For Departmental use.

Survey of India.

DEPARTMENTAL PAPER—No. 7.

THE BAR COMPARISONS OF 1907 AND 1908.

BY

MAJOR H. M. COWIE, R.E.,

DEPUTY SUPERINTENDENT, SURVEY OF INDIA.

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PREFACE.

The following pages are based on a report and notes by Major Cowie. Major Cowie was absent on the Turco-Persian Frontier Commission at the time when the paper was being passed through the press, and some discretion had to be used in deciding what should be printed. In some cases the arrangement and wording was slightly altered when this appeared desirable. Minor inconsistencies were removed whenever these were noticed.

Babu Rasik Chandra Ray of the Computing Office scrutinised the copy and read all the proofs.

DEHRA DUN,
April, 1915.

J. de GRAAFF HUNTER.

THE BAR COMPARISONS OF 1907 AND 1908.

During the summer of 1907 the question of adopting the metre as the unit of length in geodetic operations in India was brought prominently forward, and the arguments for and against this step were considered and discussed by the Survey of India and eminent geodesists in England. The immediate cause, which gave rise to this question, was the prospective acquisition by the Survey of India of invar wires for the measurement of bases by the Jäderin method. These wires were to be made and tested at Sévres, where all the apparatus for the construction and the later standardizing of wires is adapted to the metre unit and where customs and procedure have been moulded to suit wires 24 metres in length, this being the length generally adopted by European Geodetic bodies. The Survey of India had to consider whether it would follow European example and use 24-metre wires, or whether, adhering to the 10-foot unit upon which all its past geodetic operations were based, it would provide itself with wires whose length was some multiple of this unit. The former alternative involved difficulties of standardizing the wires from time to time in the field and the referring of base measurements of the future to those of the past. With the latter alternative had to be considered the fact that the Indian 10-foot Bar (made about the year 1830) had now been outclassed by modern standards, both as regards design and construction,—also that this standard had already served its purpose as a unit for the Indian Survey and that the time was approaching when this survey* would be linked up with others based on the International Metre as unit. It was finally decided to adopt the metre as the geodetic unit and to use wires of 24 metres length; to procure a new 4-metre standard bar of invar†, for the standardizing of these wires whose length should be known in terms of the International Metre; and, to compare the old 10-foot Standard Bar **A** with the International Metre for the connection of future base measurements with those of the past.

* A connection with Russian Triangulation has been completed in 1913.

† A more complete set of standards together with the necessary comparator apparatus has since been acquired.

It is true that there already existed a value of the Indian Standard **A** in terms of the old metre. This value was not obtained, however, from direct comparisons, but through the sister bar **B**, the bar $\mathbf{I}_S$ and the Ordnance Yard, $\mathbf{Y}_{55}$.

The different steps of the deduction are as follows :—

$$\mathbf{I}_S - \mathbf{B} = +86\cdot81$$

millionths of a yard (later on abbreviated into *m.y*), determined by Clarke's comparisons in 1865 in England.

$$\mathbf{I}_S - \mathbf{A} = +82\cdot52\ m.y$$

as derived from the observations made between 1867 and 1870 in India. Combining these two values,

$$\mathbf{A} = \mathbf{B} + 4\cdot29\ m.y.$$

Further, from Clarke's determinations in 1865

$$\mathbf{B} = 3\cdot333{,}315{,}90\ \mathbf{Y}_{55}$$

and hence,

$$\mathbf{A} = 3\cdot333{,}320{,}19\ \mathbf{Y}_{55}$$

also from Clarke's determinations

$$\mathbf{Y}_{55} = 0\cdot914{,}391{,}43\ \mathrm{M}$$

where M represents the old metre.

Whence is derived

$$\mathbf{A} = 3\cdot047{,}959{,}42\ \mathrm{M}$$

and by introducing the value of M in terms of the International Metre, the length of **A** can be referred to the latter.

There were two objections, however, to adopting the relation between **A** and the International Metre arrived at as outlined above. One was that many stages were involved in the comparison, each step being a possible source of error. The value of **B** may have been fairly well known in terms of the metre, but to connect **A** with the metre, recourse had to be made to the comparison of both **A** and **B** with the bar $\mathbf{I}_S$. Now **B** was compared with this bar in England in 1865, **A** was compared with it in India in 1867-70. In the interim, the bar had been conveyed from England to India and the observations available offer no data for ascertaining whether the bar was or was not affected by the journey, and whether the absolute length of the bar on its arrival at Dehra Dūn was the same as it had been at Southampton. The value of the relation between **A** and the old metre thus depends, in great measure, on the degree of invariability maintained by the bar $\mathbf{I}_S$ during the period 1865–1870.

The other point was that the date at which the comparison had been made was so far distant, that it was quite reasonable to doubt whether the relationship then ascertained still held good. It is known that with time metal bars may undergo certain changes which affect their absolute length. The advisability of using for purposes of connecting new geodetic measurements, in terms of one unit, with old work in terms of another, a factor determined 50 years previously and for a metal bar possibly affected by time, was open to doubt.

For these reasons the adoption of 24-metre wires for the measurement of future geodetic bases necessitated the direct comparison of the Standard of India, Bar **A**, with the International Metre. For this purpose, the bar had to be sent to the Pavillon Breteuil at Sévres and, in order that some means should be available for indicating whether the absolute length of the bar had been unaffected or not by its transport, and, if affected, of determining the magnitude of the change, it was advisable that careful comparisons should be made in India both before and after its journey to Europe. These comparisons were made in November, December of 1907 and January of 1908 and in November and December of 1908, the bar in the interval going to Sévres and being compared with the International Metre. The comparisons carried out in India were of the Standard Bar **A** with the cast steel bar I_S and the bar I_B of Baily's metal (an alloy of copper, tin and zinc).

These two bars I_S and I_B were made in 1864 by Messrs. Troughton and Simms. The object of their construction was to settle questions that had been raised as to the possible variation of length which the standard might have suffered in the course of its several journeys from the Survey Head Quarters to the various base lines at which it was used.

Our knowledge of the relative lengths of the three bars was based on the following investigations:—

In 1834 and 1835, the bars **A** and **B** were compared at Dehra Dūn by Sir George Everest. The result he obtained was

$$\mathbf{B} - \mathbf{A} = 1{\cdot}24\ m.y, \text{ afterwards corrected to } 0{\cdot}64\ m.y.$$

This value, however, was not considered a very reliable one, on account of the difficulty there had been of determining the true temperatures of the bars during comparison, by reason both of the particular construction of the thermometers used and the imperfect knowledge of the errors of graduation of their scales.

The value adopted for the absolute expansion of **A**, in the first discussion of these comparisons, was $22{\cdot}669\ m.y$ for 1° F. This quantity had been determined by observation at Calcutta in 1832. Further examination of the various comparisons made at the different base lines, between this bar and the Colby compensated bars, showed that this value was probably too large. Further investigations, made in 1870, gave the result $21 \cdot 797$ *m.y** which has been employed in the reduction of all later measures made with this bar.

Of the expansion of bar **B** no direct determinations have ever been made. In the reduction of the 1834-35 comparisons, the observation equations were therefore formed to involve two unknown quantities, the difference between the lengths of the bars at 62° F and the difference of their absolute expansions.

These comparisons between bars **B** and **A**, when rediscussed, using the 1870 value of the expansion of **A**, gave the result $0 \cdot 64$ *m.y*, stated above, as the difference between the lengths of the bars and the quantity $- 0 \cdot 153$ as the difference in the values of their absolute expansions, making that for **B**, $21 \cdot 644$ *m.y.*

Clarke, in 1865, made comparisons between the bars **B**, $\mathbf{I}_B$, $\mathbf{I}_S$, $\mathbf{O}_1$, $\mathbf{OI}_1$, and $\mathbf{Y}_{55}$, the last three belonging to the Ordnance Survey, and found

$$\mathbf{I}_S - \mathbf{B} = 86 \cdot 81 \ m.y$$
$$\mathbf{I}_B - \mathbf{B} = 218 \cdot 27 \ \text{,,}$$

In the reduction of these observations, Clarke assumed that the expansion of **B** was the same as that of $\mathbf{O}_1$, which had been obtained by comparison with that of $\mathbf{OI}_1$. The absolute expansion of this latter bar was determined by direct experiment. The quantity thus deduced for **B** was $21 \cdot 532$ *m.y.*

The expansions used for $\mathbf{I}_B$ and $\mathbf{I}_S$ had been determined simultaneously by direct experiment, in 1865, by Clarke. The values were:—

$$\text{Expansion of } \mathbf{I}_B = 32 \cdot 759 \ m.y$$
$$\mathbf{I}_S = 21 \cdot 159 \ \text{,,}$$

The combination of Clarke's 1865 determination of the relative lengths of $\mathbf{I}_S$, $\mathbf{I}_B$ and **B** with Everest's comparison of **B** and **A** gave the first available values of $\mathbf{I}_S$ and $\mathbf{I}_B$ in terms of **A**.

From Everest's observations of 1834-35, using the later value of the expansion of **B**, we have

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

Clarke's values of 1865 were

$$\mathbf{I}_S - \mathbf{B} = 86 \cdot 81 \ m.y$$
$$\mathbf{I}_B - \mathbf{B} = 218 \cdot 27 \ \text{,,}$$

* Hennessey's value of 1870.

from which may be derived

$$I_S - A = 87 \cdot 45 \; m.y$$

$$I_B - A = 218 \cdot 91 \;\;,,$$

It is to be noted, however, that in the two series of comparisons, from which these quantities are deduced, slightly different values were allotted to the absolute expansion of bar **B**. In the comparisons with **A** the expansion was assumed to be 21·644 and in those with I_B and I_S the value 21·532 was used.

The first series of direct comparisons between the three bars **A**, I_B and I_S was carried out in 1867 at Dehra, measurements being made of the differences of length for each pair of bars. In the reduction of the observations the expansions adopted for I_B and I_S were those determined by Clarke in 1865 and for **A**, the value given by Everest. Thus the following expansions were used :—

Expansion of $I_B = 32 \cdot 759$ *m.y* per 1° F.

$I_S = 21 \cdot 159$,, ,, ,,

$A = 22 \cdot 669$,, ,, ,,

and the results of these observations were

$$I_B - I_S = 131 \cdot 40 \; m.y$$

$$I_B - A = 221 \cdot 32 \;\;,,$$

$$I_S - A = 89 \cdot 94 \;\;,,$$

In 1870, Mr. J. B. N. Hennessey undertook the redetermination of the expansions of the bars **A** and I_S. With this object, a comprehensive series of experiments was carried out at Mussooree, using apparatus adapted from that employed by Clarke in 1864–65. The results of these observations were

expansion of $A = 21 \cdot 797$ *m.y* per 1° F.

$I_S = 21 \cdot 290$,, ,, ,, ,,

This value of the expansion of I_S was then combined with Clarke's determination, 21·159, (resulting from Clarke's second series of observations) and the mean value thus deduced, 21·225, has been adopted in all measurements in which I_S has played a part since 1870. Since that date no further investigations have been made of the absolute expansions of the bars **A**, I_B and I_S, the following being accepted as final values :—

Expansion of $A = 21 \cdot 797$ *m.y* per 1° F.

