SPECIFICATIONS FOR SECOND ORDER TELLUROMETER TRAVERSING

These Specifications, which should be read in conjunction with the specimen Traverse Field Book, comprise 7 Sections as follows:-

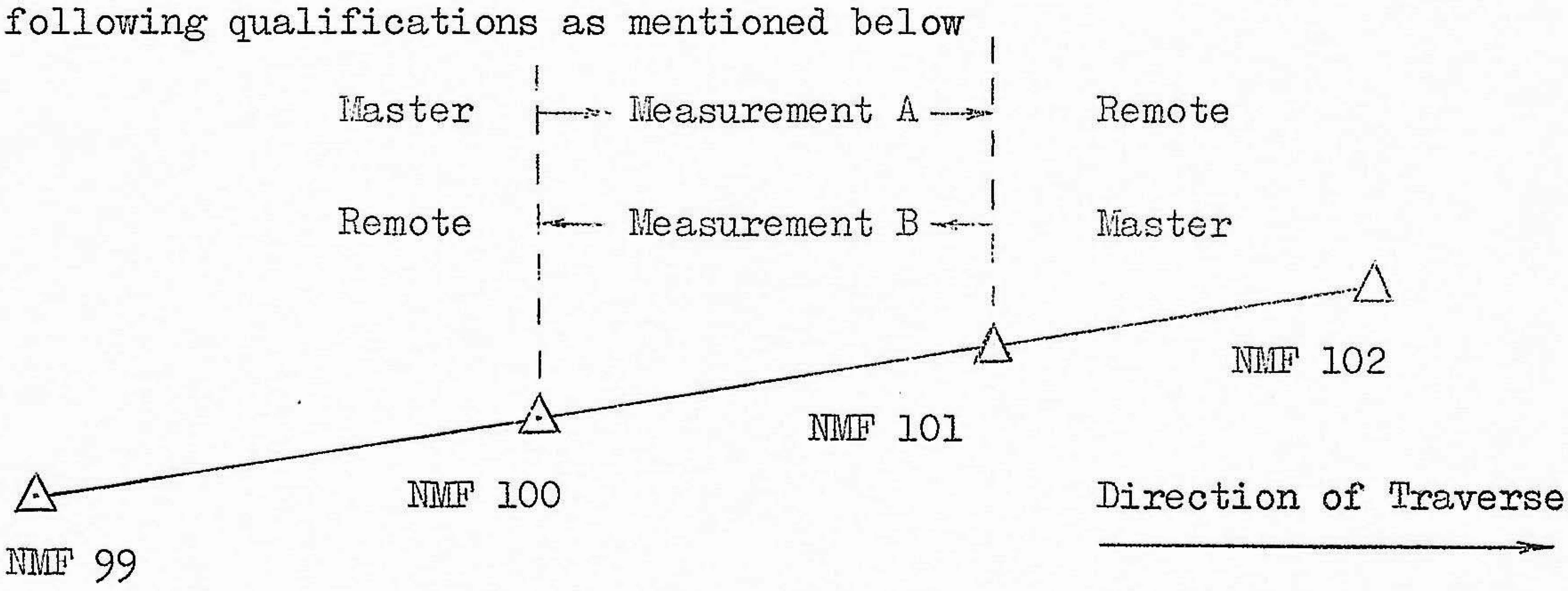
1. Second Order Tellurometer Measurements.
2. Second Order Horizontal Angles using Wild T3 or T2.
3. Second Order Vertical Angles using Wild T3 or T2.
4. Second Order Traverse Marking.
5. Second Order Azimuth Observations using Wild T3 or T2.
6. Access Notes.
7. Field Computation.

SPECIFICATIONS - SECOND ORDER TELLUROMETER TRAVERSE

1. 2ND ORDER TELLUROMETER MEASUREMENTS

1.1. In general, well-established procedures as outlined in the Instruction Manual issued by the makers will be observed at all times, with the following qualifications as mentioned below

1.2.



A complete Tellurometer measurement will comprise two distinct parts:-

1.2.1. Measurement A, from Ground Mark to Ground Mark, with master at the rear station (NMF 100), measuring towards the forward station (NMF 101).

1.2.2. Measurement B, from Ground Mark to Ground Mark, with master at the forward station (NMF 101), measuring towards the rear station (NMF 100).

1.2.3. The arithmetic mean of Measurement A and Measurement B will be adopted as the final measurement.

1.2.4. Normally all measurements will be observed from the Ground mark, but where it is not possible to set over the Ground Mark (for example, to avoid dismantling and rebuilding a large cairn), an Eccentric Station will be established over one of the Reference Marks. This Eccentric Station will be connected by angle to an adjacent distant station; by angle and distance to the centre pole of the cairn if standing, otherwise to the estimated centre of the cairn; and by angles and distances to all other Reference Marks. The theodolite will then be set over a second Reference Mark and angles and distances taken to centre pole of cairn, and also to all other Reference Marks. This will give a complete check on the Eccentric Station and on the Reference Marks.

1.2.5. All traverse angles and all Tellurometer measurements will be read from such an Eccentric Station and reduced to the centre of the Ground Mark. (See Specimen Field Book)

1.2.6. Angles and Tellurometer measurements read at an Eccentric Station will be clearly marked "Eccentric".

* 16 CAVITIES TO BE READ ~~1.3. Fine readings will be taken on cavities 10, 9, 8, 7, 6, 5, 4, 3.~~

1.4. If ground swings exceed 6 mms, or the comparison of Measurement A with Measurement B is worse than 1:75,000 both measurements will be repeated using 16 cavities, 10, $9\frac{1}{2}$, 9, $8\frac{1}{2}$, 8, $7\frac{1}{2}$, 7, $6\frac{1}{2}$, 6, $5\frac{1}{2}$, 5, $4\frac{1}{2}$, 4, $3\frac{1}{2}$, 3, $2\frac{1}{2}$.

1.5. Vapour pressure readings at each end must agree to less than .040 unless sufficient evidence of stable atmospheric conditions can be furnished.

1.6. Atmospherics will be observed with approved psychrometers, and with approved barometers (or altimeters) in batteries of three, which have been calibrated not more than one month previously against a mercury barometer of the Kew or Fortin type. These atmospherics will be taken at each end immediately before and after the fine readings of Measurement A, and also before and after the fine readings of Measurement B.

