SURVEY OF INDIA

DEPARTMENTAL PAPER No. 10

FOURTH EDITION

THE HUNTER SHORT BASE

PUBLISHED BY ORDER OF
THE SURVEYOR GENERAL OF INDIA

PRINTED AT THE 103 (P.Z.O.) PRINTING GROUP OF SURVEY OF INDIA, DEHRA DŪN.

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For Departmental Use

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LIST OF PARTS AND TOOLS WITH THE SHORT BASE

1. Box (in canvas case) containing the following :—

Name of part or tool	Purpose	Number
Targets Big A_2 and C	For base extension	2
Booklet of instruction	For general guidance	1
Spare wing nuts	Spare	4
Target A and B with lever S_2	To hold the tape ends in catenary on posts	2
Small target D	To measure slope	1
Scale and Dividers	To measure junction links and terminals of tape	2
Thermometers	For taking temperature of tape	2
Plumb bob	To help centering when a theodolite is not available	1
Lead weight of 1 Kg.	For attachment to the lever on target B	1
Jointed steel tape 80 metres long rolled on a drum	For measuring	1
Calibration certificate	For computations	1

2. Ruck sack containing the following :—

Name of part or tool	Purpose	Number
Posts A and B with metal arms	End supports	2
Post C	Support for target C	1
Posts P, Q and R	Intermediate supports	3
Metal rods with socket joints (in a tube)	Supports for target D	3
Canvas bags	To be filled with earth or stones for stability of posts A, B and C	3

The plumb bob is for use in centering when a theodolite is not available, as under a beacon when carrying out a double extension traverse.

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		1
		1
		2
		1
		3
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Correction Slip to Departmental Paper No. 10 (The Hunter Short Base), Fourth Edition 1972.

Page iii.—

fourteenth line from bottom, *add* the words 'of 1 kg' *after* the words 'lead weight'.

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PREFACE

1. The Hunter Short Base was designed to provide short bases for topographical purposes, but it has in the main been used in the Survey of India to provide gross checks on scale in topographical triangulation and for deriving the starting base for exploratory triangulation or in limited areas where an old base is not available. The base is provided by four measuring tapes, each 66 feet long, joined together and kept under a known tension.

2. These tapes have been in use in the department for a number of years but it has only been found lately that there have been several irregularities in the method of their calibration as well as their use in the field.

Firstly, they used to be calibrated on a mural base on which foot marks have been put by a bevelled bar graduated in terms of a 10-foot bar I_S. The length of this substandard bar I_S in terms of our standard 10-foot bar A and consequently in terms of European standards was determined in 1866 and 1907. The 1907 comparisons were not considered very reliable and with lapse of such a long interval (during which these bars have not been always treated with the care they deserved), the length of bar I_S is not known to any high order of accuracy. Our fundamental 10-foot bar A is bent and has been discarded since the beginning of this century and really speaking the prototype of the Indian foot does not exist at all.

The Standard of Length used in the Survey of India now is the International metre of which we possess several prototypes and our only means of getting lengths in feet is to apply conversion ratio to bases measured in metres. Test measurements have revealed that the foot marks on the mural base established by means of the obsolete 10-foot I_S bar are not in consonance with our current metric standards.

Some tapes were measured on the flat on the mural base and they were also measured on the 24-metre comparator in catenary and then reduced to flat. There was a systematic difference of 0·014 feet between the two measures, which is very significant.

Secondly, the intention was that each equipment should have its own tensioning weight dependent on cross-sections of the wire in such a way that the same catenary correction would be applicable to all tapes. This catenary correction was meant to be of universal usage and was printed on the back of the form used for the reduction of observations. For the usual length of the base of 264 feet, weight of steel tapes has been found to range between 30 oz. and 36 oz. and the catenary tables were based on the condition that the lead weight supplied with each equipment should be equal to the weight of 293·3 feet of the tape. This condition got over-looked in the course of time and an identical lead weight of 2 lb. was supplied with each equipment producing a constant tension of 12 lb. The final reduced length of the base was thus wrong on account of using an incorrect table.

Finally, the tapes used to be standardized under different conditions to those in which they were used in the field. They were laid on the flat on the mural base under somewhat varying tensions, while in the field they were used in a catenary. On an unsupported 4-chain base, the combined effect of error in the catenary correction and in the length due to wrong tension can be considerable.

... introduced. One is,

Page v, para 3, sub-para 2 .—

second line, *add* the words 'of 1 kg' *after* the word 'weight'.

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... eight. The

necessity of applying catenary correction is thus obviated.

