48·5	
	9 41		46	83·8	78·27	183·4	46·6	29·3	51·6	70·2	46·5	35·8	46·7	
	10 8		47	85·1	79·67	205·1	49·0	27·2	51·6	70·4	45·3	37·0	46·8	
	10 34		48	86·2	81·07	228·4	46·8	29·2	51·3	72·1	42·8	38·5	46·8	
	1 25	P.M.	49	88·6	87·22	318·6	41·2	33·1	54·1	73·0	47·2	32·1	46·8	
	1 47		50	87·8	87·47	323·5	47·1	31·1	55·2	74·6	47·8	34·7	48·4	
	2 8		51	87·2	87·57	323·3	46·6	34·8	58·0	74·8	47·1	35·7	49·5	
	2 31		52	86·9	87·55	319·9	47·3	37·0	61·2	72·7	44·5	37·3	50·0	
	2 57		53	86·7	87·45	318·6	49·2	36·0	58·3	74·7	45·0	37·3	50·1	
	3 25		54	86·3	87·32	317.2	47·8	37·6	58·0	74·1	43·0	35·1	49·3	
	3 51		55	85·7	87·07	311·3	45·5	37·6	58·8	75·9	41·7	35·0	49·1	
	4 18		56	84·8	86·70	302·9	47·0	35·2	60·2	74·1	40·1	30·8	47·9	
	4 46		57	83·8	86·20	292·4	46·0	30·7	59·7	72·7	36·4	27·2	45·5	
			Means		80·65	246·80	75·84	60·69	84·35	100·62	72·41	63·84	76·29	

Before the measurement—(Continued.)

Let the mean length of the compensated bars minus the Standard **A** at 62° *F.* be denoted by x, and the observed excess of the compensated bars by δ when the temperature of **A** is $t°$. Then, the expansion of **A** for 1° being $(E_a - dE_a)$, we have

$$x - (t° - 62°)\,(E_a - dE_a) - \delta = 0$$

Treating the preceding bar comparisons as shewn in this equation, we obtain the following series of results :—

$x - 7{\cdot}97$	$(E_a - dE_a)$	$+\ 2{\cdot}7 = 0$	$x - 24{\cdot}07$	$(E_a - dE_a)$	$+256{\cdot}9 = 0$
$x - 9{\cdot}65$	„	$+\ 32{\cdot}3 = 0$	$x - 24{\cdot}27$	„	$+257{\cdot}1 = 0$
$x - 11{\cdot}65$	„	$+\ 64{\cdot}5 = 0$	$x - 24{\cdot}35$	„	$+258{\cdot}8 = 0$
$x - 13{\cdot}75$	„	$+\ 96{\cdot}9 = 0$	$x - 24{\cdot}35$	„	$+258{\cdot}1 = 0$
$x - 15{\cdot}47$	„	$+127{\cdot}7 = 0$	$x - 24{\cdot}30$	„	$+256{\cdot}3 = 0$
$x - 17{\cdot}12$	„	$+155{\cdot}0 = 0$	$x - 24{\cdot}17$	„	$+252{\cdot}8 = 0$
$x - 18{\cdot}75$	„	$+181{\cdot}1 = 0$	$x - 24{\cdot}02$	„	$+250{\cdot}4 = 0$
$x - 20{\cdot}27$	„	$+204{\cdot}6 = 0$	$x - 23{\cdot}82$	„	$+244{\cdot}2 = 0$
$x - 25{\cdot}35$	„	$+277{\cdot}7 = 0$	$x - 8{\cdot}97$	„	$+\ 14{\cdot}6 = 0$
$x - 25{\cdot}82$	„	$+284{\cdot}2 = 0$	$x - 9{\cdot}17$	„	$+\ 17{\cdot}8 = 0$
$x - 26{\cdot}07$	„	$+288{\cdot}3 = 0$	$x - 9{\cdot}60$	„	$+\ 26{\cdot}9 = 0$
$x - 26{\cdot}32$	„	$+292{\cdot}5 = 0$	$x - 10{\cdot}27$	„	$+\ 39{\cdot}7 = 0$
$x - 26{\cdot}55$	„	$+293{\cdot}2 = 0$	$x - 11{\cdot}15$	„	$+\ 53{\cdot}7 = 0$
$x - 26{\cdot}60$	„	$+290{\cdot}8 = 0$	$x - 12{\cdot}25$	„	$+\ 73{\cdot}0 = 0$
$x - 26{\cdot}35$	„	$+286{\cdot}3 = 0$	$x - 13{\cdot}52$	„	$+\ 92{\cdot}5 = 0$
$x - 25{\cdot}95$	„	$+279{\cdot}4 = 0$	$x - 14{\cdot}90$	„	$+115{\cdot}3 = 0$
$x - 25{\cdot}35$	„	$+266{\cdot}7 = 0$	$x - 16{\cdot}27$	„	$+136{\cdot}7 = 0$
$x - 7{\cdot}62$	„	$-\ 7{\cdot}4 = 0$	$x - 17{\cdot}67$	„	$+158{\cdot}3 = 0$
$x - 7{\cdot}75$	„	$-\ 5{\cdot}4 = 0$	$x - 19{\cdot}07$	„	$+181{\cdot}6 - 0$
$x - 8{\cdot}40$	„	$+\ 8{\cdot}5 = 0$	$x - 25{\cdot}22$	„	$+271{\cdot}8 = 0$
$x - 9{\cdot}22$	„	$+\ 23{\cdot}2 = 0$	$x - 25{\cdot}47$	„	$+275{\cdot}1 = 0$
$x - 10{\cdot}10$	„	$+\ 38{\cdot}5 = 0$	$x - 25{\cdot}57$	„	$+273{\cdot}8 = 0$
$x - 11{\cdot}15$	„	$+\ 57{\cdot}4 = 0$	$x - 25{\cdot}55$	„	$+269{\cdot}9 = 0$
$x - 12{\cdot}20$	„	$+\ 76{\cdot}4 = 0$	$x - 25{\cdot}45$	„	$+268{\cdot}5 = 0$
$x - 13{\cdot}30$	„	$+\ 95{\cdot}9 = 0$	$x - 25{\cdot}32$	„	$+267{\cdot}9 = 0$
$x - 14{\cdot}60$	„	$+117{\cdot}9 = 0$	$x - 25{\cdot}07$	„	$+262{\cdot}2 = 0$
$x - 16{\cdot}07$	„	$+140{\cdot}7 = 0$	$x - 24{\cdot}70$	„	$+255{\cdot}0 = 0$
$x - 17{\cdot}40$	„	$+162{\cdot}8 = 0$	$x - 24{\cdot}20$	„	$+246{\cdot}9 = 0$
$x - 23{\cdot}65$	„	$+249{\cdot}7 = 0$			

Before the measurement—(Continued.)

And from the mean of these results,

$$x = -\overset{d}{170{\cdot}51} + 18{\cdot}65\,(E_a - dE_a):$$

adopting the original value of the expansion of **A** given at page (9),

$$E_a = \overset{m.y}{22{\cdot}67} = \overset{d}{16{\cdot}388},$$

$$\text{and } x = \overset{d}{135{\cdot}13} - 18{\cdot}65\,dE_a = \overset{m.y}{186{\cdot}93} - 18{\cdot}65\,dE_a = \mathrm{L} - \mathbf{A};$$

where L denotes the mean length of the compensated bars obtained from *all* the comparisons, as represented by the mean micrometer reading $\overset{d}{76{\cdot}29}$, page IV—5

Comparing this reading with the mean reading of each compensated bar given on the same page we obtain the following:—

In terms of	A − L	B − L	C − L	D − L	E − L	H − L
Micrometer divisions	−0·45	−15·60	+ 8·06	+24·33	−3·88	−12·45
Millionths of a yard.	−0·62	−21·58	+11·15	+33·66	−5·37	−17·22

Also combining the values in this table with the equivalent of L—**A** above determined, there result,

$$\begin{aligned}
\mathrm{A} - \mathbf{A} &= \overset{d}{134{\cdot}68} - 18{\cdot}65\,dE_a = \overset{m.y}{186{\cdot}31} - 18{\cdot}65\,dE_a \\
\mathrm{B} - \mathbf{A} &= 119{\cdot}53 - \quad ,, \quad = 165{\cdot}35 - \quad ,, \\
\mathrm{C} - \mathbf{A} &= 143{\cdot}19 - \quad ,, \quad = 198{\cdot}08 - \quad ,, \\
\mathrm{D} - \mathbf{A} &= 159{\cdot}46 - \quad ,, \quad = 220{\cdot}59 - \quad ,, \\
\mathrm{E} - \mathbf{A} &= 131{\cdot}25 - \quad ,, \quad = 181{\cdot}56 - \quad ,, \\
\mathrm{H} - \mathbf{A} &= 122{\cdot}68 - \quad ,, \quad = 169{\cdot}71 - \quad ,,
\end{aligned}$$

$$\text{and } 6\,x = \overset{m.y}{1121{\cdot}6} - 111{\cdot}9\,dE_a.$$

Comparisons between the Standard Bar* A *and the Compensated Bars* A, B, C, D, E, H, *made near the village of Malgi, after the measurement.

Micrometer Readings in Divisions. 1 Division = $\frac{1}{20080 \cdot 34}$ Cary's Inch [7.8], = 1·3826 m.y. of A

1841. Decr.	Mean of the times of observing A	No. of comparison	Temperature of Air	Corrected mean temperature of A	Mean A	A	B	C	D	E	H	Mean of the compensated bars	Remarks.
	h. m.		°	°	+	+	+	+	+	+	+	+	
6th	6 55 A.M.	1	62·2	59·97	167·2	321·2	303·0	318·3	338·4	306·9	313·0	316·8	Lt. Waugh at the micrometer microscope; Lt. Renny at the plain microscope.
	7 23	2	63·7	60·42	169·2	323·0	295·3	315·8	339·2	303·0	307·0	313·9	
	7 46	3	65·7	61·02	176·0	318·9	299·2	317·1	333·9	304·0	304·9	313·0	
	8 8	4	68·0	61·77	189·9	316·9	291·4	311·9	331·7	304·0	304·6	310·1	
	8 34	5	70·6	63·07	209·1	312·3	288·3	310·0	326·1	302·8	300·2	306·6	
	9 1	6	73·4	64·82	234·7	309·3	282·0	304·6	322·9	296·1	294·4	301·6	
	9 25	7	75·3	66·50	257·7	304·2	280.0	302·9	318·7	296·0	293·0	299·1	
	9 47	8	76·4	68·02	278·2	300·9	276·8	299·3	314·9	293·4	289·2	295·8	
	10 9	9	77·3	69·57	300·6	299·8	274·9	297·9	312·1	289·7	287·4	293·6	
	10 34	10	78·1	71·17	323·6	293·0	272·8	291·3	311·9	290·2	284·9	290·7	
	1 22 P.M.	11	81·1	79·20	438·4	294·2	277·0	299·2	319·1	292·4	286·8	294·8	
	1 43	12	81·3	79·57	443·9	295·0	279·0	301·3	317·4	290·9	285·3	294·8	
	2 2	13	81·4	79·95	449·0	296·2	278·0	300·1	318·0	292·3	284·7	294·9	
	2 28	14	81·6	80·30	456·1	297·0	279·7	301·9	318·2	293·8	285·9	296·1	
	2 52	15	81·6	80·57	460·7	294·2	280·9	304·2	317·3	294·0	287·0	296·3	
	3 16	16	81·3	80·72	461·5	297·4	279·1	304·0	317·7	292·3	285·0	295·9	
	3 41	17	81·0	80·87	460.5	293·3	279·3	301·2	312·4	289·8	282·9	293·2	
	4 11	18	80·4	80·87	458·5	293·0	277·8	297·1	312·2	287·9	281·1	291·5	
	4 42	19	79·4	80·62	453·9	290·2	275·0	300·0	312·3	286·1	277·2	290·1	
7th	6 58 A.M.	20	62·2	60·72	109·1	257·9	235·0	254·0	269·9	242·3	247·9	251·2	
	7 20	21	63·4	60·92	111·4	255·1	233·0	256·0	270·3	239·0	244·4	249·6	
	7 44	22	65·5	61·35	117·1	255·9	231·0	254·3	266·3	239·8	240·9	248·0	
	8 8	23	67·9	62·10	127·7	248·2	227·0	251·0	266·1	241·1	239·1	245·4	
	8 30	24	70·1	63·10	142·1	250·0	223·5	247·9	263·1	237·0	238·0	243·3	
	8 49	25	72·1	64·25	159·2	246·3	218·5	246·2	260·2	234·3	233·8	239·9	
	9 18	26	74·1	65·85	183·2	240·9	214·6	240·1	255·9	232·1	229·3	235·5	
	9 45	27	75·7	67·67	210·0	238·0	215·1	241·3	252·2	232·0	226·3	234·2	
	10 8	28	76·8	69·22	233·5	232·0	210·7	235·1	250·0	230·0	224·2	230·3	
	10 42	29	78·7	71·42	263·1	230·0	207·1	234·1	248·1	228·9	220·1	228·1	
	1 24 P.M.	30	81·8	78·72	354·0	220·4	198·1	231·8	241·0	217·4	206·2	219·2	Lts. Waugh and Renny changed places at the microscopes.
	1 48	31	82·1	79·40	363·1	216·1	196·6	229·8	242·0	211·8	204·9	216·9	
	2 10	32	82·0	79·90	370·6	217·0	199·7	228·0	239·9	217·6	206·3	218·1	
	2 33	33	82·0	80·37	376·9	217·0	200·0	231·8	243·1	215·5	205·6	218·8	
	2 56	34	82·0	80·75	381·9	219·2	198·7	230·0	243·1	215·3	206·3	218·8	
	3 20	35	81·6	80·97	385·5	219·7	199·2	228·7	242·1	216·0	206·3	218·7	
	3 43	36	81·3	81·12	385·1	219·7	200·0	228·6	239·3	212·0	203·8	217·2	
	4 26	37	80·3	81·12	383·0	219·2	198·1	226·7	238·0	210·8	202·0	215·8	
	4 46	38	79·8	80·92	380·1	215·0	196·0	227·3	235·1	207·2	201·3	213·7	

After the measurement—(Continued.)

1841 Decr.	Mean of the times of observing A	No. of comparison	Temperature of Air	Corrected mean temperature of A	Mean A	A	B	C	D	E	H	Mean of the compensated bars	Remarks.
					Micrometer Readings in Divisions: 1 Division = $\frac{1}{20080 \cdot 34}$ Cary's Inch [7.8] = 1·3826 m.y of A								
	h. m.		°	°	+	+	+	+	+	+	+	+	
8th	7 0 A.M.	39	62·8	59·47	14·9	186·5	156·8	182.6	192·3	164·8	170·7	175·6	
	7 22	40	63·7	59·92	20·4	182·0	157·0	178·8	193·1	164·4	168·0	173·9	
	7 47	41	64·8	60·52	29·5	180·9	154·1	179·8	188·4	163·1	165·0	171·9	
	8 11	42	67·0	61·27	40·9	175·1	150·0	174·6	188·1	161·8	163·8	168·9	
	8 34	43	69·5	62·30	54·9	170·0	147·2	169.8	184·0	160·7	161·0	165·5	
	8 56	44	71·7	63·55	71·7	169·2	145·0	167·1	181·0	157·3	158·0	162·9	
	9 18	45	73·6	64·95	92·0	167·7	141·6	168·0	178·2	157·3	155·4	161·4	
	9 39	46	75·6	66·35	112·8	161·8	139·0	158·1	176·0	155·8	154·0	157·5	
	10 20	47	79·0	69·47	159·5	155·0	134·7	159·2	175·4	154·8	149·5	154·8	
	10 38	48	80·2	71·00	180·2	154·4	134·1	161·1	175·0	155·4	150·6	155·1	
	1 20 P.M.	49	83·5	80·60	316·8	159·0	136·3	168·0	180·1	150·1	146·8	156·7	
	1 42	50	84·0	81·30	329·0	154·8	136·6	167·2	179·8	154·0	146·6	156·5	
	2 2	51	84·2	81·90	339·4	157·2	137·4	167·6	178·0	155·2	146·3	157·0	The weather throughout these comparisons was clear and steady. Wind at N.E.
	2 21	52	84·1	82·35	347·7	156·2	136·1	169·0	178·4	156·3	145·4	156·9	
	2 40	53	83·4	82·70	353·8	157·0	137·8	166·4	177·5	155·0	145·6	156·6	
	2 58	54	83·2	82·95	356·5	155·2	138·7	166·0	179·7	153·7	145·9	156·2	
	3 16	55	83·3	83·12	358·2	157·1	136·3	165·3	178·1	153·1	144·0	155·7	
	4 1	56	83·2	83·27	358·3	154·0	138·7	165·2	174·3	149·0	139·8	153·5	
	4 18	57	82·7	83·25	357·2	154·7	137·5	166·1	174·7	148·3	138·6	153·3	
			Means	72·27	268·75	232·90	211·69	236·85	250·74	225·54	221·30	229·84	

After the measurement—(Continued)

As on page IV—5 we have

$$x - (t^\circ - 62^\circ)(E_a - dE_a) - \delta = 0;$$

and from the preceding bar comparisons, we obtain the following series of results :—

$x + 2·03$	$(E_a - dE_a)$	$-149·6 = 0$	$x - 16·72$	$(E_a - dE_a)$	$+134·8 = 0$
$x + 1·58$	„	$-144·7 = 0$	$x - 17·40$	„	$+146·2 = 0$
$x + 0·98$	„	$-137·0 = 0$	$x - 17·90$	„	$+152·5 = 0$
$x + 0·23$	„	$-120·2 = 0$	$x - 18·37$	„	$+158·1 = 0$
$x - 1·07$	„	$-97·5 = 0$	$x - 18·75$	„	$+163·1 = 0$
$x - 2·82$	„	$-66·9 = 0$	$x - 18·97$	„	$+166·8 = 0$
$x - 4·50$	„	$-41·4 = 0$	$x - 19·12$	„	$+167·9 = 0$
$x - 6·02$	„	$-17·6 = 0$	$x - 19·12$	„	$+167·2 = 0$
$x - 7·57$	„	$+7·0 = 0$	$x - 18·92$	„	$+166·4 = 0$
$x - 9·17$	„	$+32·9 = 0$	$x + 2·53$	„	$-160·7 = 0$
$x - 17·20$	„	$+143·6 = 0$	$x + 2·08$	„	$-153·5 = 0$
$x - 17·57$	„	$+149·1 = 0$	$x + 1·48$	„	$-142·4 = 0$
$x - 17·95$	„	$+154·1 = 0$	$x + 0·73$	„	$-128·0 = 0$
$x - 18·30$	„	$+160·0 = 0$	$x - 0·30$	„	$-110·6 = 0$
$x - 18·57$	„	$+164·4 = 0$	$x - 1·55$	„	$-91·2 = 0$
$x - 18·72$	„	$+165·6 = 0$	$x - 2·95$	„	$-69·4 = 0$
$x - 18·87$	„	$+167·3 = 0$	$x - 4·35$	„	$-44·7 = 0$
$x - 18·87$	„	$+167·6 = 0$	$x - 7·47$	„	$+4·7 = 0$
$x - 18·62$	„	$+163·8 = 0$	$x - 9·00$	„	$+25·1 = 0$
$x + 1·28$	„	$-142·1 = 0$	$x - 18·60$	„	$+160·1 = 0$
$x + 1·08$	„	$-138·2 = 0$	$x - 19·30$	„	$+172·5 = 0$
$x + 0·65$	„	$-130·9 = 0$	$x - 19·90$	„	$+182·4 = 0$
$x - 0·10$	„	$-117·7 = 0$	$x - 20·35$	„	$+190·8 = 0$
$x - 1·10$	„	$-101·2 = 0$	$x - 20·70$	„	$+197·2 = 0$
$x - 2·25$	„	$-80·7 = 0$	$x - 20·95$	„	$+200·3 = 0$
$x - 3·85$	„	$-52·3 = 0$	$x - 21·12$	„	$+202·5 = 0$
$x - 5·67$	„	$-24·2 = 0$	$x - 21·27$	„	$+204·8 = 0$
$x - 7·22$	„	$+3·2 = 0$	$x - 21·25$	„	$+203·9 = 0$
$x - 9·42$	„	$+35·0 = 0$			

After the measurement—(Continued.)

And from the mean of these results,

$$x = -\overset{d}{38{\cdot}91} + 10{\cdot}27\,(E_a - dE_a):$$

adopting the original value of the expansion of **A** given at page (9),

$$E_a = \overset{m.y}{22{\cdot}67} = \overset{d}{16{\cdot}397},$$

$$\text{and } x = \overset{d}{129{\cdot}49} - 10{\cdot}27\,dE_a = \overset{m.y}{179{\cdot}03} - 10{\cdot}27\,dE_a = \text{L} - \textbf{A}.$$

where L denotes the mean length of the compensated bars obtained from *all* the comparisons, as represented by the mean micrometer reading $\overset{d}{229{\cdot}84}$ page IV—9.

Proceeding as on page IV—7 we obtain:

In terms of	A − L	B − L	C − L	D − L	E − L	H − L
Micrometer divisions.	+3·06	−18·15	+7·01	+20·90	−4·30	− 8·54
Millionths of a yard.	+4·23	−25·09	+9·69	+28·90	−5·95	−11·81

Also the following;

$$\begin{aligned}
\text{A} - \textbf{A} &= \overset{d}{132{\cdot}55} - 10{\cdot}27\,dE_a = \overset{m.y}{183{\cdot}26} - 10{\cdot}27\,dE_a\\
\text{B} - \textbf{A} &= 111{\cdot}34 - \quad \text{''} \quad = 153{\cdot}94 - \quad \text{''}\\
\text{C} - \textbf{A} &= 136{\cdot}50 - \quad \text{''} \quad = 188{\cdot}72 - \quad \text{''}\\
\text{D} - \textbf{A} &= 150{\cdot}39 - \quad \text{''} \quad = 207{\cdot}93 - \quad \text{''}\\
\text{E} - \textbf{A} &= 125{\cdot}19 - \quad \text{''} \quad = 173{\cdot}08 - \quad \text{''}\\
\text{H} - \textbf{A} &= 120{\cdot}95 - \quad \text{''} \quad = 167{\cdot}22 - \quad \text{''}
\end{aligned}$$

$$\text{and } 6\,x = \overset{m.y}{1074{\cdot}2} - 61{\cdot}6\,dE_a.$$

Final deduction of the total length measured with the compensated bars.

From page IV—7 the excess of the 6 compensated bars above 6 times **A**	*before* the measurement		m.y. $= 1121{\cdot}6 - 111{\cdot}9\ dE_a$
„ IV—11 „	*after* „		$= 1074{\cdot}2 - 61{\cdot}6\ dE_a$
Therefore the mean excess of „	applicable to the base-line		$= 1097{\cdot}9 - 86{\cdot}8\ dE_a$

And the mean length of a set of 6 compensated bars in feet of the standard $= 60{\cdot}0032937\ \frac{\mathbf{A}}{10} - 86{\cdot}8\ dE_a$

Hence the total lengths measured with the compensated bars

		feet of **A**
in sets Nos.	1 to 244	$= 14640{\cdot}8037 - 21179\ dE_a$
„	245 to 518	$= 16440{\cdot}9025 - 23783\ dE_a$
„	519 to 660	$= 8520{\cdot}4677 - 12326\ dE_a$
„	1 to 660	$= 39602{\cdot}1739 - 57288\ dE_a$

Now the mean temperature of **A** during the above bar comparisons was $62° + \frac{86°{\cdot}8}{6} = 76°{\cdot}5$, for which temperature the corresponding expansion of **A** from page (19) is 21·738 *m.y.* Comparing this value of expansion with the original value = 22·67 *m.y.*, used in the foregoing; it is found that $dE_a = + 0{\cdot}932$ *m.y.*; and substituting for dE_a this numerical value, there result,

Total lengths measured with the compensated bars

			feet of **A**
in sets Nos.	1 to 244 or W. End,	to Stn. A	= (14640·8037 − ·0592) = 14640·7445
„	245 to 518 or Stn. A,	to Stn. B	= (16440·9025 − ·0665) = 16440·8360
„	519 to 660 or Stn. B,	to E. End	= (8520·4677 − ·0345) = 8520·4332
„	1 to 660 or W. End,	to E. End	= (39602·1739 − ·1602) = 39602·0137

Comparisons between the Compensated Microscopes and their 6-inch brass scales during the measurement, and provisional determination of Microscope errors with respect to the 6-inch brass scale A, expressed in millionths of an inch (m.i.)

When compared — 1841		Microscope.	Scale compared with.	Corrected temperature.	Reduction to 62° Fah. Expansion of 6″ scale for 1° = *E* = 62·5 m.i.	Microscope − Microscope Scale. *Observed value in terms of* Divisions 10000 = 1″.	Microscope − Microscope Scale. *Observed value in terms of* *m.i.*	Micros : Scale − *A*, at 62° Fah.	Micros : − Scale *A*, at 62° Fah. *m.i.*	Reference number.
October 18th	Before the measurement.	*U*	*U*	80°·55	+1159	·00	0	+ 283	+1442	1
		S	*S*	78·27	1017	·00	0	− 75	942	2
		M	*M*	77·36	960	·00	0	− 21	939	3
		O	*R*	83·21	1326	·00	0	+ 93	1419	4
		N	*N*	80·42	1151	− 1·63	− 163	+ 363	1351	5
		P	*T*	79·25	1078	·00	0	− 97	981	6
		T	*T*	72·85	678	+ 1·00	+ 100	− 97	681	7
„ 25th	Between sets No. 48 and 49.	*U*	*U*	83·95	+1372	− 0·73	− 73	+ 283	+1582	8
		S	*S*	85·31	1457	4·07	407	− 75	975	9
		*S**	*S*	85·51	1469	2·13	213	75	1181	10
		M	*M*	84·76	1423	14·73	1473	21	− 71	11
		O	*R*	85·11	1445	·00	0	+ 93	+1538	12
		N	*N*	83·52	1345	− 2·37	− 237	363	1471	13
		P	*T*	83·45	1340	3·17	317	− 97	926	14
		T	*T*	84·35	1397	5·73	573	97	727	15
November 4th	Between sets No. 155 and 156.	*U*	*U*	68·18	+ 386	+ 7·10	+ 710	+ 283	+1379	16
		S	*S*	68·94	434	3·27	327	− 75	686	17
		M	*M*	68·56	410	− 7·87	− 787	− 21	− 398	18
		O	*R*	68·41	401	+ 6·20	+ 620	+ 93	+1114	19
		N	*N*	69·75	484	3·23	323	363	1170	20
		P	*T*	74·01	751	1·67	167	− 97	821	21
		T	*T*	73·35	709	4·40	440	97	1052	22
„ 9th	Between sets No. 244 and 245.	*U*	*U*	83·65	+1353	− 3·70	− 370	+ 283	+1266	23
		S	*S*	85·77	1486	6·70	670	− 75	741	24
		M	*M*	83·13	1321	13·63	1363	− 21	− 63	25
		O	*R*	84·81	1426	·00	0	+ 93	+1519	26
		N	*N*	84·42	1401	− 5·50	− 550	+ 363	1214	27
		P	*T*	82·88	1305	·53	53	− 97	1155	28
		T	*T*	85·15	1447	5·67	567	97	783	29
„ 16th	Between sets No. 353 and 354.	*U*	*U*	80·55	+1159	− 1·80	− 180	+ 283	+1262	30
		*U**	*U*	80·88	1180	·87	87	283	1376	31
		S	*S*	80·77	1173	2·20	220	− 75	878	32
		M	*M*	81·00	1187	11·67	1167	21	− 1	33
		O	*R*	82·01	1251	·00	0	+ 93	+1344	34
		*O**	*R*	81·94	1246	+ 1·43	+ 143	93	1482	35
		N	*N*	81·85	1240	− 4·90	− 490	363	1113	36
		P	*T*	82·55	1284	1·83	183	− 97	1004	37
		R	*R*	82·41	1276	2·43	243	+ 93	1126	38
		T	*T*	81·85	1240	3·80	380	− 97	763	39

* These microscopes were compared a second time, because they were adjusted after the first comparison.

Microscope Comparisons—(Continued.)

When compared — 1841		Microscope.	Scale compared with.	Corrected temperature.	Reduction to 62° Fah. Expansion of 6″ scale for 1° = *E* = 62·5 *m.i.*	Microscope — Microscope Scale. Observed value in terms of Divisions 10000 = 1″	Microscope — Microscope Scale. Observed value in terms of *m.i.*	Micros: Scale − *A*, at 62° Fah.	Micros: — Scale *A*, at 62° Fah. *m.i.*	Reference number.
November 26th	Between sets No. 518 and 519.	*U*	*U*	77°·55	+ 972	+ 1·17	+ 117	+ 283	+ 1372	40
		S	*S*	79·34	1084	− 1·40	− 140	− 75	869	41
		M	*M*	78·26	1017	11·50	1150	− 21	− 154	42
		O	*R*	79·35	1084	+ 3·10	+ 310	+ 93	+ 1487	43
		N	*N*	79·25	1078	− 2·27	− 227	363	1214	44
		P	*T*	78·55	1034	− 0·93	93	− 97	844	45
		R	*R*	79·31	1082	·00	0	+ 93	1175	46
		T	*T*	79·55	1097	− 2·27	227	− 97	773	47
December 4th	After the measurement.	*S*	*S*	74·71	+ 794	+ 3·30	+ 330	− 75	+ 1049	48
		U	*U*	76·72	920	1·60	160	+ 283	1363	49
		M	*M*	76·26	892	− 10·20	− 1020	− 21	− 149	50
		O	*R*	77·48	967	+ 3·63	+ 363	+ 93	+ 1423	51
		N	*N*	76·62	914	·00	0	363	1277	52
		P	*T*	76·05	878	·00	0	− 97	781	53
		T	*T*	73·65	728	·00	0	97	631	54

The required combinations of individual microscope errors taken from pages IV—13 and IV—14, are expressed as follows;

Reference numbers. — *m.i.* — *mean temp:*

$$e_1 = 2 + 3 + 4 + 5 + 6 + \frac{1+7}{2} = +6694 \text{ at } (62^\circ + 17^\circ{\cdot}20)$$ before the measurement.

$$e_2 = 9 + 11 + 12 + 13 + 14 + \frac{8+15}{2} = +5994 \text{ at } (62 + 22{\cdot}38)$$ between sets 48 & 49

$$e_3 = 10 + 11 + 12 + 13 + 14 + \frac{8+15}{2} = +6200 \text{ at } (62 + 22{\cdot}42)$$ „ do.

$$e_4 = 17 + 18 + 19 + 20 + 21 + \frac{16+22}{2} = +4609 \text{ at } (62 + 8{\cdot}07)$$ From comparisons made „ 155 & 156

$$e_5 = 24 + 25 + 26 + 27 + 28 + \frac{23+29}{2} = +5591 \text{ at } (62 + 22{\cdot}24)$$ „ 244 & 245

$$e_6 = 32 + 33 + 34 + 36 + 37 + \frac{30+39}{2} = +5351 \text{ at } (62 + 19{\cdot}56)$$ „ 353 & 354

$$e_7 = 31 + 33 + 35 + 36 + 37 + \frac{38+39}{2} = +5919 \text{ at } (62 + 19{\cdot}73)$$ „ do.

$$e_8 = 33 + 35 + 36 + 37 + 38 + \frac{31+39}{2} = +5794 \text{ at } (62 + 19{\cdot}85)$$ „ do.

$$e_9 = 40 + 42 + 43 + 44 + 45 + \frac{46+47}{2} = +5737 \text{ at } (62 + 16{\cdot}73)$$ „ 518 & 519

$$e_{10} = 42 + 43 + 44 + 45 + 46 + \frac{40+47}{2} = +5639 \text{ at } (62 + 16{\cdot}88)$$ „ do.

$$e_{11} = 40 + 42 + 43 + 44 + 45 + \frac{41+47}{2} = +5584 \text{ at } (62 + 16{\cdot}74)$$ „ do.

$$e_{12} = 49 + 50 + 51 + 52 + 53 + \frac{48+54}{2} = +5535 \text{ at } (62 + 14{\cdot}22)$$ after the measurement.

Microscope Comparisons—(Continued.)

And from the foregoing, we obtain the following equations for the microscope errors per set (or *m.e.*); where *dE* expresses the error in the adopted value of the expansion of the 6-inch scales.

$(m.e.)_1 = \frac{e_1 + e_2}{2}$	$= + \overset{m.i.}{6344} - 6 \times 19{\cdot}79\ dE$	applicable to sets Nos.		1 to 48
$(m.e.)_2 = \frac{e_3 + e_4}{2}$	$= + 5405 - 6 \times 15{\cdot}25\ dE$	,,	,,	49 to 155
$(m.e.)_3 = \frac{e_4 + e_5}{2}$	$= + 5100 - 6 \times 15{\cdot}16\ dE$	,,	,,	156 to 244
$(m.e.)_4 = \frac{e_5 + e_6}{2}$	$= + 5471 - 6 \times 20{\cdot}90\ dE$	,,	,,	245 to 353
$(m.e.)_5 = \frac{e_7 + e_9}{2}$	$= + 5828 - 6 \times 18{\cdot}23\ dE$	,,	,,	354 & 355
$(m.e.)_6 = \frac{e_8 + e_{10}}{2}$	$= + 5717 - 6 \times 18{\cdot}37\ dE$	,,	,,	356 to 518
$(m.e.)_7 = \frac{e_{11} + e_{12}}{2}$	$= + 5560 - 6 \times 15{\cdot}48\ dE$	,,	,,	519 to 660

Hence the total microscope errors are as follows :—

			m.i		feet of A	
In sets Nos. 1 to 244 =	48 $(m.e)_1$ =	304512 −	5700 *dE* =	·0254 −	5700 *dE*
	107 $(m.e)_2$ =	578335 −	9791 *dE* =	·0482 −	9791 *dE*
	89 $(m.e)_3$ =	453900 −	8095 *dE* =	·0378 −	8095 *dE*
			sum =	·1114 −	23586 *dE*
In sets Nos. 245 to 518 =	109 $(m.e)_4$ =	596339 −	13669 *dE* =	·0497 −	13669 *dE*
	2 $(m.e)_5$ =	11656 −	219 *dE* =	·0010 −	219 *dE*
	163 $(m.e)_6$ =	931871 −	17966 *dE* =	·0777 −	17966 *dE*
			sum =	·1284 −	31854 *dE*
In sets Nos. 519 to 660 =	142 $(m.e)_7$ =	789520 −	13189 *dE* =	·0658 −	13189 *dE*

Microscope Comparisons—(Continued.)

Final deduction of the total lengths measured with the compensated microscopes.

Hitherto the microscope errors have been determined only provisionally; *i.e* in terms of the 6-inch brass scale *A*. But from page (31), we have $2\ A = 1{\cdot}0000192\ \frac{\mathbf{A}}{10}$, value in 1835. Also the coefficient of expansion for brass, has been taken at ·000,010,417 in the foregoing reductions, whereas it appears from page (17) that ·000,009,855 is a more probable value. Accepting the latter, it may be found that $dE = 3{\cdot}372\ (m.i)$. Hence, remembering that the length measured with a set of microscopes is equal to 3 feet of A + the corresponding (*m.e*), we have,

Total length measured with the compensated microscopes

		feet of A			feet of A
In sets Nos. 1 to 244 or W. End, to Stn. A	...... =	{244 × 3 + ·1114}	− 23586 dE =	(732·1255 − ·0066) =	732·1189
" 245 to 518 or Stn. A, to Stn. B	...... =	{274 × 3 + ·1284}	− 31854 dE =	(822·1442 − ·0090) =	822·1352
" 519 to 660 or Stn. B, to E. End	...... =	{142 × 3 + ·0658}	− 13189 dE =	(426·0740 − ·0037) =	426·0703
" 1 to 660 or W. End, to E. End	....			= (1980·3437 − ·0193) =	1980·3244

Disposition of the bars and microscopes during the measurement.

The following typical illustrations show the permutations and combinations of the bars and microscopes during the measurement. The instruments are here named in the succession that actually occurred, commencing from the rear-end of a set; and the numbers assigned to the illustrations, will be found employed in the table of "Extracts from the Field Book &c."

Bar Illustration.

No. 1
A
B
C
D
E
H

Statement.

No. 1 occurs throughout, *i.e.*, in sets Nos. 1 to 660.

Microscope Illustration.

No. 1	No. 2	No. 3	No. 4
½U	½R	½U	½S
S	U	R	U
M	M	M	M
O	O	O	O
N	N	N	N
P	P	P	P
½T	½T	½T	½T

Statement.

No. 1 occurs in sets Nos. 1 to 353.
No. 2 " Nos. 354 and 355.
No. 3 " Nos. 356 to 518.
No. 4 " Nos. 519 to 660.

DETAILS OF THE MEASUREMENT.

Extracts from the Field Book of the measurement, and calculated heights of sets above the origin.

Adopted heights above mean sea level.
West-End (origin) = 1980·2 feet.
East-End (terminus) = 1957·1 feet.

1841	No. of the Set	Temperature of Air	Mean time of ending	No. of bars used	Height of Set above origin	Numeral shewing arrangement of: Bars.	Micros:	1841	No. of the Set	Temperature of Air	Mean time of ending	No. of bars used	Height of Set above origin	Numeral shewing arrangement of: Bars.	Micros:
		°	h. m.		feet					°	h. m.		feet		
19th Oct.	1	72·1	6 50 A.M.	6 +	1·5	1	1	23rd Oct.	42	73·3	4 51 P.M.	6 −	27·3	1	1
	2	75·3	8 50	6 −	0·8	1	1	25th „	43	72·8	6 56 A.M.	6	28·3	1	1
	3	79·2	9 54	6	3·3	1	1		44	75·5	7 49	6	29·7	1	1
	4	81·0	10 53	6	4·8	1	1		45	77·9	8 27	6	31·5	1	1
	5	88·6	2 0 P.M.	6	4·9	1	1		46	81·6	9 16	6	33·8	1	1
	6	89·3	2 59	6	5·0	1	1		47	85·0	10 8	6	36·2	1	1
	7	88·0	4 10	6	6·4	1	1		48	85·9	11 0	6	38·9	1	1
	8	79·8	5 0	6	8·6	1	1		49	86·0	4 7 P.M.	6	41·3	1	1
20th „	9	73·1	6 59 A.M.	6	10·3	1	1		50	82·6	4 51	6	44·3	1	1
	10	76·2	7 59	6	11·5	1	1		51	81·7	5 28	6	45·1	1	1
	11	79·5	8 55	6	12·3	1	1	26th „	52	72·0	6 40 A.M.	6	45·7	1	1
	12	83·5	9 52	6	12·9	1	1		53	71·7	7 28	6	45·8	1	1
	13	84·7	10 48	6	13·5	1	1		54	74·3	8 18	6	46·3	1	1
	14	85·4	11 39	6	15·5	1	1		55	78·0	8 55	6	47·0	1	1
	15	88·4	2 25 P.M.	6	16·3	1	1		56	81·0	9 39	6	47·6	1	1
	16	84·6	3 16	6	16·7	1	1		57	83·8	10 16	6	48·6	1	1
	17	90·1	4 16	6	17·6	1	1		58	86·0	10 48	6	49·9	1	1
	18	89·5	5 0	6	18·6	1	1		59	86·1	1 32 P.M.	6	50·0	1	1
22nd „	19	70·2	6 38 A.M.	6	19·1	1	1		60	85·5	2 20	6	49·6	1	1
	20	73·8	7 23	6	19·5	1	1		61	87·8	3 4	6	48·4	1	1
	21	76·7	8 15	6	19·8	1	1		62	87·3	3 47	6	48·1	1	1
	22	80·1	8 59	6	20·2	1	1		63	81·2	4 29	6	48·3	1	1
	23	83·1	9 51	6	21·6	1	1		64	79·3	5 16	6	49·1	1	1
	24	86·2	10 38	6	22·1	1	1	27th „	65	71·1	6 42 A.M.	6	50·0	1	1
	25	84·3	1 29 P.M.	6	22·3	1	1		66	72·3	7 22	6	50·8	1	1
	26	80·5	2 10	6	22·0	1	1		67	73·7	8 8	6	51·4	1	1
	27	82·0	2 47	6	21·4	1	1		68	75·0	8 45	6	51·5	1	1
	28	83·9	3 25	6	21·8	1	1		69	76·2	9 24	6	51·5	1	1
	29	83·9	4 11	6	21·6	1	1		70	78·2	9 57	6	51·6	1	1
	30	82·8	4 50	6	21·9	1	1		71	80·0	10 30	6	53·1	1	1
	31	81·6	5 26	6	22·1	1	1		72	82·1	11 2	6	53·5	1	1
23rd „	32	72·3	7 26 A.M.	6	22·2	1	1		73	82·5	1 32 P.M.	6	54·2	1	1
	33	73·7	8 5	6	22·8	1	1		74	82·0	2 3	6	54·7	1	1
	34	76·1	8 45	6	23·3	1	1		75	82·5	2 38	6	55·2	1	1
	35	78·2	9 21	6	23·5	1	1		76	82·3	3 14	6	55·8	1	1
	36	80·5	10 5	6	23·7	1	1		77	82·0	3 49	6	56·0	1	1
	37	83·0	10 44	6	23·8	1	1		78	81·3	4 21	6	57·7	1	1
	38	85·6	11 23	6	24·5	1	1		79	80·6	4 52	6	58·6	1	1
	39	82·0	2 8 P.M.	6	24·9	1	1		80	79·7	5 25	6	59·8	1	1
	40	76·4	3 12	6	25·3	1	1	28th „	81	70·7	6 45 A.M.	6	60·9	1	1
	41	77·7	3 57	6	26·0	1	1		82	71·0	7 14	6	61·1	1	1

The rear-end of set No. 1 stood exactly over the dot at West-End.

(3) Morning cloudy. (5) Afternoon cloudy and threatening. (13) Cloudy and threatening. (39) Heavy shower after the measurement of this set. (42) Raining. (52) Sky clear. (53) Sky overcast with clouds. (57) Sky clearing. (64) Raining slightly. (71) Cloudy morning. (73) Cloudy afternoon. (82) Cloudy and foggy.

Extracts from the Field Book—(Continued.)

1841	No. of the Set.	Temperature of Air	Mean time of ending	No. of bars used	Height of Set above origin	Numeral shewing arrangement of Bars.	Numeral shewing arrangement of Micros:
		°	h. m.		feet.		
28th Oct.	83	71·2	7 50 A.M.	6	— 61·2	1	1
	84	72·1	8 24	6	62·3	1	1
	85	74·7	9 0	6	63·1	1	1
	86	78·6	9 33	6	63·6	1	1
	87	81·4	10 18	6	64·0	1	1
	88	83·2	10 48	6	64·1	1	1
	89	83·6	2 47 P.M.	6	63·5	1	1
	90	85·0	3 17	6	63·3	1	1
	91	85·0	4 0	6	63·1	1	1
	92	84·0	4 30	6	62·8	1	1
	93	81·8	5 8	6	63·2	1	1
29th „	94	79·3	6 33 A.M.	6	63·5	1	1
	95	71·0	7 12	6	63·9	1	1
	96	73·6	7 52	6	64·3	1	1
	97	76·5	8 30	6	65·5	1	1
	98	78·9	9 1	6	66·2	1	1
	99	79·7	9 31	6	66·6	1	1
	100	80·4	10 2	6	67·7	1	1
	101	81·5	10 31	6	68·7	1	1
	102	82·1	11 2	6	69·5	1	1
	103	83·4	1 41 P.M.	6	70·1	1	1
	104	82·2	2 14	6	71·1	1	1
	105	82·0	2 52	6	71·5	1	1
	106	81·2	3 25	6	71·7	1	1
	107	82·0	4 0	6	72·4	1	1
	108	81·1	4 33	6	73·1	1	1
	109	80·3	5 8	6	73·8	1	1
30th „	110	73·3	6 58 A.M.	6	74·4	1	1
	111	74·1	7 49	6	75·3	1	1
	112	74·8	8 24	6	75·6	1	1
	113	76·2	9 1	6	76·0	1	1
	114	76·7	9 35	6	76·4	1	1
	115	77·7	10 11	6	76·9	1	1
	116	79·3	10 46	6	76·7	1	1
	117	78·8	1 20 P.M.	6	76·2	1	1
	118	79·5	1 51	6	75·6	1	1
	119	79·7	2 22	6	75·4	1	1
	120	79·1	2 51	6	75·5	1	1
	121	78·7	3 25	6	75·0	1	1
	122	78·4	3 52	6	74·3	1	1
	123	77·0	4 34	6	74·4	1	1
	124	86·0	5 3	6	74·8	1	1
2nd Nov.	125	73·3	7 17 A.M.	6	75·4	1	1
	126	75·9	7 58	6	74·6	1	1
	127	78·2	8 41	6	73·0	1	1
	128	80·3	9 16	6	72·4	1	1
	129	82·4	9 50	6	71·4	1	1
	130	83·0	10 24	6	70·6	1	1
	131	85·1	11 9	6	69·6	1	1
	132	87·0	1 59 P.M.	6	69·4	1	1

1841	No. of the Set.	Temperature of Air	Mean time of ending	No. of bars used	Height of Set above origin	Numeral shewing arrangement of Bars.	Numeral shewing arrangement of Micros:
		°	h. m.		feet.		
2nd Nov.	133	87·8	2 35 P.M.	6	— 68·6	1	1
	134	86·2	3 9	6	68·0	1	1
	135	85·9	3 43	6	67·0	1	1
	136	85·3	4 21	6	66·6	1	1
	137	83·1	4 55	6	66·3	1	1
	138	77·0	5 36	6	65·9	1	1
3rd „	139	71·1	6 50 A.M.	6	65·7	1	1
	140	72·2	7 25	6	65·3	1	1
	141	73·9	8 0	6	64·4	1	1
	142	76·2	8 33	6	63·6	1	1
	143	78·9	9 11	6	62·0	1	1
	144	81·7	9 46	6	62·1	1	1
	145	82·4	10 25	6	61·8	1	1
	146	83·8	10 57	6	61·0	1	1
	147	85·3	1 24 P.M.	6	60·6	1	1
	148	86·1	1 54	6	59·9	1	1
	149	85·0	2 23	6	58·8	1	1
	150	84·6	2 48	6	58·1	1	1
	151	84·0	3 14	6	57·5	1	1
	152	84·0	3 38	6	56·7	1	1
	153	84·3	4 12	6	55·3	1	1
	154	83·1	4 41	6	54·5	1	1
	155	80·1	5 10	6	53·7	1	1
4th „	156	75·5	8 46 A.M.	6	52·7	1	1
	157	77·7	9 18	6	52·3	1	1
	158	79·6	9 52	6	51·5	1	1
	159	80·6	10 18	6	50·6	1	1
	160	82·8	10 49	6	50·2	1	1
	161	86·2	1 20 P.M.	6	49·5	1	1
	162	86·9	1 46	6	48·3	1	1
	163	88·0	2 15	6	47·4	1	1
	164	88·3	2 46	6	46·5	1	1
	165	87·4	3 16	6	45·7	1	1
	166	87·5	3 41	6	45·5	1	1
	167	86·0	4 19	6	45·4	1	1
	168	84·6	4 48	6	45·9	1	1
	169	78·3	5 23	6	46·3	1	1
5th „	170	71·1	6 37 A.M.	6	47·4	1	1
	171	71·8	7 8	6	48·5	1	1
	172	73·0	7 44	6	49·3	1	1
	173	74·0	8 11	6	49·8	1	1
	174	76·1	8 41	6	51·0	1	1
	175	78·0	9 3	6	51·8	1	1
	176	80·6	9 31	6	52·7	1	1
	177	82·0	9 58	6	53·4	1	1
	178	82·2	10 29	6	53·7	1	1
	179	84·5	10 58	6	54·0	1	1
	180	87·5	1 35 P.M.	6	54·5	1	1
	181	88·0	2 6	6	56·3	1	1
	182	89·2	2 29	6	57·3	1	1

(106) A slight shower of rain. (110) Morning cloudy and damp. (121) Rainy and cloudy. (127) A fine clear sunshiny day.

Extracts from the Field Book—(Continued.)

1841	No. of the Set	Temperature of Air	Mean time of ending	No. of bars used	Height of Set above origin	Numeral shewing arrangement of Bars.	Numeral shewing arrangement of Micros:	1841	No. of the Set.	Temperature of Air	Mean time of ending	No. of bars used	Height of Set above origin	Numeral shewing arrangement of Bars.	Numeral shewing arrangement of Micros:
		°	h. m.		feet.					°	h. m.		feet.		
5th Nov.	183	88·4	2 55 P.M.	6	− 57·7	1	1	8th Nov.	215	80·6	9 23 A.M.	6	− 57·8	1	1
	184	88·7	3 18	6	58·2	1	1		216	81·9	9 48	6	57·2	1	1
	185	86·3	3 50	6	58·7	1	1		217	83·9	10 17	6	57·1	1	1
	186	86·4	4 17	6	59·5	1	1		218	84·8	10 40	6	56·7	1	1
	187	83·0	4 47	6	60·1	1	1		219	86·6	11 4	6	56·2	1	1
	188	80·6	5 16	6	60·7	1	1		220	88·0	1 41 P.M.	6	55·6	1	1
6th ,,	189	72·6	6 40 A.M.	6	61·4	1	1		221	88·8	2 7	6	54·7	1	1
	190	73·7	7 14	6	61·6	1	1		222	89·1	2 31	6	54·4	1	1
	191	74·2	7 42	6	61·3	1	1		223	89·6	2 58	6	53·4	1	1
	192	78·0	8 18	6	61·8	1	1		224	89·4	3 22	6	52·8	1	1
	193	80·3	8 45	6	61·1	1	1		225	88·6	3 48	6	52·2	1	1
	194	82·0	9 10	6	60·6	1	1		226	87·7	4 13	6	51·5	1	1
	195	83·7	9 35	6	59·9	1	1		227	83·2	4 40	6	50·4	1	1
	196	85·9	10 4	6	58·6	1	1		228	82·1	5 2	6	49·7	1	1
	197	88·4	10 35	6	57·4	1	1		229	78·8	5 24	6	49·2	1	1
	198	89·7	11 1	6	56·7	1	1	9th ,,	230	70·7	6 32 A.M.	6	48·4	1	1
	199	90·7	1 24 P.M.	6	55·7	1	1		231	71·3	6 58	6	47·2	1	1
	200	91·2	1 51	6	55·2	1	1		232	73·8	7 26	6	46·7	1	1
	201	91·8	2 20	6	54·7	1	1		233	75·7	7 53	6	45·5	1	1
	202	92·8	2 44	6	55·6	1	1		234	77·7	8 29	6	45·2	1	1
	203	92·9	3 11	6	56·1	1	1		235	78·5	8 52	6	44·3	1	1
	204	93·0	3 41	6	56·3	1	1		236	80·4	9 18	6	43·8	1	1
	205	89·1	4 9	6	57·1	1	1		237	82·8	9 41	6	43·2	1	1
	206	88·5	4 33	6	57·5	1	1		238	83·6	10 6	6	43·1	1	1
	207	84·6	5 0	6	58·4	1	1		239	85·0	10 32	6	42·3	1	1
	208	81·9	5 20	6	58·7	1	1		240	88·7	1 14 P.M.	6	41·7	1	1
8th ,,	209	71·3	6 36 A.M.	6	58·5	1	1		241	88·7	1 44	6	41·0	1	1
	210	72·1	7 5	6	58·4	1	1		242	88·0	2 8	6	40·8	1	1
	211	73·9	7 37	6	58·4	1	1		243	89·3	2 36	6	40·0	1	1
	212	75·1	8 2	6	58·5	1	1		244	86·0	3 41	6	40·2	1	1
	213	76·9	8 27	6	58·6	1	1								
	214	78·3	8 54	6	58·5	1	1				Total	—	12278·5		

The advanced-end of set No. 244 fell in defect (*i. e.* west) of the dot at Station A, 0·1033 feet, as measured on Cary's brass scale with a pair of compasses.

Height of set No. 244 above Station A = 1·6 feet.

The terminal point of set No. 244 was the point of origin for set No. 245.

10th ,,	245	70·9	6 57 A.M.	6	− 40·2	1	1	10th ,,	258	88·6	3 18 P.M.	6	− 47·1	1	1
	246	74·0	7 28	6	41·7	1	1		259	90·2	3 46	6	47·9	1	1
	247	76·9	7 57	6	42·9	1	1		260	87·0	4 14	6	49·1	1	1
	248	78·0	8 26	6	43·6	1	1		261	84·6	5 1	6	50·1	1	1
	249	81·0	8 56	6	43·1	1	1	11th ,,	262	70·5	6 45 A.M.	6	50·1	1	1
	250	84·6	9 22	6	42·2	1	1		263	73·4	7 14	6	51·5	1	1
	251	84·0	9 50	6	42·7	1	1		264	76·2	7 48	6	52·4	1	1
	252	87·0	10 17	6	43·2	1	1		265	77·8	8 17	6	53·5	1	1
	253	87·8	10 44	6	44·6	1	1		266	79·1	8 48	6	54·5	1	1
	254	88·0	11 10	6	44·7	1	1		267	81·2	9 11	6	56·4	1	1
	255	87·5	1 50 P.M.	6	44·8	1	1		268	84·2	9 35	6	57·4	1	1
	256	88·2	2 17	6	45·5	1	1		269	85·7	9 57	6	58·5	1	1
	257	87·3	2 48	6	46·5	1	1		270	85·0	10 22	6	59·8	1	1

Extracts from the Field Book—(Continued.)

1841	No. of the Set.	Temperature of Air	Mean time of ending	No. of bars used	Height of Set above origin	Numeral shewing arrangement of Bars.	Micros:
		°	h. m.		feet.		
11th Nov.	271	86·4	10 50 A.M.	6	— 60·2	1	1
	272	90·0	1 23 P.M.	6	62·0	1	1
	273	91·9	1 48	6	62·8	1	1
	274	88·7	2 17	6	63·3	1	1
	275	90·4	2 41	6	65·1	1	1
	276	89·4	3 6	6	66·2	1	1
	277	90·0	3 31	6	67·3	1	1
	278	90·2	3 55	6	68·3	1	1
	279	86·4	4 18	6	68·8	1	1
	280	83·5	4 41	6	69·6	1	1
	281	81·4	5 5	6	70·2	1	1
12th "	282	66·0	6 35 A.M.	6	70·8	1	1
	283	68·1	7 9	6	71·9	1	1
	284	71·9	7 35	6	72·9	1	1
	285	73·8	8 1	6	74·0	1	1
	286	75·5	8 27	6	75·1	1	1
	287	77·1	8 49	6	75·7	1	1
	288	79·1	9 14	6	76·3	1	1
	289	80·4	9 39	6	76·6	1	1
	290	81·5	10 2	6	77·1	1	1
	291	82·6	10 28	6	77·4	1	1
	292	83·9	10 56	6	78·6	1	1
	293	86·0	1 21 P.M.	6	79·4	1	1
	294	87·0	1 42	6	80·0	1	1
	295	87·9	2 5	6	80·4	1	1
	296	86·8	2 28	6	81·3	1	1
	297	87·8	2 52	6	82·1	1	1
	298	86·1	3 13	6	83·2	1	1
	299	84·9	3 37	6	83·8	1	1
	300	82·4	3 59	6	84·6	1	1
	301	79·7	4 25	6	85·4	1	1
	302	81·2	4 47	6	86·3	1	1
	303	79·5	5 11	6	87·1	1	1
13th "	304	60·8	6 37 A.M.	6	88·1	1	1
	305	63·9	7 9	6	89·0	1	1
	306	67·1	7 36	6	91·3	1	1
	307	69·8	7 59	6	92·4	1	1
	308	71·1	8 21	6	93·5	1	1
	309	73·4	8 45	6	95·0	1	1
	310	75·6	9 11	6	96·3	1	1
	311	78·0	9 36	6	98·0	1	1
	312	79·6	10 2	6	100·1	1	1
	313	80·9	10 24	6	100·9	1	1
	314	81·8	10 51	6	102·3	1	1
	315	84·3	2 26 P.M.	6	103·5	1	1
	316	84·0	2 53	6	105·1	1	1
	317	83·7	3 19	6	106·5	1	1
	318	83·4	3 44	6	107·3	1	1
	319	82·4	4 5	6	109·5	1	1
	320	78·6	4 24	6	110·7	1	1
13th Nov.	321	76·7	4 50 P.M.	6	— 111·6	1	1
	322	75·1	5 11	6	112·8	1	1
15th "	323	47·6	6 47 A.M.	6	112·9	1	1
	324	51·1	7 15	6	113·2	1	1
	325	59·6	7 49	6	114·0	1	1
	326	64·1	8 18	6	114·6	1	1
	327	67·9	8 43	6	114·8	1	1
	328	70·3	9 6	6	115·1	1	1
	329	73·2	9 34	6	115·9	1	1
	330	74·3	9 57	6	116·3	1	1
	331	75·1	10 24	6	116·3	1	1
	332	76·4	10 55	6	115·8	1	1
	333	79·4	1 25 P.M.	6	115·7	1	1
	334	79·7	1 49	6	115·6	1	1
	335	80·4	2 21	6	116·4	1	1
	336	80·0	2 45	6	116·3	1	1
	337	79·7	3 12	6	116·5	1	1
	338	79·4	3 32	6	117·7	1	1
	339	78·7	4 2	6	118·0	1	1
	340	74·0	4 22	6	118·0	1	1
	341	71·9	4 45	6	117·8	1	1
	342	68·9	5 12	6	118·6	1	1
16th "	343	47·4	6 38 A.M.	6	119·1	1	1
	344	49·0	7 6	6	120·0	1	1
	345	55·1	7 35	6	120·4	1	1
	346	61·2	7 58	6	120·6	1	1
	347	66·2	8 23	6	120·8	1	1
	348	70·1	8 49	6	122·6	1	1
	349	73·1	9 13	6	122·9	1	1
	350	75·9	9 37	6	123·6	1	1
	351	78·0	10 7	6	125·2	1	1
	352	80·9	10 30	6	126·7	1	1
	353	80·6	10 56	6	127·6	1	1
	354	83·0	3 23 P.M.	6	127·4	1	2
	355	82·7	3 56	6	127·3	1	2
	356	81·0	4 44	6	127·3	1	3
	357	70·3	5 15	6	127·2	1	3
17th "	358	49·9	6 40 A.M.	6	126·6	1	3
	359	53·0	7 9	6	125·5	1	3
	360	58·5	7 35	6	125·1	1	3
	361	64·2	8 3	6	124·8	1	3
	362	70·2	8 28	6	125·0	1	3
	363	74·8	8 54	6	124·9	1	3
	364	77·2	9 22	6	126·1	1	3
	365	79·4	9 48	6	127·1	1	3
	366	81·2	10 19	6	128·8	1	3
	367	82·2	10 48	6	132·2	1	3
	368	85·0	11 23	6	132·1	1	3
	369	85·5	1 49 P.M.	6	132·3	1	3
	370	85·4	2 17	6	130·9	1	3

Extracts from the Field Book—(Continued.)

1841	No. of the Set.	Temperature of Air	Mean time of ending	No. of bars used	Height of Set above origin	Numeral shewing arrangement of		1841	No. of the Set.	Temperature of Air	Mean time of ending	No. of bars used	Height of Set above origin	Numeral shewing arrangement of	
						Bars.	Micros :							Bars.	Micros :
		°	*h. m.*		*feet.*					°	*h. m.*		*feet.*		
17th Nov.	371	84·7	2 43 P.M.	6	—130·1	1	3	20th Nov.	421	84·5	1 30 P.M.	6	— 62·3	1	3
	372	84·9	3 12	6	129·8	1	3		422	86·9	1 55	6	61·9	1	3
	373	84·0	3 49	6	128·3	1	3		423	85·9	2 25	6	61·8	1	3
	374	82·4	4 13	6	128·0	1	3		424	86·0	2 46	6	61·7	1	3
	375	74·5	4 44	6	127·3	1	3		425	84·8	3 11	6	62·0	1	3
	376	69·8	5 15	6	127·0	1	3		426	84·2	3 35	6	62·4	1	3
18th „	377	52·4	6 35 A.M.	6	126·9	1	3		427	79·9	4 4	6	62·9	1	3
	378	55·0	7 4	6	126·8	1	3		428	77·0	4 30	6	63·6	1	3
	379	61·4	7 35	6	126·8	1	3		429	76·1	4 52	6	64·2	1	3
	380	66·4	8 2	6	126·8	1	3		430	73·3	5 21	6	64·9	1	3
	381	70·9	8 28	6	127·1	1	3	22nd „	431	60·6	6 35 A.M.	6	66·5	1	3
	382	74·0	8 49	6	126·5	1	3		432	62·9	7 8	6	67·8	1	3
	383	77·7	9 11	6	126·0	1	3		433	69·1	7 54	6	68·8	1	3
	384	80·0	9 35	6	125·7	1	3		434	73·2	8 31	6	69·4	1	3
	385	81·8	10 1	6	125·1	1	3		435	75·9	8 59	6	70·6	1	3
	386	84·3	10 40	6	124·5	1	3		436	78·0	9 26	6	72·0	1	3
	387	85·2	11 20	6	122·3	1	3		437	78·6	9 51	6	72·9	1	3
	388	86·0	1 47 P.M.	6	120·5	1	3		438	79·5	10 24	6	74·3	1	3
	389	86·2	2 20	6	119·1	1	3		439	81·4	10 54	6	75·3	1	3
	390	86·4	2 49	6	117·2	1	3		440	80·7	1 23 P.M.	6	76·1	1	3
	391	85·7	3 28	6	114·6	1	3		441	80·1	1 52	6	77·4	1	3
	392	85·5	4 3	6	112·3	1	3		442	83·2	2 22	6	78·8	1	3
	393	83·0	4 38	6	109·6	1	3		443	84·5	2 46	6	79·1	1	3
	394	73·8	5 10	6	107·8	1	3		444	81·2	3 14	6	79·0	1	3
19th „	395	56·2	6 41 A.M.	6	105·3	1	3		445	81·4	3 41	6	79·2	1	3
	396	62·8	7 40	6	102·4	1	3		446	78·6	4 18	6	78·4	1	3
	397	73·0	8 33	6	99·4	1	3		447	75·4	4 50	6	78·5	1	3
	398	78·6	9 22	6	95·3	1	3		448	72·4	5 15	6	78·3	1	3
	399	81·7	10 3	6	92·9	1	3	23rd „	449	58·4	6 40 A.M.	6	78·3	1	3
	400	82·7	10 31	6	91·8	1	3		450	61·4	7 10	6	78·6	1	3
	401	83·9	11 0	6	89·9	1	3		451	65·6	7 39	6	79·2	1	3
	402	85·9	1 29 P.M.	6	87·8	1	3		452	69·8	8 8	6	79·3	1	3
	403	85·4	1 57	6	85·7	1	3		453	72·9	8 38	6	79·6	1	3
	404	85·7	2 27	6	84·0	1	3		454	74·1	9 3	6	79·6	1	3
	405	85·6	2 59	6	83·2	1	3		455	77·5	9 32	6	79·5	1	3
	406	87·5	3 24	6	82·0	1	3		456	77·6	9 57	6	79·5	1	3
	407	85·0	3 54	6	80·1	1	3		457	79·9	10 24	6	79·3	1	3
	408	78·3	4 18	6	79·2	1	3		458	80·7	10 58	6	79·2	1	3
	409	77·3	4 47	6	77·5	1	3		459	82·7	1 38 P.M.	6	80·7	1	3
	410	74·9	5 13	6	75·8	1	3		460	83·5	2 5	6	81·5	1	3
20th „	411	57·7	6 38 A.M.	6	74·6	1	3		461	81·6	2 31	6	82·1	1	3
	412	59·5	7 11	6	72·4	1	3		462	80·5	2 57	6	82·6	1	3
	413	64·0	7 41	6	70·9	1	3		463	82·5	3 21	6	83·8	1	3
	414	68·0	8 8	6	70·1	1	3		464	82·4	3 41	6	85·8	1	3
	415	71·2	8 36	6	68·5	1	3		465	78·7	4 7	6	86·0	1	3
	416	74·7	9 3	6	67·2	1	3		466	75·1	4 31	6	86·1	1	3
	417	78·3	9 34	6	65·5	1	3		467	72·3	5 1	6	86·5	1	3
	418	80·3	9 58	6	64·7	1	3		468	70·4	5 23	6	86·8	1	3
	419	81·3	10 29	6	63·5	1	3	24th „	469	55·1	6 40 A.M.	6	84·9	1	3
	420	82·5	10 55	6	62·7	1	3		470	57·9	7 14	6	83·4	1	3

Extracts from the Field Book—(Continued.)

1841	No. of the Set	Temperature of Air	Mean time of ending	No. of bars used	Height of Set above origin	Numeral shewing arrangement of: Bars.	Micros:
		°	h. m.		feet.		
24th Nov.	471	62·8	7 43 A.M.	6	— 82·0	1	3
	472	66·5	8 13	6	80·4	1	3
	473	70·4	8 47	6	78·8	1	3
	474	73·9	9 24	6	77·9	1	3
	475	75·7	9 53	6	77·4	1	3
	476	76·8	10 26	6	75·1	1	3
	477	78·0	10 51	6	73·9	1	3
	478	81·0	1 20 P.M.	6	73·3	1	3
	479	79·6	1 48	6	73·1	1	3
	480	80·6	2 14	6	73·1	1	3
	481	80·0	2 40	6	72·4	1	3
	482	80·4	3 7	6	71·5	1	3
	483	79·6	3 29	6	70·5	1	3
	484	79·8	3 54	6	69·6	1	3
	485	77·2	4 17	6	68·6	1	3
	486	74·6	4 38	6	68·5	1	3
	487	73·2	5 0	6	68·4	1	3
	488	71·0	5 22	6	68·3	1	3
25th „	489	53·1	6 44 A.M.	6	67·3	1	3
	490	55·4	7 14	6	66·3	1	3
	491	61·4	7 48	6	65·5	1	3
	492	65·6	8 15	6	64·7	1	3
	493	67·9	8 37	6	64·2	1	3
	494	70·7	9 2	6	63·2	1	3
	495	72·1	9 24	6	62·4	1	3
25th Nov.	496	73·4	9 47 A.M.	6	— 61·3	1	3
	497	74·7	10 8	6	60·9	1	3
	498	75·3	10 30	6	59·5	1	3
	499	78·6	0 52 P.M.	6	59·2	1	3
	500	80·1	1 16	6	58·3	1	3
	501	81·5	1 41	6	57·8	1	3
	502	80·1	2 3	6	56·2	1	3
	503	81·1	2 26	6	55·7	1	3
	504	80·7	2 48	6	54·6	1	3
	505	80·7	3 16	6	53·0	1	3
	506	80·6	3 37	6	51·9	1	3
	507	79·9	4 2	6	51·6	1	3
	508	75·3	4 29	6	51·0	1	3
	509	73·9	4 50	6	50·8	1	3
	510	71·4	5 18	6	50·1	1	3
26th „	511	57·3	6 55 A.M.	6	48·6	1	3
	512	60·3	7 23	6	48·0	1	3
	513	64·0	7 51	6	46·8	1	3
	514	66·7	8 14	6	45·9	1	3
	515	69·6	8 40	6	44·9	1	3
	516	71·4	9 2	6	43·7	1	3
	517	72·5	9 29	6	43·5	1	3
	518	77·9	10 45	6	42·0	1	3
				Total	— 23263·9		

The advanced-end of set No. 518 fell in excess (*i. e.* east) of the dot at Station B, 0·2631 feet, as measured on Cary's brass scale with a pair of compasses.

Height of set No. 518 above Station B = 1·6 feet.

The terminal point of set No. 518 was the point of origin for set No. 519.

1841	No. of the Set	Temperature of Air	Mean time of ending	No. of bars used	Height of Set above origin	Bars.	Micros:
26th Nov.	519	83·4	2 43 P.M.	6	— 42·1	1	4
	520	83·1	3 8	6	42·1	1	4
	521	84·0	3 35	6	42·1	1	4
	522	83·0	4 0	6	42·9	1	4
	523	81·7	4 25	6	44·5	1	4
	524	75·2	4 48	6	45·5	1	4
	525	73·2	5 12	6	46·3	1	4
27th „	526	58·2	6 49 A.M.	6	46·8	1	4
	527	61·2	7 19	6	47·3	1	4
	528	65·1	7 48	6	47·9	1	4
	529	72·6	8 59	6	48·4	1	4
	530	74·7	9 25	6	49·6	1	4
	531	75·9	9 45	6	50·7	1	4
	532	77·0	10 8	6	51·5	1	4
	533	77·6	10 31	6	52·5	1	4
	534	78·4	10 58	6	52·9	1	4
	535	82·8	1 19 P.M.	6	54·4	1	4
	536	82·9	1 39	6	55·1	1	4
	537	83·7	2 5	6	55·8	1	4
	538	85·0	2 26	6	56·6	1	4
27th Nov.	539	84·8	2 48 P.M.	6	— 57·2	1	4
	540	85·4	3 9	6	57·9	1	4
	541	83·9	3 30	6	58·7	1	4
	542	84·9	3 50	6	59·5	1	4
	543	78·5	4 13	6	61·2	1	4
	544	77·1	4 31	6	61·9	1	4
	545	75·3	4 55	6	63·0	1	4
	546	73·9	5 17	6	63·8	1	4
29th Nov.	547	63·2	6 54 A.M.	6	64·6	1	4
	548	65·2	7 21	6	65·8	1	4
	549	67·5	7 47	6	66·8	1	4
	550	70·2	8 8	6	67·8	1	4
	551	72·1	8 30	6	69·0	1	4
	552	73·4	8 52	6	70·2	1	4
	553	75·0	9 18	6	71·0	1	4
	554	77·2	9 47	6	73·2	1	4
	555	79·1	10 15	6	76·4	1	4
	556	80·5	11 0	6	79·7	1	4
	557	82·3	11 30	6	83·8	1	4
	558	82·0	1 50 P.M.	6	85·5	1	4

Extracts from the Field Book—(Continued.)

1841	No. of the Set	Temperature of Air	Mean time of ending	No. of bars used	Height of Set above origin	Numeral shewing arrangement of Bars.	Numeral shewing arrangement of Micros:
		°	h. m.		feet.		
29th Nov.	559	84·9	2 16 P.M.	6	— 85·6	1	4
	560	86·4	2 51	6	83·7	1	4
	561	85·4	3 17	6	82·8	1	4
	562	84·2	3 39	6	82·1	1	4
	563	81·6	4 2	6	81·5	1	4
	564	79·6	4 25	6	80·3	1	4
	565	76·0	5 0	6	76·2	1	4
	566	71·4	5 33	6	73·8	1	4
30th „	567	63·9	6 50 A.M.	6	72·7	1	4
	568	65·0	7 19	6	71·2	1	4
	569	67·3	7 42	6	69·8	1	4
	570	69·9	8 5	6	68·1	1	4
	571	73·0	8 32	6	66·1	1	4
	572	74·9	8 57	6	65·0	1	4
	573	76·8	9 20	6	64·5	1	4
	574	78·7	9 46	6	64·3	1	4
	575	80·0	10 3	6	63·8	1	4
	576	82·2	10 26	6	63·1	1	4
	577	82·2	10 50	6	63·1	1	4
	578	86·4	1 14 P.M.	6	63·1	1	4
	579	88·4	1 39	6	63·1	1	4
	580	89·5	2 2	6	63·0	1	4
	581	88·4	2 28	6	60·9	1	4
	582	88·0	2 54	6	60·3	1	4
	583	88·3	3 15	6	60·2	1	4
	584	86·7	3 40	6	59·5	1	4
	585	86·6	4 9	6	59·5	1	4
	586	83·0	4 34	6	59·1	1	4
	587	79·5	5 0	6	58·3	1	4
	588	76·6	5 23	6	57·2	1	4
1st Dec.	589	67·1	6 40 A.M.	6	56·5	1	4
	590	68·1	7 7	6	55·7	1	4
	591	69·4	7 36	6	54·7	1	4
	592	71·7	8 4	6	53·1	1	4
	593	73·9	8 28	6	51·8	1	4
	594	76·1	8 52	6	51·1	1	4
	595	78·0	9 18	6	50·3	1	4
	596	79·2	9 38	6	49·1	1	4
	597	80·7	10 2	6	48·3	1	4
	598	81·4	10 21	6	47·4	1	4
	599	82·9	10 43	6	46·2	1	4
	600	85·3	1 3 P.M.	6	45·9	1	4
	601	86·0	1 30	6	46·0	1	4
	602	84·0	2 1	6	46·3	1	4
	603	85·1	2 24	6	46·7	1	4
	604	86·9	2 50	6	47·9	1	4
	605	87·3	3 13	6	48·1	1	4
	606	88·0	3 37	6	48·3	1	4
	607	86·6	3 58	6	48·5	1	4
	608	81·9	4 23	6	48·7	1	4
	609	80·1	4 43	6	48·7	1	4
	610	78·1	5 7	6	48·7	1	4
2nd „	611	65·1	6 46 A.M.	6	48·8	1	4

1841	No. of the Set	Temperature of Air	Mean time of ending	No. of bars used	Height of Set above origin	Numeral shewing arrangement of Bars.	Numeral shewing arrangement of Micros:
		°	h. m.		feet.		
2nd Dec.	612	65·2	7 14 A.M.	6	— 48·6	1	4
	613	67·5	7 40	6	48·6	1	4
	614	70·1	8 0	6	48·6	1	4
	615	72·9	8 24	6	48·6	1	4
	616	75·4	8 45	6	48·7	1	4
	617	77·2	9 10	6	49·1	1	4
	618	78·4	9 30	6	50·1	1	4
	619	79·0	9 53	6	50·5	1	4
	620	80·0	10 19	6	51·2	1	4
	621	81·0	10 42	6	51·0	1	4
	622	81·2	11 1	6	50·3	1	4
	623	85·1	1 27 P.M.	6	49·6	1	4
	624	85·0	1 50	6	48·6	1	4
	625	84·3	2 13	6	48·0	1	4
	626	85·7	2 39	6	47·8	1	4
	627	84·4	3 1	6	47·6	1	4
	628	85·1	3 23	6	47·2	1	4
	629	84·0	3 44	6	46·7	1	4
	630	83·7	4 7	6	45·8	1	4
	631	82·3	4 25	6	44·8	1	4
	632	79·4	4 49	6	44·5	1	4
	633	77·5	5 11	6	43·9	1	4
3rd „	634	62·1	6 44 A.M.	6	42·9	1	4
	635	63·6	7 13	6	41·0	1	4
	636	66·2	7 39	6	39·3	1	4
	637	68·9	8 4	6	38·4	1	4
	638	71·4	8 25	6	37·6	1	4
	639	73·7	8 49	6	36·3	1	4
	640	76·2	9 11	6	34·8	1	4
	641	78·1	9 34	6	33·6	1	4
	642	79·4	9 58	6	31·3	1	4
	643	80·1	10 20	6	30·4	1	4
	644	80·2	10 44	6	29·0	1	4
	645	81·4	11 10	6	28·1	1	4
	646	84·1	1 40 P.M.	6	27·0	1	4
	647	84·1	2 4	6	26·1	1	4
	648	84·4	2 28	6	25·2	1	4
	649	84·3	2 53	6	24·1	1	4
	650	83·9	3 21	6	23·4	1	4
	651	83·5	3 46	6	22·8	1	4
	652	83·1	4 10	6	22·3	1	4
	653	80·0	4 32	6	22·2	1	4
	654	78·1	4 51	6	22·2	1	4
	655	76·3	5 17	6	22·0	1	4
4th „	656	61·4	6 46 A.M.	6	21·9	1	4
	657	63·1	7 9	6	21·9	1	4
	658	65·1	7 33	6	21·5	1	4
	659	68·1	8 0	6	20·8	1	4
	660	74·4	9 10	6	19·1	1	4
			Total		— 7335·7		

The advanced-end of set No. 660 fell in defect (*i. e.* west) of the dot at East-End 0·1792 feet, as measured on Cary's brass scale with a pair of compasses.

Height of set No. 660 above East-End = 1·6 feet.

Reduction to Mean Sea Level.

Let the sections into which this base-line is divided be denoted as follows:

West-End to Station A by Section I;
Station A to „ B „ II;
„ B to East-End „ III;

Then in the notation of (7) page I—22 we have

$H = 1980$; $h = -23{\cdot}1$; $\delta h = -2{\cdot}4$; Log. $R = 7{\cdot}31990$, all in feet; and $n = 660$.

	$[h]_1^p$	a	n	dh	F	λ	C_2	C_1	C
	−			−	−		+	−	−
Section I ...	12279	0	244	0·9	12389	15373	·0374	1·4572	1·4198
„ II ...	23264	0	274	1·0	23648	17263	·0713	1·6364	1·5651
„ III ...	7336	0	142	0·5	7642	8947	·0230	0·8481	0·8251

Final length of the Base-Line and of its parts in feet of Standard A.

Section	Measured with: Compensated bars page IV—12	Measured with: Compensated microscopes page IV—16	Measured with: Beam compass pages IV—19 to IV—23	Reduction to sea level as above	Total Length	Log.
W. End to Stn. A ...	14640·7445	732·1189	+ ·1033	− 1·4198	15371·5469	4·18671,7574
Stn. A to Stn. B ...	16440·8360	822·1352	− ·2631	− 1·5651	17261·1430	4·23706,9566
Stn. B to E. End ...	8520·4332	426·0703	+ ·1792	− 0·8251	8945·8576	3·95162,1981
W. End to E. End ...	39602·0137	1980·3244	+ ·0194	− 3·8100	41578·5475	4·61886,9314

Verificatory Minor Triangulation.

No. of Triangle	Name of Station	Corrected Angle	Log. Sine	Log. Distance	Distance in Feet	Distance in Miles	Error of Triangle
1	West-End of Base,	° ′ ″ 35 38 55·976	9·765531782	3·953883110			
	Station A, ...	59 19 4·101	9·934503940	4·122855268			
	" α	85 1 59·951	9·998366246	4·186717574	15371·5469	2·911	″ −0·604
		180 0 0·028					
2	Station α	65 42 8·460	9·959718617	4·190456991			
	" A, ...	82 23 7·083	9·996153218	4·226891592			+0·384
	" β	31 54 44·490	9·723144736	3·953883110			
		180 0 0·033					
3	Station A, ...	38 17 47·754	9·792204194	4·036425546			
	" β	79 37 43·242	9·992845758	4·237067110	17261·0460	3·269	−0·472
	" B, ...	62 4 29·043	9·946235639	4·190456991			
		180 0 0·039					
4	Station β	33 46 10·766	9·744961863	3·791825871			
	" B, ...	68 44 32·017	9·969396658	4·016260666			−1·270
	" γ	77 29 17·232	9·989561538	4·036425546			
		180 0 0·015					
5	Station B, ...	49 11 1·120	9·878985996	3·831170608			
	" γ	87 5 11·209	9·999438251	3·951622863	8945·8758	1·694	−0·741
	East-End of Base,	43 43 47·681	9·839641259	3·791825871			
		180 0 0·010		Sum	41578·4687	7·874	

Note.—Each side of a triangle is given in the same horizontal line with the angle which it subtends.

The angles of the verificatory triangulation were measured with a 3-foot Theodolite (either the one by Troughton or that by Barrow) read by 5 micrometer-microscopes. At all the stations 3 measures were made on each of 8 zeros. The stations on the line are W. End, A, B, and E. End. The auxiliary stations are α, β and γ.

Comparison in feet between the values computed by means of the verificatory triangulation and the measured value.

Of the entire line.

			Log.
West-End to East-End by the measurement, page IV—24		41578·5475	4·618 869 314
„	computed in terms of West-End to Station A page IV—25	41578·4687	4·618 868 491
	Log. computed value — Log. measured value =		— 0·000 000 823

In terms of the entire line by measurement.

	Computed	Computed — Measured*
West-End to Station A	15371·5760	+0·0291
Station A to Station B	17261·0787	—0·0643
„ B to East-End	8945·8928	+0·0352

Of each section in terms of the others.

	West-End to Station A	Station A to Station B	Computed — Measured	Station B to East-End	Computed — Measured
Measured lengths* ..	15371·5469	17261·1430	.. ..	8945·8576	.. ..
Computed on base West-End to Station A	.. ..	17261·0460	—·0970	8945·8758	+·0182
Computed on base Station A to Station B	.. ..	.. ..	.. ..	8945·9264	+·0688

NOTE.—Since $\text{Log}_e(x + dx) = \text{Log}_e x + \frac{(dx)}{x} + \frac{(dx)^2}{2x^2} + \&c.$

$$dx = \left\{\text{Log}_{10}(x + dx) - \text{Log}_{10} x\right\} \frac{x}{\text{Modulus}}$$ nearly, by which expression the required variations in the foregoing natural numbers have been calculated.

Description of Stations.

WEST-END OF BIDER BASE, Lat. 17° 58′, Long. 77° 34′, is situated on the lands of Marcal village; pargana Bider of the Hydrabad district (Nizam's dominions). The circumjacent places, with their distances and bearings, are as follows; Bider fortress 2 miles S.; Gadgi village 1·4 miles S.E.; the Mausoleum near Fatepur 1·5 miles N.E., and Bankeli village nearly 1 mile N. The station is not on the highest part of the ridge, having been selected at a lower level for convenience in measuring the base-line.

The following description is taken from the original record by Colonel Everest:—

"The platform is 16·9 inches high, with a foundation of 21·5 inches on basalt rock. The distance be- "tween upper and lower marks is 21·4 inches; the marks are dots engraved on brass plugs, fixed in long basalt stones "by means of lead. The pier for the great theodolite is of stone masonry 4 feet in diameter and circumscribed by an "annulus also of masonry, by which it is isolated from the rest of the platform. The rock *in situ* occurs 3 inches "below the surface of the ground, and therefore the footing of the pier has been sunk 18·5 inches into the rock; the latter "is a basaltic trap of a friable nature, readily splitting into small rhomboidal fragments, and on account of this pecu- "liarity of structure it was impracticable to mark the rock itself."*

EAST-END OF BIDER BASE, Lat. 17° 54′, Long. 77° 39′, is situated on the lands of Malgi village; pargana Bider of the Hydrabad district (Nizam's dominions). The village of Malgi is about 1 mile W. of the station and the town of Bider some 5 miles to the W.N.W.

The following description is taken from the original record by Colonel Everest:—

"The platform is 17 inches high, and constructed on the isolating principle, the pier and annulus being "both of stone masonry. There are 3 marks in the pier; an upper mark, 17 inches above the ground, and a middle "and lower mark at 4 inches and 33·75 inches respectively below the surface. The marks are engraved on brass plugs, "fixed in long basalt stones."*

STATION A.* Is on the line and 2·934 miles from the West-End; and is situated on a gentle swell of land, about a quarter of a mile north of the small village of Sholapur.

The station is marked by a dot on a silver stud let into a slip of brass imbedded in stone.

STATION B.* Is on the line and 1·744 miles from the East-End, and is situated on a swell in the fields N.W. of Malgi village. This swell is the only ground available for the trisectional division of the base.

The station is marked precisely after the method adopted for station A.

AUXILIARY STATION α OR BIDER FORT, COUNTERSCARP OF DITCH.* This is the only position available for the minor triangulation. The ditch of the fort has been excavated in the iron-stone rock, leaving a ridge 14 feet thick at the edge of the hill. The village of Mamankheri is N. 30° W. ⅝ mile; Hamelapur N. 39° E. 1 mile; Mirganj N. 56° E. ¼ mile; Agrar N. 81° E. ½ mile; Waldodi, N. 118° E. ½ mile.

AUXILIARY STATION β OR MALKAPUR HILL.* The village of Malkapur is situated between two isolated hills of trap formation, capped with iron-stone. There are fakir's

* Taken from pages 72-74 Everest's Meridional Arc of India, 1847.

Description of Stations—(Continued.)

tombs on both these hills; one of these tombs offered no obstruction, but the other occupied the only available ground at top, and therefore the station has been placed on the northern face of the hill.

AUXILIARY STATION γ OR MALENA,* This station is at the foot of Malena hill, connected with that on which Malgi G. T. Survey station is fixed, and it is of the same geological character.

* Taken from pages 72-74 Everest's Meridional Arc of India, 1847.

J. B. N. HENNESSEY.

SONAKHODA BASE-LINE.

The middle point of this base-line is in Latitude N. 26° 17′, Longitude E. 88° 17′; the Azimuth of Rámgunj or North-East End at Sonákhoda or South-West End is 233° 57′, and the line is 6·95 Miles in length.

The measurement was effected under the directions of Lieut.-Colonel* A. S. Waugh, R.E., with the aid of the following:

Captain T. Renny, R.E.
Mr. G. Logan
„ C. Lane
„ H. Keelan
„ T. Olliver
„ J. W. Rossenrode
„ J. B. N. Hennessey
„ J. O. N. James
„ J. H. Lawrence
„ A. T. Haycock
„ —— Lawler
Mir Siud Mohsin

* Now General Sir A. S. Waugh.

INTRODUCTION.

This base-line was measured on the stretch of level ground which lies between the villages of Sonákhoda and Rámganj in the Purneah district, province of Bengal. The line was selected and prepared for measurement under the immediate directions of Lieutenant-Colonel A. S. Waugh, R.E., who was assisted in the selection by Lieutenant R. Walker, R.E.

The measurement was commenced at Sonákhoda or South-West-End, bar-tongues pointing North-West, and carried on *continuously* to Rámganj or North-East-End, so that every succeeding set originated at the point marking the terminus of its predecessor. The line was divided into 4 sections by the sub-dividing points A, B and C, to admit of verificati on by minor triangulation.

The compensated bars were compared with the standard **A** before and after the measurement, as was customary at all the preceding base-lines; and they were also similarly compared for the first time about the middle of the measurement, a procedure which was adhered to at all the subsequent base-lines. On all these three occasions of comparisons, the comparing piers were set up parallel to and within a few feet of the line, but before the measurement near the South-West-End, the ends of the bars were reversed to obtain a more favorable light, so that the bar-tongues pointed South-East during these comparisons. After set No. 291 the comparing piers stood in the vicinity of Section Station B, and after the measurement they were placed near the North-East-End: on both these occasions of comparsions the bar-tongues pointed North-West as they did during the measurement. 53 comparisons were made before the measurement, 60 after set No. 291 at B and 80 after the measurement had been completed.

One of the comparing microscopes employed in the preceding bar comparisons was fitted with a micrometer, while the other had its wires (or lines) fixed.

The compensated microscopes were compared with their scales on 6 occasions, including the comparisons taken prior and subsequent to the measurement.

In respect to time, the first set of bar comparisons was made on the 27th November 1847, the last on the 21st of the following January.

The stations of the verificatory triangulation were 9 in number, forming a single series of triangles. Of these stations, 5 were in the alignment, *viz.* South-West-End, A, B, C and North-East-End, while the auxiliary stations α, β, γ and δ were placed on suitable sites North-West of the line. The angles were observed by Mr. C. Lane with Troughton's 3-foot theodolite at 8 equidistant zeros; three méasures were taken on each zero so that 24 measures in all were made of each angle.

Comparisons between the Standard Bar **A** *and the Compensated Bars* A, B, C, D, E, H, *made at Sonakhoda, or South-West-End of the base-line, before the measurement.*

1847 Novr.	Mean of the times of observing A	No. of comparison	Temperature of Air	Corrected mean temperature of A	Micrometer Readings in Divisions — 1 Division = $\frac{1}{31603 \cdot 4}$ Cary's Inch [7.8],= 1·2851 m.y of A — Mean A	A	B	C	D	E	H	Mean of the compensated bars	Remarks
	h m		°	°	+	+	+	+	+	+	+	+	
27th	7 45 A.M.	1	63·5	60·85	101·0	268·5	247·1	264·9	291·0	260·5	263·9	266·0	Foggy morning. No clouds. Capt. Waugh at the micrometer micros: Capt. Renny at the plain micros.
	8 39	2	65·7	61·60	115·5	266.0	250·0	269·9	294·5	266·0	264·0	268·4	
	9 19	3	68·7	63·20	144·5	269·1	250·0	270·7	292·8	265·0	264·4	268·7	
	9 54	4	71·2	65·15	178·5	267·2	247·5	270·8	295.0	265·9	266·2	268·8	
	10 25	5	73·3	67·10	211·1	269·8	247·1	273·1	296·0	269·0	267·2	270·4	
	10 53	6	74·8	68·85	258·5	269·0	249·1	273·1	296·2	270·0	266·0	270·6	
	1 31 P.M.	7	79·2	77·30	370·2	241·5	241·7	279·9	304·9	272·1	257·9	266·3	Sky cloudy.
	2 1	8	79·1	78·18	384·3	239·1	240·3	275·0	300·1	269·3	253·5	262·9	
	2 31	9	78·8	78·78	394·6	246·1	240·2	272·0	297·3	266·2	253·2	262·5	
	3 0	10	78·3	79·03	399·0	251·0	241·0	272·0	295·9	264·9	253·0	263·0	
	3 30	11	77·6	79·15	399·1	256·0	243·7	267·1	291·7	262·8	249·1	261·7	
	3 59	12	76·8	79·13	395·7	260·7	244·0	269·5	294·0	263·1	251·0	263·7	
	4 28	13	75·2	78·30	389·1	260·1	247·1	270·3	295·0	260·0	251·0	263·9	
29th	6 56 A.M.	14	60·3	60·20	73·1	249·8	230·6	249·8	275·6	240·0	246·2	248·7	Capt. Renny at the micrometer microscope; Mr. Logan at the plain microscope.
	7 33	15	62·7	60·38	75·2	253·6	235·4	256·3	278·2	244·6	249·0	252·9	
	8 5	16	65·7	61·15	91·7	255·0	235·2	255·1	279·2	248·0	250·0	253·8	
	8 37	17	68·5	62·33	114·2	254·0	233·4	256·8	279·8	246·1	249·3	253·2	
	9 6	18	70·7	63·78	139·3	252·1	233·0	258·2	282·0	246·1	250·1	253·6	
	9 32	19	72·4	65·43	168·4	252·1	231·8	258·8	280·3	252·5	250·6	254·4	
	9 59	20	73·7	67·23	197·2	252·1	231·8	259·0	280·0	251·1	248·8	253·8	
	10 26	21	75·0	68·98	224·8	250·0	230·0	258·8	280·4	249·8	249·0	253·0	
	10 50	22	75·9	70·43	249·5	250·1	231·2	260·7	280·5	249·5	248·2	253·4	
	1 23 P.M.	23	77·9	75·53	329·8	247·2	234·8	266·0	289·1	254·5	242·8	255·7	
	1 46	24	78·1	76·15	339·4	246·3	233·0	264·0	286·5	254·8	245·1	255·0	
	2 12	25	78·3	76·80	350·3	244·2	233·2	261·0	282·5	255·8	242·0	253·1	
	2 38	26	78·1	77·35	359·1	245·3	232·0	261·3	283·1	251·3	239·5	252·1	
	3 1	27	77·8	77·73	364·7	246·8	230·6	260·5	278·4	249·6	239·7	250·9	
	3 25	28	77·3	77·93	365·9	242·5	228·3	258·2	278·7	248·4	236·7	248·8	
	3 50	29	76·5	77·95	364·4	244·0	226·8	257·8	279·7	248·0	237·5	249·0	
	4 11	30	75·6	77·88	362·2	247·2	228·1	257·3	279·8	245·8	237·0	249·2	
	4 34	31	73·5	77·65	355·3	246·1	231·3	258·0	281·1	245·4	235·4	249·6	
30th	7 3 A.M.	32	58·0	58·08	29·3	241·8	222·5	245·8	264·8	230·6	236·0	240·3	Mr. Logan at the micrometer microscope; Mr. Keelan at the plain microscope.
	7 28	33	59·2	58·10	30·2	248·2	225·4	247·2	262·3	230·8	237·3	241·9	
	7 51	34	61·2	58·45	37·9	248·4	222·0	248·8	269·8	238·2	240·2	244·6	
	8 13	35	62·8	59·03	48·8	249·0	228·2	247·3	267·5	236·7	242·5	245·2	
	8 33	36	64·0	59·65	59·7	247·3	224·5	244·9	267·2	234·7	238·3	242·8	
	8 55	37	65·6	60·60	76·0	248·7	225·0	248·0	268·0	237·8	241·3	244·8	
	9 17	38	67·6	61·75	98·1	248·0	228·5	249·2	270·0	242·2	242·8	246·8	
	9 40	39	69·1	63·05	121·0	246·4	223·3	245·8	270·8	240·3	243·3	245·0	
	10 2	40	70·5	64·45	143·4	246·3	224·5	252·8	272·9	244·0	243·8	247·4	
	10 22	41	71·9	65·68	164·6	248·3	222·7	251·8	276·4	243·5	243·1	247·6	
	10 41	42	72·7	66·80	184·7	242·8	226·5	254·9	274·2	248·2	242·2	248·1	

Before the measurement—(Continued.)

1847 Novr.	Mean of the times of observing A	No. of comparison	Temperature of Air	Corrected mean temperature of A	Micrometer Readings in Divisions. 1 Division = $\frac{1}{21603\cdot4}$ Cary's Inch [7.8], = 1·2851 m.y of A — Mean A	A	B	C	D	E	H	Mean of the compensated bars	Remarks
	h m		°	°	+	+	+	+	+	+	+	+	
30th	1 19 P.M.	43	75·7	73·40	286·8	235·2	223·3	254·0	273·5	241·8	233·2	243·5	
	1 40	44	76·3	74·00	295·4	232·3	223·2	254·7	272·0	239·5	231·0	242·1	
	1 58	45	76·3	74·43	300·6	230·3	218·2	251·2	270·0	238·3	230·2	239·7	
	2 15	46	76·2	74·90	306·2	234·0	220·8	251·8	272·0	240·0	231·8	241·7	
	2 35	47	76·5	75·30	311·3	235·3	222·0	252·0	271·8	239·3	229·0	241·6	
	2 57	48	75·9	75·55	314·9	236·7	219·9	250·2	269·0	239·8	230·0	240·9	
	3 19	49	75·6	75·73	317·2	238·3	220·0	245·7	271·0	236·8	229·3	240·2	
	3 38	50	75·9	75·83	318·5	237·3	222·2	248·3	271·3	237·0	228·8	240·8	
	3 55	51	75·6	75·85	320·3	240·0	218·3	248·7	270·8	235·7	226·1	239·9	
	4 13	52	74·7	75·88	322·2	235·5	218·5	244·3	268·5	235·3	227·7	238·3	
	4 31	53	74·0	75·83	320·6	238·2	218·5	244·6	267·1	234·0	223·3	237·6	
		Means		70·07	238·74	248·13	231·27	257·88	280·00	248·69	243·93	251·65	

Before the measurement—(Continued.)

Let the mean length of the compensated bars minus the Standard **A** at 62° *F.* be denoted by x, and the observed excess of the compensated bars by δ when the temperature of **A** is $t°$. Then, the expansion of **A** for 1° being $(E_a - dE_a)$, we have

$$x - (t° - 62°)(E_a - dE_a) - \delta = 0$$

Treating the preceding bar comparisons as shewn in this equation, we obtain the following series of results :—

		d			d
x + 1·15	$(E_a - dE_a)$	−165·0 = 0	x − 15·93	$(E_a - dE_a)$	+117·1 = 0
x + ·40	"	−152·9 = 0	x − 15·95	"	+115·4 = 0
x − 1·20	"	−124·2 = 0	x − 15·88	"	+113·0 = 0
x − 3·15	"	− 90·3 = 0	x − 15·65	"	+105·7 = 0
x − 5·10	"	− 59·3 = 0	x + 3·92	"	−211·0 = 0
x − 6·85	"	− 32·1 = 0	x + 3·90	"	−211·7 = 0
x − 15·30	"	+103·9 = 0	x + 3·55	"	−206·7 = 0
x − 16·18	"	+121·4 = 0	x + 2·97	"	−196·4 = 0
x − 16·78	"	+132·1 = 0	x + 2·35	"	−183·1 = 0
x − 17·03	"	+136·0 = 0	x + 1·40	"	−168·8 = 0
x − 17·15	"	+137·4 = 0	x + ·25	"	−148·7 = 0
x − 17·13	"	+132·0 = 0	x − 1·05	"	−124·0 = 0
x − 16·30	"	+125·2 = 0	x − 2·45	"	−104·0 = 0
x + 1·80	"	−175·6 = 0	x − 3·68	"	− 83·0 = 0
x + 1·62	"	−177·7 = 0	x − 4·80	"	− 63·4 = 0
x + ·85	"	−162·1 = 0	x − 11·40	"	+ 43·3 = 0
x − ·33	"	−139·0 = 0	x − 12·00	"	+ 53·3 = 0
x − 1·78	"	−114·3 = 0	x − 12·43	"	+ 60·9 = 0
x − 3·43	"	− 86·0 = 0	x − 12·90	"	+ 64·5 = 0
x − 5·23	"	− 56·6 = 0	x − 13·30	"	+ 69·7 = 0
x − 6·98	"	− 28·2 = 0	x − 13·55	"	+ 74·0 = 0
x − 8·43	"	− 3·9 = 0	x − 13·73	"	+ 77·0 = 0
x − 13·53	"	+ 74·1 = 0	x − 13·83	"	+ 77·7 = 0
x − 14·15	"	+ 84·4 = 0	x − 13·85	"	+ 80·4 = 0
x − 14·80	"	+ 97·2 = 0	x − 13·88	"	+ 83·9 = 0
x − 15·35	"	+107·0 = 0	x − 13·83	"	+ 83·0 = 0
x − 15·73	"	+113·8 = 0			

Before the measurement—(Continued.)

And from the mean of these results,

$$x = \overset{d}{12{\cdot}91} + 8{\cdot}07\,(E_a - dE_a):$$

adopting the original value of the expansion of **A** given at page (9),

$$E_a = \overset{m.y}{22{\cdot}67} = \overset{d}{17{\cdot}641},$$

$$\text{and } x = \overset{d}{155{\cdot}27} - 8{\cdot}07\,dE_a = \overset{m.y}{199{\cdot}54} - 8{\cdot}07\,dE_a = \text{L} - \textbf{A};$$

where L denotes the mean length of the compensated bars obtained from *all* the comparisons, as represented by the mean micrometer reading $\overset{d}{251{\cdot}65}$, page V—5.

Comparing this reading with the mean reading of each compensated bar given on the same page we obtain the following:—

In terms of	A – L	B – L	C – L	D – L	E – L	H – L
Micrometer divisions.	–3·52	–20·38	+6·23	+28·35	–2·96	–7·72
Millionths of a yard.	–4·52	–26·19	+8·01	+36·43	–3·80	–9·92

Also combining the values in this table with the equivalent of L – **A** above determined, there result,

$$\begin{aligned}
\text{A} - \textbf{A} &= \overset{d}{151{\cdot}75} - 8{\cdot}07\,dE_a = \overset{m.y}{195{\cdot}02} - 8{\cdot}07\,dE_a\\
\text{B} - \textbf{A} &= 134{\cdot}89 - \quad " \quad = 173{\cdot}35 - \quad "\\
\text{C} - \textbf{A} &= 161{\cdot}50 - \quad " \quad = 207{\cdot}55 - \quad "\\
\text{D} - \textbf{A} &= 183{\cdot}62 - \quad " \quad = 235{\cdot}97 - \quad "\\
\text{E} - \textbf{A} &= 152{\cdot}31 - \quad " \quad = 195{\cdot}74 - \quad "\\
\text{H} - \textbf{A} &= 147{\cdot}55 - \quad " \quad = 189{\cdot}62 - \quad "
\end{aligned}$$

$$\text{and } 6\,x = \overset{m.y}{1197{\cdot}2} - 48{\cdot}4\,dE_a.$$

Comparisons between the Standard Bar **A** *and the Compensated Bars* A, B, C, D, E, H, *made on a site selected about the middle of the base-line, after set No.* 291.

1847 Decr.	Mean of the times of observing A	No. of comparison	Temperature of Air	Corrected mean temperature of A	Mean A	A	B	C	D	E	H	Mean of the compensated bars	Remarks
					MICROMETER READINGS IN DIVISIONS — 1 Division = $\frac{1}{21642 \cdot 0}$ Cary's Inch [7.8], = 1·2828 m.y of A								
	h m		°	°	+	+	+	+	+	+	+	+	
29th	1 44 P.M.	1	73·7	68·55	301·6	298·3	288·6	317·3	346·0	324·5	307·2	313·7	Capt. Renny at the micrometer microscope; Mr. Keelan at the plain microscope.
	2 10	2	73·7	69·38	317·0	309·7	293·5	325·1	351·3	327·8	317·0	320·7	
	2 30	3	73·7	69·98	326·9	314·5	292·3	328·6	354·8	328·6	320·0	323·1	
	2 50	4	73·7	70·50	334·9	320·0	297·8	328·6	351·8	328·8	323·8	325·1	
	3 10	5	73·5	70·95	343·9	324·3	303·2	329·6	358·6	331·8	323·8	328·6	
	3 47	6	72·9	71·68	362·6	335·0	315·0	344·0	369·0	341·8	334·0	339·8	
	4 9	7	72·3	71·90	365·5	341·0	318·0	346·1	371·4	346·2	334·3	342·8	Very foggy.
	4 33	8	71·8	72·03	366·8	339·6	321·0	349·6	370·0	345·0	336·8	343·7	
30th	7 51 A.M.	9	53·0	54·20	89·5	361·7	341·1	369·1	385·0	352·8	358·7	361·4	
	8 29	10	54·4	54·05	89·4	365·0	338·2	364·2	383·2	355·6	359·8	361·0	
	8 59	11	56·2	54·25	94·9	367·0	341·5	364·2	385·6	354·8	358·6	362·0	
	9 24	12	58·2	54·70	104·4	358·0	329·0	363·1	381·0	351·6	354·2	356·2	
	9 47	13	60·0	55·35	115·7	355·0	328·3	359·0	376·2	350·2	350·8	353·3	
	10 6	14	61·6	56·13	128·5	351·7	320·6	353·0	375·3	349·2	347·8	349·6	
	10 25	15	63·3	56·98	142·7	347·5	318·3	352·6	372·8	347·3	344·0	347·1	
	10 46	16	64·8	58·03	160·0	339·8	314·8	346·2	367·3	344·0	342·0	342·4	
	1 23 P.M.	17	71·0	65·48	310·6	372·5	352·0	383·1	411·3	382·7	369·0	378·4	
	1 44	18	71·7	66·48	328·2	367·4	350·8	382·5	410·1	386·1	370·6	377·9	
	2 4	19	72·0	67·40	344·4	369·0	356·8	388·1	413·7	387·1	376·8	381·9	
	2 24	20	72·4	68·25	359·3	368·0	355·1	389·0	413·8	389·6	378·3	382·3	
	2 45	21	72·3	69·10	371·4	375·5	356·2	389·6	412·8	389·6	379·3	383·8	Cloudy.
	3 5	22	71·9	69·70	380·2	379·6	360·0	392·4	413·8	392·1	381·2	386·5	
	3 27	23	71·8	70·18	386·5	380·1	363·4	393·8	416·0	388·0	381·6	387·2	
	3 48	24	71·5	70·58	390·9	385·1	362·8	396·2	419·2	390·8	382·0	389·4	
	4 6	25	71·4	70·80	393·8	388·0	361·5	394·8	417·0	389·1	381·3	388·6	
	4 26	26	70·8	70·93	394·3	389·8	367·0	394·2	418·3	390·2	382·0	390·3	
31st	7 10 A.M.	27	52·8	55·63	143·8	393·0	370·8	394·1	413·2	382·9	394·1	391·4	Mr. Logan at the micrometer microscope: Mr. Keelan at the plain microscope.
	7 33	28	52·9	55·28	139·0	398·3	373·0	396·5	417·1	384·0	392·5	393·6	
	7 55	29	54·3	55·03	138·9	402·5	376·5	399·5	416·8	389·3	393·2	396·3	
	8 15	30	55·9	54·98	139·7	397·8	373·0	396·7	417·5	389·2	395·5	395·0	
	8 35	31	57·2	55·10	143·7	402·9	378·0	401·0	422·0	393·6	394·8	398·7	
	8 53	32	58·6	55·38	148·8	400·2	376·9	401·2	420·9	393·7	395·2	398·0	
	9 12	33	59·8	55·75	156·2	400·0	372·0	397·9	421·0	390·3	391·1	395·4	
	9 38	34	61·4	56·55	170·2	397·4	372·8	400·3	421·5	392·5	390·9	395·9	
	10 0	35	62·6	57·35	183·7	395·7	366·0	393·8	415·7	389·5	388·8	391·6	
	10 21	36	63·8	58·20	195·3	389·2	363·2	392·0	412·3	384·5	382·2	387·2	
	10 42	37	65·0	59·10	207·9	380·5	355·7	385·7	407·7	383·3	375·9	381·5	

After set No. 291—(Continued.)

1847-48 Dec. & Jan.	Mean of the times of observing A	No. of comparison	Temperature of Air	Corrected mean temperature of A	Micrometer Readings in Divisions. 1 Division = $\frac{1}{21642 \cdot 0}$ Carry's Inch [7·8], = 1·2833 m·y of A — Mean A	A	B	C	D	E	H	Mean of the compensated bars	Remarks
	h. m.		°	°	+	+	+	+	+	+	+	+	
31st	1 10 P.M.	38	71·3	64·73	297·7	376·1	356·3	387·2	404·2	384·2	365·9	379·0	
	1 26	39	72·0	65·38	309·0	371·3	351·5	386·4	405·2	383·5	369·3	377·9	
	1 42	40	72·2	66·03	320·6	370·3	350·3	379·4	404·5	381·6	366·4	375·4	
	2 1	41	72·7	66·75	332·4	368·3	348·3	383·0	407·5	382·9	369·0	376·5	
	2 20	42	73·2	67·55	344·9	373·5	350·8	387·7	407·5	384·3	373·4	379·5	
	2 38	43	73·3	68·30	356·4	378·3	357·0	389·2	414·2	387·5	376·5	383·8	
	2 58	44	73·3	69·05	367·9	381·2	354·2	389·5	414·0	389·7	375·5	384·0	
	3 20	45	73·3	69·68	376·9	379·1	362·3	394·3	412·4	394·0	377·4	386·6	
	3 38	46	73·2	70·13	383·2	382·7	361·5	395·3	413·2	393·7	379·0	387·6	
	3 55	47	72·9	70·48	388·0	380·0	359·3	392·1	412·8	386·7	377·5	384·7	
	4 12	48	72·5	70·75	391·4	384·7	360·1	393·7	416·0	392·0	379·9	387·7	
	4 29	49	71·8	70·98	395·3	387·0	361·2	396·2	416·8	390·0	379·2	388·4	
1st	6 57 A.M.	50	53·9	56·68	160·1	399·9	368·0	392·8	418·5	386·8	390·4	392·7	
	7 20	51	53·6	56·35	154·8	400·8	372·0	400·4	420·4	390·9	394·7	396·5	
	7 43	52	54·3	56·08	154·1	403·8	375·8	399·9	423·5	394·9	394·7	398·8	
	8 3	53	55·7	55·98	156·2	408·5	376·3	408·4	423·4	397·8	395·2	401·6	
	8 22	54	57·0	56·00	157·6	407·2	375·4	402·8	422·8	394·6	397·7	400·1	
	8 40	55	58·4	56·05	161·4	407·2	379·5	404·8	426·5	392·2	395·4	400·9	
	8 59	56	60·0	56·38	168·7	404·0	376·4	407·0	424·1	398·4	393·2	400·5	
	9 18	57	61·5	56·80	176·5	405·1	374·2	402·8	422·2	394·3	394·7	398·9	
	9 41	58	63·3	57·53	189·6	400·9	368·7	398·5	421·0	393·8	391·4	395·7	
	10 11	59	65·0	58·60	205·8	392·0	364·8	394·8	416·8	384·0	391·3	390·6	
	10 35	60	66·8	59·58	220·2	391·3	363·2	394·3	413·3	387·3	383·0	388·7	
		Means		62·70	254·00	375·23	351·53	381·39	403·20	376·72	371·66	376·62	

After set No. 291—(Continued.)

As on page V—6 we have

$$x - (t^\circ - 62^\circ)\,(E_a - dE_a) - \delta = 0\,;$$

and from the preceding bar comparisons, we obtain the following series of results :—

			d				d
$x - 6·55$	$(E_a - dE_a)$	$-$	$12·1 = 0$	$x - 6·90$	$(E_a - dE_a)$	$-$	$255·0 = 0$
$x - 7·38$	,,	$-$	$3·7 = 0$	$x - 6·62$	,,	$-$	$249·2 = 0$
$x - 7·98$	,,	$+$	$3·8 = 0$	$x - 6·25$	,,	$-$	$239·2 = 0$
$x - 8·50$	,,	$+$	$9·8 = 0$	$x - 5·45$	,,	$-$	$225·7 = 0$
$x - 8·95$	,,	$+$	$15·3 = 0$	$x - 4·65$	,,	$-$	$207·9 = 0$
$x - 9·68$	,,	$+$	$22·8 = 0$	$x - 3·80$	,,	$-$	$191·9 = 0$
$x - 9·90$	,,	$+$	$22·7 = 0$	$x - 2·90$	,,	$-$	$173·6 = 0$
$x - 10·03$	,,	$+$	$23·1 = 0$	$x - 2·73$	,,	$-$	$81·3 = 0$
$x + 7·80$	,,	$-$	$271·9 = 0$	$x - 3·38$	,,	$-$	$68·9 = 0$
$x + 7·95$	,,	$-$	$271·6 = 0$	$x - 4·03$	,,	$-$	$54·8 = 0$
$x + 7·75$	,,	$-$	$267·1 = 0$	$x - 4·75$	,,	$-$	$44·1 = 0$
$x + 7·30$	,,	$-$	$251·8 = 0$	$x - 5·55$	,,	$-$	$34·6 = 0$
$x + 6·65$	,,	$-$	$237·6 = 0$	$x - 6·30$	,,	$-$	$27·4 = 0$
$x + 5·87$	,,	$-$	$221·1 = 0$	$x - 7·05$	,,	$-$	$16·1 = 0$
$x + 5·02$	,,	$-$	$204·4 = 0$	$x - 7·68$	,,	$-$	$9·7 = 0$
$x + 3·97$	,,	$-$	$182·4 = 0$	$x - 8·13$	,,	$-$	$4·4 = 0$
$x - 3·48$	,,	$-$	$67·8 = 0$	$x - 8·48$	,,	$+$	$3·3 = 0$
$x - 4·48$	,,	$-$	$49·7 = 0$	$x - 8·75$	,,	$+$	$3·7 = 0$
$x - 5·40$	,,	$-$	$37·5 = 0$	$x - 8·98$	,,	$+$	$6·9 = 0$
$x - 6·25$	,,	$-$	$23·0 = 0$	$x + 5·32$	,,	$-$	$232·6 = 0$
$x - 7·10$	,,	$-$	$12·4 = 0$	$x + 5·65$	,,	$-$	$241·7 = 0$
$x - 7·70$	,,	$-$	$6·3 = 0$	$x + 5·92$	,,	$-$	$244·7 = 0$
$x - 8·18$	,,	$-$	$0·7 = 0$	$x + 6·02$	,,	$-$	$245·4 = 0$
$x - 8·58$	,,	$+$	$1·5 = 0$	$x + 6·00$	,,	$-$	$242·5 = 0$
$x - 8·80$	,,	$+$	$5·2 = 0$	$x + 5·95$	,,	$-$	$239·5 = 0$
$x - 8·93$	,,	$+$	$4·0 = 0$	$x + 5·62$	,,	$-$	$231·8 = 0$
$x + 6·37$	,,	$-$	$247·6 = 0$	$x + 5·20$	,,	$-$	$222·4 = 0$
$x + 6·72$	,,	$-$	$254·6 = 0$	$x + 4·47$	,,	$-$	$206·1 = 0$
$x + 6·97$	,,	$-$	$257·4 = 0$	$x + 3·40$	,,	$-$	$184·8 = 0$
$x + 7·02$	,,	$-$	$255·3 = 0$	$x + 2·42$	,,	$-$	$168·5 = 0$

After set No. 291—(Continued.)

And from the mean of these results,

$$x = \overset{d}{122{\cdot}62} + 0{\cdot}70\,(E_a - dE_a):$$

adopting the original value of the expansion of **A** given at page (9),

$$E_a = \overset{m.y}{22{\cdot}67} = \overset{d}{17{\cdot}672},$$

$$\text{and } x = \overset{d}{134{\cdot}99} - 0{\cdot}70\,dE_a = \overset{m.y}{173{\cdot}17} - 0{\cdot}70\,dE_a = \mathrm{L} - \mathbf{A}\,;$$

where L denotes the mean length of the compensated bars obtained from *all* the comparisons, as represented by the mean micrometer reading $\overset{d}{376{\cdot}62}$, page V—9.

Comparing this reading with the mean reading of each compensated bar given on the same page we obtain the following:—

In terms of	A – L	B – L	C – L	D – L	E – L	H – L
Micrometer divisions.	– 1·39	–25·09	+4·77	+26·58	+ 0·10	– 4·96
Millionths of a yard.	– 1·78	–32·19	+6·12	+34·10	+ 0·13	– 6·36

Also combining the values in this table with the equivalent of L—**A** above determined, there result,

$$
\begin{aligned}
\mathrm{A} - \mathbf{A} &= \overset{d}{133{\cdot}60} - 0{\cdot}70\,dE_a = \overset{m.y}{171{\cdot}39} - 0{\cdot}70\,dE_a\\
\mathrm{B} - \mathbf{A} &= 109{\cdot}90 - \quad ,, \quad = 140{\cdot}98 - \quad ,,\\
\mathrm{C} - \mathbf{A} &= 139{\cdot}76 - \quad ,, \quad = 179{\cdot}29 - \quad ,,\\
\mathrm{D} - \mathbf{A} &= 161{\cdot}57 - \quad ,, \quad = 207{\cdot}27 - \quad ,,\\
\mathrm{E} - \mathbf{A} &= 135{\cdot}09 - \quad ,, \quad = 173{\cdot}30 - \quad ,,\\
\mathrm{H} - \mathbf{A} &= 130{\cdot}03 - \quad ,, \quad = 166{\cdot}81 - \quad ,,
\end{aligned}
$$

$$\text{and } 6\,x = \overset{m.y}{1039{\cdot}0} - 4{\cdot}2\,dE_a.$$

Comparisons between the Standard Bar **A** *and the Compensated Bars* A, B, C, D, E, H, *made at Ramganj, or North-East end of the base-line, after the measurement.*

1848 Jany.	Mean of the times of observing **A**	No. of comparison	Temperature of Air	Corrected mean temperature of **A**	MICROMETER READINGS IN DIVISIONS 1 Division = $\frac{1}{21602 \cdot 8}$ Cary's Inch [7.8], = 1·2852 m.y of **A** — Mean **A**	A	B	C	D	E	H	Mean of the compensated bars	REMARKS
	h. m.		°	°	+	+	+	+	+	+	+	+	
18th	1 15 P.M.	1	71·2	64·30	317·7	388·2	393·3	422·9	427·5	406·0	396·0	405·7	Mr. Logan at the micrometer microscope; Mr. Keelan at the plain microscope.
	1 34	2	71·6	65·15	330·0	393·1	395·2	427·8	431·6	409·3	400·3	409·6	
	1 51	3	71·8	65·83	341·9	391·3	390·0	427·0	433·0	409·3	400·0	408·4	
	2 7	4	72·2	66·48	352·0	394·2	390·0	425·5	435·0	409·8	399·3	409·0	
	2 23	5	72·6	67·08	362·5	396·2	390·8	425·1	437·7	410·2	401·3	410·2	
	2 40	6	72·5	67·58	370·7	403·0	388·0	423·5	438·3	411·2	402·2	411·0	
	2 56	7	72·3	68·03	376·7	401·7	384·3	419·8	435·0	410·1	402·0	408·8	
	3 12	8	72·2	68·48	382·8	404·5	388·7	419·5	437·7	411·0	402·1	410·6	
	3 28	9	72·0	68·85	384·6	407·9	387·9	421·8	437·0	409·5	405·2	411·6	
	3 46	10	71·6	69·18	389·3	407·2	387·3	421·8	441·2	412·0	405·2	412·5	
	4 4	11	71·2	69·45	396·4	411·2	388·2	419·0	439·0	413·0	406·0	412·7	
	4 21	12	70·8	69·65	398·1	412·0	389·3	420·2	439·3	416·2	416·0	415·5	
	4 36	13	70·4	69·78	399·4	413·3	388·3	424·7	444·0	415·8	408·2	415·7	
	4 50	14	70·0	69·83	401·6	414·3	385·0	423·3	441·0	411·5	407·0	413·7	
19th	7 12 A.M.	15	50·5	52·23	114·9	421·8	394·0	420·4	463·3	409·7	419·2	421·4	
	7 40	16	51·0	51·78	111·9	425·4	394·3	421·2	450·2	418·3	420·7	421·7	
	8 0	17	52·0	51·60	113·7	425·8	394·2	427·3	450·9	421·8	422·8	423·8	
	8 17	18	53·0	51·65	116·4	426·2	393·2	428·1	449·8	421·2	423·0	423·6	
	8 35	19	53·7	51·80	120·4	428·7	395·2	427·3	450·7	419·2	422·0	423·9	
	8 54	20	54·7	52·03	126·4	428·3	397·2	425·0	448·0	421·0	422·5	423·7	
	9 13	21	56·1	52·40	134·1	428·5	397·1	428·0	449·5	420·7	419·5	423·9	
	9 32	22	58·1	52·88	142·2	427·0	394·9	425·5	448·5	418·5	421·2	422·6	
	9 48	23	59·6	53·40	153·3	423·2	392·3	425·1	447·0	419·3	422·2	421·5	
	10 2	24	60·5	53·93	164·8	421·1	391·2	425·7	447·0	420·0	422·2	421·2	
	10 18	25	62·0	54·63	176·9	421·5	389·0	421·8	443·5	422·0	417·7	419·3	
	10 36	26	63·0	55·53	191·2	415·0	388·5	420·4	440·3	419·9	414·0	416·4	
	10 52	27	63·8	56·33	204·0	412·0	381·7	418·0	437·7	418·0	413·3	413·5	
	1 4 P.M.	28	68·8	62·45	298·1	403·0	393·8	426·9	442·2	422·0	405·4	415·6	
	1 19	29	69·3	63·13	308·5	407·2	392·9	426·8	450·0	425·4	410·7	418·8	
	1 33	30	69·5	63·78	320·3	407·8	391·2	425·2	449·0	421·8	409·9	417·5	
	1 51	31	69·7	64·50	331·5	408·0	390·0	422·4	448·8	422·1	412·5	417·3	
	2 9	32	70·2	65·20	342·3	410·8	391·2	422·7	448·5	425·0	416·0	419·0	
	2 25	33	70·6	65·73	354·7	409·2	389·2	427·0	450·8	426·0	412·8	419·2	
	2 42	34	70·6	66·30	363·5	407·3	389·9	422·1	449·4	421·6	414·2	417·4	
	2 57	35	70·6	66·80	369·6	411·7	391·7	422·4	445·8	425·8	416·3	419·0	
	3 17	36	70·6	67·43	377·2	412·0	396·2	426·2	449·2	421·3	413·9	419·8	
	3 39	37	70·5	67·98	383·8	411·0	393·0	427·2	452·0	419·2	413·1	419·3	
	4 2	38	70·3	68·38	389·0	415·0	393·5	427·9	453·0	422·5	417·2	421·5	
	4 24	39	69·8	68·68	391·8	418·2	396·8	429·0	452·8	421·0	416·2	422·3	
	4 42	40	69·6	68·75	394·0	424·8	397·8	430·7	453·3	423·0	418·3	424·7	
	4 59	41	69·3	68·80	395·6	422·8	396·8	431·2	452·0	422·5	417·9	423·9	

After the measurement—(Continued.)

1848 Jany.	Mean of the times of observing A	No. of comparison	Temperature of Air	Corrected mean temperature of A	Micrometer Readings in Divisions — 1 Division = $\frac{1}{21602 \cdot 8}$ Cary's Inch [7.8], = 1·2852 m.y of A — Mean A	A	B	C	D	E	H	Mean of the compensated bars	Remarks
	h. m.		°	°	+	+	+	+	+	+	+	+	
20th	7 14 A.M.	42	50·8	53·08	136·1	431·3	400·4	425·6	452·2	422·7	427·8	426·7	Capt. Renny at the micrometer microscope; Mr. Keelan at the plain microscope.
	7 41	43	51·4	52·65	134·0	434·1	403·1	433·8	457·1	425·0	431·1	430·7	
	8 4	44	52·5	52·45	135·6	437·2	405·8	434·5	458·6	428·8	433·1	433·0	
	8 27	45	53·8	52·45	140·5	436·0	410·8	436·8	461·2	430·5	436·3	435·3	
	8 47	46	55·4	52·65	148·6	440·5	410·8	437·8	461·0	432·4	435·4	436·3	
	9 5	47	57·0	53·08	158·1	438·7	409·8	439·7	462·4	434·1	436·1	436·8	
	9 24	48	58·2	53·65	168·5	436·8	407·2	437·0	462·7	429·7	434·0	434·6	
	9 45	49	59·6	54·35	181·3	435·6	406·3	436·0	458·8	430·0	431·8	433·1	
	10 5	50	61·3	55·18	196·5	431·2	404·8	436·1	456·5	432·0	427·1	431·0	
	10 24	51	63·1	56·15	213·5	427·8	401·7	432·7	457·1	430·3	427·1	429·5	
	10 41	52	64·3	57·03	229·6	427·3	401·1	430·0	456·8	430·8	425·3	428·6	
	10 56	53	65·0	57·80	243·1	425·0	399·4	433·[illegible]	456·1	429·2	424·6	427·9	
	1 14 P.M.	54	69·5	63·68	329·8	418·1	398·0	436·8	454·2	426·0	413·2	424·4	
	1 33	55	70·0	64·50	343·1	419·0	399·5	435·1	457·0	424·9	416·1	425·3	
	1 49	56	70·6	65·23	354·6	419·6	398·0	434·9	457·0	426·2	418·0	425·6	
	2 5	57	71·1	65·83	364·2	420·0	398·7	436·1	458·8	430·0	417·2	426·8	
	2 22	58	71·2	66·50	374·6	420·8	399·5	436·4	457·2	429·3	419·3	427·1	
	2 40	59	71·3	67·20	384·2	423·2	401·2	434·0	459·0	432·8	421·6	428·6	
	2 56	60	71·8	67·68	391·3	424·5	401·8	436·1	458·3	430·1	421·2	428·7	
	3 11	61	71·9	68·13	398·6	419·8	402·0	440·2	459·0	429·2	421·0	428·5	
	3 29	62	71·5	68·65	405·6	428·0	403·5	442·7	462·7	432·1	421·2	431·7	
	3 47	63	71·3	69·05	410·8	427·8	407·1	440·7	464·8	432·3	423·2	432·7	
	4 5	64	71·0	69·40	414·7	431·1	406·0	439·8	460·4	431·0	424·8	432·2	
	4 22	65	70·7	69·68	418·4	431·6	405·8	441·2	463·4	435·1	426·2	433·9	
	4 37	66	70·4	69·83	421·0	433·3	411·2	438·0	466·1	434·6	426·8	435·0	
	4 54	67	70·0	69·90	422·0	436·2	411·0	445·0	467·3	433·5	428·8	437·0	
21st	7 7 A.M.	68	53·2	55·53	179·2	428·8	408·1	430·8	450·2	428·2	427·6	429·0	Foggy morning.
	7 29	69	53·4	55·13	174·7	437·8	405·5	431·8	453·8	429·0	427·2	430·9	
	7 49	70	54·0	54·90	172·8	435·8	407·0	435·6	457·1	428·1	430·7	432·4	
	8 9	71	54·7	54·80	172·8	437·8	408·4	438·4	462·0	430·1	433·0	435·0	
	8 30	72	55·8	54·78	176·1	439·3	412·6	437·1	460·0	433·0	433·8	436·0	
	8 50	73	56·9	54·95	179·6	440·3	413·7	440·7	460·2	431·8	430·8	436·3	
	9 8	74	58·1	55·23	185·7	440·1	409·8	442·8	462·1	433·0	435·5	437·2	
	9 23	75	58·8	55·58	195·2	437·6	409·8	438·7	461·1	432·1	434·6	435·7	
	9 39	76	60·1	56·08	204·6	437·8	405·6	436·8	456·6	431·8	429·0	432·9	
	9 56	77	61·9	56·68	215·7	433·2	406·1	436·6	459·2	432·2	431·0	433·1	
	10 13	78	63·3	57·38	229·6	431·4	402·3	433·3	457·5	430·8	430·8	431·0	
	10 29	79	64·7	58·23	245·0	428·0	398·1	429·8	457·7	431·2	427·9	428·8	
	10 49	80	66·1	59·25	262·4	426·8	402·0	432·2	455·6	431·1	426·2	429·0	
		Means		61·15	277·57	421·51	398·08	430·23	451·74	423·86	419·65	424·18	

After the measurement—(Continued.)

As on page V—6 we have

$$x - (t^{\circ} - 62^{\circ})\,(E_a - dE_a) - \delta = 0$$

and from the preceding bar comparisons we obtain the following series of results :—

		d			d
x − 2·30	$(E_a - dE_a)$	− 88·0 = 0	x − 6·80	$(E_a - dE_a)$	− 28·3 = 0
x − 3·15	,,	− 79·6 = 0	x + 8·92	,,	−290·6 = 0
x − 3·83	,,	− 66·5 = 0	x + 9·35	,,	−296·7 = 0
x − 4·48	,,	− 57·0 = 0	x + 9·55	,,	−297·4 = 0
x − 5·08	,,	− 47·7 = 0	x + 9·55	,,	−294·8 = 0
x − 5·58	,,	− 40·3 = 0	x + 9·35	,,	−287·7 = 0
x − 6·03	,,	− 32·1 = 0	x + 8·92	,,	−278·7 = 0
x − 6·48	,,	− 27·8 = 0	x + 8·35	,,	−266·1 = 0
x − 6·85	,,	− 27·0 = 0	x + 7·65	,,	−251·8 = 0
x − 7·18	,,	− 23·2 = 0	x + 6·82	,,	−234·5 = 0
x − 7·45	,,	− 16·3 = 0	x + 5·85	,,	−216·0 = 0
x − 7·65	,,	− 17·4 = 0	x + 4·97	,,	−199·0 = 0
x − 7·78	,,	− 16·3 = 0	x + 4·20	,,	−184·8 = 0
x − 7·83	,,	− 12·1 = 0	x − 1·68	,,	− 94·6 = 0
x + 9·77	,,	−306·5 = 0	x − 2·50	,,	− 82·2 = 0
x + 10·22	,,	−309·8 = 0	x − 3·23	,,	− 71·0 = 0
x + 10·40	,,	−310·1 = 0	x − 3·83	,,	− 62·6 = 0
x + 10·35	,,	−307·2 = 0	x − 4·50	,,	− 52·5 = 0
x + 10·20	,,	−303·5 = 0	x − 5·20	,,	− 44·4 = 0
x + 9·97	,,	−297·3 = 0	x − 5·68	,,	− 37·4 = 0
x + 9·60	,,	−289·8 = 0	x − 6·13	,,	− 29·9 = 0
x + 9·12	,,	−280·4 = 0	x − 6·65	,,	− 26·1 = 0
x + 8·60	,,	−268·2 = 0	x − 7·05	,,	− 21·9 = 0
x + 8·07	,,	−256·4 = 0	x − 7·40	,,	− 17·5 = 0
x + 7·37	,,	−242·4 = 0	x − 7·68	,,	− 15·5 = 0
x + 6·47	,,	−225·2 = 0	x − 7·83	,,	− 14·0 = 0
x + 5·67	,,	−209·5 = 0	x − 7·90	,,	− 15·0 = 0
x − 0·45	,,	−117·5 = 0	x + 6·47	,,	−249·8 = 0
x − 1·13	,,	−110·3 = 0	x + 6·87	,,	−256·2 = 0
x − 1·78	,,	− 97·2 = 0	x + 7·10	,,	−259·6 = 0
x − 2·50	,,	− 85·8 = 0	x + 7·20	,,	−262·2 = 0

After the measurement—(Continued.)

$x - 3{\cdot}20\,(E_a - dE_a) - 76{\cdot}7 = 0$	$x + 7{\cdot}22\,(E_a - dE_a) - 259{\cdot}9 = 0$
$x - 3{\cdot}73$ „ $- 64{\cdot}5 = 0$	$x + 7{\cdot}05$ „ $-256{\cdot}7 = 0$
$x - 4{\cdot}30$ „ $- 53{\cdot}9 = 0$	$x + 6{\cdot}77$ „ $-251{\cdot}5 = 0$
$x - 4{\cdot}80$ „ $- 49{\cdot}4 = 0$	$x + 6{\cdot}42$ „ $-240{\cdot}5 = 0$
$x - 5{\cdot}43$ „ $- 42{\cdot}6 = 0$	$x + 5{\cdot}92$ „ $-228{\cdot}3 = 0$
$x - 5{\cdot}98$ „ $- 35{\cdot}5 = 0$	$x + 5{\cdot}32$ „ $-217{\cdot}4 = 0$
$x - 6{\cdot}38$ „ $- 32{\cdot}5 = 0$	$x + 4{\cdot}62$ „ $-201{\cdot}4 = 0$
$x - 6{\cdot}68$ „ $- 30{\cdot}5 = 0$	$x + 3{\cdot}77$ „ $-183{\cdot}8 = 0$
$x - 6{\cdot}75$ „ $- 30{\cdot}7 = 0$	$x + 2{\cdot}75$ „ $-166{\cdot}6 = 0$

And from the mean of these results,

$$x = \overset{d}{146{\cdot}61} - 0{\cdot}85\,(E_a - dE_a):$$

adopting the original value of the expansion of **A** given at page (9),

$$E_a = \overset{m.y}{22{\cdot}67} = \overset{d}{17{\cdot}639},$$

$$\text{and } x = \overset{d}{131{\cdot}62} + 0{\cdot}85\,dE_a = \overset{m.y}{169{\cdot}16} + 0{\cdot}85\,dE_a = \mathrm{L} - \mathbf{A}.$$

Proceeding as on page V—7 we obtain:—

In terms of	A − L	B − L	C − L	D − L	E − L	H − L
Micrometer divisions.	−2·67	−26·10	+6·05	+27·56	−0·32	−4·53
Millionths of a yard.	−3·43	−33·54	+7·78	+35·42	−0·41	−5·82

Also the following;

$$\begin{aligned}
\mathrm{A} - \mathbf{A} &= \overset{d}{128{\cdot}95} + 0{\cdot}85\,dE_a = \overset{m.y}{165{\cdot}73} + 0{\cdot}85\,dE_a \\
\mathrm{B} - \mathbf{A} &= 105{\cdot}52 + \text{ „ } = 135{\cdot}62 + \text{ „} \\
\mathrm{C} - \mathbf{A} &= 137{\cdot}67 + \text{ „ } = 176{\cdot}94 + \text{ „} \\
\mathrm{D} - \mathbf{A} &= 159{\cdot}18 + \text{ „ } = 204{\cdot}58 + \text{ „} \\
\mathrm{E} - \mathbf{A} &= 131{\cdot}30 + \text{ „ } = 168{\cdot}75 + \text{ „} \\
\mathrm{H} - \mathbf{A} &= 127{\cdot}09 + \text{ „ } = 163{\cdot}34 + \text{ „}
\end{aligned}$$

$$\text{and } 6\,x = \overset{m.y}{1015{\cdot}0} + 5{\cdot}1\,dE_a.$$

Final deduction of the total length measured with the compensated bars.

		m.y
From page V—7 the excess of the 6 compensated bars above 6 times **A** *before* the measurement	=	1197·2 − 48·4 dE_a
„ V—11 „ „ „ *after* set No. 291	=	1039·0 − 4·2 dE_a
„ V—15 „ „ „ *after* the measurement or set No. 583	=	1015·0 + 5·1 dE_a
Therefore the mean excess of „ applicable to sets Nos. 1 to 291	=	1118·1 − 26·3 dE_a
and „ „ „ 292 to 582	=	1027·0 + 0·5 dE_a
Also the mean length of a set of 6 compensated bars in feet of the standard, applicable to sets Nos. 1 to 291	=	60·0033543 $\frac{A}{10}$ − 26·3 dE_a
and „ applicable to sets Nos. 292 to 582	=	60·0030810 $\frac{A}{10}$ + 0·5 dE_a

		m.y
Similarly from pages V—11 and V—15 the mean excess of the two compensated bars A and H above twice **A**	=	333·6 + 0·2 dE_a
and the mean length of the set of compensated bars A and H in feet of the standard	=	20·0010008 $\frac{A}{10}$ + 0·2 dE_a

Hence the total lengths measured with the compensated bars

			feet of A
in sets Nos.	1 to 145	....	= 8700·4864 − 3814 dE_a
„	146 to 291	....	= 8760·4897 − 3840 dE_a
„	292 to 445	....	= 9240·4745 + 77 dE_a
„	446 to 582	....	= 8220·4221 + 69 dE_a
in set No.	583	....	= 20·0010 + 0 dE_a
in sets Nos.	1 to 583	....	=34941·8737 − 7508 dE_a

Now the mean temperature of **A** during the bar comparisons *before* the measurement and *after* set No. 291 was $62° + \frac{26°\cdot3}{6} = 66°\cdot4$, for which temperature the corresponding expansion of **A** from page (19) is 21·675 *m.y.* Also the mean temperature of **A** during the bar comparisons *after* set No. 291 and *after* the measurement was $62° - \frac{0°\cdot5}{6} = 61°\cdot9$, for which temperature the corresponding expansion of **A** from page (19) is 21·647 *m.y.* Comparing these values of expansion with the original value = 22·67 *m.y*, used in the foregoing; it is found that dE_a = + 0·995 *m.y*, for sets Nos. 1 to 291, and = + 1·023 *m.y*, for sets Nos. 292 to 583. Substituting for dE_a respectively these numerical values, there result,

Total lengths measured with the compensated bars

			feet of	A
in sets Nos.	1 to 145 or S.W. End,	to Stn. A	= (8700·4864 − ·0114)	= 8700·4750
„	146 to 291 or Stn. A,	to Stn. B	= (8760·4897 − ·0115)	= 8760·4782
„	292 to 445 or Stn. B,	to Stn. C	= (9240·4745 + ·0002)	= 9240·4747
„	446 to 583 or Stn. C,	to N.E. End	= (8240·4231 + ·0002)	= 8240·4233
„	1 to 583 or S.W. End,	to N.E. End	=(34941·8737 − ·0225)	=34941·8512

Comparisons between the Compensated Microscopes and their 6-inch brass scales during the measurement, and provisional determination of Microscope errors with respect to the 6-inch brass scale A, expressed in millionths of an inch (m.i.)

When compared — 1847-48			Microscope.	Scale compared with.	Corrected temperature.	Reduction to 62° Fah. Expansion of 6″ scale for 1° = E = 62·5 m.i.	Microscope − Microscope Scale. Observed value in terms of Divisions 10000=1″.	Microscope − Microscope Scale. Observed value in terms of m.i.	Micros : Scale − A, at 62° Fah.	Micros : − Scale A, at 62° Fah. m.i.	Reference number.
December	3rd	Before the measurement.	*U*	*U*	73·55°	+ 722	− 4·0	− 400	+ 283	+ 605	1
			S	*S*	74·77	798	5·6	560	− 75	163	2
			P	*P*	75·70	856	2·8	280	+ 350	926	3
			M	*M*	75·26	829	0·0	000	− 21	808	4
			N	*N*	76·92	933	4·0	400	+ 363	896	5
			O	*R*	76·01	876	9·0	900	93	69	6
			T	*T*	72·45	653	1·9	190	− 97	366	7
„	10th	Between sets No. 66 and 67.	*U*	*U*	69·75	+ 484	− 3·3	− 330	+ 283	+ 437	8
			S	*S*	70·47	529	4·7	470	− 75	− 16	9
			P	*P*	73·72	733	1·4	140	+ 350	+ 943	10
			M	*M*	70·96	560	+ 3·1	+ 310	− 21	849	11
			N	*N*	72·92	683	− 1·9	− 190	+ 363	856	12
			O	*R*	69·71	482	5·3	530	93	45	13
			T	*T*	70·05	503	+ 1·0	+ 100	− 97	506	14
„	16th	Between sets No. 145 and 146.	*U*	*U*	60·55	− 91	+ 1·6	+ 160	+ 283	+ 352	15
			*U**	*U*	64·35	+ 147	0·2	20	283	450	16
			S	*S*	63·37	86	− 1·1	− 110	− 75	− 99	17
			*S**	*S*	66·97	311	2·8	280	75	44	18
			P	*P*	64·12	133	+ 2·8	+ 280	+ 350	+ 763	19
			M	*M*	64·46	154	8·6	860	− 21	993	20
			N	*N*	67·12	320	1·1	110	+ 363	793	21
			O	*R*	61·41	− 37	− 1·1	− 110	93	− 54	22
			T	*T*	63·35	+ 84	+ 4·3	+ 430	− 97	+ 417	23
January	1st	Between sets No. 291 and 292.	*S*	*S*	73·27	+ 704	− 6·0	− 600	− 75	+ 29	24
			U	*U*	74·15	759	4·6	460	+ 283	582	25
			P	*P*	76·72	920	3·0	300	350	970	26
			M	*M*	70·06	879	+ 2·2	+ 220	− 21	1078	27
			N	*N*	75·12	820	− 4·2	− 420	+ 363	763	28
			O	*R*	75·21	826	9·0	900	93	19	29
			T	*T*	72·75	672	0·0	000	− 97	575	30
„	11th	Between sets No. 445 and 446.	*S*	*S*	71·77	+ 611	− 5·0	− 500	− 75	+ 36	31
			U	*U*	71·25	578	2·5	250	+ 283	611	32
			P	*P*	74·92	808	3·2	320	350	838	33
			*P**	*P*	75·42	839	5·5	550	350	639	34
			M	*M*	73·96	748	+ 1·2	+ 120	− 21	847	35
			N	*N*	74·52	783	− 3·3	− 330	+ 363	816	36
			O	*R*	73·01	688	8·9	890	93	− 109	37
			T	*T*	71·85	616	0·0	000	− 97	+ 519	38

* These microscopes were compared a second time, because they were adjusted after the first comparison.

Microscope Comparisons—(Continued.)

When compared — 1848		Microscope.	Scale compared with.	Corrected temperature.	Reduction to 62° Fah. Expansion of 6″ scale for 1° = E = 62·5 *m.i.*	Microscope — Microscope Scale. Observed value in terms of Divisions 10000 = 1″	*m.i.*	Micros : Scale − *A*, at 62° Fah.	Micros : − Scale *A*, at 62° Fah. *m.i.*	Reference number.
January 18th	After the measurement.	*S*	*S*	70°37	+ 523	− 3·0	− 300	− 75	+ 148	39
		U	*U*	66·25	266	0·9	90	+ 283	459	40
		P	*P*	74·02	751	1·2	120	350	981	41
		M	*M*	66·76	298	+ 6·0	+ 600	− 21	877	42
		N	*N*	65·62	226	1·6	160	+ 363	749	43
		O	*R*	65·11	194	− 4·2	− 420	93	− 133	44
		T	*T*	71·25	578	+ 0·9	+ 90	− 97	+ 571	45

The required combinations of individual microscope errors taken from pages V—17 and V—18, are expressed as follows;

	Reference numbers.	*m.i.*	*mean temp :*	
$e_1 =$	$2 + 3 + 4 + 5 + 6 + \frac{1+7}{2}$	$= + 3348$	at (62° + 13°28)	before the measurement.
$e_2 =$	$9 + 10 + 11 + 12 + 13 + \frac{8+14}{2}$	$= + 3149$	at (62 + 9·28)	between sets 66 & 67
$e_3 =$	$17 + 19 + 20 + 21 + 22 + \frac{15+23}{2}$	$= + 2781$	at (62 + 1·74)	From comparisons made ,, 145 & 146
$e_4 =$	$18 + 19 + 20 + 21 + 22 + \frac{16+23}{2}$	$= + 2885$	at (62 + 2·66)	,, do.
$e_5 =$	$25 + 26 + 27 + 28 + 29 + \frac{24+30}{2}$	$= + 3714$	at (62 + 12·05)	,, 291 & 292
$e_6 =$	$32 + 33 + 35 + 36 + 37 + \frac{31+38}{2}$	$= + 3281$	at (62 + 11·25)	,, 445 & 446
$e_7 =$	$32 + 34 + 35 + 36 + 37 + \frac{31+38}{2}$	$= + 3082$	at (62 + 11·33)	,, do.
$e_8 =$	$32 + \frac{31+38}{2}$	$= + 889$	at (62 + 9·53)	,, do.
$e_9 =$	$40 + 41 + 42 + 43 + 44 + \frac{39+45}{2}$	$= + 3293$	at (62 + 6·10)	after the measurement.
$e_{10} =$	$40 + \frac{39+45}{2}$	$= + 819$	at (62 + 6·53)	,, do.

Microscope Comparisons—(Continued.)

And from the foregoing, we obtain the following equations for the microscope errors per set (or *m.e.*); where dE expresses the error in the adopted value of the expansion for the 6-inch scales.

$$(m.e.)_1 = \frac{e_1 + e_2}{2} = + \overset{m.i.}{3249} - 6 \times 11{\cdot}28\, dE \quad \text{applicable to sets Nos.} \quad 1 \text{ to } 66$$

$$(m.e.)_2 = \frac{e_2 + e_3}{2} = + 2965 - 6 \times 5{\cdot}51\, dE \quad \text{"} \quad \text{"} \quad 67 \text{ to } 145$$

$$(m.e.)_3 = \frac{e_4 + e_5}{2} = + 3300 - 6 \times 7{\cdot}36\, dE \quad \text{"} \quad \text{"} \quad 146 \text{ to } 291$$

$$(m.e.)_4 = \frac{e_5 + e_6}{2} = + 3498 - 6 \times 11{\cdot}65\, dE \quad \text{"} \quad \text{"} \quad 292 \text{ to } 445$$

$$(m.e.)_5 = \frac{e_7 + e_9}{2} = + 3188 - 6 \times 8{\cdot}72\, dE \quad \text{"} \quad \text{"} \quad 446 \text{ to } 582$$

$$(m.e.)_6 = \frac{e_8 + e_{10}}{2} = + 854 - 2 \times 8{\cdot}03\, dE \quad \text{"} \quad \text{set No.} \quad 583$$

Hence the total microscope errors are as follows,

$$\text{In sets Nos. } 1 \text{ to } 145 = \begin{cases} 66\,(m.e)_1 = + \overset{m.i}{214434} - 4467\, dE = + \overset{\textit{feet of A}}{{\cdot}0179} - 4467\, dE \\ 79\,(m.e)_2 = + 234235 - 2612\, dE = + {\cdot}0195 - 2612\, dE \end{cases}$$

$$\text{sum} = + {\cdot}0374 - 7079\, dE$$

$$\text{In sets Nos. } 146 \text{ to } 291 = 146\,(m.e)_3 = + 481800 - 6447\, dE = + {\cdot}0402 - 6447\, dE$$

$$\text{In sets Nos. } 292 \text{ to } 445 = 154\,(m.e)_4 = + 538692 - 10765\, dE = + {\cdot}0449 - 10765\, dE$$

$$\text{In sets Nos. } 446 \text{ to } 583 = \begin{cases} 137\,(m.e)_5 = + 436756 - 7168\, dE = + {\cdot}0364 - 7168\, dE \\ 1\,(m.e)_6 = + 854 - 16\, dE = + {\cdot}0001 - 16\, dE \end{cases}$$

$$\text{sum} = + {\cdot}0365 - 7184\, dE$$

Final deduction of the total lengths measured with the compensated microscopes.

Hitherto the microscope errors have been determined only provisionally; *i.e* in terms of the 6-inch brass scale A. But from page (31), we have $2\,A = 1{\cdot}0000192\,\frac{\mathbf{A}}{10}$, value in 1835. Also the coefficient of expansion for brass, has been taken at ·000,010,417 in the foregoing reductions, whereas it appears from page (17) that ·000.009,855 is a more probable value. Accepting the latter, it may be found that $dE = 3{\cdot}372\ (m.i)$. Hence, remembering that the length measured with a set of microscopes is equal to 3 feet of A + the corresponding (*m.e*), we have,

Microscope Comparisons—(Continued.)

Total lengths measured with the compensated microscopes

		feet of A		feet of A
In sets Nos. 1 to 145, or S.W. End, to Stn. A	...... =	{145 × 3 + ·0374} − 7079 dE	= (435·0458 − ·0020) =	435·0438
" 146 to 291, or Stn. A, to Stn. B	...... =	{146 × 3 + ·0402} − 6447 dE	= (438·0486 − ·0018) =	438·0468
" 292 to 445, or Stn. B, to Stn. C	...... =	{154 × 3 + ·0449} − 10765 dE	= (462·0538 − ·0030) =	462·0508
" 446 to 583, or Stn. C to N.E. End	...... =	{137 × 3 + ·0364 / + 1 × 1 + ·0001} − 7184 dE	= (412·0444 − ·0020) =	412·0424
" 1 to 583, or S.W. End, to N.E. End	....		= (1747·1926 − ·0088) =	1747·1838

Disposition of the bars and microscopes during the measurement.

The following typical illustrations shew the permutations and combinations of the bars and microscopes during the measurement. The instruments are here named in the succession that actually occurred, commencing from the rear-end of a set, and the numbers assigned to the illustrations, will be found employed in the tables of "Extracts from the Field Book &c."

Bar Illustration.

No. 1	No. 2
A	A
B	H
C	
D	
E	
H	

Statement.

No. 1 occurs in sets Nos. 1 to 582.
" 2 " set No. 583.

Microscope Illustration.

No. 1	No. 2	No. 3
½U	½S	½S
S	U	U
P	P	½T
M	M	
N	N	
O	O	
½T	½T	

Statement.

No. 1 occurs in sets Nos. 1 to 145.
" 2 " 146 to 582.
" 3 " set No. 583.

DETAILS OF THE MEASUREMENT.

Extracts from the Field Book of the measurement, and calculated heights of sets above the origin.

Adopted heights above mean sea level.

South-West-End (origin) = 222·5 feet.

North-East-End (terminus) = 246·9 feet.

1847	No. of the Set.	Temperature of Air	Mean time of ending	No. of bars used	Height of Set above origin	Numeral shewing arrangement of Bars.	Numeral shewing arrangement of Micros.
		°	h. m.		feet.		
4th Dec.	1	63·1	8 31 A.M.	6 +	1·4	1	1
	2	67·3	9 46	6	·7	1	1
	3	74·0	10 54	6 —	·0	1	1
	4	78·0	2 4 P.M.	6	·2	1	1
	5	78·0	2 49	6	·1	1	1
	6	76·9	3 29	6	·3	1	1
	7	76·2	4 18	6	·3	1	1
6th „	8	58·3	7 27 A.M.	6	·4	1	1
	9	60·4	8 14	6	·5	1	1
	10	63·9	9 9	6	·3	1	1
	11	67·5	9 55	6	·3	1	1
	12	71·2	10 45	6	·4	1	1
	13	74·1	1 29 P.M.	6	·3	1	1
	14	75·7	2 9	6	·0	1	1
	15	77·0	2 47	6 +	·1	1	1
	16	76·9	3 32	6	·2	1	1
	17	75·9	4 22	6	·3	1	1
	18	73·9	5 2	6	·5	1	1
7th „	19	58·0	7 35 A.M.	6	·6	1	1
	20	61·2	8 19	6	·3	1	1
	21	64·7	9 3	6	·7	1	1
	22	67·3	9 43	6	·6	1	1
	23	70·0	10 15	6	·2	1	1
	24	72·1	10 54	6 —	·5	1	1
	25	76·3	1 41 P.M.	6	·9	1	1
	26	76·0	2 20	6	1·0	1	1
	27	76·0	2 52	6	1·0	1	1
	28	75·7	3 26	6	1·2	1	1
	29	75·6	4 5	6	1·4	1	1
	30	74·6	4 39	6	1·3	1	1
8th „	31	58·0	7 15 A.M.	6	1·5	1	1
	32	60·3	7 55	6	1·4	1	1
	33	63·0	8 27	6	1·3	1	1
	34	65·6	8 59	6	1·2	1	1
	35	68·7	9 43	6	·9	1	1
	36	70·7	10 18	6	·6	1	1
	37	72·6	10 58	6	·5	1	1
	38	76·3	1 47 P.M.	6	·7	1	1
	39	76·4	2 20	6	·1	1	1
	40	77·6	2 54	6	·0	1	1
	41	76·9	3 31	6 +	·5	1	1
	42	76·3	4 5	6	·3	1	1
8th Dec.	43	74·7	4 40 P.M.	6 +	·2	1	1
9th „	44	55·9	7 0 A.M.	6 —	·1	1	1
	45	57·5	7 33	6	·0	1	1
	46	60·2	8 5	6	·1	1	1
	47	62·0	8 34	6 +	·1	1	1
	48	64·5	9 6	6 —	·2	1	1
	49	66·9	9 34	6	·3	1	1
	50	70·1	10 7	6	·5	1	1
	51	72·3	10 36	6	·2	1	1
	52	74·0	11 10	6	·1	1	1
	53	77·0	1 42 P.M.	6 +	·4	1	1
	54	77·2	2 12	6	·1	1	1
	55	77·6	2 44	6 —	·1	1	1
	56	77·6	3 11	6	·1	1	1
	57	77·2	3 47	6 +	·4	1	1
	58	76·8	4 18	6	·7	1	1
	59	75·0	4 57	6	1·2	1	1
10th „	60	56·2	6 59 A.M.	6	·8	1	1
	61	58·1	7 36	6	·9	1	1
	62	60·5	8 8	6	·7	1	1
	63	63·5	8 43	6	1·0	1	1
	64	66·2	9 18	6	1·0	1	1
	65	68·2	9 44	6	1·0	1	1
	66	70·7	10 15	6	·9	1	1
	67	77·1	2 33 P.M.	6	·8	1	1
	68	76·7	3 3	6	·4	1	1
	69	76·2	3 33	6	·5	1	1
	70	75·7	4 1	6	·3	1	1
	71	74·8	4 31	6	·4	1	1
	72	73·0	5 0	6	·4	1	1
11th „	73	54·5	6 50 A.M.	6	·4	1	1
	74	56·1	7 22	6	·3	1	1
	75	58·7	7 55	6	·5	1	1
	76	61·4	8 25	6	·5	1	1
	77	64·4	8 53	6	·3	1	1
	78	67·1	9 25	6	·4	1	1
	79	71·2	10 5	6	·2	1	1
	80	72·9	10 29	6 —	·6	1	1
	81	74·2	11 1	6	·3	1	1
	82	77·2	1 25 P.M.	6	·4	1	1
	83	78·2	1 51	6	·4	1	1
	84	78·0	2 20	6	·3	1	1

NOTE.—The rear-end of set No. 1 stood exactly over the dot at South-West-End.
December 4th. (3) Cloudy.
December 6th and 7th. Foggy morning.

Extracts from the Field Book—(Continued.)