1.7. Coarse readings will be taken on cavities 10, 5, 3 immediately before the first atmospherics and also after the second atmospherics of each measurement for both Measurement A and Measurement B. These coarse sets will be resolved at once and compared before breaking contact. This is essential.

1.8. Tellurometers must cycle 4 times before commencing fine readings.

1.9. Summarizing

1.9.1. Make contact on cavity 5.

1.9.2. Coarse readings on cavities 5, 3, & 10.

1.9.3. Atmospherics.

1.9.4. Fine readings on 10, 9, 8, 7, 6, 5, 4, & 3. USE ½ CAVITIES

1.9.5. Atmospherics.

1.9.6. Coarse readings on cavities 3, 5, 10.

1.9.7. Switch to remote operation.

1.9.8. Coarse readings on 10, 5, & 3, and re-tune back on cavity 10.

1.9.9. Atmospherics.

1.9.10. Fine readings as above in 1.9.4.

1.9.11. Atmospherics.

1.9.12. Coarse readings on 3, 5, & 10.

1.9.13. Break out and compare means of coarse sets of Measurement A and of Measurement B.

2. 2ND ORDER HORIZONTAL ANGLES USING WILD T3 or T2.

2.1. Observing Technique:

Generally the observing procedure for geodetic observations will be used, as follows:-

2.1.1. Targets will be observed in the late afternoon.

2.1.2. Wild T3 or Wild T2 or equivalent 1" instruments will be used, and four sets, each set of six arcs, will be observed. Unless there is obvious trouble, four sets with such instruments will suffice. (See typical sets of horizontal observations and also circle and micrometer settings, for Wild T3 and Wild T2, which are attached).

2.1.3. Since two stations only will be observed in most instances on this work, the procedure Face Left Swing Left, and Face Right Swing Right will apply (see attached examples).

2.1.4. The usual system of double pointings and readings will be used, thus: Face Left, pointing, reading, pointing, reading on Rear Station, then swing Left to Forward Station and take pointing, reading, pointing, reading on it. The instrument is then reversed Face Right on the Forward Station and pointing, reading, pointing

Reading are made on it, and then swung Right to Rear Station to take pointing, reading, pointing, reading. The circle and micrometer are then moved to the next setting. In pointing, the cross wire is brought on the target against the spring of the tangent screw, the micrometer read, the cross wire moved slightly, then again intersecting the target against the tangent spring and the micrometer read a second time.

2.1.5. An arc of double pointings forms a zero or arc, and six zeros form one set. See attached example.

2.1.6. If the range of readings of the six arcs of a set exceeds 8 seconds, another set will be observed when conditions are better. The most accurate period to observe horizontal angles is from 2 hours before Sunset until about 1 hour after Sunset.

2.2. Random Arcs:

From a random initial reading on the R.O. or Back Station in one of the sets, two arcs will be read (consisting of two pointings Face Left, then two pointings Face Right) to the Forward Station. This will ensure that the degrees and minutes have not been read consistently wrong. (See examples).

2.3. Targets:

Targets will be lamps or helios or opaque signals placed, wherever possible, on the line from Ground Mark to Ground Mark (possibly over a Reference Mark on line as described in the notes on Marking, Paragraph 4.2.3.2.)

THE CONTRACTOR WILL RECORD WHAT TYPE OF TARGET IS OBSERVED (WHETHER LAMP, HELIO, BEACON, ETC) AND THAT TARGETS ARE ON LINE OR ECCENTRIC.

2.4. Theodolite Stand-Point:

This is the greatest source of angular errors and care will be exercised in all set-ups. All nuts, screws, shoes, etc., will be inspected frequently for correct tension. A set-up on solid rock or on hard earth surface is usually quite satisfactory, although on occasions plaster of paris or rocks will be needed to prevent slipping. In sand or loose gravel or spongy clay, gypsum, etc., 36" X 3" X 3" or 18" X 3" X 3" pegs will be driven, in the direction of each leg, and the tops bored for the ferrules of the legs. When the ground is stony, one inch internal diameter pointed pipes 15" long, will be necessary.

2.5. Screens:

The theodolite and legs will be protected from dislevelment and twist caused by the sun by a well-guyed umbrella or screen. A screen will be used where wind can affect accuracy.

2.6. Sequence:

The sequence of setting first on the Rear Station as R O then swinging to read the Forward Station will be followed. Thus any traverse angle shown in the field book or any list of angles will be the clockwise angles from Rear Station to Forward Station.

3. 2ND ORDER VERTICAL ANGLES USING WILD T2 and T3.

3.1. Time of Observations:

Vertical angles will be truly simultaneous by radio or helio flash, and will be read between 1400 hrs. and 1600 hrs. L.M.T. when the air is most evenly heated. However, if lines are less than 10 miles in length, they may be observed from 1000 hrs. to 1700 hrs., but they still must be observed simultaneously. Lines less than 2 miles in length may be read non-simultaneously.

3.2. Observing Technique:

A system of double pointings on each face is to be used, as in horizontal angles, intersecting the cross-hair on the target twice on each face against the tangent spring.

Typical sets of vertical observations as observed with T2 and T3 theodolites are shown in the attached notes.

Two such sets of vertical angles are required, with about half an hour between the sets.

- Note that a Face Left and Face Right form an arc or zero, and that two such arcs, (always commencing each arc or Face Left and then Face Right), totalling 8 pointings in all, comprise one set when observing with a Wild T3.

- Note that three such arcs (always commencing each arc or Face Left and then Face Right) and totalling 12 pointings in all, comprise one set when observing with a Wild T2.

IT IS ESSENTIAL THAT THE VERTICAL BUBBLE BE MOVED AFTER EACH POINTING AND RECENTRALIZED IMMEDIATELY PRIOR TO READING THE MICROMETER, EVEN THOUGH THE BUBBLE IS APPARENTLY CENTRAL FROM THE PREVIOUS READING. THIS HELPS TO EVEN OUT ERRONEOUS READINGS ARISING FROM FLAT SPOTS IN THE GRINDING OF THE LEVEL VIAL.

3.3 Targets:

Targets will be Lucas lamps or helios or approved signals and the respective heights of theodolites and targets will be recorded immediately after each set of observations.

3.4 Accuracy:

Where A1 and A2 = Vertical angles at A
and B1 and B2 = " " " B

$$\text{if} \quad \frac{A1 + (-B1)}{2} = P \quad \text{and} \quad \frac{A2 + (-B2)}{2} = Q$$

then (P - Q) will not exceed 3 seconds of arc for a line 40 miles in length.