4. In view of the important fundamental changes described in para 3 above, the instructions contained in this pamphlet supersede all previous orders on the subject.

DEHRA DŪN :
January, 1951

B. L. GULATEE, M.A. (CANTAB.),
F.R.I.C.S., M.I.S. (INDIA),
Director, Geodetic & Training Circle.

PREFACE TO THE FOURTH EDITION

This edition is a reprint of the third edition, with minor corrections consequent on the introduction of metric system in the Department.

Important changes made since the last edition have been sidelined.

DEHRA DŪN :
14-12-1972

DR. HARI NARAIN, M.Sc., D.Phil., Ph.D.,
Surveyor General of India.

THE HUNTER SHORT BASE

1. **Introduction.**—This apparatus is useful in times of war or under circumstances in which triangulation cannot be connected to a geodetic framework, or where topographical triangulation is carried a long way without any check on its sides.

Hunter short base is at present (1972) being used, with satisfactory results, in the department for providing initial scale or closing side for purposes of topographical triangulation.

It will provide a base of sufficient accuracy for transfrontier triangulation, or triangulation with an expeditionary force or boundary commission. It may also be used as a subtense for traverse operations.

Its advantages are :—

(1) One observer with the help of *khalasis* can set it up.

(2) It carries its own marks and so saves labour and errors of transfer.

(3) It avoids the need for line clearing, and is workable on sloping, undulating or broken ground.

2. **Description.**—The apparatus consists of a jointed steel tape made up of four sections, with swivel junctions at 20 metres intervals, the total length being 80 metres approximately. Each 20-metre section is painted with a distinctive colour (red, white, blue or green) for a length of 20 cm at either end, and the whole tape is rolled on a drum. Generally the whole length of the tape will be extended and supported, not only on the terminal posts A and B but also on the intermediate posts P, Q and R at intervals of 20 metres (see the general diagram at end). Occasions may arise, however, when the ground admits of only two or three sections of the tape being used, or when the whole tape has to be slung across a ravine with only the end supports.

3. **End Supports.**—The end supports A and B of the steel tape are each made of three rectangular wooden posts, one foreleg about 25 mm thick and 1 metre long and two others a bit thinner and about 15 cm shorter, made stable with a canvas bag filled up with stones or earth. They are each fitted with a metal arm about 30 cm long with a horizontal metal pin on top for holding the targets. These supports can be distinguished by the painting on their metal arms, A being red and B green. The two tripods are placed with their forelegs under the tape. It is essential that the forelegs should be in the same vertical plane as the tape, in order that the targets may also be in this plane. The foreleg must be turned (after loosening the wing nut at its upper end) until its sides are vertical.

4. **Post C.**—Post C for target C is similar in construction to posts A and B, but has a thinner foreleg and no metal arm. It is not coloured.

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Page 1, para 6.—

seventh line, *add* the words ' of 1 kg ' *after* the word ' weight '.

No. 1, Dated 10-9-74.

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6. **Targets.**—There are five targets supplied with the base, viz. 2 medium size targets A_1, B (about 15 cm × 10 cm), 1 small target D (about 5 cm × 2·5 cm) and 2 large targets A_2 and C (about 30 cm × 20 cm), made of sheet tin and painted diagonally black and white. Target A_1 has a hinged long arm, having three slots (teeth) at the farther end. The lower half hinged to the upper half of the arm can move freely round the hinge. Target B also has a hinged long arm, but has no slot. It has a small hole at the farthest end for carrying the weight. The lower half of the hinged arm can be brought in the same line as the upper half but cannot be moved beyond that position because of a catch provided to restrict its motion. A_2 has a slit running across its centre (of about the length of target A_1) while C has a slit in one half of it only. Target A_1 has a hook to which the red end of the tape is attached while the green end of the tape is connected to a similar hook with target B.

7. **Setting up the base.**—The setting up of the base and the use of the targets are more fully explained in the instructions which follow, which are primarily concerned with the case when the tape is in four sections, supported at each 20-metre length (see the general diagram at end).

8. **Setting up post A.**—Take the tripod whose metal arm is coloured red and spread it so that its foreleg is towards the proposed lay-out of the base, i.e., towards B. Fill the canvas bag with stones or earth to make it stable. Target A_1 is then taken out, the inclined slit is slid on the horizontal pin on the top of the metal arm and the hinged arm is moved to engage one of the slots with the wing nut on one side of the foreleg.

9. **Setting up post B.**—Take the tripod whose metal arm is coloured green and spread it so that its foreleg is towards A. Fill the bag with earth or stones to make it stable.

