SURVEY OF INDIA

MACHINE COMPUTATION

FIRST EDITION

This pamphlet is a Supplement to Chapters VIII & XII of the Survey of India Handbook of Topography

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PUBLISHED BY ORDER OF
THE SURVEYOR GENERAL OF INDIA

PRINTED AT THE OFFICE OF THE GEODETIC BRANCH,
SURVEY OF INDIA, DEHRA DUN, 1944.

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CONTENTS

PREFACE

1. This pamphlet contains worked examples with instructions for machine computing of all forms normally required for triangulation, traverse and Air Survey. The following types of rotary calculating machines may be used :—

(i) The Marchant XL.
(ii) The Brunsviga 10.
(iii) The Brunsviga 15.
(iv) The Brunsviga 18.
(v) The Brunsviga 20
(vi) The Brunsviga Twin 13-Z.

Of the above Nos. (i) to (v) are single calculating machines, while (vi) consists of two identical machines coupled together with a gear lever, which in different positions enables one machine to be driven singly, or both machines to be driven in the same or opposite directions.

All forms can be worked with a single rotary machine except 33 Mach. which is designed for the Brunsviga Twin 13-Z. Forms 4, 5, 17, 21 and 34 Mach. may also be computed with a twin machine.

2. Separate booklets describing in detail the working of each type of machine exist. Some general notes, which are likely to be of use are given below :—

(a) *General description*:—All computing machines that will be met with in Field Survey Companies, are of the same fundamental design.

They consist of a drum carrying the setting levers which can be rotated forwards or backwards by the operating handle. This drum is composed of a number of plates, each one carrying a setting lever. Movemement of a setting lever projects from 1 to 9 teeth, according to the amount of movement, around a segment of the circumference of the plate.

When the drum is rotated, these projected teeth will engage, indirectly, a wheel carrying 10 teeth right round the circumference. On the circumference are also printed the figures 0 to 9. These figures are viewed through a window one digit in size. The wheel carries a stud so that when it passes from 0 to 9 or from 9 to 0 the next wheel to the left is moved one division for the carry over.

The revolutions of the drum are recorded by a revolution counter.

The setting levers are referred to as S.L. hereafter, the drum revolution counter as M.R. (multiplier register) and the series of windows through which the numbered wheels are viewed as the P.R. (product register).

The whole carriage of the P.R. can be moved relatively to the S.L. drum so that the S.L. plates can operate on any of the wheels in the P.R. Movement of the P.R. carriage moves the indication in the M.R. a corresponding amount.

The functioning of the revolution counter in the M.R. varies with different machines. In the Brunsvigas, the M.R. records revolutions in the direction of the first turn after the last clearance of the M.R. In some earlier machines there is no carry over in the M.R. In the Marchant machines the M.R. records forward turns when a lever is set to $\times$ and backward turns when the lever is set at $\div$. Turns in the opposite direction reduce the total shown in the M.R.

(b) *Addition and subtraction*:—When a setting lever is moved to, say, position 4, four teeth are projected. The complete forward rotation of the drum by the handle causes the numbered wheel to move forward four—tenths of a turn thus increasing the indication of the numbering seen in the fixed window by four.

With the setting lever at, say, position 8, eight-tenths are projected and rotation of the drum adds eight to the indication of the numbered wheel. In a similar way rotating the drum backwards decreases the number indicated on the wheel thus effecting subtraction.

The S.L., M.R. and P.R. of the machines can be cleared by means of "clearing levers" i.e. they can be made to read 00000.

In the Brunsviga Twin 13-Z, there are S.L., M.R. and P.R. for each component machine. For the left-hand (referred to hereafter as L.H.) machine, these are referred to as L.H. S.L., L.H. M.R. and L.H. P.R., and for the right-hand (referred to as R.H.) machine as R.H. S.L., R.H.M.R. and R.H.P.R. respectively. In this machine there is a means by which the M.R. of the L.H. machine can count in the reverse direction to normal. This consists of a milled knot in the left hand side of the L.H. machine. If this knot is pushed inwards, the M.R. counts normally. If it is pulled out the M.R. counts in the reverse manner.

Decimal point markers are provided in S.L., M.R. and P.R.

(c) *Multiplication*.—Multiplication is dealt with as continued addition. That is to say, 7×4 is equivalent to $7+7+7+7$. To form this product, 7 is set on S.L., and the handle turned four times. This 4 appears in M.R. and the product in P.R. To enable one to multiply by large numbers quickly, the cogs connected to P.R. are movable to the right

relative to the cogs on the drum. By moving P.R. one place to the right each turn will add the number in S.L. into P.R. one place to the left of normal, i.e., will add ten times that number. Thus to multiply by 142, handle turns are made as follows : 1 with the carriage two places to the right, 4 with it one place, and 2 in the normal or units position. A great saving of time can be made by "short-cutting". That is, one could multiply by 7109 with 17 turns as described above, but with 7 by turning the handle 1311 f times, where a bar denotes backward turns. To attain speed in multiplying, it is essential to look at the multiplier as written on the paper all the time and to count the handle turns. As the handle is being turned the eye should be on the next number so that one can decide whether to turn one more forward and then back or not ; in fact, whether "short-cutting" is necessary.

(d) *Division.*—A machine can be used for division in three ways. The most common and useful being equivalent to the long division method as taught to children. The dividend is set in the S.L. and multiplied by 1 with as many naughts after it as decimal places required in the answer. The divisor is then set and the handle turned backwards until the P.R. has been reduced to the smallest possible amount. To do this the handle is turned backwards in each position of the carriage until one more turn would make the P.R. less than 0. The same is then done in the next position. After practice it is possible to "short-cut" by turning too far in one position and forward in the next where turns are saved by this means. It is worth noting here that a negative number in the P.R., say —14, appears as a complement i.e., 999.. ..9986. All machines have a device so that their M.R. counts upwards, either forward or backward according to whether the first turn is forward or backwards. If more handle turns are subsequently made the opposite way to the first the M.R. will show a complement.

A second method is to build up the dividend in the P.R. with the divisor in the S.L. to get the quotient in the M.R.

The third method is to obtain the reciprocal of the divisor and multiply by the dividend. This way is used when a series of dividends are to be divided by the same divisor, as, after one product is formed, the dividend in the M.R. is altered to the next dividend and the quotient in the P.R. is altered to the next one required automatically.

(e) *Square roots.*—To obtain square root the following procedure should be adopted :—

(i) Obtain approximate square root by means of slide-rule or 10 Math. (Part II, Aux. Tables).

(ii) Set the number whose square root is required on S.L. starting with L.H. extreme S.L.). Turn handle forwards once with the carriage in the extreme R.H. position, bringing it into P.R. Clear S.L. and M.R.

(iii) Set the approximate square root obtained in (i) above on S.L. starting with the L.H. S.L. and divide until twice as many figures as are set on S.L. appear in M.R.

(iv) Mentally take the mean of the number appearing in M.R. and the number set on S.L. adding noughts to the latter so as to make the number of digits in both of these numbers the same.

This mean is a value of the square root of the number required. To decide how many digits are correct, note the number of figures, starting from the beginning that are the same in both the mean and the number set on S.L. This number doubled is the number of digits to which the square root is correct. For example—if the number set on S.L. was 67,320,000 and the mean of this number and the number appearing in M.R. is 67, 347,806 then since 3 figures (673) are common to both numbers the mean is correct to $3 \times 2 = 6$ digits.

(v) If more digits are required, set the mean obtained in (iv) above on S.L. Clear P.R. and M.R. and turn handle forwards until the number whose square root is required appears in the P.R. Again, take the mean of the number appearing in the M.R. and that set on S.L. This mean is a better value of the required square root, and it is correct to twice as many digits as were correct in the number now appearing on S.L.

(vi) Check the final accepted square root by multiplying it by itself.

(f) *Short-cut methods.*—The process of turning the handle backwards as well as forwards to reduce the number of turnings is known as "Short-cutting". Much time is saved and the method should therefore always be used. Short-cut the numbers 6, 7, 8, 9 and their combinations and 5's when it is preceded by a number greater than five, e.g.

To multiply by 9, multiply by 10 then subtract 1
To multiply by 47, multiply by 50 then subtract 3
To multiply by 789, multiply by 1000 then subtract 211

and so on. Thus 7, 3 and 19 turns respectively are saved in the above 3 operations.

(g) *Complements.*—Whenever a number is set on S.L. and subtracted from a number appearing in the P.R. which is less than it, the P.R. will show a figure which is called a "complement". Such a figure will normally have the left-hand digits all nines.

Similarly if, in the Marchant machine, M.R. is cleared, the gear lever is set to $\div$ and the handle is turned forwards, the M.R. will show a "complement" or, with Brunsviga machine, if after clearing M.R. the handle is given one turn in one direction followed by two turns in the opposite direction, the M.R. will show a "complement".

Note that "complements" should never be set on S.L. for any operation. The direct number should always be formed mentally and set, note being taken of the appropriate sign when doing so (see sub-para i).

(h) *Decimal points, setting and signs.*—In the 'instructions' contained in this Supplement no rule of thumb is given for setting of numbers, or for placing the decimal point (except in the case of Form 6 Mach.). The general rule that the number of decimal places on S.L.+ number of decimal places on M.R.=number of decimal places on P.R. must always be applied.

When making a series of similar computations, the decimal point must always be set at the commencement. Care must always be taken that the decimal point markers are so set that the required number of decimal places is obtained in the result.

Similarly, where necessary it must be decided by inspection whether the sign is positive or negative.

(i) *Checks.*—Checks must always be applied. Instructions attached to forms indicate all checks that can conveniently be made. In particular, when transferring a number from P.R. to S.L., after setting it on S.L. the handle should always be given one backward turn, and it should be checked that the P.R. shows 00000. This check is not necessary in the case of the Brunsviga 15 which has the automatic transfer device. If it is necessary to transfer the complement of the figure in the P.R. to S.L., check by turning the handle forwards once and seeing that P.R. reads 1·00000.

"Before beginning a new calculation, it is essential to see that all registers have been cleared. If it is suspected that the clearing levers do not clear all the figures in one operation, the machine should be examined for defects".

(j) *Arrangement and order of work.*—The detailed instructions for machine working of each form are so designed that the work is reduced to a minimum. They should be followed exactly.

The principle of machine working is that the number of settings made on S.L. should be reduced to a minimum, and this fact should always be borne in mind. If one setting is common to all of several deductions on one form, the operation involving this setting should be carried out for all deductions consecutively. In such a case to compute each deduction separately from start to finish would be waste of time.

(k) *Hints for rapid working.*—Keep the table on which you work clear of surplus papers. Fill in all necessary data on forms before starting machine work.

Work with machine directly in front of the body. Have the form being worked just clear of the machine, and to the *right* of it. Keep any tables required on the *left-hand* side and turn pages with the left-hand. Hold pen or pencil in the right-hand the whole time. Do not put it down while operating the handle.

In multiplication do not watch the M.R. while turning the handle. Keep looking at the multiplier written on the form and mentally count the turns forwards and backwards.

Practise setting by touch i.e., look at the number to be set and not at the S.L. while setting. Use the left-hand for setting. It is always best to set figures on S.L. from left to right as they are read off.

(l) *Care of machines.*—It must be remembered that a calculating machine is a finely constructed mechanical device which naturally requires careful treatment.

Observe all rules framed by the makers for care of machines. Turn the handle evenly, quickly, but without sudden jerks. Never force a machine if it jams. Find out what is locking it, and release it. If the operator handles the machine carefully he may expect the greatest efficiency from it, and will find that repairs are hardly ever required.

When not in use, keep the machine covered in order to protect it against dust and dirt. Do not leave it exposed to hot sunshine or in very damp or hot premises.

Pack machines carefully and correctly according to the makers' instructions when in transit.

It is advisable for every computing section to carry a screw driver, spare screws to fit each type of machine, best machine-oil with oil can and a soft brush so that minor repairs and dusting and oiling, if required, may be carried out by the computers themselves.

I MACH.

1. Complete headings, entering Grid, Origin, Spheroid in use and striking out METRES or YARDS whichever is not applicable.

2. Complete lines 1 to 5 as instructed on the form.

3. Set 48 481 368 on S.L. and multiply by ΔL in seconds (line 5). Record product from P.R. in line 6 with the same sign as line 5, noting the decimal point correctly. Clear S.L., P.R. and M.R.

4. Set δL (line 6) on S.L. and multiply by itself, i.e. by δL. The product is δL^2. Clear S.L. and M.R. Transfer product from P.R. to S.L. and clear P.R. Multiply by A from the table at the bottom of the form for the grid concerned. Record the product in line 7. Clear P.R. and M.R.

5. δL^2 is already on S.L. Multiply this by itself, i.e. by δL^2, the figure on S.L. The product is δL^4. Clear S.L. and M.R. Transfer product to S.L. Clear P.R. and multiply by B from the table at the bottom of the form for the particular grid. Record the product in line 8 with correct decimal point. Clear S.L., M.R. and P.R.

6. Set (1 + line 8) on S.L. Turn handle forwards once. Clear S.L. and M.R. Set line 7 on S.L. and turn handle backwards once. Record result from P.R. in line 9. Clear M.R. and P.R. Multiply the figure on S.L. by 1·5. Clear S.L. and M.R. Set line 9 on S.L. with 9th decimal as zero. Turn handle forwards once and record result from P.R. in line 10, carefully noting the decimal point. Clear S.L., M.R. and P.R.

NOTE :—It is generally quicker to add 1 mentally to line 8 and subtract line 7 by hand, recording the result in line 9 ; and similarly to add 1 mentally to line 8 and add $\frac{1}{2}$ of line 7, recording the result in line 10.

7. Complete lines 11 to 15.

8. Set line 15 on S.L. and turn handle forwards once. Clear S.L. and M.R. Set line 14 on S.L. and multiply by line 13 by turning the handle forwards or backwards according as the signs of lines 13 and 15 are the same or opposite, carefully noting the decimal point. Record the product in line 16 with same sign as line 15. Clear S.L., M.R. and P.R.

9. Set D (from table at the bottom of the form for the grid concerned) on S.L. and turn handle forwards once. Clear S.L. and M.R. Set S_p (line 16) on S.L. and multiply by sin λ_0 (from table at the bottom of the form for the particular grid) by turning the handle backwards or forwards according as S_p (line 16) is positive or negative. Clear S.L. and M.R. Transfer the product to S.L. Clear P.R. Multiply by line 9 and clear S.L. and M.R. Transfer the product to S.L. Clear P.R. Multiply by line 6 and record the product in line 17 with the same sign as line 6. Clear S.L. and M.R. In all these operations care should be taken in noting the decimal point.

10. (*a*) Divide the figure in P.R. or line 17 mentally by 2 and set it on S.L. Clear P.R. and multiply by sin λ_0 from table at the bottom of the form for the particular grid. Clear S.L. and M.R. Transfer the product from P.R. to S.L. Clear P.R. and multiply by δL (line 6). Clear S.L. and M.R. Transfer product to S.L. Clear P.R. and multiply by Σ_2 (line 10). Clear S.L. and M.R.

Now use whichever of the following methods is applicable : –

(*b*) When S_p (line 16) is positive : Set S_p (line 16) on S.L. and turn handle forwards once, recording the result from P.R. in line 18 with positive sign.

(*c*) When S_p (line 16) is negative and numerically less than the figure in P.R. : Set S_p (line 16) on S.L. and turn handle backwards once, recording the result from P.R. in line 18 with positive sign.

(*d*) When S_p (line 16) is negative and numerically greater than the figure in P.R. : Transfer the figure from P.R. to S.L. Clear P.R. and turn handle backwards once. Clear S.L. and M.R. Set S_p (line 16) on S.L. and turn handle forwards once. Record result from P.R. in line 18 with negative sign. Clear S.L., M.R. and P.R.

11. Complete lines 19 and 20.

NOTE :—As an alternative after item 9 proceed as follows :—

(i) When line 17 is positive : Set E_0 (from table at the bottom of the form for the particular grid) on S.L. and turn handle forwards once. Record result from P.R. in line 19, carefully noting the decimal point. Turn handle backwards once. Clear S.L. and proceed as instructed in 10 (*a*).

(ii) When line 17 is negative : Transfer the product to S.L. Clear P.R. Turn handle backwards once. Clear S.L. and M.R. Set E_0 (same as above) on S.L. and turn handle forwards once. Record result from P.R. in line 19, carefully noting the decimal point. Clear S.L., M.R. and P.R. and proceed as instructed in item 10 (*a*).

After carrying out the operation in item 10 (*a*) above, set N_0 (from table at the bottom of the form for the particular grid) on S.L. and turn handle forwards once. Clear S.L. and M.R. Set S_p (line 16) on S.L. and turn handle forwards or backwards once according as S_p (line 16) is positive or negative, noting the decimal point carefully. Record result from P.R. in line 20, no entry being made in line 18.

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B **SECTION** No. 3 Ind. Eq. Surv. **COMPANY.** **DATE** June 1940 **SHEET No.**

Machine deduction of grid co-ordinates from spherical

Grid II B λ_0 26° 00′ L_0 80° 00′

Formulæ :—(1) $\Sigma_1 = 1 - A\,\delta L^2 + B\,\delta L^4$ (i)
(2) $\Sigma_2 = \Sigma_1 + \frac{3}{2}\,A\,\delta L^2$
(3) $E_p = (D - S_p \sin\lambda_0)\,\delta L \times \Sigma_1$
(4) $N_p = \frac{1}{2}\,E_p\,\delta L \sin\lambda_0 \times \Sigma_2 + S_p$

Everest SPHEROID **METRES** or YARDS

1	Point P	Calcu.	Hill		
2	Latitude of P $= \lambda_p$	22° 03′ 59·01	29° 58′ 52·43	° ′ ″ .	° ′ ″ .
3	Longitude of P $= L_p$	108° 01′ 02·96	81° 01′ 00·38	.	.
4	$\Delta L = L_p - L_0$ (i)	+16° 01′ 02·96	− 8° 58′ 59·62	− .	− .
5	ΔL in seconds	+ 64 862·96″	− 32 339·62″	− .″	− .″
6	$\delta L = \Delta L \times 4\,848\,136\,8 \times 10^{-13}$ (8 places)	+0·314 40 450	−0·156 78 690	−0·	−0·
7	$A \times \delta L^2$ (8 places) (i)	0·00 00 770	0·00 078 732	0·	0·
8	$B \times \delta L^4$ (8 places) (i)	0·00 000 001	0·00 000 019	0·	0·
9	Σ_1 [formula (1)] (ii) = 1 + line (8) − line (7)	0·99 923 231	0·99 921 287	0·	0·
10	Σ_2 [formula (2)] = line (9) + 1·5 × line (7)	1·00 158 66	1·00 039 305	1·	1·
11	Nearest latitude to P $= \lambda_a$ (iii)	22° 04′ 00·00	29° 58′ 00·00	° ′ 00·00	° ′ 00·00
12	$\lambda_p - \lambda_a = \Delta\lambda_p$	− 31·99	+ 52·43	− .	− .
13	$\Delta\lambda_p$ in seconds	− 31·99″	+ 52·43″	− .″	− .″
14	Δ for $\lambda_a = \Delta_a$ (iii)	33·673	33·713	.	.
15	S for $\lambda_a = S_a$ (iii)	− 476 184·3	+ 480 492·6	− .	− .
16	$S_a + \Delta_a \times \Delta\lambda_p = S_p$	− 477 261·5	+ 482 260·2	− .	− .
17	E_p [formula (3)] (ii)	+ 2 029 425·2	− 948 354·5	− .	− .
18	N_p [formula (4)] (ii)	− 337 159·2	+ 514 863·6	− .	− .
19	$E_p = E_0 + E_p$ (i)	5 029 425·2	2 051 645·5	.	.
20	$N_p = N_0 + N_p$ (i)	662 840·8	1 514 863·6	.	.

(i) Values of constants to be ascertained for grid in use from table below.
(ii) For instructions on machine working, see Supplement to T. H. B. Chapter VIII.
(iii) From 1 Grid, for the spheroid on which the spherical co-ordinates of P have been calculated.

	Grid B	Grid C	Grid O	Grid I	Grid II A	Grid II B	Grid III A	Grid III B	Grid IV A	Grid IV B
L_0	45°	45°	68°	68°	74°	90°	80°	100°	80°	104°
λ_0	32° 30′	39° 30′	39° 30′	32° 30′	26° 00′		19° 00′		12° 00′	
sin λ_0	0·53729961	0·63607823	0·63607823	0·53729961	0·43837115		0·32556815		0·20791169	
$A = \frac{1}{6}\sin^2\lambda_0$	0·04811515	0·06743259	0·06743259	0·04811515	0·03202821		0·01766577		0·00720455	
$B = \frac{1}{120}\sin^4\lambda_0$	0·00069452	0·00136415	0·00136415	0·00069452	0·00030774		0·00009382		0·00001557	
$D = F_0\,\nu_0\cos\lambda_0$ Clarke	5,378,116·6	4,920,819·5	...	...	...		...		...	
$D = F_0\,\nu_0\cos\lambda_0$ Everest	5,377,191·8	4,919,925·0	5,380,500·1	5,880,573·6*	6,264,858·4		6,588,655·6		6,814,603·9	
$D = F_0\,\nu_0\cos\lambda_0$ Walbeck	...	4,919,571·3	...	...	...		...		...	
$D = F_0\,\nu_0\cos\lambda_0$ Bessel	...	...	5,380,618·5	...	...		...		...	
E_0	1,500,000	2,155,500	2,355,500	3,000,000	3,000,000		3,000,000		3,000,000	
N_0	1,166,200	675,000	2,590,000	1,000,000	1,000,000		1,000,000		1,000,000	
Units	Metres	Metres	Yards	Yards	Yards		Yards		Yards	

* This is an adjusted value.

Computed by *Date* *Checked by* *Date*

G.B.—P.O.—J.S. 28—19·1·44—500.

INSTRUCTIONS

I (A) MACH.

1. Complete headings entering the name of the grid, the true (spherical) co-ordinates of its origin, spheroid in use and the value of FE (grid easting of origin), striking out 'Metres' or 'yards' whichever is not applicable.

2. Complete lines 1 to 3.

3. Now interpolate values of r and y' for ϕ_P as follows :—

(i) Set upper tabular value of r in P.R. on machine, set "Diff. for 1″" on S.L., multiply, turning handle backwards, with seconds in ϕ_P, and record figures in P.R. in line 4, left-hand column.

(ii) Continue multiplying, turning handle backwards, till M.R. shows 60·00.

(iii) Check that P.R. now reads lower tabular value.

Repeat the above process for y', turning handle forward, and record the result after process (i) in line 4, right-hand column.

NOTE :—As the Diff. for 1″ for r and y' is the same it is sometimes more rapid to set "Diff. for 1″" on S.L. and multiply with seconds of ϕ_P and subtract the result mentally from upper tabular value of r and add to the upper tabular value of y' and then continue to multiply till M.R. shows 60·00, add the upper value of y' and see that P.R. reads lower value of y'.

4. From Table II set sin θ for $\Delta\lambda$ to the whole minutes in P.R. Set difference for 1″ corresponding to it on S.L. and multiply with seconds in $\Delta\lambda$ turning handle forward. Record figures in P.R. in line 5. Continue to multiply till M.R. shows 60·00. Check that P.R. now reads tabular value for next whole minute of $\Delta\lambda$. Clear S.L., M.R. and P.R. Repeat the same process for tan $\frac{1}{2}\theta$, line 5 right-hand column.

5. Set 'r' (line 4, left-hand column) on S.L. and multiply with sin θ (line 5, left-hand column) and record with proper sign figures in P.R. in line 6, left-hand column. Clear S.L. and M.R. Transfer figures on P.R. to S.L. and multiply with tan $\frac{1}{2}\theta$ (line 5, right-hand column). Record figures with proper sign in P.R. in line 6, right-hand column.

6. Complete lines 7 and 8.

1(A) Mach. **Survey of India** Page.....

B **SECTION** No3 Ind. Fd. Svy **COMPANY** **DATE** March 1940

Machine deduction of grid co-ordinates from spherical with American tables

GRID ORIGIN III A $\begin{cases} \phi_0 \text{ (Lat.)} & ° \quad ' \\ \lambda_0 \text{ (Long.)} & \end{cases}$

FORMULÆ:—(1) $E_p = FE + x'$, $x' = r \sin \theta$. (2) $N_p = y' + y'' = y' + x' \tan \frac{1}{2}\theta$.

SPHEROID Everest FE (Grid Easting of Origin) = 3 000 000 METRES or YARDS

1	Point P		Garan S									
2	Latitude of $P = \phi_p$	Longitude of $P = \lambda_p$	° ' "	° ' "	° ' "	° ' "	° ' "	° ' "	° ' "	° ' "	° ' "	° ' "
3		$\Delta\lambda = \lambda_p - \lambda_0$										
4	$r^{(i)}$ for ϕ_p	$y'^{(i)}$ for ϕ_p										
5	Sin $\theta^{(ii)}$ for $\Delta\lambda$	$\tan \frac{1}{2}\theta^{(ii)}$ for $\Delta\lambda$			0·	0·	0·	0·	0·	0·	0·	0·
6	$x'^{(iii)} = r \sin\theta$	$y''^{(iv)} = x' \tan \frac{1}{2}\theta$										
7	Constant FE	y' (from line 4)										
8	Sum = E_p (Easting of P)	Sum = N_p (Northing of P)										

1	Point P											
2	Latitude of $P = \phi_p$	Longitude of $P = \lambda_p$	° ' "	° ' "	° ' "	° ' "	° ' "	° ' "	° ' "	° ' "	° ' "	° ' "
3		$\Delta\lambda = \lambda_p - \lambda_0$										
4	$r^{(i)}$ For ϕ_p	$y'^{(i)}$ for ϕ_p										
5	Sine $\theta^{(ii)}$ for $\Delta\lambda$	$\tan \frac{1}{2}\theta^{(ii)}$ for $\Delta\lambda$	0·	0·	0·	0·	0·	0·	0·	0·	0·	0·
6	$x'^{(iii)} = r \sin\theta$	$y''^{(iv)} = x' \tan \frac{1}{2}\theta$										
7	Constant FE	y' (from line 4)										
8	Sum = E_p (Easting of P)	Sum = N_p (Northing of P)										

(i) By interpolation from Table I for the appropriate Grid.
(ii) By interpolation from Table II for the appropriate Grid.
(iii) x' has the same sign as $\Delta\lambda$ (line 3).
(iv) y'' is + for north latitudes but − for south latitudes.

Computed by *Date* *Checked by* *Date*

G.B.—P.O.—J.S. 241—1-5-46—4,000.

2 MACH.

1. Complete headings, entering Name of Grid with Origin, Spheroid in use and striking out METRES or YARDS whichever is not applicable.

2. Complete lines 1 to 6 as instructed on the form.

3. Set D (from table at the bottom of the form for the grid concerned) on S.L. and turn handle forwards once. Clear S.L. and M.R. Set sin λ_0 (from table at the bottom of the form for the particular grid) on S.L. and multiply by N_P (line 5) by turning the handle backwards or forwards according as N_P (line 5) is positive or negative. Record the product in line 7. Clear S.L., M.R. and P.R.

4. Divide line 4 by line 6 by the built-up method, or otherwise. Record the quotient in line 8 with correct decimal point and same sign as line 4. Clear S.L., M.R. and P.R.

5. Set T (line 8) on S.L. and multiply by itself, i.e. by T, carefully noting the decimal point. The product is T^3. Divide this mentally by 3 and record the quotient in line 9. Clear S.L. and M.R. Transfer the product, i.e. T^3 to S.L. Clear P.R. and multiply by itself, i.e. by T^2, noting the decimal point carefully. The product is T^4. Divide this mentally by 5 and record the quotient in line 10. Clear S.L. and M.R. Transfer the product, i.e. T^4 to S.L. Clear P.R. and multiply by line 9. Clear S.L. and M.R. Transfer the product to S.L. Clear P.R. and multiply by 0·429. Record the product in line 11 with correct decimal point. Clear S.L., M.R. and P.R.

6. Set (1 + line 10) on S.L. and turn handle forwards once. Clear S.L. and M.R. Set line 9 on S.L. and turn handle backwards once. Clear S.L. and M.R. Set line 11 on S.L. and turn handle backwards once. Record the result from P.R. in line 12. Clear S.L., M.R. and P.R.

7. Divide line 4 by line 7 by the built-up method, or otherwise. Record the quotient in line 13 with correct decimal point and same sign as line 4. Clear S.L., M.R. and P.R.

8. Set line 12 on S.L. and multiply by line 13. Record the product in line 14 with the same sign as line 4. Clear S.L., M.R. and P.R.

9. Set 206 264·81 on S.L. and multiply by line 14. Record the product in line 15 with the same sign as line 4. Clear S.L., M.R. and P.R. Complete line 16 with the same sign as line 4.

10. Set (1·6 + line 10) on S.L. and multiply by 0·625. Clear S.L. and M.R. Set line 9 on S.L. and multiply by 0·75 by turning the handle backwards. Record the product in line 17 with correct decimal point. Clear S.L., M.R. and P.R.

11. Set $\frac{1}{2} E_P$ (i.e. $\frac{1}{2}$ of the figure in line 4) on S.L. Multiply by Σ_8 (line 17). Clear S.L. and M.R. Transfer the product to S.L. with correct decimal point. Clear P.R. and multiply by T (line 8). Clear S.L. and M.R. Now use whichever of the following methods is applicable :—

(*a*) When N_P (line 5) is negative: Set N_P (line 5) on S.L. and turn handle forwards once. Record the result in line 18 with negative sign. Clear S.L., M.R. and P.R.

(*b*) When N_P (line 5) is positive and numerically less than the figure in P.R.: Set N_P (line 5) on S.L. and turn handle backwards once. Record the result in line 18 with negative sign. Clear S.L., M.R. and P.R.

(*c*) When N_P (line 5) is positive and numerically greater than the figure in P.R.: Transfer the figure from P.R. to S.L. Clear P.R. and turn handle backwards once. Clear S.L. and M.R. Set N_P (line 5) on S.L. and turn handle forwards once. Record the result in line 18 with positive sign. Clear S.L., M.R. and P.R.

12. Complete lines 19, 20, 21 and 24.

13. Set line 21 on S.L. and turn handle forwards until P.R. shows line 20, i.e. divide line 20 by line 21 by the built-up method. Record the quotient from M.R. in line 22 with correct decimal point and same sign as line 20. Clear S.L., M.R. and P.R.

14. Complete lines 23, 25 and 26 according to the instructions given on the form.

B SECTION No. 3. Ind Fd. Svy. COMPANY. DATE June 1940 SHEET No.

Machine deduction of spherical co-ordinates from grid.

Formulæ:—(1) $T = \frac{E_p}{R_0 - N_p}$ (2) $\Sigma_1 = 1 - \frac{T^2}{3} + \frac{T^4}{5} - \frac{T^6}{7}$ (3) $\Sigma_2 = 1 - \frac{T^2}{4} + \frac{T^4}{8}$ (4) $\Delta L = \frac{E_p}{D - N_p \sin \lambda_0} \times \Sigma_1$ (5) $S_p = N_p - \frac{1}{2} E_p \times T \times \Sigma_2$

Grid (i) IIB λ_0 26° 00′ L_0 90° 00′

Everest SPHEROID METRES ~~or~~ YARDS

1	Point P	Cairn			Hill							
2	Easting of P = E_p	5 029 425·2			2 051 645·5							
3	Northing of P = N_p	662 840·8			1 514 863·6							
4	$E_p = E_p - E_0$ (i)	+ 2 029 425·2			− 948 354·5			−			−	
5	$N_p = N_p - N_0$ (i)	− 337 159·2			+ 514 863·6			−			−	
6	$R_0 - N_p$ (i)	14 628 379·1			13 726 356·3							
7	$D - N_p \sin \lambda_0$ (i)	6 412 659·3			6 039 157·1							
8	T = line (4) ÷ line (6) (8 places)	+0·13 873 206			−0·06 883 928			−0			−0·	
9	$\frac{T^2}{3}$ (8 places)	0·0 0 641 553			0·0 0 157 962			0·0			0·0	
10	$\frac{T^4}{5}$ (8 places)	0·000 07 409			0·000 00 449			0·000			0·000	
11	$\frac{T^6}{7}$ (8 places)	0·0000 0002			0·0000 0002			0·0000 00			0·0000 00	
12	Σ_1 [formula (2)] (ii)	0·99 365 754			0·99 842 485			0·			0	
13	line (4) ÷ line (7) (8 places)	+0·31 647 170			−0·15 703 425			−0			−0·	
14	ΔL = line (12) × line (13) (8 places)	+0·31 446 449			−0·15 678 690			−0			−0	
15	$\Delta L''$ = line (14) × 206264·81	+ 64 862″·96			− 32 339″·02			−		″	−	″
16	ΔL	+ 18	01′	02″·96	− 8	58′	59″·02	−	′	″	−	′ ″
17	$\Sigma_2 = 1 - 0·75 \times$ line (9) $+ 0·625 \times$ line (10) (ii)	0·99 523 466			0·99 881 809			0			0·	
18	S_p [formula (5)] (ii)	− 477 261·5			+ 482 260·2			−			−	
19	$S_a = S$ nearest to S_p (iii)	− 476 184·3			+ 480 492·6			−			−	
20	$S_p - S_a$	− 1 077·2			+ 1 767·6			−			−	
21	Δ for S_a (iii)	31″·673			33″·713							
22	$\Delta\lambda'' = $ line (20) ÷ line (21)	− 31″·99			+ 52″·43			−		″	−	″
23	$\Delta\lambda$	− 0°	00′	31″·99	+ 0°	00′	52″·43	− 0°	′	″	− 0°	′ ″
24	λ_a = lat. corresponding to S_a (iii)	22°	04′	00·00	29°	58′	00·00			00·00		00·00
25	$\lambda_p = \lambda_a + \Delta\lambda$ = lat. of P	22°	03′	28·01	29°	58′	52·43					
26	$L_p = L_0 + \Delta L$ = long. of P (i)	108°	01′	02·96	81°	01′	00·38					

(i) Values of constants to be ascertained for grid in use from table below.
(ii) For instructions on machine working, see Supplement to T.H.B. Chapter VIII.
(iii) From 1 Grid, for the spheroid on which the spherical co-ordinates of P are required.