SET OF HORIZONTAL ANGLES

WILD T3

At Station NM F 162
Observer N. Davy
Recorder G. Gray
Theodolite Wild T3 29123

Day and Date Wednesday 18th August, 1966
Weather Humid, 5/8 cloud in West, calm.
Visibility Slight shimmer to both stations
Time Started 1800
Time Finished 1809

NM/F/161	R.O.	Lucas Light	NM/F/163	Lucas Light		
12° 26'	06.3 06.3	12.6	228° 38'	59.4 59.2	58.6	46.0
192° 26'	01.8 02.5	04.3	48° 38'	56.8 58.1	54.9	50.6
255° 00'	25.6 25.3	50.9	14'	18.4 19.9	38.3	47.4
75° 00'	29.0 29.0	58.0	14'	24.6 24.0	48.6	50.6
135° 00'	46.2 46.6	32.8	14'	40.1 39.8	19.9	47.1
315° 00'	41.5 41.9	23.4	14'	35.5 37.1	12.6	49.2
00° 00'		00"00	216° 13'		6	50.9 48.48"

SET OF HORIZONTAL ANGLES

WILD T2

At Station NM G 122
Observer L. Smith
Recorder D. Brown
Theodolite Wild T2 27419

Day and Date Monday 17th April 1966
Weather Cool, clear: gusty E. breeze
Visibility Good to both stations
Time Started 1742
Time Finished 1751

NM G 121	R.O.	Lucas Light	NM G 123	Lucas Light		
208° 33'	14 12	13.0	342° 55'	14 16	15.0	02.0
28° 33'	13 16	14.5	162° 55'	17 18	17.5	03.0
90° 05'	31 32	31.5	27'	36 37	36.5	05.0
270° 05'	28 28	28.0	27'	35 33	34.0	06.0
330° 08'	50 51	50.5	30'	52 51	51.5	01.0
150° 08'	54 54	54.0	30'	56 55	55.5	01.5
00° 00'		00"0	134° 22'		6	18.5 03"08

SET OF VERTICAL ANGLES

At Station:	NM F 185
Day, Date & Time:	Tuesday 28th August, 1962 14.48 W.A.T.
Reliability of Observation:	Light, gusty wind; considerable
	shimmer, Simultaneous Reciprocal.
Station Observed:	NM F 184
Target Observed:	Helio
Ht. Inst. above Ecce:	
Ht. Inst. above Station Mark:	5!01
Ht. Target Shown above:	0!76 below Inst.
Ht. Target Shown above Station Mark:	4!25

WILD T3

L	89	54	26.1 26.7	89	54	52.8	
R	90	04	12.0 12.1	90	04	24.1	- 00° 09' 31"3
L	89	54	27.4 25.7	89	54	53.1	
R	90	04	13.9 12.0	90	04	25.9	- 00° 09' 32"8

4.1

Mean - 00° 09' 32"0

WILD T2

L	89	32	24 27	25.5	00	27	34.5	
R	270	27	33 31	32.0		27	32	+ 00° 27' 33"2
L	89	32	27 28	27.5	00	27	32.5	
R	270	27	25 29	27.0		27	27	+ 00° 27' 29"8
L	89	32	25 28	26.5	00	27	33.5	
R	270	27	27 28	27.5		27	27.5	+ 00° 27' 30"5

3.5

Mean + 00° 27' 31"2

2ND ORDER TRAVERSE

WILD T3 SETTINGS

	1.						2.			
L. Face	00°	00'	05"	Swing L.		R. Face	210°	02'	15"	Swing R.
R. "	180	00	05	" R.		L. "	30	02	15	" L.
R. "	240	00	25	" R.		L. "	90	02	35	" L.
L. "	60	00	25	" L.		R. "	270	02	35	" R.
L. "	120	00	45	" L.		R. "	330	02	55	" R.
R. "	300	00	45	" R.		L. "	150	02	55	" L.

	3.						4.			
L. Face	13°	17'	05"	Swing L.		R. Face	225°	02'	15"	Swing R.
R. "	193	17	05	" R.	(Random)	L. "	45	02	15	" L.
R. "	255	00	25	" R.		L. "	105	02	35	" L.
L. "	75	00	25	" L.		R. "	285	02	35	" R.
L. "	135	00	45	" L.		R. "	345	02	55	" R.
R. "	315	00	45	" R.		L. "	165	02	55	" L.

WILD T2 SETTINGS

	1.						2.			
L. Face	00°	00'	30"	Swing L.		R. Face	210°	02'	10"	Swing R.
R. "	180	00	30	" R.		L. "	30	02	10	" L.
R. "	240	03	50	" R.		L. "	90	05	30	" L.
L. "	60	03	50	" L.		R. "	270	05	30	" R.
L. "	120	07	10	" L.		R. "	330	08	50	" R.
R. "	300	07	10	" R.		L. "	150	08	50	" L.

	3.						4.			
L. Face	13°	23'	30"	Swing L.		R. Face	225°	02'	10"	Swing R.
R. "	193	23	30	" R.	(Random)	L. "	45	02	10	" L.
R. "	225	03	50	" R.		L. "	105	05	30	" L.
L. "	75	03	50	" L.		R. "	285	05	30	" R.
L. "	135	07	10	" L.		R. "	345	08	50	" R.
R. "	315	07	10	" R.		L. "	165	08	50	" L.

4. <u>2ND ORDER TRAVERSE MARKING</u>

4.1. 2nd Order Tellurometer Traverses will be carried out either:-

4.1.1. to mark points of control along parallels of latitude, or along meridians of longitude, at approximately degree and half degree intervals;

4.1.2. or when specified by the Director of National Mapping, to measure and mark a control survey around or across some irregular area.

4.2. <u>Placing Control along Parallels or Meridians</u>:

4.2.1. Where points of control are required along parallels or along meridians, they will be placed at each degree or half degree position within the following tolerances:-

4.2.1.1. The point of control, marked on the ground, will not be further than 0.25 miles in Latitude and 2.0 miles in Longitude from the desired position.

4.2.1.2. In some instances the required position will be defined on a map or diagram and the marking will conform to this position.

4.2.2. Wherever possible such degree and half degree marks will form part of the continuous traverse, and will not be the terminal station of some spur connection.