$I_S = 21 \cdot 225$,, ,, ,, ,,

$I_B = 32 \cdot 759$,, ,, ,, ,,

Using these quantities, the comparisons of 1867 were reconsidered and the values given below deduced.

$$\mathbf{I}_S - \mathbf{A} = 80\cdot84\ m.y \quad \text{at } 62^\circ$$
$$\mathbf{I}_B - \mathbf{A} = 212\cdot64 \quad ,, \quad ,,$$
$$\mathbf{I}_B - \mathbf{I}_S = 132\cdot06 \quad ,, \quad ,,$$

Further, discussing the expansion experiments of 1870 by themselves, the relation between $\mathbf{I}_S$ and $\mathbf{A}$ was found to be

$$\mathbf{I}_S - \mathbf{A} = 84\cdot03\ m.y.$$

Four series of comparisons have thus been carried out, involving the bars $\mathbf{A}$, $\mathbf{B}$, $\mathbf{I}_B$ and $\mathbf{I}_S$.

Recapitulating, these are :—

No. of comparison	Bars compared	Year	Results
1	$\mathbf{B}$ and $\mathbf{A}$	1834–35	$\mathbf{B} - \mathbf{A} = 0\cdot64\ m.y$
2	$\mathbf{I}_S$, $\mathbf{I}_B$ and $\mathbf{B}$	1865 (a)	$\mathbf{I}_B - \mathbf{B} = 218\cdot27$,,
		(b)	$\mathbf{I}_S - \mathbf{B} = 86\cdot81$,,
		(c)	$\mathbf{I}_B - \mathbf{I}_S = 131\cdot46$,,
3	$\mathbf{I}_S$, $\mathbf{I}_B$ and $\mathbf{A}$	1867 (d)	$\mathbf{I}_S - \mathbf{A} = 80\cdot84$,,
		(e)	$\mathbf{I}_B - \mathbf{A} = 212\cdot64$,,
		(f)	$\mathbf{I}_B - \mathbf{I}_S = 132\cdot06$,,
4	$\mathbf{I}_S$ and $\mathbf{A}$	1870	$\mathbf{I}_S - \mathbf{A} = 84\cdot03$,,

By combining results (c) of comparison No. 2 with (e) of comparison No. 3, a value of $\mathbf{I}_S - \mathbf{A}$ is derived, viz. $81\cdot18\ m.y.$ Again, combining this value with result (d) of comparison No. 3 and the result of No. 4 comparison, and giving double weight to the latter, we get as a mean value

$$\mathbf{I}_S - \mathbf{A} = 82\cdot52\ m.y.$$

Combining this with Clarke's value of $\mathbf{I}_B - \mathbf{I}_S$, + $131\cdot46\ m.y$, we get

$$\mathbf{I}_B - \mathbf{A} = 213\cdot98\ m.y.$$

In 1870 these were accepted as the most probable values of the differences of length of the three bars.

No further investigations were made until the end of 1907, when the comparisons to be now described, were undertaken. The causes that led to this enquiry have already been stated.

It was at first intended to carry out a complete determination of the coefficients of expansion as well as of the relative lengths of the bars. With this object in view, suitable apparatus was designed. In consequence, however, of the necessary observers having to be obtained from field parties, the normal work of which would be temporarily suspended, the investigation of the expansions which would take a considerable time if results of any value were to be obtained, was abandoned, and the available means devoted to a careful comparison of the relative lengths at temperatures differing but little from 62° F.

The observations were commenced on 21st November, 1907, and were finished on 11th January, 1908, the observers being Major G. P. Lenox Conyngham, R.E., Captain H. M. Cowie, R.E. and Mr. J. de Graaff Hunter, M.A.

Of the difference $\mathbf{I}_S - \mathbf{A}$, 42 determinations were made, the temperatures during the observations ranging from 56°·5 to 68°·9. Of the two bars $\mathbf{I}_B$ and $\mathbf{A}$, 38 comparisons were carried out at temperatures varying from 55°·5 to 69°·2.

The final results of the observations were

$$\mathbf{I}_S - \mathbf{A} = 83{\cdot}12\ m.y \text{ at } 62^\circ$$

the mean temperature during comparison being 61°·15,

and
$$\mathbf{I}_B - \mathbf{A} = 196{\cdot}73\ m.y \text{ at } 62^\circ$$

the mean temperature during comparison being 61°·38.

The details of these observations are given later. On the conclusion of these investigations, bar $\mathbf{A}$ was sent to Sévres for comparison with the International Metre; after which it was once more returned to Dehra Dūn.

On its receipt there, the second series of comparisons was made. This was commenced on 17th November and concluded on 1st December, 1908, the observers being Captains H. H. Turner, R.E. and H. M Cowie, R.E. Twenty sets of comparisons were made of each bar $\mathbf{I}_B$ and $\mathbf{I}_S$ with $\mathbf{A}$. In the case of the observations of $\mathbf{I}_S - \mathbf{A}$, the temperatures ranged from 61°·1 to 65°·0 and during the comparisons of $\mathbf{I}_B$ and $\mathbf{A}$, they varied from 57°·0 to 65°·5.

The results obtained were

$$\mathsf{I}_S - \mathbf{A} = 81 \cdot 13 \; m.y \text{ at } 62^\circ$$

the mean temperature being $63^\circ \cdot 74$,

and

$$\mathsf{I}_B - \mathbf{A} = 193 \cdot 38 \; m.y \text{ at } 62^\circ$$

the mean temperature during observations being $61^\circ \cdot 99$.

A comparison of these two sets of values will at once show that it is probable no change took place in the length of the Standard Bar **A** between the time it left Dehra and the date of its return from Sévres.

In the reduction of the observations, the absolute expansions used were those adopted in 1870, viz.,

$$\text{Expansion of } \mathbf{A} = 21 \cdot 797 \; m.y \quad \text{for } 1^\circ \text{ F.}$$

$$\mathsf{I}_S = 21 \cdot 225 \quad ,, \qquad ,,$$

$$_B = 32 \cdot 759 \quad ,, \qquad ,,$$

The comparisons were carried out in the Bar Room at Dehra. This room has three outer walls, along one of which runs a verandah. It is double rooted, the inner flat roof being of concrete, the outer sloping one. of corrugated iron. To protect the building from the sun's direct rays, two outer walls and the roof were first covered with thick thatching and then outside this, leaving an air space of some 4 feet, were erected thick thatch walls, enclosing the whole building. Provision was also made to prevent the ingress of air from the outside when the observers and recorder entered the room. Two small glazed openings were left in the thatch walls to admit sufficient light to illuminate the defining marks of the bars when these were brought under the microscopes.

Within the room, the comparing microscopes, G and H, were placed on isolated brick pillars, east and west of one another. Between the pillars a travelling platform 8 feet 3 inches long and 4 feet 3 inches wide, was mounted on rails and capable of movement from north to south. On this platform were supported the bars and the bar boxes, the former on camels, the latter on wooden blocks as their weight and design made it impracticable to place them on the camels.

On account of the dimensions of bar **A** differing slightly from those of bars I_B and I_S, the box for the former was not exactly the same size as the box for the latter. The box consisted of two parts, an inner **U** shaped, double walled tank of galvanized iron fitting in an outer wooden case, the space between the two being packed with coarse felt and wool. The hollow U tank had been intended for the expansion experiments which were afterwards abandoned. In this investigation it had been proposed to bring the bar under consideration to any required temperature by means of hot or cold water admitted into this tank. Through the bottom of the tank were openings to admit the blocks carrying the rollers on which the bar rested. The interstices between these blocks and the tank were filled loosely with felt. Each box was provided with four thermometers one at each end dipping into the interior of the tank, to indicate the temperature of the water, and two more in the central channel in which the bar was disposed. These thermometers, passing through holes in the top of the tank and kept in position by felt wads, had to be withdrawn to be read.

Each bar in addition was provided with two bent bulb thermometers, the bulbs of which were placed in wells in the bar, filled with mercury or oil according to the nature of the bar. These thermometers were viewed through glazed openings covered by a felt flap removable at will, in the top of the tank and box.

The bar and its enclosing box each had its own supports. The box was supported on the travelling platform by four pairs of wooden blocks, cut to a suitable height to allow the bar, when adjusted with its defining marks in focus under the microscopes, to lie centrally in the inner channel of the tank.

The bar itself was carried by its rollers at the usual points of support. These rollers were mounted on wooden blocks, which passing through the openings in the tank and wooden case, were fixed to the longitudinal beam, which, in turn, rested on two camels. The openings in the box were of such a size as to allow of a small amount of traversing of the blocks carrying the rollers. This traversing was effected by means of the adjusting screws of the camels which acted directly on the longitudinal beam.

The two bars under comparison were arranged in their respective boxes, side by side on the traveller, by moving which each bar could be brought in turn under the microscopes. The defining marks at the ends of the bars were brought into focus in the usual way by means of the camel screws. It may be remarked here that an adjustment once made was maintained by the bars for a considerable time, and it was found that the movement of the traveller did not cause any disturbance of the focal adjustment.

In the top of the iron tank was an opening over each defining mark of the bar, to allow of the latter being viewed in the microscope. These openings could be covered when observations were not in progress by felt and a flap, hinged to the cover of the wooden case.

The thermometers used in the comparisons were:—

Bar A.

In the bar,	east end		β
,,	west ,,		a
In the central channel,	east ,,	Hicks,	379900
,,	west ,,	,,	361379
In the tank,	east ,,	,,	no number
,,	west ,,	,,	,,

Bars I_B and I_S.

In the bar,	east end	Casella,	7349
,,	west ,,	,,	7344
In the central channel,	east ,,	Hicks,	719477
,,	west ,,	Casella,	11923
In the tank,	east ,,	Hicks,	No. 8
,,	west ,,	,,	no number.

Between 14th and 22nd November, 1907, these thermometers and others were compared with the Standards Nos. 105368 and 105369 at temperatures ranging from 33° to 100° F. During the comparisons all the thermometers were wholly immersed in water in a glass tank. The water was brought to the required temperature by the introduction of either ice or hot water and thoroughly agitated to dispel irregularities of temperature. The readings were made by means of a telescope.

The corrections to thermometers 7344, 7349, 719477, 11923, 379900, 361379, No. 8, a and β as tabulated in Table I were deduced from the observations, and are based on the assumption that the mean corrected reading of the two standards indicated the true temperature.

TABLE I.—Corrections to Thermometers.