Grid		B	C	O	I	II A	II B	III A	III B	IV A	IV B
L_0		45°	45°	68°	68°	74°	90°	80°	100°	80°	104°
Units		Metres	Metres	Indian Yards	Indian Yards	Indian Yards		Indian Yards		Indian Yards	
E_0		1,500,000	2,155,500	2,355,500	3,000,000	3,000,000		3,000,000		3,000,000	
N_0		1,166,200	675,000	2,590,000	1,000,000	1,000,000		1,000,000		1,000,000	
R_0	Clarke	10,000,530·2	7,736,186·1	...	...	...		...		...	
	Everest	10,007,808·8	7,734,779·9	8,458,865·5	10,944,682·4	14,201,219·0		20,237,408·1		32,776,434·5	
	Walbeck	...	7,734,223·8	...	...	...		...		...	
	Bessel	...	...	8,459,051·6	...	...		...		...	
$F_0 \nu_0 \cos \lambda_0 = D$	Clarke	5,378,116·6	4,920,819·5	...	...	...		...		...	
	Everest	5,377,191·8	4,919,925·0	5,380,500·1	5,880,573·6*	6,264,858·4		6,588,655·6		6,814,603·9	
	Walbeck	...	4,919,571·3	...	...	...		...		...	
	Bessel	...	...	5,380,618·5	...	...		...		...	
$\sin \lambda_0$		0·53729961	0·63607823	0·63607823	0·53729961	0·43837115		0·32556815		0·20791169	
λ_0		32° 30′	39° 30′	39° 30′	32° 30′	26° 00′		19° 00′		12° 00′	

*This is an adjusted value.

Computed by *Date* *Checked by* *Date*

G.B.—P.O.—J.S. 29—19-1-44.—500.

INSTRUCTIONS

2 (A) MACH.

1. Complete headings entering the name of the grid, the true (spherical) co-ordinates of its origin, values of r_o. FE (grid easting) and FN (grid northing) of origin for that grid, and striking out 'Metres' or 'Yards' whichever is not applicable.

2. Complete lines 1 to 4.

3. Set line 4, right-hand column on S.L. and multiply until P.R. shows x' (line 4, left-hand column). Record figures now appearing in M.R. in line 5 left-hand column, with correct decimal point.

4. Complete line 6 of left-hand column.

5. From Table II interpolate $\Delta\lambda$ for tan θ (line 5, left-hand column) as follows :—

(i) Set upper tabular value in P.R. on machine ; set "Diff. for 1"' on S.L.

(ii) Multiply till P.R. shows the value in line 5, left-hand column.

(iii) Note figures in M.R., which are the seconds of $\Delta\lambda$, to be added with correct decimal point to the value of $\Delta\lambda$ corresponding to the upper value of tan θ set in P.R. in (i). Enter $\Delta\lambda$ in line 7 left-hand column.

(iv) Continue multiplying till M.R. shows 60·000.

(v) Check that P.R. now reads lower tabular value.

Clear S.L., M.R. and P.R.

6. Interpolate value of tan $\frac{1}{2}\theta$ from Table II for $\Delta\lambda$, line 7 of left-hand column, as follows :—

Set Diff. for 1" for tan $\frac{1}{2}\theta$ on S.L. and multiply by seconds of $\Delta\lambda$. Add to figures in P.R. the tabular value of tan $\frac{1}{2}\theta$ correspoding to $\Delta\lambda$ to minutes, and record in line 5 right-hand column. Clear S.L., M.R. and P.R.

7. Set N_P (line 2, right-hand column) in P.R. Set tan $\frac{1}{2}\theta$ (line 5, right-hand column) on S.L. and multiply (turning handle backwards or forwards according as ϕ_P (is N. or S.) with x' (line 4 of left-hand column). Record value in P.R. in line 7 of right-hand column. Clear S.L., M.R. and P.R.

8. From Table I, interpolate ϕ_P for the value in line 7 of right-hand column, according to the method described in para 5 above.

2(A) Mach. Survey of India Page.....

B SECTION No 5 Ind Fd. Svy. COMPANY DATE March 1940 SHEET No. 5 K

Machine deduction of spherical co-ordinates from grid with American tables.

Formulæ :— (1) $x' = E_p - FE$. (2) $\text{Tan } \theta = x'/(r_o + FN - N_p)$. (3) $y'' = x' \tan \frac{1}{2}\theta$.

GRID ORIGIN III A ϕ_o (Lat.) 19° 0′ λ_o (Long.) 80° 0′

SPHEROID Everest r_o= 20 237 408.00 FE= 3 000 000 FN= 1 000 931

~~METRES~~ or YARDS

1	Point P		Ganam S											
2	Easting of P = E_p	Northing of P = N_p	3 249 469.9		766 891.3									
3	FE	$r_o + FN$	3 000 000.0		21 237 408.1									
4	$x' = E_p - FE$	$r_o + FN - N_p$	+ 249 469.9		20 470 516.8		−			−			−	
5	$\text{Tan } \theta = x'/(r_o + FN - N_p)$	$\text{Tan } \frac{1}{2}\theta$ (i)	0.012 186 7906		0.012 060 931 689		0·		0·	0·		0·	0·	0·
6	λ_o		80°	00′	00·00″									
7	$\Delta\lambda$ (i) (same sign as x')	$y' = N_p - y''$ (ii)	+ 2	06	40.60	765 371.2	−			−			−	
8	Sum = λ_p = Longitude of P	ϕ_p (iii) Latitude of P	82	06	40.60	17	03	34.8						

1	Point P													
2	Easting of P = E_p	Northing of P = N_p												
3	FE	$r_o + FN$												
4	$x' = E_p - FE$	$r_o + FN - N_p$	−				−			−			−	
5	$\text{Tan } \theta = x'/(r_o + FN - N_p)$	$\text{Tan } \frac{1}{2}\theta$ (i)	0·			0·	0·		0·	0·		0·	0·	0·
6	λ_o													
7	$\Delta\lambda$ (i) (same sign as x')	$y' = N_p - y''$ (ii)	−				−			−			−	
8	Sum = λ_p = Longitude of P	ϕ_p (iii) Latitude of P												

(i) By interpolation from table II for the appropriate Grid. (ii) y" is + for north latitudes and − for south latitudes. (iii) By interpolation from Table I for the appropriate Grid.

Computed by *Date* *Checked by* *Date*

G.B.—P.O.—J.S. 242—2-5-44—2,000.

INSTRUCTIONS

3 MACH.

1. Complete headings and lines 1 to 9.

2. (*a*) When ΔN (line 9) is numerically less than ΔE (line 6) and the left-hand side ($\cot \beta$) is to be computed : Set ΔE (line 6) on S.L. and turn handle forwards until P.R. shows ΔN (line 9), i.e. divide line 9 by line 6 by the built-up method. Record quotient from M.R. in line 10 with correct decimal point and enter small (c) after it to indicate that it is $\cot \beta$.

(*b*) When ΔN (line 9) is numerically greater than ΔE (line 6) and the right-hand side ($\tan \beta$) is to be computed : Set ΔN (line 9) on S.L. and turn handle forwards until P.R. shows ΔE (line 6), i.e. divide line 6 by line 9 by the built-up method. Record quotient from M.R. in line 10 with correct decimal point and enter (T) after it to indicate that it is $\tan \beta$.

3. Clear M.R. and P.R. but not S.L.

4. Complete lines 11, 12, 13 and 15 according to the instructions given on the form.

5. Multiply the figure on S.L. by line 13 [right-hand side for case 2 (*a*) and left-hand side for case 2 (*b*) above] and record the product in line 14 with correct decimal point. Clear S.L., M.R. and P.R.

6. Set line 15 on S.L. and turn handle forwards until P.R. shows line 14, i.e. divide line 14 by line 15 by the built-up method. Record quotient from M.R. in line 16 with correct decimal point.

NOTE :—If a large number of deductions are required to be computed it is economical to substitute the following procedure for paras 3 to 5 above :—

(*a*) Clear S.L., M.R. and P.R. and complete lines 11, 12, 13 and 15.

(*b*) Set ΔE (line 6) or ΔN (line 9) on S.L. according as left-hand or right-hand is to be computed (see para 2 above) and multiply by line 13. Record the result in line 14 with correct decimal point. Multiplication of lines 14 and 15 should also be done across the form for all deductions.

Machine computation of distance and grid bearings, from grid co-ordinates

Grid I $\begin{cases} \lambda_0 & 32^\circ \quad 30 \\ L_0 & 68 \quad 00 \end{cases}$ $\lambda_m = 33^\circ\ 32'$ Distance in Metres / Yards $\lambda_m = 33^\circ\ 19'$

1	Deduction Number	1	2				
2	Station B	Shinwari h.s.	Ziarat Tsailai h.s.				
3	Station A	Gurgurra h.s.	Chapri h.s.				
4	Easting of B $= E_B$	3 233 820 ·4	3 215 761 ·6	·	·	·	·
5	Easting of A $= E_A$	3 290 551 ·7	3 279 926 ·8	·	·	·	·
6	$\Delta E = E_B - E_A$	− 56 731 ·3	− 64 165 ·2	− ·	− ·	− ·	− ·
7	Northing of B $= N_B$	1 160 962 ·2	1 077 865 ·9	·	·	·	·
8	Northing of A $= N_A$	1 095 807 ·9	1 126 901 ·0	·	·	·	·
9	$\Delta N = N_B - N_A$	+ 65 154 ·3	− 49 035 ·1	− ·	− ·	− ·	− ·
10	$\cot\beta = \frac{\Delta N}{\Delta E}$ (i) | $\tan\beta = \frac{\Delta E}{\Delta N}$ (i)	0· 87 072 (T)	0· 76 420 (c)	0·	0·	0·	0·
11	β (ii) = Grid Bearing at A of B	318° 57′ 12″	232° 36′ 47″	° ′ ″	° ′ ″	° ′ ″	° ′ ″
12	$180^\circ + \beta$ = Grid Bearing at B of A	138 57 12	52 36 47				
13	cosec β (i) | sec β (i)	1· 32 595	1· 25 857	1·	1·	1·	1·
14	ΔE cosec β | ΔN sec β = AB (grid distance)	86 391 ·3	80 756 ·4	·	·	·	·
15	Scale factor = F. (iii)	0· 99 895	0· 99 889	·	·	·	·
16	Line 14 ÷ line 15 = AB (true distance)	86 482 ·1	80 846 ·1	·	·	·	·

(i) Use left side if ΔN is numerically less than ΔE, otherwise use right side.

(ii) β is in 1st, 2nd, 3rd or 4th quadrant as $\frac{\Delta N}{\Delta E}$ is $\frac{+}{+}$, $\frac{-}{+}$, $\frac{-}{-}$ or $\frac{+}{-}$.

(iii) From 2 Grid, using best estimate of latitude available.

Computed by *Date* *Checked by* *Date*

G.B.—P.O.—J.S. 30—19-1-44—1,000.

4 MACH.

1. Complete headings. Enter names of stations A and B and that of station or intersected point C. Enter observed angles (corrected for 3 Grid). In the case of stations (all three angles observed), sum up the three angles and work out triangular error. Distribute triangular error and write the corrected angles. In the case of C being an intersected point, the angle at C is deduced [180° - (A + B)] and written down in red and no entries are made in columns headed 'triangular error' and 'corrected angle', the corrected angles and the observed angles being the same.

Write down the sines of corrected angles and side AB for each triangle.

2. Computation may now be carried out with a single or twin machine.

(*a*) *With a Single Machine.*—Set AB on S.L. Turn handle forwards once. Clear S.L. and M.R. Set sin C on S.L. and divide. Clear S.L. and P.R. Transfer the number appearing in M.R. to S.L. Multiply by sin A and record the product in P.R. against side BC. Continue multiplying until M.R. reads sin B and record the number in P.R. against CA. Continue multiplying until M.R. reads sin C and check the number in P.R. = side AB.

(*b*) *With a Twin Machine.*—Set AB on right-hand S.L. Turn handle forwards once. Clear S.L. and M.R. Set sin C on R.H. S.L. and divide on right-hand machine. Clear S.L. and both P.R.'s. Connect machine in parallel. Set sin A on L.H. S.L. and sin B on R.H. S.L. Turn handle until M.R. reads 000000. Record figures in L.H. P.R. against BC and R.H. P.R. in CA.

SECTION No 3 Ind Fd Svy COMPANY. DATE May 1941 Grid I $\begin{cases} \lambda\ 32^\circ\ 30' \\ L\ 68\ 00 \end{cases}$

Machine Computation of sides of Triangulation

$$BC = \frac{AB}{\sin C} \times \sin A; \quad CA = \frac{AB}{\sin C} \times \sin B.$$

Station or Intersected Point		Observed Angle (i)			Δ″ error	Correct d Angle			Sines	Sides (ii)	See Δ No.....	Side
Tarkhoban h.s.	A	77°	24′	42″	+02″	77°	24′	45″	0·97597	8 077·1		BC
Panebai h.s.	B	41	13	07	+01	41	13	08	0·65894	5 453·4		CA
Sir Narai h.s.	C	61	22	05	+02	61	22	07	0·87771	7 263·9		AB
Δ No.....1	Total	179	59	55	+05	180	00	00				
Sir Narai h.s.	A	72	08	44	-02	72	08	42	0·95183	10 065·4		BC
Panebai h.s.	B	58	03	15	-01	58	03	14	0·84955	8 973·2		CA
Kohi Sar h.s.	C	49	48	05	-01	49	48	04	0·76351	8 077·1		AB
Δ No.....2	Total	180	00	04	-04	180	00	00				
Sir Narai h.s.	A	55	17	56	-				0·82212	7 408·8		BC
Kohi Sar h.s.	B	41	27	49	-				0·66216	5 983·3		CA
Kamardin hill mark.	C	83	14	21	-				0·99364	8 973.2		AB
Δ No.....3	Total											
	A				-				0·	·		BC
	B				-				0·	·		CA
	C				-				0·	·		AB
Δ No.....4	Total											
	A				-				0·	·		BC
	B				-				0·	·		CA
	C				-				0·	·		AB
Δ No.....5	Total											
	A				-				0·	·		BC
	B				-				0·	·		CA
	C				-				0·	·		AB
Δ No.....6	Total											
	A				-				0·	·		BC
	B				-				0·	·		CA
	C				-				0·	·		AB
Δ No. 7	Total											
	A				-				0·	·		BC
	B				-				0·	·		CA
	C				-				0·	·		AB
Δ No.....8	Total											
	A				-				0·	·		BC
	B				-				0·	·		CA
	C				-				0·	·		AB
Δ No.....9	Total											
	A				-				0·	·		BC
	B				-				0·	·		CA
	C				-				0·	·		AB
Δ No.....0	Total											

(i) Corrected for 3 Grid,
(ii) In grid units.

Computed by *Date* *Checked by* *Date*

G.B.—P.O.—J.S. 43—10·1·44—1,000.

5 MACH.

1. Complete headings.

2. Complete lines 1 to 10 of both right-hand and left-hand sides according to the instructions given on the form. In the case of stations, where results are computed to 0·1 yard (or metre), lines 8 and 9 should be entered to 6 places of decimals if distances are greater than 5,000 yards or metres. Strike out yards or metres whichever is not applicable in line 10.

3. Now each side will be computed separately as follows :—

With Single Machine.—Computation of E_C (line 11): Set line 3 on S.L. and put the indicator to indicate the unit place. Shift P.R. until the unit place of P.R. (to be determined mentally) is in line with the unit place of line 3. Now turn handle forwards once. Clear S.L. and M.R. Now set line 10 on S.L. and multiply by line 8 turning the handle forwards or backwards according as line 8 is positive or negative and record the result in P.R. in line 11 with correct decimal point.

Computation of N_C (line 12): Proceed as above, substituting lines 4, 9 and 12 for lines 3, 8 and 11 respectively.

With Twin Machine.—Set E_A on L.H.S.L. Set N_A on R.H.S.L. Connect machines in parallel and turn handle forwards once. Clear S.L. and M.R. Set $\sin \beta_1$ on L.H. S.L. and $\cos \beta_1$ on R.H. S.L. Connect machines in parallel if signs of $\sin \beta_1$ and $\cos \beta_1$ are the same and in reverse if the signs are opposite. Multiply by AC turning handle forwards if $\cos \beta_1$ is positive and backwards, if negative. E_C then appears in L.H.P.R. and N_C in R.H P.R. Check by recomputing, substituting E_B, N_B, BC, $\sin \beta_2$ and $\cos \beta_2$ for E_A, N_A, AC, $\sin \beta_1$ and $\cos \beta_1$ respectively. Check that both values of E_C and of N_C agree.

4. Complete lines 13 to 18 according to the instructions given on the form.

5. Compute each side separately as follows :—

Set line 10 on S.L. Multiply by 3 or 3·28084 according as distance is in yards or in metres. Clear S.L. and set figures appearing in P.R. on S.L. Clear P.R. and M.R. Multiply by line 17. Clear S.L. and M.R. Set F on S.L. and divide. Record quotient in M.R. in line 19 with the same sign as in line 14 in case of cases I and II, and line 16 in case III.

6. Complete lines 20 to 24 as instructed on the form. Check that the heights from both sides in line 24 are in reasonable agreement.

7. Complete line 25. The line is entered to the nearest foot.

5 Mach. Survey of India Page

B SECTION No.1 Ind. Fd Svy. COMPANY. DATE Aug 1940 Grid [32° 30' 00 / 68]

Computation of grid co-ordinates & heights given grid distance and grid bearing

SURVEY Waziristan.

1	Ref. No.	Station C	Classification	Δ1	Sir Narai h.s.	A			
2	Station A	Station B		Tarkhobai h.s.	Panebai h.s.				
3	Easting of A = E_A	Easting of B = E_B		3 254 019·7	3 247 441·4				
4	Northing of A = N_A	Northing of B = N_B		1 100 366·3	1 097 285·7				
5	Bearing at A of B	Bearing at B of A		244 54 22	64 54 22				
6	Corrected angle CAB	Corrected angle ABC		+ 77 24 45	− 41 13 08				
7	Sum = β_1 = bearing at A of C	Sum = β_2 = bearing at B of C		322 19 07	23 41 14				
8	sin β_1 $\frac{+ve}{-ve}$ $\frac{0-180}{180-360}$	sin β_2 $\frac{+ve}{-ve}$ $\frac{0-180}{180-360}$		− ·611 270	+ ·401 744	− ·	− ·	− ·	− ·
9	cos β_1 $\frac{+ve}{-ve}$ $\frac{270-90}{90-270}$	cos β_2 $\frac{+ve}{-ve}$ $\frac{270-90}{90-270}$		+ ·791 422	+ ·915 752	− ·	− ·	− ·	− ·
10	Distance AC (grid $\frac{yards}{metres}$)	Distance BC (grid $\frac{yards}{metres}$)		5 453·4	8 077·1				
11	Easting of C = E_C (i)	Easting of C = E_C (i)		3 250 686·2	3 250 686·3				
12	Northing of C = N_C (i)	Northing of C = N_C (i)		1 104 682·2	1 104 686·3				
13	Case (ii)			I	III				
14	Vertical ∠ at A of C = e_1	Vertical ∠ at B of C = e_2		+ 1 49 24	− 1 44 05	−	−	−	−
15	Vertical ∠ at C of A = e_3	Vertical ∠ at C of P = e_4		−	+ 1 40 40	−	−	−	−
16	½ (e_1 − e_3) Case III only	½ (e_2 − e_4) Case III only		−	− 1 42 23	−	−	−	−
17	tan θ (iii)	tan θ (iii)		+ ·03 184	− ·02 979	− ·	− ·	− ·	− ·
18	Scale factor F (iv)	Scale factor F (iv)		·99 889	·99 888				
19	δh feet (v)	δh feet (v)		+ 521·5	− 722·7	− ·	− ·	− ·	− ·
20	Correction for curvature (vi) refraction & ht. of inst.	Correction for curvature (vi) refraction & ht. of inst.		+ 10·5	+ ·	+ ·	+ ·	+ ·	+ ·
21	Correction for ht. of Signal (vii)	Correction for ht. of Signal (vii)		− 4·0	+ 1·5	− ·	− ·	− ·	− ·
22	Sum = $h_c - H_a$ (viii)	Sum = $h_c - H_b$ (viii)		+ 528·0	− 721·2	− ·	− ·	− ·	− ·
23	Ht. of A (feet) = H_a	Ht. of B (feet) = H_b		2 989·	4 240·				
24	Sum = Ht. of C = h_c	Sum = Ht. of C = h_c		3 517·	3 519·				
25	Mean Height of C = H_c			3 518					

NOTES :— (i) Formula :- $E_C = E_A + AC \sin \beta_1 = E_B + BC \sin \beta_2$. $N_C = N_A + AC \cos \beta_1 = N_B + BC \cos \beta_2$.

(ii) Case I.– Observation at A or B only. Case II.– Observation at C only. Case III.– Observation at A & C or B & C.

(iii) $\theta = e_1$ or e_3 (Case I). e_2 or e_4 (Case II) or line 16 (Case III).

(iv) From 2 Grid or equivalent table ; may generally be taken as 1.

NOTES :—(v) Formula $\delta h = \frac{3}{F} \times AC$ (or BC) × tan θ if working in yards or

$\frac{3.28084}{F} \times AC$ (or BC) × tan θ if working in metres.

(vi) From 41 Grid (or equivalent table) for AC or BC ; not required for Case III.

(vii) *Minus* ht. of Signal at C (Case I) and A or B (Case II) or ½ ($S_a - S_c$) or ½ ($S_b - S_c$) (Case III).

(viii) Change sign for Case II.

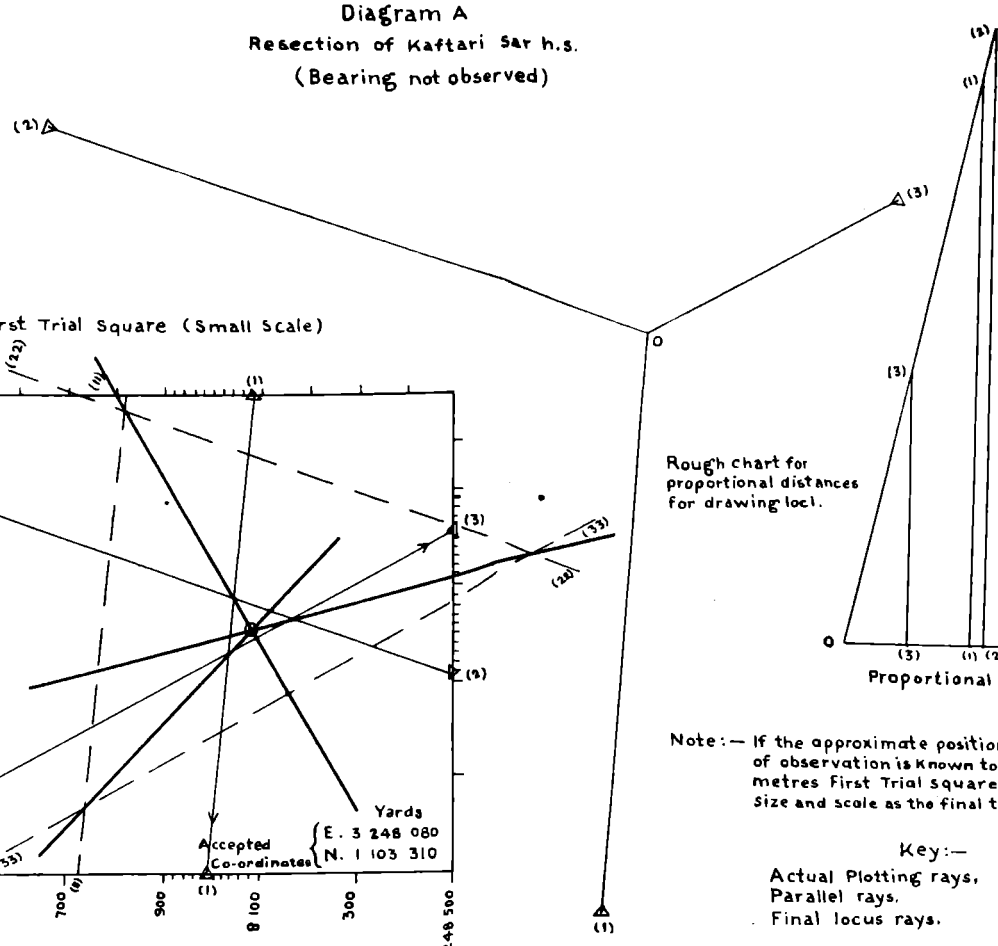
Computed by *Date* *Checked by* *Date*

G.B. P.O. – J.S. 352-B/276 – 1-8-44 – 500.

Diagram A

Resection of Kaftari Sar h.s.

(Bearing not observed)



First Trial Square (Small Scale)

Rough chart for proportional distances for drawing locl.

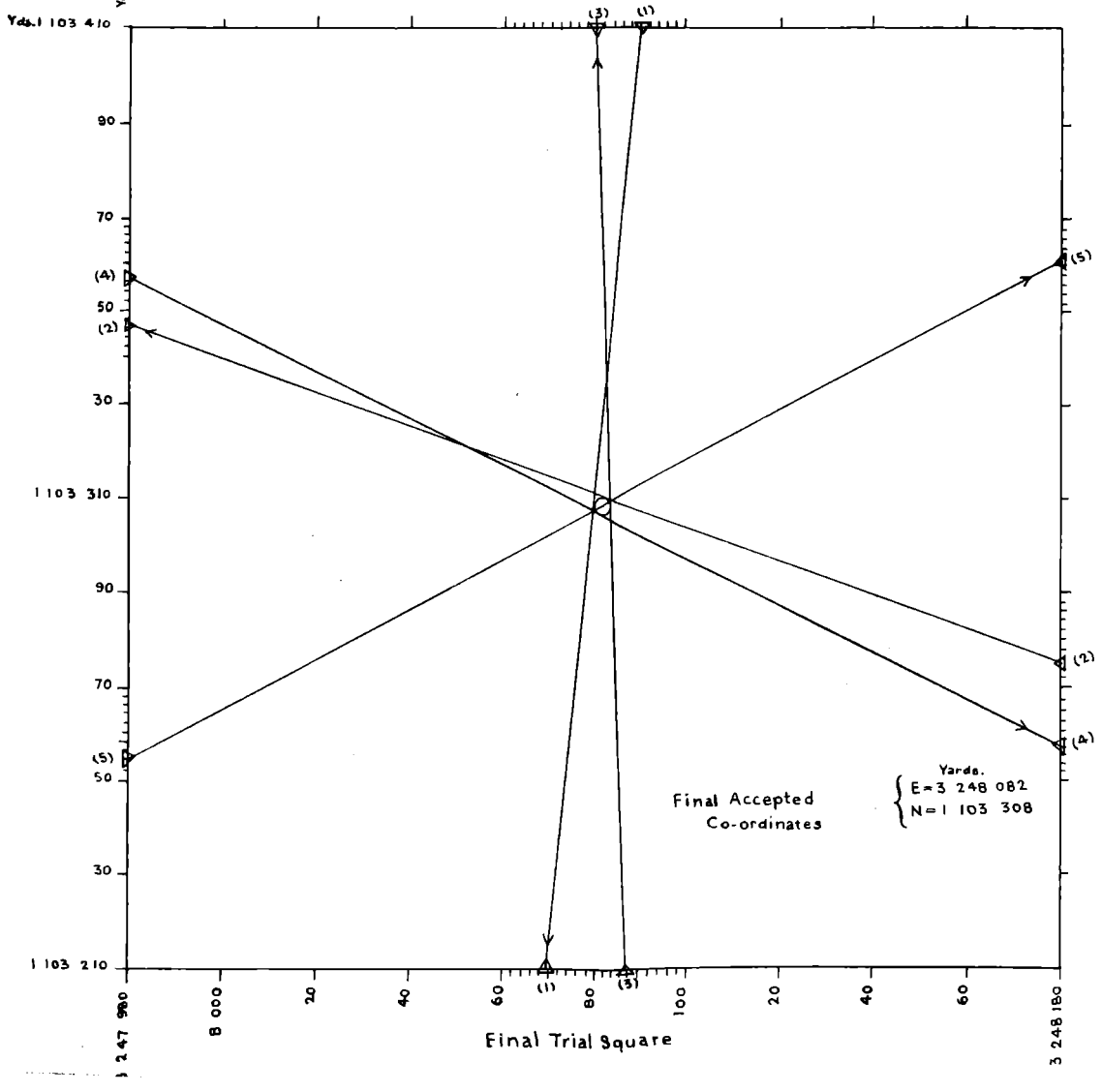
Note:— If the approximate position of the station of observation is known to within 300 yds/ metres First Trial square may be the same size and scale as the final trial square.

Key:—

Actual Plotting rays, ——

Parallel rays, — — — —

Final locus rays. ▬▬



6 MACH.

A. Bearing not observed at station

1. Complete headings striking out "Back Ray", "Polaris", and "Sun" against "Initial bearing from"

2. Enter names of fixed stations observed in line 1 (L.H. col.). Enter their co-ordinates in line 12. Enter angle book bearings having first applied necessary correction for 3 Grid, in line 2. Enter all rays to fixed stations roughly at their correct bearings on the diagram and label them. Decide whether to use E_T and tan or N_T and cot for each ray as shown there in the diagram.

3. Select fixed station (a reliable distant point from a rough chart) for computing the initial bearing and enter in line 30. Enter its co-ordinates in line 31 and those of the 1st trial point (1st approximation) in line 32. Complete line 36. Obtain tan β_1 or cot β_1 (depending on what has been selected for that station in para 2 above), and β_1 in line 32 (right-hand end).

4. Enter β_1 in line 4 (L.H. col.) for selected station. Obtain first correction = β_1 − line 2. Enter this in line 3 (L.H. col.) for all other stations. Complete line 4.

5. Select for further computation 3 reliable stations whose rays intersect at a good angle. Look up and record tan β_1 or cot β_1 (para 2 above) for each of these with proper sign ($+^{ve}$ for β_1 between 0°–90° and 180°–270°) in line 4 (R.H. col.).

6. Select a grid square with a side of 1,000 yds./metres as the first trial square surrounding the first trial point. Enter the co-ordinates of its SW. corner in line 13 for each station of para 5 above.

7. *For Marchant XL.*—Set E_T (N_T) on S.L. (the first decimal place being occupied by the 2nd setting lever counting from the extreme right, the carriage being in the normal position). Turn handle forwards once. Clear S.L. and M.R. Set tan β_1 (cot β_1) on S.L. the first decimal place being set on the 9th (extreme left) lever and multiply by N_T (E_T) [the first decimal place occupying the extreme right in M.R.] turning the handle forwards if line 4 is $-^{ve}$ and backwards if $+^{ve}$. Now clear M.R. only and multiply by N_T (E_T) [the first decimal place occupying the extreme right place in M.R.] turning handle forwards if tan β_1 (cot β_1) is $+^{ve}$ and backwards if $-^{ve}$ Record the product so obtained (1st cutting point) in line 15 (L.H. half column).

The first decimal place of the point will be at 10th place from right in P.R. Now increase the number in M.R. by 1,000 and register the new product (2nd cutting point) in R.H. half col. of line 15, as before, the first decimal of the product being at 10th place from right.

With Brunsviga 10.—Set last five figures of E_T on first five S.L. Pull carriage to R.H. end of run and turn handle forwards once. Clear S.L. and M.R. Set tan β on last five S.L. Multiply by last five figures of N_T* turning handle backwards if tan β is positive and forwards if negative. Clear M.R. Multiply by last five figures of E_T* (co-ordinates of S.W. corner of cutting square) turning handle forwards if tan β is positive and backwards if negative. First five figures in P.R. are the last five figures of the Easting of the first cutting point (E_{cut}). Add the missing first two figures by inspection and record in line 15 (L.H. half col.). Continue multiplying in same direction until figure in M.R. has been increased by 1,000. Record figures in P.R. as before in line 15 (R.H. half col.).

Using Brunsviga 10 it is not possible to compute decimals of a yard (or metre). In the instructions therefore figures after the decimal point in co-ordinates are ignored. In larger machines full co-ordinates can be set and working adjusted accordingly.

8. Draw first trial square on squared paper to a scale of 1 small division = 20 yds./metres. Plot cutting points, draw corresponding lines and loci, if required, (as described in T.H.B. Chap. VIII App. IV, para 18) and thus obtain 2nd trial point and record its co-ordinates in line 33.

9. Obtain corrected bearing β_2 of distant fixed station A by line 30 *et seq.* Obtain 2nd correction ($=\beta_2-\beta_1$) and enter the same in line 5 for all stations. Complete line 6.

10. Repeat the whole computation from para 4 *et seq.* with following changes :—

Substitute β_2 for β_1. Choose new trial square of side 200 yds./metres surrounding 2nd trial point. Compute *all* available rays. Substitute new values of E_T and N_T in formula used. To obtain 2nd cutting point in line 16, increase the number in M.R. by 200 instead of 1,000 as done before. Plot trial square to a scale of 1 small division = 2 yds./metres. Plot cutting points and show direction of rays by arrows but *do not* draw loci. Obtain best position for station of observation by inspection and have it checked by officer in-charge and record in line 34. If this position is satisfactory, complete final bearing in line 30 *et seq.* for selected distant station (A) and enter against β_4 for that station in line 10. Thus obtain 4th correction (line 9) and find bearings for all stations. Complete line 11.

11. If diagram obtained in para 10 is not satisfactory the whole computation must be repeated using position selected and obtaining a new bearing β_3 in the same manner that β_2 was obtained in para 9.

B. When bearing to any station is known.

12. Enter method by which bearing was obtained in head of form and proceed as in paras 2 *et seq.* Enter known bearing against β_1 for station concerned and obtain 1st correction and enter β_1 for all stations.

13. Complete computations for two reliable rays, which intersect at a good angle, as in para 5. Plot these two rays as in para 8 and take the intersection as 2nd trial point and obtain 2nd trial square of 200 yds./metres surrounding it.

14. Keeping the same bearing β_1 repeat the computation for all stations as described in para 7. Select final position. Have it checked by officer in charge and if necessary correct bearing by means of line 30 *et seq.* and complete lines 10 and 11.

(Note :—This last is never necessary if bearing was obtained from Polaris. Such a bearing should always be accepted. Sun bearings may be altered by up to 30 seconds).

C. Heights.

15. Enter final accepted co-ordinates at top L.H. of the form and in line 18. Complete form to line 22 as instructed thereon.

16. Complete line 23 as follows :—(L.H. or R.H. half col.). Set $\Delta E/\Delta N$ on S.L. Multiply by 3 (if working in metres multiply by 3·28084) turning handle forwards. Set contents of P.R. on S.L. Turn handle backwards once and check that P.R. reads 0000. Clear P.R. and M.R. and multiply by cosec β_4/sec β_4 turning handle forwards. Set contents of P.R. on S.L. Clear P.R. and M.R. and multiply by line 21 (tan e). Clear S.L. and M.R. Set scale factor F (if significant) on S.L. and divide. Record figures in M.R. with correct decimal point and same sign as line 21, in line 23. Complete remainder of form as instructed entering best mean value for height in line 29.

Note :—The form can also be used for the computation of intersected points by semi-graphic method. In this case enter the bearings at stations of observation to the intersected point against β_4 (line 10). The rest is to be done as in the case of stations except for height computation where the sign of line 26 is to be changed. Ordinarily *6A Mach.* is used for intersected points.