10. **Setting up medium size targets A_1 and B.**—Target A_1 fixes on to the metal arm of post A by means of an inclined slit and the hinged long arm with slots. The longer axis of the target should be made vertical by engaging the correct slot with the bolt on the side of the foreleg, a finer adjustment being possible by loosening the two wing nuts on this leg and sliding the metal arm. Unless this axis is vertical, centering over the slots at the top of the target will suffer in accuracy. Centering should not be done with large target A_2 in position.

Target B is fixed on to the metal arm of post B by means of a slit. A weight hooks on to its long arm in order to apply the proper tension to the tape when hanging in catenary. This tension (about 6 kg for a tape of 1·30 sq mm cross-section) is equal to that given to the tape AB in catenary at time of standardization at Dehra Dun. In order to apply this tension correctly, when hanging in catenary, the long arm (lever arm) of target B is made roughly horizontal by sliding the metal arm on the post up or down and clamping it in position. If the lever arm is considerably inclined to the horizontal, use the plumb-bob to help centering, and disregard the slot in the top edge of the target. Adjust the angle of the lever arm by loosening the wing nuts on the foreleg and sliding the arm.

Next, the red end of the tape is attached to the hook on target A_1 and the whole tape is unreeled from its drum in the required direction, holding the tape drum by the leather strap, so that the tape unwinds freely without kinking. Now clip B target on to the green end of the tape and hook the weight at the far end of the lever, which should point away from A.

11. **Adjusting Tension.**—Correct tension on AB will be applied when the lever arm of the target B is horizontal. Its final adjustment is made by clamping the metal arm at the correct height, after the intermediate supports have been set up (see para 12 below). Great accuracy is unnecessary. It is sufficient if the lever looks approximately horizontal.

12. **Setting up Intermediate Posts P, Q & R.**—Now, if the ground permits, set up the intermediate supports between the sections of the tape (see para 5). These should be aligned by eye on AB.

13. **Setting up target D.**—The small target D, which is intended for observing the slope of the sections of the tape, can be placed in turn on intermediate posts P, Q, R or on A and B. It is set up on one or more of the three metal rods provided for the purpose, which fit one into the other. The base of the rod carrying the target must be put on the tops at the end posts A & B and at the intermediate supports P, Q & R, the rod being held vertical by hand. It must not be put on the pins as these are only intended to hold the tape. The height of the target itself is set by means of a thumb screw at such a point of the metal rod that when placed on post A, it is at the same height above the tape as the axis of the telescope.

14. **Setting up big targets A_2 and C.**—The two big targets A_2 and C are used when carrying out base extension.

Target A_2 fixes on to target A_1 by means of the slit across its centre and the two notches, one on top of target A_1 and the other in the metallic piece fixed to the first half of the arm.

Target C fastens on to post C by means of a bolt on the top of the post. Centre over the bolt before putting on the latter. If it is to be observed from one side only, use the upper end of the slit ; if from both sides, use the lower end so that the target can be observed clear of the stand ; in this case see that the 2 lateral legs of the stand are in vertical plane.

15. **Measurement of the junction and end links.**—As the junction and end links of the tape are liable to slight extension under rough use, they should be measured occasionally. The measurement should be taken between the terminal marks at the end of each tape in case of the junction links, and between the terminal marks and the centre of the targets on posts A and B in the case of the end links, by means of the scale and dividers provided for the purpose.

16. **Taking temperature readings of tape.**—As the base is standardized at 30°C (see Table A), the temperature of the tape is wanted when measuring the small angle α at C (see para 18). For this purpose it will be sufficient if the air temperature in the shade is taken a number of times at C and the mean of the readings taken when applying the temperature correction from table B. To avoid appreciable difference of temperature between the tape and the air and also for favourable measurement of the angle ACB it is preferable to observe the base on a dull day or early in the morning or late afternoon. It may be added that an error of 4·5°C in the temperature of the tape will cause an error of 1 : 20,000 in the length of the short base.

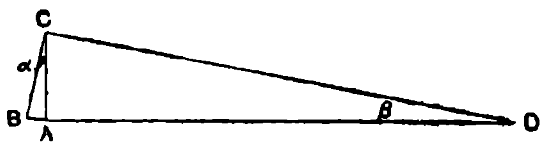
17. **Marking Sites of A, B and C.**—It is essential to use the small targets at A and B when measuring the small angle α (see para 18). It will be understood that the object of marking the sites of A, B and C is only for subsequent operations.