Indicated Temperature	Thermometer number								
	7344	7349	719477	11923	379900	361379	No. 8	α	β
°	°	°	°	°	°	°	°	°	°
33	...	...	...	...	...	...	...	+0·30	...
34	−1·10	−1·05	...	...	...	...	...	,,	−1·00
35	,,	,,	...	...	...	...	...	,,	,,
36	,,	,,	...	...	...	...	...	,,	,,
37	−1·15	,,	...	...	...	...	...	,,	,,
38	,,	,,	−0·75	−0·55	−0·70	−0·20	−0·35	+0·25	,,
39	,,	,,	,,	,,	,,	,,	,,	,,	,,
40	,,	,,	,,	,,	,,	,,	−0·30	+0·20	,,
41	,,	,,	,,	,,	,,	,,	−0·25	,,	,,
42	,,	,,	,,	,,	,,	,,	,,	+0·15	,,
43	,,	,,	,,	−0·60	,,	,,	−0·20	,,	−1·00
44	,,	,,	,,	,,	−0·65	,,	,,	+0·10	−1·05
45	−1·10	,,	,,	,,	,,	,,	,,	,,	,,
46	,,	,,	,,	,,	,,	,,	,,	+0·05	,,
47	−1·15	,,	,,	−0·65	,,	,,	,,	,,	−1·05
48	,,	,,	,,	,,	,,	,,	,,	,,	−1·10
49	,,	,,	,,	−0·70	,,	,,	,,	0·00	,,
50	,,	−1·10	,,	,,	,,	,,	,,	,,	,,
51	,,	,,	,,	,,	−0·70	,,	−0·15	−0·05	,,
52	,,	,,	,,	−0·75	,,	,,	,,	,,	,,
53	,,	,,	,,	,,	,,	,,	,,	−0·10	,,
54	,,	−1·05	,,	,,	−0·75	−0·25	,,	,,	,,
55	,,	,,	,,	−0·80	−0·80	,,	,,	,,	,,
56	,,	,,	,,	,,	,,	,,	,,	−0·15	,,
57	,,	,,	,,	,,	−0·85	,,	,,	,,	−1·10
58	,,	,,	,,	−0·85	,,	,,	,,	−0·20	−1·05
59	,,	,,	,,	,,	−0·90	,,	,,	,,	,,
60	−1·10	,,	,,	,,	,,	,,	,,	,,	,,
61	,,	,,	−0·80	,,	−0·95	,,	,,	,,	,,
62	,,	−1·00	,,	,,	,,	,,	,,	,,	,,
63	,,	,,	,,	−0·90	−1·00	,,	,,	,,	−1·05
64	,,	,,	−0·85	,,	,,	,,	,,	,,	−0·95
65	,,	,,	,,	,,	,,	,,	,,	−0·25	,,
66	,,	,,	,,	,,	,,	,,	,,	,,	,,
67	,,	,,	,,	,,	−1·05	,,	,,	,,	,,
68	,,	−1·05	,,	,,	,,	,,	,,	,,	,,
69	,,	,,	,,	,,	,,	,,	,,	,,	,,
70	−1·05	,,	,,	,,	,,	,,	,,	,,	,,
71	,,	,,	,,	,,	−1·00	,,	−0·10	−0·30	,,
72	,,	,,	,,	,,	,,	−0·20	,,	,,	,,
73	,,	,,	,,	,,	,,	,,	,,	,,	−0·95
74	−1·10	,,	,,	,,	−0·95	,,	,,	,,	−1·00
75	,,	,,	,,	,,	,,	,,	,,	−0·35	,,
76	,,	,,	,,	,,	,,	,,	−0·05	,,	−1·10
77	,,	,,	,,	,,	,,	,,	,,	,,	,,
78	−1·15	,,	,,	,,	,,	,,	,,	,,	,,
79	,,	,,	,,	,,	,,	,,	,,	−0·30	−1·15
80	,,	,,	,,	,,	,,	,,	,,	,,	,,
81	,,	,,	,,	,,	,,	,,	0·00	,,	,,
82	,,	,,	,,	,,	,,	,,	,,	,,	−1·15
83	,,	,,	,,	,,	,,	,,	,,	,,	−1·10
84	,,	,,	,,	,,	,,	,,	,,	−0·35	,,
85	,,	,,	,,	,,	,,	,,	,,	−0·40	−1·05
86	,,	,,	,,	,,	,,	,,	,,	−0·45	,,
87	,,	,,	,,	−0·95	,,	,,	,,	,,	,,
88	,,	,,	,,	,,	,,	,,	,,	,,	,,
89	,,	,,	,,	,,	,,	−0·25	,,	,,	,,
90	,,	,,	,,	,,	,,	,,	,,	,,	,,
91	,,	,,	,,	,,	,,	,,	,,	,,	−1·10
92	,,	,,	,,	,,	,,	,,	,,	,,	,,
93	,,	−1·10	,,	,,	,,	−0·30	,,	,,	−1·15
94	−1·20	,,	−0·90	,,	−1·00	,,	,,	,,	,,
95	,,	−1·15	,,	,,	,,	,,	,,	−0·50	,,
96	,,	,,	,,	,,	,,	,,	,,	,,	,,
97	,,	−1·20	,,	,,	,,	−0·35	,,	,,	,,
98	,,	,,	,,	−0·90	−1·05	,,	,,	−0·55	,,
99	,,	−1·00	,,	,,	,,	,,	,,	−0·60	,,
100	,,	,,	−0·95	,,	,,	,,	,,	,,	,,

The values of the micrometer screws of G and H microscopes were determined between the 21st and 29th November, 1907, by measuring, in terms of these screws, the spaces between the dots 3·0 and 3·5; 3·5 and 4·0; 7·5 and 8·0; 9·0 and 9·5 of the inch "a b" of the steel Foot IF, the value of all these spaces being accurately known. To indicate the temperature of IF, thermometer No. 4246 was fitted to the bar, its bent bulb projecting into a well, filled with mercury.

The bar itself was supported by a short iron girder resting on two camels, by means of the screws of which girder and bar could be moved in any desired direction.

Six sets of observations were made with each microscope, the observers being Major G. P. Lenox Conyngham, R. E., Captain H. M. Cowie, R. E. and Mr. J. de Graaff Hunter, M.A.

The values of the sub-divisions of the inch "a b," determined in 1870-71 are recorded in Appendix No. 9 of Vol. I of the Account of the Operations of the Great Trigonometrical Survey of India. These values were adopted for the purposes of the present investigation. For the spaces observed they are

			m.y
Space	3·0 to 3·5	=	1385·573
,,	3·5 to 4·0	=	1388·853
,,	7·5 to 8·0	=	1388·913
,,	9·0 to 9·5	=	1391·323.

The coefficient of expansion of IF was taken to be 0·000006367, the same as that of the steel bar I_S (*vide* p. (19), Vol. I).

The observations and the results obtained are summarized in Tables II and III.

TABLE II.—Determination of Micrometer Value of G Microscope.

Set	Date	Observer	Space of inch "a b"	Mean observed value of space in terms of G	Mean Temperature	Reduced value of 1 div. of G in *m. y*
	1907			*divisions*	°	
1	Nov. 21	H. M. C.	3·0–3·5	1202·54	68·56	1·1523
			3·5–4·0	1206.82	68·44	1·1509
			7·5–8·0	1205·62	68·30	1·1521
			9·0–9·5	1208·50	68·14	1·1513
					Mean	1·1516
2	Nov. 21	H. M. C.	3·0–3·5	1203·08	67·21	1·1517
			3·5–4·0	1205·28	67·47	1·1523
			7·5–8·0	1205·94	67·79	1·1518
			9·0–9·5	1208·62	68·07	1·1512
					Mean	1·1517
3	Nov. 22	G. P. L. C.	3·0–3·5	1200·34	67·09	1·1544
			3·5–4·0	1206·50	67·16	1·1512
			7·5–8·0	1213·12	67·23	1·1545
			9·0–9·5	1207·70	67·27	1·1521
					Mean	1·1531
4	Nov. 22	G. P. L. C.	3·0–3·5	1202·22	67·75	1·1526
			3·5–4·0	1204·32	67·60	1·1533
			7·5–8·0	1204·58	67·85	1·1531
			9·0–9·5	1207·72	67·93	1·1521
					Mean	1·1528
5	Nov. 23	J. de G. H.	3·0–3·5	1201·70	67·16	1·1530
			3·5–4·0	1203·90	67·04	1·1537
			7·5–8·0	1205·42	66·90	1·1523
			9·0–9·5	1208·98	66·75	1·1509
					Mean	1·1525
6	Nov. 23	J. de G. H.	3·0–3·5	1201·94	67·25	1·1528
			3·5–4·0	1204·22	67·20	1·1534
			7·5–8·0	1204·76	67·14	1·1529
			9·0–9·5	1207·72	67·06	1·1521
					Mean	1·1528

Final value of 1 division of G = 1·15241 *m. y.*

TABLE III.—Determination of Micrometer Value of H Microscope.

Set	Date	Observer	Space of inch "a b"	Mean observed value of space in terms of H	Mean Temperature	Reduced value of 1 div. of H in *m. y*
	1907			*divisions*	°	
1	Nov. 25	H. M. C.	3·0–3·5	1253·32	66·20	1·1056
			3·5–4·0	1256·28	66·35	1·1056
			7·5–8·0	1256·16	66·51	1·1057
			9·0–9·5	1259·36	66·66	1·1048
					Mean	1·1054
2	Nov. 25	G. P. L. C.	3·0–3·5	1252·60	66·94	1·1062
			3·5–4·0	1254·26	66·84	1·1073
			7·5–8·0	1254·62	66·71	1·1071
			9·0–9·5	1256·78	66·53	1·1071
					Mean	1·1069
3	Nov. 25	J. de G. H.	3·0–3·5	1252·80	67·60	1·1060
			3·5–4·0	1255·26	67·54	1·1065
			7·5–8·0	1256·52	67·44	1·1054
			9·0–9·5	1259·52	67·32	1·1047
					Mean	1·1057
4	Nov. 26	H. M. C.	3·0–3·5	1253·64	65·66	1·1053
			3·5–4·0	1257·32	65·99	1·1046
			7·5–8·0	1256·82	66·29	1·1051
			9·0–9·5	1260·42	66·50	1·1039
					Mean	1·1047
5	Nov. 26	J. de G. H.	3·0–3·5	1252·94	67·35	1·1059
			3·5–4·0	1255·12	67·23	1·1066
			7·5–8·0	1255·64	67·01	1·1062
			9·0–9·5	1259·50	66·78	1·1047
					Mean	1·1059
6	Nov. 28	G. P. L. C.	3·0–3·5	1255·16	66·57	1·1039
			3·5–4·0	1255·42	66·75	1·1063
			7·5–8·0	1255·74	66·88	1·1061
			9·0–9·5	1257·88	67·00	1·1061
					Mean	1·1056

Final value of 1 division of H = 1·10570 *m. y*.

Hence, 1 division of H = 0·95947 division of G.

The errors of the thermometers and the micrometer values of the two microscopes having been determined, the comparisons of the bars were commenced.

The procedure of the observations was as follows:—On the traveller were disposed the two bars, **A** and either $\mathbf{I}_S$ or $\mathbf{I}_B$, carefully adjusted in position and levelled. One bar was then brought under the microscopes, which were then adjusted correctly over the defining marks, levelled and set so that the images of the marks were in sharp focus. The mounting of these microscopes is very stable and throughout the operations there arose no reason to suspect any change of setting or position. The two microscopes, thus adjusted, constituted the comparator and from this point onwards, the lengths of the bars were referred to the distance between the zeros of the microscopes, which quantity was necessarily assumed to remain constant. This assumption is justifiable, as the interval of time between the measurement of one bar and the measurement of the other to be compared with it is very small. At each microscope was an observer, who also took readings of one of the two thermometers giving the temperature inside the tank, one of the two thermometers in the central channel and one of the two bar thermometers. The eastern observer, in addition, read the thermometer giving the temperature in the room.