* If the sixth figure from the decimal point in N_T is different from that in N_T it will not be sufficient to multiply by the last five figures only. If the difference between the sixth figures is one it is necessary to turn the handle ten times in the appropriate direction with the carriage in the extreme right-hand position before multiplying by either N_T or N_T whichever is the larger. When multiplying by the smaller of these two no special action is necessary. In rare cases when the difference between sixth figures is 2, substitute "twenty times" for "ten times" in above.

(A)

Station of observation (S) Jaftari Sar h.s. A **SECTIO**

Semi-gra

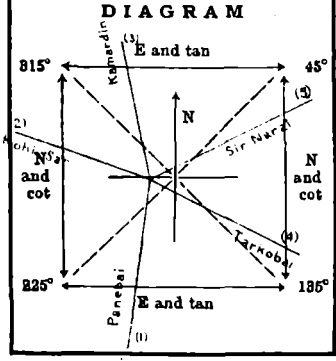
Final co-ordinates $\begin{cases} E_S = 246\ 082 \\ N_S = 103\ 308 \end{cases}$ yards / metres

Height $H_S = 680$ feet

Observer Mr. A. Karim

			Panebai h.s.	
1	Fixed point observed = F	Easting (E_F) and tan (ii) or Northing (N_F) and cot		E_F and tan (ii) — or — N_F and cot
2	Angle book bearing (i)		185 ° 35 ′ 36 ″	
3	1st correction		– 16 12	
4	Sum = β_1	tan β_1 or cot β_1 (ii)	185 19 38 +	–09 912
5	2nd correction	+	23 08	+
6	Sum = β_2	tan β_2 or cot β_2 (ii)	186 02 46 +	–0·592
7	3rd correction		–	
8	Sum = β_3	tan β_3 or cot β_3 (ii)		–0·
9	4th correction	+	01 16	
10	Sum = β_4 (or final bearing)	tan β_4 or cot β_4 (ii)	186 04 02	–0·
11	Total corrn. = line 10 – line 2	+	08 12	
12	Easting of fixed stn. = E_F	Northing of fixed stn. = N_F	3 247 441·9	1 097 285 8
13	SW. corner of cutting square Easting = E_T (1st Trial)	Northing = N_T (1st Trial)	3 247 500·0	1 102 800 ·0
14	E_T (2nd & 3rd Trials)	N_T (2nd & 3rd Trials)	3 247 980·0	1 103 210 0
15	Cutting points E_{cut} or N_{cut} (iii) 1st Trial Square	1st Trial Square	3 247 988 5	3 248 087 ·6
16	2nd Trial Square	2nd Trial Square	3 248 069 4·	3 248 090 ·6
17	3rd Trial Square	3rd Trial Square	·	·
18	Final Position Easting = E_S	Northing = N_S	3 248 082·0	1 103 308 ·0
19	$\Delta E = E_F - E_S$ (iv)	$\Delta N = N_F - N_S$ (iv)	· –	6 022 ·2 –
20	cosec β_4 (iv)	sec β_4 (iv)	· –	00 563 –
21	Vertical angle = e	tan e +	01 ° 43 ′ 26 ″ +	03 009 +
22	Scale factor = F (v)	Scale factor = F (v)	·	99 888
23	$\frac{3}{F}\Delta E$ cosec β_4 tan e (vi)	$\frac{3}{F}\Delta N$ sec β_4 tan e (vi)	– · +	547·3 +
24	Correction for curvature, refraction and height of inst. (vii)		+ ·	+ 11·8 +
25	Minus height of signal		– ·	– 0·0 –
26	Sum = $H_F - h_S$ (feet)		– · +	559 ·1 +
27	Height of fixed point = H_F		·	4 240 ·
28	Height of point = line 27 – line 26		·	3 681 ·
29	Mean height (feet)			

DIAGRAM



30		
31	Easting of A = E_A	3 247 441·9
32	Easting of 1st Trial Point = E_1	3 248 040 0
33	„ „ 2nd „ „ = E_2	3 248 080 0
34	„ „ 3rd „ „ = E_3	
35	„ „ 4th „ „ = E_4	3 248 082 ·0
36	$E_A - E_1 = \Delta E_1$	– 598 1
37	$E_A - E_2 = \Delta E_2$	– 638 1
38	$E_A - E_3 = \Delta E_3$	–
39	$E_A - E_4 = \Delta E_4$	– 640 1

(i) Corrected for 3 Grid.

(ii) Use E_F and tan or N_F and cot, depending on bearing in line 4 (see diagram). Strike out whichever is

(iii) Formulæ:—(1) $E_{cut} = E_F - N_F \tan \beta + N_T \tan \beta$. Use formula (1) if E_F and tan entered in line

(2) $N_{cut} = N_F - E_F \cot \beta + E_T \cot \beta$. See T.H.B. Chapter VIII Supplement for much

(iv) Use L.H. column if N_F and cot entered in line 1, otherwise use R.H. column.

Computed by *Date* *Checked by*

G.B.—P.O.—J.S. 31—19-1-44—500.

urbey of India

Ind. Fd. Svy. COMPANY. DATE August 1940. Grid I λ_0 32 30 / L_0 68 00

esection for Rotary Calculating Machine

ient Wild No. 100 Time 10·30 A.M. Initial bearing from ~~Back ray~~ / Polaris / ~~Sun~~ / ~~Approximation~~

Bar	(2) ~~E_F and tan~~ (ii) or N_F and cot	Kamardin	(3) E_F and tan (ii) or ~~N_F and cot~~	Tavkhoba	(4) ~~E_F and tan~~ (ii) or N_F and cot	Sivi Narai	(5) ~~E_F and tan~~ (ii) or N_F and cot
11		367 24 32		116 13 45		62 04 42	
51		+ 0 07 51		+ 0 07 51		+ 0 07 51	
02	0·36 135	357 32 23	0·04 297	116 21 36	0·49 954	62 12 33	+ 0·52 703
		–		–		–	
	−0·		−0·		−0·		−0·
		–		–		–	
	−0·		−0·		−0·		−0·
		–		–		–	
02	−0·	357 32 23	−0·		−0·		−0·
51		+ 0 07 51		–		–	
760·7	1 105 392·8	3 247 797·5	1 109 920·0	3 254 019·2	1 100 366·3	3 250 686·1	1 104 681·4
·	·	·	·	3 247 540	1 102 820 ·	·	·
00·	1 103 200 ·	3 248 000 ·	1 103 200 ·	3 248 000.	1 103 200 ·	3 248 000.	1 103 200 ·
·	·	·	·	1 103 081·5	1 103 577 ·	·	·
66·0	1 103 338·2	3 248 077·7	3 248 086·2	1 103 249·9	1 103 349·1	1 103 371·5	1 103 265·7
·	·	·	·	·	·	·	·
32·	1 103 308 ·	3 248 082 ·	1 103 308 ·	3 248 082	1 103 308 ·	3 248 082·	1 103 308 ·
21·3		·	+ 6 612·0	+ 5 937·2	·	2 604·1	·
	·	·	+1·00 092	+1· 11 610	·	+1· 13 033	·
11"	+ ·07 408	+ 0° 29′ 38"	+ ·00 862	− 2° 01′ 46"	− ·03 543	− 1° 05′ 40"	− ·01 910
9	·	·	· 99 890	· 99 886	·	· 99 889	·
95·5	– ·	– ·	+ 171·3	– 705·1	– ·	– 168·8	– ·
13·5	+ ·	+ ·	+ 13·3	+ 13·3	+ ·	+ 6·6	+ ·
0·0	– ·	– ·	– 0·0	– 0·0	– ·	– 0·0	– ·
09·0	– ·	– ·	– 184.6	– 691·8	– ·	– 162·2	– ·
89.	·	·	3 865.	2989 .	·	3 518 .	·
80.	·	·	3 680 .	3681 .	·	3 680.	·
	→	←		3680	→		→

Computation of bearing. Distant fixed point selected (A):–

Northing of A = N_A	·	For tan β or cot β see formula below			′ ″
hing of 1st Trial Point = N_1		tan β_1 or cot β_1 (ii)	– ·	β_1	
„ 2nd „ „ = N_2		tan β_2 or cot β_2 (ii)	– ·	β_2	
„ 3rd „ „ = N_3		tan β_3 or cot β_3 (ii)	– ·	β_3	
„ 4th „ „ = N_4		tan β_4 or cot β_4 (ii)	– ·	β_4	

For entry in lines 4, 6, 8 or 10.

$N_A - N_1 = \Delta N_1$	– ·	$\tan \beta = \frac{\Delta E}{\Delta N}$
$N_A - N_2 = \Delta N_2$	– ·	
$N_A - N_3 = \Delta N_3$	– ·	$\cot \beta = \frac{\Delta N}{\Delta E}$
$N_A - N_4 = \Delta N_4$	– ·	

e formula (2).

(v) Enter scale factor for mean latitude (if significant) from 2 Grid.

(vi) Same sign as line 21. See T.H.B. Chapter VIII Supplement for machine working. If working in metres line 23 will be $\frac{3 \cdot 28084}{F} \Delta E \operatorname{cosec} \beta_4 \tan \alpha$ or $\frac{3 \cdot 28084}{F} \Delta N \sec \beta_4 \tan \alpha$.

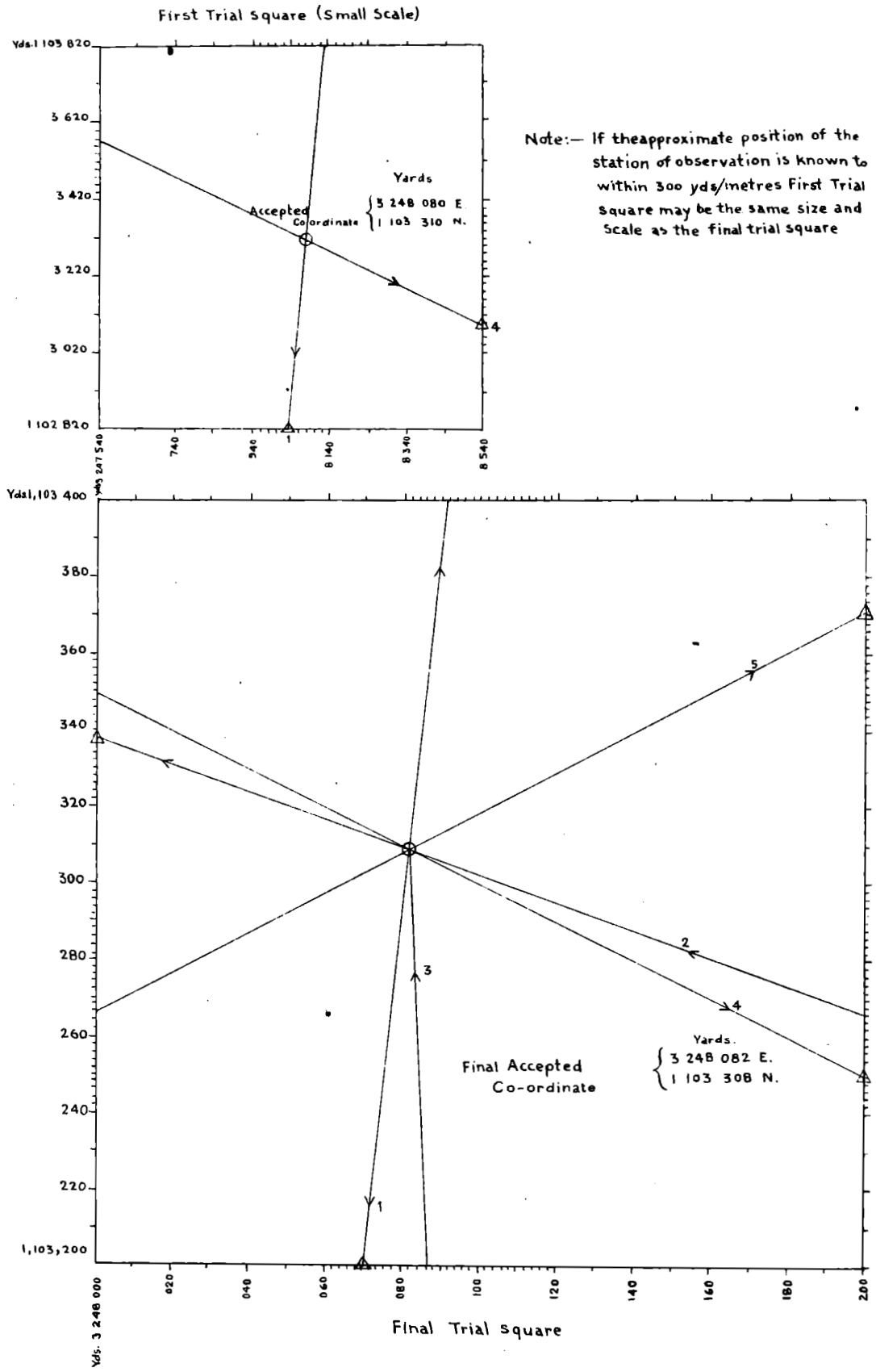
(vii) From 41 Grid or equivalent table in metres.

Date *Final Position passed* *Section Officer*

Diagram B

Resection of Kaftari Sar h.s.

(Bearing previously observed)



6A MACH.

1. Complete headings.

2. Enter names of fixed stations from which the point has been observed in line 1 (L.H. col.). Enter their co-ordinates in line 5. Enter angle book bearings having first applied the necessary correction for 3 Grid. Enter the final angle book correction from angle book and complete line 4 (L.H. col.).

3. Enter all rays to intersected point roughly at their correct bearings on the diagram and label them. By inspecting diagram decide whether to use E_S and tan or N_S and cot for each ray and strike out whichever is not applicable in all places where note (ii) applies. Look up tan β or cot β for all the rays and enter in line 4 (R.H. col.) with proper sign ($+^{ve}$ if β lies between 0°–90° and 180°–270°).

4. Select a grid square with a side of 1,000 yds./metres as the first trial square surrounding the first approximate position of the intersected point. [Choose two rays (and a third one for checking if necessary) which intersect at a good angle for further computations]. Enter the co-ordinates of SW. corner of 1st trial square in line 6 for these stations. Compute the cutting points as follows :—

Set E_S (N_S) on S.L. Shift P.R. to the correct decimal point. Turn handle forwards once. Clear S.L. and M.R. Set tan β (cot β) on S.L. and multiply by N_S (E_S) turning handle forwards if tan β (cot β) is $-^{ve}$ and backwards if $+^{ve}$. Clear M.R. only and multiply by N_T (E_T) turning the handle forwards if tan β (cot β) is $+^{ve}$ and backwards if $-^{ve}$. Record figures appearing in P.R. in line 8 (L.H. col.) with proper decimal place. Increase the number in M.R. by 1,000 and record the figure in P.R. as before in line 8 (R.H. col.).

NOTE :—If position of I.P. can be obtained from the chart correct to the nearest 300 yds./metres para 4 can be omitted, i.e. the point may be computed straight away using a 200 yds./metres cutting square.

5. Draw trial square on squared paper at a scale of 1 small division = 20 yds./metres. Plot cutting lines and thus obtain a position for the point.

6. Now repeat the computation for all rays as described in para 4 with following differences.

Choose new trial square of side 200 yds./metres surrounding position obtained in para 5 above. Compute *all* the available rays. Substitute new values of E_T and N_T in formula used. To obtain 2nd cutting point in line 9, increase the figure in M.R. by 200 instead of 1,000 as previously. Plot trial square to a scale of 1 small division = 2 yds./metres. Plot the cutting lines.

Find by trial the least circle which will contain some part of all the rays. Record the centre of the circle as the final position. Record the classification of the point as A, B, C or D where the radius of the circle is less than 2, 7 or 20 yards or more than 20 yards.

7. Complete form up to line 14.

8. Set ΔE (ΔN) on S.L. Multiply by 3 (if working in metres multiply by 3·28084) turning handle forwards. Set contents of P.R. on S.L. Turn handle backwards once and check that P. R. reads 0000. Clear M. R. and P.R. and multiply by cosec β (sec β) turning handle forwards. Set contents of P.R. on S.L. Clear P.R. and M.R. and multiply by line 13 (tan e). Clear S.L. and M.R. Set scale factor F on S.L. (if significant) and divide. Record figure in M.R. in line 15 with correct decimal point and same sign as 'e' in line 13. Complete lines 16 to 20 as instructed on the form and enter the best mean value for height in line 21.

These instructions apply to all rotary calculating machines except the Brunsviga 10, whose small capacity requires instructions to be specially modified . For these modifications see instructions to form 6 Mach.

6A Mach.

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INTERSECTED POINT Y_5 B **SECTION** No. 1 Ind. Fd. Svy **COMPANY.** **DATE** May, 1941

Grid I λ_0 32 30 ; L_0 68 00

Semi-graphic intersection for rotary calculating machine

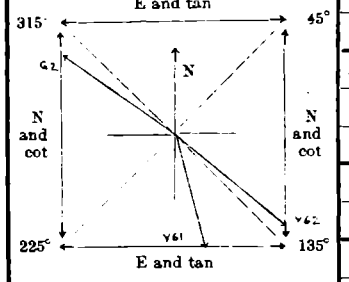
Final co-ordinates E_P = 3 203 160 ; N_P = 1 035 986 Class A

Approximate position E_P = 3 203 000 ; N_P = 1 036 000

Formulæ:—(1) $E_{cut} = E_S - N_S \tan\beta + N_T \tan\beta$.
(2) $N_{cut} = N_S - E_S \cot\beta + E_T \cot\beta$.

			Y62 h.s.		Y61 h.s.		G2 h.s.		
1	Fixed station of obsn. = S	Easting (E_S) and tan(ii) or Northing (N_S) and cot		E_S and tan(ii) or N_S and cot		E_S and tan(ii) or N_S and cot		E_S and tan(ii) or N_S and cot	
2	Angle book bearing of P (i)		° ′ ″ 134 04 02		° ′ ″ 164 11 34		° ′ ″ 302 15 18		° ′ ″
3	Angle book correction		− 16 08		− 57 51		+ 05 57		−
4	Sum = Bearing for computation = β	tan β or cot β (ii)	133 47 54	−0·95 891	163 13 43	−0·30 137	302 21 15	−0·63 350	−0·
5	Easting of fixed station = E_S	Northing of fixed station = N_S	3 199 495·7	1 039 499·8	3 201 357·7	1 041 969·0	3 204 462·2	1 035 160·6	.
6	SW. corner of cutting square Easting = E_T (1st Trial)	Northing = N_T (1st Trial)	3 202 700·0	1 035 500·0	3 202 700·0	1 035 500·0	3 202 700·0	1 035 500·0	.
7	E_T (2nd Trial)	N_T (2nd Trial)	3 203 100·0	1 035 900·0	3 203 100·0	1 035 900·0	3 203 100·0	1 035 900·0	.
8	Cutting Points E_{cut} or N_{cut} (iii) 1st Trial Square	1st Trial Square	1 036 427·2	1 035 468·3	3 203 307·3	3 203 005·9	1 036 277·0	1 035 643·5	.
9	2nd Trial Square	2nd Trial Square	1 036 043·6	1 035 851·8	3 203 185·7	3 203 126·4	1 036 023·6	1 035 896·9	.
10	Final Position Easting = E_P	Northing = N_P	3 203 160·	1 035 986·	3 203 160·	1 035 986·	3 203 160·	1 035 986·	.
11	$\Delta E = E_P - E_S$ (iv)	$\Delta N = N_P - N_S$ (iv)	3 664·3		5 983·0		1 302·2		
12	Cosec β (iv)	Sec β (iv)	1·38 546		1·04 443		1·18 378		.
13	Vertical angle = e	Tan e	+ ° 2 ′ 08 ″ 02	+ 0·03 726	+ ° 3 ′ 45 ″ 31	+ 0·06 570	− ° 1 ′ 09 ″ 39	− 0·02 026	− ° ′ ″ − .
14	Scale factor = F (v)		0·99 880		0·99 880		0·99 880		.
15	$\frac{3}{F}\Delta E \operatorname{cosec}\beta \tan e$ (vi)	$\frac{3}{F}\Delta N \sec\beta \tan e$ (vi)	+ 568·2		+ 1 233·1		− 93·8		− .
16	Correction for curvature, refraction and height of inst. (vii)		+ 10·		+ 12·		+ 5·		+
17	Minus height of signal		− 0·0		− 0·0		− 0·0		−
18	Sum = $h_P - H_S$ (feet)		+ 578·2		+ 245·1		− 88·8		− .
19	Height of fixed station = H_S		5 697·1		5 036·7		6 362·0		.
20	Sum = Height of point = h_P		6 275·3		6 281·8		6 273·2		
21	Mean height of P		←		6 277		→		

DIAGRAM



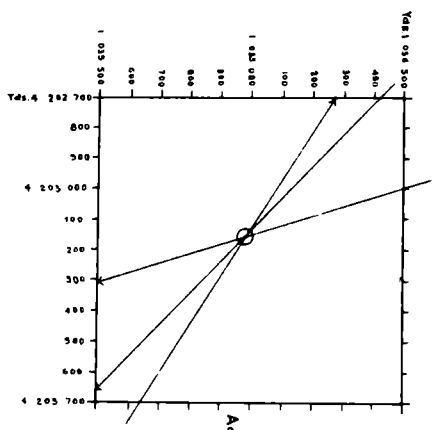
(i) Corrected for 3 Grid or equivalent table.
(ii) Use E_S and tan or N_S and cot, depending on bearing in line 4 (see diagram). Strike out whichever is not applicable.
(iii) Use formula (1) if E_S and tan entered in line 1, R.H. column, otherwise use formula (2). See T.H.B. Chapter VIII Supplement for machine working.
(iv) Use L.H. column if N_S and cot entered in line 1, otherwise use R.H. column.
(v) Enter scale factor for mean latitude (if significant) from 2 Grid or equivalent table.
(vi) Same sign as line 13. See T.H.B. Chapter VIII Supplement for machine working. If working in metres line 15 will be $\frac{3{\cdot}28084}{F}\Delta E \operatorname{cosec}\beta \tan e$ or $\frac{3{\cdot}28084}{F}\Delta N \sec\beta \tan e$.
(vii) From 41 Grid or equivalent table in metres.

Computed by *Date* *Checked by* *Date*

G B.—P.O.—J.S. 32—19-1-44—500.

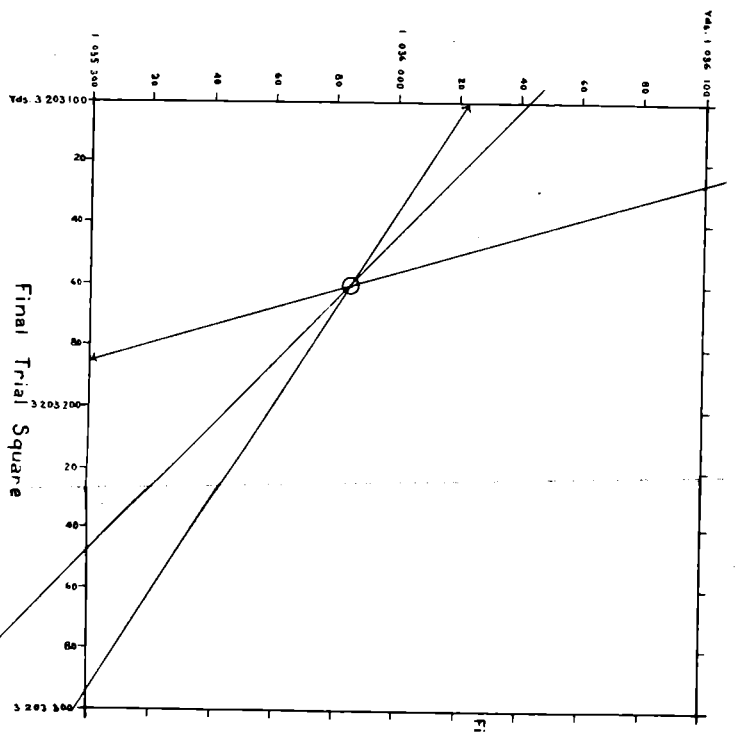
I. P. Y_5

First Trial Square (Small Scale)



Note:-First Trial square is only necessary if the approximate position of the I.P. is not known to within 300 yds/metres

Accepted Co-ordinates E 3 203 160 Yards/Metres ; N 1 035 985 Yards/Metres



Final Trial Square

North

Final Accepted Co-ordinates E 3 203 160 Yards/Metres ; N 1 035 986 Yards/Metres

Class A

INSTRUCTIONS

7 MACH.

1. Complete headings.

2. Complete lines 1 to 21 as instructed on the form. When temperature and barometer are not recorded leave lines 9, 10 and 11 blank and enter the value under 'r_t' from table 42A Sur. in line 12.

3. Compute line 22 according to the instructions given in footnote (iii) of the form.

4. Complete lines 23 to 28 .

7 Mach. **Survey of India** Page.....

B SECTION No. 3 Ind. Fd. Svy COMPANY DATE August 1942

Computation of Grid Bearings from Sun or Star, horizontal and vertical angles observed simultaneously, using rotary calculating machine.

Observer Capt. R.C.A Edge Instrument Tac 37 008 Grid M.C. λ_0 00° 00′ L_0 73 30

Formula :—Cos A = sec h sec λ sin δ − tan h tan λ.

1	Name of Station		←			Hitaddu Azimuth Stn.						→				
2	Name of referring mark					Tree Stump										
3	Longitude of station of observation		73°	04′	56″	°	′	″	°	′	″	°	′	″		
4	Time of observation	Sun only	Date 30/8	h 17	m 58	Date 30/8	h 18	m 02	Date 31/8	h 09	m 56	Date 31/8	h 09	m 00		
5	Longitude in time (i)			6	00		6	00		6	00		6	00		
6	G.M.T. = Line (4) − Line (5)		Date 30/8	11	58	Date 30/8	12	02	Date 31/8	02	56	Date 31/8	03	00		
7	Sun/Star E. or W. of meridian		Sun W			Sun W			Sun E			Sun E				
8	Observed altitude		18°	55′	56″	17°	53′	41″	25°	40′	22″	26°	38′	54″		
9	Refraction (42 A Sur)		0			0			0			0				
10	Correction for Temperature.....°		− 0			− 0			− 0			− 0				
11	Correction for Barometer.....inches		− 0			− 0			− 0			− 0				
12	Sum = Total refraction		0	02	41	0	02	50	0	01	56	0	01	51		
13	Parallax (21 Sur) for Sun only		0	0	08	0	0	09	0	0	08	0	0	08		
14	Corrected altitude = lines (8) + (13) − (12) = h		18	53	23	17	51	00	25	38	34	26	37	11		
15	Latitude = λ North+ve / South−ve		− 00	34	50				—			—				
16	Declination = δ (ii) North+ve / South−ve		+ 09	08	15	+ 09	08	11	+ 08	54	52	+ 08	54	48		
17	Sin δ		+0.15 880			+0.15 879			+0.15 496			+0.15 494				
18	Sec λ		1.00 005			.			.			.				
19	Sec h		1.05 692			1.05 057			1.10 925			1.11 857				
20	Tan h		0.34 217			0.32 203			0.48 004			0.50 120				
21	Tan λ		− 0.01 013			− .			− .			− .				
22	Cos A (iii)		+0.17 131			+0.17 009			+0.17 677			+0.17 840				
23	A = True bearing of Sun/Star (iv)		279°	51′	50″	279°	47′	35″	79°	49′	06″	79°	43′	25″		
24	Reading to R.M. (v) − Reading to Sun*/Star		+130	08	19	+130	12	40	− 29	48	42	− 29	42	58		
25	Sum = True bearing of R.M.		50	00	09	50	00	15	50	00	24	50	00	27		
26	Convergence at line 3 (4 Grid)		+		15	+		15	+		15	+		15		
27	Lines (25) − (26) = Grid bearing of R.M.		49	59	54	50	00	00	50	00	09	50	00	12		
28	Mean value					50	00	04								

NOTES:—(i) Longitude of the local/standard meridian according as the time in line (4) is local mean/standard time.

(ii) From N. A. For G.M.T. in line 6 for Sun.

(iii) Compute Cos A on machine using the formula in heading.
(1) Set Sec h on S.L. and multiply by Sec λ.
(2) Set product on S.L., turn backwards and check that P.R. reads 0000, clear M.R. and P.R.
(3) Multiply by sin δ turning backwards if δ is positive (or North) or forwards if negative (or South).
(4) Clear S.L. and M.R., set tan h on S.L. and multiply by tan λ, turning forwards/backwards if λ is North/South.
(5) If result in P.R. is direct, enter with *minus* sign in line 22; if it is a complement, subtract from 1 and enter with *plus* sign.

(iv) If Sun or Star is E/W A is in 1st or 2nd / 4th or 3rd quadrant depending on whether Cos A is + or −.

(v) Corrected for 3 Grid.

* Note—Reduced to Sun's Centre, if necessary

Computed by *Date* *Checked by* *Date*

G.S.—P.O.—J.S. 33—19-1-44—500.

INSTRUCTIONS

8 MACH.

1. Complete headings.

With Time and Horizontal Angle observed, left-hand column of the form is to be used.

2. Complete lines 1 to 13, (line 11 being blank) leaving left-hand side of line 3 blank if direction of Polaris has not been recorded in the angle book.

3. Calculate t in arc (line 14) from 45 Sur. with 't' in time (line 13) as argument. Complete lines 15,16 and 17 and line 3 (if not previously completed).

4*. Set Δ'' (line 17) on S.L. and multiply by cos t (line 15) for first deduction turning the handle forwards or backwards according as cos t is positive or negative. Record product in line 18 to the nearest second with appropriate sign. Continue multiplying until cos t of the next deduction appears in M.R. Record product as before. Continue thus multiplying by cos t for all deductions (if there are more than two). Clear M.R. and P.R. but not S.L. Complete lines 19 to 23.

5*. With Δ'' (line 17) already set on S.L. multiply by sin t (line 23) turning the handle forwards. Clear S.L. and M.R. Set cos ($\alpha + \lambda$) (line 22) on S.L. and divide. Record quotient from M.R. in line 24 with sign $+^{ve}/-^{ve}$ according as Polaris is E/W of meridian (see line 3).

With Horizontal and Vertical Angle observed, right-hand column of the form is to be used.

6. Complete lines 1 to 17, (lines 0 and 14 being blank).

7*. Set Δ'' (line 17) on S.L. Turn handle forwards until 'α' (line 15) for first deduction appears in P.R. Record figure in M.R. in line 18 with same sign as 'α' (line 15). Continue turning handle until 'α' (line 15) for all remaining deductions in turn appears in M.R. Record in line 18 as before. Complete line 19 for all deductions following footnote (vi) given in the form. Complete lines 22 and 23.

8. Complete remainder of form as in para 5 above.

* The computations in paras 4, 5 and 7 above may be made on Slide Rule thus :—

Para 4. Set Δ'' (line 17) on scale A under one end of scale S. Slide cursor to the complements of angle 't' (line 14) on scale S. Record values on scale A under the cursor in line 18 with proper sign.

Para 5. Set Δ'' (line 17) on scale A under one end of scale S. Slide cursor to angle 't' (line 14) on scale S. Bring the complement of angle ($\alpha + \lambda$) line 21 on scale S under the cursor. Read value on scale A above one end of scale S and record in line 18.

Para 7. Set Δ'' (line 17) on scale C above 1 on scale D. Slide cursor to each value of 'α' (line 18) in turn on scale C and read off corresponding values of cos t on scale D.

B **SECTION** No. 1 Ind. Fd. Svy. **COMPANY** **DATE** March, 1940

Machine computation of grid bearing from Polaris (*time or altitude observed*)

Grid λ_0 32° 30 / L_0 68 00

Observer Capt. R.C.N. Jenney

Instrument Tavistock No. 1000

Formulæ :— (a) $A = \frac{\Delta \sin t}{\cos(\lambda + a)}$ (b) $\cos t = \frac{a}{\Delta}$

← Left-hand column → ← Right-hand column →

1	Station of observation		Marble Rocks ——→						←—— Marble				Rocks ——→			
2	Referring mark		Chhajut Sar h. s.						Chhajut				Sar h. s.			
3	Polaris "W" or "E" (i)	Date	W	7	March 1940		W	7	March 1940	W	7	March 1940		W	7	March 1940	
4	Longitude of station in arc		71°	59′	20″		°	′	″	71°	59′	20″		°	′	″
5	Time observed (ii)	Altitude observed = h (ii)	18	34	16		18	36	23	34	44	19		34	43	54
6	Long. of station in time (34 Sur.)		4	47	57		4	47	57							
7	Interval from G.M.M. (iii)	Refraction for line (5) (42 A Sur.)	13	04	16		13	06	23	0	01	20		0	01	20
8	A for line (7) (22 Sur.) (iv)	Corrn. for Temperature 52..°F	+	02	09		+	02	09	+ 0	00	04		+ 0	00	04
9	Sid. T. or "R" for G.M.M. (0 hrs.)	Corrn. for Barometer 29.8in.	10	58	15		10	58	15	− 0	00	02		− 0	00	02
10	Sum = L.S.T. of observation	Sum = Total refraction = r	4	52	37		4	54	44	+ 0	01	22		+ 0	01	22
11		Corrected altitude = h − r								34	42	57		34	42	32
12	R.A. of Polaris	Latitude of station = λ	1	42	19		1	42	19	34	01	47		34	01	47
13	Lines (10) − (12) = t in time (v)	Lines (11) − (12) = a	3	10	18		3	12	25	+ 0	41	10		+ 0	40	45
14	t in arc (45 Sur.)		47	34	30		48	06	15							
15	cos t	a in seconds	+ 0·67 463				+ 0·66 777			+ 2 470				+ 2 445		
16	N.P.D. = (90 − δ) = Δ	N.P.D. = (90 − δ) = Δ	1°	01′	01″		1°	01′	01″	1°	01′	01″		1°	01′	01″
17	Δ in seconds	Δ in seconds	3 661″				3 661″			3 661″				3 661″		
18	Δ″ cos t = a in seconds	a″/Δ″ = cos t	+ 2 470				+ 2 445			+ 0·67 468				+ 0·66 785		
19	a	t in arc (vi)	0°	41′	10″		0°	40′	45″	47″	34′	15″		48″	05′	55″
20	Latitude of station = λ		34	01	47		34	01	47							
21	Sum = a + λ	h − r [from line (11)]	34	42	57		34	42	32	34	42	57		34	42	32
22	cos (a + λ)	cos (h − r)	0 82 199				0·82 206			0·82 199				0·82 206		
23	sin t	sin t	0·73 816				0·74 436			0·73 811				0·74 429		
24	$\frac{\Delta'' \sin t}{\cos(a+\lambda)}$ = A in seconds	$\frac{\Delta'' \sin t}{\cos(h-r)}$ = A in seconds	3 288″				3 315″			3 287″				3 315″		
25	A ($\frac{+ve}{-ve}$ Polaris $\frac{E}{W}$)		− 0	54	48		− 0	55	15	− 0	54	47		− 0	55	15
26	Reading to R.M. (vii) − Reading to Polaris		171	30	40		171	31	10	170	30	40		171	31	10
27	Sum		170	35	52		170	35	55	170	35	53		170	35	55
28	Convergence (viii)		+ 2	08	36		+ 2	08	36	+ 2	08	36		+ 2	08	36
29	Diff. = lines (27) − (28) = grid bearing of R.M.		168	27	16		168	27	19	168	27	17		168	27	19
30	Mean value		168	27	18					168	27	18				

(i) With time observed Polaris is "W" if t (line 14) is between 0–180°; with altitude observed it is "W" if h (line 5) is decreasing

(ii) Use left hand column if time is observed, and right hand column if altitude is observed; strike out whichever is not applicable.