Put a peg flush with the ground, centre a theodolite over it and erect the post A so that its target is centred under the theodolite. Alternatively, the target may be centred over a peg by means of a plumb-bob before filling the bag with stones, but in this case it is liable to be disturbed when fixing the other extreme end of tape to B : whereas, with a theodolite at A this can be checked and corrected, if required. It is not necessary to mark the position of B unless the base is extended from B; in which case post B is marked as above while A is left unmarked. Similarly, the site of C is marked with a peg after the small angle α has been measured.

The pegs are driven flush with the ground so that helios instead of targets may be put over them, if necessary, when observing angle β from D (see para 18).

18. **Theory and use of the apparatus.**—By means of the apparatus a base can be rapidly fixed between two points A and B on almost any type of ground. Preferably the base should not be set up on a slope over 20°, for in this case the slope of each section requires direct measurement and cannot be easily deduced by the methods given below. The short base AB should not be set up until the site for post C has been selected, as it is *essential* that the small angle α (see figure below) is measured with the small targets at A and B.

The first theodolite measurement is that of the slopes of AP, AQ, AR, AB as mentioned in para 13. This is done immediately after the base is erected. Data are then sufficient to compute the precise distance between the two targets A and B except for the temperature correction which will be deduced from the mean temperature observed (see para 16).



In the figure, CA may be any distance from 400 to 1,000 metres roughly at right angles to AB, and DA from 1·5 to 10 km according to the length of CA, nearly in the same line as BA. Grazing rays (i.e. rays passing within 6 metres in height above intervening ground) should be avoided in the case of CD and AD. If the ground admits, the point C may be chosen on an elevation so that the rays CA, CB are well above the intervening ground.

Next, with the theodolite still at A, measure the angle BAC, keeping the large target at C facing towards A. As this angle will be nearly a right angle a beacon or flag at C may alternatively serve the purpose. Again, if the site for station D has been selected and marked with a beacon, the angle CAD will also be observed. If not, the angle ACD may be measured subsequently instead of the angle CAD.

Now move the theodolite from A to C and observe the angle a with targets at A and B by the method of repetition (see para 19).

Similarly, the small angle β at D is observed by repetition with the targets at A and C. But if the targets are not visible, helios may be put at A and C ; or beacons may have to serve this purpose, although they are likely to introduce some reduction in precision, due to centering difficulties.

The extension being from a short base, the angles a and β will be between 5° and 12°. The smaller the angles the more measures are made by repetition in the manner described in para 19, the rule being to measure round the limb 180°. The rest of the angles of the figure are of minor importance and normally only two measures are made of the angles DAC and CAB. The angles DCA and ABC are not generally observed. If three angles of a triangle are observed (which is quite unnecessary) no share of the triangular errors must be distributed to the small angles a and β.

19. **Method of measuring small angles by repetition.**—It is necessary to measure the small angles with higher accuracy than is usual with the ordinary angles of triangulation. This is done by measuring them by repetition round the whole circle thus eliminating graduation error, and without reading the limb at each intersection. By this method the error should not exceed 1 in 20,000 for the sides DC or DA, even with a vernier theodolite, provided it has two good clamps, a fine vertical wire, a rigid stand, and a freely moving axis. The horizontal collimation and the levelling of the transit axis of the theodolite should be correct to about half a minute. The actual procedure is as follows :—

(*a*) Unclamp the upper plate of the theodolite, set it to 0° approximately and clamp it again.

(*b*) Unclamp the lower plate and intersect the left-hand target A with the lower tangent screw. Unclamp the upper plate and rotate the theodolite several times to take up back-lash, reclamp the upper plate, intersect with the upper tangent screw and read the limb.

(*c*) Unclamp the upper plate, point at target B, clamp and intersect with the upper tangent screw. Read the limb and take out this first measure of the subtended angle, which will be a check against gross errors later. It is not essential to read the limb again until the whole series of intersections has been completed, but as a guard against blunder it is wise to record readings after every fifth repetition.

(*d*) Unclamp the lower plate, swing right round the circle (nearly 360°) on to A (instead of swinging backwards) clamp and intersect with the lower tangent screw.

(*e*) Repeat (*c*) and (*d*) a sufficient number of times, so that finishing on B the reading of the limb is about 180°. Subtract the mean of the first reading taken as in (*b*) from the mean of this final reading, and divide the result by the number of measures made ; this gives the final value of the subtended angle, which should be checked against the first measure found by (*c*), lest the number of repetitions has been wrongly counted, or a gross error made in reading.