1847	No. of the Set	Temperature of Air	Mean time of ending	No. of bars used	Height of Set above origin	Numeral shewing arrangement of: Bars.	Micros:	1847	No. of the Set	Temperature of Air	Mean time of ending	No. of bars used	Height of Set above origin	Numeral shewing arrangement of: Bars.	Micros:
		°	h. m.		feet.					°	h. m.		feet.		
11th Dec.	85	77·9	2 46 P.M.	6 −	·3	1	1	14th Dec.	117	75·7	1 23 P.M.	6 +	3·0	1	1
	86	77·3	3 15	6	·6	1	1		118	76·0	1 50	6	3·0	1	1
	87	76·8	3 43	6	·2	1	1		119	76·8	2 20	6	3·1	1	1
	88	75·8	4 24	6	·1	1	1		120	77·3	2 46	6	3·2	1	1
	89	74·1	4 53	6	·1	1	1		121	77·2	3 18	6	3·2	1	1
13th „	90	54·8	6 55 A.M.	6	·1	1	1		122	76·3	3 44	6	3·8	1	1
	91	55·7	7 23	6	·2	1	1		123	75·7	4 17	6	4·1	1	1
	92	57·4	7 50	6	·4	1	1		124	74·0	4 45	6	4·4	1	1
	93	59·4	8 14	6	·5	1	1	15th „	125	52·8	7 2 A.M.	6	4·6	1	1
	94	61·9	8 46	6	·6	1	1		126	53·9	7 35	6	4·8	1	1
	95	64·6	9 12	6	·7	1	1		127	56·3	8 8	6	5·3	1	1
	96	67·9	9 42	6	·8	1	1		128	59·2	8 41	6	6·0	1	1
	97	70·2	10 8	6	·9	1	1		129	62·2	9 13	6	6·3	1	1
	98	72·3	10 37	6	1·2	1	1		130	65·0	9 42	6	6·7	1	1
	99	74·4	11 8	6	1·0	1	1		131	68·0	10 17	6	6·6	1	1
	100	76·4	1 35 P.M.	6	·9	1	1		132	69·6	10 41	6	6·3	1	1
	101	76·8	2 5	6	·7	1	1		133	71·2	11 14	6	5·9	1	1
	102	77·0	2 35	6	·6	1	1		134	75·2	1 45 P.M.	6	6·1	1	1
	103	77·0	3 3	6	·5	1	1		135	75·8	2 15	6	6·0	1	1
	104	76·3	3 31	6	·7	1	1		136	76·0	2 41	6	5·7	1	1
	105	75·7	4 0	6	·0	1	1		137	76·1	3 4	6	5·4	1	1
	106	74·9	4 34	6 +	·3	1	1		138	75·6	3 30	6	5·4	1	1
	107	72·7	5 8	6	·3	1	1		139	74·7	3 56	6	4·9	1	1
14th „	108	54·7	6 58 A.M.	6	·7	1	1		140	74·0	4 26	6	5·5	1	1
	109	56·0	7 30	6	·9	1	1		141	72·0	4 57	6	6·3	1	1
	110	57·0	8 1	6	1·4	1	1	16th „	142	51·3	6 56 A.M.	6	6·3	1	1
	111	58·9	8 30	6	1·9	1	1		143	52·7	7 28	6	6·3	1	1
	112	59·5	8 58	6	2·1	1	1		144	53·5	8 0	6	6·4	1	1
	113	62·0	9 26	6	2·2	1	1		145	57·3	8 52	6	6·4	1	1
	114	64·7	9 54	6	2·4	1	1								
	115	67·5	10 18	6	2·4	1	1				Total	+	156·2		
	116	70·0	10 47	6	2·8	1	1								

The dot denoting Station A was fixed exactly in the normal at the advanced-end of set No. 145.
Height of set No. 145 above Station A = 1·4 feet.
The terminal point of set No. 145 was the point of origin for set No. 146.

1847	No. of the Set	Temperature of Air	Mean time of ending	No. of bars used	Height of Set above origin	Bars.	Micros:	1847	No. of the Set	Temperature of Air	Mean time of ending	No. of bars used	Height of Set above origin	Bars.	Micros:
16th „	146	72·4	1 52 P.M.	6 +	6·7	1	2	17th „	159	64·0	9 58 A.M.	6 +	5·7	1	2
	147	72·3	2 22	6	6·6	1	2		160	66·3	10 25	6	5·9	1	2
	148	72·4	2 55	6	6·2	1	2		161	68·0	10 53	6	6·3	1	2
	149	72·3	3 22	6	6·1	1	2		162	74·0	1 28 P.M.	6	6·7	1	2
	150	72·0	3 52	6	5·8	1	2		163	74·1	1 56	6	6·6	1	2
	151	70·7	4 22	6	5·3	1	2		164	73·5	2 23	6	7·2	1	2
	152	67·9	4 54	6	5·6	1	2		165	73·3	2 51	6	7·3	1	2
17th „	153	52·1	7 5 A.M.	6	5·4	1	2		166	73·4	3 20	6	7·1	1	2
	154	54·0	7 34	6	5·1	1	2		167	73·3	3 49	6	6·5	1	2
	155	55·9	8 9	6	5·0	1	2		168	72·0	4 18	6	6·2	1	2
	156	57·7	8 35	6	5·2	1	2		169	70·0	4 47	6	5·9	1	2
	157	59·5	9 3	6	5·0	1	2	18th „	170	51·4	7 2 A.M.	6	6·0	1	2
	158	61·8	9 29	6	5·5	1	2		171	53·0	7 38	6	6·1	1	2

December 14th. (108) Cloudy morning.

Extracts from the Field Book—(Continued.)

1847	No. of the Set	Temperature of Air	Mean time of ending	No. of bars used	Height of Set above origin	Numeral shewing arrangement of Bars.	Numeral shewing arrangement of Micros:
		°	h. m.		feet.		
18th Dec.	172	55·7	8 11 A.M.	6 +	6·2	1	2
	173	57·9	8 40	6	6·3	1	2
	174	61·4	9 9	6	6·5	1	2
	175	64·2	9 34	6	6·5	1	2
	176	67·3	10 4	6	7·0	1	2
	177	69·5	10 29	6	7·2	1	2
	178	70·8	10 59	6	7·4	1	2
	179	75·3	1 45 P.M.	6	7·3	1	2
	180	75·3	2 13	6	7·5	1	2
	181	76·5	2 46	6	7·5	1	2
	182	75·7	3 17	6	7·9	1	2
	183	75·0	3 44	6	8·2	1	2
	184	74·3	4 10	6	8·4	1	2
	185	73·4	4 34	6	8·5	1	2
	186	71·5	4 59	6	8·6	1	2
20th „	187	53·1	7 14 A.M.	6	8·5	1	2
	188	55·3	7 45	6	8·6	1	2
	189	58·3	8 12	6	8·0	1	2
	190	60·0	8 33	6	7·7	1	2
	191	62·8	8 58	6	7·6	1	2
	192	64·9	9 26	6	7·4	1	2
	193	67·4	9 56	6	7·8	1	2
	194	69·5	10 22	6	8·0	1	2
	195	70·3	10 48	6	8·4	1	2
	196	74·2	1 46 P.M.	6	8·3	1	2
	197	74·3	2 10	6	8·3	1	2
	198	73·9	2 37	6	8·6	1	2
	199	74·2	3 1	6	9·0	1	2
	200	73·7	3 27	6	9·4	1	2
	201	73·5	3 49	6	9·4	1	2
	202	72·9	4 13	6	9·4	1	2
	203	71·8	4 41	6	9·4	1	2
21st „	204	52·2	7 12 A.M.	6	9·5	1	2
	205	52·0	7 41	6	9·2	1	2
	206	59·4	9 30	6	9·0	1	2
	207	61·5	9 58	6	8·7	1	2
	208	64·5	10 27	6	8·8	1	2
	209	67·2	10 54	6	8·8	1	2
	210	72·3	1 41 P.M.	6	8·7	1	2
	211	72·4	2 7	6	8·6	1	2
	212	72·3	2 36	6	8·9	1	2
	213	72·2	2 59	6	8·6	1	2
	214	72·2	3 25	6	8·6	1	2
	215	72·0	3 51	6	8·6	1	2
	216	71·5	4 16	6	8·6	1	2
	217	70·9	4 43	6	8·8	1	2
22nd „	218	51·5	7 16 A.M.	6	9·3	1	2
	219	52·1	7 44	6	9·1	1	2
	220	53·4	8 14	6	9·2	1	2
	221	55·4	8 42	6	9·2	1	2
	222	57·8	9 10	6	9·4	1	2

1847	No. of the Set	Temperature of Air	Mean time of ending	No. of bars used	Height of Set above origin	Numeral shewing arrangement of Bars	Numeral shewing arrangement of Micros:
		°	h. m.		feet.		
22nd Dec.	223	60·5	9 38 A.M.	6 +	9·4	1	2
	224	63·1	10 9	6	9·6	1	2
	225	65·2	10 36	6	9·3	1	2
	226	66·8	11 2	6	9·1	1	2
	227	72·7	2 8 P.M.	6	9·0	1	2
	228	72·7	2 35	6	9·1	1	2
	229	73·0	3 10	6	9·2	1	2
	230	73·1	3 35	6	9·5	1	2
	231	72·3	4 7	6	9·3	1	2
	232	71·8	4 33	6	9·2	1	2
	233	70·2	5 1	6	9·2	1	2
23rd „	234	53·0	7 22 A.M.	6	9·3	1	2
	235	54·7	7 46	6	9·6	1	2
	236	57·1	8 16	6	10·1	1	2
	237	59·6	8 41	6	10·0	1	2
	238	61·7	9 7	6	10·5	1	2
	239	63·5	9 30	6	10·6	1	2
	240	66·0	9 54	6	10·9	1	2
	241	67·7	10 19	6	10·9	1	2
	242	70·2	10 54	6	11·1	1	2
	243	73·2	1 43 P.M.	6	10·8	1	2
	244	74·0	2 9	6	10·8	1	2
	245	74·9	2 38	6	10·2	1	2
	246	75·1	3 4	6	10·3	1	2
	247	74·9	3 30	6	10·0	1	2
	248	74·7	3 52	6	9·8	1	2
	249	74·0	4 18	6	9·2	1	2
	250	72·7	4 49	6	9·0	1	2
27th „	251	52·0	7 27 A.M.	6	8·6	1	2
	252	54·5	7 57	6	8·8	1	2
	253	58·1	8 33	6	8·8	1	2
	254	61·1	9 4	6	9·1	1	2
	255	63·5	9 33	6	8·7	1	2
	256	66·5	10 0	6	8·6	1	2
	257	68·4	10 29	6	8·6	1	2
	258	70·2	10 57	6	8·9	1	2
	259	75·3	1 48 P.M.	6	9·1	1	2
	260	74·7	2 18	6	9·8	1	2
	261	74·7	2 45	6	9·7	1	2
	262	74·5	3 12	6	9·4	1	2
	263	74·3	3 39	6	9·4	1	2
	264	74·0	4 5	6	9·6	1	2
	265	73·0	4 30	6	9·7	1	2
	266	71·7	4 57	6	10·3	1	2
28th „	267	50·5	7 22 A.M.	6	10·3	1	2
	268	52·1	7 53	6	10·3	1	2
	269	55·4	8 24	6	10·4	1	2
	270	57·9	8 53	6	10·2	1	2
	271	60·4	9 28	6	9·6	1	2
	272	63·0	9 59	6	9·7	1	2
	273	65·1	10 24	6	9·6	1	2

December 21st, 22nd and 28th. Foggy morning.

Extracts from the Field Book—(Continued.)

1847-48	No. of the Set	Temperature of Air	Mean time of ending	No. of bars used	Height of Set above origin	Numeral shewing arrangement of Bars	Numeral shewing arrangement of Micros:
		°	h. m.		feet.		
28th Dec.	274	67·5	10 55 A.M.	6 +	9·9	1	2
	275	73·1	1 36 P.M.	6	10·0	1	2
	276	73·1	2 7	6	9·9	1	2
	277	74·8	2 36	6	9·9	1	2
	278	75·0	3 1	6	10·3	1	2
	279	74·3	3 27	6	10·1	1	2
	280	74·2	3 48	6	10·1	1	2
	281	73·2	4 22	6	10·2	1	2
	282	71·8	4 55	6	10·4	1	2
29th „	283	51·3	7 10 A.M.	6	10·8	1	2

1847-48	No. of the Set	Temperature of Air	Mean time of ending	No. of bars used	Height of Set above origin	Numeral shewing arrangement of Bars.	Numeral shewing arrangement of Micros:
		°	h. m.		feet.		
29th Dec.	284	52·9	7 37 A.M.	6 +	11·3	1	2
	285	55·0	8 3	6	11·5	1	2
	286	57·1	8 27	6	12·0	1	2
	287	59·9	8 54	6	12·2	1	2
	288	61·7	9 23	6	12·6	1	2
	289	64·4	9 52	6	12·9	1	2
	290	66·3	10 17	6	13·2	1	2
	291	70·9	11 31	6	13·1	1	2
				Total +	1274·0		

The dot denoting Station B was fixed exactly in the normal at the advanced-end of set No. 291.
Height of set No. 291 above Station B = 0·4 feet.

1847-48	No. of the Set	Temperature of Air	Mean time of ending	No. of bars used	Height of Set above origin	Bars	Micros:
3rd Jan.	292	51·5	7 12 A.M.	6 +	13·1	1	2
	293	51·9	7 43	6	12·9	1	2
	294	53·3	8 9	6	13·0	1	2
	295	56·0	8 37	6	13·1	1	2
	296	57·7	9 6	6	13·4	1	2
	297	59·7	9 37	6	13·5	1	2
	298	60·9	10 6	6	14·0	1	2
	299	62·0	10 31	6	14·0	1	2
	300	63·9	11 2	6	14·2	1	2
	301	71·3	1 30 P.M.	6	13·9	1	2
	302	71·9	1 54	6	14·0	1	2
	303	72·3	2 23	6	13·9	1	2
	304	72·1	2 51	6	14·2	1	2
	305	72·0	3 13	6	14·3	1	2
	306	71·9	3 39	6	14·8	1	2
	307	71·2	4 5	6	14·7	1	2
	308	70·6	4 28	6	14·9	1	2
	309	69·3	4 55	6	14·9	1	2
4th „	310	51·3	7 17 A.M.	6	15·2	1	2
	311	51·5	7 49	6	15·1	1	2
	312	52·2	8 17	6	15·3	1	2
	313	53·8	8 46	6	14·8	1	2
	314	56·0	9 26	6	14·7	1	2
	315	58·3	10 0	6	14·9	1	2
	316	60·0	10 26	6	16·0	1	2
	317	62·8	10 54	6	16·0	1	2
	318	70·5	1 11 P.M.	6	15·9	1	2
	319	71·8	1 36	6	15·6	1	2
	320	72·0	1 59	6	15·3	1	2
	321	72·3	2 21	6	15·4	1	2
	322	72·2	2 42	6	15·5	1	2
	323	72·8	3 5	6	15·8	1	2
	324	72·5	3 28	6	16·0	1	2
	325	72·0	3 52	6	16·0	1	2
	326	71·5	4 13	6	15·9	1	2

1847-48	No. of the Set	Temperature of Air	Mean time of ending	No. of bars used	Height of Set above origin	Bars.	Micros:
4th Jan.	327	70·8	4 35 P.M.	6 +	16·0	1	2
	328	69·9	5 1	6	15·7	1	2
5th „	329	51·2	7 4 A.M.	6	16·1	1	2
	330	51·7	7 32	6	16·3	1	2
	331	53·2	7 57	6	16·1	1	2
	332	54·4	8 22	6	16·1	1	2
	333	55·9	8 49	6	16·2	1	2
	334	58·0	9 14	6	16·2	1	2
	335	60·1	9 38	6	16·8	1	2
	336	61·9	10 2	6	16·5	1	2
	337	63·9	10 22	6	16·4	1	2
	338	66·0	10 45	6	16·6	1	2
	339	71·0	1 5 P.M.	6	16·7	1	2
	340	72·1	1 29	6	16·8	1	2
	341	72·7	1 53	6	17·1	1	2
	342	72·8	2 18	6	17·4	1	2
	343	72·8	2 40	6	17·3	1	2
	344	72·8	2 59	6	17·3	1	2
	345	72·5	3 24	6	17·5	1	2
	346	72·3	3 45	6	17·5	1	2
	347	71·8	4 8	6	17·7	1	2
	348	71·5	4 29	6	18·4	1	2
	349	70·4	4 53	6	18·4	1	2
6th „	350	50·4	7 4 A.M.	6	18·5	1	2
	351	51·2	7 33	6	18·7	1	2
	352	53·4	8 1	6	18·7	1	2
	353	54·9	8 25	6	19·0	1	2
	354	57·0	8 55	6	19·3	1	2
	355	58·0	9 17	6	19·0	1	2
	356	59·8	9 40	6	18·9	1	2
	357	61·0	10 5	6	18·8	1	2
	358	62·8	10 25	6	18·7	1	2
	359	64·3	10 48	6	18·9	1	2
	360	69·9	1 13 P.M.	6	19·2	1	2
	361	70·5	1 34	6	18·9	1	2

January 4th. Foggy morning.

Extracts from the Field Book—(Continued.)

1848	No. of the Set	Temperature of Air	Mean time of ending	No. of bars used	Height of Set above origin	Numeral shewing arrangement of Bars.	Numeral shewing arrangement of Micros:
		°	h. m.		feet.		
6th Jan.	362	71·3	1 57 P.M.	6	+ 19·0	1	2
	363	72·0	2 20	6	19·0	1	2
	364	72·0	2 44	6	18·8	1	2
	365	72·0	3 7	6	19·2	1	2
	366	71·2	3 35	6	19·4	1	2
	367	70·9	3 58	6	19·1	1	2
	368	69·9	4 20	6	19·2	1	2
	369	69·1	4 40	6	19·2	1	2
	370	67·8	5 3	6	18·9	1	2
7th „	371	47·3	7 6 A.M.	6	19·0	1	2
	372	48·0	7 36	6	19·3	1	2
	373	49·8	8 1	6	19·3	1	2
	374	51·2	8 24	6	19·5	1	2
	375	52·9	8 48	6	19·5	1	2
	376	54·0	9 12	6	19·2	1	2
	377	55·2	9 33	6	19·3	1	2
	378	57·0	9 56	6	19·4	1	2
	379	58·9	10 17	6	19·2	1	2
	380	60·4	10 37	6	18·9	1	2
	381	62·9	11 1	6	19·0	1	2
	382	68·2	1 21 P.M.	6	18·8	1	2
	383	69·1	1 42	6	19·1	1	2
	384	69·7	2 6	6	19·2	1	2
	385	70·0	2 26	6	18·7	1	2
	386	70·2	2 48	6	18·5	1	2
	387	70·2	3 9	6	18·1	1	2
	388	70·1	3 36	6	17·3	1	2
	389	69·7	3 58	6	17·3	1	2
	390	69·0	4 19	6	17·4	1	2
	391	68·7	4 39	6	17·1	1	2
	392	67·5	5 1	6	17·2	1	2
8th „	393	47·5	7 7 A.M.	6	17·3	1	2
	394	48·7	7 36	6	17·1	1	2
	395	49·5	8 0	6	17·6	1	2
	396	50·9	8 24	6	18·0	1	2
	397	53·3	8 50	6	17·8	1	2
	398	55·7	9 14	6	17·9	1	2
	399	58·1	9 39	6	17·9	1	2
	400	61·2	10 1	6	17·6	1	2
	401	63·9	10 27	6	18·2	1	2
	402	65·5	10 48	6	18·5	1	2
	403	68·0	11 13	6	18·3	1	2
	404	72·0	1 28 P.M.	6	18·1	1	2
	405	72·3	1 52	6	17·5	1	2

1848	No. of the Set	Temperature of Air	Mean time of ending	No. of bars used	Height of Set above origin	Numeral shewing arrangement of Bars.	Numeral shewing arrangement of Micros:
		°	h. m.		feet.		
8th Jan.	406	72·7	2 16 P.M.	6	+ 17·4	1	2
	407	72·3	2 39	6	17·6	1	2
	408	72·2	3 3	6	17·7	1	2
	409	72·1	3 23	6	17·5	1	2
	410	71·9	3 47	6	17·4	1	2
	411	71·5	4 4	6	17·4	1	2
	412	71·2	4 24	6	17·2	1	2
	413	70·5	4 45	6	17·5	1	2
	414	69·2	5 6	6	17·8	1	2
10th „	415	50·1	7 19 A.M.	6	17·8	1	2
	416	51·1	7 42	6	17·9	1	2
	417	52·8	8 6	6	18·0	1	2
	418	55·1	8 26	6	18·0	1	2
	419	57·0	8 52	6	18·3	1	2
	420	59·0	9 14	6	18·8	1	2
	421	61·4	9 40	6	18·8	1	2
	422	63·3	10 3	6	18·7	1	2
	423	65·2	10 24	6	18·7	1	2
	424	66·2	10 47	6	18·4	1	2
	425	67·3	11 13	6	18·5	1	2
	426	72·5	1 37 P.M.	6	18·9	1	2
	427	72·7	1 58	6	18·5	1	2
	428	73·4	2 22	6	18·5	1	2
	429	73·2	2 44	6	18·4	1	2
	430	73·5	3 8	6	18·4	1	2
	431	73·2	3 31	6	18·9	1	2
	432	73·0	3 55	6	19·3	1	2
	433	72·5	4 15	6	18·9	1	2
	434	71·8	4 38	6	18·8	1	2
	435	71·1	5 2	6	18·5	1	2
11th „	436	50·4	7 9 A.M.	6	18·1	1	2
	437	50·0	7 37	6	18·4	1	2
	438	52·2	8 7	6	18·8	1	2
	439	54·0	8 31	6	19·0	1	2
	440	56·4	8 57	6	19·3	1	2
	441	59·2	9 23	6	19·6	1	2
	442	62·0	9 48	6	19·5	1	2
	443	63·5	10 12	6	19·9	1	2
	444	65·2	10 38	6	20·3	1	2
	445	68·8	11 31	6	20·3	1	2
			Total		+ 2681·5		

The dot denoting Station C was fixed exactly in the normal at the advanced-end of set No. 445.
Height of set No. 445 above Station C = 0·3 feet.
The terminal point of set No. 445 was the point of origin for set No. 446.

Extracts from the Field Book—(Continued.)

1848	No. of the Set	Temperature of Air	Mean time of ending	No. of bars used	Height of Set above origin	Numeral shewing arrangement of Bars.	Numeral shewing arrangement of Micros :
		°	h. m.		feet.		
11th Jan.	446	72·2	3 13 P.M.	6	+ 20·4	1	2
	447	72·7	3 37	6	20·5	1	2
	448	72·9	3 57	6	20·4	1	2
	449	72·3	4 19	6	20·7	1	2
	450	72·0	4 41	6	20·8	1	2
	451	70·9	5 3	6	20·3	1	2
12th "	452	50·7	7 11 A.M.	6	20·2	1	2
	453	50·8	7 36	6	20·3	1	2
	454	52·1	7 56	6	20·2	1	2
	455	53·7	8 15	6	20·4	1	2
	456	55·0	8 37	6	20·6	1	2
	457	56·5	8 56	6	20·5	1	2
	458	57·5	9 20	6	20·5	1	2
	459	59·0	9 40	6	20·6	1	2
	460	60·7	10 3	6	20·6	1	2
	461	62·5	10 22	6	20·5	1	2
	462	64·2	10 45	6	20·4	1	2
	463	66·1	11 6	6	20·5	1	2
	464	72·0	1 15 P.M.	6	20·7	1	2
	465	72·2	1 37	6	20·8	1	2
	466	72·7	1 55	6	20·8	1	2
	467	73·0	2 17	6	20·8	1	2
	468	73·2	2 38	6	21·0	1	2
	469	73·4	2 57	6	20·8	1	2
	470	73·5	3 18	6	20·5	1	2
	471	73·2	3 39	6	20·6	1	2
	472	72·7	4 1	6	19·7	1	2
	473	72·2	4 18	6	19·6	1	2
	474	71·9	4 40	6	19·5	1	2
	475	71·1	5 5	6	19·7	1	2
13th "	476	50·2	7 10 A.M.	6	19·9	1	2
	477	50·2	7 38	6	20·1	1	2
	478	51·5	8 4	6	20·1	1	2
	479	53·4	8 28	6	20·1	1	2
	480	55·7	8 52	6	20·2	1	2
	481	59·0	9 15	6	20·2	1	2
	482	60·0	9 36	6	20·0	1	2
	483	62·1	9 57	6	20·1	1	2
	484	64·3	10 20	6	20·1	1	2
	485	66·0	10 40	6	20·1	1	2
	486	67·5	11 6	6	20·2	1	2
	487	72·3	1 17 P.M.	6	20·2	1	2
	488	72·0	1 35	6	20·2	1	2
	489	73·1	1 54	6	20·2	1	2
	490	72·8	2 13	6	20·2	1	2
	491	73·2	2 34	6	20·2	1	2
	492	73·3	2 51	6	20·2	1	2
	493	73·2	3 10	6	20·3	1	2
	494	73·3	3 30	6	20·2	1	2
	495	72·8	3 48	6	20·2	1	2

1848	No. of the Set	Temperature of Air	Mean time of ending	No. of bars used	Height of Set above origin	Numeral shewing arrangement of Bars	Numeral shewing arrangement of Micros :
		°	h. m.		feet.		
13th Jan.	496	72·1	4 6 P.M.	6	+ 20·1	1	2
	497	70·9	4 30	6	20·2	1	2
	498	70·2	4 48	6	20·2	1	2
	499	69·0	5 8	6	20·3	1	2
14th "	500	50·7	7 6 A.M.	6	20·3	1	2
	501	50·9	7 27	6	20·3	1	2
	502	51·5	7 50	6	20·3	1	2
	503	52·5	8 9	6	20·3	1	2
	504	54·0	8 31	6	20·3	1	2
	505	55·5	8 52	6	20·3	1	2
	506	57·0	9 14	6	20·3	1	2
	507	58·7	9 35	6	20·2	1	2
	508	61·3	9 58	6	20·4	1	2
	509	64·1	10 21	6	20·4	1	2
	510	65·3	10 41	6	20·4	1	2
	511	66·2	11 3	6	20·5	1	2
	512	71·2	1 13 P.M.	6	20·3	1	2
	513	71·8	1 58	6	20·3	1	2
	514	72·0	2 3	6	20·4	1	2
	515	72·0	2 22	6	20·5	1	2
	516	71·7	2 42	6	20·5	1	2
	517	71·5	3 0	6	20·7	1	2
	518	71·1	3 20	6	20·9	1	2
	519	70·9	3 39	6	20·8	1	2
	520	70·0	3 59	6	20·8	1	2
	521	69·2	4 15	6	20·5	1	2
	522	69·0	4 34	6	20·6	1	2
	523	68·2	4 55	6	20·4	1	2
15th "	524	49·1	7 11 A.M.	6	20·5	1	2
	525	50·0	7 37	6	20·7	1	2
	526	52·0	7 58	6	21·1	1	2
	527	52·5	8 20	6	21·2	1	2
	528	54·8	8 42	6	21·2	1	2
	529	56·0	9 2	6	21·2	1	2
	530	58·1	9 26	6	21·3	1	2
	531	60·0	9 46	6	21·4	1	2
	532	61·5	10 5	6	21·4	1	2
	533	63·1	10 21	6	21·4	1	2
	534	64·9	10 39	6	21·6	1	2
	535	66·8	11 2	6	21·6	1	2
	536	71·5	1 17 P.M.	6	21·6	1	2
	537	71·3	1 38	6	21·5	1	2
	538	72·0	1 58	6	21·5	1	2
	539	71·9	2 15	6	21·3	1	2
	540	72·3	2 32	6	21·2	1	2
	541	72·5	2 51	6	21·4	1	2
	542	72·1	3 13	6	21·1	1	2
	543	71·9	3 30	6	21·1	1	2
	544	71·5	3 50	6	21·1	1	2
	545	71·3	4 8	6	21·2	1	2

Extracts from the Field Book—(Coutinued.)

1848	No. of the Set	Temperature of Air	Mean time of ending	No. of bars used	Height of Set above origin	Numeral shewing arrangement of Bars	Micros:	1848	No. of the Set	Temperature of Air	Mean time of ending	No. of bars used	Height of Set above origin	Numeral shewing arrangement of Bars.	Micros:
		°	h. m.		feet.					°	h. m.		feet.		
15th Jan.	546	71·3	4 26 P.M.	6	+ 21·2	1	2	17th Jan.	566	73·1	2 49 P.M.	6	+ 21·3	1	2
	547	70·9	4 45	6	21·3	1	2		567	73·1	3 6	6	20·6	1	2
	548	68·7	5 12	6	21·4	1	2		568	73·0	3 27	6	20·5	1	2
17th „	549	51·3	7 4 A.M.	6	21·4	1	2		569	72·7	3 47	6	20·7	1	2
	550	52·2	7 27	6	21·4	1	2		570	72·3	4 9	6	20·8	1	2
	551	54·0	7 49	6	21·4	1	2		571	71·9	4 26	6	20·8	1	2
	552	55·7	8 11	6	21·5	1	2		572	71·5	4 44	6	20·9	1	2
	553	57·2	8 32	6	21·6	1	2		573	70·0	5 4	6	20·9	1	2
	554	58·6	8 51	6	21·5	1	2	18th „	574	49·2	7 8 A.M.	6	21·0	1	2
	555	60·1	9 9	6	21·6	1	2		575	50·3	7 31	6	21·0	1	2
	556	61·2	9 27	6	21·7	1	2		576	51·5	7 51	6	21·0	1	2
	557	62·9	9 49	6	21·5	1	2		577	52·5	8 9	6	21·0	1	2
	558	64·0	10 6	6	21·4	1	2		578	54·1	8 31	6	21·1	1	2
	559	65·7	10 25	6	21·3	1	2		579	55·2	8 50	6	21·0	1	2
	560	67·1	10 43	6	21·3	1	2		580	57·0	9 12	6	20·9	1	2
	561	68·9	11 5	6	21·4	1	2		581	58·7	9 33	6	20·6	1	2
	562	73·7	1 27 P.M.	6	21·5	1	2		582	61·4	10 5	6	20·8	1	2
	563	73·7	1 47	6	21·6	1	2		583	66·0	10 37	2	21·7	2	3
	564	73·4	2 8	6	21·8	1	2								
	565	73·1	2 28	6	21·7	1	2					Total	+ 2861·1		

The advanced-end of set No. 583 fell in excess (*i. e.* north-east) of the dot at North-East-End 2·8243 feet, as measured on Cary's brass scale with a beam compass.

Height of set No. 583 above North-East-End = 1·4 feet.

Reduction to Mean Sea Level.

Let the sections into which this base-line is divided be denoted as follows:

South-West-End to Station A by Section I; Station B to Station C by Section III;
Station A to „ B „ II; „ C to North-East-End „ IV.

Then in the notation of (7) page I—22 we have

$H = 223$; $h = 24{\cdot}4$; $\delta h = +4{\cdot}1$; Log $R = 7{\cdot}32010$, all in feet; and $n = 582$.

	$[h]_1^p$	a	n	dh	F	λ	C_2	C_1	C
	+			+	+		—	—	—
Section I ...	156	0	145	1·0	229	9136	·0007	·0975	·0982
„ II ...	1274	0	146	1·0	1494	9199	·0045	·0982	·1027
„ III ...	2682	0	154	1·1	3075	9703	·0093	·1035	·1128
„ IV ...	2861	−14	137	1·0	3341	8650	·0101	·0923	·1024

Final length of the Base-Line and of its parts in feet of Standard A.

Section	*Measured with*			Reduction to sea level page V—27	Total Length	Log.
	Compensated bars page V—16	Compensated microscopes page V—20	Beam compass pages V—22 to V—27			
S. W. End to Stn. A ...	8700·4750	435·0438	·0000	— ·0982	9135·4206	3·96072,8547
Stn. A to Stn. B ...	8760·4782	438·0468	·0000	— ·1027	9198·4223	3·96371,3344
Stn. B to Stn. C ...	9240·4747	462·0508	·0000	— ·1128	9702·4127	3·98687,9744
Stn. C to N. E. End ...	8240·4233	412·0424	— 2·8243	— ·1024	8649·5390	3·93699,2961
S. W. End to N. E. End	34941·8512	1747·1838	— 2·8243	— ·4161	36685·7946	4·56449,7930

Verificatory Minor Triangulation.

No. of Triangle	Name of Station	Corrected Angle	Log. Sine	Log. Distance	Distance in Feet	Distance in Miles	Error of Triangle
		° ′ ″					″
1	South-West-End of Base, or Sonakhoda T.S.	47 33 27·115	9·868030072	3·849552995			
	Station A, ...	60 1 54·189	9·937669349	3·919192272			+0·637
	„ α	72 24 38·709	9·979205624	3·960728547	9135·4206	1·730	
		180 0 0·013					
2	Station α	62 12 50·183	9·946793283	3·904550389			
	„ A, ...	66 34 28·434	9·962643098	3·920400204			−0·672
	„ β	51 12 41·395	9·891795889	3·849552995			
		180 0 0·012					
3	Station A, ...	53 23 33·021	9·904574618	3·892603031			
	„ β	71 0 21·242	9·975685459	3·963713872	9198·4335	1·742	+0·536
	„ B, ...	55 36 5·751	9·916521976	3·904550389			
		180 0 0·014					
4	Station β	68 35 6·116	9·968931234	3·974156831			
	„ B, ...	60 55 10·383	9·941480679	3·946706276			−0·405
	„ γ	50 29 43·516	9·887377434	3·892603031			
		180 0 0·015					
5	Station B, ...	63 28 41·780	9·951709024	4·002746106			
	„ γ	59 37 2·546	9·935843215	3·986880297	9702·4251	1·838	−0·159
	„ C, ...	56 54 15·693	9·923119749	3·974156831			
		180 0 0·019					
6	Station γ	53 59 41·470	9·907929287	3·942372464			
	„ C, ...	57 37 49·207	9·926656983	3·961100160			−0·308
	„ δ	68 22 29·341	9·968302929	4·002746106			
		180 0 0·018					
7	Station C, ...	65 27 54·702	9·958902578	3·973713042			
	„ δ	56 42 55·530	9·922182964	3·936993428	8649·5483	1·638	−0·756
	North-East-End of Base, or Ramganj T.S.	57 49 9·784	9·927562000	3·942372464			
		180 0 0·016			36685·8275	6·948	

NOTE.—Each side of a triangle is given in the same horizontal line with the angle which it subtends.

The angles of the verificatory triangulation were measured with a 3-foot Theodolite by Troughton and Simms, read by 5 micrometer-microscopes. At all the stations 3 measures were made on each of 8 zeros. The stations on the line are South-West-End, A, B, C, and North-East-End.—The auxiliary stations are α, β and γ.

Comparison in feet between the values computed by means of the verificatory triangulation and the measured value.

Of the entire line.

		Log.
South-West-End to North-East-End by the measurement page V—28	36685·7946	4·564 4979 30
" computed in terms of South-West-End to Station A page V—29	36685·8275	4·564 4983 20
Log. computed value — Log. measured value = +		0·000 0003 90

In terms of the entire line by measurement.

	Computed	Computed — Measured*
South-West-End to Station A	9135·4124	—·0082
Station A to Station B	9198·4253	+·0030
" B to " C	9702·4164	+·0037
" C to North-East-End	8649·5405	+·0015

Of each section in terms of the others.

	South West-End to Station A	Station A to Station B	Computed — Measured	Station B to Station C	Computed — Measured	Station C to North East-End	Computed — Measured
Measured lengths* ..	9135·4206	9198·4223	.. ..	9702·4127	.. ..	8649·5390	.. ..
Computed on base South-West-End to Station A	.. ..	9198·4335	+·0112	9702·4251	+·0124	8649·5483	+·0093
Computed on base Station A to Station B	.. ..	.. ..	.. ..	9702·4133	+·0006	8649·5378	—·0012
Computed on base Station B to Station C	.. ..	.. ..	.. ..	.. ..	.. ..	8649·5373	—·0017

NOTE.—Since $\text{Log}_e (x + dx) = \text{Log}_e x + \frac{(dx)}{x} - \frac{(dx)^2}{2x^2} + \&c.$

$dx = \left\{ \text{Log}_{10} (x + dx) - \text{Log}_{10} x \right\} \frac{x}{\text{Modulus}}$ nearly, by which expression the required variations in the foregoing natural numbers have been calculated.

Description of Stations.

SOUTH-WEST-END OF SONAKHODA BASE, OR SONAKHODA TOWER STATION, lat. 26° 15′, long. 88° 15′ is situated in thána Kalíáganj of the Púrnea district, and stands at a distance of 200 yards to the N. of the village of Sonákhoda, and close to a cart road leading to Kishanganj. The village of Hátgaon is about 3 miles towards the S.W.; Páhárkáta, nearly 5 miles to the W. by S., and Gernábári, about 2½ miles nearly due west.

The tower at this station is entirely of masonry, 24 feet high and 14 feet square at top, and as it marks the extremity of a *base-line*, its construction is adapted to the requirements of the measurement by means of a vaulted passage running through it, on a level with the ground, in the direction of the line. In the centre of the tower, on the floor of the vaulted passage, there is a small plate of brass let into stone: the station mark is engraved on the brass and was transferred to the top of the tower through the hole in the vault. The pillar for the theodolite is built on the vault of the passage, and is separated by a small annular space from the rest of the building so as to be isolated from it. When all the observations had been taken at this station, the two openings of the vaulted passage were closed with masonry, and a cone of masonry 3 feet high was built on the top of the tower over the theodolite pillar. The distance between the upper mark on the top of the pillar, and the mark on the floor of the vaulted passage is 21·6 feet. A flight of steps is built along one side of the tower with a landing place at top, the portion which adjoins the tower being of masonry, but the lower part which projects beyond it was of mud, and was removed after the observations had been all taken, so as to prevent idle people gaining access to the top.

NORTH-EAST-END OF SONAKHODA BASE, OR RAMGANJ TOWER STATION, lat. 26° 19′, long. 88° 20′, is situated in thána Kalíáganj of the Púrnea district, and stands close to the S.W. side of the village of Rámganj. The village of Ghágra, is about 1¼ miles towards the S.S.E., and that of Manikpúr about 1½ miles nearly due W.

The station is marked in the same manner as Sonákhoda Tower Station, with the difference that the height of the tower here is 20 feet above the surface of the ground, and the distance between the upper and lower marks is 18 feet.

STATION A. Is situated in thána Kalíáganj of the Púrnea district, on the straight line joining Sonákhoda and Rámganj Tower Stations and at about 1¾ miles from the former point. The nearest village to it is Balanja which is about a mile to the S.W.

The mark consists of a dot on a brass pin fixed in the head of a stout wooden picket, driven about 5 feet into the ground and projecting 14 inches above the surface. This picket is surrounded by 3 others of equal height for the support of the theodolite stand, and an isolated platform of earth of about 14 feet square was raised around these pickets which are also connected together with earth work.

STATION B. Is situated in thána Kalíáganj of the Púrnea district, nearly mid-way between the ends of the base-line. The village of Bhatgáon is distant about a mile to the S.E.

The mark and platform at this station are similar to those at Station A.

STATION C. Is situated in thána Kalíáganj of the Púrnea district, on the straight line joining Sonákhoda and Rámganj Tower Stations and at about 1¾ miles from the latter point. The nearest village is Madárípúr, distant about half a mile to the N.E.

The mark and platform at this station are similar to those at Station A.

AUXILIARY STATION *a* OR MUNAPARA. Is situated in thána Kalíáganj of the Púrnea district, and stands on the south bank of a tank, about half a mile S.E. of the village of Munápára.

It is denoted by a platform of earth 18 inches high and 14 feet square at top, with a central masonry pillar, 4 feet in diameter and isolated from the rest of the platform by an annulus of masonry, 2 feet thick, built at a small interval around the pillar. There are markstones at top and bottom of pillar.

Description of Stations—(Continued.)

AUXILIARY STATION β OR PANASI. Is situated in thána Kaliáganj of the Púrnea district, and stands on the S.E. bank of a tank adjoining the S.S.W. side of the village of Panási.

A platform, similar to and of the same height as that at Auxiliary Station α, marks the station.

STATION γ OR GAGNATI. Is situated in thána Kaliáganj of the Púrnea district, and stands close to the western edge of a jheel, about 250 yards to the east of the village of Gagnati.

A platform, similar to that at Auxiliary Station α, but 7 feet 5 inches in height, marks the station.

STATION δ OR MANIPUR. Is in thána Kaliágunj of the Púrnea district, and stands on a slight swell of ground about 200 yards S.E. of a long narrow jheel, ¼ of a mile N.E. of the village of Manipúr, and half a mile N. W. of Mánikpúr.

A platform, similar to that at Auxiliary Station α, but 7 feet 7 inches in height, marks the station.

J. B. N. HENNESSEY.

CHACH OR ATTOK BASE-LINE.

The middle point of this base-line is in Latitude N. 33° 55′, Longitude E. 72° 29′; the Azimuth of North-East-End at South-West-End is 234° 41′, and the line is 7·83 Miles in length.

The measurement was effected under the directions of Lieut.-Colonel* A. S. Waugh, R.E., with the aid of the following:

Captain A. Strange
Mr. G. Logan
Lieut. J. T. Walker R.E.
„ T. G. Montgomerie R.E.
Mr. H. Keelan
„ J. Mulheran
„ W. N. James
„ J. B. N. Hennessey
„ G. H. W. Shelverton
„ N. A. Belletty
„ W. H. Johnson
„ C. J. Carty

* Now General Sir A. S. Waugh.

INTRODUCTION.

This base-line was measured on the plain of Chach, East of Attok in the province of the Punjaub, the West-End being East of the Attok fort about 8 Miles. The line was selected under the personal superintendence of Lieut. Colonel A. S. Waugh R.E., and the ground prepared by Mr. J. O. N. James.

The measurement was commenced at Kálu or South-West-End, bar-tongues pointing North-West, and carried on *continuously* to Agzar or North-East-End, so that every succeeding set originated at the point marking the terminus of its predecessor. The line was divided into 4 sections by the sub-dividing points A, B and C to admit of verification by minor triangulation.

Comparisons between the compensated bars and the standard **A** were made on three different occasions, *i.e.* before the measurement near the South-West-End, after set No. 341 at about the centre of the base and after the measurement near the North-East-End. The comparing piers were in all three cases set up parallel to the line and within a few feet of it; but on the first occasion, when 47 comparisons were made, the ends of the bars were reversed to obtain a more favorable light, so that the bar-tongues pointed South-East; in the second series of 83 comparisons the bar-tongues pointed as during the measurement to the North-West, and there are reasons for concluding that this latter direction for the bar-tongues was maintained in the third series consisting of 93 comparisons, taken on the conclusion of the measurement.

One of the two comparing microscopes employed in the preceding bar comparisons was provided with a micrometer, while the other had its wires (or lines) fixed.

The compensated microscopes were compared with their scales on 6 occasions, including the comparisons taken prior and subsequent to the measurement.

In respect to time, the first set of bar comparisons was made on the 6th December 1853, the last on the 22nd of the following February.

The stations of the verificatory triangulation were 9 in number, forming a single series of triangles. Of these stations, 5 were in the alignment, *viz.* South-West-End, A, B, C and North-East-End, while the auxiliary points α, β, γ and δ were placed on suitable sites South-East of the line. The angles were measured by Lieut. T. G. Montgomerie R.E., with Barrow's 3-foot theodolite on 10 equidistant zeros; three measures were taken on each zero, so that 30 measures in all were taken of each angle.

Comparisons between the Standard Bar **A** *and the Compensated Bars* A, B, C, D, E, H, *made at Kálu, or South-West-End of the base-line, before the measurement.*

Micrometer Readings in Divisions: 1 Division = $\frac{1}{21571\cdot68}$ Cary's Inch [7.8], = 1·2870 *m.y.* of **A**

1853 Dec.	Mean of the times of observing **A**	No. of comparison	Temperature of Air	Corrected mean temperature of **A**	Mean **A**	A	B	C	D	E	H	Mean of the compensated bars	Remarks
	h. m.		°	°	+	+	+	+	+	+	+	+	
6th	7 48 A.M.	1	36·4	33·73	406·6	1028·9	1002·2	1026·1	1056·0	1017·5	1040·0	1028·5	Lt.-Col. Waugh at the micrometer microscope: Lt. Montgomerie at the plain microscope.
	10 11	2	52·3	40·58	532·0	1031·9	999·0	1033·0	1058·2	1024·0	1034·9	1030·2	
	11 39	3	58·6	48·83	669·5	1026·9	1003·9	1033·8	1064·0	1025·0	1031·9	1030·9	
	0 32 P.M.	4	60·3	52·80	735·0	1032·8	1005·0	1040·0	1063·8	1026·9	1028·8	1032·9	
	1 26	5	61·9	56·00	789·3	1030·0	1003·0	1042·0	1064·1	1030·0	1030·9	1033·3	
	2 59	6	62·9	59·70	842·5	1030·0	1003·0	1046·0	1071·0	1028·0	1025·5	1033·9	
	3 45	7	61·8	60·70	856·0	1031·9	1005·8	1048·2	1065·0	1027·9	1027·5	1034·4	
7th	7 21 A.M.	8	35·9	35·23	429·4	1017·9	990·8	1020·6	1048·2	1011·6	1034·1	1020·4	Lieut. Montgomerie at the micrometer microscope: Mr. Keelan at the plain microscope.
	8 19	9	40·9	35·73	446·7	1027·4	1001·4	1033·0	1054·6	1021·0	1045·4	1030·5	
	9 10	10	46·3	37·85	485·8	1030·6	1000·5	1031·1	1058·4	1024·9	1036·8	1030·4	
	9 54	11	52·5	40·95	536·9	1028·1	998·2	1032·6	1059·9	1022·2	1035·2	1029·4	
	10 30	12	57·7	44·30	590·1	1026·8	991·1	1031·0	1055·9	1021·8	1029·8	1026·8	
	11 4	13	60·1	47·88	645·4	1020·0	995·2	1030·6	1050·8	1018·9	1022·2	1022·3	
	0 2 P.M.	14	61·8	53·20	736·4	1023·1	993·1	1037·1	1058·9	1021·9	1024·2	1026·4	
	0 33	15	63·2	55·33	772·9	1023·3	991·8	1037·4	1061·7	1023·9	1025·4	1027·3	
	1 7	16	64·4	57·53	810·9	1022·4	997·3	1038·9	1065·1	1025·4	1024·7	1029·0	
	1 42	17	64·9	59·48	843·6	1025·8	999·6	1044·3	1070·1	1027·2	1024·9	1032·0	
	2 14	18	65·3	60·85	865·8	1028·5	1000·5	1048·1	1067·1	1027·3	1025·2	1032·8	
	2 48	19	65·6	62·08	884·1	1031·0	1003·5	1049·6	1072·8	1030·2	1027·0	1035·7	
	3 31	20	65·1	63·13	901·2	1025·8	1006·9	1048·8	1073·9	1030·7	1030·0	1036·0	
8th	8 7 A.M.	21	42·4	38·98	478·0	1005·9	982·1	1014·0	1051·2	1001·2	1026·7	1013·5	Cloudy morning. Mr. Keelan at the micrometer microscope: Lt. Walker at the plain micros:
	9 14	22	49·6	41·18	518·3	1012·8	986·8	1018·3	1043·4	1004·1	1021·7	1014·5	
	10 20	23	55·0	45·75	597·6	1010·6	983·1	1021·8	1050·4	1010·8	1015·6	1015·4	
	11 42	24	60·4	51·73	703·3	1007·2	984·3	1022·8	1051·1	1008·3	1007·1	1013·5	
	0 25 P.M.	25	62·7	54·78	754·3	1009·9	985·5	1028·0	1050·0	1008·0	1010·0	1015·2	
	1 10	26	64·6	57·73	799·9	1014·9	989·1	1032·1	1052·3	1013·7	1013·5	1019·3	
	1 56	27	66·1	60·20	839·1	1015·1	986·0	1030·4	1057·0	1013·0	1010·8	1018·7	
	2 40	28	66·5	62·10	868·7	1012·3	981·4	1029·1	1051·9	1010·1	1008·1	1015·5	
	3 28	29	65·4	63·50	888·5	1009·3	984·3	1029·1	1056·6	1006·8	1006·9	1015·5	
9th	7 5 A.M.	30	36·4	38·33	442·1	986·8	965·1	991·0	1019·3	984·0	1005·0	991·9	Lt.-Col. Waugh at the micrometer microscope: Mr. Keelan at the plain microscope.
	7 37	31	38·2	37·70	435·5	989·2	970·9	993·9	1023·9	984·8	1008·0	995·1	
	8 5	32	40·7	37·65	438·5	997·1	973·2	999·1	1025·1	989·8	1010·0	999·1	
	8 33	33	43·5	38·23	449·1	1002·0	978·0	1003·1	1031·0	992·0	1013·0	1003·2	
	9 2	34	46·7	39·55	473·3	1002·2	982·0	1006·0	1033·6	996·2	1014·0	1005·7	
	9 26	35	49·2	40·98	500·3	1005·0	981·6	1008·9	1037·3	1001·0	1017·5	1008·6	
	9 49	36	51·5	42·53	529·2	1017·0	983·9	1014·9	1041·9	1005·4	1017·9	1013·5	
	10 11	37	53·9	44·28	559·5	1011·5	985·0	1016·0	1045·1	1006·2	1018·9	1013·8	
	10 33	38	56·6	46·23	591·0	1013·8	985·7	1025·9	1050·0	1009·9	1018·4	1017·3	
	10 57	39	59·3	48·25	624·5	1013·9	986·1	1022·0	1050·1	1009·9	1015·9	1016·3	
	11 45	40	63·9	52·48	697·3	1008·0	978·0	1019·0	1043·0	1004·1	1004·9	1009·5	

January 6th. At 2 *h.* 12 *m.* P.M., a violent earthquake occurred, apparently from W. to E. The stone pillars rocked to and fro, and the levels were all much disturbed.

Before the measurement—(Continued.)

1853. Dec.	Mean of the times of observing A	No. of comparison	Temperature of Air	Corrected mean temperature of A	Micrometer Readings in Divisions. 1 Division = $\frac{1}{21571 \cdot 68}$ Cary's Inch [7·8], = 1·2870 m.y. of A — Mean A	A	B	C	D	E	H	Mean of the compensated bars	Remarks
	h. m.		°	°	+	+	+	+	+	+	+	+	
9th	0 8 P.M.	41	65·5	54·60	729·2	993·7	972·3	1013·9	1040·0	1002·9	1000·0	1003·8	
	0 31	42	67·0	56·65	762·0	998·0	972·1	1015·0	1033·0	998·9	995·9	1002·2	
	0 58	43	68·4	58·78	796·9	993·1	969·9	1008·0	1029·2	996·0	990·1	997·7	
	1 31	44	68·5	61·23	837·2	991·2	963·8	1006·9	1029·5	993·2	988·0	995·4	
	2 7	45	68·4	63·30	868·0	991·0	962·9	1004·1	1025·3	992·9	988·5	994·1	
	2 40	46	69·2	64·63	890·2	991·1	962·9	1010·6	1028·2	993·0	988·4	995·7	
	3 31	47	67·3	65·75	914·3	994·9	967·8	1007·0	1033·9	991·9	986·1	996·9	
		Means		50·49	675·87	1013·61	987·14	1024·32	1049·42	1010·94	1017·13	1017·09	

Let the mean length of the compensated bars minus the Standard A at 62° F be denoted by x, and the observed excess of the compensated bars by δ when the temperature of A is $t°$. Then, the expansion of A for 1° being $(E_a - dE_a)$, we have

$$x - (t° - 62°)(E_a - dE_a) - \delta = 0;$$

Treating the preceding bar comparisons as shewn in this equation, we obtain the following series of results :—

		d			d
$x + 28{\cdot}27$	$(E_a - dE_a)$	$-621{\cdot}9 = 0$	$x + 14{\cdot}12$	$(E_a - dE_a)$	$-376{\cdot}9 = 0$
$x + 21{\cdot}42$	,,	$-498{\cdot}2 = 0$	$x + 8{\cdot}80$	,,	$-290{\cdot}0 = 0$
$x + 13{\cdot}17$	,,	$-361{\cdot}4 = 0$	$x + 6{\cdot}67$	,,	$-254{\cdot}4 = 0$
$x + 9{\cdot}20$	,,	$-297{\cdot}9 = 0$	$x + 4{\cdot}47$	,,	$-218{\cdot}1 = 0$
$x + 6{\cdot}00$	,,	$-244{\cdot}0 = 0$	$x + 2{\cdot}52$	,,	$-188{\cdot}4 = 0$
$x + 2{\cdot}30$	,,	$-191{\cdot}4 = 0$	$x + 1{\cdot}15$	,,	$-167{\cdot}0 = 0$
$x + 1{\cdot}30$	,,	$-178{\cdot}4 = 0$	$x - 0{\cdot}08$	,,	$-151{\cdot}6 = 0$
$x + 26{\cdot}77$	,,	$-591{\cdot}0 = 0$	$x - 1{\cdot}13$	,,	$-134{\cdot}8 = 0$
$x + 26{\cdot}27$	,,	$-583{\cdot}8 = 0$	$x + 23{\cdot}02$	,,	$-535{\cdot}5 = 0$
$x + 24{\cdot}15$	,,	$-544{\cdot}6 = 0$	$x + 20{\cdot}82$	,,	$-496{\cdot}2 = 0$
$x + 21{\cdot}05$	,,	$-492{\cdot}5 = 0$	$x + 16{\cdot}25$	,,	$-417{\cdot}8 = 0$
$x + 17{\cdot}70$	,,	$-436{\cdot}7 = 0$	$x + 10{\cdot}27$	,,	$-310{\cdot}2 = 0$

Before the measurement—(Continued)

$x + 7{\cdot}22$	$(E_a - dE_a)$	$\overset{d}{-260{\cdot}9} = 0$	
$x + 4{\cdot}27$	„	$-219{\cdot}4 = 0$	
$x + 1{\cdot}80$	„	$-179{\cdot}6 = 0$	
$x - 0{\cdot}10$	„	$-146{\cdot}8 = 0$	
$x - 1{\cdot}50$	„	$-127{\cdot}0 = 0$	
$x + 23{\cdot}67$	„	$-549{\cdot}8 = 0$	
$x + 24{\cdot}30$	„	$-559{\cdot}6 = 0$	
$x + 24{\cdot}35$	„	$-560{\cdot}6 = 0$	
$x + 23{\cdot}77$	„	$-554{\cdot}1 = 0$	
$x + 22{\cdot}45$	„	$-532{\cdot}4 = 0$	
$x + 21{\cdot}02$	„	$-508{\cdot}3 = 0$	
$x + 19{\cdot}47$	„	$-484{\cdot}3 = 0$	
$x + 17{\cdot}72$	$(E_a - dE_a)$	$\overset{d}{-454{\cdot}3} = 0$	
$x + 15{\cdot}77$	„	$-426{\cdot}3 = 0$	
$x + 13{\cdot}75$	„	$-391{\cdot}8 = 0$	
$x + 9{\cdot}52$	„	$-312{\cdot}2 = 0$	
$x + 7{\cdot}40$	„	$-274{\cdot}6 = 0$	
$x + 5{\cdot}35$	„	$-240{\cdot}2 = 0$	
$x + 3{\cdot}22$	„	$-200{\cdot}8 = 0$	
$x + 0{\cdot}77$	„	$-158{\cdot}2 = 0$	
$x - 1{\cdot}30$	„	$-126{\cdot}1 = 0$	
$x - 2{\cdot}63$	„	$-105{\cdot}5 = 0$	
$x - 3{\cdot}75$	„	$-82{\cdot}6 = 0$	

And from the mean of these results,

$$x = \overset{d}{341{\cdot}22} - 11{\cdot}51\,(E_a - dE_a):$$

adopting the original value of the expansion of **A** given at page (9),

$$E_a = \overset{m.y}{22{\cdot}67} = \overset{d}{17{\cdot}615},$$

$$\text{and } x = \overset{d}{138{\cdot}47} + 11{\cdot}51\, dE_a = \overset{m.y}{178{\cdot}21} + 11{\cdot}51\, dE_a = \mathrm{L} - \mathbf{A};$$

where L denotes the mean length of the compensated bars obtained from *all* the comparisons, as represented by the mean micrometer reading $\overset{d}{1017{\cdot}09}$, page VI—5.

Comparing this reading with the mean reading of each compensated bar given on the same page we obtain the following:—

In terms of	A − L	B − L	C − L	D − L	E − L	H − L
Micrometer divisions.	−3·48	−29·95	+7·23	+32·33	−6·15	+0·04
Millionths of a yard.	−4·48	−38·55	+9·31	+41·61	−7·91	+0·05

Also combining the values in this table with the equivalent of L—**A** above determined, there result,

$$\mathrm{A} - \mathbf{A} = \overset{d}{134{\cdot}99} + 11{\cdot}51\, dE_a = \overset{m.y}{173{\cdot}73} + 11{\cdot}51\, dE_a$$
$$\mathrm{B} - \mathbf{A} = 108{\cdot}52 + \quad „ \quad = 139{\cdot}66 + \quad „$$
$$\mathrm{C} - \mathbf{A} = 145{\cdot}70 + \quad „ \quad = 187{\cdot}52 + \quad „$$
$$\mathrm{D} - \mathbf{A} = \overset{d}{170{\cdot}80} + 11{\cdot}51\, dE_a = \overset{m.y}{219{\cdot}82} + 11{\cdot}51\, dE_a$$
$$\mathrm{E} - \mathbf{A} = 132{\cdot}32 + \quad „ \quad = 170{\cdot}30 + \quad „$$
$$\mathrm{H} - \mathbf{A} = 138{\cdot}51 + \quad „ \quad = 178{\cdot}26 + \quad „$$

$$\text{and } 6\,x = \overset{m.y}{1069{\cdot}3} + 69{\cdot}1\, dE_a.$$

Comparisons between the Standard Bar **A** *and the Compensated Bars* A, B, C, D, E, H, *made on a site selected about the middle of the base-line, after set No.* 341.

1854 Jan.	Mean of the times of observing **A**	No. of comparison	Temperature of Air	Corrected mean temperature of **A**	MICROMETER READINGS IN DIVISIONS. 1 Division = $\frac{1}{21627 \cdot 47}$ Cary's Inch [7.8], = 1·2837 *m.y.* of **A** — Mean **A**	A	B	C	D	E	H	Mean of the compensated bars	REMARKS
	h. m.		°	°	+	+	+	+	+	+	+	+	
18th	1 10 P.M.	1	61·0	54·08	713·1	993·9	966·4	1013·9	1038·0	993·9	987·2	998·9	Capt. Strange at the micro: micros: Mr. Mulheran at the plain microscope.
	2 10	2	64·5	58·00	779·4	988·1	970·6	1016·0	1039·6	996·0	991·6	1000·3	
	3 7	3	66·1	61·05	828·1	992·1	970·5	1018·0	1038·7	993·0	989·7	1000·3	
19th	8 1 A.M.	4	42·8	41·30	478·5	968·0	945·4	979·0	1004·9	965·8	977·4	973·4	Very cloudy morning.
	8 46	5	46·5	42·20	497·7	974·5	950·3	979·7	1007·2	967·1	980·9	976·6	
	9 35	6	52·4	44·48	539·7	976·5	953·0	983·2	1009·8	970·9	984·8	979·7	
	10 41	7	56·5	48·65	609·2	981·1	954·0	987·1	1016·0	977·0	980·4	982·6	
	0 25 P.M.	8	55·0	53·05	678·7	980·9	952·0	995·5	1020·2	974·8	978·0	983·6	
	1 2	9	56·3	53·83	693·3	983·0	948·3	994·8	1020·9	978·6	980·2	984·3	
	1 39	10	57·5	54·75	711·1	985·8	958·8	999·6	1022·1	981·9	984·3	988·8	
	2 14	11	57·9	55·60	725·9	987·8	959·2	994·2	1022·0	981·4	983·7	988·1	
	2 56	12	58·5	56·48	739·1	988·0	960·9	993·6	1019·5	979·3	981·9	987·2	
	3 35	13	58·7	57·05	749·6	987·5	959·8	997·3	1022·0	982·0	984·8	988·9	
	4 13	14	58·2	57·40	753·5	987·9	962·0	993·1	1021·0	980·4	982·2	987·8	Very cloudy throughout the day.
20th	7 42 A.M.	15	47·8	46·85	567·8	972·2	943·3	970·3	1005·2	961·7	973·1	971·0	Cloudy morning. Lieut. Walker at the micrometer microscope; Mr. Keelan at the plain microscope.
	8 21	16	50·6	47·20	576·0	975·1	944·0	966·3	1001·8	962·5	970·3	970·0	
	8 59	17	53·5	48·28	593·4	973·3	942·6	976·5	1005·2	961·9	969·4	971·5	
	9 34	18	55·6	49·58	617·2	974·2	946·9	972·0	1004·3	965·1	973·5	972·7	
	10 10	19	57·6	51·18	644·3	973·1	947·2	976·9	1010·1	970·1	974·8	975·4	
	10 40	20	59·1	52·68	671·9	976·7	948·9	985·6	1013·2	973·8	977·3	979·3	
	0 10 P.M.	21	65·5	57·85	762·6	988·4	963·7	1000·0	1031·2	990·7	987·2	993·5	Sunshine.
	0 35	22	67·3	59·38	790·0	987·7	960·4	1004·7	1033·7	989·3	984·3	993·4	
	0 56	23	67·8	60·73	810·9	985·3	961·3	1004·1	1029·1	991·8	984·2	992·6	
	1 16	24	67·4	61·78	828·8	984·1	959·9	999·8	1029·7	989·3	982·9	991·0	
	1 35	25	67·3	62·63	842·6	985·2	960·7	1000·7	1027·8	987·8	983·9	991·0	
	1 53	26	67·9	63·30	853·6	985·1	958·8	1000·0	1025·3	988·3	983·9	990·2	
	2 14	27	68·0	63·95	866·7	987·2	961·7	1002·2	1024·9	989·9	986·7	992·1	
	2 31	28	67·6	64·43	875·5	991·9	965·2	1006·5	1028·7	988·6	981·8	993·8	
	2 51	29	67·4	64·88	882·3	991·5	960·8	1000·8	1031·9	993·6	987·8	994·4	
	3 8	30	67·5	65·15	885·6	988·4	965·0	1002·3	1029·0	989·3	989.3	993·9	
	3 25	31	67·2	65·38	888·9	991·5	963·8	999·2	1030·6	987·6	983·1	992·6	
	3 43	32	66·6	65·58	889·8	989·8	963·0	999·7	1027·2	988·3	980·2	991·4	
	4 3	33	65·5	65·60	887·2	986·1	962·9	1000·3	1028·0	978·8	976·9	988·8	Sunny afternoon.
21st	7 35 A.M.	34	36·0	36·98	397·1	964·7	941·5	959·0	993·0	951·0	972·6	963·6	Cloudy morning. Col. Waugh at the micrometer microscope; Lt. Walker at the plain microscope.
	8 17	35	39·1	37·13	400·4	965·1	946·1	961·8	995·0	958·2	974·7	966·8	
	9 1	36	43·9	38·28	424·4	967·7	943·1	964·5	995·9	957·5	970·2	966·5	
	9 36	37	48·2	40·10	458·6	971·6	944·2	968·9	998·6	959·3	972·2	969·1	
	10 8	38	52·7	42·48	501·4	970·0	946·2	970·0	999·1	969·1	972·5	971·2	
	10 40	39	56·7	45·05	547·9	972·0	945·0	970·9	1003·3	970·1	973·8	972·5	
	11 8	40	59·3	47·68	596·4	974·5	945·6	976·0	1009·9	969·0	974·0	974·8	

January 18th. (1) Very cloudy morning. (3) Sunny afternoon.

After set No. 341—(Continued.)

1854 Jany.	Mean of the times of observing A	No. of comparison	Temperature of Air	Corrected mean temperature of A	Micrometer Readings in Divisions — 1 Division = $\frac{1}{21627 \cdot 47}$ Cary's Inch [7.8], = 1·2837 m.y. of A — Mean A	A	B	C	D	E	H	Mean of the compensated bars	Remarks
	h. m.		°	°	+	+	+	+	+	+	+	+	
21st	0 30 P.M.	41	64·0	54·98	715·1	973·7	951·0	989·9	1022·0	978·3	976·6	981·9	
	1 0	42	65·3	57·20	752·4	980·9	954·9	988·2	1026·0	982·4	981·0	985·6	
	1 41	43	65·9	59·73	794·7	984·9	960·1	998·9	1029·8	986·0	982·8	990·4	
	2 7	44	66·5	61·03	814·5	986·1	957·0	996·1	1029·2	981·0	983·0	988·7	
	2 29	45	67·3	61·83	827·5	982·8	958·0	988·8	1024·0	984·0	981·1	986·5	
	2 51	46	67·4	62·53	837·0	985·0	956·3	989·0	1019·9	983·0	983·0	986·0	
	3 12	47	66·9	63·13	844·6	983·0	957·0	992·0	1025·8	980·0	978·0	986·0	
	3 34	48	66·5	63·55	851·6	983·1	954·0	987·3	1022·2	982·9	979·8	984·9	
	3 57	49	66·1	63·85	856·9	982·0	958·1	988·2	1021·9	980·1	980·1	985·1	
	4 20	50	65·6	64·03	860·4	982·9	956·1	986·1	1022·0	977·0	976·2	983·4	
22nd	7 39 A.M.	51	46·1	48·75	590·0	967·4	938·7	969·9	991·8	955·9	968·7	965·4	Cloudy morning. Lt. Walker at the micrometer microscope; Mr. Keelan at the plain micros:
	8 2	52	46·2	48·35	582·9	966·1	940·6	968·1	995·1	959·1	966·1	965·9	
	8 23	53	48·0	47·98	579·0	968·3	935·7	963·9	992·3	951·3	962·9	962·4	
	8 44	54	50·8	47·83	581·4	964·6	936·1	960·6	990·3	950·9	958·1	960·1	
	9 3	55	51·3	48·13	587·2	962·7	935·1	960·1	988·3	951·0	954·0	958·5	
	9 22	56	51·4	48·43	592·4	957·7	927·4	953·6	983·7	948·7	954·0	954·2	Cloudy.
	9 38	57	53·5	48·75	599·2	959·1	927·3	952·0	986·0	946·9	952·8	954·0	
	9 54	58	55·8	49·38	611·2	956·4	931·8	956·0	985·0	949·3	955·1	955·6	
	10 10	59	56·9	50·18	626·0	959·2	932·3	958·2	990·2	953·8	959·2	958·8	
	10 27	60	57·8	51·08	641·6	964·2	934·9	963·6	995·7	959·1	962·8	963·4	
	10 44	61	59·1	52·00	657·3	961·7	937·2	966·3	995·6	960·8	963·9	964·3	
23rd	7 30 A.M.	62	36·2	40·75	457·8	974·0	943·4	963·4	990·4	949·5	970·0	965·1	Capt. Strange at the micrometer microscope; Mr. Mulheran at the plain microscope.
	7 58	63	37·9	40·15	449·2	970·6	941·8	967·7	992·0	954·0	971·2	966·2	
	8 20	64	41·6	40·00	450·1	966·0	941·5	962·1	991·4	953·3	966·9	963·5	
	8 44	65	46·4	40·45	463·7	962·6	939·4	960·0	986·2	950·2	963·7	960·4	
	9 10	66	51·0	41·75	490·3	964·9	931·9	960·4	987·4	949·0	957·9	958·6	
	9 35	67	54·7	43·73	524·7	960·2	932·9	959·1	990·4	953·9	965·4	960·3	Cloudy.
	10 3	68	57·2	46·13	565·3	963·4	935·4	967·3	993·8	957·2	965·2	963·7	
	10 24	69	57·9	47·95	595·6	965·2	937·5	966·2	995·5	957·6	965·0	964·5	
	10 43	70	58·2	49·38	619·9	966·2	936·1	972·5	996·6	962·2	968·0	966·9	The morning promised a fine day but this expectation was not realized.
	11 1	71	59·0	50·68	642·5	970·0	941·0	975·5	999·1	964·8	968·9	969·9	
	0 25 P.M.	72	64·4	56·85	746·0	977·1	951·8	994·1	1028·5	979·1	975·2	984·3	
	0 43	73	64·7	58·10	766·5	978·9	955·6	1001·2	1025·4	979·0	977·9	986·3	
	1 0	74	64·5	59·13	781·8	976·8	954·4	1000·0	1027·0	978·6	974·1	985·2	
	1 18	75	64·1	59·93	795·2	980·2	957·0	998·9	1026·7	984·1	979·6	987·8	
	1 34	76	63·9	60·50	803·9	978·0	954·1	998·5	1021·7	983·5	975·8	985·3	
	1 55	77	63·7	61·03	812·0	981·3	952·0	995·9	1019·1	977·2	979·4	984·2	
	2 13	78	63·2	61·35	815·2	980·9	956·8	995·0	1018·9	977·5	977·3	984·4	
	2 31	79	63·1	61·58	818·8	980·4	948·2	991·1	1021·8	979·0	977·5	983·0	
	2 51	80	63·1	61·75	823·0	980·3	958·0	989·1	1020·4	981·1	978·2	984·5	
	3 10	81	62·8	61·95	824·6	984·0	959·4	988·0	1019·6	980·3	980·9	985·4	
	3 28	82	62·4	62·05	825·0	979·5	961·9	984·2	1017·9	981·4	977·7	983·8	
	3 46	83	62·1	62·05	825·5	977·2	960·1	990·4	1019·0	979·5	976·7	983·8	
		Means		53·76	689·85	976·83	950·52	983·63	1012·53	972·51	975·41	978·57	

After set No. 341—(Continued.)

As on page VI—5 we have

$$x - (t^\circ - 62^\circ)(E_a - dE_a) - \delta = 0$$

and from the preceding bar comparisons, we obtain the following series of results :—

$x + 7.92$	$(E_a - dE_a)$	$-285.8 = 0$	$x - 3.58$	$(E_a - dE_a)$	$-101.6 = 0$
$x + 4.00$	,,	$-220.9 = 0$	$x - 3.60$	,,	$-101.6 = 0$
$x + 0.95$	,,	$-172.2 = 0$	$x + 25.02$	,,	$-566.5 = 0$
$x + 20.70$	,,	$-494.9 = 0$	$x + 24.87$	,,	$-566.4 = 0$
$x + 19.80$	,,	$-478.9 = 0$	$x + 23.72$	,,	$-542.1 = 0$
$x + 17.52$	,,	$-440.0 = 0$	$x + 21.90$	,,	$-510.5 = 0$
$x + 13.35$	,,	$-373.4 = 0$	$x + 19.52$	,,	$-469.8 = 0$
$x + 8.95$	,,	$-304.9 = 0$	$x + 16.95$	,,	$-424.6 = 0$
$x + 8.17$	,,	$-291.0 = 0$	$x + 14.32$	,,	$-378.4 = 0$
$x + 7.25$	,,	$-277.7 = 0$	$x + 7.02$	,,	$-266.8 = 0$
$x + 6.40$	,,	$-262.2 = 0$	$x + 4.80$	,,	$-233.2 = 0$
$x + 5.52$	,,	$-248.1 = 0$	$x + 2.27$	,,	$-195.7 = 0$
$x + 4.95$	,,	$-239.3 = 0$	$x + 0.97$	,,	$-174.2 = 0$
$x + 4.60$	,,	$-234.3 = 0$	$x + 0.17$	,,	$-159.0 = 0$
$x + 15.15$	,,	$-403.2 = 0$	$x - 0.53$	,,	$-149.0 = 0$
$x + 14.80$	,,	$-394.0 = 0$	$x - 1.13$	,,	$-141.4 = 0$
$x + 13.72$	,,	$-378.1 = 0$	$x - 1.55$	,,	$-133.3 = 0$
$x + 12.42$	,,	$-355.5 = 0$	$x - 1.85$	,,	$-128.2 = 0$
$x + 10.82$	,,	$-331.1 = 0$	$x - 2.03$	,,	$-123.0 = 0$
$x + 9.32$	,,	$-307.4 = 0$	$x + 13.25$	,,	$-375.4 = 0$
$x + 4.15$	,,	$-230.9 = 0$	$x + 13.65$	,,	$-383.0 = 0$
$x + 2.62$	,,	$-203.4 = 0$	$x + 14.02$	,,	$-383.4 = 0$
$x + 1.27$	,,	$-181.7 = 0$	$x + 14.17$	,,	$-378.7 = 0$
$x + 0.22$	,,	$-162.2 = 0$	$x + 13.87$	,,	$-371.3 = 0$
$x - 0.63$	,,	$-148.4 = 0$	$x + 13.57$	,,	$-361.8 = 0$
$x - 1.30$	,,	$-136.6 = 0$	$x + 13.25$	,,	$-354.8 = 0$
$x - 1.95$	,,	$-125.4 = 0$	$x + 12.62$	,,	$-344.4 = 0$
$x - 2.43$	,,	$-118.3 = 0$	$x + 11.82$	,,	$-332.8 = 0$
$x - 2.88$	,,	$-112.1 = 0$	$x + 10.92$	,,	$-321.8 = 0$
$x - 3.15$	,,	$-108.3 = 0$	$x + 10.00$	,,	$-307.0 = 0$
$x - 3.38$	,,	$-103.7 = 0$	$x + 21.25$	,,	$-507.3 = 0$

After set No. 341—(Continued.)

$x+21{\cdot}85\ (E_a-dE_a)-517{\cdot}0=0$		$x+\ 2{\cdot}87\ (E_a-dE_a)-203{\cdot}4=0$	
$x+22{\cdot}00$,, $-513{\cdot}4=0$		$x+\ 2{\cdot}07$,, $-192{\cdot}6=0$	
$x+21{\cdot}55$,, $-496{\cdot}7=0$		$x+\ 1{\cdot}50$,, $-181{\cdot}4=0$	
$x+20{\cdot}25$,, $-468{\cdot}3=0$		$x+\ 0{\cdot}97$,, $-172{\cdot}2=0$	
$x+18{\cdot}27$,, $-435{\cdot}6=0$		$x+\ 0{\cdot}65$,, $-169{\cdot}2=0$	
$x+15{\cdot}87$,, $-398{\cdot}4=0$		$x+\ 0{\cdot}42$,, $-164{\cdot}2=0$	
$x+14{\cdot}05$,, $-368{\cdot}9=0$		$x+\ 0{\cdot}25$,, $-161{\cdot}5=0$	
$x+12{\cdot}62$,, $-347{\cdot}0=0$		$x+\ 0{\cdot}05$,, $-160{\cdot}8=0$	
$x+11{\cdot}32$,, $-327{\cdot}4=0$		$x-\ 0{\cdot}05$,, $-158{\cdot}8=0$	
$x+\ 5{\cdot}15$,, $-238{\cdot}3=0$		$x-\ 0{\cdot}05$,, $-158{\cdot}3=0$	
$x+\ 3{\cdot}90$,, $-219{\cdot}8=0$			

And from the mean of these results,

$$x \overset{d}{=} 288{\cdot}72 - 8{\cdot}24\,(E_a - dE_a):$$

adopting the original value of the expansion of **A** given at page (9),

$$E_a = \overset{m.y}{22{\cdot}67} = \overset{d}{17{\cdot}660},$$

$$\text{and } x = \overset{d}{143{\cdot}20} + 8{\cdot}24\,dE_a = \overset{m.y}{183{\cdot}83} + 8{\cdot}24\,dE_a = \text{L} - \mathbf{A}.$$

Proceeding as on page VI—6 we obtain;

In terms of	A – L	B – L	C – L	D – L	E – L	H – L
Micrometer divisions.	−1·74	−28·05	+5·06	+33·96	−6·06	−3·16
Millionths of a yard.	−2·23	−36·01	+6·50	+43·59	−7·78	−4·06

Also the following;

$$\begin{aligned}
\text{A} - \mathbf{A} &= \overset{d}{141{\cdot}46} + 8{\cdot}24\,dE_a = \overset{m.y}{181{\cdot}60} + 8{\cdot}24\,dE_a\\
\text{B} - \mathbf{A} &= 115{\cdot}15 + \quad ,, \quad = 147{\cdot}82 + \quad ,,\\
\text{C} - \mathbf{A} &= 148{\cdot}26 + \quad ,, \quad = 190{\cdot}33 + \quad ,,\\
\text{D} - \mathbf{A} &= 177{\cdot}16 + \quad ,, \quad = 227{\cdot}42 + \quad ,,\\
\text{E} - \mathbf{A} &= 137{\cdot}14 + \quad ,, \quad = 176{\cdot}05 + \quad ,,\\
\text{H} - \mathbf{A} &= 140{\cdot}04 + \quad ,, \quad = 179{\cdot}77 + \quad ,,
\end{aligned}$$

$$\text{and } 6\,x = \overset{m.y}{1103{\cdot}0} + 49{\cdot}4\,dE_a.$$

Comparisons between the Standard Bar **A** *and the Compensated Bars* A, B, C, D, E, H, *made at Agzar, or North-East-End of the base-line, after the measurement.*

1854 Feb.	Mean of the times of observing **A**	No. of comparison	Temperature of Air	Corrected mean temperature of **A**	MICROMETER READINGS IN DIVISIONS (1 Division = $\frac{1}{21617 \cdot 74}$ Cary's Inch [7.8], = 1·2843 *m.y.* of **A**) Mean **A**	A	B	C	D	E	H	Mean of the compensated bars	REMARKS
	h. m.		°	°	+	+	+	+	+	+	+	+	
16th	0 0 P.M.	1	61·0	57·58	829·1	1062·1	1041·1	1083·0	1104·3	1062·2	1063·2	1069·3	Cloudy. Col. Waugh at the micrometer microscope; Lieut. Walker at the plain microscope.
	0 40	2	60·8	58·63	852·2	1069·1	1049·1	1089·4	1113·2	1075·0	1072·9	1078·1	
	1 15	3	62·1	59·38	867·5	1079·9	1057·8	1094·0	1111·0	1078·1	1077·7	1083·1	
	1 45	4	63·6	59·98	881·0	1081·0	1058·0	1097·6	1120·9	1078·1	1082·0	1086·3	
	2 17	5	63·7	60·70	893·1	1085·4	1062·0	1093·9	1121·3	1084·8	1081·2	1088·1	
	2 47	6	61·9	60·98	897·0	1087·3	1059·9	1094·0	1122·1	1083·0	1080·1	1087·7	
	4 7	7	56·9	59·40	861·5	1071·2	1047·3	1080·1	1108·9	1074·1	1073·8	1075·9	
17th	9 28 A.M.	8	49·2	48·33	697·0	1074·4	1054·9	1079·0	1109·0	1071·0	1079·0	1077·9	Commenced comparisons after a rainy and stormy night, the weather continuing cloudy.
	10 14	9	50·7	48·88	710·0	1083·5	1059·2	1087·0	1115·2	1074·0	1080·1	1083·2	
	10 41	10	52·1	49·48	721·5	1086·0	1061·9	1083·0	1117·2	1079·1	1084·0	1085·2	
	11 8	11	53·6	50·23	735·1	1091·9	1058·2	1089·0	1118·9	1084·3	1088·1	1088·4	
18th	7 8 A.M.	12	38·1	39·33	290·1	824·3	798·3	817·9	844·0	809·8	825·7	820·0	Captain Strange at the micrometer microscope; Mr. Mulheran at the plain microscope.
	7 32	13	39·7	39·18	289·7	825·1	797·2	821·2	846·1	809·5	829·1	821·4	
	7 49	14	40·8	39·28	295·1	825·3	796·1	820·1	846·2	810·1	827·0	820·8	
	8 9	15	41·4	39·58	302·5	826·9	799·0	821·8	848·8	813·8	830·1	823·4	
	8 31	16	42·3	40·00	313·2	826·8	803·0	826·0	854·2	819·4	833·8	827·2	
	9 4	17	43·9	40·90	339·7	834·2	807·7	833·1	860·2	821·7	838·3	832·5	
	9 22	18	45·0	41·43	344·8	834·5	808·9	836·6	866·1	827·1	841·1	835·7	
	9 41	19	46·0	42·05	355·6	839·7	813·9	839·9	869·5	831·8	846·7	840·3	
	9 59	20	46·8	42·75	370·0	840·8	812·5	843·0	872·9	835·6	844·6	841·6	
	10 18	21	47·8	43·50	383·9	847·0	820·0	845·5	874·6	837·4	847·0	845·3	
	11 51	22	50·7	47·28	445·1	855·8	823·1	857·9	894·3	854·3	853·0	856·4	
	0 11 P.M.	23	51·5	47·98	459·5	850·3	825·8	859·2	893·5	856·1	854·0	856·5	
	0 33	24	52·2	48·73	471·1	855·8	827·5	862·0	892·4	852·2	856·6	857·8	
	0 52	25	52·6	49·38	482·4	855·0	828·4	857·8	894·9	853·4	859·2	858·1	
	1 9	26	53·1	49·93	493·4	858·4	830·0	862·0	892·1	857·1	861·3	860·2	
	1 34	27	53·6	50·75	507·4	860·9	833·0	864·8	893·1	856·6	860·2	861·4	
	1 51	28	54·1	51·25	515·9	856·2	830·4	866·2	894·6	855·9	859·8	860·5	
	2 9	29	54·2	51·75	524·9	859·4	833·9	865·5	892·8	854·3	860·2	861·0	
	2 25	30	54·0	52·20	531·5	857·4	833·9	866·5	890·9	855·4	860·4	860·8	
	2 42	31	53·9	52·55	536·9	859·5	835·0	864·1	890·7	854·4	860·2	860·7	
	3 6	32	53·7	52·93	541·7	857·3	832·3	864·4	893·2	851·1	857·4	859·3	
	3 24	33	53·8	53·13	544·6	858·8	831·8	863·7	891·0	852·3	858·4	859·3	
	3 43	34	53·9	53·30	547·0	858·8	832·0	863·2	888·0	851·0	855·9	858·2	
	4 0	35	54·2	53·35	549·7	854·9	829·8	860·0	887·8	846·8	854·9	855·7	
	4 17	36	54·6	53·43	553·3	857·3	830·4	861·6	889·3	849·2	852·0	856·6	
	4 35	37	54·6	53·60	552·9	855·7	827·0	858·6	884·3	843·8	848·3	853·0	

February 16th. After No. 5, the comparisons were stopped by rain and darkness for about ¾ of an hour.
„ 17th. (8) Raining heavy.
„ 18th. (12) Foggy. (13) to (36) Cloudy.

After the measurement—(Continued.)

1854 Feb.	Mean of the times of observing A	No. of comparison	Temperature of Air	Corrected mean temperature of A	Micrometer Readings in Divisions: 1 Division = $\frac{1}{21617\cdot74}$ Cary's Inch [7.8], = 1·2843 m.y. of A — Mean A	A	B	C	D	E	H	Mean of the compensated bars	Remarks
	h. m.		°	°	+	+	+	+	+	+	+	+	
19th	7 18 A.M.	38	40·0	41·95	355·9	846·1	822·6	844·9	873·6	836·7	848·4	845·4	Clear morning. Lt. Walker at the micrometer microscope; Mr. Keelan at the plain microscope.
	7 40	39	41·7	41·68	356·0	848·3	821·2	843·1	874·2	835·9	851·8	845·8	
	7 58	40	43·3	41·68	357·1	850·5	821·2	844·3	875·1	833·2	848·0	845·4	
	8 13	41	44·3	41·83	364·7	855·1	818·3	845·3	874·2	830·6	845·9	844·6	
	8 30	42	45·5	42·13	373·7	852·1	816·3	843·1	874·1	833·2	844·6	843·9	Cloudy.
	8 51	43	47·5	42·73	383·5	849·1	816·6	842·0	873·8	833·9	845·3	843·5	
	9 9	44	49·0	43·43	394·2	850·3	817·0	848·9	875·9	836·4	846·8	845·9	
	9 26	45	50·3	44·18	407·3	852·2	822·8	850·9	877·1	838·8	849·9	848·6	
	9 42	46	51·3	45·00	425·3	849·7	822·1	851·2	879·8	841·1	853·7	849·6	
	9 58	47	52·4	45·93	441·9	857·3	824·8	856·4	888·5	845·7	854·0	854·5	
	10 22	48	54·1	47·25	463·2	862·1	830·8	861·9	891·2	851·8	858·1	859·3	Cloudy.
	10 41	49	54·5	48·30	484·1	867·3	833·0	866·2	895·7	853·1	860·1	862·6	
	11 46	50	55·8	51·40	531·5	873·2	836·9	876·2	908·0	863·3	869·3	871·2	
	0 2 P.M.	51	56·5	52·08	543·1	873·2	839·7	880·9	910·4	864·7	869·1	873·0	
	0 18	52	56·9	52·80	554·8	875·2	839·8	880·8	909·7	864·8	872·4	873·8	
	0 37	53	57·4	53·50	567·7	876·3	845·5	881·8	914·9	869·2	871·1	876·5	
	0 50	54	57·6	53·98	575·6	879·4	846·8	881·7	914·3	866·6	875·2	877·3	Cloudy.
	1 2	55	57·6	54·35	584·2	875·8	843·3	881·6	911·9	868·2	873·2	875·7	
	1 15	56	57·7	54·75	591·4	879·4	848·7	885·0	910·5	871·4	877·2	878·7	
	1 29	57	57·9	55·15	596·0	876·9	848·6	879·1	910·7	870·3	872·8	876·4	
	1 46	58	58·2	55·68	604·2	877·3	846·6	884·9	908·6	868·6	873·4	876·6	
	1 59	59	58·1	56·08	609·2	877·8	847·8	885·0	909·8	872·7	875·8	878·2	
	2 12	60	58·2	56·35	612·4	879·0	846·2	883·2	910·4	870·3	873·8	877·2	Cloudy.
	2 26	61	57·9	56·58	615·7	877·8	848·7	882·0	911·1	871·2	871·2	877·0	
	2 39	62	57·5	56·75	618·0	873·2	846·7	878·1	907·0	865·7	866·8	872·9	
	2 55	63	57·1	56·88	620·1	871·7	844·2	878·7	904·9	868·1	870·0	872·9	
	3 8	64	56·9	56·95	621·4	874·9	845·4	878·8	904·3	866·7	870·0	873·4	
	3 20	65	56·8	57·00	622·4	873·3	844·6	878·1	903·3	863·1	867·0	871·6	
	3 33	66	56·6	56·98	621·9	872·0	842·2	877·0	901·6	862·6	864·4	870·0	Cloudy.
	3 44	67	56·4	56·98	621·1	872·3	843·6	878·0	898·9	862·8	865·7	870·2	
	3 59	68	56·2	57·00	620·6	869·8	841·6	874·1	900·2	862·1	864·0	868·6	
	4 11	69	56·0	56·90	619·5	870·8	841·1	872·9	900·7	862·3	864·2	868·7	
	4 24	70	55·6	56·78	617·9	872·9	844·2	874·7	899·5	861·6	866·4	869·9	
	4 38	71	55·2	56·63	615·3	869·8	841·6	872·3	898·8	858·8	860·1	866·9	
22nd	7 12 A.M.	72	46·9	46·48	466·2	885·6	855·6	879·8	908·6	872·2	881·2	880·5	Lt. Walker at the micrometer microscope; Mr. Keelan at the plain microscope.
	7 45	73	48·6	46·48	469·5	883·4	854·3	879·8	905·6	870·6	879·5	878·9	
	8 16	74	50·5	46·85	478·7	877·8	850·9	876·9	905·7	867·3	877·7	876·1	
	8 49	75	52·4	47·63	493·2	877·0	849·1	874·3	901·9	865·9	873·3	873·6	
	9 22	76	54·2	48·65	512·6	878·3	847·3	881·1	906·3	867·3	876·8	876·2	
	9 47	77	55·4	49·63	529·8	881·2	851·6	881·9	907·9	871·7	878·9	878·9	

After the measurement—(Continued.)

1854 Feb.	Mean of the times of observing A	No. of comparison	Temperature of Air	Corrected mean temperature of A	Micrometer Readings in Divisions: 1 Division = $\frac{1}{21617 \cdot 74}$ Cary's Inch [7.8], = 1·2843 m.y. of A — Mean A	A	B	C	D	E	H	Mean of the compensated bars	Remarks
	h. m.		°	°	+	+	+	+	+	+	+	+	
22nd	10 16 A.M.	78	56·6	50·83	550·3	883·3	855·0	889·2	914·1	874·7	881·2	882·9	
	10 46	79	58·3	51·98	571·8	885·1	850·9	887·8	915·2	874·3	879·0	882·1	
	0 6 P.M.	80	60·7	55·53	617·1	867·3	839·0	874·0	906·5	866·9	863·7	869·6	Colonel Waugh at the micrometer microscope; Lt. Walker at the plain microscope.
	0 34	81	61·0	56·65	637·7	864·0	834·9	871·2	904·0	865·9	864·1	867·4	
	1 0	82	63·1	57·65	655·5	862·9	835·1	871·3	903·9	866·2	859·2	866·4	
	1 32	83	64·8	58·88	663·1	850·1	822·1	859·9	889·9	850·3	848·5	853·5	
	1 56	84	64·8	59·75	677·7	853·1	823·7	863·3	888·9	849·0	845·9	854·0	
	2 19	85	65·5	60·55	689·7	851·0	826·9	863·8	889·0	850·9	854·0	855·9	
	2 40	86	66·2	61·30	703·6	854·1	827·0	868·8	895·2	851·1	850·8	857·8	
	3 4	87	66·0	61·95	716·4	855·4	827·2	865·6	893·8	852·7	849·0	857·3	
	3 23	88	65·6	62·45	725·3	857·1	830·1	869·9	895·9	854·0	853·0	860·0	
	3 41	89	64·4	62·80	731·6	858·0	832·2	869·2	897·4	857·1	855·0	861·5	
	3 57	90	62·8	63·00	734·2	861·2	836·2	869·0	901·0	858·2	859·3	864·2	Cloudy with a cold wind from North.
	4 15	91	61·9	63·00	732·0	863·0	837·2	872·2	904·0	861·0	860·9	866·4	
	4 34	92	61·3	62·83	725·1	864·2	837·9	872·0	899·3	865·9	860·1	866·6	
	4 53	93	60·9	62·53	721·1	869·0	842·5	877·0	905·0	865·9	865·9	870·9	
			Means	51·92	562·15	886·80	858·68	890·66	918·81	879·66	884·88	886·58	

After the measurement—(Continued.)

As on page VI—5 we have

$$x - (t^\circ - 62^\circ)(E_a - dE_a) - \delta = 0$$

and from the preceding bar comparisons we obtain the following series of results:—

$x + 4.42$	$(E_a - dE_a)$	$- 240.2 = 0$	$x + 8.70$	$(E_a - dE_a)$	$- 311.2 = 0$
$x + 3.37$	”	$- 225.9 = 0$	$x + 8.65$	”	$- 306.0 = 0$
$x + 2.62$	”	$- 215.6 = 0$	$x + 8.57$	”	$- 303.3 = 0$
$x + 2.02$	”	$- 205.3 = 0$	$x + 8.40$	”	$- 300.1 = 0$
$x + 1.30$	”	$- 195.0 = 0$	$x + 20.05$	”	$- 489.5 = 0$
$x + 1.02$	”	$- 190.7 = 0$	$x + 20.32$	”	$- 489.8 = 0$
$x + 2.60$	”	$- 214.4 = 0$	$x + 20.32$	”	$- 488.3 = 0$
$x + 13.67$	”	$- 380.9 = 0$	$x + 20.17$	”	$- 479.9 = 0$
$x + 13.12$	”	$- 373.2 = 0$	$x + 19.87$	”	$- 470.2 = 0$
$x + 12.52$	”	$- 363.7 = 0$	$x + 19.27$	”	$- 460.0 = 0$
$x + 11.77$	”	$- 353.3 = 0$	$x + 18.57$	”	$- 451.7 = 0$
$x + 22.67$	”	$- 529.9 = 0$	$x + 17.82$	”	$- 441.3 = 0$
$x + 22.82$	”	$- 531.7 = 0$	$x + 17.00$	”	$- 424.3 = 0$
$x + 22.72$	”	$- 525.7 = 0$	$x + 16.07$	”	$- 412.6 = 0$
$x + 22.42$	”	$- 520.9 = 0$	$x + 14.75$	”	$- 396.1 = 0$
$x + 22.00$	”	$- 514.0 = 0$	$x + 13.70$	”	$- 378.5 = 0$
$x + 21.10$	”	$- 492.8 = 0$	$x + 10.60$	”	$- 339.7 = 0$
$x + 20.57$	”	$- 490.9 = 0$	$x + 9.92$	”	$- 329.9 = 0$
$x + 19.95$	”	$- 484.7 = 0$	$x + 9.20$	”	$- 319.0 = 0$
$x + 19.25$	”	$- 471.6 = 0$	$x + 8.50$	”	$- 308.8 = 0$
$x + 18.50$	”	$- 461.4 = 0$	$x + 8.02$	”	$- 301.7 = 0$
$x + 14.72$	”	$- 411.3 = 0$	$x + 7.65$	”	$- 291.5 = 0$
$x + 14.02$	”	$- 397.0 = 0$	$x + 7.25$	”	$- 287.3 = 0$
$x + 13.27$	”	$- 386.7 = 0$	$x + 6.85$	”	$- 280.4 = 0$
$x + 12.62$	”	$- 375.7 = 0$	$x + 6.32$	”	$- 272.4 = 0$
$x + 12.07$	”	$- 366.8 = 0$	$x + 5.92$	”	$- 269.0 = 0$
$x + 11.25$	”	$- 354.0 = 0$	$x + 5.65$	”	$- 264.8 = 0$
$x + 10.75$	”	$- 344.6 = 0$	$x + 5.42$	”	$- 261.3 = 0$
$x + 10.25$	”	$- 336.1 = 0$	$x + 5.25$	”	$- 254.9 = 0$
$x + 9.80$	”	$- 329.3 = 0$	$x + 5.12$	”	$- 252.8 = 0$
$x + 9.45$	”	$- 323.8 = 0$	$x + 5.05$	”	$- 252.0 = 0$
$x + 9.07$	”	$- 317.6 = 0$	$x + 5.00$	”	$- 249.2 = 0$
$x + 8.87$	”	$- 314.7 = 0$	$x + 5.02$	”	$- 248.1 = 0$

After the measurement—(Continued.)

$$x + 5{\cdot}02\,(E_a - dE_a) - \overset{d}{249{\cdot}1} = 0$$
$$x + 5{\cdot}00 \quad ,, \quad - 248{\cdot}0 = 0$$
$$x + 5{\cdot}10 \quad ,, \quad - 249{\cdot}2 = 0$$
$$x + 5{\cdot}22 \quad ,, \quad - 252{\cdot}0 = 0$$
$$x + 5{\cdot}37 \quad ,, \quad - 251{\cdot}6 = 0$$
$$x + 15{\cdot}52 \quad ,, \quad - 414{\cdot}3 = 0$$
$$x + 15{\cdot}52 \quad ,, \quad - 409{\cdot}4 = 0$$
$$x + 15{\cdot}15 \quad ,, \quad - 397{\cdot}4 = 0$$
$$x + 14{\cdot}37 \quad ,, \quad - 380{\cdot}4 = 0$$
$$x + 13{\cdot}35 \quad ,, \quad - 363{\cdot}6 = 0$$
$$x + 12{\cdot}37 \quad ,, \quad - 349{\cdot}1 = 0$$
$$x + 11{\cdot}17 \quad ,, \quad - 332{\cdot}6 = 0$$
$$x + 10{\cdot}02 \quad ,, \quad - 310{\cdot}3 = 0$$
$$x + 6{\cdot}47 \quad ,, \quad - 252{\cdot}5 = 0$$

$$x + 5{\cdot}35\,(E_a - dE_a) - \overset{d}{229{\cdot}7} = 0$$
$$x + 4{\cdot}35 \quad ,, \quad - 210{\cdot}9 = 0$$
$$x + 3{\cdot}12 \quad ,, \quad - 190{\cdot}4 = 0$$
$$x + 2{\cdot}25 \quad ,, \quad - 176{\cdot}3 = 0$$
$$x + 1{\cdot}45 \quad ,, \quad - 166{\cdot}2 = 0$$
$$x + 0{\cdot}70 \quad ,, \quad - 154{\cdot}2 = 0$$
$$x + 0{\cdot}05 \quad ,, \quad - 140{\cdot}9 = 0$$
$$x - 0{\cdot}45 \quad ,, \quad - 134{\cdot}7 = 0$$
$$x - 0{\cdot}80 \quad ,, \quad - 129{\cdot}9 = 0$$
$$x - 1{\cdot}00 \quad ,, \quad - 130{\cdot}0 = 0$$
$$x - 1{\cdot}00 \quad ,, \quad - 134{\cdot}4 = 0$$
$$x - 0{\cdot}83 \quad ,, \quad - 141{\cdot}5 = 0$$
$$x - 0{\cdot}53 \quad ,, \quad - 149{\cdot}8 = 0$$

And from the mean of these results,

$$x = \overset{d}{324{\cdot}43} - 10{\cdot}08\,(E_a - dE_a):$$

adopting the original value of the expansion of **A** given at page (9),

$$E_a = \overset{m.y}{22{\cdot}67} = \overset{d}{17{\cdot}652},$$

$$\text{and } x = \overset{d}{146{\cdot}50} + 10{\cdot}08\,dE_a = \overset{m.y}{188{\cdot}15} + 10{\cdot}08\,dE_a = \text{L} - \textbf{A}.$$

Proceeding as on page VI—6 we obtain :—

In terms of	A − L	B − L	C − L	D − L	E − L	H − L
Micrometer divisions.	+0·22	−27·90	+4·08	+32·23	−6·92	−1·70
Millionths of a yard.	+0·28	−35·83	+5·24	+41·39	−8·89	−2·18

Also the following,

$$\text{A} - \textbf{A} = \overset{d}{146{\cdot}72} + 10{\cdot}08\,dE_a = \overset{m.y}{188{\cdot}43} + 10{\cdot}08\,dE_a$$
$$\text{B} - \textbf{A} = 118{\cdot}60 + \quad ,, \quad = 152{\cdot}32 + \quad ,,$$
$$\text{C} - \textbf{A} = 150{\cdot}58 + \quad ,, \quad = 193{\cdot}39 + \quad ,,$$
$$\text{D} - \textbf{A} = \overset{d}{178{\cdot}73} + 10{\cdot}08\,dE_a = \overset{m.y}{229{\cdot}54} + 10{\cdot}08\,dE_a$$
$$\text{E} - \textbf{A} = 139{\cdot}58 + \quad ,, \quad = 179{\cdot}26 + \quad ,,$$
$$\text{H} - \textbf{A} = 144{\cdot}80 + \quad ,, \quad = 185{\cdot}97 + \quad ,,$$

$$\text{and } 6\,x = \overset{m.y}{1128{\cdot}9} + 60{\cdot}5\,dE_a.$$

Final deduction of the total length measured with the compensated bars.

		m.y
From page VI—6 the excess of the 6 compensated bars above 6 times **A** *before* the measurement	=	$1069{\cdot}3 + 69{\cdot}1\ dE_a$
„ VI—10 „ „ „ *after* set No. 341	=	$1103{\cdot}0 + 49{\cdot}4\ dE_a$
„ VI—15 „ „ „ *after* the measurement	=	$1128{\cdot}9 + 60{\cdot}5\ dE_a$
Therefore the mean excess of „ applicable to sets Nos. 1 to 341	=	$1086{\cdot}2 + 59{\cdot}3\ dE_a$
and „ „ „ Nos. 342 to 656	=	$1116{\cdot}0 + 55{\cdot}0\ dE_a$
Also the mean length of a set of 6 compensated bars in feet of the standard, applicable to sets Nos. 1 to 341	=	$60{\cdot}0032586\ \frac{\mathbf{A}}{10} + 59{\cdot}3\ dE_a$
and „ applicable to sets Nos. 342 to 656	=	$60{\cdot}0033480\ \frac{\mathbf{A}}{10} + 55{\cdot}0\ dE_a$

		m.y
Similarly from pages VI—10 and VI—15 the mean excess of the two compensated bars A and H above twice **A**	=	$367{\cdot}9 + 18{\cdot}4\ dE_a$
and the mean length of the set of compensated bars A and H in feet of the standard	=	$20{\cdot}0011037\ \frac{\mathbf{A}}{10} + 18{\cdot}4\ dE_a$

Hence the total lengths measured with the compensated bars

			feet of **A**
in sets Nos.	1 to 167	=	$10020{\cdot}5442 + 9903\ dE_a$
„	168 to 341	=	$10440{\cdot}5670 + 10318\ dE_a$
„	342 to 494	=	$9180{\cdot}5122 + 8415\ dE_a$
„	495 to 656	=	$9720{\cdot}5424 + 8910\ dE_a$
in set No.	657_1	=	$20{\cdot}0011 + 18\ dE_a$
in sets Nos.	1 to 657_1....................	=	$39382{\cdot}1669 + 37564\ dE_a$

Now the mean temperature of **A** during the bar comparisons *before* the measurement and *after* set No. 341 was $62° - \frac{59°{\cdot}3}{6} = 52°{\cdot}1$, for which temperature the corresponding expansion of **A** from page (19) $= 21{\cdot}586$ *m.y.* Also the mean temperature of **A** during the bar comparisons *after* set No. 341 and *after* the measurement was $62° - \frac{55°{\cdot}0}{6} = 52°{\cdot}8$, for which temperature the corresponding expansion of **A** from page (19) $= 21{\cdot}590$ *m.y.* Comparing these values of expansion respectively with the original value $= 22{\cdot}67$ *m.y*, used in the foregoing, it is found that $dE_a = +1{\cdot}084$ *m.y.* for sets Nos. 1 to 341, and $= +1{\cdot}080$ *m.y*, for sets Nos. 342 to 657_1. Substituting for dE_a respectively these numerical values, there result,

Total lengths measured with the compensated bars

			feet of **A**
in sets Nos.	1 to 167 or S.W. End, to Station A	=	(10020·5442 + ·0322) = 10020·5764
„	168 to 341 or Station A, to Station B	=	(10440·5670 + ·0336) = 10440·6006
„	342 to 494 or Station B, to Station C	=	(9180·5122 + ·0273) = 9180·5395
„	495 to 657_1 or Station C, to N.E. End	=	(9740·5435 + ·0289) = 9740·5724
„	1 to 657_1 or S.W. End, to N.E. End	=	(39382·1669 + ·1220) = 39382·2889

Comparisons between the Compensated Microscopes and the 6-inch brass scales during the measurement, and provisional determination of Microscope errors with respect to the 6-inch brass scale A, expressed in millionths of an inch (m.i.)

When compared — 1853-54		Microscope.	Scale compared with.	Corrected temperature.	Reduction to 62° Fah. Expansion of 6″ scale for 1° = *E* = 62·5 *m.i.*	Microscope — Microscope Scale. Observed value in terms of Divisions 10000 = 1″.	*m.i.*	Micros : Scale − *A*, at 62° Fah.	Micros : − Scale *A*, at 62° Fah. *m.i.*	Reference number.
December 15th	Before the measurement.	*T*	*T*	66°·25	+ 266	0·00	0	− 97	+ 169	1
		M	*M*	66·76	+ 298	0·00	0	− 21	+ 277	2
		O	*U*	68·15	+ 384	0·00	0	+ 283	+ 667	3
		R	*R*	69·21	+ 451	0·00	0	+ 93	+ 544	4
		N	*N*	64·35	+ 147	+ 4·86	+ 486	+ 363	+ 996	5
		P	*P*	69·95	+ 497	+ 1·37	+ 137	+ 350	+ 984	6
" 12th	"	*S*	*S*	60·67	− 83	0·00	0	− 75	− 158	7
" 26th	Between sets No. 55 and 56.	*T*	*T*	30·58	−1964	+16·37	+1637	− 97	− 424	8
		M	*M*	31·69	−1894	+17·37	+1737	− 21	− 178	9
		*M**	*M*	35·43	−1661	+16·30	+1630	− 21	− 52	10
		O	*U*	34·70	−1706	+16·37	+1637	+ 283	+ 214	11
		R	*R*	44·03	−1123	+11·25	+1125	+ 93	+ 95	12
		N	*N*	31·65	−1897	+18·60	+1860	+ 363	+ 326	13
		P	*P*	33·69	−1769	+15·47	+1547	+ 350	+ 128	14
		S	*S*	32·80	−1825	+12·27	+1227	− 75	− 673	15
January 4th	Between sets No. 167 and 168.	*T*	*T*	60·15	− 116	+ 9·10	+ 910	− 97	+ 697	16
		M	*M*	60·29	− 107	+ 4·93	+ 493	− 21	+ 365	17
		O	*U*	57·88	− 258	+ 4·20	+ 420	+ 283	+ 445	18
		R	*R*	59·99	− 126	+ 3·90	+ 390	+ 93	+ 357	19
		N	*N*	60·32	− 105	+ 5·50	+ 550	+ 363	+ 808	20
		*N**	*N*	32·09	−1869	+18·13	+1813	+ 363	+ 307	21
		P	*P*	62·00	0	+ 4·45	+ 445	+ 350	+ 795	22
		*P**	*P*	33·59	−1776	+11·10	+1110	+ 350	− 316	23
		S	*S*	60·70	− 81	− 3·43	− 343	− 75	− 499	24
" 15th	Between sets No. 318 & 319.	*S*	*S*	64·27	+ 142	− 303	− 303	− 75	− 236	25
" 17th	Between sets No. 341 and 342.	*T*	*T*	64·05	+ 128	+ 8·03	+ 803	− 97	+ 834	26
		*T**	*T*	57·62	− 274	+14·77	+1477	− 97	+1106	27
		M	*M*	65·14	+ 196	+ 1·08	+ 108	− 21	+ 283	28
		*M**	*M*	65·56	+ 223	0·00	0	− 21	+ 202	29
		P	*P*	66·45	+ 278	− 3·18	− 318	+ 350	+ 310	30
		R	*R*	64·99	+ 187	− 1·23	− 123	+ 93	+ 157	31
		N	*N*	65·29	+ 206	+ 2·80	+ 280	+ 363	+ 849	32
		O	*U*	63·05	+ 66	+ 3·00	+ 300	+ 283	+ 649	33
		S	*S*	63·80	+ 113	− 2·60	− 260	− 75	− 222	34
February 2nd	Between sets No. 416 and 417	*N*	*N*	54·82	− 449	+ 8·47	+ 847	+ 363	+ 761	35
		*N**	*N*	53·29	− 544	+ 4·77	+ 477	+ 363	+ 296	36

* These microscopes were compared a second time, because they were adjusted after the first comparison.

Microscope Comparisons—(Continued.)

When compared — 1854		Microscope.	Scale compared with.	Corrected temperature.	Reduction to 62° Fah. Expansion of 6″ scale for 1° = E = 62·5 m.i.	Microscope — Microscope Scale. Observed value in terms of Divisions 10000 = 1″	m.i.	Micros: Scale — A, at 62° Fah.	Micros: — Scale A, at 62° Fah. m.i.	Reference number.
February 6th	Between sets No. 494 and 495.	T	T	55°·52	− 405	+ 17·50	+ 1750	− 97	+ 1248	37
		T*	T	56·15	− 366	+ 17·33	+ 1733	− 97	+ 1270	38
		M	M	55·59	− 401	+ 6·00	+ 600	− 21	+ 178	39
		P	P	59·92	− 130	+ 2·65	+ 265	+ 350	+ 485	40
		R	R	57·09	− 307	+ 2·80	+ 280	+ 93	+ 66	41
		N	N	54·82	− 449	+ 5·03	+ 503	+ 363	+ 417	42
		O	U	56·65	− 334	+ 5·17	+ 517	+ 283	+ 466	43
		S	S	56·57	− 339	+ 2·23	+ 223	− 75	− 191	44
„ 16th	After the measurement.	T	T	49·78	− 764	+ 18·38	+ 1838	− 97	+ 977	45
		M	M	49·96	− 753	+ 8·33	+ 833	− 21	+ 59	46
		P	P	55·22	− 424	+ 2·90	+ 290	+ 350	+ 216	47
		R	R	51·87	− 633	+ 4·92	+ 492	+ 93	− 48	48
		N	N	49·82	− 761	+ 8·37	+ 837	+ 363	+ 439	49
		O	U	51·48	− 658	+ 9·40	+ 940	+ 283	+ 565	50
		S	S	61·87	− 8	0·00	0	− 75	− 83	51

The required combinations of individual microscope errors taken from pages VI—17 and VI—18 are expressed as follows;

	Reference numbers.	*m.i.*	*mean temp:*	*From comparisons made*
e_1	$= 2 + 3 + 4 + 5 + 6 + \frac{1+7}{2}$	$= + 3474$	at (62° + 4°·98)	before the measurement.
e_2	$= 9 + 11 + 12 + 13 + 14 + \frac{8+15}{2}$	$= + 36$	at (62 − 27·42)	between sets 55 & 56
e_3	$= 10 + 11 + 12 + 13 + 14 + \frac{8+15}{2}$	$= + 162$	at (62 − 26·80)	„ do.
e_4	$= 17 + 18 + 19 + 20 + 22 + \frac{16+24}{2}$	$= + 2869$	at (62 − 1·85)	„ 167 & 168
e_5	$= 17 + 18 + 19 + 21 + 23 + \frac{16+24}{2}$	$= + 1257$	at (62 − 11·29)	„ do.
e_6	$= 28 + 30 + 31 + 32 + 33 + \frac{24+26}{2}$	$= + 2416$	at (62 + 2·55)	„ 167 & 168, and 341 & 342
e_7	$= 17 + 18 + 19 + 21 + 23 + \frac{16+25}{2}$	$= + 1389$	at (62 − 10·99)	„ do. and 318 & 319
e_8	$= 28 + 30 + 31 + 32 + 33 + \frac{26+34}{2}$	$= + 2554$	at (62 + 2·81)	„ 341 & 342,
e_9	$= 29 + 30 + 31 + 32 + 33 + \frac{27+34}{2}$	$= + 2609$	at (62 + 2·34)	„ do.
e_{10}	$= 39 + 40 + 41 + 32 + 43 + \frac{37+44}{2}$	$= + 2573$	at (62 − 3·57)	„ do. and 494 & 495
e_{11}	$= 29 + 30 + 31 + 33 + 35 + \frac{27+34}{2}$	$= + 2521$	at (62 + 0·60)	„ do. and 416 & 417
e_{12}	$= 29 + 30 + 31 + 33 + 36 + \frac{27+34}{2}$	$= + 2056$	at (62 + 0·34)	„ do. do.
e_{13}	$= 39 + 40 + 41 + 35 + 43 + \frac{37+44}{2}$	$= + 2485$	at (62 − 5·31)	„ 416 & 417 and 494 & 495

Microscope Comparisons—(Continued.)

Reference numbers.	*m.i.*	*mean temp:*		
$e_{14} = 39 + 40 + 41 + 42 + 43 + \frac{37+44}{2}$	$= + 2141$	at $(62^\circ - 5^\circ 31)$	From comparisons made	between sets 494 & 495,
$e_{15} = 39 + 40 + 41 + 42 + 43 + \frac{38+44}{2}$	$= + 2152$	at $(62 - 5{\cdot}26)$		„ do.
$e_{16} = 46 + 47 + 48 + 49 + 50 + \frac{45+51}{2}$	$= + 1678$	at $(62 - 9{\cdot}64)$		after the measurement.
$e_{17} = 46 + \frac{45+51}{2}$	$= + 506$	at $(62 - 9{\cdot}10)$		do.

And from the foregoing, we obtain the following equations for the microscope errors per set (or *m.e.*); where dE expresses the error in the adopted value of the expansion for the 6-inch scales.

	m.i.		
$(m.e.)_1 = \frac{e_1 + e_2}{2}$	$= + 1755 + 6 \times 11{\cdot}22\, dE$	applicable to sets Nos.	1 to 55
$(m.e.)_2 = \frac{e_3 + e_4}{2}$	$= + 1516 + 6 \times 14{\cdot}32\, dE$	„	56 to 167
$(m.e.)_3 = \frac{e_5 + e_6}{2}$	$= + 1837 + 6 \times 4{\cdot}37\, dE$	„	168 to 318
$(m.e.)_4 = \frac{e_7 + e_8}{2}$	$= + 1972 + 6 \times 4{\cdot}09\, dE$	„	319 to 341
$(m.e.)_5 = \frac{e_9 + e_{10}}{2}$	$= + 2591 + 6 \times 0{\cdot}61\, dE$	„	342 to 416
$(m.e.)_6 = \frac{e_{11} + e_{13}}{2}$	$= + 2503 + 6 \times 2{\cdot}35\, dE$	„	417 to 436
$(m.e.)_7 = \frac{e_{12} + e_{14}}{2}$	$= + 2099 + 6 \times 2{\cdot}48\, dE$	„	437 to 494
$(m.e.)_8 = \frac{e_{15} + e_{16}}{2}$	$= + 1915 + 6 \times 7{\cdot}45\, dE$	„	495 to 656
$(m.e.)_9 = e_{17}$	$= + 506 + 2 \times 9{\cdot}10\, dE$	„	set No. 657_1

Hence the total microscope errors are as follows,

		m.i.		*feet of A*
In sets Nos. 1 to 167	$55(m.e)_1 =$	$+ 96525 + 3703\, dE$	$= 0{\cdot}0080 +$	$3703\, dE$
	$112(m.e)_2 =$	$+ 169792 + 9623\, dE$	$= 0{\cdot}0141 +$	$9623\, dE$
		sum	$= 0{\cdot}0221 +$	$13326\, dE$
In sets Nos. 168 to 341	$151(m.e)_3 =$	$+ 277387 + 3959\, dE$	$= 0{\cdot}0231 +$	$3959\, dE$
	$23(m.e)_4 =$	$+ 45356 + 564\, dE$	$= 0{\cdot}0038 +$	$564\, dE$
		sum	$= 0{\cdot}0269 +$	$4523\, dE$
In sets Nos. 342 to 494	$75(m.e)_5 =$	$+ 194325 + 275\, dE$	$= 0{\cdot}0162 +$	$275\, dE$
	$20(m.e)_6 =$	$+ 50060 + 282\, dE$	$= 0{\cdot}0042 +$	$282\, dE$
	$58(m.e)_7 =$	$+ 121742 + 863\, dE$	$= 0{\cdot}0101 +$	$863\, dE$
		sum	$= 0{\cdot}0305 +$	$1420\, dE$
In sets Nos. 495 to 657_1	$162(m.e)_8 =$	$+ 310230 + 7241\, dE$	$= 0{\cdot}0259 +$	$7241\, dE$
	$1(m.e)_9 =$	$+ 506 + 18\, dE$	$= {\cdot}0000 +$	$18\, dE$
			$0{\cdot}0259 +$	$7259\, dE$

Microscope Comparisons—(Continued.)

Final deduction of the total lengths measured with the compensated microscopes.

Hitherto the microscope errors have been determined only provisionally; *i.e.* in terms of the 6-inch brass scale *A*. But from page (31), we have $2\,A = 1{\cdot}0000192\,\frac{\text{A}}{10}$, value in 1835. Also the coefficient of expansion for brass, has been taken at ·000,010,417 in the foregoing reductions, whereas it appears from page (17) that ·000,009,855 is a more probable value. Accepting the latter, it may be found that $dE = 3{\cdot}372$ (*m.i*). Hence, remembering that the length measured with a set of microscopes is equal to 3 feet of *A* + the corresponding (*m.e*) we have,

Total lengths measured with the compensated microscopes

		feet of *A*			feet of A
In sets Nos. 1 to 167 or S.W. End to Stn. A	...... =	{167 × 3 + ·0221}	+ 13326 *dE*	= (501·0317 + ·0037) =	501·0354
„ Nos. 168 to 341 or Stn. A, to Stn. B	...... =	{174 × 3 + ·0269}	+ 4523 *dE*	= (522·0369 + ·0013) =	522·0382
„ Nos. 342 to 494 or Stn. B, to Stn. C	...... =	{153 × 3 + ·0305}	+ 1420 *dE*	= (459·0393 + ·0004) =	459·0397
„ Nos. 495 to 657_1 or Stn. C, to N.E. End	...... =	{162 × 3 + ·0259 + 1 × 1 + ·0000}	+ 7259 *dE*	= (487·0353 + ·0020) =	487·0373
„ Nos. 1 to 657_1 or S.W. End to N.E. End	....			= (1969·1432 + ·0074) =	1969·1506

Disposition of the bars and microscopes during the measurement.

The following typical illustrations show the permutations and combinations of the bars and microscopes during the measurement. The instruments are here named in the succession that actually occurred, commencing from the rear-end of a set; and the numbers assigned to the illustrations, will be found employed in the tables of "Extracts from the Field Book &c."

Bar Illustration.

No. 1	No. 2	No. 3	No. 4
A	D	A	A
B	E	B	H
C	H	C	
		D	
		E	
		H	

Statement.

No. 1 occurs in sets Nos. 1_1, 2_1, 3_1, 4_1, 5_1, 655_1, 656_1.
No. 2 „ Nos. 1_2, 2_2, 3_2, 4_2, 5_2, 655_2, 656_2.
No. 3 „ Nos. 6 to 654.
No. 4 „ set No. 657_1.

Microscope Illustration.

No. 1	No. 2	No. 3	No. 4	No. 5	No. 6	No. 7
½T	½R	½T	½T	½T	½R	½T
M	N	M	M	M	N	M
O	P	O	P	P	O	½S
½R	½S	R	R	½R	½S	
		N	N			
		P	O			
		½S	½S			

Statement.

No. 1 occurs in sets Nos. 1_1, 2_1, 3_1, 4_1, 5_1.
No. 2 „ Nos. 1_2, 2_2, 3_2, 4_2, 5_2.
No. 3 „ Nos. 6 to 167.
No. 4 „ Nos. 168 to 654.
No. 5 „ Nos. 655_1 and 656_1.
No. 6 „ Nos. 655_2 and 656_2.
No. 7 „ No. 657_1.

DETAILS OF THE MEASUREMENT.

Extracts from the Field Book of the measurement, and calculated heights of sets above the origin.

Adopted heights above mean sea level.
South-West-End (origin) = 1014·6 feet.
North-East-End (terminus) = 1049·3 feet.

1853	No. of the Set.	Temperature of Air	Mean time of ending	No. of bars used	Height of Set above origin	Numeral shewing arrangement of Bars.	Numeral shewing arrangement of Micros :	1853	No. of the Set.	Temperature of Air	Mean time of ending	No. of bars used	Height of Set above origin	Numeral shewing arrangement of Bars	Numeral shewing arrangement of Micros :
		°	h. m.		feet.					°	h. m.		feet.		
17th Dec.	1_1	62·2	10 25 A.M.	3	+ 0·9	1	1	23rd Dec.	37	55·6	10 5 A.M.	6	− 10·7	3	3
	1_2	69·5	0 45 P.M.	3	− 1·1	2	2		38	63·2	11 0	6	10·8	3	3
	2_1	70·8	2 0	3	3·1	1	1		39	68·8	0 30 P.M.	6	10·9	3	3
	2_2	67·7	3 15	3	4·9	2	2		40	68·2	1 17	6	10·9	3	3
19th „	3_1	46·2	8 50 A.M.	3	6·2	1	1		41	68·4	1 55	6	11·0	3	3
	3_2	54·5	9 55	3	7·7	2	2		42	69·3	2 30	6	11·1	3	3
	4_1	61·1	11 0	3	8·9	1	1		43	69·9	3 1	6	11·1	3	3
	4_2	65·8	0 25 P.M.	3	10·1	2	2		44	67·7	3 58	6	11·6	3	3
	5_1	67·7	1 19	3	11·6	1	1	24th „	45	37·3	7 50 A.M.	6	11·6	3	3
	5_2	68·8	2 4	3	13·0	2	2		46	45·1	8 30	6	11·6	3	3
	6	66·6	3 19	6	15·4	3	3		47	49·6	9 14	6	11·7	3	3
20th „	7	38·9	7 57 A.M.	6	16·6	3	3		48	55·4	10 10	6	11·8	3	3
	8	51·6	9 5	6	17·1	3	3		49	63·1	10 58	6	11·5	3	3
	9	60·4	10 15	6	16·7	3	3		50	64·8	0 21 P.M.	6	11·9	3	3
	10	64·2	0 0 P.M.	6	15·8	3	3		51	66·3	1 3	6	12·0	3	3
	11	66·8	0 48	6	15·4	3	3		52	68·1	1 40	6	11·9	3	3
	12	68·8	1 50	6	14·8	3	3		53	69·0	2 30	6	11·7	3	3
	13	69·3	2 50	6	14·7	3	3		54	69·1	3 5	6	11·6	3	3
	14	68·6	3 47	6	14·2	3	3		55	68·8	3 50	6	11·6	3	3
21st „	15	31·6	7 55 A.M.	6	12·1	3	3	26th „	56	63·1	10 36 A.M.	6	11·7	3	3
	16	43·3	8 42	6	12·1	3	3		57	66·3	11 27	6	11·8	3	3
	17	50·7	9 35	6	12·1	3	3		58	70·9	0 55 P.M.	6	11·6	3	3
	18	55·2	10 23	6	12·0	3	3		59	72·2	1 40	6	11·7	3	3
	19	65·9	11 36	6	11·9	3	3		60	72·9	2 19	6	11·6	3	3
	20	69·7	0 10 P.M.	6	11·6	3	3		61	72·8	3 4	6	11·7	3	3
	21	71·8	1 23	6	11·3	3	3		62	71·6	3 45	6	11·6	3	3
	22	72·2	2 27	6	11·4	3	3	27th „	63	30·8	7 55 A.M.	6	11·5	3	3
	23	71·6	3 30	6	11·0	3	3		64	39·2	8 40	6	11·6	3	3
22nd „	24	32·8	7 50 A.M.	6	11·2	3	3		65	47·8	9 20	6	11·6	3	3
	25	44·8	8 44	6	11·1	3	3		66	53·6	9 57	6	11·5	3	3
	26	53·3	9 40	6	11·0	3	3		67	57·3	10 37	6	11·5	3	3
	27	57·7	10 30	6	11·0	3	3		68	62·2	11 12	6	11·4	3	3
	28	62·2	11 20	6	10·8	3	3		69	67·9	0 25 P.M.	6	11·4	3	3
	29	68·6	0 43 P.M.	6	11·0	3	3		70	70·4	1 23	6	11·2	3	3
	30	71·3	1 27	6	10·9	3	3		71	72·6	2 5	6	11·7	3	3
	31	70·6	2 10	6	11·0	3	3		72	73·1	2 39	6	12·0	3	3
	32	70·0	3 0	6	11·0	3	3		73	73·3	3 14	6	11·9	3	3
	33	69·7	3 40	6	10·8	3	3		74	71·8	4 0	6	11·2	3	3
23rd „	34	37·3	7 50 A.M.	6	10·8	3	3	28th „	75	29·9	7 53 A.M.	6	10·7	3	3
	35	43·3	8 40	6	10·9	3	3		76	38·8	8 45	6	10·4	3	3
	36	50·0	9 15	6	10·9	3	3		77	46·2	9 32	6	10·3	3	3

NOTE.—The rear-end of set No. 1 stood exactly over the dot at South-West-End.
(4_2) and (5_1) Windy. (20) to (23) High wind. (34) to (40) Cloudy. (58) and (59) High wind.

Extracts from the Field Book—(Continued.)

1853-54	No. of the Set.	Temperature of Air	Mean time of ending	No. of bars used	Height of Set above origin	Numeral shewing arrangement of Bars.	Numeral shewing arrangement of Micros:
		°	h. m.		feet.		
28th Dec.	78	51·8	10 10 A.M.	6	− 10·4	3	3
	79	57·7	10 52	6	10·3	3	3
	80	66·9	0 0 P.M.	6	10·2	3	3
	81	70·0	1 14	6	10·2	3	3
	82	71·9	2 10	6	9·9	3	3
	83	71·7	3 5	6	9·9	3	3
	84	70·9	3 50	6	9·6	3	3
29th „	85	31·6	8 3 A.M.	6	9·7	3	3
	86	43·3	9 3	6	9·5	3	3
	87	50·0	9 55	6	9·6	3	3
	88	55·2	10 35	6	9·1	3	3
	89	60·0	11 10	6	8·9	3	3
	90	65·9	0 40 P.M.	6	8·8	3	3
	91	68·9	1 4	6	8·8	3	3
	92	70·2	1 31	6	8·7	3	3
	93	70·9	2 6	6	8·5	3	3
	94	71·3	2 35	6	8·5	3	3
	95	71·2	3 8	6	8·4	3	3
	96	70·8	3 45	6	8·4	3	3
30th „	97	28·4	7 54 A.M.	6	8·2	3	3
	98	35·8	8 29	6	8·2	3	3
	99	43·4	9 10	6	8·0	3	3
	100	50·4	9 52	6	7·9	3	3
	101	54·7	10 33	6	8·0	3	3
	102	59·6	11 14	6	8·0	3	3
	103	66·3	0 35 P.M.	6	7·5	3	3
	104	67·7	1 3	6	7·5	3	3
	105	69·7	1 40	6	7·5	3	3
	106	70·6	2 15	6	7·3	3	3
	107	71·0	2 55	6	7·0	3	3
	108	70·8	3 35	6	6·9	3	3
	109	69·1	4 7	6	6·8	3	3
31st „	110	28·3	7 41 A.M.	6	6·8	3	3
	111	34·3	8 23	6	6·7	3	3
	112	41·8	9 3	6	6·7	3	3
	113	47·5	9 35	6	6·7	3	3
	114	53·6	10 9	6	6·7	3	3
	115	57·8	10 57	6	6·6	3	3
	116	62·1	0 10 P.M.	6	6·6	3	3
	117	65·1	0 50	6	6·6	3	3
	118	66·6	1 30	6	6·6	3	3
	119	67·9	1 58	6	6·6	3	3
	120	69·1	2 46	6	6·6	3	3
	121	69·4	3 26	6	6·5	3	3
	122	67·7	4 15	6	6·5	3	3
2nd Jan.	123	25·1	7 39 A.M.	6	6·6	3	3

1854	No. of the Set.	Temperature of Air	Mean time of ending	No. of bars used	Height of Set above origin	Numeral shewing arrangement of Bars.	Numeral shewing arrangement of Micros:
		°	h. m.		feet.		
2nd Jan.	124	35·0	8 30 A.M.	6	− 6·6	3	3
	125	40·8	9 10	6	6·6	3	3
	126	44·9	9 39	6	6·6	3	3
	127	48·8	10 8	6	6·6	3	3
	128	53·9	10 38	6	6·4	3	3
	129	58·3	11 19	6	6·3	3	3
	130	61·3	0 20 P.M.	6	6·0	3	3
	131	63·0	0 50	6	6·0	3	3
	132	64·3	1 22	6	6·0	3	3
	133	66·0	1 50	6	6·1	3	3
	134	67·1	2 15	6	6·0	3	3
	135	67·4	2 45	6	5·7	3	3
	136	67·9	3 10	6	5·8	3	3
	137	67·8	3 37	6	5·9	3	3
	138	67·0	4 5	6	6·2	3	3
3rd „	139	25·1	7 35 A.M.	6	6·2	3	3
	140	30·9	8 8	6	6·0	3	3
	141	36·9	8 44	6	6·1	3	3
	142	43·6	9 18	6	6·2	3	3
	143	48·4	9 53	6	6·3	3	3
	144	52·8	10 25	6	5·8	3	3
	145	55·4	10 55	6	5·9	3	3
	146	57·1	11 25	6	5·9	3	3
	147	62·1	0 26 P.M.	6	5·8	3	3
	148	63·7	0 54	6	5·8	3	3
	149	65·4	1 24	6	5·8	3	3
	150	66·1	1 45	6	5·8	3	3
	151	66·9	2 16	6	5·6	3	3
	152	67·3	2 40	6	5·6	3	3
	153	66·8	3 27	6	5·7	3	3
	154	66·1	3 56	6	5·6	3	3
4th „	155	26·1	7 43 A.M.	6	5·5	3	3
	156	36·1	8 46	6	5·5	3	3
	157	40·4	9 25	6	5·1	3	3
	158	47·0	9 58	6	4·9	3	3
	159	55·0	10 29	6	4·9	3	3
	160	56·9	11 0	6	4·9	3	3
	161	57·8	11 35	6	4·9	3	3
	162	62·6	0 30 P.M.	6	5·0	3	3
	163	64·2	1 25	6	5·0	3	3
	164	64·3	2 0	6	5·3	3	3
	165	64·0	2 30	6	5·2	3	3
	166	62·8	3 3	6	5·2	3	3
	167	61·8	3 51	6	5·1	3	3
				Total —	1545·3		

The dot denoting Station A was fixed exactly in the normal at the advanced-end of set No. 167.
Height of set No. 167 above Station A = 1·9 feet.
The terminal point of set No. 167 was the point of origin for set No. 168.

(155) Cloudy.

Extracts from the Field Book—(Continued.)

1854	No. of the Set	Temperature of Air	Mean time of ending	No. of bars used	Height of Set above origin	Numeral shewing arrangement of Bars.	Numeral shewing arrangement of Micros:
		°	h. m.		feet.		
5th Jan.	168	38·2	9 6 A.M.	6	− 4·6	3	4
	169	45·9	9 43	6	4·6	3	4
	170	48·7	10 12	6	4·6	3	4
	171	52·2	10 46	6	4·6	3	4
	172	53·7	11 35	6	4·5	3	4
	173	57·3	0 38 P.M.	6	4·5	3	4
	174	60·2	1 12	6	4·5	3	4
	175	61·9	1 48	6	4·4	3	4
	176	61·2	2 10	6	4·4	3	4
	177	60·6	2 33	6	4·4	3	4
	178	60·0	3 0	6	4·4	3	4
	179	59·7	3 25	6	4·4	3	4
	180	59·3	4 0	6	4·4	3	4
6th „	181	40·3	7 50 A.M.	6	4·4	3	4
	182	42·6	8 25	6	4·4	3	4
	183	45·0	8 56	6	4·5	3	4
	184	50·3	9 25	6	4·5	3	4
	185	55·0	9 55	6	4·3	3	4
	186	58·3	10 20	6	4·3	3	4
	187	61·1	10 55	6	4·3	3	4
	188	66·1	0 5 P.M.	6	4·0	3	4
	189	68·2	0 35	6	4·0	3	4
	190	68·8	1 0	6	4·1	3	4
	191	70·8	1 26	6	4·7	3	4
	192	72·0	1 55	6	4·8	3	4
	193	72·8	2 20	6	4·3	3	4
	194	74·0	2 45	6	3·9	3	4
	195	73·3	3 10	6	3·8	3	4
	196	72·8	3 31	6	3·9	3	4
	197	70·8	4 0	6	3·9	3	4
7th „	198	28·6	7 47 A.M.	6	3·6	3	4
	199	31·3	8 18	6	3·9	3	4
	200	36·1	8 55	6	4·0	3	4
	201	42·4	9 20	6	4·0	3	4
	202	50·2	9 50	6	4·0	3	4
	203	53·3	10 15	6	4·0	3	4
	204	54·3	10 45	6	4·2	3	4
	205	57·0	11 15	6	4·0	3	4
	206	61·4	0 10 P.M.	6	3·4	3	4
	207	64·6	0 34	6	3·5	3	4
	208	66·9	0 56	6	3·4	3	4
	209	67·9	2 2	6	3·8	3	4
	210	67·9	2 30	6	3·8	3	4
	211	66·7	2 58	6	3·8	3	4
	212	68·0	3 20	6	3·8	3	4
	213	67·6	3 50	6	3·7	3	4
9th „	214	35·3	8 37 A.M.	6	3·8	3	4
	215	42·6	9 7	6	3·8	3	4
	216	48·3	9 40	6	3·8	3	4
	217	54·0	10 11	6	3·3	3	4
	218	56·3	10 38	6	3·3	3	4
	219	58·3	11 8	6	3·3	3	4
	220	64·9	0 15 P.M.	6	3·3	3	4
9th Jan.	221	66·7	0 37 P.M.	6	− 3·2	3	4
	222	69·2	1 3	6	3·3	3	4
	223	70·8	1 29	6	3·3	3	4
	224	71·9	1 50	6	3·3	3	4
	225	72·7	2 15	6	3·1	3	4
	226	72·0	2 43	6	3·1	3	4
	227	70·9	3 10	6	3·1	3	4
	228	69·6	3 36	6	3·2	3	4
	229	67·6	4 12	6	3·2	3	4
10th „	230	28·9	7 41 A.M.	6	3·1	3	4
	231	33·6	8 15	6	3·1	3	4
	232	38·0	8 50	6	3·1	3	4
	233	43·2	9 23	6	3·0	3	4
	234	48·9	10 0	6	3·0	3	4
	235	52·6	10 25	6	2·9	3	4
	236	56·3	10 56	6	3·0	3	4
	237	59·2	11 30	6	2·9	3	4
	238	63·4	0 33 P.M.	6	2·9	3	4
	239	65·4	1 0	6	2·8	3	4
	240	66·7	1 25	6	2·8	3	4
	241	67·6	1 55	6	2·9	3	4
	242	68·2	2 25	6	3·0	3	4
	243	69·9	3 0	6	3·0	3	4
	244	70·4	3 30	6	3·0	3	4
	245	69·8	4 0	6	2·8	3	4
11th „	246	30·6	7 37 A.M.	6	2·8	3	4
	247	33·4	8 7	6	2·8	3	4
	248	35·4	8 40	6	2·8	3	4
	249	39·8	9 7	6	2·9	3	4
	250	47·4	9 38	6	2·8	3	4
	251	50·7	10 4	6	2·9	3	4
	252	54·7	10 30	6	3·1	3	4
	253	57·6	11 0	6	3·3	3	4
	254	62·8	0 0 P.M.	6	3·3	3	4
	255	65·0	0 27	6	3·3	3	4
	256	67·3	0 51	6	3·3	3	4
	257	67·9	1 17	6	3·1	3	4
	258	68·3	1 47	6	3·0	3	4
	259	69·9	2 13	6	2·9	3	4
	260	69·8	2 40	6	2·4	3	4
	261	69·3	3 4	6	2·3	3	4
	262	69·3	3 30	6	2·2	3	4
	263	68·0	3 58	6	2·3	3	4
12th „	264	26·6	7 35 A.M.	6	2·3	3	4
	265	30·9	8 6	6	2·1	3	4
	266	37·3	8 43	6	2·1	3	4
	267	41·8	9 10	6	2·0	3	4
	268	46·8	9 42	6	1·8	3	4
	269	50·7	10 3	6	1·8	3	4
	270	54·6	10 30	6	1·7	3	4
	271	59·0	11 5	6	1·5	3	4
	272	62·3	0 3 P.M.	6	1·5	3	4
	273	63·7	0 30	6	1·5	3	4

(168) to (197), (211), (242) and (261) to (263) Cloudy.

Extracts from the Field Book—(Continued.)

1854	No. of the Set.	Temperature of Air	Mean time of ending	No. of bars used	Height of Set above origin	Numeral shewing arrangement of Bars.	Numeral shewing arrangement of Micros:
		°	h. m.		feet.		
12th Jan.	274	65·7	1 3 P.M.	6	− 1·5	3	4
	275	67·0	1 32	6	1·6	3	4
	276	67·6	2 0	6	1·5	3	4
	277	68·6	2 22	6	1·6	3	4
	278	68·9	2 50	6	1·6	3	4
	279	69·6	3 14	6	1·5	3	4
	280	68·7	3 37	6	1·5	3	4
	281	67·4	4 3	6	1·6	3	4
13th „	282	30·4	7 42 A.M.	6	1·5	3	4
	283	33·9	8 14	6	1·5	3	4
	284	40·5	8 52	6	1·3	3	4
	285	44·9	9 19	6	1·2	3	4
	286	49·0	9 50	6	1·1	3	4
	287	52·4	10 18	6	·9	3	4
	288	55·8	10 47	6	·9	3	4
	289	58·9	11 14	6	·8	3	4
	290	62·6	0 14 P.M.	6	·8	3	4
	291	64·3	0 42	6	·8	3	4
	292	65·7	1 11	6	·8	3	4
	293	67·3	1 39	6	·9	3	4
	294	67·9	2 9	6	1·0	3	4
	295	68·2	2 34	6	1·0	3	4
	296	68·4	3 1	6	·9	3	4
	297	68·6	3 27	6	·7	3	4
	298	67·9	3 51	6	·8	3	4
	299	67·3	4 24	6	·9	3	4
14th „	300	31·8	7 51 A.M.	6	1·0	3	4
	301	36·6	8 21	6	1·1	3	4
	302	42·9	8 53	6	1·1	3	4
	303	46·5	9 19	6	1·1	3	4
	304	48·8	9 48	6	·9	3	4
	305	52·3	10 12	6	·9	3	4
	306	55·8	10 39	6	·6	3	4
	307	58·0	11 11	6	·5	3	4
	308	62·3	0 23 P.M.	6	·5	3	4
14th Jan.	309	62·5	0 47 P.M.	6	− ·7	3	4
	310	62·9	1 8	6	·7	3	4
	311	63·9	1 29	6	·7	3	4
	312	64·9	1 54	6	·5	3	4
	313	64·4	2 15	6	·6	3	4
	314	64·9	2 43	6	·5	3	4
	315	66·0	3 3	6	·4	3	4
	316	64·8	3 25	6	·4	3	4
	317	64·7	3 42	6	·4	3	4
	318	62·2	4 13	6	·2	3	4
16th „	319	30·1	7 55 A.M.	6	·0	3	4
	320	35·0	8 27	6	·0	3	4
	321	41·6	9 3	6	+ ·1	3	4
	322	47·7	9 35	6	·1	3	4
	323	50·0	10 6	6	·1	3	4
	324	52·9	10 39	6	·3	3	4
	325	57·4	11 20	6	·4	3	4
	326	60·8	11 45	6	·4	3	4
	327	65·0	1 4 P.M.	6	·4	3	4
	328	66·1	1 32	6	·3	3	4
	329	67·8	1 57	6	·3	3	4
	330	68·3	2 23	6	·4	3	4
	331	67·8	2 50	6	·4	3	4
	332	68·2	3 18	6	·4	3	4
	333	68·3	3 45	6	·5	3	4
	334	68·2	4 11	6	·5	3	4
17th „	335	33·1	7 51 A.M.	6	·5	3	4
	336	36·2	8 28	6	·6	3	4
	337	41·7	9 3	6	·7	3	4
	338	45·3	9 29	6	·8	3	4
	339	49·8	10 3	6	·7	3	4
	340	53·9	10 43	6	·7	3	4
	341	61·1	0 15 P.M.	6	·8	3	4
				Total	− 395·4		

The dot denoting Station B was fixed exactly in the normal at the advanced-end of set No. 341.
Height of set No. 341 above Station B = 2·4 feet.
The terminal point of set No. 341 was the point of origin for set No. 342.

1854	No. of the Set.	Temperature of Air	Mean time of ending	No. of bars used	Height of Set above origin	Bars.	Micros:
24th Jan.	342	50·4	8 40 A.M.	6	+ ·8	3	4
	343	51·2	9 15	6	·9	3	4
	344	51·9	9 55	6	1·1	3	4
	345	52·7	10 28	6	1·2	3	4
	346	54·3	11 3	6	1·3	3	4
	347	54·4	11 30	6	1·3	3	4
	348	54·4	0 30 P.M.	6	1·5	3	4
	349	54·6	0 52	6	1·5	3	4
	350	54·7	1 20	6	1·6	3	4
	351	54·7	1 45	6	1·6	3	4
	352	54·9	2 12	6	1·7	3	4
	353	55·1	2 34	6	1·8	3	4
	354	54·5	3 0	6	1·7	3	4
24th Jan.	355	54·3	3 26 P.M.	6	+ 1·7	3	4
	356	54·1	3 53	6	1·8	3	4
25th „	357	50·3	7 50 A.M.	6	1·9	3	4
	358	51·3	8 25	6	2·0	3	4
	359	52·4	8 50	6	1·8	3	4
	360	53·0	9 11	6	1·7	3	4
	361	54·3	9 35	6	1·7	3	4
	362	55·1	10 0	6	1·7	3	4
	363	58·2	10 26	6	1·7	3	4
	364	61·0	11 0	6	1·7	3	4
	365	62·9	0 0 P.M.	6	1·3	3	4
	366	62·4	0 23	6	1·2	3	4
	367	58·6	0 52	6	1·0	3	4

(298) to (341) Cloudy. January 24th Rainy night and cloudy throughout this day's measurement, with occasional rain in the forenoon. January 25th Rainy night and cloudy throughout this day's measurement.

Extracts from the Field Book—(Continued.)

1854	No. of the Set	Temperature of Air	Mean time of ending	No. of bars used	Height of Set above origin	Numeral shewing arrangement of Bars.	Numeral shewing arrangement of Micros:	1854	No. of the Set	Temperature of Air	Mean time of ending	No. of bars used	Height of Set above origin	Numeral shewing arrangement of Bars	Numeral shewing arrangement of Micros:
		°	h. m.		feet.					°	h. m.		feet.		
25th Jan.	368	58·0	1 21 P.M.	6	+ ·9	3	4	2nd Feb.	423	47·0	10 4 A.M.	6	+ 2·7	3	4
	369	57·6	1 50	6	·8	3	4		424	48·9	10 35	6	2·9	3	4
	370	57·5	2 15	6	·4	3	4		425	51·0	11 5	6	3·0	3	4
	371	57·5	2 40	6	·3	3	4		426	54·4	0 0 P.M.	6	2·9	3	4
	372	57·3	3 2	6	− ·0	3	4		427	55·2	0 32	6	2·7	3	4
	373	56·8	3 27	6	·2	3	4		428	56·1	0 56	6	2·4	3	4
	374	56·7	3 58	6	·3	3	4		429	56·6	1 17	6	3·2	3	4
30th "	375	57·6	9 30 A.M.	6	·4	3	4		430	57·0	1 38	6	3·4	3	4
	376	59·3	10 0	6	·5	3	4		431	57·0	2 5	6	3·7	3	4
	377	62·2	10 52	6	·5	3	4		432	57·2	2 29	6	4·2	3	4
	378	63·0	0 0 P.M.	6	·4	3	4		433	57·8	2 52	6	4·6	3	4
	379	63·8	0 36	6	·8	3	4		434	57·6	3 15	6	4·9	3	4
	380	62·9	1 7	6	1·1	3	4		435	57·7	3 39	6	5·2	3	4
	381	62·8	1 40	6	1·2	3	4		436	56·9	4 17	6	5·4	3	4
	382	63·0	2 7	6	1·2	3	4	3rd "	437	40·6	7 53 A.M.	6	5·7	3	4
	383	63·7	2 43	6	1·4	3	4		438	41·9	8 21	6	5·9	3	4
	384	60·6	3 36	6	2·0	3	4		439	43·6	9 0	6	6·1	3	4
31st "	385	42·8	7 47 A.M.	6	2·3	3	4		440	45·8	9 28	6	6·4	3	4
	386	43·7	8 19	6	2·7	3	4		441	46·8	10 3	6	6·6	3	4
	387	46·0	9 8	6	2·8	3	4		442	47·5	10 30	6	6·8	3	4
	388	47·8	9 36	6	2·9	3	4		443	48·1	11 10	6	7·0	3	4
	389	49·3	10 10	6	2·5	3	4		444	49·0	11 41	6	6·8	3	4
	390	50·4	10 41	6	2·1	3	4		445	50·3	0 38 P.M.	6	6·8	3	4
	391	51·9	11 20	6	2·2	3	4		446	51·0	0 57	6	7·0	3	4
	392	54·1	0 29 P.M.	6	1·8	3	4		447	51·7	1 19	6	7·3	3	4
	393	54·9	1 10	6	2·7	3	4		448	52·9	1 39	6	7·6	3	4
	394	55·0	1 38	6	3·3	3	4		449	53·0	1 58	6	7·7	3	4
	395	54·8	2 7	6	3·3	3	4		450	52·1	2 14	6	7·6	3	4
	396	55·1	2 40	6	3·3	3	4		451	51·9	2 34	6	7·8	3	4
	397	54·9	3 23	6	2·9	3	4		452	53·2	2 51	6	7·8	3	4
	398	55·0	3 54	6	2·9	3	4		453	53·6	3 9	6	7·8	3	4
1st Feb.	399	38·5	7 31 A.M.	6	3·0	3	4		454	52·7	3 28	6	8·0	3	4
	400	40·6	8 2	6	2·7	3	4		455	51·6	3 51	6	8·1	3	4
	401	42·9	8 45	6	2·1	3	4		456	51·4	4 9	6	8·1	3	4
	402	44·9	9 16	6	1·8	3	4		457	50·9	4 32	6	8·5	3	4
	403	46·7	9 54	6	1·7	3	4	4th "	458	45·0	7 34 A.M.	6	8·5	3	4
	404	48·5	10 27	6	1·6	3	4		459	46·1	8 0	6	8·6	3	4
	405	49·6	10 56	6	1·4	3	4		460	47·6	8 31	6	8·7	3	4
	406	50·7	11 22	6	1·2	3	4		461	49·3	8 55	6	9·0	3	4
	407	52·8	0 25 P.M.	6	1·0	3	4		462	51·0	9 28	6	9·2	3	4
	408	53·9	0 50	6	1·0	3	4		463	52·2	9 53	6	9·3	3	4
	409	54·7	1 14	6	·6	3	4		464	53·9	10 23	6	9·5	3	4
	410	55·4	1 39	6	·4	3	4		465	56·5	10 45	6	9·5	3	4
	411	55·5	2 2	6	·2	3	4		466	54·2	11 15	6	9·8	3	4
	412	55·6	2 25	6	·0	3	4		467	54·1	11 42	6	9·6	3	4
	413	56·0	2 50	6	+ ·1	3	4		468	56·4	0 29 P.M.	6	9·6	3	4
	414	55·6	3 13	6	·4	3	4		469	59·2	0 47	6	9·6	3	4
	415	55·3	3 40	6	·6	3	4		470	58·1	1 6	6	9·3	3	4
	416	55·1	4 2	6	·9	3	4		471	60·7	1 23	6	9·3	3	4
	417	54·6	4 32	6	1·2	3	4		472	62·3	1 42	6	9·1	3	4
2nd "	418	34·4	7 22 A.M.	6	1·5	3	4		473	64·4	2 2	6	9·0	3	4
	419	38·1	7 55	6	2·0	3	4		474	63·0	2 25	6	8·7	3	4
	420	41·0	8 30	6	2·1	3	4		475	60·8	2 45	6	8·8	3	4
	421	42·5	9 0	6	2·2	3	4		476	60·8	3 4	6	9·1	3	4
	422	44·4	9 34	6	2·4	3	4		477	60·4	3 25	6	9·0	3	4

(375) to (384) High wind. (385) to (398) Hazy. (437) to (457) Cloudy. (458) to (479) Cloudy with occasional sunshine.

Extracts from the Field Book—(Continued.)

1854	No. of the Set.	Temperature of Air	Mean time of ending	No. of bars used	Height of Set above origin	Numeral shewing arrangement of Bars.	Numeral shewing arrangement of Micros:
		°	h. m.		feet.		
4th Feb.	478	60·2	3 46 P.M.	6	+ 8·8	3	4
	479	59·7	4 20	6	8·7	3	4
6th „	480	37·0	7 41 A.M.	6	8·8	3	4
	481	40·0	8 7	6	8·7	3	4
	482	44·3	8 42	6	9·0	3	4
	483	46·3	9 8	6	9·0	3	4
	484	48·5	9 42	6	8·8	3	4
	485	50·2	10 5	6	8·8	3	4
	486	52·3	10 36	6	9·2	3	4
	487	54·9	11 8	6	9·1	3	4
6th Feb.	488	56·7	0 12 P.M.	6	+ 9·1	3	4
	489	57·4	0 36	6	9·0	3	4
	490	56·1	0 58	6	8·9	3	4
	491	55·7	1 21	6	8·6	3	4
	492	56·4	1 47	6	8·5	3	4
	493	55·9	2 6	6	8·4	3	4
	494	58·0	2 45	6	8·2	3	4
				Total	+ 525·0		

The dot denoting Station C was fixed exactly in the normal at the advanced-end of set No. 494.
Height of set No. 494 above Station C = 2·2 feet.
The terminal point of set No. 494 was the point of origin for set No. 495.

1854	No. of the Set.	Temperature of Air	Mean time of ending	No. of bars used	Height of Set above origin	Bars.	Micros:
7th Feb.	495	36·0	7 45 A.M.	6	+ 8·3	3	4
	496	41·3	8 20	6	8·3	3	4
	497	45·7	8 54	6	8·1	3	4
	498	48·3	9 23	6	8·2	3	4
	499	49·6	9 54	6	8·0	3	4
	500	51·1	10 14	6	8·0	3	4
	501	53·2	10 52	6	7·9	3	4
	502	55·5	11 25	6	7·0	3	4
	503	57·3	0 21 P.M.	6	6·5	3	4
	504	58·2	0 43	6	6·8	3	4
	505	59·1	1 6	6	7·6	3	4
	506	60·3	1 29	6	8·5	3	4
	507	61·1	2 0	6	8·7	3	4
	508	61·6	2 24	6	8·6	3	4
	509	62·0	2 45	6	8·5	3	4
	510	62·5	3 8	6	8·4	3	4
	511	62·6	3 26	6	8·3	3	4
	512	62·2	3 45	6	8·2	3	4
	513	62·1	4 4	6	8·3	3	4
	514	62·0	4 23	6	8·5	3	4
	515	61·3	4 50	6	8·7	3	4
8th „	516	39·9	7 31 A.M.	6	8·6	3	4
	517	42·7	7 57	6	8·3	3	4
	518	44·9	8 30	6	8·4	3	4
	519	47·3	8 52	6	8·5	3	4
	520	50·0	9 26	6	8·9	3	4
	521	50·2	9 52	6	9·3	3	4
	522	51·7	10 25	6	9·8	3	4
	523	52·9	10 48	6	10·1	3	4
	524	55·0	11 16	6	9·9	3	4
	525	56·8	11 41	6	10·0	3	4
	526	57·6	0 35 P.M.	6	10·4	3	4
	527	60·4	0 54	6	10·6	3	4
	528	63·2	1 11	6	10·9	3	4
	529	63·9	1 32	6	11·2	3	4
	530	62·8	1 52	6	11·6	3	4
	531	62·6	2 11	6	11·6	3	4
	532	62·5	2 29	6	11·5	3	4
	533	62·5	2 46	6	11·7	3	4
8th Feb.	534	62·8	3 4 P.M.	6	+ 12·1	3	4
	535	61·8	3 23	6	12·2	3	4
	536	60·9	3 44	6	12·4	3	4
	537	60·6	4 11	6	12·4	3	4
9th „	538	40·6	7 29 A.M.	6	12·7	3	4
	539	43·4	8 3	6	12·9	3	4
	540	45·3	8 36	6	13·0	3	4
	541	46·3	9 3	6	13·1	3	4
	542	48·7	9 36	6	13·2	3	4
	543	50·2	10 0	6	13·4	3	4
	544	51·7	10 30	6	13·4	3	4
	545	53·2	11 0	6	13·5	3	4
	546	52·7	0 4 P.M.	6	13·3	3	4
	547	53·0	0 25	6	12·9	3	4
	548	53·0	0 45	6	12·3	3	4
	549	52·6	1 3	6	12·2	3	4
	550	52·7	1 24	6	12·3	3	4
	551	54·0	1 45	6	12·0	3	4
	552	53·0	2 5	6	11·7	3	4
	553	53·2	2 24	6	11·6	3	4
	554	53·0	2 51	6	11·0	3	4
	555	52·1	3 13	6	10·9	3	4
	556	49·3	3 48	6	10·8	3	4
10th „	557	54·0	0 4 P.M.	6	10·8	3	4
	558	56·4	0 34	6	11·0	3	4
	559	57·6	1 4	6	11·1	3	4
	560	57·9	1 26	6	11·2	3	4
	561	58·1	1 51	6	11·2	3	4
	562	58·4	2 14	6	11·6	3	4
	563	57·7	2 42	6	12·1	3	4
	564	59·9	3 7	6	12·4	3	4
	565	56·9	3 39	6	11·6	3	4
	566	56·2	4 10	6	10·4	3	4
11th „	567	41·6	8 10 A.M.	6	9·8	3	4
	568	44·4	8 39	6	9·3	3	4
	569	49·0	9 21	6	9·2	3	4
	570	52·1	9 52	6	9·4	3	4
	571	54·2	10 18	6	9·4	3	4
	572	54·8	10 53	6	9·6	3	4

(485) to (494) Cloudy. (516) to (556) Cloudy. January 10th. Heavy rain throughout the night, cloudy throughout the day. (567) Heavy fog delayed the measurement of this set.