(iii) If line (5) is L.M.T., Interval is line (5) − line (6).
If line (5) is Local Standard Time, Interval is line (5) − Standard longitude in time (for India except Calcutta, 5 hrs. 30 mins.).

(iv) Same sign as line (7).

(v) Add 24 hours if negative.

(vi) t is between $\frac{0\text{–}180°}{180°\text{–}360°}$ if h [line (5′)] is $\frac{\text{decreasing}}{\text{increasing}}$.

(vii) Corrected from 3 Grid.

(viii) From 4 Grid.

Computed by *Date* *Checked by* *Date*

G.B.—P.O.—J.S. 34—19-1-44—500.

INSTRUCTIONS

13 MACH.

1. Complete headings and lines 1 to 20, using left-hand column for line 9 to 11 for Sun and right-hand for Star.

2. Set line 16 on S.L. Multiply by line 17 by turning handle forwards if line 15 is $+^{ve}$ and backwards if $-^{ve}$. Clear S.L. and M.R. Set line 18 on S.L. and multiply by line 19 turning handle backwards if the product sin λ cos t is $+^{ve}$ and forwards if $-^{ve}$. Clear S.L. and M.R. [If it is complement in P.R., set (1 — figures in P.R.) on S.L. Clear P.R. Turn handle forwards once. Clear S.L. and M.R.]. Set line 20 on S.L. and divide. Record the figure in M.R. in line 21 for cot A if less than 3·00000. If more than 3·00000 transfer the figures in M.R. to S.L. Clear P.R. and M.R. and multiply turning handle forwards so that 1·00000 appears in P.R. (reciprocal of cot A by "built-up" method). Record the figure in M.R. in line 21 for tan A. The sign may be determined by inspection or as follows :—

If before dividing by sin t, P.R. shows positive sign, line 21 has the opposite sign to that of line 20, and if P.R. shows the complement, line 21 has the same sign as in line 20.

3. Complete the rest of the form as instructed on the form.

B SECTION No.1 Ind. Fd. Jvy COMPANY. DATE June 1940

Computation of grid bearing from Sun or Star, time and latitude being known

Grid I (For Kinturk) λ_0 32° 30′ L_0 68 00

Grid IVA (For Bangalore) λ_0 12° 00′ L_0 80 00

Observer Sun K.A. Sheikh. Star B.N. Murti

Instrument Sun Tavistock no 1000 Star Tavistock no 1000

Formulæ:—(a) $\cot A = \dfrac{\tan\delta\cos\lambda - \sin\lambda\cos t}{-\sin t}$ (b) $\tan A = \dfrac{-\sin t}{\tan\delta\cos\lambda - \sin\lambda\cos t}$

1	Station of observation		Kinturk							Bangalore S							
2	Referring mark		Hill Top							Bannergatta H.S.							
3	Sun/Star E. or W.	Date	Sun W	7	6			194		∝ Lyrae E (Vega)	8	6			194		
4	Latitude of station = λ	North +ve South −ve	+	33	54	25	—			+	12	58	41	—			
5	Longitude of station in arc			73	23	34					77	36	19				
6	Time of observation (i), corrected for chronometer error		h	16	m 33	s 01	h	m	s	h	22	m 34	s 16	h	m	s	
7	Longitude in time (ii)			5	30	00					5	30	00				
8	Line (6) − line (7)		+	11	03	01	—			+	17	04	16	—			
9	For Sun "E" for line (8) (iii)	For Stars "R" or S.T. at G.M.M.		12	01	19					17	04	54				
10		A for line (8) (22 Sur) (iv)	—	0			—	0		+	0	02	24	—	0		
11		*Minus* R.A. of Star	—				—			−	18	34	57	—			
12	Longitude of station in time (34 Sur)			4	53	34					5	10	25				
13	Sum = hour angle t (add 24 hours if negative)			3	57	54					20	47	02				
14	t in arc (45 Sur)		°	59	′ 28	″ 30	°	′	″	°	311	′ 45	″ 30	°	′	″	
15	Declination at line (8) = δ	+ve North −ve South	+	22	45	41	—			+	38	43	41	—			
16	tan δ			+0·41 957			— ·				+0·80 196			— ·			
17	cos λ			0·82 994			0·				0·97 446			0·			
18	sin λ			+0·55 785			−0·				+0·22 458			−0·			
19	cos t			+0·50 792			−0·				+0·66 599			−0·			
20	sin t			+0·86 141			−0·				−0·74 596			−0·			
21	cot A or tan A (v)			−0·07 531			— ·				+0·84 711			— ·			
22	A = true bearing of Sun/Star (vi)		°	274	′ 18	″ 24	°	′	″	°	49	′ 43	″ 54	°	′	″	
23	Reading to R.M. (vii) − Reading to Sun/Star			60	56	34					140	04	16				
24	Sum			335	14	58					189	48	10				
25	Convergence at line (5) (4 Grid)		−	2	53	51	—			+		29	56	—			
26	Lines (24) − (25) = Grid bearing of R.M.			332	21	07					190	18	06				
27	Mean value																

Notes:—(i) For Stars, if local Sidereal Time is known, enter it in line (6); neglect lines (7) to (10) and (12), and enter in line (13) the sum of lines (6) and (11).

(ii) Longitude of local/standard meridian according as time in line (6) is local mean/standard time.

(iii) From Abridged N.A.; if Standard N.A. is used. "E" is 12 hours + Eqn. of time.

(iv) Same sign as line (8).

(v) See formulæ at the top. For separate instructions for machine working, see Supplement to T.H.B Chap. VIII. Use Formula (a)/Formula (b) if cot A is numerically less/greater than 3·00000.

(vi) A is less than/greater than 180°, when Sun or Star is E/W.

(vii) Corrected for 3 Grid.

Computed by *Date* *Checked by* *Date*

G.B.—P.O.—J.S. 437-J/13—29-8-44—800.

14 MACH.

1. Complete headings entering spheroid in use, sheet number, striking out 'Metres' or 'Yards' whichever is not applicable.

2. Complete lines 1 to 5, 7, 9 to 17, 23 and 24 as instructed on the form. For lines 13, 16 and 24 set ($\lambda_P - \lambda_T$) on S.L. once for all, multiply by corresponding changes for 1″ and record the results for the corresponding quantities.

3. Set line 5 on S.L. Multiply by itself turning handle forwards and record the product in line 6 with proper decimal point (considering 10^{-6} also, i.e. the decimal point in P.R. to be shifted by six places more to the left). Complete line 8. Continue multiplication until M.R. reads line 17 and record P.R. in line 18. Clear S.L. and M.R. Set line 14 on S.L. Multiply by line 11 turning handle backwards if ΔL is numerically greater than 30,000″ otherwise forwards. Record the figure in P.R. in line 20 (leaving line 19 blank) with the same sign as in line 5. Enter in line 21 the constant appropriate to the grid used. Complete line 22. Clear M.R. and P.R. but not S.L. Multiply by line 8. Record the figure in P.R. in line 26. Complete line 27 (leaving line 25 blank).

14 Mach. **Survey of India** Page ......

B **SECTION** No. 1 Ind. Fd. Svy. **COMPANY. DATE** August 1940

Machine Deduction of Grid Co-ordinates from Spherical Grid I $\begin{cases}\lambda_0 & 32°\ 30'\\ L_0 & 68°\ 00'\end{cases}$

Formulæ:— (1) $E_P = E_K \Delta L'' + F_E N_{2K} + E_0$
(2) $N_P = N_{1K} + N_{2K}\left(\frac{\Delta L''^2}{10^6} + F_N\right)$

Everest SPHEROID ~~METRES~~ OF YARDS

Sheet No. 38 K/7

1	Point = P	Panebni h.s.					
2	Latitude of P = λ_P	33° 16' 47.50"	° ' "	° ' "	° ' "	° ' "	° ' "
3	Longitude of P = L_P	70 25 55.50					
4	$\Delta L = L_P - L_0$	+ 2 25 55.50	−	−	−	−	−
5	$\Delta L''$	+ 8 755.50	−	−	−	−	−
6	$(\Delta L'')^2 \times 10^{-6}$	76.659					
7	F_N for ΔL (i)	+ 0.036	−	−	−	−	−
8	Sum = line 6 + line 7 = (a)	76.695					
9	F_E for ΔL_T (i)	+ 6.228	−	−	−	−	−
10	Interpolation for $(\Delta L - \Delta L_T)$ secs. (i)	+ 0.032	− 0·	− 0·	− 0·	− 0·	− 0·
11	Sum = F_E for ΔL (ii)	+ 6.260	−	−	−	−	−
12	N_{2K} for λ_T (iii)	36 79 885					
13	Interpolation for $(\lambda_P - \lambda_T)$ secs. (iii)	− ·00 532	− ·0	− ·0	− ·0	− ·0	− ·0
14	Sum = N_{2K} for λ_P	36 79 343					
15	E_K for λ_T (iii)	28 239 157					
16	Interpolation for $(\lambda_P - \lambda_T)$ secs. (iii)	− ·004 160	− ·0	− ·0	− ·0	− ·0	− ·0
17	Sum = E_K for λ_P	28 234 997					
18	$E_K \times \Delta L''$ = (line 17 × line 5)	+ 247 211.5	−	−	−	−	−
19	$N_{2K} \times F_E$ = (line 14 × line 11)	−	−	−	−	−	−
20	Sum = E_P	+ 247 441.8	−	−	−	−	−
21	Constant E_0 (to make all Eastings positive)	3 000 000.0	00·0	00·0	00·0	00·0	00·0
22	Sum = E_P (Easting of P)	3 247 441.8					
23	N_{1K} for λ_T (iii)	1 092 865.5					
24	Interpolation for $(\lambda_P - \lambda_T)$ secs. (iii)	+ 598.5	+	+	+	+	+
25	Sum = N_{1K} for λ_P						
26	N_{2K} × (a) = (line 14 × line 8)	2 821.9					
27	Sum = N_P (Northing of P)	1 097 285.9					

(i) From Table 10 Grid., ΔL_T is the tabular entry next smaller than ΔL. (ii) Change sign if ΔL (line 4 or 5) is negative. (iii) From Table 1 Grid., λ_T is the tabular entry next smaller than λ_P.

Computed by *Date* *Checked by* *Date*

G.B.—P.O.—J.S. 120 –19-2-44 –1,000.

INSTRUCTIONS

15 MACH.

1. Complete headings. Record lengths of tapes A, B, C and D, measured lengths of junctions, tape number, latitude, temperature, height above M.S.L. and draw catenary diagram showing supports. Enter observed angles of slope (in minutes) to each support, writing the angle for the nearest end against a_1 and working upwards. Enter signs of angles (positive for elevation or negative for depression).

2. Set a_4 on S.L. Multiply by 4 turning handle forwards if a_4 is $+^{ve}$ and backwards if $-^{ve}$. Clear S.L. and M.R. Set a_3 and multiply by 3 turning handle backwards if a_3 is $+^{ve}$ and forwards if $-^{ve}$. Record figure in P.R. against β_4 (if P.R. shows complement, find direct number mentally and record). Clear P.R. Turn handle until M.R. reads 0000, thereby registering $3a_3$ on P.R. for next operation for β_3. Clear S.L. Set a_2 on S.L. Multiply by 2 turning handle backwards if a_2 is $+^{ve}$ and forwards if $-^{ve}$. Record figures in P.R. against β_3 as before. Clear P.R. Turn handle until M.R. reads 0000. Clear S.L. Set a_1 on S.L. Turn handle backwards once if a_1 is $+^{ve}$ and forwards if $-^{ve}$. Record figure in P.R. against β_2 as before. Record a_1 against β_1.

3. Look up slope corrections for each value of β in table on back of form and record in appropriate places in right-hand column. If one or more supports are missing, follow special instructions in 'Note' on back of form. Also find out corrections for temperature, height, catenary and enter them. Catenary correction for 3-chain base with one support missing is the sum of corrections for 2-chain base with 2-chain interval and 1-chain base with 1-chain interval. Similarly, for 4 chains it is the sum of corrections for each section. Add the entries and transfer total correction to left-hand column in the appropriate place.

4. To get base in grid yards set 'I' on S.L. and multiply by scale factor (= F) and record figures in P.R. against " Base in grid yds. ". If length of base is required in metres, transfer figure in P.R. to S.L. Multiply by 0·91440 and record the product against "Base in grid metres".

5. If using log tables complete right-hand bottom of the form (directed by arrow mark) as instructed thereon.

NOTE :—Temp. and Height corrections for 3-chain base are the sums of corrections for 1 & 2-chain base.

Corrections for Catenary, Temperature & Height.

	Interval between supports	1-chain base	2-chain base	3-chain base	4-chain base
		feet	*feet*	*feet*	*feet*
Catenary	1 chain	−0·004	−0·008	−0·012	−0·016
	2 chains	...	−0·031	...	−0·062
	3 chains	...	...	−0·104	...
	4 chains	...	...	...	−0·248
Temperature (Fahrenheit)	30	−0·026	−0·052	−0·077	−0·103
	40	−0·022	−0·043	−0·064	−0·086
	50	−0·017	−0·034	−0·052	−0·069
	60	−0·013	−0·026	−0·039	−0·052
	70	−0·009	−0·017	−0·026	−0·034
	80	−0·004	−0·009	−0·013	−0·017
	90	Nil	Nil	Nil	Nil
	100	+0·004	+0·009	+0·013	+0·017
	110	+0·009	+0·017	+0·026	+0·034
	120	+0·013	+0·026	+0·039	+0·052
	130	+0·017	+0·034	+0·052	+0·069
Height in feet above M.S.L.	0	·000	·000	·000	·000
	1,000	−0·003	−0·006	−0·009	−0·013
	2,000	−0·006	−0·013	−0·019	−0·026
	3,000	−0·010	−0·019	−0·028	−0·038
	4,000	−0·013	−0·025	−0·038	−0·050
	5,000	−0·016	−0·032	−0·047	−0·063
	6,000	−0·019	−0·038	−0·057	−0·076
	7,000	−0·022	−0·044	−0·066	−0·089
	8,000	−0·025	−0·050	−0·076	−0·101
	9,000	−0·028	−0·057	−0·085	−0·114
	10,000	−0·032	−0·063	−0·095	−0·126

Correction in feet for slope for one section (always − ^{ve})

β Min.	Correction	β Min.	Correction	β Min.	Correction	β Min.	Correction
0	0·000	110	0·034	176	0·086	242	0·163
14	0·001	112	0·035	178	0·088	244	0·166
24	0·002	114	0·036	180	0·090	246	0·169
30	0·003	116	0·038	182	0·092	246	0·172
36	0·004	118	0·039	184	0·095	250	0·174
41	0·005	120	0·040	186	0·097	252	0·177
45	0·006	122	0·042	188	0·099	254	0·180
49	0·007	124	0·043	190	0·101	256	0·183
52	0·008	126	0·044	192	0·103	258	0·186
56	0·009	128	0·046	194	0·105	260	0·189
59	0·010	130	0·047	196	0·107	262	0·192
62	0·011	132	0·049	198	0·109	264	0·195
65	0·012	134	0·050	200	0·112	266	0·197
67	0·013	136	0·052	202	0·114	268	0·200
70	0·014	138	0·053	204	0·116	270	0·203
73	0·015	140	0·055	206	0·118	272	0·206
75	0·016	142	0·056	208	0·121	274	0·210
77	0·017	144	0·058	210	0·123	276	0·213
80	0·018	146	0·060	212	0·125	278	0·216
82	0·019	148	0·061	214	0·128	280	0·219
84	0·020	150	0·063	216	0·130	282	0·222
86	0·021	152	0·064	218	0·133	284	0·225
88	0·022	154	0·066	220	0·135	286	0·228
90	0·023	156	0·068	222	0·138	288	0·231
92	0·024	158	0·070	224	0·140	290	0·235
94	0·025	160	0·071	226	0·143	292	0·238
96	0·026	162	0·073	228	0·145	294	0·241
98	0·027	164	0·075	230	0·148	296	0·245
100	0·028	166	0·077	232	0·150	298	0·248
102	0·029	168	0·079	234	0·153	300	0·251
104	0·030	170	0·081	236	0·155		
106	0·031	172	0·083	238	0·158		
108	0·033	174	0·085	240	0·161		

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 $\beta = \frac{ma_m - na_n}{m-n}$, 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.

15 ~~Mach.~~ / ~~Lamb.~~ **Hunter Short Base** Grid I λ_0 32° 30 / L_0 68 00

Description The base is on sloping Ground outside the perimeter of SARKARI compounds east and west. The east end is marked by a ⊙ **Observer** A T Shakir

Date August 1940

← To be entered at site →

Tape	Length (ft.)	Junctions	Observed angle		Tape No.	3	Corrections (all negative except temperature over 80°) feet
		0·271	a_4 (2)	+ 187·3′	Latitude	33° 17′	
A	65·741	0·266	a_3 (2)	+ 170·2′	(1) Temperature	76°F	−0·023 (3)
B	65·738	0·262	a_2 (2)	+ 195·7′	Height above M.S.L.	3500 ft.	−0·044 (3)
C	65·746	0·266	a_1 (2) (near end)	+ 272·8′	Catenary	Diagram	−0·016 (3)
D	65·826	0·280	$4a_4$	— ′	(4) $\beta_4 = 4a_4 - 3a_3$	238·6′	−0·160 (3)
(Enter total if all tapes used)			$3a_3$	— ′	$\beta_3 = 3a_3 - 2a_2$	119·2	−0·040
Total	263·051	1·345	$2a_2$	— ′	$\beta_2 = 2a_2 - a_1$	118·6	−0·040
Sum		264·396	a_1	— ′	$\beta_1 = a_1$	272·8	−0·208
Total corrections		− ·531				Total corrections	− ·531
Sum = Length of base in feet		263·865					
Length in yds. = l		87·955	→ If using log tables, complete computation below:				
Scale Factor = F (5)		0·99888					
$l \times F$ = Base in grid yds.		87·856					
Conversion factor		× 0·91440					
Base in grid metres		80·336					

Slope corrections

Log length in yards	1·
Log scale factor (from 2 Grid)	·
Sum = log base in grid yards	1·
Log conversion factor	1·96114
Sum = log base in grid metres	1·

(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 reverse.
(4) Each β is the *algebraic* difference; the signs of $4a_4$, $3a_3$ etc., must therefore be taken into account. See back of form if any supports are omitted. See p. 8 of Departmental Paper No. 10 for precise formula if any β is greater than 300′.
(5) From 2 Grid.

Computed by *Date* *Checked by* *Date*

INSTRUCTIONS

16 MACH.

1. Complete headings striking out "Stations" or "Points" whichever is not applicable.

2. Complete lines 1 to 11 (except lines 7 and 10) as instructed on the form deleting metres or yards whichever is not applicable in line 8. Enter lines 15 and 23 and find out "k" [line 7 ; see footnote (ii)]. Complete line 10.

3. Set line 8 on S.L. Multiply by 3 (or 3·28084 if working in metres) by turning handle forwards. Clear S.L. and M.R. Set scale factor and divide. Record the figure in M.R. in line 12.

4. Set line 10 on S.L. and multiply by line 12 turning handle forwards. Transfer figure appearing in P.R. to S.L. Clear M.R. and P.R. and multiply by line 11 turning handle forwards. Record product in line 13. Complete lines 14, 16 and 17.

5. Set line 12 on S.L. Multiply by line 17 and record the product in line 18 with the same sign as in line 16.

6. Complete the remainder of the form as instructed thereon.

16 Mach.

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B **SECTION** 1 Ind. Fd. Svy. **COMPANY. DATE** April, 1940

Grid I $\begin{cases} \lambda_0 & 32\ 30' \\ L_0 & 68\ 00 \end{cases}$

Height computations by machine, of Triangulated Stations or Points

1	Deduction Nos. (i)	...1 A	...2 A	...3	...4	...5	...6	...7	...8	...9	...0
2	Fixed station A	Tor Tsapparhs	Spinat Sukahs								
3	Deduced station B	23	23								
4	Barometer	25.1 inches	25.3 inches	· inches	· inches	· inches	· inches	· inches	· inches	· inches	· inches
5	Thermometer	75°	76°	°	°	°	°	°	°	°	°
6	Hour and date of obsn.	h 12 d 24 m 4 1940	h 12 d 23 m 4 1940	h d m 194	h d m 194	h d m 194	h d m 194	h d m 194	h d m 194	h d m 194	h d m 194
7	Refraction coefft. = k (ii)	0·0	0·0	0·0	0·0	0·0	0·0	0·0	0·0	0·0	0·0
8	Distance AB (Grid $\frac{\text{metres}}{\text{yards}}$)	21 352·0	21 249.0	·	·	·	·	·	·	·	·
9	Bearing of B = A	159°	172°	°	°	°	°	°	°	°	°
10	$(1-2k)^{(ii)}$	0.860 8	0.860 6	0·	0·	0·	0·	0·	0·	0·	0·
11	Factor from 6 (a) Sur (iii)	0·00494	0·00494	0·0049	0·0049	0·0049	0·0049	0·0049	0·0049	0·0049	0·0049
12	Distance AB (true feet) (iv)	64116.9	638 07·6	·	·	·	·	·	·	·	·
13	ψ in seconds (= lines 10 × 11 × 12)	+ 273″	+ 271″	+ ″	+ ″	+ ″	+ ″	+ ″	+ ″	+ ″	+ ″
14	ψ	+ 0° 04′ 33″	+ 0° 04′ 31″	+ 0° ′ ″	+ 0° ′ ″	+ 0° ′ ″	+ 0° ′ ″	+ 0° ′ ″	+ 0° ′ ″	+ 0° ′ ″	+ 0° ′ ″
15	Observed altitude = a_0 (v)	− 0 46 00	− 0 38 30	−	−	−	−	−	−	−	−
16	$a = a_0 + \psi$	− 0 41 27	− 0 33 59	−	−	−	−	−	−	−	−
17	Tan a	− .01 206	− .00 989	− ·	− ·	− ·	− ·	− ·	− ·	− ·	− ·
18	Δh = line 12 × line 17 (vi)	− 773·2	− 631·1	− ·	− ·	− ·	− ·	− ·	− ·	− ·	− ·
19	δh from 7 Sur (vii)	− 0·2	− 0·2	− ·	− ·	− ·	− ·	− ·	− ·	− ·	− ·
20	Height of instrument	+ 5·4	+ 5·3	+ ·	+ ·	+ ·	+ ·	+ ·	+ ·	+ ·	+ ·
21	Height of signal (viii)	− 0·0	− 0·0	− ·	− ·	− ·	− ·	− ·	− ·	− ·	− ·
22	Sum = $h_b - H_a$ (ix)	− 767·8	− 626·0	− ·	− ·	− ·	− ·	− ·	− ·	− ·	− ·
23	Height of A = H_a	5 281·	5 145·	·	·	·	·	·	·	·	·
24	Sum = Height of B = h_b	4 513·	4 519·	·	·	·	·	·	·	·	·
25	Mean Height of B = H_b	45 16									

Notes:—(i) Enter "A" or "B" after deduction number to indicate the station at which observations were made.
(ii) Table 5(a) Sur., Auxiliary Tables, Part III. Tabular values may be used if k is not otherwise known.
(iii) Auxiliary Tables, Part III. Enter table with argument A and λ (values to the nearest degree).
(iv) True distance = grid distance + scale factor, from 2 Grid. To convert grid metres to grid feet multiply by 3·28084.

Notes:—(v) a_0 is + or − according as the observed angle is elevation or depression.
(vi) Δh has same sign as lines 16 and 17.
(vii) δh has same sign as Δh.
(viii) Sign for signal always −.
(ix) Change sign of sum if B is station of observation.

Computed by *Date* *Checked by* *Date*

G.B.—P.O.—J.S. 440-J/16—29-8-44—300.

INSTRUCTIONS

17 MACH.

1. Complete headings. In upper half of the form set up stations, enter observed angles (corrected for 3 Grid), Δ^r error, and corrected angles in appropriate columns. Write down sines of corrected angles and side AB for each triangle.

2. *With Single Machine.*—Set AB on S.L. Turn handle forwards once. Clear S.L. and M.R. Set sin C on S.L. and divide. Set the figure in M.R. on S.L. Clear P.R. and M.R. Multiply by sin A and record the product against side BC. Continue multiplication until M.R. reads sin B. Record the product against side CA. Continue multiplication until M.R. reads sin C. Check that the figure in P.R. equals side AB.

With Twin Machine.—Set AB on R.H. S.L. Turn handle forwards once. Clear S.L. and M.R. Set sin C on R.H. S.L. and divide on right-hand machine. Clear S.L. and both P.R.'s. Connect machines in parallel. Set sin A on L.H. S.L. and sin B on R.H. S.L. Turn handle until M.R. reads 0000. Record figures in L.H. P.R. against side BC and R.H. P.R. against side CA.

3. Enter stations whose co-ordinates are required in line 1 on lower-half of the form. Complete lines 2 to 10 according to instructions given thereon, striking out yards or metres not applicable in line 10.

4. *With Single Machine.*—Set line 3 (E_A or E_B) on S.L. Turn handle forwards once. Clear M.R. and S.L. Set AC line 10 (AC or BC from upper-half of the form) on S.L. and multiply by sin β_1 line 8 (or sin β_2) turning the handle forwards or backwards according as sin β_1 (line 8) is $+^{ve}$ or $-^{ve}$. Record and enter the figure in P.R. in line 11.

Similarly obtain N_C substituting N_A (or N_B), cos β_1 (or cos β_2) for E_A (or E_B), sin β_1 (or sin β_2) respectively in the above instructions.

With Twin Machine.—Set E_A on L.H. S.L. Set N_A on R.H. S.L. Connect machines in parallel and turn handle forwards once. Clear S.L. and M.R. Set sin β_1 on L.H. S.L. and cos β_1 on R.H. S.L. Connect machines in parallel or opposite according as signs of sin β_1 and cos β_1 are same or opposite and multiply by AC turning handle forwards or backwards according as cos β_1 is positive or negative. E_C then appears in L.H. P.R. and N_C in R.H. P.R. Check by recomputing, substituting E_B, N_B, BC, sin β_2 and cos β_2 for E_A, N_A, AC, sin β_1 and cos β_1. Check that both values of E_C and of N_C agree.

5. Complete lines 13 to 18.

6. Set AC line 10(or BC) on S.L. Multiply by 3 (or 3·28084 if working in metres). Set figure appearing in P.R. on S.L. Clear P.R. and M.R. Multiply by line 17. Clear S.L. and M.R. Set scale factor F (line 18) on S.L. and divide. Record the figure in M.R. in line 19 with the same sign as in line 17.

7. Complete remainder of form as instructed thereon. Check agreement of heights and enter classification of points in line 1 R.H. half column.

B **SECTION** Ind fd /vy. **COMPANY. DATE** Aug 1940 **Grid I** $\{\lambda_0$ 32 30 L_0 68 00

Machine computation of sides, co-ordinates and heights of triangulation

Formulæ:—

(1) $\begin{cases} BC = \frac{AB}{\sin C} \times \sin A \\ CA = \frac{AB}{\sin C} \times \sin B \end{cases}$ (2) $\begin{cases} E_C = E_A + AC \sin \beta_1 = E_B + BC \sin \beta_2 \\ N_C = N_A + AC \cos \beta_1 = N_B + BC \cos \beta_2 \end{cases}$ (3) $\delta h = \frac{AC \text{ (or } BC) \times \tan \theta}{F} \times$ [3 (distance in yards) or 3·28084 (distance in metres)]

Station or Intersected Point		Observed Angle (corrected for 3 Grid)			Δ' error	Corrected Angle			Sines	Sides [formula (1)]	Side
Tarkhobai h.s.	A	77	24	45	−	77	24	45	0·97 597	8077·1	BC
Panchai h.s.	B	41	13	08	−	41	13	08	0·65 894	5453·4	CA
I P 20	C	61	22	07	−D	61	22	07	0·87 771	7263·9	AB
Δ No. 1	Total	180	00	00		180	00	00			
	A				−				0·	·	BC
	B				−				0·	·	CA
	C				−				0·	·	AB
Δ No. 2	Total										
	A				−				0·	·	BC
	B				−				0·	·	CA
	C				−				0·	·	AB
Δ No. 3	Total										

1	Station or point C No.	Classification	IP no.20			S									
2	Station $\frac{A}{B}$		Tarkhobai h.s			Panchai h.s.									
3	Easting of $\frac{A}{B} = \frac{E_A}{E_B}$		3 254 019·7			3 247 441·4				·			·		
4	Northing of $\frac{A}{B} = \frac{N_A}{N_B}$		1 100 366·3			1 097 285·7				·			·		
5	Bearing at $\frac{A \text{ of } B}{B \text{ of } A}$		244	54	22	64	54	22							
6	Corrected angle $\frac{BAC}{ABC}$		+ 77	24	45	− 41	13	08	+			−			
7	Sum $= \frac{\beta_1}{\beta_2}$ = bearing at $\frac{A}{B}$ of C		322	19	07	23	41	14							
8	sin $\frac{\beta_1 \ +^{ve} \ 0-180}{\beta_2 \ -^{ve} \ 180-360}$		−0·61 127			+0·40 174			−0·			−0·			
9	cos $\frac{\beta_1 \ +^{ve} \ 270-90}{\beta_2 \ -^{ve} \ 90-270}$		+0·79 142			+0·91 575			−0·			−0·			
10	Distance $\frac{AC}{BC}$ (grid $\frac{\text{yards}}{\text{metres}}$)		5 453·4			8 077·1				·			·		
11	Easting of C = E_C [formula (2)]		3 250 686·2			3 250 686 3				·			·		
12	Northing of C = N_C [formula (2)]		1 104 682·2			1 104 682·3				·			·		
13	Case (i)		I			I									
14	Vertical ∠ at $\frac{A}{B}$ of C = $\frac{e_1}{e_2}$		+ 1	49	24	− 1	44	05							
15	Vertical ∠ at C of $\frac{A}{B} = \frac{e_3}{e_4}$		−			−			−			−			
16	$\frac{\frac{1}{2}(e_1 - e_3)}{\frac{1}{2}(e_2 - e_4)}$ Case III only		−			−			−			−			
17	tan θ (ii)		+ ·03 184			− ·03 029			− ·			− ·			
18	Scale factor F (iii)		·99 888			·99 888			·			·			
19	δh feet (iv) [formula (3)]		+ 521·5			− 734·8			−	·		−	·		
20	Correction for curvature (v) refraction & ht. of inst.		+ 10·5			+ 17·3			+	·		+	·		
21	Correction for ht. of Signal (vi)		− 0·0			− 0 0			−	·		−	·		
22	Sum = $h_c - \frac{H_a}{H_b}$ (vii)		+ 532·0			− 717·5			−	·		−	·		
23	Ht. of $\frac{A}{B}$ (feet) = $\frac{H_a}{H_b}$		2 989·0			4 240·0				·			·		
24	Sum = Ht. of C = h_c		3 521·0			3 522 5				·			·		
25	Mean height of C in feet		3 522												

NOTES :— (i) Case I.— Observation at A or B only. Case II.—Observation at C only. Case III.—Observation at A & C or B & C.
(ii) $\theta = e_1$ or e_2 (Case I), e_3 or e_4 (Case II) or line 16 (Case III).
(iii) From 2 Grid; may generally be taken as unity.
(iv) Same sign as line (17).
(v) From 41 Grid (or equivalent table) for AC or BC; not required for Case III.
(vi) *Minus* ht. of Signal at C (Case I) and A or B (Case II), or $\frac{1}{2}(S_A - S_C)$ or $\frac{1}{2}(S_B - S_C)$ (Case III).
(vii) Change sign for Case II.

Computed by *Date* *Checked by* *Date*

G.B.—P.O.—J.S 37 —10-1-44—500.

18 MACH.

1. Fill in the headings and complete the form to line 7.

2. Compute line 8 from the formula (1) given at the top of the form as follows :—

Set line 5 on S.L. Multiply by 2. Transfer product to S.L. and turn handle backwards once to check that P.R. reads 0000. Clear M.R. Multiply by line 6. Transfer the product* to S.L. as above. Clear M.R. and P.R., and multiply by line 7 turning handle forwards or backwards according as the sign of line 7 is $+^{ve}$ or $-^{ve}$.

* NOTE :—In cases where the number of digits of such product excluding the decimals is 9, it will be enough to take the number correct to the nearest integer. The Marchant Machine is not suitable if such product contains figures more than 9 integers.

Clear M.R. and S.L. Set line 5 on S.L. and multiply by the same line turning handle forwards. Clear M.R. and S.L. Set line 6 on S.L. and multiply by the same line by turning handle forwards. Record the figures appearing in P.R. in line 8.

NOTE :—Care must be taken to set the numbers in S.L. with due regard to decimal places.

3. Obtain square root of figures appearing in P.R. by the method described in the Preface to this Supplement page v. Record the square root in line 9.

4. Complete line 10.

5. Set line 9 on S.L. and turn handle forwards until line 10 appears in P.R. Set figures appearing in M.R. on S.L. Clear M.R. and P.R. Multiply by line 5. Record product in line 11. Continue multiplication until line 6 appears in M.R. Record product in line 12. Continue multiplication until line 9 appears in M.R. Check that P.R. now shows line 10.

6. Complete lines 13 and 14.

Grid 1 λ_0 32° 30 L_0 68 00

B **SECTION** No. 1 Ind. Fd. Svy. **COMPANY.** **DATE** June 1940

Machine Computation of triangles given two sides and the included angle.

SURVEY Waziristan

Formulæ:—(1) $AB = \sqrt{2\,BC.AC\,(-\cos C) + BC^2 + AC^2}$ (2) $\sin A = \frac{\sin C}{AB} \times BC$; $\sin B = \frac{\sin C}{AB} \times AC$.