4.2.3. These degree and half degree positions will be marked as follows:-

4.2.3.1. The Ground Mark will be a 3 to 6 inch length of $\frac{1}{2}$ inch diameter copper tube set centrally in a concrete block 7" X 7" X 15" deep, poured in situ. Where the ground allows, a length of $\frac{1}{2}$ inch diameter galvanized pipe or a star picket, 24 inches long will be driven vertically and centrally in the hole before the cement is poured. This will help prevent subsequent disturbance or removal of the mark. The top of this driven pipe or picket will be about an inch below the bottom of the central copper tube. The top of the copper tube will be just flush with the top of the concrete and will not protrude. It is important that the copper tube is central in the top of the concrete formation, the top surface of which will be a pyramid about 2 inches high above the ground level and painted with white plastic paint such as Berger Breeze. The number of the station will be painted neatly and boldly in black plastic paint on the white surface.

4.2.3.2. Two Reference Marks will be emplaced vertically about 20 feet from the Ground Mark, and exactly along the lines of the two observed adjacent stations. These Reference Marks will be star pickets or preferably $\frac{1}{2}$ inch diameter galvanized water pipe 24 inches long. They will be driven vertically and flush with the ground, or to refusal, and then cut off at ground level. The exact centre of the top of the star picket or of the top of the pipe will be the reference point.

4.2.3.3. Wherever stone is reasonably available, a ring of rocks about 12 inches high, 12 inches wide at the top, and 12 feet in diameter, will be built symmetrically around the Ground Mark. The tops of these stones will be painted with a mixture of powdered lime (LIMIL) 4 parts; and cement 1 part, and water.

Where stone is not reasonably available, a symmetrical circular trench, 12 ft. in diameter, 2 feet wide and 18" to 24" deep, will be dug symmetrically around the Ground Mark. The spoil will be neatly mounded in a ring outside the trench, with the inner edge of the spoil 12 inches from the outer edge of the trench, so that it will not fall back into the trench.

4.2.3.4. Where suitable trees are available, one or two referenced blazes will be made, and the reference measurements made to galvanized roofing nails driven symmetrically in the shields.

4.2.3.5. A witness Post, 4 feet long by 2 inch diameter galvanized water pipe will be emplaced about 20 feet from the Ground Mark and referenced by bearing and distance. It will be vertical, about 18 to 24 inches in the ground, with a concrete bedding 5" X 5" X 6" deep at the bottom of the hole to prevent withdrawal. The replaced soil will be well rammed as the hole around the pipe is filled in. It will be found that a narrow drainer's shovel with high sides and a long handle is a useful tool for digging these holes. The top of the pipe will be enclosed with concrete. The number or name of the station will be stamped or painted on the pipe. A small pile of stones, if available, about 2 feet in diameter and 2 feet high will be built around the Witness Post.

4.2.3.6. Good sharp sand and gravel or aggregate will be used in the concrete.

4.2.3.7. Each Ground Mark will be photographed from about 6 ft. distance, with a foot rule or some object included in the picture, which will give an indication of the dimensions of the concrete block. The number painted on the block must be readable in the printed photograph.

Two additional photographs will be taken from different directions, each showing the Witness Post, circular ring of stones or trench, Ground Mark and the general close vicinity. The approximate True Bearings of the directions in which the photographs were taken will be written on the printed photographs, when these photographs are lodged with field books at the conclusion of the work.

4.2.3.8. Each of the degree and half degree Marks will be fully described in the relevant field book, and will be certified by a professional surveyor as meeting the best practicable standard, and as having been personally inspected by him on the completion of the marking.

4.2.3.9. Additional intermediate stations will need to be occupied in a traverse which emplaces the above degree and half degree marks. These intermediate stations will be marked as follows:-

4.2.3.9.1. <u>On firm ground</u> :- A star picket 24 inches long or a half inch diameter galvanised pipe 24 inches long will be driven vertically with 3 inches protruding above the ground surface. If stones are available a small pile, 24 inches in diameter by 24 inches high will be built over the picket or pipe. If no stone is readily available, a mound of earth 24 inches in diameter and 24 inches high, when firmly compacted with the back of a

4.2.3.11. Re-occupation of Previously Established Stations

The commencement and completion of a traverse will usually be on previously established 1st or 2nd order stations.

Where these old stations have fallen into disrepair or were initially poorly marked, they will be re-marked at least to the standards described in previous Paragraphs 4.2.3.1 to 4.2.3.8.

If a cairn has collapsed, it will be further dismantled only so far as to give a firm and solid structure on which to re-build, always provided previously established reference marks are located which prove the accurate position of the Ground Mark.

If reference marks are not found or do not give such proof, the original Ground Mark will be located, reference marks and witness post connected or emplaced, and the cairn re-built.

It is likely that no centre pole. steel struts or vanes, etc., will be available on 2nd Order traversing in which case the cairn will be re-built symmetrically and neatly domed, without pole and vanes.

Photographs will be taken which clearly show the number or name of the station spirit-pencilled on paper if necessary, the condition of all old marks (to which a 2nd Order traverse is connected) as first found and as finally left, the photographs being taken at distances which clearly indicate the appearance and condition of such marks and their near vicinity, and wherever possible including the erected theodolite tripod. Where a cairn forms the main mark, photographs from two positions, to show its full outside surface, will be taken when the station is vacated.

Any previously established station, which is re-visited in the course of a 1st or 2nd Order control survey, will be repaired if needed and will be left in the best condition practicable, so that the great cost of both initially establishing the station, and of re-visiting it, will be preserved.

Where better access has become available since a station's initial establishment or last re-occupation, old access notes will be corrected, or a new diagram made (whichever will show the new approach more clearly) and lodged with the final report. This report will describe, in addition to the photographs, the condition of old marks as first found, and as left, and will note any discrepancies to reference marks or witness posts as compared with the original data. It will supplement the Control Station Record Cards (CDO 10292).

spade, will be built over the picket or pipe. The number of the station will be painted or stamped on a piece of galvanised flat iron, or aluminium sheeting 4 inches by 7 inches and not less than 20 gauge thick, and attached firmly by wire to the picket or pipe. If a solid tree is available, a reference shield will be cut, measured to, and the number neatly painted on it. The measurement will be made to a galvanized roofing nail fully driven symmetrically in the shield.