Extracts from the Field Book—(Continued.)

1854	No. of the Set.	Temperature of Air	Mean time of ending	No. of bars used	Height of Set above origin	Numeral shewing arrangement of Bars.	Numeral shewing arrangement of Micros:
		°	h. m.		feet.		
11th Feb.	573	56·7	11 49 A.M.	6	+ 9·7	3	4
	574	57·5	0 11 P.M.	6	10·0	3	4
	575	59·0	0 35	6	10·0	3	4
	576	59·5	0 56	6	10·1	3	4
	577	60·4	1 17	6	10·2	3	4
	578	60·4	1 36	6	10·2	3	4
	579	61·1	1 57	6	10·1	3	4
	580	62·0	2 19	6	10·3	3	4
	581	62·2	2 38	6	10·6	3	4
	582	62·4	2 57	6	11·0	3	4
	583	62·8	3 17	6	11·1	3	4
	584	63·2	3 32	6	11·1	3	4
	585	63·0	3 53	6	11·9	3	4
	586	61·9	4 17	6	12·3	3	4
13th „	587	40·7	7 27 A.M.	6	13·1	3	4
	588	44·0	7 53	6	13·2	3	4
	589	47·3	8 25	6	13·3	3	4
	590	49·0	8 50	6	13·2	3	4
	591	51·2	9 20	6	13·4	3	4
	592	53·0	9 43	6	13·8	3	4
	593	55·1	10 15	6	13·8	3	4
	594	57·0	10 42	6	13·6	3	4
	595	58·4	11 4	6	13·4	3	4
	596	59·1	11 26	6	13·4	3	4
	597	62·6	0 18 P.M.	6	13·1	3	4
	598	63·5	0 32	6	12·7	3	4
	599	64·0	0 48	6	12·6	3	4
	600	64·6	1 3	6	12·9	3	4
	601	64·7	1 19	6	12·8	3	4
	602	65·0	1 35	6	12·9	3	4
	603	65·3	1 52	6	13·2	3	4
	604	65·6	2 9	6	13·3	3	4
	605	66·0	2 27	6	13·5	3	4
	606	66·3	2 44	6	13·8	3	4
	607	66·0	3 8	6	14·0	3	4
	608	66·6	3 23	6	14·2	3	4
	609	66·7	3 43	6	14·7	3	4
	610	66·4	4 7	6	15·5	3	4
	611	65·7	4 32	6	15·8	3	4
14th „	612	41·0	7 10 A.M.	6	16·2	3	4
	613	43·0	7 34	6	16·8	3	4
	614	46·3	8 12	6	17·3	3	4
	615	49·5	8 35	6	17·8	3	4
	616	52·9	9 0	6	17·9	3	4
	617	54·8	9 23	6	18·5	3	4
14th Feb.	618	55·7	9 45 A.M.	6	+ 18·7	3	4
	619	57·0	10 5	6	19·0	3	4
	620	59·0	10 29	6	18·9	3	4
	621	59·9	10 50	6	19·4	3	4
	622	60·2	11 37	6	19·9	3	4
	623	61·0	11 55	6	19·9	3	4
	624	61·9	0 15 P.M.	6	19·5	3	4
	625	63·2	0 32	6	19·5	3	4
	626	64·0	0 52	6	19·8	3	4
	627	64·7	1 12	6	19·9	3	4
	628	64·9	1 32	6	20·4	3	4
	629	65·0	1 54	6	20·8	3	4
	630	65·0	2 12	6	21·4	3	4
	631	65·7	2 27	6	21·7	3	4
	632	66·0	2 46	6	22·1	3	4
	633	66·5	3 4	6	22·6	3	4
	634	66·6	3 23	6	22·9	3	4
	635	66·2	3 41	6	22·9	3	4
	636	65·8	4 6	6	22·7	3	4
	637	65·3	4 31	6	22·8	3	4
15th „	638	39·4	7 7 A.M.	6	22·8	3	4
	639	40·7	7 34	6	23·1	3	4
	640	43·3	8 6	6	23·3	3	4
	641	46·2	8 28	6	23·3	3	4
	642	49·8	8 54	6	23·3	3	4
	643	52·8	9 15	6	23·3	3	4
	644	53·7	9 43	6	23·3	3	4
	645	55·5	10 0	6	22·9	3	4
	646	56·7	10 29	6	22·6	3	4
	647	56·2	10 58	6	22·5	3	4
	648	57·3	11 22	6	22·2	3	4
	649	60·9	0 17 P.M.	6	22·0	3	4
	650	63·3	0 34	6	21·7	3	4
	651	64·9	0 52	6	21·8	3	4
	652	65·8	1 10	6	22·3	3	4
	653	65·4	1 45	6	23·4	3	4
	654	65·1	2 36	6	26·4	3	4
	655_1	62·8	3 15	3	28·5	1	5
	655_2	61·1	3 54	3	30·3	2	6
	656_1	60·1	4 26	3	32·2	1	5
	656_2	59·4	4 53	3	33·9	2	6
	657_1	56·2	5 30	2	34·6	4	7
				Total	+ 2362·9		

The advanced-end of set No. 657_1 fell in excess (*i.e.* North-East) of the dot at North-East-End 4·0065 feet, as measured on Cary's brass scale with a pair of compasses.

Height of set No. 657_1 above North-East-End = 1·4 feet.

Reduction to Mean Sea Level.

Let the sections into which this base-line is divided be denoted as follows;

South-West-End to Station A	by Section	I
Station A to „ B	„	II
„ B to „ C	„	III
„ C to North-East-End	„	IV

Then in the notation of (7) page I—22 we have

$H = 1015$; $h = 34{\cdot}7$; $\delta h = +\,1{\cdot}5$; Log. $R = 7{\cdot}32042$, and $n = 656$.

	$[h]_1^p$	a	n	dh +	F	λ	C_2	C_1 −	C −
Section I ...	−1545	+ 33	167	0·4	−1478	10522	+·0045	·5107	·5062
„ II ...	− 395	0	174	0·4	− 290	10963	+·0009	·5321	·5312
„ III ...	+ 525	0	153	0·3	+ 671	9640	−·0021	·4679	·4700
„ IV ...	+2363	− 86	162	0·4	+2488	10224	−·0075	·4962	·5037

Final length of the Base-Line and of its parts in feet of Standard A.

Section	*Measured with*			Reduction to sea level as above	Total Length	Log.
	Compensated bars page VI—16	Compensated microscopes page VI—20	Beam compass pages VI—22 to VI—27			
S. W. End to Stn. A ...	10020·5764	501·0354	0·0000	−0·5062	10521·1056	4·02206 1379
Stn. A to Stn. B ...	10440·6006	522·0382	0·0000	−0·5312	10962·1076	4·03989 4060
Stn. B to Stn. C ...	9180·5395	459·0397	0·0000	−0·4700	9639·1092	3·98403 6900
Stn. C to N.E. End ...	9740·5724	487·0373	−4·0065	−0·5037	10223·0995	4·00958 2588
S.W.End to N.E. End ...	39382·2889	1969·1506	−4·0065	−2·0111	41345·4219	4·61642 7428

Verificatory Minor Triangulation.

No. of Triangle	Name of Station	Corrected Angle	Log. Sine	Log. Distance	Distance in Feet	Distance in Miles	Error of Triangle
		° ′ ″					″
1	South-West-End of Base, or Kálu Station	60 1 45·219	9·937658453	4·021033802			
	Station A, ...	59 42 19·235	9·936233461	4·019608810			
	„ α	60 15 55·569	9·938686030	4·022061379	10521·1056	1·993	+0·097
		180 0 0·023					
2	Station α	56 33 48·734	9·921424960	4·067053921			
	„ A, ...	74 47 40·729	9·984523705	4·130152666			+0·352
	„ β	48 38 30·565	9·875404841	4·021033802			
		180 0 0·028					
3	Station A, ...	45 30 3·049	9·853248348	3·943314187			
	„ β	62 59 12·239	9·949829623	4·039895462	10962·1430	2·076	+0·508
	„ B, ...	71 30 44·734	9·976988082	4·067053921			
		180 0 0·022					
4	Station β	87 42 43·003	9·999653616	4·043479177			
	„ B, ...	39 47 3·407	9·806111338	3·849936899			+1·225
	„ γ	52 30 13·605	9·899488626	3·943314187			
		180 0 0·015					
5	Station B, ...	68 42 12·614	9·969282354	4·069452882			
	„ γ	49 56 21·837	9·883868103	3·984038631	9639·1476	1·826	+1·467
	„ C, ...	61 21 25·572	9·943308649	4·043479177			
		180 0 0·023					
6	Station γ	69 33 45·259	9·971764652	4·095428097			
	„ C, ...	48 28 24·616	9·874278363	3·997941808			−0·296
	„ δ	61 57 50·151	9·945789437	4·069452882			
		180 0 0·026					
7	Station C, ...	70 10 5·510	9·973447721	4·119383557			
	„ δ	46 55 55·971	9·863647744	4·009583580	10223·1229	1·936	+0·302
	North-East-End of Base, or Agzar Station	62 53 58·547	9·949492261	4·095428097			
		180 0 0·028		Sum	41345·5191	7·831	

Note.—Each side of a triangle is given in the same horizontal line with the angle which it subtends.

The angles of the verificatory triangulation were measured with a 3-foot Theodolite by Barrow read by 5 micrometer microscopes. At all the stations 3 measures were made on each of 10 zeros. The stations on the line are South-West-End, A, B, C and North-East-End. The auxiliary stations are α, β, γ and δ.

Comparison in feet between the values computed by means of the verificatory triangulation and the measured value.

Of the entire line.

	feet	*Log.*
South-West-End to North-East-End by the measurement, page VI—28	41345·4219	4·616 427 428
„ computed in terms of South-West-End to Station A, page VI—29	41345·5191	4·616 428 449
Log. computed value — Log. measured value = +		0·000 001 021

In terms of the entire line by measurement.

	Computed	Computed — Measured*
South-West-End to Station A	10521·0809	—·0247
Station A to Station B	10962·1172	+·0096
„ B to „ C	9639·1249	+·0157
„ C to „ North-East-End . .	10223·0989	—·0006

Of each section in terms of the others.

	South-West-End to Station A	Station A to Station B	Computed — Measured	Station B to Station C	Computed — Measured	Station C to N.E. End	Computed — Measured
Measured lengths* ..	10521·1056	10962·1076	.. ..	9639·1092	.. ..	10223·0995	.. ..
Computed on base S.W. End to Station A	.. ..	10962·1430	+·0354	9639·1476	+·0384	10223·1229	+·0234
Computed on base Station A to Station B	.. ..	.. ..	.. ..	9639·1165	+·0073	10223·0899	—·0096
Computed on base Station B to Station C	.. ..	.. ..	.. ..	.. ..	.. ..	10223·0822	—·0173

NOTE.—Since $\text{Log}_e(x + dx) = \text{Log}_e x + \frac{(dx)}{x} - \frac{(dx)^2}{2x^2} + \&c.$

$dx = \left\{ \text{Log}_{10}(x + dx) - \text{Log}_{10} x \right\} \frac{x}{\text{Modulus}}$ nearly, by which expression the required variations in the foregoing natural numbers have been calculated.

Description of Stations.

SOUTH-WEST-END OF CHACH BASE OR KALU STATION, Lat. 33° 53′, Long. 72° 25′, is situated on the south end of a mound to the S. of the village of that name, in the Chach valley; thana Hazro, pargana Attok, tappa Haveli, tahsil Hassan Abdal, and district Rawul Pindi.

The pillar is solid, and 4·5 feet high. It contains three mark-stones, one at top, another at bottom and the third 2 feet below the former. Of these marks, the one uppermost was used in the measurement of the base-line. The dot in question is on a piece of silver let into a strip of brass, which latter is fixed in the stone. The pillar and mark-stones are protected by a hemispherical dome of masonry, on the key stone of which a mark for ordinary reference will be found; the height of this mark above the base-line dot is 3·54 feet. The pillar is enclosed in a platform of earth-work some 14 feet square.

The South-West-End was connected in 1860, by a double line of spirit levels with the mean sea level at Karáchi, when it was found that the height of the markstone on the dome of masonry was 1018·15 feet above this datum.

NORTH-EAST-END OF CHACH BASE OR AGZAR STATION, Lat. 33° 57′, Long. 72° 32′, is situated on the southern end of a mound in the Chach valley; mouza Agzar, thana Hazro, tappa Sarkani, pargana Attok, tahsil Hassan Abdal, and district Rawul Pindi.

The pillar is solid, and 5·2 feet high. It contains three mark-stones, one at top, another at bottom, and a third 2·8 feet below the former. Of these marks the uppermost one was used in the measurement of the base-line. The dot in question, and the means employed for its protection, are similar to those adopted for the South-West-End of this base. The height of the mark on the dome of masonry is 3·41 feet above the base-line dot. The pillar is enclosed in a platform of earth-work some 14 feet square.

STATION A. Is on the straight line from Kálu Station to Agzar Station, and distant 1·99 miles from the former.

The mark consists of a dot on a brass pin fixed in the head of a stout wooden picket, driven about 5 feet into the ground and projecting 14 inches above the surface. This picket is in the centre of an equilateral triangle formed by 3 other pickets of equal height on which the feet of the theodolite stand rest and the spaces between the pickets are filled up with masonry so as to form a triangular pillar; the latter is isolated from the platform of earth-work, some 14 feet square, in which it is enclosed.

STATION B. Is on the straight line from Kálu Station to Agzar Station, and distant 4·07 miles from the former.

The mark and platform at this station are similar to those at Station A.

STATION C. Is on the straight line from Kálu Station to Agzar Station, and distant 1·94 miles from the latter.

The mark and platform at this station are similar to those at Station A.

AUXILIARY STATIONS α, β, γ, and δ, are situated on suitable swells of land lying to the S.E. of the base-line.

The stations are marked by a central isolated pillar of masonry, surrounded by a platform of stones and earth, about 14 feet square. There are mark-stones at top and bottom of the pillar.

J. B. N. HENNESSEY.

KARACHI BASE-LINE.

The middle point of this base-line is in Latitude N. 24° 56′, Longitude E. 67° 13′; the Azimuth of North-End at South-End is 205° 24′, and the line is 7·32 Miles in length.

The measurement was effected under the supervision of Lieut.-Colonel* A. S. Waugh, R.E. by Major† A. Strange assisted by the following:

Lieut. J. F. Tennant, R.E.
„ D. J. Nasmyth, R.E.
„ T. G. Montgomerie, R.E.
Mr. C. Lane
„ H. Keelan
„ N. A. Belletty
„ C. H. Burt
„ C. J. Carty
„ J. H. Smith
„ J. McGill
Mir Siud Mohsim

* Now General Sir A. S. Waugh.
† Now Colonel A. Strange.

INTRODUCTION.

This base-line was measured East of the town of Karachi in the province of Sind, the South-End of the line being at an azimuth of about 255° from Karachi church and distant from thence 8·2 miles. The line was selected by Mr. W. C. Rossenrode and the preliminary arrangements made by Major A. Strange.

The measurement was commenced at South-End, bar-tongues pointing West, and carried on *continuously* to North-End, so that every succeeding set originated at the point marking the terminus of its predecessor. The line was divided into 4 sections by the sub-dividing points A, B and C, to admit of verification by minor triangulation; and in addition four points, called *Posterity-marks* *a*, *e*, *f*, and *g*, were laid down in the measurement. Of these, *a* was at 10 sets or about 630 feet, *e* at 21 sets or nearly ¼ mile, *f* at 42 sets or some ½ mile and *g* at 84 sets or 1 mile, all reckoned from the South-End. It is also to be noticed that the extremities of the line were connected by means of the triangulation with the tide-gauge set up at Manora point in Karachi harbour, where the mean sea level was determined by Lieutenant J. F. Tennant, R.E.

The compensated bars were compared with the standard **A** on three occasions, *i.e.* before the measurement near South-End, after set No. 306 near Section Station B and after the measurement near North-End. On all these occasions the comparing piers were set up parallel to the line and within a few feet of it, while the bar-tongues pointed West as they did during the measurement. The series of comparisons at South-End comprised 109 sets, that at B consisted of 93 sets and 85 sets were taken at North-End.

One of the comparing microscopes employed in the preceding bar comparisons was fitted with a micrometer, while the other had its wires (or lines) fixed.

The compensated microscopes were compared with their scales on 6 occasions, including the comparisons taken prior and subsequent to the measurement.

In respect to time, the first set of bar comparisons was taken on the 30th November 1854, the last on the 29th of the following January.

The stations of the verificatory triangulation were 9 in number, forming a single series of triangles. Of these stations, 5 were in the alignment, *viz.* South-End, A, B, C and North-End, while the auxiliary stations α, β, γ and δ were placed on suitable sites West of the line. The angles were measured by Lieut. J. F. Tennant, R.E., with Troughton's 3-foot theodolite on 10 equidistant zeros; three measures were made on each zero, so that 30 measures in all were made of each angle.

Comparisons between the Standard Bar* A *and the Compensated Bars* A, B, C, D, E, H, *made at the South-End of the base-line, before the measurement.

1854 Nov. & Dec.	Mean of the times of observing A	No. of comparison	Temperature of Air	Corrected mean temperature of A	Micrometer Readings in Divisions. 1 Division = $\frac{1}{21604 \cdot 10}$ Cary's Inch [7.8], = 1·2851 m.y. of A — Mean A	A	B	C	D	E	H	Mean of the compensated bars	Remarks
	h. m.		°	°	+	+	+	+	+	+	+	+	
30th	7 1 A.M.	1	64·6	63·50	959·5	1089·2	1070·6	1094·5	1125·0	1084·0	1090·1	1092·2	Major Strange at the micrometer microscope; Mr. Keelan at the plain microscope.
	7 24	2	65·3	63·50	963·2	1092·5	1075·0	1097·0	1128·5	1088·9	1089·2	1095·2	
	7 42	3	65·9	63·63	968·4	1098·0	1073·5	1099·0	1128·7	1088·5	1094·9	1097·1	
	7 58	4	66·5	63·83	974·5	1097·5	1076·0	1104·1	1130·5	1096·2	1094·6	1099·8	
	8 15	5	66·9	64·13	980·9	1102·5	1077·9	1104·4	1134·2	1097·2	1096·2	1102·1	
	8 30	6	67·2	64·45	986·0	1101·7	1078·0	1102·7	1134·2	1097·0	1095·2	1101·5	
	8 45	7	68·1	64·80	991·9	1102·6	1079·5	1101·8	1133·2	1099·8	1097·3	1102·4	
	9 0	8	69·3	65·20	998·8	1103·0	1079·3	1104·6	1133·9	1098·5	1098·3	1102·9	
	9 16	9	69·7	65·65	1008·6	1104·2	1081·0	1107·5	1138·5	1103·4	1099·0	1105·6	Sky obscured by dense clouds. Sharp wind from N.E.
	9 31	10	69·4	66·20	1018·4	1106·5	1084·5	1107·5	1137·6	1103·0	1102·5	1106·9	
	11 4	11	72·3	68·25	1051·0	1104·3	1078·8	1114·0	1146·0	1102·9	1098·8	1107·5	
	11 21	12	73·5	68·80	1062·8	1104·2	1080·5	1118·5	1141·6	1100·9	1094·6	1106·7	
	11 32	13	74·2	69·35	1071·1	1107·0	1079·0	1115·6	1143·5	1101·9	1096·1	1107·2	
	11 46	14	74·0	69·90	1080·1	1105·2	1081·0	1118·4	1143·7	1102·9	1097·3	1108·1	
	0 3 P.M.	15	74·1	70·43	1089·2	1108·0	1081·5	1119·5	1145·2	1104·4	1098·4	1109·5	
	0 18	16	74·4	70·85	1096·6	1110·0	1083·8	1114·3	1144·9	1104·0	1097·0	1109·0	
	0 32	17	74·9	71·23	1104·3	1108·9	1083·0	1117·3	1143·6	1104·2	1098·0	1109·2	
	0 46	18	75·4	71·68	1111·4	1109·8	1085·8	1119·6	1148·0	1105·8	1100·0	1111·5	
	0 59	19	75·8	72·00	1116·9	1109·5	1084·2	1115·6	1144·9	1106·0	1099·7	1110·0	
	1 13	20	76·1	72·33	1123·9	1108·0	1083·0	1115·0	1146·5	1107·4	1100·3	1110·0	
	1 26	21	76·4	72·78	1130·5	1111·0	1084·7	1116·2	1146·6	1107·9	1101·9	1111·4	
	1 50	22	76·0	73·43	1139·3	1113·1	1087·1	1120·7	1149·6	1107·6	1103·8	1113·7	
	2 4	23	75·7	73·78	1144·7	1112·5	1089·1	1122·5	1152·0	1111·5	1104·0	1115·3	
	2 20	24	75·3	74·08	1148·5	1113·7	1087·8	1124·0	1152·7	1111·7	1105·4	1115·9	
	2 36	25	75·1	74·20	1150·5	1114·7	1091·0	1126·9	1152·0	1113·4	1103·0	1116·8	
	2 51	26	75·2	74·28	1152·0	1113·0	1089·6	1122·6	1151·8	1108·2	1100·6	1114·3	Sunshine and clouds alternating throughout the afternoon.
	3 8	27	74·8	74·28	1155·2	1112·8	1090·5	1124·7	1149·2	1108·8	1103·2	1114·9	
	3 23	28	74·4	74·35	1156·1	1109·2	1089·0	1120·2	1149·2	1107·7	1102·6	1113·0	
1st	6 39 A.M.	29	56·1	56·78	866·3	1114·0	1090·8	1109·7	1139·2	1099·2	1112·8	1111·0	Lt. Montgomerie at the micrometer microscope; Lieut. Nasmyth at the plain microscope.
	7 24	30	59·8	56·63	867·4	1114·5	1088·0	1108·6	1137·8	1099·9	1107·7	1109·4	
	8 0	31	64·7	57·43	885·4	1110·6	1083·6	1108·8	1138·0	1102·9	1101·9	1107·6	
	8 25	32	68·4	58·78	908·5	1106·4	1081·2	1108·4	1138·0	1099·4	1099·9	1105·6	
	8 44	33	71·2	60·30	938·3	1104·0	1075·1	1106·8	1135·6	1100·2	1099·8	1103·6	
	9 14	34	74·1	62·68	981·5	1108·7	1076·7	1110·8	1138·3	1103·6	1100·6	1106·5	
	9 34	35	76·1	64·65	1016·6	1105·1	1080·4	1110·2	1141·8	1104·4	1101·1	1107·2	
	9 56	36	77·6	66·43	1048·0	1104·6	1079·4	1112·9	1143·2	1104·0	1100·4	1107·4	
	11 35	37	79·0	73·65	1170·1	1115·2	1092·0	1156·7	1164·0	1117·0	1100·8	1124·3	
	11 55	38	78·1	74·58	1186·4	1116·9	1094·6	1158·6	1169·0	1122·2	1105·1	1127·7	Sunshine with occasional clouds.
	0 16 P.M.	39	77·0	75·15	1196·7	1121·2	1098·4	1159·7	1172·0	1127·2	1107·7	1131·0	
	0 36	40	77·7	75·55	1202·5	1127·8	1103·7	1157·2	1175·0	1129·9	1116·9	1135·1	
	0 56	41	78·9	75·93	1209·2	1124·7	1107·0	1154·6	1176·2	1131·8	1121·1	1135·9	
	1 16	42	79·1	76·33	1220·8	1135·1	1113·8	1158·6	1178·2	1136·8	1130·2	1142·1	

Before the measurement—(Continued.)

1854 Dec.	Mean of the times of observing A	No. of comparison	Temperature of Air	Corrected mean temperature of A	Micrometer Readings in Divisions (1 Division = $\frac{1}{21604 \cdot 10}$ Cary's Inch [7.8], = 1·2851 *m.y.* of A) Mean A	A	B	C	D	E	H	Mean of the compensated bars	Remarks
	h. m.		°	°	+	+	+	+	+	+	+	+	
1st	1 39 P.M.	43	79.6	76.90	1231.7	1144.6	1116.4	1157.2	1178.6	1139.8	1134.9	1145.3	
	1 59	44	79.4	77.35	1242.0	1142.1	1122.6	1160.3	1182.2	1147.4	1138.2	1148.8	
	2 19	45	79.3	77.80	1248.9	1146.2	1121.2	1158.8	1180.2	1143.2	1135.8	1147.6	
	2 46	46	78.8	78.18	1256.3	1144.9	1122.6	1163.4	1189.2	1145.0	1136.7	1150.3	
	3 6	47	78.2	78.28	1261.1	1145.7	1128.1	1163.0	1192.7	1149.0	1141.3	1153.3	
	3 26	48	77.9	78.30	1260.2	1151.6	1124.7	1159.0	1186.1	1150.9	1140.8	1152.2	
2nd	6 40 A.M.	49	58.7	59.73	932.7	1129.4	1106.8	1132.1	1149.8	1116.7	1130.5	1127.6	Major Strange at the micrometer microscope; Mr. Keelan at the plain microscope.
	6 55	50	59.8	59.50	930.1	1133.1	1106.0	1126.0	1153.6	1119.8	1127.4	1127.7	
	7 8	51	61.0	59.48	928.0	1131.0	1104.9	1129.5	1150.9	1118.9	1126.9	1127.0	
	7 19	52	62.3	59.50	929.1	1132.0	1105.0	1126.9	1152.8	1120.6	1126.7	1127.3	
	7 30	53	63.4	59.60	932.4	1128.9	1105.1	1126.8	1154.1	1117.9	1125.1	1126.3	
	7 42	54	64.6	59.85	937.7	1125.2	1101.0	1126.1	1153.0	1116.4	1120.2	1123.7	
	7 58	55	66.5	60.33	947.8	1125.5	1101.7	1123.8	1149.0	1117.3	1120.5	1123.0	
	8 10	56	67.9	60.75	958.6	1124.1	1097.8	1123.6	1148.5	1115.7	1120.4	1121.7	
	8 23	57	69.9	61.38	970.7	1122.5	1096.4	1121.7	1149.8	1118.5	1118.8	1121.3	
	8 35	58	71.6	62.03	983.6	1124.0	1096.9	1122.0	1155.2	1117.6	1119.6	1122.6	
	8 46	59	72.8	62.80	997.3	1121.9	1097.0	1124.1	1154.5	1115.8	1117.5	1121.8	
	8 59	60	74.3	63.80	1015.3	1122.2	1095.9	1122.3	1154.7	1116.8	1115.1	1121.2	
	9 10	61	75.6	64.78	1033.2	1122.5	1094.5	1123.5	1154.0	1119.2	1115.8	1121.6	
	9 21	62	76.6	65.65	1050.4	1119.5	1094.9	1124.1	1157.0	1120.1	1116.9	1122.1	
	9 32	63	77.5	66.50	1067.3	1121.0	1096.1	1125.3	1154.8	1120.7	1119.0	1122.8	
	9 42	64	78.2	67.33	1083.1	1121.8	1097.1	1130.5	1160.9	1124.8	1120.3	1125.9	
	9 52	65	78.6	68.18	1098.8	1123.5	1095.0	1128.0	1157.9	1124.9	1120.6	1125.0	
	11 15	66	79.7	74.08	1207.4	1144.0	1120.3	1176.2	1185.8	1135.9	1128.9	1148.5	Sea breeze set in from the S.W.
	11 25	67	79.8	74.63	1217.7	1146.0	1124.5	1179.5	1183.7	1140.5	1132.0	1151.0	
	11 35	68	79.8	75.05	1225.9	1145.9	1125.6	1179.2	1186.3	1144.7	1133.0	1152.5	
	11 45	69	79.8	75.48	1234.1	1149.5	1126.4	1178.0	1191.4	1150.5	1136.1	1155.3	
	11 56	70	79.8	75.90	1243.4	1156.9	1130.4	1179.4	1191.8	1148.8	1140.1	1157.9	
	0 6 P.M.	71	79.9	76.25	1249.6	1157.3	1133.3	1183.6	1193.5	1153.5	1144.0	1160.9	
	0 15	72	79.9	76.63	1255.4	1159.4	1137.2	1181.1	1196.5	1156.1	1147.0	1162.9	
	0 26	73	79.8	76.98	1262.0	1161.4	1138.8	1180.1	1198.2	1160.4	1151.3	1165.0	
	0 37	74	79.9	77.28	1267.4	1162.7	1140.5	1181.8	1199.9	1160.0	1153.8	1166.5	
	0 49	75	80.0	77.55	1272.4	1169.0	1141.8	1185.4	1198.9	1163.0	1156.5	1169.1	
	1 0	76	80.6	77.83	1276.4	1168.5	1139.9	1182.1	1203.6	1164.6	1159.6	1169.7	
	1 15	77	80.4	78.18	1287.6	1167.6	1145.7	1186.1	1209.2	1168.0	1162.3	1173.2	
	1 25	78	80.8	78.48	1291.5	1172.5	1146.8	1187.2	1207.0	1171.1	1161.2	1174.3	
	1 35	79	80.9	78.70	1294.7	1171.9	1147.0	1185.4	1212.0	1170.0	1162.2	1174.8	
	1 44	80	81.0	78.90	1297.4	1172.6	1149.1	1186.2	1209.8	1172.5	1164.5	1175.8	
	1 53	81	81.0	79.08	1302.1	1174.8	1150.1	1187.0	1213.7	1173.5	1164.6	1177.3	
	2 3	82	81.0	79.23	1306.2	1176.6	1153.7	1190.5	1213.0	1175.0	1166.5	1179.2	
	2 13	83	81.1	79.43	1309.5	1179.1	1154.2	1191.5	1216.3	1176.2	1167.4	1180.8	
	2 22	84	81.0	79.58	1311.4	1179.2	1152.1	1191.1	1217.0	1177.8	1170.2	1181.2	

Before the measurement—(Continued.)

1854 Decr.	Mean of the times of observing A	No. of comparison	Temperature of Air	Corrected mean temperature of A	Micrometer Readings in Divisions 1 Division = $\frac{1}{21604 \cdot 10}$ Cary's Inch [7.8], = 1·2851 *m.y.* of A Mean A	A	B	C	D	E	H	Mean of the compensated bars	Remarks
	h. m.		°	°	+	+	+	+	+	+	+	+	
2nd	2 32 P.M.	85	80·9	79·68	1313·4	1180·7	1156·8	1192·8	1216·8	1178·9	1173·4	1183·2	
	2 41	86	80·9	79·78	1317·1	1182·5	1154·2	1191·8	1221·2	1180·3	1171·2	1183·5	
	2 50	87	80·8	79·83	1319·2	1182·2	1159·0	1195·2	1221·5	1183·3	1172·0	1185·5	
	3 0	88	80·6	79·88	1319·8	1180·5	1157·0	1191·3	1222·1	1180·7	1174·1	1184·3	
	3 11	89	80·5	79·93	1320·9	1184·8	1160·8	1193·5	1221·5	1184·0	1177·0	1186·9	
	3 21	90	80·3	79·98	1321·1	1183·2	1160·0	1197·2	1220·9	1182·2	1175·2	1186·5	
4th	6 34 A.M.	91	58·0	58·55	958·0	1169·9	1146·6	1167·8	1199·0	1164·7	1172·9	1170·2	Lieut. Tennant at the micrometer microscope; Mr. Lane at the plain microscope.
	7 4	92	60·2	58·48	957·5	1175·0	1149·8	1172·8	1195·9	1162·9	1167·1	1170·6	
	7 29	93	63·7	58·68	965·3	1171·6	1145·7	1171·9	1196·1	1157·8	1165·4	1168·1	
	7 53	94	66·3	59·68	983·0	1170·6	1143·1	1169·7	1194·3	1160·0	1163·6	1166·9	
	8 17	95	69·2	61·23	1006·9	1166·5	1140·3	1165·4	1193·8	1158·6	1157·7	1163·7	
	8 45	96	71·5	63·05	1043·8	1163·1	1139·3	1169·2	1195·6	1163·3	1159·1	1164·9	
	9 5	97	72·9	64·33	1066·4	1161·4	1136·4	1168·0	1189·9	1159·2	1156·4	1161·9	
	9 24	98	74·4	65·63	1088·0	1164·4	1133·6	1168·2	1194·3	1160·8	1158·6	1163·3	
	9 45	99	75·4	67·05	1110·7	1163·8	1134·9	1171·7	1196·4	1162·3	1155·6	1164·1	
	11 24	100	79·1	72·45	1204·7	1178·4	1148·5	1191·7	1210·6	1175·1	1167·8	1178·7	
	0 0 P.M.	101	79·8	73·63	1228·3	1177·8	1149·1	1193·7	1210·6	1179·3	1170·6	1180·2	
	0 33	102	80·0	74·78	1252·3	1178·1	1153·6	1197·3	1213·6	1178·8	1171·2	1182·1	
	0 56	103	80·4	75·78	1269·4	1181·9	1155·2	1195·8	1217·0	1180·6	1172·7	1183·9	
	1 44	104	80·1	77·38	1295·3	1189·0	1165·2	1204·0	1225·5	1190·3	1178·8	1192·1	
	2 4	105	80·1	77·93	1303·8	1188·2	1166·5	1203·8	1225·4	1192·0	1183·0	1193·2	
	2 26	106	80·1	78·23	1310·6	1195·0	1170·8	1207·6	1229·6	1196·4	1189·8	1198·2	
	2 49	107	79·8	78·45	1315·1	1196·4	1173·0	1208·3	1235·8	1199·6	1190·0	1200·5	
	3 10	108	79·3	78·68	1317·9	1200·2	1177·4	1212·8	1234·4	1201·0	1196·4	1203·7	
	3 31	109	78·5	78·85	1318·8	1204·3	1180·8	1214·1	1242·9	1202·3	1196·9	1206·9	
		Means		70·41	1127·96	1139·35	1114·79	1149·50	1174·25	1136·20	1131·88	1141·00	

Before the measurement—(Continued.)

Let the mean length of the compensated bars minus the Standard **A** at 62° F be denoted by x, and the observed excess of the compensated bars by δ when the temperature of **A** is $t°$. Then, the expansion of **A** for 1° being $(E_a - dE_a)$, we have

$$x - (t° - 62°)(E_a - dE_a) - \delta = 0;$$

Treating the preceding bar comparisons as shewn in this equation, we obtain the following series of results:—

		d			d
$x-$ 1·50	$(E_a - dE_a)$	−132·7 = 0	$x+$ 5·37	$(E_a - dE_a)$	−242·0 = 0
$x-$ 1·50	„	−132·0 = 0	$x+$ 4·57	„	−222·2 = 0
$x-$ 1·63	„	−128·7 = 0	$x+$ 3·22	„	−197·1 = 0
$x-$ 1·83	„	−125·3 = 0	$x+$ 1·70	„	−165·3 = 0
$x-$ 2·13	„	−121·2 = 0	$x-$ 0·68	„	−125·0 = 0
$x-$ 2·45	„	−115·5 = 0	$x-$ 2·65	„	− 90·6 = 0
$x-$ 2·80	„	−110·5 = 0	$x-$ 4·43	„	− 59·4 = 0
$x-$ 3·20	„	−104·1 = 0	$x-$11·65	„	+ 45·8 = 0
$x-$ 3·65	„	− 97·0 = 0	$x-$12·58	„	+ 58·7 = 0
$x-$ 4·20	„	− 88·5 = 0	$x-$13·15	„	+ 65·7 = 0
$x-$ 6·25	„	− 56·5 = 0	$x-$13·55	„	+ 67·4 = 0
$x-$ 6·80	„	− 43·9 = 0	$x-$13·93	„	+ 73·3 = 0
$x-$ 7·35	„	− 36·1 = 0	$x-$14·33	„	+ 78·7 = 0
$x-$ 7·90	„	− 28·0 = 0	$x-$14·90	„	+ 86·4 = 0
$x-$ 8·43	„	− 20·3 = 0	$x-$15·35	„	+ 93·2 = 0
$x-$ 8·85	„	− 12·4 = 0	$x-$15·80	„	+101·3 = 0
$x-$ 9·23	„	− 4·9 = 0	$x-$16·18	„	+106·0 = 0
$x-$ 9·68	„	− 0·1 = 0	$x-$16·28	„	+107·8 = 0
$x-$10·00	„	+ 6·9 = 0	$x-$16·30	„	+108·0 = 0
$x-$10·33	„	+ 13·9 = 0	$x+$ 2·27	„	−194·9 = 0
$x-$10·78	„	+ 19·1 = 0	$x+$ 2·50	„	−197·6 = 0
$x-$11·43	„	+ 25·6 = 0	$x+$ 2·52	„	−199·0 = 0
$x-$11·78	„	+ 29·4 = 0	$x+$ 2·50	„	−198·2 = 0
$x-$12·08	„	+ 32·6 = 0	$x+$ 2·40	„	−193·9 = 0
$x-$12·20	„	+ 33·7 = 0	$x+$ 2·15	„	−186·0 = 0
$x-$12·28	„	+ 37·7 = 0	$x+$ 1·67	„	−175·2 = 0
$x-$12·28	„	+ 40·3 = 0	$x+$ 1·25	„	−163·1 = 0
$x-$12·35	„	+ 43·1 = 0	$x+$ 0·62	„	−150·6 = 0
$x+$ 5·22	„	−244·7 = 0	$x-$ 0·03	„	−139·0 = 0

Before the measurement—(Continued.)

		d
$x - 0.80$	$(E_a - dE_a)$	$-124.5 = 0$
$x - 1.80$	"	$-105.9 = 0$
$x - 2.78$	"	$-88.4 = 0$
$x - 3.65$	"	$-71.7 = 0$
$x - 4.50$	"	$-55.5 = 0$
$x - 5.33$	"	$-42.8 = 0$
$x - 6.18$	"	$-26.2 = 0$
$x - 12.08$	"	$+58.9 = 0$
$x - 12.63$	"	$+66.7 = 0$
$x - 13.05$	"	$+73.4 = 0$
$x - 13.48$	"	$+78.8 = 0$
$x - 13.90$	"	$+85.5 = 0$
$x - 14.25$	"	$+88.7 = 0$
$x - 14.63$	"	$+92.5 = 0$
$x - 14.98$	"	$+97.0 = 0$
$x - 15.28$	"	$+100.9 = 0$
$x - 15.55$	"	$+103.3 = 0$
$x - 15.83$	"	$+106.7 = 0$
$x - 16.18$	"	$+114.4 = 0$
$x - 16.48$	"	$+117.2 = 0$
$x - 16.70$	"	$+119.9 = 0$
$x - 16.90$	"	$+121.6 = 0$
$x - 17.08$	"	$+124.8 = 0$
$x - 17.23$	"	$+127.0 = 0$
$x - 17.43$	"	$+128.7 = 0$
$x - 17.58$	"	$+130.2 = 0$

		d
$x - 17.68$	$(E_a - dE_a)$	$+130.2 = 0$
$x - 17.78$	"	$+133.6 = 0$
$x - 17.83$	"	$-133.7 = 0$
$x - 17.88$	"	$+135.5 = 0$
$x - 17.93$	"	$+134.0 = 0$
$x - 17.98$	"	$+134.6 = 0$
$x + 3.45$	"	$-212.2 = 0$
$x + 3.52$	"	$-213.1 = 0$
$x + 3.32$	"	$-202.8 = 0$
$x + 2.32$	"	$-183.9 = 0$
$x + 0.77$	"	$-156.8 = 0$
$x - 1.05$	"	$-121.1 = 0$
$x - 2.33$	"	$-95.5 = 0$
$x - 3.63$	"	$-75.3 = 0$
$x - 5.05$	"	$-53.4 = 0$
$x - 10.45$	"	$+26.0 = 0$
$x - 11.63$	"	$+48.1 = 0$
$x - 12.78$	"	$+70.2 = 0$
$x - 13.78$	"	$+85.5 = 0$
$x - 15.38$	"	$+103.2 = 0$
$x - 15.93$	"	$+110.6 = 0$
$x - 16.23$	"	$+112.4 = 0$
$x - 16.45$	"	$+114.6 = 0$
$x - 16.68$	"	$+114.2 = 0$
$x - 16.85$	"	$+111.9 = 0$

Before the measurement—(Continued.)

And from the mean of these results,

$$x = \overset{d}{13{\cdot}04} + 8{\cdot}41\,(E_a - dE_a):$$

adopting the approximate value of the expansion of **A** given at page (9),

$$E_a = \overset{m.y}{22{\cdot}67} = \overset{d}{17{\cdot}641},$$

$$\text{and } x = \overset{d}{161{\cdot}40} - 8{\cdot}41\,dE_a = \overset{m.y}{207{\cdot}42} - 8{\cdot}41\,dE_a = \text{L} - \mathbf{A};$$

where L denotes the mean length of the compensated bars obtained from *all* the comparisons, as represented by the mean micrometer reading $\overset{d}{1141{\cdot}00}$, page VII—6.

Comparing this reading with the mean reading of each compensated bar given on the same page we obtain the following:—

In terms of	A − L	B − L	C − L	D − L	E − L	H − L
Micrometer divisions.	−1·65	−26·21	+ 8·50	+33·25	−4·80	− 9·12
Millionths of a yard.	−2·12	−33·68	+10·92	+42·73	−6·17	−11·72

Also combining the values in this table with the equivalent of L—**A** above determined, there result,

$$\begin{aligned}
\text{A} - \mathbf{A} &= \overset{d}{159{\cdot}75} - 8{\cdot}41\,dE_a = \overset{m.y}{205{\cdot}30} - 8{\cdot}41\,dE_a\\
\text{B} - \mathbf{A} &= 135{\cdot}19 - \quad ,, \quad = 173{\cdot}74 - \quad ,,\\
\text{C} - \mathbf{A} &= 169{\cdot}90 - \quad ,, \quad = 218{\cdot}34 - \quad ,,\\
\text{D} - \mathbf{A} &= 194{\cdot}65 - \quad ,, \quad = 250{\cdot}15 - \quad ,,\\
\text{E} - \mathbf{A} &= 156{\cdot}60 - \quad ,, \quad = 201{\cdot}25 - \quad ,,\\
\text{H} - \mathbf{A} &= 152{\cdot}28 - \quad ,, \quad = 195{\cdot}70 - \quad ,,
\end{aligned}$$

$$\text{and } 6\,x = \overset{m.y}{1244{\cdot}5} - 50{\cdot}5\,dE_a.$$

***Comparisons between the Standard Bar* A *and the Compensated Bars* A, B, C, D, E, H, *made on a site selected at the centre of the base-line, after set No.* 306.**

1855 Jany.	Mean of the times of observing A	No. of comparison	Temperature of Air	Corrected mean temperature of A	Micrometer Readings in Divisions (1 Division = $\frac{1}{21590\cdot30}$ Cary's Inch [7.8], = 1·2859 m.y. of A) Mean A	A	B	C	D	E	H	Mean of the compensated bars	Remarks
	h. m.		°	°	+	+	+	+	+	+	+	+	
2nd	7 12 A.M.	1	55·3	54·45	862·1	1151·2	1122·4	1140·0	1171·0	1132·3	1143·9	1143·5	Lieut. Tennant at the micrometer microscope: Mr. Lane at the plain microscope.
	7 42	2	58·2	54·55	863·8	1148·4	1121·3	1141·2	1169·7	1133·4	1144·8	1143·1	
	8 9	3	61·0	55·18	873·5	1139·6	1112·5	1132·8	1160·5	1125·8	1136·0	1134·5	
	8 34	4	64·5	56·28	895·2	1139·3	1110·8	1135·3	1166·2	1127·7	1133·6	1135·5	
	9 7	5	69·3	58·45	935·7	1133·8	1105·8	1135·8	1164·0	1129·7	1128·2	1132·9	
	9 32	6	71·7	60·48	971·8	1132·9	1104·6	1134·6	1163·3	1125·0	1128·3	1131·5	Cold wind from N. till 10 o'clock A.M.
	9 54	7	73·6	62·40	1004·5	1132·8	1099·0	1134·8	1164·8	1131·7	1127·3	1131·7	
	11 3	8	78·3	68·60	1100·3	1113·3	1087·2	1135·3	1157·7	1122 3	1110·1	1121·0	
	11 21	9	79·0	70·10	1126·1	1111·1	1082·7	1136·3	1158·7	1125·0	1111·6	1120·9	
	11 41	10	79·9	71·43	1151·0	1114·7	1087·1	1137·6	1163·8	1125·7	1114·4	1123·9	
	0 5 P.M.	11	80·6	72·83	1176·3	1113·4	1087·7	1140·3	1164·2	1125·6	1118·0	1124·9	
	0 29	12	81·1	74·23	1200·0	1124·4	1095·9	1144·0	1167·7	1131·7	1124·4	1131·4	
	0 51	13	81·6	75·33	1218·8	1127·7	1105·7	1149·6	1169·6	1137·2	1126·9	1136·1	
	1 13	14	82·1	76·23	1235·5	1130·4	1108·6	1153·7	1177·1	1139·4	1130·8	1140·0	
	1 42	15	82·4	77·30	1254·9	1142·0	1116·8	1159·5	1183·6	1145·9	1138·0	1147·6	
	2 4	16	82·2	78·13	1268·5	1147·3	1118·4	1162·3	1188·4	1147·4	1140·0	1150·6	
	2 30	17	81·7	78 83	1278·8	1148·9	1123·5	1162·2	1191·0	1154·1	1143·9	1153·9	
	2 57	18	81·4	79·28	1286·2	1154·6	1126·7	1169·4	1191·7	1155·4	1150·9	1158·1	Light clouds during the afternoon.
	3 24	19	80·4	79·53	1289·9	1157·3	1134·6	1171·8	1197·7	1160·0	1150·9	1162·1	
3rd	7 5 A.M.	20	56·0	58·20	915·5	1136·2	1117·6	1133·2	1166·1	1131·5	1141·3	1137·7	Major Strange at the micrometer microscope: Mr. Lane at the plain microscope.
	7 24	21	56·4	57·83	908·7	1144·8	1118·8	1137·0	1163·6	1128·9	1138·9	1138·7	
	7 40	22	57·0	57·58	906·2	1143·2	1115·3	1134·1	1164·1	1130·7	1142·4	1138·3	
	7 56	23	58·0	57·48	906·7	1140·7	1117·8	1134·0	1163·8	1129·6	1139·9	1137·6	
	8 14	24	59·3	57·45	907·4	1142·4	1116·5	1133·1	1164·8	1130·0	1137·2	1137·3	
	8 40	25	61·3	57·73	915·4	1141·3	1114·1	1134·6	1161·8	1129·0	1135·0	1136·0	
	9 3	26	63·1	58·30	926·5	1144·4	1111·9	1135·4	1163·3	1131·0	1135·9	1137·0	
	9 23	27	64·5	58·95	938·5	1139·8	1112·5	1134·8	1162·6	1133·7	1134·9	1136·4	
	9 40	28	65·5	59·68	951·1	1138·0	1110·7	1137·5	1164·2	1133·8	1134·5	1136·5	
	9 56	29	66·5	60·30	961·4	1136·8	1110·3	1137·0	1161·8	1131·0	1133·0	1135·0	
	11 16	30	70·7	64·25	1028·5	1132·0	1103·3	1143·8	1162·6	1128·3	1124·6	1132·4	
	11 34	31	71·9	65·28	1048·5	1133·0	1105·4	1144·5	1166·0	1130·5	1126·0	1134·2	
	11 55	32	73·0	66·35	1068·5	1133·5	1110·0	1144·4	1167·9	1133·7	1127·3	1136·1	
	0 12 P.M.	33	73·9	67·20	1084·3	1135·9	1110·4	1145·4	1167·7	1134·5	1130·8	1137·5	
	0 30	34	74·8	68·15	1101·3	1134·8	1110·9	1144·3	1167·5	1138·0	1130·8	1137·7	
	0 42	35	75·3	69·10	1117·2	1135·5	1113·0	1147·6	1169·0	1139·9	1131·2	1139·4	
	0 58	36	75·7	69·98	1130·9	1138·9	1114·1	1147·3	1170·5	1141·9	1131·7	1140·7	
	1 34	37	76·6	71·43	1155·3	1141·0	1115·5	1153·3	1175·5	1144·0	1136·4	1144·3	
	1 49	38	77·0	72·10	1168·5	1142·9	1116·0	1156·4	1178·0	1144·8	1137·2	1145·9	
	2 5	39	77·2	72·70	1178·9	1144·9	1119·8	1159·7	1180·9	1152·1	1138·0	1149·2	
	2 19	40	77·3	73·25	1186·7	1147·4	1120·3	1159·7	1182·5	1149·6	1142·0	1150·3	
	2 33	41	77·5	73·68	1195·5	1151·2	1125·5	1161·8	1186·6	1152·8	1145·8	1154·0	
	2 48	42	77·4	74·18	1204·9	1152·0	1129·0	1164·8	1189·6	1155·0	1147·1	1156·3	
	3 3	43	77·2	74·68	1212·3	1155·9	1130·1	1166·9	1191·4	1156·2	1149·3	1158·3	
	3 20	44	77·2	74·93	1218·1	1159·3	1128·5	1169·1	1193·5	1160·7	1150·7	1160·3	
	3 37	45	77·1	75·28	1223·9	1160·0	1132·8	1171·9	1195·8	1159·0	1153·0	1162·1	

January 2nd. Rained this evening.

After set No. 306—(Continued.)

1855 Jany.	Mean of the times of observing A	No. of comparison	Temperature of Air	Corrected mean temperature of A	Mean A	A	B	C	D	E	H	Mean of the compensated bars	Remarks
					Micrometer Readings in Divisions. 1 Division = $\frac{1}{21590\cdot30}$ Cary's Inch [7.8], = 1·2859 m.y. of A								
	h. m.		°	°	+	+	+	+	+	+	+	+	
6th	7 21 A.M.	46	56·2	57·45	919·8	1139·1	1134·0	1146·4	1173·7	1139·4	1152·3	1147·5	Lieut. Tennant at the micrometer microscope: Mr. Lane at the plain microscope.
	7 51	47	58·3	57·15	915·6	1136·7	1127·4	1142·8	1170·8	1138·1	1147·7	1143·9	
	8 15	48	61·1	57·28	921·7	1136·5	1127·3	1141·2	1169·3	1134·3	1146·5	1142·5	
	8 40	49	64·8	57·95	936·6	1135·8	1125·1	1141·9	1171·4	1137·3	1145·6	1142·9	
	9 7	50	68·3	59·38	961·9	1131·7	1121·5	1142·3	1169·0	1133·6	1143·0	1140·2	
	9 27	51	70·3	60·73	986·9	1131·0	1119·4	1142·0	1169·7	1135·0	1140·6	1139·6	
	9 47	52	71·8	62·13	1011·5	1128·1	1119·9	1144·8	1168·9	1139·1	1138·1	1139·8	
	11 6	53	75·8	67·93	1112·5	1132·6	1120·1	1161·4	1181·4	1145·2	1136·7	1146·2	
	11 26	54	76·9	69·20	1131·8	1137·7	1122·4	1161·6	1185·6	1146·1	1139·0	1148·7	
	11 43	55	77·4	70·25	1150·7	1138·7	1124·1	1164·1	1185·6	1149·7	1143·2	1150·9	
	0 4 P.M.	56	78·1	71·30	1170·6	1139·9	1128·3	1169·7	1187·4	1156·6	1150·7	1155·4	
	0 28	57	78·6	72·23	1188·7	1145·9	1132·3	1171·9	1191·8	1160·5	1152·4	1159·1	
	0 50	58	78·9	73·13	1205·4	1152·8	1136·9	1178·6	1198·0	1163·4	1156·2	1164·3	
	1 8	59	79·1	73·95	1219·7	1157·2	1142·1	1181·5	1198·3	1167·9	1159·8	1167·8	
	1 37	60	79·0	74·93	1235·6	1162·4	1147·8	1186·2	1203·5	1172·6	1164·7	1172·9	
	2 0	61	78·7	75·48	1245·7	1159·8	1149·8	1189·7	1209·2	1170·9	1168·2	1174·6	
	2 20	62	78·3	75·98	1253·7	1165·1	1151·0	1192·2	1210·5	1177·3	1169·1	1177·5	
	2 40	63	77·6	76·40	1258·8	1171·4	1158·2	1194·2	1214·9	1179·6	1175·5	1182·3	
	2 58	64	76·8	76·55	1262·3	1174·4	1161·8	1199·3	1217·0	1180·3	1175·2	1184·7	
	3 16	65	77·0	76·65	1259·9	1177·0	1161·3	1190·0	1209·7	1171·7	1165·4	1179·2	
9th	7 11 A.M.	66	56·7	58·88	956·9	1153·2	1146·3	1163·1	1185·8	1153·2	1164·0	1160·9	Major Strange at the micrometer microscope; Mr. Lane at the plain microscope.
	7 28	67	56·9	58·58	951·9	1150·9	1146·5	1160·3	1189·0	1151·8	1163·8	1160·4	
	7 42	68	57·3	58·43	948·0	1151·8	1143·6	1160·4	1189·0	1152·3	1163·0	1160·0	
	7 57	69	57·9	58·28	945·1	1151·1	1144·8	1163·6	1188·3	1151·1	1164·0	1160·5	
	8 12	70	58·7	58·23	944·0	1152·2	1142·9	1163·5	1191·2	1154·0	1162·9	1161·1	
	8 28	71	59·6	58·28	946·0	1152·3	1144·8	1165·5	1191·6	1150·6	1163·2	1161·3	
	8 50	72	60·6	58·35	950·5	1149·5	1142·6	1163·2	1190·7	1153·0	1161·0	1160·0	
	9 7	73	61·3	58·58	955·5	1151·8	1142·3	1164·4	1188·8	1150·1	1161·9	1159·9	
	9 21	74	61·9	58·90	961·8	1148·5	1140·8	1164·0	1192·0	1151·8	1162·8	1160·0	
	9 36	75	62·6	59·23	968·8	1151·1	1144·6	1167·2	1193·0	1155·3	1161·2	1162·1	
	9 52	76	63·3	59·68	975·7	1151·6	1143·6	1166·1	1189·6	1156·0	1160·2	1161·2	
	11 22	77	65·6	62·13	1015·7	1148·5	1138·0	1170·0	1194·2	1155·3	1158·7	1160·8	
	11 35	78	65·6	62·43	1021·5	1148·8	1141·1	1167·9	1196·9	1154·9	1162·0	1161·9	
	11 48	79	65·9	62·63	1025·1	1151·0	1136·3	1171·8	1195·0	1156·4	1159·7	1161·7	
	0 1 P.M.	80	66·1	62·95	1030·6	1146·9	1140·3	1168·0	1197·9	1159·2	1162·8	1162·5	
	0 14	81	66·3	63·25	1036·0	1147·2	1138·9	1169·7	1196·0	1157·3	1163·4	1162·1	
	0 25	82	66·6	63·53	1041·3	1151·5	1140·8	1170·1	1195·2	1158·9	1163·1	1163·3	
	0 40	83	66·9	63·80	1045·8	1151·8	1142·2	1171·7	1196·2	1162·0	1164·8	1164·8	
	0 56	84	66·9	64·08	1051·5	1150·0	1141·6	1172·0	1196·5	1164·0	1164·6	1164·8	
	1 12	85	67·0	64·38	1057·1	1155·7	1143·5	1174·4	1197·2	1164·5	1165·8	1166·9	
	1 41	86	67·5	64·95	1064·0	1156·3	1148·6	1177·1	1201·6	1163·5	1169·8	1169·5	
	1 55	87	67·8	65·25	1068·6	1157·7	1147·7	1178·5	1203·6	1168·2	1169·2	1170·8	
	2 9	88	67·9	65·53	1073·2	1158·5	1146·7	1179·8	1205·2	1167·3	1168·2	1171·0	
	2 23	89	67·8	65·70	1078·0	1163·7	1149·8	1181·0	1209·0	1169·9	1171·2	1174·1	
	2 38	90	67·8	65·88	1084·1	1163·0	1152·6	1183·8	1205·5	1171·3	1170·7	1174·5	
	2 53	91	67·9	66·15	1087·4	1162·3	1153·3	1182·8	1207·9	1172·7	1173·2	1175·4	
	3 12	92	68·1	66·43	1090·7	1167·0	1155·1	1184·7	1209·5	1172·5	1173·2	1177·0	
	3 30	93	68·1	66·60	1095·6	1170·9	1154·5	1186·8	1211·7	1172·7	1174·6	1178·5	
		Means		65·88	1068·53	1145·67	1127·38	1158·51	1183·29	1148·11	1148·06	1151·84	

January 8th. Rained heavily this morning.

After set No. 306—(Continued.)

As on page VII—7 we have

$$x - (t^\circ - 62^\circ)\,(E_a - dE_a) - \delta = 0;$$

and from the preceding bar comparisons we obtain the following series of results:—

		d			d
$x + 7.55$	$(E_a - dE_a)$	$-281.4 = 0$	$x - 6.15$	$(E_a - dE_a)$	$-36.4 = 0$
$x + 7.45$	,,	$-279.3 = 0$	$x - 7.10$	,,	$-22.2 = 0$
$x + 6.82$	,,	$-261.0 = 0$	$x - 7.98$	,,	$-9.8 = 0$
$x + 5.72$	,,	$-240.3 = 0$	$x - 9.43$	,,	$+11.0 = 0$
$x + 3.55$	,,	$-197.2 = 0$	$x - 10.10$	,,	$+22.6 = 0$
$x + 1.52$	,,	$-159.7 = 0$	$x - 10.70$	,,	$+29.7 = 0$
$x - 0.40$	,,	$-127.2 = 0$	$x - 11.25$	,,	$+36.4 = 0$
$x - 6.60$	,,	$-20.7 = 0$	$x - 11.68$	,,	$+41.5 = 0$
$x - 8.10$	,,	$+5.2 = 0$	$x - 12.18$	,,	$+48.6 = 0$
$x - 9.43$	,,	$+27.1 = 0$	$x - 12.68$	,,	$+54.0 = 0$
$x - 10.83$	,,	$+51.4 = 0$	$x - 12.93$	,,	$+57.8 = 0$
$x - 12.23$	,,	$+68.6 = 0$	$x - 13.28$	,,	$+61.8 = 0$
$x - 13.33$	,,	$+82.7 = 0$	$x + 4.55$	,,	$-227.7 = 0$
$x - 14.23$	,,	$+95.5 = 0$	$x + 4.85$	,,	$-228.3 = 0$
$x - 15.30$	,,	$+107.3 = 0$	$x + 4.72$	,,	$-220.8 = 0$
$x - 16.13$	,,	$+117.9 = 0$	$x + 4.05$	,,	$-206.3 = 0$
$x - 16.83$	,,	$+124.9 = 0$	$x + 2.62$	,,	$-178.3 = 0$
$x - 17.28$	,,	$+128.1 = 0$	$x + 1.27$	,,	$-152.7 = 0$
$x - 17.53$	,,	$+127.8 = 0$	$x - 0.13$	,,	$-128.3 = 0$
$x + 3.80$	,,	$-222.2 = 0$	$x - 5.93$	,,	$-33.7 = 0$
$x + 4.17$	,,	$-230.0 = 0$	$x - 7.20$	,,	$-16.9 = 0$
$x + 4.42$	,,	$-232.1 = 0$	$x - 8.25$	,,	$-0.2 = 0$
$x + 4.52$	,,	$-230.9 = 0$	$x - 9.30$	,,	$+15.2 = 0$
$x + 4.55$	,,	$-229.9 = 0$	$x - 10.23$	,,	$+29.6 = 0$
$x + 4.27$	,,	$-220.6 = 0$	$x - 11.13$	,,	$+41.1 = 0$
$x + 3.70$	,,	$-210.5 = 0$	$x - 11.95$	,,	$+51.9 = 0$
$x + 3.05$	,,	$-197.9 = 0$	$x - 12.93$	,,	$+62.7 = 0$
$x + 2.32$	,,	$-185.4 = 0$	$x - 13.48$	,,	$+71.1 = 0$
$x + 1.70$	,,	$-173.6 = 0$	$x - 13.98$	,,	$+76.2 = 0$
$x - 2.25$	,,	$-103.9 = 0$	$x - 14.40$	,,	$+76.5 = 0$
$x - 3.28$	,,	$-85.7 = 0$	$x - 14.55$	,,	$+77.6 = 0$
$x - 4.35$	,,	$-67.6 = 0$	$x - 14.65$	,,	$+80.7 = 0$
$x - 5.20$	,,	$-53.2 = 0$	$x + 3.12$	,,	$-204.0 = 0$

After set No. 306—(Continued.)

$x + 3.42\ (E_a - dE_a) - \overset{d}{208.5} = 0$
$x + 3.57$ „ $-212.0 = 0$
$x + 3.72$ „ $-215.4 = 0$
$x + 3.77$ „ $-217.1 = 0$
$x + 3.72$ „ $-215.3 = 0$
$x + 3.65$ „ $-209.5 = 0$
$x + 3.42$ „ $-204.4 = 0$
$x + 3.10$ „ $-198.2 = 0$
$x + 2.77$ „ $-193.3 = 0$
$x + 2.32$ „ $-185.5 = 0$
$x - 0.13$ „ $-145.1 = 0$
$x - 0.43$ „ $-140.4 = 0$
$x - 0.63$ „ $-136.6 = 0$
$x - 0.95$ „ $-131.9 = 0$

$x - 1.25\ (E_a - dE_a) - \overset{d}{126.1} = 0$
$x - 1.53$ „ $-122.0 = 0$
$x - 1.80$ „ $-119.0 = 0$
$x - 2.08$ „ $-113.3 = 0$
$x - 2.38$ „ $-109.8 = 0$
$x - 2.95$ „ $-105.5 = 0$
$x - 3.25$ „ $-102.2 = 0$
$x - 3.53$ „ $-97.8 = 0$
$x - 3.70$ „ $-96.1 = 0$
$x - 3.88$ „ $-90.4 = 0$
$x - 4.15$ „ $-88.0 = 0$
$x - 4.43$ „ $-86.3 = 0$
$x - 4.60$ „ $-82.9 = 0$

And from the mean of these results,

$$x = \overset{d}{83.31} + 3.88\ (E_a - dE_a):$$

adopting the original value of the expansion of **A** given at page (9),

$$E_a = \overset{m.y}{22.67} = \overset{d}{17.630},$$

and $x = \overset{d}{151.71} - 3.88\ dE_a = \overset{m.y}{195.08} - 3.88\ dE_a = \mathrm{L} - \mathbf{A}$.

Proceeding as on page VII—9 we obtain :—

In terms of	A − L	B − L	C − L	D − L	E − L	H − L
Micrometer divisions.	−6.17	−24.46	+6.67	+31.45	−3.73	−3.78
Millionths of a yard.	−7.93	−31.45	+8.58	+40.44	−4.80	−4.86

Also the following,

$\mathrm{A} - \mathbf{A} = \overset{d}{145.54} - 3.88\ dE_a = \overset{m.y}{187.15} - 3.88\ dE_a$
$\mathrm{B} - \mathbf{A} = 127.25 -$ „ $= 163.63 -$ „
$\mathrm{C} - \mathbf{A} = 158.38 -$ „ $= 203.66 -$ „

$\mathrm{D} - \mathbf{A} = \overset{d}{183.16} - 3.88\ dE_a = \overset{m.y}{235.52} - 3.88\ dE_a$
$\mathrm{E} - \mathbf{A} = 147.98 -$ „ $= 190.28 -$ „
$\mathrm{H} - \mathbf{A} = 147.93 -$ „ $= 190.22 -$ „

$$\text{and } 6\,x = \overset{m.y}{1170.5} - 23.3\ dE_a.$$

Comparisons between the Standard Bar **A** *and the Compensated Bars* A, B, C, D, E, H, *made at the North-End of the base-line, after the measurement.*

1855 Jany.	Mean of the times of observing **A**	No. of comparison	Temperature of Air	Corrected mean temperature of **A**	Micrometer Readings in Divisions — 1 Division = $\frac{1}{21620 \cdot 18}$ Cary's Inch [7.8], = 1·2841 *m.y.* of **A** — Mean **A**	A	B	C	D	E	H	Mean of the compensated bars	Remarks
	h. m.		°	°	+	+	+	+	+	+	+	+	
25th	7 39 A.M.	1	54·7	54·45	867·6	1135·5	1130·0	1154·6	1177·4	1135·3	1152·0	1147·5	Major Strange at the micrometer microscope; Mr. Keelan at the plain microscope.
	8 6	2	57·2	54·45	873·2	1142·2	1129·9	1155·8	1175·0	1141·2	1151·1	1149·2	
	8 30	3	60·7	54·98	885·5	1139·1	1127·9	1152·5	1173·0	1139·5	1145·5	1146·3	
	8 49	4	63·4	55·78	898·5	1135·1	1123·9	1151·0	1170·0	1135·2	1144·2	1143·2	
	9 7	5	65·7	56·80	918·6	1129·8	1117·1	1149·5	1169·0	1133·4	1136·7	1139·3	
	9 26	6	68·1	58·18	944·1	1126·9	1114·5	1148·3	1167·0	1133·0	1131·8	1136·9	
	9 49	7	70·9	59·93	974·3	1126·2	1109·0	1147·0	1164·6	1131·9	1127·5	1134·4	
	11 9	8	74·3	66·40	1078·9	1113·8	1103·5	1152·9	1167·8	1133·2	1118·1	1131·6	
	11 19	9	75·0	67·15	1092·9	1111·1	1102·8	1154·8	1168·0	1135·1	1121·8	1132·3	
	11 31	10	75·6	67·90	1106·8	1112·2	1105·3	1154·7	1169·6	1135·1	1121·0	1133·0	
	11 46	11	76·2	68·68	1119·8	1114·9	1107·7	1158·7	1170·9	1138·0	1125·2	1135·9	
	11 58	12	76·6	69·35	1130·1	1118·0	1107·0	1158·9	1172·8	1139·3	1125·5	1136·9	
	0 9 P.M.	13	76·7	69·93	1139·6	1122·1	1110·5	1159·0	1171·8	1139·4	1126·6	1138·2	
	0 21	14	76·9	70·55	1150·8	1126·6	1111·9	1160·5	1178·3	1141·9	1131·1	1141·7	
	0 33	15	76·9	71·15	1161·1	1128·2	1114·8	1164·6	1177·8	1145·5	1134·0	1144·2	
	0 46	16	77·2	71·73	1171·3	1130·0	1117·8	1165·9	1179·5	1147·5	1135·5	1146·0	
	0 59	17	77·5	72·33	1181·5	1134·0	1120·1	1168·7	1182·0	1149·0	1139·4	1148·9	
	1 12	18	77·8	72·88	1190·7	1138·2	1123·5	1170·0	1186·0	1154·5	1144·8	1152·8	
	1 34	19	77·9	73·78	1208·2	1142·1	1124·8	1173·0	1187·8	1156·1	1148·6	1155·4	
	1 49	20	78·4	74·35	1219·1	1146·1	1130·8	1177·4	1193·5	1162·6	1150·3	1160·1	
	2 4	21	78·9	74·90	1229·8	1148·0	1133·0	1178·2	1195·8	1162·0	1152·7	1161·6	
	2 16	22	78·8	75·38	1237·1	1150·4	1137·9	1180·2	1195·9	1166·8	1155·9	1164·5	
	2 29	23	78·5	75·73	1244·0	1154·0	1140·9	1180·2	1199·0	1164·0	1157·5	1165·9	
	2 40	24	78·4	76·08	1250·7	1158·2	1143·6	1185·5	1201·2	1167·3	1162·5	1169·7	
	2 52	25	78·7	76·45	1256·0	1160·5	1146·5	1187·1	1205·5	1172·0	1163·9	1172·6	
	3 8	26	79·0	76·73	1260·7	1160·5	1152·0	1191·4	1205·7	1174·8	1167·9	1175·4	
	3 28	27	79·1	77·08	1267·3	1161·1	1151·3	1192·3	1209·0	1174·8	1169·7	1176·4	
26th	6 55 A.M.	28	53·4	54·70	870·8	1136·3	1125·2	1140·2	1169·1	1135·6	1152·1	1143·1	Lieut. Tennant at the micrometer microscope; Mr. Keelan at the plain microscope.
	7 15	29	53·6	54·48	867·4	1136·3	1125·6	1143·6	1167·1	1132·4	1151·2	1142·7	
	7 30	30	54·7	54·38	865·0	1136·4	1123·3	1142·2	1171·6	1130·4	1149·9	1142·3	
	7 42	31	56·1	54·35	866·0	1134·9	1124·6	1142·2	1170·1	1129·9	1149·3	1141·8	
	7 55	32	57·8	54·45	869·3	1133·9	1118·3	1140·3	1166·8	1135·4	1145·1	1140·0	
	8 9	33	59·6	54·78	876·2	1129·6	1118·9	1136·8	1166·2	1135·2	1140·2	1137·8	
	8 25	34	61·7	55·33	888·6	1127·3	1113·2	1142·7	1163·4	1131·7	1139·7	1136·3	
	8 46	35	64·3	56·35	907·4	1122·3	1108·4	1137·4	1159·4	1128·0	1133·6	1131·5	
	8 59	36	65·5	57·10	917·9	1119·8	1107·7	1137·0	1158·3	1127·8	1131·7	1130·4	
	9 11	37	66·4	57·85	931·1	1117·9	1106·9	1137·3	1157·1	1127·8	1128·7	1129·3	
	9 24	38	67·2	58·70	947·7	1116·7	1104·2	1136·4	1155·4	1125·4	1125·0	1127·2	
	9 37	39	68·2	59·65	964·0	1116·4	1103·8	1134·2	1156·1	1129·3	1125·3	1127·5	
	9 51	40	69·4	60·50	977·9	1114·2	1104·8	1134·4	1159·6	1130·0	1125·4	1128·1	
	10 47	41	73·7	64·50	1046·6	1110·3	1103·2	1140·9	1161·2	1129·0	1117·4	1127·0	
	11 0	42	74·4	65·45	1063·5	1109·3	1100·0	1144·9	1162·0	1127·2	1117·8	1126·9	

After the measurement—(Continued.)

1855 Jany.	Mean of the times of observing A	No. of comparison	Temperature of Air	Corrected mean temperature of A	Micrometer Readings in Divisions (1 Division = $\frac{1}{21620 \cdot 18}$ Cary's Inch [7.8], = 1·2841 *m.y.* of A) Mean A	A	B	C	D	E	H	Mean of the compensated bars	Remarks
	h. m.		°	°	+	+	+	+	+	+	+	+	
26th	11 13 A.M.	43	74·8	66·33	1077·9	1106·3	1098·0	1144·3	1159·9	1132·2	1118·4	1126·5	
	11 25	44	75·3	67·18	1091·8	1109·4	1101·5	1144·4	1163·2	1133·3	1118·6	1128·4	
	11 37	45	75·9	68·00	1105·4	1111·5	1101·4	1144·1	1161·8	1133·9	1118·7	1128·6	
	11 50	46	76·2	68·70	1118·6	1113·7	1103·4	1148·0	1164·5	1132·0	1119·2	1130·1	
	0 3 P.M.	47	76·6	69·43	1133·0	1113·6	1103·4	1148·1	1163·8	1136·7	1124·3	1131·7	
	0 15	48	77·0	70·25	1145·8	1115·1	1105·6	1150·8	1167·9	1136·1	1125·8	1133·6	
	0 29	49	77·5	71·00	1156·8	1119·4	1103·8	1149·1	1166·0	1135·6	1127·8	1133·6	
	0 42	50	78·2	71·70	1169·4	1117·7	1108·3	1151·4	1170·1	1139·2	1130·1	1136·1	
	1 10	51	79·2	73·15	1201·9	1135·0	1123·0	1163·0	1182·7	1152·7	1140·6	1149·5	
	1 22	52	79·5	73·83	1214·1	1135·5	1122·7	1169·5	1183·6	1154·6	1141·1	1151·2	
	1 36	53	79·2	74·53	1225·7	1137·3	1125·2	1172·0	1186·2	1156·5	1144·5	1153·6	
	1 51	54	79·1	75·10	1235·5	1139·9	1130·0	1175·8	1191·6	1159·6	1149·3	1157·7	
	2 6	55	79·3	75·70	1245·9	1146·4	1133·9	1181·0	1195·0	1161·7	1153·7	1162·0	
	2 21	56	79·8	76·25	1256·5	1152·8	1139·9	1182·0	1203·3	1167·7	1159·1	1167·5	
	2 36	57	80·0	76·70	1266·1	1157·4	1145·6	1184·3	1208·5	1174·3	1162·7	1172·1	
	2 49	58	80·0	77·13	1273·2	1160·7	1149·4	1188·4	1206·2	1175·7	1165·3	1174·3	
	3 2	59	80·1	77·45	1278·7	1163·3	1150·5	1191·6	1209·3	1175·0	1169·2	1176·5	
	3 15	60	80·2	77·73	1284·0	1164·0	1151·8	1191·5	1212·4	1177·4	1170·1	1177·9	
	3 26	61	80·1	78·00	1288·9	1168·8	1156·3	1192·6	1209·2	1178·4	1170·1	1179·2	
29th	7 38 A.M.	62	61·8	58·45	951·5	1150·6	1136·0	1157·1	1186·0	1148·0	1161·3	1156·5	Major Strange at the micrometer microscope; Mr. Keelan at the plain microscope.
	8 5	63	64·6	59·08	962·8	1151·4	1139·5	1157·0	1182·9	1147·7	1158·6	1156·2	
	8 27	64	66·7	60·00	978·9	1150·8	1133·5	1155·0	1180·1	1149·0	1153·1	1153·6	
	8 51	65	69·4	61·25	1002·9	1147·5	1133·0	1155·1	1181·7	1146·8	1153·0	1152·9	
	9 11	66	72·0	62·45	1026·2	1146·6	1130·9	1154·9	1184·0	1148·0	1150·0	1152·4	
	9 25	67	73·5	63·45	1046·8	1143·1	1130·3	1157·1	1185·8	1150·0	1148·1	1152·4	
	9 38	68	74·2	64·40	1064·3	1143·9	1131·6	1156·0	1185·0	1149·8	1150·6	1152·8	
	9 51	69	74·9	65·35	1080·0	1147·1	1129·5	1161·8	1183·8	1151·3	1151·0	1154·1	
	11 8	70	79·2	70·75	1173·9	1157·3	1139·9	1184·9	1203·5	1167·9	1158·3	1168·6	Wind strong but not cold. N.E. wind. Cloudy.
	11 22	71	79·3	71·63	1188·7	1157·5	1142·1	1186·1	1205·1	1170·8	1160·3	1170·3	
	11 36	72	79·7	72·45	1201·6	1159·5	1143·0	1190·0	1208·5	1175·3	1162·4	1173·1	
	11 49	73	79·9	73·20	1213·8	1162·8	1146·3	1191·0	1210·3	1174·2	1165·4	1175·0	
	0 7 P.M.	74	80·0	74·13	1229·9	1167·8	1150·5	1196·0	1213·8	1180·0	1169·0	1179·5	
	0 30	75	80·6	75·13	1247·5	1171·3	1155·0	1197·9	1216·3	1184·1	1173·8	1183·1	
	0 48	76	80·7	75·73	1259·3	1172·4	1158·0	1201·2	1218·4	1186·8	1173·0	1185·0	
	1 1	77	80·4	76·18	1266·8	1173·1	1157·5	1200·0	1217·7	1184·6	1174·0	1184·5	
	1 35	78	81·0	77·23	1283·6	1172·8	1161·6	1206·8	1222·3	1186·3	1178·8	1188·1	
	1 49	79	81·2	77·58	1290·7	1174·0	1161·1	1205·0	1224·1	1187·4	1176·8	1188·1	
	2 1	80	81·1	77·93	1296·0	1174·5	1163·9	1208·1	1222·9	1186·7	1177·9	1189·0	
	2 17	81	80·9	78·23	1301·0	1178·6	1167·0	1208·2	1225·0	1192·0	1180·1	1191·8	
	2 37	82	80·5	78·50	1307·6	1182·3	1170·0	1208·6	1226·8	1193·0	1184·0	1194·1	
	2 57	83	80·3	78·73	1312·2	1182·5	1171·7	1212·8	1230·8	1195·0	1186·7	1196·6	
	3 12	84	80·1	78·80	1312·8	1182·2	1172·9	1215·0	1232·4	1197·8	1184·8	1197·5	
	3 24	85	79·8	78·85	1312·6	1185·6	1177·2	1215·8	1231·1	1198·5	1186·3	1199·1	
		Means		68·27	1117·63	1141·52	1129·20	1167·25	1186·36	1153·26	1148·22	1154·30	

After the measurement—(Continued.)

As on page VII—7 we have

$$x - (t^\circ - 62^\circ)(E_a - dE_a) - \delta = 0$$

and from the preceding bar comparisons we obtain the following series of results:—

$x + 7{\cdot}55$	$(E_a - {}_d E_a)$	$-279{\cdot}9 = 0$	$x + 7{\cdot}55$	$(E_a - {}_d E_a)$	$-270{\cdot}7 = 0$
$x + 7{\cdot}55$	"	$-276{\cdot}0 = 0$	$x + 7{\cdot}22$	"	$-261{\cdot}6 = 0$
$x + 7{\cdot}02$	"	$-260{\cdot}8 = 0$	$x + 6{\cdot}67$	"	$-247{\cdot}7 = 0$
$x + 6{\cdot}22$	"	$-244{\cdot}7 = 0$	$x + 5{\cdot}65$	"	$-224{\cdot}1 = 0$
$x + 5{\cdot}20$	"	$-220{\cdot}7 = 0$	$x + 4{\cdot}90$	"	$-212{\cdot}5 = 0$
$x + 3{\cdot}82$	"	$-192{\cdot}8 = 0$	$x + 4{\cdot}15$	"	$-198{\cdot}2 = 0$
$x + 2{\cdot}07$	"	$-160{\cdot}1 = 0$	$x + 3{\cdot}30$	"	$-179{\cdot}5 = 0$
$x - 4{\cdot}40$	"	$-52{\cdot}7 = 0$	$x + 2{\cdot}35$	"	$-163{\cdot}5 = 0$
$x - 5{\cdot}15$	"	$-39{\cdot}4 = 0$	$x + 1{\cdot}50$	"	$-150{\cdot}2 = 0$
$x - 5{\cdot}90$	"	$-26{\cdot}2 = 0$	$x - 2{\cdot}50$	"	$-80{\cdot}4 = 0$
$x - 6{\cdot}68$	"	$-16{\cdot}1 = 0$	$x - 3{\cdot}45$	"	$-63{\cdot}4 = 0$
$x - 7{\cdot}35$	"	$-6{\cdot}8 = 0$	$x - 4{\cdot}33$	"	$-48{\cdot}6 = 0$
$x - 7{\cdot}93$	"	$+1{\cdot}4 = 0$	$x - 5{\cdot}18$	"	$-36{\cdot}6 = 0$
$x - 8{\cdot}55$	"	$+9{\cdot}1 = 0$	$x - 6{\cdot}00$	"	$-23{\cdot}2 = 0$
$x - 9{\cdot}15$	"	$+16{\cdot}9 = 0$	$x - 6{\cdot}70$	"	$-11{\cdot}5 = 0$
$x - 9{\cdot}73$	"	$+25{\cdot}3 = 0$	$x - 7{\cdot}43$	"	$+1{\cdot}3 = 0$
$x - 10{\cdot}33$	"	$+32{\cdot}6 = 0$	$x - 8{\cdot}25$	"	$+12{\cdot}2 = 0$
$x - 10{\cdot}88$	"	$+37{\cdot}9 = 0$	$x - 9{\cdot}00$	"	$+23{\cdot}2 = 0$
$x - 11{\cdot}78$	"	$+52{\cdot}8 = 0$	$x - 9{\cdot}70$	"	$+33{\cdot}3 = 0$
$x - 12{\cdot}35$	"	$+59{\cdot}0 = 0$	$x - 11{\cdot}15$	"	$+52{\cdot}4 = 0$
$x - 12{\cdot}90$	"	$+68{\cdot}2 = 0$	$x - 11{\cdot}83$	"	$+62{\cdot}9 = 0$
$x - 13{\cdot}38$	"	$+72{\cdot}6 = 0$	$x - 12{\cdot}53$	"	$+72{\cdot}1 = 0$
$x - 13{\cdot}73$	"	$+78{\cdot}1 = 0$	$x - 13{\cdot}10$	"	$+77{\cdot}8 = 0$
$x - 14{\cdot}08$	"	$+81{\cdot}0 = 0$	$x - 13{\cdot}70$	"	$+83{\cdot}9 = 0$
$x - 14{\cdot}45$	"	$+83{\cdot}4 = 0$	$x - 14{\cdot}25$	"	$+89{\cdot}0 = 0$
$x - 14{\cdot}73$	"	$+85{\cdot}3 = 0$	$x - 14{\cdot}70$	"	$+94{\cdot}0 = 0$
$x - 15{\cdot}08$	"	$+90{\cdot}9 = 0$	$x - 15{\cdot}13$	"	$+98{\cdot}9 = 0$
$x + 7{\cdot}30$	"	$-272{\cdot}3 = 0$	$x - 15{\cdot}45$	"	$+102{\cdot}2 = 0$
$x + 7{\cdot}52$	"	$-275{\cdot}3 = 0$	$x - 15{\cdot}73$	"	$+106{\cdot}1 = 0$
$x + 7{\cdot}62$	"	$-277{\cdot}3 = 0$	$x - 16{\cdot}00$	"	$+109{\cdot}7 = 0$
$x + 7{\cdot}65$	"	$-275{\cdot}8 = 0$	$x + 3{\cdot}55$	"	$-205{\cdot}0 = 0$

After the measurement—(Continued.)

$$x + 2.92\,(E_a - dE_a) - \overset{d}{193.4} = 0$$
$$x + 2.00 \quad " \quad - 174.7 = 0$$
$$x + 0.75 \quad " \quad - 150.0 = 0$$
$$x - 0.45 \quad " \quad - 126.2 = 0$$
$$x - 1.45 \quad " \quad - 105.6 = 0$$
$$x - 2.40 \quad " \quad - 88.5 = 0$$
$$x - 3.35 \quad " \quad - 74.1 = 0$$
$$x - 8.75 \quad " \quad + 5.3 = 0$$
$$x - 9.63 \quad " \quad + 18.4 = 0$$
$$x - 10.45 \quad " \quad + 28.5 = 0$$
$$x - 11.20 \quad " \quad + 38.8 = 0$$
$$x - 12.13 \quad " \quad + 50.4 = 0$$
$$x - 13.13\,(E_a - dE_a) + \overset{d}{64.4} = 0$$
$$x - 13.73 \quad " \quad + 74.3 = 0$$
$$x - 14.18 \quad " \quad + 82.3 = 0$$
$$x - 15.23 \quad " \quad + 95.5 = 0$$
$$x - 15.58 \quad " \quad + 102.6 = 0$$
$$x - 15.93 \quad " \quad + 107.0 = 0$$
$$x - 16.23 \quad " \quad + 109.2 = 0$$
$$x - 16.50 \quad " \quad + 113.5 = 0$$
$$x - 16.73 \quad " \quad + 115.6 = 0$$
$$x - 16.80 \quad " \quad + 115.3 = 0$$
$$x - 16.85 \quad " \quad + 113.5 = 0$$

And from the mean of these results,

$$x = \overset{d}{36.67} + 6.27\,(E_a - dE_a):$$

adopting the original value of the expansion of **A** given at page (9),

$$E_a = \overset{m.y}{22.67} = \overset{d}{17.654},$$

$$\text{and } x = \overset{d}{147.36} - 6.27\,dE_a = \overset{m.y}{189.22} - 6.27\,dE_a = \text{L} - \textbf{A}.$$

Proceeding as on page VII—9 we obtain;

In terms of	A − L	B − L	C − L	D − L	E − L	H − L
Micrometer divisions.	−12.78	−25.10	+12.95	+32.06	−1.04	−6.08
Millionths of a yard.	−16.41	−32.23	+16.63	+41.17	−1.34	−7.81

Also the following;

$$\text{A} - \textbf{A} = \overset{d}{134.58} - 6.27\,dE_a = \overset{m.y}{172.81} - 6.27\,dE_a$$
$$\text{B} - \textbf{A} = 122.26 - \quad " \quad = 156.99 - \quad "$$
$$\text{C} - \textbf{A} = 160.31 - \quad " \quad = 205.85 - \quad "$$
$$\text{D} - \textbf{A} = \overset{d}{179.42} - 6.27\,dE_a = \overset{m.y}{230.39} - 6.27\,dE_a$$
$$\text{E} - \textbf{A} = 146.32 - \quad " \quad = 187.88 - \quad "$$
$$\text{H} - \textbf{A} = 141.28 - \quad " \quad = 181.41 - \quad "$$

$$\text{and } 6\,x = \overset{m.y}{1135.3} - 37.6\,dE_a.$$

Final deduction of the total length measured with the compensated bars.

			m.y
From page VII—9 the excess of the 6 compensated bars above 6 times **A**		*before* the measurement	$= 1244{\cdot}5 - 50{\cdot}5\ dE_a$
„ VII—13 „	„	*after* set No. 306	$= 1170{\cdot}5 - 23{\cdot}3\ dE_a$
„ VII—17 „	„	*after* the measurement	$= 1135{\cdot}3 - 37{\cdot}6\ dE_a$
Therefore the mean excess	„	applicable to sets Nos. 1 to 306	$= 1207{\cdot}5 - 36{\cdot}9\ dE_a$
and „	„	applicable to sets Nos. 307 to 613	$= 1152{\cdot}9 - 30{\cdot}5\ dE_a$
Also the mean length of a set of 6 compensated bars in feet of the standard, corrected for error* in the thermometer readings, applicable to sets Nos. 1 to 306			$= 60{\cdot}0033940\ \frac{\mathbf{A}}{10} - 33{\cdot}5\ dE_a$
and „		applicable to sets Nos. 307 to 613	$= 60{\cdot}0032302\ \frac{\mathbf{A}}{10} - 27{\cdot}1\ dE_a$

Hence the total lengths measured with the compensated bars

			feet of **A**
in sets Nos.	1 to 156	=	$9360{\cdot}5295 - 5225\ dE_a$
„	157 to 306	=	$9000{\cdot}5091 - 5025\ dE_a$
„	307 to 457	=	$9060{\cdot}4878 - 4092\ dE_a$
„	458 to 613	=	$9360{\cdot}5039 - 4228\ dE_a$
„	1 to 613	=	$36782{\cdot}0303 - 18570\ dE_a$

Now the mean temperature of **A** during the bar comparisons *before* the measurement and *after* set No. 306 was $62° + \frac{33°{\cdot}5}{6} = 67°{\cdot}6$, for which temperature the corresponding expansion of **A** from page (19) $= 21{\cdot}683$ *m.y.* Also the mean temperature of **A** during the bar comparisons *after* set No. 306 and *after* the measurement was $62° + \frac{27°{\cdot}1}{6} = 66°{\cdot}5$, for which temperature the corresponding expansion of **A** from page (19) $= 21{\cdot}676$ *m.y.* Comparing these values of expansion with the original value $= 22{\cdot}67$ *m.y,* used in the foregoing; it is found that $dE_a = +\ 0{\cdot}987$ *m.y,* for sets Nos. 1 to 306, and $= +\ 0{\cdot}994$ *m.y,* for sets Nos. 307 to 613. Substituting for dE_a respectively these numerical values, there result,

Total lengths measured with the compensated bars

				feet of **A**
in sets Nos.	1 to 156 or S. End,	to Stn. A	= (9360·5295 − ·0155) =	9360·5140
„	157 to 306 or Stn. A,	to Stn. B	= (9000·5091 − ·0149) =	9000·4942
„	307 to 457 or Stn. B,	to Stn. C	= (9060·4878 − ·0122) =	9060·4756
„	458 to 613 or Stn. C,	to N. End	= (9360·5039 − ·0126) =	9360·4913
„	1 to 613 or S. End,	to N. End	= (36782·0303 − ·0552) =	36781·9751

* It is shewn in Appendix No. 8 of this volume, that a correction of $-\ 0°{\cdot}56$ is due to the mean thermometer readings of the Standard bar **A** at the Karachi base-line. The linear value of this correction for a set of 6 bars $= -\ 6 \times 0{\cdot}56\ (E_a - dE_a) = -\ {\cdot}0002285\ \frac{\mathbf{A}}{10} + 3{\cdot}4\ dE_a.$

Comparisons between the Compensated Microscopes and their 6-inch brass scales during the measurement, and provisional determination of Microscope errors with respect to the 6-inch brass scale A, expressed in millionths of an inch (m.i.)

When compared — 1854-55		Microscope.	Scale compared with.	Corrected temperature.	Reduction to 62° Fah. Expansion of 6″ scale for 1° = E = 62·5 *m.i.*	Microscope — Microscope Scale. Observed value in terms of: Divisions 10000 = 1″.	*m.i.*	Micros : Scale − A, at 62° Fah.	Micros : — Scale A, at 62° Fah. *m.i.*	Reference number.
December 5th	Before the measurement.	*T*	*T*	65°·08	+ 193	+ 2·60	+ 260	− 97	+ 356	1
		M	*M*	66·79	299	0·65	65	21	343	2
		O	*U*	81·48	1217	− 1·25	− 125	+ 283	1375	3
„ 6th		*N*	*N*	54·85	− 447	+ 9·63	+ 963	363	879	4
„ 4th		*R*	*R*	78·78	+ 1049	− 2·67	− 267	93	875	5
„ 5th		*P*	*P*	80·16	1135	0·00	0	350	1485	6
		S	*S*	77·34	959	+ 2·37	+ 237	− 75	1121	7
„ 15th	Between sets No. 84 and 85.	*T*	*T*	74·25	+ 765	− 2·27	− 227	− 97	+ 441	8
		M	*M*	73·96	748	0·00	0	21	727	9
		O	*U*	77·20	950	+ 1·20	+ 120	+ 283	1353	10
		N	*N*	76·42	901	0·00	0	363	1264	11
		R	*R*	75·81	863	0·00	0	93	956	12
		P	*P*	76·42	901	1·67	167	350	1418	13
		S	*S*	75·71	857	1·47	147	− 75	929	14
„ 21st	Between sets No. 156 and 157.	*T*	*T*	79·05	+ 1065	− 5·20	− 520	− 97	+ 448	15
		M	*M*	80·33	1146	2·67	267	21	858	16
		O	*U*	79·65	1103	0·00	0	+ 283	1386	17
		N	*N*	80·05	1128	3·27	327	363	1164	18
		R	*R*	79·11	1069	0·00	0	93	1162	19
		P	*P*	79·19	1074	0·00	0	350	1424	20
		S	*S*	79·37	1086	0·00	0	− 75	1011	21
„ 30th	Between sets No. 306 and 307.	*T*	*T*	79·88	+ 1118	− 4·00	− 400	− 97	+ 621	22
		M	*M*	80·19	1137	4·15	415	21	701	23
		O	*U*	79·65	1103	0·00	0	+ 283	1386	24
		N	*N*	79·42	1088	3·63	363	363	1088	25
		R	*R*	79·91	1119	1·70	170	93	1042	26
		P	*P*	80·29	1143	0·00	0	350	1493	27
		S	*S*	80·17	1136	0·00	0	− 75	1061	28
January 16th	Between sets No. 465 and 466.	*T*	*T*	77·35	+ 959	0·00	0	− 97	+ 862	29
		M	*M*	77·30	956	− 2·18	− 218	21	717	30
		O	*U*	76·10	881	+ 1·28	+ 128	+ 283	1292	31
		N	*N*	77·42	963	0·00	0	363	1326	32
		*N**	*N*	77·42	963	0·00	0	363	1326	33
		R	*R*	76·38	899	4·00	400	93	1392	34
		P	*P*	76·44	902	4·93	493	350	1745	35
		*P**	*P*	77·19	949	4·80	480	350	1779	36
		S	*S*	76·91	932	3·07	307	− 75	1164	37

* These microscopes were compared a second time, because they were adjusted after the first comparison.

Microscope Comparisons—(Continued.)

When compared — 1854-55			Microscope.	Scale compared with.	Corrected temperature.	Reduction to 62° Fah. Expansion of 6″ scale for 1° = E = 62·5 *m.i.*	Microscope — Microscope Scale. Observed value in terms of Divisions 10000 = 1″.	*m.i.*	Micros: Scale − *A*, at 62° Fah.	Micros: − Scale *A*, at 62° Fah. *m.i.*	Reference number.
January	22nd	After the measurement.	*T*	*T*	72°·45	+ 653	+ 0·77	+ 77	− 97	+ 633	38
„	24th		*M*	*M*	76·66	916	− 1·40	− 140	21	·755	39
			O	*U*	76·65	916	+ 1·23	+ 123	+ 283	1322	40
			N	*N*	78·32	1020	0·00	0	363	1383	41
			R	*R*	77·45	965	− 0·90	− 90	93	968	42
„	23rd		*P*	*P*	79·79	1112	0·00	0	350	1462	43
„	24th		*S*	*S*	76·17	886	0·00	0	− 75	811	44

The required combinations of individual microscope errors taken from pages VII—19 and VII—20, are expressed as follows;

Reference numbers.	*m.i.*	*mean temp:*		
$e_1 = 2 + 3 + 4 + 5 + 6 + \frac{1+7}{2}$	$= + 5696$	at (62° + 10°·21)		before the measurement.
$e_2 = 9 + 10 + 11 + 12 + 13 + \frac{8+14}{2}$	$= + 6403$	at (62 + 13·80)	From comparisons made	between sets 84 & 85
$e_3 = 16 + 17 + 18 + 19 + 20 + \frac{15+21}{2}$	$= + 6724$	at (62 + 17·59)		„ 156 & 157
$e_4 = 23 + 24 + 25 + 26 + 27 + \frac{22+28}{2}$	$= + 6551$	at (62 + 17·92)		„ 306 & 307
$e_5 = 30 + 31 + 32 + 34 + 35 + \frac{29+37}{2}$	$= + 7485$	at (62 + 14·80)		„ 465 & 466
$e_6 = 30 + 31 + 33 + 34 + 36 + \frac{29+37}{2}$	$= + 7519$	at (62 + 14·92)		„ do.
$e_7 = 39 + 40 + 41 + 42 + 43 + \frac{38+44}{2}$	$= + 6612$	at (62 + 15·20)		after the measurement.

And from the foregoing, we obtain the following equations for the microscope errors per set (or *m.e.*); where *dE* expresses the error in the adopted value of the expansion for the 6-inch scales.

	m.i.		
$(m.e.)_1 = \frac{e_1 + e_2}{2}$	$= + 6050 - 6 \times 12·01\, dE$	applicable to sets Nos.	1 to 84
$(m.e.)_2 = \frac{e_2 + e_3}{2}$	$= + 6564 - 6 \times 15·70\, dE$	„ „	85 to 156
$(m.e.)_3 = \frac{e_3 + e_4}{2}$	$= + 6638 - 6 \times 17·76\, dE$	„ „	157 to 306
$(m.e.)_4 = \frac{e_4 + e_5}{2}$	$= + 7018 - 6 \times 16·36\, dE$	„ „	307 to 465
$(m.e.)_5 = \frac{e_6 + e_7}{2}$	$= + 7066 - 6 \times 15·06\, dE$	„ „	466 to 613

Microscope Comparisons—(Continued.)

Hence the total microscope errors are as follows :—

			m.i.		feet of A	
In sets Nos.	1 to 156 =	84 $(m.e)_1$ =	508200	− 6053 dE =	0·0424	− 6053 dE
		72 $(m.e)_2$ =	472608	− 6782 dE =	0·0394	− 6782 dE
				Sum =	0·0818	− 12835 dE
„	157 to 306 =	150 $(m.e)_3$ =	995700	− 15984 dE =	0·0830	− 15984 dE
„	307 to 457 =	151 $(m.e)_4$ =	1059718	− 14822 dE =	0·0883	− 14822 dE
„	458 to 613 =	8 $(m.e)_4$ =	56144	− 785 dE =	0·0047	− 785 dE
		148 $(m.e)_5$ =	1045768	− 13373 dE =	0·0871	− 13373 dE
				Sum =	0·0918	− 14158 dE

Final deduction of the total lengths measured with the compensated microscopes.

Hitherto the microscope errors have been determined only provisionally; *i.e.* in terms of the 6-inch brass scale *A*. But from page (31), we have 2 *A* = 1·0000192 $\frac{A}{10}$, value in 1835. Also the co-efficient of expansion for brass, has been taken at ·000,010,417 in the foregoing reductions, whereas it appears from page (17) that ·000,009,855 is a more probable value. Accepting the latter, it may be found that $dE = 3{\cdot}372$ (*m.i.*). Hence, remembering that the length measured with a set of microscopes is equal to 3 feet of *A* + the corresponding ***(m.e)***, we have,

Total lengths measured with the compensated microscopes

		feet of A		feet of A
In sets Nos. 1 to 156 or S. End, to Stn. A	=	{156 × 3 + ·0818} − 12835 dE	= (468·0908 − ·0036) =	468·0872
„ 157 to 306 or Stn. A, to Stn. B	=	{150 × 3 + ·0830} − 15984 dE	= (450·0916 − ·0045) =	450·0871
„ 307 to 457 or Stn. B, to Stn. C	=	{151 × 3 + ·0883} − 14822 dE	= (453·0970 − ·0042) =	453·0928
„ 458 to 613 or Stn. C to N. End	=	{156 × 3 + ·0918} − 14158 dE	= (468·1008 − ·0040) =	468·0968
„ 1 to 613 or S. End to N. End			= (1839·3802 − ·0163) =	1839·3639

DETAILS OF THE MEASUREMENT.

Disposition of the bars and microscopes during the measurement.

Each set in the base-line was invariably measured with 6 bars and 7 microscopes, whose order of succession was as follows:—

Bars.	*Microscopes.*
A, B, C, D, E, H.	½T, M, O, N, R, P, ½S.

Extracts from the Field Book of the measurement, and calculated heights of sets above the origin.

Adopted heights above mean sea level.
South-End (origin) = 46·4 feet.
North-End (terminus) = 204·4 feet.

Dec. 1854	No. of the Set	Temperature of Air	Mean time of ending	Height of Set above origin
		°	h. m.	feet
7th	1	60·4	6 40 A.M.	+ 1·2
	2	75·1	7 50	1·5
	3	84·8	10 45	1·8
	4	85·0	11 58	2·1
	5	86·0	0 35 P.M.	2·0
	6	85·9	1 24	1·9
	7	84·3	2 6	1·9
	8	80·6	2 48	1·9
8th	9	59·8	6 18 A.M.	1·9
	10	72·0	7 16	2·2
	11	78·1	8 40	2·3
	12	81·7	9 35	2·4
	13	84·7	11 5	2·5
	14	82·3	11 53	2·8
	15	82·6	0 36 P.M.	2·9
	16	81·0	1 36	3·1
	17	81·8	2 20	3·3
	18	79·1	3 5	3·4
9th	19	57·7	6 18 A.M.	3·5
	20	67·0	7 13	3·8
	21	76·0	8 11	4·1
	22	79·2	9 23	4·4
	23	83·2	11 5	4·5
	24	85·0	0 7 P.M.	4·6
	25	85·5	1 15	4·7
	26	84·0	2 13	5·1
	27	81·3	3 0	5·1
11th	28	65·1	6 20 A.M.	5·5
11th	29	72·0	7 33 A.M.	+ 5·6
	30	75·3	8 39	5·8
	31	81·2	11 15	5·9
	32	81·0	11 57	6·3
	33	80·8	0 52 P.M.	6·5
	34	80·9	1 43	6·4
	35	80·4	2 27	6·5
	36	78·9	3 12	6·5
12th	37	68·3	6 25 A.M.	6·8
	38	70·2	7 25	7·3
	39	72·2	8 7	7·7
	40	74·0	8 50	7·8
	41	77·2	10 57	8·1
	42	79·0	11 33	8·3
	43	80·8	0 16 P.M.	8·7
	44	81·0	1 8	8·9
	45	81·4	1 47	9·0
	46	80·8	2 23	9·2
	47	78·8	2 53	9·5
13th	48	66·9	6 24 A.M.	10·1
	49	70·1	7 50	10·4
	50	72·7	8 29	10·8
	51	75·0	8 55	10·8
	52	77·2	9 26	10·8
	53	80·4	10 43	11·0
	54	81·7	11 9	11·4
	55	82·3	11 43	11·7
	56	82·0	0 13 P.M.	12·0
13th	57	83·0	0 39 P.M.	+ 12·2
	58	85·9	1 7	12·6
	59	87·2	1 34	12·9
	60	87·2	1 59	13·1
	61	87·1	2 31	13·5
	62	85·8	3 0	13·8
14th	63	60·2	6 20 A.M.	13·9
	64	63·0	7 5	14·3
	65	66·8	7 35	14·4
	66	69·8	8 2	14·8
	67	72·4	8 30	15·0
	68	75·1	9 4	15·3
	69	76·0	9 38	15·5
	70	80·4	11 0	15·6
	71	82·1	11 35	15·9
	72	83·4	0 19 P.M.	16·3
	73	83·2	0 48	16·8
	74	84·1	1 26	17·1
	75	81·9	2 2	17·3
	76	81·1	2 32	17·4
	77	78·9	2 58	17·8
15th	78	54·7	6 30 A.M.	18·1
	79	56·8	7 3	18·6
	80	60·4	7 37	18·8
	81	63·9	8 9	19·0
	82	67·0	8 40	19·1
	83	70·2	9 10	19·3
	84	76·8	9 42	19·5

NOTE.—The rear-end of set No. 1 stood exactly over the dot at South-End.

The dots denoting "Posterity-marks" *a*, *e*, *f* and *g* were fixed exactly in the normal at the advanced-ends respectively of sets Nos. 10, 21, 42 and 84.

(29) Violent wind from N.E. bringing dense clouds of dust.

(42) „ heavy clouds and thick dust.

Extracts from the Field Book—(Coutinued.)

Dec. 1854	No. of the Set	Temperature of Air	Mean time of ending	Height of Set above origin	Dec. 1854	No. of the Set	Temperature of Air	Mean time of ending	Height of Set above origin	Dec. 1854	No. of the Set	Temperature of Air	Mean time of ending	Height of Set above origin
		°	h. m.	feet.			°	h. m.	feet.			°	h. m.	feet.
16th	85	54·8	6 25 A.M.	+ 19·8	18th	110	80·2	11 40 A.M.	+ 25·8	19th	135	87·2	3 3 P.M.	+ 32·4
	86	61·9	7 26	20·3		111	80·2	0 5 P.M.	26·0	20th	136	55·0	6 35 A.M.	32·7
	87	67·8	8 16	20·5		112	80·9	0 34	26·4		137	59·7	7 7	32·9
	88	71·7	8 55	20·8		113	81·0	1 3	26·6		138	63·2	7 43	33·2
	89	74·2	9 23	21·1		114	80·7	1 32	27·0		139	66·8	8 7	33·3
	90	77·3	9 54	21·2		115	81·2	2 2	27·1		140	69·0	8 31	33·6
	91	79·4	11 7	21·4		116	81·2	2 30	27·6		141	74·1	8 52	33·7
	92	81·1	11 31	21·8		117	80·3	2 56	27·8		142	77·0	9 23	34·1
	93	82·5	11 57	21·8	19th	118	60·2	6 55 A.M.	27·9		143	81·3	9 46	34·3
	94	82·1	0 25 P.M.	22·1		119	62·9	7 25	28·3		144	82·4	10 58	34·4
	95	83·4	0 48	22·2		120	66·6	7 59	28·5		145	85·1	11 19	34·8
	96	85·1	1 26	22·7		121	69·2	8 25	28·9		146	86·4	11 42	35·0
	97	85·0	1 50	23·0		122	73·2	8 49	29·1		147	87·8	0 5 P.M.	35·3
	98	82·4	2 16	23·3		123	76·0	9 15	29·3		148	89·0	0 28	35·6
	99	81·3	2 42	23·4		124	78·9	9 43	29·4		149	88·8	0 48	35·7
	100	79·2	3 7	23·7		125	81·0	10 45	29·8		150	88·9	1 7	36·0
18th	101	50·9	6 25 A.M.	23·8		126	82·3	11 11	30·0		151	89·7	1 22	36·3
	102	55·3	7 11	24·2		127	83·8	11 30	30·3		152	89·6	1 45	36·6
	103	60·8	7 39	24·4		128	84·4	11 51	30·6		153	88·3	2 5	36·9
	104	64·7	8 10	24·5		129	88·0	0 12 P.M.	30·9		154	88·5	2 25	37·2
	105	69·1	8 39	24·9		130	89·4	0 50	31·1		155	85·7	2 39	37·4
	106	72·5	9 8	25·1		131	90·0	1 16	31·4		156	83·5	3 0	37·6
	107	75·0	9 35	25·3		132	89·2	1 42	31·6					
	108	77·4	10 45	25·5		133	89·1	2 3	31·9				Total	+ 2841·0
	109	79·0	11 12	25·7		134	88·5	2 40	32·1					

The advanced-end of set No. 156 fell in excess (*i.e.* North) of the dot denoting Station A 0·0669 feet, as measured on Cary's brass scale with a pair of compasses.

Height of set No. 156 above Station A = 1·2 feet.

The terminal point of set No. 156 was the point of origin for set No. 157.

Dec. 1854	No. of the Set	Temperature of Air	Mean time of ending	Height of Set above origin	Dec. 1854	No. of the Set	Temperature of Air	Mean time of ending	Height of Set above origin	Dec. 1854	No. of the Set	Temperature of Air	Mean time of ending	Height of Set above origin
22nd	157	61·8	6 45 A.M.	+ 38·0	23rd	177	60·0	7 0 A.M.	+ 43·0	23rd	197	78·1	2 38 P.M.	+ 48·0
	158	63·2	7 24	38·3		178	62·0	7 25	43·2		198	77·8	3 3	48·1
	159	65·7	7 50	38·4		179	64·3	7 45	43		199	77·1	3 19	48·4
	160	67·2	8 16	38·7		180	66·3	8 7	43·8	26th	200	48·4	6 55 A.M.	48·8
	161	70·1	8 37	39·1		181	68·3	8 26	44·1		201	53·2	7 23	49·2
	162	71·8	9 3	39·2		182	69·2	8 45	44·3		202	57·2	7 50	49·5
	163	73·0	9 26	39·5		183	70·5	9 5	44·5		203	61·7	8 17	49·7
	164	76·0	9 50	39·8		184	71·9	9 27	44·6		204	65·0	8 38	50·0
	165	77·1	11 16	39·9		185	73·7	9 48	44·9		205	68·3	8 57	50·3
	166	77·1	11 41	40·4		186	74·6	10 50	45·1		206	71·3	9 22	50·5
	167	78·6	0 6 P.M.	40·6		187	76·3	11 12	45·3		207	75·6	9 45	50·9
	168	78·4	0 30	40·7		188	78·0	11 33	45·6		208	79·3	11 0	51·3
	169	79·1	0 53	41·0		189	79·0	11 57	45·8		209	79·0	11 25	51·7
	170	79·0	1 16	41·1		190	79·4	0 24 P.M.	46·0		210	80·2	11 50	52·0
	171	79·5	1 36	41·4		191	80·0	0 45	46·4		211	79·9	0 7 P.M.	52·3
	172	80·0	1 58	41·6		192	79·9	1 5	46·5		212	80·0	0 26	52·6
	173	79·9	2 20	41·9		193	79·8	1 23	46·9		213	81·0	0 43	53·1
	174	79·4	2 41	42·1		194	79·7	1 39	47·4		214	79·9	1 1	53·[illegible]
	175	79·0	3 0	42·4		195	79·4	2 0	47·7		215	79·9	1 19	53·9
	176	78·3	3 20	42·7		196	78·9	2 20	48·0		216	80·0	1 37	54·0

December 19th. A heavy fog till near 7 o'clock A.M. (157) to (199) Strong and cold N.E. wind.

Extracts from the Field Book—(Continued.)

Dec. 1854 & Jan. 1855	No. of the Set	Temperature of Air	Mean time of ending	Height of Set above origin
		°	h. m.	feet.
26th	217	81·4	2 0 P.M.	+ 54·1
	218	80·0	2 20	54·5
	219	80·9	2 37	54·8
	220	80·2	2 57	55·0
	221	80·4	3 12	55·2
27th	222	55·9	6 40 A.M.	55·4
	223	58·9	7 10	55·8
	224	61·6	7 32	56·1
	225	64·8	7 52	56·3
	226	66·4	8 15	56·6
	227	68·2	8 30	56·9
	228	70·4	8 47	56·9
	229	73·4	9 2	57·1
	230	75·2	9 22	57·5
	231	78·2	9 38	57·6
	232	80·5	10 30	57·9
	233	81·0	10 52	58·1
	234	82·7	11 10	58·3
	235	82·4	11 25	58·7
	236	84·4	11 41	58·9
	237	85·0	11 58	58·9
	238	85·4	0 14 P.M.	58·9
	239	85·9	0 29	58·7
	240	86·1	0 44	58·9
	241	85·4	0 59	59·2
	242	85·2	1 15	59·5
	243	85·4	1 28	59·8
	244	87·0	1 45	60·0
	245	86·2	2 0	60·3
	246	86·1	2 17	60·5
	247	86·4	2 31	60·7

Dec. 1854 & Jan. 1855	No. of the Set	Temperature of Air	Mean time of ending	Height of Set above origin
		°	h. m.	feet.
27th	248	85·2	2 48 P.M.	+ 61·0
	249	83·6	3 4	61·4
	250	81·8	3 20	61·7
28th	251	51·9	6 45 A.M.	62·0
	252	54·4	7 11	62·3
	253	57·1	7 29	62·5
	254	60·0	7 55	62·8
	255	63·8	8 13	63·1
	256	67·0	8 35	63·2
	257	69·6	8 53	63·6
	258	71·3	9 18	64·0
	259	74·1	9 37	64·1
	260	77·9	10 35	64·4
	261	78·8	10 52	64·4
	262	80·3	11 15	64·8
	263	80·2	11 33	64·9
	264	81·6	11 55	65·3
	265	82·4	0 15 P.M.	65·6
	266	82·9	0 33	65·7
	267	83·1	0 49	66·0
	268	83·1	1 12	66·5
	269	83·9	1 36	66·8
	270	83·0	2 4	67·2
	271	83·0	2 23	67·4
	272	82·7	2 42	67·8
	273	81·8	3 0	68·2
	274	81·8	3 16	68·5
29th	275	54·8	6 34 A.M.	68·9
	276	56·0	7 2	69·3
	277	59·5	7 20	69·6
	278	62·4	7 45	70·0

Dec. 1854 & Jan. 1855	No. of the Set	Temperature of Air	Mean time of ending	Height of Set above origin
		°	h. m.	feet.
29th	279	63·9	8 4 A.M.	+ 70·3
	280	65·8	8 25	70·7
	281	67·3	8 45	71·1
	282	70·9	9 5	71·5
	283	72·6	9 24	71·9
	284	73·8	9 43	72·2
	285	76·2	10 43	72·6
	286	77·8	11 2	72·9
	287	78·2	11 20	73·1
	288	79·9	11 40	73·5
	289	79·3	11 59	73·6
	290	79·3	0 20 P.M.	73·8
	291	80·4	0 37	73·8
	292	80·6	0 58	73·9
	293	80·6	1 16	73·9
	294	79·8	1 36	74·2
	295	79·9	2 0	74·4
	296	80·0	2 20	74·6
	297	78·9	2 40	75·0
	298	78·3	3 0	75·3
30th	299	61·2	6 45 A.M.	75·5
	300	63·0	7 11	75·9
	301	65·0	7 35	76·1
	302	66·4	8 0	76·3
	303	68·8	8 20	76·6
	304	70·8	8 45	76·8
	305	72·3	9 6	77·0
	306	75·0	9 30	77·5
			Total	+ 8615·2

The advanced-end of set No. 306 fell in defect (*i.e.* South) of the dot denoting station B 0·1403 feet, as measured on Cary's brass scale with a pair of compasses.

Height of set No. 306 above Station B = 1·2 feet.

The terminal point of set No. 306 was the point of origin for set No. 307.

Dec. 1854 & Jan. 1855	No. of the Set	Temperature of Air	Mean time of ending	Height of Set above origin
10th	307	48·0	6 30 A.M.	+ 77·6
	308	51·4	8 3	77·9
	309	55·4	8 29	78·2
	310	58·2	9 2	78·5
	311	60·9	9 23	78·7
	312	62·9	9 45	78·9
	313	67·1	10 45	79·0
	314	68·1	11 6	79·3
	315	70·9	11 27	79·6
	316	73·7	11 46	79·9
	317	74·0	0 5 P.M.	80·2
	318	75·0	0 25	80·5
	319	75·2	0 46	80·7
	320	74·9	1 7	81·1

Dec. 1854 & Jan. 1855	No. of the Set	Temperature of Air	Mean time of ending	Height of Set above origin
10th	321	75·8	1 28 P.M.	+ 81·4
	322	76·2	1 47	81·7
	323	76·5	2 8	81·9
	324	77·0	2 30	82·3
	325	76·2	2 50	82·5
	326	75·3	3 10	82·8
	327	75·7	3 35	83·1
11th	328	48·2	6 36 A.M.	83·3
	329	49·1	7 6	83·5
	330	52·3	7 28	83·7
	331	53·9	7 50	84·0
	332	55·2	8 14	84·3
	333	57·3	8 35	84·5
	334	58·2	8 55	84·8

Dec. 1854 & Jan. 1855	No. of the Set	Temperature of Air	Mean time of ending	Height of Set above origin
11th	335	61·1	9 14 A.M.	+ 85·0
	336	62·8	9 33	85·3
	337	66·0	9 54	85·5
	338	69·1	11 6	85·8
	339	71·1	11 25	86·1
	340	71·8	11 49	86·3
	341	71·9	0 9 P.M.	86·5
	342	71·1	0 29	86·8
	343	71·4	0 47	87·1
	344	70·9	1 7	87·4
	345	71·5	1 24	87·6
	346	71·0	1 45	87·8
	347	72·7	2 0	87·9
	348	71·0	2 17	88·0

(275) to (300) Light clouds. (328) to (348) Cloudy.

Extracts from the Field Book—(Continued.)

Jan. 1855	No. of the Set	Temperature of Air	Mean time of ending	Height of Set above origin	Jan. 1855	No. of the Set	Temperature of Air	Mean time of ending	Height of Set above origin	Jan. 1855	No. of the Set	Temperature of Air	Mean time of ending	Height of Set above origin
		°	*h. m.*	*feet.*			°	*h. m.*	*feet.*			°	*h. m.*	*feet.*
11th	349	72·0	2 31 P.M.	+ 88·1	13th	386	45·8	7 23 A.M.	+ 97·7	15th	423	66·8	9 6 A.M.	+106·7
	350	70·6	2 46	88·4		387	48·3	7 39	98·0		424	68·1	9 25	106·9
	351	71·0	3 1	88·5		388	50·4	7 57	98·2		425	70·4	9 42	107·0
	352	69·9	3 19	88·6		389	53·2	8 12	98·5		426	72·4	10 0	107·2
12th	353	50·9	6 40 A.M.	88·8		390	55·0	8 31	98·6		427	76·5	10 49	107·4
	354	51·2	7 5	89·2		391	56·7	8 45	98·9		428	74·8	11 10	107·4
	355	51·9	7 21	89·2		392	59·8	9 2	99·1		429	74·6	11 25	107·8
	356	53·6	7 38	89·4		393	61·8	9 17	99·3		430	75·5	11 42	107·9
	357	54·8	7 55	89·5		394	64·0	9 33	99·5		431	75·9	11 57	108·1
	358	55·7	8 13	89·7		395	66·1	9 49	99·8		432	74·8	0 14 P.M.	108·3
	359	56·9	8 29	89·6		396	68·7	10 35	99·9		433	74·7	0 30	108·6
	360	57·8	8 48	89·8		397	69·4	10 50	100·2		434	73·8	0 47	108·8
	361	58·9	9 3	89·9		398	71·4	11 6	100·4		435	74·3	1 6	109·0
	362	60·0	9 17	90·1		399	72·1	11 24	100·6		436	75·3	1 21	109·1
	363	60·8	9 30	90·5		400	73·2	11 41	100·8		437	75·6	1 35	109·4
	364	61·8	9 45	90·9		401	74·0	11 58	100·9		438	76·8	1 52	109·8
	365	64·6	10 33	91·2		402	74·5	0 15 P.M.	101·1		439	75·9	2 9	109·9
	366	65·2	10 47	91·5		403	75·4	0 29	101·3		440	75·3	2 27	109·9
	367	66·0	11 2	91·5		404	75·9	0 46	101·5		441	75·3	2 44	110·2
	368	66·6	11 20	91·8		405	76·5	1 2	101·7		442	74·6	3 3	110·5
	369	67·2	11 36	92·0		406	75·6	1 18	101·9		443	74·8	3 20	110·8
	370	68·0	11 53	92·4		407	75·8	1 33	102·1		444	74·1	3 37	111·0
	371	69·1	0 9 P.M.	92·6		408	76·0	1 52	102·2	16th	445	51·6	6 45 A.M.	111·1
	372	69·9	0 33	92·8		409	76·7	2 8	102·5		446	52·8	7 8	111·3
	373	70·7	0 51	93·3		410	76·5	2 23	102·8		447	54·2	7 27	111·6
	374	70·9	1 8	93·4		411	77·0	2 40	103·1		448	56·1	7 50	111·6
	375	70·5	1 23	93·9		412	76·8	2 55	103·4		449	58·7	8 6	111·7
	376	71·6	1 39	94·3		413	76·9	3 10	104·0		450	61·2	8 24	111·7
	377	71·3	1 53	94·4		414	76·2	3 25	104·1		451	63·6	8 41	111·7
	378	72·6	2 9	94·8	15th	415	51·3	6 40 A.M.	104·4		452	65·9	9 2	111·8
	379	72·8	2 24	95·4		416	52·3	7 4	104·8		453	68·2	9 18	111·9
	380	73·3	2 40	95·7		417	53·7	7 21	105·2		454	69·9	9 35	111·8
	381	72·7	2 55	96·0		418	55·1	7 38	105·4		455	71·7	9 51	112·0
	382	72·9	3 9	96·4		419	56·8	7 53	105·9		456	72·6	10 9	112·2
	383	72·9	3 23	96·6		420	59·2	8 12	106·0		457	74·4	10 27	112·9
13th	384	42·8	6 35 A.M.	96·9		421	61·9	8 30	106·2					
	385	44·0	7 3	97·3		422	63·9	8 48	106·2				Total +	14502·6

The advanced-end of set No. 457 fell in defect (*i.e.* South) of the dot denoting Station C 0·1083 feet, as measured on Cary's brass scale with a pair of compasses.

Height of set No. 457 above Station C = 1·1 feet.

The terminal point of set No. 457 was the point of origin for set No. 458.

16th	458	76·8	11 27 A.M.	+112·9	17th	466	51·0	6 46 A.M.	+ 114·6	17th	474	66·2	9 6 A.M.	+116·2
	459	75·8	11 51	112·8		467	52·7	7 13	114·7		475	68·1	9 21	116·3
	460	75·8	0 19 P.M.	113·0		468	54·4	7 32	114·8		476	69·9	9 37	116·3
	461	78·0	0 34	113·0		469	56·0	7 49	115·1		477	71·6	9 54	116·9
	462	79·1	0 50	113·2		470	57·9	8 5	115·3		478	75·3	10 54	117·4
	463	79·4	1 7	113·3		471	60·0	8 20	115·6		479	76·4	11 14	117·6
	464	79·8	1 32	113·7		472	62·2	8 37	115·8		480	77·8	11 34	117·7
	465	81·0	1 50	114·3		473	64·5	8 51	116·0		481	79·1	11 52	118·2

(349) and (350) Cloudy.

Extracts from the Field Book—(Continued.)

Jan. 1855	No. of the Set	Temperature of Air	Mean time of ending	Height of Set above origin
		°	h. m.	feet.
17th	482	78.5	0 8 P.M.	+118.6
	483	79.4	0 22	118.9
	484	76.4	0 40	119.2
	485	77.4	0 56	119.7
	486	76.8	1 15	120.1
	487	76.9	1 30	120.5
	488	76.3	1 50	121.0
	489	77.7	2 8	121.3
	490	76.2	2 24	121.5
	491	78.2	2 38	122.0
	492	76.7	2 53	122.3
	493	77.2	3 7	122.5
	494	75.7	3 23	122.7
18th	495	47.8	6 42 A.M.	123.0
	496	48.4	6 59	123.2
	497	49.7	7 15	123.6
	498	51.3	7 35	123.8
	499	54.1	7 51	124.2
	500	58.2	8 6	124.6
	501	62.1	8 23	125.0
	502	63.7	8 48	124.8
	503	65.6	9 2	125.4
	504	66.0	9 17	125.7
	505	67.4	9 31	125.9
	506	69.1	9 47	126.5
	507	70.7	10 37	126.6
	508	72.0	10 51	126.8
	509	72.3	11 6	127.1
	510	73.4	11 22	127.4
	511	73.9	11 36	127.6
	512	73.8	11 55	127.8
	513	74.0	0 10 P.M.	128.1
	514	74.7	0 27	128.3
	515	74.0	0 42	128.7
	516	74.5	0 59	128.9
	517	75.4	1 15	129.1
	518	74.8	1 30	129.4
	519	75.5	1 46	129.8
	520	75.0	2 1	130.1
	521	75.2	2 15	130.5
	522	75.1	2 29	130.8
	523	74.4	2 43	131.2
	524	74.3	2 59	131.6
	525	74.6	3 11	131.9
	526	74.0	3 26	132.1
19th	527	44.8	6 43 A.M.	+132.6
	528	46.9	7 2	132.9
	529	50.1	7 21	133.2
	530	52.7	7 40	133.6
	531	54.6	7 55	133.8
	532	56.9	8 11	134.1
	533	59.7	8 26	134.5
	534	61.0	8 41	134.6
	535	62.9	8 55	134.8
	536	64.8	9 10	135.0
	537	65.9	9 27	135.1
	538	67.3	9 44	135.2
	539	69.7	10 37	135.5
	540	70.8	10 52	135.8
	541	71.5	11 8	136.0
	542	71.9	11 26	136.3
	543	72.4	11 41	136.7
	544	73.5	11 58	136.9
	545	74.1	0 15 P.M.	137.3
	546	74.6	0 35	137.5
	547	75.1	0 53	137.8
	548	75.0	1 11	138.2
	549	74.9	1 25	138.5
	550	74.0	1 42	138.8
	551	74.3	1 59	139.2
	552	73.7	2 17	139.5
	553	73.3	2 31	139.8
	554	72.9	2 48	140.1
	555	72.8	3 3	140.3
	556	72.1	3 22	140.6
	557	71.5	3 38	140.9
20th	558	48.9	6 40 A.M.	141.2
	559	50.8	7 2	141.5
	560	52.5	7 20	141.9
	561	53.9	7 36	142.2
	562	56.3	7 53	142.4
	563	58.6	8 15	142.7
	564	60.2	8 35	142.9
	565	61.9	8 50	143.2
	566	63.0	9 6	143.5
	567	64.5	9 22	143.8
	568	64.9	9 37	144.0
	569	66.4	9 51	144.3
	570	67.2	10 40	144.6
	571	68.9	10 56	144.8
20th	572	69.3	11 14	+145.2
	573	70.0	11 32	145.6
	574	70.7	11 49	145.8
	575	70.9	0 7 P.M.	146.2
	576	71.4	0 24	146.4
	577	72.1	0 41	146.6
	578	72.1	0 59	147.0
	579	72.8	1 15	147.3
	580	72.9	1 36	147.5
	581	72.2	1 58	147.9
	582	72.2	2 9	148.2
	583	72.1	2 24	148.5
	584	71.8	2 41	149.0
	585	71.7	2 55	149.3
	586	71.5	3 12	149.6
	587	70.9	3 27	150.1
22nd	588	61.6	6 53 A.M.	150.4
	589	62.4	7 16	150.7
	590	63.1	7 34	151.1
	591	63.8	7 52	151.5
	592	62.2	8 9	151.7
	593	63.7	8 31	152.1
	594	66.1	8 46	152.4
	595	66.5	9 0	152.6
	596	69.4	9 16	152.9
	597	69.7	9 33	153.2
	598	70.4	9 51	153.4
	599	71.3	10 45	153.8
	600	72.8	11 2	154.1
	601	73.4	11 18	154.3
	602	72.8	11 35	154.6
	603	72.4	11 50	154.9
	604	75.9	0 9 P.M.	155.2
	605	75.5	0 25	155.5
	606	76.4	0 46	155.8
	607	77.5	1 3	156.0
	608	76.4	1 17	156.4
	609	76.2	1 36	156.7
	610	76.0	1 53	157.0
	611	77.1	2 12	157.4
	612	76.6	2 29	157.6
	613	73.5	2 52	158.2
			Total	+ 21022.3

The advanced-end of set No. 613 fell in defect (*i.e.* South) of the dot at North-End 3·0289 feet, as measured on Cary's brass scale with a beam compass.

Height of set No. 613 above North-End = 1·1 feet.

(527) to (587) Strong N.E. wind. (588) to (613) Strong N.E. wind; sunshine and clouds alternating; slight shower of rain in the morning.

Reduction to Mean Sea Level.

Let the sections into which this base-line is divided be denoted as follows;

South-End to Station A by Section I; Station B to Station C by Section III;
Station A to „ B by „ II; „ C to North-End by „ IV.

Then in the notation of (7) page I—22 we have

$$H = 46;\ h = 158{\cdot}0;\ \delta h = +\,0{\cdot}9;\ \text{Log. } R = 7{\cdot}31894;\ \text{and } n = 613.$$

	$[h]_1^p$	a	n	dh	F	λ	C_2	C_1	C
	+			+	+		—	—	—
Section I ...	2841	0	156	0·2	2857	9829	·0086	·0217	·0303
„ II ...	8615	0	150	0·2	8660	9451	·0262	·0209	·0471
„ III ...	14503	0	151	0·2	14579	9514	·0441	·0210	·0651
„ IV ...	21022	0	156	0·3	21139	9829	·0639	·0217	·0856

Final length of the Base-Line and of its parts in feet of Standard A.

Section	*Measured with*			Reduction to sea level as above	Total Length	Log.
	Compensated bars page VII—18	Compensated microscopes page VII—21	Beam compass pages VII—23 to VII—26			
S. End to Stn. A ...	9360·5140	468·0872	— 0·0669	—·0303	9828·5040	3·99248 7419
Stn. A to Stn. B ...	9000·4942	450·0871	+ 0·1403	—·0471	9450·6745	3·97546 2805
Stn. B to Stn. C ...	9060·4756	453·0928	+ 0·1083	—·0651	9513·6116	3·97834 5417
Stn. C to N. End ...	9360·4913	468·0968	+ 3·0289	—·0856	9831·5314	3·99262 1171
S. End to N. End ...	36781·9751	1839·3639	+ 3·2106	—·2281	38624·3215	4·58686 0863

Lengths in feet of Standard A, between South-End and the *Posterity-Marks*, at the levels of measurement.

	Measured with		
	Bars	Micros:	Total.
South-End to *Posterity-Mark* *a*	600·0329	30·0054	630·0383
„ „ *e*	1260·0692	63·0114	1323·0806
„ „ *f*	2520·1383	126·0227	2646·1610
„ „ *g*	5040·2768	252·0455	5292·3223

Verificatory Minor Triangulation.

No. of Triangle	Name of Station	Corrected Angle	Log. Sine	Log. Distance	Distance in Feet	Distance in Miles	Error of Triangle
					Feet	Miles	
1	South-End of Base, ...	61° 34′ 38″·152	9·944215970	4·017607935			
	Station A, ...	62 19 14·134	9·947218297	4·020610262			+0″·509
	„ α	56 6 7·735	9·919095454	3·992487419	9828·5040	1·861	
		180 0 0·021					
2	Station α	63 35 30·712	9·952137652	4·024208591			
	„ A, ...	54 30 24·012	9·910722081	3·982793020			+0·189
	„ β	61 54 5·297	9·945536996	4·017607935			
		180 0 0·021					
3	Station A, ...	63 10 23·889	9·950547695	4·022501501			
	„ β	53 12 13·315	9·903507804	3·975461610	9450·6485	1·790	−0·211
	„ B, ...	63 37 22·817	9·952254785	4·024208591			
		180 0 0·021					
4	Station β	63 31 15·220	9·951870103	4·038281043			
	„ B, ...	56 48 21·661	9·922632982	4·009043922			−0·60[illegible]
	„ γ	59 40 23·142	9·936090561	4·022501501			
		180 0 0·023					
5	Station B, ...	59 34 15·631	9·935636976	4·009640670			
	„ γ	53 21 2·708	9·904339326	3·978343020	9513·5591	1·802	−0·561
	„ C, ...	67 4 41·682	9·964277349	4·038281043			
		180 0 0·021					
6	Station γ	66 40 10·142	9·962954111	4·023668844			
	„ C, ...	50 34 35·298	9·887883219	3·948597952			+1·460
	„ δ	62 45 14·580	9·948925937	4·009640670			
		180 0 0·020					
7	Station C, ...	62 20 41·793	9·947315061	4·024214931			
	„ δ	55 26 49·951	9·915718417	3·992618287	9831·4661	1·862	−1·372
	North-End of Base, ...	62 12 28·278	9·946768974	4·023668844			
		180 0 0·022		Sum	38624·1777	7·315	

Note.—Each side of a triangle is given in the same horizontal line with the angle which it subtends.

The angles of the verificatory triangulation were measured with Troughton's 3-foot Theodolite, read by 5 micrometer microscopes. At all the stations 3 measures were made on each of 10 zeros. The stations on the line are South-End, A, B, C and North-End. The auxiliary stations are α, β, γ and δ.

Comparison in feet between the values computed by means of the verificatory triangulation and the measured value.

Of the entire line.

		feet	Log.
South-End to North-End by the measurement, page VII—27		38624·3215	4·586 860 863
"	in terms of South-End to Station A, page VII—28	38624·1777	4·586 859 246
	Log. computed value — Log. measured value		— 0·000 001 617

In terms of the entire line by measurement.

	Computed	Computed — Measured*
South-End to Station A	9828·5406	+·0366
Station A to Station B	9450·6837	+·0092
" B to " C	9513·5945	—·0171
" C to " North-End . . .	9831·5027	—·0287

Of each section in terms of the others.

	South-West-End to Station A	Station A to Station B	Computed — Measured	Station B to Station C	Computed — Measured	Station C to North-End	Computed — Measured
Measured lengths* ..	9828·5040	9450·6745	.. ..	9513·6116	.. ..	9831·5314	.. ..
Computed on base South-End to Station A	.. ..	9450·6485	—·0260	9513·5591	—·0525	9831·4661	—·0653
Computed on base Station A to Station B	.. ..	.. ..	.. ..	9513·5853	—·0263	9831·4932	—·0382
Computed on base Station B to Station C	.. ..	.. ..	.. ..	.. ..	.. ..	9831·5204	—·0110

NOTE.—Since $\text{Log}_e(x + dx) = \text{Log}_e x + \frac{(dx)}{x} - \frac{(dx)^2}{2x^2} + \&c.$

$dx = \left\{ \text{Log}_{10}(x + dx) - \text{Log}_{10} x \right\} \frac{x}{\text{Modulus}}$ nearly, by which expression the required variations in the foregoing natural numbers have been calculated.

Description of Stations.

SOUTH-END OF KARACHI BASE, Lat. 24° 53′ Long. 67° 12′ is situated in the district of Karâchi, and within a few yards of the road from Karâchi to Tattah. It is about 2 miles from the halting ground called Jamadar-ka-Landi, and some 9 miles E.S.E. from Karâchi.

The station is marked by a tower 22·9 feet high. An arched passage at the level of the ground, and parallel to the base-line, runs through the tower. On this arch and in the centre of the tower is an isolated and perforated pillar rising to the level of the top of the tower. The continuation of this pillar into the basement of the tower, contains the mark-stones. These are three in number, the first being at the level of the passage-floor, the second and third 1·8 feet and 3 feet respectively lower down, and all in the same normal. The uppermost mark consists of a dot on silver let into a brass plug, the latter being embedded in a slab of stone. This dot was used in the measurement of the base-line. It is protected by a small brass plate and a masonry dome of some 6 inches internal radius: the entrances to the passage are closed with brick work.

The South-End was connected in 1860, by a double line of spirit levels with the mean sea level at Karâchi, when it was found that the height of the surface of pillar containing the ground-level mark-stone was 46·38 feet above this datum.

NORTH-END OF KARACHI BASE, Lat. 24° 59′, Long. 67° 15′, is situated in the Karâchi district, and stands on an open plain entirely devoid of habitations.

The station is marked and protected similarly to the South-End of this base-line, the only difference being that the tower here is 18·4 feet high.

The North-End was connected similarly to the South-End with the mean sea level at Karâchi and it was found that the height of the surface of pillar containing the ground-level mark-stone was 204·40 feet above this datum.

STATIONS A, B, C. Are on the straight line from South-End to North-End of the base-line, and distant respectively 1·86, 3·65, 5·45 and 7·32 miles from the former.

The stations are marked by a dot on a silver pin let into a brass bar about 7 inches long embedded in stone, and covered over with a plate of brass; the stone is enclosed in an isolated pillar of masonry surrounded by a platform of stones and earth and has an earthen mound 12 or 15 feet in height raised over it.

POSTERITY-MARKS *a*, *e*, *f*, *g*. Are on the straight line from South-End to Station A, and distant respectively about 630 feet, ¼, ½ and 1 mile from the former.

These points are marked in the same manner as Stations A, B, C, with the difference that there is no platform here surrounding the pillar of masonry.

AUXILIARY STATIONS α, β, γ, δ. Are situated on suitable sites to the W. of the base-line.

The stations are marked by a central isolated pillar of masonry, surrounded by a platform of stones and earth about 14 feet square.

J. B. N. HENNESSEY.

VIZAGAPATAM BASE-LINE.

The middle point of this base-line is in Latitude N. 17° 58′, Longitude E. 83° 15′; the Azimuth of North-End at South-End is 199° 38′, and the line is 6·59 Miles in length.

The measurement was effected under the directions of Major J. T. Walker R.E. with the assistance of the following:

Captain J. P. Basevi, R.E.
Mr. J. B. N. Hennessey
Captain B. R. Branfill
Lieut. W. M. Campbell, R.E.
Mr. H. H. Taylor
„ R. Clarkson
„ F. Ryall
„ J. Wood
„ J. W. Mitchell
„ J. R. L. O'Neill

INTRODUCTION.

This base-line was measured on the plain between Waltair (near Vizagapatam) and Vizianagram in the Madras Presidency, the South-End of the line being some 17 Miles N.W. by North from the former place. The line was selected by Captain J. P. Basevi, R.E. assisted by Captain B.R. Branfill and the ground prepared under their supervision.

The measurement was commenced at South-End, bar-tongues pointing West, and was carried on *continuously* to the North-End, so that every succeeding set originated at the point marking the terminus of its predecessor. The line was divided into 3 sections by the sub-dividing points A and B to admit of verification by minor triangulation; and in addition four points called *Posterity-marks*, No. 1, No. 2, No. 3 and M were laid down in the measurement. Of these, the first named was fixed at the end of 6 sets or about 378 feet, the second at 12 sets or about 756 feet, and the third at 18 sets or about 1134 feet, all reckoned from the South-End. The point M was laid down at the end of the 173rd set from the same origin, near a site about the middle of the line suited for bar comparisons. It is also to be noticed that the South-End was connected by a single line of spirit levels, executed by Captain B. R. Branfill, with the tide gauge set up in the back water at Vizagapatam. The tidal observations for determining the mean sea level on the gauge were taken by Mr. R. Clarkson in November and December 1860.

The compensated bars were compared with the standard **A** on three occasions, *i.e.* before the measurement near South-End, after set 173 near the Posterity-mark M and after the measurement near North-End. On all these occasions the comparing piers were set up parallel to the line and within a few feet of it, while the bar-tongues pointed West as they did during the measurement. The series of comparisons at South-End comprised 66 sets, that at M consisted of 80 sets and 90 sets were taken at North-End.

One of the comparing microscopes employed in the preceding bar comparisons was fitted with a micrometer, while the other had its wires (or lines) fixed.

The compensated microscopes were compared with their scales on 5 occasions including the comparisons taken prior and subsequent to the measurement.

In respect to time, the first set of bar comparisons was taken on the 8th December 1862, the last on the 4th of the following February.

The verificatory triangulation was made to consist for the first time of a double series of triangles, *i.e.* a series was projected on either flank of the line, forming in all a complete figure of 10 triangles. Of the stations involved, S. End, A, B and N. End were in the alignment, and the remainder were selected on suitable sites, 3 to the West and as many East of the line. The angles were measured by Captain B. R. Branfill with Troughton and Simm's 24-inch theodolite No. 1 on 10 equidistant zeros; two measures were taken on each zero, so that 20 measures in all were made of each angle.

Comparisons between the Standard Bar **A** *and the Compensated Bars* A, B, C, D, E, H, *made at the South-End of the base-line, before the measurement.*

1862 Decr.	Mean of the times of observing **A**	No. of comparison	Temperature of Air	Corrected mean temperature of **A**	Micrometer Readings in Divisions — 1 Division = $\frac{1}{21572 \cdot 76}$ Cary's Inch [7.8], = 1·2870 *m.y.* of **A** — Mean **A**	A	B	C	D	E	H	Mean of the compensated bars	Remarks
	h. m.		°	°	+	+	+	+	+	+	+	+	
8th	9 28 A.M.	1	72·3	67·92	1109·9	1146·8	1141·4	1166·7	1177·4	1148·4	1150·3	1155·2	Major Walker at the micrometer microscope; Captain Branfill at the plain microscope.
	10 7	2	73·6	69·67	1144·0	1144·4	1138·3	1163·0	1181·0	1153·2	1155·9	1156·0	
	10 40	3	75·5	71·17	1169·1	1142·5	1129·3	1161·8	1177·3	1155·1	1159·5	1154·3	
	0 11 P.M.	4	77·9	75·37	1240·2	1140·7	1130·7	1164·8	1187·0	1174·7	1169·0	1161·2	
	0 42	5	78·3	76·57	1263·0	1142·3	1134·0	1168·5	1192·3	1180·1	1168·5	1164·3	
	1 7	6	79·5	77·55	1280·7	1148·0	1135·7	1164·6	1194·5	1177·6	1170·9	1165·2	
	1 38	7	80·5	78·45	1301·5	1152·3	1139·8	1178·0	1201·1	1182·0	1181·0	1172·4	Observers changed places.
	2 9	8	80·1	79·27	1317·5	1159·2	1150·8	1186·9	1203·2	1195·0	1188·0	1180·5	
	2 39	9	80·6	79·82	1329·1	1169·7	1155·0	1185·6	1211·7	1186·7	1184·6	1182·2	
	3 9	10	80·8	80·15	1336·6	1179·0	1163·5	1201·2	1221·2	1197·2	1195·8	1193·0	
	3 36	11	79·8	80·30	1339·2	1187·7	1171·7	1207·0	1227·2	1202·6	1202·1	1199·7	
	3 59	12	78·7	80·15	1336·2	1188·8	1180·0	1212·1	1228·9	1211·0	1199·2	1203·3	
9th	6 57 A.M.	13	62·4	63·55	1051·7	1203·8	1180·3	1219·7	1226·1	1188·3	1210·2	1204·7	Captain Branfill at the micrometer microscope; Mr. Taylor at the plain microscope.
	7 37	14	63·9	63·07	1054·8	1199·8	1187·4	1219·2	1233·3	1204·7	1195·5	1206·7	
	8 12	15	66·1	63·37	1063·7	1192·8	1172·5	1212·0	1225·3	1190·9	1201·8	1199·2	
	8 44	16	68·5	64·15	1080·7	1186·3	1179·0	1204·0	1215·1	1187·5	1197·0	1194·8	
	9 24	17	71·2	65·67	1111·8	1187·5	1169·5	1209·5	1213·3	1184·5	1187·5	1192·0	Observers changed places.
	9 58	18	72·9	67·35	1135·5	1176·7	1162·6	1183·6	1207·9	1188·8	1189·7	1184·9	
	10 27	19	74·6	68·97	1170·0	1172·0	1160·8	1191·2	1204·2	1183·8	1188·5	1183·4	
	10 56	20	76·3	70·62	1200·8	1177·5	1171·8	1195·8	1212·4	1190·2	1188·0	1189·3	
	0 25 P.M.	21	78·8	75·65	1292·8	1180·6	1181·3	1226·1	1245·2	1207·8	1206·9	1208·0	Mr. Hennessey at the micrometer microscope; Captain Basevi at the plain microscope.
	0 57	22	79·6	76·97	1320·2	1192·0	1187·1	1229·8	1247·4	1215·6	1209·9	1213·6	
	1 28	23	79·9	78·07	1342·4	1200·7	1193·2	1233·7	1251·2	1227·6	1218·8	1220·9	
	1 52	24	80·0	78·72	1356·3	1212·6	1196·7	1241·9	1263·5	1237·1	1232·1	1230·7	
	2 21	25	80·6	78·95	1366·2	1218·2	1201·2	1243·6	1263·7	1236·8	1231·5	1232·5	Observers changed places.
	2 49	26	80·6	79·50	1377·5	1214·1	1207·8	1248·0	1265·8	1240·1	1241·0	1236·1	
	3 13	27	80·2	79·77	1381·9	1224·8	1214·2	1249·1	1272·2	1246·0	1240·9	1241·2	
	3 35	28	79·5	79·77	1384·1	1234·7	1218·9	1258·0	1279·9	1257·3	1244·8	1248·9	
	3 56	29	78·1	79·72	1383·8	1237·7	1223·1	1265·0	1277·9	1257·1	1248·4	1251·5	
	4 17	30	76·1	79·75	1375·9	1238·6	1229·2	1265·3	1290·1	1262·7	1255·4	1256·9	Observers changed places.
10th	6 48 A.M.	31	58·1	61·42	1070·3	1250·5	1231·3	1257·6	1286·8	1247·1	1256·2	1254·9	Major Walker at the micrometer microscope; Captain Basevi at the plain microscope.
	7 13	32	59·8	60·77	1061·4	1250·9	1229·0	1257·8	1280·7	1248·9	1252·9	1253·4	
	7 33	33	61·3	60·45	1062·0	1251·4	1230·4	1251·2	1282·8	1242·8	1253·7	1252·1	
	7 55	34	62·3	60·40	1062·2	1246·0	1228·8	1252·3	1278·2	1241·3	1246·1	1248·8	
	8 22	35	64·6	60·35	1068·8	1244·7	1224·9	1248·0	1273·5	1240·1	1249·9	1246·9	Observers changed places.
	8 42	36	66·6	60·92	1081·2	1238·3	1222·1	1250·2	1272·6	1241·2	1248·0	1245·4	
	9 1	37	68·1	61·52	1096·5	1237·3	1221·5	1250·0	1272·7	1240·0	1243·3	1244·1	
	9 18	38	69·4	62·25	1111·6	1236·2	1216·0	1248·4	1265·2	1236·0	1241·8	1240·6	
	11 5	39	75·2	68·82	1222·0	1221·0	1213·0	1255·0	1271·1	1239·9	1229·2	1238·2	Captain Branfill at the micrometer microscope; Mr. Clarkson at the plain microscope.
	11 27	40	76·1	70·05	1245·4	1225·2	1212·2	1255·0	1265·1	1243·3	1231·8	1238·8	
	11 46	41	76·7	71·05	1260·7	1229·0	1208·1	1248·7	1274·3	1245·1	1238·7	1240·7	
	0 6 P.M.	42	77·4	72·10	1277·8	1229·3	1213·8	1253·3	1272·9	1247·1	1250·9	1244·6	

December 8th, 9th, 10th. (1) to (42). Wind N.E. sky clear.

Before the measurement—(Continued.)

1862 Decr.	Mean of the times of observing **A**	No. of comparison	Temperature of Air	Corrected mean temperature of **A**	Micrometer Readings in Divisions: 1 Division $= \frac{1}{21572 \cdot 76}$ Cary's Inch [7.8], = 1·2870 *m.y.* of **A** — Mean **A**	A	B	C	D	E	H	Mean of the compensated bars	Remarks
	h. m.		°	°	+	+	+	+	+	+	+	+	
10th	0 27 P.M.	43	78·0	73·10	1295·5	1224·3	1218·2	1256·5	1272·2	1260·8	1251·2	1247·2	
	0 47	44	78·9	73·90	1311·3	1233·0	1220·4	1257·1	1279·8	1252·7	1257·0	1250·0	
	1 11	45	80·1	74·70	1330·9	1239·3	1230·8	1267·5	1289·2	1265·6	1260·5	1258·8	Observers changed places.
	1 33	46	80·6	75·55	1348·0	1249·0	1236·0	1271·3	1289·0	1267·0	1266·5	1263·1	
	1 55	47	80·6	76·40	1364·3	1251·0	1243·2	1278·9	1295·0	1274·9	1273·5	1269·4	
	2 15	48	80·6	77·07	1377·1	1257·1	1243·4	1282·2	1294·8	1276·8	1277·8	1272·0	
	2 34	49	80·6	77·52	1384·1	1260·0	1243·1	1278·3	1299·5	1276·0	1275·9	1272·1	
	2 53	50	80·2	77·95	1393·6	1259·6	1244·3	1286·2	1305·3	1280·9	1283·3	1276·6	
	3 13	51	80·0	78·37	1405·8	1266·9	1248·5	1294·7	1309·9	1290·4	1282·7	1282·2	
	3 32	52	80·1	78·65	1411·4	1272·0	1251·2	1294·4	1312·0	1288·2	1285·0	1283·8	
	3 55	53	79·6	78·95	1410·9	1269·9	1255·1	1297·5	1314·1	1290·7	1285·0	1285·4	Observers changed places.
	4 18	54	77·6	79·02	1409·0	1272·1	1263·5	1293·3	1321·7	1296·3	1287·5	1289·1	
11th	6 38 A.M.	55	58·4	62·47	1147·0	1284·9	1278·5	1299·3	1324·7	1296·2	1302·2	1297·6	Captain Basevi at the micrometer microscope; Captain Branfill at the plain microscope.
	6 55	56	58·9	62·12	1136·8	1292·0	1279·0	1303·0	1322·8	1302·7	1302·5	1300·3	
	7 11	57	59·8	61·75	1128·5	1296·7	1276·1	1303·5	1324·5	1300·0	1292·5	1298·9	
	7 28	58	61·2	61·37	1126·6	1295·8	1276·6	1301·8	1323·1	1297·8	1299·1	1299·0	
	7 45	59	62·8	61·17	1128·0	1291·4	1268·3	1302·2	1320·6	1293·4	1303·7	1296·6	
	8 5	60	64·5	61·62	1131·0	1287·7	1267·2	1301·0	1318·0	1293·2	1296·9	1294·0	Observers changed places.
	8 23	61	66·1	61·92	1136·0	1284·1	1271·7	1302·0	1318·1	1292·4	1294·7	1293·8	
	8 42	62	67·5	62·42	1145·9	1281·5	1264·4	1294·4	1319·7	1289·4	1291·8	1290·2	
	9 3	63	68·9	63·12	1157·7	1276·4	1262·1	1289·8	1309·2	1279·7	1287·2	1284·1	
	9 23	64	70·0	63·95	1171·5	1276·1	1258·6	1286·1	1308·7	1279·0	1285·8	1282·4	
	9 42	65	71·1	64·77	1187·3	1271·1	1256·3	1287·1	1304·2	1285·6	1285·4	1281·6	
	10 0	66	72·7	65·27	1202·4	1269·7	1256·8	1286·4	1301·6	1284·0	1280·6	1279·9	Observers changed places.
		Means		70·81	1234·51	1225·35	1211·68	1245·42	1264·71	1239·35	1238·84	1237·56	

December 10th and 11th. (43) to (60) Wind N.E. Sky clear.

Before the measurement—(Continued.)

Let the mean length of the compensated bars minus the Standard **A** at 62° F be denoted by x, and the observed excess of the compensated bars by δ when the temperature of **A** is $t°$. Then, the expansion of **A** for 1° being $(E_a - dE_a)$, we have

$$x - (t° - 62°)(E_a - dE_a) - \delta = 0;$$

Treating the preceding bar comparisons as shewn in this equation, we obtain the following series of results :—

		d				d	
$x - 5·92$	$(E_a - dE_a)$	$-45·3$	$= 0$	$x - 17·75$	$(E_a - dE_a)$	$+119·0$	$= 0$
$x - 7·67$	„	$-12·0$	$= 0$	$x + 0·58$	„	$-184·6$	$= 0$
$x - 9·17$	„	$+14·8$	$= 0$	$x + 1·23$	„	$-192·0$	$= 0$
$x - 13·37$	„	$+79·0$	$= 0$	$x + 1·55$	„	$-190·1$	$= 0$
$x - 14·57$	„	$+98·7$	$= 0$	$x + 1·60$	„	$-186·6$	$= 0$
$x - 15·55$	„	$+115·5$	$= 0$	$x + 1·65$	„	$-178·1$	$= 0$
$x - 16·45$	„	$+129·1$	$= 0$	$x + 1·08$	„	$-164·2$	$= 0$
$x - 17·27$	„	$+137·0$	$= 0$	$x + 0·48$	„	$-147·6$	$= 0$
$x - 17·82$	„	$+146·9$	$= 0$	$x - 0·25$	„	$-129·0$	$= 0$
$x - 18·15$	„	$+143·6$	$= 0$	$x - 6·82$	„	$-16·2$	$= 0$
$x - 18·30$	„	$+139·5$	$= 0$	$x - 8·05$	„	$+6·6$	$= 0$
$x - 18·15$	„	$+132·9$	$= 0$	$x - 9·05$	„	$+20·0$	$= 0$
$x - 1·55$	„	$-153·0$	$= 0$	$x - 10·10$	„	$+33·2$	$= 0$
$x - 1·07$	„	$-151·9$	$= 0$	$x - 11·10$	„	$+48·3$	$= 0$
$x - 1·37$	„	$-135·5$	$= 0$	$x - 11·90$	„	$+61·3$	$= 0$
$x - 2·15$	„	$-114·1$	$= 0$	$x - 12·70$	„	$+72·1$	$= 0$
$x - 3·67$	„	$-80·2$	$= 0$	$x - 13·55$	„	$+84·9$	$= 0$
$x - 5·35$	„	$-49·4$	$= 0$	$x - 14·40$	„	$+94·9$	$= 0$
$x - 6·97$	„	$-13·4$	$= 0$	$x - 15·07$	„	$+105·1$	$= 0$
$x - 8·62$	„	$+11·5$	$= 0$	$x - 15·52$	„	$+112·0$	$= 0$
$x - 13·65$	„	$+84·8$	$= 0$	$x - 15·95$	„	$+117·0$	$= 0$
$x - 14·97$	„	$+106·6$	$= 0$	$x - 16·37$	„	$+123·6$	$= 0$
$x - 16·07$	„	$+121·5$	$= 0$	$x - 16·65$	„	$+127·6$	$= 0$
$x - 16·72$	„	$+125·6$	$= 0$	$x - 16·95$	„	$+125·5$	$= 0$
$x - 16·95$	„	$+133·7$	$= 0$	$x - 17·02$	„	$+119·9$	$= 0$
$x - 17·50$	„	$+141·4$	$= 0$	$x - 0·47$	„	$-150·6$	$= 0$
$x - 17·77$	„	$+140·7$	$= 0$	$x - 0·12$	„	$-163·5$	$= 0$
$x - 17·77$	„	$+135·2$	$= 0$	$x + 0·25$	„	$-170·4$	$= 0$
$x - 17·72$	„	$+132·3$	$= 0$	$x + 0·63$	„	$-172·4$	$= 0$

Before the measurement—(Continued.)