To illuminate the scales of the thermometers and the drums of the micro meter, small electric glow lamps were used.

The following is the programme of the observations of one set; bar $\mathbf{I}_S$, let us say, being under comparison.

Bar **A** was brought under the microscopes and examination was made of the quality of the focal setting of the defining marks. The same was then done for $\mathbf{I}_S$.

The focal setting and positions of the bars having been examined and corrected if necessary, the eastern observer read the thermometer giving the room temperature. Then followed in order

(1)	The readings of the tank thermometers,	For bar $\mathbf{I}_S$
(2)	,, ,, central channel thermometers,	
(3)	,, ,, bar thermometers,	
(4)	,, ,, microscopes G and H,	
(5)	,, ,, bar thermometers; after which the traveller was moved till bar **A** came in position.	

(6) The readings of the bar thermometers,
(7) „ „ microscopes G and H,
(8) „ „ bar thermometers,
(9) „ „ central channel thermometers,
(10) „ „ tank thermometers,
(11) „ „ bar thermometers,
(12) „ „ microscopes G and H,
(13) „ „ bar thermometers; after which the bar $\mathbf{I}_S$ was again moved under the microscopes.

} For bar $\mathbf{A}$

(14) The readings of the bar thermometers,
(15) „ „ microscopes G and H,
(16) „ „ bar thermometers,
(17) „ „ central channel thermometers,
(18) „ „ tank thermometers; after which the room thermometer was again read by the eastern observer.

} For bar $\mathbf{I}_S$

This constituted one set of observations. The observers then changed places and a similar set was taken.

Each day two sets were observed while the temperature of the outer air was rising and two while it was falling. At each observation with the microscope at least three intersections of the defining mark were made. The intersections of the east and west marks were made simultaneously and no readings were taken unless both observers were satisfied that their respective intersections were good. In all observations whether with the microscopes or the thermometers, the eastern observer made his reading first.

During sets Nos. 1–10, 22–32, the heads of the micrometers were turned towards one another and in the remaining sets, away from one another. In the former case, increasing micrometer readings corresponded with an increasing length of the bar. Thus if D represents the distance between the zeros of the microscopes, L the length of the bar and M the sum of the micrometer readings,

$$L = D + M.$$

In the latter case, where the micrometer heads were turned away from each other, increasing readings corresponded with a decreasing length of the bar.

Hence,
$$L = D - M.$$

On the 31st December, to maintain the temperature at the required point, two small stoves were placed in the room and kept at a low heat. On the 4th January two more stoves were introduced.

Table IV is an abstract of the observations and shows the resulting values of $\mathbf{I}_S - \mathbf{A}$: and Table V gives the same information with respect to the bar $\mathbf{I}_B$. The values of $\mathbf{I}_S - \mathbf{A}$ and $\mathbf{I}_B - \mathbf{A}$ together with the mean temperature of the bars compared are summarized in Table VI.

In all cases G microscope was at the east end and H microscope at the west end.

TABLE IV.—Abstract of Comparisons between **A** *and* I_S *with deduced results.*
(Micrometer heads turned towards each other).

No. of set	Date		Position of observers		Bar	Corrected Mean temperatures			Mean observed values of I_S − D and **A** − D		Reduction to 62° F.	I_S − **A** at 62° F.
			East end	West end		Room	Air space	Bar	in terms of G	in $m.y$		
	1907					°	°	°	divns.		$m.y$	$m.y$
1	Dec.	16	H. M. C.	J de G. H.	I_S	59·65	58·50	58·26	1642·38	1892·70	+ 79·38	
					A		58·98	58·28	1569·20	1808·36	+ 81·08	82·64
2	,,	16	J. de G. H.	H. M. C.	I_S	59·80	58·93	58·39	1643·29	1893·74	+ 76·62	
					A		59·33	58·48	1571·07	1810·52	+ 76·73	83·11
3	,,	17	J. de G. H	H. M. C.	I_S	58·78	58·25	58·33	1638·35	1888·05	+ 77·90	
					A		58·23	58·05	1559·04	1796·65	+ 86·10	83·20
4	,,	17	H. M. C.	J. de G. H.	I_S	59·05	58·35	58·34	1639·09	1888·90	+ 77·68	
					A		58·38	57·98	1561·25	1799·20	+ 87·62	79·76
5	,,	17	H. M. C.	J. de G. H.	I_S	59·18	58·63	58·43	1641·23	1891·37	+ 75·77	
					A		58·73	58·28	1563·77	1802·10	+ 81·08	83·96
6	,,	17	J. de G. H.	H. M. C	I_S	59·55	58·90	58·48	1645·40	1896·18	+ 74·71	
					A		58·73	58·36	1564·67	1803·14	+ 79·34	88·41
7	,,	18	J. de G. H.	H. M. C.	I_S	58·63	58·09	58·09	1632·21	1880·98	+ 82·99	
					A		57·90	57·84	1550·87	1787·24	+ 90·68	86·05
8	,,	18	H. M. C.	J. de G. H.	I_S	58·75	58·23	58·05	1633·55	1882·52	+ 83·84	
					A		58·10	57·75	1554·13	1790·99	+ 92·64	82·73
9	,,	18	H. M. C.	J. de G. H.	I_S	59·25	58·35	58·12	1634·90	1884·08	+ 82·35	
					A		58·33	57·90	1558·66	1796·22	+ 89·37	80·84
10	,,	18	J. de G. H.	H. M. C.	I_S	59·45	58·29	58·19	1638·89	1888·67	+ 80·87	
					A		58·50	58·05	1562·02	1800·08	+ 86·10	83·36
22	,,	24	G. P. L. C.	H. M. C.	I_S	57·70	57·03	56·78	1602·90	1847·20	+ 110·79	
					A		56·70	56·51	1528·43	1761·38	+ 119·67	76·94
23	,,	24	G. P. L. C.	H. M. C.	I_S	57·90	57·18	56·86	1607·02	1851·95	+ 109·10	
					A		57·05	56·79	1533·64	1767·38	+ 113·56	80·11
24	,,	24	H. M. C.	G. P. L. C.	I_S	58·20	57·20	56·88	1611·29	1856·87	+ 108·67	
					A		57·15	56·83	1533·22	1766·90	+ 112·69	85·95

Mean value of I_S − **A** (micrometer heads turned towards each other) 82·85 $m.y$
Mean temperature ... ... 57°·86 F.

TABLE IV.—Abstract of Comparisons between A and I_S with deduced results.—(Contd.)
(Micrometer heads turned away from one another).

No. of set	Date	Position of observers		Bar	Corrected Mean temperatures			Mean observed values of D − I_S and D − A		Reduction to 62° F.	I_S − A at 62° F.
		East end	West end		Room	Air space	Bar	in terms of G	in m.y		
	1907				°	°	°	divns.		m.y	m.y
11	Dec. 19	J. de G. H.	H. M. C.	I_S	58·50	57·77	57·79	2305·53	2656·92	− 89·36	
				A		57·80	57·54	2387·49	2751·37	− 97·21	86·60
12	„ 19	H. M. C.	J. de G. H.	I_S	58·65	58·02	57·81	2305·21	2656·55	− 88·93	
				A		58·00	57·47	2390·52	2754·86	− 98·74	88·50
13	„ 19	H. M. C.	J. de G. H.	I_S	58·70	58·08	57·91	2305·30	2656·65	− 86·81	
				A		58·25	57·67	2381·69	2744·68	− 94·38	80·46
14	„ 19	J. de G. H.	H. M. C.	I_S	59·10	58·23	57·95	2300·66	2651·30	− 85·96	
				A		58·25	57·82	2379·40	2742·04	− 91·11	85·59
15	„ 20	J. de G. H.	H. M. C.	I_S	58·15	57·48	57·52	2312·64	2665·11	− 95·09	
				A		57·40	57·25	2392·65	2757·31	−103·54	83·75
16	„ 20	H. M. C.	J. de G. H.	I_S	58·35	57·82	57·53	2314·15	2666·85	− 94·88	
				A		57·60	57·22	2394·12	2759·01	−104·19	82·85
17	„ 20	J. de G. H.	H. M. C.	I_S	58·70	57·83	57·60	2309·74	2661·77	− 93·39	
				A		57·65	57·54	2387·00	2750·80	− 97·21	85·21
18	„ 20	H. M. C.	J. de G. H.	I_S	58·95	58·03	57·62	2310·26	2662·37	− 92·97	
				A		57·80	57·53	2387·24	2751·08	− 97·43	84·25
19	„ 23	H. M. C.	G. P. L. C.	I_S	57·78	57·15	56·90	2324·06	2678·27	−108·25	
				A		57·00	56·78	2406·73	2773·54	−113·78	89·74
20	„ 23	G. P. L. C.	H. M. C.	I_S	58·08	57·20	56·97	2323·60	2677·74	−106·76	
				A		57·30	56·88	2400·87	2766·79	−111·60	84·21
21	„ 24	H. M. C.	G. P. L. C.	I_S	57·40	56·93	56·80	2328·13	2682·96	−110·37	
				A		56·70	56·45	2413·03	2780·80	−120·97	87·24
	1908										
53	Jan. 4	H. M. C.	G. P. L. C.	I_S	65·70	64·15	64·06	1917·10	2209·29	+ 43·72	
				A		64·03	63·81	1993·63	2297·48	+ 39·45	83·92
54	„ 4	G. P. L. C.	H. M. C.	I_S	65·85	64·15	64·05	1918·76	2211·20	+ 43·51	
				A		64·08	63·86	1989·76	2293·02	+ 40·54	78·85

TABLE IV.—*Abstract of Comparisons between* A *and* I_S *with deduced results—(Contd.)*
(Micrometer heads turned away from one another).