4.2.3.9.2. On a sandridge :- A length of half inch diameter galvanized water pipe 5 feet long will be emplaced vertically. About 12 inches of the pipe will protrude above the general surface of the sand. A metal tag as described in the preceeding sub-paragraph will be firmly attached by wire to the top of the pipe. Any suitable nearby trees will be blazed, and the number of the station will be painted thereon. The trees will be referenced to the ground mark by bearing and distance. Measurement will be to a galvanized roofing nail fully driven symmetrically in the shield.

4.2.3.10. Permanency of Degree and Half Degree Marks

The permanency of these degree and half degree marks is vital and sites will be chosen with this in mind. Should one of these positions fall on a sandridge or on ground subject to erosion, the permanent mark will be emplaced on the nearest firm ground, such as the flat area between the sandridges, usually about 200 yards away, and will be connected by two mutually checking measurements from the mark on the sandridge. A measured base about 200 yards long, whether on the sandridge or on the flat, will be used for this purpose and in the resulting triangle all angles and distances will be measured.

Where such a mark is placed on a flat, off a sandridge, it is important that the sandridge station can be re-established, since it may be required, subsequently, as an aerodist station, where a good line of sight, all around, is important.

4.3. Control Survey not along Meridians or Parallels

4.3.1. A 2nd Order Tellurometer Traverse may be required not necessarily along Meridians or Parallels nor at degree or half degree positions.

4.3.2. On such a survey, marks as described in 4.2.3.1. to 4.2.3.8. inclusive, and also in 4.2.3.10. may be required at every station, or at distances not greater than 20 miles apart along the traverse, with intermediate stations marked as described in 4.2.3.9.1. and 4.2.3.9.2.

4.3.3. Where such control is required, special attention will be drawn to it, in maps, diagrams and/or Special Conditions of Contract.

5. 2ND ORDER SIGMA OCTANTIS AZIMUTHS USING WILD T3 AND T2 THEODOLITES.

5.1. Main Equipment Necessary :

1. Wild T3 or T2 Theodolite and lighting set.

2. Radio capable of receiving W.W.V. or Lyndhurst - preferably a small transistor.

3. Split hand stop watch.

4. Pocket watch with second hand.

5. Observing screen or tent.

6. Small table and booking lamp.

7. Torch for reading plate bubble and stop watch.

8. Lucas lamp and time switch.

9. A small shaded light to hang under tripod can be an advantage.

5.2. Time of Observation :

Observations will be commenced immediately after sunset or as soon as Sigma Octantis is visible. This is the most accurate period in which to observe as the R.O. light is usually at its steadiest at this time.

5.3. Reference Object :

A Lucas lamp or other suitable light will be used. It is important, particularly on low lines, to keep the lamp as high above the ground as possible. The lamp will be plumbed over the station mark or placed exactly on line.

5.4. Stand Point :

The same care will be taken with the stand point as for horizontal angles. See paragraph 2.4.

5.5. General Preparations :

1. The altitude and azimuth of Sigma Octantis to the nearest 2' of arc is calculated for the approximate start time of the observation. This is best done by means of a suitable graph. (see Annexures A1 and A2). Before looking up the graph it is necessary to calculate the L.S.T. at which it is desired to commence observing.

2. The pocket watch will be set approximately 10 secs. fast on standard time.

3. The stop watch will be started at a suitable time, i.e.
   if a 30 min. dial at 00 or 30 mins.,
   " " 15 " " " 00, 15, 30, or 45 mins.
   It will be started, within 1 or 2 seconds, to the same reading as the pocket watch. This means that both watches are approximately 10 secs. fast on standard time, and therefore any errors are more easily detected.

4. The stop watch will be compared with the Lydnhurst, W.W.V. or W.W.V.H. time signal, noting the error to the nearest 1/10th second just prior to commencement of azimuth observations, and also after every three double arcs, thus:- at the commencement, after the third double arc, and after the sixth double arc.

5.6. Technique of Azimuth Observations

A simultaneous reciprocal azimuth determination consisting of two sets, each set of 3 double arcs, will be observed on each fourth line of a traverse, and also along the last line which joins the terminal station. Should cloudy weather interrupt azimuth observations, such observations may be observed on either the fourth, fifth or sixth line but the spacing must be such that there are three azimuth determinations for every twelve lines of traverse, at least three stations apart.

Simultaneous reciprocal azimuths do not demand exact simultaneity of pointing, by each observer. However, it is important that the two observers at each end of the line, commence observing together and finish the six double areas within 5 to 10 minutes of each other.

These azimuth determinations are important to the Contractor, since they may assist in making progress payments in the event that angular misclosures fall outside the acceptable limit.

A system of double pointings will be employed, as in horizontal angles. The plate bubble will be read after each pointing on the star counting the divisions outwards from the most central division and always reading the East end first.

Altitudes, which change slowly, will be read before changing face on the star.

The theodolite will be re-levelled carefully before each double arc.

5.7. Point to Point Description of Actual Observing Method on Wild T2 and T3

After checking that the instrument has been levelled, parallax and focusing adjusted, and the lighting in the telescope and scales checked, then:-

1. Take two pointings and two micrometer readings on R.O. light in the same manner as for horizontal angles.

2. Set on altitude and azimuth of the star as called out by the booker.

3. Intersect star with single vertical wire and call "up", at the same time pressing the stop watch button. Booker at this point records the coarse time from the pocket watch to the nearest second.

4. Call out the stop watch reading and the plate bubble readings, East and West, in that order.

5. Bring the scales into coincidence and read off the horizontal angle.

6. Take a fresh pointing and micrometer reading, again reading the stop watch and the plate bubble.

7. A vertical circle reading will now be taken to the star.

8. Change face on the star. The booker will call out the vertical and horizontal circle settings if desired by the observer.

9. Take two more pointings, and bubble readings, etc., on the star as before.

10. Swing back on the R.O. light and take two pointings and micrometer readings. This completes one double arc.

11. Re-level the instrument carefully before commencing the next double arc.

5.8. Azimuth Closure

The maximum acceptable misclosures between azimuth stations will be:-

5.8.1. At intervals of 4 lines _ _ _ _ _ _ _ _ 3.5"

5.8.2. At intervals of 5 or 6 lines _ _ _ _ _ 4.5"

5.8.3. The overall misclosure throughout the traverse shall not exceed 2.0" $\sqrt{N}$; where N is the number of horizontal angle stations between fixed azimuths resulting from the National Geodetic Adjustment.