$x + 0{\cdot}83\,(E_a - dE_a) - \overset{d}{168{\cdot}6} = 0$	$x - 1{\cdot}12\,(E_a - dE_a) - \overset{d}{126{\cdot}4} = 0$
$x + 0{\cdot}38$ „ $-163{\cdot}0 = 0$	$x - 1{\cdot}95$ „ $-110{\cdot}9 = 0$
$x + 0{\cdot}08$ „ $-157{\cdot}8 = 0$	$x - 2{\cdot}77$ „ $-94{\cdot}3 = 0$
$x - 0{\cdot}42$ „ $-144{\cdot}3 = 0$	$x - 3{\cdot}27$ „ $-77{\cdot}5 = 0$

And from the mean of these results,

$$x = \overset{d}{3{\cdot}05} + 8{\cdot}81\,(E_a - dE_a);$$

adopting the original value of the expansion of **A** given at page (9),

$$E_a = \overset{m.y}{22{\cdot}67} = \overset{d}{17{\cdot}615},$$

$$\text{and } x = \overset{d}{158{\cdot}24} - 8{\cdot}81\,dE_a = \overset{m.y}{203{\cdot}65} - 8{\cdot}81\,dE_a = \mathrm{L} - \mathbf{A}.$$

where L denotes the mean length of the compensated bars obtained from *all* the comparisons, as represented by the mean micrometer reading $\overset{d}{1237{\cdot}56}$, page VIII—5.

Comparing this reading with the mean reading of each compensated bar given on the same page we obtain the following:—

In terms of	A − L	B − L	C − L	D − L	E − L	H − L
Micrometer divisions.	−12·21	−25·88	+ 7·86	+27·15	+1·79	+1·28
Millionths of a yard.	−15·71	−33·31	+10·12	+34·94	+2·30	+1·65

Also combining the values in this table with the equivalent of L—**A** above determined, there result,

$\mathrm{A} - \mathbf{A} = \overset{d}{146{\cdot}03} - 8{\cdot}81\,dE_a = \overset{m.y}{187{\cdot}94} - 8{\cdot}81\,dE_a$	$\mathrm{D} - \mathbf{A} = \overset{d}{185{\cdot}39} - 8{\cdot}81\,dE_a = \overset{m.y}{238{\cdot}59} - 8{\cdot}81\,dE_a$
$\mathrm{B} - \mathbf{A} = 132{\cdot}36 -$ „ $= 170{\cdot}34 -$ „	$\mathrm{E} - \mathbf{A} = 160{\cdot}03 -$ „ $= 205{\cdot}95 -$ „
$\mathrm{C} - \mathbf{A} = 166{\cdot}10 -$ „ $= 213{\cdot}77 -$ „	$\mathrm{H} - \mathbf{A} = 159{\cdot}52 -$ „ $= 205{\cdot}30 -$ „

$$\text{and } 6\,x = \overset{m.y}{1221{\cdot}9} + 52{\cdot}9\,dE_a.$$

Comparisons between the Standard Bar **A** *and the Compensated Bars* A, B, C, D, E, H, *made on a site selected at the centre of the base-line, after set No.* 266.

1863 Jany.	Mean of the times of observing A	No. of comparison	Temperature of Air	Corrected mean temperature of A	Micrometer Readings in Divisions — 1 Division = $\frac{1}{21573\cdot80}$ Cary's Inch [7.8], = 1·2869 m.y. of A — Mean A	A	B	C	D	E	H	Mean of the compensated bars	Remarks
	h. m.		°	°	+	+	+	+	+	+	+	+	
7th	11 44 A.M.	1	82·6	80·10	703·4	536·0	522·0	577·5	583·1	557·8	538·3	552·5	Mr. Hennessey at the micrometer microscope; Captain Branfill at the plain microscope;
	0 37 P.M.	2	84·8	82·25	743·5	536·8	526·2	580·2	592·1	561·2	553·1	558·3	
	0 56	3	84·3	82·80	754·4	551·9	527·8	581·1	595·2	574·6	557·2	564·6	
	1 9	4	84·5	83·15	759·8	552·4	542·4	589·1	599·8	585·3	565·2	572·4	
	1 21	5	84·0	83·35	768·8	562·1	544·8	594·1	611·8	587·8	571·3	578·7	Sky cloudy.
	1 39	6	82·7	83·65	768·6	566·8	562·5	597·3	603·0	583·7	569·0	580·4	Observers changed places.
	1 54	7	82·2	83·80	769·9	563·8	562·4	597·5	608·0	588·1	570·7	581·8	
	2 7	8	82·0	83·87	775·3	564·5	549·8	607·0	621·8	582·8	567·9	582·3	
	2 21	9	82·7	83·92	774·9	557·5	551·2	601·1	612·3	590·7	569·5	580·4	
	2 35	10	82·4	83·85	770·5	563·6	552·6	601·8	605·0	586·1	572·7	580·3	
	2 50	11	81·1	83·72	766·2	569·3	548·5	594·8	600·2	575·1	561·9	575·0	
	3 5	12	80·1	83·65	765·2	560·2	549·5	593·8	601·9	572·0	566·5	574·0	
	3 18	13	79·9	83·45	764·3	564·6	549·7	596·0	605·8	578·3	560·7	575·9	
	3 33	14	80·9	82·97	754·1	563·3	554·9	599·2	595·8	578·8	561·0	575·5	Observers changed places.
	3 47	15	80·1	82·60	743·6	576·2	546·8	588·7	594·1	573·9	557·9	572·9	
	4 3	16	78·8	82·15	747·4	570·4	559·8	588·4	600·0	575·6	558·8	575·5	
8th	7 1 A.M.	17	66·1	66·87	490·1	576·0	547·8	579·2	606·4	566·6	572·6	574·8	Major Walker at the micrometer microscope; Lieut. Campbell at the plain microscope.
	8 20	18	72·3	66·82	478·0	547·8	536·5	554·5	577·6	553·1	554·0	553·9	
	8 50	19	74·1	67·82	499·6	540·8	531·5	557·0	573·0	549·0	549·0	550·1	
	9 16	20	75·6	68·97	521·2	540·5	525·0	548·0	567·5	549·7	550·4	546·9	
	9 41	21	76·7	70·32	542·5	540·3	522·0	544·3	560·8	550·5	551·0	544·8	Sky clear.
	11 29	22	83·0	76·05	629·8	519·7	504·0	553·5	567·2	546·0	517·1	534·6	Captain Branfill at the micrometer microscope; Mr. Hennessey at the plain microscope.
	11 43	23	83·6	76·75	648·6	534·0	511·3	553·2	571·9	541·8	521·2	538·9	
	11 56	24	83·1	77·35	654·1	531·8	504·5	552·8	565·8	548·0	530·7	538·9	
	0 9 P.M.	25	82·9	77·97	658·6	527·0	500·6	554·9	561·1	544·1	525·6	535·6	
	0 20	26	82·9	78·45	670·4	533·0	506·7	550·7	557·8	536·5	529·6	535·7	
	0 31	27	82·8	78·80	677·0	527·8	516·5	548·6	565·8	539·3	525·8	537·3	
	0 43	28	82·7	79·15	682·6	532·7	518·1	562·3	561·8	547·8	536·3	543·2	
	0 54	29	83·0	79·55	693·1	534·8	511·2	557·1	572·1	548·8	540·6	544·1	
	1 4	30	83·8	79·82	709·6	545·2	518·1	566·8	569·2	558·5	549·9	551·3	
	1 15	31	84·5	80·07	715·0	542·1	522·2	570·7	573·8	550·7	551·0	551·8	
	1 31	32	84·7	80·55	712·6	544·2	518·8	567·4	571·7	562·4	544·4	551·5	Observers changed places
	1 40	33	84·7	80·77	715·8	540·9	521·8	564·0	571·2	560·6	545·4	550·7	
	1 49	34	84·3	80·90	719·0	541·2	532·4	572·7	586·3	559·8	544·8	556·2	
	1 58	35	84·4	81·05	724·2	551·0	525·7	564·4	582·8	565·6	553·7	557·2	
	2 7	36	84·2	81·27	729·0	536·8	533·7	570·3	582·2	558·4	548·6	555·0	
	2 17	37	83·8	81·47	733·6	547·3	525·1	574·2	585·6	562·4	553·8	558·1	
	2 28	38	83·4	81·57	734·1	545·1	529·9	575·9	587·8	565·0	550·7	559·1	
	2 39	39	83·3	81·65	734·9	554·6	529·0	569·7	584·6	566·2	548·7	558·8	
	2 48	40	83·4	81·67	733·7	550·8	528·3	571·6	579·4	558·4	546·2	555·8	
	2 58	41	83·3	81·70	727·5	556·4	528·8	576·3	592·0	556·6	559·0	561·5	
	3 8	42	83·4	81·75	729·3	554·6	532·0	571·3	582·4	571·4	563·6	562·6	

After set No. 266—(Continued.)

1863 Jany.	Mean of the times of observing A	No. of comparison	Temperature of Air	Corrected mean temperature of A	Mean A	A	B	C	D	E	H	Mean of the compensated bars	Remarks
					Micrometer Readings in Divisions: 1 Division = $\frac{1}{21573.80}$ Cary's Inch [7.8], = 1.2869 m.y. of A								
	h. m.		°	°	+	+	+	+	+	+	+	+	
8th	3 18 P.M.	43	83.4	81.75	733.8	556.1	538.3	579.6	578.4	569.4	564.9	564.5	
	3 33	44	83.1	81.80	729.5	559.2	538.2	579.7	585.9	561.3	569.7	565.7	Observers changed places.
	3 45	45	82.8	81.80	731.3	554.3	543.0	586.0	585.2	569.1	560.7	566.4	
9th	7 3 A.M.	46	61.7	62.67	407.8	552.5	550.3	580.5	581.4	560.2	578.0	567.2	Mr. Taylor at the micrometer microscope; Mr. Clarkson at the plain microscope.
	7 30	47	64.2	62.30	411.6	565.0	551.0	579.4	592.0	566.2	570.0	570.6	
	7 50	48	66.1	62.35	415.4	565.0	543.0	587.1	591.8	569.6	572.7	571.5	
	8 12	49	67.2	62.60	420.8	562.1	542.0	574.2	581.8	561.2	565.7	564.5	
	8 32	50	68.5	63.02	430.9	553.9	545.0	564.6	575.7	555.2	567.9	560.4	
	8 51	51	70.1	63.72	444.9	548.7	530.6	560.0	572.9	557.3	557.7	554.5	
	9 15	52	71.5	64.60	460.9	546.2	529.4	554.8	574.0	558.8	558.1	553.6	Sky clear.
	9 34	53	73.1	65.65	478.5	537.4	529.9	554.0	567.8	556.2	556.7	550.3	
	9 50	54	74.5	66.62	496.8	538.3	524.5	552.5	570.0	553.8	554.4	548.9	
	10 7	55	76.1	67.55	511.1	539.8	522.8	546.8	570.4	555.4	549.1	547.4	
	10 27	56	77.2	68.87	526.9	531.0	521.5	549.4	564.3	556.4	552.7	545.9	
	0 0 P.M.	57	84.1	75.15	629.9	529.0	514.5	558.1	566.5	540.2	536.0	540.7	Observers changed places.
	0 21	58	85.1	76.40	655.1	527.6	516.9	554.9	565.9	556.0	549.9	545.2	
	0 39	59	85.6	77.27	672.3	536.2	522.1	556.0	573.9	552.9	541.2	547.1	
	0 57	60	85.8	78.20	688.2	538.5	525.0	557.0	577.8	557.0	544.0	549.9	
	1 14	61	85.0	79.00	699.8	542.0	519.7	559.6	572.8	559.5	557.2	551.8	
	1 34	62	84.9	79.75	715.1	542.0	530.1	571.2	581.2	555.2	568.7	558.1	
	1 54	63	85.6	80.50	724.9	542.9	533.9	569.5	587.9	574.9	561.0	561.7	
	2 13	64	85.5	81.15	727.3	548.2	542.2	568.3	583.6	580.9	566.5	565.0	
	2 31	65	85.2	81.52	741.8	553.8	543.0	572.8	585.9	577.8	564.8	566.4	
	2 50	66	85.0	81.72	753.9	550.9	540.5	568.0	592.1	572.5	573.3	566.2	
	3 9	67	84.8	82.02	753.9	563.9	546.0	586.5	588.9	574.5	572.5	572.1	
	3 26	68	84.1	82.32	749.2	571.3	551.0	588.1	596.9	583.2	573.1	577.3	
	3 48	69	82.6	82.40	755.4	573.8	559.7	588.7	609.6	590.1	581.4	583.9	Observers changed places.
	4 5	70	81.9	82.40	755.5	568.9	555.7	596.4	607.8	590.1	581.0	583.3	Sky clear.
10th	6 53 A.M.	71	60.6	62.90	426.2	586.8	558.8	591.6	601.7	577.8	576.2	582.2	Major Walker at the micrometer microscope; Captain Basevi at the plain microscope.
	7 15	72	61.8	62.50	416.8	579.8	560.6	583.8	599.2	576.4	573.7	578.9	
	7 33	73	63.7	62.25	415.8	578.2	565.8	587.0	599.7	578.4	578.2	581.2	
	7 49	74	65.2	62.17	419.3	571.6	560.4	584.0	598.6	575.0	576.5	577.7	
	8 6	75	67.1	62.27	424.0	574.9	552.8	582.8	595.0	573.2	575.5	575.7	Sky clear.
	8 25	76	69.9	62.27	432.7	569.2	564.4	570.8	591.0	569.0	572.0	572.7	Observers changed places.
	8 41	77	70.7	62.85	444.6	569.1	555.1	566.5	589.2	574.6	575.9	571.7	
	8 57	78	71.7	63.55	457.3	565.5	549.0	568.5	579.0	559.2	562.6	564.0	
	9 14	79	73.1	64.30	470.2	567.0	548.8	564.9	585.2	568.6	566.1	566.8	
	9 28	80	73.8	65.02	484.7	560.0	548.0	563.0	583.6	573.2	561.9	565.0	
		Means		75.67	637.60	552.21	536.32	572.82	584.90	565.12	557.91	561.55	

After set No. 266—(Continued.)

As on page VIII—6 we have

$$x - (t^\circ - 62^\circ)(E_a - dE_a) - \delta = 0;$$

and from the preceding bar comparisons, we obtain the following series of results:—

$x-18.10$	$(E_a - dE_a)$	$+150.9 = 0$	$x-18.90$	$(E_a - dE_a)$	$+162.8 = 0$
$x-20.25$	„	$+185.2 = 0$	$x-19.05$	„	$+167.0 = 0$
$x-20.80$	„	$+189.8 = 0$	$x-19.27$	„	$+174.0 = 0$
$x-21.15$	„	$+187.4 = 0$	$x-19.47$	„	$+175.5 = 0$
$x-21.35$	„	$+190.1 = 0$	$x-19.57$	„	$+175.0 = 0$
$x-21.65$	„	$+188.2 = 0$	$x-19.65$	„	$+176.1 = 0$
$x-21.80$	„	$+188.1 = 0$	$x-19.67$	„	$+177.9 = 0$
$x-21.87$	„	$+193.0 = 0$	$x-19.70$	„	$+166.0 = 0$
$x-21.92$	„	$+194.5 = 0$	$x-19.75$	„	$+166.7 = 0$
$x-21.85$	„	$+190.2 = 0$	$x-19.75$	„	$+169.3 = 0$
$x-21.72$	„	$+191.2 = 0$	$x-19.80$	„	$+163.8 = 0$
$x-21.65$	„	$+191.2 = 0$	$x-19.80$	„	$+164.9 = 0$
$x-21.45$	„	$+188.4 = 0$	$x-0.67$	„	$-159.4 = 0$
$x-20.97$	„	$+178.6 = 0$	$x-0.30$	„	$-159.0 = 0$
$x-20.60$	„	$+170.7 = 0$	$x-0.35$	„	$-156.1 = 0$
$x-20.15$	„	$+171.9 = 0$	$x-0.60$	„	$-143.7 = 0$
$x-4.87$	„	$-84.7 = 0$	$x-1.02$	„	$-129.5 = 0$
$x-4.82$	„	$-75.9 = 0$	$x-1.72$	„	$-109.6 = 0$
$x-5.82$	„	$-50.5 = 0$	$x-2.60$	„	$-92.7 = 0$
$x-6.97$	„	$-25.7 = 0$	$x-3.65$	„	$-71.8 = 0$
$x-8.32$	„	$-2.3 = 0$	$x-4.62$	„	$-52.1 = 0$
$x-14.05$	„	$+95.2 = 0$	$x-5.55$	„	$-36.3 = 0$
$x-14.75$	„	$+109.7 = 0$	$x-6.87$	„	$-19.0 = 0$
$x-15.35$	„	$+115.2 = 0$	$x-13.15$	„	$+89.2 = 0$
$x-15.97$	„	$+123.0 = 0$	$x-14.40$	„	$+109.9 = 0$
$x-16.45$	„	$+134.7 = 0$	$x-15.27$	„	$+125.2 = 0$
$x-16.80$	„	$+139.7 = 0$	$x-16.20$	„	$+138.3 = 0$
$x-17.15$	„	$+139.4 = 0$	$x-17.00$	„	$+148.0 = 0$
$x-17.55$	„	$+149.0 = 0$	$x-17.75$	„	$+157.0 = 0$
$x-17.82$	„	$+158.3 = 0$	$x-18.50$	„	$+163.2 = 0$
$x-18.07$	„	$+163.2 = 0$	$x-19.15$	„	$+162.3 = 0$
$x-18.55$	„	$+161.1 = 0$	$x-19.52$	„	$+175.4 = 0$
$x-18.77$	„	$+165.1 = 0$	$x-19.72$	„	$+187.7 = 0$

After the set No. 266—(Continued.)

$x-20{\cdot}02\,(E_a - dE_a) + \overset{d}{181{\cdot}8} = 0$ $x-0{\cdot}17\,(E_a - dE_a) - \overset{d}{158{\cdot}4} = 0$

$x-20{\cdot}32$ „ $+171{\cdot}9 = 0$ $x-0{\cdot}27$ „ $-151{\cdot}7 = 0$

$x-20{\cdot}40$ „ $+171{\cdot}5 = 0$ $x-0{\cdot}27$ „ $-140{\cdot}0 = 0$

$x-20{\cdot}40$ „ $+172{\cdot}2 = 0$ $x-0{\cdot}85$ „ $-127{\cdot}1 = 0$

$x-0{\cdot}90$ „ $-156{\cdot}0 = 0$ $x-1{\cdot}55$ „ $-106{\cdot}7 = 0$

$x-0{\cdot}50$ „ $-162{\cdot}1 = 0$ $x-2{\cdot}30$ „ $-96{\cdot}6 = 0$

$x-0{\cdot}25$ „ $-165{\cdot}4 = 0$ $x-3{\cdot}02$ „ $-80{\cdot}3 = 0$

And from the mean of these results,

$$x = -\overset{d}{76{\cdot}05} + 13{\cdot}67\,(E_a - dE_a):$$

adopting the original value of the expansion of **A** given at page (9),

$$E_a = \overset{m.y}{22{\cdot}67} = \overset{d}{17{\cdot}616},$$

and $x = \overset{d}{164{\cdot}76} - 13{\cdot}67\,dE_a = \overset{m.y}{212{\cdot}03} - 13{\cdot}67\,dE_a = \mathrm{L} - \mathbf{A}.$

Proceeding as on page VIII—7 we obtain:—

In terms of	A − L	B − L	C − L	D − L	E − L	H − L
Micrometer divisions.	− 9·34	−25·23	+11·27	+23·35	+3·57	−3·64
Millionths of a yard.	−12·02	−32·47	+14·50	+30·05	+4·59	−4·68

Also the following,

$$\begin{aligned}
\mathrm{A} - \mathbf{A} &= \overset{d}{155{\cdot}42} - 13{\cdot}67\,dE_a = \overset{m.y}{200{\cdot}01} - 13{\cdot}67\,dE_a\\
\mathrm{B} - \mathbf{A} &= 139{\cdot}53 - \text{„} = 179{\cdot}56 - \text{„}\\
\mathrm{C} - \mathbf{A} &= 176{\cdot}03 - \text{„} = 226{\cdot}53 - \text{„}\\
\mathrm{D} - \mathbf{A} &= 188{\cdot}11 - \text{„} = 242{\cdot}08 - \text{„}\\
\mathrm{E} - \mathbf{A} &= 168{\cdot}33 - \text{„} = 216{\cdot}62 - \text{„}\\
\mathrm{H} - \mathbf{A} &= 161{\cdot}12 - \text{„} = 207{\cdot}35 - \text{„}
\end{aligned}$$

and $6\,x = \overset{m.y}{1272{\cdot}2} - 82{\cdot}0\,dE_a.$

Comparisons between the Standard Bar **A** *and the Compensated Bars* A, B, C, D, E, H, *made at the North-End of the base-line, after the measurement.*

1863 Jany. and Feby.	Mean of the times of observing A	No. of comparison	Temperature of Air	Corrected mean temperature of A	MICROMETER READINGS IN DIVISIONS 1 Division = $\frac{1}{21638 \cdot 35}$ Cary's Inch [7.8], = 1·2831 m.y. of A — Mean A	A	B	C	D	E	H	Mean of the compensated bars	REMARKS
	h. m.		°	°	+	+	+	+	+	+	+	+	
31st	7 29 A.M.	1	66·7	65·57	817·1	919·4	902·9	929·9	952·1	917·0	919·1	923·4	Mr. Hennessey at the micrometer microscope: Lieutenant Campbell at the plain microscope.
	7 50	2	67·7	65·52	816·2	914·0	900·0	924·2	950·6	918·2	916·2	920·5	
	8 5	3	68·2	65·67	818·0	914·1	902·1	923·3	946·8	918·6	919·0	920·7	
	8 19	4	69·2	65·90	823·4	916·6	895·3	923·8	945·7	919·2	915·8	919·4	
	8 35	5	69·8	66·27	832·3	911·3	898·0	918·0	941·2	920·7	918·2	917·9	
	8 58	6	72·0	67·00	846·7	905·7	887·4	918·1	941·4	913·9	914·9	913·6	Observers changed places.
	9 17	7	73·1	67·60	863·2	905·3	890·0	924·0	939·9	922·0	922·5	917·3	
	9 36	8	74·7	68·37	875·9	911·5	888·2	918·0	941·1	918·1	920·3	916·2	
	9 53	9	76·7	69·22	884·2	909·0	885·0	920·1	938·3	916·5	921·1	915·0	
	10 8	10	77·6	70·02	898·3	904·3	886·4	923·3	935·0	913·6	919·9	913·8	
	11 20	11	83·0	75·27	985·0	882·7	871·3	910·8	931·0	907·7	902·4	901·0	Observers changed places.
	11 43	12	84·4	76·90	1011·9	885·8	878·4	916·3	942·8	914·1	908·8	907·7	
	0 8 P.M.	13	85·5	78·62	1043·5	901·3	885·3	927·8	954·8	928·1	917·9	919·2	
	0 29	14	84·2	80·07	1068·6	895·5	893·8	942·6	961·9	930·9	926·4	925·2	
	0 59	15	83·1	81·47	1092·9	912·6	905·3	940·7	963·7	940·1	934·8	932·9	
	1 23	16	83·4	82·07	1101·2	915·0	905·4	950·9	968·0	943·3	932·9	935·9	Observers changed places.
	1 42	17	84·0	82·37	1105·7	921·1	910·0	952·1	970·1	946·2	933·5	938·8	
	2 1	18	83·4	82·62	1105·9	917·6	907·3	955·9	966·6	937·3	932·1	936·1	
	2 21	19	82·3	82·70	1107·1	925·0	908·3	952·2	972·0	944·9	930·0	938·7	Light clouds scattered about the sky.
	2 43	20	81·5	82·62	1106·3	926·1	915·7	947·6	970·0	945·9	934·9	940·0	
	3 4	21	80·7	82·50	1103·8	928·4	913·3	951·0	965·3	940·0	938·1	939·4	
	3 26	22	80·7	82·22	1103·6	928·1	925·6	958·2	976·0	944·2	937·3	944·9	Observers changed places.
2nd	6 59 A.M.	23	65·7	68·72	872·2	917·7	908·2	931·3	949·4	924·0	927·8	926·4	Major Walker at the micrometer microscope; Lieut. Campbell at the plain microscope.
	7 21	24	67·0	68·30	860·0	922·7	909·0	929·8	949·8	923·7	922·7	926·3	
	7 40	25	68·5	68·05	856·2	918·7	906·5	926·3	950·5	920·7	923·1	924·3	
	7 59	26	70·5	67·95	858·0	917·6	906·5	926·0	949·0	921·5	923·0	923·9	
	8 19	27	71·1	68·07	862·6	917·5	897·5	922·8	941·2	917·8	921·3	919·7	
	8 47	28	73·9	68·55	874·9	905·5	893·6	915·8	942·1	918·7	913·7	914·9	Observers changed places.
	9 7	29	75·4	69·20	886·2	902·4	889·9	910·4	937·8	912·8	912·2	910·9	
	9 25	30	77·2	70·00	898·4	903·5	886·6	914·9	933·2	911·2	908·3	909·6	
	9 43	31	78·7	70·85	912·4	895·4	879·4	906·2	929·7	907·2	906·3	904·0	
	10 0	32	80·5	71·72	926·7	892·3	877·5	902·8	623·8	905·9	905·1	901·2	
	11 19	33	85·5	76·80	1009·8	885·0	872·0	904·2	932·0	894·8	890·1	896·4	Mr. Taylor at the micrometer microscope; Mr. Clarkson at the plain microscope.
	11 41	34	87·1	78·20	1035·5	880·2	864·2	908·9	929·0	903·9	892·8	896·5	
	0 3 P.M.	35	87·8	79·52	1058·6	878·3	872·0	910·8	933·0	910·0	899·8	900·7	
	0 25	36	87·9	80·80	1080·1	887·2	872·4	914·0	930·4	905·4	905·2	902·4	
	0 44	37	89·8	82·05	1100·6	887·0	872·7	908·0	931·6	912·2	904·0	902·6	
	1 19	38	89·4	83·92	1130·1	900·6	877·0	913·0	937·4	917·0	911·5	909·4	Observed changed places.
	1 42	39	89·7	84·82	1146·3	892·5	886·0	918·9	938·0	927·0	918·8	913·5	
	2 2	40	89·2	85·57	1156·3	901·0	887·2	923·5	946·0	918·8	921·0	916·3	
	2 19	41	88·8	86·17	1163·7	903·0	890·9	922·5	948·8	926·5	921·0	918·8	
	2 35	42	87·9	86·55	1170·1	908·4	892·5	926·0	943·0	926·0	921·0	919·5	
	2 51	43	87·3	86·72	1172·8	912·0	904·6	936·0	954·2	931·0	924·8	927·1	
	3 11	44	87·3	86·95	1173·0	916·4	901·8	930·2	952·3	928·7	928·9	926·4	Do. do.
	3 27	45	86·7	87·00	1173·4	916·9	903·2	940·9	954·4	933·7	923·2	928·7	Do. do.
	3 46	46	86·1	86·70	1170·3	918·0	905·2	937·0	962·1	934·0	929·7	931·0	Do. do.

After the measurement—(Continued.)

1863 Feby.	Mean of the times of observing A (h. m.)	No. of comparison	Temperature of Air (°)	Corrected mean temperature of A (°)	Micrometer Readings in Divisions: 1 Division = $\frac{1}{21638\cdot35}$ Cary's Inch [7.8], = 1·2831 *m.y.* of A — Mean A (+)	A (+)	B (+)	C (+)	D (+)	E (+)	H (+)	Mean of the compensated bars (+)	Remarks
3rd	6 54 A.M.	47	63·6	66·22	813·1	904·9	894·2	920·0	932·5	913·6	911·4	912·8	Major Walker at the micrometer microscope Lt. Campbell at the plain microscope.
	7 15	48	65·3	65·75	806·0	903·0	889·0	919·8	938·2	905·5	909·0	910·3	
	7 36	49	67·3	65·50	801·3	904·5	885·5	906·8	936·5	904·9	908·4	907·8	
	7 56	50	69·0	65·50	802·7	895·0	883·5	915·2	933·5	904·3	904·0	905·9	
	8 13	51	70·7	65·70	806·5	894·3	880·2	909·0	927·8	899·2	901·1	901·9	
	8 38	52	73·8	66·22	814·9	889·6	875·0	902·6	923·0	895·9	895·4	896·9	Observers changed places.
	8 57	53	75·7	66·90	828·7	880·0	867·1	898·8	917·1	892·9	899·1	892·5	
	9 13	54	77·1	67·62	844·7	877·0	863·8	893·1	915·4	897·3	893·4	890·0	
	9 29	55	78·8	68·45	860·1	872·9	860·3	896·0	907·4	887·1	891·1	885·8	
	9 46	56	79·9	69·50	874·2	873·2	858·6	892·1	906·4	885·1	884·0	883·2	
	11 16	57	86·8	75·90	977·0	848·0	844·0	884·4	909·2	874·2	861·5	870·2	Mr. Taylor at the micrometer microscope; Mr. Clarkson at the plain microscope.
	11 33	58	88·4	77·10	996·8	848·3	843·0	879·0	905·4	880·4	877·0	872·2	
	11 49	59	89·1	78·27	1017·3	851·0	840·9	882·9	907·3	881·3	877·9	873·6	
	0 27 P.M.	60	90·6	80·87	1066·0	864·0	856·0	884·0	912·0	893·0	882·2	881·9	
	0 43	61	91·0	82·00	1087·3	861·0	856·5	887·6	912·3	895·7	886·2	883·2	Observers changed places.
	0 56	62	91·6	83·07	1105·0	861·4	852·8	894·9	912·9	895·9	893·0	885·2	
	1 12	63	91·1	84·10	1122·3	867·0	864·9	895·0	917·2	897·0	898·7	890·0	
	1 27	64	91·0	85·17	1140·3	868·5	857·2	894·5	914·0	906·0	900·2	890·1	
	1 44	65	92·3	86·27	1155·9	873·0	863·0	898·0	914·7	896·7	898·7	890·7	
	2 1	66	92·1	87·17	1170·2	875·5	873·5	904·5	921·8	900·3	902·2	896·3	
	2 22	67	91·7	88·25	1182·8	881·0	874·2	902·3	923·3	902·9	898·3	897·0	Observers changed places.
	2 40	68	91·4	88·95	1193·2	876·0	872·3	913·7	929·2	905·7	903·7	900·1	
	2 56	69	91·6	89·35	1201·1	891·3	877·2	911·1	935·0	909·9	896·7	903·5	
	3 13	70	92·2	89·75	1207·1	893·8	879·1	916·0	932·4	906·0	900·0	904·6	
4th	7 7 A.M.	71	67·0	69·15	855·6	902·8	892·0	915·0	935·5	905·2	905·0	909·3	Major Walker at the micrometer micros: Mr. Clarkson at the plain microscope.
	7 25	72	68·3	68·72	849·8	905·0	894·0	914·0	937·0	906·8	907·0	910·6	
	7 43	73	69·6	68·55	850·8	907·0	888·0	907·5	927·6	900·9	905·8	906·1	
	8 1	74	71·2	68·50	852·7	897·3	884·6	908·9	925·9	904·4	906·1	904·5	
	8 24	75	73·5	68·67	859·2	903·5	889·3	912·4	936·5	908·4	911·0	910·2	Observers changed places.
	8 39	76	74·9	69·12	869·8	896·2	891·0	912·6	932·2	910·1	910·7	908·8	
	8 54	77	76·7	69·80	883·3	900·7	889·0	906·1	932·7	908·0	913·8	908·4	
	9 12	78	78·5	70·52	896·7	895·8	889·8	907·5	928·9	908·1	912·8	907·2	
	11 33	79	88·5	78·82	1030·1	870·4	868·0	901·7	925·7	890·1	891·1	891·2	Lieut. Campbell at the micrometer microscope; Mr. Hennessey at the plain microscope.
	11 46	80	89·6	79·65	1044·7	873·4	859·2	898·9	930·1	891·4	890·1	890·5	
	11 59	81	90·5	80·60	1062·1	870·1	863·2	900·2	927·2	890·0	892·5	890·5	
	0 12 P.M.	82	90·6	81·55	1077·6	869·7	863·3	897·4	922·0	887·2	889·9	888·3	
	0 23	83	91·4	82·32	1091·0	863·1	861·6	893·0	921·3	897·9	893·2	888·4	
	0 34	84	92·6	83·10	1105·8	861·6	860·8	893·6	907·5	891·3	890·4	884·2	
	0 49	85	93·1	84·12	1124·2	869·9	859·8	895·7	916·6	897·2	892·3	888·6	Observers changed places.
	1 1	86	93·3	84·92	1136·5	869·4	858·8	897·4	919·8	894·4	893·7	888·9	
	1 12	87	92·6	85·65	1149·5	870·9	860·7	899·6	917·1	895·6	894·3	889·7	
	1 23	88	92·4	86·35	1160·3	871·1	861·4	898·1	920·3	895·5	896·5	890·5	
	1 35	89	92·9	87·02	1169·1	872·3	866·4	902·4	919·4	903·1	896·2	893·3	
	1 47	90	93·3	87·65	1180·2	879·2	868·6	902·2	921·7	903·6	899·1	895·7	
		Means		76·69	1000·92	893·68	882·14	914·16	935·14	910·59	908·18	907·32	

After the measurement—(Continued.)

As on page VIII—6 we have

$$x - (t^\circ - 62^\circ)\,(E_a - dE_a) - \delta = 0;$$

and from the preceding bar comparisons, we obtain the following series of results :—

		d			d
$x-$ 3·57	$(E_a - dE_a)$	−106·3 = 0	$x-$ 9·72	$(E_a - dE_a)$	+ 25·5 = 0
$x-$ 3·52	„	−104·3 = 0	$x-$14·80	„	+113·4 = 0
$x-$ 3·67	„	−102·7 = 0	$x-$16·20	„	+139·0 = 0
$x-$ 3·90	„	− 96·0 = 0	$x-$17·52	„	+157·9 = 0
$x-$ 4·27	„	− 85·6 = 0	$x-$18·80	„	+177·7 = 0
$x-$ 5·00	„	− 66·9 = 0	$x-$20·05	„	+198·0 = 0
$x-$ 5·60	„	− 54·1 = 0	$x-$21·92	„	+220·7 = 0
$x-$ 6·37	„	− 40·3 = 0	$x-$22·82	„	+232·8 = 0
$x-$ 7·22	„	− 30·8 = 0	$x-$23·57	„	+240·0 = 0
$x-$ 8·02	„	− 15·5 = 0	$x-$24·17	„	+244·9 = 0
$x-$13·27	„	+ 84·0 = 0	$x-$24·55	„	+250·6 = 0
$x-$14·90	„	+104·2 = 0	$x-$24·72	„	+245·7 = 0
$x-$16·62	„	+124·3 = 0	$x-$24·95	„	+246·6 = 0
$x-$18·07	„	+143·4 = 0	$x-$25·00	„	+244·7 = 0
$x-$19·47	„	+160·0 = 0	$x-$24·70	„	+239·3 = 0
$x-$20·07	„	+165·3 = 0	$x-$ 4·22	„	− 99·7 = 0
$x-$20·37	„	+166·9 = 0	$x-$ 3·75	„	−104·3 = 0
$x-$20·62	„	+169·8 = 0	$x-$ 3·50	„	−106·5 = 0
$x-$20·70	„	+168·4 = 0	$x-$ 3·50	„	−103·2 = 0
$x-$20·62	„	+166·3 = 0	$x-$ 3·70	„	− 95·4 = 0
$x-$20·50	„	+164·4 = 0	$x-$ 4·22	„	− 82·0 = 0
$x-$20·22	„	+158·7 = 0	$x-$ 4·90	„	− 63·8 = 0
$x-$ 6·72	„	− 54·2 = 0	$x-$ 5·62	„	− 45·3 = 0
$x-$ 6·30	„	− 66·3 = 0	$x-$ 6·45	„	− 25·7 = 0
$x-$ 6·05	„	− 68·1 = 0	$x-$ 7·50	„	− 9·0 = 0
$x-$ 5·95	„	− 65·9 = 0	$x-$13·90	„	+106·8 = 0
$x-$ 6·07	„	− 57·1 = 0	$x-$15·10	„	+124·6 = 0
$x-$ 6·55	„	− 40·0 = 0	$x-$16·27	„	+143·7 = 0
$x-$ 7·20	„	− 24·7 = 0	$x-$18·87	„	+184·1 = 0
$x-$ 8·00	„	− 11·2 = 0	$x-$20·00	„	+204·1 = 0
$x-$ 8·85	„	+ 8·4 = 0	$x-$21·07	„	+219·8 = 0

After the measurement—(Continued.)

$x - 22{\cdot}10\,(E_a - dE_a) + \overset{d}{232{\cdot}3} = 0$	$x - 7{\cdot}80\,(E_a - dE_a) - \overset{d}{25{\cdot}1} = 0$
$x - 23{\cdot}17$,, $+ 250{\cdot}2 = 0$	$x - 8{\cdot}52$,, $- 10{\cdot}5 = 0$
$x - 24{\cdot}27$,, $+ 265{\cdot}2 = 0$	$x - 16{\cdot}82$,, $+ 138{\cdot}9 = 0$
$x - 25{\cdot}17$,, $+ 273{\cdot}9 = 0$	$x - 17{\cdot}65$,, $+ 154{\cdot}2 = 0$
$x - 26{\cdot}25$,, $+ 285{\cdot}8 = 0$	$x - 18{\cdot}60$,, $+ 171{\cdot}6 = 0$
$x - 26{\cdot}95$,, $+ 293{\cdot}1 = 0$	$x - 19{\cdot}55$,, $+ 189{\cdot}3 = 0$
$x - 27{\cdot}35$,, $+ 297{\cdot}6 = 0$	$x - 20{\cdot}32$,, $+ 202{\cdot}6 = 0$
$x - 27{\cdot}75$,, $+ 302{\cdot}5 = 0$	$x - 21{\cdot}10$,, $+ 221{\cdot}6 = 0$
$x - 7{\cdot}15$,, $- 53{\cdot}7 = 0$	$x - 22{\cdot}12$,, $+ 235{\cdot}6 = 0$
$x - 6{\cdot}72$,, $- 60{\cdot}8 = 0$	$x - 22{\cdot}92$,, $+ 247{\cdot}6 = 0$
$x - 6{\cdot}55$,, $- 55{\cdot}3 = 0$	$x - 23{\cdot}65$,, $+ 259{\cdot}8 = 0$
$x - 6{\cdot}50$,, $- 51{\cdot}8 = 0$	$x - 24{\cdot}35$,, $+ 269{\cdot}8 = 0$
$x - 6{\cdot}67$,, $- 51{\cdot}0 = 0$	$x - 25{\cdot}02$,, $+ 275{\cdot}8 = 0$
$x - 7{\cdot}12$,, $- 39{\cdot}0 = 0$	$x - 25{\cdot}65$,, $+ 284{\cdot}5 = 0$

And from the mean of these results,

$$x = -\overset{d}{93{\cdot}60} + 14{\cdot}69\,(E_a - dE_a):$$

adopting the original value of the expansion of **A** given at page (9),

$$E_a = \overset{m.y}{22{\cdot}67} = \overset{d}{17{\cdot}668},$$

$$\text{and } x = \overset{d}{165{\cdot}94} + 14{\cdot}69\,dE_a = \overset{m.y}{212{\cdot}92} - 14{\cdot}69\,dE_a = \mathrm{L} - \mathbf{A}.$$

Proceeding as on page VIII—7 we obtain :—

In terms of	A – L	B – L	C – L	D – L	E – L	H – L
Micrometer divisions.	−13·64	−25·18	+6·84	+27·82	+3·27	+0·86
Millionths of a yard.	−17·50	−32·31	+8·78	+35·70	+4·20	+1·10

Also the following,

$\mathrm{A} - \mathbf{A} = \overset{d}{152{\cdot}30} - 14{\cdot}69\,dE_a = \overset{m.y}{195{\cdot}42} - 14{\cdot}69\,dE_a$	$\mathrm{D} - \mathbf{A} = \overset{d}{193{\cdot}76} - 14{\cdot}69\,dE_a = \overset{m.y}{248{\cdot}62} - 14{\cdot}69\,dE_a$
$\mathrm{B} - \mathbf{A} = 140{\cdot}76 -$,, $= 180{\cdot}61 -$,,	$\mathrm{E} - \mathbf{A} = 169{\cdot}21 -$,, $= 217{\cdot}12 -$,,
$\mathrm{C} - \mathbf{A} = 172{\cdot}78 -$,, $= 221{\cdot}70 -$,,	$\mathrm{H} - \mathbf{A} = 166{\cdot}80 -$,, $= 214{\cdot}02 -$,,

$$\text{and } 6\,x = \overset{m.y}{1277{\cdot}5} - 88{\cdot}1\,dE_a.$$

Final deduction of the total length measured with the compensated bars.

		m.y
From page VIII—7 the excess of the 6 compensated bars above 6 times **A** *before* the measurement	=	1221·9 − 52·9 dE_a
„ VIII—11 „ „ „ *after* set No. 266	=	1272·2 − 82·0 dE_a
„ VIII—15 „ „ „ *after* the measurement	=	1277·5 − 88·1 dE_a
Therefore the mean excess of „ applicable to sets Nos. 1 to 266	=	1247·1 − 67·5 dE_a
and „ „ „ Nos. 267 to 552	=	1274·9 − 85·1 dE_a
Also the mean length of a set of 6 compensated bars in feet of the standard, corrected for error* in the ther : readings, applicable to sets Nos. 1 to 266	=	60·0035005 $\frac{A}{10}$ − 64·0 dE_a
and „ applicable to sets Nos. 267 to 552	=	60·0035839 $\frac{A}{10}$ − 81·6 dE_a

Hence the total lengths measured with the compensated bars

			feet of A
in sets Nos.	1 to 173	=	10380·6056 − 11072 dE_a
„	174 to 266	=	5580·3255 − 5952 dE_a
„	267 to 359	=	5580·3333 − 7589 dE_a
„	360 to 552	=	11580·6917 − 15749 dE_a
in sets Nos.	1 to 552	=	33121·9561 − 40362 dE_a

Now the mean temperature of **A** during the bar comparisons *before* the measurement and *after* set No. 266 was $62° + \frac{64°·0}{6} = 72°·7$, for which temperature the corresponding expansion of **A** from page (19) = 21·714 *m.y.* Also the mean temperature of **A** during the bar comparisons *after* set No. 266 and *after* the measurement was $62° + \frac{81°·6}{6} = 75°·6$, for which temperature the corresponding expansion of **A** from page (19) = 21·732 *m.y.* Comparing these values of expansion with the original value = 22·67 *m.y,* used in the foregoing; it is found that dE_a = +0·956 *m.y,* for sets Nos. 1 to 266, and = + 0·938 *m.y,* for sets Nos. 267 to 552. Substituting for dE_a respectively these numerical values, there result,

Total lengths measured with the compensated bars

			feet of		A
in sets Nos.	1 to 173 or S. End, to Station A	=	(10380·6056 − ·0318)	=	10380·5738
„	174 to 359 or Station A, to Station B	=	{ 5580·3255 − ·0171 + 5580·3333 − ·0214 }	=	11160·6203
„	360 to 552 or Station B, to N. End	=	(11580·6917 − ·0443)	=	11580·6474
„	1 to 552 or S. End, to N. End	=	(33121·9561 − ·1146)	=	33121·8415

* It is shewn in Appendix No. 8 of this volume, that a correction of − 0°·59 is due to the mean thermometer readings of the Standard Bar **A** at the Vizagapatam base-line. The linear value of this correction for a set of 6 bars = − 6 × 0·59 ($E_a - dE_a$) = − ·0002408 $\frac{A}{10}$ + 3·5 dE_a.

Comparisons between the Compensated Microscopes and their 6-inch brass scales during the measurement, and provisional determination of Microscope errors with respect to the 6-inch brass scale A, expressed in millionths of an inch (m.i.)

When compared — 1862-63		Microscope.	Scale compared with.	Corrected temperature.	Reduction to 62° Fah. Expansion of 6″ scale for 1° = E = 62·5 *m.i.*	Microscope — Microscope Scale. Observed value in terms of Divisions 10000 = 1″.	Microscope — Microscope Scale. Observed value in terms of *m.i.*	Micros : Scale — *A*, at 62° Fah.	Micros : — Scale *A*, at 62° Fah. *m.i.*	Reference number.
December 12th	Before the measurement.	*T*	*T*	80°·90	+1181	0·00	0	− 97	+1084	1
		M	*M*	80·33	1146	− 6·13	− 613	21	512	2
		O	*P*	80·47	1154	7·77	777	+ 350	727	3
		N	*N*	79·76	1110	11·77	1177	363	296	4
		R	*R*	81·03	1189	3·20	320	93	962	5
		P	*P*	80·40	1150	5·80	580	350	920	6
		S	*S*	80·85	1178	+ 8·27	+ 827	− 75	1930	7
" 17th	Between sets No. 24 and 25.	*U*	*U*	75·23	+ 827	0·00	0	+ 283	+1110	8
" 30th	Between sets No. 173 and 174.	*R*	*R*	82·77	+1298	− 2·10	− 210	+ 93	+1181	9
		T	*T*	83·21	1326	0·00	0	− 97	1229	10
		M	*M*	87·41	1588	4·77	477	− 21	1090	11
		N	*N*	82·11	1257	14·07	1407	+ 363	213	12
		O	*P*	82·40	1275	9·70	970	350	655	13
		U	*U*	83·56	1348	6·13	613	283	1018	14
		S	*S*	82·03	1252	+ 5·57	+ 557	− 75	1734	15
January 7th	Between sets No. 266 and 267.	*R*	*R*	73·82	+ 739	+ 1·38	+ 138	+ 93	+ 970	16
		T	*T*	75·41	838	2·95	295	− 97	1036	17
		M	*M*	73·73	733	1·50	150	21	862	18
		N	*N*	68·54	409	−10·70	−1070	+ 363	− 298	19
		O	*P*	74·04	753	8·70	870	350	+ 233	20
		U	*U*	73·90	744	0·00	0	283	1027	21
		S	*S*	76·20	888	+ 7·03	+ 703	− 75	1516	22
" 10th	"	*T*	*T*	65·35	+ 209	+14·00	+1400	− 97	+1512	23
" 16th	Between sets No. 358 and 359.	*N*	*N*	83·35	+1334	−12·87	−1287	+ 363	+ 410	24
" 17th	"	*R*	*R*	70·08	+ 505	+ 1·67	+ 167	+ 93	+ 765	25
		T	*T*	71·17	573	+ 6·10	610	− 97	1086	26
		M	*M*	69·88	493	5·60	560	21	1032	27
		O	*P*	70·68	543	− 5·97	− 597	+ 350	296	28
		U	*U*	70·89	556	0·00	0	283	839	29
		S	*S*	71·65	603	+ 8·70	+ 870	− 75	1398	30
" 19th	"	*N*	*N*	82·34	+1271	−17·00	−1700	+ 363	− 66	31
" 30th	After the measurement.	*T*	*T*	70·85	+ 553	+ 7·70	+ 770	− 97	+1226	32
		R	*R*	70·60	538	0·00	0	+ 93	631	33
		M	*M*	71·28	580	3·60	360	− 21	919	34
		N	*N*	70·61	538	−10·00	−1000	+ 363	− 99	35
		O	*P*	70·99	562	8·67	867	350	+ 45	36
		U	*U*	71·31	582	0·00	0	283	865	37
		S	*S*	74·29	768	+ 8·87	+ 887	− 75	1580	38

Microscope Comparisons—(Continued.)

The required combinations of individual microscope errors taken from page VIII—17 are expressed as follows;

	Reference numbers.	*m.i.*	*mean temp:*	From comparisons made
$e_1 =$	$1 + 2 + 3 + 4 + 6 + \frac{5+7}{2}$	$= + 4985$	at $(62^{\circ} + 18^{\circ}{\cdot}47)$	before the measurement.
$e_2 =$	$1 + 2 + 3 + 4 + 8 + \frac{5+7}{2}$	$= + 5175$	at $(62 + 17{\cdot}61)$	between sets 24 & 25, and do.
$e_3 =$	$2 + 3 + 4 + 5 + 8 + \frac{1+7}{2}$	$= + 5114$	at $(62 + 17{\cdot}62)$	„ do. do.
$e_4 =$	$10 + 11 + 12 + 13 + 6 + \frac{9+15}{2}$	$= + 5565$	at $(62 + 20{\cdot}99)$	„ 173 & 174, and do.
$e_5 =$	$10 + 11 + 12 + 13 + 14 + \frac{9+15}{2}$	$= + 5663$	at $(62 + 21{\cdot}52)$	„ do.
$e_6 =$	$9 + 11 + 12 + 13 + 14 + \frac{10+15}{2}$	$= + 5639$	at $(62 + 21{\cdot}48)$	„ do.
$e_7 =$	$17 + 18 + 19 + 20 + 21 + \frac{16+22}{2}$	$= + 4103$	at $(62 + 11{\cdot}44)$	„ 266 & 267
$e_8 =$	$18 + 19 + 20 + 21 + 23 + \frac{16+22}{2}$	$= + 4579$	at $(62 + 9{\cdot}76)$	„ do.
$e_9 =$	$23 + \frac{16+22}{2}$	$= + 2755$	at $(62 + 8{\cdot}18)$	„ do.
$e_{10} =$	$19 + 20 + 21 + \frac{16+22}{2}$	$= + 2205$	at $(62 + 10{\cdot}87)$	„ do.
$e_{11} =$	$24 + 26 + 27 + 28 + 29 + \frac{25+30}{2}$	$= + 4745$	at $(62 + 10{\cdot}81)$	„ 358 & 359, and 359 & 360
$e_{12} =$	$24 + 28 + 29 + \frac{25+30}{2}$	$= + 2627$	at $(62 + 11{\cdot}95)$	„ do. do.
$e_{13} =$	$26 + 27 + 28 + 29 + 31 + \frac{25+30}{2}$	$= + 4269$	at $(62 + 10{\cdot}64)$	„ do.
$e_{14} =$	$25 + 27 + 28 + 29 + 31 + \frac{26+30}{2}$	$= + 4108$	at $(62 + 10{\cdot}55)$	„ do.
$e_{15} =$	$26 + \frac{25+30}{2}$	$= + 2168$	at $(62 + 9{\cdot}02)$	„ 359 & 360, and after meast:
$e_{16} =$	$32 + 34 + 35 + 36 + 37 + \frac{33+38}{2}$	$= + 4062$	at $(62 + 9{\cdot}25)$	after the measurement.
$e_{17} =$	$33 + 34 + 35 + 36 + 37 + \frac{32+38}{2}$	$= + 3764$	at $(62 + 9{\cdot}23)$	do.

And from the foregoing, we obtain the following equations for the microscope errors per set (or *m.e.*); where dE expresses the error in the adopted value of the expansion for the 6-inch scales.

		m.i.		
$(m.e.)_1 =$	$\frac{e_1 + e_4}{2}$	$= + 5275 - 6 \times 19{\cdot}73\, dE$	applicable to sets Nos.	1 to 24
$(m.e.)_2 =$	$\frac{e_3 + e_6}{2}$	$= + 5377 - 6 \times 19{\cdot}55\, dE$	„ set No.	25
$(m.e.)_3 =$	$\frac{e_2 + e_5}{2}$	$= + 5419 - 6 \times 19{\cdot}57\, dE$	„ sets Nos.	26 to 173
$(m.e.)_4 =$	$\frac{e_6 + e_7}{2}$	$= + 4871 - 6 \times 16{\cdot}46\, dE$	„ „	174 to 266
$(m.e.)_5 =$	$\frac{e_9 + e_{15}}{2}$	$= + 2462 - 2 \times 8{\cdot}60\, dE$	„ set No.	311_1
$(m.e.)_6 =$	$\frac{e_{10} + e_{12}}{2}$	$= + 2416 - 4 \times 11{\cdot}41\, dE$	„ „	311_2
$(m.e.)_7 =$	$\frac{e_8 + e_{11}}{2}$	$= + 4662 - 6 \times 10{\cdot}29\, dE$	„ sets Nos.	267 to 310 and 312 to 359
$(m.e.)_8 =$	$\frac{e_{13} + e_{16}}{2}$	$= + 4166 - 6 \times 9{\cdot}95\, dE$	„ „	360 to 484
$(m.e.)_9 =$	$\frac{e_{14} + e_{17}}{2}$	$= + 3936 - 6 \times 9{\cdot}89\, dE$	„ „	485 to 552

Microscope Comparisons—(Continued.)

Hence the total microscope errors are as follows,

		m.i		feet of A	
In sets Nos. 1 to 173 =	$24\,(m.e)_1 =$	$+\,126600 -$	$2841\,dE =$	$+\,{\cdot}0106 -$	$2841\,dE$
	$1\,(m.e)_2 =$	$+\,5377 -$	$117\,dE =$	$+\,{\cdot}0004 -$	$117\,dE$
	$148\,(m.e)_3 =$	$+\,802012 -$	$17378\,dE =$	$+\,{\cdot}0668 -$	$17378\,dE$
			sum $=$	$+\,{\cdot}0778 -$	$20336\,dE$

In sets Nos. 174 to 359 =	$93\,(m.e)_4 =$	$+\,453003 -$	$9185\,dE =$	$+\,{\cdot}0378 -$	$9185\,dE$
	$1\,(m.e)_5 =$	$+\,2462 -$	$17\,dE =$	$+\,{\cdot}0002 -$	$17\,dE$
	$1\,(m.e)_6 =$	$+\,2416 -$	$46\,dE =$	$+\,{\cdot}0002 -$	$46\,dE$
	$92\,(m.e)_7 =$	$+\,428904 -$	$5680\,dE =$	$+\,{\cdot}0357 -$	$5680\,dE$
			sum $=$	$+\,{\cdot}0739 -$	$14928\,dE$

In sets Nos. 360 to 552 =	$125\,(m.e)_8 =$	$+\,520750 -$	$7463\,dE =$	$+\,{\cdot}0434 -$	$7463\,dE$
	$68\,(m.e)_9 =$	$+\,267648 -$	$4035\,dE =$	$+\,{\cdot}0223 -$	$4035\,dE$
			sum $=$	$+\,{\cdot}0657 -$	$11498\,dE$

Final deduction of the total lengths measured with the compensated microscopes.

Hitherto the microscope errors have been determined only provisionally; *i.e* in terms of the 6-inch brass scale A. But from page (31), we have $2\,A = 1{\cdot}0000192\,\frac{\mathbf{A}}{10}$, value in 1835. Also the coefficient of expansion for brass, has been taken at ·000,010,417 in the foregoing reductions, whereas it appears from page (17) that ·000,009,855 is a more probable value. Accepting the latter, it may be found that $dE = 3{\cdot}372\ (m.i)$. Hence, remembering that the length measured with a set of microscopes is equal to 3 feet of A + the corresponding $(m.e)$ we have,

Total lengths measured with the compensated microscopes

			feet of A
In sets Nos. 1 to 173 or S. End to Stn. A	$= \left\{173\times3+{\cdot}0778\right\} - 20336\,dE =$	$(519{\cdot}0878 - {\cdot}0057) =$	$519{\cdot}0821$
„ Nos. 174 to 359 or Stn. A. to Stn. B.	$= \left\{186\times3+{\cdot}0739\right\} - 14928\,dE =$	$(558{\cdot}0846 - {\cdot}0042) =$	$558{\cdot}0804$
„ Nos. 360 to 552 or Stn. B. to N. End	$= \left\{193\times3+{\cdot}0657\right\} - 11498\,dE =$	$(579{\cdot}0768 - {\cdot}0032) =$	$579{\cdot}0736$
„ Nos. 1 to 552 or S. End to N. End	.... =	$(1656{\cdot}2492 - {\cdot}0131) =$	$1656{\cdot}2361$

DETAILS OF THE MEASUREMENT.

Disposition of the bars and microscopes during the measurement.

The following typical illustrations show the permutations and combinations of the bars and microscopes during the measurement. The instruments are here named in the succession that actually occurred, commencing from the rear-end of a set; and the numbers assigned to the illustrations, will be found employed in the tables of "Extracts from the Field Book &c."

Bar Illustration.

No. 1	No. 2	No. 3
A	A	C
B	B	D
C		E
D		H
E		
H		

Statement.

No. 1 occurs in sets Nos. 1 to 310, 312 to 316 and 317 to 552.
No. 2 „ set No. 311_1.
No. 3 „ No. 311_2.

Microscope Illustration.

No. 1	No. 2	No. 3	No. 4	No. 5
½R	½R	½T	½R	½R
T	T	R	T	N
M	M	M	½S	O
N	N	N		U
O	O	O		½S
P	U	U		
½S	½S	½S		

Statement.

No. 1 occurs in sets Nos. 1 to 24.
No. 2 „ Nos. 26 to 310, 312 to 316 & 317 to 484.
No. 3 „ Nos. 25 and 485 to 552.
No. 4 „ set No. 311_1.
No. 5 „ No. 311_2.

Extracts from the Field Book of the measurement, and calculated heights of sets above the origin.

Adopted heights above mean sea level.
South-End (origin) = 310·6 feet.
North-End (terminus) = 180·8 feet.

1862	No. of the Set	Temperature of Air	Mean time of ending	No. of bars used	Height of Set above origin	Numeral shewing arrangement of Bars.	Numeral shewing arrangement of Micros:	1862	No. of the Set	Temperature of Air	Mean time of ending	No. of bars used	Height of Set above origin	Numeral shewing arrangement of Bars.	Numeral shewing arrangement of Micros:
		°	h. m.		feet					°	h. m.		feet		
13th Dec.	1	85·5	0 35 P.M.	6 +	0·9	1	1	15th Dec.	9	85·4	1 0 P.M.	6 —	10·9	1	1
	2	87·5	1 56	6 —	0·5	1	1		10	86·5	1 52	6	12·4	1	1
	3	85·8	2 56	6	1·4	1	1		11	82·3	2 35	6	13·9	1	1
	4	85·6	3 45	6	2·5	1	1	16th „	12	62·3	6 30 A.M.	6	14·8	1	1
15th „	5	60·7	6 50 A.M.	6	3·6	1	1		13	69·5	8 15	6	15·9	1	1
	6	66·3	7 54	6	4·8	1	1		14	73·5	9 3	6	17·4	1	1
	7	76·0	10 0	6	7·1	1	1		15	77·3	9 45	6	18·3	1	1
	8	82·3	0 15 P.M.	6	9·0	1	1		16	82·7	11 40	6	19·4	1	1

NOTE.—The rear-end of set No. 1 stood exactly over the dot at South-End.

Extracts from the Field Book—(Continued.)

1862	No. of the Set.	Temperature of Air	Mean time of ending	No. of bars used	Height of Set above origin	Numeral shewing arrangement of	
						Bars.	Micros:
		°	h. m.		feet.		
16th Dec.	17	83·7	0 20 P.M.	6	− 21·8	1	1
	18	84·6	1 0	6	23·2	1	1
	19	84·5	2 51	6	24·2	1	1
	20	84·1	3 28	6	25·2	1	1
17th „	21	64·3	6 40 A.M.	6	26·7	1	1
	22	68·2	7 16	6	28·1	1	1
	23	70·5	7 46	6	28·9	1	1
	24	73·7	8 20	6	30·1	1	1
	25	75·8	8 49	6	31·0	1	3
	26	78·7	9 45	6	32·2	1	2
	27	79·8	11 15	6	33·9	1	2
	28	81·8	11 46	6	34·9	1	2
	29	84·6	0 16 P.M.	6	35·9	1	2
	30	86·1	0 48	6	36·5	1	2
	31	86·2	1 27	6	38·2	1	2
	32	86·0	1 56	6	39·4	1	2
	33	86·1	2 32	6	39·7	1	2
	34	85·1	3 8	6	41·3	1	2
	35	84·3	3 37	6	41·9	1	2
18th „	36	63·7	6 25 A.M.	6	42·8	1	2
	37	66·8	7 6	6	44·4	1	2
	38	69·7	7 45	6	45·4	1	2
	39	73·1	8 12	6	46·2	1	2
	40	74·2	8 46	6	47·7	1	2
	41	75·3	9 12	6	48·1	1	2
	42	78·1	11 10	6	48·6	1	2
	43	81·6	11 43	6	50·1	1	2
	44	81·6	0 16 P.M.	6	52·4	1	2
	45	83·7	0 54	6	54·1	1	2
	46	85·3	1 28	6	54·6	1	2
	47	86·7	1 54	6	55·6	1	2
19th „	48	65·7	6 45 A.M.	6	55·9	1	2
	49	67·6	7 18	6	56·8	1	2
	50	70·7	8 20	6	58·0	1	2
	51	73·0	8 52	6	58·9	1	2
	52	76·0	9 50	6	60·1	1	2
	53	76·1	11 30	6	61·9	1	2
	54	78·4	0 3 P.M.	6	62·2	1	2
	55	78·8	0 32	6	62·5	1	2
	56	79·3	1 12	6	63·2	1	2
	57	81·3	1 47	6	62·2	1	2
	58	80·5	2 16	6	61·8	1	2
	59	79·7	2 55	6	60·3	1	2
20th „	60	68·6	6 51 A.M.	6	60·3	1	2
	61	69·8	7 24	6	58·3	1	2
	62	71·3	8 14	6	58·2	1	2
	63	72·6	8 43	6	58·4	1	2
	64	72·3	9 18	6	59·2	1	2
	65	71·7	9 52	6	58·0	1	2
	66	70·7	11 9	6	58·6	1	2
20th Dec.	67	73·3	11 49 A.M.	6	− 58·8	1	2
	68	75·5	0 21 P.M.	6	58·5	1	2
	69	73·8	0 54	6	58·8	1	2
	70	75·1	1 25	6	58·8	1	2
	71	73·8	1 57	6	59·7	1	2
	72	73·8	2 33	6	59·1	1	2
	73	73·3	3 6	6	59·0	1	2
22nd „	74	66·4	6 37 A.M.	6	58·7	1	2
	75	70·7	7 15	6	59·2	1	2
	76	69·7	7 44	6	58·9	1	2
	77	72·3	8 14	6	59·2	1	2
	78	73·3	8 41	6	58·8	1	2
	79	78·2	9 12	6	58·6	1	2
	80	79·2	9 38	6	58·1	1	2
	81	80·3	10 7	6	58·5	1	2
	82	82·4	11 30	6	59·8	1	2
	83	83·7	0 5 P.M.	6	61·2	1	2
	84	85·2	0 35	6	62·1	1	2
	85	85·7	1 8	6	62·2	1	2
	86	88·0	1 40	6	61·6	1	2
	87	86·5	2 14	6	60·1	1	2
	88	85·3	2 43	6	58·8	1	2
	89	85·2	3 13	6	58·4	1	2
23rd „	90	63·4	6 39 A.M.	6	58·6	1	2
	91	67·6	7 20	6	59·9	1	2
	92	69·3	7 45	6	60·5	1	2
	93	71·4	8 11	6	61·1	1	2
	94	73·9	8 39	6	61·1	1	2
	95	75·4	9 9	6	61·6	1	2
	96	76·7	9 34	6	62·8	1	2
	97	78·4	10 52	6	63·3	1	2
	98	81·9	11 24	6	63·8	1	2
	99	82·4	11 53	6	63·7	1	2
	100	83·8	0 20 P.M.	6	63·7	1	2
	101	85·3	0 47	6	62·1	1	2
	102	87·4	1 25	6	62·8	1	2
	103	86·5	1 55	6	64·6	1	2
	104	86·0	2 25	6	64·8	1	2
	105	86·3	3 1	6	64·7	1	2
26th „	106	71·2	6 50 A.M.	6	66·0	1	2
	107	73·5	7 25	6	67·3	1	2
	108	74·2	7 53	6	69·1	1	2
	109	75·3	8 26	6	71·9	1	2
	110	75·9	8 52	6	72·5	1	2
	111	76·3	9 17	6	73·5	1	2
	112	76·6	9 40	6	74·1	1	2
	113	75·3	11 2	6	74·2	1	2
	114	77·1	11 32	6	74·2	1	2
	115	77·7	0 2 P.M.	6	74·4	1	2
	116	78·7	0 37	6	74·7	1	2

December 20th. Drizzling rain the whole day.

Extracts from the Field Book—(Continued.)

1862-63	No. of the Set	Temperature of Air	Mean time of ending	No. of bars used	Height of Set above origin	Numeral shewing arrangement of Bars.	Numeral shewing arrangement of Micros:	1862-63	No. of the Set	Temperature of Air	Mean time of ending	No. of bars used	Height of Set above origin	Numeral shewing arrangement of Bars.	Numeral shewing arrangement of Micros:
		°	h. m.		feet.					°	h. m.		feet.		
26th Dec.	117	78·3	1 8 P.M.	6	− 74·2	1	2	29th Dec.	147	80·6	11 52 A.M.	6	− 71·1	1	2
	118	78·0	1 35	6	74·9	1	2		148	81·8	0 16 P.M.	6	71·0	1	2
	119	78·3	1 57	6	76·5	1	2		149	83·5	0 43	6	71·6	1	2
	120	77·9	2 27	6	76·2	1	2		150	84·3	1 7	6	71·2	1	2
	121	77·6	2 58	6	73·9	1	2		151	85·3	1 29	6	71·9	1	2
	122	77·3	3 33	6	74·2	1	2		152	86·1	1 54	6	72·5	1	2
27th „	123	69·2	6 40 A.M.	6	74·3	1	2		153	86·7	2 20	6	72·3	1	2
	124	69·6	7 19	6	73·7	1	2		154	87·4	2 41	6	73·0	1	2
	125	71·3	7 50	6	72·6	1	2		155	87·6	3 8	6	72·9	1	2
	126	72·0	8 15	6	71·8	1	2		156	87·4	3 29	6	73·4	1	2
	127	74·8	8 42	6	69·7	1	2	30th „	157	58·2	6 28 A.M.	6	73·9	1	2
	128	77·7	9 10	6	68·3	1	2		158	57·8	6 56	6	74·6	1	2
	129	79·6	9 35	6	67·5	1	2		159	59·5	7 25	6	74·5	1	2
	130	84·3	11 10	6	66·6	1	2		160	61·7	7 47	6	75·1	1	2
	131	84·5	11 40	6	66·6	1	2		161	63·7	8 10	6	74·8	1	2
	132	87·2	0 10 P.M.	6	68·3	1	2		162	65·3	8 31	6	75·4	1	2
	133	88·2	0 35	6	70·0	1	2		163	67·7	8 53	6	75·7	1	2
	134	87·0	1 50	6	71·3	1	2		164	69·9	9 14	6	76·7	1	2
	135	85·2	2 28	6	72·2	1	2		165	71·7	9 39	6	76·0	1	2
	136	83·8	2 59	6	72·3	1	2		166	77·5	11 5	6	77·0	1	2
	137	83·2	3 32	6	71·5	1	2		167	79·8	11 29	6	76·9	1	2
29th „	138	59·8	6 30 A.M.	6	70·8	1	2		168	81·7	11 51	6	77·2	1	2
	139	61·3	7 1	6	71·1	1	2		169	83·3	0 13 P.M.	6	77·7	1	2
	140	64·2	7 32	6	72·9	1	2		170	84·4	0 41	6	79·1	1	2
	141	66·4	8 3	6	72·4	1	2		171	85·4	1 5	6	78·4	1	2
	142	69·6	8 30	6	73·1	1	2		172	86·0	1 25	6	79·4	1	2
	143	72·3	8 59	6	74·1	1	2		173	87·3	1 47	6	79·8	1	2
	144	73·5	9 25	6	72·6	1	2								
	145	77·5	10 54	6	72·3	1	2				Total	−	9826·9		
	146	78·5	11 21	6	71·1	1	2								

The dot denoting Station A was fixed exactly in the normal at the advanced-end of set No. 173.

Height of set No. 173 above Station A = 1·7 feet.

The terminal point of set No. 173 was the point of origin for set No. 174.

The dots denoting Posterity-Marks Nos. 1, 2 and 3 were fixed exactly in the normal at the advanced-ends respectively of sets Nos. 6, 12 and 18.

31st Dec.	174	81·6	11 45 A.M.	6	− 80·0	1	2	1st Jan.	189	69·8	8 31 A.M.	6	− 87·2	1	2
	175	84·5	0 23 P.M.	6	81·1	1	2		190	71·4	8 52	6	88·1	1	2
	176	85·3	0 49	6	81·1	1	2		191	72·4	9 11	6	87·8	1	2
	177	86·0	1 10	6	81·8	1	2		192	77·3	10 32	6	88·6	1	2
	178	86·8	1 32	6	81·9	1	2		193	78·5	10 52	6	89·4	1	2
	179	88·2	1 53	6	82·5	1	2		194	79·7	11 12	6	89·9	1	2
	180	88·8	2 17	6	82·5	1	2		195	81·2	11 31	6	90·6	1	2
	181	89·6	2 43	6	83·4	1	2		196	81·4	11 48	6	91·6	1	2
	182	88·2	3 6	6	83·5	1	2		197	82·7	0 14 P.M.	6	91·6	1	2
	183	88·7	3 27	6	84·0	1	2		198	83·3	0 39	6	91·7	1	2
1st Jan.	184	61·4	6 34 A.M.	6	84·5	1	2		199	84·9	1 1	6	91·6	1	2
	185	66·3	7 1	6	84·1	1	2		200	85·3	1 24	6	92·6	1	2
	186	66·7	7 26	6	84·9	1	2		201	83·6	1 46	6	93·9	1	2
	187	67·7	7 51	6	85·8	1	2		202	81·7	2 6	6	95·3	1	2
	188	68·6	8 10	6	86·3	1	2		203	81·2	2 34	6	96·2	1	2

Extracts from the Field Book—(Continued.)

1863	No. of the Set	Temperature of Air	Mean time of ending	No. of bars used	Height of Set above origin	Numeral shewing arrangement of Bars	Numeral shewing arrangement of Micros:
		°	h. m.		feet		
1st Jan.	204	80·7	2 56 P.M.	6	− 97·1	1	2
	205	80·8	3 20	6	97·9	1	2
2nd „	206	62·7	6 33 A.M.	6	96·8	1	2
	207	62·3	7 0	6	97·0	1	2
	208	63·0	7 24	6	97·1	1	2
	209	64·3	7 46	6	97·4	1	2
	210	65·5	8 5	6	97·4	1	2
	211	67·4	8 25	6	98·7	1	2
	212	69·1	8 46	6	98·2	1	2
	213	71·2	9 7	6	98·8	1	2
	214	71·7	9 26	6	98·7	1	2
	215	76·3	10 47	6	99·3	1	2
	216	78·6	11 12	6	99·5	1	2
	217	80·3	11 31	6	100·5	1	2
	218	82·6	0 3 P.M.	6	101·8	1	2
	219	84·2	0 34	6	104·1	1	2
	220	84·4	1 6	6	105·9	1	2
	221	84·9	1 38	6	108·4	1	2
	222	85·9	2 3	6	108·8	1	2
	223	86·3	2 32	6	108·9	1	2
	224	85·3	3 10	6	110·3	1	2
	225	84·4	3 36	6	111·9	1	2
5th „	226	68·2	6 30 A.M.	6	113·3	1	2
	227	69·3	7 25	6	113·5	1	2
	228	71·2	7 46	6	114·3	1	2
	229	72·3	8 8	6	114·3	1	2
	230	74·3	8 31	6	115·3	1	2
	231	76·2	8 57	6	115·1	1	2
	232	77·7	9 18	6	115·1	1	2
	233	84·2	10 33	6	115·3	1	2
	234	84·8	10 55	6	115·9	1	2
	235	85·2	11 19	6	117·5	1	2
	236	87·9	11 41	6	117·8	1	2
	237	88·9	0 1 P.M.	6	118·8	1	2
	238	89·7	0 21	6	119·0	1	2
	239	90·2	0 43	6	120·0	1	2
	240	90·2	1 4	6	120·1	1	2
	241	90·8	1 30	6	120·0	1	2
	242	91·1	1 51	6	121·1	1	2
	243	89·7	2 11	6	121·4	1	2
	244	89·1	2 32	6	122·0	1	2
	245	87·6	2 52	6	122·4	1	2
	246	86·8	3 13	6	122·7	1	2
6th „	247	67·1	6 30 A.M.	6	124·2	1	2
	248	67·2	6 56	6	124·1	1	2
	249	68·7	7 21	6	124·4	1	2
	250	70·3	7 41	6	124·4	1	2
	251	71·8	8 2	6	125·0	1	2
	252	73·3	8 22	6	125·5	1	2
	253	75·6	8 44	6	126·2	1	2
6th Jan.	254	77·1	9 6 A.M.	6	− 125·5	1	2
	255	78·4	9 27	6	125·6	1	2
	256	82·6	10 52	6	125·7	1	2
	257	84·7	11 16	6	126·5	1	2
	258	85·2	11 36	6	126·5	1	2
	259	87·3	11 58	6	125·9	1	2
	260	87·6	0 24 P.M.	6	126·9	1	2
	261	87·8	0 46	6	127·7	1	2
	262	88·5	1 7	6	126·8	1	2
	263	88·5	1 31	6	127·1	1	2
	264	89·1	1 52	6	128·1	1	2
	265	88·9	2 14	6	128·6	1	2
	*266	86·1	2 46	6	129·0	1	2
12th „	267	61·7	6 33 A.M.	6	129·2	1	2
	268	63·8	7 26	6	129·2	1	2
	269	67·0	8 0	6	130·2	1	2
	270	69·1	8 27	6	130·0	1	2
	271	71·2	8 54	6	130·5	1	2
	272	73·7	9 19	6	131·5	1	2
	273	79·2	10 57	6	131·2	1	2
	274	82·2	11 18	6	131·1	1	2
	275	83·8	11 41	6	131·8	1	2
	276	83·2	0 5 P.M.	6	132·7	1	2
	277	83·9	0 32	6	133·7	1	2
	278	85·3	0 58	6	133·3	1	2
	279	86·4	1 22	6	133·5	1	2
	280	86·3	1 47	6	133·2	1	2
	281	87·7	2 19	6	133·7	1	2
	282	88·3	2 41	6	133·0	1	2
	283	87·2	3 6	6	133·5	1	2
	284	86·6	3 29	6	133·5	1	2
13th „	285	62·1	6 40 A.M.	6	133·7	1	2
	286	62·6	7 17	6	133·7	1	2
	287	63·6	7 39	6	133·9	1	2
	288	65·6	8 7	6	134·3	1	2
	289	67·6	8 33	6	134·7	1	2
	290	69·5	8 56	6	135·4	1	2
	291	71·5	9 21	6	135·8	1	2
	292	77·6	10 42	6	135·5	1	2
	293	79·3	11 10	6	135·7	1	2
	294	80·7	11 34	6	136·1	1	2
	295	82·3	11 55	6	137·0	1	2
	296	83·7	0 19 P.M.	6	137·9	1	2
	297	85·4	0 44	6	136·8	1	2
	298	86·9	1 13	6	136·9	1	2
	299	86·8	1 40	6	137·9	1	2
	300	88·1	2 7	6	138·7	1	2
	301	88·3	2 29	6	138·7	1	2
	302	89·0	2 52	6	138·9	1	2
	303	89·3	3 23	6	138·7	1	2

* The advanced-end of set No. 266 fell in excess (*i.e.* north) of the dot denoting Posterity-Mark M 0·6552 feet, as measured on Cary's brass scale with a beam compass.

Extracts from the Field Book—(Continued.)

1863	No. of the Set.	Temperature of Air	Mean time of ending	No. of bars used	Height of Set above origin	Numeral shewing arrangement of Bars.	Numeral shewing arrangement of Micros:
		°	h. m.		feet.		
14th Jan.	304	61·7	6 34 A.M.	6	−139·4	1	2
	305	62·0	7 1	6	139·4	1	2
	306	63·1	7 27	6	140·1	1	2
	307	64·4	7 54	6	139·7	1	2
	308	66·4	8 18	6	139·6	1	2
	309	68·0	8 43	6	140·4	1	2
	310	70·0	9 4	6	140·9	1	2
	311_1	74·2	9 34	2	141·5	2	4
	312	78·7	10 46	6	141·5	1	2
	313	80·5	11 11	6	141·8	1	2
	314	80·6	11 32	6	141·9	1	2
	315	82·7	11 52	6	143·0	1	2
	316	84·2	0 14 P.M.	6	143·1	1	2
	311_2	85·1	0 36	4	143·1	3	5
	317	85·7	1 11	6	144·0	1	2
	318	87·7	1 48	6	144·1	1	2
	319	89·7	2 17	6	145·0	1	2
	320	89·3	2 37	6	145·4	1	2
	321	88·4	2 59	6	145·9	1	2
	322	87·3	3 20	6	145·5	1	2
15th „	323	62·2	6 35 A.M.	6	145·4	1	2
	324	62·2	7 10	6	146·0	1	2
	325	64·2	7 34	6	146·1	1	2
	326	65·6	7 56	6	146·7	1	2
	327	67·3	8 15	6	146·3	1	2
	328	69·2	8 42	6	145·9	1	2
	329	70·6	8 59	6	146·6	1	2
	330	73·2	9 24	6	146·8	1	2
	331	80·0	10 55	6	147·1	1	2
	332	80·7	11 14	6	147·6	1	2

1863	No. of the Set.	Temperature of Air	Mean time of ending	No. of bars used	Height of Set above origin	Numeral shewing arrangement of Bars.	Numeral shewing arrangement of Micros:
		°	h. m.		feet.		
15th Jan.	333	82·4	11 35 A.M.	6	147·5	1	2
	334	83·3	11 59	6	149·3	1	2
	335	84·5	0 27 P.M.	6	150·8	1	2
	336	85·6	0 51	6	151·0	1	2
	337	87·5	1 14	6	149·9	1	2
	338	88·1	1 37	6	150·0	1	2
	339	89·7	2 4	6	149·7	1	2
	340	90·2	2 34	6	150·0	1	2
	341	88·3	2 55	6	151·5	1	2
	342	85·6	3 22	6	153·6	1	2
16th „	343	62·2	6 37 A.M.	6	155·0	1	2
	344	62·3	7 5	6	155·6	1	2
	345	64·1	7 31	6	154·4	1	2
	346	67·0	7 56	6	152·5	1	2
	347	68·7	8 25	6	150·7	1	2
	348	71·3	8 52	6	150·3	1	2
	349	73·5	9 11	6	150·4	1	2
	350	74·8	9 32	6	150·3	1	2
	351	79·7	10 50	6	150·5	1	2
	352	81·5	11 9	6	151·5	1	2
	353	81·7	11 31	6	151·0	1	2
	354	82·3	11 52	6	150·7	1	2
	355	84·2	0 11 P.M.	6	150·7	1	2
	356	85·6	0 32	6	150·7	1	2
	357	86·3	0 54	6	150·0	1	2
	358	87·3	1 18	6	150·9	1	2
17th „	359	63·3	6 55 A.M.	6	149·8	1	2
				Total —	23199·8		

The dot denoting Station B was fixed exactly in the normal at the advanced-end of set No. 359.
Height of set No. 359 above Station B = 1·2 feet.
The terminal point of set No. 359 was the point of origin for set No. 360.

1863	No. of the Set.	Temperature of Air	Mean time of ending	No. of bars used	Height of Set above origin	Numeral shewing arrangement of Bars.	Numeral shewing arrangement of Micros:
19th Jan.	360	63·6	6 34 A.M.	6	−149·5	1	2
	361	64·6	7 5	6	149·4	1	2
	362	66·6	7 29	6	149·2	1	2
	363	68·2	7 52	6	150·1	1	2
	364	69·2	8 14	6	149·9	1	2
	365	71·6	8 38	6	150·6	1	2
	366	73·6	8 58	6	150·7	1	2
	367	76·3	9 26	6	150·6	1	2
	368	82·4	11 23	6	150·2	1	2
	369	83·2	11 47	6	151·2	1	2
	370	84·2	0 10 P.M.	6	151·1	1	2
	371	85·1	0 30	6	151·0	1	2
	372	86·2	0 50	6	150·8	1	2

1863	No. of the Set.	Temperature of Air	Mean time of ending	No. of bars used	Height of Set above origin	Numeral shewing arrangement of Bars.	Numeral shewing arrangement of Micros:
19th Jan.	373	86·8	1 11 P.M.	6	−151·1	1	2
	374	87·0	1 29	6	151·3	1	2
	375	88·2	1 49	6	152·4	1	2
	376	88·2	2 13	6	152·0	1	2
	377	89·3	2 36	6	152·1	1	2
	378	89·7	2 55	6	152·2	1	2
	379	88·3	3 17	6	152·6	1	2
20th „	380	65·8	6 35 A.M.	6	152·7	1	2
	381	66·4	7 13	6	153·8	1	2
	382	67·5	7 37	6	153·6	1	2
	383	68·6	8 0	6	153·8	1	2
	384	69·5	8 22	6	155·3	1	2
	385	71·5	8 45	6	156·6	1	2

Extracts from the Field Book—(Continued.)

1863	No. of the Set	Temperature of Air	Mean time of ending	No. of bars used	Height of Set above origin	Numeral shewing arrangement of: Bars.	Micros:	1863	No. of the Set	Temperature of Air	Mean time of ending	No. of bars used	Height of Set above origin	Numeral shewing arrangement of: Bars.	Micros:
		°	h. m.		feet.					°	h. m.		feet.		
20th Jan.	386	72·8	9 14 A.M.	6	−158·6	1	2	22nd Jan.	435	86·0	0 0 P.M.	6	−162·8	1	2
	387	77·7	10 40	6	159·5	1	2		436	88·0	0 23	6	162·9	1	2
	388	79·3	11 4	6	159·9	1	2		437	91·5	0 46	6	162·4	1	2
	389	80·7	11 24	6	159·6	1	2		438	89·7	1 5	6	163·1	1	2
	390	82·3	11 46	6	159·6	1	2		439	88·4	1 26	6	162·4	1	2
	391	84·1	0 9 P.M.	6	160·7	1	2		440	88·3	1 50	6	162·4	1	2
	392	84·6	0 29	6	160·6	1	2		441	89·8	2 13	6	162·2	1	2
	393	85·7	0 50	6	160·8	1	2		442	90·1	2 34	6	162·0	1	2
	394	86·3	1 17	6	161·3	1	2		443	89·9	2 55	6	162·9	1	2
	395	88·3	1 40	6	161·8	1	2		444	88·7	3 20	6	162·2	1	2
	396	88·4	2 0	6	162·3	1	2	23rd „	445	66·0	6 42 A.M.	6	162·2	1	2
	397	88·0	2 22	6	162·0	1	2		446	66·6	7 7	6	162·5	1	2
	398	88·3	2 42	6	162·2	1	2		447	67·4	7 28	6	162·7	1	2
	399	88·8	3 1	6	162·7	1	2		448	67·6	7 47	6	162·3	1	2
	400	88·4	3 21	6	163·7	1	2		449	69·4	8 8	6	162·5	1	2
	401	88·4	3 50	6	163·7	1	2		450	71·2	8 27	6	163·2	1	2
21st „	402	64·8	6 37 A.M.	6	162·2	1	2		451	72·3	8 47	6	162·1	1	2
	403	64·7	7 9	6	162·3	1	2		452	74·7	9 16	6	161·4	1	2
	404	66·2	7 40	6	163·7	1	2		453	81·6	10 39	6	161·5	1	2
	405	67·7	8 5	6	163·7	1	2		454	83·3	11 2	6	162·4	1	2
	406	68·8	8 25	6	163·8	1	2		455	83·3	11 26	6	163·1	1	2
	407	71·8	8 46	6	164·3	1	2		456	84·6	11 44	6	163·2	1	2
	408	73·8	9 10	6	164·0	1	2		457	85·6	0 5 P.M.	6	163·9	1	2
	409	76·6	9 32	6	165·2	1	2		458	85·7	0 25	6	163·5	1	2
	410	81·5	10 46	6	165·3	1	2		459	86·4	0 45	6	163·8	1	2
	411	82·1	11 9	6	165·9	1	2		460	86·4	1 7	6	163·6	1	2
	412	82·8	11 28	6	166·0	1	2		461	87·0	1 29	6	163·7	1	2
	413	84·3	11 49	6	166·7	1	2		462	87·3	1 55	6	165·2	1	2
	414	85·2	0 9 P.M.	6	166·8	1	2		463	86·7	2 18	6	164·7	1	2
	415	85·6	0 29	6	166·5	1	2		464	87·7	2 38	6	166·6	1	2
	416	85·3	0 49	6	167·4	1	2		465	87·7	3 3	6	166·9	1	2
	417	86·1	1 14	6	168·5	1	2		466	87·6	3 22	6	167·2	1	2
	418	86·5	1 33	6	168·2	1	2	26th „	467	66·2	6 40 A.M.	6	168·8	1	2
	419	87·7	1 55	6	169·4	1	2		468	67·1	7 12	6	168·9	1	2
	420	88·4	2 15	6	169·8	1	2		469	69·5	7 40	6	169·1	1	2
	421	88·3	2 38	6	169·3	1	2		470	71·7	8 2	6	169·3	1	2
	422	86·2	3 2	6	168·8	1	2		471	74·6	8 26	6	170·2	1	2
	423	85·2	3 25	6	167·8	1	2		472	77·2	8 51	6	169·6	1	2
22nd „	424	66·7	6 37 A.M.	6	167·8	1	2		473	79·2	9 17	6	168·7	1	2
	425	67·4	7 3	6	166·9	1	2		474	83·4	10 35	6	169·5	1	2
	426	68·6	7 27	6	166·6	1	2		475	84·0	10 59	6	171·4	1	2
	427	69·0	7 46	6	166·1	1	2		476	85·5	11 22	6	172·0	1	2
	428	70·7	8 9	6	165·7	1	2		477	87·5	11 43	6	172·5	1	2
	429	71·7	8 32	6	166·0	1	2		478	87·7	0 3 P.M.	6	172·6	1	2
	430	73·5	8 53	6	166·3	1	2		479	88·7	0 26	6	173·1	1	2
	431	75·5	9 14	6	167·1	1	2		480	89·1	0 45	6	173·8	1	2
	432	81·4	10 35	6	166·0	1	2		481	88·7	1 7	6	174·0	1	2
	433	83·0	10 59	6	163·8	1	2		482	87·6	1 27	6	174·6	1	2
	434	83·2	11 30	6	163·2	1	2		483	87·0	1 57	6	176·2	1	2

Extracts from the Field Book—(Continued.)

1863	No. of the Set	Temperature of Air	Mean time of ending	No. of bars used	Height of Set above origin	Numeral shewing arrangement of Bars	Numeral shewing arrangement of Micros:
		°	h. m.		feet.		
26th Jan.	484	85·7	2 22 P.M.	6	−176·5	1	2
	485	86·5	2 47	6	175·9	1	3
	486	85·4	3 20	6	176·4	1	3
27th „	487	73·0	6 40 A.M.	6	174·2	1	3
	488	73·7	7 12	6	173·6	1	3
	489	74·5	7 39	6	172·4	1	3
	490	75·7	8 4	6	172·0	1	3
	491	76·7	8 30	6	172·6	1	3
	492	78·0	8 52	6	172·0	1	3
	493	79·6	9 15	6	171·1	1	3
	494	83·6	10 32	6	170·0	1	3
	495	84·7	10 52	6	168·4	1	3
	496	85·3	11 13	6	167·7	1	3
	497	87·4	11 33	6	166·1	1	3
	498	87·6	11 55	6	165·5	1	3
	499	86·6	0 17 P.M.	6	164·3	1	3
	500	87·2	0 39	6	164·1	1	3
	501	88·6	0 59	6	163·5	1	3
	502	85·6	1 22	6	162·6	1	3
	503	85·8	1 42	6	161·8	1	3
	504	86·0	2 4	6	160·9	1	3
	505	86·0	2 27	6	160·2	1	3
	506	84·8	2 50	6	159·1	1	3
	507	84·4	3 13	6	158·5	1	3
28th „	508	71·7	6 37 A.M.	6	158·0	1	3
	509	71·7	7 2	6	157·3	1	3
	510	72·4	7 25	6	156·5	1	3
	511	73·5	7 54	6	156·0	1	3
	512	75·7	8 23	6	155·4	1	3
	513	78·2	8 47	6	154·1	1	3
	514	79·2	9 13	6	154·0	1	3
	515	83·7	10 30	6	152·7	1	3
	516	84·7	10 49	6	153·2	1	3
	517	84·4	11 12	6	152·1	1	3
	518	84·7	11 30	6	151·2	1	3
	519	85·2	11 50	6	150·4	1	3

1863	No. of the Set	Temperature of Air	Mean time of ending	No. of bars used	Height of Set above origin	Numeral shewing arrangement of Bars.	Numeral shewing arrangement of Micros:
		°	h. m.		feet.		
28th Jan.	520	88·6	0 12 P.M.	6	−149·7	1	3
	521	88·8	0 30	6	149·5	1	3
	522	89·0	0 54	6	149·6	1	3
	523	86·5	1 16	6	147·9	1	3
	524	88·2	1 39	6	147·2	1	3
	525	87·5	2 1	6	146·3	1	3
	526	87·3	2 22	6	145·2	1	3
	527	87·2	2 47	6	146·0	1	3
	528	85·5	3 9	6	145·8	1	3
	529	84·6	3 35	6	145·2	1	3
29th „	530	67·0	6 31 A.M.	6	144·7	1	3
	531	66·4	6 54	6	144·0	1	3
	532	68·2	7 17	6	143·7	1	3
	533	69·6	7 37	6	142·4	1	3
	534	72·0	8 3	6	141·3	1	3
	535	73·7	8 29	6	140·8	1	3
	536	75·6	8 51	6	140·2	1	3
	537	77·6	9 11	6	139·7	1	3
	538	82·6	10 30	6	138·5	1	3
	539	83·6	10 49	6	138·2	1	3
	540	84·6	11 11	6	137·6	1	3
	541	86·2	11 32	6	137·0	1	3
	542	87·5	11 54	6	137·1	1	3
	543	88·7	0 20 P.M.	6	135·9	1	3
	544	89·5	0 43	6	135·4	1	3
	545	90·3	1 4	6	134·7	1	3
	546	90·7	1 29	6	134·5	1	3
	547	90·6	1 49	6	133·6	1	3
	548	90·3	2 12	6	132·7	1	3
	549	88·1	2 35	6	133·5	1	3
	550	85·7	2 56	6	132·9	1	3
30th „	551	65·6	6 30 A.M.	6	132·4	1	3
	552	65·6	6 56	6	132·2	1	3
			Total		−30657·4		

January 27th. Sky covered with clouds througout the day.

The advanced-end of set No. 552 fell in defect (*i. e.* south) of the dot at North-End 0·6438 feet, as measured on Cary's brass scale with a beam compass.

Height of set No. 552 above North-End = 1·5 feet.

Reduction to Mean Sea Level.

Let the sections into which this base-line is divided be denoted as follows;

South-End to Station A	by Section	I
Station A to „ B	„	II
„ B to North-End	„	III

Then in the notation of (7) page I—22 we have

$$H = 311\,;\ h = -\ 129{\cdot}8\,;\ \delta h = +\ 3{\cdot}9\,;\ \text{Log. } R = 7{\cdot}31845, \text{ and } n = 552.$$

	$[h]_1^p$	a	n	dh	F	λ	C_2	C_1	C
	−			+	−		+	−	−
Section I ...	9827	0	173	1·2	9723	10900	·0294	·1628	·1334
„ II ...	23200	+142	186	1·3	22713	11719	·0687	·1751	·1064
„ III ...	30657	0	193	1·4	30038	12160	·0909	·1817	·0908

Final length of the Base-Line and of its parts in feet of Standard A.

Section	*Measured with*			Reduction to sea level as above	Total Length	Log.
	Compensated bars page VIII—16	Compensated microscopes page VIII—19	Beam compass pages VIII—22 to VIII—26			
S. End to Stn. A ...	10380·5738	519·0821	·0000	− ·1334	10899·5225	4·03740 7472
Stn. A to Stn. B ...	11160·6203	558·0804	·0000	− ·1064	11718·5943	4·06887 5519
Stn. B to N. End ...	11580·6474	579·0736	+ ·6438	− ·0908	12160·2740	4·08494 3360
S. End to N. End ...	33121·8415	1656·2361	+ ·6438	− ·3306	34778·3908	4·54130 9483

Lengths in feet of Standard A, between South-End and the *Posterity-Marks*, at the levels of measurement.

	Measured with			
	Bars	Micros:	Beam compass.	Total.
South-End to *Posterity-Mark* No. 1	360·0199	18·0027	·0000	378·0226
„ „ No. 2	720·0398	36·0056	·0000	756·0454
„ „ No. 3	1080·0597	54·0083	·0000	1134·0680
„ „ M	15960·8823	798·1226	−·6552	16758·3497

Verificatory Minor Triangulation.

No. of Triangle	Name of Station	Corrected Angle	Log. Sine	Log. Distance	Distance in Feet	Distance in Miles	Error of Triangle
		° ′ ″					″
	South-End of Base,	69 48 37·728	9·972460259	4·092687569			
1	Station A, ...	54 27 38·889	9·910473937	4·030701247			−0·610
	Nandi H.S., ...	55 43 43·413	9·917180162	4·037407472	10899·5225	2·064	
		180 0 0·030					
	Station A, ...	61 36 16·513	9·944327989	4·039634914			
2	Nandi H.S., ...	34 40 54·750	9·755127086	3·850434011			+0·550
	Ganiwada H.S., ...	83 42 48·757	9·997380644	4·092687569			
		180 0 0·020					
	Station A, ...	63 56 5·035	9·953418535	4·029526790			
3	Ganiwada H.S., ...	79 34 16·716	9·992765959	4·068874205	11718·5588	2·219	+0·020
	Station B, ...	36 29 38·269	9·774325756	3·850434011			
		180 0 0·020					
	Ganiwada H.S., ...	50 47 9·316	9·889183537	3·941843377			
4	Station B, ...	57 44 57·795	9·927227675	3·979887515			−0·560
	Dasalapalam T.S., ...	71 27 52·909	9·976866950	4·029526799			
		180 0 0·020					
	Station B, ...	85 45 20·897	9·998807391	4·159693360			
5	Dasalapalam T.S., ...	57 5 42·844	9·924059321	4·084945290	12160·3280	2·303	+2·010
	North-End of Base,	37 8 56·289	9·780957408	3·941843377			
		180 0 0·030					
	South-End of Base,	59 3 28·303	9·933328810	4·105897854			
6	Station A, ...	73 50 28·975	9·982495074	4·155064118			+0·580
	Gumru H.S., ...	47 6 2·752	9·864838428	4·037407472	10899·5225	2·064	
		180 0 0·030					
	Station A, ...	52 58 29·416	9·902204812	4·029847354			
7	Gumru H.S., ...	55 0 18·957	9·913392450	4·041034992			−1·400
	Raipili P.S., ...	72 1 11·657	9·978255312	4·105897854			
		180 0 0·030					
	Station A, ...	53 11 1·172	9·903394154	4·008016105			
8	Raipili P.S., ...	67 4 13·504	9·964252253	4·068874204	11718·5588	2·219	+0·640
	Station B, ...	59 44 45·344	9·936413041	4·041034992			
		180 0 0·020					

Verificatory Minor Triangulation.

No. of Triangle	Name of Station	Corrected Angle	Log. Sine.	Log. Distance	Distance in Feet	Distance in Miles	Error of Triangle
		° ′ ″					
9	Raipili P.S., ...	48 39 16·603	9·875490171	3·924940599			
	Station B, ...	65 58 38·467	9·960653681	4·010104109			″ −1·060
	Alamanda H.S., ...	65 22 4·950	9·958565677	4·008016105			
		180 0 0·020					
10	Station B, ...	54 16 39·227	9·909478428	3·998230387			
	Alamanda H.S., ...	82 25 29·951	9·996193328	4·084945287	12160·3279	2·303	−0·250
	North-End of Base,	43 17 50·842	9·836188640	3·924940599			
		180 0 0·020		Sum	34778·4093	6·586	

NOTE.—Each side of a triangle is given in the same horizontal line with the angle which it subtends.

The angles of the verificatory triangulation were measured with Troughton and Simms' 2-foot Theodolite No. 1, read by 5 micrometer microscopes. At all the stations 2 measures were taken on each of 12 zeros. The stations on the line are S. End, A, B, and N. End.—The auxiliary stations are Nandi H.S., Ganiwada H.S., Dasalapalam T.S., Gumru H.S., Raipili P.S., and Alamanda H.S.

Comparison in feet between the values computed by means of the verificatory triangulation and the measured value.

Of the entire line.

		feet	Log.
South-End to North-End by the measurement, page VIII—27		34778·3908	4·541 309 483
„	computed in terms of South-End to Station A, page VIII—29	34778·4093	4·541 309 714
	Log. computed value — Log. measured value =		+ 0·000 000 231

In terms of the entire line by measurement.

	Computed	Computed — Measured*
South-End to Station A	10899·5167	−0·0058
Station A to Station B	11718·5526	−0·0417
„ B to North-End	12160·3215	+0·0475

Of each section in terms of the others.

	South-End to Station A	Station A to Station B	Computed — Measured	Station B to North-End	Computed — Measured
Measured lengths* ..	10899·5225	11718·5943	.. ..	12160·2740	.. ..
Computed on base South-End to Station A	.. ..	11718·5588	−·0355	12160·3280	+·0540
Computed on base Station A to Station B	.. ..	.. ..	.. ..	12160·3648	+·0908

NOTE.—Since $\text{Log}_e(x + dx) = \text{Log}_e x + \frac{(dx)}{x} + \frac{(dx)^2}{2x^2} + \&c.$

$$dx = \left\{\text{Log}_{10}(x + dx) - \text{Log}_{10} x\right\} \frac{x}{\text{Modulus}}$$ nearly, by which expression the required variations in the foregoing natural numbers have been calculated.

Description of Stations.

SOUTH-END OF VIZAGAPATAM BASE, Lat. 17° 56′, Long. 83° 14′, is situated in the Pedagadi tálúk of the Vizagapatam district, on the northern slope of the rocky ridge running East and West between Gumrukonda and Nandimetta. The village of Bulgottam lies about ½ of a mile to the E.N.E., that of Kotevalsa being about 3 miles distant.

It was built in the first instance as a simple platform station, with 3 circular markstones each 38″ in diameter, and 6″ thick placed vertically over each other, the lowest stone resting on hard clay 2 feet below the surface of the ground, with a 4-inch layer of masonry between the bottom and middle stone and a 9-inch layer between the middle and top stone. Subsequently a wall of cut stone masonry 1½ feet thick and forming an enclosure 5′ 10″ square, was built round the markstones to the depth of 4 feet below the ground for the better protection of the marks and to serve as a foundation for the dome erected over the station. The mark as usual is represented by a dot on silver in a brass plug let into the stone. Each of the 3 stones has this mark, the two upper ones being carefully plumbed over the lowest. The uppermost mark is the one to which the measurement was referred; it is protected by a brass plate about 1″ in diameter carrying a coarser mark for the signallers to plumb over. A pyramidal stone about 20″ square by 15″ high, hollowed out at the base, is placed as a cap over the mark and a cut-stone masonry dome rises to the height of about 12 feet over the station. The dome is without any opening so to prevent access to the marks.

The South-End was connected in 1863, by a single line of spirit levels with the mean sea level at Vizagapatam, when it was found that its height was 310·57 feet above this datum.

NORTH-END OF VIZAGAPATAM BASE, Lat. 18° 1′, Long. 83° 16′, is situated in the Bonengi tálúk of the Vizagapatam district, about ¾ miles S.E. of the village of Rambudra-puram-Agraharum, and nearly 2 miles N.W. from Alamanda H.S.

The foundation of the station is a solid mass of rubble masonry 9 feet square, and 4 feet deep below the ground level, resting on a hard bed of gravel. In the foundation, but isolated from it by an annulus, there are 3 circular markstones, 38″ in diameter by 6″ thick, the lowermost resting about 2 feet from the bottom, and the two others in order vertically, at intervals of 3″ apart. Above the ground level there is a platform of cut-stone masonry, 8′ square and 1′ high reaching to the edge of the annulus; there is also a fourth markstone, resting over the others and separated from the nearest by a 6-inch layer of masonry. In the lowest markstone a dot surrounded by a circle has been engraved on the stone, on the others the mark is the usual dot on silver in a brass plug 1″ square by 2″ deep let into the stone. The three upper marks were carefully plumbed over the lowest one. A pyramidal stone cap about 20″ square by 15″ high protects the uppermost mark, and a cut-stone masonry dome similar to that at South-End is erected over it. The uppermost mark is the one to which the measurement was referred.

STATION A. This station is on the straight line from South-End to North-End, and 2·1 miles from the former.

It is marked by a stone 27 inches square at base, 15 inches square at top and 5 feet 3 inches in length which has been sunk to a depth of 3 feet 9 inches below the surface of the ground and is embedded in a block of masonry 8 feet square and 6½ feet deep. There are two marks on the upper surface of the stone-slab; the Posterity-Mark (or P_a) is a dot on silver let into a brass plug 6″ long and 1″ square sunk into the *middle* of the stone; the mark made at the termination of the 173rd set (or Station A) is on a brass plug ½″ in diameter and 1½″ deep let into the stone and is situated N. of the mark P_a 4·829 inches. The theodolite was plumbed over A when the angles of the verificatory minor triangulation were measured. The marks are protected by a cap of stone surmounted by a solid pyramidal pillar of cut-stone masonry about 8 feet in height and 6′ square at base.

STATION B. This station is on the straight line from South-End to North-End and 2·3 miles from the latter.

It is marked and protected in the same manner as Station A with the difference that there is only one brass plug carrying a dot at this station: the plug is about 3″ N. of the centre of the stone.

POSTERITY-MARKS Nos. 1, 2, 3, are on the straight line from South-End to Station A, and distant respectively about 378, 756, and 1134 feet from the former.

These points are marked by a dot on a brass plug let into a large granite boulder which is embedded in a 4 feet deep foundation of rubble masonry, over which a pyramidal block of the same materials has been erected.

Description of Stations—(Continued.)

POSTERITY-MARK M, is on the straight line from South-End to Station B and 3·2 miles from the former.

It is marked on a stone 27″ square at base, 15″ square at top and 5′ 3″ in length which has been sunk to a depth of 3′ 9″ below the surface of the ground and is embedded in a block of masonry 8 feet square and 6½ feet deep. There are two marks on the upper surface of the stone-slab; the Posterity-Mark (or M) is a dot on silver let into a brass plug 6″ long and 1″ square sunk into the *middle* of the stone; the mark made at the termination of the 266th set is on a brass plug let into the North edge of the stone and is situated N. of the mark M 7·863 inches. The marks are protected by a cap of stone surmounted by a solid pyramidal pillar of cut-stone masonry about 8′ in height and 6′ square at base.

GUMRU AUXILIARY HILL STATION, Lat. 17° 56′, Long. 83° 17′, is situated in the Vizagapatam district, on the summit of the highest group of low hills lying between the great range and the sea. It is about 16 miles to the South-West of the town and cantonment of Vizianagram, and is well known in the neighbourhood by its name of Gumrukonda. The small village of Sonkerpalam is about 1 mile W. of the station.

The station is marked by an isolated masonry pillar surrounded by a platform of stones and earth. There are two mark-stones in the pillar, one embedded in the hill and the other 1 foot 10½ inches above, on a level with the surface of the pillar.

RAIPILI AUXILIARY PLATFORM STATION, is situated in the Vizagapatam district, on the high ground about ¾ of a mile E. of the village of that name, and little less than half-way from Alamanda H.S. to Gumru H.S. The village of Katkapili lies about ½ mile to the S. and the hills of Kudipallam about the same distance North.

The station is marked by an isolated masonry pillar surrounded by a platform of stones and earth. There are two mark-stones in the pillar, one embedded in the rock *in situ*, and the other on a level with the surface of the pillar.

ALAMANDA AUXILIARY HILL STATION, is situated in the Vizagapatam district, on the summit of the small hill S. of the village of that name and close to that part of Vizianagram road which runs between Bhimsingi and Kotevalsa travellers' bungalows.

The station is marked by an isolated masonry pillar surrounded by a platform of stones and earth.

DASALAPALAM AUXILIARY TOWER STATION, is situated in the Vizagapatam district, close to and E. of the village of that name, and about 3 miles W. of Alamanda H.S.

The station is marked by a tower 12 feet in height.

GANIWADA AUXILIARY HILL STATION, is situated in the Vizagapatam district, on the highest part of a small rocky ridge S.W. of the hamlet of the same name.

The station is denoted by an isolated pillar surrounded by a platform of stones and earth. There are two marks in the pillar; one on its upper surface and the other on the rock *in situ*.

NANDI AUXILIARY HILL STATION, is situated in the Vizagapatam district, on the summit of an isolated hill of that name and about 4½ miles in a direct line W. from Gumru H.S. The village of Ganga Pude is immediately below the N.E. shoulder of the hill.

The station is marked by an isolated masonry pillar surrounded by a platform of stones and earth. There are two marks, one engraved in the rock *in situ*, and the other on a stone embedded flush with the surface of the pillar.

J. B. N. HENNESSEY.

BANGALORE BASE-LINE.

The middle point of this base-line is in Latitude N. 13° 3′, Longitude E. 77° 40′; the Azimuth of North-East-End at South-West-End is 224°·31′ and the line is 6·83 Miles in length.

The measurement was effected under the directions of Mr. J. B. N. Hennessey with the assistance of the following:

Lieut. J. Herschel, R.E.
„ W. M. Campbell, R.E.
„ M. W. Rogers, R.E.
Mr. A. W. Donnelly
„ G. Anding
„ J. W. Mitchell
„ A. Christie
„ O. V. Norris
„ J. Bond
„ C. D. Potter

INTRODUCTION.

This base line was measured on the high undulating land North of the cantonment of Bangalore in the province of Mysore, the South-West-End being distant from St. John's Church 2·5 miles at an azimuth of 125°. It was originally intended that this line, measured under the orders of Colonel J. T. Walker, R.E., should coincide with Colonel Lambton's base in this vicinity; but as a railway now runs across the latter the intention was necessarily relinquished. The South-West-End of Colonel Walker's line is about 5 miles West of the North-End of Colonel Lambton's base. The former line, under notice, was selected by Lieutenant W. M. Campbell, R.E.

The measurement was commenced at South-West-End, bar-tongues pointing North-West, and was carried on *continuously* to the North-East-End, so that every succeeding set originated at the point marking the terminus of its predecessor. The line was divided into 3 sections by the sub-dividing points A and B to admit of verification by minor triangulation; and its South-West-End was connected with the Bench-Mark at the Railway Station in Bangalore by means of a double line of spirit levels executed by Mr. A. W. Donnelly. This Bench-Mark had been connected by the Railway Engineers with "Colonel D'Haveland's B.M." near Fort St. George Madras, the height of the latter B.M. above mean sea level being known.

The compensated bars were compared with the standard **A** on three occasions, *i.e.* before the measurement near South-West-End, after set No. 287 about the middle of the base, and after the measurement near North-East-End. On all these occasions the comparing piers were set up parallel to the line and within a few feet of it, while the bar-tongues pointed North-West as they did during the measurement. The series of comparisons at South-West-End comprised 50 sets, that after set No. 287 consisted of 80 sets and 76 sets were taken after the measurement.

The same comparing microscopes hitherto employed for bar comparisons at base-lines were used on this occasion, with the improvement that the eye end of the microscope with fixed wires was removed and a micrometer substituted in its place, so that both microscopes were now adapted for making micrometrical measurements.

The compensated microscopes were compared with their scales on 6 occasions including the comparisons taken prior and subsequent to the measurement.

In respect to time, the first set of bar comparisons was taken on the 6th January 1868, the last on the 10th of the following March.

The verificatory triangulation was made to consist of a double series of triangles, *i.e.* a series was projected on either flank of the line, forming in all a complete figure of 10 triangles. Of the stations involved, South-West-End, A, B, and North-East-End were in the alignment, and the remainder were selected on suitable sites, 3 to the North-West and as many South-East of the line. The angles were measured by Lieut. M. W. Rogers, R.E., with Barrow's 24-inch theodolite No. 2 on 10 equidistant zeros; three measures were taken on each zero, so that 30 measures in all were made of each angle.

Comparisons between the Standard Bar **A** *and the Compensated Bars* A, B, C, D, E, H,

1868 Jany.	Mean of the times of observing A	No. of comparison	Temperature of Air	Corrected mean temperature of A	Mean A: K L	Mean A: K + L in terms of K	A: K L	A: K + L in terms of K	B: K L	B: K + L in terms of K	C: K L	C: K + L in terms of K
					Micrometer Readings in Divisions — 1 Division of K = $\frac{1}{21739\cdot02}$ Inch [a.b] on steel foot =							
	h. m.		°	°	+	+	+	+	+	+	+	+
6th	8 33 A.M.	1	60·9	60·85	118·1 174·9	294·7	240·2 227·4	469·9	232·3 208·0	442·4	246·5 245·0	494·0
	9 22	2	63·2	60·83	112·0 178·0	291·8	251·9 203·9	457·8	200·6 236·8	439·8	240·9 245·0	488·4
	9 58	3	66·2	61·33	155·4 151·4	308·3	220·1 239·1	461·6	173·5 267·1	443·3	218·8 266·1	487·6
	0 4 P.M.	4	72·9	66·23	200·4 187·3	389·6	222·5 202·0	426·5	213·8 210·8	426·7	272·2 203·9	478·1
	0 43	5	74·7	67·82	239·3 180·8	421·9	249·9 185·0	436·8	231·8 195·5	429·3	216·1 260·5	479·2
	1 29	6	76·1	69·63	198·4 258·9	459·9	184·9 263·3	450·8	283·8 158·4	443·8	232·8 261·4	496·8
	2 2	7	76·8	70·88	211·7 269·9	484·3	239·9 218·3	460·4	227·0 223·1	452·3	290·0 206·2	498·3
	2 31	8	77·7	71·85	224·2 276·5	503·5	252·6 209·4	464·1	201·0 250·5	454·0	256·8 245·9	505·2
	3 5	9	78·1	72·87	255·3 266·6	524·6	264·8 207·3	474·2	208·1 252·2	462·8	254·0 256·0	512·6
7th	7 36 A.M.	10	61·3	62·21	181·0 153·2	335·7	225·1 258·0	485·7	202·8 262·8	468·2	257·2 258·5	518·3
	8 13	11	62·7	61·96	185·8 142·5	329·7	255·8 227·4	485·5	256·6 205·0	463·7	275·0 237·0	514·4
	8 47	12	64·5	61·96	177·0 155·2	333·8	249·8 225·8	477·9	248·2 206·4	456·7	225·9 281·1	509·8
	9 14	13	66·0	62·31	162·4 177·6	341·8	229·2 241·1	472·7	201·2 249·8	453·5	253·8 243·0	499·2
	9 39	14	57·7	62·88	137·4 209·4	348·9	262·0 201·4	465·4	246·7 195·9	444·6	234·8 253·2	490·5
	10 3	15	69·2	63·60	155·4 203·2	360·6	238·4 217·6	458·2	240·8 195·6	438·4	246·6 236·8	485·8
	11 59	16	75·0	68·17	220·5 221·7	444·4	220·0 215·9	438·1	235·8 194·0	431·7	255·4 228·0	485·7
	0 26 P.M.	17	76·0	69·69	225·3 238·1	465·8	228·6 206·9	437·6	247·4 189·0	438·3	229·4 256·8	488·8
	0 43	18	75·7	70·32	199·5 276·8	479·1	209·6 228·0	439·9	215·9 222·9	441·0	216·3 276·1	495·2
	0 57	19	76·1	70·93	221·9 266·8	491·4	245·2 198·0	445·2	258·7 181·3	441·8	332·4 162·0	496·0
	1 14	20	76·9	71·50	235·7 263·6	501·9	218·4 231·0	451·7	229·9 217·9	450·0	232·2 266·1	501·0

made at the South-West-End of the base-line, before the measurement.

No. of comparison	Micrometer Readings in Divisions = 1·27772 *m.y.* of **A** = ·9901 × 1 Division of L — D: K L	D: K + L in terms of K	E: K L	E: K + L in terms of K	H: K L	H: K + L in terms of K	Mean of the compensated bars	Remarks
	+	+	+	+	+	+	+	
1	301·6 232·9	536·8	233·3 247·9	483·7	279·2 194·9	476·0	483·8	Mr. Hennessey at micrometer K; Lieutenant Campbell „ L.
2	229·0 300·0	532·0	231·4 243·0	476·8	330·4 142·9	474·7	478·3	Sky completely clouded; fog in the distance.
3	242·6 287·1	532·6	207·4 268·9	479·0	217·9 257·1	477·6	480·3	Observers changed places.
4	278·1 247·5	528·1	287·8 182·0	471·6	225·9 232·8	461·0	465·3	Lieutenant Herschel at micrometer K; „ Rogers „ L.
5	241·6 288·0	532·5	237·8 239·2	479·4	251·8 215·2	469·2	471·1	
6	237·6 303·8	544·4	256·4 233·0	491·7	241·7 238·4	482·5	485·0	Observers changed places.
7	258·0 284·0	544·8	267·8 224·9	494·9	252·7 236·8	491·9	490·4	
8	294·3 258·8	555·7	231·6 270·1	504·4	273·2 223·7	499·1	497·1	
9	257·2 300·0	560·2	191·6 318·1	512·9	236·2 265·0	503·9	504·4	
10	279·8 272·5	555·0	249·7 255·8	508·1	243·6 254·5	500·6	506·0	Lieutenant Herschel at micrometer K; „ Rogers „ L.
11	268·0 283·8	554·6	272·1 223·0	497·3	277·8 214·5	494·4	501·7	
12	271·8 276·0	550·6	255·0 234·1	491·4	283·6 209·0	494·7	496·9	
13	251·4 285·1	539·4	200·0 280·1	482·9	261·7 218·2	482·1	488·3	Observers changed places.
14	267·6 265·1	535·4	284·5 193·8	480·2	253·0 223·0	478·2	482·4	
15	213·2 214·2	529·5	240·2 235·8	478·4	222·0 250·0	474·5	477·5	
16	303·2 243·0	548·6	294·5 182·8	479·1	274·8 191·0	467·7	475·2	Mr. Hennessey at micrometer K; Lieutenant Campbell „ L.
17	255·7 293·4	552·0	252·9 227·6	482·8	218·4 247·8	468·7	478·0	Few light cirri near horison.
18	246·4 303·8	553·2	248·6 236·3	487·3	254·6 219·2	476·0	482·1	
19	311·6 241·0	555·0	283·8 205·2	491·1	275·5 203·3	480·8	485·0	
20	258·3 298·0	559·3	254·9 240·8	498·1	283·3 199·8	485·1	490·9	

Before the

1868 Jany.	Mean of the times of observing A	No. of comparison	Temperature of Air	Corrected mean temperature of A	Mean A K/L	Mean A K + L in terms of K	A K/L	A K + L in terms of K	B K/L	B K + L in terms of K	C K/L	C K + L in terms of K
					MICROMETER READINGS IN DIVISIONS — 1 Division of K = $\frac{1}{21739 \cdot 02}$ Inch [a.b] on Steel Foot =							
	h. m.		°	°	+	+	+	+	+	+	+	+
7th	1 31 P.M.	21	77·5	72·06	233·0 277·0	512·8	256·6 198·1	456·7	244·4 209·1	455·6	239·5 262·0	504·1
	1 49	22	79·1	72·64	237·0 286·3	526·2	233·7 228·0	464·0	234·8 225·0	462·1	238·4 271·1	512·2
	2 7	23	79·9	73·27	267·3 269·4	539·4	260·8 209·2	472·1	288·8 174·0	464·5	277·8 238·9	519·1
	2 32	24	79·0	74·03	257·2 294·6	554·7	258·3 216·1	476·6	221·7 246·8	471·0	287·7 230·7	520·7
	2 53	25	79·1	74·59	209·6 352·2	565·3	223·4 260·9	486·9	185·0 290·4	478·3	178·0 348·3	529·8
	3 13	26	79·1	75·05	233·8 336·3	573·5	279·6 208·2	489·9	158·1 320·2	481·5	269·4 260·0	532·0
	3 30	27	78·8	75·40	250·4 328·6	582·3	264·3 224·4	490·9	247·0 236·3	485·7	260·5 271·3	534·5
	3 47	28	78·7	75·69	233·7 350·2	587·4	219·0 277·0	498·8	212·4 271·1	486·2	256·0 278·2	537·0
8th	7 27 A.M.	29	60·8	62·57	217·0 140·2	358·6	186·2 300·6	489·8	272·6 204·4	479·0	297·0 227·3	526·6
	7 50	30	60·3	62·25	221·1 127·5	349·9	284·8 206·2	493·1	311·1 163·3	476·0	279·6 243·2	525·2
	8 8	31	60·4	62·01	212·5 130·5	344·3	257·4 233·2	492·9	275·0 200·0	477·0	238·0 282·4	523·2
	8 25	32	61·6	61·86	207·8 130·6	339·7	207·4 281·6	491·8	251·6 219·6	473·4	270·9 244·8	518·1
	8 42	33	63·1	61·79	194·8 141·0	337·2	261·4 226·0	489·7	320·4 145·6	467·5	312·8 201·6	516·4
	9 4	34	64·5	61·84	176·0 157·5	335·1	258·3 225·7	486·3	275·3 183·0	460·1	270·8 239·0	512·2
	9 21	35	65·8	62·00	197·4 139·8	338·6	228·1 248·9	479·5	346·4 107·4	454·9	287·8 216·0	506·0
	9 36	36	67·3	62·28	194·9 147·6	344·0	286·3 183·5	471·6	294·8 158·8	455·2	292·4 207·4	501·9
	9 50	37	68·1	62·66	170·4 178·0	350·2	245·6 222·0	469·8	273·0 179·9	454·7	280·9 215·0	498·1
	10 5	38	68·9	63·11	171·8 185·2	358·9	248·4 220·0	470·6	227·0 219·7	448·9	230·4 263·0	496·0
	11 42	39	75·9	67·21	233·8 201·0	436·8	191·8 263·0	457·4	180·9 263·8	447·3	262·3 233·5	498·1
	0 1 P.M.	40	76·5	68·11	219·3 227·6	449·2	270·8 179·1	451·7	232·2 213·5	447·8	241·8 251·0	495·3

measurement—(Continued.)

No. of comparison	MICROMETER READINGS IN DIVISIONS = 1·27772 *m.y.* of A = ·9901 × 1 Division of L — D: K L	D: K + L in terms of K	E: K L	E: K + L in terms of K	H: K L	H: K + L in terms of K	Mean of the compensated bars	REMARKS
	+	+	+	+	+	+	+	
21	250·4 306·6	560·1	226·6 271·5	500·8	222·7 265·0	490·4	494·6	
22	243·9 318·5	565·6	237·2 265·6	505·5	249·9 244·0	496·3	501·0	
23	257·4 309·0	569·5	244·4 262·8	509·8	296·5 202·0	500·5	505·9	
24	270·4 300·7	574·1	269·4 245·3	517·2	301·5 204·1	507·6	511·2	Observers changed places.
25	257·6 318·1	578·9	255·4 264·8	522·8	262·2 248·9	513·6	518·4	
26	254·6 326·7	584·6	262·0 262·1	526·7	252·8 262·1	517·5	522·0	
27	252·0 328·7	584·0	287·0 235·4	524·8	312·6 207·4	522·1	523·7	
28	232·8 352·9	589·2	247·5 279·6	529·9	217·6 301·3	521·9	527·2	
29	268·0 305·6	576·7	288·0 226·6	516·9	258·6 255·7	516·9	517·7	Lieutenant Campbell at micrometer K; Mr. Hennessey at „ L.
30	258·0 312·2	573·3	247·0 263·2	512·8	242·9 269·7	515·3	516·0	
31	224·0 345·3	572·8	243·0 268·0	513·7	237·5 268·1	508·3	514·7	
32	265·8 300·4	569·2	249·0 260·1	511·7	242·6 264·2	509·4	512·3	
33	274·3 287·1	564·3	251·0 253·6	507·1	234·6 266·4	503·7	508·1	
34	292·8 260·1	555·5	298·6 195·3	495·9	301·7 190·7	494·3	500·7	Observers changed places.
35	281·8 268·9	553·4	307·2 186·4	495·5	289·8 199·0	490·8	496·7	
36	287·6 257·0	547·2	280·4 209·0	491·5	279·9 207·0	489·0	492·7	
37	277·4 265·1	545·2	271·2 218·9	492·3	288·7 195·8	486·5	491·1	
38	216·7 322·0	541·9	242·5 244·1	489·0	232·6 251·2	486·3	488·8	
39	260·0 285·0	547·9	181·8 305·0	489·9	249·9 220·2	472·3	485·5	Lieutenant Herschel at micrometer K; „ Rogers at „ L.
40	230·6 318·0	551·8	251·3 236·8	490·5	214·6 262·5	479·7	486·1	

Before the

1868 Jany.	Mean of the times of observing A	No. of comparison	Temperature of Air	Corrected mean temperature of A	Micrometer Readings in Divisions — 1 Division of K = $\frac{1}{21739 \cdot 02}$ Inch [a.b] on Steel Foot =							
					Mean A		A		B		C	
					K L	K + L in terms of K	K L	K + L in terms of K	K L	K + L in terms of K	K L	K + L in terms of K
	h. m.		°	°	+	+	+	+	+	+	+	+
8th	0 20 P.M.	41	76·9	69·06	210·9 255·6	469·1	218·3 233·5	454·1	203·3 239·8	445·5	220·6 282·2	505·6
	0 38	42	77·3	69·92	213·5 272·2	488·4	239·1 218·1	459·4	202·7 248·6	453·8	268·2 237·4	508·0
	0 57	43	78·2	70·80	216·5 283·1	502·4	183·7 279·4	465·9	221·2 232·9	456·4	240·6 267·0	510·3
	1 19	44	78·8	71·80	243·4 273·5	519·6	220·0 248·6	471·1	229·0 230·2	461·5	254·4 256·9	513·9
	1 51	45	80·0	73·16	280·5 267·2	550·4	230·4 244·1	476·9	238·5 230·0	470·8	282·1 241·2	525·7
	2 12	46	80·5	73·91	278·8 283·1	564·7	231·4 251·8	485·7	230·5 242·9	475·8	245·3 281·2	529·3
	2 34	47	80·4	74·66	280·3 297·5	580·8	237·5 251·1	491·1	252·3 229·0	483·6	270·5 263·2	536·3
	2 58	48	80·2	75·36	298·4 296·0	597·4	240·6 254·1	497·2	258·2 232·5	493·0	278·2 266·1	547·0
	3 20	49	80·1	75·87	308·3 294·1	605·3	250·0 252·2	504·7	258·8 235·9	497·1	261·1 285·9	549·9
	3 39	50	80·1	76·24	294·9 314·7	612·7	263·1 247·0	512·6	234·9 261·0	498·5	267·8 283·5	554·1
			Means	68·18		447·73		471·18		459·70		510·23

About the middle of the base-line,

1868	Mean of the times of observing A	No. of comparison	Temperature of Air	Corrected mean temperature of A	Mean A K L	Mean A K + L in terms of K	A K L	A K + L in terms of K	B K L	B K + L in terms of K	C K L	C K + L in terms of K
Feb.	h. m.		°	°								
11th	9 0 A.M.	1	72·0	62·11	213·3 130·9	345·5	206·8 272·3	481·8	242·4 209·0	453·4	268·8 233·2	504·3
	11 35	2	78·6	69·11	214·6 235·1	452·0	266·7 180·5	449·0	237·9 190·2	430·0	282·4 196·7	481·0
	11 54	3	79·1	70·15	222·6 244·7	469·7	214·8 230·7	447·8	233·4 197·0	432·3	284·9 200·3	487·2
	0 10 P.M.	4	79·5	71·02	270·6 209·2	481·9	228·3 218·8	449·2	206·4 220·0	428·6	243·1 236·3	481·7
	1 11	5	82·3	73·99	328·0 234·3	564·6	237·8 242·5	482·7	230·2 131·7	464·2	259·3 254·5	516·3
	1 24	6	82·3	74·59	300·5 271·4	574·6	236·9 241·8	481·1	232·2 231·7	466·2	306·4 211·8	520·3

measurement—(Continued.)

Micrometer Readings in Divisions = 1·27772 *m.y.* of **A** = ·9901 × 1 Division of L

No. of comparison	D K / L	D K + L in terms of K	E K / L'	E K + L in terms of K	H K / L	H K + L in terms of K	Mean of the compensated bars	Remarks
	+	+	+	+	+	+	+	
41	283·8 268·2	554·7	234·0 260·0	496·6	245·3 238·5	486·2	490·5	
42	251·1 306·0	560·2	233·0 268·2	503·9	222·8 264·3	489·7	495·8	
43	284·8 270·6	558·1	257·0 244·5	503·9	243·9 246·0	492·4	497·8	
44	284·2 278·3	565·3	242·3 262·5	507·4	255·5 241·0	498·9	503·0	
45	313·2 263·0	578·8	278·8 239·2	520·4	262·7 247·8	513·0	514·3	Observers changed places.
46	286·5 293·7	583·1	256·3 265·2	524·2	258·9 253·1	514·5	518·8	
47	300·8 286·2	589·9	257·9 269·3	529·9	257·8 263·1	523·5	525·7	
48	276·5 311·9	591·5	275·9 260·3	538·8	258·8 270·0	531·5	533·2	
49	315·0 282·2	600·0	279·6 263·5	545·7	265·8 264·2	532·6	538·3	
50	294·0 304·1	601·1	263·8 276·0	542·6	275·2 264·4	542·2	541·9	
Means		559·75		502·58		495·71	499·86	

after set No. 287.

1 Division K = $\frac{1}{21732·71}$ Inch [*a.b.*] on Steel Foot = 1·27810 *m.y* of **A** = ·9903 × 1 Division L

No. of comparison	D K / L	D K + L in terms of K	E K / L'	E K + L in terms of K	H K / L	H K + L in terms of K	Mean of the compensated bars	Remarks
1	312·8 236·2	551·3	253·4 242·7	498·5	266·1 224·9	493·2	497·1	Mr. Hennessey at micrometer K; Lieutenant Campbell " L.
2	324·3 195·8	522·0	242·8 218·9	463·8	273·9 200·0	475·9	470·3	Mr. Hennessey " K; Lieutenant Herschel " L.
3	303·6 213·2	518·9	259·0 204·8	465·8	293·8 180·6	476·2	471·4	
4	277·7 243·8	523·9	228·6 234·8	465·7	261·0 219·5	482·7	472·0	
5	278·7 276·2	557·6	241·8 258·5	502·8	232·6 274·8	510·1	505·6	
6	316·6 241·0	560·0	251·6 251·0	505·1	276·0 232·5	510·8	507·3	

About the middle of the base-line,

1868 Feby.	Mean of the times of observing A	No. of comparison	Temperature of Air	Corrected mean temperature of A	Micrometer Readings in Divisions. 1 Division of K = $\frac{1}{21732·71}$ Inch [a.b] on Steel Foot = — Mean A: K L	Mean A: K + L in terms of K	A: K L	A: K + L in terms of K	B: K L	B: K + L in terms of K	C: K L	C: K + L in terms of K
	h. m.		°	°	+	+	+	+	+	+	+	+
11th	1 37 P.M.	7	82·6	75·13	294·8 287·4	585·0	208·8 274·0	485·5	246·0 218·2	466·3	303·8 217·3	523·2
	1 53	8	82·7	75·81	318·0 279·9	600·6	219·8 263·0	485·4	212·9 254·6	470·0	294·0 233·2	529·5
	2 9	9	83·2	76·36	326·6 280·5	609·8	238·0 245·6	486·0	223·2 245·8	471·4	303·2 224·2	529·6
	2 23	10	83·8	76·89	354·9 262·2	619·7	256·7 231·0	490·0	237·2 231·3	470·8	298·9 229·7	530·9
	2 35	11	84·2	77·34	335·4 288·7	626·9	246·3 245·8	494·5	232·8 240·6	475·8	297·0 234·9	534·2
	2 49	12	83·6	77·80	292·0 339·0	634·3	183·2 306·2	492·4	263·9 212·0	478·0	297·0 234·2	533·5
	3 6	13	83·5	78·30	294·9 343·0	641·3	260·7 230·3	493·3	266·7 214·2	483·0	269·0 265·6	537·2
	3 21	14	84·3	78·75	304·0 341·8	649·1	233·2 259·8	495·5	236·9 245·1	484·4	236·2 302·2	541·4
	3 33	15	83·7	79·11	304·6 347·5	655·5	249·3 244·6	496·3	252·6 227·2	482·0	278·8 260·8	542·2
12th	7 28 A.M.	16	63·5	63·88	245·9 132·2	379·4	219·1 278·3	500·1	247·8 222·2	472·2	284·0 243·8	530·2
	7 44	17	64·3	63·79	187·4 188 8	378 0	252·9 249·8	505·1	251·1 222·4	475·7	263·1 267·0	532·7
	7 58	18	64·8	63·76	177·9 198·5	378·3	240·3 255·0	497·8	249·7 224·9	476·8	262·2 265·5	530·3
	8 13	19	65·2	63·76	186·9 190·5	379·3	244·8 249·0	496·2	273·5 201·5	477·0	270·8 258·6	531·9
	8 35	20	66·0	63·88	180·6 196·4	378·9	249·0 243·2	494·6	225·9 247·3	475·6	256·0 273·2	531·9
	8 51	21	67·0	64·05	171·5 209·5	383·1	261·0 230·5	493·8	214·1 258·0	474·6	247·6 276·7	527·0
	9 5	22	68·3	64·25	178·6 207·7	388·3	228·9 255·2	486·6	229·6 239·2	471·1	265·0 259·4	526·9
	11 58	23	79·2	70·10	241·2 231·2	474·7	209·7 241·4	453·5	184·4 254·6	441·5	222·2 263·0	487·8
	0 15 P.M.	24	79·6	70·90	267·5 221·3	491·0	208·0 249·2	459·6	198·8 240·1	441·3	248·0 237·2	487·5
	0 32	25	80·4	71·76	275·8 227·8	505·8	225·2 233·0	460·5	204·2 234·7	441·2	247·0 241·3	490·7
	0 44	26	81·0	72·41	279·2 234·4	515·9	222·0 235·0	459·3	209·8 227·6	439·6	255·8 231·4	489·5

after set No. 287—(Continued.)

No. of comparison	Micrometer Readings in Divisions = 1·27810 *m.y.* of A = ·9903 × 1 Division of L — D — K / L	D — K + L in terms of K	E — K / L	E — K + L in terms of K	H — K / L	H — K + L in terms of K	Mean of the compensated bars	Remarks
	+	+	+	+	+	+	+	
7	362·4 200·6	565·0	268·4 236·5	507·2	279·0 233·8	515·1	510·4	
8	313·3 250·3	566·1	286·9 227·8	516·9	274·8 236·8	513·9	513·6	Lieutenant Herschel at micrometer K ; Mr. Hennessey „ L.
9	358·7 213·8	574·6	276·8 235·6	514·7	296·7 218·8	517·6	515·7	
10	348·2 225·0	575·4	265·0 250·8	518·3	276·1 242·2	520·7	517·7	
11	350·6 223·6	576·4	271·0 244·2	517·6	282·3 236·4	521·0	519·9	
12	335·6 239·2	577·1	289·8 228·3	520·3	216·5 303·4	522·9	520·7	
13	267·7 311·1	581·8	255·1 265·4	523·1	263·7 258·2	524·4	523·8	
14	304·2 281·7	588·7	262·7 260·9	526·2	269·2 253·6	525·3	526·9	
15	287·3 295·7	585·9	277·9 245·6	525·9	255·8 264·8	523·2	525·9	
16	285·3 282·7	570·8	280·2 234·2	516·7	293·3 219·9	515·4	517·6	Lieutenant Herschel at micrometer K ; „ Campbell „ L.
17	289·4 282·0	574·2	273·3 238·2	513·8	269·3 243·0	514·7	519·4	
18	284·8 285·2	572·8	266·8 243·7	512·9	266·0 246·0	514·4	517·5	
19	296·0 276·6	575·3	264·7 249·6	516·7	266·7 244·7	513·8	518·5	
20	274·4 293·2	570·5	258·6 254·5	515·6	264·5 249·1	516·0	517·4	Observers changed places.
21	283·6 283·7	570·1	238·7 276·2	517·6	264·7 249·1	516·2	516·6	
22	260·0 301·2	564·2	263·0 248·8	514·2	254·7 257·2	514·4	512·9	
23	273·7 253·4	529·6	223·4 246·4	472·2	237·0 249·4	488·8	478·9	Lieutenant Campbell at micrometer K ; Mr. Hennessey „ L.
24	284·4 243·2	530·0	232·0 238·1	472·4	256·4 227·6	486·2	479·5	
25	282·4 251·3	536·2	205·7 266·4	474·7	218·0 266·4	587·0	481·7	
26	302·0 230·7	535·0	240·7 233·4	476·4	260·4 226·2	488·8	481·4	

About the middle of the base-line,

1868 Feby.	Mean of the times of observing A	No. of comparison	Temperature of Air	Corrected mean temperature of A	Micrometer Readings in Divisions 1 Division of K = $\frac{1}{21732 \cdot 71}$ Inch [a.b] on Steel Foot = Mean A K L	Mean A K + L in terms of K	A K L	A K + L in terms of K	B K L	B K + L in terms of K	C K L	C K + L in terms of K
	h. m.		°	°	+	+	+	+	+	+	+	+
12th	0 55 P.M.	27	80·8	72·93	281·2 241·3	524·9	234·0 222·6	458·8	226·8 210·6	439·5	272·6 216·2	490·9
	1 7	28	80·8	73·47	272·7 258·1	533·3	218·9 240·8	462·1	186·1 250·4	439·0	234·9 258·3	495·7
	1 19	29	81·2	74·03	283·9 256·3	542·7	215·2 242·4	460·0	208·1 232·1	442·5	252·0 241·2	495·6
	1 31	30	81·7	74·55	300·8 250·0	553·3	206·1 252·8	461·4	199·9 239·6	441·8	248·0 249·3	499·7
	1 56	31	82·8	75·61	310·5 249·2	562·1	238·8 213·9	454·8	219·6 218·0	439·7	274·8 217·9	494·8
	2 6	32	83·3	76·02	333·3 235·0	570·6	213·7 242·6	458·7	185·0 253·4	440·9	260·9 236·1	499·3
	2 17	33	83·4	76·45	338·1 236·9	577·3	245·1 213·7	460·9	206·0 234·0	442·3	267·4 229·0	498·6
	2 29	34	83·6	76·88	335·1 249·4	586·9	192·0 265·6	460·2	172·4 267·0	442·0	281·8 216·6	500·5
	2 40	35	83·1	77·26	345·0 245·1	592·5	226·9 234·0	463·2	204·6 236·4	443·3	272·9 223·5	498·6
	2 50	36	82·8	77·60	351·7 241·6	595·7	232·8 227·2	462·2	208·7 231·4	442·4	282·3 218·5	502·9
	3 0	37	83·0	77·94	358·9 241·1	602·4	226·6 233·7	462·6	209·5 231·7	443·5	260·3 237·9	500·5
	3 13	38	83·0	78·38	372·8 230·1	605·2	219·6 241·0	463·0	213·9 228·5	444·6	276·6 227·0	505·8
13th	7 58 A.M.	39	66·3	64·96	182·2 175·2	359·1	243·6 210·1	455·8	250·2 188·8	440·9	266·1 224·4	492·7
	8 18	40	67·4	65·01	180·9 179·8	362·5	211·7 251·2	465·4	217·8 219·0	438·9	248·1 242·0	492·5
	8 33	41	68·1	65·15	183·0 180·3	365·1	223·1 234·4	459·8	225·7 210·3	438·1	246·6 243·3	492·3
	8 51	42	69·3	65·43	207·0 158·4	367·0	225·5 227·0	454·7	239·9 190·0	431·8	243·6 238·4	484·3
	9 6	43	70·5	65·73	220·3 152·4	374·2	206·6 244·0	453·0	217·4 213·2	432·7	228·8 250·2	481·5
	9 19	44	71·3	66·08	210·3 170·2	382·2	244·2 200·2	446·4	239·2 188·2	429·2	231·9 248·3	482·6
	9 32	45	71·9	66·48	200·1 188·1	390·0	207·2 235·2	444·7	225·6 196·0	423·5	232·5 242·0	476·9
	11 15	46	77·4	69·93	227·5 209·5	439·1	178·4 251·8	432·7	181·3 231·2	414·8	238·0 238·8	479·1

after set No. 287—(Continued.)

No. of comparison	D K / L	D K + L in terms of K	E K / L	E K + L in terms of K	H K / L	H K + L in terms of K	Mean of the compensated bars	Remarks
	Micrometer Readings in Divisions = 1·27810 *m.y.* of A = ·9903 × 1 Division of L							
	+	+	+	+	+	+	+	
27	318·9 / 219·4	540·5	244·4 / 233·1	479·8	250·0 / 236·1	488·4	483·0	
28	264·8 / 273·1	540·6	191·5 / 287·4	481·7	191·4 / 291·1	485·4	484·1	
29	311·1 / 230·9	544·3	243·9 / 236·2	482·4	256·7 / 230·8	489·8	485·8	
30	282·7 / 258·0	543·2	215·1 / 267·2	484·9	230·0 / 257·0	489·5	486·8	
31	302·6 / 236·0	540·9	262·2 / 221·8	486·2	240·9 / 243·0	486·3	483·8	Observers changed places.
32	279·9 / 259·6	542·0	235·8 / 251·0	489·3	239·2 / 242·7	484·3	485·8	
33	315·7 / 226·0	543·9	245·5 / 241·5	489·4	232·8 / 249·9	485·1	486·7	
34	312·0 / 232·6	546·9	253·4 / 236·1	491·8	238·4 / 246·0	486·8	488·0	
35	335·2 / 209·0	546·2	248·4 / 240·4	491·2	246·4 / 240·4	489·2	488·6	
36	343·4 / 203·0	548·4	260·7 / 225·4	488·3	258·0 / 229·9	490·2	489·1	
37	319·0 / 225·3	546·5	252·8 / 237·0	492·1	244·0 / 246·8	493·2	489·7	
38	326·6 / 221·0	549·8	257·3 / 232·3	491·9	260·0 / 228·9	491·1	491·0	
39	310·2 / 225·2	537·6	264·2 / 219·8	486·2	241·8 / 234·1	478·2	481·9	Lieutenant Herschel at micrometer K; Mr. Hennessey „ L.
40	268·9 / 265·9	537·4	247·2 / 235·8	485·3	233·2 / 241·8	477·4	482·8	
41	270·0 / 260·8	533·4	235·8 / 247·8	486·0	226·8 / 245·2	474·4	480·7	
42	254·4 / 273·2	530·3	236·7 / 239·0	478·0	236·5 / 234·3	473·1	475·4	Observers changed places.
43	252·4 / 274·4	529·5	246·4 / 225·8	474·4	248·4 / 222·0	472·6	474·0	
44	265·3 / 261·5	529·4	246·8 / 223·7	472·7	227·8 / 241·0	471·2	471·9	
45	258·1 / 265·1	525·8	237·6 / 226·0	465·8	244·4 / 225·2	471·8	468·1	
46	249·8 / 258·0	510·3	227·5 / 227·1	456·8	223·5 / 237·0	462·8	459·4	Lieutenant Campbell at micrometer K; Lieutenant Herschel „ L.

About the middle of the base-line,

1868 Feby.	Mean of the times of observing A	No. of comparison	Temperature of Air	Corrected mean temperature of A	MICROMETER READINGS IN DIVISIONS 1 Division of K = $\frac{1}{21732{\cdot}71}$ Inch [a.b] on Steel Foot =							
					Mean A		A		B		C	
					K L	K + L in terms of K	K L	K + L in terms of K	K L	K + L in terms of K	K L	K + L in terms of K
	h. m.		°	°	+	+	+	+	+	+	+	+
13th	11 28 A.M.	47	78·5	70·54	232·6 216·0	450·7	201·6 231·1	435·0	176·9 238·1	417·3	240·3 227·4	469·9
	11 42	48	79·5	71·15	227·6 235·2	463·1	210·5 218·9	431·5	225·4 188·2	415·4	231·0 236·2	469·5
	11 54	49	79·6	71·75	246·0 222·9	471·1	208·3 219·2	429·6	207·4 204·2	413·6	228·6 236·3	467·2
	0 7 P.M.	50	80·2	72·32	260·2 217·8	480·1	217·0 212·2	431·3	211·0 199·3	412·3	235·1 227·9	465·2
	0 38	51	81·6	73·72	242·1 250·3	494·9	215·0 208·0	425·0	213·5 191·4	406·8	227·8 234·2	464·3
	0 50	52	82·0	74·23	250·4 252·3	505·2	202·9 220·5	425·6	201·0 204·0	407·0	239·2 222·0	463·4
	1 1	53	81·8	74·71	245·1 265·0	512·7	212·0 207·3	421·3	222·8 183·9	408·5	235·2 226·1	463·5
	1 14	54	81·7	75·18	250·7 267·0	520·3	211·9 210·7	424·7	207·7 200·0	409·7	225·2 237·1	464·6
	1 26	55	82·4	75·63	264·0 261·0	527·6	205·5 215·4	423·0	205·7 201·8	409·5	235·2 230·2	467·7
	2 4	56	83·5	77·07	266·5 276·2	545·4	206·0 211·4	419·5	202·9 205·8	410·7	242·0 216·2	460·3
	2 19	57	83·5	77·52	277·3 275·7	555·7	219·2 202·8	424·0	195·6 216·2	413·9	241·5 220·3	464·0
	2 33	58	83·8	77·95	284·2 278·6	565·5	205·0 218·8	425·9	209·0 205·3	416·3	232·4 232·0	466·7
	2 54	59	84·4	78·56	291·7 279·8	574·2	216·2 208·1	426·3	198·6 213·0	413·7	228·9 240·4	471·7
	3 6	60	84·9	78·88	292·1 284·5	579·4	216·6 208·8	427·4	211·0 203·0	416·0	242·1 227·2	471·5
	3 18	61	84·8	79·24	289·2 293·9	586·0	209·2 220·6	432·0	201·3 215·1	418·5	236·2 234·0	472·5
14th	7 0 A.M.	62	61·8	64·66	185·6 131·1	318·0	255·4 168·0	425·0	246·5 161·0	409·1	244·0 215·9	462·0
	7 10	63	62·3	64·53	193·0 124·5	318·7	227·2 195·0	424·1	219·4 187·1	408·3	212·7 247·0	462·1
	7 20	64	62·9	64·40	212·3 104·0	317·3	208·8 216·4	427·3	224·7 181·9	408·4	224·2 234·0	460·5
	7 29	65	63·6	64·32	200·8 113·9	315·8	225·4 198·6	425·9	230·4 175·0	407·1	226·8 233·0	462·1
	7 38	66	64·0	64·27	170·9 146·0	318·3	244·6 182·1	428·5	234·9 171·0	407·6	216·4 243·9	462·7

after set No. 287—(Continued.)

MICROMETER READINGS IN DIVISIONS
= 1·27810 *m.y.* of A = ·9903 × 1 Division of L

No. of comparison	D K L	D K + L in terms of K	E K L	E K + L in terms of K	H K L	H K + L in terms of K	Mean of the compensated bars	REMARKS
	+	+	+	+	+	+	+	
47	247·1 261·0	510·7	231·2 224·0	457·4	229·0 232·9	464·2	459·1	
48	264·0 246·0	512·4	231·0 223·2	456·4	229·1 232·2	463·6	458·1	
49	269·0 240·6	512·0	226·1 228·7	457·0	238·0 223·8	464·0	457·2	
50	252·0 257·2	511·7	223·0 231·3	456·6	218·8 239·0	460·1	456·2	
51	244·9 263·5	511·0	223·8 225·0	451·0	236·0 215·0	453·1	451·9	Observers changed places.
52	261·0 247·2	510·6	218·7 232·5	453·5	233·3 216·7	452·1	452·0	
53	253·0 253·0	508·5	228·9 216·1	447·1	231·2 217·7	451·0	450·0	
54	247·9 258·3	508·7	220·2 225·6	448·0	235·7 214·0	451·8	451·3	
55	256·3 252·0	510·8	229·2 222·6	454·0	225·2 224·9	452·3	452·9	
56	244·0 261·1	507·7	216·0 235·7	454·0	215·7 231·0	449·0	450·2	
57	252·8 254·8	510·1	236·0 218·1	456·2	227·4 222·1	451·7	453·3	
58	257·6 253·5	513·6	229·8 222·4	454·4	221·5 229·5	453·2	455·0	
59	254·8 259·7	517·0	221·8 235·0	459·1	228·8 225·4	456·4	457·4	Lieutenant Campbell at micrometer K; Lieutenant Herschel „ L.
60	255·7 259·0	517·2	226·0 229·4	457·6	224·8 228·1	455·1	457·5	
61	259·0 259·5	521·0	222·8 233·1	458·2	230·4 224·8	457·4	459·9	
62	261·8 231·0	495·1	243·6 201·8	447·4	249·6 189·1	440·6	446·5	Mr. Hennessey at micrometer K; Lieutenant Campbell „ L.
63	211·1 294·2	508·2	214·6 233·6	450·5	214·4 225·3	441·9	449·2	
64	219·8 287·0	509·6	217·4 226·9	446·5	222·2 217·8	442·1	449·1	
65	231·8 275·2	509·7	216·7 228·7	447·6	233·8 208·4	444·2	449·4	
66	268·8 234·2	505·3	212·2 233·6	448·1	222·6 218·8	443·5	449·3	

About the middle of the base-line,

1868 Feby. Mean of the times of observing A	No. of comparison	Temperature of Air	Corrected mean temperature of A	Micrometer Readings in Divisions — 1 Division of K = $\frac{1}{21732 \cdot 71}$ Inch [a.b] on Steel Foot = — Mean A: K / L	Mean A: K + L in terms of K	A: K / L	A: K + L in terms of K	B: K / L	B: K + L in terms of K	C: K / L	C: K + L in terms of K
h. m.		°	°	+	+	+	+	+	+	+	+
14th 7 47 A.M.	67	64·8	64·24	164·7 152·3	318·5	220·0 201·9	423·9	235·4 169·8	406·9	229·9 224·0	456·1
8 21	68	68·8	64·45	180·0 145·7	327·1	237·6 182·8	422·2	236·7 166·3	404·6	222·9 235·3	460·5
8 32	69	69·4	64·62	169·4 158·6	329·6	215·7 202·8	420·5	206·6 194·6	403·1	236·0 218·4	456·5
8 43	70	70·1	64·86	171·2 160·9	333·7	204·0 211·9	418·0	201·8 197·8	401·5	231·7 221·4	455·3
8 53	71	71·0	65·14	171·2 165·4	338·2	213·4 199·6	415·0	197·6 199·5	399·1	235·4 215·3	452·8
9 2	72	71·8	65·47	173·5 168·3	343·4	223·0 191·9	416·8	196·3 198·4	396·6	232·8 216·0	450·9
9 13	73	72·7	65·86	180·4 168·1	350·1	203·9 204·8	410·7	207·6 185·0	394·4	235·5 209·8	447·4
11 33	74	82·3	72·53	252·0 190·9	444·8	217·6 160·5	379·7	182·9 178·3	362·9	206·8 209·8	418·7
11 48	75	82·6	73·29	245·7 213·2	461·0	190·0 193·3	385·2	174·6 189·2	365·7	212·9 205·0	419·9
0 1 P.M.	76	82·6	73·96	237·4 231·7	471·4	191·2 191·2	384·3	178·0 190·4	370·3	207·7 213·0	422·8
0 12	77	82·6	74·55	242·2 236·7	481·2	199·6 178·4	379·7	190·2 180·8	372·8	209·2 215·8	427·1
0 38	78	84·0	75·78	248·6 251·6	502·7	186·4 196·0	384·3	182·4 189·4	373·7	212·9 214·1	429·1
1 1	79	83·9	76·82	259·8 257·1	519·4	192·3 196·3	390·5	192·5 179·5	373·8	218·1 210·2	430·4
1 13	80	84·4	77·30	264·1 261·1	527·8	194·2 193·0	389·1	198·3 176·5	376·5	210·3 219·4	431·9
		Means	71·48		477·73		447·64		430·33		484·93

At North-East-End of the base-line,

Mar. h. m.		°	°								
7th 7 27 A.M.	1	68·2	68·73	183·6 184·2	369·6	205·4 200·0	407·3	240·3 143·1	384·8	216·7 212·3	431·0
7 47	2	69·7	68·53	178·7 183·9	364·4	207·0 197·0	405·9	210·1 175·9	387·7	199·8 231·7	433·7

after set No. 287—(Continued.)