1	Station A	Sir Narai h.s.			
2	Station B	Pariebai h.s.			
3	Station C	Kohi Sar h.s.			
4	Included angle C(i)	49° 48′ 05″	° ′ ″	° ′ ″	° ′ ″
5	BC (ii)	10 065.4	.	.	.
6	AC(ii)	8 973.2	.	.	.
7	*Minus* cos C	−0·64 544	−0·	−0·	−0·
8	AB^2 (iii) [from formula (1)]	65 239 80[illegible]5	.	.	.
9	AB(iii) [from formula (1)]	8 077.1	.	.	.
10	Sin C	0·76 381	0·	0·	0·
11	Sin A(iii) [from formula (2)]	0·95 183	0·	0·	0·
12	Sin B(iii) [from formula (2)]	0·84 855	0·	0·	0·
13	Angle A(iv)	72° 08′ 40″	° ′ ″	° ′ ″	° ′ ″
14	Angle B(iv)	58 03 15			

1	Station A				
2	Station B				
3	Station C				
4	Included angle C(i)	° ′ ″	° ′ ″	° ′ ″	° ′ ″
5	BC(ii)	.	.	.	.
6	AC(ii)	.	.	.	.
7	*Minus* cos C	−0·	−0·	−0·	−0·
8	AB^2 (iii) [from formula (1)]	.	.	.	.
9	AB(iii) [from formula (1)]	.	.	.	.
10	Sin C	0·	0·	0·	0·
11	Sin A(iii) [from formula (2)]	0·	0·	0·	0·
12	Sin B(iii) [from formula (2)]	0·	0·	0·	0·
13	Angle A(iv)	° ′ ″	° ′ ″	° ′ ″	° ′ ″
14	Angle B(iv)				

Notes:—(i) Corrected for 3 Grid.
(ii) Grid distance.
(iii) See T.H.B. Chap. VIII Supplement for machine working.
(iv) If angle C is less than 90°, check quadrants of angles A and B by computing first the angle whose Sin (line 11 or 12) is smaller; this angle will be in the first quadrant. Then verify that the angles at A, B and C total 180°.

Computed by *Date* *Checked by* *Date*

G.B.—P.O.—J.S. 442-J 18—29-8-44—100.

21 MACH.

1. Complete headings and enter names of stations and offsets (para 6 below) in column 1.

2. Complete columns 2, 3 and 4. In col. 3, the correction to the observed angles is to be entered if bearing is observed at beginning and end of line in which case the correction is to be applied evenly among all the angles observed.

3. Complete column 5, care being taken to see that the distance 'd' is corrected for slope and it is in grid yards or metres, striking out whichever is not applicable. To convert true yards or metres to grid set scale factor on S.L. and multiply by horizontal distance in true yards.

4. Complete cols. 6 and 7 with appropriate signs for all stations and offsets (see para 6 below).

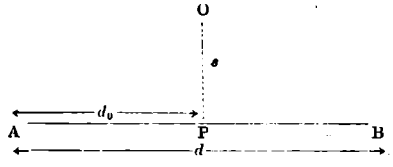
5. Enter Easting and Northing of starting station in cols. 8 and 9 and compute them for all other stations (and offsets) according to formula (a) on L.H. top of form as follows, striking out yards or metres whichever is not applicable :—

With Single Machine.—Set Easting of starting station (E_1) on S.L. Turn handle forwards once. Set sin β (Col. 6) for first leg on S.L. and multiply by d (Col. 5) for first leg turning handle forwards, if sin β is positive or backwards if negative. Easting of second station (E_2) will then appear in P.R. Clear S.L. and M.R. only. Set sin β (Col. 6) for second leg on S.L. and multiply as above by d (Col. 5) for second leg. Easting of third station will then appear in P.R. Continue as above for all stations (and offsets). It is only necessary to record Eastings of stations which are required for further observation or computation.

Northings (Col. 9) of all stations (and offsets) are now computed in exactly the same way as Eastings, except that the northing of the first station is initially set and thereafter cos β instead of sin β is set on S.L. for multiplication by 'd'. Here, however, the second formula in (a) should be used.

With Twin Machine.—If a twin machine is used Eastings and Northings can be computed simultaneously using the L.H. machine for Eastings and R.H. for Northings. Multiplication by 'd' for each leg is done with the coupling direct/reversed if sin β and cos β have same/opposite sign.

6. Offsets are entered in their correct position in the line in the same column as stations with (R) or (L) and the distance (s) along the offset ray written against them. In col. 5, the distance (d_0) along the line to the point from which the offset was made is entered in brackets. In col. 4, the bearing of the offset ray equals the bearing of leg $+90°$ for offsets on right and $-90°$ for those on left. The offset is then computed as follows :—(See diagram)



Let P be the point on line AB from which the offset was taken. When P.R. still shows the easting of A, set on S.L. sin β (value from column 6 against B, i.e., for bearing AB) and multiply by d_0, the distance in brackets in column 5. Clear S.L. and M.R.

Now set on S.L. sin β (value from column 6 against offset, i.e., for offset bearing) and multiply by s, the distance from P to the offset.

P.R. will now show the easting of the offset. Record it in the form within brackets. Now turn handle till M.R. shows 0000. Clear S.L. Set sin β (value from column 6 against B for bearing AB) and multiply by the *difference* ($d - d_0$) of the distances in column 5, that against B *minus* that in brackets against offset. P.R. will now show Easting of B.

To compute northing of the offset from northing of A, repeat the above procedure with the corresponding values in column 7.

7. Triangles are computed separetely on form 34 Mach. with single machine, or 33 Mach. if twin machine is available.

8. Corrections to co-ordinates are made in spaces provided if traverse starts from and closes on stations of known co-ordinates. Corrections to co-ordinates *should be applied in proportion to the lengths of the lines.*

9. Complete columns 10 and 11 and fill in height of first station in column 12. Set this height (H_1) on S.L. and turn handle forwards once. Clear S.L. and M.R. Set tan e for first leg on S.L. Multiply by 3 (or 3·281) × d for first leg turning handle forwards, if tan e is positive and backwards if negative. Height of second station then appears in P.R. Continue as above for all stations and offsets.

If line starts from and closes on stations of known heights, distribute corrections to heights in column provided among the longest sides and not in those whose differences are greatest.

21 Mach.

Survey of India

B SECTION No. 1 Ind. Fd. Svy. COMPANY. DATE August, 1940

Formulæ:—(a) $E_2 = E_1 + d \sin \beta$
$N_2 = N_1 + d \cos \beta$
(b) $H_2 = H_1 + d \tan e \times \left[\begin{matrix} 3\,(d \text{ in yards}) \\ \text{or} \\ 3{\cdot}281\,(d \text{ in metres}) \end{matrix}\right]$

Machine computation of traverse co-ordinates and heights.

Grid I λ_0 32 30, L_0 68 00

Traverse from Abbottabad to Haripur by X

Instrument C T S & Wild

1	2	3			4				5		6	7	8		9		10			11	12		13
Description of Stations, Offsets and Connections	Station Letters	Observed Angles			Grid Bearings from North = β				Distance = d		Sin β (+ve 0 to 180°, −ve 180° to 360°)	Cos β (+ve 270° to 90°, −ve 90° to 270°)	Easting of Station or Point = E [Formula (a)]		Northing of Station or Point = N [Formula (a)]		Vertical Angle = e			Tan e	Height of Station or Point = H [Formula (b)]		Remarks
		°	′	″	°	′	″	Cor.	grid yards / metres				grid yards / metres	Cor.	grid yards / metres	Cor.	E or D	°	′		feet	Cor.	
Rejected Stn.	1										−	−	3 526 565	−	1 212 668	+				−	4 267	−	
	2A	158	40	+3 13	239	07	15		3 435	6	−·85 825	−·51 323	3 523 606	2	1 210 905		D	0	42	−·01 222	4 141		
	3	170	33	+2 26	317	47	31		3 110	7	−·61 280	−·79 024	3 521 700	3	1 208 447		D	2	17	−·03 987	3 769		
	4A	187	11	+2 32	208	20	59		2 984	5	−·47 486	−·88 006	3 520 283	4	1 205 820		D	2	55	−·05 395	3 313		
	5	131	15	+2 47	215	32	34		3 707	8	−·58 132	−·81 368	3 518 128	6	1 202 803		D	1	25	−·02 473	3 038		
	6A	228	14	+3 08	166	48	23		2 660	1	+·22 824	−·97 360	3 518 735	7	1 200 213		D	2	08	−·03 725	2 740		
	7A	195	05	+2 49	215	02	34		4 010	2	−·57 419	−·81 872	3 516 432	10	1 196 930	1	D	0	49	−·01 425	2 569		
	8	189	50	+3 08	230	08	25		3 849	0	−·76 762	−·64 091	3 513 462	12	1 194 450	2	D	0	12	−·00 349	2 529		
	9A	206	05	+2 43	239	58	36		5 099	3	−·86 582	−·50 035	3 509 047	15	1 191 899	3	D	0	03	−·00 087	2 515	1	
	10	172	43	+3 50	266	04	21		3 585	3	−·99 765	−·06 850	3 505 471	17	1 191 653		D	0	59	−·01 716	2 331	1	
	11A	184	39	+2 24	258	48	14		3 917	4	−·98 097	−·19 416	3 501 628	19	1 190 893	4	D	0	49	−·01 425	2 163	1	
Resected stn.	12	212	08	+3 02	263	27	40		4 105	6	−·99 350	−·11 388	3 497 55[illegible]		[illegible] 90 42[illegible]		D	0	41	−·01 193	2 015		
Haripur Jail. Bridge Tower	R M				295	35	45				−	−		549 / −19		425 / +4				−		+6 / −1	
					295	35	17				−	−								−			
					+ 0	00	28				−	−								−			
											−	−								−			
											−	−								−			

Note:—For machine working, see Supplement to T.H.B. Chapter VIII.

Set up by *Bearing reduced by* *Entries compared with Field Book by* *Date*

Co-ordinates and heights computed by *Co-ordinates and heights checked by* *Date*

G.B.—P.O.—J.S. 44—19-1-44—1,000.

INSTRUCTIONS

26 MACH.

1. Complete headings.

Computation of Latitude of intersection of selected grid northing on selected longitude.

2. Complete lines 1 to 5.

3. Set line 5 on S.L. and multiply by line 4. Record result to 3 decimal places in line 6. Clear S.L., M.R. and P.R.

4. Complete lines 7 to 15.

5. Set line 15 on S.L. and multiply by line 9. Put indicator to correct decimal point in P.R. Clear S.L. and M.R. and set figure in P.R. to 0·1 decimal on S.L., and clear P.R. and multiply by line 10. Put indicator to indicate the correct decimal point. Clear S.L. and M.R. Set line 13 on S.L. Shift P.R. so that unit figure in P.R. is under the unit figure of the number on S.L. If line 13 is negative, turn handle once forward and record the result in line 16 with negative sign. If line 13 is positive turn handle once backwards. P.R. shows complement. Record the number in line 16 with positive sign.

6. Now complete lines 17 to 23, computing line 20 on machine.

Computation of longitude of intersection of selected grid easting on selected latitude.

7. Complete lines 24 to 20.

8. Set line 25 on S.L. and multiply till figures of line 29 are reproduced in P.R., (i.e., divide line 29 by line 26 by 'build up' method) and record the figures in M.R. in line 30 to seven decimal places. Clear S.L., P.R. and M.R.

9. Complete lines 31 to 33.

10. Set line 33 on S.L. and divide line 32 by 'built-up' method, as in para 9 above. Record the figures in M.R. in line 34 with the same sign as line 29.

11. Complete the rest of the form according to the instructions given on it.

26 Mach

Survey of India

B SECTION No.1. Ind. Fd. Svy. COMPANY. DATE June 1940 Page.....

SHEET NO.

Machine Computation of $\frac{\text{Latitude}}{\text{Longitude}}$ *of intersection of selected grid* $\frac{\text{Northing}}{\text{Easting}}$ *on selected* $\frac{\text{Longitude}}{\text{Latitude}}$

Grid co-ordinates of True origin $\begin{cases} E_0 & 3\,000\,000 \\ N_0 & 1\,000\,000 \end{cases}$ Grid 11B $\begin{cases} \lambda_0 & 26\ 00 \\ L_0 & 90\ 00 \end{cases}$

Formulæ:—(1) $S_p = N_p - (R_0 - N_p) \tan C \tan \frac{C}{2}$. (2) $\text{Sin } C = E_p / (R_0 - S_p)$; $\Delta L = \frac{C}{\sin \lambda_0}$.

Everest SPHEROID ~~METRES~~ or YARDS

1	Selected long. $= L_p$	82 56 15			
2	Long. of origin $= L_0$	90 00 00	00	00	00
3	$\Delta L = L_p - L_0$	− 7 03 15			
4	ΔL in seconds	− 25395″	″	″	″
5	sin λ_0 (7 figures)	0·438 371 2	0·	0·	0·
6	(4) × (5) = C in seconds	11132·437″	″	″	″
7	C = convergence	3° 05′ 32·437	° ′ ·	° ′ ·	° ′ ·
8	$\frac{C}{2}$	1 32 46·218	·	·	·
9	tan C (7 figures)	0·054 0241	0·	0·	0·
10	tan $\frac{C}{2}$ (7 figures)	0·026 9923	0·	0·	0·
11	Selected northing $= N_s$	945000	0000	0000	0000
12	N_0	1000000	00	00	00
13	$N_p = N_s - N_0 = (11) - (12)$	− 55000	− 00	− 00	− 00
14	R_0	14 291 219·9	·	·	·
15	$R_0 - N_p = (14) - (13)$	14 346 219·9	·	·	·
16	S_p (from formula 1)	− 75 920·2	− ·	− ·	− ·
17	S near $S_p = S_s$(i) (enter λ_s for S_s in line 22)	− 76 632·5	−	− ·	− ·
18	$S_p - S_s = (16) - (17)$	+ 712·3	−	− ·	− ·
19	Δ for 1″ (ii)	33·610	·	·	·
20	(18) ÷ (19) = $\Delta\lambda''$ (iii)	+ 21·2″	− ″ ·	− ″ ·	− ″ ·
21	$\Delta\lambda$ (iii)	+ 0° 00′ 21·2	− 0° ′ ·	− 0° ′ ·	− 0° ′ ·
22	λ_s = Lat. corresponding to S_s	25 22 00	00	00	00
23	Sum = λ_c = Lat. of cutting point	25 22 21·2	·	·	·
24	Selected latitude = λ_p	25 22			
25	S_p (i) = S for λ_p	− 76 632·5	− ·	− ·	− ·
26	$R_0 - S_p = (14) - (25)$	14 367 852·4	·	·	·
27	Selected Easting $= E_s$	2 224000	0000	0000	0000
28	E_0	3 000 000	00	00	00
29	$E_p = E_s - E_0$	− 776 000	− 00	− 00	− 00
30	Sin C = (29) ÷ (26) (formula 2) (iv)	−0·054 0095	−0·	−0·	−0·
31	C = convergence (iv)	− 3° 05′ 45·6″	− ° ′ ·	− ′ ·	− ° ′ ·
32	C in seconds (iv)	− 11145·6	− ·	− ·	− ·
33	sin λ_0 (7 figures) from line (5)	0·438 371 2	0·	0·	0·
34	$\Delta L'' = (32) \div (33)$ (iv)	− 25425·0″	− ″ ·	− ″ ·	− ″ ·
35	ΔL (iv)	− 7° 03′ 45·0	− ° ′ ·	− ° ′ ·	− ° ′ ·
36	L_0 = Longitude of origin	90 00 00	00	00	00
37	Sum = L_c = Long. of cutting point	82 56 15·0	·	·	·

Notes:—For instructions for working on machine see T.H.B. Chap. VIII supplement.
(i) From 1 Grid: interpolate if necessary.
(ii) From 1 Grid or 30 Grid (difference for 1″ of $N_{1\pi}$).
(iii) Sign is $\pm$ as line (18) is $\pm$.
(iv) Sign is $\pm$ as line (29) is $\pm$.

Computed by *Date* *Checked by*

G.B.—P.O.—J.S. 444-J/26—29-8-44—800.

INSTRUCTIONS

27 MACH.

1. Complete headings. Complete lines 1 to 5.

2. Set line 5 on S.L. Multiply by line 4. Record in line 6 with proper sign and clear S.L., M.R. and P.R.

3. Complete lines 7 to 10.

4. Set E_0 (at bottom of form for the grid concerned) on S.L. Turn handle forwards once. Clear S.L. and MR. Set line 8 on S.L. and multiply by line 9 turning handle forwards if line 8 is $+^{ve}$ and backwards if negative. Clear M.R. only and multiply by N_0 (at bottom of form for the grid concerned) turning the handle forwards if line 8 is $+^{ve}$ and backwards if $-^{ve}$. Clear M.R. only, Multiply by line 10 turning the handle backwards if line 8 is $+^{ve}$ and forwards if $-^{ve}$. Record result in P.R. in line 11.

5. Complete lines 12 to 16.

6. Set line 15 on S.L. Turn handle forwards until line 16 for the first cutting grid line appears in P.R. Record figure in M.R. in the L.H. half column of line 17 with the same sign as line 16. Continue turning handle until line 16 for second cutting line appears in P.R. and again record figure in M.R. in R.H. half column of line 17 with proper sign.

7. Complete lines 18 to 20.

8. Set N_0 (at bottom of form for the grid concerned) on S.L. Turn handle forwards once. Clear S.L. and set line 14 on S.L. Turn handle once forward if line 14 is $+^{ve}$ and backward if $-^{ve}$. Clear S.L. and M.R. Set line 20 on S.L. Multiply by line 16 turning the handle forward if sign of the product of lines 16 and 20 is $+^{ve}$ and backward, if $-^{ve}$. Record figure in P.R. in line 21.

Paindakal **MAP** B **SECTION** Ind Fd Svy **COMPANY.** **DATE** Aug. 1940

Machine Computation of $\frac{\text{Easting}}{\text{Northing}}$ *of intersection of selected grid* $\frac{\text{Northing}}{\text{Easting}}$ *on selected* $\frac{\text{Longitude}}{\text{Latitude}}$.

Gam I $\begin{cases} \lambda_0 & 32^\circ\ 30' \\ L_0 & 68^\circ\ 00' \end{cases}$

SPHEROID EVEREST. ~~METRES~~ or YARDS

MERIDIANS OF LONGITUDE Formula (a):—$E_c = E_0 + R_0 \tan C + N_0 \tan C - N_c \tan C$, where E_c is the easting at which the meridian of L_c meets the grid line of northing N_c.

1	Cutting meridian of longitude $= L_c$	70°	43′	00″		70°	53′	00″	
2	Longitude of origin $= L_0$	68	00	00		68	00	00	
3	$\Delta L = L_c - L_0$	+ 2	43	00		+ 2	53	00	
4	ΔL in seconds	+ 9780″				+ 10 380″			
5	Sin λ_0	0 53 729 961				0 53 729 961			
6	$C'' = \Delta L \sin \lambda_0 =$ lines (4) × (5) (8 Significant figures)	+ 5 254 · 7902″				+ 5 577 · 1700″			
7	C = Convergence	+ 1°	27′	34 · 7902″		+ 1°	32′	57 · 1700″	
8	Tan C (8 places)	+ 0 02 548 146				+ 0 02 704 547			
9	R_0	10 944 682 · 4				10 944 682 · 4			
10	N_c	1106 000		1092 000		1106 000		1092 000	
11	E_c [formula (a)] (1)	3276 185 ·		3276 542 ·		3293 137 ·		3293 516 ·	

PARALLELS OF LATITUDE Formula (b):—Sin $C = E'_c/(R_0 - S)$. Formula (c):—$N_c = N_0 + S + E'_c \tan \frac{C}{2}$, where N_c is the northing at which the parallel of λ_c meets the grid line of easting E_c.

12	Cutting parallel of latitude $= \lambda_c$	33°	14′	00″		33°	20′	00″	
13	R_0	10 944 682 · 4				10 944 682 · 4			
14	S for λ_c (from 1 Grid)	+ 88 817 · 4				+ 100 941 · 8			
15	$R_0 - S =$ lines (13) − (14)	10 855 855 · 0				10 843 740 · 6			
16	$E_c - E_0 = E'_c$	+ 275 000		+ 295 000		+ 275 000		+ 295 000	
17	Sin C (7 places) [formula (b)] (1)	+ 0 · 0 253 320		+ 0 · 0 271 743		+ 0 · 0 253 603		+ 0 · 0 272 046	
18	C = Convergence	+ 1°	27′	05 · 65″	+ 1°	33′	25 · 79″	+ 1°	27′	11 · 49″	+ 1°	33′	32 · 04″
19	$\frac{1}{2} C$	+ 0	43′	32 · 82″	+ 0	46′	42 · 90″	+ 0	43′	35 · 75″	+ 0	46′	46 · 02″
20	Tan $\frac{1}{2} C$ (7 places)	+ 0 · 0126 680		+ 0 · 0 135 897		+ 0 · 0126 822		+ 0 · 0 136 048	
21	N_c [formula (c)] (1)	1092 311 ·		1092 836 ·		1104 429 ·		1104 955 ·	

Grid	B	C (Clarke)	O	I	IIA	IIB	IIC	IIIA	IIIB	IVA	IVB
L_0	45°	45°	68°	68°	74°	90°	110°	80°	100°	80°	104°
λ_0	32° 30′	39° 30′	39° 30′	32° 30′	26° 00′			19° 00′		12° 00′	
sin λ_0	0·53729961	0·63607823	0·63607823	0·53729961	0·43837115			0·32556815		0·20791169	
E_0	1,500,000	2,155,500	2,355,500	3,000,000	3,000,000			3,000,000		3,000,000	
N_0	1,166,200	675,000	2,590,000	1,000,000	1,000,000			1,000,000		1,000,000	
R_0 { Clarke	10,009,530·2	7,736,166·1	...	...	...			...		...	
R_0 { Everest	10,007,808·8	7,734,779·9	8,458,685·5	10,944,682·4	14,291,219·9			20,237,408·1		32,776,434·5	

NOTE:—(1) For instructions for working on machine see T. H. B. Chapter VIII Supplement.

Computed by *Date* *Checked by* *Date*

G.B.—P.O.—J.S. 358-J/27—1-8-44—600.

INSTRUCTIONS

28 MACH.

1. Complete headings.

2. Complete lines 1 to 23. Lines 12 to 17 (which is the same as 32 Mach.) should be used only if L.M.T. or standard time is observed. Otherwise, (i.e.), if sidereal time (S.T.) is observed, CORRECTED L.S.T. of observation should be entered in line 18 leaving lines 12 to 17 blank.

3. Set line 23 on S.L. and multiply by line 22 for the first deduction. Record figure appearing in P.R. in line 24 with proper sign. Continue multiplication till line 22 of the next deduction appears in M.R. Record figure in P.R. in the appropriate column of line 24. Continue likewise for all deductions.

4. Complete the remainder of the form.

28 Mach. **Survey of India** Page.....

B **SECTION** 1 Ind. Fd. Svy **COMPANY.** **DATE** August 1940.

Machine computation of latitude from Polaris, time and altitude being observed

Grid I λ_0 32 30 / L_0 68 00

Observer D. R. Crone Instrument C. T. S. no. 1000 Formulæ:— $a = \Delta \cos t$ $\lambda = h' - a + \beta$.

1	Deduction Number	1			2			3			4		
2	Station of observation	←			Ishpushta			Astro			→		
3	Longitude of station	68	05	14	68	05	14	68	05	14	68	05	14
4	Hour and date of observation	22	1 d	4 m 1940	22	1 d	4 m 1940	22	1 d	4 m 194	22	1 d	4 m 1940
5	Observed altitude = h	34	33	37	34	32	48	34	32	28	34	31	45
6	Refraction (42 A Sur)	0	01	20	0	01	20	0	01	20	0	01	20
7	Correction for Temperature..35.°F.	+ 0	00	07	+ 0	00	07	+ 0	00	07	+ 0	00	07
8	Correction for Barometer.29.5 inches	− 0	00	12	− 0	00	12	− 0	00	12	− 0	00	12
9	Sum = Total refraction = r	0	01	15	0	01	15	0	01	15	0	01	15
10	Corrected altitude = $h - r = h'$	34	32	22	34	31	33	34	31	13	34	30	30
11	N.P.D. = 90° − Declination = Δ	1	01	09	1	01	09	1	01	09	1	01	09
12	Corrected time of observation (i) (L.M.T ~~or standard time~~)	22 h	19 m	47 s	22 h	24 m	42 s	22 h	27 m	37 s	22 h	31 m	32 s
13	Longitude in time (ii)	4	32	21	4	32	21	4	32	21	4	32	21
14	Line (12) − line (13)	+ 17	47	26	+ 17	52	21	+ 17	55	16	+ 17	59	11
15	"R" or S.T. for G.M.M. (from N.A.)	12	36	48	12	36	48	12	36	48	12	36	48
16	A for line (14) with same sign (from 22 Sur)	+ 0	02	55	+ 0	02	56	+ 0	02	57	+ 0	02	57
17	Longitude of station in time (34 Sur)	4	32	21	4	32	21	4	32	21	4	32	21
18	Sum = L.S.T. (i) of observation (iii)	10	59	30	11	04	26	11	07	22	11	11	17
19	R.A. of Polaris from N.A.	1	42	07	1	42	07	1	42	07	1	42	07
20	Line (18) − line (19) = hour angle t	9	17	23	9	22	19	9	25	15	9	29	10
21	t in arc (45 Sur)	139°	20′	45″	140°	34′	45″	141°	18′	45″	142°	17′	30″
22	cos t (iv)	−0·75865			−0·77250			−0·78057			−0·79114		
23	Δ in seconds [from line (11)]	3669″			3669″			3669″			3669″		
24	$\Delta \cos t = a$ in seconds	− 2784			− 2834			− 2864			− 2903		
25	*Minus* a	+ 0°	46′	24″	+ 0°	47′	14″	+ 0°	47′	44″	+ 0°	48′	23″
26	β (28 Sur)	0	0	10	0	0	09	0	0	09	0	0	08
27	Corrected altitude h' [line (10)]	34	32	22	34	31	33	34	31	13	34	30	30
28	Sum = λ = Latitude	35	18	56	35	18	56	35	19	06	35	19	01
29	Mean	←			35	19	00						→

(i) With M.T. Chronometer, enter time in line (12).
With Sid. T. Chronometer, omit lines (12)–(17) and enter time in line (18).

(ii) Longitude of $\frac{\text{local}}{\text{standard}}$ meridian according as time in line (12) is $\frac{\text{local mean}}{\text{standard}}$ time.

(iii) Increase by 24 hrs. if less than R.A. of Polaris.

(iv) Sign of cos t is − ve if t lies between 90° and 270°; otherwise + ve

Computed by *Date* *Checked by* *Date*

G.B.—P.O.—J.S. 505—26-11-42—1,000.

INSTRUCTIONS

29 MACH.

1. Complete headings, etc., on front of form. Complete lines 1 to 4 on this side.

2. If the sun is observed, complete lines 5 to 7, otherwise omit. Complete columns 8 to 12. Enter in the instructions column in line 9, the instant for which the error of the chronometer is recorded. Enter the error at this instant in the working column of the same line. If this instant is before time obtained in line 10 and the clock has a gaining/losing rate, the sign of line 11 is $+^{ve}/-^{ve}$. If this instant is after time obtained in line 10 and the clock has a losing/gaining rate, the sign of line 11 is $+^{ve}/-^{ve}$.

3. In line 13, enter the observed altitude of the star/sun, when it is closest to the meridian, i.e., the maximum/minimum observed altitude if star or sun is $\frac{\text{south or between Pole and Zenith}}{\text{between Pole and North horizon}}$ for north latitudes and $\frac{\text{north or between Pole and Zenith}}{\text{between Pole and south horizon}}$ for south latitudes.

4. Complete lines 14 to 17. Record rate of change of refraction per degree change of altitude in line 18. Complete line 19 if sun is observed.

5. Complete lines 20 and 21 and also line 22 using footnote (v) to get the approximate latitude λ_d. Complete lines 23 to 25 to 6 decimals.

6. Complete lines 26 and 27 as follows :—

Set line 23 on S.L. Turn handle forwards until line 24 appears in P.R. Record figure in M.R. in line 26. Clear S.L., M.R. and P.R. Set line 25 on S.L. and multiply by line 26 turning handle forwards and record the produots in line 27.

7. Complete line 28. Clear S.L., M.R. and P.R. Set 2·424 on S.L. and multiply by line 28 and record product in line 29.

8. Now turn to back of form and complete lines 1 to 8 for all observations each face separately deleting upper or lower whichever is not applicable in line 1. Clear S.L., P.R. and M.R. Set line 27 (factor A) from front side of form on S.L. and multiply by line 7 (*m*) in seconds on back of form for each deduction of the same object. Record products in line 9 with signs as in footnote (ii).

9. Enter collimation corrections for instrument (found from previous observations) in line 10. Complete lines 11 and 12.

10. Complete line 13 as follows :—

Set line 9 on S.L. and multiply by itself. Transfer figure in P.R. on S.L. and multiply by line 20 (from front side of form) for each deduction from the same object in turn. Record products in line 13, with proper decimal places (divide these quantities by 10^8) and signs according to footnote (v).

11. Complete lines 14 and 15. If the value of any particular face (say F.L.) is not consistent with other values obtained in line 14, it may be rejected and half weight may be given to it. Otherwise both the values of the same face (R. or L.) are to be rejected. If, however, the mean of both faces are considered (as in specimen example for sun) and any particular observation leads to inconsistent results, it is to be rejected altogether.

Enter result from line 15, in line 30 on front side of the form (mentally adding correction for parallax from line 19 in the case of the sun.)

12. Complete line 31 putting N. or S. before the result according as it is positive or negative.

29 Mach. **Survey of India** Page.....

B **SECTION** No. 1 Ind. Fd Svy. **COMPANY.** **DATE** April 1940

Machine Computation of Latitude by Circum-meridional altitudes λ_0 32° 30′

Survey Afghanistan Observer × Chronometer ~~M.T.~~/S.T. No. 86 Grid I L_0 68 00

Clock rate +7·44 per hour Instrument C.T.S No. 37008

Formulæ:—$\lambda = \pm 90^\circ \pm \delta \pm h_m$ (iv) $A = \frac{\cos\delta \cos\lambda_a}{\cos h}$ $B = 2{\cdot}424 \tan h$

1	Station of observation		Ishpushta Astro									
2	Star or Sun N. or S.		γ Ursæ Majoris N									
3	Hour and date of observation		23	1d	4m 1940	h	d	m 194	h	d	m 194	
4	Longitude in time = l (34 Sur.)		4	m 32	s 20·9	h	m	s	h	m	s	
5	For Stars	For Sun "E"(i) for G.M.T. 0 hrs.										
6		24 hrs. − "E" − l										
7		"E"(i) for time in line 6	−			−			−			
8	R.A. of Star	$24^h\ 00^m\ 00^s$	11	50	43·5							
9	Chrono. error at 23.h.10.m.02 s (chrono. time) on L.S.T.	on ~~L.M.T.~~	+ 11	17	39·9	−			−			
10	Sum		23	08	23·4							
11	Correction for clock rate (ii)		+ 0	00	00·2	−			−			
12	Sun = Chrono. time of transit		23	08	23·6							
13	Observed altitude when nearest meridian		71°	17′	53″	°	′	″	°	′	″	
14	Refraction (42 A Sur.)		0	00	19·8	0			0			
15	Correction for Temperature... 33 °F		+ 0	00	00·8	− 0			− 0			
16	Correction for Barometer 25.5 inches		− 0	00	03·2	− 0			− 0			
17	Sum = Total Refraction		0	00	17·4	0			0			
18	Change in refraction per 1° altitude		0	0	01·2	0	0		0	0		
19	Parallax (21 Sur.) for Sun only		0	0		0	0		0	0		
20	Corrected altitude = h = line 13 − line 17 (+ line 19 for Sun)		71	17	36							
21	Declination = δ North +ve South −ve		+ 54	01	34	−			−			
22	$\lambda_a = \pm 90^\circ \pm \delta \pm h$ (v)		35	19	10							
23	$\cos h$		0·320 723			0·			0·			
24	$\cos \delta$		0·587 414			0·			0·			
25	$\cos \lambda_a$		0·815 941			0·			0·			
26	$\frac{\cos\delta}{\cos h}$		1·831 537			·			·			
27	$\frac{\cos\delta}{\cos h} \times \cos\lambda_a$ = Factor A (iii)		1·494 426			·			·			
28	$\tan h$		2·953 241			·			·			
29	$2{\cdot}424 \tan h$ = Factor B (iii)		7·158 656			·			·			
30	Mean meridional altitude = h_m (iv) (from reverse)		71°	17′	36″	°	′	″	°	′	″	
31	Latitude = $\lambda = \pm 90^\circ \pm \delta \pm h_m$ (v)		35	19	04							

Notes: (i) From Abridged N.A. If using complete N.A., "E" is 12 hrs. + Eqn. of time; this is always *minus* in line 7.
(ii) For interval between instant given in line 9 and time in line 10.
(iii) See formula at head of form. See Supplement to T.H.B. Chapters VIII and XII for machine working.
(iv) Add line 19 for Sun.
(v) If Star or Sun is South $\lambda_a = 90^\circ + \delta - h$ and $\lambda = 90^\circ + \delta - h_m$. If Star or Sun is North at $\frac{\text{Upper Transit}}{\text{Lower Transit}}$

$$\lambda_a = \frac{h + \delta - 90^\circ}{90^\circ + h - \delta} \text{ and } \lambda = \frac{h_m + \delta - 90^\circ}{90^\circ + h_m - \delta}.$$

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29 Mach.—(*Contd.*)

Formula :—$h_m = h + Am - B\,(Am)^2 \times 10^{-6}$

		FL			FR			FR			FL			FL			FR			FR			FL		
1	Star or Sun observed $\frac{\text{upper}}{\text{lower}}$ transit	←									γ Ursæ Majoris North												→		
2	Chrono. time of Transit (from line 12 of reverse)	h 23	m 08	s 23·6	h 23	m 08	s 23·6	h 23	m 08	s 23·6	h 23	m 08	s 23·6	h 23	m 08	s 23·6	h 23	m 08	s 23·6	h 23	m 08	s 23·6	h 23	m 08	s 23·6
3	Chrono. time of observation	22	53	33·8	22	58	46·5	23	01	43·6	23	04	06·1	23	09	06·1	23	13	54·7	23	16	30·6	23	21	16·1
4	Difference = chrono. interval	+ 0	14	49·8	+ 0	09	37·1	+ 0	06	40·0	+ 0	02	17·5	+ 0	00	42·5	+ 0	05	31·1	+ 0	08	07·0	+ 0	12	46·5
5	Clock rate correction for line 4 (i)	+ 0	00	02·4	+ 0	00	01·4	+ 0	00	01·1	+ 0	00	00·4	+ 0	00	00·1	+ 0	00	00·9	+ 0	00	01·3	+ 0	00	02·1
6	Sum = hour angle = t	0	14	52·2	0	09	38·7	0	06	41·1	0	02	17·9	0	00	42·6	0	05	32·0	0	08	08·3	0	12	48·6
7	m for line 6 (24 Sur.)	0	07	14	0	03	03	0	01	28	0	00	10	0	00	01	0	01	00	0	02	10	0	05	22
8	Observed altitude	° 71	′ 07	″ 04	° 71	′ 13	″ 13	° 71	′ 15	″ 36	° 71	′ 17	″ 32	° 71	′ 17	″ 56	° 71	′ 16	″ 18	° 71	′ 14	″ 28	° 71	′ 09	″ 37
9	1st correction = m × Factor A (ii)	+ 0	10	49	+ 0	04	33	+ 0	02	12	+ 0	00	15	+ 0	00	01	+ 0	01	30	+ 0	03	14	+ 0	08	01
10	Collimation correction	− 0	00	03	+ 0	00	03	+ 0	00	03	− 0	00	03	− 0	00	03	+ 0	00	03	+ 0	00	03	− 0	00	03
11	Refraction correction (iii)	− 0	00	17	− 0	00	17	− 0	00	17	− 0	00	17	− 0	00	17	− 0	00	17	− 0	00	17	− 0	00	17
12	Change in refraction (iv)	− 0	0	00	− 0	0	00	− 0	0	00	− 0	0	00	− 0	0	00	− 0	0	00	− 0	0	00	− 0	0	00
13	2nd correction = (line 9)$^2 \times 10^{-6}$ × Factor B (v)	− 0	0	03	− 0	0	01	− 0	0	00	− 0	0	00	− 0	0	00	− 0	0	00	− 0	0	00	− 0	00	02
14	Sum = Meridional altitude	71	17	30	71	17	31	71	17	34	71	17	27	71	17	37	71	17	34	71	17	28	71	17	16
15	Mean Meridional altitude	←									71	17	30										→		

NOTES:—(i) Rate on sidereal time for Star or on mean time for Sun.