ANNEXURE B1

REFERENCE MARK SKETCH

This sketch must be completed at time of Observation.
Show position of Instrument at time of Azimuth Observation.
Show position of Light shown to other Station.

—N—

EXAMPLE

RECORDING OF AZIMUTH OBSERVATION - 2ND ORDER TRAVERSE

STAR: σ OCTANTIS

THEODOLITE: WILD T3

ANNEXURE B2

REFERENCE MARK SKETCH

This sketch must be completed at time of Observation.
Show position of Instrument at time of Azimuth Observation.
Show position of Light shown to other Station.

—N—

EXAMPLE

RECORDING OF AZIMUTH OBSERVATION - 2ND ORDER TRAVERSE

STAR: σ OCTANTIS

THEODOLITE: WILD T2

INITIAL DATA

for Pages 17 to 20 incl.

Station: NM/G/216 △ R.O.: NM/G/218 △

Date: Year, Month, Day, & Decimal (G.M.T.) 1966, 9, 16·4. (Friday)

Observers Initials, Instrument Type & No. R.H.L. Wild T3. 82990.

Level: Value per Division 6·5 Secs. Readings per Zero Hence Constant:

South Latitude: — East Longitude: —

Right Ascension: Declination: —

Sidereal Time at 00 Hours G.M.T.

TIME CHECKS

Watch: Make, Type & No. Omega 6421 Time Zone: C.A.T.

Time by Radio	Stopwatch Readings	Mean	Correction Fast or Slow
19 00	·7, ·7, ·7, ·8, ·7,	·7	+ 16·7 s
2007	·1, ·2, ·1, ·1, ·1.	·1	+ 17·1 s

Position of Light shown to Other Station: —

Sketch on Page —

Observer: R.H. Langdon. Recorder: H. W. Robertson

Weather: Warm, clear & still.

Visibility: Good, slight sea mist.

INITIAL DATA

for Pages 17 to 20 incl.

Station: NM/G/216 △ R.O.: NM/G/218 △

Date: Year, Month, Day, & Decimal (G.M.T.) 1966, 9, 16·4 (Friday)

Observers Initials, Instrument Type & No. P.H.L. Wild T2, 62988

Level: Value per Division 20 Secs. Readings per Zero Hence Constant:

South Latitude: — East Longitude: —

Right Ascension: Declination: —

Sidereal Time at 00 Hours G.M.T.

TIME CHECKS

Watch: Make, Type & No. Omega 6421 Time Zone: C.A.T

Time by Radio	Stopwatch Readings	Mean	Correction Fast or Slow
1900	·7, ·7, ·7, ·8, ·7,	·7	+ 16·7
2007	·1, ·2, ·1, ·1, ·1,	·1	+ 17·1

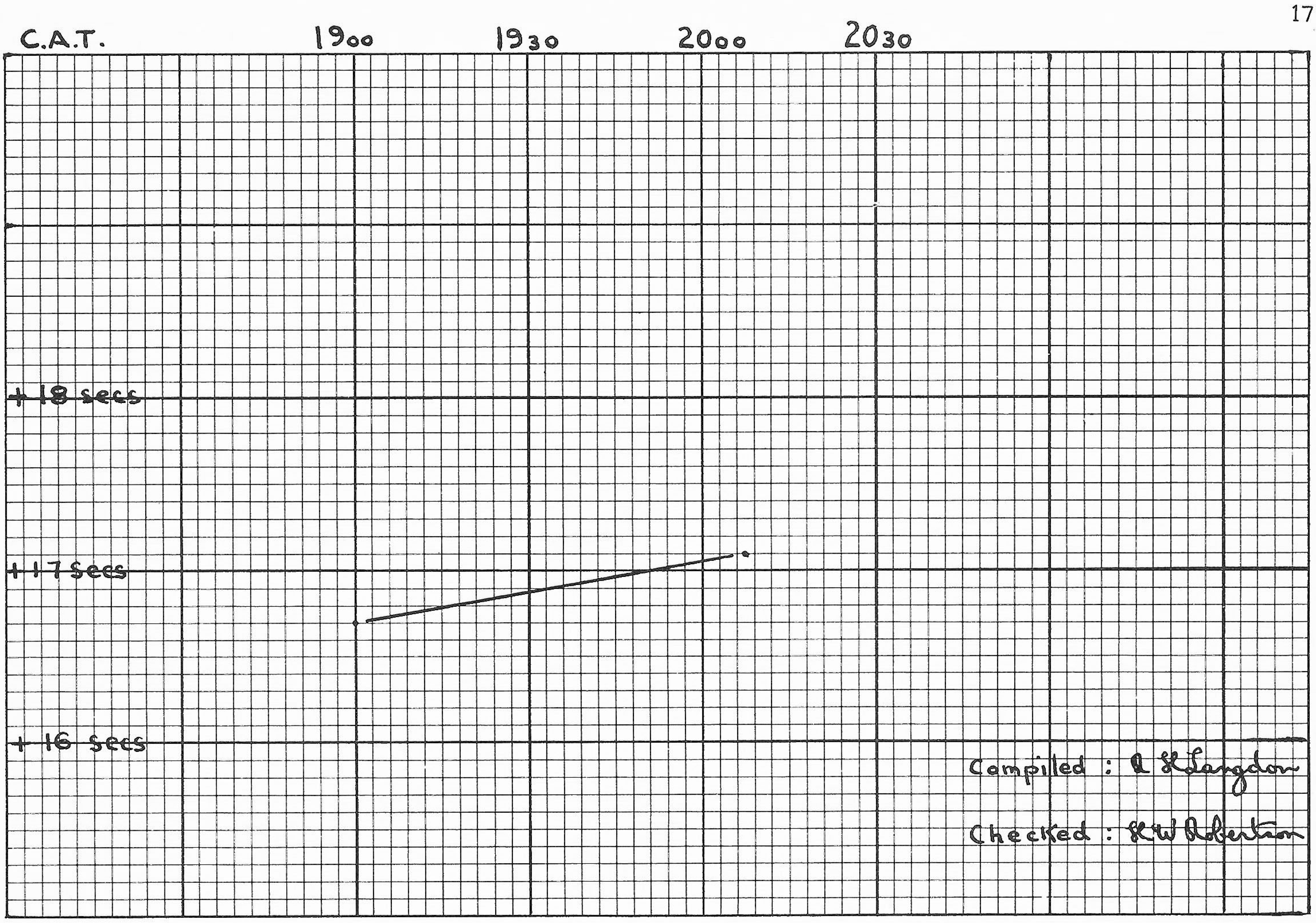
Position of Light shown to Other Station: —