MICROMETER READINGS IN DIVISIONS
= 1·27810 *m.y.* of A = ·9903 × 1 Division of L

No. of comparison	D K L	D K + L in terms of K	E K L	E K + L in terms of K	H K L	H K + L in terms of K	Mean of the compensated bars	REMARKS
	+	+	+	+	+	+	+	
67	299·4 205·6	507·0	226·6 215·9	444·6	224·4 215·8	442·3	446·8	
68	222·9 277·8	503·4	216·0 226·3	444·5	217·3 225·5	445·0	446·7	Observers changed places.
69	255·6 246·6	504·6	216·0 223·0	441·2	223·3 217·0	442·4	444·7	
70	251·0 247·8	501·2	223·0 213·9	439·0	222·9 216·2	441·2	442·7	
71	248·0 251·2	501·7	213·0 221·3	436·5	233·0 203·9	438·9	440·7	
72	248·0 251·6	502·1	216·0 218·8	436·9	220·1 219·6	441·9	440·9	
73	258·6 235·3	496·2	221·5 213·1	436·7	223·0 212·0	437·1	437·1	
74	232·1 226·8	461·1	209·9 189·0	400·8	193·9 215·3	411·3	405·8	Lieutenant Herschel at micrometer K; Mr. Hennessey „ L.
75	232·2 229·3	463·7	188·2 215·6	405·9	200·1 212·3	414·5	409·2	
76	223·8 242·5	468·7	205·2 202·2	409·4	203·2 208·6	413·8	411·6	
77	234·9 231·9	469·1	207·1 198·8	407·8	209·0 205·4	416·4	412·2	
78	226·9 242·6	471·9	217·0 196·6	415·5	204·6 210·7	417·4	415·3	Observers changed places.
79	238·8 235·1	476·2	204·8 210·9	417·8	204·7 210·0	416·8	417·6	
80	236·7 236·2	475·2	201·1 214·2	417·4	207·9 207·2	417·1	417·9	
Means		529·17		471·80		473·41	472·88	

after the measurement. 1 Division K = $\frac{1}{21726·41}$ Inch [*a.b.*] on Steel Foot = 1·27847 *m.y* of A = ·9905 × 1 Division L

No. of comparison	D K L	D K + L in terms of K	E K L	E K + L in terms of K	H K L	H K + L in terms of K	Mean of the compensated bars	REMARKS
1	249·9 236·0	488·2	194·8 229·0	426·0	203·0 217·0	422·1	426·6	Mr. Hennessey at micrometer K; Lieutenant Campbell „ L.
2	244·4 242·0	488·7	226·8 197·6	426·3	169·5 249·8	421·7	427·3	

After the

1868 Mar.	Mean of the times of observing A	No. of comparison	Temperature of Air	Corrected mean temperature of A	MICROMETER READINGS IN DIVISIONS — 1 Division of K = $\frac{1}{21726 \cdot 41}$ Inch [a.b] on Steel Foot = Mean A: K / L	Mean A: K + L in terms of K	A: K / L	A: K + L in terms of K	B: K / L	B: K + L in terms of K	C: K / L	C: K + L in terms of K
	h. m.		°	°	+	+	+	+	+	+	+	+
7th	7 58 A.M.	3	70·7	68·51	219·5 141·9	362·8	228·6 175·0	405·3	250·7 132·1	384·1	293·9 139·7	434·9
	8 8	4	71·3	68·53	224·1 138·5	363·9	252·4 152·0	405·9	255·4 127·8	384·4	235·2 196·3	433·4
	8 29	5	72·6	68·73	203·6 160·6	365·7	279·2 118·1	398·4	280·7 96·5	378·1	185·0 247·1	434·5
	8 40	6	73·5	68·88	172·9 194·0	368·8	203·5 194·6	400·0	206·8 166·6	375·0	197·5 231·4	431·1
	8 50	7	74·0	69·05	204·0 165·1	370·7	190·4 205·4	397·8	211·0 160·4	372·9	194·2 234·1	430·5
	8 59	8	74·6	69·24	221·5 149·7	372·6	231·0 161·7	394·3	209·0 162·1	372·7	223·6 202·8	428·3
	11 7	9	82·4	73·43	251·6 191·6	445·0	240·7 143·0	385·1	262·4 100·7	364·1	267·0 161·6	430·2
	11 16	10	83·0	73·82	267·1 182·6	451·5	259·9 123·6	384·7	253·8 111·8	366·7	264·2 165·0	430·8
	11 25	11	83·5	74·22	263·9 191·8	457·5	263·7 120·2	385·1	245·8 118·8	365·7	252·9 175·2	429·8
	11 35	12	83·7	74·58	249·6 211·9	463·5	269·1 114·2	384·4	282·0 84·0	366·8	244·0 185·2	431·0
	11 45	13	84·1	74·95	207·6 260·9	471·0	232·0 154·8	388·3	217·7 149·1	368·2	209·6 219·0	430·7
	11 53	14	84·7	75·35	201·9 273·8	478·3	188·0 195·4	385·3	200·3 167·0	368·9	208·0 219·6	429·7
	0 12 P.M.	15	85·1	76·13	215·7 261·4	479·6	204·0 167·6	373·2	225·0 131·8	358·1	215·3 204·2	421·5
	0 19	16	85·6	76·45	225·9 259·6	488·0	207·5 162·9	372·0	203·8 153·3	358·6	208·0 210·8	420·8
	0 28	17	86·0	76·78	256·0 234·7	493·0	250·0 122·4	373·6	262·0 94·8	357·7	258·1 160·8	420·4
	0 36	18	86·1	77·10	291·6 203·0	496·5	267·6 105·4	374·0	268·0 87·6	356·4	255·6 162·9	420·1
	0 43	19	86·3	77·41	291·0 210·9	503·9	279·6 93·0	373·5	295·0 62·9	358·5	296·5 118·4	416·0
	0 51	20	86·5	77·71	234·8 273·0	510·4	230·4 143·9	375·7	240·6 115·6	357·3	223·1 195·6	420·6
	1 12	21	87·0	78·52	250·8 271·3	524·7	248·2 126·6	376·0	239·7 118·1	358·9	252·3 168·0	421·9
	1 19	22	87·2	78·85	242·0 284·5	529·2	192·4 181·0	375·1	193·3 167·0	361·9	177·5 243·4	423·2
	1 27	23	87·5	79·14	224·7 304·2	531·8	225·0 149·1	375·5	210·3 147·8	359·5	199·1 221·1	422·3

measurement—(Continued.)

No. of comparison	D K / L	D K + L in terms of K	E K / L	E K + L in terms of K	H K / L	H K + L in terms of K	Mean of the compensated bars	Remarks
	+	+	+	+	+	+	+	
3	309·9 173·6	485·2	293·8 130·2	425·2	240·2 177·0	418·9	425·6	
4	251·8 225·0	479·0	217·8 205·0	424·8	117·6 295·6	416·0	423·9	
5	196·2 281·0	479·9	193·8 228·2	424·2	211·9 202·4	416·2	421·9	Lieutenant Campbell at micrometer K; Mr. Hennessey „ L.
6	198·0 281·8	482·5	193·2 227·2	422·6	194·0 221·3	417·4	421·4	
7	205·7 273·1	481·4	224·3 194·1	420·3	231·0 182·6	415·4	419·7	
8	235·4 242·4	480·1	222·6 196·7	421·2	222·0 190·6	414·4	418·5	
9	260·9 215·2	478·2	269·1 145·8	416·3	261·9 155·3	418·7	415·4	
10	279·6 198·0	479·5	273·0 142·8	417·2	249·4 167·9	418·9	416·3	
11	271·3 208·6	481·9	257·6 159·0	418·1	263·9 152·4	417·8	416·4	
12	260·6 217·0	479·7	266·8 150·3	418·5	265·0 151·0	417·4	416·3	
13	205·6 272·7	480·9	206·6 210·0	418·6	183·3 234·0	419·5	417·7	
14	176·1 303·7	482·7	201·7 218·6	422·4	214·0 202·9	418·8	418·0	
15	208·3 259·0	469·8	196·7 210·2	408·9	223·0 179·9	404·6	406·0	
16	207·5 261·8	471·8	197·5 208·4	407·9	201·8 201·1	404·8	406·0	
17	272·3 196·1	470·3	284·7 124·2	410·1	265·5 140·8	407·7	406·6	
18	270·8 197·2	469·9	266·0 141·0	408·4	287·2 119·0	407·3	406·0	
19	194·1 278·3	475·1	213·0 195·9	410·8	226·5 180·1	408·3	407·0	
20	215·9 258·4	476·8	219·1 190·8	411·7	212·9 192·8	407·6	408·3	
21	295·4 176·0	473·1	244·8 164·9	411·3	232·2 174·0	407·9	408·2	Mr. Hennessey at micrometer K; Lieutenant Campbell „ L.
22	233·0 236·0	471·3	250·7 159·0	411·2	213·2 192·7	407·7	408·4	
23	228·3 240·6	471·2	226·2 183·0	411·0	194·1 212·7	408·8	408·1	

Micrometer Readings in Divisions = 1·27847 *m.y.* of **A** = ·9905 × 1 Division of L

After the

1868 Mar.	Mean of the times of observing A	No. of comparison	Temperature of Air	Corrected mean temperature of A	Micrometer Readings in Divisions — 1 Division of K = $\frac{1}{21726 \cdot 41}$ Inch [a.b] on Steel Foot = — Mean A: K / L	Mean A: K + L in terms of K	A: K / L	A: K + L in terms of K	B: K / L	B: K + L in terms of K	C: K / L	C: K + L in terms of K
	h. m.		°	°	+	+	+	+	+	+	+	+
7th	1 35 P.M.	24	87·6	79·41	264·2 271·0	537·8	253·8 122·1	377·1	247·8 115·0	363·9	200·4 221·0	423·5
	1 42	25	87·8	79·68	295·8 244·6	542·7	198·4 176·0	376·1	228·3 133·3	362·9	222·1 199·2	423·2
	1 49	26	87·9	79·97	259·4 285·1	547·2	236·4 139·8	377·5	278·8 86·1	365·7	213·4 209·6	425·0
	2 14	27	87·9	80·86	245·1 316·1	564·2	253·4 125·0	379·6	226·4 141·4	369·2	251·2 174·5	427·4
	2 20	28	88·0	81·06	208·7 355·9	568·0	200·4 178·6	380·7	201·6 166·7	369·9	197·7 229·0	428·9
	2 27	19	87·8	81·27	222·2 346·4	571·9	202·2 180·1	384·0	225·7 141·5	368·6	232·9 192·4	427·1
	2 34	30	87·5	81·50	235·0 337·9	576·1	226·5 154·4	382·4	240·5 127·4	369·1	240·9 185·0	427·7
	2 42	31	87·9	81·72	246·2 332·6	585·0	201·5 180·8	384·0	182·1 185·7	369·6	214·6 213·4	430·0
	2 50	32	88·2	81·92	244·6 339·0	586·9	234·6 150·2	386·2	163·6 204·0	369·6	175·9 254·0	432·3
9th	7 20 A.M.	33	69·8	70·28	226·6 107·5	335·1	197·1 148·4	346·9	163·8 169·6	335·0	151·5 229·3	383·0
	7 33	34	70·5	70·18	224·3 109·8	335·2	169·8 173·0	344·5	168·7 160·6	330·8	192·0 186·3	380·1
	7 45	35	71·2	70·14	192·9 141·4	335·7	169·9 172·3	343·9	164·6 165·8	332·0	177·0 202·9	381·8
	7 57	36	71·9	70·13	185·9 147·8	335·1	174·6 167·4	343·6	164·2 163·2	329·0	187·7 188·6	378·1
	8 29	37	74·5	70·50	194·9 140·6	336·8	188·9 145·5	335·8	178·8 139·3	319·4	171·1 199·4	372·4
	8 44	38	75·6	70·79	179·0 160·9	341·4	167·4 164·0	333·0	152·6 165·1	319·3	143·3 224·2	369·7
	8 58	39	76·7	71·12	173·3 172·1	347·1	171·3 161·8	334·7	164·9 151·6	318·0	186·7 182·3	370·8
	9 10	40	77·6	71·46	194·3 156·0	351·8	177·8 155·2	334·5	165·9 149·1	316·4	182·6 187·4	371·8
	11 3	41	84·9	76·47	204·0 238·7	445·0	225·2 108·8	335·0	167·2 149·2	317·8	183·8 189·0	374·6
	11 15	42	84·6	76·90	193·6 254·2	450·2	167·1 167·0	335·7	171·2 150·1	322·7	185·6 189·1	377·5
	11 24	43	85·2	77·31	192·6 263·9	459·0	178·8 158·2	338·5	173·4 146·2	321·0	189·0 189·0	379·8

measurement—(Continued.)

No. of comparison	D K/L	D K + L in terms of K	E K/L	E K + L in terms of K	H K/L	H K + L in terms of K	Mean of the compensated bars	Remarks
	Micrometer Readings in Divisions = 1·27847 m.y. of A = ·9905 × 1 Division of L							
	+	+	+	+	+	+	+	
24	210·4 260·0	472·9	181·1 229·0	412·3	160·7 248·5	411·6	410·2	
25	197·4 276·0	476·0	229·4 181·4	412·5	232·5 174·3	408·5	409·9	
26	249·4 220·5	472·0	216·6 194·1	412·6	242·3 163·5	407·4	410·0	
27	249·8 225·0	477·0	243·4 170·0	415·0	209·5 200·7	412·1	413·4	
28	243·2 *133·7	378·2	214·4 200·0	416·3	208·4 202·3	412·6	397·8	
29	229·4 244·5	476·2	213·2 200·7	415·8	220·8 190·5	413·1	414·1	
30	261·3 212·2	475·5	261·3 155·5	418·3	225·3 187·8	414·9	414·7	
31	268·8 208·8	479·6	212·3 205·0	419·3	230·8 180·0	412·5	415·8	
32	190·8 286·9	480·5	239·4 179·0	420·1	230·2 181·8	413·7	417·1	
33	181·3 240·8	424·4	192·9 177·7	372·3	220·5 140·6	362·4	370·7	Lieutenant Herschel at micrometer K; Mr. Hennessey " L.
34	207·3 213·7	423·1	183·4 186·3	371·5	178·8 180·2	360·7	368·5	
35	214·9 204·4	421·3	189·4 176·8	367·9	181·5 179·1	362·3	368·2	
36	219·3 200·4	421·6	175·2 192·6	369·6	178·8 181·6	362·1	367·3	
37	218·4 202·7	423·0	205·5 157·5	364·5	170·4 183·5	355·7	361·8	Observers changed places.
38	202·2 217·4	421·7	158·3 200·8	361·0	177·6 177·2	356·5	360·2	
39	219·9 197·6	419·4	173·9 187·9	363·6	179·4 175·2	356·3	360·5	
40	196·6 221·0	419·7	177·4 183·2	362·4	182·8 172·8	357·3	360·4	
41	218·0 203·8	423·8	190·4 170·8	362·8	182·8 182·8	367·4	363·6	
42	208·7 216·0	426·8	186·6 176·1	364·4	190·8 175·5	368·0	365·9	
43	213·6 208·3	423·9	185·6 177·6	364·9	187·6 179·8	369·1	366·2	

* This quantity evidently should be 233·7. The mistake was however detected only in correcting proofs for the press, too late to rectify in the calculations; the corresponding correction to the length of the entire base-line is hardly appreciable, being only + ·0008 feet.

After the

1868 Mar.	Mean of the times of observing A	No. of comparison	Temperature of Air	Corrected mean temperature of A	Micrometer Readings in Divisions 1 Division of K = $\frac{1}{21726·41}$ Inch [a.b] on Steel Foot =							
					Mean A		A		B		C	
					K L	K + L in terms of K	K L	K + L in terms of K	K L	K + L in terms of K	K L	K + L in terms of K
	h. m.		°	°	+	+	+	+	+	+	+	+
9th	11 35 A.M.	44	85·5	77·73	207·6 257·1	467·2	174·8 162·0	338·4	159·8 159·0	320·3	203·6 174·5	379·8
	0 6 P.M.	45	87·5	79·14	236·4 255·7	494·6	186·5 154·4	342·4	158·8 165·5	325·9	182·2 200·4	384·5
	0 17	46	87·5	79·60	253·7 246·3	502·4	176·3 163·5	341·4	164·9 157·6	324·0	187·4 195·5	384·8
	0 28	47	88·1	80·08	264·9 245·4	512·7	174·2 166·3	342·1	151·9 170·7	324·2	192·7 193·8	388·4
	0 40	48	88·0	80·56	266·2 253·6	522·2	172·8 169·6	344·0	177·1 147·8	326·3	189·9 199·2	391·0
	1 18	49	89·3	82·04	261·4 283·0	547·1	197·2 146·0	344·6	192·8 138·5	332·6	192·2 196·7	390·8
	1 29	50	88·9	82·42	266·4 286·5	555·7	191·4 153·9	346·8	187·6 145·1	334·1	192·5 196·3	390·7
	1 40	51	88·6	82·82	277·4 284·7	564·8	196·6 150·6	348·6	165·9 167·8	335·3	189·5 204·2	395·7
	1 52	52	88·8	83·22	275·5 294·6	572·9	181·1 168·2	350·9	187·4 150·0	338·8	203·2 194·1	399·2
	2 20	53	90·6	84·15	284·8 308·9	596·7	176·8 182·8	361·4	182·8 164·3	348·7	201·8 205·2	409·0
	2 30	54	90·4	84·48	293·8 309·3	606·1	194·0 168·5	364·1	174·8 176·2	352·7	209·1 201·5	412·5
	2 48	55	90·8	85·12	303·1 315·7	621·8	196·4 173·4	371·5	197·8 160·6	359·9	179·2 236·3	417·8
	3 5	56	90·1	85·73	322·3 312·3	637·6	195·8 178 8	376·3	192·5 172·4	366·6	207·0 216·1	425·2
10th	7 38 A.M.	57	71·5	70·32	168·3 157·0	326·8	183·6 148·9	333·9	176·8 143·1	321·3	184·7 181·2	367·6
	7 52	58	72·4	70·29	167·8 157·4	326·7	160·9 173·0	335·6	165·0 155·2	321·7	176·7 190·1	368·6
	8 18	59	73·8	70·40	166·4 162·6	330·6	171·9 160·6	334·0	160·9 159·0	321·4	180·2 185·4	367·4
	8 31	60	74·5	70·50	163·6 167·2	332·4	176·2 156·0	333·7	154·4 165·5	321·5	178·1 189·0	368·9
	8 46	61	75·4	70·74	166·6 173·1	341·4	178·9 158·0	338·4	148·2 175·0	324·9	185·0 186·2	373·0
	8 58	62	76·1	70·93	169·5 175·1	346·3	169·0 168·5	339·1	167·0 158·3	326·8	182·1 193·0	377·0
	9 11	63	76·8	71·12	168·3 180·6	350·6	184·7 154·0	340·2	157·2 168·1	326·9	177·9 197·0	376·8

measurement—(Continued.)

No. of comparison	Micrometer Readings in Divisions = 1·27847 *m.y.* of A = ·9905 × 1 Division of L							Remarks
	D		E		H		Mean of the compensated bars	
	K L	K + L in terms of K	K L	K + L in terms of K	K L	K + L in terms of K		
	+	+	+	+	+	+	+	
44	213·4 213·6	429·1	177·8 185·7	365·3	176·4 191·8	370·0	367·2	
45	213·6 215·2	430·9	189·5 180·2	371·4	186·9 183·1	371·8	371·2	Lieutenant Herschel at micrometer K; Mr. Hennessey „ L.
46	226·2 203·9	432·1	187·0 186·2	375·0	181·4 192·1	375·3	372·1	
47	221·5 210·3	433·8	184·8 188·2	374·8	186·2 189·2	377·2	373·4	
48	201·2 234·3	437·7	189·0 186·8	377·6	198·5 174·6	374·8	375·2	
49	222·1 213·6	437·8	189·9 189·6	381·3	195·3 185·2	382·3	378·2	Observers changed places.
50	222·3 217·8	442·2	196·3 182·6	380·7	196·8 183·0	381·6	379·4	
51	210·8 227·8	440·8	183·8 197·9	383·6	183·3 197·8	383·0	381·2	
52	222·8 221·8	446·7	188·8 195·0	385·7	195·6 189·8	387·2	384·8	
53	222·2 231·6	456·0	206·7 189·2	397·7	188·2 204·3	394·5	394·6	Observers changed places.
54	233·1 220·4	455·6	213·4 182·6	397·8	197·7 199·9	399·5	397·0	
55	210·6 254·7	467·7	197·5 206·4	405·9	194·0 209·8	405·8	404·8	
56	229·1 238·3	469·7	198·2 211·2	411·4	220·2 189·2	411·2	410·1	
57	211·9 199·9	413·7	185·6 170·7	357·9	174·5 176·9	353·1	357·9	Lieutenant Herschel at micrometer K; Mr. Hennessey „ L.
58	201·2 213·2	416·4	179·5 177·7	358·9	179·1 176·0	356·8	359·7	
59	204·6 210·7	417·3	187·9 170·7	360·2	172·1 184·1	358·0	359·7	
60	204·9 210·9	417·8	174·8 184·5	361·1	172·3 182·7	356·8	360·0	
61	207·0 212·8	421·8	175·6 186·7	364·1	169·3 191·8	362·9	364·2	Observers changed places.
62	206·1 215·4	423·6	178·0 184·6	364·4	176·4 186·0	364·2	365·9	
63	219·9 205·2	427·1	188·0 178·7	368·4	170·0 191·6	363·4	367·1	

After the

1868 Mar.	Mean of the times of observing A	No. of comparison	Temperature of Air	Corrected mean temperature of A	Micrometer Readings in Divisions 1 Division of K = $\frac{1}{21726·41}$ Inch [a.b] on Steel Foot = Mean A K L	 Mean A K + L in terms of K	 A K L	 A K + L in terms of K	 B K L	 B K + L in terms of K	 C K L	 C K + L in terms of K
	h. m.		°	°	+	+	+	+	+	+	+	+
10th	9 22 A.M.	64	77·3	71·35	164·9 188·2	354·9	163·8 177·0	342·5	173·3 151·3	326·1	184·5 191·1	377·4
	11 43	65	86·6	75·90	175·9 243·8	422·0	200·6 129·7	331·5	175·0 142·9	319·3	179·0 191·1	371·9
	11 53	66	87·5	76·36	187·3 242·8	432·4	166·8 168·0	336·4	153·1 165·3	320·0	176·4 194·1	372·4
	0 3 P.M.	67	88·1	76·83	210·9 229·5	442·6	160·0 176·2	337·9	160·7 158·7	320·9	184·5 185·6	371·9
	0 23	68	88·0	77·47	212·6 239·9	454·8	171·1 167·0	339·7	170·0 147·1	318·5	181·1 193·7	376·7
	1 23	69	89·1	80·25	249·8 259·8	512·1	179·9 164·7	346·2	164·8 164·8	331·2	192·8 194·3	389·0
	1 33	70	88·3	80·62	246·7 269·6	518·9	180·1 167·0	348·7	194·9 131·9	328·1	190·2 194·1	386·2
	1 43	71	87·7	80·95	262·0 260·3	524·8	175·9 172·5	350·1	171·0 158·0	330·5	197·0 191·3	390·1
	1 54	72	87·7	81·25	267·0 260·9	530·4	171·2 176·7	349·6	175·5 156·1	333·1	191·9 196·1	389·9
	2 34	73	89·0	82·42	274·7 276·9	554·3	178·1 173·9	353·7	177·8 159·5	338·8	192·9 203·9	398·7
	2 43	74	89·0	82·67	273·6 283·6	559·9	181·9 172·2	355·8	183·0 158·0	342·5	198·3 199·0	399·2
	2 55	75	89·1	83·10	278·4 288·8	570·0	168·9 189·1	365·8	172·0 173·5	347·2	198·6 200·3	400·8
	3 6	76	88·8	83·44	265·5 310·2	578·7	162·4 190·8	355·0	184·0 159·4	344·9	189·4 210·0	401·4
			Means	76·46		466·14		361·72		345·95		402·70

Let the mean length of the compensated bars minus the Standard A at 62° F be denoted by x, and the observed excess of the compensated bars by δ when the temperature of A is $t°$. Then, the expansion of A for 1° being $(E_a - dE_a)$, we have

$$x - (t° - 62°)(E_a - dE_a) - \delta = 0;$$

Treating the bar comparisons "*Before the measurement*" as shewn in this equation, we obtain the following series of results :—

measurement— (Continued.)

No. of comparison	D K L	D K + L in terms of K	E K L	E K + L in terms of K	H K L	H K + L in terms of K	Mean of the compensated bars	Remarks
	Micrometer Readings in Divisions = 1·27847 m.y. of A = ·9905 x 1 Division of L							
	+	+	+	+	+	+	+	
64	213·3 209·0	424·3	199·0 167·3	367·9	187·0 174·9	363·6	367·0	
65	190·0 227·0	419·2	171·7 183·6	357·1	176·5 185·7	364·0	360·5	Lieutenant Campbell at micrometer K; Lieutenant Herschel „ L.
66	203·1 213·0	418·1	193·0 163·8	358·4	180·0 183·3	365·1	361·7	
67	211·9 206·8	420·7	175·7 182·9	360·4	178·3 186·0	366·1	363·0	
68	203·7 218·6	424·4	179·6 179·0	360·3	182·3 182·5	366·6	364·4	
69	212·6 219·3	434·0	181·2 189·6	372·6	186·9 188·1	376·8	375·0	Observers changed places.
70	213·7 218·8	434·6	183·2 188·9	373·9	177·2 197·7	376·8	374·7	
71	225·7 206·0	433·7	187·2 189·0	378·0	183·0 194·0	378·9	376·9	
72	208·8 226·0	437·0	183·7 191·0	376·5	194·9 181·8	377·4	377·3	
73	224·8 214·0	440·9	194·1 187·0	382·9	191·1 190·7	383·6	383·1	
74	214·2 227·5	443·9	198·0 183·9	383·7	190·7 193·2	385·8	385·2	
75	217·4 227·2	446·8	190·9 195·2	388·0	202·8 185·5	390·1	389·8	Observers changed places.
76	221·9 225·6	449·7	195·7 191·0	388·5	192·9 193·2	388·0	387·9	
Means		449·72		391·47		389·66	390·43	

Before the measurement—(Continued.)

		d				d	
$x + 1·15$	$(E_a - dE_a)$	$-189·1$	$= 0$	$x - 10·87$	$(E_a - dE_a)$	$+ 20·2$	$= 0$
$x + 1·17$	„	$-186·5$	$= 0$	$x - 0·21$	„	$-170·3$	$= 0$
$x + 0·67$	„	$-172·0$	$= 0$	$x + 0·04$	„	$-172·0$	$= 0$
$x - 4·23$	„	$- 75·7$	$= 0$	$x + 0·04$	„	$-163·1$	$= 0$
$x - 5·82$	„	$- 49·2$	$= 0$	$x - 0·31$	„	$-146·5$	$= 0$
$x - 7·63$	„	$- 25·1$	$= 0$	$x - 0·88$	„	$-133·5$	$= 0$
$x - 8·88$	„	$- 6·1$	$= 0$	$x - 1·60$	„	$-116·9$	$= 0$
$x - 9·85$	„	$+ 6·4$	$= 0$	$x - 6·17$	„	$- 30·8$	$= 0$

Before the measurement—(Continued.)

$$x - 7{\cdot}69\,(E_a - dE_a) - \overset{d}{12{\cdot}2} = 0$$
$$x - 8{\cdot}32 \quad „ \quad - 3{\cdot}0 = 0$$
$$x - 8{\cdot}93 \quad „ \quad + 6{\cdot}4 = 0$$
$$x - 9{\cdot}50 \quad „ \quad + 11{\cdot}0 = 0$$
$$x - 10{\cdot}06 \quad „ \quad + 18{\cdot}2 = 0$$
$$x - 10{\cdot}64 \quad „ \quad + 25{\cdot}2 = 0$$
$$x - 11{\cdot}27 \quad „ \quad + 33{\cdot}5 = 0$$
$$x - 12{\cdot}03 \quad „ \quad + 43{\cdot}5 = 0$$
$$x - 12{\cdot}59 \quad „ \quad + 46{\cdot}9 = 0$$
$$x - 13{\cdot}05 \quad „ \quad + 51{\cdot}5 = 0$$
$$x - 13{\cdot}40 \quad „ \quad + 58{\cdot}6 = 0$$
$$x - 13{\cdot}69 \quad „ \quad + 60{\cdot}2 = 0$$
$$x - 0{\cdot}57 \quad „ \quad - 159{\cdot}1 = 0$$
$$x - 0{\cdot}25 \quad „ \quad - 166{\cdot}1 = 0$$
$$x - 0{\cdot}01 \quad „ \quad - 170{\cdot}4 = 0$$
$$x + 0{\cdot}14 \quad „ \quad - 172{\cdot}6 = 0$$
$$x + 0{\cdot}21 \quad „ \quad - 170{\cdot}9 = 0$$

$$x + 0{\cdot}16\,(E_a - dE_a) - \overset{d}{165{\cdot}6} = 0$$
$$x + 0{\cdot}00 \quad „ \quad - 158{\cdot}1 = 0$$
$$x - 0{\cdot}28 \quad „ \quad - 148{\cdot}7 = 0$$
$$x - 0{\cdot}66 \quad „ \quad - 140{\cdot}9 = 0$$
$$x - 1{\cdot}11 \quad „ \quad - 129{\cdot}9 = 0$$
$$x - 5{\cdot}21 \quad „ \quad - 48{\cdot}7 = 0$$
$$x - 6{\cdot}11 \quad „ \quad - 36{\cdot}9 = 0$$
$$x - 7{\cdot}06 \quad „ \quad - 21{\cdot}4 = 0$$
$$x - 7{\cdot}92 \quad „ \quad - 7{\cdot}4 = 0$$
$$x - 8{\cdot}80 \quad „ \quad + 4{\cdot}6 = 0$$
$$x - 9{\cdot}80 \quad „ \quad + 16{\cdot}6 = 0$$
$$x - 11{\cdot}16 \quad „ \quad + 36{\cdot}1 = 0$$
$$x - 11{\cdot}91 \quad „ \quad + 45{\cdot}9 = 0$$
$$x - 12{\cdot}66 \quad „ \quad + 55{\cdot}1 = 0$$
$$x - 13{\cdot}36 \quad „ \quad + 64{\cdot}2 = 0$$
$$x - 13{\cdot}87 \quad „ \quad + 67{\cdot}0 = 0$$
$$x - 14{\cdot}24 \quad „ \quad + 70{\cdot}8 = 0$$

And from the mean of these results,

$$x = + \overset{d}{52{\cdot}13} + 6{\cdot}18\,(E_a - dE_a):$$

adopting the original value of the expansion of **A** given at page (9),

$$E_a = \overset{m.y}{22{\cdot}67} = \overset{d}{17{\cdot}743},$$

and $x = \overset{d}{161{\cdot}78} - 6{\cdot}18\,dE_a = \overset{m.y}{206{\cdot}71} - 6{\cdot}18\,dE_a = \text{L} - \textbf{A};$

where L denotes the mean length of the compensated bars obtained from *all* the comparisons, as represented by the mean micrometer reading $\overset{d}{499{\cdot}86}$, page IX—9.

Comparing this reading with the mean reading of each compensated bar given on pages IX—8 and IX—9 we obtain the following:—

In terms of	A − L	B − L	C − L	D − L	E − L	H − L
Micrometer divisions.	−28·68	−40·16	+10·37	+59·89	+2·72	−4·15
Millionths of a yard.	−36·64	−51·31	+13·25	+76·52	+3·48	−5·30

Before the measurement—(Continued.)

Also combining the values in this table with the equivalent of **L—A** just determined, there result,

$A - \mathbf{A} = \overset{d}{133{\cdot}10} - 6{\cdot}18\, dE_a = \overset{m.y}{170{\cdot}07} - 6{\cdot}18\, dE_a$
$B - \mathbf{A} = 121{\cdot}62 - \quad ,, \quad = 155{\cdot}40 - \quad ,,$
$C - \mathbf{A} = 172{\cdot}15 - \quad ,, \quad = 219{\cdot}96 - \quad ,,$

$D - \mathbf{A} = \overset{d}{221{\cdot}67} - 6{\cdot}18\, dE_a = \overset{m.y}{283{\cdot}23} - 6{\cdot}18\, dE_a$
$E - \mathbf{A} = 164{\cdot}50 - \quad ,, \quad = 210{\cdot}19 - \quad ,,$
$H - \mathbf{A} = 157{\cdot}63 - \quad ,, \quad = 201{\cdot}41 - \quad ,,$

$$\text{and } 6\,x = \overset{m.y}{1240{\cdot}3} - 37{\cdot}1\, dE_a.$$

About the middle of the base-line.

Again from the bar comparisons "*After set No.* 287", we obtain the following series of results :—

$x - 0{\cdot}11\, (E_a - dE_a) - \overset{d}{151{\cdot}6} = 0$
$x - 7{\cdot}11 \quad ,, \quad - 18{\cdot}3 = 0$
$x - 8{\cdot}15 \quad ,, \quad - 1{\cdot}7 = 0$
$x - 9{\cdot}02 \quad ,, \quad + 9{\cdot}9 = 0$
$x - 11{\cdot}99 \quad ,, \quad + 59{\cdot}0 = 0$
$x - 12{\cdot}59 \quad ,, \quad + 67{\cdot}3 = 0$
$x - 13{\cdot}13 \quad ,, \quad + 74{\cdot}6 = 0$
$x - 13{\cdot}81 \quad ,, \quad + 87{\cdot}0 = 0$
$x - 14{\cdot}36 \quad ,, \quad + 94{\cdot}1 = 0$
$x - 14{\cdot}89 \quad ,, \quad + 102{\cdot}0 = 0$
$x - 15{\cdot}34 \quad ,, \quad + 107{\cdot}0 = 0$
$x - 15{\cdot}80 \quad ,, \quad + 113{\cdot}6 = 0$
$x - 16{\cdot}30 \quad ,, \quad + 117{\cdot}5 = 0$
$x - 16{\cdot}75 \quad ,, \quad + 122{\cdot}2 = 0$
$x - 17{\cdot}11 \quad ,, \quad + 129{\cdot}6 = 0$
$x - 1{\cdot}88 \quad ,, \quad - 138{\cdot}2 = 0$
$x - 1{\cdot}79 \quad ,, \quad - 141{\cdot}4 = 0$
$x - 1{\cdot}76 \quad ,, \quad - 139{\cdot}2 = 0$
$x - 1{\cdot}76 \quad ,, \quad - 139{\cdot}2 = 0$
$x - 1{\cdot}88 \quad ,, \quad - 138{\cdot}5 = 0$
$x - 2{\cdot}05 \quad ,, \quad - 133{\cdot}5 = 0$
$x - 2{\cdot}25 \quad ,, \quad - 124{\cdot}6 = 0$
$x - 8{\cdot}10 \quad ,, \quad - 4{\cdot}2 = 0$
$x - 8{\cdot}90 \quad ,, \quad + 11{\cdot}5 = 0$
$x - 9{\cdot}76 \quad ,, \quad + 24{\cdot}1 = 0$

$x - 10{\cdot}41\, (E_a - dE_a) + \overset{d}{34{\cdot}5} = 0$
$x - 10{\cdot}93 \quad ,, \quad + 41{\cdot}9 = 0$
$x - 11{\cdot}47 \quad ,, \quad + 49{\cdot}2 = 0$
$x - 12{\cdot}03 \quad ,, \quad + 56{\cdot}9 = 0$
$x - 12{\cdot}55 \quad ,, \quad + 66{\cdot}5 = 0$
$x - 13{\cdot}61 \quad ,, \quad + 78{\cdot}3 = 0$
$x - 14{\cdot}02 \quad ,, \quad + 84{\cdot}8 = 0$
$x - 14{\cdot}45 \quad ,, \quad + 90{\cdot}6 = 0$
$x - 14{\cdot}88 \quad ,, \quad + 98{\cdot}9 = 0$
$x - 15{\cdot}26 \quad ,, \quad + 103{\cdot}9 = 0$
$x - 15{\cdot}60 \quad ,, \quad + 106{\cdot}6 = 0$
$x - 15{\cdot}94 \quad ,, \quad + 112{\cdot}7 = 0$
$x - 16{\cdot}38 \quad ,, \quad + 114{\cdot}2 = 0$
$x - 2{\cdot}96 \quad ,, \quad - 122{\cdot}8 = 0$
$x - 3{\cdot}01 \quad ,, \quad - 120{\cdot}3 = 0$
$x - 3{\cdot}15 \quad ,, \quad - 115{\cdot}6 = 0$
$x - 3{\cdot}43 \quad ,, \quad - 108{\cdot}4 = 0$
$x - 3{\cdot}73 \quad ,, \quad - 99{\cdot}8 = 0$
$x - 4{\cdot}08 \quad ,, \quad - 89{\cdot}7 = 0$
$x - 4{\cdot}48 \quad ,, \quad - 78{\cdot}1 = 0$
$x - 7{\cdot}93 \quad ,, \quad - 20{\cdot}3 = 0$
$x - 8{\cdot}54 \quad ,, \quad - 8{\cdot}4 = 0$
$x - 9{\cdot}15 \quad ,, \quad + 5{\cdot}0 = 0$
$x - 9{\cdot}75 \quad ,, \quad + 13{\cdot}9 = 0$
$x - 10{\cdot}32 \quad ,, \quad + 23{\cdot}9 = 0$

About the middle of the base-line, after set No. 287—(Continued.)

$x - 11.72\,(E_a - dE_a) + \overset{d}{43.0} = 0$
$x - 12.23$ „ $+ 53.2 = 0$
$x - 12.71$ „ $+ 62.7 = 0$
$x - 13.18$ „ $+ 69.0 = 0$
$x - 13.63$ „ $+ 74.7 = 0$
$x - 15.07$ „ $+ 95.2 = 0$
$x - 15.52$ „ $+ 102.4 = 0$
$x - 15.95$ „ $+ 110.5 = 0$
$x - 16.56$ „ $+ 116.8 = 0$
$x - 16.88$ „ $+ 121.9 = 0$
$x - 17.24$ „ $+ 126.1 = 0$
$x - 2.66$ „ $- 128.5 = 0$
$x - 2.53$ „ $- 130.5 = 0$
$x - 2.40$ „ $- 131.8 = 0$
$x - 2.32$ „ $- 133.6 = 0$

$x - 2.27\,(E_a - dE_a) - \overset{d}{131.0} = 0$
$x - 2.24$ „ $- 128.3 = 0$
$x - 2.45$ „ $- 119.6 = 0$
$x - 2.62$ „ $- 115.1 = 0$
$x - 2.86$ „ $- 109.0 = 0$
$x - 3.14$ „ $- 102.5 = 0$
$x - 3.47$ „ $- 97.5 = 0$
$x - 3.86$ „ $- 87.0 = 0$
$x - 10.53$ „ $+ 39.0 = 0$
$x - 11.29$ „ $+ 51.8 = 0$
$x - 11.96$ „ $+ 59.8 = 0$
$x - 12.55$ „ $+ 69.0 = 0$
$x - 13.78$ „ $+ 87.4 = 0$
$x - 14.82$ „ $+ 101.8 = 0$
$x - 15.30$ „ $+ 109.9 = 0$

And from the mean of these results,

$$x = -\overset{d}{4.85} + 9.48\,(E_a - dE_a):$$

adopting the original value of the expansion of **A** given at page (9),

$$E_a = \overset{m.y}{22.67} = \overset{d}{17.738},$$

$$\text{and } x = \overset{d}{163.31} - 9.48\,dE_a = \overset{m.y}{208.72} - 9.48\,dE_a = \mathrm{L} - \mathbf{A}.$$

Proceeding as on page IX—26 we obtain;

In terms of	A − L	B − L	C − L	D − L	E − L	H − L
Micrometer divisions.	−25.24	−42.55	+12.05	+56.29	−1.08	+0.53
Millionths of a yard.	−32.26	−54.38	+15.40	+71.94	−1.38	+0.68

Also the following;

$\mathrm{A} - \mathbf{A} = \overset{d}{138.07} - 9.48\,dE_a = \overset{m.y}{176.46} - 9.48\,dE_a$
$\mathrm{B} - \mathbf{A} = 120.76 -$ „ $= 154.34 -$ „
$\mathrm{C} - \mathbf{A} = 175.36 -$ „ $= 224.12 -$ „

$\mathrm{D} - \mathbf{A} = \overset{d}{219.60} - 9.48\,dE_a = \overset{m.y}{280.66} - 9.48\,dE_a$
$\mathrm{E} - \mathbf{A} = 162.23 -$ „ $= 207.34 -$ „
$\mathrm{H} - \mathbf{A} = 163.84 -$ „ $= 209.40 -$ „

$$\text{and } 6\,x = \overset{m.y}{1252.3} - 56.9\,dE_a.$$

After the measurement—(Continued.)

Also from the bar comparisons "*After the measurement*," we obtain the following series of results :—

		d			d
$x - 6·73$	$(E_a - dE_a)$	$- 57·0 = 0$	$x - 8·14$	$(E_a - dE_a)$	$- 32·5 = 0$
$x - 6·53$	„	$- 62·9 = 0$	$x - 8·13$	„	$- 32·2 = 0$
$x - 6·51$	„	$- 62·8 = 0$	$x - 8·50$	„	$- 25·0 = 0$
$x - 6·53$	„	$- 60·0 = 0$	$x - 8·79$	„	$- 18·8 = 0$
$x - 6·73$	„	$- 56·2 = 0$	$x - 9·12$	„	$- 13·4 = 0$
$x - 6·88$	„	$- 52·6 = 0$	$x - 9·46$	„	$- 8·6 = 0$
$x - 7·05$	„	$- 49·0 = 0$	$x - 14·47$	„	$+ 81·4 = 0$
$x - 7·24$	„	$- 45·9 = 0$	$x - 14·90$	„	$+ 84·3 = 0$
$x - 11·43$	„	$+ 29·6 = 0$	$x - 15·31$	„	$+ 92·8 = 0$
$x - 11·82$	„	$+ 35·2 = 0$	$x - 15·73$	„	$+ 100·0 = 0$
$x - 12·22$	„	$+ 58·9 = 0$	$x - 17·14$	„	$+ 123·4 = 0$
$x - 12·58$	„	$+ 47·2 = 0$	$x - 17·60$	„	$+ 130·3 = 0$
$x - 12·95$	„	$+ 53·3 = 0$	$x - 18·08$	„	$+ 139·3 = 0$
$x - 13·35$	„	$+ 60·3 = 0$	$x - 18·56$	„	$+ 147·0 = 0$
$x - 14·13$	„	$+ 73·6 = 0$	$x - 20·04$	„	$+ 168·9 = 0$
$x - 14·45$	„	$+ 82·0 = 0$	$x - 20·42$	„	$+ 176·3 = 0$
$x - 14·78$	„	$+ 86·4 = 0$	$x - 20·82$	„	$+ 183·6 = 0$
$x - 15·10$	„	$+ 90·5 = 0$	$x - 21·22$	„	$+ 188·1 = 0$
$x - 15·41$	„	$+ 96·9 = 0$	$x - 22·15$	„	$+ 202·1 = 0$
$x - 15·71$	„	$+ 102·1 = 0$	$x - 22·48$	„	$+ 209·1 = 0$
$x - 16·52$	„	$+ 116·5 = 0$	$x - 23·12$	„	$+ 217·0 = 0$
$x - 16·85$	„	$+ 120·8 = 0$	$x - 23·73$	„	$+ 227·5 = 0$
$x - 17·14$	„	$+ 123·7 = 0$	$x - 8·32$	„	$- 31·1 = 0$
$x - 17·41$	„	$+ 127·6 = 0$	$x - 8·29$	„	$- 33·0 = 0$
$x - 17·68$	„	$+ 132·8 = 0$	$x - 8·40$	„	$- 29·1 = 0$
$x - 17·97$	„	$+ 137·2 = 0$	$x - 8·50$	„	$- 27·6 = 0$
$x - 18·86$	„	$+ 150·8 = 0$	$x - 8·74$	„	$- 22·8 = 0$
$x - 19·06$	„	$+ 170·2 = 0$	$x - 8·93$	„	$- 19·6 = 0$
$x - 19·27$	„	$+ 157·8 = 0$	$x - 9·12$	„	$- 16·5 = 0$
$x - 19·50$	„	$+ 161·4 = 0$	$x - 9·35$	„	$- 12·1 = 0$
$x - 19·72$	„	$+ 169·2 = 0$	$x - 13·90$	„	$+ 61·5 = 0$
$x - 19·92$	„	$+ 169·8 = 0$	$x - 14·36$	„	$+ 70·7 = 0$
$x - 8·28$	„	$- 35·6 = 0$	$x - 14·83$	„	$+ 79·6 = 0$
$x - 8·18$	„	$- 33·3 = 0$	$x - 15·47$	„	$+ 90·4 = 0$

After the measurement—(Continued.)

$x - 18{\cdot}25\,(E_a - \overset{d}{dE_a}) + 137{\cdot}1 = 0$
$x - 18{\cdot}62$ „ $+ 144{\cdot}2 = 0$
$x - 18{\cdot}95$ „ $+ 147{\cdot}9 = 0$
$x - 19{\cdot}25$ „ $+ 153{\cdot}1 = 0$

$x - 20{\cdot}42\,(E_a - \overset{d}{dE_a}) + 171{\cdot}2 = 0$
$x - 20{\cdot}67$ „ $+ 174{\cdot}7 = 0$
$x - 21{\cdot}10$ „ $+ 180{\cdot}2 = 0$
$x - 21{\cdot}44$ „ $+ 190{\cdot}8 = 0$

And from the mean of these results,

$$x = -\overset{d}{75{\cdot}94} + 14{\cdot}46\,(E_a - dE_a):$$

adopting the original value of the expansion of **A** given at page (9),

$$E_a = \overset{m.y}{22{\cdot}67} = \overset{d}{17{\cdot}732},$$

and $x = \overset{d}{180{\cdot}46} - 14{\cdot}46\,dE_a = \overset{m.y}{230{\cdot}72} - 14{\cdot}46\,dE_a = \mathrm{L} - \mathbf{A}$;

Proceeding as on page IX—26 we obtain:—

In terms of	A – L	B – L	C – L	D – L	E – L	H – L
Micrometer divisions.	–28·48	–44·25	+12·50	+59·52	+1·27	–0·54
Millionths of a yard.	–36·41	–56·57	+15·98	+76·10	+1·62	–0·69

Also the following;

$\mathrm{A} - \mathbf{A} = \overset{d}{151{\cdot}98} - 14{\cdot}46\,dE_a = \overset{m.y}{194{\cdot}31} - 14{\cdot}46\,dE_a$
$\mathrm{B} - \mathbf{A} = 136{\cdot}21 -$ „ $= 174{\cdot}15 -$ „
$\mathrm{C} - \mathbf{A} = 192{\cdot}96 -$ „ $= 246{\cdot}70 -$ „
$\mathrm{D} - \mathbf{A} = 239{\cdot}98 -$ „ $= 306{\cdot}82 -$ „
$\mathrm{E} - \mathbf{A} = 181{\cdot}73 -$ „ $= 232{\cdot}34 -$ „
$\mathrm{H} - \mathbf{A} = 179{\cdot}92 -$ „ $= 230{\cdot}03 -$ „

and $6\,x = \overset{m.y}{1384{\cdot}3} - 86{\cdot}8\,dE_a$.

Final deduction of the total length measured with the compensated bars.

	m.y
From page IX_{27} the excess of the 6 compensated bars above 6 times **A** *before* the measurement	$= 1240{\cdot}3 - 37{\cdot}1\, dE_a$
„ IX_{28} „ „ *after* set No. 287	$= 1252{\cdot}3 - 56{\cdot}9\, dE_a$
„ IX_{30} „ „ *after* the measurement	$= 1384{\cdot}3 - 86{\cdot}8\, dE_a$
Therefore the mean excess „ applicable to sets Nos. 1, & 3 to 287	$= 1246{\cdot}3 - 47{\cdot}0\, dE_a$
and „ „ applicable to sets Nos. 288 to 572	$= 1318{\cdot}3 - 71{\cdot}9\, dE_a$
Also the mean length of a set of 6 compensated bars in feet of the standard, applicable to sets Nos. 1, & 3 to 287	$= 60{\cdot}0037389\, \frac{\mathbf{A}}{10} - 47{\cdot}0\, dE_a$
and „ applicable to sets Nos. 288 to 572	$= 60{\cdot}0039549\, \frac{\mathbf{A}}{10} - 71{\cdot}9\, dE_a$
Similarly from pages IX_{27} and IX_{28} the mean excess of the 3 compensated bars A, C, H above 3 times **A**	m.y $= 600{\cdot}7 - 23{\cdot}5\, dE_a$
and the mean length of a set of compensated bars A, C, H in feet of the standard, applicable to sets Nos. 2_1 and 2_2	$= 30{\cdot}0018021\, \frac{\mathbf{A}}{10} - 23{\cdot}5\, dE_a$
Also from pages IX_{27} and IX_{28} the mean excess of the 4 compensated bars A, B, C, D above 4 times **A**	m.y $= 832{\cdot}1 - 31{\cdot}3\, dE_a$
and the mean length of the set of compensated bars A, B, C, D in feet of the standard applicable to set $*_1$	$= 40{\cdot}0024963\, \frac{\mathbf{A}}{10} - 31{\cdot}3\, dE_a$
Similarly from pages IX_{28} and IX_{30} the mean excess of the 2 compensated bars A, B above twice **A**	m.y $= 349{\cdot}6 - 23{\cdot}9\, dE_a$
and the mean length of the set of compensated bars A, B in feet of the standard, applicable to set $*_2$	$= 20{\cdot}0010488\, \frac{\mathbf{A}}{10} - 23{\cdot}9\, dE_a$
Also from pages IX_{28} and IX_{30} the mean excess of the 5 compensated bars A, B, C, D, H above 5 times **A**	m.y $= 1098{\cdot}5 - 59{\cdot}9\, dE_a$
and the mean length of the set of compensated bars A, B, C, D, H in feet of the standard applicable to set No. 573_1	$= 50{\cdot}0032955\, \frac{\mathbf{A}}{10} - 59{\cdot}9\, dE_a$

Hence the total lengths measured with the compensated bars,

	feet of **A**		feet of **A**
In sets Nos. 1 to $*_1$ or S.W. End to Station A =	$201\,(60{\cdot}0037389 - 47{\cdot}0\, dE_a)$	= . . .	$12060{\cdot}7515 - 9447\, dE_a$
	$2\,(30{\cdot}0018021 - 23{\cdot}5\, dE_a)$	= . . .	$60{\cdot}0036 - 47\, dE_a$
	$1\,(40{\cdot}0024963 - 31{\cdot}3\, dE_a)$	= . . .	$40{\cdot}0025 - 31\, dE_a$
	Sum	= . . .	$12160{\cdot}7576 - 9525\, dE_a$
In sets Nos. $*_1$ to $*_2$ or Stn. A to Stn. to B =	$-\ 1\,(40{\cdot}0024963 - 31{\cdot}3\, dE_a)$	= . . .	$-\ 40{\cdot}0025 + 31\, dE_a$
	$85\,(60{\cdot}0037389 - 47{\cdot}0\, dE_a)$	= . . .	$5100{\cdot}3178 - 3995\, dE_a$
	$74\,(60{\cdot}0039549 - 71{\cdot}9\, dE_a)$	= . . .	$4440{\cdot}2927 - 5321\, dE_a$
	$1\,(20{\cdot}0010488 - 23{\cdot}9\, dE_a)$	= . . .	$20{\cdot}0010 - 24\, dE_a$
	Sum	= . . .	$9520{\cdot}6090 - 9309\, dE_a$
In sets Nos. $*_2$ to 573_1 or Stn. B to N.E. End =	$-\ 1\,(20{\cdot}0010488 - 23{\cdot}9\, dE_a)$	= . . .	$-\ 20{\cdot}0010 + 24\, dE_a$
	$211\,(60{\cdot}0039549 - 71{\cdot}9\, dE_a)$	= . . .	$12660{\cdot}8345 - 15171\, dE_a$
	$1\,(50{\cdot}0032955 - 59{\cdot}9\, dE_a)$	= . . .	$50{\cdot}0033 - 60\, dE_a$
	Sum	= . . .	$12690{\cdot}8368 - 15207\, dE_a$
In sets Nos. 1 to 573_1 or S.W. End to N.E. End		= . . .	$34372{\cdot}2034 - 34041\, dE_a$

Final deduction of the total length measured with the compensated bars—(Continued.)

Now the mean temperature of **A** during the bar comparisons *before* the measurement and *after* set No. 287 was $62° + \frac{47°\cdot 0}{6} = 69°\cdot 8$, for which temperature the corresponding expansion of **A** from page (19) = 21·696 *m.y.* Again the mean temperature of **A** during the bar comparisons *after* set No. 287 and *after* the measurement was $62° + \frac{71°\cdot 9}{6} = 74°\cdot 0$, for which temperature the corresponding expansion of **A** from page (19) = 21·722 *m.y.* Comparing these values of expansion respectively with the original value = 22·67 *m.y,* used in the foregoing; it is found that the values of dE_a = + 0·974 *m.y,* for sets Nos. 1 to 287, and = + 0·948 *m.y,* for sets Nos. 288 to 573. Substituting for dE_a respectively these numerical values, there result,

Total lengths measured with the compensated bars

	feet of	A
in sets Nos. 1 to $*_1$ or S. W. End, to Station A =	(12160·7576 — ·0278)	= 12160·7298
„ $*_1$ to $*_2$ or Station A, to Station B =	(9520·6090 — ·0268)	= 9520·5822
„ $*_2$ to 573_1 or Station B, to N. E. End =	(12690·8368 — ·0432)	= 12690·7936
„ 1 to 573_1 or S. W. End, to N. E. End =	(34372·2034 — ·0978)	= 34372·1056

Comparisons between the Compensated Microscopes and the 6-inch brass scales during the measurement, and provisional determination of Microscope errors with respect to the 6-inch brass scale A, expressed in millionths of an inch (m.i.)

When compared — 1868			Microscope.	Scale compared with.	Corrected temperature.	Reduction to 62° Fah. Expansion of 6″ scale for 1° = E = 62·5 m.i.	Microscope — Microscope Scale. Observed value in terms of Divisions 10000 = 1″.	Microscope — Microscope Scale. Observed value in terms of m.i.	Micros : Scale — A, at 62° Fah.	Micros : — Scale A, at 62° Fah. m.i.	Reference number.
January	10th	Before the measurement.	V	V	78°·4	+1025	— 9·7	— 389	— 133	+ 503	1
			T	T	79·1	1069	8·8	880	18	171	2
			M	M	74·7	794	11·5	1150	+ 122	— 234	3
			N	N	75·0	813	9·3	930	468	+ 351	4
			O	S	77·3	956	2·3	230	4	730	5
			U	U	76·7	919	22·2	2220	392	— 909	6
„	12th	Do.	S	S	77·7	+ 981	— 6·1	— 610	+ 4	+ 375	7
„	19th	After set No. 50.	T	T	78·3	+1019	+ 1·7	+ 170	— 18	+1171	8
„	20th	Do.	V	V	78·3	+1019	— 13·8	— 553	— 133	+ 333	9

Microscope Comparisons—(Continued.)

When compared — 1868		Microscope.	Scale compared with.	Corrected temperature.	Reduction to 62° Fah. Expansion of 6″ scale for 1° = E = 62·5 *m.i.*	Microscope — Microscope Scale. Observed value in terms of: Divisions 10000 = 1″	*m.i.*	Micros : Scale − *A*, at 62° Fah.	Micros : − Scale *A*, at 62° Fah. *m.i.*	Reference number.
January 27th	After set No. 131.	*T*	*T*	76°·4	+ 900	− 1·4	− 140	− 18	+ 742	10
		V	*V*	75·8	863	10·2	409	133	321	11
		M	*M*	73·8	738	10·0	1000	+ 122	− 140	12
		N	*N*	72·4	650	5·2	520	468	+ 598	13
		O	*S*	76·4	900	10·1	1010	4	− 106	14
		U	*U*	79·9	1119	16·4	1640	392	129	15
		S	*S*	72·9	681	+ 3·0	+ 300	4	+ 985	16
„ 28th	After set No. 136.	*N*	*N*	80·0	+1125	− 13·0	−1300	468	+ 293	17
February 4th	After set No. 221.	*T*	*T*	85·4	+1463	− 11·5	−1150	− 18	+ 295	18
		S	*S*	84·3	1394	0·9	90	+ 4	1308	19
		T	*T*	78·4	1025	12·3	1230	− 18	− 223	20
„ 11th	After set No. 287.	*V*	*V*	64·3	+ 144	+ 10·3	+ 413	− 133	+ 424	21
		M	*M*	61·5	− 31	4·5	450	+ 122	541	22
		N	*N*	63·1	+ 69	− 1·4	− 140	468	397	23
		O	*S*	62·9	56	+ 3·3	+ 330	4	390	24
		U	*U*	64·9	181	− 3·4	− 340	392	233	25
„ 14th	Do.	*T*	*T*	84·9	+1431	− 11·7	−1170	− 18	+ 243	26
		S	*S*	80·7	1169	0·9	90	+ 4	1083	27
„ 28th	After set No. 479.	*T*	*T*	91·6	+1850	− 13·1	−1310	− 18	+ 522	28
		V	*V*	89·6	1725	31·4	1259	133	333	29
		M	*M*	88·2	1638	13·5	1350	+ 122	410	30
		O	*S*	88·8	1675	12·9	1290	4	389	31
		N	*N*	87·8	1613	10·3	1030	468	1051	32
		U	*U*	90·0	1750	20·8	2080	392	62	33
		S	*S*	90·5	1781	3·2	320	4	1465	34
„ 29th	Do.	*V*	*V*	89·1	+1694	− 29·0	−1163	− 133	+ 398	35
March 6th	After the measurement.	*T*	*T*	86·4	+1525	− 10·0	−1000	− 18	+ 507	36
		V	*V*	85·6	1475	25·7	1031	133	311	37
		M	*M*	83·8	1363	10·0	1000	+ 122	485	38
		O	*S*	86·3	1519	9·9	990	4	533	39
		N	*N*	84·8	1425	8·9	890	468	1003	40
		U	*U*	87·2	1575	18·6	1860	392	107	41
		S	*S*	85·8	1488	1·9	190	4	1302	42

Microscope Comparisons—(Continued.)

The required combinations of individual microscope errors taken from pages IX_{-32} and IX_{-33} are expressed as follows;

	Reference numbers.	*m.i.*	*mean temp:*		
e_1	$= 2 + 3 + 4 + 5 + 6 + \frac{1+7}{2}$	$= + 548$	at $(62^\circ + 14^\circ 81)$		before the measurement.
e_2	$= 2 + 4 + \frac{1+7}{2}$	$= + 961$	at $(62 + 15·38)$		do.
e_3	$= 8 + 13 + \frac{9+16}{2}$	$= + 2428$	at $(62 + 13·43)$		between sets 50 & 51, and 131 & 132
e_4	$= 8 + 12 + 13 + 14 + 15 + \frac{9+16}{2}$	$= + 2053$	at $(62 + 14·07)$		" do. do.
e_5	$= 3 + 4 + 5 + 6 + 9 + \frac{7+8}{2}$	$= + 1044$	at $(62 + 14·67)$		before the measurement and between sets 50 & 51
e_6	$= 11 + 12 + 13 + 14 + 15 + \frac{10+16}{2}$	$= + 1408$	at $(62 + 13·49)$		between sets 131 & 132
e_7	$= 17 + 21 + 22 + 24 + 25 + \frac{18+19}{2}$	$= + 2683$	at $(62 + 7·74)$		" 136 & 137, 221 & 222, 287 & 288
e_8	$= 11 + 12 + 14 + 15 + 17 + \frac{10+16}{2}$	$= + 1103$	at $(62 + 14·76)$		" 136 & 137, and 131 & 132
e_9	$= 11 + 12 + 14 + 15 + 17 + \frac{19+20}{2}$	$= + 782$	at $(62 + 15·88)$		" do. do. and 221 & 222
e_{10}	$= 11 + 12 + 17 + \frac{10+16}{2}$	$= + 1338$	at $(62 + 14·06)$	From comparisons made	" 131 & 132, and 136 & 137
e_{11}	$= 21 + 22 + 23 + 24 + 25 + \frac{18+19}{2}$	$= + 2787$	at $(62 + 4·93)$		" 221 & 222 and 287 & 288
e_{12}	$= 21 + 22 + 23 + 24 + 25 + \frac{26+27}{2}$	$= + 2648$	at $(62 + 4·58)$		" 287 & 288
e_{13}	$= 21 + 22 + 23 + \frac{18+19}{2}$	$= + 2164$	at $(62 + 6·44)$		" do. and 221 & 222
e_{14}	$= 21 + \frac{26+27}{2}$	$= + 1087$	at $(62 + 11·55)$		" do.
e_{15}	$= 29 + 30 + 31 + 32 + 33 + \frac{28+34}{2}$	$= + 3239$	at $(62 + 27·24)$		" 479 & 480.
e_{16}	$= 29 + \frac{28+34}{2}$	$= + 1327$	at $(62 + 28·33)$		" do.
e_{17}	$= 30 + 31 + 32 + 33 + 35 + \frac{28+34}{2}$	$= + 3304$	at $(62 + 27·16)$		" do.
e_{18}	$= 37 + 38 + 39 + 40 + 41 + \frac{36+42}{2}$	$= + 3344$	at $(62 + 23·63)$		after the measurement.
e_{19}	$= 30 + 31 + 32 + 35 + \frac{28+34}{2}$	$= + 3242$	at $(62 + 26·99)$		between sets 479 & 480.
e_{20}	$= 37 + 38 + 39 + 40 + \frac{36+42}{2}$	$= + 3237$	at $(62 + 23·32)$		after the measurement.

Microscope Comparisons—(Continued.)

And from the foregoing, we obtain the following equations for the microscope errors per set (or *m.e.*); where *dE* expresses the error in the adopted value of the expansion for the 6-inch scales.

$(m.e.)_1 = \frac{e_1 + e_4}{2} = +1301 - 6 \times 14{\cdot}44\, dE$ (m.i.)	applicable to sets Nos.		1 and 3 to 50
$(m.e.)_2 = \frac{e_2 + e_3}{2} = +1695 - 3 \times 14{\cdot}41\, dE$	„	„	2_1 to 2_3
$(m.e.)_3 = \frac{e_5 + e_6}{2} = +1226 - 6 \times 14{\cdot}08\, dE$	„	„	51 to 131
$(m.e.)_4 = \frac{e_6 + e_7}{2} = +2046 - 6 \times 10{\cdot}62\, dE$	„	„	132 to 136
$(m.e.)_5 = \frac{e_8 + e_{11}}{2} = +1945 - 6 \times 9{\cdot}85\, dE$	„	„	137 to 202 and 203 to 221
$(m.e.)_6 = \frac{e_{10} + e_{13}}{2} = +1751 - 4 \times 10{\cdot}25\, dE$	„	set No. $*_1$	
$(m.e.)_7 = \frac{e_9 + e_{12}}{2} = +1715 - 6 \times 10{\cdot}23\, dE$	„	sets Nos. 222 to 287	
$(m.e.)_8 = \frac{e_{12} + e_{15}}{2} = +2944 - 6 \times 15{\cdot}91\, dE$	„	„	288 to 361 and 362 to 479
$(m.e.)_9 = \frac{e_{14} + e_{18}}{2} = +1207 - 2 \times 19{\cdot}94\, dE$	„	set No. $*_2$	
$(m.e.)_{10} = \frac{e_{17} + e_{18}}{2} = +3324 - 6 \times 25{\cdot}40\, dE$	„	sets Nos. 480 to 571	
$(m.e.)_{11} = \frac{e_{19} + e_{20}}{2} = +3240 - 5 \times 25{\cdot}16\, dE$	„	set No. 573_1	

Hence the total microscope errors are as follows :—

		m.i.		feet of A	
In sets Nos. 1 to $*_1$ =	$+49\,(m.e)_1 =$	+ 63749	− 4245 *dE* =	·0053	− 4245 *dE*
	$+2\,(m.e)_2 =$	+ 3390	− 86 *dE* =	·0003	− 86 *dE*
	$+81\,(m.e)_3 =$	+ 99306	− 6843 *dE* =	·0083	− 6843 *dE*
	$+5\,(m.e)_4 =$	+ 10230	− 319 *dE* =	·0009	− 319 *dE*
	$+66\,(m.e)_5 =$	+ 128370	− 3901 *dE* =	·0107	− 3901 *dE*
	$+1\,(m.e)_6 =$	+ 1751	− 41 *dE* =	·0001	− 41 *dE*
			Sum =	·0256	− 15435 *dE*
In sets Nos. $*_1$ to $*_2$	$-1\,(m.e)_6 =$	− 1751	+ 41 *dE* =	− ·0001	+ 41 *dE*
	$+19\,(m.e)_5 =$	+ 36955	− 1123 *dE* =	+ ·0031	− 1123 *dE*
	$+66\,(m.e)_7 =$	+ 113190	− 4051 *dE* =	+ ·0094	− 4051 *dE*
	$+74\,(m.e)_8 =$	+ 217856	− 7064 *dE* =	+ ·0182	− 7064 *dE*
	$+1\,(m.e)_9 =$	+ 1207	− 40 *dE* =	+ ·0001	− 40 *dE*
			Sum =	+ ·0307	− 12237 *dE*
In sets Nos. $*_2$ to $*573_1$	$-1\,(m.e)_9 =$	− 1207	+ 40 *dE* =	− ·0001	+ 40 *dE*
	$+118\,(m.e)_8 =$	+ 347392	− 11264 *dE* =	+ ·0289	− 11264 *dE*
	$+93\,(m.e)_{10} =$	+ 309132	− 14173 *dE* =	+ ·0258	− 14173 *dE*
	$+1\,(m.e)_{11} =$	+ 3240	− 126 *dE* =	+ ·0003	− 126 *dE*
			Sum =	+ ·0549	− 25523 *dE*

Final deduction of the total lengths measured with the compensated microscopes.

Hitherto the microscope errors have been determined only provisionally: *i.e.* in terms of the 6-inch brass scale *A*. But from page (31), we have 2 *A* = 1·0000192 $\frac{A}{10}$, value in 1835. Also, the co-efficient of expansion for brass, has been taken at ·000,010,417 in the foregoing reductions, whereas it appears from page (17) that ·000,009,855 is a more probable value. Accepting the latter, it may be found that $dE = 3·372$ *m.i.* Hence, remembering that the length measured with a set of microscopes is equal to 3 feet of *A* + the corresponding *(m.e)*, we have,

Total length measured with the compensated microscopes

	feet of *A*			feet of A
In sets Nos. 1 to $*_1$ or S.W. End to Stn. A . . . . . =	{ 202 × 3 + 1 × 2	+ ·0256 }	− 15435 dE	= (608·0373 − ·0043) = 608·0330
In sets Nos. $*_1$ to $*_2$ or Stn. A to Stn. B . . . . . =	{ − 1 × 2 + 159 × 3 + 1 × 1	+ ·0307 }	− 12237 dE	= (476·0398 − ·0034) = 476·0364
In sets Nos. $*_2$ to 573_1 or Stn. B to N.E. End . . . . . =	{ − 1 × 1 + 211 × 3 + 1 × 2·5	+ ·0549 }	− 25523 dE	= (634·5671 − ·0072) = 634·5599
In sets Nos. 1 to 573_1 or S.W. End to N.E. End				= (1718·6442 − ·0149) = 1718·6293

DETAILS OF THE MEASUREMENT.

Disposition of the bars and microscopes during the measurement.

The following typical illustrations shew the permutations and combinations of the bars and microscopes during the measurement. The instruments are here named in the succession that actually occurred, commencing from the rear-end of a set, and the numbers assigned to the illustrations, will be found employed in the tables of "Extracts from the Field Book &c."

Bar Illustration.

No. 1	No. 2	No. 3	No. 4	No. 5
A	A	A	A	A
B	C	B	B	B
C	H	C		C
D		D		D
E				H
H				

Statement.

No. 1 occurs in sets Nos. 1,3 to 202,203 to 361 and 362 to 572.
No. 2 „ Nos. 2_1 and 2_2.
No. 3 „ No. $*_1$.
No. 4 „ No. $*_2$.
No. 5 „ No. 573_1.

Microscope Illustration.

No. 1	No. 2	No. 3	No. 4	No. 5	No. 6	No. 7
½V	½V	½T	½T	½T	½T	½T
T	T	V	V	V	V	V
M	N	M	M	½S	M	M
N	½S	N	N		O	O
O		O	½S		N	N
U		U			U	½S
½S		½S			½S	

Statement.

No. 1 occurs in sets Nos. 1 and 3 to 50.
No. 2 „ Nos. 2_1 and 2_2.
No. 3 „ Nos. 51 to 202, 203 to 361 and 362 to 479.
No. 4 „ set No. $*_1$.
No. 5 „ No. $*_2$.
No. 6 „ sets Nos. 480 to 572.
No. 7 „ set No. 573_1.

Extracts from the Field Book of the measurement, and calculated heights of sets above the origin.

Adopted heights above mean sea level.
South-West-End (origin) = 3118·3 feet.
North-East-End (terminus) = 3009·3 feet.

1868	No. of the Set	Temperature of Air	Mean time of ending	No. of bars used	Height of Set above origin	Numeral shewing arrangement of Bars	Numeral shewing arrangement of Micros:	1868	No. of the Set	Temperature of Air	Mean time of ending	No. of bars used	Height of Set above origin	Numeral shewing arrangement of Bars	Numeral shewing arrangement of Micros:
		°	h. m.		feet					°	h. m.		feet		
13th Jan.	1	64·0	8 40 A.M.	6	+ 1·63	1	1	14th Jan.	8	80·4	2 5 P.M.	6	− 15·86	1	1
	2_1	70·5	10 5	3	− 0·51	2	2		9	80·0	3 25	6	17·84	1	1
	2_2	77·5	0 25 P.M.	3	2·31	2	2	15th „	10	60·0	7 45 A.M.	6	19·79	1	1
	3	79·0	2 30	6	4·56	1	1		11	69·0	8 55	6	21·79	1	1
	4	80·0	3 35	6	7·35	1	1		12	73·8	10 15	6	24·04	1	1
14th „	5	64·0	8 25 A.M.	6	9·93	1	1		13	81·0	0 45 P.M.	6	26·06	1	1
	6	68·5	9 30	6	11·79	1	1		14	83·0	1 40	6	28·08	1	1
	7	78·0	0 30 P.M.	6	13·66	1	1		15	84·0	2 25	6	30·06	1	1

NOTE.—The rear-end of set No. 1 stood exactly over the dot at South-West-End.

Extracts from the Field Book—(Continued.)

1868	No. of the Set	Temperature of Air	Mean time of ending	No. of bars used	Height of Set above origin	Numeral shewing arrangement of Bars.	Numeral shewing arrangement of Micros:	1868	No. of the Set	Temperature of Air	Mean time of ending	No. of bars used	Height of Set above origin	Numeral shewing arrangement of Bars.	Numeral shewing arrangement of Micros:
		°	h. m.		feet.					°	h. m.		feet		
15th Jan.	16	82·0	3 30 P.M.	6 —	32·12	1	1	21st Jan.	66	71·4	9 7 A.M.	6 —	107·45	1	3
	17	62·0	8 5 A.M.	6	34·27	1	1		67	77·0	10 50	6	109·58	1	3
	18	71·0	9 25	6	35·62	1	1		68	79·2	11 25	6	111·70	1	3
	19	83·0	11 45	6	37·43	1	1		69	83·0	0 0 P.M.	6	113·39	1	3
	20	84·5	0 25 P.M.	6	39·35	1	1		70	85·2	0 32	6	115·27	1	3
	21	86·0	1 5	6	41·30	1	1		71	80·7	1 3	6	116·69	1	3
	22	86·5	1 45	6	42·65	1	1		72	81·0	1 38	6	117·63	1	3
	23	87·0	2 20	6	44·36	1	1		73	81·0	2 20	6	117·72	1	3
	24	87·3	3 0	6	46·32	1	1		74	81·4	2 55	6	116·29	1	3
	25	86·0	3 45	6	47·61	1	1		75	82·0	3 25	6	114·97	1	3
17th „	26	62·5	7 20 A.M.	6	48·71	1	1		76	80·0	4 15	6	113·09	1	3
	27	64·0	8 0	6	49·92	1	1	22nd „	77	62·2	7 10 A.M.	6	111·50	1	3
	28	67·5	8 33	6	50·52	1	1		78	65·6	8 0	6	108·93	1	3
	29	71·2	9 10	6	51·89	1	1		79	68·4	8 33	6	107·04	1	3
	30	74·0	9 40	6	52·86	1	1		80	72·5	9 10	6	104·94	1	3
	31	81·8	11 25	6	53·33	1	1		81	76·0	9 45	6	103·16	1	3
	32	80·0	0 0 P.M.	6	54·06	1	1		82	78·5	11 30	6	102·04	1	3
	33	82·9	0 30	6	55·54	1	1		83	83·7	0 2 P.M.	6	100·38	1	3
	34	85·3	1 10	6	56·82	1	1		84	85·4	0 37	6	98·71	1	3
	35	86·0	1 40	6	58·11	1	1		85	85·5	1 0	6	98·06	1	3
	36	87·2	2 25	6	58·77	1	1		86	85·2	1 53	6	98·09	1	3
	37	87·0	3 0	6	60·26	1	1		87	85·2	2 25	6	97·36	1	3
	38	85·0	3 45	6	61·94	1	1		88	86·0	2 58	6	98·49	1	3
18th „	39	61·2	7 15 A.M.	6	63·13	1	1		89	83·0	3 40	6	99·13	1	3
	40	66·0	8 10	6	64·77	1	1	23rd „	90	66·3	7 7 A.M.	6	99·78	1	3
	41	70·8	8 50	6	66·51	1	1		91	68·0	7 40	6	101·00	1	3
	42	74·8	9 30	6	67·94	1	1		92	68·9	8 5	6	101·15	1	3
	43	83·4	11 30	6	68·81	1	1		93	71·2	8 33	6	101·85	1	3
	44	84·2	0 15 P.M.	6	70·83	1	1		94	77·0	9 6	6	102·91	1	3
	45	85·2	0 50	6	72·31	1	1		95	78·5	9 40	6	104·07	1	3
	46	86·8	1 30	6	74·06	1	1		96	85·6	11 27	6	105·83	1	3
	47	84·5	2 0	6	75·64	1	1		97	87·0	11 57	6	107·83	1	3
	48	84·0	2 30	6	76·66	1	1		98	85·6	0 28 P.M.	6	109·07	1	3
	49	84·7	3 15	6	77·86	1	1		99	87·0	0 50	6	111·03	1	3
	50	84·0	4 0	6	78·55	1	1		100	86·4	1 13	6	112·82	1	3
20th „	51	62·2	7 20 A.M.	6	80·40	1	3		101	86·0	1 37	6	114·56	1	3
	52	68·6	8 6	6	81·63	1	3		102	84·0	2 3	6	116·18	1	3
	53	72·0	8 40	6	82·23	1	3		103	83·6	2 32	6	118·84	1	3
	54	76·0	9 20	6	83·65	1	3		104	81·0	2 55	6	121·08	1	3
	55	78·0	10 0	6	85·91	1	3		105	79·8	3 32	6	122·78	1	3
	56	84·7	11 50	6	87·50	1	3	24th „	106	68·2	7 45 A.M.	6	124·78	1	3
	57	84·7	0 25 P.M.	6	88·48	1	3		107	69·8	8 17	6	127·14	1	3
	58	84·0	1 0	6	91·52	1	3		108	72·0	8 50	6	129·02	1	3
	59	83·4	1 35	6	93·11	1	3		109	75·1	9 25	6	131·05	1	3
	60	84·2	2 10	6	94·73	1	3		110	80·5	11 12	6	133·00	1	3
	61	84·4	2 45	6	97·04	1	3		111	80·9	11 46	6	135·54	1	3
	62	82·5	3 30	6	98·71	1	3		112	84·4	0 25 P.M.	6	137·54	1	3
21st „	63	60·3	7 15 A.M.	6	100·56	1	3		113	82·6	0 58	6	139·31	1	3
	64	62·5	8 0	6	102·76	1	3		114	81·3	1 38	6	141·47	1	3
	65	66·5	8 30		105·51	1	3		115	80·5	2 5	6	143·69	1	3

January 22nd Cloudy during the day. January 23rd and 24th Sky spread over with clouds throughout the day.

Extracts from the Field Book—(Continued.)

1868	No. of the Set	Temperature of Air	Mean time of ending	No. of bars used	Height of Set above origin	Numeral shewing arrangement of Bars.	Numeral shewing arrangement of Micros:
		°	h. m.		feet.		
24th Jan.	116	79·8	2 43 P.M.	6	−145·58	1	3
	117	79·6	3 10	6	147·93	1	3
	118	78·8	3 45	6	149·71	1	3
25th „	119	67·5	7 50 A.M.	6	152·25	1	3
	120	68·4	8 20	6	154·81	1	3
	121	71·6	8 50	6	156·45	1	3
	122	74·0	9 26	6	158·15	1	3
	123	76·5	11 20	6	160·05	1	3
	124	75·0	11 55	6	162·31	1	3
	125	74·4	0 22 P.M.	6	164·24	1	3
	126	74·5	0 55	6	165·82	1	3
	127	73·5	1 25	6	167·77	1	3
	128	72·1	1 57	6	167·66	1	3
	129	71·7	2 30	6	169·21	1	3
	130	72·4	3 5	6	171·31	1	3
	131	70·4	3 51	6	172·06	1	3
27th „	132	77·0	1 30 P.M.	6	172·38	1	3
	133	77·0	2 0	6	173·31	1	3
	134	78·2	2 40	6	173·62	1	3
	135	79·7	3 10	6	174·32	1	3
	136	80·8	4 10	6	173·80	1	3
28th „	137	66·9	7 15 A.M.	6	173·52	1	3
	138	69·4	7 45	6	174·02	1	3
	139	70·8	8 25	6	175·02	1	3
	140	73·5	8 55	6	175·21	1	3
	141	76·9	9 30	6	174·29	1	3
	142	83·5	11 35	6	175·47	1	3
	143	85·9	0 10 P.M.	6	175·12	1	3
	144	85·9	0 40	6	175·46	1	3
	145	89·0	1 20	6	175·89	1	3
	146	87·5	1 50	6	175·57	1	3
	147	87·0	2 10	6	175·98	1	3
	148	87·3	2 45	6	175·00	1	3
	149	84·7	3 30	6	175·80	1	3
29th „	150	65·5	7 15 A.M.	6	176·43	1	3
	151	68·4	7 45	6	176·10	1	3
	152	71·3	8 15	6	176·67	1	3
	153	73·4	8 45	6	176·92	1	3
	154	75·5	9 25	6	177·37	1	3
	155	83·3	11 15	6	178·02	1	3
	156	84·0	11 50	6	179·11	1	3
	157	83·8	0 20 P.M.	6	178·54	1	3
	158	85·0	0 45	6	178·95	1	3
	159	86·2	1 15	6	179·04	1	3
	160	86·5	1 50	6	179·52	1	3
29th Jan.	161	86·3	2 20 P.M.	6	−178·84	1	3
	162	84·4	3 13	6	178·99	1	3
	163	83·8	3 45	6	178·30	1	3
30th „	164	65·3	7 15 A.M.	6	177·02	1	3
	165	66·3	7 45	6	176·10	1	3
	166	72·0	8 45	6	174·66	1	3
	167	75·0	9 15	6	172·38	1	3
	168	77·4	9 55	6	170·99	1	3
	169	85·0	11 40	6	169·31	1	3
	170	84·8	0 13 P.M.	6	167·29	1	3
	171	86·3	0 43	6	165·49	1	3
	172	87·9	1 14	6	164·05	1	3
	173	87·5	1 44	6	161·81	1	3
	174	87·0	2 9	6	159·69	1	3
	175	87·0	2 37	6	158·74	1	3
	176	85·8	3 10	6	157·29	1	3
31st „	177	65·9	7 5 A.M.	6	155·96	1	3
	178	67·8	7 38	6	154·72	1	3
	179	69·7	8 6	6	152·70	1	3
	180	72·0	8 31	6	151·81	1	3
	181	75·1	8 57	6	150·32	1	3
	182	78·1	9 30	6	149·63	1	3
	183	84·9	11 18	6	148·43	1	3
	184	87·5	11 48	6	147·47	1	3
	185	84·0	0 18 P.M.	6	146·54	1	3
	186	85·3	0 46	6	144·98	1	3
	187	88·5	1 16	6	144·02	1	3
	188	88·5	1 40	6	143·40	1	3
	189	89·8	2 8	6	142·41	1	3
	190	85·3	2 37	6	142·10	1	3
	191	85·8	3 15	6	141·48	1	3
1st Feb.	192	65·3	6 58 A.M.	6	140·27	1	3
	193	67·3	7 24	6	140·35	1	3
	194	69·7	8 2	6	139·24	1	3
	195	72·6	8 29	6	138·82	1	3
	196	75·7	8 50	6	138·14	1	3
	197	77·8	9 15	6	139·05	1	3
	198	83·6	11 18	6	138·57	1	3
	199	85·7	11 48	6	138·32	1	3
	200	87·6	0 32 P.M.	6	138·65	1	3
3rd „	201	67·6	7 5 A.M.	6	139·24	1	3
	202	70·2	7 42	6	139·27	1	3
	$*_1$	72·2	9 0	4	140·48	3	4
				Total	−23515·18		

The advanced-end of set No. $*_1$ fell in excess (*i. e.* North-East) of the dot defining Station A 4·8132 feet, as measured on Cary's brass scale with a beam compass.

Height of set No. $*_1$ above Station A = 2·92 feet.

The terminal point of set No. 202 was the point of origin for set No. 203.

January 25th (124) Cloudy throughout the day; light showers in the afternoon.

„ 27th (132) Rain in the forenoon.

Extracts from the Field Book—(Continued.)

1868	No. of the Set	Temperature of Air	Mean time of ending	No. of bars used	Height of Set above origin	Numeral shewing arrangement of Bars	Numeral shewing arrangement of Micros:	1868	No. of the Set	Temperature of Air	Mean time of ending	No. of bars used	Height of Set above origin	Numeral shewing arrangement of Bars.	Numeral shewing arrangement of Micros:
		°	h. m.		feet.					°	h. m.		feet.		
3rd Feb.	203	71·4	8 12 A.M.	6	−140·47	1	3	7th Feb.	253	73·6	8 52 A.M.	6	−213·97	1	3
	204	86·8	11 40	6	140·69	1	3		254	77·4	9 21	6	214·97	1	3
	205	89·5	0 34 P.M.	6	142·00	1	3		255	81·4	11 23	6	215·25	1	3
	206	85·2	1 14	6	142·43	1	3		256	84·3	11 55	6	215·71	1	3
	207	88·0	1 53	6	144·01	1	3		257	86·8	0 27 P.M.	6	216·37	1	3
	208	88·5	2 23	6	145·12	1	3		258	89·1	1 51	6	216·38	1	3
	209	88·8	2 45	6	145·97	1	3		259	89·5	2 36	6	216·40	1	3
	210	87·8	3 30	6	147·62	1	3		260	85·2	3 17	6	217·19	1	3
4th "	211	65·3	6 55 A.M.	6	149·03	1	3	8th "	261	65·7	6 53 A.M.	6	217·43	1	3
	212	67·8	7 27	6	149·88	1	3		262	66·5	7 38	6	218·81	1	3
	213	69·7	7 59	6	152·13	1	3		263	68·1	8 8	6	219·07	1	3
	214	72·0	8 31	6	153·87	1	3		264	73·5	8 47	6	218·92	1	3
	215	75·7	9 15	6	155·90	1	3		265	76·5	9 20	6	218·51	1	3
	216	83·4	11 22	6	157·63	1	3		266	84·0	11 12	6	218·85	1	3
	217	83·9	11 55	6	159·67	1	3		267	85·1	0 1 P.M.	6	217·91	1	3
	218	85·3	0 18 P.M.	6	161·63	1	3		268	84·8	0 37	6	217·62	1	3
	219	86·5	0 47	6	163·45	1	3		269	86·3	1 12	6	217·84	1	3
	220	86·5	2 57	6	165·40	1	3		270	86·3	1 45	6	218·05	1	3
	221	87·5	3 43	6	167·76	1	3		271	87·0	2 18	6	218·54	1	3
5th "	222	66·5	6 58 A.M.	6	169·34	1	3		272	84·5	3 0	6	220·10	1	3
	223	70·0	7 42	6	171·71	1	3		273	84·2	3 43	6	220·53	1	3
	224	72·4	8 15	6	173·74	1	3	10th "	274	53·9	7 1 A.M.	6	220·97	1	3
	225	75·7	8 47	6	175·71	1	3		275	58·5	7 42	6	221·20	1	3
	226	77·8	9 15	6	177·89	1	3		276	63·9	8 17	6	221·56	1	3
	227	85·0	11 26	6	180·24	1	3		277	69·5	8 48	6	221·18	1	3
	228	87·4	11 55	6	182·09	1	3		278	73·0	9 16	6	222·04	1	3
	229	88·1	0 15 P.M.	6	184·52	1	3		279	81·3	11 14	6	222·20	1	3
	230	88·9	0 47	6	186·75	1	3		280	81·2	11 45	6	221·81	1	3
	231	89·1	1 22	6	187·68	1	3		281	82·9	0 17 P.M.	6	221·17	1	3
	232	89·8	1 50	6	189·60	1	3		282	84·3	0 51	6	221·11	1	3
	233	88·2	2 24	6	191·55	1	3		283	83·9	1 20	6	221·44	1	3
	234	87·6	2 56	6	193·29	1	3		284	84·8	1 54	6	221·43	1	3
	235	88·7	3 31	6	194·79	1	3		285	86·0	2 25	6	221·32	1	3
6th "	236	68·4	7 29 A.M.	6	196·62	1	3		286	86·4	2 57	6	221·21	1	3
	237	70·1	8 0	6	198·04	1	3		287	85·9	3 43	6	221·52	1	3
	238	72·3	8 30	6	198·95	1	3	15th "	288	62·7	7 28 A.M.	6	222·07	1	3
	239	75·3	8 55	6	200·38	1	3		289	65·9	8 6	6	222·82	1	3
	240	79·1	9 27	6	201·30	1	3		290	72·2	8 36	6	223·52	1	3
	241	86·4	11 25	6	202·09	1	3		291	74·7	9 11	6	223·75	1	3
	242	87·1	11 58	6	203·65	1	3		292	77·8	9 50	6	222·87	1	3
	243	83·0	0 36 P.M.	6	205·57	1	3		293	86·9	11 41	6	221·67	1	3
	244	84·9	1 7	6	207·28	1	3		294	88·1	0 15 P.M.	6	221·70	1	3
	245	86·7	1 42	6	208·69	1	3		295	88·9	0 48	6	221·13	1	3
	246	88·7	2 15	6	208·70	1	3		296	89·5	1 19	6	221·44	1	3
	247	86·5	2 43	6	209·66	1	3		297	89·5	1 46	6	221·14	1	3
	248	85·1	3 22	6	211·82	1	3		298	88·4	2 15	6	221·37	1	3
7th "	249	66·4	6 48 A.M.	6	211·49	1	3		299	88·8	2 46	6	220·87	1	3
	250	67·5	7 22	6	212·13	1	3		300	88·0	3 20	6	221·12	1	3
	251	69·0	7 53	6	212·17	1	3	17th "	301	57·0	7 15 A.M.	6	220·77	1	3
	252	71·7	8 24	6	212·91	1	3		302	61·0	7 46	6	220·95	1	3

Extracts from the Field Book—(Continued.)

1868	No. of the Set.	Temperature of Air	Mean time of ending	No. of bars used	Height of Set above origin	Numeral shewing arrangement of Bars.	Numeral shewing arrangement of Micros:
		°	h. m.		feet.		
17th Feb.	303	66·2	8 20 A.M.	6	—220·39	1	3
	304	71·0	8 51	6	220·42	1	3
	305	74·3	9 22	6	220·43	1	3
	306	83·6	11 9	6	220·71	1	3
	307	85·4	11 37	6	220·07	1	3
	308	86·4	0 10 P.M.	6	219·85	1	3
	309	87·3	0 41	6	220·26	1	3
	310	87·8	1 13	6	220·22	1	3
	311	87·9	1 40	6	220·42	1	3
	312	87·9	2 13	6	219·87	1	3
	313	86·7	2 44	6	219·97	1	3
	314	87·0	3 29	6	218·81	1	3
18th „	315	57·5	7 13 A.M.	6	217·29	1	3
	316	60·4	7 45	6	216·78	1	3
	317	64·4	8 13	6	215·80	1	3
	318	71·5	8 50	6	215·82	1	3
	319	77·3	9 24	6	214·40	1	3
	320	87·3	11 26	6	213·58	1	3
	321	89·0	11 56	6	212·00	1	3
	322	91·2	0 25 P.M.	6	210·30	1	3
	323	91·7	1 3	6	208·05	1	3
	324	92·5	1 37	6	206·18	1	3
	325	91·5	2 13	6	204·30	1	3
	326	91·7	2 41	6	203·38	1	3
	327	91·0	3 11	6	202·39	1	3
	328	89·8	3 46	6	200·05	1	3
19th „	329	58·0	7 0 A.M.	6	198·58	1	3
	330	59·4	7 32	6	196·91	1	3
	331	62·9	8 0	6	195·01	1	3
	332	68·3	8 30	6	193·68	1	3
	333	75·0	9 0	6	191·78	1	3

1868	No. of the Set.	Temperature of Air	Mean time of ending	No. of bars used	Height of Set above origin	Numeral shewing arrangement of Bars	Numeral shewing arrangement of Micros:
		°	h. m.		feet.		
19th Feb.	334	79·0	9 26 A.M.	6	—189·90	1	3
	335	89·0	11 26	6	188·21	1	3
	336	90·1	11 53	6	186·69	1	3
	337	91·0	0 13 P.M.	6	185·21	1	3
	338	92·8	0 45	6	183·50	1	3
	339	93·0	1 12	6	181·71	1	3
	340	93·4	1 35	6	179·88	1	3
	341	93·0	1 59	6	178·89	1	3
	342	92·9	2 25	6	177·28	1	3
	343	93·0	2 54	6	175·73	1	3
	344	92·5	3 21	6	174·28	1	3
	345	91·4	3 45	6	173·01	1	3
20th „	346	59·1	6 58 A.M.	6	171·36	1	3
	347	61·9	7 17	6	170·23	1	3
	348	63·5	7 40	6	169·29	1	3
	349	66·7	8 0	6	167·97	1	3
	350	70·4	8 20	6	167·00	1	3
	351	74·5	8 40	6	165·92	1	3
	352	78·5	9 2	6	165·46	1	3
	353	82·0	9 26	6	163·83	1	3
	354	91·8	11 22	6	162·91	1	3
	355	91·5	11 47	6	162·53	1	3
	356	92·0	0 11 P.M.	6	161·99	1	3
	357	91·8	0 34	6	161·77	1	3
	358	93·4	0 53	6	161·08	1	3
	359	93·5	1 13	6	161·04	1	3
	360	93·2	1 33	6	160·34	1	3
	361	95·4	1 55	6	160·16	1	3
	*$_2$	94·5	2 55	2	159·74	4	5
				Total —	31465·39		

The advanced-end of set No. *$_2$ fell in defect (*i.e.* South-West) of the dot defining Station B 6·3153 feet, as measured on Cary's brass scale with a beam compass.

Height of set No. *$_2$ above Station B = 2·43 feet

The terminal point of set No. 361 was the point of origin for set No. 362.

1868	No. of the Set.	Temperature of Air	Mean time of ending	No. of bars used	Height of Set above origin	Bars	Micros
20th Feb.	362	94·8	2 25 P.M.	6	—159·74	1	3
	363	93·1	3 32	6	159·36	1	3
21st „	364	61·5	6 49 A.M.	6	159·18	1	3
	365	63·9	7 21	6	159·42	1	3
	366	67·7	7 51	6	158·41	1	3
	367	72·8	8 25	6	158·33	1	3
	368	77·0	8 52	6	157·83	1	3
	369	80·5	9 19	6	157·45	1	3
	370	91·7	11 16	6	157·87	1	3
	371	92·5	11 42	6	158·10	1	3
	372	93·6	0 7 P.M.	6	158·15	1	3
	373	94·7	0 34	6	157·89	1	3
	374	94·9	1 0	6	157·78	1	3
	375	95·8	1 26	6	157·89	1	3

1868	No. of the Set.	Temperature of Air	Mean time of ending	No. of bars used	Height of Set above origin	Bars	Micros
21st Feb.	376	96·0	1 54 P.M.	6	—157·84	1	3
	377	95·3	2 22	6	157·64	1	3
	378	94·9	2 48	6	157·04	1	3
	379	94·7	3 13	6	156·72	1	3
	380	93·9	3 39	6	156·72	1	3
22nd „	381	63·0	7 5 A.M.	6	156·83	1	3
	382	65·3	7 33	6	156·20	1	2
	383	69·6	7 59	6	156·57	1	3
	384	73·8	8 32	6	156·09	1	3
	385	78·5	9 4	6	156·24	1	3
	386	82·6	9 34	6	155·98	1	3
	387	91·0	11 26	6	154·94	1	3
	388	91·3	11 56	6	154·63	1	3
	389	92·9	0 30 P.M.	6	154·02	1	3

Extracts from the Field Book—(Continued.)

1868	No. of the Set	Temperature of Air	Mean time of ending	No. of bars used	Height of Set above origin	Numeral shewing arrangement of Bars.	Numeral shewing arrangement of Micros:
		°	h. m.		feet.		
22nd Feb.	390	92·7	0 56 P.M.	6—	153·52	1	3
	391	93·4	1 28	6	152·88	1	3
	392	93·1	1 56	6	152·30	1	3
	393	92·9	2 21	6	151·77	1	3
	394	92·8	2 45	6	151·29	1	3
	395	92·9	3 17	6	150·32	1	3
24th „	396	63·9	7 0 A.M.	6	149·77	1	3
	397	65·3	7 33	6	149·81	1	3
	398	67·8	8 0	6	149·43	1	3
	399	70·6	8 32	6	148·49	1	3
	400	75·0	9 4	6	147·70	1	3
	401	78·4	9 34	6	147·18	1	3
	402	90·6	11 22	6	147·49	1	3
	403	92·8	11 58	6	148·28	1	3
	404	92·2	0 24 P.M.	6	147·99	1	3
	405	93·2	0 53	6	148·15	1	3
	406	92·2	1 18	6	148·88	1	3
	407	92·8	1 49	6	149·73	1	3
	408	94·7	2 18	6	150·89	1	3
	409	94·5	2 46	6	151·88	1	3
	410	94·2	3 14	6	151·89	1	3
25th „	411	65·4	7 12 A.M.	6	153·24	1	3
	412	67·3	7 37	6	154·84	1	3
	413	70·0	7 58	6	156·49	1	3
	414	71·6	8 18	6	155·86	1	3
	415	74·0	8 45	6	155·33	1	3
	416	76·7	9 19	6	157·58	1	3
	417	79·7	9 48	6	159·80	1	3
	418	88·8	11 19	6	160·60	1	3
	419	91·6	11 41	6	161·34	1	3
	420	91·7	0 3 P.M.	6	161·75	1	3
	421	93·0	0 32	6	162·67	1	3
	422	94·3	0 50	6	162·83	1	3
	423	95·2	1 17	6	161·87	1	3
	424	97·2	1 40	6	161·11	1	3
	425	97·0	2 3	6	160·26	1	3
	426	96·8	2 26	6	159·98	1	3
	427	96·8	2 46	6	159·56	1	3
	428	96·5	3 13	6	159·01	1	3
	429	96·5	3 41	6	158·35	1	3
26th „	430	72·5	8 14 A.M.	6	157·93	1	3
	431	75·8	8 38	6	157·43	1	3
	432	79·6	8 59	6	157·02	1	3
	433	83·2	9 22	6	156·10	1	3
	434	85·6	9 50	6	155·80	1	3
	435	91·6	11 25	6	155·88	1	3
	436	92·9	11 48	6	155·26	1	3
	437	94·8	0 8 P.M.	6	154·62	1	3
	438	95·1	0 29	6	153·79	1	3
	439	95·9	0 50	6	153·09	1	3

1868	No. of the Set	Temperature of Air	Mean time of ending	No. of bars used	Height of Set above origin	Numeral shewing arrangement of Bars.	Numeral shewing arrangement of Micros:
		°	h. m.		feet.		
26th Feb.	440	95·5	1 10 P.M.	6—	152·67	1	3
	441	96·1	1 34	6	152·07	1	3
	442	96·0	1 55	6	152·04	1	3
	443	96·0	2 19	6	151·57	1	3
	444	95·4	2 43	6	1[illegible]0·37	1	3
	445	94·8	3 8	6	150·56	1	3
	446	95·0	3 32	6	149·73	1	3
27th „	447	66·1	7 11 A.M.	6	149·48	1	3
	448	69·2	7 36	6	148·40	1	3
	449	70·5	7 58	6	148·44	1	3
	450	73·5	8 22	6	147·63	1	3
	451	77·0	8 48	6	147·36	1	3
	452	79·8	9 9	6	146·48	1	3
	453	82·8	9 33	6	146·30	1	3
	454	89·6	11 14	6	145·87	1	3
	455	91·0	11 33	6	145·14	1	3
	456	93·0	11 52	6	144·72	1	3
	457	93·8	0 10 P.M.	6	143·86	1	3
	458	95·0	0 31	6	143·63	1	3
	459	94·8	0 53	6	143·36	1	3
	460	95·0	1 15	6	142·53	1	3
	461	96·0	1 35	6	142·41	1	3
	462	96·0	1 57	6	142·00	1	3
	463	95·6	2 19	6	142·24	1	3
	464	96·1	2 43	6	141·62	1	3
	465	96·0	3 4	6	141·44	1	3
	466	94·1	3 36	6	141·71	1	3
28th „	467	67·1	7 18 A.M.	6	141·28	1	3
	468	69·5	7 40	6	141·84	1	3
	469	71·6	8 4	6	142·00	1	3
	470	74·2	8 27	6	142·77	1	3
	471	77·1	8 46	6	143·60	1	3
	472	79·8	9 4	6	144·22	1	3
	473	82·0	9 25	6	145·08	1	3
	474	83·6	9 47	6	145·99	1	3
	475	89·0	11 40	6	147·23	1	3
	476	90·5	0 4 P.M.	6	148·97	1	3
	477	90·5	0 27	6	150·02	1	3
	478	90·8	0 53	6	150·70	1	3
	479	92·0	1 23	6	152·20	1	3
2nd Mar.	480	63·5	7 18 A.M.	6	153·28	1	6
	481	67·3	7 43	6	154·69	1	6
	482	70·6	8 14	6	156·27	1	6
	483	74·8	8 43	6	158·52	1	6
	484	79·5	9 12	6	160·31	1	6
	485	83·6	9 42	6	161·90	1	6
	486	92·6	11 21	6	163·23	1	6
	487	92·0	11 47	6	164·35	1	6
	488	93·0	0 23 P.M.	6	166·82	1	6
	489	94·6	0 52	6	169·46	1	6

February 28th. (479) A strong breeze from the E. which stopped further work for the day.

Extracts from the Field Book—(Continued.)

1868	No. of the Set	Temperature of Air	Mean time of ending	No. of bars used	Height of Set above origin	Numeral shewing arrangement of — Bars.	Numeral shewing arrangement of — Micros:
		°	h. m.		feet.		
2nd Mar.	490	95·8	1 16 P.M.	6	−171·70	1	6
	491	95·3	1 41	6	173·56	1	6
	492	96·3	2 6	6	175·42	1	6
	493	96·1	2 26	6	177·21	1	6
	494	95·8	2 44	6	179·73	1	6
	495	97·0	3 4	6	180·19	1	6
	496	97·3	3 28	6	181·55	1	6
	497	96·0	3 55	6	182·51	1	6
3rd „	498	62·0	6 50 A.M.	6	182·72	1	6
	499	62·6	7 11	6	182·55	1	6
	500	64·5	7 31	6	182·40	1	6
	501	67·0	8 0	6	182·09	1	6
	502	68·8	8 22	6	180·40	1	6
	503	71·5	8 51	6	177·63	1	6
	504	74·8	9 10	6	175·90	1	6
	505	76·8	9 33	6	174·04	1	6
	506	86·8	11 9	6	171·70	1	6
	507	89·4	11 36	6	169·03	1	6
	508	91·4	11 57	6	166·98	1	6
	509	94·2	0 30 P.M.	6	164·52	1	6
	510	93·0	0 54	6	162·58	1	6
	511	93·8	1 16	6	160·27	1	6
	512	94·3	1 39	6	158·67	1	6
	513	94·8	2 3	6	156·10	1	6
	514	96·0	2 25	6	153·93	1	6
	515	95·8	2 46	6	152·21	1	6
	516	95·0	3 15	6	151·02	1	6
4th „	517	62·8	6 51 A.M.	6	149·63	1	6
	518	63·5	7 19	6	148·58	1	6
	519	66·2	7 42	6	147·22	1	6
	520	69·4	8 7	6	146·66	1	6
	521	71·8	8 24	6	145·61	1	6
	522	74·3	8 45	6	144·73	1	6
	523	76·8	9 4	6	144·12	1	6
	524	78·0	9 27	6	144·22	1	6
	525	83·2	11 2	6	144·68	1	6
	526	85·2	11 21	6	143·63	1	6
	527	88·0	11 43	6	142·00	1	6
	528	90·2		6	141·15	1	6
	529	93·0		6	140·24	1	6
	530	91·2	0 54 P.M.	6	140·55	1	6
	531	94·0	1 14	6	140·05	1	6
	532	93·8	1 33	6	139·82	1	6
	533	95·0	1 49	6	139·48	1	6
4th Mar.	534	94·5	2 11 P.M.	6	−138·73	1	6
	535	92·8	2 33	6	139·10	1	6
	536	94·2	2 55	6	138·91	1	6
	537	93·5	3 18	6	138·95	1	6
	538	92·2	3 41	6	138·22	1	6
5th „	539	58·8	6 44 A.M.	6	138·00	1	6
	540	60·2	7 8	6	137·78	1	6
	541	62·5	7 30	6	137·23	1	6
	542	64·7	7 51	6	137·48	1	6
	543	67·6	8 8	6	137·13	1	6
	544	70·3	8 28	6	137·34	1	6
	545	72·0	8 43	6	137·44	1	6
	546	73·5	8 57	6	136·73	1	6
	547	75·2	9 13	6	135·56	1	6
	548	78·0	9 39	6	133·92	1	6
	549	82·5	11 33	6	132 33	1	6
	550	90·0	11 53	6	130·41	1	6
	551	90·5	0 17 P.M.	6	128 87	1	6
	552	94·0	0 35	6	127·60	1	6
	553	93·5	0 55	6	125·97	1	6
	554	91·8	1 14	6	124·38	1	6
	555	93·8	1 35	6	122·33	1	6
	556	93·6	1 53	6	120·76	1	6
	557	95·0	2 12	6	119·31	1	6
	558	95·5	2 29	6	118·03	1	6
	559	94·1	2 47	6	116 68	1	6
	560	94·2	3 14	6	115·68	1	6
	561	93·0	3 40	6	114·21	1	6
6th „	562	65·0	6 55 A.M.	6	113·26	1	6
	563	66·3	7 15	6	112·39	1	6
	564	68·0	7 33	6	111·73	1	6
	565	69·8	7 53	6	111·10	1	6
	566	71·0	8 12	6	110·49	1	6
	567	72·0	8 29	6	110·05	1	6
	568	73·5	8 48	6	109·46	1	6
	569	74·3	9 7	6	108·65	1	6
	570	77·0	9 28	6	108·58	1	6
	571	84·3	11 31	6	108·12	1	6
	572	85·2	11 58	6	108·68	1	6
	573_1	87·0	0 12 P.M.	5	109·68	5	7
				Total	− 31642·50		

The advanced-end of set No. 573_1 fell in excess (*i. e.* North-East) of the dot at North-East-End 1·9718 feet, as measured on Cary's brass scale with a beam compass.

Height of set No. 573_1 above North-East-End = 3·61 feet.

Reduction to Mean Sea Level.

Let the sections into which this base-line is divided be denoted as follows;

South-West-End to Station A			by Section	I
Station A	to	„ B	„	II
„ B	to	North-East-End	„	III

Then in the notation of (7) page I_{22} we have

$H = 3118$; $h = -109{\cdot}0$; $\delta h = +4{\cdot}3$; Log. $R = 7{\cdot}31936$, and $n = 572$

	$[h]_1^p$	a	n	dh	F	λ	C_2	C_1	C
	−	+		+	−		+	−	−
Section I ...	23515	48	202	1·5	23315	12764	0·0704	1·9078	1·8374
„ II ...	31465	200	159	1·2	30931	10008	0·0934	1·4959	1·4025
„ III ...	31643	72	211	1·6	30832	13317	0·0931	1·9905	1·8974

Final length of the Base-Line and of its parts in feet of Standard A.

Section	Measured with			Reduction to sea level as above	Total Length	Log.
	Compensated bars page IX_{32}	Compensated microscopes page IX_{36}	Beam compass pages IX_{39} to IX_{43}			
S. W. End to Stn. A ...	12160·7298	608·0330	− 4·8132	−1·8374	12762·1122	4·10592 2558
Stn. A to Stn. B ...	9520·5822	476·0364	+11·1285	−1·4025	10006·3446	4·00027 5455
Stn. B to N.E. End ...	12690·7936	634·5599	− 8·2871	−1·8974	13315·1690	4·12434 6683
S.W.End to N.E. End ...	34372·1056	1718·6293	− 0·4697	−5·1373	36083·6258	4·55731 0170

Verificatory Minor Triangulation.

No. of Triangle	Name of Station	Corrected Angle	Log. Sine	Log. Distance	Distance in Feet	Distance in Miles	Error of Triangle
		° ′ ″					″
	South-West-End of Base,	58 23 56·677	9·930296059	4·170482202			
1	Station A, ...	74 22 20·610	9·983641104	4·223827247			+0·537
	Machalbetta S, ...	47 13 42·756	9·865736415	4·105922558	12762·1122	2·417	
		180 0 0·043					
	Station A, ...	55 46 12·925	9·917394505	4·104875583			
2	Machalbetta S, ...	50 9 22·294	9·885244629	4·072725707			−1·344
	Ainur S, ...	74 4 24·815	9·983001124	4·170482202			
		180 0 0·034					
	Station A, ...	49 51 24·976	9·883341730	3·970674821			
3	Ainur S, ...	54 55 13·239	9·912941111	4·000274202	10006·3157	1·895	+0·349
	Station B, ...	75 13 21·806	9·985392616	4·072725707			
		180 0 0·021					
	Ainur S, ...	63 50 34·567	9·953077496	4·085816642			
4	Station B, ...	72 38 29·787	9·979756469	4·112495615			−0·926
	Gubi S, ...	43 30 55·672	9·837935675	3·970674821			
		180 0 0·026					
	Station B, ...	32 8 7·904	9·725849381	3·853744675			
5	Gubi S, ...	82 40 51·760	9·996447025	4·124342319			
	North East-End of Base,	65 10 60·356	9·957921348	4·085816642	13315·0352	2·522	−0·210
		180 0 0·020					
	South-West-End of Base,	60 9 41·726	9·938235482	4·048872681			
6	Station A, ...	38 15 56·240	9·791906707	3·902543906			+0·979
	Gadalhalli S, ...	81 34 22·055	9·995285359	4·105922558	12762·1122	2·417	
		180 0 0·021					
	Station A, ...	54 24 43·897	9·910210514	3·974775363			
7	Gadalhalli S, ...	50 53 51·266	9·889872737	3·954437586			−0·229
	Basanguta S, ...	74 41 24·856	9·984307832	4·048872681			
		180 0 0·019					
	Station A, ...	87 19 21·352	9·999525654	4·118749010			
8	Basanguta S, ...	49 30 2·970	9·881050844	4·000274200	10006·3157	1·895	+0·179
	Station B, ...	43 10 35·699	9·835214230	3·954437586			
		180 0 0·021					

Verificatory Minor Triangulation—(Continued.)

No. of Triangle	Name of Station	Corrected Angle	Log. Sine	Log. Distance	Distance in Feet	Distance in Miles	Error of Triangle
		° ′ ″					
9	Basanguta S, ...	33 44 44·616	9·744690462	3·907530575			″ +0·005
	Station B, ...	81 38 15·446	9·995357877	4·158197990			
	Sampanhalli T.S.	64 36 59·963	9·955908897	4·118749010			
		180 0 0·025					
10	Station B, ...	55 11 9·358	9·914347941	4·039109315			+0·109
	Sampanhalli T.S.	87 29 0·283	9·999580942	4·124342316	13315·0351	2·522	
	North-East-End of Base,	37 19 50·380	9·782769201	3·907530575			
•		180 0 0·021		Sum	36083·4631	6·834	

NOTE.—Each side of a triangle is given in the same horizontal line with the angle which it subtends.

The angles of the verificatory triangulation were measured with Barrow's 24-inch Theodolite No. 2 read by 5 micrometer microscopes. At all the stations 3 measures were made on each of 10 zeros. The stations on the line are S.W. End, A, B, and N.E. End.—The auxiliary stations are Machalbetta, Ainur, Gubi, Sampanhalli, Basanguta and Gadalhalli.

Comparison in feet between the values computed by means of the verificatory triangulation and the measured value.

Of the entire line.

		Log.
South-West-End to North-East-End by the measurement, page IX—44	36083·6258	4·557 310 170
,, computed in terms of South-West-End to Station A, page IX—46	36083·4631	4·557 308 212
Log. computed value — Log. measured value		— 0·000 001 958

In terms of the entire line by measurement.

	Computed	Computed — Measured*
South-West-End to Station A	12762·1698	+ 0·0576
Station A to Station B	10006·3608	+ 0·0162
,, B to North-East-End	13315·0952	— 0·0738

Of each section in terms of the others.

	South-West-End to Station A	Station A to Station B	Computed — Measured	Station B to North-East-End	Computed — Measured
Measured lengths* ..	12762·1122	10006·3446	.. ..	13315·1690	.. ..
Computed on base S.W. End to Station A	.. ..	10006·3157	— 0·0289	13315·0352	— 0·1338
Computed on base Station A to Station B	.. ..	.. ..	.. ..	13315·0736	— 0·0954

Description of Stations.

SOUTH-WEST-END OF BANGALORE BASE, OR UIALDINNA OBSERVATORY STATION, Lat. 13° 1′, Long. 77° 37′, is situated in the district of Bangalore, province Mysore, on the highest part of the undulating ground to the N. generally of Bangalore cantonment. An old small square building of about 7 feet side, consisting of a pyramidal roof raised on 4 stone pillars, stands some 70 feet S.E. of the station. The azimuths and distances of some of the circumjacent places are as follows;—St. John's Church, 304° 37′; miles 2·51. Scotch Kirk, 327° 16′; miles 2·73. Commissioner's Flag, 342° 30′; miles 2·23.

The point to which the measurement was referred is denoted by a dot drilled into a plug of brass; the dot being placed at the centre of a small circle on the brass and of a larger one 4″ in diameter on the stone. The plug is let into a block of gneiss, pyramidal in form, 36″ square at base, 8″ square at top and 42″ in height. The block rests on the reddish indurated clay of which the highland is here composed. The base-line dot is covered for protection with a plate of brass some 2½″ × 5″ × 0″·15. The plate carries a coarser dot and circle and is so adjusted that the two dots are in the same normal. Subsequent to the measurement an observatory was erected over the station. In the first instance, a pillar resting on stone-beams, thrown across the well in which the markstone is sunk, was built over the mark and carried up flush with the roof of the observatory; the theodolite rested on this pillar while the principal angles and azimuth were observed at this station. After these observations were concluded, the pillar and its supporting stone-beams were removed. A stone cap was placed over the mark and an isolated pillar of cut-stone built over it to a height of 5″ below the level of the observatory floor; there is a mark on a brass plug let into the surface of this pillar adjusted to agree with the normal of the lower mark: the distance between these two marks is 3′ 1″⅓. The upper mark is covered over with stone flags, flush with the floor of the observatory, a rough dot and circle being engraved on the stone exactly over the marks below. The observatory also contains an isolated platform 5′ 6″ square, the centre of which is on the prime vertical of the station already described and to the W.: the distance between the two centres is about 6′¾. The platform was provided for the pendulum observations subsequently taken at this point. The observatory is 15′ 6″ by 11′ 1″, being a rectangle with the 2 eastern angles cut off. It is raised to a height of 12 feet above the ground-floor and is provided with a meridional aperture for Latitude observations. There are two abutment walls on the western side of the building which carry a flight of stone steps from the level of the roof to within 8 feet of the ground. A block of stone fixed in the roof carries a rough mark adjusted in the normal of the base-line dot.

The South-West-End was connected by spirit levelling in 1868 with the Railway Bench-mark at the Bangalore Railway Station by two independent routes; this Bench-mark is on the East end of arrival platform at the Railway Station and is stated by the Resident Engineer to be 3033·07 feet above mean sea level at Madras. Accepting this value, the height above mean sea level of the base-line dot was found to be 3118·3 feet.

NORTH-EAST-END OF BANGALORE BASE, OR KANNUR OBSERVATORY STATION, Lat. 13° 5′, Long. 77° 42′, is situated in the district of Bangalore, province Mysore, on the crest of the high land S. of Kannúr and west of Gubbi (Chota) village. The azimuths and distances of some of the villages are as follows;—Kannúr, 185°; miles 0·998. Gubbi (Chota), 287°; miles 0·689.

The Station is marked in the manner adopted for the South-West-End Station with the following differences,—the surface of the cut-stone pillar built over the base-line dot is 4″ below the ground-floor and 2′ 7″ above the base-line dot. The roof of the observatory is 12′ 8″ above the ground floor.

STATION A, OR NAGVARAM, Lat. 13° 2′, Long. 77° 39′, is on the straight line from South-West-End to North-East-End, being distant 2·4 miles from the former, and is situated in the Bangalore district, province Mysore, on the northern slope of the high land W. of the small village of Nágváram. There is a large tank of water about 0·4 miles to the N. The azimuths and distances of some of the circumjacent places are as follows;—Nágváram village, 302°; miles 0·51. St. John's Church, 353° 17′; miles 3·17. Commissioner's Flag staff, 14° 53′; miles 3·99.

The point to which the measurement was referred is denoted in precisely the same manner as at the South-West-End Station. The superstructure consists of a solid stone platform 10′ 6″ square and 1′ above the ground level, on which rest four stone pillars carrying an upper platform. The former platform has a mark engraved on stone in the normal of the station and the upper platform carries a circular slab of stone with an orifice in it. The theodolite rested on this slab during the measurement of the principal angles. After the angles had been measured, a cut-stone pyramid 2′ square at base and 6′ 3″ high was erected on the slab. The heights above the base-line dot are as follows;—Dot on lower platform 1′ 7″; Surface of slab in upper platform 10′ 2″.

Description of Stations—(Continued.)

STATION B, OR RACHINHALLI, Lat. 13° 3′, Long. 77° 40′, is on the straight line from South-West-End to North-East-End, being 2·5 miles from the latter, and is situated in the Bangalore district, province Mysore, on the rising ground between the villages of Ráchinhallí and Tanísandar. The azimuths and distances of these villages are as follows;—Ráchinhallí, 92°; miles 0·11. Tanísandar, 282°; miles 0·46. The Scotch Kirk is distant 5·59 miles at an azimuth of 16° 6′.

The point to which the measurement was referred is denoted in precisely the same manner as at the South-West-End Station, the pyramidal mark-stone being sunk in a well and surrounded by concrete, but having its top rising about 12″ above the well in which it is sunk. A circular isolated pillar is built over the mark, the latter being protected as usual by a hollow stone cap. A second mark is engraved on the pillar in the normal of the lower or base-line mark and 2′ 3″ above it. To protect the pillar and its mark, stone slabs have been placed over the whole, resting on the annulus wall, so as not to touch the pillar at all. These slabs form a circular platform 5′ in diameter, and 9″ high; and having two lines cut into it intersecting over the mark. A pyramid of cut-stone surmounts the platform.

MACHALBETTA AUXILIARY STATION, OR MUCHULGUTTA, Lat. 13° 0′, Long. 77° 40′, is situated in the Bangalore district on the summit of a rocky eminence 500 or 600 yards N. of the Madras Railway; ¼ mile S.S.W. from Lingarajapuram, and 1¼ miles N.E. by E. from St. John's Church.

The station is marked by an isolated circular masonry pillar 1 foot high, surrounded by a platform of stones and earth. The former contains a mark-stone at top, and another at bottom.

AINUR AUXILIARY STATION, OR YENNUR, Lat. 13° 2′, Long. 77° 41′, is situated in the Bangalore district on the top of the rocks above a stone quarry about ½ mile E.N.E. from the village, and ½ mile N.W. from Agraram.

The station is denoted by an isolated circular masonry pillar 2 feet high, surrounded by a platform of stones and earth. The former contains a mark-stone at top, and another at bottom.

GUBI AUXILIARY STATION, Lat. 13° 4′, Long. 77° 42′, is situated in the Bangalore district on rising ground 1 mile S. of Pedda Gubi village, ½ mile W. of Kalsanhalli village and about 8 miles W. by S. from Huskota.

The station is denoted by an isolated circular masonry pillar 2 feet high, surrounded by a platform of stones and earth. The former contains a mark-stone at top, and another at bottom.

GADALHALLI AUXILIARY STATION, OR GETHALHALLI, Lat. 13° 2′, Long. 77° 37′, is situated in the Bangalore district, and is distant about 350 yards N. by W. from the village and 1½ miles N. by W. from the South-West-End of the base-line.

The station is denoted by an isolated circular masonry pillar 7 feet high, surrounded by a platform of stones and earth. The former contains a mark-stone at top, and another at bottom.

BASANGUTA AUXILIARY STATION, OR BASWANGUTTA, Lat. 13° 3′, Long. 77° 38′, is situated in the Bangalore district on a rocky hillock, 200 yards W. of the Ballari road and ½ mile S. of Badrayanpuram.

The station is denoted by an isolated circular masonry pillar 1 foot high, surrounded by a platform of stones and earth. The former contains a mark-stone at top, and another at bottom.

SAMPANHALLI AUXILIARY TOWER STATION, Lat. 13° 5′, Long. 77° 40′, is situated in the Bangalore district on top of a bare rock about 500 or 600 yards E. of the village and ¼ mile N.E. of Striramapuram village.

The pillar is perforated and 12 feet high. It has a mark engraved on the rock *in situ*.

J. B. N. HENNESSEY.

CAPE COMORIN BASE-LINE.

This base-line is situated at the southern extremity of the Peninsula of India, a few miles to the north-east of the Cape from which it's name is derived. The middle point is in latitude N. 8° 15′ and long. E. 77° 45′; the direction is nearly meridional, the azimuth of the north end from the south end being 185° 56′; the length is 1·688 miles; the line was measured four times.

The line was selected and all the necessary preliminary arrangements were made, by Captain B. R. Branfill, in the field season of 1867-68, and in the following field season the measurement was effected under the supervision of Captain J. P. Basevi, R.E., with the aid of the following Officers and Assistants—

Captain J. Herschel, R.E.	Mr. A. Christie.
Captain B. R. Branfill.	„ J. McDougall.
Lieutenant M. W. Rogers, R.E.	„ O. V. Norris.
Mr. G. Anding.	„ J. Bond.
„ J. W. Mitchell.	„ C. D. Potter.
„ G. Belcham.	„ C. Torrens.

The reductions of the observations and of the measurements were carried on, for the most part, under the superintendence of Captain Herschel, but they were completed at the Head Quarters of the Trigonometrical Survey, under Colonel Walker's instructions.

INTRODUCTION.

In order to ascertain the magnitude of the probable errors of base-lines measured with the apparatus of compensation bars and microscopes, from the intrinsic evidence of the operations themselves, instead of the evidence afforded by triangulation connecting the several sections of the base, the usual procedure was deviated from at Cape Comorin, and, instead of measuring a line of the length of 6 to 8 miles—divided into sections to be compared by triangulation—once for all, a line of 1·688 miles or about one-fourth the usual length, was measured four times. This line was extended in opposite directions to a length of 7·635 miles by triangulation on both flanks, thus affording for the contiguous Principal Triangulation a side of verification of similar length to the previous base-lines. In fact the first intention had been to measure a base-line of the usual length in the usual manner, and a line was selected accordingly, and divided into three sections, for mutual verification by triangulation on both flanks; but meanwhile strong representations were made to Colonel Walker by Captain Herschel, who was then engaged in reducing the measurements of the Bangalore base-line, to the effect that the accuracy of the compensation apparatus was very questionable; he therefore decided to depart from the usual procedure of operation, and directed that the central section only should be measured, but that the measurements should be repeated four times, and be conducted in such a manner as to indicate, with all possible certainty, the actual magnitude of the probable errors of base-lines measured with the apparatus.

The entire line lies between, and nearly at right angles to, the crests of the low ridges or undulations of Kúdankólam and Ráthápúram in the táluk of Nángunéri. The southern station, Kúdankólam, is nearly 4 miles E.N.E. of Colonel Lambton's astronomical station of Punnœ, the southernmost point of the well known meridional arc which extends from thence to the Himalayas. Proceeding northwards from Kúdankólam, the line passes through the stations of Shánganéri and Parméspuram, the distance between which was measured four times by the compensation apparatus, and which are therefore the terminal stations of the linear measurements.—The entire length was determined by triangulation from the measured section, and the stations at the extremities of the entire line are the terminal stations of the Principal Triangulation between Bangalore and Cape Comorin.

The preliminary arrangements and the general programme of the operations have been fully described in section 2 of Chapter VIII, which should be referred to for further information on the subject.

The comparisons of the compensation bars with the standard were made with the pair of microscopes which had been used at all previous base-lines and are described in Appendix No. 1, but with the addition—at Bangalore and at this base—of a micrometer to the microscope which originally carried a fixed wire only. This addition was a great improvement, as regards the delicacy of the operations, but it added very considerably to the bulk of the record and to the labor of the reductions; thus it is not desirable to print the whole of the original micrometer readings and reductions, as they would occupy about eight times the space which sufficed for the record of the micrometer readings at the preceding base-lines; in this place will be given the resulting excess of each bar over the standard, at the temperature of 62°, as reduced with the old value of the factor of expansion of the standard, which was determined in Calcutta in 1832, and which is indicated in the theoretical investigation of the changes in the length of a compensation bar and invariably throughout Chapters VII and VIII, by the symbol E'_a

Thus in the following tables of the results of the comparisons of the compensation bars with the standard, the quantities in column B are the numerical values of x'' for bar B in equation 10 page (65), and those in the column for the mean are the numerical values of X'' in equation 15 page (69). They are expressed in divisions of the micrometer K, the value of which, determined from runs taken on inch [*a.b*] of the standard foot, was found to be 21758 *divisions* = 1 *inch* of standard **A**; and thus E'_a, the preliminary value of the expansion of the standard for 1°F, = 17·74 K-divisions.

The temperatures in the table are the observed temperatures corrected for the calibration and index errors of the thermometers which are given in Appendix No. 8.

All the comparisons of the compensation bars with the standard were made in the vicinity of the Parmésprúram station—the northern terminus of the measurement—in the base-line tents; the comparing microscopes were fixed on stone caps, resting at three points on substantial pyramidal blocks of stone which were carefully isolated and placed parallel to the direction of the base-line; when the position of the bars were reversed, as described at page (64), the stone caps carrying the microscopes were also reversed on their supports.

As soon as sufficient practice made it possible, the rule was observed of beginning a comparison of the set of compensation bars with the standard at every half-hour, and thus distributing the operations with equal regularity over the whole of the working hours; every comparison of the set of bars commenced and terminated with an observation of the standard.

The operations for the measurement of this base-line differ most materially from those of all the previous base-lines in the arrangements which were made for measuring the thermal inequalities of the components of the compensation bars. It has been shown in Section 3 of Chapter VII that a knowledge of the differences of temperature of the components is essentially necessary for the determination of the normal length of a compensation bar; therefore one of the bars was fitted with thermometers, and taken as a representative of all the others (Section 4, Chapter VII), and the temperatures of the components of this bar were systematically observed, throughout the whole of the operations.

Preliminary results of the comparisons of the compensation bars A, B, C, D, E, H, *with the Standard, before and after the* 1*st measurement. Brass components West.*

Group and Date 1869.	Times of comparisons.	No. of comparison	Temperature of Air.	Temperature of Standard.	Preliminary excess of bars over Standard at 62° Fahrenheit in divisions of K. micrometer, 1 *division* = 1·277 *m.y* of **A**: A	B (x'')	C	D	E	H	Mean (X'')	Temperatures of components of B.: $62° + T_b$ Temp: of brass bar.	t, excess of iron over brass.	REMARKS.
	h. m.		°	°										
I, 1. 9th January.	7 37 A.M.	1	75·4	74·10	152·6	160·1	195·4	246·5	187·8	181·3	187·3	73· 7	+·02	Capt. Basevi at L. or S. end; Capt. Branfill at K or N. end. Observers changed places.
	8 36	2	77·7	74·47	153·7	162·7	202·8	249·8	191·7	182·9	190·6	74·25	·04	
	9 20	3	79·1	75·10	143·5	160·5	200·6	249·8	191·0	179·7	187·5	75·17	·07	
	9 49	4	80·6	75·70	145·5	160·8	205·6	252·6	196·1	186·9	191·3	75·85	·13	
	10 23	5	82·3	76·54	146·0	169·5	213·0	259·0	203·5	189·1	196·7	76·85	·24	
	11 0	6	83·6	77·56	154·2	173·8	214·9	261·7	206·6	188·6	200·0	78·11	·39	
	11 37	7	85·0	78·62	154·2	179·5	223·2	269·0	215·7	197·2	206·5	79·40	·43	
	0 8 P.M.	8	85·6	79·58	156·1	183·3	222·7	272·9	213·2	196·0	207·4	80·47	·44	
	0 55	9	86·0	80·95	154·3	179·2	223·9	266·8	208·1	195·6	204·7	82·11	·39	
	1 29	10	86·2	81·76	158·6	*183·1	225·6	269·2	209·5	198·9	207·5	82·90	·38	Col. Walker, at K. or N. end; Lieut. Rogers, at L. or S. end. Observers changed places.
	2 1	11	85·8	82·42	158 9	182·6	221·4	267·7	208·8	194·9	205·7	83·56	·38	
	2 34	12	85·9	82·94	164·8	183·4	223·1	266·7	209·9	195·2	207·2	84·06	·33	
	3 3	13	85·9	83·36	161·0	183·3	225·0	266·6	205·9	196·9	206·5	84·40	·35	
	3 34	14	85·7	83·73	160·7	182·6	223·0	265·6	209·0	195·9	206·1	84·70	·33	
	4 3	15	85·2	83·98	163·1	181·8	224·2	266·8	202·2	193·1	205·2	84·83	·32	
I, 2. 11th January.	6 59 A.M.	1	74·4	74·15	145·8	161·7	197·0	239·0	182·4	181·2	184·5	73·65	·06	Col. Walker, at K. or N. end; Lieut. Rogers, at L. or S. end. Observers changed places.
	7 33	2	75·9	74·11	143·1	158·7	197·4	236·7	181·6	181·6	183·2	73·76	·12	
	8 1	3	77·1	74·31	142·8	162·0	199·3	239·5	186·9	182·2	185·5	74·09	·13	
	8 29	4	78·4	74·65	145·0	161·5	201·8	243·0	189·1	185·8	187·7	74·61	·15	
	9 1	5	79·5	75·20	152·9	168·9	209·2	255·1	202·0	197·2	197·6	75·40	·26	
	9 33	6	80·6	75·84	157·1	174·7	211·7	261·1	208·4	200·8	202·3	76·36	·33	
	9 59	7	81·3	76·44	160·2	177·9	217·0	267·5	207·8	200·6	205·2	77·12	·37	
	11 13	8	84·0	78·18	164·4	175·9	221·1	264·5	213·3	201·4	206·8	79· 4	· 3	
	11 40	9	84·8	78·93	163·6	183·2	225·7	272·9	215·6	202·9	210·7	80· 4	· 4	Captain Branfill, at K; Lt. Herschel at L.
	0 10 P.M.	10	85·7	79·82	160·3	183·2	226·9	274·8	223·3	208·1	212·8	81· 4	· 4	
	0 44	11	86·4	80·75	164·2	179·4	221·3	272·7	213·8	206·9	209·7	82· 4	· 4	
	1 10	12	87·1	81·48	163·2	181·3	222·5	269·4	215·2	202·6	209·0	83· 2	· 4	
	1 43	13	87·4	82·40	162·4	179·8	220·2	265·8	209·5	196·8	205·8	84· 1	· 4	
	2 20	14	87·9	83·34	163·5	182·7	220·1	263·0	208·7	195·6	205·6	85· 0	· 2	Observers changed places.
	2 47	15	87·9	83·97	159·9	179·8	217·8	260·9	203·5	194·9	202·8	85· 5	· 2	
	3 13	16	87·9	84·51	158·4	172·7	213·6	252·7	201·3	192·6	198·6	86· 0	· 1	
	3 45	17	88·0	85·06	156·5	172·4	216·0	256·3	198·2	191·4	198·5	86· 4	· 1	
	4 15	18	87·3	85·43	153·3	170·4	204·3	249·2	194·1	186·2	192·9	86· 7	· 0	

The thermometers on Standard **A** were No. 7295 and 7298.

January 9th—On Bar B, left end, thermometer on iron No. 7296, on brass No. 7293; Right end, thermometer on iron No. 4206, on brass No. 4216.

„ 11th—(1) to (7) On Bar B, Left end, thermometer iron No. 7296, on brass No. 7293; Right end, thermometer on iron No. 4206, on brass No. 4216.

„ (8) to (15) On Bar B, Left end, thermometer iron No. 7296, on brass No. 7293; Right end, thermometer on iron No. 7347, on brass No. 7349.

„ (16) to (18) On Bar B, Left end, thermometer iron No. 7348, on brass No. 7293; Right end, thermometer on iron No. 2406, on brass No. 4216.

January 9th—(1) Slight clouds at sunrise; afterwards clear with strong north breeze; towards noon cumuli formed.

„ (11) Light clouds, sun occasionally obscured.

„ 11th—(1) Light clouds at sunrise, afterwards clear.

„ (5) Strong wind from north.

* The original record gives 203·1 which is evidently erroneous and has been altered to 183·1.

Preliminary results of the comparisons of the compensation bars* A, B, C, D, E, H, *with the Standard, before and after the* 1*st measurement. Brass components West.

Group and Date, 1869.	Times of comparisons.	No. of comparison.	Temperature of Air.	Temperature of Standard.	Preliminary excess of bars over Standard at 62° Fahrenheit, in divisions of K micrometer, 1 *division* = 1·277 *m.y* of A							Temperatures of componets of B.		REMARKS.
					A	B (x'')	C	D	E	H	Mean (X'')	$62° + T_b$ Temp: of brass bar.	t, excess of iron over brass.	
	h. m.		°	°										
I, 3. 25th January.	7 10 A.M.	1	76.6	77.44	147.2	162.2	198.6	239.9	184.6	178.6	185.2	77.14	+.10	Lt. Herschel at K.
	7 44	2	78.7	77.44	152.9	162.4	199.2	245.4	189.4	184.3	188.9	77.27	.08	Capt. Basevi at L.
	8 12	3	79.5	77.68	153.5	163.8	206.4	245.0	186.8	185.2	190.1	77.69	.12	
	8 40	4	80.7	78.04	157.3	167.8	204.0	253.1	195.8	190.6	194.8	78.18	.19	
	9 11	5	82.0	78.54	161.1	171.4	215.6	260.7	202.5	200.4	202.0	78.89	.25	
	9 40	6	83.3	79.18	167.9	180.8	224.8	266.0	209.6	205.2	209.1	79.77	.42	
	10 11	7	84.5	79.98	171.5	190.3	229.9	278.3	219.7	208.2	216.3	80.78	.57	
	10 41	8	85.5	80.79	173.0	188.5	236.4	277.2	220.6	212.6	218.1	81.90	.67	
	11 19	9	86.2	81.84	178.3	192.2	237.3	280.5	227.4	212.3	221.3	83.05	.70	Col. Walker, and
	11 52	10	87.4	82.72	176.4	195.7	237.5	284.6	228.5	214.4	222.9	84.12	.68	Lt. Rogers.
	0 19 P.M.	11	88.2	83.45	177.6	192.4	239.6	280.1	225.3	210.5	220.9	84.97	.64	
	0 46	12	89.0	84.21	175.3	193.2	239.3	285.0	225.8	213.1	222.0	85.80	.56	
	1 16	13	89.2	85.06	177.0	189.5	236.6	283.1	223.6	210.5	220.1	86.66	.55	
	1 49	14	89.5	85.92	173.7	190.7	240.7	281.9	224.5	213.0	220.8	87.59	.59	Observers chang-
	2 17	15	90.2	86.61	173.3	192.1	240.1	282.7	227.7	212.3	221.4	88.33	.58	ed places.
	2 46	16	89.9	87.28	175.0	190.6	234.2	280.7	222.1	212.2	219.1	88.93	.54	
	3 17	17	89.1	87.78	170.9	188.3	233.2	276.8	221.1	210.7	216.8	89.39	.48	
	3 46	18	87.2	88.05	174.2	189.3	234.1	279.0	219.4	208.5	217.4	89.53	.47	
	4 9	19	86.2	88.03	175.4	189.6	231.5	273.8	216.3	206.5	215.5	89.38	.43	
I, 4. 26th January.	7 2 A.M.	1	75.4	77.04	149.7	163.0	202.2	243.1	185.2	181.2	187.4	78.01	+.10	Capt. Basevi at K.
	7 22	2	76.3	76.93	153.3	164.7	205.3	247.9	192.2	187.1	191.8	77.84	.09	Lt. Herschel at L.
	7 42	3	77.4	76.93	154.5	168.6	204.8	248.6	191.0	184.9	192.1	77.78	.10	
	8 16	4	79.4	77.20	159.5	168.9	208.7	255.3	201.4	192.0	197.6	78.00	.19	
	8 44	5	80.7	77.65	162.6	175.2	213.3	259.9	210.3	200.2	203.6	78.47	.23	
	9 17	6	82.0	78.30	157.8	175.9	218.0	266.2	214.4	204.8	206.2	79.17	.31	
	9 42	7	83.1	78.93	162.8	184.3	227.5	269.5	221.4	212.2	213.0	79.86	.42	
	10 9	8	84.0	79.60	167.0	192.8	232.6	277.7	222.4	217.0	218.3	80.72	.55	
	10 39	9	85.1	80.42	170.8	194.8	237.2	280.9	228.7	219.2	221.9	81.74	.64	
	11 9	10	86.0	81.26	176.1	196.0	241.3	281.4	227.6	220.3	223.8	82.70	.67	
	45	11	87.1	82.30	173.8	196.0	240.5	281.8	233.2	221.2	224.4	83.83	.69	Captain Branfill,
	0 15 P.M.	12	87.8	83.14	175.5	201.1	244.9	286.9	235.5	218.3	227.0	84.83	.68	at K. Lieut. Ro-
	44	13	87.8	83.91	179.4	201.6	244.1	287.2	235.4	220.8	228.1	85.71	.65	gers, at L.
	1 11	14	88.7	84.61	174.6	196.0	237.2	287.6	231.1	219.6	224.4	86.45	.57	
	1 45	15	89.0	85.41	176.5	197.7	236.4	285.2	231.6	219.2	224.4	87.31	.51	
	2 14	16	89.0	86.00	169.2	191.5	229.4	278.4	224.1	209.9	217.1	87.88	.51	Observers chang-
	45	17	89.1	86.58	172.2	191.4	229.4	280.6	224.5	212.7	218.5	88.40	.43	ed places.
	3 12	18	89.1	86.99	172.1	190.4	229.8	281.8	223.4	211.9	218.2	88.65	.46	
	43	19	89.3	87.42	174.5	189.8	228.5	279.8	220.3	206.4	216.6	89.97	.42	
	4 14	20	88.4	87.69	168.7	189.7	229.2	275.9	216.5	203.5	213.9	89.14	.35	
Mean of 4 days comparisons				80.78	162.6	180.2	221.5	266.5	210.4	200.4	206.3	81.80	+.35	

On Bar B, Left end thermometer, on iron No. 7291, on brass No. 7287; Right end thermometer, on iron No. 7292 on brass No. 7290.

January 25th. (1) Fine morning; few cumuli, light wind N.E., afternoon rather cloudy.
" (12) Sunshine and a few cirri.
" (15) Wind from S.E.
" (1) Fine morning, cirri and strati. Wind light N.E.

Preliminary results of the comparisons of the compensation bars* A, B, C, D, E, H, *with the Standard, before and after the 2nd measurement. Brass components East.

Group and date 1869.	Times of comparisons.	No. of comparison.	Temperature of Air.	Temperature of Standard.	Preliminary excess of bars over Standard at 62° Fahrenheit in divisions of K micrometer, 1 *division* = 1·277 *m.y* of A							Temperatures of components of B.		Remarks.
					A	B (x'')	C	D	E	H	Mean (X'')	$62° + T_b$ Temp: of brass bar.	t, excess of iron over brass.	
	h. m.		°	°										
II, 1. 28th January.	7 14 A.M.	1	76.0	77.64	148.7	160.9	201.0	242.4	186.2	182.8	187.0	79.07	+.01	
	7 39	2	77.2	77.50	147.1	160.0	198.6	240.4	187.4	179.8	185.6	78.81	−.02	
	8 12	3	77.8	77.57	147.8	157.4	201.5	241.4	185.4	181.7	185.9	78.78	.08	
	8 41	4	79.1	77.74	149.0	161.2	198.6	241.3	190.7	185.9	187.8	78.82	.07	
	9 16	5	82.2	78.29	145.7	157.1	198.7	237.4	179.8	177.4	182.7	79.27	.04	
	9 42	6	83.1	78.96	144.7	157.6	195.2	238.3	181.0	180.9	183.0	80.05	.07	
	10 12	7	84.5	79.81	147.8	156.1	195.6	240.2	183.0	183.8	184.4	81.02	.10	
	10 40	8	85.7	80.71	150.1	158.4	194.5	241.0	182.7	182.2	184.8	82.02	.12	
	11 12	9	86.3	81.71	147.1	157.4	199.3	241.7	188.4	187.1	187.0	83.11	.17	Capt. Branfill at K
	11 40	10	87.7	82.59	144.4	153.2	198.3	236.4	182.1	184.8	183.2	84.07	.26	Lt. Herschel at L.
	0 11 P.M.	11	89.0	83.64	140.0	154.3	194.9	235.8	184.0	184.1	182.2	85.22	.32	
	0 43	12	90.4	84.72	142.9	153.5	197.2	230.4	185.5	194.3	184.0	86.43	.32	
	1 11	13	90.7	85.64	151.0	160.7	202.3	239.6	192.4	194.5	190.1	87.35	.21	
	1 39	14	91.0	86.51	154.2	165.1	214.9	244.0	197.3	198.5	195.7	88.16	.06	
	2 10	15	91.0	87.42	161.7	173.9	218.8	260.8	203.0	203.9	203.7	89.02	+.11	Observers changed
	2 39	16	90.8	88.00	170.1	179.4	225.5	268.1	206.9	207.9	209.7	89.63	.18	places.
	3 12	17	91.6	88.65	169.0	174.6	220.5	256.8	208.4	205.4	205.8	90.16	.27	
	3 40	18	91.5	89.16	173.9	185.8	230.9	269.0	215.8	215.3	215.1	90.62	.34	
	4 9	19	91.2	89.60	183.9	197.2	230.7	277.0	224.6	222.6	222.7	90.96	.43	
II, 2. 29th January.	6 42 A.M.	1	76.5	79.33	155.4	165.1	200.6	249.7	187.2	180.3	189.7	79.83	+.15	Lt. Herschel, at K.
	7 13	2	77.1	79.05	150.9	164.0	201.0	250.3	191.5	181.3	189.8	79.39	.07	
	7 44	3	78.2	78.89	150.1	158.7	201.0	248.9	192.7	178.6	188.3	79.14	.03	Capt. Branfill at L.
	8 10	4	79.6	78.93	150.9	160.6	198.2	243.5	180.4	172.7	184.4	79.13	−.03	
	8 42	5	81.4	79.19	146.5	158.6	199.9	237.7	182.7	178.2	183.9	79.49	.12	Observers changed
	9 11	6	82.6	79.61	142.1	153.7	188.0	231.7	179.0	170.9	177.6	80.14	.19	places.
	9 42	7	83.7	80.20	141.9	152.9	187.0	232.6	180.3	175.8	178.4	80.91	.22	
	10 14	8	85.1	80.89	141.7	150.4	198.3	228.9	180.6	175.8	179.3	81.79	.23	
	10 41	9	86.4	81.61	142.3	152.8	193.7	234.2	183.6	179.3	181.0	82.70	.22	
	11 12	10	88.0	82.55	140.9	157.0	193.1	238.0	187.9	184.0	183.5	83.83	.23	Capt. Basevi at K.
	11 43	11	89.3	83.61	142.5	155.2	196.6	237.3	184.7	184.8	183.5	85.10	.21	Lt. Rogers at L.
	0 9 P.M.	12	89.7	84.48	147.5	164.0	203.7	238.2	193.3	188.5	189.2	86.08	.17	
	9 42	13	90.0	85.57	146.7	164.6	206.7	246.5	190.3	189.1	190.7	87.28	.18	
	1 13	14	89.8	86.54	154.5	174.7	220.0	256.6	202.6	195.7	200.7	88.18	.00	
	1 47	15	88.7	87.22	158.2	176.0	220.9	258.5	205.6	195.8	202.5	88.40	+.11	Observers changed
	2 12	16	88.0	87.44	162.4	186.7	224.6	265.2	213.7	211.0	210.6	88.32	.16	places.
	2 39	17	87.5	87.58	159.5	178.4	220.9	258.1	202.7	201.2	203.5	88.14	.18	
	3 14	18	87.5	87.65	174.4	188.4	225.2	262.2	210.9	206.3	211.2	87.85	.25	
	3 41	19	87.6	87.67	176.9	189.9	227.4	265.1	211.5	213.0	214.0	87.66	.32	
	4 9	20	87.0	87.64	177.1	190.2	228.7	265.6	217.6	209.3	214.8	87.47	.40	

The thermometers used on Standard A were Nos. 7295 and 7298.

On Bar B, Left end, thermometer on iron No. 7291, on brass No. 7287; Right end, thermometer on iron No. 7292, on brass No. 7290.

January 28th (13) A few clouds and little or no wind.
„ 29th (11) and (12). Alternate cloud and sunshine.
„ (13) (18), (19) and (20). Sunshine.
„ (14) Wind changed to East.

Preliminary results of the comparisons of the compensation bars* A, B, C, D, E, H, *with the Standard, before and after the 2nd measurement. Brass components East.

Group and Date, 1869.	Times of comparisons.	No. of comparison.	Temperature of Air.	Temperature of Standard.	Preliminary excess of bars over Standard at 62° Fahrenheit in divisions of K micrometer, 1 *division* = 1.277 *m.y* of A							Temperatures of components of B.		Remarks.
					A	B (x'')	C	D	E	H	Mean (X'')	$62° + T_b$ Temp: of brass bar.	t. excess of iron over brass.	
	h. m.		°	°										
II, 3. 10th February.	6 59 A.M.	1	77.1	78.27	148.8	160.3	198.2	240.0	180.8	176.5	184.1	79.54	+.04	Capt. Branfill at K.
	7 21	2	78.3	78.10	147.9	160.4	195.2	239.3	177.9	174.3	182.5	79.35	−.02	Lt. Herschel at L
	40	3	79.5	78.03	145.4	154.2	190.1	233.7	175.1	172.6	178.5	79.31	.06	
	8 13	4	82.3	78.24	135.6	146.0	180.8	224.8	167.2	164.5	169.8	79.62	.18	
	8 42	5	84.2	78.74	129.4	142.1	178.5	217.4	161.1	157.9	164.4	80.41	.35	
	9 12	6	85.1	79.49	124.7	140.3	178.7	217.8	162.1	156.6	163.4	81.45	.52	Observers changed
	40	7	86.6	80.22	116.5	135.3	172.6	216.7	158.8	156.7	159.4	82.40	.59	places.
	10 4	8	88.0	81.01	119.3	133.0	173.3	212.7	162.4	157.9	159.8	83.33	.64	
	41	9	89.2	82.34	117.9	138.1	178.1	218.3	169.2	163.3	164.2	84.80	.58	
	11 11	10	90.5	83.45	128.4	146.5	181.8	225.4	179.3	169.5	171.8	85.93	.49	
	39	11	91.1	84.66	133.4	151.8	187.8	227.8	176.9	173.8	175.3	87.16	.49	Capt. Basevi at L.
	0 10 P.M.	12	91.3	85.81	138.2	157.0	194.3	230.9	180.9	178.6	180.0	88.26	.44	Lt. Rogers at K.
	41	13	91.5	86.96	144.1	162.1	197.9	234.7	184.9	180.6	184.1	89.31	.37	
	1 9	14	91.6	87.78	144.4	161.4	196.3	241.4	192.4	181.6	186.3	89.99	.30	
	39	15	91.3	88.50	151.2	170.0	209.6	246.4	197.4	189.0	193.9	90.53	.21	
	2 9	16	90.9	89.05	158.8	178.9	213.8	257.5	202.8	195.3	201.2	90.90	.10	
	40	17	90.8	89.52	163.8	180.4	221.3	263.3	206.2	199.5	205.8	91.21	+.03	
	3 8	18	90.5	89.80	166.9	186.8	224.7	268.3	212.6	202.7	210.3	91.37	.13	
	3 38	19	90.6	90.07	169.8	189.2	230.7	273.8	217.2	207.8	214.8	91.48	.24	
	4 10	20	90.7	90.21	171.5	191.1	232.7	279.0	218.0	209.6	217.0	91.48	.32	
II, 4. 11th February.	6 50 A.M.	1	75.9	77.91	143.7	159.2	199.1	243.7	185.9	175.9	184.6	78.43	+.11	Capt. Basevi at K.
	7 20	2	77.0	77.65	147.5	163.3	198.0	244.3	183.7	177.2	185.7	78.19	.03	Lt. Rogers at L.
	41	3	78.3	77.54	144.4	160.4	195.6	239.8	183.6	176.8	183.4	78.13	−.04	
	8 11	4	80.3	77.63	137.5	151.8	188.2	230.2	172.3	170.3	175.1	78.37	.14	
	41	5	82.3	78.07	137.2	149.3	185.7	225.9	172.2	167.1	172.9	79.03	.26	
	9 9	6	83.9	78.66	133.7	147.8	181.9	223.6	170.4	165.1	170.4	79.83	.35	Observers changed
	39	7	86.0	79.50	133.0	149.5	187.7	226.8	175.1	164.6	172.8	80.86	.42	places.
	10 10	8	87.6	80.58	128.1	145.2	180.7	225.0	170.5	162.6	168.7	82.24	.48	
	39	9	89.2	81.70	123.2	140.1	175.9	219.8	170.4	163.0	165.4	83.55	.55	
	11 11	10	91.4	83.05	124.9	145.3	182.0	227.2	175.9	167.9	170.5	85.21	.58	
	39	11	93.0	84.31	125.2	142.5	181.2	220.6	170.1	167.2	167.8	86.60	.60	Lt. Herschel at K.
	0 10 P.M.	12	94.7	85.83	130.5	146.2	186.2	230.2	174.2	170.5	173.0	88.07	.56	Capt. Branfill at L.
	41	13	93.4	87.12	133.3	155.1	196.4	244.0	185.7	181.6	182.7	89.10	.42	
	1 9	14	93.3	87.89	137.0	162.7	202.1	249.4	191.7	188.2	188.5	89.47	.25	
	37	15	93.7	88.59	146.0	165.8	205.9	249.3	194.4	195.1	192.8	89.87	.20	
	2 10	16	93.2	89.31	149.4	167.0	210.3	250.0	196.9	198.2	195.3	90.27	.10	Observers changed
	42	17	92.3	89.80	161.5	179.9	215.9	262.1	205.5	208.0	205.5	90.41	+.04	places.
	3 17	18	91.5	90.02	167.6	186.4	224.3	268.8	212.7	216.9	212.8	90.41	.12	
	42	19	90.8	90.11	170.8	191.7	228.3	272.2	217.1	221.4	216.9	90.35	.21	
	4 8	20	89.8	90.10	174.5	190.0	230.9	274.9	217.2	222.0	218.3	90.23	.30	
Mean of 4 days comparisons,				83.50	147.9	162.7	201.8	243.4	189.3	185.5	188.5	84.80	−.12	

February 10th (1) Fine morning up to 10 o'clock.
" (8) Cumuli occasionally obscuring sun.
" (10) Sunshine, generally, for the remainder of the day. Sea breeze set in about noon, but the wind was gentler than usual.
" 11th Fine clear day, no clouds until the afternoon and then a few cumuli only.

Preliminary results of the comparisons of the compensation bars A, B, C, D, E, H, with the Standard before and after the 3rd measurement. Brass components West.

Group and Date 1869.	Times of comparisons.	No. of comparison.	Temperature of Air.	Temperature of Standard.	Preliminary excess of bars over Standard at 62° Fahrenheit in divisions of K micrometer, 1 *division* = 1·277 *m.y* of A							Temperatures of components of B.		Remarks.
					A	B (x'')	C	D	E	H	Mean (X'')	$62° + T_b$ Temp: of brass bar.	t, excess of iron over brass.	
	h. m.		°	°										
III, 1. 12th February.	6 54 A.M.	1	77·8	79·51	146·0	166·9	202·4	245·1	189·7	185·4	189·3	81·16	+·12	Lt. Herschel at K.
	7 14	2	79·1	79·43	149·3	163·9	204·3	249·4	189·2	180·0	189·4	80·88	·13	„ Rogers at L.
	7 40	3	81·0	79·68	148·5	167·5	205·4	252·5	194·3	185·3	192·3	80·76	·12	
	8 10	4	82·8	80·20	151·8	168·3	206·0	254·9	199·5	190·0	195·1	80·98	·10	
	8 44	5	84·9	80·96	154·0	172·1	212·8	259·3	206·7	193·8	199·8	81·56	·14	
	9 14	6	86·1	81·81	152·2	174·1	210·3	263·9	207·3	195·2	200·5	82·37	·17	Observers chang-
	9 41	7	86·7	82·60	156·0	176·7	217·2	269·7	209·3	199·0	204·7	83·18	·25	ed places.
	10 11	8	87·6	83·53	159·1	175·3	218·4	269·9	210·8	198·0	205·3	84·10	·20	
	10 40	9	87·7	84·42	152·9	176·6	216·5	271·6	208·8	194·3	203·5	85·11	·14	
	11 8	10	88·4	85·19	155·7	176·9	218·1	268·8	216·4	198·2	205·7	86·01	·06	Capt. Basevi at K.
	11 36	11	89·2	85·93	150·1	176·2	215·9	263·7	210·7	191·0	201·3	86·91	—·02	„ Branfill at L.
	0 7 P.M.	12	87·9	86·46	150·3	173·7	212·7	259·8	205·0	190·3	198·6	87·72	·14	
	0 38	13	89·7	87·00	149·5	171·4	209·0	252·5	200·6	183·7	194·5	88·47	·29	
	1 8	14	90·0	87·51	141·7	163·9	201·4	249·1	192·4	180·5	188·2	89·19	·33	
	1 40	15	90·9	88·09	144·0	158·3	199·4	248·3	190·4	181·2	186·9	90·00	·42	Observers chang-
	2 9	16	91·3	88·63	142·8	159·8	198·3	246·0	187·9	183·1	186·3	90·54	·38	ed places.
	2 38	17	91·4	89·14	142·9	163·5	201·8	246·1	190·8	184·5	188·3	90·98	·37	
	3 8	18	90·1	89·50	143·5	162·4	203·0	250·0	193·9	189·0	190·3	91·30	·37	
	3 40	19	90·7	89·73	145·4	166·6	203·6	254·8	193·3	192·5	192·7	91·48	·37	
	4 11	20	90·0	89·87	142·8	161·6	204·0	249·4	191·1	186·7	189·3	91·59	·40	
III, 2. 13th February.	6 50 A.M.	1	75·4	79·52	155·0	178·5	211·2	258·3	199·4	191·7	199·0	80·54	+·22	Capt. Basevi at L.
	7 9	2	75·2	79·21	158·2	173·9	212·5	254·5	195·6	188·1	197·1	80·11	·20	„ Branfill at K.
	7 38	3	77·0	78·82	155·3	169·1	208·3	255·3	192·6	186·4	194·5	79·56	·19	
	8 10	4	79·8	78·84	152·1	168·4	210·9	257·8	196·8	186·8	195·5	79·40	·15	
	8 42	5	79·8	79·17	150·0	170·1	208·1	254·1	197·0	186·8	194·4	79·66	·12	
	9 7	6	81·0	79·41	149·5	167·5	205·1	254·4	199·1	189·0	194·1	79·90	·10	
	9 38	7	83·5	79·95	149·3	169·6	204·7	253·9	199·5	185·6	193·8	80·45	·08	Lt. Rogers at L.
	10 9	8	84·8	80·69	151·0	169·3	208·3	258·4	202·2	191·8	196·8	81·27	·03	Capt. Basevi at K.
	10 37	9	84·7	81·45	146·8	167·7	203·8	253·5	196·9	189·1	193·0	82·08	—·03	„ Branfill at K.
	11 8	10	84·8	82·14	144·0	166·2	200·2	251·3	195·6	185·7	190·5	82·87	·07	Lt. Rogers at L.
	11 40	11	86·7	82·86	151·9	168·6	201·9	248·8	192·8	188·5	192·1	83·69	·12	Observers chang-
	0 11 P.M.	12	88·0	83·60	149·4	165·2	201·6	247·3	190·9	186·8	190·2	84·52	·20	ed places.
	0 40	13	89·4	84·38	145·5	160·3	193·3	241·7	179·9	175·4	182·7	85·51	·33	Lt. Rogers at K.
	1 12	14	89·1	85·26	142·2	152·8	190·4	237·7	181·5	177·1	180·3	86·68	·39	Capt. Basevi at L.
	1 38	15	89·1	85·94	139·9	153·1	187·1	236·1	178·1	179·9	179·0	87·53	·44	
	2 8	16	88·0	86·48	139·1	153·3	191·3	242·2	184·1	176·7	181·1	88·09	·41	
	2 39	17	89·3	86·95	145·5	162·9	199·2	245·5	187·1	180·3	186·8	88·54	·30	
	3 7	18	89·3	87·37	147·1	163·9	205·9	253·5	200·6	188·4	193·2	89·04	·27	Observers chang-
	3 37	19	88·4	87·71	145·3	165·6	206·6	252·9	198·2	189·1	193·0	89·41	·26	ed places.
	4 10	20	87·2	87·88	146·1	167·7	209·5	257·9	198·9	187·6	194·6	89·54	·23	

The thermometers on Standard **A** were Nos. 7295 and 7298.