No. of set	Date	Position of observers: East end	Position of observers: West end	Bar	Corrected Mean temperatures: Room	Corrected Mean temperatures: Air space	Corrected Mean temperatures: Bar	Mean observed values of D − I_S and D − A: in terms of G	Mean observed values of D − I_S and D − A: in m.y	Reduction to 62° F.	I_S − A at 62° F.
	1908				°	°	°	dirns.		m.y	m. y
55	Jan. 4	G. P. L. C.	H. M. C.	I_S	69·00	65·50	65·01	1902·00	2191·88	+ 63·89	
				A		65·83	64·98	1969·44	2269·60	+ 64·96	78·79
56	„ 4	H. M. C.	G. P. L. C.	I_S	69·15	66·13	65·28	1903·35	2193·44	+ 69·62	
				A		65·93	65·02	1970·75	2271·11	+ 65·83	73·88
57	„ 5	G. P. L. C.	H. M. C.	I_S	71·00	69·05	68·57	1800·42	2074·82	+139·45	
				A		68·90	68·47	1868·02	2152·72	+141·03	79·48
58	„ 5	H. M. C.	G. P. L. C.	I_S	70·25	68·95	68·85	1852·90	2135·30	+145·39	
				A		68·95	68·72	1925·59	2219·07	+146·48	84·86
59	„ 5	H. M. C.	G. P. L. C.	I_S	69·10	69·03	68·89	1873·88	2159·48	+146·24	
				A		68·85	68·77	1945·60	2242·13	+147·57	83·98
60	„ 5	G. P. L. C.	H. M. C.	I_S	69·30	69·08	68·92	1879·37	2165·80	+146·88	
				A		68·95	68·84	1947·23	2244·01	+149·09	80·42
61	„ 6	J. de G. H.	H. M. C.	I_S	65·75	65·08	65·25	1989·54	2292·77	+ 68·98	
				A		64·88	64·93	2064·81	2379·51	+ 63·87	81·63
62	„ 6	H. M. C.	J. de G. H.	I_S	66·05	65·08	65·18	1992·10	2295·72	+ 67·50	
				A		64·98	64·82	2070·38	2385·93	+ 61·47	84·18
63	„ 6	J. de G. H.	H. M. C.	I_S	66·30	65·08	65·08	2007·60	2313·58	+ 65·37	
				A		65·08	64·90	2082·82	2400·26	+ 63·21	84·52
64	„ 6	H. M. C.	J. de G. H.	I_S		65·10	65·08	2009·88	2316·21	+ 65·37	
				A	66·45	64·78	64·83	2084·00	2401·62	+ 61·69	81·73
65	„ 7	G. P. L. C.	J. de G. H.	I_S		65·33	65·00	1944·29	2240·62	+ 63·68	
				A	66·45	64·98	64·75	2019·33	2327·10	+ 59·94	82·74
66	„ 7	J. de G. H.	G. P. L. C.	I_S		65·10	64·99	1941·28	2237·15	+ 63·46	
				A	66·65	65·08	64·78	2019·42	2327·20	+ 60·60	87·19
67	„ 7	J. de G. H.	H. M. C.	I_S		65·58	65·32	1872·45	2157·83	+ 70·47	
				A	67·70	65·68	65·21	1944·68	2241·07	+ 69·97	82·74
68	„ 7	H. M. C.	J. de G. H.	I_S		65·65	65·39	1872·28	2157·63	+ 71·95	
				A	68·05	65·83	65·27	1944·98	2241·41	+ 71·28	83·11

TABLE IV.—Abstract of Comparisons between* A *and* I_s *with deduced results.—(Contd.)
(Micrometer heads turned away from one another).

Set of No.	Date	Position of observers		Bar	Corrected Mean temperatures			Mean observed values of D − I_s and D − A		Reduction to 62° F	s − A at 62° F
		East end	West end		Room	Air space	Bar	in terms of G	in $m.y$		
	1906				°	°	°	divns.		$m.y$	$m.y$
69	Jan. 8	J. de G. H	H. M. C.	I_s	67·55	66·0	65·82	1909·66	2200·71	+81·08	82·69
				A		65·95	65·67	1982·36	2284·49	+79·99	
70	„ 8	H. M. C.	J. de G. H.	I_s	67·80	65·98	65·86	1909·55	2200·58	+81·93	80·66
				A		65·98	65·59	1982·73	2284·92	+78·25	

Mean value of I_s − A (micrometer heads turned away from one another) 83·23 $m.y$
Mean temperature ... ... 62°·63 F.

TABLE V.—Abstract of Comparisons between **A** *and* I_B *with deduced results.*
(Micrometer heads turned towards each other).

No. of set	Date		Position of observers: East end	Position of observers: West end	Bar	Corrected Mean temperatures: Room	Corrected Mean temperatures: Air space	Corrected Mean temperatures: Bar	Mean observed values of I_B – D and A – D: in terms of G	Mean observed values of I_B – D and A – D: in *m.y*	Reduction to 62° F.	I_B – A at 62° F.
	1907					°	°	°	*divns.*		*m.y*	*m.y*
25	Dec.	26	H. M. C.	G. P. L. C.	I_B	56·50	56·03	55·93	1626·44	1874·33	+198·85	
					A		55·78	55·45	1503·25	1732·36	+142·77	198·05
26	,,	26	G. P. L. C.	H. M. C.	I_B	56·70	56·18	55·92	1624·58	1872·18	+199·17	
					A		55·78	55·47	1505·74	1735·22	+142·33	193·80
27	,,	26	G. P. L. C.	H. M. C.	I_B	57·15	56·23	55·93	1625·80	1873·59	+198·85	
					A		56·30	55·74	1511·98	1742·42	+136·45	193·57
28	,,	26	H. M. C.	G. P. L. C.	I_B	57·40	56·30	55·95	1629·42	1877·76	+198·19	
					A		56·20	55·78	1510·20	1740·37	+135·58	200·00
29	,,	27	J. de G. H.	H. M. C.	I_B	56·40	55·98	55·83	1623·00	1870·36	+202·12	
					A		55·78	55·53	1503·80	1732·99	+141·03	198·46
30	,,	27	H. M. C.	J. de G. H.	I_B	56·60	56·18	55·85	1623·45	1870·88	+201·47	
					A		56·18	55·46	1503·57	1732·73	+142·55	197·07
31	,,	27	J. de G. H.	H. M. C.	I_B	56·95	56·15	55·85	1626·29	1874·15	+201·47	
					A		56·38	55·79	1512·76	1743·32	+135·40	196·90
32	,,	27	J. de G. H.	H. M. C.	I_B	57·25	56·28	55·93	1628·68	1876·91	+198·85	
					A		56·28	55·80	1512·00	1742·44	+135·14	198·18

Mean value of I_B – A (micrometer heads turned towards each other) 197·00 *m.y*
Mean temperature ... ... 55°·76 F.

TABLE V.—Abstract of Comparisons between **A** *and* I_B *with deduced results—(Contd.).*
(Micrometer heads turned away from one another).

No. of set	Date		Position of observers: East end	Position of observers: West end	Bar	Corrected Mean temperatures: Room	Corrected Mean temperatures: Air space	Corrected Mean temperatures: Bar	Mean observed values of D − I_B and D − A: in terms of G	Mean observed values of D − I_B and D − A: in m.y	Reduction to 62° F.	I_B − A at 62° F.
	1907					°	°	°	divns.		m.y	m.y
33	Dec.	28	G. P. L. C.	J. de G. H.	I_B	56·50	56·05	55·97	2309·72	2661·74	−197·54	
					A		55·88	55·77	2430·04	2800·40	−135·80	200·40
34	,,	28	J. de G. H.	G. P. L. C.	I_B	56·80	56·18	55·92	2308·43	2660·26	−199·17	
					A		55·98	55·70	2430·77	2801·24	−137·32	202·83
35	,,	28	J. de G. H.	G. P. L. C.	I_B	56·75	56·28	55·95	2306·89	2658·48	−198·19	
					A		56·15	55·84	2426·00	2795·75	−134·27	201·19
36	,,	28	G. P. L. C.	J. de G. H.	I_B	57·30	56·23	55·98	2307·01	2658·62	−197·21	
					A		56·45	55·85	2425·39	2795·04	−134·45	199·18
37	,,	29	G. P. L. C.	H. M. C.	I_B	56·35	56·08	55·94	2311·44	2663·73	−198·52	
					A		55·78	55·66	2430·11	2800·48	−138·19	197·08
38	,,	29	H. M. C	G. P. L. C.	I_B	56·65	56·15	55·93	2309·68	2661·70	−198·85	
					A		55·93	55·63	2431·30	2801·85	−138·85	200·15
39	,,	29	G. P. L. C.	H. M. C.	I_B	56·70	56·23	55·93	2310·29	2662·40	−198·85	
					A		56·30	55·82	2424·56	2794·09	−134·71	195·83
40	,,	29	H. M. C.	G. P. L. C.	I_B	57·10	56·38	55·94	2307·10	2658·73	−198·52	
					A		56·35	55·82	2427·85	2797·88	−134·71	202·96
	1908											
41	Jan.	1	G. P. L. C.	H. M. C.	I_B	63·60	62·00	61·70	1843·06	2123·96	− 9·83	
					A		61·70	61·40	2015·25	2322·39	− 13·08	195·18
42	,,	1	H. M. C.	G. P. L. C.	I_B	64·00	62·10	61·86	1834·53	2114·13	− 4·59	
					A		62·13	61·66	2008·09	2314·14	− 7·41	197·19
43	,,	1	H. M. C.	G. P. L. C.	I_B	64·30	62·58	62·13	1835·41	2115·14	+ 4·26	
					A		62·78	61·95	2007·56	2313·53	− 1·09	193·04
44	,,	1	G. P. L. C.	H. M. C.	I_B	64·75	62·80	62·18	1834·10	2113·64	+ 5·90	
					A		62·88	62·19	2002·15	2307·30	+ 4·14	191·90
45	,,	2	G. P. L. C.	J. de G. H.	I_B	64·15	62·93	62·93	1802·77	2077·53	+ 30·47	
					A		62·83	62·69	1983·11	2285·36	+ 15·04	192·40

TABLE V.—Abstract of Comparisons between **A** *and* I_B *with deduced results—(Contd.).*
(Micrometer heads turned away from one another).

No. of set	Date		Position of observers		Bar	Corrected Mean temperatures			Mean observed values of D − I_B and D − A		Reduction to 62° F.	I_B − A at 62° F.
			East end	West end		Room	Air space	Bar	in terms of G	in m.y		
	1908					°	°	°	divns.		m.y	m.y
46	Jan.	2	J. de G. H.	G. P. L. C.	I_B	64·20	63·10	62·90	1811·88	2088·03	+ 29·48	
					A		63·17	62·76	1993·11	2296·88	+ 16·57	195·94
47	,,	2	J. de G. H.	G. P. L. C.	I_B	64·65	63·13	62·98	1834·04	2113·57	+ 32·10	
					A		63·32	62·90	2014·60	2321·65	+ 19·62	195·60
48	,,	2	G. P. L. C.	J. de G. H.	I_B	65·05	63·15	63·01	1835·68	2115·46	+ 33·09	
					A		63·28	62·93	2014·94	1322·04	+ 20·27	193·76
49	,,	3	J. de G. H.	H. M. C.	I_B	65·68	64·03	63·90	1714·61	1975·93	+ 62·24	
					A		63·88	63·73	1905·71	2196·16	+ 37·71	195·70
50	,,	3	H. M. C.	J. de G. H.	I_B	65·93	64·03	63·90	1717·79	1979·60	+ 62·24	
					A		64·13	63·70	1909·92	2201·01	+ 37·05	196·22
51	,,	3	J. de G. H.	H. M. C.	I_B	66·40	64·38	64·21	1728·62	1992·08	+ 72·40	
					A		64·48	64·11	1920·99	2213·77	+ 45·99	195·28
52	,,	3	H. M. C.	J. de G. H.	I_B	66·73	64·53	64·27	1733·64	1997·86	+ 74·36	
					A		64·72	64·20	1925·15	2218·56	+ 47·95	194·29
71	,,	9	J. de G. H.	H. M. C.	I_B	68·80	68·38	68·31	1779·45	2050·66	+ 206·71	
					A		68·35	68·11	2012·05	2318·71	+ 133·18	194·52
72	,,	9	H. M. C.	J. de G. H.	I_B	69·05	68·33	68·30	1777·90	2048·87	+ 206·38	
					A		68·35	68·06	2012·05	2318·71	+ 132·09	195·55
73	,,	9	G. P. L. C.	H. M. C.	I_B	71·45	68·85	68·42	1763·04	2031·74	+ 210·31	
					A		68·95	68·37	1994·00	2297·91	+ 138·85	194·71
74	,,	9	H. M. C.	G. P. L. C.	I_B	71·60	69·73	68·46	1760·29	2028·58	+ 211·62	
					A		69·05	68·42	1993·57	2297·41	+ 139·94	197·15
75	,,	10	G. P. L. C.	J. de G. H.	I_B	69·80	69·38	69·23	1695·12	1953·47	+ 236·85	
					A		69·20	69·02	1936·45	2231·58	+ 153·01	194·27
76	,,	10	J. de G. H.	G. P. L. C.	I_B	69·70	68·10	69·18	1701·17	1960·45	+ 235·21	
					A		68·85	68·95	1948·24	2245·17	+ 151·49	201·00
77	,,	10	J. de G. H.	G. P. L. C.	I_B	70·35	69·13	69·01	1738·79	2003·80	+ 229·64	
					A		68·90	68·80	1981·74	2283·78	+ 148·22	198·56

TABLE V.—Abstract of Comparisons between **A** *and* I_B *with deduced results—(Contd.).*
(Micrometer heads turned away from one another).