Sketch on Page —

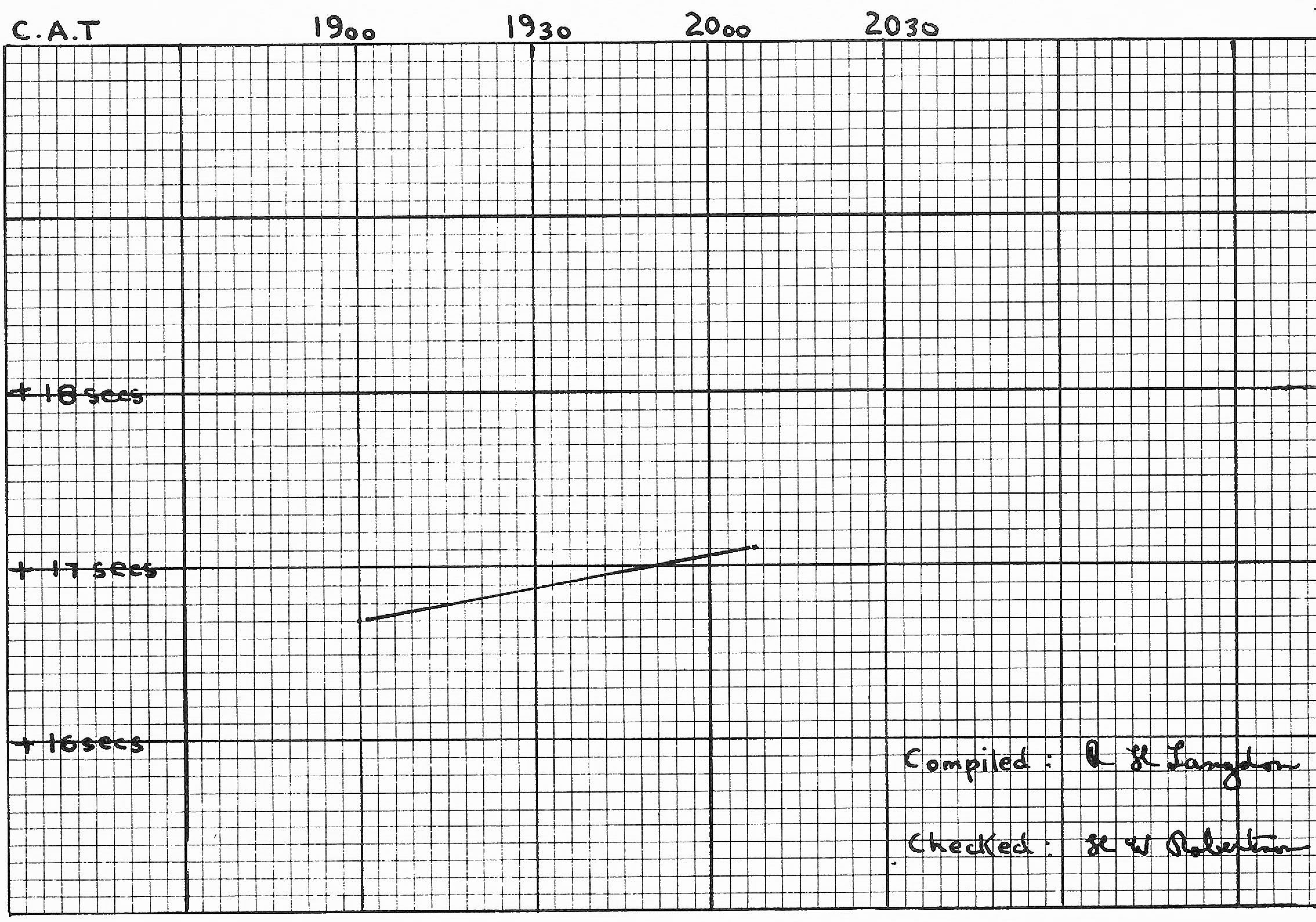
Observer: R.H. Langdon Recorder: H.W. Robertson

Weather: Warm, clear, still.

Visibility: Good, slight sea mist


C.A.T.
1900
1930
2000
2030
+ 18 secs
+ 17 secs
+ 16 secs
Compiled :
Checked :

17


C.A.T
1900
1930
2000
2030
+ 18 secs
+ 17 secs
+ 16 secs
Compiled :
Checked :

Station: NM|G|216 △ — Reference Object: NM|G|218 △ (Light)

Day & Date: Friday 16 Sept 1966 — Initial Data on Page: 16 — Star: σ Octantis

No of Zero	Horizontal Circle: Reference Object	Horizontal Circle: Star	Time: Approximate	Time: Stopwatch	Vertical Circle	Level E	Level W	Chord to Arc
L	00 00 04·8	90 24 10·9	19 01 51	01 49·2	98 12 54/54	4·0	5·0	
L	04·0	24 16·9	02 42	02 42·4		3·9	4·9	
R	180 00 02·2	270 24 25·4	04 21	04 21·1		5·1	5·0	
R	02·0	24 29·7	05 01	05 00·3		5·0	5·1	
	2) 13·0	2) 82·9		4) 13 53·0		18·0	20·0	
	00 00 06·5	90 24 41·45		19 03 28·2				
		−00 00 06·50		−09 30 16·7				
	00° 00′ 00″	90° 24′ 34·95″	GMT	09h 33m 11·5s	16°28	W 2·0		
R	240 00 25·1	330 26 22·5	19 09 16	09 16·1	81 44 45/45	4·2	5·2	
R	27·6	26 25·4	09 58	09 56·5		4·1	5·1	
L	60 00 31·2	150 26 33·7	10 58	10 56·5		4·8	5·0	
L	29·9	26 37·3	11 31	11 31·6		4·9	5·1	
	2) 113·8	2) 118·9		4) 41 40·7		18·0	20·4	
	240 00 56·9	330 26 59·45		19 10 25·2				
		−240 00 56·90		−09 30 16·8				
	00° 00′ 00″	90° 26′ 02·55″	GMT	09h 40m 08·4s	16°29′	W 2·4		