(ii) Factor A from reverse. Sign is $\pm$ at $\frac{\text{upper}}{\text{lower}}$ transit.

(iii) Line 17 from reverse, with *minus* sign.

(iv) From line 18 from reverse, for line 9 : sign is $\pm$ if altitude (line 8) is $\frac{\text{increasing}}{\text{decreasing}}$

(v) See Supplement to T.H.B. Chapters VIII and XII for machine working. 2·424 tan h (= Factor B) from reverse. Sign is opposite to that of line 9

Computed by *Date* *Checked by* *Date*

G.B.—P.O.—J.S. 619—22-12-44—4.

INSTRUCTIONS

30 MACH.

1. Complete headings, etc. Complete lines 1 to 11.

2. Enter instant at which chronometer error on L.S.T. (for star) and L.M.T. (for sun) was last determined in the instructions column of line 12. Enter the error at this instant in the working column of the same line with opposite sign.

3. Enter the correction for clock rate between instant noted in the instructions column of line 12 and the time of observation in line 11. If the instant noted was before time of observation and the clock has a losing/gaining rate, the sign of line 13 is $+^{ve}/-^{ve}$. If this instant was after the time of observation and the clock has a losing/gaining rate, sign of line 13 is $-^{ve}/+^{ve}$.

4. Complete lines 14 to 22, entering 6 decimals in lines 19 to 22.

5. Set line 19 on S.L. Multiply by line 20 turning the handle forwards. Record result in P.R. in line 23 with correct sign.

6. Complete lines 24 and 25, entering sign of line 24 as that of line 23. Set line 25 on S.L. and multiply by line 22 turning handle forwards. Record result in P.R. in line 26.

7. Clear S.L. and M.R. Set line 21 on S.L. and divide. Enter figure in M.R. in line 27.

8. Complete lines 28 to 30.

30 Mach

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B SECTION No 1 Ind. Fd Svy COMPANY. DATE April 1940

Machine computation of Latitude from ex-meridional altitudes Grid 1 λ_0 32 30 / L_0 66 00

Observer *D R Crone.* Instrument C. T. S No. 1000 Chronometer S. T. No. 86

Formulæ:—(1) $\cot \phi = \cot \delta \cos t$. (2) $\cos \phi' = \frac{\sin \phi \sin h}{\sin \delta}$ (3) Latitude $= \phi \pm \phi'$.

Clock rate −10^s per hour

1	Station of observation	Ishpushta Astro															
2	Observation on $\frac{\text{Star}}{\text{Sun}}$	γ Ursæ Majoris															
3	Hour & date of Observation	h 22	m 41	s 4	1940	h	m	s	194	h	m	s	194	h	m	s	194
4	Observed altitude	° 70	′ 42	″ 06		°	′	″		°	′	″		°	′	″	
5	Refraction (42 A Sur)	0	00	19		0				0				0			
6	Correction for Temperature...33.°F	+ 0	00	02		− 0				− 0				− 0			
7	Correction for Barometer 25.5 inches	− 0	00	03		− 0				− 0				− 0			
8	Sum = Total Refraction	0	00	18		0				0				0			
9	Parallax (21 Sur) for Sun only	0	0			0	0			0	0			0	0		
10	Corrected altitude = h = line 4 − line 8 (+ line (9) for Sun)	70	41	48													
11	Chrono. time of observation	h 22	m 41	s 14·3		h	m	s		h	m	s		h	m	s	
12	Minus error at 23 h 19 m	− 11	17	39·86		−				−				−			
13	Corrn. for clock rate (i)	− 0	00	047		−				−				−			
14	Sum = time of observation	11	23	29·74													
15	R.A. of Star or L.M.T. of transit (ii) for Sun	11	50	43·47													
16	Line (14) − line (15) = hour angle t	− h 0	m 27	s 13·73		−				−				−			
17	t in arc (45 Sur)	− ° 6	′ 48	″ 26		−				−				−			
18	Declination (iii) $= \delta$ $\frac{+ \text{ North}}{- \text{ South}}$	+ 54	01	34		−				−				−			
19	cot δ	± ·725	846			− ·				− ·				− ·			
20	cos t	±0·992	950			−0·				−0·				−0·			
21	sin δ	+0·809	285			−0·				−0·				−0·			
22	sin h	0·943	782			0·				0·				0·			
23	cot ϕ = cot δ × cos t	± ·720	729			− ·				− ·				− ·			
24	ϕ (between 0 and 180°)	+ ° 54	′ 13	″ 07		−				−				−			
25	sin ϕ	0·811	254			0·				0·				0·			
26	sin ϕ × sin h	0·765	647			0·				0·				0·			
27	Line 26 ÷ sin δ = cos ϕ'	0·946	078			0·				0·				0·			
28	ϕ' (between 0 and 90°)	° 18	′ 54	″ 05		°	′	″		°	′	″		°	′	″	
29	$\phi \pm$ (iv) $\phi' =$ Latitude	35	19	02N													
30	Mean Latitude																

Notes:—(i) For interval between instant given in line (12) and time in line (11). If a mean time chronometer is used for star observations, consider it as an S.T. chronometer losing 0·164275 seconds per clock minute.
(ii) L.M.T. of transit of Sun = 24 hrs. − E hrs. from Abridged N.A., or 12 hrs. − Eqn. of time, with sign there given from complete N.A.
(iii) For G.M.T. corresponding to time in line (14).
(iv) Decide whether sign is + or − by inspection, knowing approximate latitude.

Computed by *Date* *Checked by* *Date*

G.B.—P.O.—J.S. 389—17·9·42—500.

31 MACH

1. Complete headings, etc.

Complete lines 1 to 20 as instructed on form, filling in correct signs. Enter values to 6 decimals, in lines 15 to 22. If no secant tables are available, set line 18 on S.L. and turn handle forwards till P.R. reads 1·000,000. Then line 19 appears in M.R. Clear S.L., M.R. and P.R.

Set line 17 on S.L. and turn handle forwards until P.R. reads line 19. Record figure in M.R. in line 21. Clear S.L., M.R. and P.R.

2. Complete line 22 as follows : --

Set line 15 on S.L. Multiply by line 16 turning handle backwards/forwards if signs of lines 15 and 16 are the same/opposite. Clear M.R. and S.L. Set line 21 on S.L. and multiply by line 20 turning handle forwards. Record result in line 22 with $+^{ve}/-^{ve}$ sign if result in P.R. is direct/complement.

3. Complete lines 23 to 28 as instructed on form. Use L.H./R.H. half column in the lines 25 and 26 (instructions) if star/sun is observed. In lines 29 and 30 against $\ldots\ldots^{h}\ldots\ldots^{m}$ fill in hour and minute at which the error of chronometer is required. In line 29, fill in the amount of time the chronometer has gained or lost between this time and the instant of each deduction using the known values of the rate of chronometer. If this instant at which the chronometer error is required is after the chronometer time of observation and the chronometer has a losing/gaining rate on sidereal time, the sign of line 29 is $-^{ve}/+^{ve}$. If this instant is before the time of observation and the chronometer has a losing/gaining rate on sidereal time the sign of line 29 is $+^{ve}/-^{ve}$.

Enter mean error of chronometer in line 31.

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B SECTION No 1. Ind. Fd. Svy. COMPANY. DATE April, 1940

Machine Computation of Time by East and West Stars or by Sun

Ref: Forms Pages Observer D. R. Crone Chronometer S.T. No. 86

Formula:—$\text{Cos } t = -\tan\lambda \tan\delta + \frac{\sec\lambda}{\cos\delta} \sin h.$ Instrument C.T.S. No. 1000

Clock rate -9·6 per hour

1	Deduction No.	1						2						3				4				5			
2	Station	←												Ishpushta Astro								→			
3	Longitude	° 68	′ 05	″ 14				°	′	″				°	′	″		°	′	″		°	′	″	
4	Hour & date of observation	h 21	d 1	m 4				h	d	m				h	d	m		h	d	m		h	d	m	
			194 0						194						194				194				194		
5	Star or Sun: E. or W.	γ Geminorum W																							
6	Observed altitude	° 49	′ 15	″ 18				° 48	′ 35	″ 12				° 47	′ 11	″ 25		° 46	′ 32	″ 36		° 45	′ 54	″ 44	
7	Refraction (42 A Sur)	0	00	48				0	00	49				0	00	52		0	00	53		0	00	54	
8	Correction for Temperature 36...°F	+ 0	00	04				+ 0	00	04				+ 0	00	04		+ 0	00	04		+ 0	00	05	
9	Correction for Barometer 25·5 inches	— 0	00	07				— 0	00	07				— 0	00	08		— 0	00	08		— 0	00	08	
10	Sum = Total Refraction	0	00	45				0	00	46				0	00	48		0	00	49		0	00	51	
11	Parallax (21 Sur) for Sun only																								
12	Corrected altitude = h = line 6 − line 10 (+ line 11 for Sun)	49	14	33				48	34	24				47	10	37		46	31	47		45	53	53	
13	Declination = $\delta^{(i)}$ North +ve / South −ve	+ 16	26	56				—						—				—				—			
14	Latitude = λ North +ve / South −ve	+ 35	19	00				—						—				—				—			
15	tan λ	+ ·708 476						— ·						— ·				— ·				— ·			
16	tan δ	+ ·295 243						— ·						— ·				— ·				— ·			
17	cos δ	0·959 073						0·						0·				0·				0·			
18	cos λ	0·815 970						0·						0·				0·				0·			
19	sec λ	1·225 536						·						·				·				·			
20	sin h	0·757 480						·749 810						·733 456				·725 731				·718 103			
21	sec λ/cos δ	1·277 834						·						·				·				·			
22	cos $t^{(ii)}$	+ 0·758 762						+ 0·748 960						+ 0·728 062				+ 0·718 191				+ 0·708 446			
23	t in arc (less than 180°)	° 40	′ 38	″ 41				° 41	′ 29	″ 59				° 43	′ 16	″ 33		° 44	′ 05	″ 41		° 44	′ 53	″ 30	
24	t in time (34 Sur.)$^{(iii)}$	h + 2	m 42	s 34·7				h + 2	m 45	s 59·9				h + 2	m 53	s 04·2		h + 2	m 56	s 22·7		h + 2	m 59	s 34·0	
25	R. A. of star $E^{(iv)}$ for Sun$^{(i)}$	6	34	15·9				6	34	15·9				6	34	15·9		6	34	15·9		6	34	15·9	
26	Sum = LST of obs. / line 24 − line 25 = LMT of obs.	9	16	50·6				9	20	15·8				9	27	22·1		9	30	38·6		9	33	49·9	
27	Chronometer time	20	34	55·0				20	38	21·3				20	45	25·3		20	48	41·8		20	51	52·4	
28	line 27 − line 26 = error on LST (or on LMT for Sun)	+ 11	18	04·4				+ 11	18	05·5				+ 11	18	03·2		+ 11	18	03·2		+ 11	18	02·5	
29	Rate to $^{h}_{20}$ $^{m}_{40}$ on LST (Star) / LMT (Sun) $^{(v)}$	—		00·8				—		00·3				+		00·9		+		01·4		+		01·9	
30	Sum = error at	+ 11	18	03·6				+ 11	18	05·2				+ 11	18	04·1		+ 11	18	04·6		+ 11	18	04·4	
31	Mean error at	—	←	·				—						+ 11	18	04·4		—				—	→	·	

Notes:—(i) For G.M.T. corresponding to line 4 (time in line 4 *minus* longitude in time of standard meridian).

(ii) From formula above. See T.H.B. Chapter VIII Supplement for machine working.

(iii) t is $\frac{-}{+}$ as object is $\frac{E}{W}$ of meridian.

(iv) From Abridged N.A., or 12 hrs. + Equation of time, from Standard N.A.

(v) Enter chronometer instant to which all times are reduced. Mean time chronometer may be considered as a sidereal time chronometer with a losing rate of 0·164275 sec's. per clock minute.

Computed by *Date* *Compared by* *Date*

G.B.—P.O.—J.S. 421—29-9-42—1,000.

INSTRUCTIONS

32 MACH.

NOTE.—This form should be used to convert any variety of known time to the variety which is required for computation of any other form.

Complete headings.

MEAN TIME TO SIDEREAL TIME, ETC.

Complete lines 1 to 4.

Enter in the appropriate line the time that is given and which has to be converted, i.e., if Local Standard or Mean Time is given enter it in line 5. In the specimen, Standard time is given in the first two deductions while Local Mean in the rest. If G.M.T. is given, enter it in line 7. Next complete the form until required time is obtained.

SIDEREAL TIME TO MEAN TIME, ETC.

Complete lines 13 to 16.

Complete in manner similar to that given above, i.e., enter the time which is given and which has to be converted in the appropriate line and complete the form until required time is obtained.

B SECTION No 1 Ind Fd.Svy. COMPANY. DATE 1940

Conversion of Mean time to Sidereal time

For conversion of Standard Time or L.M.T. to G.M.T., G.M.T. to G.S.T. and G.S.T. to L.S.T.

1	Station		No. 2 Risalpur Bungalow				No. 2 Risalpur Bungalow				Ispushta Astro				No. 2 Risalpur Bungalow			
2	Date		26 . 7 . 40				26 . 7 . 40				1 . 4 . 40				26 . 7 . 40			
3	Ref. Forms :—Pages :—										28 Mach Page 1							
4	Longitude of station in arc		71°	59′	50″		71°	59′	50″		68°	05′	14″		71°	59′	50″	
5	Standard time	L.M.T.	S.T. 16h	20m	30s		S.T. 4h	40m	50s		L.M.T. 22h	19m	47s		L.M.T. 3h	58m	49s	
6	Standard longitude in time	Longitude of station in time (34 Sur)	Standard Long. 5h	30m	00s		Standard Long. 5h	30m	00s		4h	32m	21s		4h	47m	59s	
7	Line (5) − line (6) = Interval from G.M.M. (for G.M.T.) (i)		+ 10h	50m	30s		− 0h	49m	10s		+ 17h	47m	26s		− 0h	49m	10s	
8	"*R*" or S.T. at G.M.M. from N.A.		20h	14m	09s		20h	14m	09s		12h	36m	48s		20h	14m	09s	
9	A for line (7) (22 Sur)		+ 0h	01m	47s		− 0h	00m	08s		+ 0h	02m	55s		− 0h	00m	08s	
10	Sum = G.S.T.		7h	06m	26s		19h	24m	51s		6h	27m	09s		19h	24m	51s	
11	Longitude of station in time (34 Sur)		4h	47m	59s		4h	47m	59s		4h	32m	21s		4h	47m	59s	
12	Sum = L.S.T.		11h	54m	25s		0h	12m	50s		10h	59m	30s		0h	12m	50s	

Conversion of Sidereal time to Mean time

For conversion of L.S.T. to G.S.T., G.S.T. to G.M.T., and G.M.T. to Standard Time or L.M.T.

13	Station		No. 2 Risalpur Bungalow				No. 2 Risalpur Bungalow				Ispushta Astro				No. 2 Risalpur Bungalow			
14	Date		26 7 40				26 . 7 . 40				1 . 4 . 40				26 . 7 . 40			
15	Ref. Forms :—Pages :—										28 Mach Page 1							
16	Longitude of station in arc		71°	59′	50″		71°	59′	50″		68°	05′	14″		71°	59′	50″	
17	L.S.T.		11h	54m	25s		0h	12m	50s		10h	59m	30s		0h	12m	50s	
18	Longitude of station in time (34 Sur)		4h	47m	59s		4h	47m	59s		4h	32m	21s		4h	47m	59s	
19	Line (17) − line (18) = G.S.T. (ii)		7h	06m	26s		19h	24m	51s		6h	27m	09s		19h	24m	51s	
20	"*R*" or S.T. at G.M.M. from N.A. (iii)		20h	14m	09s		20h	14m	09s		12h	36m	48s		20h	14m	09s	
21	Line (19) − line (20) (ii)		+ 10h	52m	17s		− 0h	49m	18s		+ 17h	50m	21s		− 0h	49m	18s	
22	R for line (21) (23 Sur)		+ 0h	01m	47s		− 0h	00m	08s		+ 0h	02m	55s		− 0h	00m	08s	
23	Line (21) − line (22) = G.M.T.		+ 10h	50m	30s		− 0h	49m	10s		+ 17h	47m	26s		− 0h	49m	10s	
24	Standard longitude in time	Longitude of station in time	5h	30m	00s		5h	30m	00s		4h	32m	21s		4h	47m	59s	
25	Line (23) + line (24) = Standard time	Line (23) + line (24) = L.M.T.	Standard Time 16h	20m	30s		Standard Time 4h	40m	50s		L.M.T. 22h	19m	47s		L.M.T. 3h	58m	49s	

Notes :—(i) If − ve, add 24 hrs. and take "*R*." or S.T. (line 8) for previous date.
(ii) If − ve, add 24 hrs.
(iii) Take "*R*" or S.T. for $\frac{\text{same}}{\text{previous}}$ date as (L.S.T. − "*R*" or S.T.) is $\frac{\text{greater}}{\text{less}}$ than Longitude (line 18)

Computed by *Date* *Checked by* *Date*

G.B.—P.O—J.S 38—19-1-44—500.

33 MACH.

1. Complete headings, etc., and complete lines 1 to 3.

2. Complete lines 4 and 5 observing the rule at footnote (ii). Complete lines 6 to 8 entering in line 8, the names of the first pair of stations from whose intersecting rays the co-ordinates of P are to be computed. For the purpose of the formulæ given and the following instructions, these two stations are considered as K_1 and K_2 with co-ordinates E_{K_1} & N_{K_1} and E_{K_2} & N_{K_2} respectively and with intersecting rays at bearings of β_1 and β_2 respectively.

3. (*a*) Connect machines in parallel. Set line 6 (E_{K_1}) on L.H.S.L. and (E_{K_2}) on R.H. S.L. Turn handle forwards once. Clear S.L. and M.R. Set line 4 (tan β_1) on L.H. S.L. and multiply by line 7 (N_{K_1}) turning the handle backwards/forwards if line 4 (tan β_1) is $+^{ve}/-^{ve}$. Clear both M.R's. only. Disconnect the machines and set line 4 (tan β_2) on R.H. S.L. and multiply by line 7 (N_{K_2}) turning the handle backwards/forwards if line 4 (tan β_2) is $+^{ve}/-^{ve}$. Clear M.R. only. Connect machines in Parallel/opposite if line 4 (tan β_1 and tan β_2) have the same/opposite signs. See whether R.H. P.R. or L.H. P.R. contains the greater number. Equalize both P.R's turning the handle forwards/backwards if line 4 (tan β_2) is $+^{ve}/-^{ve}$.

(*b*) While equalizing, remember the following rules :—

If R.H. P.R. is greater/less than L.H. P.R. before equalizing was started, then, at any stage during equalization, if R.H. P.R. is again greater/less than L.H. P.R., the handle should be turned in the same direction as the first turn was made. But, if however, at any stage R.H. P.R. is less/greater than L.H. P.R., the handle should be turned in the reverse direction. This will enable 'short-cut' method to be used.

Record figures appearing in P.R. in L.H. half column of line 9 (against E_P) with correct decimal points. (Choose the figure from the P.R. of the machine upon which the numerically smaller tan β is set). Record figure in M.R. in R.H. half column of line 9 (against N_P) with correct decimal point.

(*c*) If using any pair of stations the conditions of note (ii) apply, i.e. if either or both of the intersecting rays are between 70° and 110° or between 250° and 290° line 5 must be completed for these stations only and in the above instructions for machine working 'cot β' must be substituted for 'tan β', E_K and N_K interchanged and figures appearing in P.R. recorded in the R.H. half column of line 9 (against N_P) and those in M.R. in the L.H. half column of line 9 (against E_P).

4. Complete lines 10 to 13 in a similar manner and record final mean E_P and N_P in line 14.

5. (*a*) Heights from two stations may be worked simultaneously. Select the first two stations used. Complete lines 15 and 16. See footnote (ii) to decide whether to use ΔE and cosec or ΔN and sec. Complete lines 17, 18 and 19.

(*b*) Suppose, ΔE and cosec in formula (2) at top of form are to be used for both stations. (In the following instructions the suffixes 1 and 2 indicate the first and second of the stations used).

Set line 17 (ΔE_1) on L.H. S.L. and ΔE_2 on R.H. S.L. Connect machines in parallel and multiply by 3 if working in yards (if working in metres multiply by 3·28084 instead of 3) turning the handle forwards. Clear both S.L's. and M.R's. Transfer product from L.H. P.R. to L.H. S.L. Turn handle backwards once and check that L.H. P.R. reads 0000. Clear L.H. P.R. and L.H. M.R. and multiply by line 18 (cosec β_1) turning the handle forwards. Disconnect the machines and transfer product from R.H. P.R. to R.H. S.L. Turn handle backwards once and check that R.H. P.R. reads 0000. Clear R.H. P.R. and R.H. M.R. and multiply by line 17 (cosec β_2) turning the handle forwards. Clear both S.L's. and M.R's.

(*c*) Connect the machines in parallel. Transfer figures from L.H. P.R. to L.H. S.L. and turn handle backwards once and check that L.H. P.R. reads 0000. Clear L.H. P.R. and L.H. M.R. and multiply by line 16 (tan e_1). Clear L.H. S.L. and L.H. M.R. If line 19 (F) is not significant, record figure in L.H. P.R. in line 20 with correct sign, otherwise set line 19 (F) on L.H. S.L. and divide. Record quotient from L.H. M.R. in line 20 with correct sign and decimal point. Disconnect machines and repeat as in above for the second station using R.H. machine only.

If for either station it is necessary to use ΔN and sec in formula (2) at top of form, make the necessary substitutions in the instructions given above in this para i.e., substitute ΔN for ΔE and sec β for cosec β.

Complete remainder of the form entering classification of point in line 25.

Survey of India

B SECTION 1 Ind Fd Svy COMPANY. DATE August 1940 Grid λ_0 32 30 / I_0 68 00

Computation of grid co-ordinates and heights of Intersected Points direct from grid bearings using Twin machine

SURVEY Waziristan

Formulæ:— (1) $E_P = E_{K_1} - N_{K_1} \tan \beta_1 + N_P \tan \beta_1 = E_{K_2} - N_{K_2} \tan \beta_2 + N_P \tan \beta_2$ (ii)

(2) $\delta h = \frac{3}{F} \Delta E \operatorname{cosec} \beta \tan e = \frac{3}{F} \Delta N \sec \beta \tan e$ (If ΔE or ΔN are in metres, substitute $\frac{3{\cdot}29084}{F}$ for $\frac{3}{F}$)

1	Intersected point = P	←	Y_2	→							
2	Station of observation = K	Y62 h.s	Y61 h.s	G2 H.S							
3	Bearing at K of P = β (i)	133 ° 47 ′ 54 ″	163 ° 13 ′ 43 ″	302 ° 21 ′ 15 ″	° ′ ″	° ′ ″	° ′ ″	° ′ ″	° ′ ″	° ′ ″	° ′ ″
4	tan β	− 1·04285	− 0·30137	− 1·57854	− .	− .	− .	− .	− .	− .	− .
5	(cot β) (ii)	− .	− .	− .	− .	− .	− .	− .	− .	− .	− .
6	Easting of K = E_K	3199495·7	3201357·7	3204462·2	.	.	.	.	.	.	.
7	Northing of K = N_K	1039499·6	1041969·0	1035160·6	.	.	.	.	.	.	.
8	Fixing stations K_1 and K_2	Y62 h.s	Y61 h.s								
9	Easting of P = E_P (iii) Northing of P = N_P (iii)	3203161·1	1035985·1		.	.	.	.	.	.	.
10	Fixing stations K_1 and K_2	G2 H.S	Y61 h.s								
11	Easting of P = E_P (iii) Northing of P = N_P (iii)	3203161·2	1035984·8		.	.	.	.	.	.	.
12	Fixing stations K_1 and K_2	G2 H.S	Y62 h.s								
13	Easting of P = E_P (iii) Northing of P = N_P (iii)	3203161·6	1035984·5	(for check only)	.	.	.	.	.	.	.
14	Mean E_P Mean N_P	3203161 ·	1035985 ·		.	.	.	.	.	.	.
15	Vertical angle at K of P = e	⊤ 2 ° 08 ′ 02 ″	⊤ 3 ° 45 ′ 31 ″	− 1 ° 09 ′ 39 ″	− ° ′ ″	° ′ ″	° ′ ″	° ′ ″	° ′ ″	° ′ ″	° ′ ″
16	tan e	⊤ 0·03726	⊤ 0·06570	− 0·02026	− .	.	.	.	.	.	.
17	$\Delta E = E_P - E_K$ or $\Delta N = N_P - N_K$ (iv)	3665 ·	5984 ·	1301 ·	.	.	.	.	.	.	.
18	cosec β or sec β (iv)	1·38546	1·04443	1·18378	.	.	.	.	.	.	.
19	Scale factor = F (v)	0·99880	0·99880	0·99880	.	.	.	.	.	.	.
20	δh [from formula (2)] (vi)	⊤ 568·3	⊤ 1233·3	− 93·7	− .	.	.	.	− .	.	.
21	Correction from 41 Grid (vii)	+ 9·0	+ 12·3	+ 5·4	+ .	.	.	.	+ .	.	+ .
22	Minus height of signal	− 0·0	− 0·0	− 0·0	− .	.	.	.	− .	.	− .
23	Height of K	5697 ·	5037 ·	6362 ·	.	.	.	.	.	.	.
24	Sum = height of P	6275 ·	6283 ·	6273 ·	.	.	.	.	.	.	.
25	Mean height of P and classification	←	6277	→ Class A							

(i) Corrected bearings (angle book and grid corrections applied).
(ii) Line 5 (cot β) need only be completed if β (line 3) for *both* fixing stations lies between 70° and 110° or 250° and 290°. In this case use the following formula instead of formula (1) to obtain lines 9, 11 and 13:—
$N_P = N_{K_1} - E_{K_1} \cot \beta_1 + E_P \cot \beta_1 = N_{K_2} - E_{K_2} \cot \beta_2 + E_P \cot \beta_2$.

(iii) From formula (1) with fixing stations given in preceding line (but see note (ii) above).
For instructions for working lines 9, 11 and 13 on Twin machine see Supplement to T.H.B. Chap. VIII.
(iv) If bearing (line 3) is between 45° and 135° or 225° and 315° use ΔE and cosec, otherwise ΔN and sec.
(v) From 2 Grid (if significant).
(vi) Same sign as lines 15 and 16; see Supplement to T.H.B. Chap. VIII for machine working.
(vii) Or equivalent table in metres; for distance of line 17 × line 18.

Computed by *Date*

Checked by *Date*

G.B.—P.O.—J.S. 447-J/33—29-5-44—100.

34 MACH.

1. Complete headings, etc.

Complete lines 1, 2 and 3.

Observing the rule at footnote (ii), decide which set of formulæ is to be used and enter the set chosen in line 4.

2. Complete lines 5 and 6 using the functions which correspond to the set of formulæ chosen. Complete lines 7 and 8.

3. Complete lines 9 and 10 according to formulæ at top of form. If Set I formulæ are used, compute first Easting of P (E_P) using formula (1) and record the result in line 9. Next compute Northing of P (N_P) by formulæ (2 a) and (2 b) of the same set, using the value for E_P deduced above and record the results in first and second half columns respectively of line 10. Similarly if Set II formulæ are used, compute N_P first and record the result in line 9 using formula (1). Next compute E_P and record the results in line 10 using formulæ (2 a) and (2 b). Instructions for machine working are as follows :—

(*a*) When Set I formulæ are used :—

Set L.H. half column of line 7 (E_A) on S.L. Multiply by line 5 (cot α) of the same half turning the handle forwards/backwards if the latter (cot α) is $+^{ve}/-^{ve}$. Clear S.L. and M.R. Set R.H. half column of line 7 (E_B) on S.L. and multiply by line 5 (cot β) of the same half turning handle backwards/forwards if the latter (cot β) is $+^{ve}/-^{ve}$. Clear S.L. and M.R. Set L.H. half column of line 8 (N_A) on S.L. Turn handle backwards once. Clear S.L. Set R.H. half column of line 8 (N_B) on S.L. and turning handle forwards once. Clear S.L. only. Set line 6, (cot α − cot β) on S.L. and divide (turning handle forwards, if P.R. shows complement). Record quotient with correct decimal place in line 9.

(*b*) Clear S.L., M.R. and P.R. Set L.H. half column of line 8 (N_A) on S.L. and turn handle forwards once. Clear S.L. and M.R. Set line 5 (cot α) of the same half on S.L. and multiply by line 9 (E_P) turning handle forwards/backwards if the latter (cot α) is $+^{ve}/-^{ve}$. Clear M.R. only. Multiply by L.H. half column of line 7 (E_A) turning the handle backwards/forwards if the latter (cot α) is $+^{ve}/-^{ve}$. Record figure in P.R. in L.H. half column of line 10.

(*c*) Repeat computations substituting R.H. half column of line 8 (N_B), line 5 (cot β) and of line 7 (E_B) for L.H. half column of the same lines N_A, cot α, and E_A respectively in para 3(*b*) above. Check that R.H. half column of line 10 (N_P) thus obtained agrees with that obtained in para 3(*b*) above. If there is a small difference not due to computation error, accept value of line 10 (N_P) from deduction for which line 5 is numerically smaller.

(*d*) When Set II formulæ are used, follow the instructions in para 3(*a*) to obtain line 9 (N_P) *but* interchange line 7 (E_A and E_B) with line 8 (N_A and N_B) and substitute tans for cots in the instructions. Using the value of line 9 (N_P) thus obtained, compute line 10 (E_P) following the instructions given in para 3(*b*) & (*c*) above with the modification noted above in this sub-para and in addition substituting N_P for E_P.

4. Complete lines 11 and 12. See note (iv) to decide whether to use ΔE and cosec or ΔN and sec. Complete lines 13, 14 and 15, the subtraction in line 13 being done by machine.

Compute line 16 as follows :—

Set line 13 (ΔE or ΔN) on S.L. and multiply by 3 (or 3·28084 if working in metres). Clear S.L. Transfer figure in P.R. on S.L. Turn handle backwards once and check that P.R. reads 0000. Clear M.R. and multiply by $\frac{\text{cosec } \alpha \text{ (or } \beta)}{\text{sec } \alpha \text{ (or } \beta)}$. Clear S.L. Transfer figure in P.R. on S.L. and Multiply by tan e_1 (or tan e_2) turning the handle forwards. If line 15 (scale factor) is not significant, record figure with proper sign in line 16: otherwise clear S.L. and M.R. and divide figure in P.R. by line 15. Record figure in M.R. in line 16. Complete the remainder of the form following the instructions.

B SECTION No.1 Ind.Fd Svy. COMPANY. DATE Aug. 1940 Grid I $\begin{cases} \lambda_0 & 32^\circ\ 30' \\ L_0 & 68^\circ\ 00' \end{cases}$

Direct machine computation of grid co-ordinates and heights from grid bearings.

Survey Waziristan etc.