On Bar B, left end, Thermometer on iron No. 7291, on brass No. 7287; right end, Thermometer on iron No. 7292, on brass No. 7290.

February 12th (1) Rather cloudy morning, strong N.E. wind.
„ „ (11) Cloudy.
„ „ (14) North East wind all day.
„ 13th (1) Cloudy morning, few drops of rain fell during the set. Slight fall of rain at about 4 A.M.
„ „ (3) Sunshine. (4) Wind North. (5) Clouds. (6) (7) and (8) Sunshine. (12) Sunshine. (14) Clouds.

Preliminary results of the comparisons of the compensation bars* A, B, C, D, E, H, *with the Standard before and after the 3rd measurement. Brass components West.

Group and Date 1869.	Times of comparisons.	No. of comparison.	Temperature of Air.	Temperature of Standard.	Preliminary excess of bars over Standard at 62° Fahrenheit in divisions of K micrometer, 1 *division* = 1·277 *m.y* of A: A	B (x'')	C	D	E	H	Mean (X'')	Temperatures of components of B: $62° + T_b$ Temp: of brass bar.	t, excess of iron over brass.	REMARKS.
	h. m.		°	°										
III, 3. 24th February.	6 57 A.M.	1	78·0	79·71	150·1	165·5	204·0	247·5	193·0	184·1	190·7	80·06	+·04	Lt. Herschel at K.
	7 22	2	78·3	79·58	151·8	162·9	200·4	245·5	189·4	181·8	188·6	79·95	·02	„ Rogers at L.
	7 46	3	78·8	79·52	146·2	157·7	201·4	246·3	186·7	183·2	186·9	79·84	·02	
	8 16	4	79·2	79·55	143·7	155·7	198·4	239·1	190·9	181·3	184·9	79·87	−·04	
	8 42	5	79·7	79·64	143·4	162·1	196·6	239·4	187·0	182·5	185·2	79·94	·09	
	9 14	6	82·5	79·94	143·7	155·2	195·4	243·4	189·2	180·2	184·5	80·33	·21	
	9 43	7	83·7	80·50	143·3	157·3	196·0	238·6	186·2	181·9	183·9	80·94	·24	Observers chang-
	10 14	8	85·5	81·32	139·7	146·4	192·9	237·6	182·1	179·9	179·8	82·02	·38	ed places.
	10 46	9	86·2	82·33	137·3	148·9	189·7	232·2	179·7	176·3	177·4	83·48	·48	
	11 9	10	86·9	82·94	135·9	153·8	194·0	237·8	182·1	184·6	181·4	84·29	·55	Capt. Basevi at K.
	11 41	11	88·3	83·86	131·3	150·3	190·0	237·8	181·9	180·6	178·7	85·24	·56	„ Branfill at L.
	0 12 P.M.	12	88·9	84·74	131·3	149·1	189·6	234·5	182·5	182·4	178·2	86·49	·64	
	0 40	13	90·1	85·58	130·0	149·4	189·3	232·2	186·5	183·4	178·5	87·46	·66	
	1 10	14	90·5	86·42	126·3	149·5	193·0	238·1	184·3	184·7	179·3	88·47	·65	
	1 44	15	90·6	87·28	137·6	158·1	199·4	247·4	193·0	192·6	188·0	89·29	·63	Observers chang-
	2 11	16	90·6	87·81	129·7	155·8	198·4	244·2	187·4	187·4	183·8	89·90	·60	ed places.
	2 38	17	90·0	88·21	135·5	155·7	199·7	244·4	192·0	189·2	186·1	90·31	·63	
	3 10	18	89·5	88·54	137·4	150·1	198·2	237·8	190·4	187·0	183·5	90·68	·64	
	3 41	19	88·8	88·66	143·5	158·1	196·3	244·7	191·8	190·2	187·4	90·88	·70	
	4 12	20	87·9	88·69	137·4	152·9	200·5	242·3	186·8	186·2	184·4	90·91	·67	
III, 4. 25th February.	6 52 A.M.	1	76·7	78·26	149·8	163·7	203·5	247·2	192·8	186·9	190·7	78·48	+·05	Capt. Herschel at K.
	7 11	2	77·3	78·19	152·6	166·9	206·7	251·3	193·6	184·6	192·6	78·38	·05	„ Branfill at L.
	7 42	3	78·6	78·20	148·8	166·8	205·2	245·1	192·7	186·2	190·8	78·35	·05	
	8 9	4	79·6	78·39	150·5	165·4	207·4	249·4	195·4	188·9	192·8	78·60	·02	
	8 42	5	81·3	78·86	152·8	164·2	208·9	249·1	195·1	189·1	193·2	79·13	·03	
	9 11	6	82·4	79·47	152·3	163·8	211·8	250·2	196·9	193·1	194·7	79·90	·01	Observers chang-
	9 41	7	83·3	80·13	150·3	165·3	207·5	251·8	196·1	189·1	193·4	80·75	−·06	ed places.
	10 11	8	84·0	80·80	149·6	163·2	208·4	251·1	194·9	185·4	192·1	81·78	·21	
	10 39	9	85·9	81·54	143·1	156·0	202·5	240·3	188·5	179·4	185·0	82·65	·26	
	11 10	10	87·5	82·46	144·7	152·4	201·9	246·5	188·6	178·3	185·4	83·87	·35	Capt. Basevi at K.
	11 40	11	88·5	83·46	142·8	151·8	194·0	237·7	186·5	177·4	181·7	85·08	·44	Lt. Rogers at L.
	0 11 P.M.	12	89·1	84·49	138·7	148·5	196·5	235·5	183·8	175·3	179·7	86·35	·56	
	0 38	13	90·2	85·32	145·6	151·0	194·9	239·8	188·0	183·6	183·8	87·31	·64	
	1 8	14	90·8	86·20	143·8	147·4	190·2	238·6	185·1	182·0	181·2	88·31	·67	
	1 40	15	90·7	87·07	143·1	146·5	193·9	238·8	186·4	183·0	182·0	89·26	·70	Observers chang-
	2 9	16	90·7	87·69	146·3	155·0	199·9	248·9	191·5	186·5	188·0	89·89	·68	ed places.
	2 37	17	90·5	88·12	140·8	145·6	195·3	244·4	189·5	182·4	183·0	90·38	·70	
	3 7	18	90·2	88·51	137·0	149·3	196·1	245·4	191·1	183·3	183·7	90·83	·67	
	3 36	19	90·0	88·74	145·5	151·7	197·7	246·1	191·9	183·3	186·0	91·16	·77	
	4 7	20	89·7	88·90	136·6	148·7	193·6	237·8	191·8	185·1	182·3	91·40	·78	
Mean of 4 days comparisons				83·70	145·4	161·4	202·0	248·1	192·7	185·7	189·2	85·00	−·24	

February 24th (1) Dull cloudy morning following on a rainy day. No sunshine till near the 7th set.
„ „ (7) and (9) Still cloudy. (12) Sunshine. (13) Sunshine, strong N. wind. (18) Wind changed to E. sea breeze.
„ 25th (1) Bright morning, wind from N.E.
„ „ (10) Wind gusty, day generally bright.

Preliminary results of the comparisons of the compensation bars* A, B, C, D, E, H, *with the Standard before and after the 4th measurement. Brass components East.

Group and Date 1869.	Times of comparisons.	No. of comparison.	Temperature of Air.	Temperature of Standard.	Preliminary excess of bars over Standard at 62° Fahrenheit, in divisions of K micrometer, 1 *division* = 1·277 *m.y* of A: A	B (x'')	C	D	E	H	Mean (X'')	Temperatures of components of B: 62° + T, Temp: of brass bar.	t, excess of iron over brass.	Remarks.
	h. m.		°	°										
IV, 1. 26th February.	6 52 A.M.	1	77.9	79.57	149.3	158.0	203.0	245.3	189.0	187.4	188.7	80.47	+ .01	Capt. Basevi at K.
	7 9	2	78.6	79.45	156.3	164.6	207.5	249.9	192.0	183.2	192.3	80.28	.01	Lt. Rogers at L.
	7 37	3	79.9	79.37	145.4	158.4	198.6	244.1	188.6	180.0	185.9	80.16	− .05	
	8 7	4	80.6	79.51	144.7	158.0	203.2	241.7	188.8	182.6	186.5	80.41	.13	
	8 37	5	81.6	79.80	148.3	156.6	197.2	240.4	186.5	180.6	184.9	80.85	.13	
	9 9	6	82.6	80.25	145.6	153.2	194.3	256.9	180.5	181.2	182.0	81.47	.19	Observers chang-
	9 37	7	83.7	80.71	150.3	152.7	193.6	235.1	183.0	178.7	182.2	82.08	.20	ed places.
	10 10	8	85.4	81.35	145.3	152.5	189.3	234.8	179.7	176.3	179.7	82.84	.24	
	10 37	9	86.3	81.98	150.0	152.3	188.2	235.6	177.7	175.0	179.8	83.69	.28	
	11 10	10	88.1	82.86	144.9	155.6	191.1	234.7	183.8	178.3	181.4	84.79	.30	Capt. Herschel at L.
	11 40	11	89.3	83.84	148.0	156.5	193.3	238.3	187.9	182.7	184.5	85.92	.32	„ Branfill at K.
	0 9 P.M.	12	90.0	84.93	150.8	161.9	197.4	243.5	192.0	185.3	188.5	87.07	.22	
	0 40	13	90.6	85.94	151.8	165.9	203.4	247.1	197.4	190.4	192.7	87.96	.17	
	1 9	14	91.6	86.86	151.8	170.1	213.6	254.7	202.4	196.9	198.3	88.59	.09	
	1 40	15	93.0	87.73	158.4	174.0	215.3	258.8	207.0	199.5	202.2	89.25	.01	
	2 12	16	93.1	88.56	162.4	178.2	221.6	266.6	215.4	203.0	207.9	90.00	+ .06	Observers chang-
	2 41	17	93.0	89.23	162.2	180.8	226.1	275.3	222.5	205.7	212.1	90.52	.10	ed places.
	3 10	18	92.3	89.78	166.0	187.4	229.2	281.7	225.7	214.7	217.5	90.95	.17	
	3 42	19	91.2	90.16	170.9	188.1	234.1	286.8	235.5	217.5	222.2	91.17	.24	
	4 9	20	91.2	90.35	172.0	194.1	234.8	282.4	232.5	216.2	222.0	91.32	.31	
IV, 2. 27th February.	6 52 A.M.	1	78.9	81.00	158.6	170.1	206.3	253.1	198.8	190.2	196.2	81.17	− .02	Capt. Branfill at K.
	7 7	2	79.3	80.88	154.4	166.0	205.9	251.4	195.5	188.7	193.7	80.96	+ .02	Lt. Rogers at L.
	7 38	3	80.4	80.75	156.4	167.5	206.6	252.2	195.6	188.1	194.4	80.84	.01	
	8 8	4	81.4	80.79	152.1	161.2	202.0	248.5	194.1	186.6	190.8	81.02	− .05	
	8 39	5	82.3	81.03	153.2	164.7	201.7	251.2	198.9	187.7	192.9	81.44	.05	
	9 8	6	83.9	81.38	153.6	158.8	202.0	244.9	192.4	183.4	189.2	82.04	.05	Observers chang-
	9 39	7	85.4	81.90	152.1	160.1	200.4	245.1	196.0	184.9	189.8	82.84	.11	ed places.
	10 9	8	88.0	82.59	148.6	157.2	197.0	244.4	194.7	181.4	187.2	83.92	.18	
	10 40	9	89.0	83.62	148.4	161.2	199.3	245.2	196.4	183.2	189.0	85.10	.17	
	11 10	10	90.2	84.60	151.2	162.5	205.6	255.0	202.7	186.2	193.9	86.30	.14	Capt. Basevi at K.
	11 39	11	91.4	85.69	151.9	167.7	209.1	252.3	202.8	187.8	195.3	87.50	.08	„ Herschel at L.
	0 9 P.M.	12	91.4	86.74	154.6	172.3	213.4	259.0	207.4	188.2	199.2	88.67	+ .01	
	0 40	13	91.3	87.62	156.4	174.1	220.9	260.2	209.5	195.0	202.7	89.38	.04	
	1 7	14	92.1	88.31	160.0	176.5	219.0	264.4	208.9	197.9	204.5	89.89	.04	
	1 39	15	93.4	89.13	167.8	181.4	219.5	267.1	215.4	198.6	208.3	90.63	.03	
	2 9	16	92.8	89.92	171.6*	181.4	222.3	267.4	220.1	204.1	211.2	91.52	.06	Observers chang-
	2 38	17	92.4	90.53	169.1	183.1	224.0	270.7	221.9	209.6	213.1	92.12	.10	ed places.
	3 8	18	92.8	91.08	176.4	187.1	232.3	278.2	226.8	212.9	219.0	92.61	.13	
	3 38	19	92.9	91.46	175.0	191.8	233.5	281.8	229.4	214.8	221.1	92.85	.23	
	4 9	20	92.0	91.63	178.6	199.0	244.4	288.2	233.7	221.8	227.6	82.85	.37	

The thermometers on Standard A were Nos. 7295 and 7298.

On Bar B, left end, Thermometer on iron No. 7291, on brass No. 7287; right end, Thermometer on iron No. 7292, on brass No. 7290.

February 26th (13) Cloudy sky with north wind.
„ 27th (3) Clear sky, strong northerly wind.
„ „ (5) Sky partially overcast.

* In original record 171.4

Preliminary results of the comparisons of the compensation bars A, B, C, D, E, H, with the Standard before and after the 4th measurement. Brass components East.

Group and Date 1869.	Times of comparisons.	No. of comparison.	Temperature of Air.	Temperature of Standard.	Preliminary excess of bars over Standard at 62° Fahrenheit, in division of K micrometer, 1 *division* = 1·277 *m.y* of A: A	B (x'')	C	D	E	H	Mean (X'')	Temperatures of components of B: $62° + T_b$ Temp: of brass bar.	*t*, excess of iron over brass.	Remarks.
	h. m.		°	°										
IV, 3. 9th March.	6 44 A.M.	1	78.9	80.55	148.5	166.4	206.7	251.4	180.6	185.2	189.8	82.33	+ .01	Capt. Basevi at K.
	7 16	2	80.5	80.37	149.3	160.0	200.1	236.4	179.2	181.9	184.5	81.97	− .05	„ Branfill at L.
	7 42	3	82.2	80.39	152.1	164.9	204.5	241.9	178.7	181.1	187.2	81.98	.11	
	8 9	4	84.0	80.65	141.7	156.8	189.2	232.7	176.4	171.9	178.1	82.32	.22	
	8 38	5	85.7	81.20	134.3	150.4	183.1	227.1	161.5	161.2	169.6	83.07	.38	
	9 13	6	87.4	82.03	123.6	138.0	180.8	219.9	165.6	154.1	163.7	84.17	.53	Observers chang-
	9 38	7	88.4	82.75	124.4	139.0	177.8	218.9	165.1	164.0	164.9	85.11	.59	ed places.
	10 8	8	89.8	83.73	128.1	134.1	179.7	220.2	167.6	161.6	165.2	86.26	.66	
	10 37	9	91.5	84.77	127.3	141.6	176.2	221.1	167.9	164.1	166.4	87.46	.64	
	11 10	10	94.7	86.08	136.9	146.6	179.6	229.9	180.6	167.5	173.5	88.81	.55	Capt. Herschel at K.
	11 38	11	95.1	87.44	137.4	151.6	187.1	228.2	182.7	171.2	176.4	90.10	.44	Lt. Rogers at L.
	0 10 P.M.	12	95.3	88.91	143.5	164.4	196.0	249.0	206.4	184.3	190.6	91.49	.29	
	0 40	13	92.6	89.99	155.3	168.6	207.1	256.2	191.2	190.6	194.8	92.51	.16	
	1 9	14	92.8	90.55	158.9	183.5	217.0	264.3	211.2	195.8	205.1	92.79	.09	
	1 42	15	92.7	91.00	170.7	186.9	228.6	272.7	215.3	204.6	213.1	93.05	+ .07	Observers chang-
	2 9	16	92.3	91.30	171.0	186.0	229.5	269.6	210.9	200.9	211.3	93.18	.20	ed places.
	2 39	17	91.1	91.49	182.1	194.5	236.2	280.2	218.6	211.0	220.4	93.27	.32	
	3 9	18	90.2	91.53	185.3	201.9	242.7	287.9	226.4	216.6	226.8	93.16	.39	
	3 39	19	89.9	91.41	189.2	204.1	243.9	284.3	226.1	211.2	226.5	92.92	.47	
	4 10	20	89.9	91.26	188.3	204.9	244.2	291.0	227.9	215.1	228.6	92.64	.56	
IV, 4. 10th March.	6 42 A.M.	1	79.0	80.23	154.0	170.0	207.4	249.5	192.3	185.2	193.1	81.58	+ .09	Lt. Rogers, at K.
	7 8	2	80.0	80.12	152.4	170.5	206.8	253.5	194.6	189.9	194.6	81.36	.06	Capt. Basevi at L.
	7 38	3	81.4	80.14	150.4	160.5	205.1	243.6	187.8	183.8	188.5	81.44	.04	
	8 7	4	83.3	80.41	143.4	152.3	194.3	239.7	183.9	181.4	182.5	82.01	− .25	
	8 37	5	85.8	80.93	126.7	141.2	187.0	229.8	176.8	172.1	172.3	82.97	.49	
	9 8	6	87.9	81.73	130.0	140.4	183.7	229.8	175.9	172.4	172.0	84.22	.70	Observers chang-
	9 38	7	89.3	82.69	120.5	136.1	176.5	225.7	171.3	168.1	166.4	85.63	.83	ed places.
	10 7	8	89.7	83.76	117.8	136.3	175.7	225.9	173.9	168.9	166.4	86.98	.88	
	10 37	9	90.3	84.86	130.4	150.7	188.2	238.2	179.3	175.8	177.1	88.07	.68	
	11 12	10	91.4	86.07	135.2	157.8	198.8	241.7	195.8	188.5	186.2	89.22	.38	Capt. Branfill at K.
	11 38	11	93.2	87.10	140.6	157.4	201.6	246.0	198.7	191.9	189.4	90.20	.30	„ Herschel at L.
	0 9 P.M.	12	93.0	88.22	142.4	164.0	212.1	252.3	204.3	196.8	195.3	91.32	.24	
	0 39	13	92.4	89.07	155.9	173.4	216.2	256.3	207.0	203.5	202.1	91.91	.12	
	1 10	14	92.6	89.60	159.3	180.3	221.7	269.5	211.1	207.3	208.2	91.89	+ .05	
	1 40	15	92.6	89.97	164.8	184.0	226.4	268.0	212.8	212.5	211.4	91.85	.09	
	2 10	16	91.4	90.25	177.3	190.9	235.6	277.9	221.5	222.7	221.0	91.76	.16	Observers chang-
	2 40	17	89.2	90.33	172.9	189.0	233.8	276.9	224.6	222.6	220.0	91.51	.27	ed places.
	3 9	18	87.6	90.17	184.8	199.5	243.3	280.7	228.8	228.0	227.5	91.08	.44	
	3 39	19	87.2	89.81	184.5	203.0	236.6	284.9	232.1	226.5	227.9	90.50	.54	
	4 10	20	85.9	89.40	183.9	198.4	238.4	284.5	231.7	225.9	227.1	89.92	.61	
Mean of 4 days comparisons.				85.38	154.3	168.2	208.8	253.4	199.4	191.6	195.8	87.00	− .08	

March 10th (2) Early morning cloudy; afterwards finer; many cumuli, slight north wind.

Referring to section 3 of Chapter VII, and adopting the symbols there exployed, it will be seen that the normal excess of the length of a compensation bar over that of the standard at the temperature of 62° F. as determined from comparisons at any other temperatures, is

$$= B' - A' - (e'_i - de'_i)\, t \frac{m}{m-n} - \eta\, T_b + (E'_a - dE'_a)\, T_a$$

For convenience, the relations of the compensation bars to the standard were expressed, in the first instance, in divisions of K, one of the two micrometers which were used in making the comparisons; thus $E'_a = e'_i = 17{\cdot}74$ K-divisions; and $dE'_a = 0{\cdot}68$ division $= de'_i$ by assumption. The value of the quantity $m \div (m-n)$ which is dependent on the distances of the compensation points from the bars, was taken as 2·9. Thus if x is put for the normal excess of any one of the bars, as B, over the standard, in K-divisions, we have

$$x = (B' - A' + E'_a\, T_a) - 51{\cdot}4\, t - \eta\, T_b - dE'_a\, T_a + 2{\cdot}9\, t\, de'_i$$

The numerical values of the term within the brackets—which term is expressed by the symbol x'' for bar B and by the symbol X'' for the mean of all the bars, in the investigations in Chapter VIII—are given for every comparison of each bar and of the mean of the bars, with the standard, in the preceding tables; the values of t are also given, and those of T_a and T_b may be obtained by subtracting 62° from the given temperatures of the standard and of the brass component of bar B;—thus, with the exception of η, all the data are forthcoming for obtaining a value of x from each of the comparisons. Before proceeding further it was therefore necessary to determine the value of η from the comparisons of compensation bar B with the standard.

This has been done in the manner indicated in section 4 of Chapter VIII; putting $x' = x'' - 51{\cdot}4t$, we get

$$x = x' - \eta\, T_b - (T_a - 2{\cdot}9\, t)\, dE'_a$$

in which form the eight following values of x, obtained from the means of the groups of comparisons before and after each measurement of the base, are expressed.

Comparisons	I 1, and I 2,	$x = 160{\cdot}8 - 18{\cdot}1\,\eta - 16{\cdot}5\, dE'_a$
„	I 3, and I 4,	$x = 162{\cdot}5 - 21{\cdot}5$ „ $- 19{\cdot}0$ „
„	II 1, and II 2,	$x = 166{\cdot}6 - 22{\cdot}2$ „ $- 21{\cdot}2$ „
„	II 3, and II 4,	$x = 170{\cdot}8 - 23{\cdot}4$ „ $- 22{\cdot}5$ „
„	III 1, and III 2,	$x = 171{\cdot}9 - 23{\cdot}1$ „ $- 22{\cdot}2$ „
„	III 3, and III 4,	$x = 175{\cdot}5 - 22{\cdot}8$ „ $- 22{\cdot}6$ „
„	IV 1, and IV 2,	$x = 170{\cdot}5 - 23{\cdot}9$ „ $- 22{\cdot}8$ „
„	IV 3, and IV 4,	$x = 174{\cdot}3 - 26{\cdot}1$ „ $- 24{\cdot}4$ „

Eliminating x from each of the primary equations, by it's value for the group to which it appertains, and proceeding by the method of minimum squares, the eight normal equations in η which are given at page (67) were determined, whence finally $\eta = 0{\cdot}75$ K-divisions.

Having determined the value of η, the next step is to determine the normal excess of the mean of all the compensation bars over the standard, treating bar B as a representative of all the others; this process has been fully described in section 5 of Chapter VIII, which should be referred to for all particulars.

The numerical values of X″, X′ and X, are given in the following table for every comparison, as expressed in K-divisions.

Brass Components West.

No. of comp.	Comparison I, 1			Comparison I, 2			Comparison I, 3			Comparison I, 4			No. of comp.
	X″	X′	X	X″	X′	X	X″	X′	X	X″	X′	X	
1	187·3	186·3	169·3	184·5	181·4	164·6	185·2	180·1	158·5	187·4	182·3	160·3	1
2	190·6	188·5	170·9	183·2	177·0	160·1	188·9	184·8	163·0	191·8	187·2	165·4	2
3	187·5	183·9	165·2	185·5	178·8	161·6	190·1	183·9	161·6	192·1	187·0	165·2	3
4	191·3	184·6	165·2	187·7	180·0	162·2	194·8	185·0	162·3	197·6	187·8	165·9	4
5	196·7	184·4	163·8	197·6	184·2	165·6	202·0	189·1	165·7	203·6	191·8	169·3	5
6	200·0	180·0	158·1	202·3	185·3	165·8	209·1	187·5	163·2	206·2	190·3	166·9	6
7	206·5	184·4	160·8	205·2	186·2	165·8	216·3	187·0	161·8	213·0	191·4	167·3	7
8	207·4	184·8	159·8	206·8	191·8	168·3	218·1	183·7	157·3	218·3	190·0	165·1	8
9	204·7	184·7	157·5	210·7	189·7	165·2	221·3	185·3	157·4	221·9	189·0	163·0	9
10	207·5	188·0	159·5	212·8	191·8	165·9	222·9	187·9	158·5	223·8	189·4	162·1	10
11	205·7	186·2	156·8	209·7	188·7	161·4	220·9	188·0	157·4	224·4	188·9	160·1	11
12	207·2	190·2	160·1	209·0	188·0	159·6	222·0	193·2	161·3	227·0	192·0	161·9	12
13	206·5	188·5	157·8	205·8	184·8	155·1	220·1	191·8	158·7	228·1	194·7	163·3	13
14	206·1	189·1	158·0	205·6	195·6	164·2	220·8	190·5	156·2	224·4	195·1	162·6	14
15	205·2	188·8	157·3	202·8	192·8	160·6	221·4	191·6	156·3	224·4	198·2	164·3	15
16				198·6	193·6	160·5	219·1	191·3	155·0	217·1	190·9	156·2	16
17				198·5	193·5	159·7	216·8	192·1	154·9	218·5	196·4	160·7	17
18				192·9	192·9	158·5	217·4	193·2	155·8	218·2	194·6	158·5	18
19							215·5	193·4	155·9	216·6	195·0	158·2	19
20										213·9	195·9	158·8	20
Means.	200·7	186·2	161·3	200·0	187·6	162·5	211·7	188·4	159·0	213·4	191·4	162·8	

Brass Components East.

No. of comp.	Comparison II, 1			Comparison II, 2			Comparison II, 3			Comparison II, 4			No. of comp.
	X″	X′	X	X″	X′	X	X″	X′	X	X″	X′	X	
1	187·0	186·5	163·1	189·7	182·0	157·1	184·1	182·0	157·9	184·6	178·9	155·9	1
2	185·6	186·6	163·5	189·8	186·2	161·6	182·5	183·5	159·6	185·7	184·2	161·4	2
3	185·9	190·0	166·6	188·3·	186·8	162·6	178·5	181·6	157·6	183·4	185·5	162·8	3
4	187·8	191·4	168·0	184·4	185·9	161·5	169·8	179·1	154·5	175·1	182·3	159·1	4
5	182·7	184·8	160·6	183·9	190·1	165·1	164·4	182·4	156·5	172·9	186·3	162·1	5
6	183·0	186·6	161·3	177·6	187·4	161·4	163·4	190·1	162·6	170·4	188·4	162·9	6
7	184·4	189·5	162·9	178·4	189·7	162·7	159·4	189·7	160·8	172·8	194·4	167·5	7
8	184·8	191·0	163·1	179·3	191·1	162·8	159·8	192·7	162·5	168·7	193·4	164·7	8
9	187·0	195·7	166·2	181·0	192·3	163·1	164·2	194·0	162·0	165·4	193·7	163·0	9
10	183·2	196·6	165·5	183·5	195·3	164·5	171·8	197·0	163·5	170·5	200·3	167·5	10
11	182·2	198·6	165·9	183·5	194·3	161·9	175·3	200·5	165·2	167·8	198·6	163·7	11
12	184·0	200·4	166·1	189·2	197·9	164·2	180·0	202·6	165·8	173·0	201·8	164·9	12
13	190·1	200·9	165·5	190·7	200·0	164·6	184·1	203·1	164·9	182·7	204·3	166·1	13
14	195·7	198·8	162·3	200·7	200·7	164·3	186·3	201·7	162·6	188·5	201·4	162·7	14
15	203·7	198·0	160·6	202·5	196·8	160·1	193·9	204·7	164·9	192·8	203·1	163·7	15
16	209·7	200·4	162·4	210·6	202·4	165·7	201·2	206·3	166·0	195·3	200·4	160·4	16
17	205·8	191·9	153·0	203·5	194·2	157·6	205·8	204·3	163·8	205·5	203·4	163·3	17
18	215·1	197·6	158·3	211·2	198·3	161·9	210·3	203·6	162·9	212·8	206·6	166·5	18
19	222·7	200·6	160·8	214·0	197·6	161·4	214·8	202·5	161·8	216·9	206·1	166·1	19
20				214·8	194·2	158·5	217·0	200·6	159·9	218·3	202·9	163·2	20
Means.	192·7	194·0	162·9	192·8	193·2	162·1	183·3	195·1	161·8	185·2	195·8	163·4	

Brass Components West.

No. of comp.	Comparison III, 1			Comparison III, 2			Comparison III, 3			Comparison III, 4			No. of comp.
	X″	X′	X	X″	X′	X	X″	X′	X	X″	X′	X	
1	189·3	183·1	157·0	199·0	187·7	162·3	190·7	188·6	163·1	190·7	188·1	164·7	1
2	189·4	182·7	157·0	197·1	186·8	161·9	188·6	187·6	162·1	192·6	190·0	166·8	2
3	192·3	186·1	160·2	194·5	184·7	160·5	186·9	185·9	160·6	190·8	188·2	165·0	3
4	195·1	190·0	163·5	195·5	187·8	163·6	184·9	187·0	161·6	192·8	191·8	168·1	4
5	199·8	192·6	165·3	194·4	188·2	163·4	185·2	189·8	164·2	193·2	191·7	167·5	5
6	200·5	191·8	163·3	194·1	189·0	164·0	184·5	195·3	169·0	194·7	194·2	168·9	6
7	204·7	191·8	162·4	193·8	189·7	163·8	183·9	196·2	168·9	193·4	196·5	170·0	7
8	205·3	195·0	164·2	196·8	195·3	168·2	179·8	199·3	170·5	192·1	202·9	174·8	8
9	203·5	196·3	164·1	193·0	194·5	166·0	177·4	202·1	171·3	185·0	198·4	169·1	9
10	205·7	202·6	168·9	190·5	194·1	164·6	181·4	209·7	177·7	185·4	203·4	172·4	10
11	201·3	202·3	167·3	192·1	198·3	167·6	178·7	207·5	174·1	181·7	204·3	171·5	11
12	198·6	205·8	169·5	190·2	200·5	168·5	178·2	211·1	176·0	179·7	208·5	173·8	12
13	194·5	209·4	171·9	182·7	199·7	166·2	178·5	212·4	176·0	183·8	216·7	180·6	13
14	188·2	205·2	166·8	180·3	200·3	165·2	179·3	212·7	174·9	181·2	215·6	178·1	14
15	186·9	208·5	169·0	179·0	201·6	165·3	188·0	220·4	181·5	182·0	218·0	179·0	15
16	186·3	205·8	165·6	181·1	202·2	165·1	183·8	214·6	175·0	188·0	223·0	183·3	16
17	188·3	207·3	166·4	186·8	202·2	164·7	186·1	218·5	178·3	183·0	219·0	178·6	17
18	190·3	209·3	167·9	193·2	207·1	169·0	183·5	216·4	175·6	183·7	218·1	177·2	18
19	192·7	211·7	170·1	193·0	206·4	167·8	187·4	223·4	182·1	186·0	225·6	184·0	19
20	189·3	209·9	167·9	194·6	206·4	167·7	184·4	218·8	177·6	182·3	222·4	180·5	20
Means.	195·1	199·4	165·4	191·1	196·1	165·3	183·6	204·9	172·0	187·1	205·8	173·7	

Brass Components East.

No. of comp.	Comparison IV, 1			Comparison IV, 2			Comparison IV, 3			Comparison IV, 4			No. of comp.
	X″	X′	X	X″	X′	X	X″	X′	X	X″	X′	X	
1	188·7	188·2	162·3	196·2	197·2	169·9	189·8	189·3	161·5	193·1	188·5	161·6	1
2	192·3	191·8	166·3	193·7	192·7	165·5	184·5	187·1	159·5	194·6	191·5	164·7	2
3	185·9	188·5	162·9	194·4	193·9	167·1	187·2	192·9	165·2	188·5	190·6	163·6	3
4	186·5	193·2	167·2	190·8	193·4	166·2	178·1	189·4	161·2	182·5	195·4	167·4	4
5	184·9	191·6	165·1	192·9	195·5	167·9	169·6	189·1	159·5	172·3	197·5	167·8	5
6	182·0	191·8	164·4	189·2	191·8	163·5	163·7	190·9	159·6	172·0	208·0	176·5	6
7	182·2	192·5	164·3	189·8	195·5	166·2	164·9	195·2	162·6	166·4	209·1	175·7	7
8	179·7	192·0	162·7	187·2	196·5	165·7	165·2	199·1	164·8	166·4	211·6	176·3	8
9	179·8	194·2	163·7	189·0	197·7	165·4	166·4	199·3	163·4	177·1	212·1	175·6	9
10	181·4	196·8	164·9	193·9	201·1	167·2	173·5	201·8	164.2	186·2	205·7	168·2	10
11	184·5	200·9	167.6	195·3	199·4	164·0	176·4	199·0	159·7	189·4	204·8	165·9	11
12	188·5	199·8	165·0	199·2	198·7	161·9	190·6	205·5	164·5	195·3	207·6	167·3	12
13	192·7	201·4	165·3	202·7	200·6	162·7	194·8	203·0	160·8	202·1	208·8	167·7	13
14	198·3	202·9	165·8	204·5	202·4	163·7	205·1	209·7	167·0	208·2	205·6	164·5	14
15	202·2	202·7	164·7	208·3	206·8	167·0	213·1	209·5	166·6	211·4	206.8	165·6	15
16	207·9	204·8	165·8	211·2	208·1	167·1	211·3	201·0	158·1	221·0	212·8	171·5	16
17	212·1	207·0	167·3	213·1	208·0	166·2	220·4	204·0	161·0	220·0	266·1	165·3	17
18	217·5	208·8	168·5	219·0	212·3	169·8	226·8	206.8	164·1	227·5	204·9	164·8	18
19	222·2	209·9	169·3	221·1	209·3	166·6	226·5	202·3	160·0	227·9	200·1	160·9	19
20	222·0	206·1	165·4	227·6	208·6	166·0	228·6	199·8	158·0	227·1	195·7	157·4	20
Means.	194·6	198·2	165·4	201·0	200·5	166·0	191·8	198·7	162·1	196·5	203·2	167·4	

The relative lengths of each bar to the mean of all the bars are given in the following table :—

Comparisons I, 1—4.

In terms of	A − L	B − L	C − L	D − L	E − L	H − L
Micrometer divisions.	−43·7	−26·1	+15·2	+60·2	+4·1	−5·9
Millionths of a yard.	−55·8	−33·3	+19·4	+76·9	+5·2	−7·5
Comparisons II, 1—4.						
Micrometer divisions.	−40·6	−25·8	+13·3	+54·9	+0·8	−3·0
Millionths of a yard.	−51·8	−32·9	+17·0	+70·1	+1·0	−3·8
Comparisons III, 1—4.						
Micrometer divisions.	−43·8	−27·8	+12·8	+58·9	+3·5	−3·5
Millionths of a yard.	−55·9	−35·5	+16·3	+75·2	+4·5	−4·5
Comparisons IV, 1—4.						
Micrometer divisions.	−41·5	−27·6	+13·0	+57·6	+3·6	−4·2
Millionths of a yard.	−53·0	−35·2	+16·6	+73·6	+4·6	−5·4
Mean of the four groups of Comparisons.						
Micrometer divisions.	−42·4	−26·8	+13·6	+57·9	+3·0	−4·2
Millionths of a yard.	−54·1	−34·2	+17·3	+73·9	+3·8	−5·4

The only *partial* set of bars in each measurement occurs at the terminal point S, where the bars employed were A, B, and H. Since, on an average, A = L − 54·1, B = L − 34·2 and H = L — 5·4, we have

$$A + B + H = 3\,L - (93{\cdot}7\ \textit{m.y} = {\cdot}0003\ \textit{of a foot})$$

therefore — ·0001 is the correction to be applied to the actual mean lengths of all six bars at page (73) to deduce the corresponding mean length of the three bars in question, see page (76).

Comparisons between the Compensated Microscopes and the 6-inch brass scales during the four measurements, and determination of microscope errors with respect to $\frac{1}{20}$th of Standard **A**, *expressed in millionths of an inch* (m.i.)

When compared — 1869		Microscope	Scale compared with	Corrected temperature	Reduction to 62° Fah. Expansion of 6″ scale for 1° = *E* = 62·5 *m.i.*	Microscope — Microscope Scale. Observed value in terms of: Divisions	*m.i.*	Micros : Scale − $\frac{1}{20}$ **A**, at 62° Fah.	Micros : − $\frac{1}{20}$ **A**, at 62° Fah.	Errors of side telescope. Collimation	Parallelism
Before 1st measurement.	Jan. 12th	*W*	*W*	86°·7	+1544	+ 1·1	+ 44	− 47	+1541	+0′ 15″	Correct.
		M	*M*	86·2	1513	− 3·7	− 370	+122	1265	0 0	
		T	*T*	85·8	1488	6·5	650	− 18	820	0 30	
		N	*T*	86·5	1531	8·3	830	18	683	0 15	
		U	*T*	86·9	1556	5·8	580	18	958	0 55	
		S	*M*	87·3	1582	0·6	60	+122	1644	0 5	
		V	*V*	86·7	1544	23·4	938	−133	473	0 10	
	„ 16th	*O*	*M*	84·3	1394	6·9	690	+122	826	1 10	
After set No. 69	„ 19th	*W*	*W*	86·4	+1525	+30·3	+1221	− 47	+2699	Not examined.	Not examined.
		M	*M*	86·8	1550	− 4·0	− 400	+122	1272		
		T	*T*	87·6	1600	0·0	0	− 18	1582		
		N	*T*	84·9	1431	−10·5	−1050	18	363		
		U	*T*	87·3	1582	8·6	860	18	704		
		S	*M*	86·6	1538	2·9	290	+122	1370		
		V	*V*	88·4	1650	21·7	870	−133	647		
After 1st measurement.	„ 23rd	*W*	*W*	89·9	+1744	+29·0	+1169	− 47	+2866	−0 42	− 9′ 28″
		M	*M*	88·5	1656	− 6·2	− 620	+122	1158	+0 16	8 51
		O	*M*	89·8	1738	9·8	980	122	880	0 38	11 48
		N	*T*	90·3	1769	13·5	1350	− 18	401	−2 34	14 25
		U	*T*	89·8	1738	15·2	1520	18	200	+0 40	8 47
		S	*M*	90·2	1763	4·2	420	+122	1465	0 8	4 54
		V	*V*	89·3	1707	25·6	1026	−133	548	0 9	9 55
Before 2nd measurement.	„ 30th	*S*	*M*	89·7	+1731	− 3·7	− 370	+122	+1483		Correct.
	„ 29th	*W*	*W*	85·3	1456	+34·4	+1387	− 47	2796		
	„ 30th	*O*	*M*	89·2	1700	−11·3	−1130	+122	692		
	„ 29th	*N*	*T*	83·1	1319	6·3	630	− 18	671		
		U	*T*	82·6	1288	8·5	850	18	420		
	„ 30th	*M*	*M*	90·5	1782	6·7	670	+122	1234		
	„ 29th	*V*	*V*	87·7	1606	+ 6·1	+ 245	−133	1718		
After set No. 75	Feb. 4th	*S*	*S*	89·6	+1725	0·0	0	+ 4	+1729	Not examined.	+ 9 46
		W	*W*	91·4	1838	+26·7	+1076	− 47	2867		− 0 26
		O	*M*	86·8	1550	− 9·7	− 970	+122	702		0 34
		N	*T*	87·1	1569	14·1	1410	− 18	141		1 34
		U	*T*	88·0	1625	13·0	1300	18	307		+ 2 17
		M	*M*	87·6	1600	3·7	370	+122	1352		0 4
		V	*V*	88·6	1663	+12·9	+ 517	−133	2047		1 58
After 2nd measurement.	„ 9th	*S*	*S*	85·8	+1488	+ 4·3	+ 430	+ 4	+1922	+0 51	+ 0 46
		W	*W*	84·2	1388	31·7	1278	− 47	2619	−0 30	− 0 34
		O	*M*	88·6	1663	−16·2	−1620	+122	165	+1 12	0 0
		N	*T*	86·0	1500	10·5	1050	− 18	432	−2 0	+ 0 17
		U	*T*	87·1	1569	9·9	990	18	561	+0 9	+ 0 15
		M	*M*	85·1	1444	5·3	530	+122	1036	1 24	+ 0 43
		V	*V*	84·9	1431	+15·5	+ 621	−133	1919	0 21	− 0 5

Note. 1 division of V micrometer = 40·10 (*m.i.*)
1 „ W „ = 40·29 (*m.i.*)
For the micrometers of all the other scales, 1 division = 100·00 (*m.i.*)

Comparisons between the Compensated Microscopes and the 6-inch brass scales—(Continued.)

When compared — 1869		Microscope	Scale compared with	Corrected temperature	Reduction to 62° Fah. Expansion of 6″ scale for 1° = E = 62·5 m.i.	Microscope — Microscope Scale: Observed value in terms of		Micros: Scale − $\frac{1}{20}$ A, at 62° Fah.	Micros: − $\frac{1}{20}$ A, at 62° Fah.	Errors of side telescope.	
						Divisions	m. i.			Collimation	Parallelism
Before 3rd measurement.	Feb. 14th	W	W	89°·6	+1725	+27·5	+1109	− 47	+2787		
		U	T	92·7	1919	−12·4	−1240	118	661		
After set No. 70	„ 18th	W	W	94·8	+2050	+19·5	+ 786	− 47	+2789		+1′ 8″
		S	S	94·6	2038	− 3·2	− 320	+ 4	1722		1 51
		O	M	95·9	2119	15·3	1530	122	711		0 21
		N	T	95·6	2100	16·8	1680	− 18	402		−0 57
		U	T	94·4	2025	20·0	2000	18	7		+0 34
		M	M	96·2	2138	8·3	830	+122	1430		2 13
		V	V	95·9	2119	0·0	0	−133	1986		−0 19
After set No. 116	„ 21st	W	W	80·4	+1150	+67·8	+2733	− 47	+3836		
		W	W	85·9	1494	12·8	516	47	1963		
After 3rd measurement.	„ 23rd	W	W	86·9	+1556	+ 7·5	+ 302	− 47	+1811	−0′ 20″	−0 41
		S	S	88·9	1681	− 1·7	− 170	+ 4	1515	+0 53	Not examined.
		O	M	87·9	1619	11·6	1160	122	581	0 39	
		N	T	86·3	1519	6·4	640	− 18	861	−1 20	
		U	T	87·1	1569	19·7	1970	18	− 419	+1 10	
		M	N	87·4	1587	3·4	340	+122	+1369	2 50	
		V	V	86·9	1556	+18·2	+ 729	−133	2152	0 10	
Before 4th do.	„ 27th	W	W	87·4	+1587	+41·4	+1669	− 47	+3209		
After set No. 72	Mar. 4th	W	W	91·7	+1856	+28·5	+1149	− 47	+2958	Not examined.	+1 31
		S	S	91·8	1863	− 2·9	− 290	+ 4	1577		0 22
		O	M	88·9	1681	12·4	1240	122	563		0 0
		N	T	88·5	1656	11·6	1160	− 18	478		+5 29
		U	T	90·4	1775	22·3	2230	18	− 473		1 18
		M	M	91·6	1850	+19·3	+1930	+122	+3902		0 26
		V	V	95·9	2119	1·4	56	−133	2042		0 8
After set No. 124	„ 7th	T	T	86·4	+1525	− 8·8	− 880	− 18	+ 627		
After 4th measurement.	„ 8th	W	W	94·9	+2056	+23·9	+ 963	− 47	+2972	−0 25	+2 17
		S	S	93·6	1975	− 5·0	− 500	+ 4	1479	+1 43	0 32
		O	M	93·5	1969	15·6	1560	122	531	−0 8	−0 48
		T	T	91·2	1825	7·0	700	− 18	1107	0 10	+0 7
		U	T	91·7	1856	20·5	2050	18	− 212	+1 20	1 3
		M	M	91·3	1832	+18·7	+1870	+122	+3824	−0 53	0 0
		V	K	92·8	1925	− 0·9	− 36	−133	1756	0 10	0 15

The "Error of Collimation" was in all cases determined by Gauss' method, the amount of error being measured by one of the two theodolites.

The "Error of Parallelism" was found by means of a scale attached to the horns of the Boning instrument, which was read by the side telescope both "out" and "in", the bar dots being intersected in each position by the microscope.

The reading of the scale corresponding to centre of telescope of Boning instrument, *i.e.* the line of the dots, was known, $= d$ suppose; the ½ distance between the optical axis of side telescope in both positions $= a$, $c =$ effect of error of collimation on scale, $p =$ effect of error of parallelism, then

$$\text{scale reading (telescope "in")} = d + a + c + p$$
$$\text{,, \ (\ ,, \ "out")} = d - a - c + p$$
$$\text{Sum of readings} = 2d + 2p$$

whence

$$p = \tfrac{1}{2}\,\text{sum} - d.$$

The angular value of p is obtained by dividing by the distance of the microscope from Boning instrument expressed in divisions of the scale multiplied by Sin 1″.

Table of individual Microscope Errors and corresponding Temperatures, from pages $X_{—16}$ *and* $X_{—17}$*, together with the mean values adopted for each measurement.*

Measurement	When compared	M		N		O		S		T		U		V		W	
		Temp	Error	Temp	Error	Temp	Error	Temp	Error	Temp	Error	Temp	Error	Temp	Error	Temp	Error
		°	m.i.	°	m.i.	°	m.i.	°	m.i.	°	m.i.	°	m.i.	°	m.i.	°	m.i.
I	Before 1st measurement,	86·2	+1265	86·5	+683	84·3	+826	87·3	+1644	85·8	+820	86·9	+958	86·7	+473	86·7	+1541
	After set No. 69	86·8	1272	84·9	363			86·6	1370	87·6	1582	87·3	704	88·4	647	86·4	2699
	„ 1st measurement,	88·5	1158	90·3	401	89·8	880	90·2	1465	...	...	89·8	200	89·3	548	89·9	2866
	Means, ...	87·2	1232 (1)	87·2	482 (2)	87·1	853 (3)	88·0	1493 (4)	86·7	1201 (5)	88·0	621 (6)	88·1	556 (7)	86·7	1541 (8)
	„	...	...	...	...	...	...	...	...	...	...	...	...	...	...	88·2	2783 (9)
II	Before 2nd measurement,	90·5	+1234	83·1	+671	89·2	+692	89·7	+1483	...	...	82·6	+420	87·7	+1718	85·3	+2796
	After set No. 75	87·6	1352	87·1	141	86·8	702	89·6	1729	...	...	88·0	307	88·6	2047	91·4	2867
	„ 2nd measurement,	85·1	1036	86·0	432	88·6	165	85·8	1922	...	...	87·1	561	84·9	1919	84·2	2619
	Means, ...	87·7	1207 (10)	85·4	415 (11)	88·2	520 (12)	88·4	1711 (13)	...	...	85·9	429 (14)	87·1	1895 (15)	87·0	2761 (16)
III	Before 3rd measurement,	...	...	...	...	...	...	...	...	...	...	92·7	+661	...	...	89·6	+2787
	After set No. 70	96·2	+1430	95·6	+402	95·9	+711	94·6	+1722	...	...	94·4	7	95·9	+1986	94·8	2789
	„ ... 116	...	...	...	...	...	...	...	...	...	...	...	...	...	...	80·4	3836
																85·9	1963
	„ 3rd measurement,	87·4	1369	86·3	861	87·9	581	88·9	1515	...	...	87·1	−419	86·9	2152	86·9	1811
	Means, ...	91·8	1400 (17)	91·0	632 (18)	91·9	646 (19)	91·8	1619 (20)	...	...	91·4	+83 (21)	91·4	2069 (22)	88·3	3137 (23)
	„	...	...	...	...	...	...	...	...	...	...	...	...	...	...	86·4	1887 (24)
IV	Before 4th measurement,	...	...	...	...	...	...	...	...	...	...	...	...	...	...	87·4	+3209
	After set No. 72	91·6	+3902	88·5	+478	88·9	+563	91·8	+1577	...	...	90·4	−473	95·9	+2042	91·7	2958
	„ ... 124	...	...	...	...	...	...	...	...	86·4	+627						
	„ 4th measurement,	91·3	3824	...	...	93·5	531	93·6	1479	91·2	1107	91·7	−212	92·8	1756	94·9	2972
	Means, ...	91·5	3863 (25)	88·5	+478 (26)	91·2	547 (27)	92·7	1528 (28)	88·8	867 (29)	91·1	−343 (30)	94·4	1899 (31)	91·3	3046 (32)

NOTE.—The numbers written below the mean values, thus (1) (2) &c., are the "reference numbers" by which the adopted microscope errors (and temperatures) are indicated in the equations on page $X_{—19}$.

The equations which determine the microscope errors per set (*or m.e*) are the following :—

Measurement I

Reference numbers.	m.i.		
$(m.e.)_1 = 1 + 2 + 4 + 5 + 6 + \frac{7+8}{2}$	$= 6078$ at $(62^\circ + 25^\circ 4)$	applicable to sets Nos.	1 to 37
$(m.e.)_2 = 1 + 2 + 3 + 4 + 6 + \frac{5+7}{2}$	$= 5560$ at $(62 + 25{\cdot}5)$	,, ,,	38 to 43
$(m.e.)_3 = 1 + 2 + 3 + 4 + 6 + \frac{7+9}{2}$	$= 6351$ at $(62 + 25{\cdot}6)$	,, ,,	44 to 141
$(m.e.)_4 = 1 + 3 + \frac{7+9}{2}$	$= 3755$ at $(62 + 25{\cdot}5)$	,, set No.	142

Measurement II

$(m.e.)_5 = 12 + 16 + \frac{13+15}{2}$	$= 5084$ at $(62 + 25{\cdot}7)$	,, ,,	1
$(m.e.)_6 = 10 + 11 + 12 + 14 + 16 + \frac{13+15}{2}$	$= 7135$ at $(62 + 25{\cdot}0)$	,, sets Nos.	2 to 142

Measurement III

$(m.e.)_7 = 17 + 18 + 19 + 20 + 21 + \frac{22+23}{2}$	$= 6983$ at $(62 + 29{\cdot}3)$	,, ,,	1 to 116
$(m.e.)_8 = 17 + 18 + 19 + 20 + 21 + \frac{22+24}{2}$	$= 6358$ at $(62 + 29{\cdot}1)$	,, ,,	117 to 141
$(m.e.)_9 = 19 + 20 + \frac{22+24}{2}$	$= 4243$ at $(62 + 28{\cdot}9)$	,, set No.	142

Measurement IV

$(m.e.)_{10} = 27 + 28 + \frac{31+32}{2}$	$= 4548$ at $(62 + 30{\cdot}3)$	,, ,,	1
$(m.e.)_{11} = 25 + 26 + 27 + 28 + 30 + \frac{31+32}{2}$	$= 8546$ at $(62 + 29{\cdot}3)$	,, sets Nos.	2 to 97
$(m.e.)_{12} = 25 + 27 + 28 + 29 + 30 + \frac{31+32}{2}$	$= 8935$ at $(62 + 29{\cdot}4)$	,, ,,	98 to 142

Hence the total microscope errors are as follows,

Measurement I

In Section **NX** $= 35\,(m.e)_1 = \overset{m.i.}{212730} - 6 \times 35 \times 25{\cdot}4\, dE = \overset{m.i.}{212730} - 5334\, dE = \overset{\text{feet of A}}{0{\cdot}0177} - 5334\, dE$

,, **XY** $= \begin{cases} 2\,(m.e)_1 = 12156 - 6 \times 2 \times 25{\cdot}4\, dE = 12156 - 305\, dE \\ 6\,(m.e)_2 = 33360 - 6 \times 6 \times 25{\cdot}5\, dE = 33360 - 918\, dE \\ 27\,(m.e)_3 = 171477 - 6 \times 27 \times 25{\cdot}6\, dE = 171477 - 4147\, dE \end{cases}$

$216993 - 5370\, dE = 0{\cdot}0181 - 5370\, dE$

,, **YZ** $= 35\,(m.e)_3 = 222285 - 6 \times 35 \times 25{\cdot}6\, dE = 222285 - 5376\, dE = 0{\cdot}0185 - 5376\, dE$

,, **ZS** $= \begin{cases} 36\,(m.e)_3 = 228636 - 6 \times 36 \times 25{\cdot}6\, dE = 228636 - 5530\, dE \\ 1\,(m.e)_4 = 3755 - 3 \times 1 \times 25{\cdot}5\, dE = 3755 - 77\, dE \end{cases}$

$232391 - 5607\, dE = 0{\cdot}0194 - 5607\, dE$

Total microscope errors—(Continued.)

Measurement II

In Section **SZ** = $\begin{cases} 1\ (m.e)_5 = 5084 - 3 \times 1 \times 25{\cdot}7\, dE = 5084 - 77\, dE \\ 36\ (m.e)_6 = 256860 - 6 \times 36 \times 25{\cdot}0\, dE = 256860 - 5400\, dE \end{cases}$ (m.i.)

$261944 - 5477\, dE = 0{\cdot}0218 - 5477\, dE$ (feet of **A**)

„ **ZY** = $35\ (m.e)_6 = 249725 - 6 \times 35 \times 25{\cdot}0\, dE = 249725 - 5250\, dE = 0{\cdot}0208 - 5250\, dE$

„ **YX** = $35\ (m.e)_6 = 249725 - 6 \times 35 \times 25{\cdot}0\, dE = 249725 - 5250\, dE = 0{\cdot}0208 - 5250\, dE$

„ **XN** = $35\ (m.e)_6 = 249725 - 6 \times 35 \times 25{\cdot}0\, dE = 249725 - 5250\, dE = 0{\cdot}0208 - 5250\, dE$

Measurement III

In Section **NX** = $35\ (m.e)_7 = 244405 - 6 \times 35 \times 29{\cdot}3\, dE = 244405 - 6153\, dE = 0{\cdot}0204 - 6153\, dE$

„ **XY** = $35\ (m.e)_7 = 244405 - 6 \times 35 \times 29{\cdot}3\, dE = 244405 - 6153\, dE = 0{\cdot}0204 - 6153\, dE$

„ **YZ** = $35\ (m.e)_7 = 244405 - 6 \times 35 \times 29{\cdot}3\, dE = 244405 - 6153\, dE = 0{\cdot}0204 - 6153\, dE$

„ **ZS** = $\begin{cases} 11\ (m.e)_7 = 76813 - 6 \times 11 \times 29{\cdot}3\, dE = 76813 - 1934\, dE \\ 25\ (m.e)_8 = 158950 - 6 \times 25 \times 29{\cdot}1\, dE = 158950 - 4365\, dE \\ 1\ (m.e)_9 = 4243 - 3 \times 1 \times 28{\cdot}9\, dE = 4243 - 87\, dE \end{cases}$

$240006 - 6386\, dE = 0{\cdot}0200 - 6386\, dE$

Measurement IV

In Section **SZ** = $\begin{cases} 1\ (m.e)_{10} = 4548 - 3 \times 1 \times 30{\cdot}3\, dE = 4548 - 91\, dE \\ 36\ (m.e)_{11} = 307656 - 6 \times 36 \times 29{\cdot}3\, dE = 307656 - 6329\, dE \end{cases}$

$312204 - 6420\, dE = 0{\cdot}0260 - 6420\, dE$

„ **ZY** = $35\ (m.e)_{11} = 299110 - 6 \times 35 \times 29{\cdot}3\, dE = 299110 - 6153\, dE = 0{\cdot}0249 - 6153\, dE$

„ **YX** = $\begin{cases} 25\ (m.e)_{11} = 213650 - 6 \times 25 \times 29{\cdot}3\, dE = 213650 - 4395\, dE \\ 10\ (m.e)_{12} = 89350 - 6 \times 10 \times 29{\cdot}4\, dE = 89350 - 1764\, dE \end{cases}$

$303000 - 6159\, dE = 0{\cdot}0253 - 6159\, dE$

„ **XN** = $35\ (m.e)_{12} = 312725 - 6 \times 35 \times 29{\cdot}4\, dE = 312725 - 6174\, dE = 0{\cdot}0261 - 6174\, dE$

Final deduction of the total lengths measured with the compensated microscopes.

In the foregoing reductions, the co-efficient of expansion for brass has been taken at ·000,010,417; whereas it appears from page (17) that ·000,009,855 is a more probable value. Accepting the latter, it may be found that $dE = 3·372$ (*m.i*). Hence, remembering that the length measured with a complete set of microscopes is equal to 3 feet of **A** + the corresponding (*m.e*) we have,

Total lengths measured with the compensated microscopes

Measurement I

	feet of A	feet of A
In section **N X** comprising 35 sets	= .... (35 × 3 + ·0177) − 5334 dE	= (105·0177 − ·0015) = 105·0162
In section **X Y** comprising 35 sets	= .... (35 × 3 + ·0181) − 5370 dE	= (105·0181 − ·0015) = 105·0166
In section **Y Z** comprising 35 sets	= .... (35 × 3 + ·0185) − 5376 dE	= (105·0185 − ·0015) = 105·0170
In section **Z S** comprising 36½ sets	= .... (36·5 × 3 + ·0194) − 5607 dE	= (109·5194 − ·0016) = 109·5178
In **N S** ...	... ...	= (424·5737 − ·0061) = 424·5676

Measurement II

In section **N X** comprising 35 sets	= .... (35 × 3 + ·0208) − 5250 dE	= (105·0208 − ·0015) = 105·0193
In section **X Y** comprising 35 sets	= .... (35 × 3 + ·0208) − 5250 dE	= (105·0208 − ·0015) = 105·0193
In section **Y Z** comprising 35 sets	= .... (35 × 3 + ·0208) − 5250 dE	= (105·0208 − ·0015) = 105·0193
In section **Z S** comprising 36½ sets	= .... (36·5 × 3 + ·0218) − 5477 dE	= (109·5218 − ·0016) = 109·5202
In **N S** ...	... ...	= (424·5842 − ·0061) = 424·5781

Measurement III

In section **N X** comprising 35 sets	= .... (35 × 3 + ·0204) − 6153 dE	= (105·0204 − ·0017) = 105·0187
In section **X Y** comprising 35 sets	= .... (35 × 3 + ·0204) − 6153 dE	= (105·0204 − ·0017) = 105·0187
In section **Y Z** comprising 35 sets	= .... (35 × 3 + ·0204) − 6153 dE	= (105·0204 − ·0017) = 105·0187
In section **Z S** comprising 36½ sets	= .... (36·5 × 3 + ·0200) − 6386 dE	= (109·5200 − ·0018) = 109·5182
In **N S** ...	... ...	= (424·5812 − ·0069) = 424·5743

Measurement IV

In section **N X** comprising 35 sets	= .... (35 × 3 + ·0261) − 6174 dE	= (105·0261 − ·0017) = 105·0244
In section **X Y** comprising 35 sets	= .... (35 × 3 + ·0253) − 6159 dE	= (105·0253 − ·0017) = 105·0236
In section **Y Z** comprising 35 sets	= .... (35 × 3 + ·0249) − 6153 dE	= (105·0249 − ·0017) = 105·0232
In section **Z S** comprising 36½ sets	= .... (36·5 × 3 + ·0260) − 6420 dE	= (109·5260 − ·0018) = 109·5242
In **N S** ...	... ...	= (424·6023 − ·0069) = 424·5954

Extracts from the Field Book of MEASUREMENT I, *and calculated heights of sets above the origin.*

Adopted heights above mean sea level.
North-End = ~~125·1~~ 112·0 feet.
South-End = ~~130·0~~ 122·0 feet.

Section NX

When compared — 1869	No. of the set	Mean time of ending	No. of bars used	Height of set above origin	Arrangement of Microscopes	Bar B $62° + T_b$	Bar B t	When compared — 1869	No. of the set	Mean time of ending	No. of bars used	Height of set above origin	Arrangement of Microscopes	Bar B $62° + T_b$	Bar B t
		h. m.		feet		°	°			h. m.		feet		°	°
Jany. 13th	1	7 54 A.M.	6	+ 2·90	(m.e)₁	73·88	− ·02	Jany. 14th	19	3 50 P.M.	6	+ 7·78	(m.e)₁	86·93	+ ·23
	2	9 28	6	3·58	,,	75·01	+ ·06	,, 15th	20	11 52 A.M.	6	8·09	,,	76·15	− ·03
	3	11 48	6	3·75	,,	80·14	·47		21	0 22 P.M.	6	8·69	,,	77·16	+ ·03
	4	0 44 P.M.	6	3·68	,,	81·42	·45		22	0 56	6	8·98	,,	78·39	·17
	5	1 33	6	3·95	,,	83·04	·43		23	1 43	6	9·13	,,	79·86	·22
	6	2 30	6	3·89	,,	84·23	·29		24	2 18	6	9·90	,,	80·99	·24
	7	3 30	6	4·84	,,	85·28	·16		25	2 47	6	10·26	,,	81·83	·22
	8	4 20	6	5·40	,,	86·03	·02		26	3 16	6	10·64	,,	82·35	·25
,, 14th	9	7 25 A.M.	6	5·21	,,	75·67	− ·02		27	3 44	6	10·99	,,	82·71	·26
	10	8 18	6	5·64	,,	75·94	+ ·02		28	4 17	6	11·19	,,	82·88	·21
	11	9 9	6	5·73	,,	76·85	·14	,, 16th	29	7 7 A.M.	6	11·55	,,	73·37	− · 1
	12	9 52	6	5·81	,,	77·84	·32		30	7 38	6	11·92	,,	73·52	− · 1
	13	11 53	6	5·44	,,	80·93	·43		31	8 18	6	12·54	,,	74·06	− ·04
	14	0 38 P.M.	6	6·00	,,	82·26	·41		32	8 43	6	12·90	,,	74·66	+ ·03
	15	1 30	6	6·50	,,	83·73	·44		33	9 10	6	13·09	,,	75·26	·11
	16	2 12	6	7·30	,,	84 77	·35		34	9 44	6	13·32	,,	75·98	·20
	17	2 44	6	7·47	,,	85·86	·34		35	0 10 P.M.	6	13·09	,,	79·03	·27
	18	3 15	6	7·44	,,	86·36	·29						Mean	79·84	+ ·191

The rear-end of set No. 1 stood exactly over the dot at North-End.
For measurements with compasses at **X**, see page X—31.

January 13th and 14th. Weather clear and bright throughout the day with much north wind chiefly about noon but more or less all day.

,, 15th. Three or four hours heavy rain this morning followed by heavily clouded sky; operations commenced a little before noon.

Section XY

When compared — 1869	No. of the set	Mean time of ending	No. of bars used	Height of set above origin	Arrangement of Microscopes	Bar B $62° + T_b$	Bar B t	When compared — 1869	No. of the set	Mean time of ending	No. of bars used	Height of set above origin	Arrangement of Microscopes	Bar B $62° + T_b$	Bar B t
Jany. 16th	36	0 42 P.M.	6	+ 14·27	(m.e)₁	80·51	+ ·25	Jany. 18th	54	1 36 P.M.	6	+ 18·94	(m.e)₃	83·39	+ ·52
	37	1 18	6	14·52	,,	81·62	·24		55	2 1	6	18·60	,,	84·24	·51
	38	1 58	6	14·71	(m.e)₂	82·77	·27		56	2 26	6	18·84	,,	84·77	·47
	39	2 40	6	14·98	,,	83·79	·26		57	2 56	6	18·74	,,	85·28	·47
	40	3 9	6	15·12	,,	84·44	·22		58	3 26	6	18·38	,,	85·66	·41
	41	3 42	6	15·79	,,	84·85	·20		59	3 48	6	17·98	,,	85·76	·39
	42	4 12	6	16·25	,,	85·07	·20	,, 19th	60	7 8 A.M.	6	17·44	,,	76·34	·01
,, 18th	43	7 19 A.M.	6	16·52	,,	74·56	·01		61	7 35	6	17·48	,,	76·20	·03
	44	7 54	6	16·61	(m.e)₃	74·57	− ·05		62	8 3	6	17·17	,,	76·41	·02
	45	8 26	6	16·91	,,	74·81	− ·04		63	8 27	6	16·74	,,	76·72	·15
	46	8 52	6	17·44	,,	75·36	+ ·06		64	8 52	6	16·52	,,	77·16	·14
	47	9 17	6	17·95	,,	75·97	·15		65	9 16	6	15·91	,,	77·56	·19
	48	9 44	6	18·10	,,	76·62	·22		66	9 45	6	15·99	,,	77·92	·17
	49	11 23	6	18·08	,,	79·20	·33		67	11 47	6	15·73	,,	80·33	·25
	50	11 51	6	18·23	,,	80·11	·34		68	0 13 P.M.	6	15·41	,,	81·03	·26
	51	0 15 P.M.	6	18·73	,,	81·04	·43		69	0 44	6	15·04	,,	81·84	·30
	52	0 38	6	18·89	,,	81·66	·44		70	3 25	6	14·08	,,	85·34	·30
	53	1 4	6	19·09	,,	82·26	·48						Mean	80·43	+ ·245

The terminal point of set No. 35 was the point of origin for set No. 36.
For measurements with compasses at **Y**, see page X—31.

January 18th. (43) Weather at first cloudy, afterwards bright with much north wind. (50) Clouds commenced gathering about noon and by the time work closed for the day and for the last 5 or 6 sets the sky was completely clouded; there was comparatively little wind.

,, 19th. (60) Sunshine and light clouds, little wind. (62) and (63) sky overcast. (67) Sunshine and light clouds.

Extracts from the Field Book of MEASUREMENT I—(Continued.)

Section YZ

When compared — 1869	No. of the set	Mean time of ending	No. of bars used	Height of set above origin	Arrangement of Microscopes	Bar B $62° + T_b$	Bar B t	When compared — 1869	No. of the set	Mean time of ending	No. of bars used	Height of set above origin	Arrangement of Microscopes	Bar B $62° + T_b$	Bar B t
		h. m.		feet		°	°			h. m.		feet		°	°
Jany. 19th	71	4 7 P.M.	6	+ 14·56	(m.e)₃	86·04	+ ·07	Jany. 21st	89	7 10 A.M.	6	+ 16·89	(m.e)₃	77·37	+ ·03
„ 20th	72	7 15 A.M.	6	14·03	„	75·96	·08		90	7 35	6	16·79	„	77·33	- ·00
	73	7 41	6	14·04	„	75·94	− ·02		91	7 58	6	16·97	„	77·39	·00
	74	8 14	6	14·41	„	75·95	− ·02		92	8 21	6	16·84	„	77·59	·05
	75	8 43	6	13·99	„	76·16	+ ·03		93	8 43	6	17·19	„	77·89	·15
	76	9 12	6	14·94	„	76·68	·12		94	9 5	6	17·11	„	78·23	·22
	77	9 47	6	14·45	„	77·43	·19		95	9 25	6	17·24	„	78·64	·28
	78	11 38	6	14·22	„	80·65	·41		96	9 49	6	17·13	„	79·13	·30
	79	0 57 P.M.	6	14·09	„	81·30	·41		97	11 20	6	16·75	„	81·19	·39
	80	0 26	6	14·89	„	81·94	·44		98	11 43	6	16·16	„	81·67	·38
	81	0 50	6	15·21	„	82·81	·51		99	0 3 P.M.	6	15·83	„	82·32	·39
	82	1 16	6	15·18	„	83·59	·56		100	0 24	6	15·55	„	82·89	·47
	83	1 42	6	15·39	„	84·26	·55		101	0 45	6	15·31	„	83·36	·49
	84	2 7	6	15·86	„	84·92	·49		102	1 5	6	14·92	„	83·80	·48
	85	2 37	6	15·84	„	85·52	·48		103	1 27	6	14·61	„	84·27	·48
	86	3 0	6	16·05	„	86·08	·42		104	1 58	6	13·92	„	84·70	·44
	87	3 24	6	16·26	„	86·44	·37		105	2 50	6	12·87	„	85·56	·40
	88	3 48	6	16·86	„	86·70	·29								
													Mean	81·19	+ ·293

The terminal point of set No. 70 was the point of origin for set No. 71.
For measurements with compasses at **Z**, see page X—31.

January 20th. (74) Sky overcast up to this, afterwards sunshine and light clouds.
„ 21st. (89) Sunshine, light clouds and high wind from north. (97) Clouds gathering, sunshine at intervals and high wind from north.

Section ZS

When compared — 1869	No. of the set	Mean time of ending	No. of bars used	Height of set above origin	Arrangement of Microscopes	Bar B $62° + T_b$	Bar B t	When compared — 1869	No. of the set	Mean time of ending	No. of bars used	Height of set above origin	Arrangement of Microscopes	Bar B $62° + T_b$	Bar B t
Jany. 21st	106	3 23 P.M.	6	+ 13·31	(m.e)₃	86·02	+ ·38	Jany. 22nd	125	2 53 P.M.	6	+ 6·08	(m.e)₃	83·97	+ ·35
	107	3 54	6	12·69	„	86·18	·36		126	3 17	6	5·39	„	84·26	·36
„ 22nd	108	7 30 A.M.	6	12·53	„	76·95	·01		127	3 41	6	5·41	„	84·61	·37
	109	7 58	6	12·16	„	76·96	− ·02		128	4 3	6	4·93	„	84·88	·33
	110	8 20	6	11·85	„	77·23	+ ·0:	„ 23rd	129	7 15 A.M.	6	4·30	„	77·14	− ·01
	111	8 41	6	11·25	„	77·50	·02		130	7 38	6	4·54	„	77·10	+ ·01
	112	8 59	6	10·78	„	77·69	·04		131	8 2	6	3·96	„	77·25	− ·02
	113	9 18	6	10·37	„	77·94	·09		132	8 24	6	4·14	„	77·49	+ ·02
	114	9 38	6	9·89	„	78·31	·11		133	8 45	6	3·49	„	77·93	·09
	115	10 9	6	9·41	„	78·72	·12		134	9 6	6	2·79	„	78·48	·19
	116	11 37	6	9·03	„	80·44	·04		135	9 32	6	1·92	„	79·03	·19
	117	11 58	6	8·52	„	80·75	·07		136	9 58	6	·96	„	79·77	·24
	118	0 21 P.M.	6	8·50	„	81·17	·13		137	11 41	6	− ·06	„	82·82	·29
	119	0 39	6	8·58	„	81·58	·17		138	0 2 P.M.	6	− ·11	„	83·52	·29
	120	1 0	6	8·32	„	82·04	·21		139	0 26	6	− ·48	„	84·18	·26
	121	1 21	6	8·08	„	82·49	·28		140	0 51	6	− 1·19	„	84·81	·26
	122	1 42	6	7·66	„	83·06	·36		141	1 23	6	− 1·60	„	85·64	·23
	123	2 6	6	6·77	„	83·52	·35		142	2 7	3	− 1·85	(m.e)₄	86·81	·22
	124	2 29	6	5·96	„	83·72	·37								
													Mean	81·14	+ ·183

The terminal point of set No. 105 was the point of origin for set No. 106.
Height of set No. 142 above dot at South-End = 1·68 feet.
For measurements with compasses at South-End, see page X—31.
January 21st. (107)—Slight rain during this set.
„ 22nd. (108)—Rain during the night, sky overcast and wind high from north. (115) Sky overcast, high wind from north. (118) Slight rain. (122) Slight rain.
„ 23rd. (129)—Sky overcast. (133) Sunshine with light clouds.

NOTE.—In set No. 142, bars A, B, and H were employed.

Extracts from the Field Book of MEASUREMENT II.

When compared — 1869	No. of the set	Mean time of ending	No. of bars used	Height of set above origin	Arrangement of Microscopes	Bar B: 62°+T_b	Bar B: t	When compared — 1869	No. of the set	Mean time of ending	No. of bars used	Height of set above origin	Arrangement of Microscopes	Bar B: 62°+T_b	Bar B: t
Section SZ															
		h. m.		feet		°	°			h. m.		feet		°	°
Jany. 30th	1	8 27 A.M.	3	+ 1·71	$(m.e)_6$	79·48	− ·21	Feb. 1st	20	2 8 P.M.	6	+ 9·38	$(m.e)_6$	90·14	+ ·37
	2	9 34	6	1·89	$(m.e)_6$	80·83	·39		21	2 45	6	10·12	„	91·20	·45
	3	10 13	6	2·14	„	83·02	·38		22	3 15	6	10·94	„	91·94	·58
	4	11 58	6	2·55	„	85·45	·06		23	3 55	6	11·22	„	92·70	·73
	5	0 31 P.M.	6	2·96	„	86·47	·0:		24	4 28	6	11·40	„	93·14	·86
	6	1 9	6	3·02	„	86·98	+ ·12	„ 2nd	25	7 5 A.M.	6	11·42	„	77·99	− ·04
	7	1 48	6	3·90	„	87·18	·24		26	7 35	6	11·76	„	77·63	·04
	8	2 23	6	4·59	„	87·28	·25		27	8 2	6	11·86	„	77·49	·08
	9	3 0	6	5·31	„	87·55	·32		28	8 35	6	12·07	„	77·70	·10
	10	3 30	6	6·25	„	88·05	·46		29	9 2	6	12·37	„	78·38	·20
Feb. 1st	11	7 40 A.M.	6	6·90	„	75·88	− ·08		30	9 50	6	13·45	„	79·32	·29
	12	8 15	6	7·29	„	76·40	·17		31	11 27	6	13·60	„	84·25	·32
	13	8 52	6	7·11	„	77·22	·26		32	11 58	6	14·10	„	85·22	·27
	14	9 33	6	7·20	„	78·53	·33		33	0 21 P.M.	6	14·51	„	86·38	·18
	15	10 31	6	7·69	„	79·90	·34		34	0 46	6	15·16	„	87·08	·06
	16	0 0 P.M.	6	8·45	„	84·78	·21		35	1 12	6	15·17	„	87·69	+ ·13
	17	0 35	6	8·45	„	85·94	·11		36	1 42	6	15·62	„	88·19	·31
	18	1 4	6	8·57	„	87·64	+ ·07		37	2 42	6	16·06	„	88·51	·45
	19	1 34	6	8·87	„	88·86	·26						Mean	86·90	− ·012

For measurements with compasses at South-End and at **Z**, see page X—31.

January 30th. (1) Cumuli, alternate shade and sunshine, E. wind rather fresh. (4) East pardas raised. (8) At this set the east pardas were let down on account of the wind.

February 1st. (11) Fine morning, little or no wind, clear sky except towards east. (20) Fresh easterly wind.

„ 2nd. (25) Fine clear morning, light N.E. wind. (32) Strong E. wind, sea breeze, sky clear.

When compared — 1869	No. of the set	Mean time of ending	No. of bars used	Height of set above origin	Arrangement of Microscopes	Bar B: 62°+T_b	Bar B: t	When compared — 1869	No. of the set	Mean time of ending	No. of bars used	Height of set above origin	Arrangement of Microscopes	Bar B: 62°+T_b	Bar B: t
Section ZY															
Feby. 2nd	38	3 20 P.M.	6	+ 16·64	$(m.e)_6$	88·80	+ ·55	Feby. 3rd	56	2 45 P.M.	6	+ 19·35	$(m.e)_6$	88·67	+ ·41
	39	3 50	6	17·17	„	88·63	·52		57	3 13	6	18·94	„	88·80	·46
„ 3rd	40	7 9 A.M.	6	17·59	„	76·10	− ·02		58	3 38	6	18·80	„	88·85	·52
	41	7 34	6	17·89	„	76·00	·06		59	4 0	6	18·78	„	89·04	·63
	42	8 3	6	17·93	„	76·14	·13	„ 4th	60	7 12 A.M.	6	18·47	„	76·56	·00
	43	8 25	6	18·35	„	76·39	·17		61	7 40	6	17·98	„	76·14	− ·12
	44	8 46	6	18·73	„	76·72	·21		62	8 6	6	17·80	„	76·05	·17
	45	9 10	6	19·05	„	77·31	·23		63	8 29	6	17·85	„	76·36	·27
	46	9 28	6	19·56	„	78·18	·23		64	8 52	6	17·41	„	76·88	·36
	47	9 55	6	19·46	„	79·20	·29		65	9 18	6	17·08	„	77·68	·45
	48	11 25	6	20·04	„	84·28	·32		66	9 41	6	17·31	„	78·81	·54
	49	11 52	6	19·92	„	85·59	·28		67	11 22	6	17·33	„	84·45	·78
	50	0 20 P.M.	6	19·71	„	86·75	·20		68	11 43	6	17·15	„	85·84	·81
	51	0 45	6	20·05	„	87·42	·06		69	0 5 P.M.	6	17·35	„	86·92	·72
	52	1 8	6	19·98	„	87·83	+ ·08		70	0 32	6	16·89	„	87·95	·51
	53	1 33	6	19·77	„	88·18	·22		71	0 53	6	16·78	„	88·83	·30
	54	1 58	6	19·46	„	88·36	·30		72	1 25	6	16·36	„	89·46	·06
	55	2 23	6	19·72	„	88·53	·34						Mean	83·47	− ·036

The terminal point of set No. 37 was the point of origin for set No. 38.
For measurements with compasses at **Y**, see page X—31.

February 3rd. (40)—Hazy morning, no wind, sky throughout the day covered with thin clouds. (53) Sea breeze set in.

„ 4th. (60)—Fine morning, horizon hazy. (71) East wind.

Extracts from the Field Book of MEASUREMENT II—(Continued.)

Section VX

When compared 1869	No. of the set	Mean time of ending	No. of bars used	Height of set above origin	Arrangement of Microscopes	Bar B $62° + T_b$	Bar B t
		h. m.		feet		°	°
Feby. 4th	73	2 12 P.M.	6	+ 17·44	$(m.e)_6$	90·45	+ ·29
	74	2 34	6	17·63	„	90·72	·36
	75	3 3	6	17·91	„	90·89	·47
„ 5th	76	7 18 A.M.	6	18·44	„	77·13	·01
	77	7 40	6	18·49	„	76·77	− ·11
	78	8 4	6	18·70	„	76·76	·14
	79	8 24	6	19·15	„	77·01	·23
	80	8 44	6	19·31	„	77·40	·28
	81	9 5	6	19·70	„	77·97	·33
	82	9 24	6	19·89	„	78·69	·43
	83	9 43	6	20·25	„	79·59	·47
	84	11 17	6	20·83	„	84·54	·65
	85	11 40	6	21·16	„	85·69	·66
	86	11 59	6	21·40	„	86·77	·60
	87	0 27 P.M.	6	21·32	„	87·78	·46
	88	0 54	6	21·50	„	88 59	·16
	89	1 14	6	21·84	„	88·96	+ ·06
	90	1 40	6	21·79	„	89·22	·22
Feby. 5th	91	2 4 P.M.	6	+ 21·49	$(m.e)_6$	89·46	+ ·37
	92	2 24	6	21·26	„	89·59	·45
	93	2 43	6	21·38	„	89·61	·48
	94	3 7	6	20·98	„	89·52	·50
	95	3 29	6	20·69	„	89·34	·53
	96	3 58	6	20·51	„	89·24	·60
„ 6th	97	7 9 A.M.	6	20·22	„	77·99	− ·02
	98	7 33	6	19·84	„	77·66	·05
	99	7 53	6	19·47	„	77·59	·06
	100	8 15	6	19·08	„	77·61	·06
	101	8 36	6	19·21	„	77·81	·04
	102	8 57	6	18·86	„	78·11	·02
	103	9 15	6	18·25	„	78·58	·02
	104	9 38	6	17·69	„	79·21	·03
	105	11 19	6	17·35	„	83·86	·22
	106	11 41	6	17·23	„	84·97	·29
	107	0 10 P.M.	6	15·97	„	86·23	·34
					Mean	83·08	− ·091

The terminal point of set No. 72 was the point of origin for set No. 73.
For measurements with compasses at **X**, see page X—31.

February 5th. (76) Fine morning, little wind, heavy bank of clouds to east and south. (86) Sea-breeze commenced, afternoon fine, cumuli.
„ (94) Cumuli and strati.
„ 6th. (97) Cloudy morning, no wind. (105) Fine, horizon hazy, strati and cirro-strati, cumuli over hills to west.

Section XN

When compared 1869	No. of the set	Mean time of ending	No. of bars used	Height of set above origin	Arrangement of Microscopes	Bar B $62° + T_b$	Bar B t
Feby. 6th	108	0 47 P.M.	6	+ 16·57	$(m.e)_6$	88·01	− ·25
	109	1 12	6	16·34	„	88·65	·12
	110	1 30	6	16·14	„	89·08	+ ·06
	111	1 59	6	15·44	„	89·46	·19
	112	2 22	6	15·01	„	89·97	·40
	113	2 42	6	14·77	„	90·12	·47
	114	3 3	6	14·62	„	90·18	·50
	115	3 23	6	14·02	„	90·19	·53
	116	3 42	6	13·50	„	90·17	·55
„ 8th	117	7 9 A.M.	6	13·25	„	79·14	− ·01
	118	7 31	6	13·09	„	79·01	·06
	119	7 51	6	12·84	„	79·12	·14
	120	8 8	6	12·08	„	79·40	·20
	121	8 26	6	11·43	„	79·79	·27
	122	8 50	6	11·14	„	80·26	·33
	123	9 9	6	10·79	„	81·17	·45
	124	9 28	6	10·23	„	81·95	·53
	125	9 49	6	10·18	„	82·81	·59
Feby. 8th	126	11 41 A.M.	6	+ 9·87	$(m.e)_6$	87·83	− ·75
	127	0 0 P.M.	6	9·53	„	89·44	·67
	128	0 21	6	9·07	„	90·30	·58
	129	0 45	6	8·68	„	91·25	·43
	130	1 8	6	8·18	„	91·80	·24
	131	1 27	6	7·83	„	92·20	·03
	132	1 47	6	7·90	„	92·37	+ ·15
	133	2 4	6	7·89	„	92·43	·28
	134	2 21	6	7·81	„	92·41	·33
	135	2 41	6	7·60	„	92·27	·42
	136	3 1	6	7·06	„	92·14	·46
	137	3 19	6	6·63	„	92·07	·51
	138	3 47	6	6·73	„	91·98	·60
„ 9th	139	7 4 A.M.	6	6·34	„	81·38	·03
	140	7 24	6	6·01	„	81·04	− ·03
	141	7 51	6	5·65	„	80·91	·07
	142	8 38	6	4·79	„	81·06	·05
					Mean	84·39	+ ·040

The terminal point of set No. 107 was the point of origin for set No. 108.
Height of set No. 142 above North-End = 2·30 feet.
For measurements with compasses at North-End, see page X—31.

February 6th. (108) Sea-breeze set in.
„ 8th. (117) Fine morning, clouds in horizon, no wind. (120) Cirri. (129) Sea-breeze set in.
„ 9th. (139) Heavy clouds to N.E., no wind.

Extracts from the Field Book of MEASUREMENT III

When compared — 1869	No. of the set	Mean time of ending	No. of bars used	Height of set above origin	Arrangement of Microscopes	Bar B 62° + T_b	Bar B t	When compared — 1869	No. of the set	Mean time of ending	No. of bars used	Height of set above origin	Arrangement of Microscopes	Bar B 62° + T_b	Bar B t
				Section NX											
		h. m.		feet		°	°			h. m.		feet		°	°
Feb. 15th	1	7 35 A.M.	6	+ 2·27	(m.e)7	77·27	+ ·17	Feb. 16th	19	7 46 A.M.	6	+ 7·36	(m.e)7	77·86	+ ·21
	2	8 25	6	2·93	„	76·97	·12		20	8 16	6	7·48	„	77·79	·22
	3	8 58	6	3·39	„	77·40	·19		21	8 41	6	8·09	„	78·10	·24
	4	9 27	6	3·72	„	78·21	·24		22	9 4	6	7·97	„	78·62	·25
	5	10 1	6	3·88	„	79·25	·30		23	9 32	6	8·77	„	79·28	·29
	6	11 32	6	3·70	„	82·86	·23		24	9 59	6	9·50	„	80·00	·34
	7	0 1 P.M.	6	4·03	„	83·62	·21		25	11 32	6	9·69	„	83·62	·21
	8	0 29	6	4·73	„	84·59	·09		26	0 4 P.M.	6	9·65	„	84·71	·10
	9	0 55	6	5·06	„	85·61	− ·03		27	0 29	6	10·48	„	85·59	·03
	10	1 17	6	4·91	„	86·73	·10		28	0 51	6	10·87	„	86.47	− ·06
	11	1 50	6	5·06	„	87·69	·14		29	1 15	6	11·01	„	87·08	·10
	12	2 15	6	5·15	„	88·77	·24		30	1 40	6	11·38	„	87·99	·14
	13	2 45	6	5·26	„	89·50	·27		31	2 5	6	11·76	„	88·92	·23
	14	3 9	6	5·43	„	90·16	·35		32	2 30	6	12·15	„	89·51	·26
	15	3 36	6	6·01	„	90·59	·42		33	2 51	6	12·71	„	90·06	·32
	16	4 12	6	6·68	„	90·93	·52		34	3 22	6	12·83	„	90·64	·39
„ 16th	17	6 54 A.M.	6	7·08	„	78·51	+ ·16		35	4 0	6	12·54	„	91·18	·41
	18	7 21	6	6·94	„	78·17	·19						Mean	84·12	− ·003

The rear-end of set No. 1 stood exactly over the dot at North-End.
For measurements with compasses at **X**, see page X—31.

February 15th. (1) Fine morning up to 10 o'clock. (7) High wind from north.
„ 16th. (33) Strong wind from N. and N.E. all the afternoon with clear sky.

When compared — 1869	No. of the set	Mean time of ending	No. of bars used	Height of set above origin	Arrangement of Microscopes	Bar B 62° + T_b	Bar B t	When compared — 1869	No. of the set	Mean time of ending	No. of bars used	Height of set above origin	Arrangement of Microscopes	Bar B 62° + T_b	Bar B t
				Section XY											
Feb. 17th	36	7 4 A.M.	6	+ 13·50	(m.e)7	77·33	+ ·14	Feb. 17th	54	3 54 P.M.	6	+ 18·28	(m.e)7	90·56	− ·38
	37	7 28	6	13·84	„	76·98	·15	„ 18th	55	7 7 A.M.	6	18·43	„	76·73	+ ·11
	38	7 53	6	14·21	„	76·96	·16		56	7 31	6	17·96	„	76·60	·13
	39	8 22	6	14·70	„	77·31	·18		57	7 50	6	17·89	„	76·58	·15
	40	8 51	6	14·76	„	77·85	·23		58	8 12	6	17·78	„	76·78	·15
	41	9 14	6	15·08	„	78·42	·29		59	8 36	6	17·74	„	77·22	·20
	42	9 41	6	15·50	„	79·36	·36		60	9 0	6	17·12	„	77·73	·25
	43	11 12	6	16·00	„	82·79	·26		61	9 28	6	16·86	„	78·57	·32
	44	11 36	6	16·03	„	83·66	·23		62	9 50	6	16·27	„	79·45	·33
	45	11 58	6	16·43	„	84·55	·15		63	11 14	6	16·06	„	82·21	·17
	46	0 21 P.M.	6	16·58	„	85·53	·08		64	11 35	6	16·17	„	83·16	·11
	47	0 46	6	17·01	„	86·47	− ·03		65	11 59	6	15·61	„	84·32	·01
	48	1 9	6	17·25	„	87·25	·09		66	0 21 P.M.	6	15·19	„	85·23	− ·07
	49	1 31	6	17·69	„	87·96	·14		67	0 53	6	14·80	„	86·52	·19
	50	2 1	6	17·66	„	88·93	·27		68	1 15	6	14·96	„	87·46	·27
	51	2 26	6	18·12	„	89·33	·26		69	1 37	6	14·55	„	88·02	·36
	52	2 55	6	18·12	„	89·75	·27		70	2 20	6	13·39	„	88·64	·40
	53	3 22	6	18·46	„	90·21	·30						Mean	82·76	+ ·035

The terminal point of set No. 35 was the point of origin for set No. 36.
For measurements with compasses at **Y**, see page X—31.

February 17th (53) Strong wind all day from N. and N.E. with clear sky.
„ 18th (68) do. do. do.

Extracts from the Field Book of MEASUREMENT III—(Continued.)

When compared — 1869	No. of the set	Mean time of ending	No. of bars used	Height of set above origin	Arrangement of Microscopes	Bar B $62° + T_b$	Bar B t	When compared — 1869	No. of the set	Mean time of ending	No. of bars used	Height of set above origin	Arrangement of Microscopes	Bar B $62° + T_b$	Bar B t

Section YZ

		h. m.		feet		°	°			h. m.		feet		°	°
Feb. 19th	71	7 6 A.M.	6	+13·74	$(m.e)_7$	76·17	+ ·08	Feb. 19th	89	2 22 P.M.	6	+16·19	$(m.e)_7$	89·02	− ·17
	72	7 28	6	13·52	„	76·10	·09		90	2 43	6	16·25	„	89·43	·21
	73	7 49	6	13·44	„	76·21	·07		91	3 5	6	16·41	„	89·86	·25
	74	8 7	6	13·68	„	76·49	·09		92	3 26	6	16·77	„	90·25	·31
	75	8 30	6	14·00	„	76·96	·17		93	3 51	6	16·70	„	90·47	·32
	76	8 54	6	13·96	„	77·72	·25	„ 20th	94	6 57 A.M.	6	16·44	„	77·38	+ ·11
	77	9 14	6	13·96	„	78·46	·33		95	7 16	6	16·26	„	77·29	·11
	78	9 32	6	13·66	„	79·16	·38		96	7 35	6	16·04	„	77·31	·10
	79	10 5	6	14·00	„	80·05	·39		97	7 54	6	16·09	„	77·50	·08
	80	11 27	6	14·46	„	83·61	·11		98	8 15	6	15·40	„	77·85	·11
	81	11 44	6	14·50	„	84·24	·08		99	8 34	6	15·03	„	78·30	·17
	82	0 2 P.M.	6	14·60	„	84·74	·05		100	8 53	6	14·80	„	78·80	·22
	83	0 20	6	15·07	„	85·26	·03		101	9 12	6	14·57	„	79·30	·27
	84	0 37	6	15·36	„	85·88	− ·01		102	9 33	6	13·93	„	79·93	·27
	85	0 58	6	15·33	„	86·57	·04		103	9 56	6	13·94	„	80·59	·24
	86	1 19	6	15·83	„	87·30	·04		104	11 23	6	13·25	„	83·94	·10
	87	1 38	6	15·75	„	87·92	·04		105	11 58	6	11·81	„	85·05	− ·06
	88	2 0	6	16·31	„	88·51	·09								
													Mean	82·10	+ ·068

The terminal point of set No. 70 was the point of origin for set No. 71.
For measurements with compasses at **Z**, see page $X_{—31}$.

February 19th (72) Wind moderate. (78) Wind from the same quarter but more moderate, sky clear. (81) Wind becoming unsteady and gusty from N. and N. E with clouds. (88) Wind set in strong with clear sky.
February 20th (102) N.E. wind with clouds all the morning.

Section ZS

Feb. 20th	106	0 27 P.M.	6	+11·98	$(m.e)_7$	86·37	− ·15	Feb. 22nd	125	9 31 A.M.	6	+ 4·71	$(m.e)_8$	81·52	+ ·23
	107	0 56	6	11·83	„	87·23	·21		126	9 50	6	4·52	„	82·26	·28
	108	1 16	6	11·37	„	87·60	·19		127	10 4	6	4·34	„	82·87	·27
	109	1 38	6	11·02	„	88·00	·21		128	11 23	6	3·84	„	85·10	− ·13
	110	1 58	6	10·48	„	88·23	·18		129	11 43	6	3·39	„	85·02	·16
	111	2 17	6	10·16	„	84·48	·17		130	0 5 P.M.	6	3·20	„	84·86	·17
	112	2 37	6	9·67	„	88·68	·12		131	0 22	6	2·98	„	84·80	·22
	113	3 1	6	9·26	„	88·90	·11		132	0 43	6	2·75	„	84·91	·24
	114	3 21	6	8·78	„	89·10	·12		133	1 0	6	2·37	„	85·31	·25
	115	3 37	6	8·30	„	89·42	·17		134	1 19	6	1·51	„	85·63	·16
	116	4 2	6	7·86	„	89·80	·25		135	1 36	6	·70	„	86·01	·09
„ 22nd	117	7 4 A.M.	6	7·67	$(m.e)_8$	78·56	+ ·04		136	1 56	6	− ·04	„	86·31	·02
	118	7 24	6	7·42	„	78·56	·03		137	2 16	6	·91	„	86·31	+ ·01
	119	7 42	6	7·59	„	78·69	− ·04		138	2 34	6	1·29	„	86·13	·07
	120	7 59	6	7·38	„	78·89	·06		139	2 50	6	1·72	„	86·18	·07
	121	8 16	6	6·65	„	79·29	·07		140	3 6	6	2·30	„	86·39	·05
	122	8 35	6	6·42	„	79·73	·04		141	3 47	6	2·76	„	86·95	− ·06
	123	8 55	6	5·68	„	80·26	+ ·03		142	4 20	3	2·93	$(m.e)_9$	87·19	·10
	124	9 14	6	5·13	„	80·90	·12								
													Mean	84·88	− ·065

The terminal point of set No. 105 was the point of origin for set No. 106.
Height of set No. 142 above South-End = 1·49 feet.
For measurements with compasses at South-End, see page $X_{—31}$.

February 20th. (109) Gusty N.E. wind with clouds.
„ 22nd. (117) Sky completely clouded especially towards the east. (122) Sky cleared somewhat towards the west.
„ „ (128) Sky again clouded completely and rain fell at intervals. (130) Slight wind occasionally. (134) Still cloudy with wind from N.E. (136) Heavy clouds and rain. (139) Clear sky with wind setting in strong from the east.

Extracts from the Field Book of MEASUREMENT IV.

Section SZ

When compared — 1869	No. of the set	Mean time of ending	No. of bars used	Height of set above origin	Arrangement of Microscopes	Bar B $62° + T_b$	Bar B t	When compared — 1869	No. of the set	Mean time of ending	No. of bars used	Height of set above origin	Arrangement of Microscopes	Bar B $62° + T_b$	Bar B t
		h. m.		feet		°	°			h. m.		feet		°	°
Mar. 1st	1	7 50 A.M.	3	+ 1·54	$(m.e)_{10}$	79·29	·00	Mar. 2nd	20	9 25 A.M.	6	+ 9·53	$(m.e)_{11}$	82·24	·00
	2	8 40	6	1·89	$(m.e)_{11}$	80·10	− ·17		21	9 52	6	10·41	,,	82·87	+ ·02
	3	9 22	6	1·99	,,	81·41	·27		22	11 35	6	10·85	,,	86·52	− ·06
	4	9 56	6	2·42	,,	82·87	·36		23	11 56	6	11·12	,,	87·19	+ ·01
	5	11 38	6	3·34	,,	86·80	·26		24	0 18 P.M.	6	11·33	,,	87·86	·09
	6	0 10 P.M.	6	3·34	,,	87·95	·14		25	0 41	6	11·67	,,	88·39	·16
	7	0 41	6	3·94	,,	88·85	+ ·06		26	1 6	6	11·55	,,	88·72	·26
	8	1 10	6	4·90	,,	89·69	·19		27	1 35	6	11·73	,,	89·55	·47
	9	1 38	6	5·76	,,	90·24	·26		28	1 57	6	12·12	,,	89·98	·43
	10	2 13	6	6·63	,,	90·77	·25		29	2 18	6	12·79	,,	90·43	·42
	11	2 43	6	7·27	,,	91·09	·31		30	2 39	6	13·33	,,	90·61	·45
	12	3 15	6	7·23	,,	91·78	·56		31	3 1	6	13·50	,,	90·50	·46
	13	3 42	6	7·67	,,	92·39	·80		32	3 20	6	13·81	,,	90·29	·48
	14	4 7	6	7·70	,,	92·67	·82		33	3 46	6	14·44	,,	90·07	·50
,, 2nd	15	7 20 A.M.	6	8·00	,,	80·90	·04	,, 3rd	34	7 5 A.M.	6	14·78	,,	78·69	− ·02
	16	7 46	6	8·65	,,	80·87	·03		35	7 29	6	15·01	,,	78·71	·06
	17	8 12	6	8·80	,,	81·12	− ·01		36	7 54	6	15·39	,,	79·06	·15
	18	8 39	6	9·05	,,	81·43	·03		37	8 28	6	15·08	,,	79·56	·24
	19	9 4	6	8·82	,,	81·81	+ ·01						Mean	87·21	+ ·204

For measurements with compasses at South-End and at **Z**, see page X—31.

March 2nd. (15) Cloudy. (16) Slightly overcast. (17) More overcast. (20 and (21) Overcast, gleams of sun-shine. (22) Overcast.

,, (23) East breeze rising. (25) More sun-shine. (30) Sun-shine. (31) Sun-shine and fresh breeze for rest of day.

,, 3rd. (34) Calm and clear. (36) Slight northerly breeze with cirri.

Section ZY

When compared — 1869	No. of the set	Mean time of ending	No. of bars used	Height of set above origin	Arrangement of Microscopes	Bar B $62° + T_b$	Bar B t	When compared — 1869	No. of the set	Mean time of ending	No. of bars used	Height of set above origin	Arrangement of Microscopes	Bar B $62° + T_b$	Bar B t
Mar. 3rd	38	9 8 A.M.	6	+ 16·13	$(m.e)_{11}$	81·02	− ·40	Mar. 4th	56	7 42 A.M.	6	+ 18·99	$(m.e)_{11}$	78·47	− ·05
	39	9 32	6	16·74	,,	82·04	·43		57	8 7	6	18·83	,,	78·80	·15
	40	9 57	6	17·33	,,	83·13	·47		58	8 29	6	18·48	,,	79·43	·23
	41	11 28	6	17·70	,,	87·63	·54		59	8 53	6	18·15	,,	80·24	·35
	42	11 50	6	17·60	,,	88·61	·41		60	9 15	6	17·71	,,	81·15	·44
	43	0 12 P.M.	6	17·79	,,	89·44	·26		61	9 36	6	17·96	,,	82·02	·50
	44	0 32	6	18·36	,,	90·33	·14		62	10 0	6	17·53	,,	83·16	·54
	45	0 56	6	18·80	,,	91·00	·05		63	11 31	6	17·57	,,	88·00	·56
	46	1 18	6	18·97	,,	91·50	+ ·09		64	11 56	6	16·88	,,	89·09	·41
	47	1 37	6	19·20	,,	91·87	·23		65	0 15 P.M.	6	16·28	,,	89·81	·28
	48	1 58	6	19·83	,,	92·08	·33		66	0 36	6	16·47	,,	90·72	·17
	49	2 20	6	19·84	,,	92·21	·48		67	0 53	6	16·79	,,	91·43	·03
	50	2 44	6	19·68	,,	92·20	·57		68	1 15	6	16·59	,,	92·15	+ ·18
	51	3 8	6	19·43	,,	92·07	·65		69	1 36	6	16·69	,,	92·47	·36
	52	3 34	6	19·60	,,	91·93	·78		70	1 57	6	16·26	,,	92·66	·41
	53	3 57	6	19·63	,,	91·73	·81		71	2 18	6	16·05	,,	92·85	·45
,, 4th	54	6 54 A.M.	6	19·30	,,	78·49	·07		72	2 50	6	15·65	,,	92·90	·46
	55	7 20	6	18·97	,,	78·42	·01						Mean	85·51	− ·057

The terminal point of set No. 37 was the point of origin for set No. 38.

For measurements with compasses at **Y**, see page X—31.

March 3rd. (39) Sun-shine. (42) Fleeting clouds. (44) East breeze rising. (45) Strong bright sun-shine.

,, 4th. (54) Calm and slightly overcast. (56) Sun-shine. (57) North breeze rising. (68) East breeze freshening.

Extracts from the Field Book of MEASUREMENT IV—(Continued.)

Section VX

When compared 1869	No. of the set	Mean time of ending	No. of bars used	Height of set above origin	Arrangement of Microscopes	Bar B $62° + T_b$	Bar B t
		h. m.		feet		°	°
Mar. 5th	73	6 54 A.M.	6	+ 16·51	$(m.e)_{11}$	79·34	+ ·09
	74	7 16	6	16·93	„	79·09	·02
	75	7 38	6	17·19	„	79·10	− ·06
	76	7 57	6	17·62	„	79·38	·18
	77	8 17	6	17·52	„	79·85	·30
	78	8 35	6	17·88	„	80·44	·44
	79	8 54	6	18·16	„	81·24	·59
	80	9 10	6	18·54	„	81·90	·63
	81	9 32	6	18·40	„	83·14	·73
	82	9 54	6	18·95	„	84·13	·76
	83	11 10	6	19·26	„	87·98	·74
	84	11 27	6	19·89	„	88·65	·62
	85	11 49	6	19·82	„	89·51	·47
	86	0 6 P.M.	6	20·21	„	90·15	·36
	87	0 24	6	20·30	„	90·77	·24
	88	0 43	6	20·63	„	91·25	·13
	89	1 1	6	20·45	„	91·48	+ ·04
	90	1 25	6	20·80	„	91·63	·24
Mar. 5th	91	1 43 P.M.	6	+ 20·29	$(m.e)_{11}$	91·68	+ ·32
	92	2 3	6	20·46	„	91·69	·37
	93	2 25	6	20·17	„	91·67	·39
	94	2 46	6	19·82	„	91·67	·43
	95	3 10	6	19·54	„	91·72	·57
	96	3 30	6	19·56	„	91·73	·63
	97	3 52	6	19·15	„	91·72	·72
„ 6th	98	6 55 A.M.	6	18·64	$(m.e)_{12}$	81·46	·04
	99	7 20	6	18·27	„	81·32	·05
	100	7 40	6	18·19	„	81·32	·04
	101	8 1	6	17·67	„	81·42	·05
	102	8 18	6	17·31	„	81·62	·05
	103	8 36	6	16·91	„	82·01	·04
	104	9 1	6	16·56	„	82·36	·04
	105	9 20	6	16·25	„	82·98	·06
	106	9 38	6	15·76	„	83·43	·08
	107	10 0	6	14·73	„	84·11	·07
					Mean	87·46	− ·012

The terminal point of set No. 73 was the point of origin for set No. 73.

For measurements with compasses at **X**, see page X—31.

March 5th. (88) Easterly breeze set in. (95) Easterly breeze very fresh.

„ 6th. (99) Calm and cloudy morning. (101) North breeze beginning. (104) Still cloudy.

Section XN

When compared 1869	No. of the set	Mean time of ending	No. of bars used	Height of set above origin	Arrangement of Microscopes	Bar B $62° + T_b$	Bar B t
Mar. 6th	108	11 27 A.M.	6	+ 14·87	$(m.e)_{12}$	86·58	+ ·15
	109	11 45	6	14·94	„	87·21	·19
	110	0 0 P.M.	6	14·51	„	87·83	·23
	111	0 20	6	14·05	„	88·26	·25
	112	0 36	6	13·48	„	88·57	·30
	113	0 51	6	13·08	„	88·72	·35
	114	1 7	6	12·93	„	88·88	·42
	115	1 24	6	12·57	„	89·10	·51
	116	1 39	6	12·16	„	89·34	·57
	117	1 52	6	11·64	„	89·54	·57
	118	2 8	6	11·42	„	89·65	·58
	119	2 27	6	11·20	„	89·83	·53
	120	2 48	6	10·73	„	89·93	·50
	121	3 4	6	10·18	„	89·96	·48
	122	3 19	6	9·63	„	89·77	·48
	123	3 36	6	9·23	„	89·58	·47
	124	3 52	6	8·94	„	89·50	·50
„ 8th	125	6 58 A.M.	6	8·69	„	81·77	− ·02
Mar. 8th	126	7 20 A.M.	6	+ 8·07	$(m.e)_{12}$	81·59	− ·01
	127	7 37	6	7·97	„	81·61	·04
	128	7 52	6	7·54	„	81·78	·04
	129	8 8	6	7·13	„	82·06	·11
	130	8 23	6	6·68	„	82·31	·13
	131	8 38	6	6·27	„	82·67	·16
	132	8 57	6	6·24	„	83·14	·14
	133	9 12	6	6·24	„	83·60	·13
	134	9 29	6	6·30	„	84·22	·12
	135	9 46	6	5·93	„	84·84	·08
	136	11 16	6	5·38	„	88·53	·08
	137	11 35	6	4·97	„	89·12	+ ·03
	138	11 54	6	5·01	„	89·53	·08
	139	0 11 P.M.	6	4·62	„	89·88	·10
	140	0 29	6	4·29	„	90·26	·17
	141	0 45	6	3·85	„	90·76	·19
	142	1 20	6	3·00	„	92·23	·42
					Mean	86·03	+ ·146

The terminal point of set No. 107 was the point of origin for set No. 108.

Height of set No. 142 above North-End = 2·23 feet.

For measurements with compasses at North-End, see page X—31.

March 6th. (109) Calm and cloudy. (110) Occasional sun-shine. (111) Slight shower. (112) Sun-shine and East breeze.

„ 8th. (137) Southerly wind. (138) Passing clouds.

Compass measurements of the distances between the terminal points of the successive measurements, and the points defining the section stations and the extremities of the base.

Let **N**, **S** be the points defining the North and South Ends of the base; and let **X**, **Y**, **Z** be points on the brass plates *South* and *West* of all the dots, in each case; and let axes of coordinates parallel and perpendicular to the base be imagined through these.

And let all measurements northward and eastward be reckoned +, and those in opposite directions —

Then the coordinates—in inches—of the terminal points of the successive measurements will be

In respect of length

For Measurement I	**N**	**X** + ·170	**Y** + ·103	**Z** + ·063	**S** — 31·10
" II	**N** — ·166	+ ·085	+ ·053	+ ·103	31·10
" III	**N**	+ ·191	+ ·154	+ ·187	30·88
" IV	**N** + ·392	+ ·475	+ ·403	+ ·353	30·89

And in respect of direction

For Measurement I	**X** + 1·10	**Y** + 1·50	**Z** + 1·40
" II	+ 0·06	+ 0·41	+ 0·35
" III	+ 1·86	+ 1·87	+ 1·48
" IV	+ 0·39	+ 0·03	+ 0·02

If now we write **NX**. I, **XY**. I, &c., **NX**. II, **XY**. II, &c., &c., to represent the distances between the points laid down by the several measurements then

NX. I = **NX** — ·170	**XY**. I = **XY** + ·067	**YZ**. I = **YZ** + ·040	**ZS**. I = **ZS** + 31·163
" II = " — ·251	" II = " + ·032	" II = " — ·050	" II = " + 31·203
" III = " — ·191	" III = " + ·037	" III = " — ·033	" III = " + 31·067
" IV = " — ·083	" IV = " + ·072	" IV = " + ·050	" IV = " + 31·243

Also

NS. I = **NS** + 31·10
" II = " + 30·934
" III = " + 30·88
" IV = " + 31·282

The compass measurements shown above were made after the operations, independently by Captain J. P. Basevi, R.E., and Lieutenant J. Herschel, R.E.

The determination of the mean actual length of the bars during the measurement of each section of the base-line is made in the manner which is indicated in Section 6 of Chapter VIII. The numerical values of the quantities

$$\frac{[_oT_b]}{r} + 62°, \text{ and } \frac{[_ot]}{r}$$

or the mean temperature of the brass component, and the mean excess of temperature of the iron over the brass component, are given at the end of the column of temperatures of bar B, in the extracts from the field book of each measurement of each section. These values are successively inserted in equation (20), which however has been erroneously printed at page (73), and should be

$$L - \mathbf{A} = X'' + \left(51{\cdot}4\frac{[_ot]}{r} + 1{\cdot}1\right) + \left(\frac{[_oT_b]}{r} - 22{\cdot}6\right)\eta - 21{\cdot}3\, dE_a' - \left(2{\cdot}9\frac{[_ot]}{r} + 0{\cdot}1\right) de_i'$$

thus the actual lengths of the bars have been determined; they are given in the table on page (73) and therefore need not be repeated in this place.

The lengths measured by the bars have been determined in the manner indicated in the first para of page (76); the details of the determinations of the lengths measured by the microscopes are given in pages X_{17} to X_{22}, and those of the lengths measured by the beam compass at page X_{31}. The several values of lengths are collected together in the table at page (75), where it is shown that the mean length of the base, at the level of the measurement, is

8912·5904 feet of standard **A**.

Reduction to Mean Sea Level.

This base-line was measured four times; and as the work commenced alternately at the North and South-Ends, the "heights of sets above origin" recorded at pages X_{23} to X_{30} are referred there correspondingly to these termini. The heights, in Measurements II and IV, may however be referred to the origin of Measurements I and III, or North-End, by applying to each height the difference between the heights of the two termini: the value of this difference adopted, is (N. End − S. End) = 3·12 feet.* All the heights of sets being thus referred to the N. End as an origin, we have in the notation of page I_{21}

* By observations made on four successive days in January 1870, it was approximately determined that the mean Sea level at Tuticorin was 6·03 feet below the G. T. S. Bench Mark on a flagstone in the portico of the Protestant Church Tuticorin. The heights following are referred to this datum and were found by spirit leveling operations.

Cape Comorin Base-Line. Height of North-End above mean Sea level 135·07 feet
(North-End − South-End) 3·12 „

Reduction to Mean Sea Level—Continued.)

		feet		$[h]^p_1$	a	h_m	δh	C_2		C_1
	H	135·1	I	1640	1	− 3·53	+ 0·41	− ·0051	$\lambda = 8913$	− ·0579 feet
Log.	R	7·31785	II	1590	1	− 2·49	− 0·63	− ·0047		
	h	− 3·12	III	1539	1	− 4·42	+ 1·30	− ·0049		
	n	141	IV	1484	1	− 0·77	− 2·35	− ·0040		

Final length of the Base-Line in feet of Standard A.

From page (75) and the preceding values of C_1 and C_2 there result

		Measured length	Reduction to sea level	Length at sea level
North-End to South-End by Measurement	I	8912·5926	− ·0630	8912·5296
" " "	II	·5856	626	·5230
" " "	III	·5892	628	·5264
" " "	IV	·5943	619	·5324
			Mean	8912·5279
			Log.	3·950 0009 02

Description of Stations.

PARMESPURAM TOWER STATION, is situated about 16 miles N.E. of Cape Comorin, the extreme southern point of the Indian Peninsula, and about 32 miles south of the town of Tinnevelly; 'táluk' of Nángúnéri; sub-division of Ráthápuram. The nearest towns and villages are as follows: Nángúnéri 16½ miles N. by W.; Ráthápuram 2 miles N.W. by N.; Pannagúdi 9½ miles N.W. by W.; Parmeshwaripuram a small village ½ mile E. by N.

Situation.

The station is the North-End of the Cape Comorin base as measured in January, February and March 1869. The position was originally selected as that of a Section Station of a longer line, but was subsequently made the Northern terminus of a short base to be repeatedly measured, and the present building was accordingly designed and built by Captain B. R. Branfill, in charge of the Great Arc Triangulation. It consists of a central isolated hollow pyramidal pillar of masonry 25′ high, surmounted by a circular slab of sandstone 39″ in diameter and 6″ or 7″ thick. The isolated pillar is surrounded by a hollow conical building 14½′ in diameter at base and 6′ at top, round and in contact with which is a tower of sun-dried bricks 20′ square at base and 15′ square at top. A masonry archway 5′ wide and 7′ 6″ high runs through the basement, in the direction of the measurement, N. and S. nearly.

The Tower.

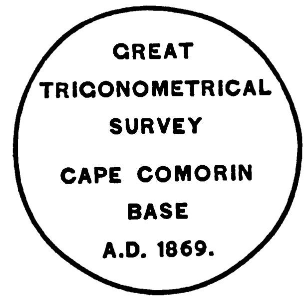
The mark to which the measurements were eventually referred is a cleanly drilled hole 0″·05 in diameter in a silver core to a substantial brass plug, which was run in with lead into the markstone. This stone is a pyramidal block 42″ high and 30″ square at base, and 21″ square at top. It rests on a bed of sand 6″ deep on three courses of bricks in the bottom of a masonry well sunk into the hard gravel subsoil of the place, 3′ below the foundations of the tower. Before and after the pier was placed, enough water was poured in to saturate the sand and allow of uniform settlement. The remainder of the well was then bricked up flush with the surface of the stone. The mark is provided with a brass covering plate having a spurious dot and circle on its upper surface.

1. The Measurement Mark.

After the completion of the measurement, a massive granite slab 32″ in diameter and 9″ or 10″ thick, having a square recess countersunk in its lower side and engraved (as in fig.) on its surface, was placed over the mark as a title. In this stone a deep cylindrical hole 1-10th″ in diameter was bored rigorously in the normal of the lower or Measurement-mark. It may be fitly described and known as the Title-stone mark. In the recess below may be found a parchment record of the measurement of the base, stating its length as 8912·5 feet. The floor of the passage was eventually raised to within an inch or two of the surface of the stone, and the archways bricked up throughout their length, leaving only a central chamber 5′ by 4′ corresponding to the hollow base of the central pillar. The surface of the stone is 11″·00 above the Measurement-mark.

2. The Title-stone Mark.

Parchment Record.



The slab of sandstone which copes the central pillar has a keystone in the middle which contains the mark employed by the trigonometrical surveyors. The height of this mark above the Measurement-mark is 24′·87.

3. The Trigonometrical Mark.

Description of Stations—(Continued.)

Levelling Bench-Mark.

After the completion of the base-line operations one of the stone comparing piers was sunk as a Bench-mark for future levelling operations. Its position is $10\frac{1}{2}'$ south of the S. Arch of the tower. It is a pyramidal block 5′ high 27″ square at base and 14″ square at top, and its surface, marked (as in fig.) is flush with the ground-level: and is 0′·47 above the base-line Measurement-mark.

G. T. S.

B. M.

Situation.

SHANGANERI TOWER STATION, is situated $1\frac{3}{4}$ miles S. $\frac{1}{2}$ W. of Parméspuram T.S. to the description of which reference is directed for further particulars. The nearest village is that of Shanganéri $\frac{3}{4}$ mile W.S.W. in the Nángúnéri 'táluk'.

Shanganéri T.S. is the S. End of the Cape Comorin Base as measured in January, February and March 1869. Its position, which is half-way down the slope of an undulation, was originally selected as that of a Section Station of the intended base, but was subsequently made the Southern extremity of a shorter distance to be repeatedly measured; and the present building was designed and built accordingly by Captain B. R. Branfill, in charge of the Great Arc Triangulation.

It consists of a central isolated hollow pyramidal pillar of masonry 22′ high surmounted by a circular slab of sandstone 39″ in diameter and 6″ or 7″ thick. The isolated pillar is surrounded by a hollow conical building 12′ in diameter at base and 6′ at top, round and in contact with which is a tower of sundried bricks 20′ square at base and 15′ square at top. A masonry archway 5′ wide and 7′ 6″ high runs through the basement in the direction of the measurement; viz. N. and S. nearly.

Description of Marks.

Vide Parméspuram T.S. for all particulars with the exception of the following. The Title-stone mark is 8″·40 above the Measurement-mark, and the Trigonometrical-mark is $21'\ 9\frac{1}{4}''$ above the same.

There is a Bench-mark at this station, similar to that at Parméspuram, about 10′ N. of the N. face of the tower.

J. T. W. & J. B. N. H.

APPENDICES.

APPENDIX.

No. 1.

DESCRIPTION OF THE METHOD OF COMPARING, AND THE APPARATUS EMPLOYED.

The comparisons have invariably been made with the aid of micrometer microscopes. When the long 10-feet bars have been under comparison, the microscopes have always been set up on pillars, usually single blocks of stone, about 5 feet high, sunk to a depth of 1½ feet in the ground and carefully isolated from the tread of the observers and the attendants; between these pillars a 'comparing table' is set up, carrying a sliding frame on which the bars are placed, one at a time, and then brought under the microscopes; the legs of this table are sunk to a depth of about 2 feet into the ground, and are also carefully isolated.

Such at least have invariably been the arrangements during the comparisons of the Standard Bar **A** with the Bar **B**, and with the compensated bars, at the several base-lines, and on all other occasions, whether the operations were conducted under tents or in a building. But in the comparisons of **A** with $\mathbf{I}_s$ and $\mathbf{I}_B$. in 1867, the microscopes were set up for the first time on carefully built brick pillars, descending to a depth of 6 feet below the ground, between which two other pillars were built to support the 'comparing carriage'; the carriage travelled in a tramway, and it's breadth admitted of two bars being placed on it together.

During the comparisons each bar rests immediately on two 'camels', at one-fourth and three-fourths of it's length. A camel is a strong brass tripod, having an axis which can be raised or lowered in it's socket by a powerful vertical screw; on the top of and perpendicular to the axis there is a sliding frame carrying a pair of small rollers, which the bar rests on, slow motion in the direction of it's length being communicated to the bar by a tangent screw, and in the direction of it's breadth by a screw acting on the frame which carries the rollers, the raising or lowering being performed by the vertical screw which acts on the axis. The camels have foot-screws by means of which they are levelled, and as the axes protrude several inches beyond the plane of the foot-screws, holes through which they are passed are cut in the surface of the comparing table or carriage.

Thus the bars are brought approximately into position by moving the carriage or the sliding frame of the table, and the final adjustments are made by means of the screws of the camel which impart motion in the direction of each of the three co-ordinates.

The comparing microscopes which have been used at all the base-lines, and on almost all other occasions of comparisons of the 10-feet bars, whether standard or compensated, between the years 1832 and 1867, are represented in plate 19 of Colonel Everest's Arc Book of 1847, and were constructed by Messrs. Troughton and Simms. One of them carries a micrometer, while the other carried—until recently—a fixed wire, under which one of the extremities of a bar was brought by means of the tangent screw attached to the adjacent camel, and then the micrometer wire of the other microscope was brought over the opposite extremity of the bar. The length of the microscope from the diaphragm to the object glass is about 5½ inches, and from the object glass to the external focus 2¼ inches, subject to slight variations of adjustment; the value of a division of the micrometer is about the $\frac{1}{21,000}$th part of an inch. The illumination is effected by means of reflectors, working in collars above the object glass.

Of late years the camels have become so much the worse for wear that it is difficult to bring the bars into position under the plain microscope, with sufficient accuracy, by means of the tangent screws appertaining to the camels; a micrometer was therefore added to this microscope in 1867, and was employed in the comparisons for the base-lines at Bangalore and Cape Comorin.

The method of fixing the microscopes on the blocks of stone on which they are set up is as follows;—each microscope is firmly soldered to the end of a gunbarrel about 18 inches in length, below and at right angles to which a bar of iron, 10 inches long, is soldered, at 3 inches from the microscope, thus forming a tribrach which is attached to the head of the stone, and adjusted by sets of pulling and pushing screws at the extermity of each of the three arms.

Each microscope carries a spirit level and is held in a collar in which it can be turned round and adjusted to verticality by means of the screws of the tribrach. The microscopes are brought as nearly as possible into a horizontal line, by setting them to focus on a bar which has been carefully leveled on the camels; afterwards the distance of any bar from a microscope is invariably regulated by raising or lowering the bar until it's surface is brought into the plane of the external focus of the object glass.

With ordinary care to bring the image of the object into the plane of the diaphragm, the object may always be brought within ·01 of an inch of the plane of the external focus of either of these microscopes. This is readily proved by examining the *runs* of the microscopes, as determined by several observers; different persons are liable to make different estimates of the focal adjustment which necessarily affect the determination of the run, and, with these microscopes, a change of ·01 of an inch in the distance of the object from the object glass will alter the run by less than 2 *per cent* of its total amount; but the runs obtained by different observers have been rarely found to differ by as much as 1 *per cent*, showing that the several estimates of focal length have not altered the distance of the object from the object glass by more than ·005 of an inch. Thus a special appliance for bringing the bars in succession to precisely the same distances below the object glasses is unnecessary.

When the new Standard Bars $\mathbf{I}_S$ and $\mathbf{I}_B$ were constructed, a pair of new micrometer microscopes was also constructed for the operations of this Survey, by the same makers, Messrs. Troughton and Simms. They are similar in almost all respects to the Ordnance Survey microscopes which are described by Captain Clarke at page 5, and figured in plates III to VI, of his *Comparisons of Standards of Length.* Each microscope is held, by two collars, in a gun-metal holder, which is a hollow cylinder having three arms at the middle of its length, with a set of three internal bearings at the upper and another at the lower extremity, for receiving the microscope collars; the three bearings are *segmentary*, and one of them is pressed by a spring which can be drawn back at pleasure by a screw for the purpose, to admit the microscope, and then relaxed to press the microscope into it's bearings.

The gun-metal holder is attached by foot-screws, at the extremities of it's three arms, to a cast iron plate, which rests on three points projecting from it's under surface, on the stone pier. Thus the microscope is held in its holder, and the holder in the iron casting, without any strain; the microscope can be raised or lowered by the screw attaching it to the holder, and, revolving in it's bearings and having an attached level, it can be made vertical.

The illumination is effected with the aid of a glass prism attached to a collar at the bottom of the tube, and having a perforation through it in the direction of the axis of the microscope.

The length of the tube, from the diaphgram to the object glass, is 13 inches, from the object glass to the external focus, $5\frac{1}{4}$ inches. The value of a division of the micrometer is about the $\frac{1}{25,000}$th part of an inch.

J. T. W.

APPENDIX.

No. 2.

COMPARISONS OF THE LENGTHS OF 10-FEET STANDARDS A AND B, AND DETERMINATIONS OF THE DIFFERENCE OF THEIR EXPANSIONS.

These bars were twice compared under Colonel Everest's superintendence; in his Office at Dehra Doon, in November 1834, and in camp after the measurement of the neighboring Base-line, in February 1835.

The comparisons were as follows (See *Everest's Arc Book of* 1847, *pages* 435, and 436)

Date, 1834.	Standard A.		Standard B.		Date, 1834.	Standard A.		Standard B.	
	Micrometer Readings 20138·2 div. to 1 inch.	Mean of Two Thermometers, Corr^n + 0·0454.	Micrometer Readings 20138·2 div. to 1 inch.	Mean of Two Thermometers, Corr^n −0·2280.		Mecrometer Readings 20138·2 div. to 1 inch.	Mean of Two Thermometers, Corr^n + 0·0454.	Micrometer Readings 20138·2 div. to 1 inch	Mean of Two Thermometers, Corr^n −0·2280.
	R. D.	°	R. D.	°		R. D.	°	R. D.	°
Nov. 13	1 49·9	65·300	1 78·0	67·150	Nov. 14	3 07·7	73·400	2 94·4	72·675
	1 76·5	67·150	1 93·5	68·300		3 18·0	73·800	3 03·8	73·350
	2 36·6	70·100	2 38·5	70·475		3 26·0	74·350	3 16·9	73·750
	2 51·5	70·950	2 48·0	71·100	15	0 76·7	57·950	0 66·9	57·050
	2 60·5	71·550	2 51·8	71·550		0 73·3	57·300	0 62·1	56·675
	2 70·5	71·850	2 67·3	72·025		0 73·0	57·250	0 67·6	56·800
	2 76·9	72·400	2 71·1	72·450		0 79·6	57·750	0 73·8	57·400
	2 82·0	72·700	2 75·0	72·700		0 89·2	58·250	0 82·0	57·850
	2 84·6	72·900	2 75·8	72·950		0 98·4	59·000	0 90·5	58·600
14	0 53·9	57·250	0 48·5	56·650		1 10·1	59·750	1 06·4	59·500
	0 51·6	56·900	0 45·5	56·400		1 24·4	60·750	1 17·0	60·400
	0 47·8	56·600	0 43·0	56·300		2 15·4	66·150	2 06·5	65·850
	0 51·4	56·825	0 51·1	56·650		2 31·7	67·150	2 20·0	66·600
	0 65·5	57·550	0 61·0	57·400		2 46·4	67·850	2 34·3	67·500
	0 80·0	58·400	0 77·4	58·300		2 64·0	68·850	2 50·1	68·450
	1 92·0	65·800	1 63·0	64·300		2 71·1	69·700	2 58·9	69·150
	2 15·5	67·225	1 83·9	65·450		2 89·1	70·675	2 76·1	70·400
	2 32·2	68·350	2 02·6	66·700		3 00·4	71·450	2 88·9	71·000
	2 47·2	69·250	2 23·0	67·825		3 12·5	72·250	3 02·0	71·650
	2 59·0	70·325	2 39·9	69·200		3 13·0	72·650	3 06·0	72·200
	2 76·0	71·300	2 55·7	70·300		3 25·5	72·950	3 11·5	72·600
	2 91·0	71·950	2 72·4	71·250		3 31·5	73·300	3 16·1	72·850
	3 00·5	72·600	2 81·3	72·000	Mean...	2 07·324	66·6167	1 97·758	66·2161

Date, 1835.	Standard A.		Stndard B.		Date, 1835.	Standard A.		Standard B.	
	Micrometer Readings 20168·7 div. to 1 inch.	Mean of Two Thermometers, Correction +0·0454.	Micrometer Readings 20168·7 div. to 1 inch.	Mean of Two Thermometers, Correction −0·2280.		Micrometer Readings 20168·7 div. to 1 inch.	Mean of Two Thermometers, Correction +0·0454.	Micrometer Readings 20168·7 div. to 1 inch.	Mean of Two Thermometers, Correction −0·2280.
	R. D.	°	R. D.	°		R. D.	°	R. D.	°
Feb. 11	−0 82·6	41·55	−0 95·8	40·75	Feb. 12	+3 51·3	71·60	+3 40·0	71·10
	−0 70·3	41·80	−0 81·8	41·30		+3 49·9	71·55	+3 39·3	71·00
	−0 57·8	42·75	−0 63·1	42·40		+3 40·1	71·15	+3 31·0	70·65
	−0 26·0	44·20	−0 35·5	43·80		+3 52·3	70·40	+3 19·9	70·00
	−0 02·5	46·25	−0 08·5	46·25	13	+0 09·0	48·70	−0 16·1	47·75
	+0 33·7	48·65	+0 26·1	48·40		+0 09·6	48·80	−0 02·5	47·95
	+0 88·5	52·35	+0 81·2	52·00		+0 27·5	49·70	+0 14·3	49·15
	+1 28·0	54·85	+1 19·0	54·60		+0 51·0	51·20	+0 42·0	50·75
	+3 30·0	68·35	+3 06·7	67·30		+0 82·0	53·20	+0 71·0	52·75
	+3 43·5	69·25	+3 25·5	68·35		+1 15·5	55·45	+1 02·6	55·10
	+3 58·8	70·40	+3 41·0	69·50		+1 46·0	57·60	+1 37·1	57·30
	+3 68·5	71·30	+3 50·0	70·50		+1 75·4	59·65	+1 69·7	59·35
	+3 70·5	71·55	+3 55·9	71·00		+3 15·2	68·95	+2 95·0	68·05
	+3 71·6	71·65	+3 57·9	71·05		+3 44·5	70·90	+3 26·5	70·10
	+3 56·5	70·90	+3 41·5	70·45		+3 74·0	72·90	+3 65·5	72·45
	+3 29·5	69·75	+3 17·5	69·45		+4 10·5	74·55	+3 92·2	74·00
12	−0 10·4	48·15	−0 28·5	47·20		+4 17·1	75·05	+3 98·4	74·45
	−0 03·9	48·10	−0 19·2	47·35		+4 12·0	75·15	+3 99·0	74·50
	+0 09·6	48·80	−0 02·5	48·25		+4 13·0	74·80	+3 93·0	74·45
	+0 28·5	49·95	+0 19·4	49·60		+3 98·0	74·20	+3 84·1	73·75
	+0 58·5	51·95	+0 50·0	51·55		−1 43·3	42·60	−1 35·2	43·35
	+0 94·0	54·05	+0 86·0	53·65		−1 36·3	42·85	−1 30·9	43·45
	+1 27·5	56·20	+1 20·0	56·05		−1 22·3	43·60	−1 16·9	44·10
	+1 61·4	58·50	+1 49·5	58·10		−1 00·0	45·00	−0 97·0	45·50
	+2 79·3	66·85	+2 61·9	66·00		−0 71·2	46·65	−0 68·9	47·00
	+3 08·9	68·80	+2 95·0	68·00		−0 40·1	48·40	−0 42·5	48·50
	+3 27·0	69·90	+3 13·4	69·20		−0 17·0	49·95	−0 22·0	49·95
	+3 42·8	71·05	+3 31·0	70·40					
	+3 47·6	71·25	+3 31·4	70·80	Mean ...	1 67·043	59·1723	1 55·957	58·7446

As no direct determinations of the expansions of **B** have ever been made, the difference of the expansions of **A** and **B** has been computed from these comparisons, in both groups of which the range of temperature was sufficiently great to permit of a fairly approximate determination of this unknown quantity, as well as of the difference of the length of the bars.

Putting t_a and t_b for the excess of the temperatures of **A** and **B** over 62°, e_a and e_b for the expansions, x for the value of **B** — **A** at the temperature of 62°, n for a measured value of **B** — **A** at the temperatures of observation, and $y = e_b - e_a$, it follows that the form of each of the primitive equations will be

$$x + t_b\, y = n - e_a\,(t_b - t_a).$$

In order to show the degree of precision which has been attained, each of the two groups has been treated separately by the method of least squares with the following results, e_a being taken at 22·669 millionths of a yard, as determined by Colonel Everest, see section 2 of Chapter II.

First Group.

$$\textit{Normal equations.}\ \begin{cases} 45\ x + 179{\cdot}465\ y = + \overset{d}{67{\cdot}597} \\ 179{\cdot}465\ x + 2464{\cdot}674\ y = - 460{\cdot}606 \end{cases}$$

$$\therefore x = 3{\cdot}162 \left(d = \frac{1 \text{ inch}}{20138{\cdot}2}\right) = 4{\cdot}362 \textit{ millionths of a yard}$$

$$y = - 0{\cdot}417 \left(d = \frac{1 \text{ inch}}{20138{\cdot}2}\right) = - 0{\cdot}575 \textit{ millionths of a yard}$$

Second Group.

$$\textit{Normal equations.}\ \begin{cases} 56\ x - 195{\cdot}068\ y = 25{\cdot}009 \\ - 195{\cdot}068\ x + 7967{\cdot}689\ y = - 647{\cdot}850 \end{cases}$$

$$\therefore x = 0{\cdot}171 \left(d = \frac{1 \text{ inch}}{20168{\cdot}7}\right) = 0{\cdot}236 \textit{ millionths of a yard}$$

$$y = - {\cdot}079 \left(d = \frac{1 \text{ inch}}{20168{\cdot}7}\right) = - {\cdot}109 \textit{ millionths of a yard}$$

By both Groups.

$$\textit{Normal equations.}\ \begin{cases} 101\ x - 15{\cdot}603\ y = 92{\cdot}531 = P \\ - 15{\cdot}603\ x + 10432{\cdot}363\ y = - 1106{\cdot}512 = Q \end{cases}$$

the absolute quantities being expressed in terms of $d = \dfrac{1}{20138{\cdot}2}$ of an inch.

From these last equations the values and the weights of x and y have been determined, as follows:—

$$x = {\cdot}0099033\ P + {\cdot}0000148\ Q$$
$$y = {\cdot}0000148\ P + {\cdot}0000959\ Q$$

and restoring the values of P and Q

$$x = \overset{d}{0{\cdot}900}, \textit{ the reciprocal weight being} = {\cdot}0099033$$
$$y = - \overset{d}{0{\cdot}105}, \quad \text{"} \quad \text{"} \quad = {\cdot}0000959$$

The errors of the different comparisons resulting from these values of x and y, indicate that the probable error of a single comparison is $= \pm \overset{d}{2{\cdot}10}$

$$\therefore x = 1{\cdot}241 \pm {\cdot}29 \textit{ millionths of a yard}$$
$$y = - 0{\cdot}145 \pm {\cdot}03 \quad \text{"} \quad \text{"}$$

After these calculations were completed the adopted value of the expansion of **A** was ascertained to be too great. The following differential computation was therefore made to determine the effect of this error on the values of x and y.

Putting de_a for the error of the expansion of standard **A**, dx and dy for the corresponding errors in the preceding values of x and y, and expressing the results in terms of millionths of a yard

$$\text{for the first group } x - dx = \overset{m.y}{4{\cdot}362} - {\cdot}703\, de_a$$
$$y - dy = -\,0{\cdot}575 + {\cdot}008\, de_a$$

$$\text{for the second group } x - dx = {\cdot}236 - {\cdot}750\, de_a$$
$$y - dy = -\,{\cdot}109 - {\cdot}015\, de_a$$

$$\text{for both groups } x - dx = 1{\cdot}241 - {\cdot}686\, de_a$$
$$y - dy = -\,{\cdot}145 - {\cdot}009\, de_a$$

putting $de_a = \overset{m.y}{0{\cdot}872}$, the excess of the value of the expansion of **A** which was determined in 1832, over the value determined in 1870, we obtain finally from all the observations

$$x - dx = \overset{m.y}{{\cdot}643}$$
$$y - dy = -\,{\cdot}153$$

W. H. COLE.

APPENDIX.

No. 3.

COMPARISONS BETWEEN THE 10-FEET STANDARDS I_B I_S AND A.

These comparisons were made in the comparing room at Dehra Doon in April 1867, with the double object of ascertaining whether the relative length of the 10-feet standards **A** and **B** had altered since Everest's comparisons of 1834-35, and of connecting **A** with the European standards of length. The observations were taken early in the morning and late in the afternoon, commencing a little before and ending a little after the maximum and minimum readings of the thermometers suspended in the comparing room had been reached, in order that the momentary variations of temperatures might be a minimum, and that the errors arising also from a *lagging* of the thermometers behind the temperatures of the bars, might be practically cancelled. Illumination of the dots and lines on the bars was obtained by lamps except in the cases where the contrary has been specified.

The comparisons were made with the pair of micrometer microscopes known as **G** and **H,** recently obtained from Messrs. Troughton and Simms, which are described at the end of Appendix No. 1. The runs of these microscopes were determined a few days previously on the inch [a b] of the new standard steel Foot **IF** and were as follows :—

1 division of the microscope **G** = 1·1511 millionths of a yard
Ditto **H** = 1·1074 Ditto

The thermometers employed were for I_B 4215, 4221, 4011, for I_S 4228, 4204, 4202 and for **A** 4227, 4217; they were compared with the standard No. 4246 immediately after the bar comparisons were completed: this standard was one of those compared by Captain Clarke with the standard No. 4142 which he had already carefully calibrated; see his *Comparisons of Standards of Length, Chapter XVI Section* 2, and Appendix No. 8 of this volume. Comparisons between these two standards were also made at Dehra during May 1867.

The factors of expansion for reducing the observed differences to what they would be at 62° were, for I_B and I_S those given by Captain Clarke p. 216, and for **A** that determined by Colonel Everest viz. :

	m.y
for I_B	32·759
„ I_S	21·159
„ **A**	22·669

The comparisons are divided into three groups

25	between	I_B and I_S
36	„	I_B and **A**
28	„	I_S and **A**

and are given on the three following on pages.

Date.	Initials of observer at Microscope.		Observed value of $I_B - I_S$ in		Corrected temperatures.		Correction to 62° Fahrenheit in *m.y*		$I_B - I_S$ at 62° in millionths of a yard.	Remarks.
	Q	H	Micrometer divisions.	Milnths. of a yard.	I_B	I_S	I_B	I_S		
22nd April 1867,	J. T. W.	T. G. M.	90·9*g* + 111·2*h*	227·78	70°·35	70°·18	273·54	173·08	127·32	Afternoon observations commencing at 4*h* 10*m* and ending at 5*h* 27*m*.
			85·4 + 119·2	230·31	70·35	70·26	273·54	174·78	131·55	
	T. G. M.	J. T. W.	126·5 + 80·5	234·76	70·59	70·48	281·40	179·43	132·79	
			84·1 + 125·2	235·46	70·77	70·61	287·30	182·18	130·34	
			124·2 + 86·0	238·19	70·92	70·73	292·21	184·72	130·70	
	J. T. W.	T. G. M.	82·6 + 129·2	238·16	71·03	70·85	295·81	187·26	129·61	
23rd „	J. T. W.	T. G. M.	107·1*g* + 109·7*h*	244·78	71·76	71·71	319·73	205·46	130·51	Morning observations commencing at 4*h* 47*m* and ending 6*h* 37*m*.
			89·8 + 124·8	241·58	71·68	71·64	317·11	203·98	128·45	
			92·0 + 122·6	241·66	71·57	71·60	313·50	203·13	131·29	
	T. G. M.	J. T. W.	113·5 + 99·7	241·07	71·58	71·50	313·83	201·01	128·25	
			111·6 + 101·0	240·31	71·50	71·48	311·21	200·59	129·69	
			105·7 + 110·1	243·60	71·45	71·40	309·57	198·90	132·93	
	J. T. W.	T. G. M.	105·8 + 107·8	241·17	71·39	71·36	307·61	198·05	131·61	
27th „	J.B.N.H.	M.W.R.	108·3*g* + 138·7*h*	278·27	74·21	74·11	399·99	256·24	134·52	Afternoon observations commencing at 4*h* 27*m* and ending at 6*h* 11*m*.
			95·4 + 154·1	280·47	74·36	74·21	404·90	258·36	133·93	
			101·1 + 149·8	282·28	74·50	74·33	409·49	260·90	133·69	
	M. W. R.	J.B.N.H.	115·0 + 135·2	282·10	74·67	74·51	415·06	264·70	131·74	
			121·0 + 130·8	284·13	74·80	74·61	419·32	266·82	131·63	
			121·0 + 132·9	286·45	74·93	74·76	423·58	269·99	132·86	
28th „	J.B.N.H.	M. W. R.	142·9*g* + 63·7*h*	235·04	71·08	71·26	297·45	195·94	133·53	Morning observations commencing at 6*h* 44*m* and ending at 8*h* 47*m*.
			119·3 + 89·5	236·44	71·09	71·28	297·78	196·36	135·02	
	M. W. R.	J.B.N.H.	101·7 + 106·4	234·89	71·14	71·34	299·42	197·63	133·10	
			96·9 + 110·5	233·91	71·27	71·44	303·68	199·74	129·97	
			71·4 + 140·5	237·78	71·42	71·55	308·59	202·07	131·26	
	J.B.N.H.	M. W. R.	78·5 + 133·6	238·31	71·55	71·61	312·85	203·34	128·80	
			Means ...		72·00	71·95			131·40	

Date.	Initials of observer at Microscope.		Observed value of $I_B - A$ in		Corrected temperatures.		Correction to 62° Fahrenheit in m.y		$I_B - A$ at 62° in millionths of a yard.	Remarks.
	G	H	Micrometer divisions.	Milnths. of a yard.	I_B	A	I_B	A		
24th April 1867,	J. T. W.	T. G. M.	113·0*g* + 139·8*h*	284·89	69·90	70·23	258·80	186·56	212·65	Afternoon observations commencing 4*h* 10*m* and ending 5*h* 9*m*. Day-light or sun-light reflected by heliotropes was employed for these observations.
			122·4 + 132·8	287·95	69·94	70·32	260·11	188·61	216·45	
			143·5 + 111·6	288·77	69·99	70·40	261·75	190·42	217·44	
	T. G. M.	J. T. W.	119·5 + 135·1	287·17	70·07	70·52	264·37	193·14	215·94	
			143·9 + 109·5	286·91	70·16	70·55	287·31	193·82	213·42	
			126·9 + 130·9	291·04	70·23	70·60	269·61	194·95	216·38	
25th "	J. T. W.	T. G. M.	138·1*g* + 147·2*h*	321·98	71·74	71·73	319·07	220·57	223·48	Morning observations commencing 4*h* 47*m* and ending 8*h* 34*m*. The first ten observations were taken by lamp-light, and the remainder by day-light or sun-light. The intensity of the light was changed whenever the observers changed microscopes and adjusted the prisms to suit their own sight; it appears that this change of circumstances affected the results considerably; though while the circumstances remained constant the results varied very little. This is supposed to be due to the different aspects of the dots on standard **A** according as they were more or less highly illuminated.
			127·4 + 155·9	319·30	71·71	71·70	318·09	219·89	221·10	
			133·3 + 148·3	317·67	71·65	71·61	316·13	217·85	219·39	
	T. G. M.	J. T. W.	148·0 + 134·0	318·76	71·61	71·53	314·82	216·03	219·97	
			148·8 + 131·2	316·58	71·53	71·50	322·19	215·35	219·74	
			143·9 + 140·4	321·13	71·47	71·41	310·23	213·31	224·21	
			149·4 + 134·6	321·03	71·37	71·31	306·95	211·05	225·13	
	J. T. W.	T. G. M.	154·8 + 122·2	313·51	71·34	71·22	305·97	209·01	216·55	
			162·8 + 115·2	314·97	71·18	71·05	300·73	205·15	219·39	
	T. G. M.	J. T. W.	139·7 + 140·1	315·96	71·15	71·03	299·75	204·70	220·91	
			155·5 + 124·6	316·99	70·95	70·81	293·19	199·71	223·51	
			150·7 + 129·3	316·67	70·91	70·73	291·88	197·90	222·69	
	J. T. W.	T. G. M.	145·4 + 128·3	309·46	70·89	70·73	291·23	197·90	216·13	
			147·5 + 125·5	308·78	70·87	70·73	290·57	197·90	216·11	
	T. G. M.	J. T. W.	143·1 + 138·2	317·77	70·83	70·71	289·26	197·45	225·96	
			151·2 + 130·4	318·45	70·84	70·71	289·59	197·45	226·31	
26th "	J.B.N.H.	M.W.R.	141·6*g* + 141·9*h*	320·15	72·75	73·24	352·16	254·80	222·79	Afternoon observations commencing 3*h* 46*m* and ending 5*h* 30*m*.
			145·4 + 139·4	321·75	72·84	73·33	355·11	256·84	223·48	
			135·4 + 153·1	325·40	72·96	73·43	359·04	259·11	225·47	
	M.W.R.	J.B.N.H.	150·1 + 137·4	324·94	73·13	73·61	364·61	263·19	223·52	
			148·3 + 140·7	326·54	73·26	73·72	368·87	265·68	223·35	
			140·7 + 151·7	329·97	73·39	73·85	373·13	268·63	225·47	
27th "	J.B.N.H.	M.W.R.	146·9*g* + 155·5*h*	341·31	73·45	73·51	375·09	260·92	227·14	Morning observations commencing 6*h* 43*m* and ending 9*h* 6*m*.
			158·6 + 139·4	336·94	73·43	73·48	374·44	260·24	222·74	
			143·6 + 159·0	341·38	73·42	73·47	374·11	260·01	227·28	
	M.W.R.	J.B.N.H.	134·4 + 164·2	336·53	73·42	73·48	374·11	260·24	222·66	
			134·8 + 165·1	337·99	73·43	73·47	374·44	260·01	223·56	
			143·5 + 156·3	338·27	73·44	73·49	374·76	260·47	223·98	
			132·3 + 163·9	333·79	73·48	73·51	376·07	260·92	218·64 }	Sun-light was employ- for these two differ ences.
	J.B.N.H.	M.W.R.	144·4 + 156·7	339·75	73·51	73·55	377·06	261·83	224·52 }	
			Means ...		71·84	71·95			221·32	

Date.	Initials of observer at Microscope. G	Initials of observer at Microscope. H	Observed value of $I_S - A$ in Micrometer divisions.	Observed value of $I_S - A$ in Milnths. of a yard.	Corrected temperatures. I_S	Corrected temperatures. A	Correction to 62° Fahrenheit in *m.y* I_S	Correction to 62° Fahrenheit in *m.y* A	$I_S - A$ at 62° in millionths of a yard.	Remarks.
23rd April 1867,	J. T. W.	T. G. M.	27·7*g* + 39·9*h*	76·08	71·02	70·99	190·86	203·79	89·01	Afternoon observations commencing 3*h* 15*m*, ending 4*h* 32*m*.
			40·9 + 24·7	74·45	71·04	71·02	191·28	204·47	87·64	
			32·2 + 33·7	74·38	71·04	71·04	191·28	204·93	88·03	
	T. G. M.	J. T. W.	32·7 + 30·8	71·75	71·07	71·04	191·92	204·93	84·76	
			34·5 + 33·2	76·47	71·09	71·07	192·34	205·61	89·74	
			31·2 + 39·6	79·76	71·12	71·12	192·97	206·74	93·53	
			44·6 + 21·5	75·15	71·14	71·19	193·40	208·33	90·08	
24th "	J. T. W.	T. G. M.	36·1*g* + 36·4*h*	81·86	70·61	70·32	182·18	188·61	88·29	Morning observations commencing 4*h* 27*m*, ending 5*h* 50*m*.
			19·6 + 51·0	79·04	70·54	70·21	180·70	186·11	84·45	
			44·5 + 27·2	81·35	70·45	70·18	178·80	185·43	87·98	
	T. G. M.	J. T. W.	42·9 + 34·3	87·37	70·38	70·09	177·32	183·39	93·44	
			38·4 + 36·6	84·72	70·32	70·01	176·05	181·58	90·25	
			38·8 + 36·8	85·41	70·28	69·93	175·20	179·76	89·97	
	J. T. W.	T. G. M.	51·8 + 22·3	84·32	70·18	69·84	173·08	177·72	88·96	
25th "	J.B.N.H.	M.W.R.	28·7*g* + 26·9*h*	62·83	72·24	72·97	216·67	248·68	94·84	Afternoon observations commencing 4*h* 0*m*, ending 5*h* 26*m*.
			33·3 + 20·9	61·48	72·31	73·03	218·15	250·04	93·37	
			29·9 + 25·3	62·44	72·47	73·18	221·54	253·44	94·34	
	M. W. R.	J.B.N.H.	23·9 + 27·8	58·30	72·59	73·30	224·08	256·16	90·38	
			27·6 + 25·2	59·68	72·74	73·44	227·25	259·33	91·76	
			26·9 + 25·2	58·88	72·86	73·53	229·79	261·37	90·46	
26th "	J.B.N.H.	M.W.R.	26·6*g* + 41·0*h*	76·03	72·63	72·68	224·92	242·10	93·21	Morning observations commencing 6*h* 38*m*, ending 8*h* 53*m*.
			28·3 + 37·9	74·55	72·59	72·57	224·08	239·61	90·08	
			34·8 + 30·2	73·49	72·51	72·51	222·39	238·25	89·35	
	M.W.R.	J.B.N.H.	26·0 + 40·3	74·56	72·49	72·49	221·96	237·80	90·40	
			33·4 + 29·9	71·56	72·49	72·48	221·96	237·57	87·17	
			30·5 + 34·6	73·42	72·50	72·47	222·17	237·34	88·59	
			38·1 + 26·1	72·76	72·53	72·52	222·81	238·48	88·43	
	J.B.N.H.	M.W.R.	39·6 + 25·5	73·82	72·56	72·56	223·44	239·38	89·76	
			Means, ...		71·64	71·71			89·94	

Computing the probable errors on the assumption that there are no constant errors in the foregoing results we have

$$\mathbf{I}_B - \mathbf{I}_S = 131{\cdot}40 \pm {\cdot}27 \text{ millionths of a yard}$$
$$\mathbf{I}_B - \mathbf{A} = 221{\cdot}32 \pm {\cdot}44 \quad \text{,,}$$
$$\mathbf{I}_S - \mathbf{A} = 89{\cdot}94 \pm {\cdot}33 \quad \text{,,}$$

Of the above mentioned groups the first was intended to shew whether the relative lengths of the standards $\mathbf{I}_B$ and $\mathbf{I}_S$ had sensibly changed from the value obtained by Captain Clarke viz. 131·46 *m.y*; see *Comparisons of Standards of Length, p.* 280; the accordance is sufficiently close to warrant the belief that no such change had taken place. Subsequent investigations have shewn that the factor adopted for **A** was slightly erroneous, and the effect of the error on the above determinations has been considered in Appendix No. 7.

W. H. COLE.

APPENDIX.

No. 4.

COMPARISONS OF THE SIX-INCH BRASS SCALES OF THE COMPENSATED MICROSCOPES.

Of these scales, known as *M, N, P, R, S, T, U, V,* and *W*, the first seven were constructed by the Mathematical Instrument Department at Calcutta, under directions from Colonel Everest; they were made of cast brass and each provided with a micrometer screw, as the microscopes to which they belonged had only fixed wires, and could not therefore be made to measure their own differences from their scales. These scales were first brought into use at the measurement of the Dehra base-line in 1835 and were then compared under Colonel Everest's superintendence with Troughton and Simms' 6-inch standard *A*. The comparisons and their reduction will be found on pages 14 and 15. The thermometers employed on that occasion were distinguished by the letters of the microscopes to which they appertained; they were compared with two standards named σ and σ_1 and index corrections were obtained to reduce them to the mean of the two latter. The comparing microscopes are described in Appendix No. 1. The run of the micrometer microscope was determined on the inch [7·8] of Cary's scale and found to be = ·000,050,841 of an inch, or 1·4123 *m.y.* The factors of expansion of all the scales were assumed to be ·000,010,417 for 1° Fahrenheit, the corresponding linear expansion being 1·736 *m.y.*

In the year 1866 two new microscopes named *V* and *W*, with scales attached, were received from Messrs. Troughton and Simms; and the following year all the scales, with the exception of *P*, which was then in England undergoing repair, were compared with the space [*d.l*] on the standard foot **IF**, by five observers employing the microscopes **G** and **H**, the linear value of one division of **G** being = 1·1511 *m.y.* and of **H** = 1·1074 *m.y.* The thermometers made use of were for

Standard Foot **IF**	... ...	4215
Brass scales *M, R, U, W, A,*	...	4204
„ *N, S, T, V,*	... ...	4011

These comparisons are given on pages 16, 17 and 18.