No. of set	Date		Position of observers		Bar	Corrected Mean temperatures			Mean observed values of D − I_B and D − A		Reduction to 62° F.	I_B − A at 62° F.
			East end	West end		Room	Air space	Bar	in terms of G	in m.y		
	1908					°	°	°	divns.		m.y	m.y
78	Jun.	10	G. P. L. C.	J. de G. H.	I_B	70·90	69·08	69·00	1740·96	2006·30	+229·31	
					A		68·95	68·83	1980·96	2282·88	+148·87	196·14
79	,,	11	J. de G. H.	H. M. C.	I_B	69·90	68·00	67·70	1747·95	2014·36	+186·73	
					A		67·70	67·54	1975·26	2276·31	+120·76	195·98
80	,,	11	H. M. C.	J. de G. H.	I_B	70·50	68·00	67·69	1745·88	2011·97	+186·40	
					A		67·90	67·53	1972·79	2273·46	+120·54	195·63

Mean value of I_B − A (micrometer heads turned away from one another) 196·65 m.y
Mean temperature ... ... 62°·88 F.

TABLE VI.—Values of $I_S - A$ *and* $I_B - A$ *reduced to 62° F. as determined at Dehra, Nov. 1907—Jan. 1908.*

No. of set	Mean temperature of Bars I_S and A	Value of $I_S - A$	No. of set	Mean temperature of Bars I_B and A	Value of $I_B - A$
	°	m.y		°	m.y
1	58·27	82·64	25	55·69	198·05
2	58·44	83·11	26	55·70	193·80
3	58·19	83·20	27	55·83	193·57
4	58·16	79·70	28	55·87	200·00
5	58·35	83·96	29	55·68	198·46
6	58·42	88·41	30	55·65	197·07
7	57·97	86·05	31	55·82	196·90
8	57·90	82·73	32	55·87	198·18
9	58·01	80·84	33	55·87	200·40
10	58·12	83·36	34	55·81	202·83
11	57·66	86·60	35	55·89	201·19
12	57·64	88·50	36	55·92	199·18
13	57·79	80·46	37	55·80	197·08
14	57·89	85·59	38	55·78	200·15
15	57·38	83·75	39	55·87	195·83
16	57·38	82·85	40	55·88	202·96
17	57·57	85·21	41	61·55	195·18
18	57·57	84·25	42	61·76	197·19
19	56·84	89·74	43	62·04	193·04
20	56·93	84·21	44	62·18	191·90
21	56·63	87·24	45	62·81	192·40
22	56·64	76·94	46	62·83	195·94
23	56·83	80·11	47	62·94	195·60
24	56·85	85·95	48	62·97	193·76
53	63·93	83·92	49	63·82	195·70
54	63·96	78·85	50	63·80	196·22
55	65·00	78·79	51	64·16	195·28
56	65·15	73·88	52	64·23	194·29
57	68·52	79·48	71	68·21	194·52
58	68·78	84·86	72	68 18	195·55

TABLE VI.—Values of I_S — A *and* I_B — A *reduced to 62° F. as determined at Dehra, Nov. 1907 —Jan. 1908—(Contd.).*

No. of set	Mean temperature of Bars I_S and A	Value of I_S — A	No. of set	Mean temperature of Bars I_B and A	Value of I_B — A
	°	m y		°	m y
59	68·83	83·98	73	68·40	194·71
61	68·88	80·42	74	68·44	197·15
60	65·09	81·63	75	69·12	194·27
62	65·00	84·18	76	69·07	201·00
63	64·99	84·52	77	68·90	198·56
64	64·96	81·73	78	68·92	196·14
65	64·87	82·74	79	67·62	195·98
66	64·89	87·19	80	67·61	195·63
67	65·27	82·74			
68	65·33	83·11			
69	65·75	82·69			
70	65·72	80·66			

TABLE VII.—Mean values of I_S — A *and* I_B — A *reduced to 62° F. from Dehra observations, Nov. 1907—Jan. 1908.*

	I_S — A and Temperature	I_B — A and Temperature
Mean value for temperatures below 62°	**83·98** *m y*	**198·22** *m.y*
Corresponding mean temperature	**57°·64** F.	**56°·46** F.
Mean value for temperatures above 62°	**81·97** *m y*	**195·38** *m.y*
Corresponding mean temperature	**65°·84** F.	**65°·81** F.
General mean value ...	**83·12 ± 0·33** *m.y*	**196·73 ± 0·30** *m.y*
General mean temperature ...	**61°·15** F.	**61°·38** F.

After these observations had been completed bar **A**, as stated above, was sent to Sévres for comparison with the International Metre. It was then returned to India, and a second set of comparisons was carried out in November and December, 1908. The same method and procedure in general was followed as had been done in the comparisons already described. No new determinations of the thermometer errors were made, but the same thermometers were used in identical places; nor were the values of the micrometer errors of G and H microscopes redetermined. The old values in both cases were accepted.

Comparisons Nos. 1 to 10 inclusive and Nos. 31 to 40 inclusive dealt with the differences $\mathbf{I}_B$ — **A**. Of these comparisons Nos. 1 to 10 were made with the micrometer heads turned towards each other and with the end of the bar **A** marked "Troughton and Simms" towards the west. In the remainder the heads of the micrometers were away from one another and "Troughton and Simms" towards the east. Comparisons Nos. 11 to 30 inclusive gave values of the quantity $\mathbf{I}_S$ — **A**. Of these Nos. 11 to 20 were made with the micrometer heads towards each other and "Troughton and Simms" towards the west. In the remaining comparisons these conditions were reversed. The two observers H. H. T. and H. M. C. as in the 1907 comparisons changed places, so that each day an even number of comparisons were made, half under one and half under the alternative conditions. At no time during the operations were stoves necessary for maintaining the temperature of the room at the required height.

The same particulars of these observations as have been given for the previous set, and their results are set forth in Tables VIII—XI.

TABLE VIII.—Abstract of Comparisons between **A** *and* I_B *with deduced results.*
(Micrometer heads turned towards each other).

No. of set	Date		Position of observers		Bar	Corrected Mean temperatures			Mean observed values of I_B − D and A − D		Reduction to 62° F.	I_B − A at 62° F.
			East end	West end		Room	Air space	Bar	in terms of G	in m.y		
	1908					°	°	°	divns.		m.y	m.y
1	Nov.	17	H. M. C.	H. H. T.	I_B	65·90	65·70	65·44	1580·87	1821·81	−112·69	
					A		65·15	65·04	1370·34	1579·19	− 66·26	196·19
2	„	17	H. H. T.	H. M. C.	I_B	66·10	65·38	65·42	1580·92	1821·87	−112·04	
					A		65·90	64·98	1377·60	1587·56	− 64·96	187·23
3	„	17	H. M. C.	H. H. T.	I_B	66·38	66·13	65·50	1587·40	1829·34	−114·66	
					A		65·85	65·46	1383·15	1593·96	− 75·42	196·14
4	„	17	H. H. T.	H. M. C.	I_B	66·68	66·10	65·48	1589·90	1832·22	−114·00	
					A		65·90	65·49	1389·26	1601·00	− 76·07	193·29
5	„	18	H. H. T.	H. M. C.	I_B	65·75	65·68	65·20	1572·37	1812·01	−104·83	
					A		64·98	64·86	1370·48	1579·35	− 62·34	190·17
6	„	18	H. M. C.	H. H. T.	I_B	65·70	65·28	65·15	1573·96	1813·85	−103·19	
					A		65·15	64·85	1370·23	1579·07	− 62·12	193·71
7	„	18	H. M. C.	H. H. T.	I_B	65·85	65·48	65·16	1576·63	1816·92	−103·52	
					A		65·38	65·06	1379·02	1589·20	− 66·70	190·90
8	„	19	H. M. C.	H. H. T.	I_B	65·10	65·03	64·85	1560·71	1798·58	− 93·36	
					A		64·88	64·56	1359·77	1567·01	− 55·80	194·01
9	„	19	H. H. T.	H. M. C.	I_B	65·20	65·05	64·81	1561·05	1798·97	− 92·05	
					A		64·68	64·41	1363·05	1570·79	− 52·53	188·66
10	„	19	H. H. T.	H. M. C.	I_B	65·35	64·90	64·78	1560·88	1798·77	− 91·07	
					A		64·73	64·52	1362·60	1570·27	− 54·93	192·36

Mean value of I_B − **A** (micrometer heads turned towards each other) ... 192·27 *m.y*
Mean temperature ... ... 65°·05 F.

TABLE VIII.—Abstract of Comparisons between **A** *and* I_B *with deduced results—(Contd.).*
(Micrometer heads turned away from one another).

No. of set	Date		Position of observers		Bar	Corrected Mean temperatures			Mean observed values of D − I_B and D − A		Reduction to 62° F.	I_B − A at 62° F.
			East end	West end		Room	Air space	Bar	in terms of G	in m.y		
	1908											
						°	°	°	divns.		m.y	m.y
31	Nov.	27	H. M. C.	H. H. T.	I_B	61·75	59·80	59·45	644·66	742·91	− 83·54	
					A		60·45	59·97	781·62	900·75	− 44·25	197·13
32	”	27	H. H. T.	H. M. C.	I_B	62·05	60·03	59·50	640·76	738·42	− 81·90	
					A		60·55	60·05	774·32	892·33	− 42·50	193·31
33	”	27	H. H. T.	H. M. C.	I_B	62·40	60·28	60·06	624·56	719·75	− 63·55	
					A		61·30	60·58	762·01	878·15	− 30·95	191·00
34	”	27	H. M. C.	H. H. T.	I_B	62·70	60·63	60·14	619·38	713·78	− 60·93	
					A		61·40	60·69	763·76	880·16	− 28·55	198·76
35	”	30	H. M. C.	H. H. T.	I_B	59·30	57·50	57·01	725·47	836·04	− 163·47	
					A		58·38	57·55	839·37	967·30	− 97·00	197·73
36	”	30	H. H. T.	H. M. C.	I_B	59·65	57·68	57·15	722·13	832·19	− 158·88	
					A		57·88	57·68	833·16	960·14	− 94·16	192·67
37	”	30	H. M. C.	H. H. T.	I_B	60·05	58·25	57·76	700·67	807·46	− 138·90	
					A		58·73	58·24	821·43	946·62	− 81·96	196·10
38	”	30	H. H. T.	H. M. C.	I_B	60·45	58·40	57·90	695·63	801·65	− 134·31	
					A		59·40	58·37	812·96	936·86	− 79·12	190·40
39	Dec.	1	H. M. C.	H. H. T.	I_B	59·95	59·18	59·23	655·55	755·46	− 90·74	
					A		59·43	59·05	804·74	927·39	− 64·30	198·37
40	”	1	H. H. T.	H. M. C.	I_B	60·30	59·20	59·27	654·30	754·02	− 89·43	
					A		59·43	59·07	796·57	917·98	− 63·87	189·52

Mean value of I_B − A (micrometer heads turned away from one another) ... 194·50 m.y
Mean temperature ... ... 58°·94 F.