FORMULÆ:

Set I

(1) $E_P = \dfrac{E_A \cot a - E_B \cot \beta - N_A + N_B}{\cot a - \cot \beta}$

(2a) $N_P = N_A + E_P \cot a - E_A \cot a$

(2b) $N_P = N_B + E_P \cot \beta - E_B \cot \beta$

Set II

(1) $N_P = \dfrac{N_A \tan a - N_B \tan \beta - E_A + E_B}{\tan a - \tan \beta}$

(2a) $E_P = E_A + N_P \tan a - N_A \tan a$

(2b) $E_P = E_B + N_P \tan \beta - N_B \tan \beta$

Height formula:—For station A, $\delta h = \frac{3}{F}(\Delta E_A) \operatorname{cosec} a \tan e_1 = \frac{3}{F}(\Delta N_A) \sec a \tan e_1$

For station B, $\delta h = \frac{3}{F}(\Delta E_B) \operatorname{cosec} \beta \tan e_2 = \frac{3}{F}(\Delta N_B) \sec \beta \tan e_2$

1	Intersected point P		20						801					
2	Station A	Station B	Tarkhobai h.s.			Panebai h.s.			A h.s.			B h.s.		
3	Bearing at A of P = a (i)	Bearing at B of P = β (i)	322°	19′	07″	23°	41′	14″	164°	26′	20″	127°	42′	16″
4	Set of formulæ used (ii)		I						II					
5	cot a or tan a (ii)	cot β or tan β (i)	− 1·29472			+ 2·27945			− 0·27848			− 1·29364		
6	(cot a − cot β) or (tan a − tan β) (ii)		− 3·57417						+ 1·01516					
7	Easting of A = E_A	Easting of B = E_B	3254 019·7			3247 441·4			4056 645·8			4056 132·9		
8	Northing of A = N_A	Northing of B = N_B	1100 366·3			1097 285·7			798 807·5			798 213·2		
9	Easting of P = E_P / Northing of P = N_P	[formula (1)] (ii)	3250 686·2						797 544·9					
10	Northing of P = N_P / Easting of P = E_P	[formula (2)] (ii)	(iii) 1104 682·2			(iii) 1104 682·1			(iii) 4056 997·4			(iii) 4056 997·4		
11	Vertical angle at A of P = e_1	Vertical angle at B of P = e_2	+ 1°	49′	24″	− 1°	44′	05″	− 13°	36′	40″	− 10°	35′	39″
12	tan e_1	tan e_2	+ 0·03184			− 0·03029			− 0·24213			− 0·18703		
13	$\Delta E_A = E_P - E_A$ or $\Delta N_A = N_P - N_A$ (iv)	$\Delta E_B = E_P - E_B$ or $\Delta N_B = N_P - N_B$ (iv)	4315·9			7396·8			1262·6			864·5		
14	cosec a or sec a (iv)	cosec β or sec β (iv)	1·26354			1·09200			1·03805			1·26394		
15	Scale factor = F (v)		0·99888			0·99888			0·99944			0·99944		
16	δh (from height formula) (vi)		+ 521·5			− 734·8			− 951·5			− 612·7		
17	Correction (vii) from 41 Grid (viii)		+ 10·5			+ 17·3			+ 5·4			+ 5·3		
18	*Minus* height of signal		− 0·0			− 0·0			− 0·0			− 0·0		
19	Height of A	Height of B	2989·			4240·			5200·			4861·		
20	Sum = height of P		3521·			3522·			4254·			4254·		
21	Mean height of P and classification		3522·			S			4254·			A		

NOTES:—(i) Corrected grid bearings.
(ii) Use Set I except when both a and β lie between 340° and 20° or 160° and 200°, in which case use Set II. In either case ignore alternatives not applicable in instructions.
(iii) Obtain two deductions for line 10 using formulæ (2a) and (2b). Accept value from deduction for which line 5 is numerically smaller.
(iv) If bearing (line 3) is between 45° and 135° or 225° and 315° use ΔE and cosec, otherwise ΔN and sec. In height formula substitute "3·28084" for "3" if working in metres.
(v) From 2 Grid (if significant).
(vi) Same sign as lines 11 and 12.
(vii) For distances AP and BP, found by multiplying line 13 by line 14.
(viii) Or from 46 Sur. or corresponding tables for metres.

Computed by *Date* *Checked by* *Date*

G.B.—P.O.- J S. 448-J/34—29-8-44—700.

35 MACH.

1. Complete headings, etc. Choose those points whose co-ordinates (E_1 & N_1) fall in the same 100 km. square and enter the co-ordinates (E_8 & N_8) of the SW. corner of this square in lines 2 & 3. With these co-ordinates (E_8 & N_8) enter 11 Grid and enter values of the constants a_0, a_1, .. a_5 and b_0, b_1, .. b_5 in lines 4 to 0. Complete lines 1 to 3 for each point. Compute values of e and n according to foot-note (ii) and record them in lines 5 and 6 respectively.

Set line 5 (e) on S.L. and multiply by line 6 (n) turning handle forwards. Record figure in P.R. in line 7 (en). Continue multiplication till line 5 (e) appears in M.R. Record figure in P.R. in line 8 (e^2). Clear S.L., M.R. and P.R. Set line 6 (n) on S.L. and multiply by itself and record figure in P.R. in line 9 (n^2). Clear S.L., M.R. and P.R.

2. *Compute* E_8 *as follows* :—Set line 4 (a_0) on S.L. and turn handle forwards once. Clear S.L. and M.R. Set line 5 (e) on S.L. and multiply by line 5 (a_1) turning handle forwards/backwards as the sign of line 5 (a_1) is +ve/−ve. Clear S.L. and M.R. Set line 6 (n) on S.L. and multiply by line 6 (a_2) turning handle forwards/backwards as the sign of line 6 (a_2) is +ve/−ve. Clear S.L. and M.R. Set line 7 (en) on S.L. and multiply by line 7 (a_3) turning handle forwards/backwards as the sign of line 7 (a_3) is +ve/−ve. Clear S.L. and M.R. Set line 8 (e^2) on S.L. and multiply by line 8 (a_4) turning handle forwards/backwards as the sign of line 8 (a_4) is +ve/−ve. Clear S.L. and M.R. Set line 9 (n^2) on S.L. and multiply by line 9 (a_5) turning handle forwards/backwards as the sign of line 9 (a_5) is +ve/−ve. Record figure in P.R. against E_8. Clear S.L., M.R. and P.R.

3. Compute N_8 in the same manner as in para 2 but using the values b_0, b_1, .. b_5 instead of a_0, a_1, .. a_5 and record the final figure against N_8.

B **SECTION** No.1 Ind. Fd Svy. **COMPANY.** **DATE** August. 1940

Conversion from Grid B *to Grid* C *by interpolation, using rotary machine (single or twin).*

Easting $= a_0 + a_1e + a_2n + a_3en + a_4e^2 + a_5n^2$ **Northing** $= b_0 + b_1e + b_2n + b_3en + b_4e^2 + b_5n^2$ GRID B $\begin{cases} \lambda_0 & 32\ 30 \\ L_0 & 45\ 00 \end{cases}$ TO GRID C $\begin{cases} \lambda_0 & 39\ 30 \\ L_0 & 45\ 00 \end{cases}$

1	100 km. square, SW. corner[1]								Pt.	1								
2	E_s	12 00,000·							E_1	123 09 87·2								
3	N_s	16 00,000·							N_1	166 81 79·6								
4	a_0	185 68 69·5			b_0	33 35 25·5			1	1·0			1·0			1·0		
5	a_1	+	9	98 81·6	b_1	−	5	75·5	$e^{(ii)}$	0·30	9873		0·			0·		
6	a_2	+		575·6	b_2	+	9	98 81·9	$n^{(ii)}$	0·68	1796		0·			0·		
7	a_3	−		192·5	b_3	−		4·1	en	0·21	1270		0·			0·		
8	a_4	−		2·0	b_4	+		96·2	e^2	0·09	6021		0·			0·		
9	a_5	+		2·0	b_5	−		96·2	n^2	0·46	4846		0·			0·		
									$E_2^{(iii)}$	188	7172·6							
									$N_2^{(iii)}$	40	1409·9							

1	100 km. square, SW. corner[1]								Pt.									
2	E_s	00,000·							E_1									
3	N_s	00,000·							N_1									
4	a_0				b_0				1	1·0			1·0			1·0		
5	a_1				b_1				$e^{(ii)}$	0·			0·			0·		
6	a_2				b_2				$n^{(ii)}$	0·			0·			0·		
7	a_3				b_3				en	0·			0·			0·		
8	a_4				b_4				e^2	0·			0·			0·		
9	a_5				b_5				n^2	0·			0·			0·		
									$E_2^{(iii)}$									
									$N_2^{(iii)}$									

(i) Enter in lines 2, 3 the co-ordinates E_s, N_s of the SW. corner of the 100 km. square containing the points for conversion. With these co-ordinates enter the table 42 Grid (Supplement to Grid Tables for Grids B and C) or corresponding table for other grids, and enter values of $a_0, a_1, \ldots, b_0, b_1$ etc. in lines 4-9.

(ii) $e = \frac{E_1 - E_s}{100{,}000}$, $n = \frac{N_1 - N_s}{100{,}000}$.

(iii) See formula at head of the form. Instructions for machine working appear in Supplement to T.H.B. Ch. VIII

G.B.—P.O.—D.S. 360-B/276—1-8-44—1,000.

35 (a) Mach.

1. Complete headings etc. Choose those points whose co-ordinates (E_1 & N_1) fall in the same 100 km. square and enter the co-ordinates (E_2 & N_2) of the SW. corner of this square in lines 2 and 3. With these co-ordinates (E_2 & N_2) enter 11 Grid and enter values of the constants $a_0, a_1, \ldots\ldots a_7$ and $b_0, b_1 \ldots\ldots b_7$ in lines 4 to 11. Complete lines 1 to 3 for each point. Compute values of e and n according to foot-note (*ii*) and record them in lines 5 and 6 respectively.

Set line 5 (e) on S.L. and multiply by line 6 (n) turning handle forwards. Record figure in P.R. in line 7 (en). Continue multiplication till line 5 (e) appears in M.R. Record figure in P.R. in line 8 (e^2). Clear S.L., M.R. and P.R. Set line 6 (n) on S.L. and multiply by itself and record figure in P.R. in line 9 (n^2). Again clear S.L., M.R. and P.R. Set line 7 (en) on S.L., multiply by line 5 (e) and record figure in P.R. in line 10 (e^2n). Continue multiplication till M.R. shows figures of line 6 (n) and record figure in P.R. in line 11 (en^2). Clear S.L., M.R. and P.R.

2. *Compute* E_2 *as follows*:—Set line 4 (a_0) on S.L. and turn handle forwards once. Clear S.L. and M.R. Set line 5 (e) on S.L. and multiply by line 5 (a_1) turning handle forwards/backwards as the sign of line 5 (a_1) is + *ve*/−*ve*. Clear S.L. and M.R. Set line 6 (n) on S.L. and multiply by line 6 (a_2) turning handle forwards/backwards as the sign of line 6 (a_2) is + *ve*/−*ve*. Clear S.L. and M.R. Set line 7 (en) on S.L. and multiply by line 7 (a_3) turning handle forwards/backwards as the sign of line 7 (a_3) is + *ve*/−*ve*. Clear S.L. and M.R. Set line 8 (e^2) on S.L. and multiply by line 8 (a_4) turning handle forwards/backwards as the sign of line 8 (a_4) is + *ve*/−*ve*. Clear S.L. and M.R. Set line 9 (n^2) on S.L. and multiply by line 9 (a_5) turning handle forwards/backwards as the sign of line 9 (a_5) is + *ve*/−*ve*. Clear S.L. and M.R. Set line 11 (en^2) on S.L. and multiply by line 11 (a_7) turning handle forwards/backwards as the sign of line 11 (a_7) is + *ve*/−*ve*. Record figure in P.R. against E_2. Clear S.L., M.R. and P.R.

3. Compute N_2 in the same manner as in para 2 but using the values $b_0, b_1, \ldots\ldots b_6$ instead of $a_0, a_1, \ldots\ldots a_7$ and line 10 (e^2n) in place of line 11 (en^2) and line 10 (b_6) in place of line 11 (a_7). Record the final figure in P.R. against N_2.

35 (a) Mach. **Survey of India** Page......

B SECTION No. I Ind Fd Svy COMPANY. DATE 1940

Machine conversion from Transverse Mercator to Lambert Grid B by interpolation.

1	100 km. square, SW. corner(i)			
2	E_s	600,000·0		
3	N_s	600,000·0		
4	a_0	437 832.7	b_0	379 291.1
5	a_1	+ 99 936.1	b_1	+ 1 512.7
6	a_2	− 1 512.7	b_2	+ 99 931.9
7	a_3	+ 52.7	b_3	+ 51.9
8	a_4	+ 19.5	b_4	− 26.3
9	a_5	− 25.3	b_5	+ 32.7
10	a_6	− 0.0	b_6	− 12.8
11	a_7	+ 12.8	b_7	− 0.0

$$\text{Easting} = a_0 + a_1e + a_2n + a_3en + a_4e^2 + a_5n^2 + a_6e^2n + a_7en^2$$
$$\text{Northing} = b_0 + b_1e + b_2n + b_3en + b_4e^2 + b_5n^2 + b_6e^2n + b_7en^2$$

Pt.	43 M				
E_1	684 041.6	.	.	.	.
N_1	605 333.1	.	.	.	.
1	1·00 0000	1·00 0000	1·00 0000	1·00 0000	1·00 0000
$e^{(ii)}$	0·840 416	0·	0·	0·	0·
$n^{(ii)}$	0·053 331	0·	0·	0·	0·
en	0·044 820	0·	0·	0·	0·
e^2	0·706 299	0·	0·	0·	0·
n^2	0·002 844	0·	0·	0·	0·
e^2n	0·037 668	0·	0·	0·	0·
en^2	0·002 390	0·	0·	0·	0·
E_2	521 755.4	.	.	.	.
N_2	1 385 875.2	.	.	.	.

1	100 km. square, SW. corner(i)			
2	E_s	00,000·0		
3	N_s	00,000·0		
4	a_0	.	b_0	.
5	a_1	.	b_1	.
6	a_2	.	b_2	.
7	a_3	.	b_3	.
8	a_4	.	b_4	.
9	a_5	.	b_5	.
10	a_6	.	b_6	.
11	a_7	.	b_7	.

Pt.					
E_1	.	.	.	.	.
N_1	.	.	.	.	.
1	1·00 0000	1·00 0000	1·00 0000	1·00 0000	1·00 0000
$e^{(ii)}$	0·	0·	0·	0·	0·
$n^{(ii)}$	0·	0·	0·	0·	0·
en	0·	0·	0·	0·	0·
e^2	0·	0·	0·	0·	0·
n^2	0·	0·	0·	0·	0·
e^2n	0·	0·	0·	0·	0·
en^2	0·	0·	0·	0·	0·
E_2	.	.	.	.	.
N_2	.	.	.	.	.

(i) Enter in lines 2, 3 the co-ordinates E_s, N_s of the SW. corner of the 100 km. square containing the points for conversion, and enter the values of $a_0, a_1, \ldots, b_0, b_1$ etc. for this square in lines 4–11.

(ii) $e = \frac{E_1 - E_s}{100,000}$, $n = \frac{N_1 - N_s}{100,000}$.

Computed by *Date* *Checked by* *Date*

G.B. —P.O.—J.S. 101 - 21-5-41—400.

35 (b) MACH.

1. Complete headings etc. Choose those points whose co-ordinates (L_p & λ_p) fall in the same 1° square and enter the co-ordinates (L_s & λ_s) of the SW. corner of this square in lines 2 & 3. With these co-ordinates (L_s & λ_s) enter 12 Grid and enter values of the constants a_0, a_1,....a_5 and b_0, b_1....b_5 in lines 4 to 9. Complete lines 1 to 3 for each point. Enter + sign when latitudes are north and − when south in line 3. Compute values of e and n according to foot-note (iv) irrespective of sign and record them in lines 5 and 6 respectively.

Set line 5 (e) on S.L. and multiply by line 6 (n) turning handle forwards. Record figure in P.R. in line 7 (en). Continue multiplication till line 5 (e) appears in M.R. Record figure in P.R. in line 8 (e^3). Clear S.L., M.R. and P.R. Set line 6 (n) on S.L. and multiply by itself and record figure in P.R. in line 9 (n^2).

2. *Compute* E_n *as follows* :—Set line 4 (a_0) on S.L. and turn handle forwards once. Clear S.L. and M.R. Set line 5 (e) on S.L. and multiply by line 5 (a_1) turning handle forwards/backwards as the sign of line 5 (a_1) is + ve/−ve. Clear S.L. and M.R. Set line 6 (n) on S.L. and multiply by line 6 (a_2) turning handle forwards/backwards as the sign of line 6 (a_2) is + ve/−ve. Clear S.L. and M.R. Set line 7 (en) on S.L. and multiply by line 7 (a_3) turning handle forwards/backwards as the sign of line 7 (a_3) is + ve/−ve. Clear S.L. and M.R. Set line 8 (e^3) on S. L. and multiply by line 8 (a_4) turning handle forwards/backwards as the sign of line 8 (a_4) is + ve/− ve. Clear S.L. and M.R. Set line 9 (n^2) on S.L. and multiply by line 9 (a_5) turning handle forwards/backwards as the sign of line 9 (a_5) is + ve/− ve. Record figure in P.R. against E_n. Clear S.L., M.R. and P.R.

Read correction from chart II from the table of the grid concerned. Note this correction with proper sign under E_n and add to get E.

3. Compute N_n in the same manner as in para 2 but using the values b_0, b_1,.....b_5 instead of a_0, a_1,.... ..a_5. Record the final figure in P.R. against N_n. as instructed on the form.

Read correction from chart I from the table of the grid concerned. Note this correction with proper sign under N_n and add to get N.

3 **SECTION** I. Ind. Fd. Svy. **COMPANY. DATE** 1940 Grid Maldive-chagos { λ_0 0° 00′ 00″ ; L_0 73° 40′ 00″ }

Conversion from Spherical to Grid Transverse Mercator *by interpolation, using rotary machine (single or twin).*

Easting $= a_0 + a_1e + a_2n + a_3en + a_4e^2 + a_5n^2$ + Chart II(i) correction. Northing $= b_0 + b_1e + b_2n + b_3en + b_4e^2 + b_5n^2$ + Chart I(ii) correction.

1	1° square, SW. corner (iii)					
2	L_s	73° 0 0				
3	λ_s	–	0° 0 0			
4	a_0	+	35 6136·9	b_0	+	145 0000·0
5	a_1	+	12 1726·3	b_1	–	9·3
6	a_2	+	9·2	b_2	+	12 0921·3
7	a_3	–	18·4	b_3	–	0·0
8	a_4	–	0·0	b_4	+	9·3
9	a_5	–	0·0	b_5	+	0·2

Pt.	001 Pw. s.s.	Moradu Naval Stn	Hiladu Naval Beacon		
L_P	73° 10′ 10″·93	73° 07′ 38″·08	73° 06′ 23″·30	° ′ ″	° ′ ″
λ_P	+ 0 41 48·92	+ 0 39 43·61	+ 0 37 43·07	–	–
1	1·0	1·0	1·0	1·0	1·0
e(iv)	0·169 7082	0·127 2444	0.106 4722	0·	0·
n(iv)	0·696 9222	0·662 1139	0·628 6305	0·	0·
en	0·118 2696	0·084 2503	0·066 93	0·	0·
e^2	0·028 7990	0·016 1911	0·011 34	0·	0·
n^2	0·485	0·438	0·395	0·	0·
E_a(v)	37 6798·4	37 1630·5	36 9101·9		
Corr. (i)	– 1·0	–	–	–	–
Sum = E	37 6797·4				
N_a(v)	136 5728·5	136 9937·3	137 3986·0		
Corr. (ii)	+ 0·5	+ 0·3	+ 0·2	–	–
Sum = N	136 5729·0	136 9937·6	137 3986·2		

(i) From chart II.
(ii) From chart I.
(iii) Enter in lines 2 and 3 the longitude and latitude (L_s, λ_s) of the SW. corner of the 1° square containing the co-ordinates (L_P, λ_P) of the points for conversion. Also enter + sign when Latitudes are North and – when South. With the co-ordinates (L_s, λ_s), enter values of a_0, a_1..., b_0, b_1, etc. in lines 4 to 9 from table 12 Grid.
(iv) $e = \frac{(L_P - L_s) \text{ in seconds}}{3{,}600}$, $n = \frac{(\lambda_P - \lambda_s) \text{ in seconds}}{3{,}600}$.
(v) See formula at head of the form. Instructions for machine working appear in Supplement to T.H.B. Chapter VIII. In Southern latitudes subtract N_a from twice the Grid northing of the origin at equator before the application of correction for Chart I.

1	1° square, SW. corner (iii)					
2	L_s	°				
3	λ_s	–	°			
4	a_0	–	·	b_0	–	·
5	a_1	–	·	b_1	–	·
6	a_2	–	·	b_2	–	·
7	a_3	–	·	b_3	–	·
8	a_4	–	·	b_4	–	·
9	a_5	–	·	b_5	–	·

Pt.					
L_P	° ′ ″	° ′ ″	° ′ ″	° ′ ″	° ′ ″
λ_P	–	–	–	–	–
1	1·0	1·0	1·0	1·0	1·0
e(iv)	0·	0·	0·	0·	0·
n(iv)	0·	0·	0·	0·	0·
en	0·	0·	0·	0·	0·
e^2	0·	0·	0·	0·	0·
n^2	0·	0·	0·	0·	0·
E_a(v)	·	·	·	·	·
Corr (i)	–	–	–	–	–
Sum = E	·	·	·	·	·
N_a(v)	·	·	·	·	·
Corr. (ii)	–	–	–	–	–
Sum = N	·	·	·	·	·

Grid Co-ordinates of the Origin { 417 000 E. ; 1 450 000 N.

Everest **SPHEROID** Yards / ~~Metres~~

Computed by *Compared by*

Date *Date*

G.B.—P.O.—J.S. 147—18-6-43—500.

36 MACH.

1. Complete headings.

2. Complete lines 1 to 12.

3. Set line 12 on S.L. and multiply by itself and record result from P.R. in line 13 with correct decimal point. Clear S.L. and M.R.

4. Set result in P.R. on S.L. Clear P.R. and multiply by line 11 turning handle forward or backwards according as line 11 is positive or negative, noting the decimal point carefully. Clear S.L. and M.R.

Set line 8 on S.L. and multiply by line 12 turning handle forward/backwards according as line 8 is +ve/−ve. Put indicator to correct decimal point in P.R.

Clear S.L. and M.R.

Set line (6) on S.L. and shift P.R. so that the unit figure of P.R. (indicator) and the unit figure in S.L. are in one line and turn handle forward once. Clear S.L. and M.R.

Set line (2) on S.L., taking care that the unit figure in it is in line with the unit figure in P.R. and turn handle backwards once. The result in P.R. is either a positive number or complement. Record the number in line 19 with correct sign and decimal point. Clear P.R., S.L. and M.R.

5. Set line 7 on S.L. starting from third place from right so that there are three decimals in all with two last decimals as zero. Turn handle forward once noting the decimal point in P.R. carefully. Clear S.L. and M.R. Now set line 12 on S.L. and multiply by line 9 turning handle forward/backwards according as line 9 is +ve/−ve. Clear S.L. and M.R.

Set result in P.R. on S.L., also recording it in line 22 with correct decimal point. Clear P.R. and multiply by itself. Put indicator to correct decimal point in P.R. Clear S.L. and M.R.

Multiply mentally line 10 by 4 and set on S.L. -Multiply by line 19 turning handle forward/backward according as lines 10 and 19 are of the different/same signs, recording the result in line 25 with correct decimal point.

6. Complete line 26. (For method of taking square root by machine see preface).

7. Complete the rest of the form. Carrying out division (line 29) on machine, keep five decimals in line 27 if this as well as line 28 are less than unity i.e. contain no integers.

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B SECTION No 1 Ind Fd Svy COMPANY. DATE June 1940

Machine Computation of Grid $\frac{Northing}{Easting}$ *on Grid* β *of the points at which lines of* $\frac{Easting}{Northing}$ *on Grid* β *cut lines of* $\frac{Northing}{Easting}$ *on Grid* a

1	Grid a	Grid β	B	C		
2	Cutting line on Grid a		152 $\times 10^4 \frac{N}{E}$		$\times 10^4 \frac{N}{E}$	$\times 10^4 \frac{N}{E}$
3	Cutting line on Grid β (i)		211 $\times 10^4 \frac{E}{N}$		$\times 10^4 \frac{E}{N}$	$\times 10^4 \frac{E}{N}$
4	N } of Grid β corresponding to line (3)		2 $\times 10^5$		$\times 10^5$	$\times 10^5$
5	E }		21 $\times 10^5$		$\times 10^5$	$\times 10^5$
6	a_0	b_0	1 467 309·7		·	·
7	a_1	b_2	+ 99 872·1		+ ·	+ ·
8	a_2	b_1	+ 105·6		− ·	− ·
9	a_3	b_3	+ 0·1		− ·	− ·
10	a_4	b_5	+ 95·1		− ·	− ·
11	a_5	b_4	− 95·1		− ·	− ·
12	$\frac{\text{Lines (3)}-\text{(5) (ii)}}{10^5}$	$\frac{\text{Lines (3)}-\text{(4) (ii)}}{10^5}$	+ 0·1		+ ·	+ ·
13	Sq. of line (12)		+ 0·01		+ ·	+ ·
14	Lines (8) × (12)		− ·		− ·	− ·
15	Lines (11) × (13)		− ·		− ·	− ·
16	Line (6)		·		·	·
17	Sum = lines (14) + (15) + (16)		·		·	·
18	Line (2)		·		·	·
19	Diff. = lines (17) − (18)		− 52 680·631		− ·	− ·
20	Lines (9) × (12)		− ·		− ·	− ·
21	Line (7)		+ ·		+ ·	+ ·
22	Sum = lines (20) + (21)		99 872·11		·	·
23	Sq. of line (22) (iii)		·		·	·
24	4 × lines (10) × (19) (iii)		− ·		− ·	− ·
25	Diff. = lines (23) − (24) (iii)		+ 9 994 478 090·7 085		+ ·	+ ·
26	Sq. root of line (25) (iii) to 3 decimals		99 972·387		·	·
27	Lines (26) − (22)		+ 100·277		− ·	− ·
28	2 × line (10)		+ 190·2		− ·	− ·
29	{ Lines (27) ÷ (28) } $\times 10^5$		52 722			
30	Lines (29) + (4) or (5) (iv)		252 722			

(i) Use $\frac{\text{right}}{\text{left}}$ hand side of lines (6) to (11) when this is $\frac{E}{N}$.

(ii) Take $\frac{(3)-(5)}{10^5}$ or $\frac{(3)-(4)}{10^5}$ as line (3) is E or N respectively.

(iii) Lines (23) to (26) can be worked directly in the machine.

(iv) Take (4) or (5) as line (3) is $\frac{E}{N}$.

Computed by *Date* *Checked by*

G.B.—P.O.—J.S. 361-J/36—1-8-44—500.

AIR SURVEY FORMS

INSTRUCTIONS

14 (a) AIR

1. This form provides for camera calibration by means of measurement of the external angles subtended by horizontal distances *a* & *b* measured on the pressure plate, first with the camera in one position and then with it rotated about its optical axis through 90°. Four columns are provided thus allowing deductions using two values of *a* & *b* for each camera position to be made. The alternative values of *a* & *b* are usually obtained by measuring to two or more central marks (symmetrically placed about the principal point) instead of to one only. If only one value of *a* & *b* for each position is taken only two columns need be computed and line 23 may be omitted.

2. Complete headings and strike out 'UP' or 'DOWN' and RIGHT or LEFT (whichever does not apply) above diagram at foot of form. (In the case of the F.24 camera or other cameras which do not have an instrument panel indicate the two positions during calibration by a diagram). Fill in the words UP or DOWN, RIGHT or LEFT (whichever applies) in line one.

3. Complete lines 2 and 5 for all camera positions by measurement of the camera pressure plate or calibration contact print. Complete lines 3 and 6 from the angle book for all camera positions. Complete lines 4, 7 and 8.

4. Complete line 9 following formula (*a*) by machine as follows :—

Set *a* (line 2) on S.L. Multiply by cot A (line 4) turning handle forwards. Clear S.L. and M.R. Set *b* (line 5) on S.L. Multiply by cot B turning handle backwards. Clear S.L. and M.R. Set ($a+b$) (line 8) on S.L. and divide. If P.R. is a complement, divide by building it up to 0. Record quotient with correct sign in line 9. Complete lines 10 to 17 for all camera positions.

5. Complete lines 18 and 19 for all camera positions on machine as follows :—

Set *a* (line 2) on S.L. Multiply by cos ($A+\theta$) (line 13) turning handle forwards. Clear S.L. Set product from P.R. on S.L. Turn handle backwards once and check that P.R. reads 0000. Clear P.R. and M.R. Multiply by cos θ (line 17). Clear S.L. and M.R. Set sin A (line 15) on S.L. and divide. Record quotient from M.R. in line 18. Repeat the computation given in this para substituting *b* (line 5) for *a*, cos ($B-\theta$) (line 14) for cos ($A+\theta$) and sin B (line 16) for sin A. Record second value of '*f*' thus obtained in line 19. Check agreement between lines 18 and 19 and record mean for each column in line 20.

6. Clear S.L. P.R. and M.R. Set '*f*' from line 20 on S.L. Multiply by tan θ (line 9) and record product in line 21. Complete for all deductions. Complete line 22. Record mean values of ($d+a$) for each camera position in line 23 and complete line 24. Record final mean focal length '*f*' from both camera positions in space provided at head of form.

NOTE.—"*d*" is the distance which the principal point is away from the central mark to which measurement was made for any deduction. For direction in which measured see note (iv) on Form.

Survey of India

Air Survey SECTION Ind.Fd Svy. COMPANY. DATE 1938-1939

Machine computation of camera calibration

Camera No. 2 WS/F Lens 10" Place Risalpur Cantt

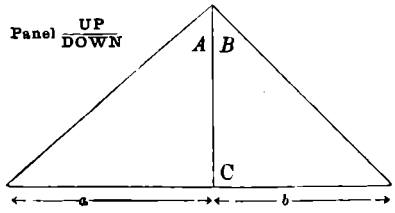
Observer Major D.R Crone Final mean focal length 256 484 Temp. 75 °F

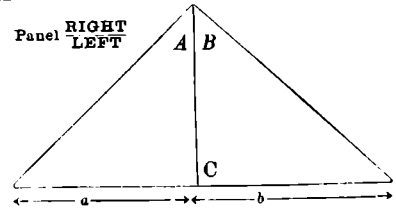
Formulæ:— (a) $\tan\theta = \dfrac{a\cot A - b\cot B}{a+b}$

(b) $f = \dfrac{a\cos(A+\theta)\cos\theta}{\sin A} = \dfrac{b\cos(B-\theta)\cos\theta}{\sin B}$

Distances in $\frac{\text{inches}}{\text{millimetres}}$

1	Instrument panel	Down	Right	Down	Right
2	Distance a	68·06	70·06	83·08	80·01
3	Angle A	14° 44′ 27″	15° 11′ 12″	18° 06′ 18″	17° 24′ 48″
4	cot A	3·80074	3·68400	3·05860	3·18840
5	Distance b	81·32	79·87	66·90	69·92
6	Angle B	17° 51′ 35″	17° 23′ 32″	14° 29′ 51″	15° 09′ 56″
7	cot B	3·10352	3·19257	3·86741	3·68938
8	$a+b$	149·98	149·93	149·98	149·93
9	$\tan\theta$ (i)	+0·029591	+0·020773	−0·030812	−0·019059
10	θ (ii)	+ 1° 41′ 42″	+ 1° 11′ 23″	− 1° 45′ 54″	− 1° 05′ 31″
11	$A+\theta$	16° 26′ 09″	16° 22′ 35″	16° 20′ 24″	16° 19′ 17″
12	$B-\theta$	16° 09′ 53″	16° 12′ 09″	16° 15′ 45″	16° 15′ 27″
13	cos $(A+\theta)$	0·95914	0·95943	0·95961	0·95970
14	cos $(B-\theta)$	0·96047	0·96028	0·95999	0·96001
15	sin A	0·25445	0·26197	0·31076	0·29926
16	sin B	0·30669	0·29891	0·25034	0·26161
17	cos θ	0·99956	0·99979	0·99952	0·99982
18	f = focal length (iii)	256·437	256·532	256·423	256·539
19	f = focal length (iii)	256·438	256·537	256·421	256·534
20	Mean f for column concerned	256·437	256·535	256·422	256·536
21	$d = f\tan\theta$ (iv)	+ 7·588	+ 5·329	− 7·901	− 4·889
22	$d+a$	75·648	75·389	75·179	75·121
23	Mean $(d+a)$ for each position	75·41	75·26	·	·
24	Mean $(d+a)-(a)$ for reference mark (v)	+ 7·35	+ 5·20	− 7·63	− 4·75





(i) Using formula (a) enter tan θ with proper sign.
(ii) Same sign as line (9).
(iii) Enter values of f from each formula of (b) in lines (18) and (19).

(iv) tan θ from line (9) and f from line (20); when d is $\frac{+ve}{-ve}$ the position of the principal point is towards $\frac{b}{a}$ from the centre C.

(v) The reference mark is the mark to which the final co-ordinates of the principal point are to be referred.

Computed by *Date* *Checked by* *Date*

G.B.—P.O.—J.S 270—22-11-40—500.

INSTRUCTIONS

20 AIR

1. Complete headings.

2. Complete lines 1 to 10, 12 to 18 and 20 to 22. For instructions see Amendment dated 22.9.42 to Appendix III. T. H. B. XII, 2nd Edition, 1939.

3. Work lines 11, 19 and 23 by slide rule according to the following instructions:—

Set the index on C scale to line 6 (scaled distance in feet) on D scale.

Bring cursor to line 10 on C scale, then set line 5 (converted to seconds) on C scale beneath cursor. Read D scale under the index on C scale and record the result in line 11 to nearest hundred.

4. Set the index on C scale to line 11 on D scale and bring cursor to line 12 on C scale.

Bring the index on C scale beneath cursor. Set cursor to line 18 on C scale. Then set line 14 on C scale beneath cursor. Then set cursor to the index of C scale. Then set line 13 on C scale beneath cursor. Then set cursor to the index of C scale. Then set 8 on C scale beneath cursor.

Read D scale against index on C scale and record the result in line 19 with correct sign.

5. Set the index on C scale to line 11 on D scale and bring cursor to line 12 on C scale. Then bring line 22 on C scale beneath the cursor. Read scale D against the index on C scale and record in line 23 to one decimal place.

Survey of India

PARTY / COY. (No.1 Ind. Fd. Svy.) SEASON 1943

Mid East Method, Tilt Corrections

Camera F.8 XI B 6" *Date of photography* 27th Sept. 35.

$$B = D\,(t_r - t_l)/(t_n - t_l)$$

$$A = \left\{ (P_B - P_D) - (P_A - P_C) \right\} Bf/8by$$

No.	Item											
1	Strip	3										
2	Overlap	26643 - 42										
3	1st Photo. No. 39 Time	54 m	24·0 s	m	. s	m . s	m . s	m . s	m . s	m . s	m . s	m . s
4	Last Photo. No. 46 Time	58	12·0		.	.	.	.	.	.	.	.
5	Time Interval = lines (3 ~ 4)	3	48·0		.	.	.	.	.	.	.	.
6	Scaled distance 1st to last P.P. = D (ft.)	37300										
7	Speed = S (ft. per sec.)	163·8										
8	Time L.H. Photo.	56 m	34·2 s	m	. s	m . s	m . s	m . s	m . s	m . s	m . s	m . s
9	Time R.H. Photo.	56	01·8		.	.	.	.	.	.	.	.
10	Overlap Interval = I		32·4		.	.	.	.	.	.	.	.
11	Overlap Base (ft.) = B = lines 7 × 10	5300										
12	Principal distance = f (mm)	152·0										
13	y (mm)	72·8 / 73·5 } 73										
14	b (mm)	60·9 / 56·7 } 58·8										
15	P_B | P_A	143·0 / 2·3	141·0 / 4·42	133 / 12·1	41·0 / 4·4							
16	P_D | P_C	140·0 / 5·5	136·0 / 8·80	138 / 7·7	134·0 / 11·0							
17	Difference = lines (15 − 16)	− 0·3	+ 0·6	− 0·6	+ 0·4							
18	Difference (Left − Right)	− 0·9 mean		− 1·0 / − 0·95								
19	⅛ lines 18 × 11 14 × 12, 13 = Amplitude (ft.)	− 22										
20	Aircraft Ht. (ft.)			16600								
21	Ht. of Known Datum (ft.)			3884								
22	Difference = H = lines (20 − 21)			12716								
23	True parallax of datum bf/H = lines 11 × 12 / 22			63·3								

Entered by *Date* *Computed by* *Date* *Checked by* *Date*

G.B.—P.O.—J.S. 300-J/53—20 6-44—500.