This method of repetition does not apply to the Wild type theodolites which have no lower plate clamps. With such instruments each angle must be observed separately and the telescope swung round on to the left-hand target for the next zero. The zeros should be spaced uniformly round the circle roughly at 0°, $a°$, $2a°$, $3a°$, etc. until 180° of the limb is traversed. The mean of all these angles is the final subtended angle.

In all cases the theodolite telescope should be swung in one direction only until the whole operation of repetition is completed. In using the slow motion screw the final movement when intersecting the target should be against the spring.

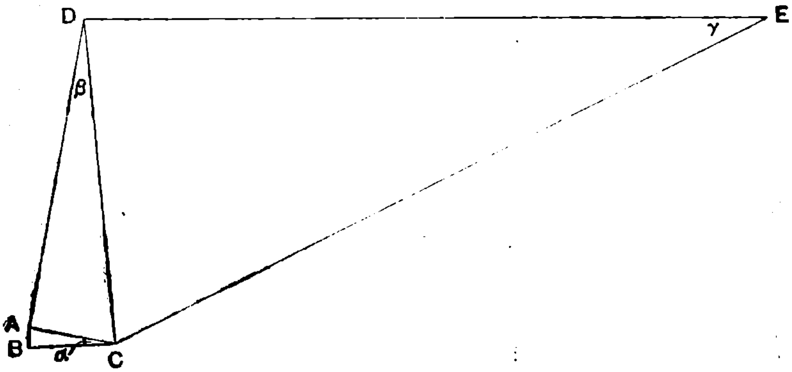


Fig. (a)

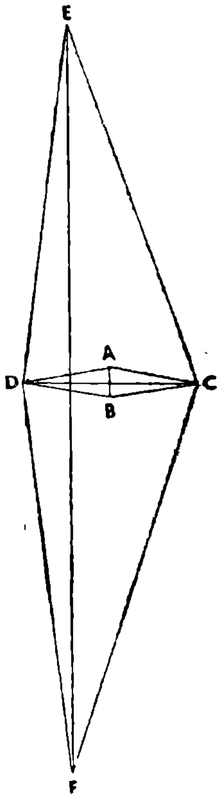


Fig. (b)

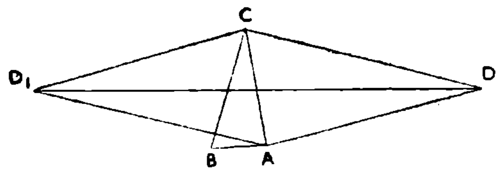


Fig. (c)

20. **Further extension.**—Under certain circumstances, the base can be further extended by three triangles as in the above figure (a). The small angles α, β & γ are observed according to the method of repetition (para 19) the normal number of observations being made of the angles EDC, DAC and CAB. If this is done the angles α, β & γ need not be so small, and the precision will be greater. Other variations of the lay-out and extensions are readily imagined. Two examples of double extension on both sides are given in figures (b) & (c).

21. **Computation of the base. Table A.**—This table supplied with each base, gives the calibration certificate for the horizontal lengths of the various sections, with or without intermediate supports, between calibrated marks when hanging in catenary under at ension of 6 kg as determined against 20-metre comparator. The three junction and the two end links should be measured in the field while the base is spread out and *added* to the total lengths of the various sectional lengths. It is important to note that the measurement of the

end links on either side should be from the centre of the punch to the calibration mark on the tape end. When the full base is not laid out, take the appropriate values of the sections used. As the calibrated lengths are determined for the tapes while hanging in catenary, no catenary corrections are needed to the field observations.

22. **Table B.**—This table contains corrections to the whole or part base length for variation of temperature, the tape being standardized at 30°C (see Table A).

23. **Table C.**—This table contains the formulæ for the correction factor for slope from which slope corrections can be taken out, and a table of correction for slope for one section.

24. **Table D.**—This table contains the correction to the base for height above mean sea-level.

25. **Reduced length of base.**—Thus the reduced length L. of the base is :—

l, its length in the catenary (from Table A) $\pm$ temperature correction, C_t (from Table B) + slope correction S (from Table C) + correction H. correction to mean sea-level (from Table D), i.e.

$$L = l \pm C_t + S + H.$$

Form 15 $\frac{\text{Mach.}}{\text{Lamb.}}$ on which this computation can be done is on page 11. The scale factor or log scale factor on this form is only required if the base is being used for computations directly in terms of the Lambert Grid.

TABLE A

CALIBRATION CERTIFICATE

Horizontal lengths of the various sections of H.S.B. tape No. 109 when hanging in catenary under a tension of 6 kg at 30°C as determined on 25–6–1968.