TABLE IX.—Abstract of Comparisons between **A** *and* I_S *with deduced results.*
(Micrometer heads turned towards each other).

No of set	Date		Position of observers		Bar	Corrected Mean temperatures			Mean observed values of I_S – D and A – D		Reduction to 62° F.	I_S – A at 62° F.
			East end	West end		Room	Air space	Bar	in terms of G	in m.y		
	1908					°	°	°	divns.		m.y	m.y
11	Nov.	19	H. H. T.	H. M. C.	I_S	65·90	65·43	64·98	1444·28	1664·40	– 63·25	
					A		65·10	64·85	1372·26	1581·41	– 62·12	81·86
12	„	20	H. M. C.	H. H. T.	I_S	65·00	64·97	64·63	1430·06	1648·02	– 55·82	
					A		64·63	64·52	1356·78	1563·57	– 54·93	83·56
13	„	20	H. H. T.	H. M. C.	I_S	65·15	65·00	64·64	1432·73	1651·09	– 56·03	
					A		64·53	64·39	1361·51	1569·02	– 52·09	78·13
14	„	20	H. M. C.	H. H. T.	I_S	65·30	65·05	64·66	1432·19	1650·47	– 56·46	
					A		64·68	64·51	1360·74	1568·13	– 54·71	80·59
15	„	20	H. M. C.	H. H. T.	I_S	65·40	65·03	64·77	1435·96	1654·81	– 58·79	
					A		65·03	64·72	1366·69	1574·99	– 59·29	80·32
16	„	20	H. H. T.	H. M. C.	I_S	65·80	65·43	64·77	1437·30	1656·36	– 58·79	
					A		64·98	64·78	1370·82	1579·75	– 60·60	78·42
17	„	23	H. M. C.	H. H. T.	I_S	64·70	64·73	64·40	1427·18	1644·70	– 50·94	
					A		64·13	64·20	1353·37	1559·64	– 47·95	82·07
18	„	23	H. H. T.	H. M. C.	I_S	64·90	64·58	64·38	1428·79	1646·55	– 50·52	
					A		64·30	64·18	1357·54	1564·44	– 47·52	79·11
19	„	23	H. M. C.	H. H. T.	I_S	65·10	64·63	64·45	1431·05	1649·16	– 52·00	
					A		64·65	64·49	1358·88	1565·99	– 54·27	85·44
20	„	23	H. H. T.	H. M. C.	I_S	65·45	64·73	64·48	1434·52	1653·16	– 52·64	
					A		64·75	64·42	1366·33	1574·57	– 52·75	78·70

Mean value of I_S – A (micrometer heads turned towards each other) ... 80·82 m.y
Mean temperature ... ... 64°·56 F.

TABLE IX.—Abstract of comparisons between **A** *and* I_S *with deduced results—(Contd.).*

(Micrometer heads turned away from one another).

No. of set	Date		Position of observers		Bar	Corrected Mean temperature			Mean observed values of D − I_S and D − A		Reduction to 62° F.	I_S − A at 62° F.
			East end	West End		Room	Air space	Bar	in terms of G	in m.y		
	1908					°	°	°	divns.		m.y	m.y
21	Nov.	24	H. H. T.	H. M. C.	I_S	64·65	63·68	63·39	617·72	711·87	+ 29·50	
					A		63·53	63·24	688·46	793·39	+ 27·03	79·05
22	"	24	H. M. C.	H. H. T.	I_S	64·75	63·85	63·43	617·75	711·90	+ 30·35	
					A		63·63	63·30	689·25	794·30	+ 28·34	80·39
23	"	24	H. M. C.	H. H. T.	I_S	64·70	63·90	63·70	610·94	704·05	+ 36·08	
					A		63·43	63·68	681·29	785·13	+ 36·62	81·62
24	"	24	H. H. T.	H. M. C.	I_S	65·05	64·03	63·75	608·09	700·77	+ 37·14	
					A		64·08	63·70	674·99	777·87	+ 37·05	77·01
25	"	25	H. M. C.	H. H. T.	I_S	63·95	63·04	62·94	631·83	728·13	+ 19·95	
					A		63·38	62·87	704·70	812·10	+ 18·96	82·98
26	"	25	H. H. T.	H. M. C.	I_S	64·25	63·08	63·01	629·21	725·11	+ 21·44	
					A		63·43	62·93	700·11	806·81	+ 20·27	80·53
27	"	25	H. H. T.	H. M. C.	I_S	64·45	63·28	63·32	619·64	714·08	+ 28·02	
					A		63·83	63·43	689·03	794·05	+ 31·17	83·12
28	"	25	H. M. C.	H. H. T.	I_S	64·75	63·48	63·41	616·79	710·79	+ 29·93	
					A		64·18	63·50	688·52	793·46	+ 32·70	85·44
29	"	26	H. M. C.	H. H. T.	I_S	63·05	61·25	61·05	674·94	777·80	− 20·16	
					A		62·08	61·21	744·96	858·50	− 17·22	83·64
30	"	26	H. H. T.	H. M. C.	I_S	63·30	61·38	61·11	671·59	773·95	− 18·89	
					A		62·13	61·32	738·04	850·52	− 14·89	80·64

Mean value of I_S **— A** (micrometer heads turned away from one another) 81·44 m.y

Mean temperature ... ... 62°·91 F.

TABLE X.—Values of $I_B - A$ *and* $I_S - A$ *reduced to 62° F. as determined at Dehra, Nov.—Dec., 1908.*

No. of set	Mean temperature of Bars I_B and A	Value of $I_B - A$	No. of set	Mean temperature of Bars I_S and A	Value of $I_S - A$
	°	m.y		°	m.y
1	65·24	196·19	11	64·92	81·86
2	65·20	187·23	12	64·58	83·56
3	65·48	196·14	13	64·52	78·13
4	65·49	193·29	14	64·59	80·59
5	65·03	190·17	15	64·75	80·32
6	65·00	193·71	16	64·78	78·42
7	65·11	190·90	17	64·30	82·07
8	64·71	194·01	18	64·28	79·11
9	64·61	188·66	19	64·47	85·44
10	64·65	192·36	20	64·45	78·70
31	59·71	197·13	21	63·32	79·05
32	59·78	193·31	22	63·37	80·39
33	60·32	191·00	23	63·69	81·62
34	60·42	198·76	24	63·73	77·01
35	57·28	197·73	25	62·91	82·98
36	57·42	192·67	26	62·97	80·53
37	58·00	196·10	27	63·38	83·12
38	58·13	190·40	28	63·46	85·44
39	59·14	198·37	29	61·13	83·64
40	59·17	189·52	30	61·22	80·64

TABLE XI.—Mean values of $I_B - A$ and $I_S - A$ reduced to 62° F. from Dehra observations, Nov.—Dec. 1908, as found by the second series of observations.

	$I_B - A$ and Temperature	$I_S - A$ and Temperature
Mean value for temperatures below 62°	194·50 *m.y*	82·14 *m.y*
Corresponding mean temperature	58°·94 F.	61°·18 F.
Mean value for temperatures above 62°	192·27 *m.y*	81·02 *m.y*
Corresponding mean temperature	65°·05 F.	64°·03 F.
General mean value	193·38 *m.y*	81·13 *m.y*
General mean temperature ...	61°·99 F.	63°·74 F.

APPENDIX No. 1

The following letter was received from the Director of the Bureau International des Poids et Mesures, Breteuil Sévres, July, 1908:—

A detailed report of the operations will be sent in a short time. The observations were made at temperature between 17° and 18° (Centigrade). Bar **A** *at 17°·5 is 3048·026 mm. The value reduced to 62° F. becomes*

3047·996 mm.

The value given in Vol. I of the Indian Survey is

3·333,318,86 yds.,

which using the equivalent determined at the Bureau International gives

3047·984 mm.

The difference is extremely small, taking into consideration the distant date of the determination of the length of the bar, the difficulty of intersecting the unsatisfactorily defined dots and finally the conversion, first, to the yard and then to the metre by an intermediate series.

Guillaume.

The length of bar **A**, as determined at Sévres, expressed in yards is accordingly

3·333,332.

The corresponding lengths of $\mathbf{I}_S$ and $\mathbf{I}_B$ determined from the observations of Nov. 1907—Jan. 1908 are as follows:—

$$\mathbf{I}_S = 3\cdot333{,}415 \text{ yds.}$$

$$\mathbf{I}_B = 3\cdot333{,}529 \text{ yds.}$$

The later observations of Nov.—Dec. 1908 were not used as the thermometer corrections had not been redetermined.

All the above are for temperature 62° F.

APPENDIX No. 2

Analysis of temperature readings during the comparisons of bars $\mathbf{I}_S$ *and* **A**, *Nov. 1907—Jan. 1908.*