DATE.	Temperatures uncorrected for index errors of thermometers. *A*	*M*	*A* − *M* in millionths of a yard. At observed temperatures.	Corrected for thermometer errors and reduced to 62°.	Temperature uncorrected for index error of thermometer. *N*	*A* − *N* in millionths of a yard. At observed temperatures.	Corrected for thermometer errors and reduced to 62°.	Temperature uncorrected for index error of thermometer. *P*	*A* − *P* in millionths of a yard. At observed temperatures.	Corrected for thermometer errors and reduced to 62°.
11th June, 1835.	64·2	65·0	− 1·4	− 1·37	64·7	− 9·9	− 10·07	64·7	− 11·3	−11·73
	64·5	65·0	·6	1·07	64·5	13·4	14·47	64·8	15·1	15·93
	65·0	66·0	3·2	2·87	65·4	7·8	8·17	65·6	12·3	12·63
	65·6	66·7	+ 1·7	+ 2·23	66·4	11·3	10·97	67·0	7·1	6·03
	67·0	68·0	·1	·43	67·9	10·6	10·07	69·0	9·2	7·03
	68·8	69·0	1·3	·23	68·8	8·5	9·57	69·3	12·7	13·13
	69·5	70·0	5·8	5·33	69·7	7·8	8·47	69·8	6·4	7·23
	70·5	70·2	1·0	− ·87	69·0	5·7	9·37	69·4	7·8	11·03
	70·9	71·5	− 5·1	5·47	71·0	13·8	14·67	71·3	12·4	13·03
	71·7	71·2	·0	2·27	70·9	10·0	12·47	71·0	10·0	12·53
	70·9	70·0	+ 1·4	1·57	69·7	8·5	11·67	69·8	10·9	14·13
	69·9	69·7	2·3	+ ·63	69·1	10·2	12·67	69·2	9·2	11·73
	69·8	69·6	·3	− 1·37	69·2	9·2	11·27	69·6	13·4	15·03
	71·7	70·3	4·0	+ ·23	70·0	5·5	9·57	70·2	7·8	11·73
12th June, "	64·3	65·3	3·2	3·53	65·0	6·9	6·77	65·1	5·5	5·43
	64·6	65·1	·4	− ·07	65·0	7·3	7·67	65·1	5·9	6·33
	65·2	66·0	− 1·0	·97	65·8	13·1	13·17	65·6	14·0	14·63
	65·8	66·2	·0	·67	66·1	12·0	12·57	66·1	7·2	8·03
	66·8	67·4	4·0	4·37	67·8	9·9	9·27	67·4	10·3	10·63
	69·0	69·0	+ ·4	·97	68·8	13·0	14·47	68·8	7·9	9·53
	70·3	70·0	5·6	+ 3·73	69·3	9·0	11·77	69·8	4·4	6·63
	70·6	70·0	3·1	·73	69·7	10·6	13·27	69·8	6·1	8·83
	69·8	70·0	1·6	·53	69·7	8·5	9·77	69·7	5·9	7·43
	70·4	70·4	− ·3	− 1·67	70·3	10·6	11·87	70·5	10·2	11·33
	72·5	70·2	+ 2·4	2·97	70·0	5·1	10·47	70·2	11·9	17·23
	71·7	70·8	1·8	1·17	70·8	7·9	10·57	70·8	10·9	13·83
	71·5	70·8	3·1	+ ·53	70·3	7·5	10·67	70·8	6·5	9·03
	71·2	70·3	− ·8	− 3·77	70·1	11·3	14·27	70·4	10·3	13·03
	70·7	70·4	+ 2·3	+ ·43	70·2	12·4	14·37	70·7	8·3	9·63
	70·7	71·2	9·9	9·43	70·8	1·4	2·27	70·8	·1	1·23
13th June, "	64·7	66·0	3·7	4·63	65·8	6·5	5·67	65·9	10·5	9·73
	65·7	67·3	1·0	2·43	67·5	5·4	3·37	67·6	5·4	3·43
	67·8	68·7	5·0	5·23	68·8	5·0	4·37	69·0	4·1	3·33
	69·5	70·0	− ·1	− ·57	70·2	10·5	10·37	70·8	7·1	6·13
	71·4	71·3	+ 4·8	+ 3·23	71·7	5·9	6·47	71·8	4·2	4·83
	72·0	72·6	− 2·8	− 3·17	71·8	12·0	13·47	72·0	11·3	12·63
	72·5	73·0	+ ·7	+ ·23	73·0	9·9	10·07	73·2	11·3	11·43
	74·2	74·0	·8	− ·87	74·0	8·3	9·77	74·2	7·2	8·53
	75·4	74·8	·7	1·67	74·7	12·9	15·17	75·0	8·5	10·53
	75·5	75·0	6·6	+ 4·33	75·4	6·8	8·07	75·6	5·4	6·53
	75·8	75·3	3·0	·73	75·7	6·2	7·47	75·9	5·0	6·13
	75·5	76·0	4·2	3·73	75·8	8·5	9·07	76·0	7·8	8·23
	77·2	75·9	− 4·2	− 7·87	75·8	11·3	14·77	75·7	12·4	16·33
	77·4	77·0	+ 2·8	+ ·73	76·8	4·2	6·27	77·5	6·8	7·93
	77·2	77·4	− ·7	− 1·77	77·5	11·3	11·87	77·5	13·8	14·63
	78·3	77·9	+ 9·3	+ 7·23	78·2	5·1	6·37	78·1	1·8	3·43
	79·0	78·9	5·6	4·03	78·4	7·2	9·27	79·0	7·5	8·83
	79·8	79·0	6·1	3·33	78·8	5·5	8·27	78·9	7·6	10·53
	80·0	79·3	7·5	4·93	79·1	6·8	9·47	79·3	6·8	9·33
	80·0	80·0	6·4	5·03	79·9	6·5	7·77	79·5	6·2	8·43
Means				+ 0·57			− 10·08			− 9·73
Probable errors				± ·31			± ·29			± ·35

BRASS SCALES IN 1835.

Temperature uncorrected for index error of thermometer.	A − R in millionths of a yard.		Temperature uncorrected for index error of thermometer.	A − S in millionths of a yard.		Temperature uncorrected for index error of thermometer.	A − T in millionths of a yard.		Temperature uncorrected for index error of thermometer.	A − U in millionths of a yard.	
R	At observed temperatures.	Corrected for thermometer errors and reduced to 62°.	S	At observed temperatures.	Corrected for thermometer errors and reduced to 62°.	T	At observed temperatures.	Corrected for thermometer errors and reduced to 62°.	U	At observed temperatures.	Corrected for thermometer errors and reduced to 62°.
64·5	+ 2·8	+ 2·06	64·2	+ 2·8	+ 1·42	64·0	+ 4·5	+ 3·01	65·6	− 3·5	− 1·76
64·5	·0	− 1·24	64·5	1·6	·22	64·2	2·5	·81	64·0	6·5	8·06
66·0	− 5·7	5·24	65·8	1·4	1·42	65·8	− 1·8	− 1·59	65·0	13·4	14·06
66·8	·4	+ ·46	66·8	4·2	4·92	66·0	+ 4·2	+ 3·71	66·5	8·5	7·56
69·3	5·4	− 2·64	68·3	3·5	4·42	68·1	6·4	7·11	67·8	4·8	4·06
69·5	5·7	5·74	69·2	2·1	1·42	69·0	1·1	·21	68·9	9·6	10·06
69·8	+ 2·1	+ 1·36	69·2	7·1	5·22	69·0	7·5	5·41	68·9	6·5	8·16
69·8	− 2·1	− 4·54	70·0	5·7	3·42	69·8	5·6	3·21	69·9	5·0	6·66
71·4	2·1	2·44	70·7	6·2	4·42	71·0	1·7	·71	70·4	10·5	12·06
70·8	5·7	8·54	70·4	1·0	− 2·68	70·6	− 1·0	− 4·09	70·2	11·3	14·56
69·3	+ ·4	3·64	69·2	7·2	+ 2·82	69·0	+ 1·8	2·69	69·0	6·8	10·76
69·5	− ·6	2·54	69·6	4·5	2·62	69·0	2·1	·69	69·1	12·1	14·16
69·6	·4	1·94	69·6	1·4	− ·38	69·3	− ·1	2·19	69·7	9·9	10·76
70·2	+ 1·8	2·04	70·0	5·1	+ ·72	70·0	+ 4·7	+ ·51	70·0	10·5	14·16
65·0	− 3·1	3·14	64·8	6·4	5·92	64·4	5·8	4·81	64·1	+ ·1	·86
65·0	5·2	5·74	65·0	4·2	3·52	64·5	7·8	6·41	64·1	− 3·1	4·66
65·5	6·2	6·94	65·5	1·8	·92	65·4	·0	− ·89	64·9	8·3	9·46
66·4	+ ·1	·14	66·2	3·7	3·02	66·0	11·6	+ 10·71	65·8	6·1	6·76
68·4	− 7·5	5·94	68·0	·6	1·32	67·7	− ·6	− ·19	67·7	10·0	9·06
69·3	2·7	3·44	69·0	2·7	1·32	68·8	+ 6·9	+ 5·41	68·3	5·2	7·06
69·9	+ ·4	1·54	69·8	5·5	3·22	69·0	7·5	4·01	68·8	3·1	6·36
69·8	− 3·0	5·64	69·9	6·9	4·32	69·1	9·9	6·11	69·0	4·4	7·86
69·8	3·1	4·34	69·8	6·8	5·42	69·5	5·1	3·41	69·1	6·2	8·06
70·4	7·1	8·34	70·2	− 1·7	− 3·48	70·4	1·4	·21	70·0	6·5	7·86
70·4	·4	5·24	70·1	+ 2·0	3·58	70·1	5·8	·41	69·8	3·5	8·86
70·9	·0	2·64	70·5	4·8	+ 1·32	70·7	3·8	·91	70·0	6·4	10·06
71·9	3·4	3·94	70·9	7·2	4·82	70·6	10·2	7·41	70·0	·3	3·56
70·7	6·4	8·54	70·4	2·8	·02	70·0	3·5	·21	70·0	6·4	9·16
71·7	3·1	2·64	70·8	1·4	·22	70·7	2·1	·91	70·1	7·1	8·76
71·0	+ 3·8	+ 3·06	70·2	12·0	9·72	70·1	12·0	9·81	70·0	+ 2·1	+ ·24
65·8	1·1	1·76	65·8	4·4	4·92	65·4	10·3	10·31	65·0	− 6·2	− 6·36
68·0	1·1	3·86	68·0	8·2	10·82	67·4	− ·7	1·11	67·9	5·8	2·66
69·4	·9	2·46	69·0	2·3	3·02	69·1	+ 5·5	6·61	68·9	8·2	6·96
72·0	− 4·1	− 1·04	70·8	·9	1·82	71·0	2·8	4·21	70·5	8·6	7·56
71·8	·4	·94	71·2	3·1	1·32	71·0	8·8	6·91	71·0	4·2	5·56
72·1	5·7	6·74	71·8	− ·7	− 2·48	71·8	·8	− ·69	71·7	12·3	13·46
73·0	·1	·44	72·8	+ ·7	·18	72·7	− 1·8	2·69	72·8	9·9	10·06
75·3	·3	+ ·36	74·0	5·8	+ 4·02	73·8	1·3	3·19	73·2	7·6	9·96
75·3	4·2	− 5·64	75·0	3·5	1·42	75·0	+ 3·5	+ 1·61	74·7	9·2	11·06
76·0	2·1	2·44	75·0	5·9	3·62	75·0	4·9	2·81	75·2	6·1	7·26
75·8	2·1	3·34	75·0	7·8	5·02	75·0	3·5	·91	75·1	6·4	8·26
76·0	·0	·34	75·3	− 1·6	− 3·38	75·7	1·7	·81	75·7	9·2	9·56
76·0	3·4	6·74	76·3	3·1	6·08	76·3	2·5	− ·29	76·0	8·2	10·96
77·2	+ 2·1	+ ·56	76·8	+ 5·4	+ 3·02	77·0	12·7	+ 10·81	76·6	2·5	4·56
78·0	− 9·6	− 9·44	77·2	− 2·8	− 4·18	77·3	2·5	1·51	77·2	8·9	9·56
78·9	+ 6·4	+ 6·16	78·1	+ 7·3	+ 5·52	78·2	14·1	12·71	78·1	+ ·7	·26
79·4	− ·7	− 1·24	78·8	10·6	8·82	79·2	4·2	3·31	78·2	− 2·8	4·86
79·2	1·8	4·04	79·0	− 2·5	− 5·28	79·4	2·3	·41	78·9	4·0	6·26
79·7	+ ·4	1·34	79·8	+ 3·2	+ 1·42	79·8	4·7	3·21	79·0	5·1	7·46
80·0	3·0	+ 1·76	80·0	4·2	2·82	80·0	3·2	2·01	79·3	3·4	5·26
		− 2·58			+ 2·08			+ 2·71			− 7·86
		± ·33			± ·34			± ·38			± ·34

COMPARISONS OF THE SIX-INCH BRASS SCALES IN 1867.

Observer's initials.	Corrected temperatures		[d.l] − M in millionths of a yard			Corrected temperatures		[d.l] − N in millionths of a yard			Corrected temperatures		[d.l] − R in millionths of a yard		
	[d.l]	M	at obsd. temp.	at 62° Fah.	Mean of each obsr.	[d.l]	N	at obsd. temp.	at 62° Fah.	Mean of each obsr.	[d.l]	R	at obsd. temp.	at 62° Fah.	Mean of each obsr.
M. W. R.	67·65	67·91	− 7·50	− 3·22		68·41	69·09	−16·74	−11·22		65·32	66·12	−11·49	− 7·85	
	69·21	69·58	− 7·45	− 1·93		69·21	69·43	−12·84	− 7·58		65·90	67·08	−11·20	− 6·51	
	69·52	69·74	− 6·75	− 1·27		69·52	69·86	−16·43	−10·74		66·32	67·15	−11·05	− 6·68	
	69·69	69·96	− 9·92	− 4·24	− 2·67	69·69	69·91	−16·38	−10·79	−10·08	66·61	67·34	− 9·69	− 5·30	−6·59
W. J. H.	67·17	67·15	− 9·19	− 5·73		67·17	67·46	−15·82	−11·82		66·95	68·37	−14·17	− 8·35	
	67·78	67·85	− 8·57	− 4·53		67·78	68·08	−16·54	−12·10		67·47	68·72	−14·08	− 8·21	
	66·38	66·87	− 8·06	− 4·25		66·38	66·41	−16·57	−13·55		67·71	68·62	−14·54	− 9·09	
	67·30	67·82	− 8·73	− 4·24	− 4·69	67·30	67·59	−16·63	−12 54	−12·50	67·85	68·70	−10·35	− 4·91	−7·64
T. G. M.	68·32	68·41	− 9·75	− 5·31		68·32	68·76	−18·47	−13·42		67·43	68·16	−12·15	− 7·21	
	68·71	68·75	−10·51	− 5·90		68·71	68·91	−19·44	−14·55		67·68	68·59	−14·51	− 9·09	
	69·04	69·37	− 9·43	− 4·09		69·04	69·40	−21·17	−15·78		67·87	68·68	−12·63	− 7·25	
	69·28	69·66	−11·28	− 5·69	− 5·25	69·28	69·46	−20·37	−15·13	−14·72	68·62	69·36	−10·90	− 5·14	−7·17
J. B. N. H.	67·10	67·34	− 7·58	− 3·71		67·10	67·39	−16·95	−12·99		67·73	70·19	−18·69	−10·54	
	67·37	67·77	− 8·65	− 4·29		67·37	67·51	−17·52	−13·61		68·13	70·33	−17·43	− 9·46	
	67·54	67·83	− 8·68	− 4·43		67 54	67·90	−17·53	−13·16		68·66	70·68	−18·90	−10·88	
	67·78	68·16	− 7·84	− 3·27	− 3·93	67·78	67·98	−17·60	−13·34	−13·28	68·95	70·75	−20·63	−12·80	−10·92
H. R. T.	66·32	66·69	− 6·09	− 2·53		66·32	66·56	−16·05	−12·71		70·23	72·04	−18·54	− 9·84	
	66·57	66·74	− 6·70	− 3·31		66·57	66·99	−12·59	− 8·77		70·33	71·92	−17·78	− 9·35	
	66·77	67·21	− 1·35	+ 2·65		66·77	67·03	−11·39	− 7·71		70·40	71·92	−18·91	−10·59	
	67·03	67·26	− 5·28	− 1·48	− 1·17	67·03	67·45	−12·15	− 8·02	− 9·30	70·49	71·82	−17·73	− 9·67	−9·86
General mean					−3·54					−11·98					−8·44
Probable error					± ·49					± ·67					± ·56

COMPARISONS OF THE SIX-INCH BRASS SCALES IN 1867.

Observer's initials.	Corrected temperatures		$[d.l] - S$ in millionths of a yard			Corrected temperatures		$[d.l] - T$ in millionths of a yard			Corrected temperatures		$[d.l] - U$ in millionths of a yard		
	$[d.l]$	S	at obsd. temp.	at 62° Fah.	Mean of each obsr.	$[d.l]$	T	at obsd. temp.	at 62° Fah.	Mean of each obsr.	$[d.l]$	U	at obsd. temp.	at 62° Fah.	Mean of each obsr.
M. W. R.	65.32	65.43	−2.51	−0.07		69.08	70.39	−5.68	+1.39		69.08	68.91	−13.48	−8.98	
	65.90	65.68	+0.58	+2.84		69.54	71.11	−7.57	+0.26		69.54	68.92	−12.16	−8.14	
	66.32	66.16	−4.45	−1.80		69.83	71.19	−5.43	+2.23		69.83	68.93	−13.11	−9.37	
	66.61	66.35	+0.26	+2.93	+0.98	70.10	71.50	−4.19	+3.72	+1.90	70.10	68.94	−11.18	−7.71	−8.55
W. J. H.	66.95	66.56	−0.74	+1.93		68.83	70.23	−4.25	+2.81		68.83	68.63	−12.82	−8.54	
	67.47	66.84	−0.40	+2.21		69.21	70.34	−2.84	+4.00		69.21	69.41	−16.22	−11.00	
	67.71	67.33	−0.56	+2.65		69.84	70.72	−3.71	+3.13		69.84	69.74	−14.04	−8.90	
	67.85	67.45	+1.31	+4.58	+2.84	69.99	70.75	−4.22	+2.51	+3.11	69.99	69.85	−15.67	−10.50	−9.74
T. G. M.	67.43	67.23	−2.23	+1.10		69.39	70.77	−4.31	+3.09		69.39	69.11	−12.04	−7.53	
	67.68	67.36	−1.53	+1.76		69.80	70.96	−3.77	+3.53		69.80	69.91	−13.43	−7.96	
	67.87	67.78	−3.07	+0.74		70.21	71.58	−5.08	+2.86		70.21	70.07	−12.59	−7.27	
	68.62	68.43	−1.10	+3.06	+1.67	70.46	71.66	−4.66	+3.15	+3.16	70.46	70.55	−15.01	−9.13	−7.97
J. B. N. H.	67.73	67.90	−4.77	−0.60		66.20	66.54	−3.83	−0.40		66.20	66.52	−15.45	−12.05	
	68.13	68.45	−3.11	+1.60		66.71	67.63	−3.63	+1.16		66.71	66.75	−16.90	−13.64	
	68.66	68.51	−4.14	+0.11		67.08	67.85	−5.33	−0.55		67.08	67.45	−15.93	−11.85	
	68.95	69.04	−5.71	−0.85	+0.07	67.34	68.39	−6.18	−0.74	−0.13	67.34	67.56	−15.67	−11.67	−12.30
H. R. T.	70.23	69.48	−2.10	+2.17		69.03	70.05	−5.23	+1.30		69.03	68.57	−16.62	−12.66	
	70.33	69.52	−1.66	+2.58		69.38	70.60	−3.56	+3.55		69.38	68.85	−14.63	−10.56	
	70.40	69.66	−2.61	+1.79		69.62	70.71	−4.85	+2.20		69.62	69.36	−16.11	−11.40	
	70.49	69.72	−1.35	+3.06	+2.40	69.87	70.95	−5.18	+2.03	+2.27	69.87	69.50	−16.48	−11.79	−11.60
				General mean	+1.59					+2.06					−10.03
				Probable error	± .33					± .37					± .56

COMPARISONS OF THE SIX-INCH BRASS SCALES IN 1867.

Observer's initials.	Corrected temperature.		[d.l] − V in millionths of a yard			Corrected temperatures.		[d.l] − W in millionths of a yard			Corrected temperatures.		[d.l] − A in millionths of a yard		
	[d.l]	V	at obsd. temp.	at 62° Fah.	Mean of each obsr.	[d.l]	W	at obsd. temp.	at 62° Fah.	mean of each obsr.	[d.l]	A	at obsd. temp.	at 62° Fah.	Mean of each obsr.
M. W. R.	68·43	69·23	+ 0·95	+ 6·69		68·43	68·44	+ 0·68	+ 5·05		67·82	68·74	− 3·40	+ 2·14	
	69·01	70·29	− 1·04	+ 5·93		69·01	68·66	− 0·06	+ 4·08		68·14	68·76	− 4·11	+ 1·12	
	69·38	70·45	− 1·96	+ 4·89		69·38	69·25	− 2·41	+ 2·36		68·18	68·74	− 5·25	− 0·09	
	69·71	70·81	− 0·87	+ 6·26	+ 5·94	69·71	69·38	− 2·63	+ 2·02	+ 3·38	68·42	68·76	− 4·03	+ 0·91	+ 1·02
W. J. H.	67·07	67·60	− 0·42	+ 3·93		67·07	67·00	− 1·48	+ 1·83		65·94	66·09	+ 6·47	+ 9·40	
	67·55	68·72	− 0·13	+ 5·66		67·55	67·21	− 0·39	+ 2·78		66·53	66·35	+ 6·12	+ 8·87	
	67·97	68·89	− 1·18	+ 4·46		67·97	67·97	− 2·70	+ 1·34		66·56	66·80	+ 6·26	+ 9·76	
	68·32	69·45	− 1·88	+ 4·36	+ 4·60	68·32	68·09	− 1·39	+ 2·49	+ 2·11	67·00	66·97	+ 4·46	+ 7·79	+ 8·96
T. G. M.	69·23	70·08	− 5·13	+ 1·24		69·23	68·95	− 7·97	− 3·56		67·57	67·50	+ 0·77	+ 4·42	
	69·46	70·46	− 4·90	+ 1·89		69·46	69·08	− 4·49	− 0·10		67·75	67·56	+ 0·88	+ 4·44	
	69·63	70·53	− 6·06	+ 0·67		69·63	69·46	− 5·59	− 0·72		67·80	67·77	+ 0·45	+ 4·32	
	69·84	70·83	− 4·14	+ 2·89	+ 1·67	69·84	69·56	− 4·03	+ 0·79	− 0·90	67·97	67·82	+ 2·69	+ 6·47	+ 4·91
J. B. N. H.	66·86	67·76	− 1·76	+ 3·09		66·86	66·50	− 1·14	+ 1·53		66·14	66·39	+ 4·01	+ 7·25	
	67·13	68·20	+ 0·22	+ 5·55		67·13	66·59	+ 1·28	+ 3·82		66·97	66·68	+ 4·23	+ 7·10	
	67·37	68·31	− 1·47	+ 3·80		67·37	67·10	− 2·93	+ 0·24		67·04	67·22	+ 3·53	+ 7·25	
	67·62	68·64	− 2·95	+ 2·63	+ 3·77	67·62	67·22	− 2·56	+ 0·55	+ 1·54	67·39	67·34	+ 4·26	+ 7·82	+ 7·36
H. R. T.	68·48	69·14	− 0·38	+ 5·16		68·48	68·42	− 1·33	+ 2·96		66·34	66·17	+ 1·21	+ 3·85	
	68·81	69·64	+ 0·39	+ 6·44		68·81	68·61	− 0·23	+ 4·04		66·45	66·53	+ 2·24	+ 5·39	
	69·03	69·75	+ 0·16	+ 6·16		69·03	68·91	− 1·42	+ 3·13		66·70	66·62	+ 3·50	+ 6·54	
	69·20	69·95	− 0·37	+ 5·80	+ 5·89	69·20	69·01	− 1·02	+ 3·52	+ 3·41	66·75	66·92	+ 2·61	+ 6·12	+ 5·48
				General mean	+ 4·37					+ 1·91					+ 5·55
				Probable error	± ·53					± ·53					± ·90

Collecting the results we have

by Colonel Everest in 1835.	by observations at Mussoorie in 1867.
$A - M = + 0{\cdot}57 \pm 0{\cdot}31$ *m.y.*	$[d.l] - M = - 3{\cdot}54 \pm {\cdot}49$ *m.y.*
$A - N = - 10{\cdot}08 \pm 0{\cdot}29$ „	$[d.l] - N = - 11{\cdot}98 \pm {\cdot}67$ „
$A - P = - 9{\cdot}73 \pm 0{\cdot}35$ „	$[d.l] - R = - 8{\cdot}44 \pm {\cdot}56$ „
$A - R = - 2{\cdot}58 \pm 0{\cdot}33$ „	$[d.l] - S = + 1{\cdot}59 \pm {\cdot}33$ „
$A - S = + 2{\cdot}08 \pm 0{\cdot}34$ „	$[d.l] - T = + 2{\cdot}06 \pm {\cdot}37$ „
$A - T = + 2{\cdot}71 \pm 0{\cdot}38$ „	$[d.l] - U = - 10{\cdot}03 \pm {\cdot}56$ „
$A - U = - 7{\cdot}86 \pm 0{\cdot}34$ „	$[d.l] - V = + 4{\cdot}37 \pm {\cdot}53$ „
	$[d.l] - W = + 1{\cdot}91 \pm {\cdot}53$ „
	$[d.l] - A = + 5{\cdot}55 \pm {\cdot}90$ „

These results are fully discussed in Section 8 of Chapter III. It only remains to state that the above probable errors of the results were determined, for the observations of 1835, from the differences between the individual comparisons and the mean of all; for the observations of 1867 they were determined from the differences between the results by each observer and the mean of the results by all the observers. Fifty comparisons with the standard were taken on the first occasion and only twenty on the second, which accounts, in some measure for the probable errors of the first comparisons being apparently less than those of the second. But this circumstance is more likely to be due to more observers having been employed in the second instance than in the first, and consequently to the influence of the personal equations in increasing the magnitude of the discordances between the individual results; see Section 1 Chapter III. On the other hand, where there is a liability to personal equations, the result of the mean of the observations of several observers is in reality preferable to that of a single or a few observers.

No details are forthcoming as to the persons by whom the comparisons in 1835 were made; for the subsequent comparisons the initials of the observers have been given.

The probable error of observation for each observer, in a single comparison of any one of the scales with the standard of reference, is as follows :—

J. B. N. H.	± 0·69
W. J. H.	± 0·69
T. G. M.	± 0·77
H. R. T.	± 0·92
M. W. R.	± 0·93
Observers in 1835	± 2·35

The probable error of observation, for each scale, in a single comparison with either standard by any one of the observers is,

in 1835.		in 1867.	
M ...	± 2·23	*M* ...	± ·97
N ...	± 2·04	*N* ...	± ·95
P ...	± 2·47	*R* ...	± ·92
R ...	± 2·32	*S* ...	± ·92
S ...	± 2·38	*T* ...	± ·62
T ...	± 2·64	*U* ...	± ·62
U ...	± 2·35	*V* ...	± ·60
		W ...	± ·91
		A ...	± ·62

W. H. COLE.

APPENDIX.

No. 5.

DETERMINATION OF THE LENGTH OF THE INCH [7.8] ON CARY'S 3-FOOT BRASS-SCALE.

The inch [7.8] on this scale was, prior to the year 1868, employed at all base-line measurements to determine the runs of the micrometers of the microscopes; but it was not until the recess season of 1869 that a favourable opportunity offered itself for investigating its relation to the 10-foot standard **A**. This investigation was then rendered simple by the possession of the standard foot **IF**, on which Captain Clarke had carefully determined the linear value of the inch [*a.b*] in terms of the ordnance standard yard $\mathbf{Y}_{55}$; and as the length of **A** relatively to that yard had been recently determined, see Chapter 3 section 6, it only remained to compare [7.8] with [*a.b*] to obtain the required relation.

Six observers were employed in taking the necessary observations; and it having been found that the microscopes **G** and **H** could not be set up at a less distance apart than five integral inches, the 5 and 6 inch spaces [*b.g*] and [*a.g*] on **IF** were selected and compared with the corresponding spaces [8.13] and [7.13] on Cary's scale. These comparisons are given in the following tables. The runs of the microscopes were

1 division of **G** = 1·1511 *m.y.* 1 division of **H** = 1·1074 *m.y.*

The thermometers employed were 4218 on **IF** and 4217 on Cary's scale, the bulb of the former was let into one of the wells in the foot and contact was secured as usual with olive oil, the latter could only be made to touch the scale externally, no hole having been bored for the reception of a thermometer; the mean of the two thermometers, after correcting for errors, was assumed as the temperature of both bars for the comparison concerned. As both scales were compared in a room subject to very slight variations of temperature, the error introduced by the assumption may be considered as insignificant. The factor made use of for **IF** was ·000,006,347,8, or Captain Clarke's second factor for $\mathbf{I}_{''}$, and it was assumed that the factor for Cary's scale was $\frac{10}{6}$ of the factor of **IF**. These assumptions are sufficiently approximate for the result sought and were made in compliance with Colonel Walker's directions.

Date.	Observer's initials.	[b.g] – [8.12] observed. In Micrometer divisions.	[b.g] – [8.12] observed. In m.y.	Corrected temperature.	Correction to 62° Fahrenheit.	[b.g] – [8.12] at 62°.	Mean of each observer in m.y.	Remarks.
1869.				°	m.y.	m.y.		h. m.
Sept. 7th	J. B. N. H.	– 0·8g – 16·3h	–18·97	68·3	+ 4·44	– 14·5		Commencing 2 45 P.M.
		1·9 16·6	20·56	68·3	4·44	16·1		Ending 3 45 „
		0·3 18·4	20·72	68·3	4·44	16·3		
		1·5 16·6	20·10	68·3	4·44	15·7		
		1·8 18·3	22·35	68·3	4·44	17·9	– 16·1	
„ 8th	T. G. M.	– 2·1g – 19·7h	–24·24	67·1	+ 3·59	– 20·7		Commencing 0 15 P.M.
		3·9 18·4	23·86	67·2	3·67	20·2		Ending 1 41 „
		0·2 22·5	25·14	67·3	3·74	21·4		
		+ 5·3 27·6	24·44	67·4	3·81	20·6		
		2·1 23·4	23·47	67·5	3·88	19·6	– 20·5	
„ 8th	C. L.	+ 3·7g – 25·5h	–23·99	68·2	+ 4·37	– 19·6		Commencing 2 50 P.M.
		0·8 21·8	23·23	68·4	4·52	18·7		Ending 4 38 „
		– 1·3 19·0	22·55	68·6	4·66	17·9		
		+ 0·1 20·3	22·37	68·7	4·72	17·7		
		+ 2·6 22·6	22·04	68·8	4·80	17·2	– 18·2	
„ 9th	H. R. T.	– 4·1g – 19·4h	–26·19	66·7	+ 3·32	– 22·9		Commencing 11 35 A.M.
		1·9 21·3	25·77	66·8	3·38	22·4		Ending 0 45 P.M.
		+ 0·3 22·3	24·36	66·9	3·46	20·9		
		+ 3·1 25·4	24·56	67·0	3·53	21·0		
		– 5·0 16·7	24·23	67·1	3·59	20·6	– 21·6	
„ 9th	H. K.	+ 1·2g – 18·0h	–18·55	67·3	+ 3·74	– 14·8		Commencing 2 30 P.M.
		2·0 19·3	19·08	67·7	4·02	15·1		Ending
		2·7 17·3	16·07	67·5	3·88	12·2		
		0·8 17·6	18·58	67·6	3·95	14·6		
		0·0 15·2	16·84	67·7	4·02	12·8	– 13·9	
„ 10th	T. T. C.	+ 1·1g – 21·3h	–22·32	65·1	+ 2·19	– 20·1		Commencing 11 0 A.M.
		0·5 18·4	19·82	65·8	2·68	17·1		Ending 1 15 P.M.
		3·3 24·0	22·77	66·0	2·82	20·0		
		10·0 31·0	22·82	66·1	2·89	19·9		
		13·2 32·9	21·23	66·1	2·89	18·3	– 19·1	
			Means	67·4			– 18·2	

Date.	Observer's initials.	[a.g] − [7·13] observed: In Micrometer divisions.	[a.g] − [7·13] observed: in m.y.	Corrected temperature.	Correction to 62° Fahrenheit.	[a.g] − [7·13] at 62°	Mean of each observer in m.y.	Remarks.
					m.y.	m.y.		h. m.
1869 Sept. 10th	J. B. N. H.	− 0·5g − 6·7h	− 7·99	66·3	+ 3·04	− 5·0		Commencing 2 20 P.M.
		+ 4·1 11·1	7·56	66·3	3·04	4·5		Ending 3 20 „
		14·5 19·7	5·12	66·4	3·10	2·0		
		4·0 11·0	7·58	66·4	3·10	4·5		
		0·1 6·8	7·43	66·4	3·10	4·3	− 4·1	
„ 13th	T. G. M.	+ 5·0g − 8·6h	− 3·78	64·4	+ 1·69	− 2·1		Commencing 11 30 A.M.
		0·9 4·5	3·95	64·5	1·77	2·2		Ending 0 30 P.M.
		− 0·6 1·7	2·57	64·6	1·83	0·7		
		2·4 0·3	3·09	64·7	1·90	1·2		
		2·1 1·7	4·30	64·8	1·98	2·3	− 1·7	
„ 13th	C. L.	− 0·9g − 5·6h	− 7·24	65·4	+ 2·40	− 4·8		Commencing 2 50 P.M.
		+ 0·5 6·5	6·63	65·6	2·54	4·1		Ending 4 17 „
		− 1·3 5·6	7·69	65·9	2·75	4·9		
		− 1·0 4·9	6·58	66·0	2·82	3·8		
		+ 0·1 6·1	6·64	66·2	2·97	3·7	− 4·3	
„ 14th	H. R. T.	− 2·2g − 8·4h	− 11·83	65·0	+ 2·12	− 9·7		Commencing 11 45 A.M.
		1·7 8·9	11·83	65·2	2·25	9·6		Ending 0 40 P.M.
		0·5 10·6	12·32	65·3	2·33	10·0		
		1·3 9·7	12·24	65·4	2·40	9·8		
		0·9 10·2	12·34	65·5	2·47	9·9	− 9·8	
„ 14th	T. T. C.	− 12·0g + 5·5h	− 7·72	66·1	+ 2·89	− 4·8		Commencing 2 0 P.M.
		− 14·1 + 8·0	7·38	66·2	2·97	4·4		Ending 3 5 „
		+ 7·9 − 13·9	6·30	66·4	3·10	3·2		
		− 17·2 + 12·9	5·51	66·5	3·17	2·3		
		+ 25·5 − 30·4	4·32	66·2	2·97	1·4	− 3·2	
„ 15th	H. K.	− 0·3g − 5·6h	− 6·55	65·5	+ 2·47	− 4·1		Commencing 11 50 A.M.
		0·2 6·4	7·33	65·6	2·54	4·8		Ending
		0·3 8·2	9·44	65·7	2·61	6·8		
		0·4 8·7	10·10	65·7	2·61	7·5		
		0·9 5·6	7·24	65·9	2·75	4·5	− 5·5	
		Means		65·7			− 4·8	

From the preceding comparisons it appears that

$$\begin{aligned} & & & m.y. \\ & [b.g] - [8.13] &=& -\ 18{\cdot}2 \\ & [a.g] - [7.13] &=& -\ \ 4{\cdot}8 \\ \text{and } & [a.b] - [7.\ 8] &=& +\ 13{\cdot}4 \pm {\cdot}98 \end{aligned} \quad \ldots\ldots\ldots\ldots\ldots \quad 1$$

The probable error has been computed from the differences between the values of [a.b] — [7.8] obtained by each observer and the general mean of the same.

From page (29) of this Volume,

$$[a.b] = \tfrac{1}{120}\,\mathbf{A} - \ 1{\cdot}30 \pm {\cdot}076 \ \ (m.y.) \quad \ldots\ldots\ldots\ldots\ldots \quad 2$$

hence by equations 1 and 2

$$[7.8] = \tfrac{1}{120}\,\mathbf{A} - 14{\cdot}7 \ \pm {\cdot}983$$

In forming equation 1 the computers fell into the error of using a table of expansion for six-inches on **IF** for reducing the five-inch spaces to 62° Fahrenheit, and this was not discovered till recently; the effect however is so slight that it has not been thought advisable to alter the computations, which would necessitate minute corrections in a large amount of work already disposed of. It will be seen from the comparisons of the five-inch spaces that

$$[b.g] - [8.13] = -18{\cdot}2 \ m.y.$$

the mean temperature of observation being $67^{\circ}{\cdot}4$. The correction for difference of expansion which was employed was ·705 *m.y.* per 1° Fahrenheit, whereas it ought to have been ·588 *m.y.*, and the difference ·117 × 5·4 gives a correction = — ·6 *m.y.* to be added to the above value of [b.g] — [8.13] which thus becomes — 18·8 *m.y.*

$$\text{therefore } [7.8] = \tfrac{1}{120}\,\mathbf{A} - 15{\cdot}3 \ m.y.$$

As the runs of the micrometers are less than $\frac{1}{20,000}$ of an inch to one division and seldom more than 200 or 300 divisions are made use of, the error caused by a difference of ·6 *m.y.* in the value of the inch would be less than $\frac{6 \times 300}{200,000}$ *m.y.* in 300 divisions of the micrometer, or ·009 *m.y.*, a quantity which is practically of no importance.

The table given on page (22) when corrected for the above-mentioned error becomes as follows :—

Observer's Initials.	[a.g.] — [7·13]	[b.g.] — [8·13]	[a.b.] — [7·8]
T. G. M. ...	— 1·7	— 21·1	+ 19·4
J. B. N. H. ...	4·1	16·8	12·7
H. R. T. ...	9·8	22·1	12·3
C. L. ...	4·3	19·0	14·7
H. K. ...	5·5	14·5	9·0
T. T. C. ...	3·2	19·5	16·3
	— 4·8	— 18·8	+ 14·0

The changes here made have no appreciable effect on the results deduced on page (23).

W. H. COLE.

APPENDIX.

No. 6.

COMPARISONS BETWEEN THE 10-FEET STANDARD BARS I_s AND A FOR DETERMINING THE EXPANSION OF BAR A.

These experiments were made at Masuri on the Himalaya mountains, in Lat. N. 30° 28′, Long. E. 78° 7′, Height above sea level about 6900 feet, during January and part of February 1870. Preference was given to this hill site, because a lower natural temperature could be commanded here than at the smaller elevation of the plain country below; and the event proved that the precaution was essential, for the winter was exceedingly mild, so that even at the altitude chosen, the lowest temperature to which the bars fell was only about 50°. For low temperatures, the natural cold prevailing was accepted. Heat was supplied by means of hot water.

(2.) The only room available for the purpose, was one built some 4 year before for Pendulum experiments. It was 14 × 12 × 10 feet in dimensions, and for comparisons of bars 10-feet in length was much too small. Further, standing on the crest of a hill, it was exposed to the influences of the sun and wind. On the other hand, the walls were so much as 2 feet thick and the roof was a solid structure of slates, bricks, gravel and lime. The doors and windows also were all double, excepting the window to the west, which during the experiments was adopted as an entrance; but as the window opened into a small transit room with a suitable outer door, this opening was also well secured.

(3.) With the exception of the western window, all the other outlets were permanently closed and stout paper pasted over the crevices. For purposes of ventilation, a tin tube 6 inches in diameter was passed through the southern wall. Its outer mouth could be partially or completely uncovered as desired: the inner orifice opened upwards, near the roof, about the centre of the bar room. Externally, the entire building (the roof as well as the walls) was coated with thatch at least 9 inches deep. And after these precautions had been taken, it was found, that the range of temperature within the closed bar-room, during the 24 hours, did not exceed 1° Fahrenheit. Owing however to the smallness of the room, this range was increased to some 2°, during a visit, by the presence of the observers and the heat from the lamps, as appears in the tables of comparisons hereafter given.

(4.) The apparatus in the bar-room was copied or adapted from that used by Captain A. R. Clarke, R.E., C.B. Ordnance Survey and described at length in his volume entitled "Comparisons of the Standards of length 1866." The comparing microscopes stood east and west of one another on slabs of stone, which were placed on solid frustums of stone pyramids isolated and sunk into the ground some 22 inches. Symmetrically between the pyramids and about 5 feet apart two beams ran meridionally across the room and were let into the walls, their continuity to the south being broken at will by the raising and lowering contrivance (or bar-trap) constructed after Captain Clarke's design. The beams carried well planed iron rails on which the bar-carriages worked easily and regularly. For greater rigidity the beams were propped up by uprights directly under the line joining the microscopes, and this was all the more necessary that the bar-carriage during observation, as at other times, stood on the beams. The bar-carriage was simply a deal plank 7·5 *feet* × 12 inch × 3·3 inch mounted on well turned brass wheels. The camels stood on the plank and they in turn supported the carefully packed case (or bar-box) containing the bar.

(5.) The bar-box was made up as follows. A deal plank 11′ × 12″ × 2″ represented the bottom of the box. The upper surface of this plank was covered over with stout country felt. Through this felt, along the middle longitudinal line, two brass rollers were screwed to the plank, at the required points of support; so that when the bar rested on them, its mid-height agreed with that of the surrounding water boxes. On both sides of the bar and also around its butts there ran the water boxes, which in transverse section were 2·6″ × 5·3″. The water boxes-were coated externally with felt, and a wooden case fastened down over them to the bottom of the bar-box. Every crack or hole in this outer wooden case was carefully stuffed with paste and wool, and finally the whole box was enveloped in a double blanket jacket. The bar was thus almost hermetically sealed, at the same time that it touched nothing but its rollers and so was perfectly free to expand and contract. The thermometers let into the bar were read through panes of glass fixed in the cover of the box, and the lines (or dots) were viewed through conical tubes similarly fixed, whose smaller ends, terminated about $\frac{1}{4}$ inch above the bar, and were some 0·2 inch in diameter.

(6.) The supply and overflow pipes, were placed on a side of the box about its mid length as in Captain Clarke's construction. The discharge pipes however protruded through the *bottom* of the bar-box at the ends of the water boxes. The supply pipe was connected by means of a flexible tube with a tap, fixed in the eastern door. The tap in turn was connected with the hot water tank of which further mention is hereafter made. The overflow and discharge pipes (each with a tap) were all connected by flexible tubes with an iron pipe laid down east and west along the floor of the room, and it was so arranged that the latter pipe discharge its water into a tub placed alongside of the hot water tank. As the tub filled, the water was returned to the tank, and thus the heat acquired was economised as far as practicable. A speaking tube admitted of communication between the bar and tank rooms.

(7.) The water boxes, contrary to requisition, were unfortunately made of thin sheet zinc, so that when the boxes were full and water was flowing through them in a continuous stream, the sheet zinc bulged at various places towards the bar, and the internal sides of the water box, next to the bar, no longer presented plane surfaces. Had time permitted the water boxes would have been replaced by others made of more rigid material, but in the absence of such improvement the tendency to bulge was anticipated and partially checked by contrivances which need not be enumerated. It was however agreed that by increasing the space between the bar and the sides of the water box, the irregularities of the latter surfaces would have smaller effect in heating the bar unequally. Accordingly these spaces were increased to 0·8 inch; and it was found after the experiments, that owing to the yielding of the zinc, they now varied from 0·8 to about 0·6 inch. The increased space naturally lead to the difficulty, that intentional changes in the temperature of the water were taken up very slowly by the bar, and it thus became necessary to maintain the temperature of the tank continuously by day and night.

(8.) It remains to notice an evil in connection with the water boxes, which from want of time could not be remedied. It was found that the end pipes did not discharge at an equal rate; and this was traced to the circumstances that the orifice of the supply pipe was not the highest point in the water box. Thus air collected at certain higher passages and obstructed the flow. This evil was controlled as far as practicable by careful watching, so that its effect became nearly constant in nature. It is however to the unequal discharge at the end pipes, that the difference in reading between the two thermometers of each bar when hot, is to be chiefly ascribed.

(9.) The tank and boiler were set up in two little rooms adjoining one another, which were built up roughly east of the bar-room. These two rooms were separated from the bar-room by an open passage some 8 feet in width, and as the boiler stood east of the tank, the fire place was thus removed as far as practicable from the bar-room.

(10.) In shape the boiler was the frustum of a cone 12″ deep, 9″ lower diameter and 12″ upper diameter. It was made of iron and its upper surface terminated in a bent tube with flanges. The tank for hot water was a rectangular box constructed of sheet iron 3′ × 2′ × 2′ in dimensions and enclosed in a wooden case. A bent iron tube was passed through and rigidly attached to the bottom of the tank: the end which opened inside the tank was covered by a perforated plate (or strainer) while the outer extremity terminated in flanges. A connecting tube, with flanges at both ends, was fixed by bolts and nuts to the tube at the top of the boiler and to the other tube at the bottom of the tank. Thus the boiler was a completely closed reservoir, and could be filled only through the tank. The connecting tube was 4′ long and 2″ in diameter. The side of the tank furtherest from the boiler was fitted near the bottom of the box with a discharge pipe whose inside orifice was covered with a strainer: this tube fed the water-boxes. The tank was also provided with a cap, which could be removed at pleasure, and with paddles for mixing the water. Its upper surface was pierced at three of the corners and fitted with short tubes. Into two of these tubes funnels with strainers were introduced. The third tube contained a thermometer by which the temperature of the warm water was ascertained. Of the funnels, the larger one served to receive the warm water from the tub as it returned from its circuit through the water-boxes (Art 6), while the smaller funnel was fed at pleasure from a tap communicating with a cistern of *cold* water. Thus the temperature could be increased or decreased at will by regulating the fire under the boiler, and it could be further diminished by resorting to the cold water tap. It was found however that the latter aid was unnecessary, excepting to restore such small volumes of water as ran to waste. The large difference between the solid measures of the boiler and tank (about 1 to 14) and the small surface which the former exposed to the fire, secured the result that sensible variations in the intensity of the fire produced but little change in the temperature of the tank. Thus a common laborer, under occasional directions, could feed the fire with sufficient nicety to maintain the hot water within $\pm$ 0°·5 of any required temperature.

(11.) From what has been stated, the following description of procedure with respect to the water supply will be readily apparent. The tank (including boiler) was in the first instance filled with water and a brisk fire lighted and maintained. As the water began to heat, the supply and discharge taps in the bar-room were opened and subsequently adjusted, so as to secure a small but decided discharge from the overflow pipe, as well as an equal discharge at the two end pipes. After these adjustments had been made, it was ascertained that were the supply cut off, the water box would empty in about 4 minutes. At the same time that the boxes were in course of filling, additional water was poured into the tank; so that in the end, the water boxes were full and discharged at the regulated rate; the discharge in the receiving tub near the tank was caught and restored back to the tank, and the water level in the latter was maintained, as required, at a constant height. It now only remained for the assistant at the thermometer in the tank to raise the temperature of the water and maintain it at the required heat. This was done gradually, the assistant (an intelligent native) as well as the workmen being relieved at intervals. As already mentioned (Art 7) it was necessary to maintain the heating process by day and night, without intermission, throughout the series or set of observations. Thus for series No. 1 (both bars hot) the heating was maintained continuously from about the evening of 4th to 13th January. In series No. 2, both bars being cold, the fire was extinguished, the supply and discharge pipes stopped, and both water boxes kept full of water which gradually settled down to the temperature of the room. For the remaining series, Nos. 3 and 4, the heating was maintained continuously from about the evening of 20th January to the 4th February.

(12.) Returning now to the bar-room. The following particulars may be collected together in this place. The counterpoises working the sliding frames in the bar-traps weighed 641 lbs. The considerable weight of the bar-boxes implied by that of the counterpoises, lead to a satisfactory amount of stability in the bars when under the microscopes. Owing to the great width of the bar-boxes, they were moved longitudinally on the camels by hand, instead of by the slow motion screw, when being brought under observation; a procedure which their weight facilitated. Even the transverse motion was obtained chiefly by moving the carriage, lest a liberal use of the screw should distroy the equilibrium of the camel. The thermometers were read through reading lenses because the air tubes in the water boxes were erroneously placed, so that the thermometer reading-tubes could not be employed. The lines (or dots) on the bars were illuminated by means of artificial light; each observer being supplied with a small oil lamp, which he used for this purpose as well as for reading the thermometers. This entailed the re-setting of the lamp to suit the prism of the microscope after *every* thermometer reading, a necessity which in the absence of experience at first caused some delay. It was however deemed of importance that no more lamps should be introduced into the bar-room during work than were absolutely necessary, so that the removal of the lamp from the microscope to the thermometer and *vice versa* became unavoidable.

(13.) The bars compared were the two 10 feet standards **I_s** (steel) and **A** (iron). They are described at pages (2) and (3) of Section 1 Chapter I. Each bar was supported at two points on brass rollers, the points of support for **I_s** being determined by Mr. Airy's formula $\frac{a}{\sqrt{(n^2-1)}}$ where a is the length of the bar and n the number of supports. **A** was supported at $2\frac{1}{2}$ feet on either side from its centre, these being the points on which this bar has always rested since its construction. Two thermometers were introduced into each bar, in the existing cavities at about $2\frac{1}{2}$ feet from its centre, and contact between the thermometer bulb and the bar was secured by means of ordinary salad oil. The thermometers had bent bulbs so that the stems were laid flat on the bar. They were graduated on the glass to every half degree from 20° to 100° Fahrenheit. The comparing microscopes employed (**G.** and **H**) were the new pair by Messrs. Troughton and Simms described at page 2 of the Appendices. They were set up so, that the distance between their zeros was always *less* than the length of either bar, and thus an increment in the reading of the microscopes denoted an *increase* in the length of the bar. Throughout the four series of bar comparisons, the microscopes were never moved or disturbed accidentally or otherwise in any way: their adjustments needed no alteration and their stability was excellent. The errors of the thermometers (see Appendix No. 8) and the linear values of the micrometer screws were ascertained directly after the conclusion of the bar comparisons. A thermometer protected by a glass case, perforated at the bottom, was hung within the room, and a similar one was suspended outside in the shade north of the building.

(14.) Owing to certain mechanical defects in the construction of the bar-boxes, it was found more convenient to adapt the bar-box of **I_s** for lowering into the bar-trap, to make the other bar pass above it, and to commence a comparison by always placing bar **A** first under the microscope. A comparison comprised 4 groups of observations as follows :—

1st Group of observations on Bar **A**		Giving one comparison
2nd "	I_S	
3rd "	I_S	
4th "	**A**	

Each group of observations consisted of the following readings, the observers being understood by *h* and *c* :—

Order	West		East		Order
	Microscope H	Thermometer	Thermometer	Microscope G	
1	....	*h*	*c*	....	1
2	*h*	....	....	*c*	2
3	*h*	....	....	*c*	3
4	*h*	....	....	*c*	4
5	....	*h*	*c*	....	5
6	....	*c*	*h*	....	6
7	*c*	....	....	*h*	7
8	*c*	....	....	*h*	8
9	*c*	....	....	*h*	9
10	....	*c*	*h*	....	10

The above readings in each horizontal line were made simultaneously, and this condition was essential in the case of the micrometer readings, because the bar when under observation could not be isolated (Art. 4), as was done during Captain Clarke's experiments. It will also appear from the foregoing, that in the table of comparisons given hereafter, each mean temperature is obtained from 16 readings, and each micrometer result from 24 readings (12 with each microscope). Hence the 120 bar comparisons taken, involved 3840 readings of the thermometers and 5760 of the micrometer.*

(15.) The Bar room was visited by the observers daily at about 9 A.M. and 2½ M.P. Commencing with the former hour; work was begun by reading the outside thermometer. The external door was next opened and closed before the observers entered by the western window (Art. 2.) The thermometer hanging in the room was read, the lamps lighted and bar **A** brought into position and focus. A bar once brought into good focus would generally remain well adjusted in this respect for days, though in the interim it had been wheeled to and fro several times, besides being sunk into the bar-trap. After taking a group of observations on **A**, the bar gave place to I_s on which two groups were taken. I_s in turn gave place to **A**, on which a group of observations being taken, one comparison stood completed in some 45 minutes of time. In general three comparisons were taken at each visit, at the end of which, the bars, when hot, were wheeled away as far as practicable from the microscopes and left in this position; after this the inside and outside thermometers were read and recorded. The temperature of the tank was now generally *raised* some ½ a degree, an increase of heat sufficiently small for the bars to acquire during the short absence of the observers. Remarks similar to the preceding apply to the visit at 2½ P.M., with this difference, that on leaving the bar room for the night, the temperature of the tank was *decreased* by about 2½ degrees, a change to which the bars adapted themselves before work was resumed next morning. In fact no large changes of temperature were practicable within the intervals of successive visits, for owing to the considerable space (0·8 Inch) between the bar and water box, the former was exceedingly slow in receiving changes of temperature. Of the two bars I_s was far the slowest in this respect, as was to be expected. Under an alteration in the tank of 2 degrees, this bar has been noticed to take so much as 2 hours in parting with the last ½ degree of altered temperature.

(16.) The bars were compared under four different conditions viz :—

Series No. 1	30	comparisons,	both bars hot.
" 2	30	"	both bars cold.
" 3	30	"	I_S hot and **A** cold.
" 4	30	"	I_S cold and **A** hot.

these comparisons are given in the following tables.

* The Bar and Thermometer comparisons and the Micrometer runs involved in these experiments were all taken by the same observers, *i.e.* by J. B. N. Hennessey, Esq. and W. H. Cole, Esq., M.A.

COMPARISONS between the 10-feet Standard Bar I_s *and* A. Series No. 1; both Bars hot.

Number of comparison	Date	Time: Beginning	Time: Ending	Inside Thermometer: Beginning	Inside Thermometer: Ending	Outside Thermometer: Beginning	Outside Thermometer: Ending	Temperature of Tank	At observed temperatures: I_s−D* (Millionths of a yard)	A−D* (Millionths of a yard)	I_s−A (Millionths of a yard)	Thermometer readings corrected for errors: I_s 7345	I_s 4217	I_s Mean	A 4227	A 4228	A Mean
	1870	h. m.	h. m.	°	°	°	°	°			+	°	°	°	°	°	°
1	6th Jan.	0 45 P.M.	2 8 P.M.	61·5	61·8	...	46·0	101·4	1370·47	1346·32	24·15	96·192	96·842	96·52	98·600	98·156	98·38
2	...	2 23	3 35	61·2	61·8	41·6	...	,,	1366·79	1344·36	22·43	·086	·848	·47	·606	·166	·39
3	...	3 56	5 4	61·2	62·3	...	39·0	,,	1367·16	1340·52	26·64	·117	·864	·49	·644	·154	·40
4	7th ,,	9 50 A.M.	10 51 A.M.	62·0	62·6	43·0	...	,,	1364·93	1328·95	35·98	·207	·882	·54	·137	97·870	·00
5	...	10 53	11 49	...	62·5	...	...	,,	1365·30	1328·53	36·77	·227	·919	·57	·100	·863	97·98
6	...	0 15 P.M.	2 6 P.M.	62·0	63·0	45·2	...	,,	1362·59	1325·94	36·65	·176	·800	·49	97·979	·723	·85
7	...	2 35	3 41	62·0	...	...	...	,,	1362·16	1325·98	36·18	·129	·718	·42	98·074	·645	·86
8	...	3 41	4 49	...	63·5	...	...	101·5	1362·15	1329·41	32·74	·133	·692	·41	·092	·672	·88
9	8th ,,	0 2	1 3	62·0	...	52·6	...	,,	1356·40	1313·32	43·08	·246	·639	·44	97·588	·361	·47
10	10th ,,	9 43 A.M.	10 56 A.M.	61·4	62·6	49·4	...	,,	1359·02	1319·05	39·97	·381	·784	·58	·845	·644	·74
11	...	10 58	0 9 P.M.	...	63·0	...	...	,,	1359·40	1318·31	41·09	·437	·748	·59	·665	·567	·62
12	...	0 12 P.M.	1 8	63·0	63·0	...	...	,,	1362·05	1317·96	44·09	·492	·759	·63	·611	·582	·60
13	...	2 45	3 46	62·4	63·5	...	47·5	,,	1363·91	1316·24	47·67	·539	·891	·72	·457	·537	·50
14	...		4 40	...	63·5	...	...	,,	1365·07	1316·92	48·15	·578	·943	·76	·585	·510	·55
15	...	4 40	5 36	63·5	63·8	...	...	,,	1364·57	1314·85	49·72	·577	·961	·77	·558	·459	·51
16	11th ,,	10 6 A.M.	10 50 A.M.	63·2	63·9	46·1	...	,,	1365·05	1321·60	43·45	·771	97·095	·93	98·011	·893	·95
17	...	10 55	11 46	...	...	...	...	,,	1365·31	1327·35	37·96	·832	·098	·97	·287	98·261	98·27
18	...	11 49	0 45 P.M.	...	64·4	...	...	,,	1365·92	1331·59	34·33	·880	·123	97·00	·526	·445	·49
19	...	2 45 P.M.	3 36	63·3	...	...	...	,,	1365·03	1335·53	29·50	·897	·035	96·97	·583	·578	·58
20	...	3 38	4 27	...	...	...	...	,,	1364·39	1335·01	29·38	·884	·032	·96	·583	·607	·60
21	...	4 27	5 15	...	64·5	...	38·9	,,	1361·27	1335·28	25·99	·827	·031	·93	·580	·621	·60
22	12th ,,	11 17 A.M.	0 4	63·5	...	47·0	...	99·5	1312·49	1275·02	37·47	94·511	95·051	94·78	96·115	95·958	96·04
23	...	0 4 P.M.	0 40	...	...	...	...	,,	1314·82	1277·44	37·38	·601	·105	·85	·232	96·044	·14
24	...	0 45	1 30	...	64·3	...	...	,,	1316·49	1282·05	34·44	·698	·218	·96	·373	·158	·27
25	...	2 49	3 29	...	...	...	...	,,	1320·73	1283·00	37·73	·892	·362	95·13	·487	·275	·38
26	...	3 29	4 14	...	...	...	...	,,	1321·10	1282·64	38·46	·883	·380	·13	·741	·287	·31
27	...	4 14	4 59	...	64·4	...	...	,,	1321·93	1281·97	39·96	·965	·436	·20	·229	·310	·27
28	18th ,,	10 7 A.M.	10 55 A.M.	62·6	...	48·6	...	,,	1317·53	1256·44	61·09	·914	·445	·18	95·462	95·336	95·40
29	...	11 11	0 14 P.M.	...	...	...	...	,,	1316·90	1261·72	55·18	·894	·396	·15	·621	·484	·55
30	...	0 26 P.M.	1 6	...	64·3	...	49·5	,,	1316·15	1274·39	41·76	·858	·380	·12	96·233	96·059	96·15
										Mean ...	38·31			96·19			97·42

* D here stands generally for the distance between the zeros of the two micrometers, reckoned as constant during *each* comparison only.

COMPARISONS between the 10-feet Standard Bars I_s *and* **A**. Series No. 2; both Bars cold.

Number of comparison	Date	Time		Inside Thermometer		Outside Thermometer		Temperature of Tank	At observed temperatures			Thermometer readings corrected for errors					
									I_s−D*	A−D*	I_s − A	I_s			A		
		Beginning	Ending	Beginning	Ending	Beginning	Ending		Millionths of a yard			7345	4217	Mean	4227	4228	Mean
	1870	h. m.	h. m.	°	°	°	°				+	°	°	°	°	°	°
31	15th Jan.	11 21 A.M.	0 16 P.M.	55·2		57·6	...	...	451·46	362·46	89·00	54·441	54·435	54·44	54·416	54·368	54·39
32	...	0 17 P.M.	0 54	...	55·3	...	...	...	452·88	363·41	89·47	54·457	54·429	54·44	54·401	54·362	54·38
33	...	0 55	1 47	...	55·5	...	54·8	...	451·15	364·19	86·96	54·457	54·423	54·44	54·410	54·368	54·39
34	...	3 8	3 58	54·0	55·5	53·3	...	...	452·44	364·78	87·66	54·447	54·446	54·45	54·414	54·396	54·41
35	...	4 3	5 15	55·5	55·5	...	...	...	454·66	363·29	91·37	54·471	54·485	54·48	54·436	54·436	54·44
36	17th "	9 55 A.M.	10 44 A.M.	53·0	53·5	44·7	...	...	418·66	326·70	91·96	52·330	52·338	52·33	52·258	52·278	52·27
37	...	10 44	11 20	53·5	53·6	...	...	...	419·44	326·34	93·10	52·345	52·314	52·33	52·255	52·275	52·27
38	...		11 55	53·6	53·7	...	...	...	418·93	326·40	92·53	52·345	52·327	52·34	52·275	52·274	52·27
39	...	11 56	0 29 P.M.	...	54·0	...	54·3	...	418·50	326·72	91·78	52·356	52·314	52·34	52·303	52·291	52·30
40	18th "	9 32	10 8 A.M.	50·8	52·6	41·0	...	...	415·13	323·57	91·56	51·809	51·859	51·83	51·686	51·768	51·73
41	...	10 9	10 41	52·6	52·5	...	...	...	414·26	322·15	92·11	51·795	51·846	51·82	51·681	51·761	51·72
42	...	10 42	11 20	52·5	52·5	...	...	...	414·25	323·15	91·10	51·774	51·836	51·81	51·678	51·758	51·72
43	...	11 21	11 54	52·5	52·5	...	...	...	414·86	323·03	91·83	51·766	51·835	51·80	51·671	51·755	51·71
44	...	11 56	0 28 P.M.	52·5	52·6	...	44·5	...	412·82	321·79	91·03	51·751	51·826	51·79	51·674	51·756	51·72
45	...	2 30 P.M.	3 18	51·0	...	47·5	...	...	415·09	325·23	89·86	51·705	51·816	51·76	51·656	51·745	51·70
46	...	3 19	3 52	53·0	...	53·2	...	...	414·98	323·54	91·44	51·690	51·814	51·75	51·649	51·740	51·69
47	...	3 54	4 32	53·2	53·2	...	42·4	...	414·78	322·14	92·64	51·693	51·809	51·75	51·650	51·743	51·70
48	19th "	9 33 A.M.	10 16 A.M.	51·0	52·0	43·5	...	...	405·38	316·22	89·16	51·112	51·156	51·13	51·115	51·133	51·12
49	...	10 18	10 56	52·0	...	...	...	...	404·80	315·56	89·24	51·104	51·119	51·11	51·111	51·127	51·12
50	...	10 57	11 29	...	52·4	...	...	...	404·15	314·97	89·18	51·102	51·114	51·11	51·108	51·132	51·12
51	...	11 30	0 6 P.M.	52·4	...	...	...	...	405·19	314·77	90·42	51·104	51·114	51·11	51·103	51·141	51·12
52	...	0 8 P.M.	0 42	...	52·5	...	50·6	...	404·94	314·40	90·54	51·104	51·115	51·11	51·109	51·147	51·13
53	...	2 45	3 20	51·0	...	47·6	...	...	405·29	316·06	89·23	51·099	51·116	51·11	51·110	51·153	51·13
54	...	3 22	3 55	...	52·5	...	...	...	406·49	317·28	89·21	51·099	51·119	51·11	51·118	51·161	51·14
55	...		4 30	52·5	52·6	...	42·7	...	405·34	315·76	89·58	51·107	51·133	51·12	51·125	51·164	51·14
56	20th "	9 46 A.M.	10 24 A.M.	49·5	...	41·0	...	...	395·55	304·64	90·91	50·223	50·358	50·29	50·217	50·377	50·30
57	...	10 25	11 1	...	51·5	...	...	...	394·97	304·01	90·96	50·182	50·354	50·27	50·202	50·364	50·28
58	...	11 2	11 33	51·5	...	...	...	...	394·48	303·61	90·87	50·172	50·328	50·25	50·201	50·359	50·28
59	...	11 36	0 10 P.M.	...	...	...	...	...	391·81	303·12	88·69	50·167	50·322	50·24	50·184	50·353	50·27
60	...	0 11 P.M.	0 45	...	51·5	...	...	...	393·70	302·84	90·86	50·164	50·322	50·24	50·177	50·343	50·26
										Mean ...	90·48			51·87			51·84

* D here stands generally for the distance between the zeros of the two micrometers, reckoned as constant during *each* comparison only.

COMPARISONS between the 10-feet Standard Bars I_S *and* A. Series No. 3; I_S hot and A cold.

Number of comparison	Date	Time: Beginning	Time: Ending	Inside Thermometer: Beginning	Inside Thermometer: Ending	Outside Thermometer: Beginning	Outside Thermometer: Ending	Temperature of Tank	At observed temperatures: I_s−D*	At observed temperatures: A−D*	At observed temperatures: I_s−A	Thermometer readings corrected for errors: I_s 7345	I_s 4217	I_s Mean	A 4227	A 4228	A Mean
									Millionths of a yard								
	1870	h. m.	h. m.	°	°	°	°	°			+	°	°	°	°	°	°
61	22nd Jan.	9 57 A.M.	10 47 A.M.	54·5	...	36·0	...	103·0	1399·59	328·71	1070·88	97·431	97·756	97·59	51·406	51·583	51·49
62	...	10 48	11 28	54·5	...	...	...	...	1399·14	329·23	1069·91	·378	·710	·54	·426	·640	·53
63	...	11 34	0 13 P.M.	54·6	...	...	...	...	1398·17	330·42	1067·75	·338	·559	·45	·472	·694	·58
64	...	0 14 P.M.	0 49	54·9	54·9	...	...	...	1399·35	331·32	1068·03	·356	·544	·45	·530	·741	·64
65	...	3 30	4 7	54·0	...	39·1	...	...	1401·71	333·13	1068·58	·555	·595	·58	·656	·800	·73
66	...	4 8	4 48	...	55·0	...	...	...	1399·79	334·10	1065·69	·531	·560	·55	·678	·820	·75
67	24th „	9 32 A.M.	10 22 A.M.	54·5	...	45·2	...	102·0	1371·25	336·81	1034·44	96·230	96·596	96·41	52·009	52·134	52·07
68	...	10 23	11 0	55·0	...	...	...	...	1372·42	337·65	1034·77	·236	·569	·40	·071	·176	·12
69	...	11 2	11 49	...	...	...	...	...	1374·02	338·78	1035·24	·324	·658	·49	·121	·235	·18
70	...	11 50	0 33 P.M.	55·5	55·7	...	49·8	...	1375·53	339·81	1035·72	·440	·744	·59	·201	·286	·24
71	...	3 30 P.M.	4 12	54·6	...	...	...	...	1377·20	345·96	1031·24	·612	·916	·76	·429	·528	·48
72	...	4 14	4 51	55·6	56·0	...	...	...	1377·43	346·46	1030·97	·605	·838	·72	·475	·569	·52
73	25th „	9 33 A.M.	10 17 A.M.	55·4	...	44·6	...	98·0	1308·80	355·58	953·22	93·208	93·575	93·39	·999	53·090	53·04
74	...	10 18	10 57	55·8	...	...	...	...	1306·44	356·93	949·51	·132	·414	·27	53·058	·140	·10
75	...	10 58	11 46	56·0	...	...	...	...	1305·70	358·09	947·61	·101	·347	·22	·121	·214	·17
76	...	11 48	0 25 P.M.	56·4	56·3	...	49·6	...	1304·51	359·23	945·28	·092	·337	·21	·185	·270	·23
77	...	3 17 P.M.	4 2	54·7	55·9	45·9	...	...	1303·84	361·91	941·93	·038	·361	·20	·355	·405	·38
78	...	4 4	4 48	55·9	56·0	...	46·1	...	1303·44	361·83	941·61	·031	·362	·20	·362	·439	·40
79	26th „	0 7	0 45	55·5	...	49·5	...	92·5	1250·64	364·14	886·50	90·927	91·157	91·04	·600	·615	·61
80	...	0 46	1 29	56·1	...	...	...	...	1251·01	365·07	885·94	·922	·103	·01	·620	·681	·65
81	...	1 30	2 2	56·3	56·5	...	...	...	1251·04	364·22	886·82	·925	·073	·00	·635	·722	·68
82	...	3 16	3 53	55·0	...	48·0	...	96·0	1253·82	364·90	888·92	91·079	·259	·17	·669	·779	·72
83	...	3 54	4 40	56·2	...	...	...	...	1253·04	365·70	887·34	·113	·280	·20	·693	·799	·75
84	...	4 41	5 17	56·3	56·7	...	41·8	...	1254·08	366·54	887·54	·123	·293	·21	·728	·855	·79
85	27th „	9 22 A.M.	10 13 A.M.	55·3	...	41·4	...	94·0	1207·77	370·92	836·85	89·200	89·238	89·22	·931	54·038	·98
86	...	10 14	10 54	56·6	...	...	...	...	1209·76	370·53	839·23	·243	·269	·26	·978	·064	54·02
87	...	10 55	11 42	56·8	56·8	...	47·6	...	1210·48	372·34	838·14	·270	·314	·29	54·041	·117	·08
88	...	2 50 P.M.	3 32 P.M.	55·1	...	46·1	...	94·5	1221·55	372·31	849·24	·663	·857	·76	·125	·177	·15
89	...	3 33	4 14	56·4	...	...	...	...	1221·68	372·76	848·92	·700	·846	·77	·120	·204	·16
90	...	4 15	4 50	56·6	56·8	...	42·5	...	1221·76	373·28	848·48	·716	·857	·79	·114	·214	·16
										Mean ...	955·88			93·59			52·98

* D here stands generally for the distance between the zeros of the two micrometers, reckoned as constant during *each* comparison only.

COMPARISONS between the 10-feet Standard Bars I_S *and* A. Series No. 4; I_S cold and A hot.

Number of comparison	Date	Time: Beginning	Time: Ending	Inside Thermometer: Beginning	Inside Thermometer: Ending	Outside Thermometer: Beginning	Outside Thermometer: Ending	Temperature of Tank	At observed temperatures: I_S-D^*	$A-D^*$	I_S-A	Thermometer readings corrected for errors: I_S 7345	I_S 4217	I_S Mean	A 4227	A 4228	A Mean
		h. m.	h. m.	°	°	°	°	°	Millionths of a yard		—	°	°	°	°	°	°
91	1870 29th Jan.	2 12 P.M.	3 8 P.M.	55.8	...	50.4	...	102.0	430.99	1324.44	893.45	52.861	52.884	52.87	98.341	98.005	98.17
92	...	3 16	3 55	...	57.0	...	...	...	432.64	1323.15	890.51	.966	53.031	53.00	.297	97.939	.12
93	31st „	9 49 A.M.	10 41 A.M.	58.0	...	45.5	...	101.5	477.01	1328.50	851.49	55.601	55.631	55.62	.825	98.624	.72
94	...	10 48	11 27	58.3	...	...	...	...	477.82	1328.37	850.55	.665	.653	.66	.896	.604	.75
95	...	11 28	0 10 P.M.	58.5	58.6	...	53.6	...	478.44	1327.69	849.25	.740	.733	.74	.946	.597	.77
96	1st Feb.	10 19	10 53 A.M.	58.2	...	51.1	...	99.0	488.66	1271.91	783.25	56.390	56.356	56.37	96.568	96.093	96.33
97	...	10 54	11 24	58.5	...	...	...	...	487.89	1271.12	783.23	.410	.374	.39	.570	.085	.33
98	...	11 25	11 51	58.7	59.0	...	58.0	...	487.42	1271.87	784.45	.426	.396	.41	.573	.090	.33
99	...	3 7 P.M.	3 41 P.M.	58.2	...	56.2	...	99.5	494.43	1284.01	789.58	.650	.641	.65	97.070	.654	.86
100	...	3 42	4 14	59.0	...	...	...	...	494.90	1285.24	790.34	.676	.698	.69	.080	.669	.87
101	...	4 15	4 55	59.2	59.3	...	48.5	...	495.55	1285.42	789.87	.765	.742	.75	.090	.690	.89
102	2nd „	9 42 A.M.	10 20 A.M.	59.0	...	48.0	...	96.0	500.57	1204.21	703.64	57.130	57.122	57.13	93.588	93.313	93.45
103	...	10 21	11 0	59.0	59.2	...	...	...	501.11	1204.11	703.00	.161	.132	.15	.583	.288	.44
104	...	11 8	11 41	59.2	...	...	...	...	500.94	1204.66	703.72	.195	.182	.19	.528	.258	.39
105	...	11 42	0 12 P.M.	59.4	59.5	...	53.0	...	502.27	1204.76	702.49	.224	.241	.23	.514	.258	.39
106	...	3 53 P.M.	4 20	58.1	...	50.9	...	96.5	507.62	1215.81	708.19	.414	.401	.41	94.173	.844	94.01
107	...	4 21	4 49	59.0	59.2	...	...	...	509.23	1215.42	706.19	.425	.431	.43	.152	.855	.00
108	...	4 57	5 29	...	59.6	47.5	44.0	...	508.14	1215.88	707.74	.434	.446	.44	.147	.847	.00
109	3rd „	9 41 A.M.	10 17 A.M.	58.5	...	52.2	...	93.0	505.01	1137.06	632.05	.380	.366	.37	90.564	90.589	90.58
110	...	10 18	10 49	59.0	...	...	...	...	505.59	1136.64	631.05	.368	.364	.37	.585	.580	.58
111	...	10 50	11 24	59.1	59.2	...	55.6	...	504.36	1138.38	634.02	.376	.364	.37	.620	.607	.61
112	...	2 29 P.M.	2 56 P.M.	58.6	...	56.9	...	93.6	506.77	1150.13	643.36	.436	.431	.43	91.355	91.027	91.19
113	...	2 57	3 21	59.2	...	...	...	...	507.04	1150.58	643.54	.449	.432	.44	.343	.017	.18
114	...	3 22	3 50	59.3	59.5	...	...	...	506.70	1151.22	644.52	.450	.457	.45	.341	.017	.18
115	4th „	9 42 A.M.	10 14 A.M.	58.5	...	51.7	...	90.0	504.28	1077.35	573.07	.369	.334	.35	88.030	87.756	87.89
116	...	10 15	10 47	58.9	...	...	...	...	503.53	1077.94	574.41	.353	.335	.34	.075	.780	.93
117	...	10 48	11 14	59.0	59.0	...	48.0	...	503.83	1078.65	574.82	.345	.332	.34	.088	.785	.94
118	...	2 15 P.M.	2 45 P.M.	57.9	...	...	...	90.6	505.68	1087.09	581.41	.360	.351	.36	.491	88.165	88.33
119	...	2 46	3 19	58.7	...	...	...	...	505.44	1086.03	580.59	.359	.345	.35	.483	.132	.31
120	...	3 20	3 51	59.1	59.5	...	44.1	...	505.40	1086.52	581.12	.358	.346	.35	.475	.121	.30
										Mean ...	709.50			56.72			93.39

* D here stands generally for the distance between the zeros of the two micrometers, reckoned as constant during *each* comparison only.

(17). Suppose now, that $I_g - A = z$ when both the bars I_g and A are at the temperature τ; also let the expansion of I_g for 1° Fahrenheit $= x$, and its lengths at temperatures τ and T respectively $= L_\tau$ and L_T. Similarly for A, let its expansion be denoted by y, and its lengths at temperatures τ and t respectively by l_τ and l_t; then

$$(T - \tau)\, x - (t - \tau)\, y = (L_T - l_t) - (L_\tau - l_\tau)$$

or writing $L_T - l_t = d$

$$(T - \tau)\, x - (t - \tau)\, y = d - z = \delta \quad \ldots\ldots\ldots\ldots\ldots\ldots\ldots\ldots \quad (1)$$

(18.) The circumstances of the comparisons of series No. 2, when both bars were cold, are most favorable for determining the *difference* of length between the bars. The mean results of this series give $I_g - A = 90·48$ *m.y* when the temperature of I_g was 51°·87 and that of A was 51°·84. Adopting Captain Clarke's value for $x = 21·159$ *m.y*, it is found, that $I_g - A = z = 89·85$ *m.y*, when *both* the bars are at the temperature $\tau = 51°·84$.

(19.) Substituting these values of z and τ, there results, from each of the comparisons Nos. 1 to 30 and Nos. 60 to 120, an equation in x and y similar to (1). The numerals of these equations may be conveniently tabulated as follows; where, for instance the first horizontal line, under "both bars hot," when read as an equation, is represented by $44·68\, x - 46·54\, y = - 65·70$ *m.y*, and so on of the others.

Series No. 1; both bars hot				Series No. 3; I_s hot, A cold				Series No. 4; I_s cold, A hot			
No. of comparison	Co-efficient of x	Co-efficient of y	δ	No. of comparison	Co-efficient of x	Co-efficient of y	δ	No. of comparison	Co-efficient of x	Co-efficient of y	δ
	+	−	−		+		+		+	−	−
1	44·68	46·54	65·70	61	45·75	+ 0·35	981·03	91	1·03	46·33	983·30
2	·63	·55	67·42	62	·70	·31	980·06	92	·16	·28	980·36
3	·65	·56	63·21	63	·61	·26	977·90	93	3·78	·88	941·34
4	·70	·16	53·87	64	·61	·20	978·18	94	·82	·91	940·40
5	·73	·14	53·08	65	·74	·11	978·73	95	·90	·93	939·10
6	·65	·01	53·20	66	·71	·09	975·84	96	4·53	44·49	873·10
7	·58	·02	53·67	67	44·57	− ·23	944·59	97	·55	·49	873·08
8	·57	·04	57·11	68	·56	·28	944·92	98	·57	·49	874·30
9	·60	45·63	46·77	69	·65	·34	945·39	99	·81	45·02	879·43
10	·74	·90	49·88	70	·75	·40	945·87	100	·85	·03	880·19
11	·75	·78	48·76	71	·92	·64	941·39	101	·91	·05	879·72
12	·79	·76	45·76	72	·88	·68	941·12	102	5·29	41·61	793·49
13	·88	·66	42·18	73	41·55	1·20	863·37	103	·31	·60	792·85
14	·92	·71	41·70	74	·43	·26	859·66	104	·35	·55	793·57
15	·93	·67	40·13	75	·38	·33	857·76	105	·39	·55	792·34
16	45·09	46·11	46·40	76	·37	·39	855·43	106	·57	42·17	798·04
17	·13	·43	51·89	77	·36	·54	852·08	107	·59	·16	796·04
18	·16	·65	55·52	78	·36	·56	851·76	108	·60	·16	797·59
19	·13	·74	60·35	79	39·20	·77	796·65	109	·53	38·74	721·90
20	·12	·76	60·47	80	·17	·81	796·09	110	·53	·74	720·90
21	·09	·76	63·86	81	·16	·84	796·97	111	·53	·77	723·87
22	42·94	44·20	52·38	82	·33	·88	799·07	112	·59	39·35	733·21
23	43·01	·30	52·47	83	·36	·91	797·49	114	·60	·34	733·39
24	·12	·43	55·41	84	·37	·95	797·69	113	·61	·34	734·37
25	·29	·54	52·12	85	37·38	2·14	747·00	115	·51	36·05	662·92
26	·29	·47	51·39	86	·42	·18	749·38	116	·50	·09	664·26
27	·36	·43	49·89	87	·45	·24	748·29	117	·50	·10	664·67
28	·34	43·56	28·76	88	·92	·31	759·39	118	·52	·49	671·26
29	·31	·71	34·67	89	·93	·32	759·07	119	·51	·47	670·44
30	·28	44·31	48·09	90	·95	·32	758·63	120	·51	·46	670·97

(20) Accepting these 90 equations as all of equal weight, and proceeding by the method of least squares, there result the normal equations

$$\begin{array}{ll} \text{in } x, \text{ or} & 112355{\cdot}57\,x - 68014{\cdot}57\,y = \overset{m.y}{909603{\cdot}81} = \alpha \\ \text{in } y, \text{ or} & -68014{\cdot}57\,x + 114634{\cdot}25\,y = 1050578{\cdot}79 = \beta \end{array} \Bigg\} \quad \ldots\ldots\ldots\ldots \quad (2)$$

The solution of group (2) gives

$$x = {\cdot}0000138886\,\alpha + {\cdot}0000082404\,\beta$$
$$y = {\cdot}0000082404\,\alpha + {\cdot}0000136126\,\beta$$

or

$$\left.\begin{array}{ll} x = \overset{m.y}{21{\cdot}2903}, & \text{with weight reciprocal} = {\cdot}0000138886 \\ y = 21{\cdot}7965, & \quad ,, \qquad ,, \qquad = {\cdot}0000136126 \end{array}\right\} \quad \ldots\ldots\ldots\ldots \quad (3)$$

(21) Substituting in the equations tabulated, the numerical values of x and y from (3), the following residual errors are obtained

No. of Series						No. of Series					
1		3		4		1		3		4	
No. of Comp.	Residual Error	No. of Comp.	Residual Error	No. of Comp.	Residual Error	No. of Comp.	Residual Error	No. of Comp.	Residual Error	No. of Comp.	Residual Error
1	− 2·54	61	− 0·63	91	+ 4·60	16	− 1·34	76	+ 4·95	106	+ 2·53
2	− 2·98	62	+ 0·33	92	3·68	17	0·71	77	5·08	107	3·89
3	+ 1·03	63	1·18	93	0·00	18	0·18	78	5·19	108	2·12
4	+ 0·58	64	2·77	94	0·75	19	2·41	79	0·65	109	4·76
5	+ 0·29	65	2·51	95	0·78	20	1·88	80	1·60	110	5·76
6	− 0·95	66	0·70	96	0·18	21	4·63	81	3·35	111	3·44
7	+ 0·29	67	0·69	97	− 0·22	22	3·18	82	2·70	112	5·47
8	− 2·51	68	2·32	98	1·87	23	2·58	83	1·13	113	4·86
9	1·74	69	2·19	99	0·56	24	5·03	84	1·99	114	3·67
10	1·95	70	1·85	100	1·95	25	2·96	85	− 2·19	115	5·54
11	3·65	71	− 1·02	101	2·33	26	3·76	86	+ 0·22	116	5·28
12	1·94	72	+ 0·43	102	+ 0·83	27	4·62	87	− 0·21	117	5·08
13	2·46	73	4·92	103	0·84	28	2·02	88	+ 2·41	118	6·58
14	1·74	74	5·06	104	− 1·82	29	4·02	89	2·10	119	7·17
15	1·25	75	5·76	105	1·44	30	3·74	90	1·23	120	6·42

(22) The sum of the squares of these residuals is 884·32; so that the probable error of a single comparison, or

$$p = 0{\cdot}6745\sqrt{\frac{884{\cdot}32}{90-2}} = 2{\cdot}1382$$

and the probable error of $x = 2{\cdot}1382\ \sqrt{{\cdot}0000138886} = \pm\,{\cdot}00796$

,, $y = 2{\cdot}1382\ \sqrt{{\cdot}0000136126} = \pm\,{\cdot}00788$

Hence, in the notation of page (12) Section I Chapter II

$$\left.\begin{array}{l} x = E_s = \overset{m.y}{21{\cdot}2903} \pm {\cdot}0080 \\ y = E_a = 21{\cdot}7965 \pm {\cdot}0079 \end{array}\right\} \quad \ldots\ldots\ldots\ldots\ldots \quad (5)$$

which are the adopted values (see page above quoted).

(23) The preceding values are arrived at by combining together *all* the 90 equations of series Nos. 1, 3 and 4. If however the 30 equations of series No. 1, when both the bars were hot, be excluded, and the remaining 60 equations of series Nos. 3 and 4 be proceeded with by the method of least squares; using $x = 89{\cdot}85$ *m.y* and $\tau = 51^{\circ}{\cdot}84$ as before; there result the normal equations

$$\begin{array}{ll} \text{in } x\text{, or} & 53333{\cdot}88\,x - 7345{\cdot}89\,y = 978226{\cdot}08 = a \\ \text{in } y\text{, or} & -7345{\cdot}89\,y + 52268{\cdot}08\,y = 979945{\cdot}22 = b \end{array} \Bigg\} \qquad (6)$$

(*m.y*)

The solution of group (6) gives

$$x = {\cdot}0000191199\,a + {\cdot}0000026872\,b$$
$$y = {\cdot}0000026872\,a + {\cdot}0000195098\,b$$

or

$$\left.\begin{array}{l} x = 21{\cdot}3369 \text{ with weight reciprocal} = {\cdot}0000191199 \\ y = 21{\cdot}7472 \qquad \text{,,} \qquad = {\cdot}0000195098 \end{array}\right\} \qquad (7)$$

(*m.y*)

(24) Substituting in the equations tabulated, Nos. 60 to 120, the numerical values of x and y from (7), the following residual errors are obtained

No. of Series				No. of Series				No. of Series			
3		4		3		4		3		4	
No. of Comp.	Residual error	No. of Comp.	Residual error	No. of Comp.	Residual error	No. of Comp.	Residual error	No. of Comp.	Residual error	No. of Comp.	Residual error
61	− 2·74	91	+ 2·27	71	− 3·14	101	− 4·77	81	+ 1·43	111	+ 1·28
62	1·78	92	1·35	72	1·69	102	1·46	82	0·77	112	3·27
63	0·93	93	− 2·48	73	+ 2·92	103	1·47	83	− 0·79	113	2·66
64	+ 0·65	94	1·75	74	3·07	104	4·12	84	+ 0·07	114	1·47
65	0·39	95	1·71	75	3·76	105	3·75	85	− 4·03	115	3·50
66	− 1·43	96	2·23	76	2·95	106	+ 0·19	86	1·64	116	3·25
67	1·40	97	2·63	77	3·08	107	1·55	87	2·07	117	3·06
68	+ 0·24	98	4·28	78	3·20	108	− 0·22	88	+ 0·53	118	4·52
69	0·09	99	3·00	79	− 1·27	109	+ 2·60	89	0·21	119	5·11
70	− 0·26	100	4·39	80	0·32	110	3·60	90	− 0·66	120	4·36

(25) The sum of the squares of these residuals is 395·57, so that the probable error of a single comparison, or

$$p = 0{\cdot}6745\sqrt{\frac{395{\cdot}57}{60-2}} = 1{\cdot}7615$$

and the probable error of $x = 1{\cdot}7615\,\sqrt{{\cdot}0000191199} = \pm\,{\cdot}00770$
,, ,, $y = 1.7615\,\sqrt{{\cdot}0000195098} = \pm\,.00777$

Hence, in the notation of page (12) Section I Chapter II

$$\left.\begin{array}{l} x = E_s = 21{\cdot}3369 \pm {\cdot}0077 \\ y = E_a = 21{\cdot}7472 \pm {\cdot}0078 \end{array}\right\} \qquad (8)$$

(*m.y.*)

(26) We may also deduce from series Nos. 1 and 2 a value for the *difference* of expansion between $I_s - A$. Now, to find the difference of length between the two bars *both* at temperature T, we have in the notation of article 5 Appendix No. 7

$$(I_s - A)_T = (I_s - A)_o - (t_a - T)(E_s - E_a) + dt_s \dot{E}_s$$

(27) In applying this expression to the comparisons of series Nos. 1 and 2, I shall adopt values of T for these series respectively of 97°·42 and 51°·84, which represent the mean temperature of A during each group of comparisons. For the expansions I employ the values on page (14) viz $E_a = 21·797$ *m.y* and $E_s = 21·225$ *m.y* so that $E_s - E_a = -0·572$ *m.y.* Under these conditions we obtain the following,

Series No. 1; both Bars hot

No. of comparison	Observed Temperature I_s	Observed Temperature A	Observed $I_s - A$	t_a − 97°·42 Fah.	dt_s	$I_s - A$ at 97°·42 Fah.	Residual Error
	°	°	*m.y*	°	°	*m.y*	
1	96·52	98·38	24·15	+ 0·96	1·86	64·18	− 0·36
2	·47	·39	22·43	0·97	1·92	63·73	·81
3	·49	·40	26·64	0·98	1·91	67·75	+ 3·21
4	·54	·00	35·98	0·58	1·46	67·30	2·76
5	·57	97·98	36·77	0·56	1·41	67·02	2·48
6	·49	·85	36·65	0·43	1·36	65·77	1·23
7	·42	·86	36·18	0·44	1·44	66·99	2·45
8	·41	·88	32·74	0·46	1·47	64·20	− 0·34
9	·44	·47	43·08	0·05	1·03	64·97	+ 0·43
10	·58	·74	39·97	0·32	1·16	64·77	·23
11	·59	·62	41·09	0·20	1·03	63·06	− 1·48
12	·63	·60	44·09	0·18	0·97	64·78	+ 0·24
13	·72	·50	47·67	0·08	0·78	64·28	− ·26
14	·76	·55	48·15	0·13	0·79	64·99	+ ·45
15	·77	·51	49·72	0·09	0·74	65·48	·94
16	·93	·95	43·45	0·53	1·02	65·40	·86
17	·97	98·27	37·96	0·85	1·30	66·04	1·50
18	97·00	·49	34·33	1·07	1·49	66·57	2·03
19	96·97	·58	29·50	1·16	1·61	64·33	− 0·21
20	·96	·60	29·38	1·18	1·64	64·86	+ ·32
21	·93	·60	25·99	1·18	1·67	62·11	− 2·43
22	94·78	96·04	37·47	− 1·38	1·26	63·42	1·12
23	·85	·14	37·38	1·28	1·29	64·03	0·51
24	·96	·27	34·44	1·15	1·31	61·58	2·96
25	95·13	·38	37·73	1·04	1·25	63·67	0·87
26	·13	·31	38·46	1·11	1·18	62·88	1·66
27	·20	·27	39·96	1·15	1·07	62·01	2·53
28	·18	95·40	61·09	2·02	0·22	64·60	+ 0·06
29	·15	·55	55·18	1·87	0·40	62·60	− 1·94
30	·12	96·15	41·76	1·27	1·03	62·89	− 1·65
Mean	96·19	97·42	38·31			64·54	

Series No. 2; both Bars cold

No. of comparison	Observed Temperature I_s	Observed Temperature A	Observed $I_s - A$	t_a − 51°·84 Fah.	dt_s	$I_s - A$ at 51°·84 Fah.	Residual Error
	°	°	*m.y*	°	°	*m.y*	
31	54·44	54·39	89·00	+ 2·55	− 0·05	89·40	− 0·45
32	·44	·38	89·47	2·54	·06	89·65	·20
33	·44	·39	86·96	2·55	·05	87·36	2·49
34	·45	·41	87·66	2·57	·04	88·28	1·57
35	·48	·44	91·37	2·60	·04	92·01	+ 2·16
36	52·33	52·27	91·96	0·43	·06	90·94	1·09
37	·33	·27	93·10	0·43	·06	92·08	2·23
38	·34	·27	92·53	0·43	·07	91·29	1·44
39	·34	·30	91·78	0·46	·04	91·19	1·34
40	51·83	51·73	91·56	− 0·11	·10	89·38	− 0·47
41	·82	·72	92·11	0·12	·10	89·92	+ ·07
42	·81	·72	91·10	0·12	·09	89·12	− ·73
43	·80	·71	91·83	0·13	·09	89·85	·00
44	·79	·72	91·03	0·12	·07	89·47	− ·38
45	·76	·70	89·86	0·14	·06	88·51	1·34
46	·75	·69	91·44	0·15	·06	90·08	+ ·23
47	·75	·70	92·64	0·14	·05	91·50	1·65
48	·13	·12	89·16	0·72	·01	88·54	− 1·31
49	·11	·12	89·24	0·72	+ ·01	89·04	·81
50	·11	·12	89·18	0·72	·01	88·98	·87
51	·11	·12	90·42	0·72	·01	90·22	+ ·37
52	·11	·13	90·54	0·71	·02	90·55	·70
53	·11	·13	89·23	0·71	·02	89·24	− ·61
54	·11	·14	89·21	0·70	·03	89·45	·40
55	·12	·14	89·58	0·70	·02	89·60	·25
56	50·29	50·30	90·91	1·54	·01	90·24	+ ·39
57	·27	·28	90·96	1·56	·01	90·28	·43
58	·25	·28	90·87	1·56	·03	90·62	·77
59	·24	·27	88·69	1·57	·03	88·43	− 1·42
60	·24	·26	90·86	1·58	·02	90·38	+ ·53
Mean	51·87	51·84	90·48			89·85	

(28) Hence for series No. 1 the probable errors are; of a single comparison $\pm$ 1·09; of $(I_s - A)_{97°.49}$, $\pm$ ·20. And for series No. 2 the corresponding probable errors are respectively $\pm$ ·76 and $\pm$ ·14. Therefore in the preceding notation

$$(I_s - A)_{51°.84} = \overset{m.y}{89 \cdot 85} \pm \cdot 14$$

$$(I_s - A)_{97°.49} = 64 \cdot 54 \pm \cdot 20$$

$$\text{and } (E_s - E_a) = -\frac{25 \cdot 31 \pm \cdot 24}{45 \cdot 58}$$

$$= - \overset{m.y}{0 \cdot 555} \pm \cdot 005$$

From the concluded values at page (14)

$$(E_s - E_a) = - 0 \cdot 572.$$

Micrometer Runs.

(29) Experiments for determining the linear values of a division of the micrometers, attached to the microscopes G and H, were made on the 10th and 11th February 1870; directly after the expansion experiments had been concluded. These values or "runs" were taken on the inch (*a.b*) of the standard steel foot, which space is divided into 20 parts each of 0.05 inch. Focus was found on the lines about the middle of the inch, and each of the 20 spaces measured in succession with the micrometer. The focus was then deranged and the process repeated by the other observer. Each space was thus measured 6 times in all, focus being found as many times, after which the run of the other microscope was found similarly. These experiments give the following linear results, which have been employed in reducing the bar comparisons.

1 Division of Micrometer G = 1·15163 *m.y* of A

1 „ H = 1·10777 „

(30) The errors of the working thermometers employed during the bar comparisons, will be found recorded in Appendix No 8.

J. B. N. HENNESSEY.

October 1870.

APPENDIX.

No. 7.

FINAL DETERMINATION OF THE DIFFERENCES IN LENGTH BETWEEN THE 10-FEET STANDARDS I_B, I_S AND A.

The particulars of the comparisons between the bars I_B, I_S and **A** made in 1867 are given in Appendix No. 3, where however the differences of length at 62° Fahrenheit are calculated with the *original* values of expansion for these bars (see page 8). To find these differences in terms of the *adopted* values of expansion (see page (14)), we proceed as follows.

2. Let any two bars, say F and G, be compared respectively at temperatures t_f and t_g, the observed excess of F above G being denoted by $(F - G)_o$, and the similar excess when both bars are reduced by calculation to 62° Fah: by $(F - G)_{62}$. Then if the expansions employed in these reductions be E_f for F, and E_g for G,

$$(F - G)_{62} = (F - G)_o - (t_f - 62^\circ)\, E_f + (t_g - 62^\circ)\, E_g \quad \ldots\ldots\ldots \quad [1]$$

and differentiating this equation with respect to the expansions

$$d\,(F - G)_{62} = -\,(t_f - 62^\circ)\, dE_f + (t_g - 62^\circ)\, dE_g \quad \ldots\ldots\ldots \quad [2]$$

3. Collecting the numerical values required, for calculating the corrections to the differences of length at 62° Fah: given in Appendix No. 3, we have the following

	E_B	E_S	E_a	
	m.y	m.y	m.y	
From page 8, *original* values of expansion	32·759	21·159	22·669	
„ page (14), *adopted* „	32·759	21·225	21·797	[3]
	$\therefore dE_B$ = 0·0	dE_S = 0·066	dE_a = − 0·872	

From page 9, comparisons of I_B and I_S	$(t_s - 62^\circ) = 9^\circ\!\cdot95$	$(I_B - I_S)_{62} = 131\cdot40$ m.y	
„ 10, „ I_B and **A**	$(t_a - 62^\circ) = 9\cdot95$	$(I_B - A)_{62} = 221\cdot32$	[4]
„ 11, „ I_S and **A**	$(t_s - 62^\circ) = 9^\circ\!\cdot64$; $(t_a - 62^\circ) = 9^\circ\!\cdot71$	$(I_S - A)_{62} = 89\cdot94$	

4. From [2], [3] and [4] there result

$$d\,(I_B - I_S)_{62} = 9\cdot95 \times \cdot066 = +\,0\cdot66 \text{ m.y}$$

$$d\,(I_B - A)_{62} = -\,9\cdot95 \times \cdot872 = -\,8\cdot68 \quad \ldots\ldots\ldots \quad [5]$$

$$d\,(I_S - A)_{62} = -\,9\cdot64 \times \cdot066 - 9\cdot71 \times \cdot872 = -\,9\cdot10$$

and from [4] and [5] we obtain the required differences of length between the bars at 62° Fahrenheit as follows, the expansions employed being the *adopted* values of page (14),

$$\begin{aligned} I_B - I_S &= \overset{m.y}{131{\cdot}40} + \overset{m.y}{0{\cdot}66} = \overset{m.y}{132{\cdot}06} \\ I_B - A &= 221{\cdot}32 - 8{\cdot}68 = 212{\cdot}64 \quad \ldots\ldots\ldots\ldots \quad [6] \\ I_S - A &= 89{\cdot}94 - 9{\cdot}10 = 80{\cdot}84 \end{aligned}$$

which are the values given at page (25) deduced from the comparisons of 1867 only.

5. Again in Appendix No. 6 comparisons of 1870, series No. 2, the mean results show, that when I_S and A were respectively at the temperatures 51°·87 and 51°·84, the former bar was longer than the latter by 90·48 *m.y.* Now in the notation of [1]

$$(I_S - A)_{62} = (I_S - A)_0 - (t_s - 62°)\, E_S + (t_a - 62°)\, E_a$$

or since $(t_s - t_a)$ and $(E_S - E_a)$ are both small, we may put $t_a = t_s - dt_a$ and write more conveniently

$$(I_S - A)_{62} = (I_S - A)_0 - (t_s - 62°)\,(E_S - E_a) - dt_a\, E_a \quad \ldots\ldots\ldots\ldots \quad [7]$$

substituting in [7], the *adopted* values of expansion from [3] and the mean results above quoted, we have

$$\begin{aligned} (I_S - A)_{62} &= 90{\cdot}48 - 10{\cdot}13 \times {\cdot}572 - {\cdot}03 \times 21{\cdot}8 \text{ expressed in } m.y \\ &= 84{\cdot}03 \; m.y \quad \ldots\ldots\ldots\ldots\ldots\ldots \quad [8] \end{aligned}$$

6. From what has been here stated and proceeding as on page (25), the following are the final resulting differences at 62° Fah :

$I_B - I_S$	=	131·46 *m.y*	determined by Captain A. R. Clarke, R.E.
$I_S - A$	=	82·52	mean of comparisons in 1867 and 1870
Hence $I_B - A$	=	213·98	

J. B. N. HENNESSEY.

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APPENDIX.

No. 8.

ON THE THERMOMETERS EMPLOYED WITH THE STANDARDS OF LENGTH.

The standard and working thermometers, employed in determining the temperatures of the standard bars when under comparison, may be suitably described under two classes or kinds; *i.e.* thermometers which are read on their attached metal scales, and those with scales marked on their own glass tubes. The former kind of thermometers were received with the base-line apparatus in 1830, and were employed up to the year 1866 when they gave place to excellent thermometers of modern construction.

Thermometers with metal scales, in use 1830 *to* 1866.

2. The two standard thermometers were constructed by Messrs. Troughton and Simms and were marked in this country σ and σ_1. There is reason to believe that they were precisely similar to one another in construction, so that a description of the latter, which alone is now (1871) forthcoming, may be considered to include the former. Thermometer σ_1 is about 16″¼ in length, terminating in a glass-hook at the upper extremity and in a spherical bulb 0″·6 in diameter at its lower end. It has a *straight-bulb*, a term, in contradistinction to *bent-bulb*, by which it is intended to express that the centre of the bulb is in the prolongation of the straight line defined by the glass tube. The thermometer is attached to a brass plate or scale by means of the glass-hook which to a certain extent acts the part of a steady-pin, and two bent metal bands which embrace the tube near its extremities and are themselves screwed down to the metal plate. The scale is graduated to half degrees from 5° to 222° Fahrenheit and the distance between the 32° and 212° strokes is 12″·3. Thermometers σ and σ_1 have been assumed as errorless, in the absence of experiments during the period of their employment for finding their errors: nor could the omission be now supplied, for the glass-hook has a play in its socket of quite a quarter of a degree, by which quantity any errors which could at present be determined may be affected. Besides this, the important variations of their zero errors cannot now be ascertained retrospectively.

3. The 4 working thermometers were, it is believed, all similar to one another: those on standard bar **A** were marked α and β and they are the two thermometers on which the observed temperatures of this bar depend during the comparisons at the Calcutta, Dehra Doon, Sironj, Bider, Sonakhoda, Chach, Karachi and Vizagapatam base-lines. The thermometers on standard **B** were marked γ and δ; they were employed with this bar, only during the comparisons of 1834-35 between standards **A** and **B**, and were sent back to England in 1843-44 with the latter bar. It is therefore sufficient to add that γ, δ, σ and σ_1 were all compared with one another in April 1835, when 25 readings of each thermometer were taken between the temperatures of 73° to 79° Fahrenheit. The mean difference gives

$$\frac{\sigma + \sigma_1}{2} - \frac{\gamma + \delta}{2} = -0^{\circ}\cdot 228.$$

Thermometers with metal scales, in use 1830 *to* 1866—(Continued.)

4. As regards the important working thermometers α and β, a description of either will answer for the other since they are exactly alike in appearance. Thus α has a *bent bulb*; the tube terminates at its upper end in the usual glass-hook which was found in December 1855 to be slightly loose in its socket, so that the tube had a longitudinal play estimated at 0°·2 as a maximum. The liability to displacement was checked by the introduction of a minute wooden wedge and the thermometer used with this precaution in the comparisons which were subsequently made. The tube is 7″ in length reckoning, from the glass-hook to the angle at the bend, and is attached to a brass plate (or scale) in the same way as the tube of σ_1. The bulb is spherical and 0″·4 in diameter; its centre is 1″·1 below the brass plate, so that the bulb when in position is situated slightly *below*(1) the centre of a transverse section of the standard **A**(2). The thermometer is graduated only to integral degrees from 5° to 140° Fahrenheit and the distance between the 32° and 140° strokes is 5″. The maker's name is not registered on α or β, but it is believed that these instruments were constructed by Messrs. Troughton and Simms.

5. The thermometers α and β were compared with certain standard thermometers on three occasions, *i.e.* in 1833, in 1854 and in 1867.

6. The comparisons of 1833 were taken by Captain(3) G. Everest, whose register of these experiments does not show the circumstances under which they were made; but it may be conjectured that the thermometers σ, σ_1, α and β were suspended near one another in a room where the temperature was tolerably equable and thus observed. The readings recorded are as follows:

TABLE I of 1833.

1833	Time	Standard σ	Standard σ_1	α	β	1833	Time	Standard σ	Standard σ_1	α	β
	h. m.	°	°	°	°		h. m.	°	°	°	°
June 13,	9 0	88·9	89·2	88·9	89·0	June 15,	7 30	87·3	87·5	87·4	87·3
	10 15	90·0	90·1	90·0	90·0		8 30	89·3	89·3	89·1	89·0
	12 0	91·1	91·2	91·1	91·0		9 30	90·5	90·5	90·5	90·3
	1 15	91·7	92·0	91·8	91·7		10 0	91·6	92·0	91·5	91·3
	3 0	92·4	92·5	92·5	92·4		12 0	92·5	92·7	92·7	92·8
14,	8 30	90·2	90·4	90·1	90·5	16	6 30	87·8	88·1	88·2	88·2
	10 0	92·6	92·7	92·5	92·8		8 0	89·9	90·1	90·0	89·9
	11 0	92·8	93·0	92·9	92·8		9 0	91·5	92·3	91·5	92·0
	12 15	94·7	94·6	94·6	94·2		11 0	93·1	93·9	93·3	93·9
	4 30	95·8	95·8	96·0	95·8		12 0	93·4	94·0	93·6	94·0
	5 30	97·1	97·0	97·1	96·8		5 0	95·5	95·6	95·5	95·7
							Means	91·805	92·023	91·855	91·882

And from the mean readings $\frac{\sigma + \sigma_1}{2} - \frac{\alpha + \beta}{2} = + 0^\circ{\cdot}045$

(1.) See description of standard **A** page (2).
(2.) In this respect these old thermometers have an advantage over most modern bent-bulbs. The bent arm carrying the bulb is generally too short in the latter instruments to reach down to the centre of the bar, and even the thermometer-wells in the bars are not always bored to a sufficient depth.
(3.) Afterwards Colonel Sir G. Everest C.B.

Thermometers with metal scales, in use 1830 *to* 1866—(Continued.)

7. In 1854 Major[(1)] A. Strange compared σ_1 α and β with one another. The thermometers appear to have been attached to "a light frame of deal wood" and "the whole immersed in a large wooden tub containing sufficient water to "completely cover them." The water was "thoroughly agitated by means of a wooden paddle in order to obtain equal-"ity of temperature throughout." The results are as follows :—

TABLE II of 1854.

No. of comparison	Readings of Standard σ_1	$\sigma_1 - \frac{\alpha+\beta}{2}$	$\alpha - \beta$	No. of comparison	Readings of Standard σ_1	$\sigma_1 - \frac{\alpha+\beta}{2}$	$\alpha - \beta$
	°	°	°		°	°	°
1	39·40	+ 0·50	− 1·40	3	53·50	+ 0·10	− 1·00
2	39·75	+ 0·83	− 1·15	4	53·25	− 0·05	− 0·80
The water was now raised to a temperature of 108° and allowed to cool down gradually							
5	95·30	− 0·43	− 0·45	9	75·00	− 0·13	− 0·35
6	90·20	− 0·30	− 0·40	10	70·50	− 0·18	− 0·55
7	85·55	− 0·20	− 0·50	11	62·30	− 0·25	− 0·70
8	80·35	− 0·13	− 0·85	12	62·60	− 0·10	− 0·60

Note.—"Stirring the water makes a difference of 1° occasionally".

8. The comparisons of 1867 were made under the directions of Colonel J. T. Walker, R.E. by J. B. N. Hennessey, Esq. and W. H. Cole, Esq. M. A. The procedure followed on this occasion will be found described further on in this paper under the head of "Thermometers with scales marked on their own glass-tubes"; it is sufficient to premise in this place that the Standard 4246 is an instrument of modern make, constructed with the skill and improvements now in practise and that its errors are all known. The experiments under notice give the following results :—

TABLE III of 1867.

No. of comparison	Corrected readings of Standard 4246	$4246 - \sigma_1$	$4246 - \frac{\alpha+\beta}{2}$	$\sigma_1 - \frac{\alpha+\beta}{2}$	$\alpha - \beta$	No. of comparison	Corrected readings of Standard 4246	$4246 - \sigma_1$	$4246 - \frac{\alpha+\beta}{2}$	$\sigma_1 - \frac{\alpha+\beta}{2}$	$\alpha - \beta$
	°	°	°	°	°		°	°	°	°	°
1	60·82	− 0·36	− 0·47	− 0·11	− 0·94	8	75·00	− 0·42	− 0·58	− 0·16	− 0·57
2	62·90	− 0·30	− 0·48	− 0·18	− 0·71	9	77·09	− 0·38	− 0·63	− 0·25	− 0·71
3	64·80	− 0·37	− 0·49	− 0·12	− 0·53	10	78·75	− 0·42	− 0·56	− 0·14	− 0·59
4	66·93	− 0·38	− 0·50	− 0·12	− 0·61	11	80·83	− 0·39	− 0·57	− 0·18	− 0·62
5	69·01	− 0·45	− 0·48	− 0·03	− 0·57	12	82·86	− 0·43	− 0·51	− 0·08	− 0·57
6	70·83	− 0·42	− 0·54	− 0·12	− 0·47	13	84·92	− 0·37	− 0·57	− 0·20	− 0·55
7	72·78	− 0·41	− 0·54	− 0·13	− 0·54	14	86·86	− 0·30	− 0·67	− 0·37	− 0·42
						15	88·93	− 0·33	− 0·62	− 0·29	− 0·46

	of σ_1	of α	of β
Readings in melting ice	32·35 °	31·6 °	32·8 °

(1) Now Colonel A. Strange.

Thermometers with metal scales, in use 1830 *to* 1866—(Continued.)

9. The correction to $\frac{\alpha + \beta}{2}$ of + 0·045 from Table I, was applied in the first instance to the observed temperatures of Standard **A** taken during the bar comparisons at all the base-lines measured prior to 1866 ; *i.e.* the lines of Calcutta, Dehra Doon, Sironj, Bider, Sonakhoda, Chach (or Attok), Karachi and Vizagapatam. Subsequently on a discussion of the subject by Colonel Walker, it appeared that means were available by which an improved value of the correction might be obtained for the base-lines at Karachi and Vizagapatam. Thus from Tables II and III the following may be deduced

From TABLE II of 1854.				From TABLE III of 1867.			
Comparisons	Temperature	$\sigma_1 - \frac{\alpha + \beta}{2}$	$\alpha - \beta$	Comparisons	Temperature	$\sigma_1 - \frac{\alpha - \beta}{2}$	$\alpha - \beta$
	°	°	°		°	°	°
Nos. 11 & 12	62·5	− 0·18	− 0·65	Nos. 1 & 2	61·9	− 0·15	− 0·83
9 & 10	72·8	·16	·45	6 & 7	71·8	·13	·51
8 & 7	83·0	·17	·68	12 & 13	83·9	·14	·56
5 & 6	92·8	·37	·43	15	88·9	·29	·46

It will be seen on comparing the values of $\sigma_1 - \frac{\alpha + \beta}{2}$ and of $\alpha - \beta$ determined at about the same temperatures in 1854 and in 1867, that the identity between these corresponding differences is sufficiently close, to justify the assumption, that the zero errors of these thermometers were sensibly identical at the two epochs of observation; and hence that the errors determined in 1867, by comparisons with a well established thermometer and under improved appliances for equalizing and sustaining the temperature, are fairly applicable to the base-lines of Karachi measured in 1854-55 and of Vizagapatam measured in 1862-63. Such retrospective application was not considered desirable to the earlier operations, both on account of the defect in α described in art. 4 and also for the more important reason, that during the period of these prior operations the zeros of the thermometers were more liable to change, as at that time α and β were comparatively of recent construction.

10. Nor, in the bar comparisons at Karachi and Vizagapatam base-lines, does it appear, that by correcting *each observed* temperature for its assigned error, a sufficient improvement would be gained to justify the labor involved. Accordingly, the *mean* temperature of Standard **A** at the Karachi base-line being about 68°, we find by taking a mean from comparisons Nos. 1 to 8 (Table III) that Standard 4246 − $\frac{\alpha + \beta}{2}$ = −0°·51 ; and similarly, the corresponding temperature for the Vizagapatam measurement being nearly 75°, the correction to $\frac{\alpha + \beta}{2}$ is − 0°·55 from comparisons Nos. 4 to 11 of Table III. As however a correction of + 0°·045 had already been applied in the reduction, we find eventually

Correction to the mean temperature of Standard **A** at Karachi base-line = − 0°·56
" " Vizagapatam " = − 0 ·59

the linear values corresponding to these thermal variations will be found duly applied at pages VII—18 and VIII—16 of this volume.

Standard Thermometers with scales marked on their own glass-tubes, in use 1866 *and subsequently.*

11. The apparatus for comparing the thermometers with one another is similar to that adopted by Captain A. R. Clarke, R.E., C.B. and described at pages 7 and 8 of his volume entitled "Comparisons of Standards of length." It consists of a water-tight trough with a tap for discharging and a funnel for admitting water. The thermometers rest on a frame which is immersed in the water, and are read through glass windows in the trough by means of a microscope

Standard Thermometers with scales marked on their own glass-tubes, in use 1866 *and subsequently*—(Continued.)

and a rectangular glass slide. The latter has eleven converging lines marked on it and is placed in the focus of the eye-piece, so that when the outer lines are made to coincide with the image of a degree, readings of the mercury can be obtained with accuracy to 1 or 2 in the second place of decimals. All these are copies of Captain Clarke's contrivances. But in the absence of appliances for heating up the comparing room to the temperature imparted to the water, the trough employed was made of larger dimensions than the one in use at Southampton. Thus Captain Clarke's trough was 29″ × 9″ × 9″ giving a cubic measurement of 2349 inches, while the one under notice is 40″ × 14″½ × 26″½ or 15,105 cubic inches in its contents. It may also be remarked that in the absence of slides similar to Captain Clarke's for moving the microscope in rectangular coordinates, other means are adopted, of sufficient rigour, for maintaining the required conditions of accuracy. The water in the trough can be thoroughly agitated and mixed by means of paddles provided for the purpose.

12. The five *Standard Thermometers* are numbered 4140, 4141, 4142, 4246, and 4347; they were constructed by Mr. L. Casella, in the year 1865 (or 1864) and received in India about the middle of 1866. Of these instruments 4347 alone has a *bent-bulb*; the other 4 have *straight-bulbs*. The bulbs are all nearly cylindrical in shape and rounded off at top and bottom. The scales in every case are marked on the glass tubes, but for protection and support each tube when in use is mounted on a metal plate. Nos. 4142 and 4246, have their scales and numerals cut into the *upper* surface of the glass-tube as usual, while a strip of white enamel runs along the opposite surface and furnishes an opaque back ground to the lines. In 4140, 4141 and 4347, the scale and numerals are cut on the *upper* surface of the tube as above and besides a corresponding scale is marked on the *opposite* or lower surface of the tube, each line of the lower scale being in the transverse section through its corresponding line on the upper scale*. The thermometers all terminate at the upper extremity in the usual glass-hook, and the hollow within the tube, at the same termination, ends in a small safety reservoir in which the mercury may collect under temperatures *above* the boiling point†.

13. The following facts have reference to the five Standard thermometers:

Number	Length		Tube diameter	Bulb		Range of graduation
	Entire	32° to 212°		Length	Diameter	
	″	″	″	″	″	° °
4140	20·55	16·58	0·25	1·55	0·40	25 to 215
4141	20·45	15·94	0·23	1·20	0·31	20 „ 220
4142	18·95	15·02	0·28	1·05	0·28	25 „ 215
4246	20·35	15·14	0·28	1·10	0·27	15 „ 220
4347	23·20	20·14	0·25	1·05	0·21	30 „ 215

the shorter bent arm of 4347 is 1½″ in length.

* The corrections given hereafter are applicable to the *upper-scale*. This system of duplicate marking, by which the plane of a transverse section through each *upper* line is indicated by a corresponding line below, was suggested by me as a ready means for placing the reader's eye in the position which it should occupy. The precaution is redundant and even vexatious in the presence of Captain Clarke's excellent reading microscope and glass-slide; but when these aids are not employed, as in the use of ordinary thermometers, the advantages of duplicate marking will be apparent. (J. B. N. H.)

† This safety reservoir is a nuisance. The column of mercury is very apt to be broken off and get detached from the bulk of the quicksilver in the bulb, and when this happens the metal is sure to run into the reservoir and pertinaciously resist all efforts to dislodge it. If the reservoir once gets quite full, no amount of tapping and coaxing will induce the mercury to descend, and in this case the hook-end of the tube must be gradually subjected to the flame of a candle when the quicksilver will readily run down. The remedy involves violence and risk, which would not be incurred, if in place of the reservoir the glass-tube and hollow were continued for 2 or 3 inches above the boiling point, *supposing this to be essential?*

Standard Thermometers with scales marked on their own glass-tubes, in use 1866 *and subsequently*—(Continued.)

14. These thermometers were handed by the makers to Captain A. R. Clarke, R.E., C.B., of the Ordnance Survey, who subjected them to elaborate examination and comparison with the aid of the appliances detailed in his Chapter XVI of "Comparisons of Standards of length." Selecting 4142 he found its *corrections* for *calibration*, or c; its *correction* for error in the relative positions of the boiling and freezing points, (*i.e.* correction to *mean* degree) or m; and its *correction* for reading of freezing point (i.e. *index* correction), or i.* He then compared 4142 with the Ordnance Survey Standard 3241 having previously found c and m for the latter thermometer. Subsequently, the corrections to the 4 working thermometers, employed by Captain Clarke in determining the expansions of the 10-foot Standard bars I_B and I_S, were found by him from comparisons with 4142; but these working thermometers were most unfortunately all broken on their way from England to Dehra Doon in India, so that a considerable portion of the time and labor expended on them was thus lost. The results of the foregoing comparisons are given in the volume and chapter above quoted and will be copied from thence into this paper.

15. But besides these *published* results, Captain Clarke found m for 4140, 4141, 4246 and 4347, and, excepting 4347 because it was too long for his trough, he compared them with 3241, and 4142. These results were furnished by him through Colonel Sir Henry James, R.E., Director of the Ordnance Survey to Colonel J. T. Walker, R.E., Superintendent Great Trigonometrical Survey of India with his letter dated October 1865.

16. Subsequently, Captain Clarke's comparisons last named were extended to lower and higher temperatures than those included in his series, by J. B. N. Hennessey, Esq. and Lieutenant M. W. Rogers, R.E., at Colonel Walker's Head-quarters' office. The following are the numerical results of the experiments enumerated in arts. 14, 15 and 16.

TABLE IV. Calibration corrections(1) *of Standard Thermometer* 4142.

Temperature	Values of c	Temperature	Values of c	Temperature	Values of c
°	°	°	°	°	°
37	+ ·023	62	+ ·035	82	− ·020
42	·068	67	·029	87	·012
47	·068	72	·046	92	·005
52	·016	77	− ·044	97	·073
57	·036				

(1) See "Comparisons of Standards of length" p. 191.

* If R be the observed reading and T the corresponding deduced true absolute temperature, then in the notation here adopted

$$T = R + c + m + i$$

where it will be noticed that c and m are constants in respect to time, whereas i, in the absence of evidence, must be expected to prove a variable. The variations of i are, generally, all in the same direction; *i.e.* i is always negative and increases numerically for some considerable period after construction. It may also be disturbed if the thermometer is subjected to extreme degrees of temperature in either direction; the more so, probably, if the extreme reading is attained to suddenly and therefore violently, instead of by a process of gradual change. The following readings of 4246 in melting ice are not without interest.

1865,	October	32°·00	by	Captain Clarke at Southampton.
1867,	April	32·28	by	Messrs. Hennessey, Rogers, and Cole at Dehra.
1867,	November	32·30	by	Messrs. Hennessey and Rogers. ,,
1870,	February	32·36	by	Messrs. Hennessey and Cole. ,,

each of the above readings is the mean of not less then 6 observations.

Standard Thermometers with scales marked on their own glass-tubes, in use 1866 *and subsequently*—(Continued.)

TABLE V. Actual Thermometer readings of the Standards 3241 *and* 4142 *corrected by* $(c+m+i)_{(2)}$

Reference No.	3241	4142	Reference No.	3241	4142
	°	°		°	°
1	97·34	97·33	11	72·00	72·03
2	94·66	94·69	12	70·01	70·04
3	92·05	92·05	13	67·18	67·16
4	90·39	90·35	14	65·05	65·08
5	87·11	87·09	15	62·13	62·14
6	85·23	85·20	16	60·15	60·16
7	82·17	82·18	17	57·46	57·49
8	80·14	80·15	18	55·52	55·53
9	77·35	77·35	19	52·16	52·20
10	75·01	75·00			
Readings in melting Ice				32·41	32·00

(2) See "Comparisons of Standards of length" p. 193.

Taking now the true temperature to be the mean of those indicated by the two thermometers in Table *V*, we have the following residual errors :

TABLE VI of residual errors.(3)

Reference Number	3241	4142	Reference Number	3241	4142
	°	°		°	°
1	+ 0·005	− 0·005	11	− 0·015	+ 0·015
2	− 0·015	+ 0·015	12	0·015	0·015
3	0·000	0·000	13	+ 0·010	− 0·010
4	+ 0·020	− 0·020	14	− 0·015	+ 0·015
5	0·010	0·010	15	0·005	0·005
6	0·015	0·015	16	0·005	0·005
7	− 0·005	+ 0·005	17	0·015	0·015
8	0·005	0·005	18	0·005	0·005
9	0·000	0·000	19	0·020	0·020
10	+ 0·005	− 0·005			

(3) See "Comparisons of Standards of length" p. 194.

Standard Thermometers with scales marked on their own glass-tubes, in use 1866 *and subsequently*—(Continued.)

TABLE VII. Determination of the correction for error in relative positions of Freezing and Boiling points for Standard Thermometers 4140, 4141, 4142, 4246, *and* 4347 (1).

1865	Thermometer	Observed boiling point	Barometer corrected and reduced to 32°	Excess over the Standard pressure	Error of boiling point	Observed freezing point	Error in relative position of freezing and boiling point	Corresponding correction to thermometer readings at Temp: t = m
		°	*inches.*	*inches.*	°	°	°	
October 2nd	4140	212·27	29·854	− ·051	+ 0·36	31·92	+ 0·44	− ·0024 ($t°$ − 32°)
"	4141	212·21	29·854	− ·051	+ 0·30	32·00	+ 0·30	− ·0017 (t − 32)
March 20th	4142	212·20	29·917	+ ·012	+ 0·18	32·00	+ 0·18	− ·0010 (t − 32)
October 2nd	4246	212·15	29·854	− ·051	+ 0·24	32·00	+ 0·24	− ·0013 (t − 32)
" 4th	4347	212·25	30·055	+ ·150	+ 0·00	32·06	− 0·06	+ ·0003 (t − 32)

(1) From Captain Clarke's letter, see art. 15 of this paper.

TABLE VIII. Comparisons between the Standard Thermometers (2)

Reference number	Number of comparisons	Observed readings of thermometer					Total correction = ($c + m + i$)		Corrected Reading		True absolute temperature	Total correction = ($c + m + i$)			Correction for constants = ($c + m$)			Observers
		3241	4142	4246	4140	4141	3241	4142	3241	4142		4246	4140	4141	4246	4140	4141	
1	2	57·15	56·66	56·71	56·61	56·70	−·58	−·08	56·57	56·58	56·57	−·14	−·04	−·13	−·03	−·04	−·05	Captain Clarke, R.E., Quarter-Master Steel, R.E., } in 1865.
2	4	62·63	62·12	62·14	62·11	62·18	−·60	−·09	62·03	62·03	62·03	−·11	−·08	−·15	·00	−·08	−·07	
3	4	67·64	67·14	67·20	67·13	67·18	−·61	−·10	67·03	67·04	67·03	−·17	−·10	−·15	−·06	−·10	−·07	
4	4	72·67	72·10	72·17	72·15	72·15	−·65	−·08	72·02	72·02	72·02	−·15	−·13	−·13	−·04	−·13	−·05	
5	4	77·97	77·45	77·46	77·47	77·44	−·66	−·17	77·31	77·28	77·29	−·17	−·18	−·15	−·06	−·18	−·07	
6	4	82·74	82·24	82·27	82·26	82·23	−·64	−·16	82·10	82·08	82·09	−·18	−·17	−·14	−·07	−·17	−·06	
7	4	87·66	87·19	87·22	87·23	87·22	−·59	−·15	87·07	87·04	87·05	−·17	−·18	−·17	−·06	−·18	−·09	
8	4	92·88	92·41	92·42	92·44	92·44	−·62	−·14	92·26	92·27	92·26	−·16	−·18	−·18	−·05	−·18	−·10	
9*	4	32·50	32·09	32·11	32·00	32·08												
10	2		42·45	42·55	42·61	42·60		−·12		42·33		−·22	−·28	−·27	+·07	−·13	−·07	J. B. N. Hennessey, Esq., Lieut. M. W. Rogers, R.E., } in 1867.
11	2		47·51	47·64	47·61	47·65		−·13		47·38		·26	−·23	·27	·03	·08	·07	
12	2		52·20	52·38	52·23	52·29		−·18		52·02		·36	−·21	·27	−·07	·06	·07	
13	2		56·31	56·48	56·31	56·40		−·17		56·14		·34	−·17	·26	·05	·02	·06	
14	2		87·30					−·25		87·05								
15	2		92·63					−·25		92·38								
16	2		97·49	97·52	97·42	97·50		−·32		97·17		−·35	−·25	−·33	−·06	−·10	−·13	
17	2		100·56	100·60		100·60		−·32		100·24		−·36		·36	·07		·16	
18	2		100·50		100·51			−·32		100·18			−·33			−·18		
19*	2		32·18	32·29	32·15	32·20												

* These readings were taken in melting Ice.

(2) The comparisons denoted by the reference numbers 1 to 9 are taken from Captain Clarke's letter, see art : 15 of this paper.

17. It will be noticed that standard 4347 (bent-bulb) is absent in the comparisons of 1867 Table *VIII.* In fact however this thermometer was compared with 4142 at regulated intervals between 42° and 100° in 1867; but as the resulting corrections were not required earlier, they were deduced only recently (1871). Unfortunately they prove unsatisfactory, exhibiting comparatively rapid variations in the corrections: they are therefore withheld until an opportunity offers for making verificatory comparisons.

Working Thermometers with scales marked on their own glass-tubes, in use 1867 *and subsequently.*

18. The working thermometers are all of the bent-bulb pattern and have their scales marked on their own glass-tubes: they are mounted as usual on metal plates. At the bulb end, the tube is first bent at right angles to itself in a *horizontal* direction and then *downwards:* the horizontal piece is some ¼″ long and the bottom of the bulb is about ¾″ beneath the metal plate. The glass-tubes are some 10″ in length, the hollow within, for the play of the mercury, terminating in the small safety reservoir mentioned in describing the standard thermometers. All the working thermometers resemble one another in the foregoing respects: otherwise they may be classified under the heads of "Long range" or "L. R", "Low range" or "l. R" and "High range" or "h. R". The L. Rs. are graduated to half degrees, from about 20° to 100°. The l. Rs. and h. Rs. read to tenths of degrees, the former from about 45° to 65°, the latter from about 60° to 85°. All these instruments were constructed by Mr. L. Casella and received in India early in 1867. They comprise the *second* batch of working thermometers obstained for use with the standards of length, the *first* batch having reached their destinatiou broken with hardly an exception from careless packing.

19. Numerous comparisons have been made for determining the corrections to the working thermometers. The thermometer compared with was the Standard 4246, and this instrument was adopted, not in preference to the calibrated standard 4241, but because the latter has sprung a slight crack in its tube and it is therefore highly desirable to avoid subjecting the instrument to the operations involved in comparisons lest the crack should thus be increased.

20. The corrections deduced are as follows, the working thermometers hereafter named being only those which have been actually employed in the bar comparisons.

TABLE IX. Total corrections to the following Long-range thermometers to find true absolute temperature, determined by comparisons with Standard 4246.

Temperature	4217	4218	4221	4227	4228	7345	7347	7348	7349
40°	−0°·28	−0°·23	−0°·28	−0°·30	−0°·41	−0°·58	−0°·30	−0°·20	−0°·34
42	·27	·27	·31	·32	·47	·63	·33	·23	·40
44	·32	·32	·32	·38	·49	·66	·37	·26	·41
46	·37	·30	·31	·43	·51	·67	·37	·26	·40
48	·40	·31	·31	·41	·51	·67	·36	·29	·40
50	·44	·33	·32	·42	·53	·67	·39	·31	·40
52	·42	·32	·30	·39	·51	·66	·38	·35	·36
54	·39	·28	·29	·39	·49	·61	·37	·29	·28
56	·40	·26	·27	·40	·46	·59	·36	·24	·27
58	·42	·28	·31	·43	·48	·60	·37	·20	·28
60	·42	·28	·31	·43	·50	·61	·40	·19	·28
62	·37	·28	·30	·34	·44	·59	·38	·16	·27
64	·36	·25	·35	·31	·44	·56	·35	·11	·25
66	·38	·26	·32	·28	·45	·59	·40	·15	·32
68	·35	·27	·32	·29	·43	·58	·40	·21	·33
70	·34	·25	·31	·28	·43	·56	·39	·23	·32
72	·38	·22	·33	·32	·48	·59	·34	·32	·33
74	·40	·28	·37	·33	·49	·60	·32	·32	·31
76	·42	·35	·37	·35	·48	·65	·38	·37	·37
78	·39	·28	·36	·34	·45	·64	·36	·31	·35
80	·41	·33	·38	·34	·47	·67	·37	·35	·35
82	·42	·31	·39	·35	·48	·71	·37	·34	·35
84	·45	·38	·38	·35	·46	·72	·39	·33	·35
86	·46	·37	·37	·35	·45	·72	·37	·35	·34
88	·49	·37	·40	·40	·47	·74	·36	·36	·35
90	·49	·36	·43	·41	·50	·73	·35	·37	·36
92	·43	·47	·46	·41	·52	·81	·40	·40	·38
94	·45	·50	·50	·41	·54	·87	·43	·43	·42
96	·47	·52	·56	·40	·57	·91	·45	·48	·44
98	·47	·55	·59	·42	·59	·94	·47	·47	·44
100							·53	·47	·53
Readings in melting Ice 1870,	32·30			32·26	32·36	32·58			

Working Thermometers with scales marked on their own glass-tubes, in use 1867 *and subsequently*—(Continued.)

TABLE X. Total corrections to the following Low-range thermometers to find true absolute temperature, determined by comparisons with Standard 4246.

Temperature	7287	7290	7291	7292	Temperture	7287	7290	7291	7292
°	°	°	°	°	°	°	°	°	°
46	−·15	−·20	−·18	+·03	58	−·21	−·19	−·19	+·05
48	·19	·23	·19	·02	60	·20	·18	·16	·10
50	·21	·22	·20	·00	62	·30	·24	·23	·04
52	·19	·19	·17	·03	64	·21	·17	·18	·08
54	·17	·17	·15	·06	66	·13	·11	·13	·07
56	·20	·18	·18	·05					

TABLE XI. Total corrections to the following High-range thermometers to find true absolute temperature, determined by comparisons with Standard 4246.

Temperature	4011	4202	4204	4206	4215	4216	7293	7295	7296	7298
°	°	°	°	°	°	°	°	°	°	°
65	−·23	−·23	−·22	−·24	−·18	−·40	−·18	−·20	−·18	−·27
67	·26	·27	·25	·28	·26	·39	·22	·24	·21	·28
69	·26	·26	·24	·27	·27	·41	·21	·24	·22	·29
71	·28	·27	·25	·33	·30	·39	·23	·26	·21	·27
73	·38	·33	·30	·32	·33	·41	·23	·25	·20	·30
75	·38	·33	·32	·30	·35	·45	·20	·25	·20	·27
77	·36	·33	·31	·28	·28	·47	·14	·18	·15	·22
79	·33	·32	·28	·32	·26	·51	·17	·20	·13	·28
81	·29	·28	·21	·28	·23	·48	·12	·20	·15	·24
83	·31	·27	·27	·30	·27	·45	·16	·23	·18	·22
85	·35	·29	·29	·35	·35	·48	·21	·25	·23	·27

(21.) The comparisons which form the basis of Tables *IX*, *X* and *XI* were all made in 1867, excepting the working thermometors 4217, 4227, 4228 and 7345, which were compared with Standard 4246 both in 1867 and again directly after the expansion experiments of appendix No. 6 in 1870. Each correction in the cases of the 4 working thermometers just named, is the mean result of 4 comparisons taken by 3 observers; all the other corrections are each derived from two independent comparisons. The observers were J. B. N. Hennessey, Esq. Lieutenent M. W. Rogers, R.E., and W. H. Cole, Esq. M.A.

Working Thermometers with scales marked on their own glass-tubes, in use 1867 *and subsequently*—(Continued.)

(22.) The occasions when these working thermometers were employed and the numbers of these instruments are as follows :—

		l.R	h.R	L.R
During the comparisons of appendix No. 3	In Standard bar I_S	....	4202, 4204	4228
	" I_B	....	4011, 4215	4221
	" **A**	....	....	4227, 4217
" " appendix No. 4	In Standard steel foot	....	4215	
	In six-inch brass scales *A, M, R, U, W*	....	4204	
	" " *N, S, T, V*	....	4011	
" " appendix No. 5	....	....	....	4217, 4218
" " appendix No. 6	see *the* appendix pages 28 to 31			
During the bar comparisons at the Bangalore Base-Line	In Standard bar **A** before measurement	7287, 7292(1)	7293, 7298(2)	
	" " at the middle of the line	7287, 7292(3)	7293, 7298(4)	
	" after measurement	....	7293, 7298(5)	7347, 7349(6)
" Cape Comorin Base-Line		see pages X—5 to X—12		

23. At the Cape Comorin base-line, in the absence of a sufficient number of L.R thermometers, the following expedient was resorted to for obtaining readings at the anticipated higher temperatures with thermometers of the kinds l.R and h.R.

"Certain of the thermometers were (under instructions from the Superintendent) adapted to the anticipated "range of temperature by breaking off mechanically portions of the mercury columns sufficient in each case to utilize "the whole graduated scale, the superfluous fluid being driven up and lodged in the excess bulb at the top of the tube. "After this had been satisfactorily effected careful comparisons were made by Captain Basevi and Lieutenant J. Herschel "to ascertain the precise zero correction in each case."

"The adaptation was completely successful and with the exception of the 2 first days' comparisons, the 6 thermometers used remained in their respective places from first to last unchanged." (J. HERSCHEL, LIEUT. R.E.)

the "zero corrections" thus ascertained were as follows :—

No. of Thermometer	Zero Correction	No. of Thermometer	Zero Correction
	°		°
7287 l. R	+ 30·50	7292 l. R	+ 29·75
7290 l. R	+ 28·30	7295 h. R	+ 10·51
7291 l. R	+ 29·27	7298 h. R	+ 10·60

Working Thermometers employed with the 6-*inch brass scales belonging to the compensated Microscopes.*

24. The brass 6-inch scales M, N, P, R, S, T, and U are provided with straight-bulb thermometers about 8″ in length reading to integral degrees and mounted on metal *scales:* their bulbs rest in hollows made in the 6-inch scales. The other two 6-inch brass scales, marked V and W, are the only ones of modern construction; their thermometers are of the bent-bulb pattern, about 5″½ in length, reading to complete degrees and mounted on metal plates: the scale is marked in duplicate on the glass-tube (see art. 12). All these thermometers were constructed by Messrs. Troughton and Simms. Each has been compared with a known Standard thermometer at some half a dozen different temperatures, and the mean difference employed, as a constant correction to the readings obtained in practise.

(1) Used in sets 1, 2, 3 and 29 to 38. (2) Used in sets 4 to 28 and 39 to 50.
(3) Do. 1 and 16 to 22. (4) Do. 2 to 15 and 23 to 80.
(5) Do. 1 to 55 and 57 to 76. (6) Do. 56.

J. B. N. HENNESSEY.

February 1871.

APPENDIX.

No. 9.

DETERMINATION OF THE LENGTHS OF THE SUB-DIVISIONS OF THE INCH [*a.b.*]

The Standard of length at present employed for determiniug the *runs* of the micrometers of microscopes, is the inch [*a.b.*] on the steel foot **IF**, which is divided into twentieths by lines engraved on gold pins let into the steel, and the operation has been conducted in two ways. One consisted in carefully leveling and focusing the inch and then running through all the spaces successively from *a* to *b* without any readjustment; the other in throwing it out of adjustment and refocusing after the measurement of each space. It is now desirable that the labour should be considerably reduced, by obtaining the absolute lengths of the several sub-divisions, so that in future any one of these may be made use of in place of the whole inch.

For this purpose sufficient data are forthcoming from the records of the Computing Office and the "Report on the measurement of the Cape Comorin Base-line". These data consist of observations for determining the *runs* of the microscopes **G** and **H** at Head Quarters and of **K** and **L** at Cape Comorin, when the former of the two methods of observation above described was adhered to. Other observations, in which the latter method was employed, have been excluded from the reduction; for the absolute length of the whole inch being already known, *see page* (29), it only remains to determine the relative lengths of the several spaces, and to do this it is necessary that they should be all in the same terms, a condition which seems best fulfilled when the same adjustment is maintained during an entire set of measurements from *a* to *b*.

The observations at Head Quarters were made by two observers, each taking three measures with each microscope. At Cape Comorin observations were made both before and after the measurement of the base-line, on the first occasion three measures being taken by each of five observers, and on the second two measures by each of four observers.

Of the lines marking the subdivisions of the inch, the 2nd, 4th, 6th &c., beginning from the extremity *a*, are numbered 1, 2, 3, &c.; the intermediate ones are not numbered, but for convenience will be denoted in the following Table by 0·5, 1·5, 2·5, &c. This Table contains the results from each group of observations with each microscope reduced to millionths of an inch, the inch [*a.b*] being taken as $\frac{1}{120}$ **A** — 1·30 *m.y*, *see page* (29), or 999953 *m.i.* In combining the groups to obtain the final values, each has been assigned a weight proportional to the number of measures from which it has been derived, and the first of the two columns of means contains these values in *m.i.* As however all linear measurements are referred to the standard bar **A**, and the unite adopted for minute quantities is a millionth of a yard, the value of each 20th is also given in terms of **A**, and its difference from $\frac{A}{2400}$ shewn in *m.y*.

In computing the probable errors, the groups have been employed instead of the original measures, a proceeding which is shewn by Chauvenet to be sufficiently accurate. No regard has been had to the *p.e.* of [*a.b*] itself, a quantity so small as to be rejectaneous when dispersed over the several subdivisions.

Linear values of the sub-divisions of the inch [a.b] *on the Standard steel foot* **IF**

Observers initials	J.B.N.H. & W.H.C.		J.T.W., J.P.B., J.H., B.R.B. & M.W.R.		J.P.B., J.H., B.R.B. & M.W.R.		Means		
No. of measures	6	6	15	15	8	8	in *m.i*	In terms of **A**	
Microscopes	G	H	K	L	K	L			
	m.i	*m.i*	*m.i*	*m.i*	*m.i*	*m.i*			*m.y*
Space *a* to 0·5	50027	49971	50019	50079	50021	50011	50030	$\frac{A}{2400}$	+ 0·83 ± 0·27
0·5 1·0	49990	49973	49979	49965	49985	49964	49975	„	− 0·69 ± 0·08
1·0 1·5	50006	49978	50016	49997	50014	49985	50002	„	+ 0·06 ± 0·11
1·5 2·0	50030	50046	50049	50055	50045	50047	50047	„	+ 1·31 ± 0·06
2·0 2·5	50040	50031	50046	50027	50047	50031	50037	„	+ 1·03 ± 0·07
2·5 3·0	50069	50095	50078	50084	50079	50078	50081	„	+ 2·25 ± 0·05
3·0 3·5	49892	49887	49879	49884	49874	49872	49881	„	− 3·31 ± 0·05
3·5 4·0	49985	50009	50019	49980	50013	49984	49999	„	− 0·03 ± 0·14
4·0 4·5	49977	49976	49945	49981	49981	49976	49970	„	− 0·83 ± 0·12
4·5 5·0	49978	49964	49973	49971	49975	49959	49970	„	− 0·83 ± 0·05
5·0 5·5	49960	50035	49967	49946	49999	49968	49972	„	− 0·78 ± 0·22
5·5 6·0	49984	50004	49990	50003	49963	49982	49989	„	− 0·31 ± 0·11
6·0 6·5	50036	50025	50006	50003	50021	50019	50014	„	+ 0·39 ± 0·09
6·5 7·0	49968	49989	49973	49988	49969	50008	49982	„	− 0·50 ± 0·11
7·0 7·5	50044	50005	50001	50003	49990	49991	50003	„	+ 0·08 ± 0·12
7·5 8·0	49996	49999	50017	49996	49965	50021	50001	„	+ 0·03 ± 0·15
8·0 8·5	50041	50025	50021	50032	50054	50069	50038	„	+ 1·06 ± 0·14
8·5 9·0	49952	49971	49967	49994	49974	49978	49975	„	− 0·69 ± 0·11
9·0 9·5	50096	50087	50084	50090	50088	50084	50088	„	+ 2·44 ± 0·03
9·5 *b*	49882	49883	49924	49875	49896	49926	49899	„	− 2·81 ± 0·18
Inch [*a.b*] =	999953	999953	999953	999953	999953	999953	999953	= $\frac{A}{120}$	− 1·30 *m.y*

N.B. The values of single divisions of the micrometers employed vary from 40 *m.i* to 46 *m.i.*

February 1871.

W. H. COLE.

APPENDIX.

No. 10.

REPORT ON THE PRACTICAL ERRORS OF THE MEASUREMENT OF THE CAPE COMORIN BASE.

This report only takes notice of certain instrumental errors and errors of observation which can be practically determined and are free from entanglement with other considerations. Other errors such as those of unit, of factor of expansion, of imperfect compensation, those due to difference of circumstances in the measurement and in the Bar comparisons, are here omitted.

The practical errors of measurement may be divided into three heads; *viz*:—

I. *Errors arising from defective alignment:*

II. *Errors arising from dislevelment of Bars and Microscopes:*

III. *Errors of intersection of the Bar and Register Dots:*

The two first sources of error will, with one exception, have the effect of always increasing the apparent length of the base; the last one is of variable sign. The three are somewhat entangled, as for instance, the errors of cross levelling the end microscopes and of intersecting the register dots affect the position of the boning instrument, and consequently the direction of the line.

The principle followed generally in this report is that of finding a maximum error, and then assuming that errors of all magnitudes between this and zero occur with equal frequency. Supposing the errors to be $o, a, 2a, \ldots (n-1)a$ and putting $x = (n-1)\,a$ for the maximum error.

$$\text{the } e.m.s^2 = \frac{a^2 + (2a)^2 + \ldots\ldots + (\overline{n-1}\,a)^2}{n}$$

$$= a^2 . \frac{n.\overline{n-1}\,.\,\overline{2n-1}}{6\,n}$$

$$\therefore\ e.m.s = \frac{x}{\sqrt{3}} \text{ when } n \text{ is large}$$

$$\therefore\ p.e = \cdot 39 \times \text{maximum error.}$$

I. *Errors of alignment.*

The sight vane stations are considered as errorless, for though *certainly* not exactly in one line, still the deviations from one are *as certainly* so small as to have no appreciable effect on the length of the base.

The remaining errors of alignment are *firstly*, those of position of the boning instrument; *secondly* those of position of the intermediate bars and microscopes. The former are due to

(a.) Error of cross levelling of boning instrument;
(b.) Collimation error, pivot error, and error due to the sliding tube of the telescope;
(c.) Errors of intersection of director and sight vane;
(d.) Error due to rear microscope;
(e.) Error due to leading microscope;

(a.) *Error of cross levelling boning instrument.* The effect of this error depends on the difference of elevation of sight vane and Director on microscope. The steepest slope on the line did not exceed 1 foot per set; the mean slope on the steepest portion was only 0·35 feet per set, viz: 19·5 feet in 3,150 feet. Supposing the height of the sight vane to be 2 feet and of boning instrument to be 5 feet, we have the maximum angle of elevation of sight vane =

$$\tan^{-1} \frac{19{\cdot}5 + 2 - 5}{3150} = 0° \, 18''$$

Again to find the maximum depression of Director.

	ft.	in.	ft.	in.
Height of boning Instrument			5	0
Least height of director	2	0		
Greatest slope of ground in half a "set"		6	2	6
Difference			2	6

Dividing this difference by the length of half a set viz. 31·5 feet, we get angle of maximum depression

$$= \tan^{-1} \frac{2{\cdot}5}{31{\cdot}5} = 4°33'.$$

Hence

maximum angle between sight vane and director = 4°51′.

Let θ = maximum dislevelment in seconds, then error in arc or apparent angular displacement of the director when the instrument is in the vertical plane passing through the vane and director = $\theta'' \tan 4°51' = \theta'' \times {\cdot}085$.

The greatest error of level was 2½ divisions or 5″; whence multiplying by 0·39

$$\text{Probable error} = \pm 0''{\cdot}166$$

and probable error of position of boning instrument in inches = $\pm 378 \times {\cdot}166 \sin 1''$, where 378 is the distance in inches from boning instrument to director,

$$= \pm 0{\cdot}0003 \qquad (a.)$$

(b) *Collimation error, pivot error &c.* To determine the combined effect of these errors, the boning instrument was set up, and a small cone placed on a trestle of the average height at a distance of 31·5 feet. The boning instrument was then placed in line with this cone and a distant sight vane first with graduated face of vertical circle to left or *F.L.* and then with graduated face of circle to right or *F.R.* the difference in the two positions being measured on the sliding portion of the instrument by a scale of 40 parts = 1 inch. The results are shewn in the Table in the margin.

F.L	F.R	Diff.
4·63	4·52	0·11
4·64	4·59	·05
4·66	4·57	·09
4·70	4·60	·10
Mean difference =		0·088
½ Do.	do. =	0·044

F.L. readings are too large consequently the telescope is too much to the right on that face. The instrument was always used on F.R. so that the telescope was always to the left by

$$- 0{\cdot}044 \text{ divisions or}$$

$$- 0{\cdot}0011 \text{ inches} \qquad (b_1)$$

From the observations here recorded it may be inferred that the probable error of setting up the boning instrument is

$$\pm 0{\cdot}0006 \text{ of an inch} \qquad (b_2)$$

(*c.*) *Errors of intersection of sight vane and director.* The maximum error of intersecting the near director

$$= \tfrac{1}{4} \text{ of silver line on director} = \tfrac{1}{4} \times \cdot 036 \text{ inches}$$
$$= 0{\cdot}009 \text{ inches}$$

$$\text{whence probable errror} = \cdot 009 \times \cdot 39 = \pm \cdot 0035 \qquad (c_1)$$

The maximum error of intersecting sight vane = entire breadth of tin line on sight vane = ·25 inch and therefore

$$\text{Probable error} = \cdot 25 \times \cdot 39 = \pm \cdot 098 \text{ inches}$$

The effect of this will vary with the distance: a mean distance of 20 sets may be assumed; whence

$$\text{Probable error} = \pm \frac{\frac{1}{2}}{20} \times \cdot 098 = \pm \cdot 0025 \text{ inch} \qquad (c_2)$$

(*d.*) *Errors of rear end microscope.* By experiment it was ascertained that the centre of the director when placed on the rear microscope did not coincide with the axis of that microscope, but that when the level faced towards the boning instrument (as it did in practice), the centre of the director was ·009 of an inch to the right: consequently the boning instrument would place itself off the true line to the right by, on an average, $\cdot 009 \times \frac{20\frac{1}{2}}{20}$

$$= + \cdot 0092 \text{ inch} \qquad (d_1)$$

The value of one division of the level scale = 5″ and taking 2 divisions = 10″ as the maximum error of cross level, the director would be displaced by
$\pm\, d \sin 1'' \times 10''$ where d = mean height of tongue above register + height of director above tongue = 8·5 + 8·5 = 17 inch.

hence probable error of position of boning instrument on this account

$$= \pm\, 17 \sin 1'' \times 10'' \times \cdot 39 \times \frac{20\frac{1}{2}}{20}$$
$$= \pm\, 0{\cdot}0004 \qquad (d_2)$$

The extreme error of intersecting register dot (including collimation error) = $\frac{1}{8}$ of the dot = $\frac{1}{8} \times \cdot 0091$ inch consequently

$$\text{Probable Error} = \pm \cdot 0004 \qquad (d_3)$$

Collecting all these errors together we find the probable error of the position of the boning instrument to be

$$= + \cdot 0081 \pm \sqrt{(\cdot 0003)^2 + (\cdot 0006)^2 + (\cdot 0035)^2 + (\cdot 0025)^2 + (\cdot 0004)^2 + (\cdot 0004)^2}$$

or

$$p = + \cdot 0081 \pm \cdot 0044 \text{ to } \textit{right} \text{ in inches.}$$

(*e*) *Error in position of boning instrument due to leading microscope.* This error will depend partly on the telescope tube of the boning instrument and partly on the same errors as occur with the rear microscope. To determine the amount due to the tube of the telescope, a scale was fastened to the top edge of a trestle at the usual distance of the leading microscope and a small cone on another trestle at the distance of the rear microscope: and then the boning instrument being aligned on the cone and a distant sight vane the readings of the scale were taken; this was done several times on both faces, the readings were, in inches.

F.L	F.R	Diff:
6·120	6·180	0·060
6·120	6·180	·060
6·156	6·204	·048
	Mean	0·056

The readings of the scale increased from right to left, consequently on F. R. the boning instrument throws to the *left* by $\frac{1}{2} \times \cdot 056 = \cdot 028$ inches.

It was also found that the axis of the advanced microscope (V), level towards the rear, was 0·0045 inch to left of the centre of director, so that the advanced register dot would be placed altogether — (·028 + ·0045) = — ·0325 inches to left.

It has been shewn however that the instrument places itself too much to the left on F. R. by ·0011 inch, consequently this must be subtracted from the above and the register dot is therefore

$$- \cdot 0314 \text{ to left} \qquad (e_1)$$

Again Probable Error of intersecting director on advanced microscope is $\pm \cdot 009 \times \cdot 39$

$$= \pm \cdot 0035 \qquad (e_2)$$

and Probable Error of level of microscope as before

$$= \pm \cdot 0004 \qquad (e_3)$$

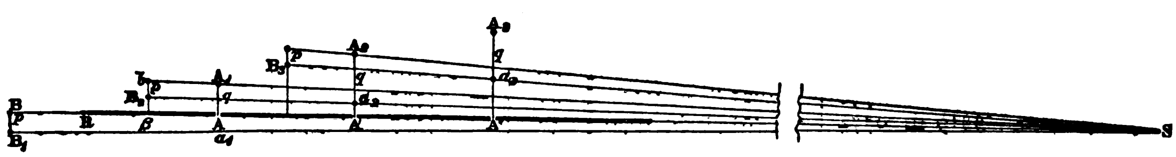
and Probable Error of intersecting register dot

$$= \pm \cdot 0004 \qquad (e_4)$$

whence combining these quantities the error of position of advanced register dot

$$= - \cdot 0314 \pm \sqrt{(\cdot 0035)^2 + (\cdot 0004)^2 + (\cdot 0004)^2}$$
$$\text{or } q = - \cdot 0314 \pm \cdot 0035$$

Next to find the effect on the line.



If S be the sight vane, B the true position of boning instrument, A the advanced and R the rear microscope; B R = ½ set, n the number of sets between R and S so that B S = $n + \frac{1}{2}$; then if B $B_1 = p$, the instrument will place itself at B_1 and will, owing to the error q, place the advanced register at A_1 instead of a_1. Again, the next set, the boning instrument will be at B_2 instead of b, and the 2nd register will be laid down at A_2 instead of a_2; and so on.

If q_r be the distance of the rth register dot from the line, we find

$$q_1 = A\,A_1 = A\,a_1 + q = \frac{n - 1}{n + \frac{1}{2}}\,p + q$$

$$= (n - 1)\left\{\frac{p}{n + \frac{1}{2}} + \frac{q}{n - 1}\right\}$$

$$q_2 = A'\,A_2 = A'\,a_2 + q = \frac{n - 2}{n - 1 + \frac{1}{2}}\,\beta\,B_2 + q.$$

$$\text{and } \beta\,B_2 = \beta\,b + p = \frac{n - 1 + \frac{1}{2}}{n - 1}\,q_1 + p$$

$$= (n - 1 + \tfrac{1}{2})\left\{\frac{p}{n + \frac{1}{2}} + \frac{p}{n - 1 + \frac{1}{2}} + \frac{q}{n - 1}\right\}$$

$$\therefore\ q_2 = (n - 2)\left\{\frac{p}{n + \frac{1}{2}} + \frac{p}{n - 1 + \frac{1}{2}} + \frac{q}{n - 1} + \frac{q}{n - 2}\right\}$$

and generally

$$q_r = (n - r)\left\{\left(\frac{1}{n + \frac{1}{2}} + \frac{1}{n - 1 + \frac{1}{2}} + \dots + \frac{1}{n - r + 1 + \frac{1}{2}}\right)p + \left(\frac{1}{n - 1} + \frac{1}{n - 2} + \dots \frac{1}{n - r}\right)q\right\}$$

If the boning instrument was originally off the line by a quantity s, then the term $\frac{n-r}{n+\frac{1}{2}}s$ must be added to the above,

Tables for both these series were formed by summing continuously a table of reciprocals.

To apply these expressions to the measurement : in measuring North to South the sight vanes were at the following distances apart in sets

53, 39, 25, 25

and in measuring from South to North the distances were

50, 39, 53

consequently, since the sight vane was always removed (except at the closing sections of course) when the measurement arrived within 4 sets of it, the values of n, for the two circumstances of measurement, are

North to South 53, 43, 29, 29

South to North 50, 43, 57

The following table gives some of the values of q for the first section the *minus* sign signifying to the East or left hand.