Section and Colour at ends	Section length	*Junction Link	*End Links	Supported at every 40 metres	Supported at every 60 metres	No intermediate support
	m	*m*	*m*	*m*	*m*	*m*
Target A						
AP Red	*20·0025*		*0·1301*			
				AQ *39·9955*		
PQ White	*20·0028*	*0·1027*				
				PR *39·9955*	AR *59·9684*	AB *79·9124*
QR Blue	*20·0025*					
		0·1030		QB *39·9958*	PB *59·9690*	
RB Green	*20·0031*					
		0·0951				
Target B			*0·1405*			
TOTAL	*80·0109*	+ *0·3008*	+ *0·2706*			

* These should be remeasured occasionally and the correct values substituted.

Note :–(*i*) The coefficient of expansion of steel is 11461×10^{-9} per °C.
(*ii*) The weight of 4 sections of the tape is 0·97 kg.

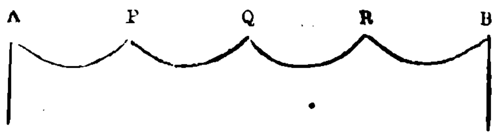


TABLE B

Corrections for Temperature (Centigrade)

		20-m base	40-m base	60-m base	80-m base
Temperature	0	−0·0069	−0·0138	−0·0206	−0·0275
	5	−0·0057	−0·0115	−0·0172	−0·0229
	10	−0·0046	−0·0092	−0·0138	−0·0183
	15	−0·0034	−0·0069	−0·0103	−0·0138
	20	−0·0023	−0·0046	−0·0069	−0·0092
	25	−0·0011	−0·0023	−0·0034	−0·0046
	30	Nil	Nil	Nil	Nil
	35	+0·0011	+0·0023	+0·0034	+0·0046
	40	+0·0023	+0·0046	+0·0069	+0·0092
	45	+0·0034	+0·0069	+0·0103	+0·0138
	50	+0·0046	+0·0092	+0·0138	+0·0183
	55	+0·0057	+0·0115	+0·0172	+0·0229

Note.—The formula for the temperature correction for the 80-metre base length is +0·000917 (t−30) where t is the temperature in centigrade, the tape being standardized at 30°C and the coefficient of expansion of steel being taken as 0·000011461 per degree C.

TABLE C

Value of S, the correction for slope

The following are the possible cases :—

When the full base is used:
1. with all intermediate supports.
2. with some intermediate supports.
3. without any intermediate support.

When part base is used:
4. with all intermediate supports.
5. with some intermediate supports.
6. without any intermediate support.

These six cases are dealt with separately below. But it is recommended that with both the whole and part base, either all or no intermediate supports should, if possible, be used, in order to simplify computation of the slope correction.

Case 1.—General case when the full length (80-metre) base is used, with all intermediate supports.

If slope of $AP = \alpha_1$, $AQ = \alpha_2$, $AR = \alpha_3$, $AB = \alpha_4$ obtained by theodolite readings from A to a target at correct height above the tape (see para 13).

and slope of each section

$$AP = \beta_1$$
$$PQ = \beta_2$$
$$QR = \beta_3$$
$$RB = \beta_4$$

then

$$\left.\begin{aligned} \beta_1 &= a_1 \\ \beta_2 &= 2a_2 - a_1 \\ \beta_3 &= 3a_3 - 2a_2 \\ \beta_4 &= 4a_4 - 3a_3 \end{aligned}\right\} \text{for slopes not greater than } 6° \text{ or } 1 \text{ in } 10.$$

For larger slopes up to 20°. β_3 and β_4 must be determined more rigorously from the following equations :—

$$\sin(\beta_3 - a_3) = \sin(a_3 - \beta_1) + \sin(a_3 - \beta_2)$$
$$= 2\sin(a_3 - a_2)\cos(a_2 - a_1).$$
$$\sin(\beta_4 - a_4) = \sin(a_4 - \beta_1) + \sin(a_4 - \beta_2) + \sin(a_4 - \beta_3).$$

For slopes more than 20°, see para 18.

Having obtained the values β_1, β_2, β_3 and β_4 the correction factor S is $\frac{1}{4}(\cos\beta_1 + \cos\beta_2 + \cos\beta_3 + \cos\beta_4)$, and the correction for slope $= -(1 - S)\,l$, where l is the length of the base.

Expressed logarithmically, it may be taken as

$$\log S = \tfrac{1}{4}(\log\cos\beta_1 + \log\cos\beta_2 + \log\cos\beta_3 + \log\cos\beta_4).$$

5-figure logarithms will be sufficient unless an accuracy of $\frac{1}{20000}$ is desired in which case this correction must be taken to 6 decimal places.