Set No.	End of Bar	Bar A: Air space temperature	Bar A: Bar temperature	Bar A: Difference Bar—Air space	Bar A: Difference E—W for Bar	Bar I_S: Air space temperature	Bar I_S: Bar temperature	Bar I_S: Difference Bar—Air space	Bar I_S: Difference E—W for Bar
1	E	58°·60	58°·38	−0·22		58°·30	58°·18	−0·12	
	W	59·35	58·19	−1·16	+0·19	58·70	58·33	−0·37	−0·15
2	E	59·50	58·56	−0·94		59·05	58·33	−0·72	
	W	59·15	58·40	−0·75	+0·16	58·80	58·45	−0·35	−0·12
3		58·30	58·00	−0·30		58·35	58·25	−0·10	
	W	58·15	58·10	−0·05	−0·10	58·15	58·40	+0·25	−0·15
4	E	58·10	57·96	−0·14		58·30	58·28	−0·02	
	W	58·65	58·01	−0·64	−0·05	58·40	58·39	−0·01	−0·11
5	E	58·70	58·33	−0·37		58·70	58·40	−0·30	
	W	58·75	58·23	−0·52	+0·10	58·55	58·46	−0·09	−0·06
6	E	58·30	58·44	+0·14		58·90	58·43	−0·47	
	W	59·15	58·28	−0·87	+0·16	58·90	58·54	−0·36	−0·11
7	E	57·85	57·89	+0·04		58·10	58·04	−0·06	
	W	57·95	57·79	−0·16	+0·10	58·08	58·14	+0·06	−0·10
8	E	58·05	57·75	−0·30		58·25	58·00	−0·25	
	W	58·15	57·74	−0·41	+0·01	58·20	58·10	−0·10	−0·10
9	E	58·10	57·95	−0·15		58·60	58·05	−0·55	
	W	58·55	57·86	−0·69	+0·09	58·10	58·19	+0·09	−0·14
10	E	58·30	58·05	−0·25		58·25	58·09	−0·16	
	W	58·70	58·05	−0·65	0·00	58·33	58·28	−0·05	−0·19
11	E	57·95	57·64	−0·31		57·65	57·75	+0·10	
	W	57·65	57·43	−0·22	+0·21	57·88	57·84	−0·04	−0·09
12	E	57·95	57·45	−0·50		58·18	57·79	−0·39	
	W	58·05	57·49	−0·56	−0·04	57·85	57·84	−0·01	−0·05
13	E	57·95	57·69	−0·26		58·45	57·88	−0·57	
	W	58·55	57·64	−0·91	+0·05	57·70	57·94	+0·24	−0·06
14	E	58·05	57·89	−0·16		58·35	57·95	−0·40	
	W	58·45	57·74	−0·71	+0·15	58·10	57·95	−0·15	0·00
15	E	57·15	57·29	+0·14		57·40	57·50	+0·10	
	W	57·65	57·20	−0·45	+0·09	57·55	57·54	−0·01	−0·04
16	E	57·45	57·30	−0·15		57·88	57·50	−0·38	
	W	57·75	57·14	−0·61	+0·16	57·75	57·55	−0·20	−0·05
17	E	57·59	57·69	+0·10		57·85	57·55	−0·30	
	W	57·75	57·38	−0·37	+0·31	57·80	57·64	−0·16	−0·09
18	E	57·95	57·55	−0·40		58·10	57·60	−0·50	
	W	57·65	57·51	−0·14	+0·04	57·95	57·63	−0·32	−0·03
19	E	57·05	56·83	−0·22		57·20	56·90	−0·30	
	W	56·95	56·73	−0·22	+0·10	57·10	56·90	−0·20	0·00
20	E	57·15	56·96	−0·19		57·25	56·95	−0·30	
	W	57·45	56·80	−0·65	+0·16	57·15	56·99	−0·16	−0·04

APPENDIX No. 2—(contd.)

Analysis of temperature readings during the comparisons of bars $\mathbf{I}_S$ *and* **A**, *Nov. 1907—Jan. 1908 (contd.).*

Set No.	End of Bar	Bar A: Air space temperature	Bar A: Bar temperature	Bar A: Difference Bar—Air space	Bar A: Difference E—W for Bar	Bar $\mathbf{I}_S$: Air space temperature	Bar $\mathbf{I}_S$: Bar temperature	Bar $\mathbf{I}_S$: Difference Bar—Air space	Bar $\mathbf{I}_S$: Difference E—W for Bar
21	E	56°·65	56°·48	−0·17		57°·10	56°·75	−0·35	
	W	56·75	56·41	−0·34	+0·07	56·75	56·85	+0·10	−0·10
22	E	56·65	56·56	−0·09		57·05	56·78	−0·27	
	W	56·75	56·46	−0·29	+0·10	57·00	56·78	−0·22	0·00
23	E	56·95	56·89	−0·06		57·25	56·86	−0·39	
	W	57·15	56·70	−0·45	+0·19	57·10	56·85	−0·25	+0·01
24	E	57·15	56·88	−0·27		57·25	56·89	−0·36	
	W	57·15	56·78	−0·37	+0·10	57·15	56·86	−0·29	+0·03
53	E	64·10	63·81	−0·29		64·20	64·03	−0·17	
	W	64·03	63·80	−0·23	+0·01	64·10	64·09	−0·01	−0·06
54	E	64·00	63·91	−0·09		64·20	64·00	−0·20	
	W	64·15	63·80	−0·35	+0·11	64·10	64·10	0·00	−0·10
55	E	65·90	65·03	−0·87		65·55	64·90	−0·65	
	W	65·75	64·93	−0·82	+0·10	65·45	65·11	−0·34	−0·21
56	E	65·90	65·08	−0·82		66·15	65·25	−0·90	
	W	65·95	64·96	−0·99	+0·12	66·10	65·31	−0·79	−0·06
57	E	68·95	68·50	−0·45		69·15	68·50	−0·65	
	W	68·95	68·45	−0·40	+0·05	68·95	68·63	−0·32	−0·13
58	E	68·95	68·69	−0·26		69·15	68·75	−0·40	
	W	68·95	68·75	−0·20	−0·06	68·75	68·95	+0·20	−0·20
59	E	68·95	68·78	−0·17		69·15	68·83	−0·32	
	W	68·75	68·75	0·00	+0·03	68·90	68·95	+0·05	−0·12
60	E	68·95	68·90	−0·05		69·15	68·89	−0·26	
	W	68·95	68·78	−0·17	+0·12	69·00	68·95	−0·05	−0·06
61	E	64·70	64·88	+0·18		65·05	65·14	+0·09	
	W	65·05	64·98	−0·07	−0·10	65·10	65·35	+0·25	−0·21
62	E	64·90	64·81	−0·09		65·20	65·13	−0·07	
	W	65·05	64·83	−0·22	−0·02	64·95	65·23	+0·28	−0·10
63	E	65·10	64·91	−0·19		65·00	65·00	0·00	
	W	65·05	64·90	−0·15	+0·01	65·15	65·15	0·00	−0·15
64	E	65·00	64·86	−0·14		65·20	65·00	−0·20	
	W	64·55	64·80	+0·25	+0·06	65·00	65·15	+0·15	−0·15
65	E	65·00	64·75	−0·25		65·15	65·00	−0·15	
	W	64·95	64·75	−0·20	0·00	65·50	64·99	−0·51	+0·01
66	E	65·00	64·80	−0·20		65·10	65·00	−0·10	
	W	65·15	64·75	−0·40	+0·05	65·10	64·99	−0·11	+0·01
67	E	65·70	65·23	−0·47		65·55	65·25	−0·30	
	W	65·65	65·19	−0·46	+0·04	65·60	65·38	−0·22	−0·13
68	E	65·90	65·35	−0·55		65·95	65·35	−0·60	
	W	65·75	65·19	−0·56	+0·16	65·35	65·43	+0·08	−0·08
69	E	65·95	65·74	−0·21		66·00	65·80	−0·20	
	W	65·95	65·60	−0·35	+0·14	66·00	65·84	−0·16	−0·04
70	E	65·90	65·63	−0·27		66·56	65·81	−0·34	
	W	66·05	65·56	−0·49	+0·07	65·80	65·90	+0·10	−0·09

APPENDIX No. 3

Analysis of temperature readings during the comparisons of bars I_S *and* **A**, *Nov. 1907—Jan. 1908.*

Set No.	Bar A				Bar I_S			
	Mean air space temperature	Change: set to set	Mean bar temperature	Change: set to set	Mean air space temperature	Change: set to set	Mean bar tempera-ture	Change: set to set
1	58°·98		58°·28		58°·50		58°·26	
2	59·33	+0·35	58·48	+0·20	58·93	+0·43	58·39	+0·13
3	58·23	−1·10	58·05	−0·43	58·25	−0·68	58·33	−0·06
4	58·38	+0·15	57·98	−0·07	58·35	+0·10	58·34	+0·01
5	58·73	+0·35	58·28	+0·30	58·63	+0·28	58·43	+0·09
6	58·73	0·00	58·36	+0·08	58·90	+0·27	58·48	+0·05
7	57·90	−0·83	57·84	−0·52	58·09	−0·81	58·09	−0·39
8	58·10	+0·20	57·75	−0·09	58·23	+0·14	58·05	−0·04
9	58·33	+0·23	57·90	+0·15	58·35	+0·12	58·12	+0·07
10	58·50	+0·17	58·05	+0·15	58·29	−0·06	58·19	+0·07
11	57·80	−0·70	57·54	−0·51	57·77	−0·52	57·79	−0·40
12	58·00	+0·20	57·47	−0·07	58·02	+0·25	57·81	+0·02
13	58·25	+0·25	57·67	+0·20	58·08	+0·06	57·91	+0·10
14	58·25	0·00	57·82	+0·15	58·23	+0·15	57·95	+0·04
15	57·40	−0·85	57·25	−0·57	57·48	−0·75	57·52	−0·43
16	57·60	+0·20	57·22	−0·03	57·82	+0·34	57·53	+0·01
17	57·67	+0·07	57·54	+0·32	57·83	+0·01	57·60	+0·07
18	57·80	+0·13	57·53	−0·01	58·03	+0·20	57·62	+0·02
19	57·00	−0·80	56·78	−0·75	57·15	−0·88	56·90	−0·72
20	57·30	+0·30	56·88	+0·10	57·20	+0·05	56·97	+0·07
21	56·70	−0·60	56·45	−0·43	56·93	−0·27	56·80	−0·17
22	56·70	0·00	56·51	+0·06	57·03	+0·10	56·78	−0·02
23	57·05	+0·35	56·79	+0·28	57·18	+0·15	56·86	+0·08
24	57·15	+0·10	56·83	+0·04	57·20	+0·02	56·88	+0·02
53	64·07		63·81		64·15		64·06	
54	64·08	+0·01	63·86	+0·05	64·15	0·00	64·05	−0·01
55	65·83	+1·75	64·98	+1·12	65·50	+1·35	65·01	+0·96
56	65·93	+0·10	65·02	+0·04	66·13	+0·63	65·28	+0·27
57	68·90	+2·97	68·47	+3·45	69·05	+2·92	68·57	+3·29
58	68·95	+0·05	68·72	+0·25	68·95	−0·10	68·85	+0·28

APPENDIX No. 3—(contd.)

Analysis of temperature readings during the comparisons of bars $\mathbf{I}_S$ *and* **A**, *Nov. 1907—Jan. 1908 (contd.).*

Set No.	Bar A				Bar I_S			
	Mean air space temperature	Change: set to set	Mean bar temperature	Change: set to set	Mean air space temperature	Change: set to set	Mean bar tempera-ture	Change: set to set
59	68°·85	−0·10	68°·77	+0·05	69°·03	+0·08	68°·89	+0·04
60	68·95	+0·10	68·84	+0·07	69·08	+0·05	68·92	+0·03
61	64·88	−4·07	64·93	−3·91	65·08	−4·00	65·25	−3·67
62	64·98	+0·10	64·82	−0·11	65·08	0·00	65·18	−0·07
63	65·08	+0·10	64·90	+0·08	65·08	0·00	65·08	−0·10
64	64·78	−0·30	64·83	−0·07	65·10	+0·02	65·08	0·00
65	64·98	+0·20	64·75	−0·08	65·33	+0·23	65·00	−0·08
66	65·08	+0·10	64·78	+0·03	65·10	−0·23	64·99	−0·01
67	65·68	+0·60	65·21	+0·43	65·58	+0·48	65·32	+0·33
68	65·83	+0·15	65·27	+0·06	65·65	+0·07	65·39	+0·07
69	65·95	+0·12	65·67	+0·40	66·00	+0·35	65·82	+0·43
70	65·98	+0·03	65·59	−0·08	65·98	−0·02	65·86	+0·04