INSTRUCTIONS

27 AIR

1. Complete headings.

2. Complete lines 1 to 8 and lines 10, 11 and 12. For instructions see Amendment dated 22-9-42 to Appendix III, T. H. B. XII, 2nd Edition, 1939.

3. Set the index on C scale to line 3 on D scale. Then set cursor to line 6 on C scale. Then set line 8 on C scale beneath cursor. Read D scale against the index on C scale and record in line 9 to unit's place with correct sign.

4. Complete lines 13 and 14 (if necessary).

27 Air

Survey of India

NO. D. D. F. C. PARTY 1942-43 SEASON Kakul SURVEY AREA STRIP

Stereoscopic Heights Sheet No. 43 F/8 Mid East Method

1	Overlap	26 643-42					
2	No. of Point	12	8	5	1	9	3
3	Depth of ~~L.H.~~ Datum Principal Point	12 720					
4	Parallax of Point measured	- 144·1	- 142·7	- 145·9	- 146·5	- 139·1	- 146·6
5	Parallax of Datum L.H. Principal Point	- 145·9					
6	Difference	+ 1·8	- 3·2	0	- 0·6	+ 6·8	- 0·7
7	Parallax from true ~~Col. W. 24 Air~~	+ 63·2					
8	Sum = (6) + (7)	65·0	66·4	63·2	62·6	70·0	62·5
9	$\frac{(3)\times(6)}{(8)}$	+ 355	+ 4·5	0	- 127	+ 1238	- 143
10	Lateral Tilt Corr.	0	+ 45	- 53	+ 244	+ 294	+ 117
11	F+A " "	+ 22	+ 20	+ 53	+ 21	+ 19	+ 54
12	Height of ~~Principal Point~~ Datum	3 884	3 884	3 884	3 884	3 884	3 884
13	" Pt. (9) + (10) + (11) + (12)	4 250	4 970	3 884	4 022	5 435	3 912
14	Mean with ref. No.						

* Enter parallax scale readings with minus sign.

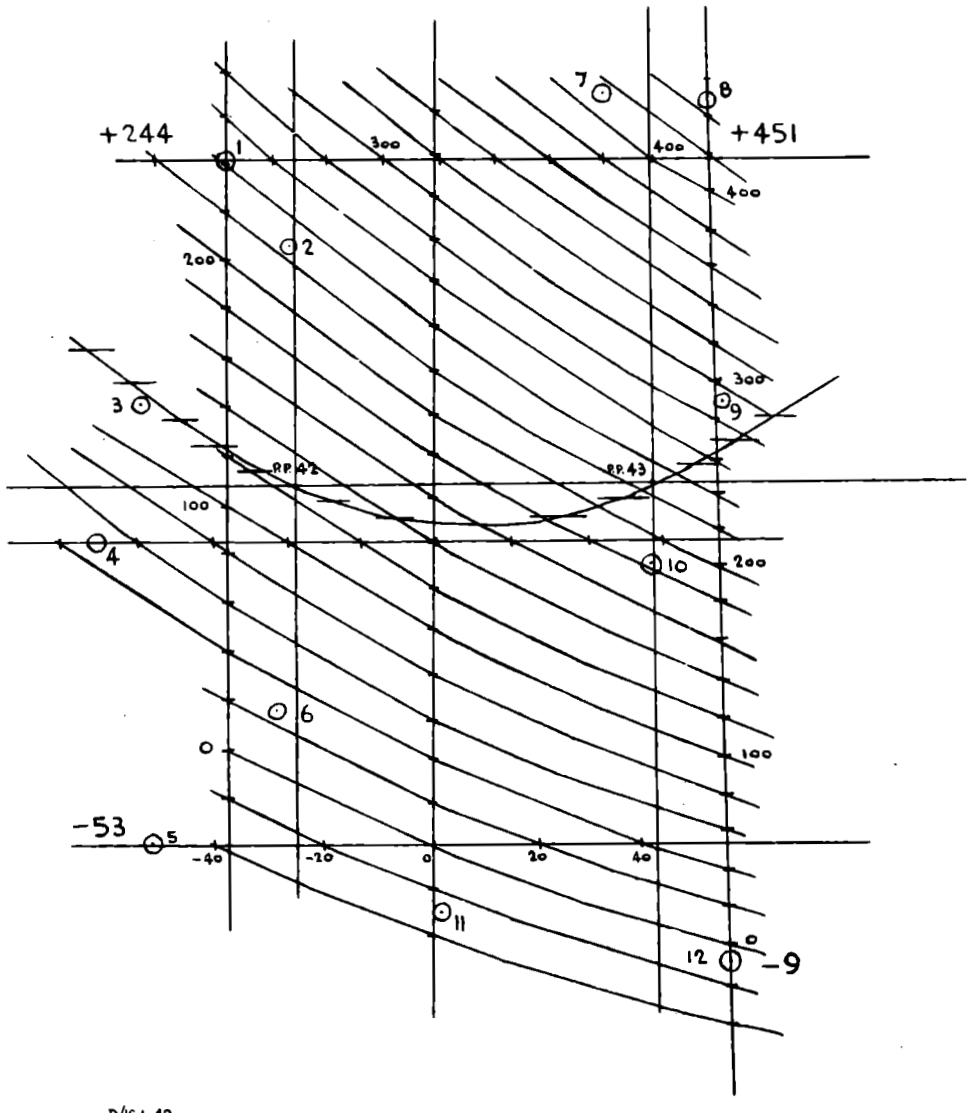
Signature of Observer

G.B.—P.O.—J.S. 560—24-12-43—50 bks. of 25 forms each.

MID EAST METHOD

CORRECTION DIAGRAM

Photo. no's 2bb42 - 43



D/16.1.49

INSTRUCTIONS

31 AIR

1. Enter headings noting whether it is the 1st, 2nd etc. horizon for which necessary corrections are to be computed.

2. In line 1 enter names of Trig. points to which measurements have been made for the purpose of correcting the horizon Points (1), (2) and (3) are the actual points to be used point (4) is to be treated as a check point.

3. In line 2 enter heights of points as computed on 32 Air. Complete lines 3 to 6 making necessary measurements from the out line compilation of the area for entry in line 5 and 6 and observing the rule of signs for line 6 given at foot of form.

4. Complete lines 7, 8 and 9 in the following manner :—For line 7 enter in first column the algebraic difference between the values in col. 1 of line 6 and col. 2 of line 6. In the second column enter the algebraic difference between the values in col. 2 of line 6 and col. 3 of line 6. Leave remaining two columns blank.

In a similar manner complete lines 8 and 9.

5. Complete line 10 on machine as follows :—

Set left hand number from line 7 on S.L. multiply by right hand number from line 8 turning handle forwards/backwards if signs of both numbers are same/opposite. Clear S.L. and M.R. Set right hand number from line 7 on S.L. Multiply by left hand number from line 8 turning handle backwards/forwards if signs of both numbers are same/opposite. Record figure appearing from P.R. in line 10 with correct sign (negative if P.R. shows a complement) and decimal point.

Similarly complete lines 11 and 12 substituting lines 8 and 9, and 7 and 9 respectively for lines 7 and 8 in the above instructions.

6. After completing line 12, transfer figures appearing in P.R. to S.L. and turn handle backwards once and check that P.R. reads 00000 (if P.R. shows a complement transfer one *minus* figures in P.R., give the handle one forward turn and check that P.R. reads 1·00000). Clear P.R. and M.R.

7. Turn handle forward until P.R. shows the number appearing in line 10. Record figure from M.R. with correct sign and decimal point in line 13. Continue turning handle until P.R. shows line 11. Record figure from M.R. with correct sign and decimal point in line 14 (first col.). Complete line 14.

8. Complete line 15, cols. 1 and 2 from form 32 Air. Compute col. 3 by slide rule. Add cols. 2 and 3 and enter in line 16 col. 1. Clear S.L., P.R. and M.R. Set tan $\delta\theta$ (line 13) on S.L. Multiply by line 16 (left hand col.) and record with correct sign and decimal point in line 16 (2nd col.).

Continue multiplication until M.R. shows line 5 for each point (including 4) in turn. Record products in appropriate columns for each point with correct sign in line 17.

9. Clear S.L., M.R. and P.R. Set tan $\delta\phi$ (line 14) on S.L. and multiply by line 6 for each point in turn, recording products in appropriate columns for each point with correct sign in line 18. Complete line 19.

10. Complete line 20 (algebraic sum of lines 17, 18 and 19). Check that line 20 for first 3 columns agrees to within 1 foot and that agreement for point 4 (check point) is within 1/700 of line 5.

NOTE :—This form may with advantage be worked with comptometer, for which it was primarily designed. It is presumed that the computer is conversant with the use of the comptometer, if not, the special booklet issued with the machine should be consulted.

Survey of India

Air Survey **SECTION** Ind Fd Sqy. **COMPANY.** **DATE** 1939-40

Determination of True Horizon on Oblique Photographs

from three known points

Survey [illegible]

Photograph No. 24085.

Horizon No. 2

1	Point			(1) $^{H}/_{25}$	(2) $^{Y}/_{211}$	(3) $^{Y}/_{236}$	(4) $^{J}/_{11}$
2	Height from Approx. Horizon			6615	7891	7459	6908
3	True Height of Point			6255	7734	7406	6379
4	Difference = Line (2) − Line (3)			+ 360	+ 157	+ 53	+ 229
5	Distance along Principal line in feet			46293	40531	10426	37243
6	Perpendicular distance to Principal line in feet (i)			- 14929	+ 4877	- 2669	- 7128
7	From line (6)	Col. (1) − (2)	Col. (2) − (3)	- 19806	+ 7546		
8	From line (4)	Col. (1) − (2)	Col. (2) − (3)	+ 203	+ 104		
9	From line (5)	Col. (1) − (2)	Col. (2) − (3)	+ 5762	+ 30105		
10	Difference of product of diagonals (NW—NE)	Lines (7) × (8) × 10^{-6}		- 2·060	+ 1·532	- 3·592	
11		Lines (8) × (9) × 10^{-6}		+ 6·111	+ 0·599	+ 5·512	
12		Lines (7) × (9) × 10^{-6}		- 596·260	+ 43·480	- 639·740	
13	$\tan \delta\theta$ = Col. (3) line (10) ÷ line (12)			+ 0·00561			
14	$\tan \delta\phi$ = Col. (3) line (11) ÷ line (12)			- 0·00862	$\delta\phi$ = (ii) ° ′ 0 30		
15	Distance of Approx. Horizon from P.P. = d	Focal length = f	$\frac{d^2}{f}$	+ 2·613	+ 10·100	+ 0·676	
16	$f + \frac{d^2}{f}$	$\tan \delta\theta \left(f + \frac{d^2}{f}\right)$ (iii)		+ 10·776	+ 0·06045 (iii)		
17	Line (13) × line (5)			+ 260	+ 227	+ 58	+ 209
18	Line (14) × line (6)			+ 129	- 42	+ 23	+ 61
19	Line (4) with opposite sign			- 360	- 157	- 53	- 229
20	Sum = Increment to approx. Height of aircraft			+ 29	+ 28	+ 28	+ 41

(i) Distances to the right of the principal line are *plus*.

(ii) The True Horizon makes this angle with the approximate horizon. On the right of the photograph the true is $\frac{above}{below}$ the approximate when ϕ is $\frac{plus}{minus}$.

(iii) The true horizon is this distance above the approximate on the principal line.

Computed by *Date* *Checked by*

G.B.—P.O.—J.S. 35—10-3-41—1,000.

32 AIR

(A) *When used to obtain data for entry on 31 Air (Determination of true horizon).*

(i) Fill in headings. Enter number of horizon used for measurements (e.g. 1st, 2nd &c.) and the relevant page of 31 Air if it is a computed horizon and not the first approximation.

(ii) Enter numbers of points of known heights and the number of photograph measured.

(iii) Complete lines 3, 4 and 12. (All above data is normally entered by surveyor).

(iv) Complete lines 5 to 11 (inclusive) as under, working according to left hand column, if a rotary calculating machine is used and according to the right hand column if a comptometer is used.

(v) *With Rotary Calculating Machine.*—Work to four decimal places throughout. Set line 4 on S.L. Multiply by (B) in heading. Set product on S.L. turn handle backward once check that P.R. reads 0000. Clear M.R. and P.R. Multiply by line 4 and record in line 6 with correct sign and decimal point.

Clear P.R. and M.R., multiply successively by line 3 for every point and record in line 9 with correct sign and decimal point.

Complete lines 8 and 10 entering sign and decimal point in each case.

Set line 3 on S.L. Multiply by line 12 clear S.L. and M.R. Set line 10 on S.L. and divide. Record figure in M.R. in line 13 with correct sign and decimal point. Complete the remaining form as in (vii) and (viii) below.

(vi) *With Comptometer.*—Work straight through according to instructions of right hand column (to four decimal places throughout) until tan θ is obtained in line 11 (enter correct sign in each case).

(vii) Complete lines 13, 14 and 15 with correct sign and decimal point. Curvature and refraction correction in line 14 is that for the distance given in line 12. (Obtained from 17 Topo or 17 Sur.).

(viii) Record algebraic sum of lines 13, 14 and 15 in line 16. This equals the height from approx. horizon to be entered upon 31 Air (line 2).

(B) *When used with slide rule to compute heights for contouring from final accepted horizon.*

(i) Proceed as in A (i), (ii) and (iii), entering the number of the horizon on each photograph in brackets against the number of the photograph.

(ii) Work lines 5 to 13 (left hand column inclusive) by slide rule, to as many decimal places as possible, according to the following instructions :—

Set cursor to line 4 on D scale.

Bring (A) on C scale beneath cursor.

Set cursor to line 4 on C scale. Record reading on D scale in line 6 with correct sign and decimal point. With the rule as set, set cursor to line 3 on C scale for each point (measured on the photo concerned) in turn, and record reading on D scale with correct sign and decimal point in each case in line 9.

Complete lines 8 and 10 entering correct sign. Bring line 10 on C scale against line 3 on D scale, set cursor to line 12 on C scale, read value on D scale and record in line 13 with correct sign and decimal point.

(iii) Complete lines 14 to 16 as in A (vii) and (viii) above.

(iv) Enter accepted mean height of point in line 17.

Air Survey **SECTION** No.1 Field Survey **COMPANY.** **DATE** 1939 – 40

Computation of Heights from Oblique Air Photographs by machine, slide rule or comptometer.

Survey Waziristan Area 3 Strip No. 18 Camera No. I.W.S/8 Lens 10" Focal Length (f) = 10·100 **(A)**

Sheet No. 38 H/14 Horizon No. See line 2 from 31 Air page First approx. horizon $1/f$ = 0·09 901 **(B)**

			← Using Comptometer →				← Using Rotary Machine →				← Using slide rule →	
1	Point No.		K/23	Y/271	Y/230	J/11	J/11	Y/271	V/50	Y/269	← Y/271 →	
2	Photograph No. (Horizon No.)		←	24 085 (1)	→	→	←	24 087 (1)	→	→	24 085 (2)	24 087 (2)
3	Elevation in inches of point above horizon on photo = E		– ·578	– ·325	– 1·621	– ·714	– ·778	– ·367	– 2·521	– 1·036	– 0 375	– 0 389
4	Distance in inches of horizon above principal point = d		2·613	2·613	2·613	2·613	2·811	2·811	2·811	2·811	2 475	2 824
5	(i)	(i) $E/f=(3)\times(B)$	–0·0572	–0·0322	–0·1605	–0·0707	–0·	–0·	–0·	–0·	–0·	–0·
6	$d^2/f=\left[\frac{(4)\div(A)}{(4)\times(B)}\right]^{(ii)}\times(4)$	$d/f=(4)\times(B)=\tan\theta$	0·2 587	0·2 587	0·2 587	0·2 587	0·7 823	0·7 823	0·7 823	0·7 823	0·7 085	0 7 8·0
7		$\tan\alpha=(5)+(6)$	+0·2 915	+0·2 265	+0·0 982	+0·1 880	–0·	–0·	–0·	–0·	–0·	–0·
8	$f+d^2/f=(A)+(6)$	$\alpha=\tan^{-1}(7)$	+ 1° 23′ 30″	+ 12° 45′ 40″	+ 5° 36′ 50″	+ 10° 38′ 50″	+10·8 823	+10·8 823	+10·8 823	+10·8 823	+10 8 085	+10·8 9·0
9	$E\times d/f=\left[\frac{(4)\div(A)}{(4)\times(B)}\right]^{(ii)}\times(3)$	$\theta=\tan^{-1}(6)$	+ 14° 30′ 20″	+ 14° 30′ 20″	+ 14° 30′ 20″	+ 14° 30′ 20″	– 0·2 165	– 0·1 021	– 0·7 016	– 0·2 883	– 0 0 993	– 0·1 089
10	(8)+(9)	$e=\alpha-\theta=(8)-(9)$	– 3° 06′ 50″	– 1° 44′ 40″	– 8° 55′ 50″	– 3° 51′ 30″	+10·6 658	+10·7 802	+10·1 807	+10·5 940	+10·7 092	+10·7 821
11		$\tan e=\tan(10)$	–0·0 544	–0·0 304	–0·1565	–0·0 674	–0·	–0·	–0·	–0·	–0·	–0·
12	Distance in feet of point from camera station along principal line		46 293	40 531	10 426	37 243	38 007	40 973	8 377	27 965	40 531	41 022
13	Diff. of height (feet) $=(3)\times(12)\div(10)$	Diff. of height (feet) $=(11)\times(12)$	– 2 518	– 1 232	– 1 632	– 2 510	– 2 771	– 1 393	– 2 074	– 2 735	– 1 418	– 1 480
14	Curvature and refraction corrn. (feet)		+ 44	+ 34	+ 2	+ 29	+ 30	+ 35	+ 1	+ 16	+ 34	+ 35
15	Height of Aircraft (in feet)		9 089	9 089	9 089	9 089	9 142	9 142	9 142	9 142	9 117	9 171
16	Algebraic sum = Ht. of point in feet		6 615	7 891	7 459	6 608	6 401	7 784	7 069	6 423	7 733	7 726
17	Accepted Mean with reference		-	-		-	-		-	-	← 7 730 →	

NOTES:—(i) Use left hand column with slide rule or rotary calculating machine. Use right hand column with comptometer, taking (B) from heading.
(ii) Take (A) or (B) from heading using (4)+(A) with slide rule and (4)×(B) with machine.

Computed by *Date* *Checked by* *Date*

G.B.—P.O.—J.S. 539-B/258—18-10-44—700.

32 (a) AIR

Line 1. Set up the points identified on the photographs using 2 or more columns if the point is to be measured in 2 or more photographs.

Line 2. Write down the numbers of the photographs on which the points have been identified and marked for measurement.

Line 3. Enter up the distances in inches of points above horizon line. (−ve if below).

Line 4. Enter up the distances in inches measured from principal point to the junction of principal line and the horizon line.

Line 5. Enter up the distances of points from plumb point measured in any units (normally inches) on plot along the principal line of the photograph concerned.

Line 6. Enter up the distances of points from plumb point of central (reference) photograph measured in any units on plot along the principal line.

Line 7. Enter up the distances of points measured in any units on plot at right angles from the principal line for the central (reference) photograph. The distances to the right left of the principal line are plus/minus.

WORKING WITH 20" SLIDE RULE.

Line 8. Set cursor to line 4 on A. Set f (in the heading) on scale B under cursor, read values on scale A against 1 on scale B and enter in line 8 with appropriate sign and decimal point.

Line 9. With rule set as in line 8, slide cursor to line 4 on scale B read values on scale A and enter them in line 9.

Line 10. Complete line 10.

Line 11. With rule set as in line 8, slide cursor to line 3 on scale B and read values on scale A and enter them in line 11, (do all points in one photograph consecutively).

Line 12. Add up lines 10 and 11.

Line 13. Set cursor to line 3 on A. Set line 12 on scale B under the cursor. Slide cursor to line 5 on scale B read off values on scale A and enter them in line 13 with appropriate sign and decimal point.

Before further computation on this form can be carried out form 32 (c) Air must be completed.

Line 14. Copy out the corrections from Form 32 (c) Air for the photographs concerned.

Complete lines 15 and 16.

Before further computation can be carried out control must be received and Form 32 (b) Air completed.

Line 17. Set Scale Factor (S) (in the heading of the form) on scale A over 1 on scale B. Slide cursor to line 16 on scale B, read off the values on scale A and enter up in line 17.

Line 18. Look up curvature corrections from 17 Sur. for the distances $X_R \times$ (S) and enter up in line 18.

NOTE :—This is not the true distance required for refraction but is sufficiently close to it for this is not very rigorous method.

Line 19. Set 1 on scale B under (S) on scale A, slide cursor to $\delta\theta$ (in the heading and constant for all) on scale B. Bring 1 on scale B under the cursor, slide cursor to line 6 on scale B, read off the values on scale A and enter up in line 19 with opposite sign.

Line 20. Set 1 on scale B under (S) on scale A, slide cursor to $\delta\phi$ (in the heading and constant for all) on scale B. Bring 1 on scale B under the cursor, slide cursor to line 7 on scale B, read off the values on scale A and enter up in line 20 with opposite sign.

Line 21. Copy out the height of Aircraft from Form 32 (b) Air with positive sign.

Line 22. Complete line 22 by adding lines 17 to 21 with proper sign.

32 (a) Air

Survey of India

Page.....

Air Survey SECTION No.1 Ind. F.d. Svy COMPANY. DATE 1940

Heights from oblique air photographs (assumed horizon)

Survey Nowshera Ex. 1939 (Shalau Area)

Camera 27 M

Focal length (f) = 10·053 in.

Scale Factor S(i) = 1962·5 (Computed from scaled plot)

From form 32 (b) Air $\begin{cases} \delta\theta = -0\cdot \\ \delta\phi = -0\cdot \end{cases}$

1	Point No.	←	→							
2	Photo No.	45 531	45 530							
3	Elevation in inches of point above horizon on photo = E	− 0·98	− 0·98	− ·	− ·	− ·	− ·	− ·	− ·	− ·
4	Distance in inches of horizon above principal point = d	2·975	3·010	·	·	·	·	·	·	·
5	$X^{(ii)}$	11·66″	11·27″							
6	$X_B{}^{(iii)}$	11·00								
7	$Y_B{}^{(iii)}$	+ 1·02	−	−	−	−	−	−	−	−
8	d/f	0·2959	0·2994	·	·	·	·	·	·	·
9	d^3/f	0·880	0·901	·	·	·	·	·	·	·
10	$f + d^2/f = f$ + line (9)	10·935	10·956	·	·	·	·	·	·	·
11	$E \times d/f$ = line (3) × line (8)	− 0·2900	− 0·2934	− ·	− ·	− ·	− ·	− ·	− ·	− ·
12	Sum = line (10) + line (11)	10·645	10·663	·	·	·	·	·	·	·
13	Line (3) × line (5) ÷ line (12) = D	− 1·073	− 1·036	− ·	− ·	− ·	− ·	− ·	− ·	− ·
14	Mean correction to $D^{(iv)}$	+ 0·004	− 0·024	− ·	− ·	− ·	− ·	− ·	− ·	− ·
15	Sum = D′	− 1·069	− 1·060	− ·	− ·	− ·	− ·	− ·	− ·	− ·
16	Mean D′	− 1·064	−	−	−	−	−	−	−	−
17	D′ × S = depth in feet	− 2 088	−	−	−	−	−	−	−	−
18	Curvature and refraction correction	+ 10	+	+	+	+	+	+	+	+
19	$-X_B\,\delta\theta \times S$	+ 235	−	−	−	−	−	−	−	−
20	$-Y_B\,\delta\phi \times S$	+ 44	−	−	−	−	−	−	−	−
21	Height of Aircraft	3 340								
22	Sum = Mean height of point	← 1 541	→							

Computed by *Date* *Checked by* *Date*

Notes:— (i) S is the factor by which X, X_B and Y_B must be multiplied to convert them to the actual distances *in feet* which they represent on the ground.

(ii) X is the distance of the point from the plumb point of the photograph concerned measured in any units along the principal line on the outline plot.

(iii) X_B and Y_B are distances in the same units as X of the point from the plumb point of the central (reference) photograph measured on the outline plot along and at right angles to the principal line of the reference photograph respectively. Distances Y_B are *plus* to the right of the principal line and *minus* to the left.

(iv) To reduce to the plane of the central (reference) air station. From form 32(c) Air.

G.B.—P.O.—J.S. 538-B/268—18-10-44—500.

COMPLETE READINGS

Line 1. Select 3 reliable points forming a good triangle and enter up in line 1 under A, B & C. Enter up the 4th point as a check point.

Line 2. Enter up the heights of points from the available data.

Lines 3 & 4. For the point concerned, copy out lines 17 and 18 of Form 32 (*a*) Air in lines 3 and 4 respectively.

Complete lines 5 and 6.

Line 7. Set 1 on scale B under (S) (from Form 32*a* Air) on scale A, slide cursor to X_R (from Form 32*a* Air for the point concerned) on scale B, read off the values on scale A and enter in line 7. (Or, Using Machine, Set (S) on S.L. and multiply by X_R for points concerned).

Line 8. With the rule set in line 7, slide cursor to Y_R (from Form 32*a* Air for the point concerned) on scale B, read off the values on scale A and enter in line 8 with resulting sign. (Or using machine, set (S) on S.L. and multiply by Y_R for points concerned).

Complete lines 9 to 11 with proper sign.

Line 12. Set cursor to line 10 on A, set line 9 on scale B under the cursor, read values on scale A against 1 on scale B and enter in line 12 with proper sign and decimal point. Repeat for line 12*a* as described for line 12. (Or, Using machine, set line 10 in P.R. and divide by line 9).

Line 13. Set cursor to line 11 on A. Set line 9 on scale B under the cursor, read values on scale A against 1 on scale B and enter in line 13 with proper sign and decimal point. Repeat for line 13*a* as described for line 13. (Or, Using machine, set line 11 in P.R. and divide by line 9).

Line 14. *Working with Brunsviga Twin 13 Z.*—Set line 13 on L.H.S.L. and line 13*a* on R.H.S.L. Connect machines in parallel or opposition according as lines 13 and 13*a* have the same or opposite sign. Turn handle once forward if line 13*a* is positive and backward if it is negative. Clear S.L. and M.R. Set line 12 on L.H.S.L. and line 12*a* on R.H.S.L. Connect machines in parallel or opposition according as lines 12 and 12*a* have the same or opposite sign. Equalise both P.Rs. Then $\delta\theta$ will appear in the P.R. and $\delta\phi$ in the M.R. If P.R. is a complement (i.e. negative) then $\delta\theta$ will be positive. $\delta\phi$ is positive when line 12*a* is + and machine was driven forwards, or when line 12*a* is — and machine was driven backwards. Otherwise it is negative.

Working with a 20-inch slide rule.—Subtract line 13 from line 13*a* with proper sign. Set cursor to result on scale A.

Subtract line 12*a* from line 12 with proper sign and set result on scale B under the cursor, read values on scale A against 1 on scale B and enter them against $\delta\phi$ with proper sign and decimal point.

With the rule set, slide cursor to line 12 on scale B, read values on scale A, add these values in line 13 mentally with proper sign and decimal point and enter sum against $\delta\theta$ with opposite sign.

Working with Single Machine.—Compute $\delta\phi$ by the second formula given at foot of form as follows:— Subtract line 12 from line 12*a* and record in last column of line 12 with correct sign. Subtract line 13*a* from line 13 and record with correct sign in last column of line 13. Divide last column line 13 by last column line 12 and record with correct sign and decimal place against $\delta\phi$.

Clear S.L., M.R., and P.R. Set $\delta\phi$ on S.L. and multiply by line 12. Add line 13 to product with correct sign. Enter $\delta\theta$ with its correct sign in line 14. (Note the formula gives $-\delta\theta$).

Check by multiplying figures set by line 12*a* and adding line 13*a*. The second value of $\delta\theta$ thus obtained should agree with the first.

Line 15. Set 1 on scale B under $\delta\theta$ on scale A, slide cursor to line 7 on scale B, read off the values on scale A and enter in line 15 with proper sign and decimal point.

Line 16. Set 1 on scale B under $\delta\phi$ on scale A, slide cursor to line 8 on scale B, read off the values on scale A and enter in line 16 with proper sign and decimal point.

Line 17. Complete line 17 by adding lines 6, 15, 16 with proper sign.

Air Survey SECTION 1 Ind Fld Sqy COMPANY. DATE [illegible]

Rectification of assumed horizon on oblique air photographs

Survey 1939 by Camera 27 [illegible] Photo No. 45529 Ref. Form 32 (a) Air, pages [illegible]
(Shimla Area)

			A	B	C	Check Point
1	Point No.		110	[illegible]	37	[illegible]
2	Height in feet		2299	1955	964	[illegible]
3	Mean height difference [from form 32(a) Air, line 17]		− 1060	− 2314	− 2182	− 2485
4	Curvature & refraction corrn.		3	3	3	4
5	Sum = δh		− 1047	− 2311	− 2179	− 2481
6	Lines (2) − (5) = h		3346	3404	3143	3438
7	X (feet) = $X_R \times S$ [from form 32(a) Air]		24410	13710	[illegible]	13806
8	Y (feet) = $Y_R \times S$ [from form 32(a) Air]		− 11780	− 3685	− [illegible]	− 3626
9	$X_A - X_B$	9a	$X_B - X_C$	+ 10700	+ 1570	
10	$Y_A - Y_B$	10a	$Y_B - Y_C$	− 7895	+ 11015	
11	$h_A - h_B$	11a	$h_B - h_C$	− 58	+ 261	
12	Line (10) / Line (9)	12a	Line (10a) / Line (9a)	− .738	+ 7.015	+ 7.753
13	Line (11) / Line (9)	13a	Line (11a) / Line (9a)	− .00542	+ .1662	− 0.17162
14	$\delta\theta$ (i)	14a	$\delta\phi$ (i)	− .0109	− .0221	
15	X · $\delta\theta$ (ii)		− 266	− 149	− 132	− 130
16	Y · $\delta\phi$ (ii)		+ 260	+ 86	+ 329	+ 62
17	Height of Aircraft = lines (6) + (15) + (16)		3340	3341	3340	3350

(i) $\delta\theta$ = line (12) × $\delta\phi$ + line (13)
= line (12a) × $\delta\phi$ + line (13a)

$\delta\phi = \frac{\text{line (13)} - \text{line (13a)}}{\text{line (12a)} - \text{line (12)}}$

$\delta\theta$ = downward angle along principal line which the assumed (nearly) horizontal reference plane makes with the truly horizontal plane.

$\delta\phi$ = angle (down on right) at right angles to the principal line which the assumed horizontal reference plane makes with the truly horizontal plane.

(ii) X and Y from lines (7) and (8) respectively.

Computed by *Date* *Checked* *Date*

G.B.—P.O.—J.S. 266—16-11-40—1,000.

32 (c) AIR

COMPLETE HEADINGS.

Column No. 1. Enter up the numbers of the two photographs (A & B) containing common points. B is the photograph whose number is nearer to that of the central (reference) photograph.

Column No. 2. Enter up the number of common points which have been marked on the two photographs A and B for measurement and computation Form 32 (a) Air.

Column No. 3. Write down the differences (D for B photograph *minus* D for A photograph) with appropriate sign, D being taken from line 13 of Form 32 (a) Air. Total the differences obtained using all common points with proper sign, write down against sum and take out the mean.

Column No. 4. Write down the number of A photograph and the algebraic sum of the mean differences for all pairs of photographs between A and the central (reference) photograph. The figure thus obtained is that required for entry at line 14 on form 32 (a) Air.

Survey of India

SECTION No.1 Ind. Ed Survey COMPANY DATE 2.12.39

Computation of Mean Corrections to Depths of points from oblique photographs
(for entry in line 14 of Form 32 (a) Air)

Survey Military Ex 1939 (Shaidu Area) Camera 27 M Strip No. 1

Focal length 10·055 ins. Ref. Form 32 (a) Air, Pages 1–11

Correction for :— (A to B) (i)	Common Point No.	$D_B - D_A$ (ii)	Total Correction for Photo A (iii)		Correction for :— (A to B) (i)	Common Point No.	$D_B - D_A$ (ii)	Total Correction for Photo A (iii)	
			Photo No.	Correction				Photo No.	Correction
34 to 33	1	+ ·005			28 to 29	17	+ ·026		
	2	+ ·010				18	+ ·036		
						19	+ ·031		
			45 534	− 0·017		18a	+ ·070	45 528	+ 0·041
						19a	+ ·055		
						21	+ ·029		
	Sum	+ ·015				Sum	+ ·247		
	Mean	+ ·007				Mean	+ ·041		
33 to 32	3	− ·028			27 to 28				
						20	+ ·042		
	4	− ·013				22	+ ·042		
			45 533	− 0·024		131	+ ·019	45 527	+ 0·075
						23	+ ·0		
	Sum	− ·041				Sum	+ ·137		
	Mean	− ·020				Mean	+ ·034		
32 to 31	5	+ ·004			26 to 27	24	+ ·040		
	6	+ ·009				25	+ ·035		
						26	+ ·014		
	7	− ·037	45 532	− 0·004		27	+ ·007	45 526	+ 0·099
						131	+ ·023		
	Sum	− ·024				Sum	+ ·119		
	Mean	− ·008				Mean	+ ·024		
31 to 30					25 to 26				
	8	+ ·035				28	+ ·036		
						29	+ ·032		
	9	+ ·037	45 531	+ 0·004		30	+ ·020	45 525	+ 0·129
	10	+ ·013				110	+ ·032		
	Sum	+ ·085				Sum	+ ·120		
	Mean	+ ·028				Mean	+ ·030		
30 to 29	11	− ·039			to				
	12	− ·025							
	13	− ·053							
	13a	− ·054	45 530	− 0·024					
	14	− ·002							
	14a	− ·016							
	15	+ ·007							
	16	− ·008							
	Sum	− ·190				Sum			
	Mean	− ·024				Mean			

NOTES. (i) A and B are photographs containing common points. The number of B is nearer to that of the central (reference) photograph.
(ii) D_B and D_A from Form 32 (a) Air, line 13.
(iii) Sum of Mean differences for all pairs of photographs between A and the central (reference) photograph.

Computed by *Date* *Checked by* *Date*

G.B.—P.O.—J.S. 244—7-11-40.—1,000.