Case 2.—Enter the slope angle in two or more appropriate places and use the following angles in the computations as though actually observed.

Thus :— (*i*) When only support P is omitted, $a_1 = a_2$.

(*ii*) When supports P & Q are omitted, $a_1 = a_2 = a_3$.

(*iii*) When only support Q is omitted, $a_2 = \dfrac{3a_3 + a_1}{4}$.

(*iv*) When only support R is omitted, $a_3 = \dfrac{2a_4 + a_2}{3}$.

(*v*) When supports Q & R are omitted, $a_2 = \dfrac{2a_4 + a_1}{3}$; $a_3 = \dfrac{8a_4 + a_1}{9}$.

(*vi*) When supports P & R are omitted, $a_1 = a_2$; $a_3 = \dfrac{2a_4 + a_2}{3}$.

Case 3.—When all intermediate supports are omitted, the slope factor for base of any length (20, 40, 60 or 80 metres) is cosine of the observed slope angle.

Case 4.—Same as Case 1, some angles being omitted. Thus with 60-metre base, fill up slopes for AP, AQ and AR (taking place of AB which is left blank).

For 60-metre base, log slope factor

$$= \tfrac{1}{3}(\log\cos\beta_1 + \log\cos\beta_2 + \log\cos\beta_3).$$

For 40-metre base, this factor

$$= \tfrac{1}{2}(\log\cos\beta_1 + \log\cos\beta_2).$$

Case 5.—Same as Case 2, some appropriate angles being omitted.

Case 6.—Same as Case 3.

The essential point is that each section requires to be multiplied by cosine of the slope of the line joining its two ends. The log slope factor of the whole base is the mean of log cosines of the slope of each section, any section of more than one chain being duly weighted when taking the mean.

Correction in metres for slope for one section (always —ve)

β Min.	Correction	β Min.	Correction	β Min.	Correction	β Min.	Correction	β Min.	Correction	β Min.	Correction	β Min.	Correction	β Min.	Correction
0	0·0000	80	0·0054	116	0·0114	152	0·0195	188	0·0299	224	0·0424	260	0·0572	296	0·0741
19	0·0003	82	0·0057	118	0·0118	154	0·0201	190	0·0305	226	0·0432	262	0·0581	298	0·0751
27	0·0006	84	0·0060	120	0·0122	156	0·0206	192	0·0312	228	0·0440	264	0·0589	300	0·0761
34	0·0010	86	0·0063	122	0·0126	158	0·0211	194	0·0318	230	0·0447	266	0·0598		
39	0·0013	88	0·0066	124	0·0130	160	0·0217	196	0·0325	232	0·0455	268	0·0607		
43	0·0016	90	0·0069	126	0·0134	162	0·0222	198	0·0332	234	0·0463	270	0·0617		
47	0·0019	92	0·0072	128	0·0139	164	0·0228	200	0·0338	236	0·0471	272	0·0626		
51	0·0022	94	0·0075	130	0·0143	166	0·0233	202	0·0345	238	0·0479	274	0·0635		
54	0·0025	96	0·0078	132	0·0147	168	0·0239	204	0·0352	240	0·0487	276	0·0644		
58	0·0028	98	0·0081	134	0·0152	170	0·0244	206	0·0359	242	0·0495	278	0·0654		
61	0·0031	100	0·0085	136	0·0156	172	0·0250	208	0·0366	244	0·0504	280	0·0663		
63	0·0034	102	0·0088	138	0·0161	174	0·0256	210	0·0373	246	0·0512	282	0·0673		
66	0·0037	104	0·0092	140	0·0166	176	0·0262	212	0·0380	248	0·0520	284	0·0682		
69	0·0040	106	0·0095	142	0·0171	178	0·0268	214	0·0387	250	0·0529	286	0·0692		
71	0·0043	108	0·0099	144	0·0175	180	0·0274	216	0·0395	252	0·0537	288	0·0701		
74	0·0046	110	0·0102	146	0·0180	182	0·0280	218	0·0402	254	0·0546	290	0·0711		
76	0·0049	112	0·0106	148	0·0185	184	0·0286	220	0·0409	256	0·0554	292	0·0721		
78	0·0051	114	0·0110	150	0·0190	186	0·0293	222	0·0417	258	0·0563	294	0·0731		