$r =$	$q =$	$\Delta q =$	$r =$	$q =$	$\Delta q =$
1	$-$ 0·0234 ± ·0055		35	$-$ 0·4689 ± ·1080	
2	$-$ ·0464 ± ·0112	$-$ 0·0230 ± ·0124	36	$-$ ·4663 ± ·1073	+ 0·0026 ± ·1522
3	$-$ ·0695 ± ·0163	$-$ ·0231 ± ·0198	37	$-$ ·4632 ± ·1062	+ ·0031 ± ·1509
4	$-$ ·0911 ± ·0216	$-$ ·0216 ± ·0271	38	$-$ ·4584 ± ·1049	+ ·0048 ± ·1492
...			...		
15	$-$ 0·3021 ± ·0703		40	$-$ 0·4436 ± ·1011	
16	$-$ ·3178 ± ·0740	$-$ 0·0157 ± ·1020	41	$-$ ·4337 ± ·0985	+ 0·0099 ± ·1411
17	$-$ ·3319 ± ·0774	$-$ ·0141 ± ·1070	42	$-$ ·4217 ± ·0956	+ ·0120 ± ·1373
...			...		
31	$-$ 0·4649 ± ·1074		46	$-$ 0·3507 ± ·0780	
32	$-$ ·4673 ± ·1079	$-$ 0·0024 ± ·1522	47	$-$ ·3256 ± ·0717	+ 0·0251 ± ·1060
33	$-$ ·4688 ± ·1082	$-$ ·0015 ± ·1528	48	$-$ ·2965 ± ·0647	+ ·0291 ± ·0966
34	$-$ ·4695 ± ·1081	$-$ ·0007 ± ·1529	49	$-$ ·2627 ± ·0564	+ ·0338 ± ·0858

The mean value of Δq from the first 34 is

$-$ ·0135 ± ·1017.

and

The mean value of Δq from the last 15 is

+ ·0147 ± ·1306.

consequently the mean value of the angle of inclination of any set to the line is clearly

$< \tan^{-1} \frac{\cdot 13}{756} = 36''$ very nearly : Now if $\theta =$ angle of inclination of a set to the true line, then the error in length of the set $= 2l \operatorname{Sin}^2 \frac{\theta}{2} = 2 \times 756 \operatorname{Sin}^2 18''$ in inches, $=$ ·0000115 inches, and the error of length of the first section $=$ ·00061 inches.

For the other sections the amount will be the same for all practical purposes, and the effect on the whole length of the base may be asserted safely to be not more than $141\frac{1}{2} \times$ ·0000115

$=$ 0·0016 inches.

It will be interesting to compare the measured differences of alignment at the Register Brasses *X Y Z* with the computed differences.

For X, measuring North to South $n = 53$, $r = 35$ therefore $X_1 = -0{\cdot}469 \pm {\cdot}109$.

For Y $n = 43$, $r = 21$ and $s = -{\cdot}262 \pm {\cdot}058$

$\therefore Y_1 = -0{\cdot}488 \pm {\cdot}087$

for Z $n = 29$, $r = 17$ and $s = -{\cdot}267 \pm {\cdot}053$

$\therefore Z_1 = -0{\cdot}369 \pm {\cdot}062$

Similarly measuring South to North we have

For Z $n = 50$, $r = 37$

whence $Z_2 = +0{\cdot}426 \pm {\cdot}098$

for Y $n = 43$, $r = 26$ $s = +0{\cdot}257 \pm {\cdot}056$

whence $Y_2 = +0{\cdot}482 \pm 0{\cdot}091$

and for X $n = 57$, $r = 22$ $s = +0{\cdot}287 \pm {\cdot}054$

whence $X_2 = +0{\cdot}582 \pm {\cdot}101$

consequently subtracting the values N to S from those S to N we have

	Computed difference	*Measured differences*		
at X	$+1{\cdot}051 \pm {\cdot}149$ inch	(II − I) + 1·033	(IV − III) + 1·521	Mean + 1·277
„ Y	$+0{\cdot}970 \pm {\cdot}126$ „	„ + 1·090	„ + 1·840	„ + 1·465
„ Z	$+0{\cdot}795 \pm {\cdot}116$ „	„ + 1·043	„ + 1·463	„ + 1·253

Though it is evident from these results that some source of error has been under-estimated, still the effect on the length will be scarcely increased, as that effect is due to the *differences* in the errors of the alignment of the several sets.

The error in length, due to defective alignment of the ends of a set, has been investigated, but, there are still the errors of alignment of the intermediate bars and microscopes to be considered.

These are

(*a*) Error of intersecting director.
(*b*) Error of cross levelling microscopes.
(*c*) Error of non-coincidence of axis of microscope with line passing through the foci.
(*d*) Error of intersecting dot on tongue of bar.
(*e*) Error of side telescope.

(*a*) The probable error of intersecting any director by the boning instrument may be taken as

$$\pm \tfrac{1}{4} \times {\cdot}036 \times {\cdot}39 = \pm {\cdot}0035 \text{ inch} \qquad (a)$$

(*b*) The maximum error of cross levelling a microscope is 3 division $= 15''$

$$\text{whence Probable error} = 15 \times {\cdot}39 = 6'' \text{ nearly}$$
$$\text{and displacement of director} = \pm 8{\cdot}5 \sin 6''$$
$$= \pm {\cdot}0003 \text{ inches} \qquad (b)$$

(*c*) In all the microscopes there was a slight excentricity of the axis; on an average it did not exceed twice the diameter of a bar dot

or ·006 inch (*c*)

(*d*) The error of placing a dot midway between the parallel wires did not exceed as a maximum the diameter of the dot so that the

$$\text{Probable Error} = \pm {\cdot}003 \times {\cdot}39 = \pm {\cdot}0012 \text{ inch} \qquad (d)$$

(*e*) Errors of the side telescope. The combined errors of collimation and parallelism were as follows:

				′	″
During I	measurement mean of 7 microscopes			9	57
II	Do.	do.		1	9
III	Do.	do.		2	0
IV	Do.	do.		1	21
			Mean	3	37

The effect of this on the position of one end of a bar is $\pm 3 \sin 3' 37'' = \pm \cdot 0032$ inches (e_1)

And if $\frac{1}{10}$ of an inch be the maximum error of intersecting the horns of the boning instrument, then

$$\text{Probable error} = \pm \cdot 1 \times \cdot 39 = \pm \cdot 039 \text{ inches.}$$

and the effect of this for the mean microscope

$$= \pm \cdot 039 \times \frac{3}{12 \times 63} = \pm \cdot 0002 \text{ inch} \qquad (e_2)$$

Lastly error on account of difference between half the space between the two horns and the space proper to each microscope. These differences and the angles subtanded thereby at the distances of the respective microscopes were as follows :—

					′	″
W	microcopes	·01	inch substanded angle		o	3
S	"	·00	"		o	o
U	"	·10	"		o	12
M	"	·06	"		o	6
N	"	·02	"		o	3
O	"	·09	"		o	15
V	"	·14	"		o	13
				Mean	o	8

$$\text{The error on this account} = \pm 3'' \sin 8'' = \pm \cdot 0001 \text{ inch} \qquad (e_3)$$

Consequently the whole amount by which one end of a bar may be placed out of line between the ends

$$= \pm \sqrt{(\cdot 0035)^2 + (\cdot 0003)^2 + (\cdot 006)^2 + (\cdot 0012)^2 + (\cdot 0032)^2 + (\cdot 0002)^2 + (\cdot 0001)^2}$$

$$= \pm \cdot 0077 \text{ inch.}$$

For the extremes of the two end bars the first two errors have been already allowed, consequently the probable error of their alignment is

$$\pm \cdot 0069 \text{ inches.}$$

The angle each end bar may make with the line is

$$= \text{Sin}^{-1} \sqrt{\frac{(\cdot 0077)^2 + (\cdot 0069)^2}{12 \times 10}} = 17''\cdot 5$$

and each intermediate bar

$$= \text{Sin}^{-1} \frac{\cdot 0077 \sqrt{2}}{12 \times 10} \qquad = 18''\cdot 7$$

and effect on the length per set

$$= 2 \times 6 \times 120 \text{ Sin}^2 9'' \qquad = \cdot 000{,}002{,}74 \text{ inch.}$$

$$\text{and on } 141\tfrac{1}{2} \text{ sets} \qquad = \cdot 0004 \text{ inches.}$$

Also the error on the part measured by the microscope due to (d) and (e) $= \pm \cdot 0034$, and the angle which the microscope makes with the line $= \text{Sin}^{-1} \frac{\cdot 0034}{6}$, whence error in length per microscope $= \frac{(\cdot 0034)^2}{2 \times 6}$, and error per set $= 6 \times \frac{(\cdot 0034)^2}{2 \times 6} = \frac{(\cdot 0034)^2}{2}$, and error in $141\frac{1}{2}$ sets

$$= \cdot 0008 \text{ inches.}$$

We have therefore the total error in length due to errors of alignment $= + \cdot 0016 + \cdot 0004 + \cdot 0008$

$$= 0\cdot 0028 \qquad (I)$$

II *The errors of level.* These are of three kinds.

(a) Errors of bar levels.
(b) Errors of microscope levels.
(c) Effect of level error of end microscopes on the length owing to look down telescopes.

The first two errors are of invariable sign.

(a) *Bar Levels*

The values of one division of the level scales were found to be as follows;

A	Bar	11″
B	"	5·
C	"	5·
D	"	6·
E	"	2·3
H	"	8·3
	Mean =	6·3

The extreme error of levelling a bar may be set down as ± 2 divisions from the *supposed* true level reading; whence Probable error = ± 12″·6 × ·39 = ± 5″ nearly.

The level readings compared with the plane of the tongues were determined before and after the first measurment and after each successive measurement. The mean of the readings before and after a measurement may be taken as the true reading, and the difference between this mean and the first of the readings (which was used in the measurement) considered as the error. These errors converted into arc were as follows:

	A	B	C	D	E	H
	″	″	″	″	″	″
I Measurement	7·7	12·0	17·5	...	15·0	31·5
II "	28·6	4·5	24·0	49·8	38·0	5·8
III "	22·0	1·0	40·0	3·0	20·7	12·4
IV "	8·8	2·5	27·5	39·0	24·2	14·1
Means	16·8	5·0	27·3	30·6	24·5	16·0

and General Mean = 20″.

Consequently error of measurement in inches per set = 720 × 2 {sin² 10″ ± sin² 2½″} = ·000,0034 ± ·000,0002 and error on 141½ sets.

$$= \cdot 0005 \pm \cdot 0000 \qquad (a)$$

(b) *Levels of Microscopes.*

The values of the level scales of the two end microscopes V and W were found to be each equal to 5″ per division, this value may be safely assumed for all the microscopes.

The maximum dislevelment may be set down as 5 divisions for the intermediate microscopes and 2½ divisions for the end microscopes, the latter being invariably levelled with very great care. Consequently the average errors may be taken as 25″ × ·39 = 10″ for the intermediate and 12″·5 × ·39 = 5″ for the end microscopes; and the error in length per set

$$= 5 \times 12 \sin^2 5'' + 12 \sin^2 2\tfrac{1}{2}'' = 12 \sin^2 1'' \, (125 + 6\cdot 25)$$
$$= 1575 \sin^2 1'' = \cdot 000{,}000{,}04$$

and on 141½ sets

$$= \cdot 0000 \qquad (b)$$

(c) *Levels of end microscopes.* Any dislevelment of the end microscopes shortens or lengthens the base according to which direction the axis of the microscope is inclined; consequently the error will be of an uncertain sign. As extra care is taken in leveling these microscopes, the maximum error has been taken as 2½ divisions and the probable error as = ± 5″

If d = distance of register from tongue at *rear* end.

And D = distance of register from tongue at *advanced* end.

Then probable error in length of one set

$$= \pm \sqrt{(d^2 + D^2)} \sin 5''$$

consequently for whole base

$$\text{Probable Error} = \pm \sin 5'' \sqrt{\Sigma (d^2) + \Sigma (D^2)}$$

$$= \pm \sin 5'' \sqrt{85{\cdot}4 + 76{\cdot}4} \text{ in feet}$$

$$= \pm {\cdot}0037 \text{ inch} \qquad (c)$$

Hence Total due to errors of Levelling

$$= {\cdot}0005 \pm {\cdot}0037 \qquad (II)$$

III. *The errors of intersection.*

The Diameters of the dots on the bars were measured and found to be as follows in inches

	Left Dot inches	Right Dot inches
Standard A	0·0026	0·0028
Bar A	0·0031	0·0025
„ B	0·0038	0·0026
„ C	0·0028	0·0021
„ D	0·0034	0·0031
„ E	0·0029	0·0023
„ H	0·0026	0·0028
Mean	0·0031	0·0025

Mean = 0·0028 inches.

Also the dots on some of the registers and pin heads were measured viz:—

Register A	·0074	Pin Dot No.	11	0·0110
„ C	·0095	„	23	·0091
„ E	·0080	„	27	·0107
		„	40	.0080

General mean = ·0091 inches.
The maximum error of intersecting register dots = $\frac{1}{8}$th of Diameter.
Do. Do. Bar = $\frac{1}{4}$th „
Whence probable error in the former

$$= \pm \frac{{\cdot}0091}{8} \times {\cdot}39 = \pm {\cdot}000{,}444 \text{ inch.}$$

and probable error in the latter

$$= \pm \frac{{\cdot}0028}{4} \times {\cdot}39 = \pm {\cdot}000{,}273 \text{ inch.}$$

and probable error per set

$$= \pm \sqrt{2 \times ({\cdot}000444)^2 + 12\,({\cdot}000273)^2}$$
$$= \pm {\cdot}001135.$$

Therefore the probable error in $141\frac{1}{2}$ sets *i.e.* on the whole base

$$= \pm {\cdot}001135 \sqrt{141\tfrac{1}{2}}$$

$$= \pm {\cdot}0135 \text{ inch} \qquad (III)$$

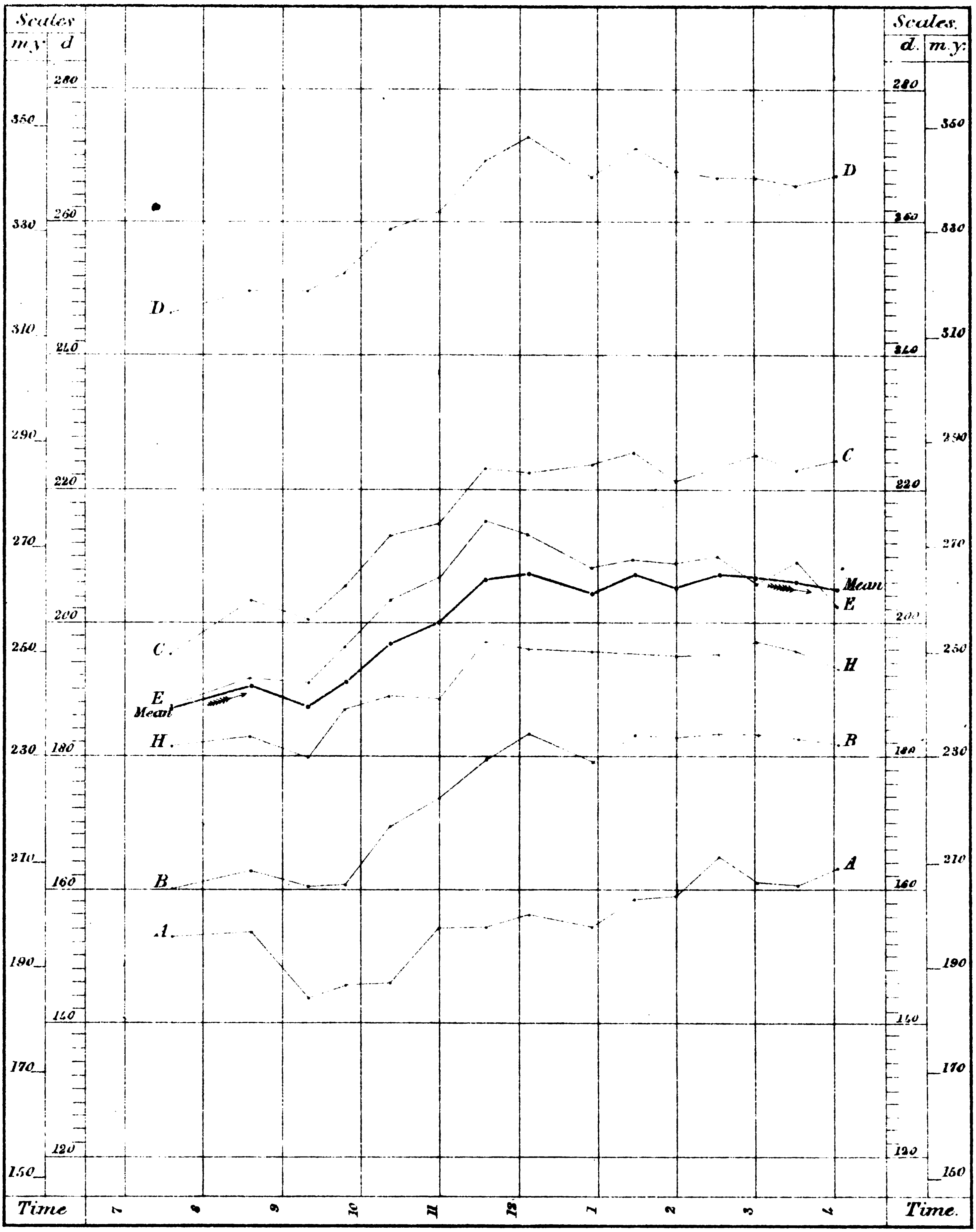
Combining errors I. II. III. together we obtain the whole error of measurement arising from the causes which have been specified.

$$= \pm {\cdot}0033^* \pm {\cdot}014{,}0 \text{ inches.}$$

* By an oversight in calculation this quantity was originally found to be + ·0017 inch = ·00014 of a foot and is quoted at this value on Page (78) Chapter VIII Section 10 of this volume.

J. P. BASEVI, CAPTAIN, R.E.

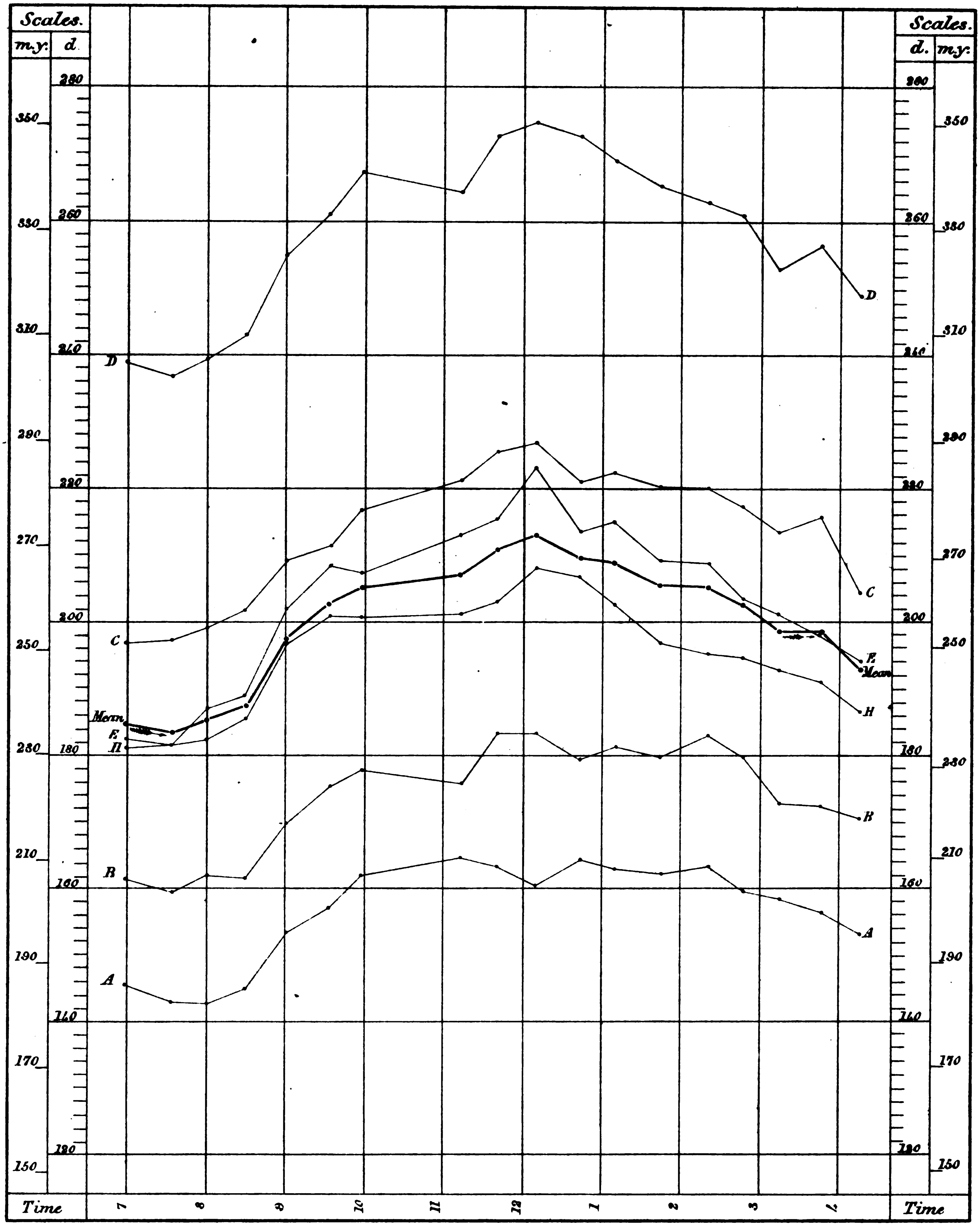
Excess of compensation bars over Standard A at 62°. Cape Comorin Base.
Brass Components West. Comparisons (I. 1.) 9th January 1869



The horizontal intervals correspond to one hour. The vertical intervals correspond to 2 divisions of the micrometer on the inner scale, and to 20 millionths of a yard on the outer scale. The observations of the Standard were reduced to 62°, with the old value of the factor of expansion, or ·000,006,801, for 1° F.

Excess of compensation bars over Standard **A** *at 62°. Cape Comorin Base*

Brass Components West. *Comparisons* (I. 2) *11th January 1869.*

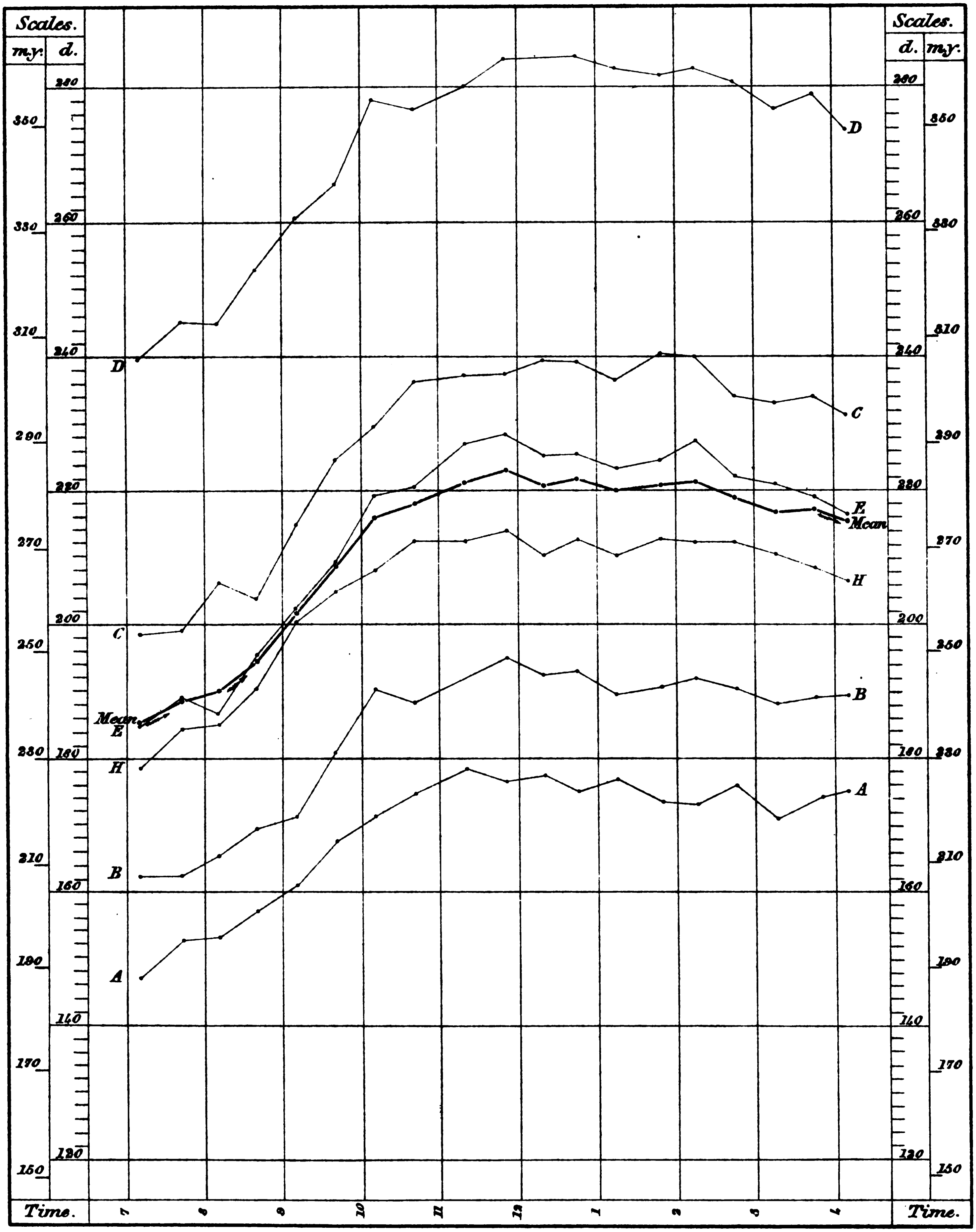


The horizontal intervals correspond to one hour. The vertical intervals correspond to 2 divisions of the micrometer on the inner scale, and to 20 millionths of a yard on the outer scale. The observations of the Standard were reduced to 62° with the old value of the factor of expansion, or ·000, 006, 801, for 1° F.

C. Dixon, Photo. C. G. Ollenbach, Zinco

Excess of compensation bars over Standard A at 62°. Cape Comorin Base.

Brass Components West. *Comparisons (I.3) 25th January 1869.*

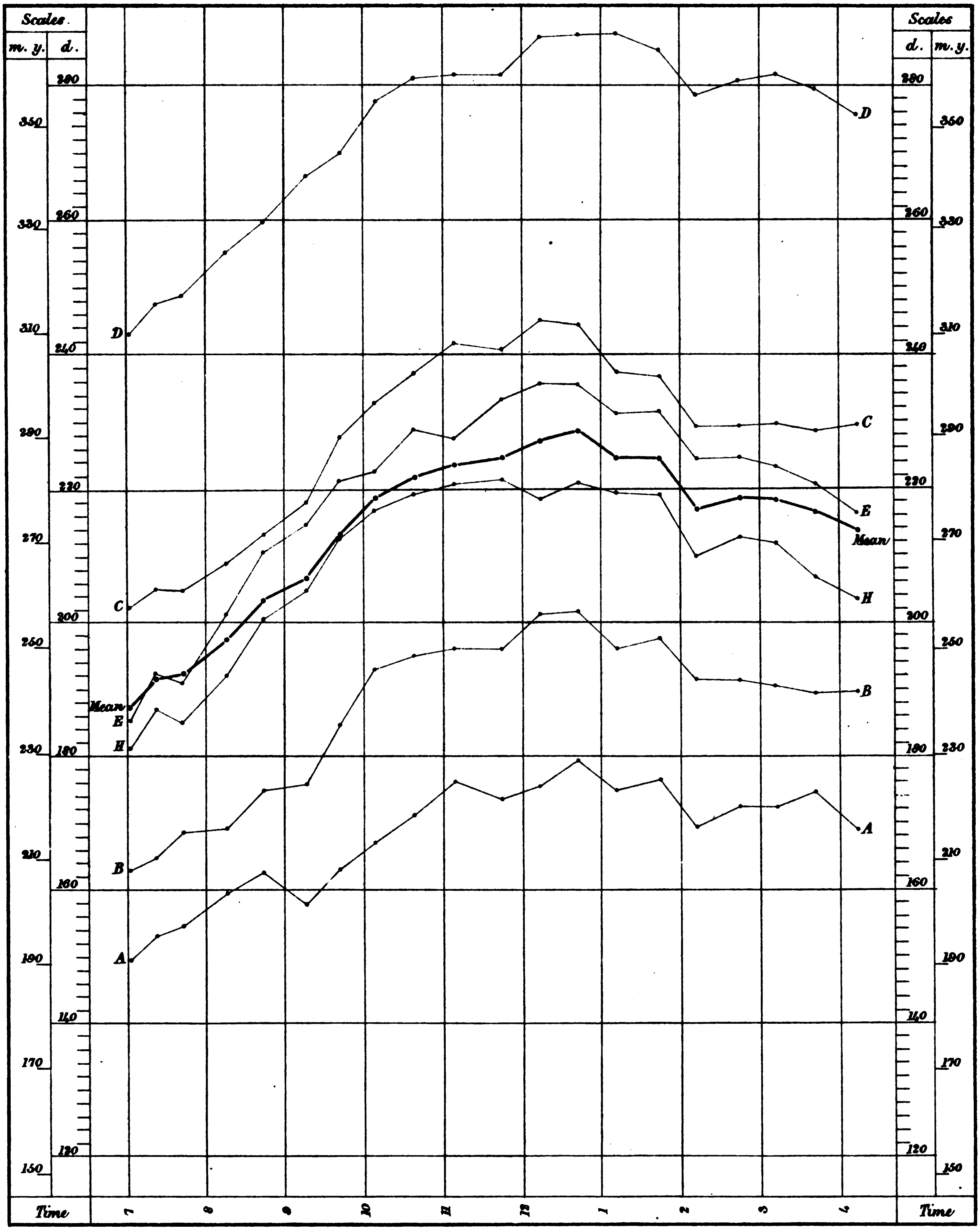


The horizontal intervals correspond to one hour. The vertical intervals correspond to 2 divisions of the micrometer on the inner scale, and to 20 millionths of a yard on the outer scale. The observations of the Standard were reduced to 62°. with the old value of the factor of expansion, or ·000,006,801, for 1° F.

C. Dyson, Photo. C. G. Ollenbach, Zinco.

Excess of compensation bars over Standard A at 62°. Cape Comorin Base.

Brass Components West. *Comparisons* (I. 4.) 26th January 1869.

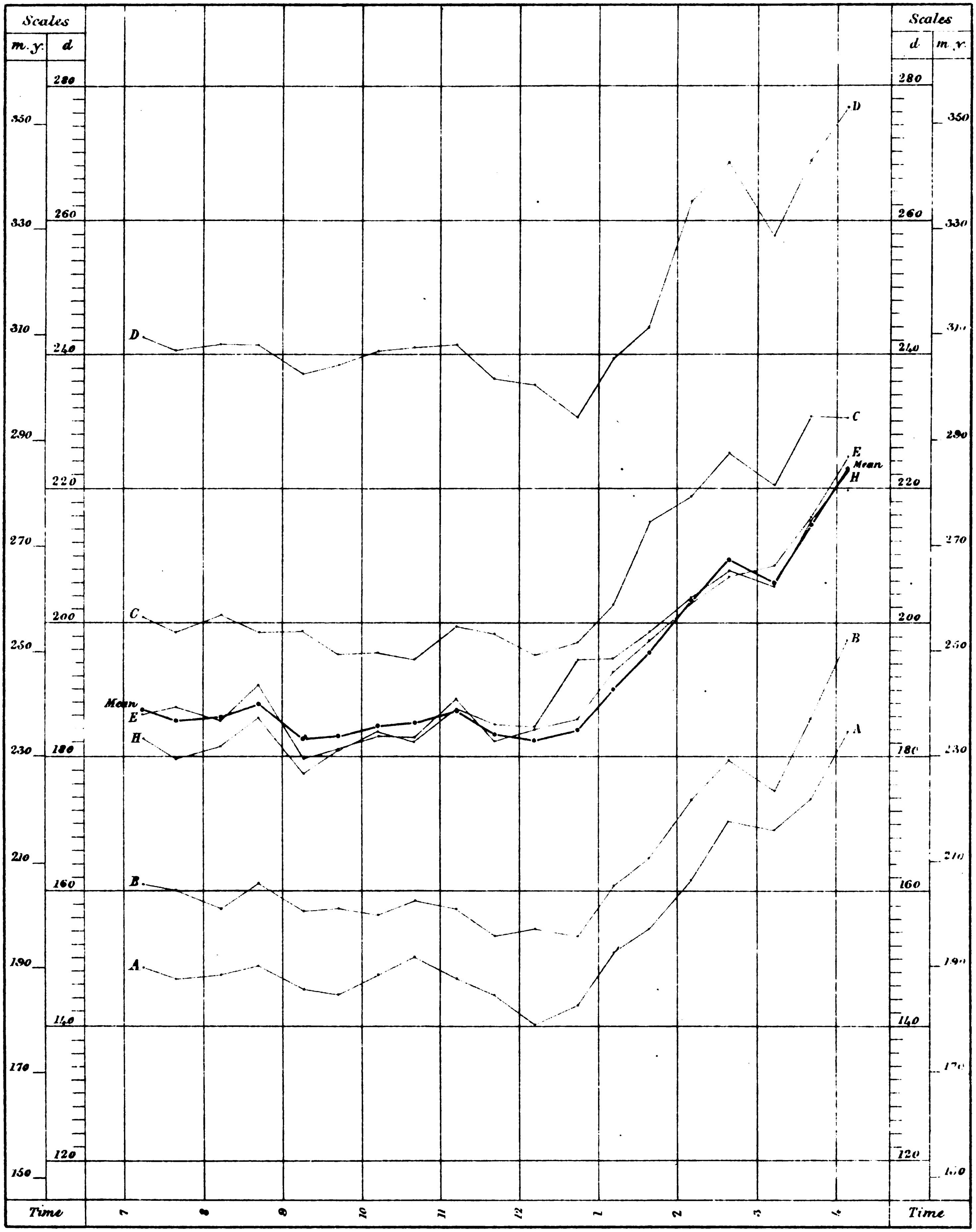


The horizontal intervals correspond to one hour. The vertical intervals correspond to 2 divisions of the micrometer on the inner scale, and to 20 millionths of a yard on the outer scale. The observations of the Standard were reduced to 62°. with the old value of the factor of expansion, or ·000,006,801, for 1° F.

C. Dyson, Photo. G. G. Ollenbach, Zinco.

Excess of compensation bars over Standard A at 62°. Cape Comorin Base

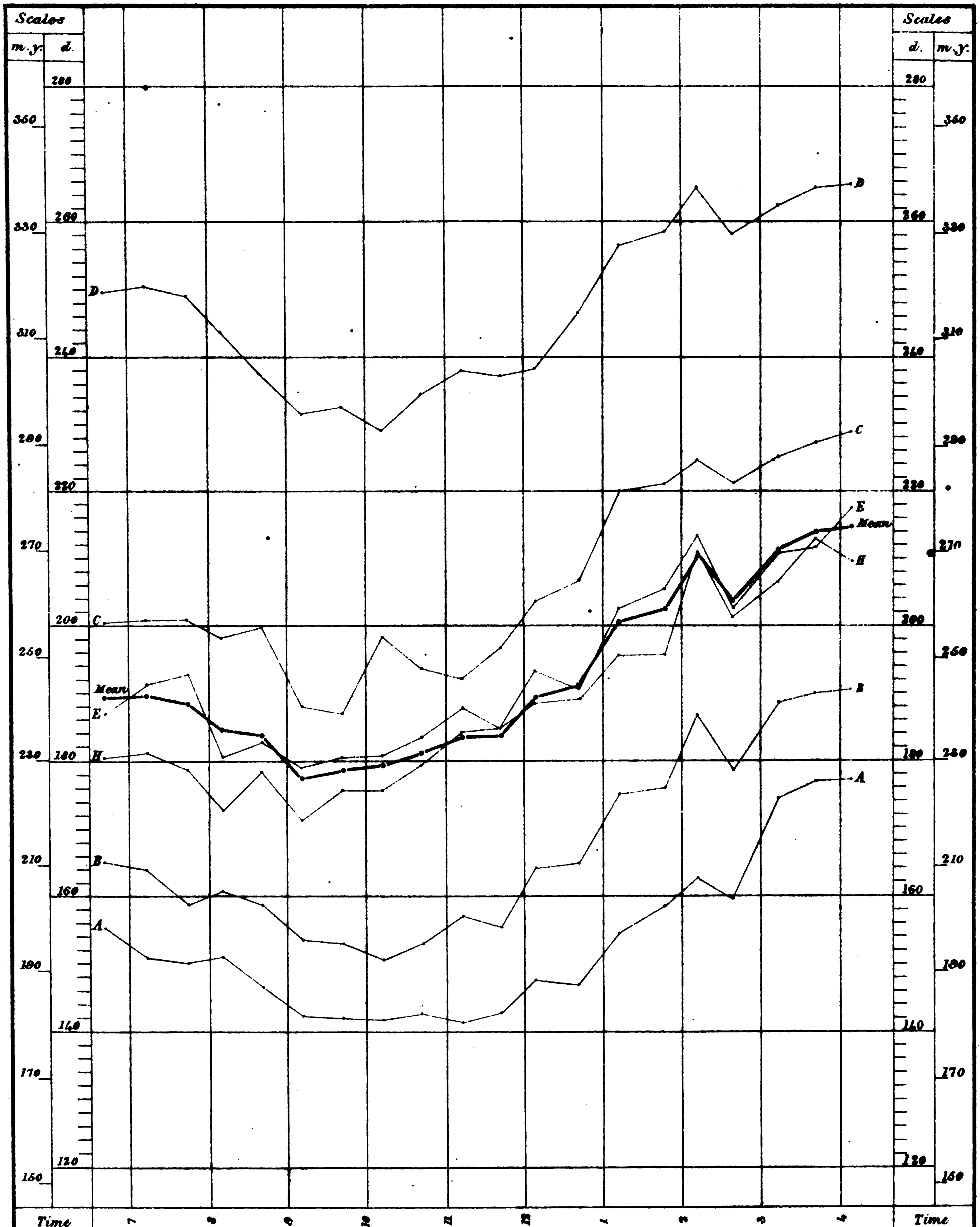
Brass Components East. *Comparisons* (II.1.) 28th *January 1869.*



The horizontal intervals correspond to one hour. The vertical intervals correspond to 2 divisions of the micrometer on the inner scale, and to 20 millionths of a yard on the outer scale. The observations of the Standard were reduced to 62° with the old value of the factor of expansion, or ·000,006,801, for 1° F.

Excess of compensation bars over Standard A at 62°. Cape Comorin Base.

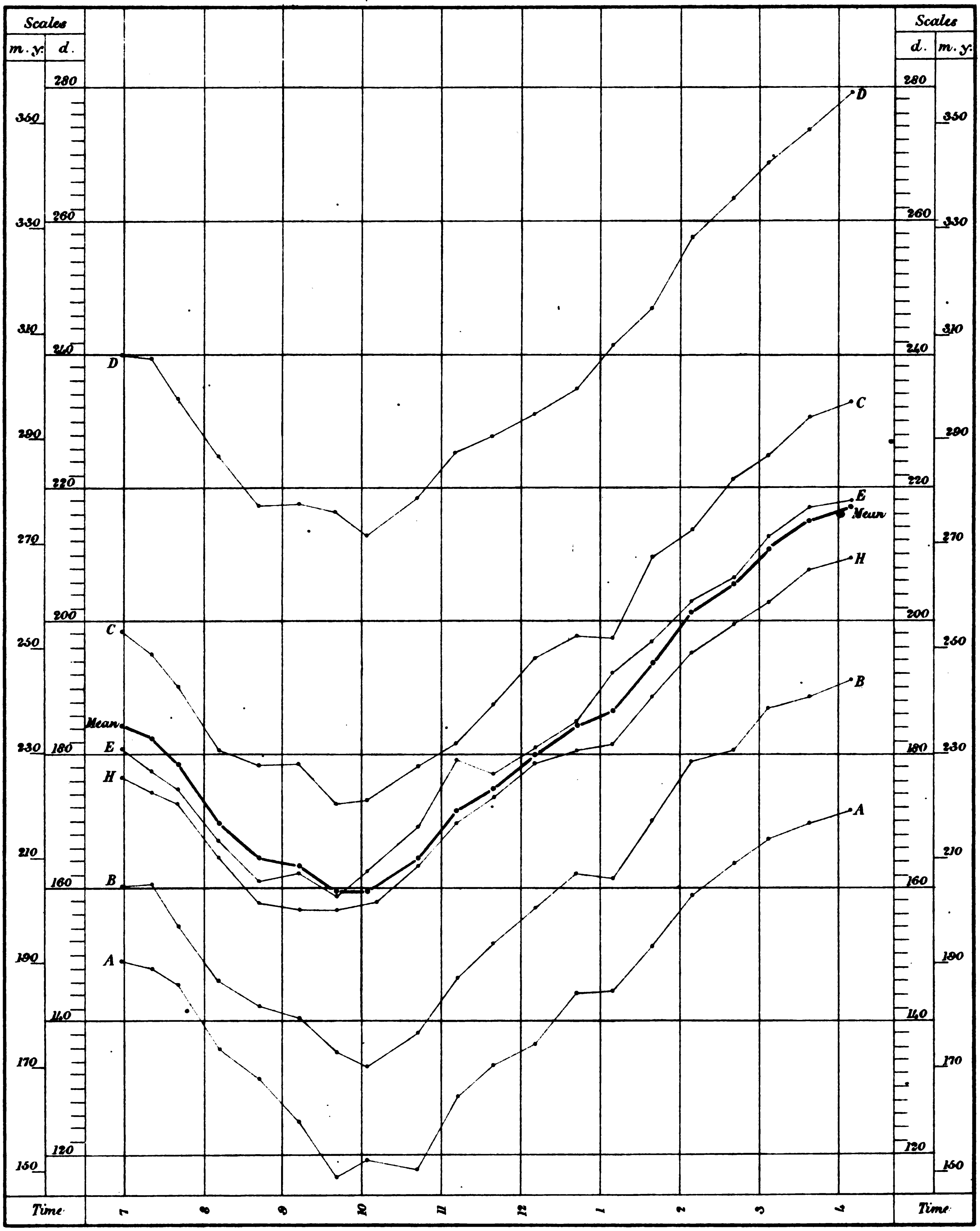
Brass Components East. *Comparisons (II.2.) 29th January 1869.*



The horizontal intervals correspond to one hour. The vertical intervals correspond to 2 divisions of the micrometer on the inner scale, and to 20 millionths of a yard on the outer scale. The observations of the Standard were reduced to 62°, with the old value of the factor of expansion, or ·000,006,801, for 1° F.

C. DYSON, Photo. C. G. OLLENBACH, Zinco.

Excess of compensation bars over Standard A at 62°. Cape Comorin Base.
Brass Components East. *Comparisons (II.3.) 10th February 1869.*

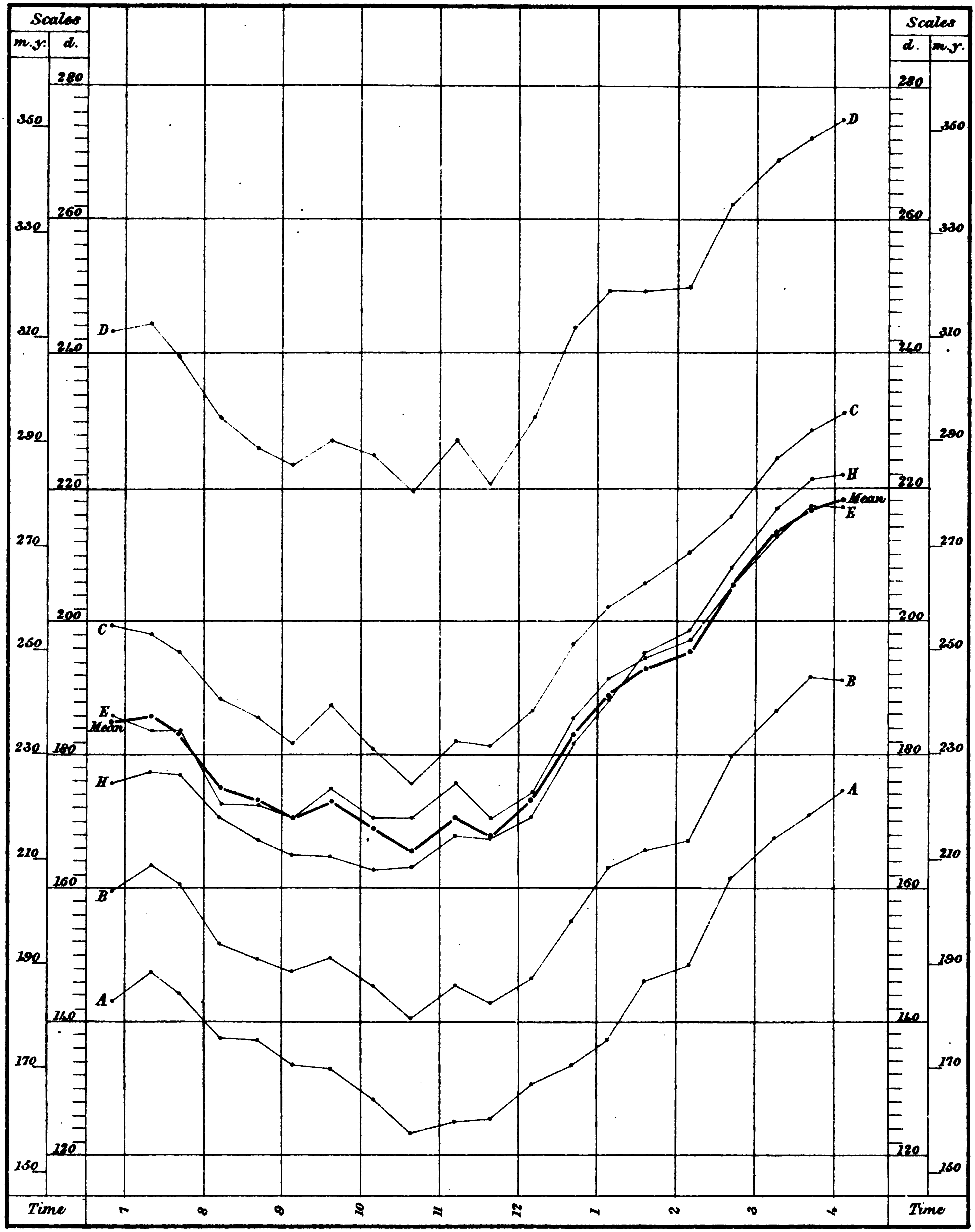


The horizontal intervals correspond to one hour. The vertical intervals correspond to 2 divisions of the micrometer on the inner scale, and to 20 millionths of a yard on the outer scale. The observations of the Standard were reduced to 62° with the old value of the factor of expansion, or ·000,006.801. for 1° F.–

C. Dyson, Photo. C. G. Ollenbach, Zinco.

Excess of compensation bars over Standard A at 62°. Cape Comorin Base.

Brass Components East. *Comparisons (II. 4.) 11th February 1869.*

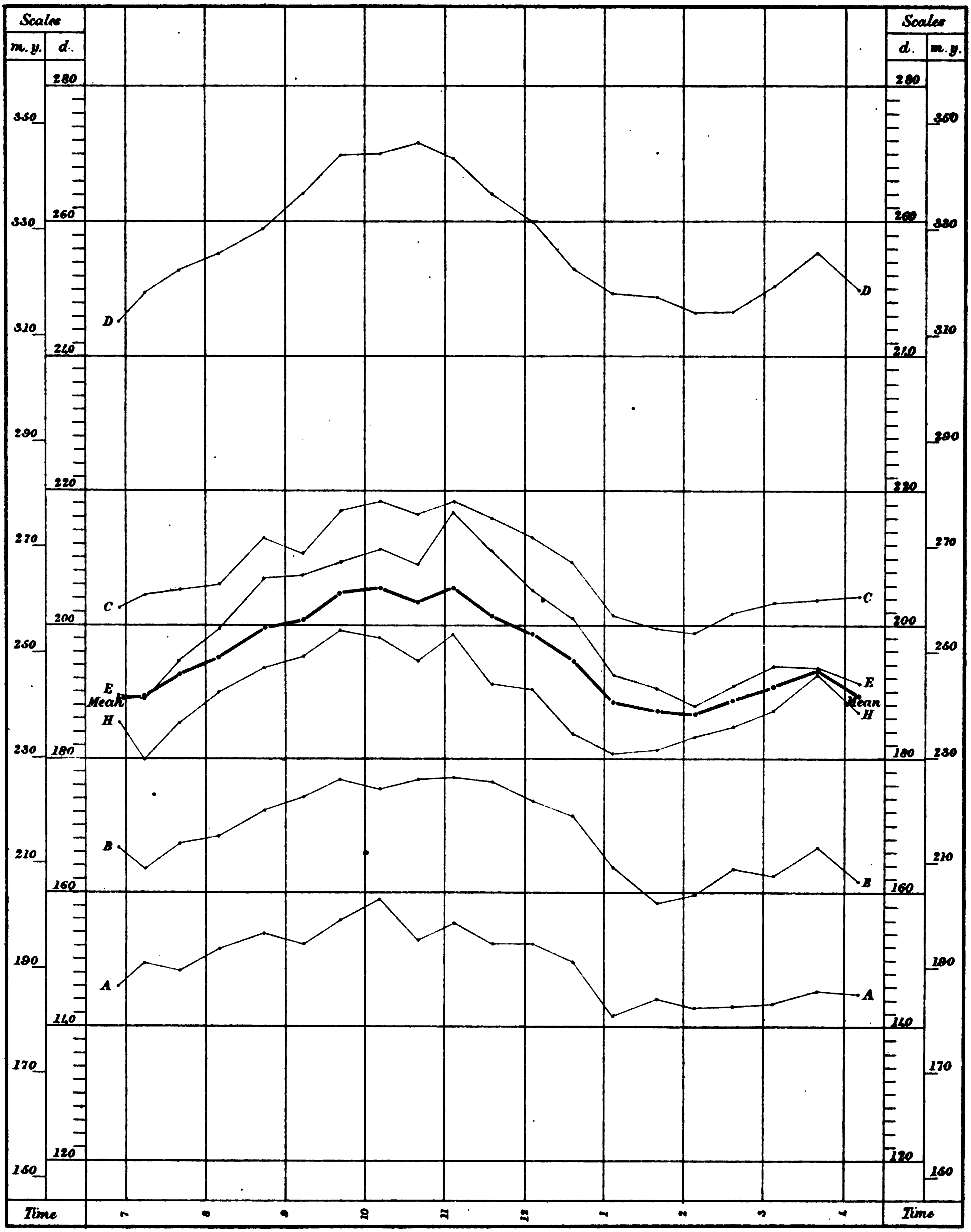


The horizontal intervals correspond to one hour. The vertical intervals correspond to 2 divisions of the micrometer on the inner scale, and to 20 millionths of a yard on the outer scale. The observations of the Standard were reduced to 62°, with the old value of the factor of expansion, or ·000,006,801, for 1° F.

C. Dyson, Photo. C. G. Ollenbach, Zinco.

Excess of compensation bars over Standard A at 62°. Cape Comorin Base.

Brass Components West. *Comparisons* (III.1.) *12th February 1869.*

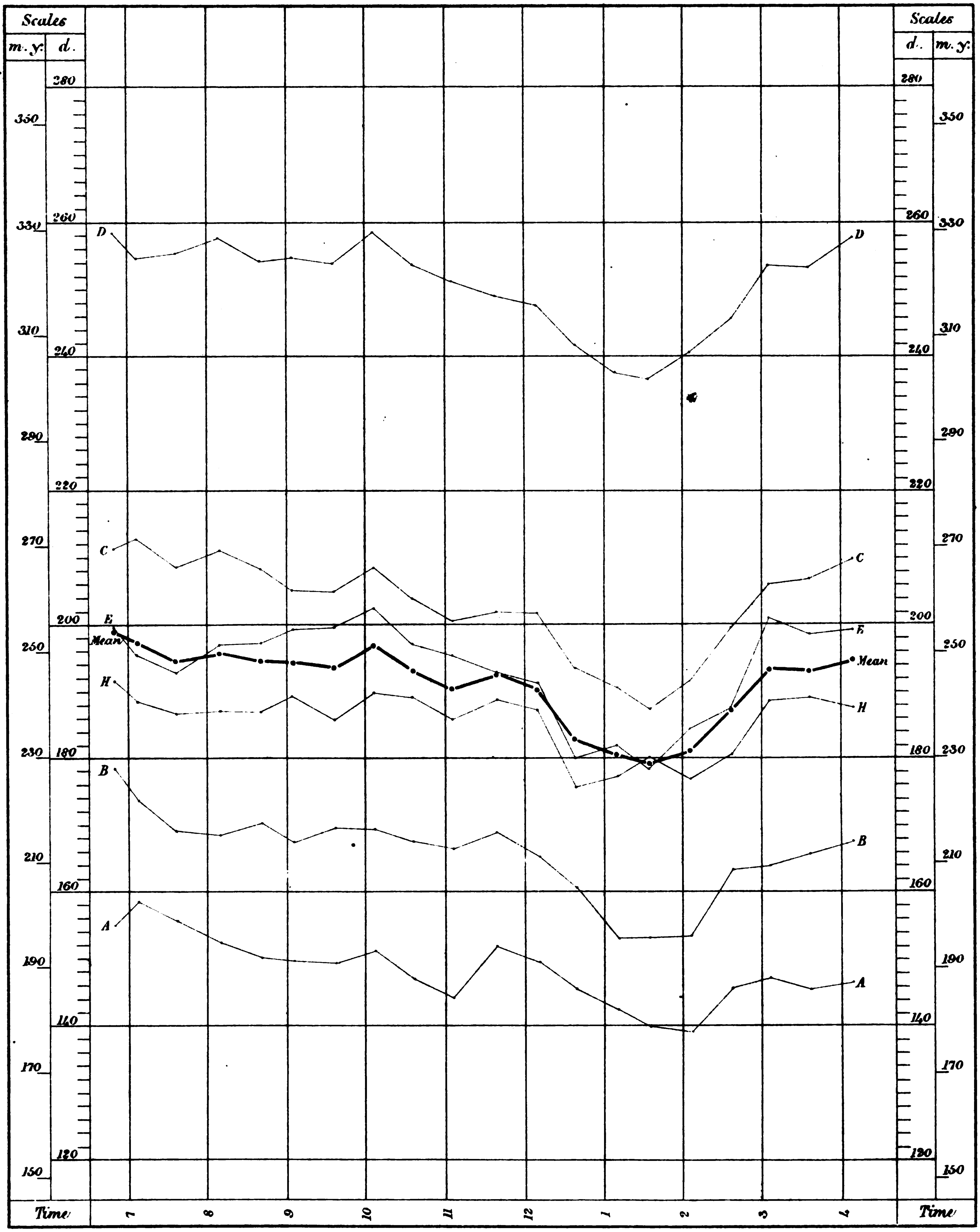


The horizontal intervals correspond to one hour. The vertical intervals correspond to 2 divisions of the micrometer on the inner scale, and to 20 millionths of a yard on the outer scale. The observations of the Standard were reduced to 62°, with the old value of the factor of expansion, or ·000, 006, 801, for 1° F.

C. Dyson, Photo. C. G. Ollenbach, Zinco.

Excess of compensation bars over Standard A at 62°. Cape Comorin Base.

Brass Components West. *Comparisons (III. 2.) 13th February 1869.*

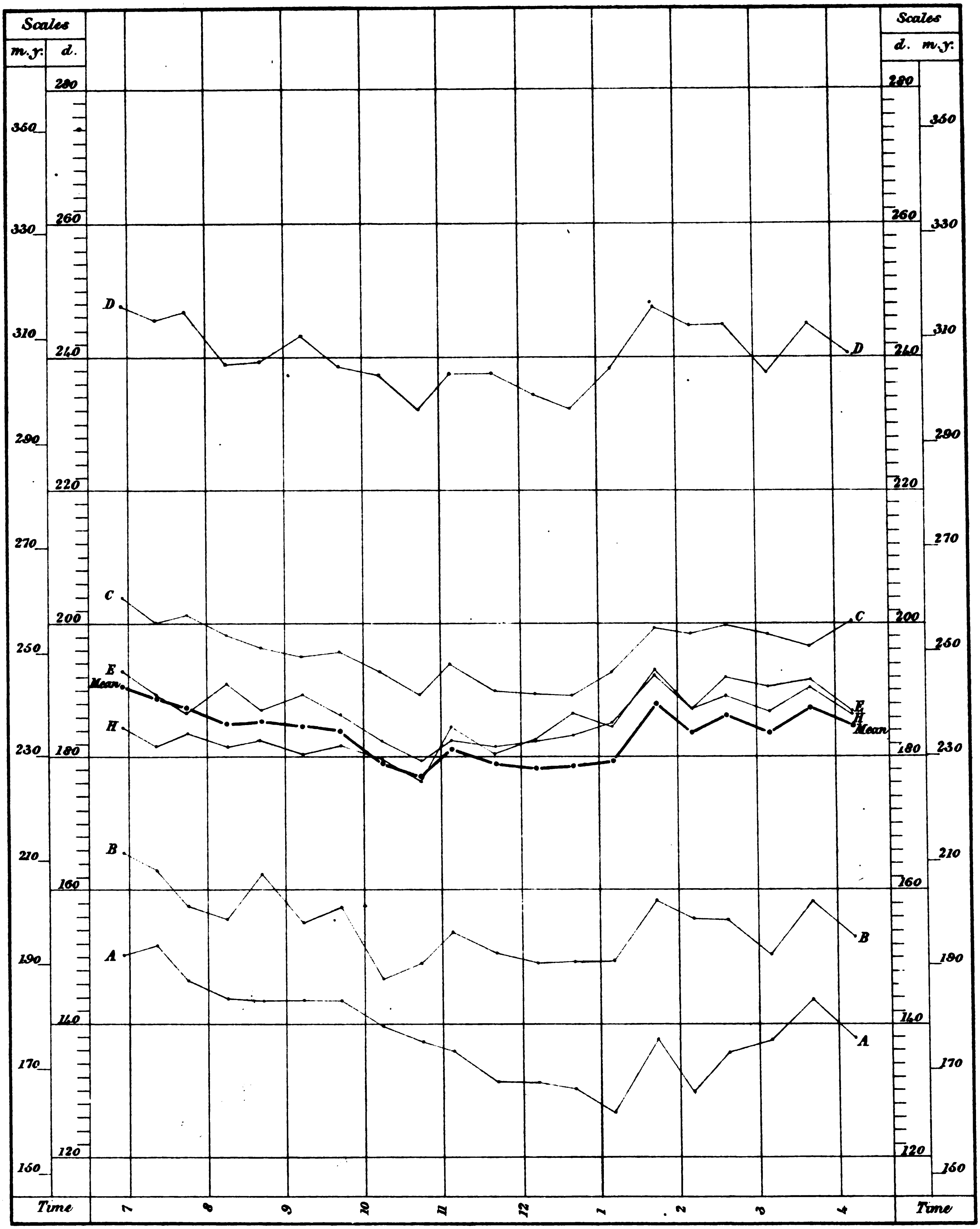


The horizontal intervals correspond to one hour. The vertical intervals correspond to 2 divisions of the micrometer on the inner scale, and to 20 millionths of a yard on the outer scale. The observations of the Standard were reduced to 62°, with the old value of the factor of expansion, or ·000,006,801, for 1° F.

C. Dyson, Photo. C. G. Ollenbach, Zinco.

Excess of compensation bars over Standard A at 62°. Cape Comorin Base.

Brass Components West. *Comparisons (III.3) 24th February 1869.*

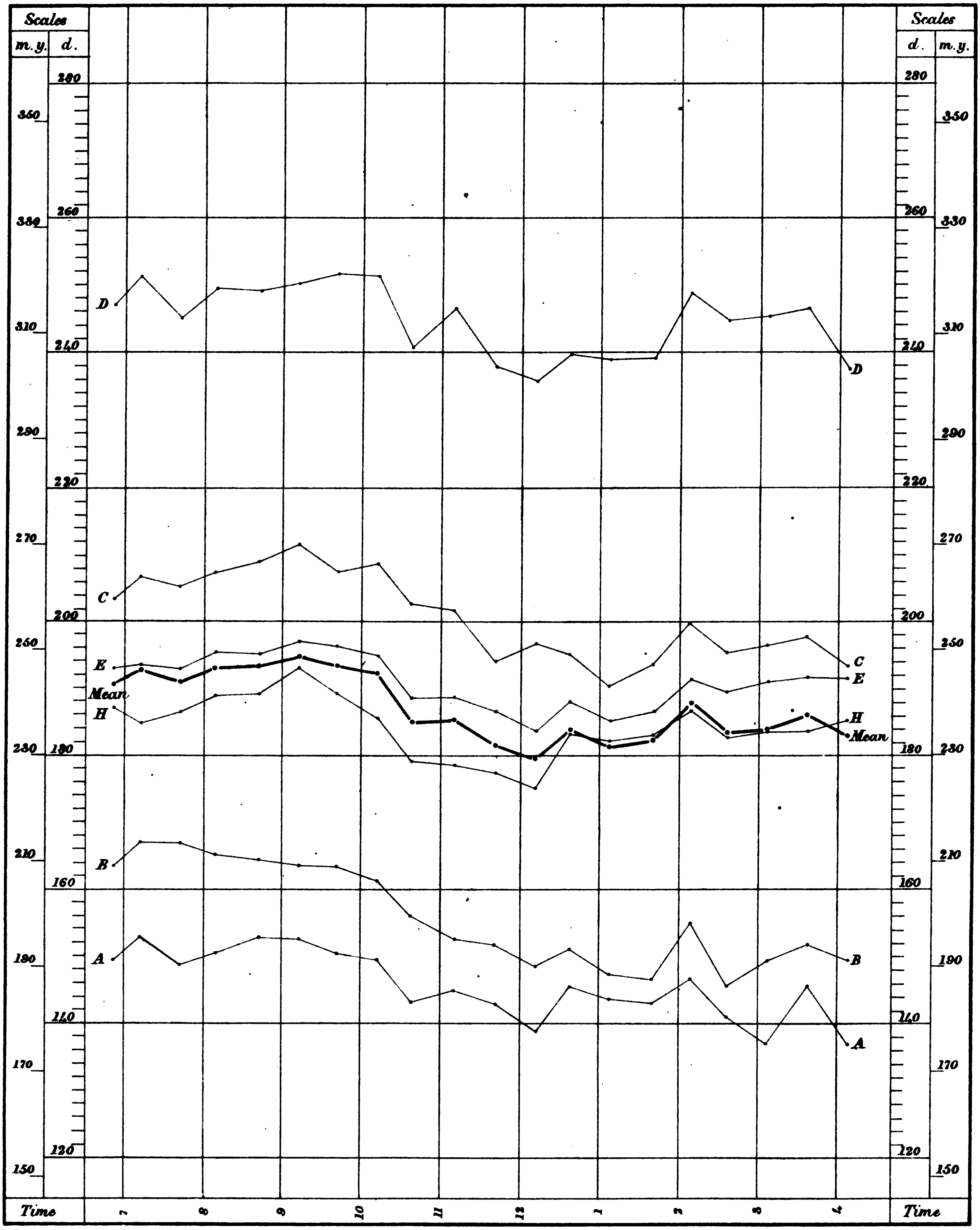


The horizontal intervals correspond to one hour. The vertical intervals correspond to 2 divisions of the micrometer on the inner scale, and to 20 millionths of a yard on the outer scale. The observations of the Standard were reduced to 62° with the old value of the factor of expansion, or ·000,006,801, for 1° F.

C. Dyson, Photo. C. G. Ollenbach, Zinco.

Excess of compensation bars over Standard A at 62° Cape Comorin Base.

Brass Components West. *Comparisons (III.4.) 25th February 1869.*

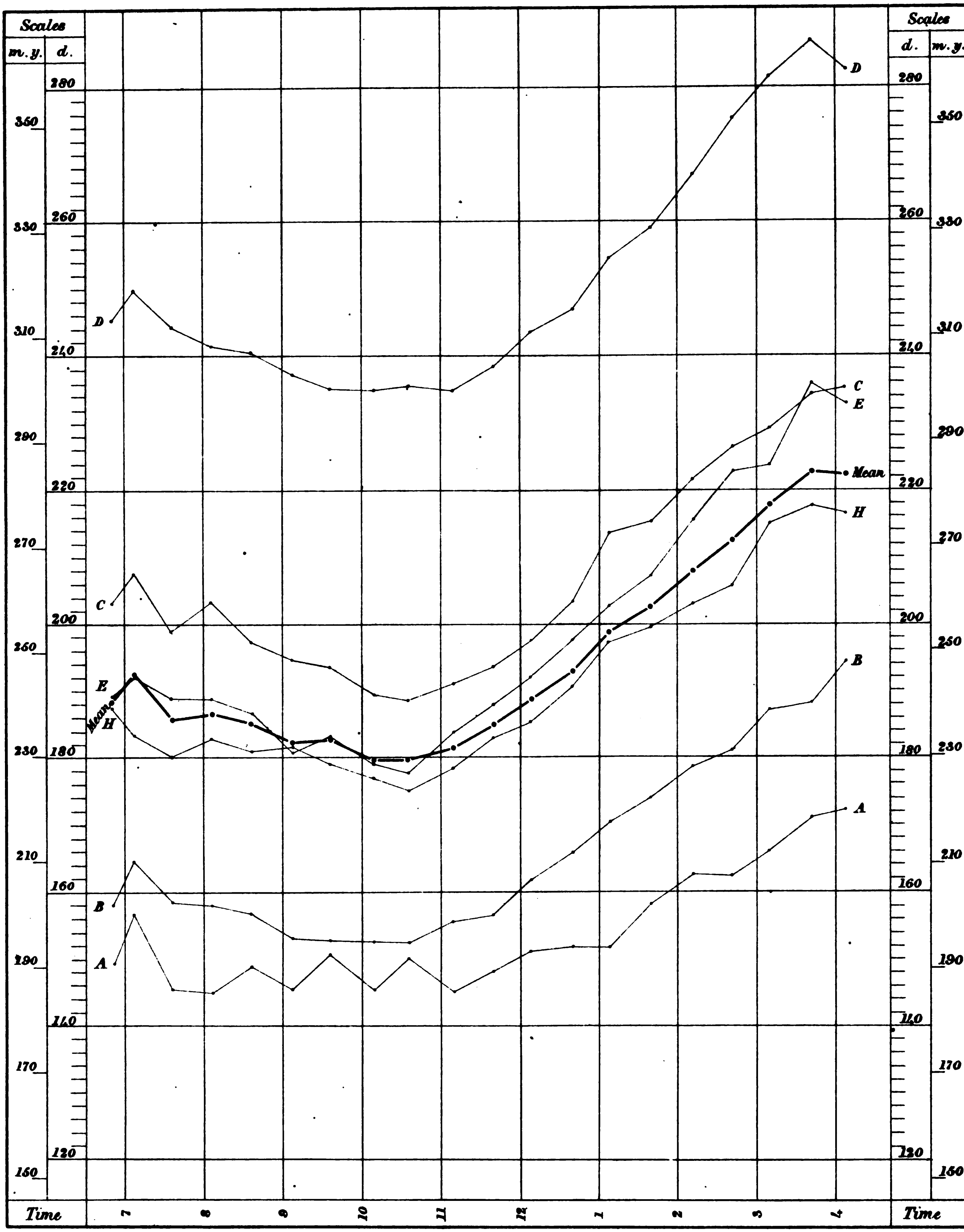


The horizontal intervals correspond to one hour. The vertical intervals correspond to 2 divisions of the micrometer on the inner scale, and to 20 millionths of a yard on the outer scale.. The observations of the Standard were reduced to 62° with the old value of the factor of expansion, or ·000,006,801, for 1° F.

C. Dyson, Photo. C. G. Ollenbach, Zinco.

Excess of compensation bars over Standard A at 62° Cape Comorin Base.

Brass Components East. Comparisons (IV. 1.) 26th February 1869.

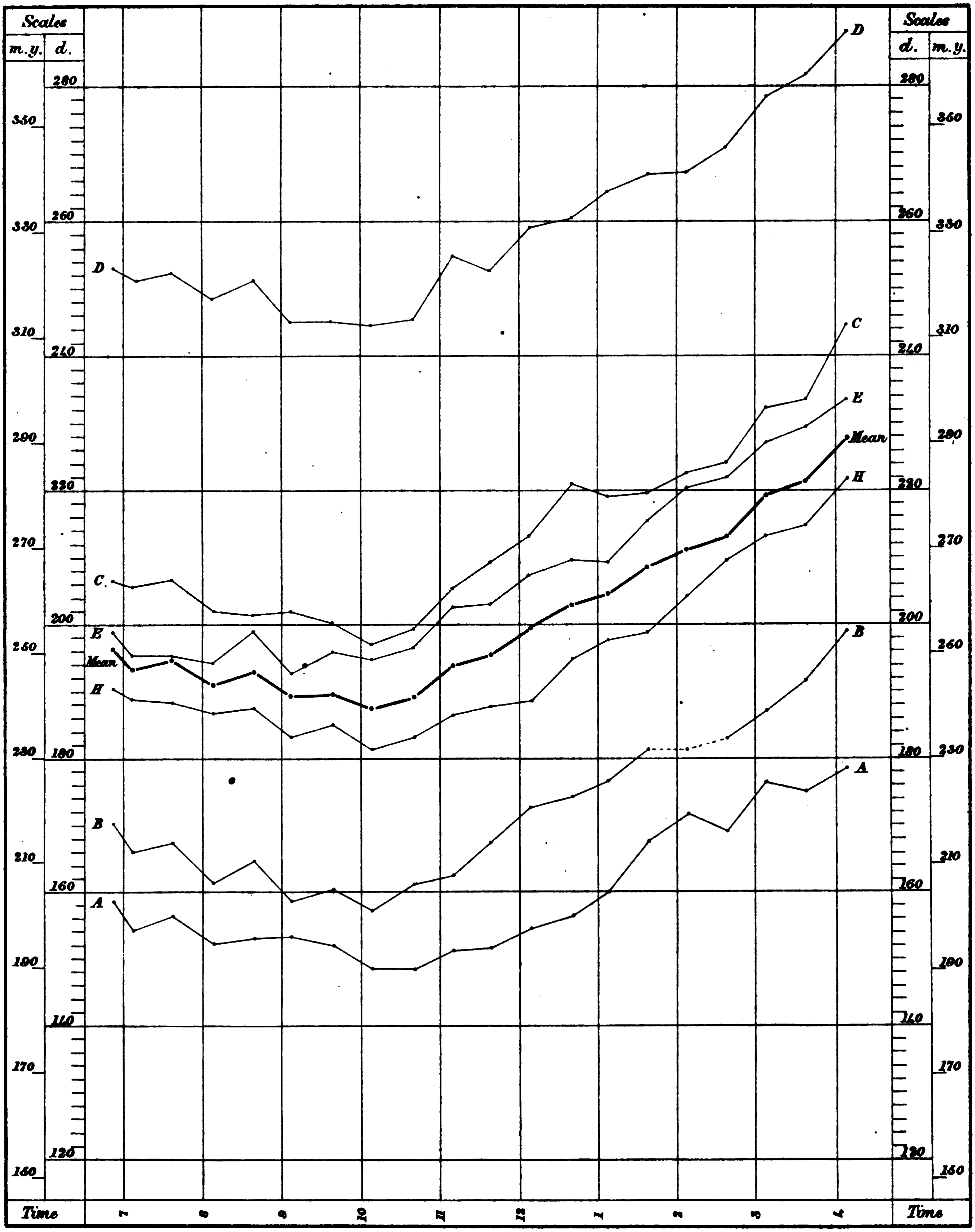


The horizontal intervals correspond to one hour.. The vertical intervals correspond to 2 divisions of the micrometer on the inner scale, and to 20 millionths of a yard on the outer scale.. The observations of the standard were reduced to 62° with the old value of the factor of expansion, or ·000,006,801 for 1° F..

C. Dyson, Photo. C. G. Ollenbach, Zinco.

Excess of compensation bars over Standard **A** *at 62°. Cape Comorin Base.*

Brass Components East. *Comparisons* (IV. 2.) 27th *February 1869.*



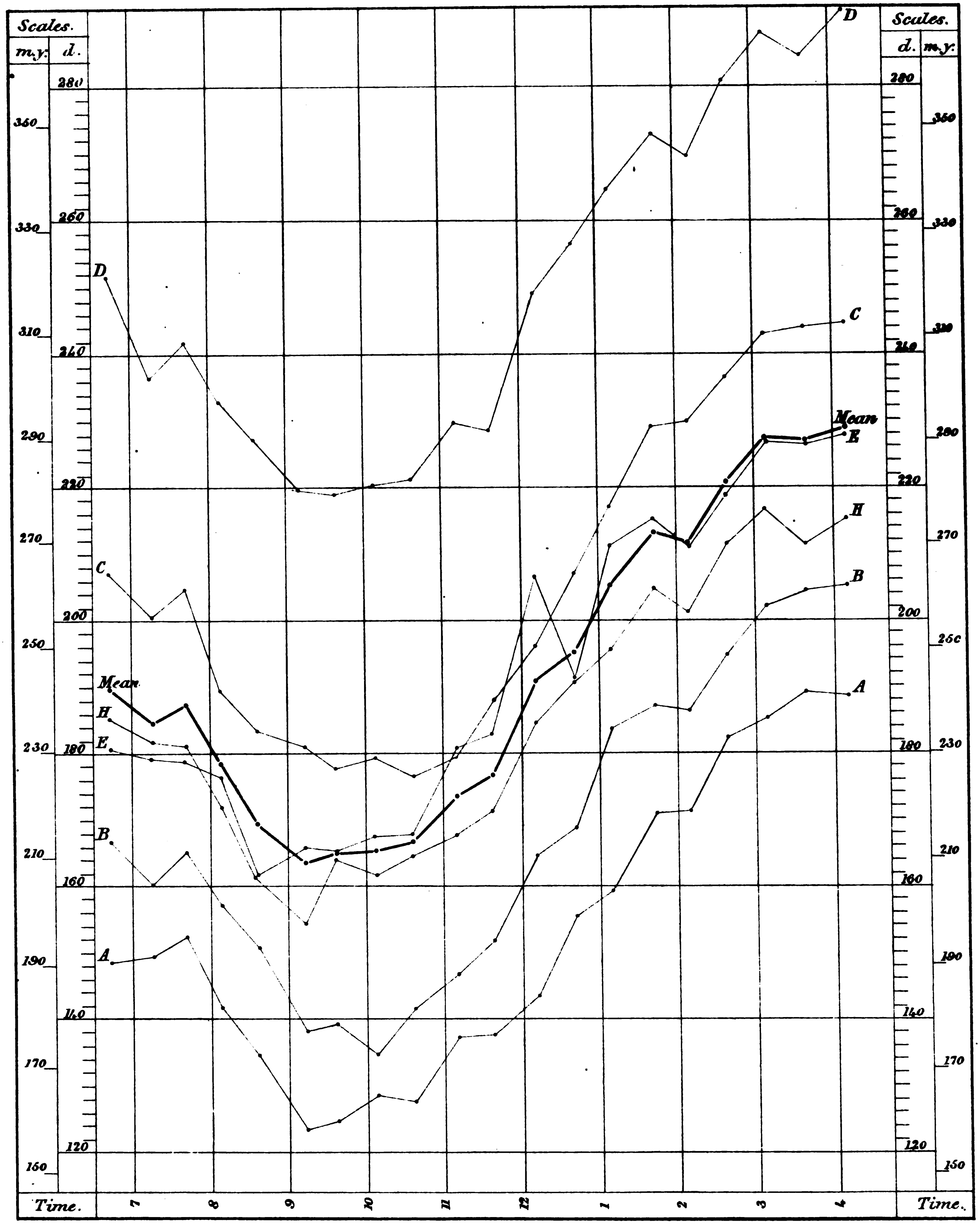
The horizontal intervals correspond to one hour.. The vertical intervals correspond to 2 divisions of the micrometer on the inner scale, and to 20 millionths of a yard on the outer scale.. The observations of the Standard were reduced to 62° with the old value of the factor of expansion, or ·000,006,801 for 1° F.

C. Dyson, Photo.

C. G. Ollenbach, Zinco.

Excess of compensation Bars over Standard A *at 62°. Cape Comorin Base.*

Brass Components East. *Comparisons* (IV. 3.) 9th *March 1869.*

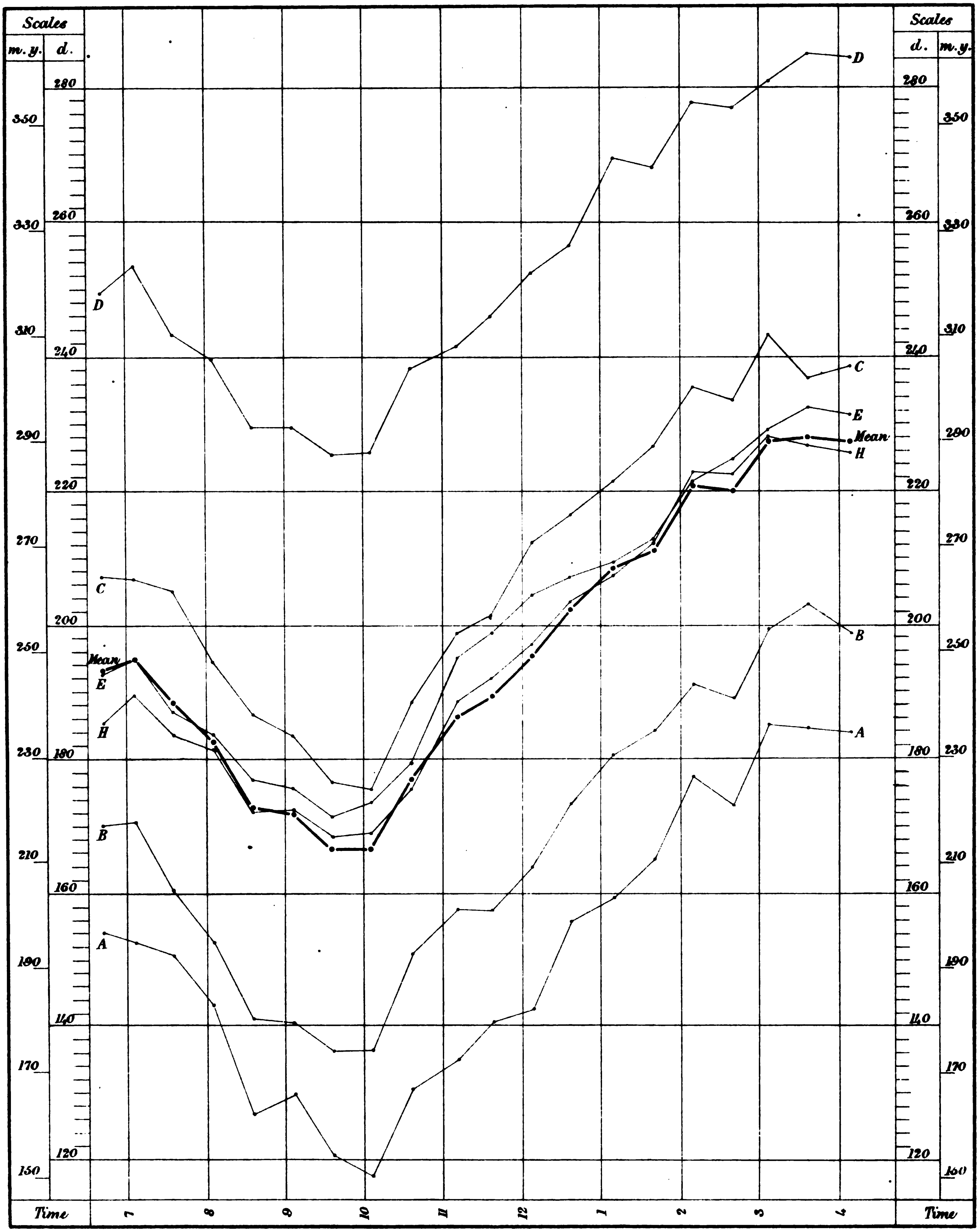


The horizontal intervals correspond to one hour. The vertical intervals correspond to 2 divisions of the micrometer on the inner scale, and to 20 millionths of a yard on the outer scale. The observations of the Standard were reduced to 62°, with the old value of the factor of expansion, or 000,006,801, for 1° F.

C. Dyson, Photo. C. G. Olleybach, Zinco.

Excess of compensation bars over Standard A at 62°. Cape Comorin Base.

Brass Components East. *Comparisons (IV.4.) 10th March 1869.*

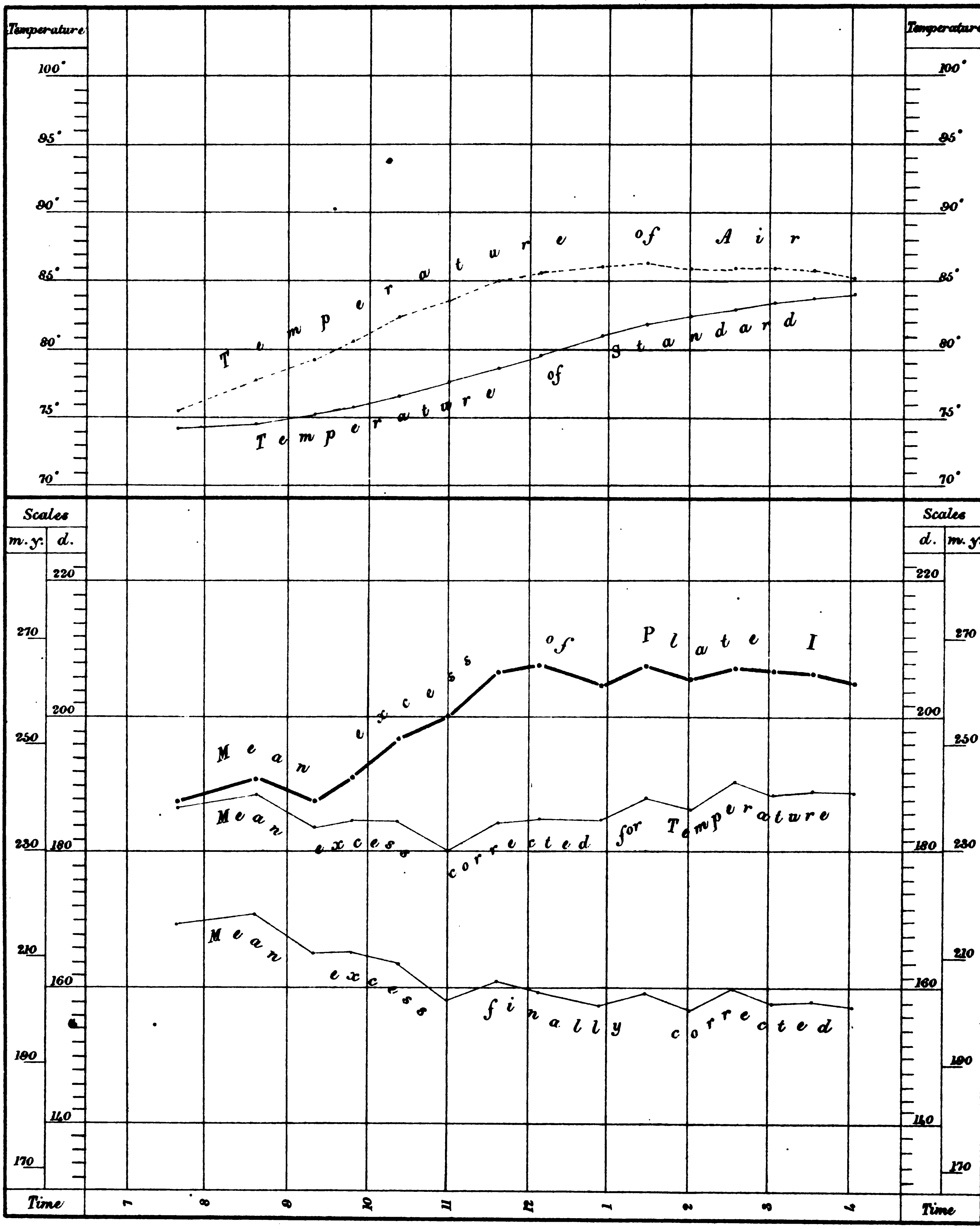


The horizontal intervals correspond to one hour. The vertical intervals correspond to 2 divisions of the micrometer on the inner scale, and to 20 millionths of a yard on the outer scale. The observations of the Standard were reduced to 62°. with the old value of the factor of expansion, or ·000,006,801, for 1°F.

C. Dyson, Photo. C. G. Ollenbach, Zinco.

Ordinary and corrected curves of excess of mean of Compensation Bars over Standard at 62° and curves of temperatures of air and of standard.

Cape Comorin Base. Brass Components West. *Comparisons* (I.1.) *9th January 1869.*

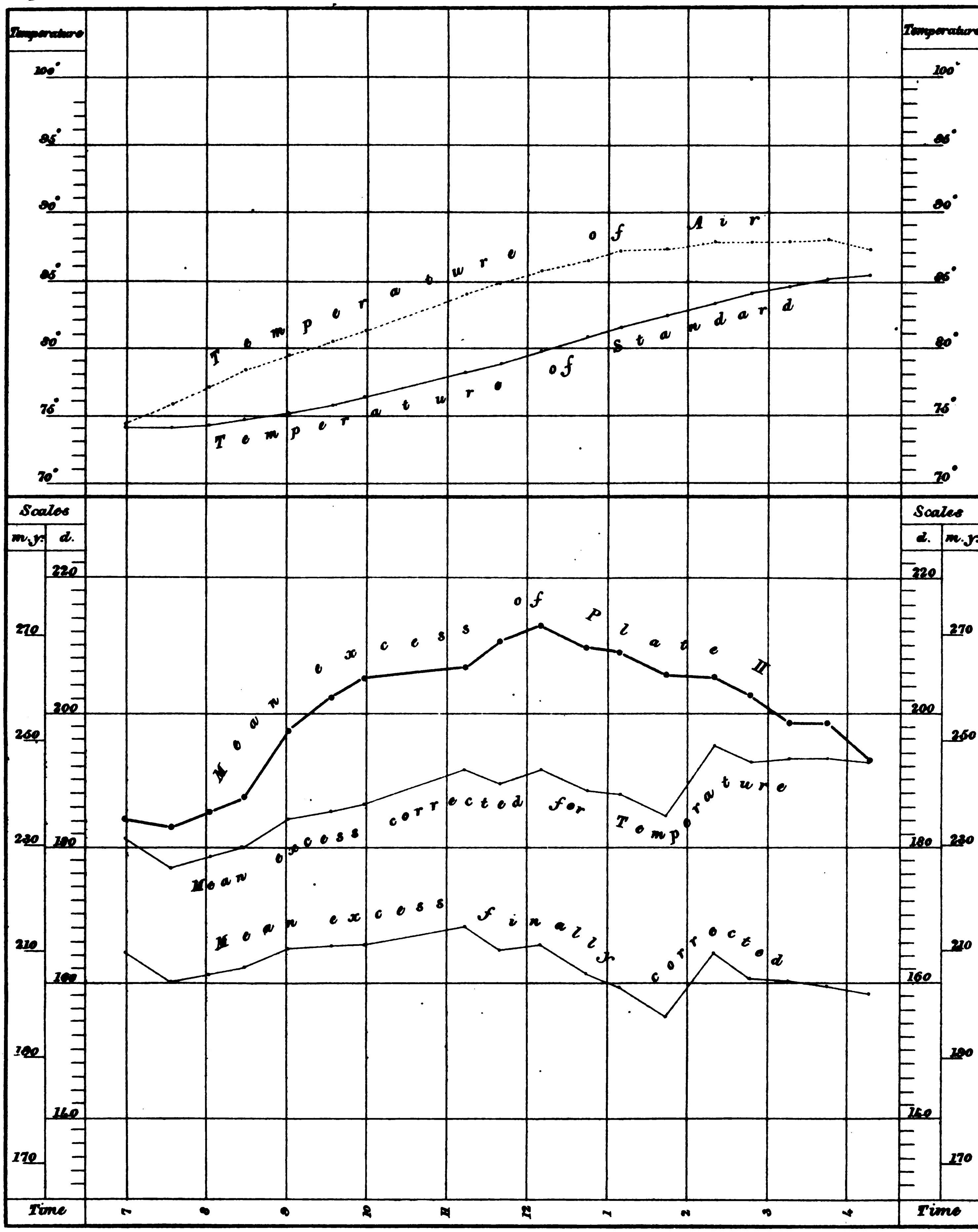


The horizontal intervals correspond to one hour. The upper vertical intervals correspond to 1° F. of temperature. The lower vertical intervals correspond to 2 divisions of the micrometer on the inner scale, and to 20 millionths of a yard on the outer scale.

C. Dixon, Photo. C. G. Ollenbach, Zinco.

Ordinary and corrected curves of excess of mean of Compensation Bars over Standard at 62° and curves of temperatures of air and of standard.

Cape Comorin Base. Brass Components West. *Comparisons* (I.2.) 11th January 1869.

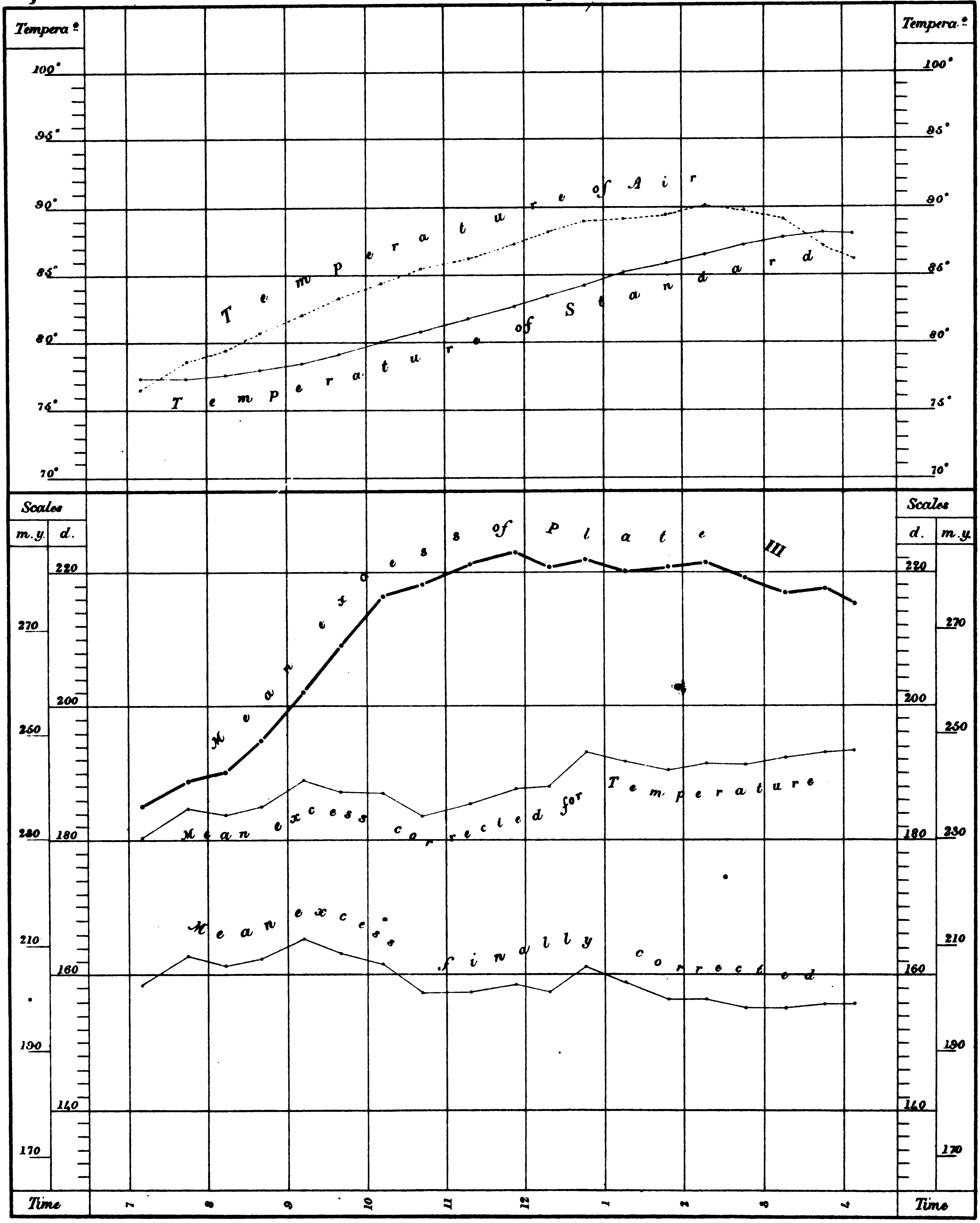


The horizontal intervals correspond to one hour. The upper vertical intervals correspond to 1° F. of temperature. The lower vertical intervals correspond to 2 divisions of the micrometer on the inner scale, and to 20 millionths of a yard on the outer scale.

C. Dyson, Photo. C. G. Ollenbach, Zinco.

Ordinary and corrected curves of excess of mean of Compensation Bars over Standard at 62° and curves of temperatures of air and of standard.

Cape Comorin Base. Brass Components West. *Comparisons* (I. 3.) 25th *January 1869.*

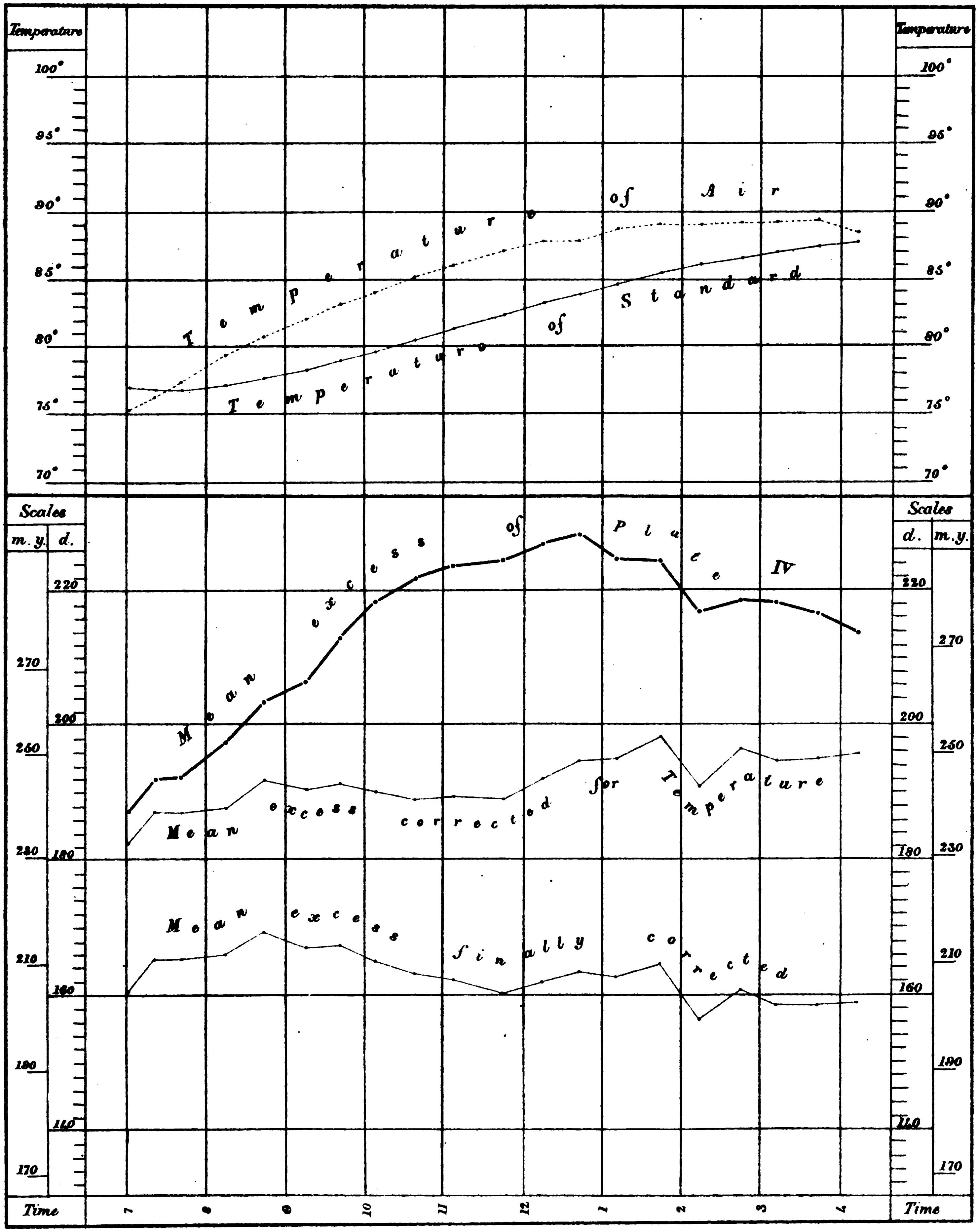


The horizontal intervals correspond to one hour. The upper vertical intervals correspond to 1° F. of temperature. The lower vertical intervals correspond to 2 divisions of the micrometer on the inner scale, and to 20 millionths of a yard on the outer scale.

C. Dyson, Photo. C. G. Ollenbach, Zinco.

Ordinary and corrected curves of excess of mean of Compensation Bars over Standard at 62° and curves of temperatures of air and of standard.

Cape Comorin Base. Brass Components West. *Comparisons* (I. 4.) 26th *January 1869.*

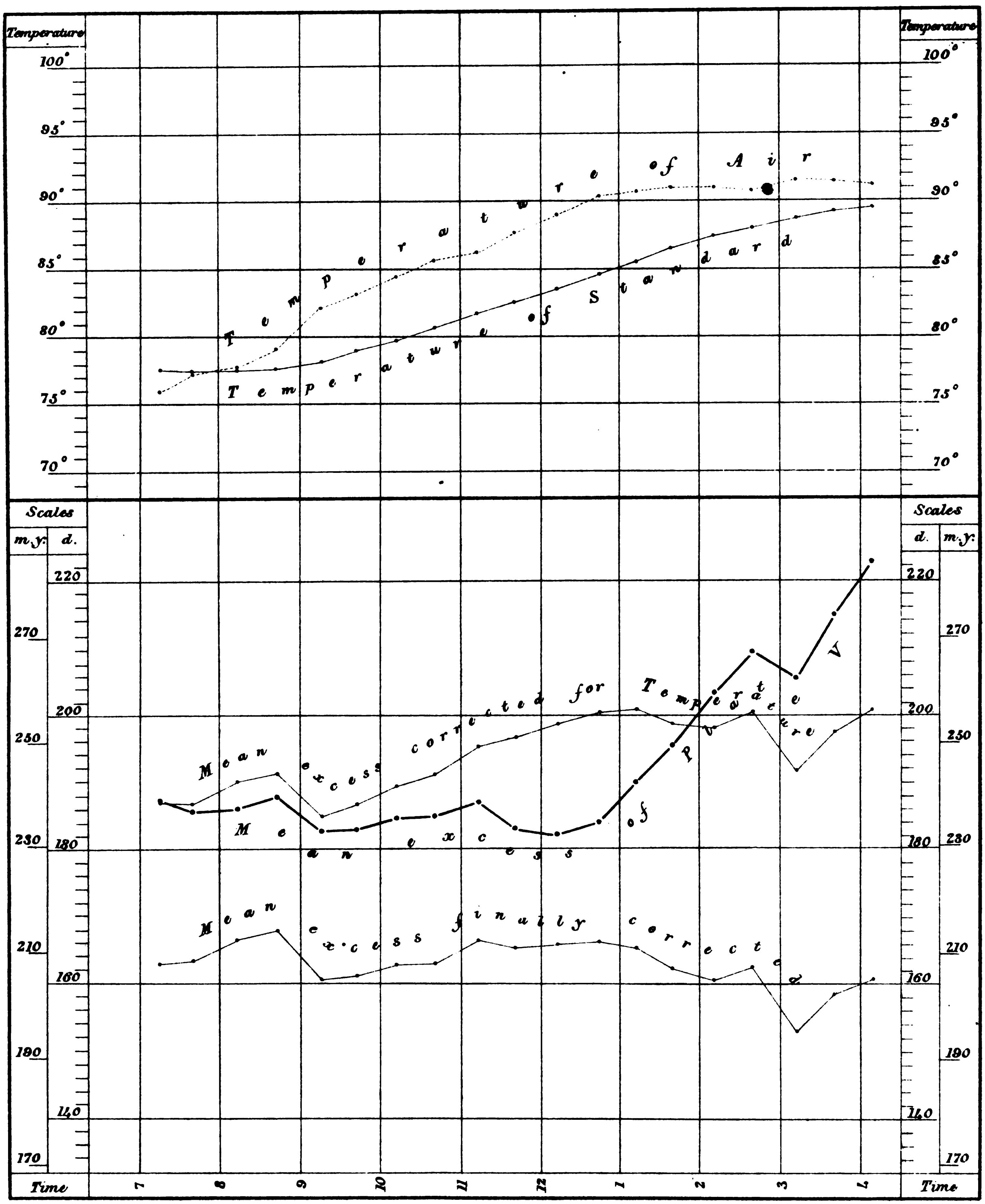


The horizontal intervals correspond to one hour. The upper vertical intervals correspond to 1° F. of temperature. The lower vertical intervals correspond to 2 divisions of the micrometer on the inner scale, and to 20 millionths of a yard on the outer scale.

C. Dixon, Photo. C. G. Ollenbach, Zinco.

Ordinary and corrected curves of excess of mean of Compensation Bars over Standard at 62° and curves of temperatures of air and of standard.

Cape Comorin Base. Brass Components East. Comparisons (II.1.) 28th January 1869.

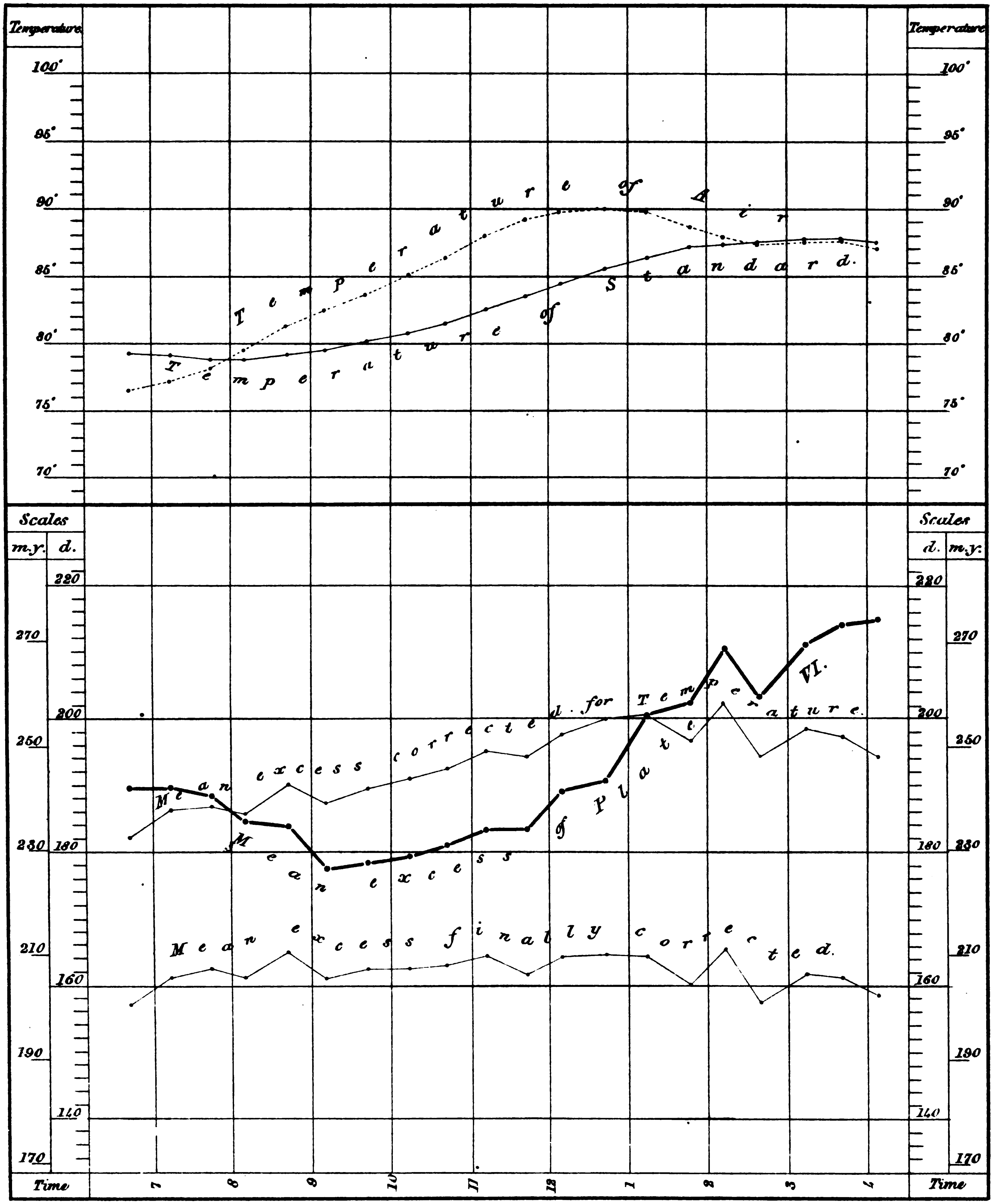


The horizontal intervals correspond to one hour. The upper vertical intervals correspond to 1° F. of temperature. The lower vertical intervals correspond to 2 divisions of the micrometer on the inner scale, and to 20 millionths of a yard on the outer scale.

C. Dyson, Photo. C. G. Ollenbach, Zinco

Ordinary and corrected curves of excess of mean of Compensation Bars over Standard at 62° and curves of temperatures of air and of standard.

Cape Comorin Base. **Brass Components East.** *Comparisons* (II. 2.) 29th *January.* 1869.

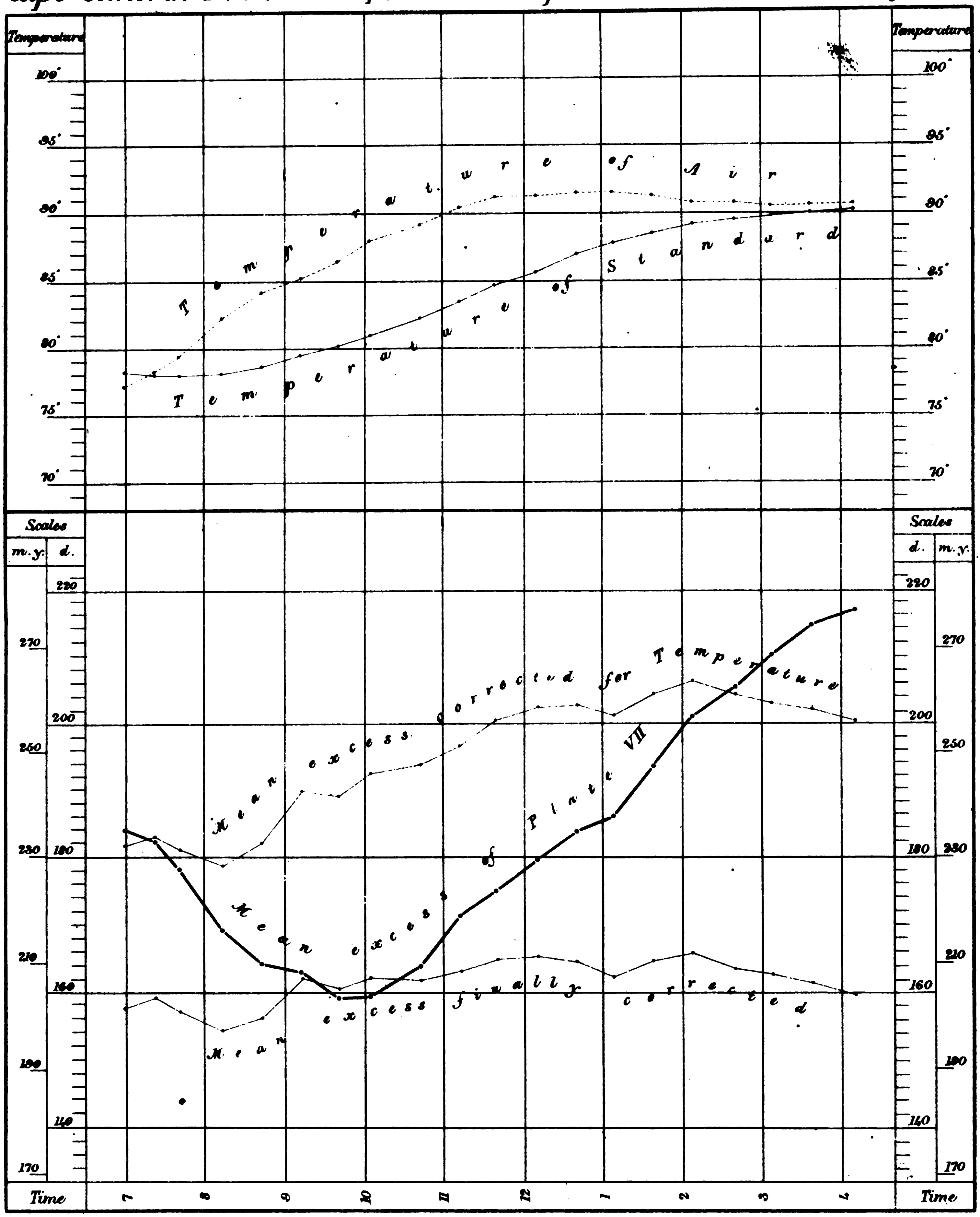


The horizontal intervals correspond to one hour. The upper vertical intervals correspond to 1° F. of temperature. The lower vertical intervals correspond to 2 divisions of the micrometer on the inner scale, and to 20 millionths of a yard on the outer scale.

C. Dyson, Photo. C. G. Ollenbach, Zinco.

Ordinary and corrected curves of excess of mean of Compensation Bars over Standard at 62° and curves of temperatures of air and of standard.

Cape Comorin Base. Brass Components East. Comparisons (II. 3.) 10th February 1869.



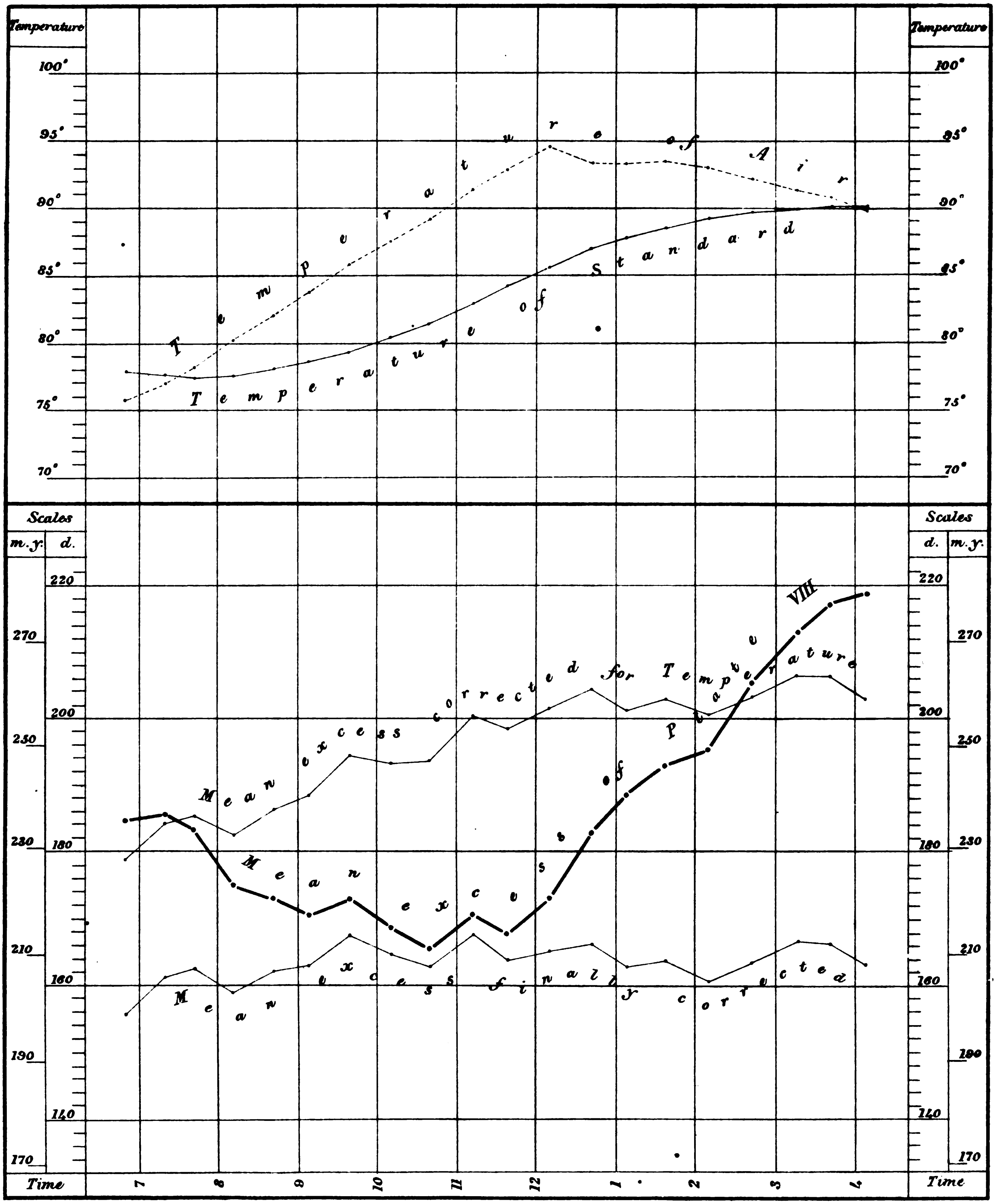
The horizontal intervals correspond to one hour. The upper vertical intervals correspond to 1° F. of temperature. The lower vertical intervals correspond to 2 divisions of the micrometer on the inner scale, and to 20 millionths of a yard on the outer scale.

C. Dyson, Photo.

C. G. Ollenbach, Zinco.

Ordinary and corrected curves of excess of mean of Compensation Bars over Standard at 62° and curves of temperatures of air and of standard.

Cape Comorin Base. Brass Components East. *Comparisons* (II.4.) *11th February 1869.*

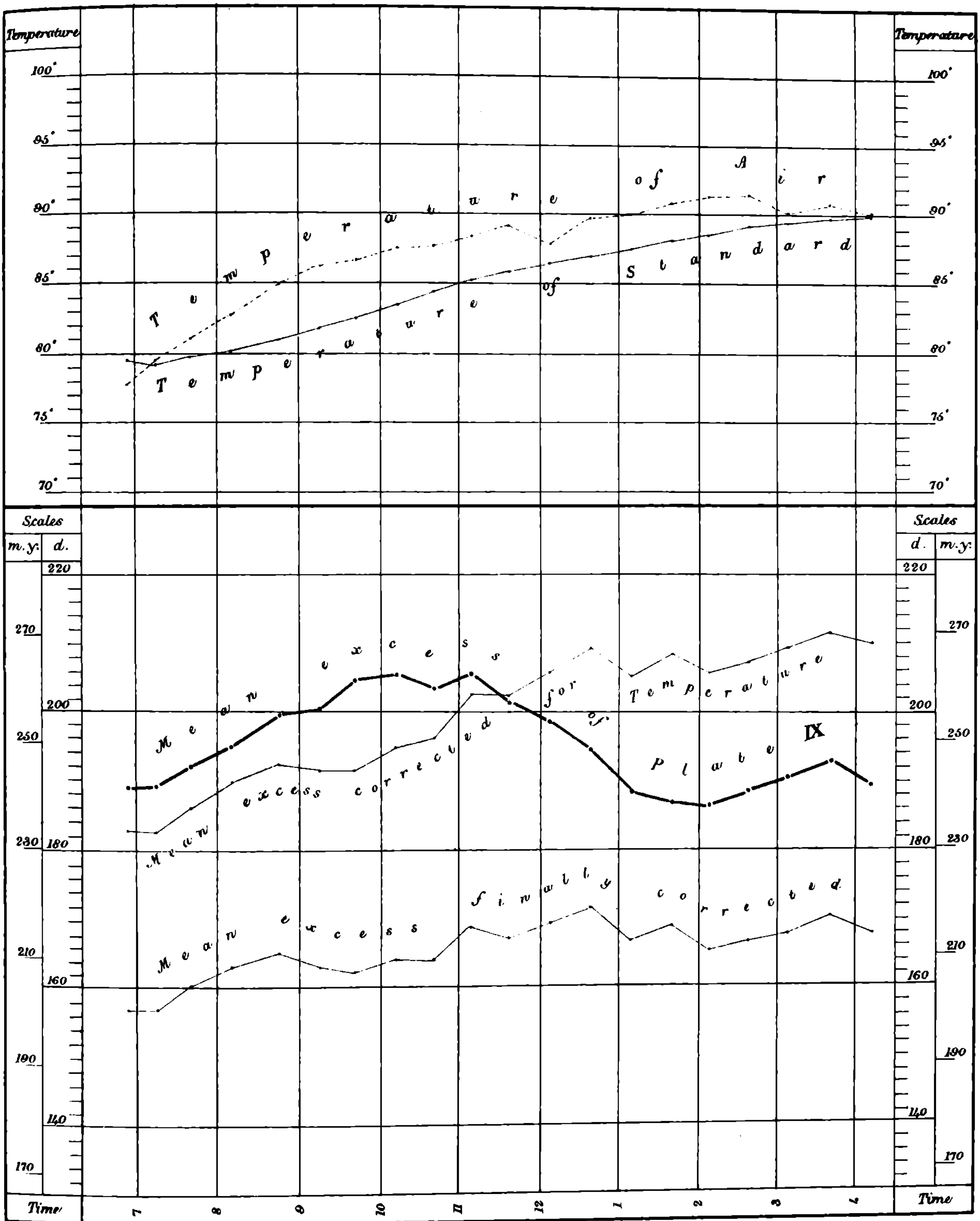


The horizontal intervals correspond to one hour. The upper vertical intervals correspond to 1°F. of temperature. The lower vertical intervals correspond to 2 divisions of the micrometer on the inner scale, and to 20 millionths of a yard on the outer scale.

C. Dixon, Photo. C. G. Ollenbach, Zinco

Ordinary and corrected curves of excess of mean of Compensation Bars over Standard at 62° and curves of temperatures of air and of standard.

Cape Comorin Base. Brass Components West. *Comparisons* (III. 1.) 12th February 1869.

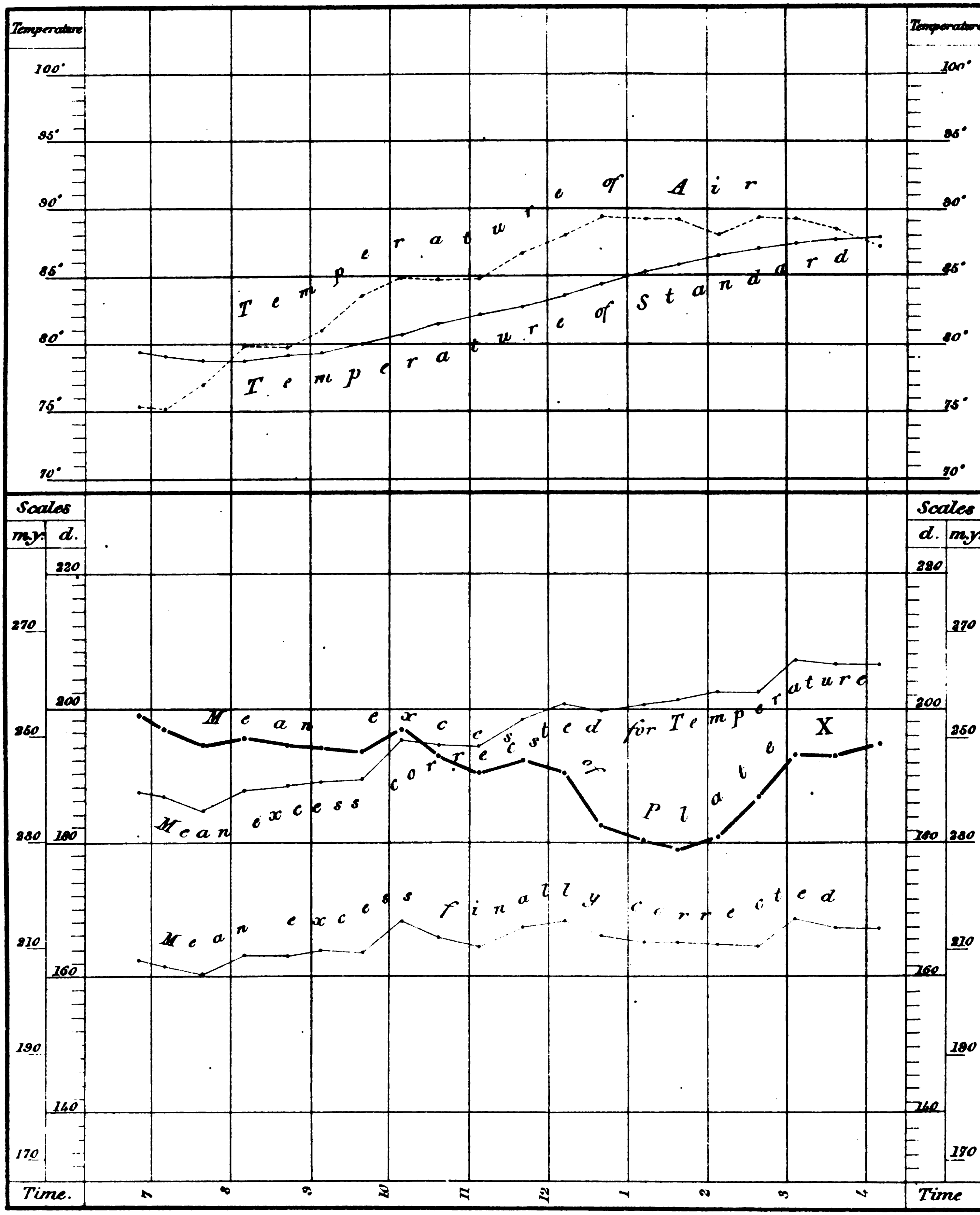


The horizontal intervals correspond to one hour. The upper vertical intervals correspond to 1° F. of temperature. The lower vertical intervals correspond to 2 divisions of the micrometer on the inner scale, and to 20 millionths of a yard on the outer scale.

C. Dray, Photo.

Ordinary and corrected curves of excess of mean of Compensation Bars over Standard at 62° and curves of temperatures of air and of standard.

Cape Comorin Base. Brass Components West. *Comparisons* (III.2.) *13th February 1869.*



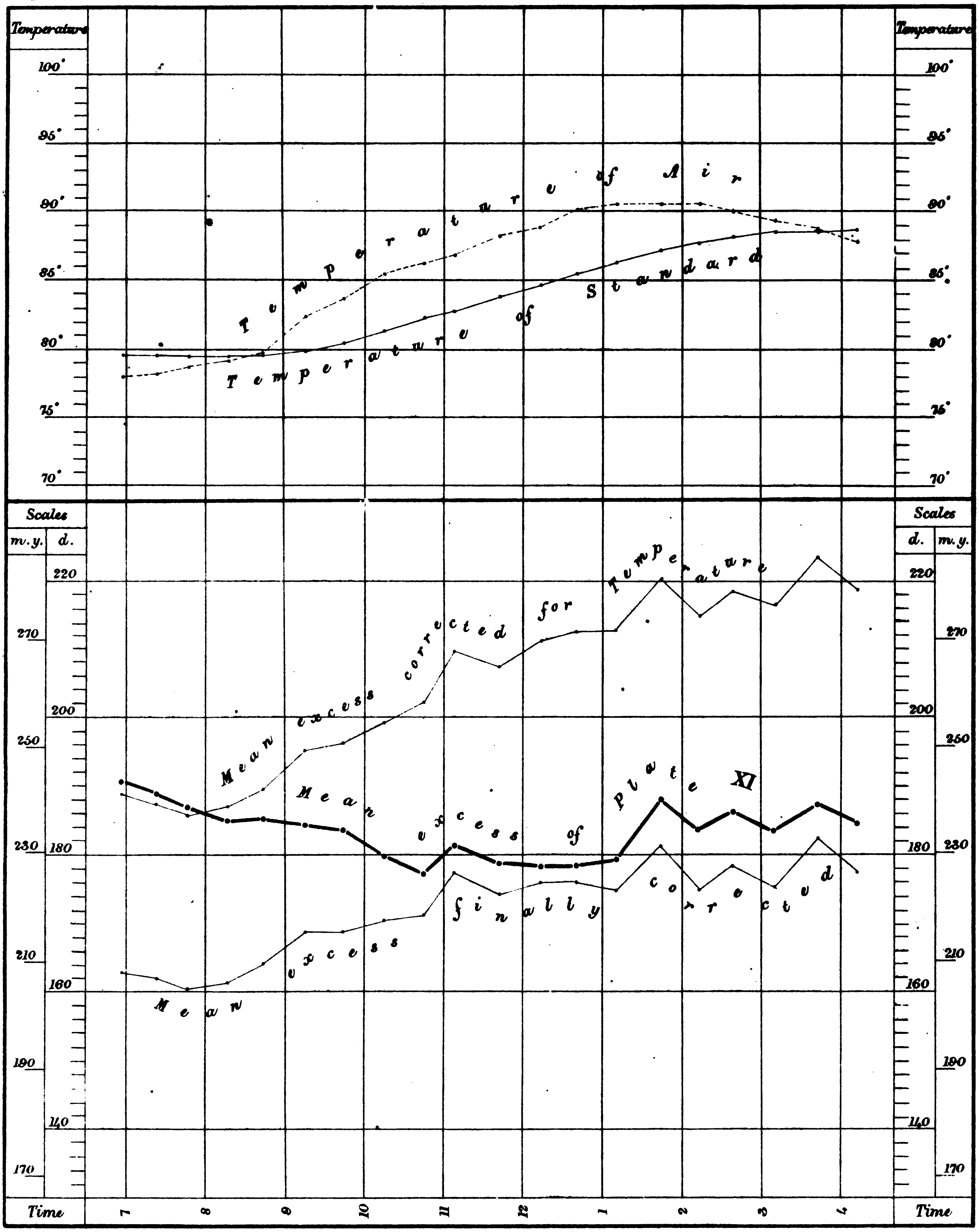
The horizontal intervals correspond to one hour. The upper vertical intervals correspond to 1° F. of temperature. The lower vertical intervals correspond to 2 divisions of the micrometer on the inner scale, and to 20 millionths of a yard on the outer scale.

C. Dyson Photo.

C. G. Ollenbach, Zinco.

Ordinary and corrected curves of excess of mean of Compensation Bars over Standard at 62° and curves of temperatures of air and of standard.

Cape Comorin Base. Brass Components West. *Comparisons* (III. 3.) *24th February 1869.*

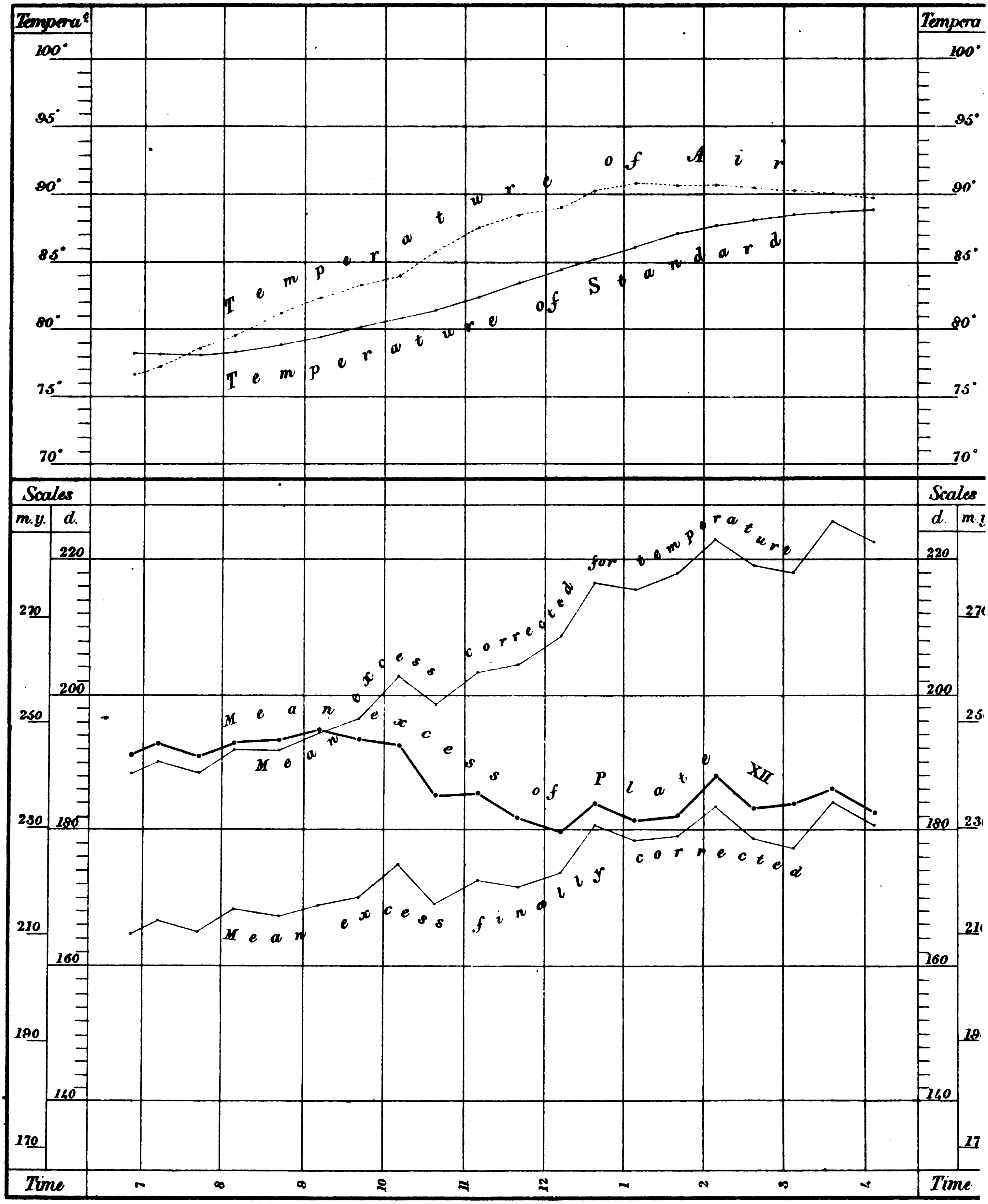


The horizontal intervals correspond to one hour. The upper vertical intervals correspond to 1° F. of temperature. The lower vertical intervals correspond to 2 divisions of the micrometer on the inner scale, and to 20 millionths of a yard on the outer scale.

C. Dyson, Photo. C. G. Olliffrach, Zinco.

Ordinary and corrected curves of excess of mean of Compensation Bars over Standard a 62° and curves of temperatures of air and of standard.

Cape Comorin Base. Brass Components West. *Comparisons* (III.4.) 25th *February* 186

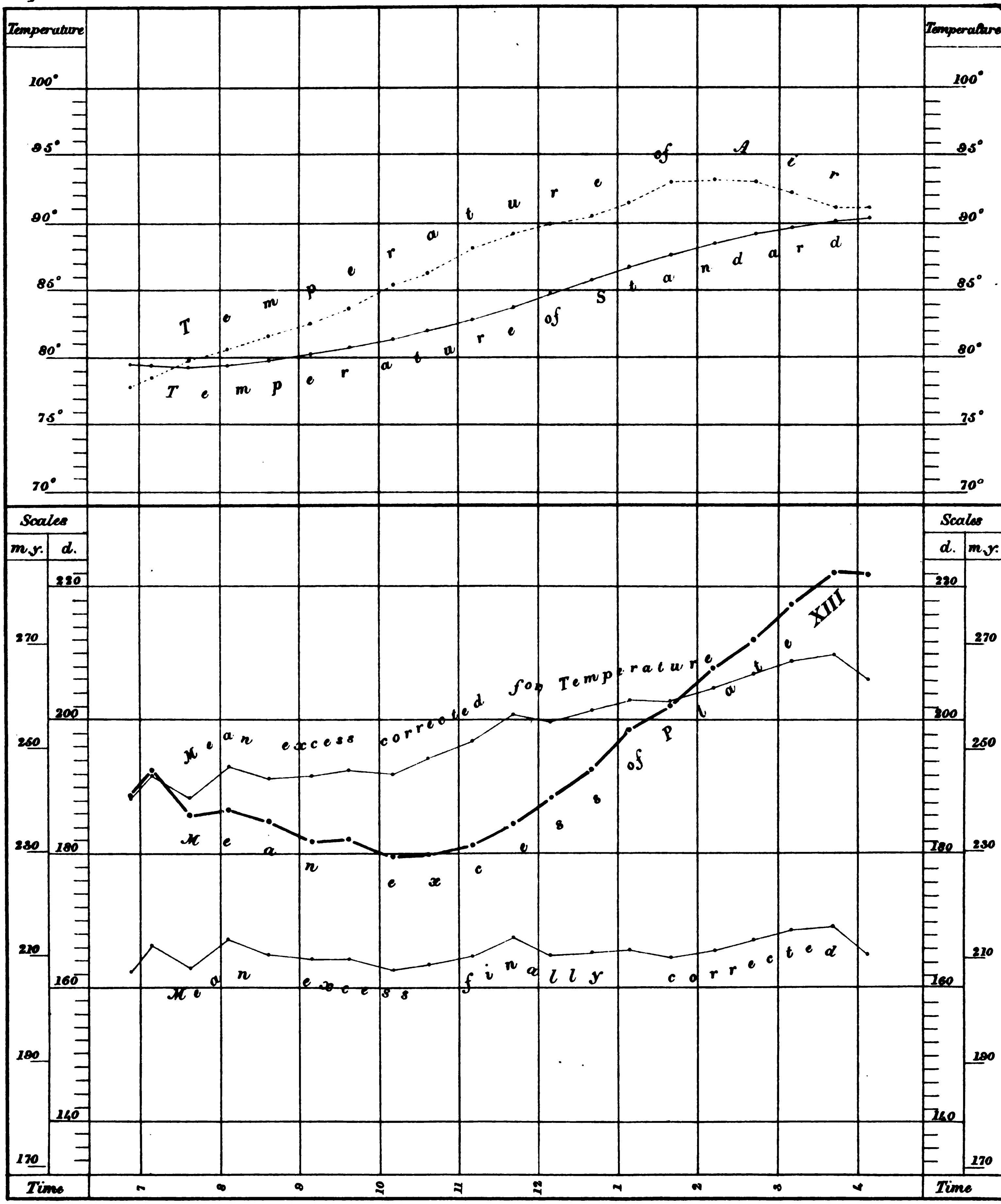


The horizontal intervals correspond to one hour. The upper vertical intervals correspond to 1° F. of temperature. . lower vertical intervals correspond to 2 divisions of the micrometer on the inner scale, and to 20 millionths of a ya on the outer scale.

C. Dyson, Photo. C. G. Ollenbach

Ordinary and corrected curves of excess of mean of Compensation Bars over Standard at 62° and curves of temperatures of air and of standard.

Cape Comorin Base . Brass Components East . *Comparisons* (IV. 1.) 26th February 1869.

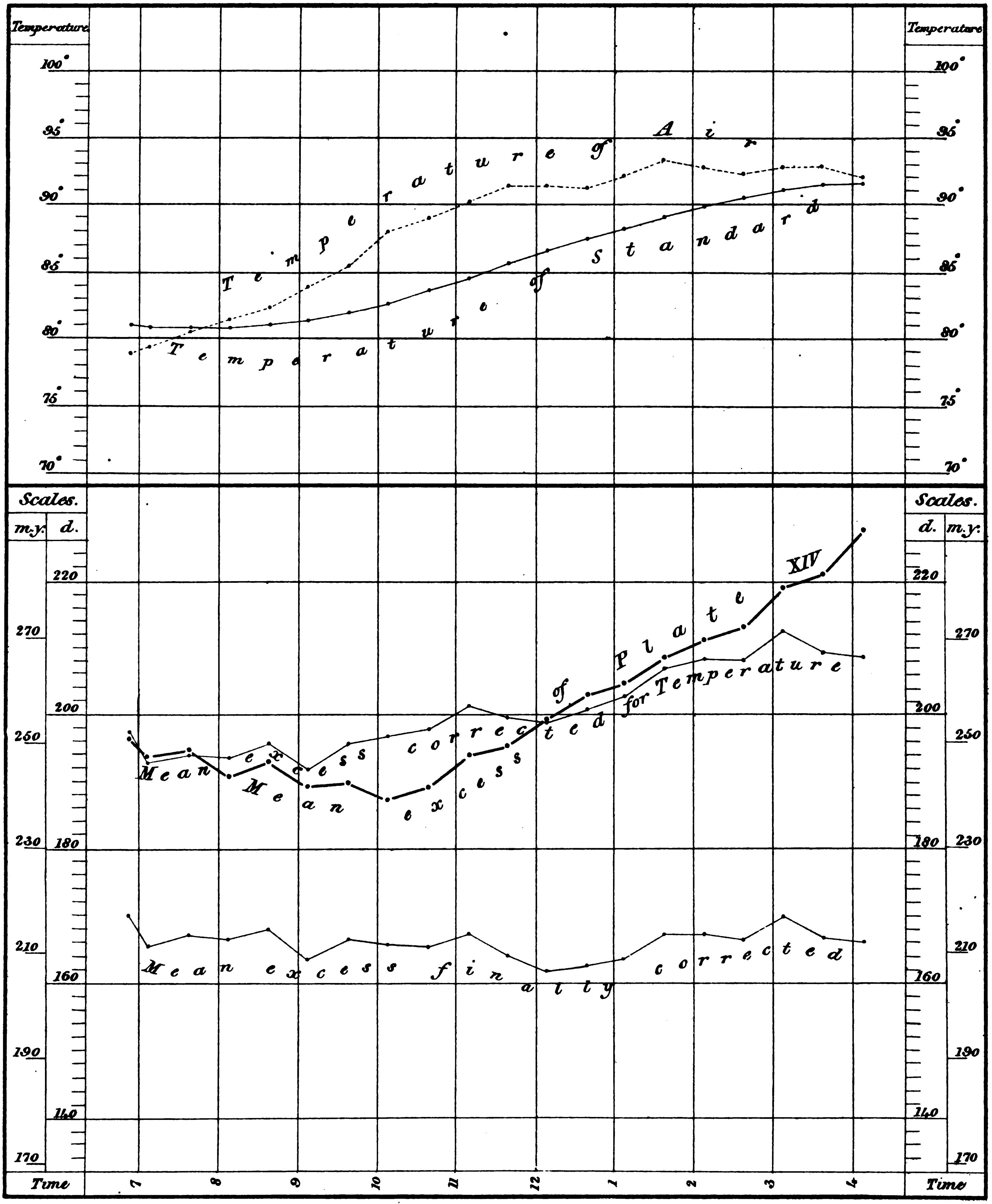


The horizontal intervals correspond to one hour. The upper vertical intervals correspond to 1° F. of temperature. The lower vertical intervals correspond to 2 divisions of the micrometer on the inner scale, and to 20 millionths of a yard on the outer scale.

C. Dixon, Photo. C. G. Ollenbach, Zinco.

Ordinary and corrected curves of excess of mean of Compensation Bars over Standard at 62°. and curves of temperatures of air and of standard.

Cape Comorin Base. Brass Components East. *Comparisons* (IV. 2.) 27th *February*. 1869.



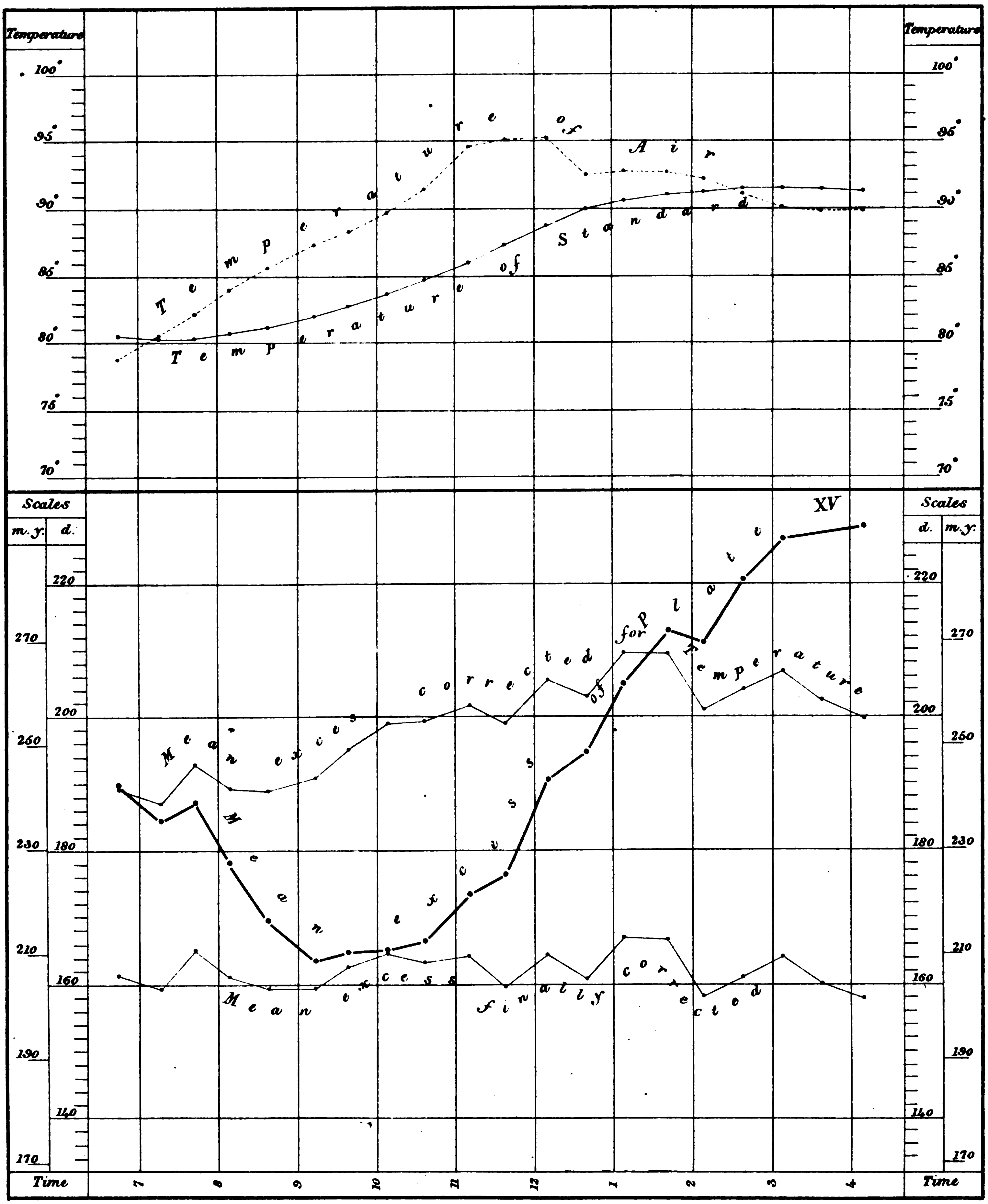
The horizontal intervals correspond to one hour. The upper vertical intervals correspond to 1°F. of temperature. The lower vertical intervals correspond to 2 divisions of the micrometer on the inner scale, and to 20 millionths of a yard on the outer scale.

C. Dyson. Photo.

C. G. Ollenbach, Zinco.

Ordinary and corrected curves of excess of mean of Compensation Bars over Standard at 62° and curves of temperatures of air and of standard.

Cape Comorin Base. Brass Components East. *Comparisons* (IV 3) *9th March 1869.*



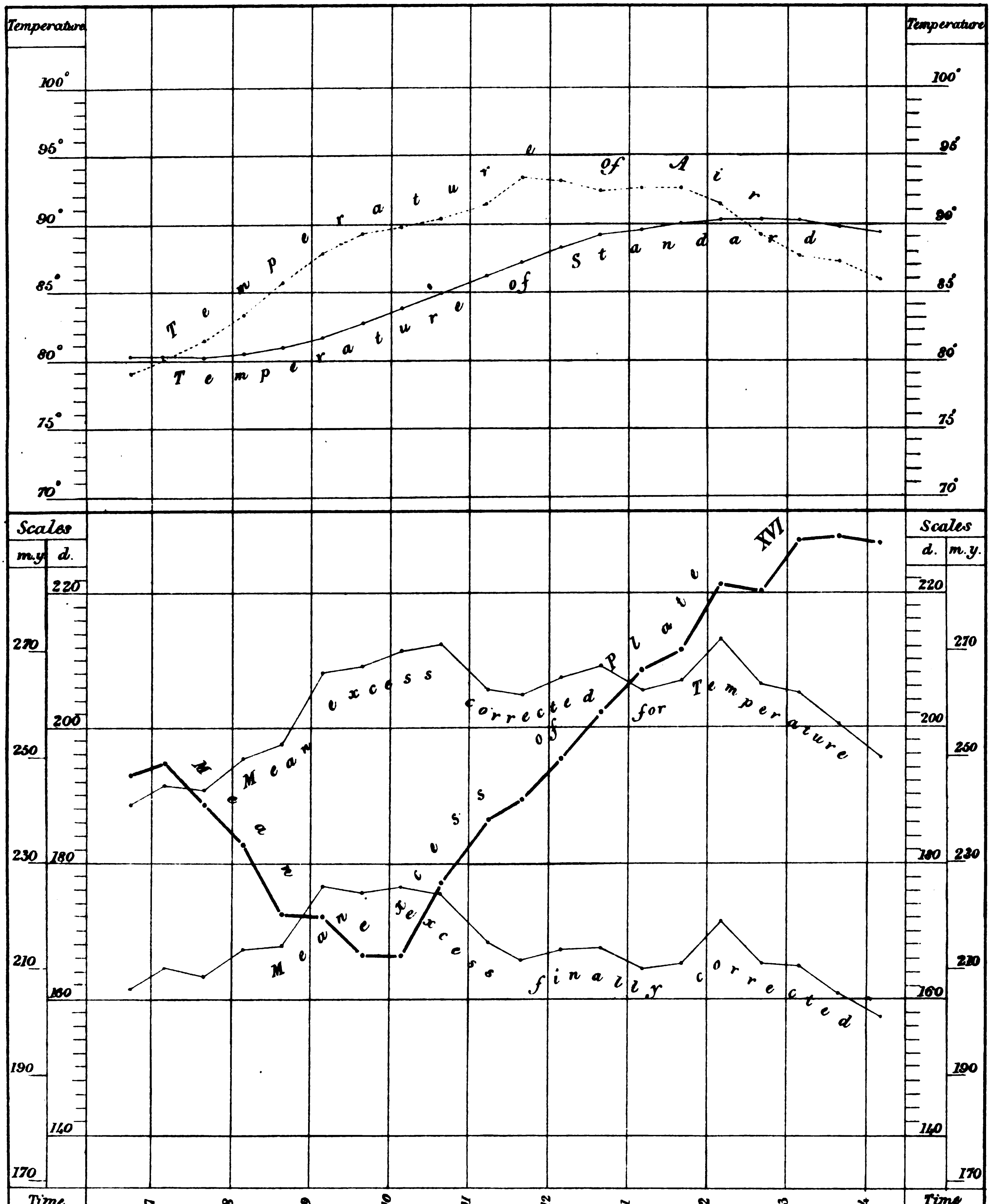
The horizontal intervals correspond to one hour. The upper vertical intervals correspond to 1° F. of temperature. The lower vertical intervals correspond to 2 divisions of the micrometer on the inner scale, and to 20 millionths of a yard on the outer scale.

C. Dyson, Photo

G. G. Ollenbach, Zinco.

Ordinary and corrected curves of excess of mean of Compensation Bars over Standard at 62° and curves of temperatures of air and of standard.

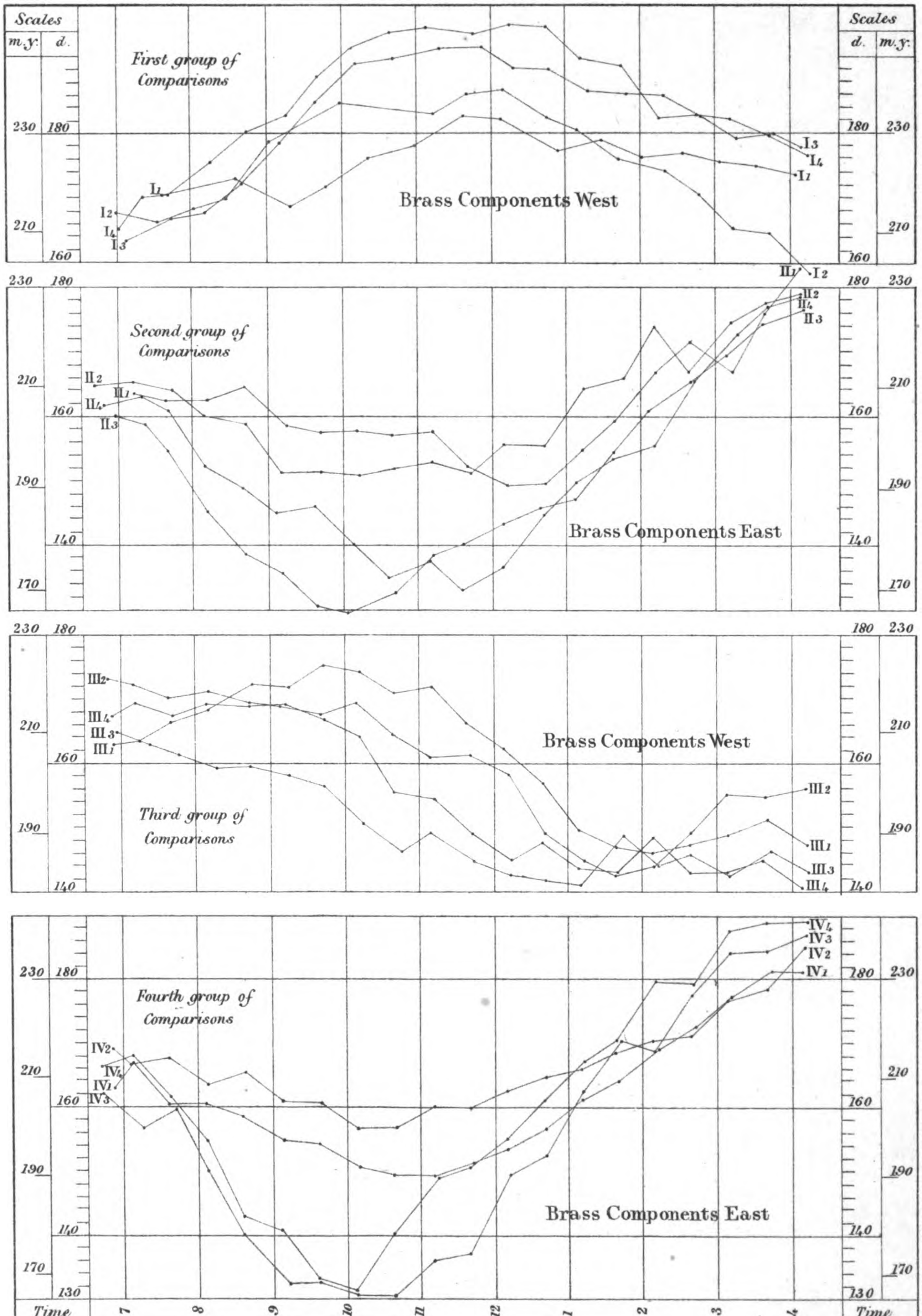
Cape Comorin Base. Brass Components East. *Comparisons (IV.4.) 10th March 1869.*



The horizontal intervals correspond to one hour The upper vertical intervals correspond to 1° F. of temperature. The lower vertical intervals correspond to 2 divisions of the micrometer on the inner scale, and to 20 millionths of a yard on the outer scale.

C. Dyson, Photo: C. G. Ollenbach, Zinco.

Cape Comorin Base. Curves of excess of mean of Compensation B[illegible]s over Standard, corrected for everything but difference of temperature of brass & iron components.



C. Dyson, Photo. C. G. Ollenbach, Zinco.