TABLE D

***Correction for height above mean sea-level** (**always —ve**)*

		20-metre base	40-metre base	60-metre base	80-metre base
Height in metres above M.S.L.	0	0·0000	0·0000	0·0000	0·0000
	300	−0·0009	−0·0019	−0·0028	−0·0038
	600	−0·0019	−0·0038	−0·0057	−0·0075
	900	−0·0028	−0·0057	−0·0085	−0·0113
	1,200	−0·0038	−0·0075	−0·0113	−0·0151
	1,500	−0·0047	−0·0094	−0·0141	−0·0188
	1,800	−0·0057	−0·0113	−0·0170	−0·0226
	2,100	−0·0066	−0·0132	−0·0198	−0·0264
	2,400	−0·0075	−0·0151	−0·0226	−0·0301
	2,700	−0·0085	−0·0170	−0·0254	−0·0339
	3,000	−0·0094	−0·0188	−0·0283	−0·0377
	3,300	−0·0104	−0·0207	−0·0311	−0·0414

Note.—The correction is $-\frac{h\,l}{R}$, where h = height of ground in metres. R = mean radius of the earth = 6,371,200 metres and l = the length of the base. (An error of 100 metres in the estimation of M.S.L. height gives an error of $\frac{1}{63,700}$).

SURVEY OF INDIA

No......PARTY (..................) SEASON 19 .

15 $\frac{\text{Mach.}}{\text{Lamb.}}$ *Hunter Short Base* Grid I A $\begin{cases} \lambda_0 & 32° \; 30′ \\ L_0 & 68 \; 00 \end{cases}$

Description. The base is on sloping ground, outside the north perimeter of SARWEKAI camp and lies east and west. The east end is marked by a circle and dot cut on a buried stone with a cairn of stones. The other end is unmarked.

Observer: N. S. R.

Date July 1968

←——— To be entered at site ———→

Tape	Length (metres)	Junctions in metres	Observed angle		Tape No.	109	Corrections (all negative except temperature over 30°) metres
		0·1301	(2) a_4	+ 187′	Latitude	33° 17′	
A	20·0025						
		0·1027	(2) a_3	+ 170′	(1) Temperature	24·4°C	(3) −0·0052
B	20·0028						
		0·1030	(2) a_2	+ 196′	Height above M.S.L.	1100 *m*	(3) −0·0138
C	20·0025						
		0·0951	(2) a_1 (near end)	+ 273′		Diagram 	
D	20·0031						
(Enter total if all tapes used)		0·1405	$4a_4$	+ 748′	(4) $\beta_4 = 4a_4 \sim 3a_3$	238′ (Slope corrections)	(3) −0·0479
Total	80·0109	0·5714	$3a_3$	+ 510′	$\beta_3 = 3a_3 \sim 2a_2$	118 (Slope corrections)	−0·0118
			$2a_2$	+ 392′	$\beta_2 = 2a_2 \sim a_1$	110 (Slope corrections)	−0·0120
			a_1	+273′	$\beta_1 = a_1$	273 (Slope corrections)	−0·0630
						Total corrections	−0·1537

Sum	80·5823
Total corrections in metres	− 0·1537
Sum = Length of base in metres = l	80·4286
Scale Factor (5)	0·99888
$l \times F$ = Base in grid metres	80·3385

If using log tables, complete computation below :

Log length in metres	1·90541
Log scale factor (from 2 Grid)	$\bar{1}$·99951
Sum = log base in grid metres	1·90492

(1) Mean temperature during observations of small angle.
(2) In minutes ; ignore if all a's are less than 4′.
If any support is missing, leave the corresponding angle blank.
(3) From table on pages 7 to 10.
(4) Each β is the *algebraic* difference ; the signs of $4a_4$, $3a_3$ etc., must therefore be taken into account. See NOTE given below if any supports are omitted. See page 0 for precise formula if any β is greater than 300′.
(5) From 2 Grid.

NOTE :—If one or more supports are omitted the following procedure is to be adopted :—

(*i*) In column for a_4, a_3 etc., the lines corresponding to the missing supports are to be left blank, i.e., if the 3rd support from the near end is missing, leave a_3 blank.

(*ii*) In the column giving β_4, β_3 etc., for bays in which one or more supports are missing, β for each tape in the bay is given by the formula $\beta = \frac{m a_m - n a_n}{m - n}$, where the further support of the bay is at the m^{th} junction between tapes from the near end and the nearer support is at the n^{th} junction ; the vertical angles to these supports being a_m & a_n respectively.

Computed by H. R. M. *Date* 1–8–68 *Checked by* S. Singh *Date* 1–8–68

DIAGRAM OF HUNTER SHORT BASE AS ERECTED

NOT TO SCALE