Reduced: L W Robertson — Checked: R H Langdon

Station: NM|G|216 △ — Reference Object: NM|G|218 △ (Light)

Day & Date: Friday 16 Sept 1966 — Initial Data on Page: 16 — Star: σ Octantis

No of Zero	Horizontal Circle: Reference Object	Horizontal Circle: Star	Time: Approximate	Time: Stopwatch	Vertical Circle	Level E	Level W	Chord to Arc
L	00 00 30	90 24 43	19 01 51	01 49·2	73° 32′	2·3	2·4	
L	29	54	02 42	02 42·4		2·3	2·3	
R	180 00 28	270 25 15	04 21	04 21·1		2·0	2·9	
R	27	22	05 01	05 00·3		2·0	3·0	
	4) 114	4) 254·0		4) 13 53·0		8·6	10·6	
	00 00 28·5	90 25 03·5		19 03 28·2				
		−00 00 28·5		−09 30 16·7				
	00° 00′ 00″	90° 24′ 35·0″	GMT	09h 33m 11·5s	16° 28′	W 2·0		
R	240 03 50	330 29 42	19 09 16	09 16·1	286° 29′	2·2	2·5	
R	03 49	48	09 58	09 56·5		2·3	2·4	
L	60 03 51	150 29 57	10 58	10 56·5		1·9	3·0	
L	03 52	30 05	11 31	11 31·6		2·0	2·9	
	4) 202	4) 212		4) 41 40·7		8·4	10·8	
	240 03 50·5	330 29 53·0		19 10 25·2				
		−240 03 50·5		−09 30 16·7				
	00° 00′ 00″	90° 26′ 02·5″	GMT	09 40 08·4	16°29′	W 2·4		

Reduced: L W Robertson — Checked: R H Langdon.

Station: NM|G|216 △ — Reference Object: NM|G|218 △ (Light)

Day & Date: Friday 16 Sept 1966 — Initial Data on Page: 16 — Star: σ Octantis

No of Zero	Horizontal Circle: Reference Object	Horizontal Circle: Star	Time: Approximate	Time: Stopwatch	Vertical Circle	Level E	Level W	Chord to Arc
L	120 00 46·6	210 28 11·7	19 14 18	14 18·6	98 14 18/18	5·8	3·8	
L	47·0	28 19·3	15 24	15 24·0		5·5	4·0	
R	300 00 43·0	30 28 23·1	16 30	16 31·3		5·1	5·1	
R	42·7	28 26·3	17 00	16 59·2		4·9	4·9	
	2) 179·3	2) 80·4		4) 63 13·1		21·3	17·8	
	120 01 29·6	210 28 40·2		19 15 48·3				
		−120 01 29·6		−09 30 16·8				
	00° 00′ 00″	90° 27′ 10·6″	GMT	10h 45m 31·5s	16°29′	E 3·5		
R	210 02 14·1	300 30 19·1	19 20 21	20 20·5	81 44 25/25	5·9	3·8	
R	14·0	30 23·1	20 56	20 55·0		5·7	3·8	
L	30 02 16·9	120 30 29·2	21 45	21 44·7		5·2	5·0	
L	16·1	33·1	22 13	22 13·3		5·1	4·9	
	2) 61·1	2) 104·5		4) 85 13·5		21·9	17·5	
	210 02 30·55	300 30 52·25		19 21 18·4				
		−210 02 30·55		−09 30 16·8				
	00° 00′ 00″	90° 28′ 21·70″	GMT	09h 51m 01·6s	16°30′	E 4·4		

Reduced: H W Robertson — Checked: R H Langdon

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Station: NM|G|216 △ — Reference Object: NM|G|218 △

Day & Date: Friday 16 Sept 1966 — Initial Data on Page: 16 — Star: σ Octantis

No of Zero	Horizontal Circle: Reference Object	Horizontal Circle: Star	Time: Approximate	Time: Stopwatch	Vertical Circle	Level E	Level W	Chord to Arc
L	120 07 10	210 34 01	19 14 18	14 18·6	73°31′	2·8	0·8	
L	07 11	34 15	15 24	15 24·0		2·5	1·0	
R	300 07 08	30 34 29	16 30	16 31·3		2·1	2·0	
R	07 09	34 35	17 00	16 59·2		1·9	2·0	
	4) 38	4) 80		4) 63 13·1		9·3	5·8	
	120 07 09·5	210 34 20·0		19 15 48·3				
		−120 07 09·5		−09 30 16·8				
	00° 00′ 00″	90 27 10·5	GMT	10h 45m 31·5s	16°29′	E 3·5		
R	210 02 10	300 30 21	19 20 21	20 20·5	286°30′	2·9	0·8	
R	02 09	30 29	20 56	20 55·0		2·7	0·8	
L	30 02 12	120 30 36	21 45	21 44·7		2·2	2·0	
L	02 11	30 43	22 13	22 13·3		2·1	1·9	
	4) 42	4) 129		4) 85 13·5		9·9	5·5	
	10·5	300 30 32·2		19 21 18·4				
		−210 02 10·5		−09 30 16·8				
	00° 00′ 00″	90 28 21·7	GMT	09 51 01·6	16°30′	E 4·4		

Reduced: H W Robertson — Checked: R H Langdon

Station NM/G/216 △ Reference Object NM/G/218 △ (Light)

Day & Date Friday 16 Sept 1966 Initial Data on Page 16 Star: σ Octantis

No of Zero	Horizontal Circle		Time		Vertical Circle	Level		Chord to Arc
	Reference Object	Star	Approximate	Stopwatch		E	W	
L	90 02 37·3	180 32 11·9	19 24 43	24 43·3	98 14 38 38	3·9	5·1	
L	37·0	32 17·7	25 39	25 39·3		4·0	5·0	
R	270 02 35·4	00 32 22·5	26 45	26 44·6		5·1	4·9	
R	35·4	32 24·6	27 22	27 21·8		5·2	4·8	
	2) 145·1	2) 76·7		4) 104 29·0		18·2	19·8	
	90 03 12·55	180 32 38·35		19 26 07·2				
		−90 03 12·55		−09 30 16·9				
	00° 00′ 00″	90° 29′ 25·80″	GMT	09h 55m 50·3s	16°31′	W 1·6		
R	330 02 54·6	60 34 01·8	19 30 00	30 00·4	81 44 07 07	5·1	4·1	
R	54·0	34 09·2	31 14	31 14·4		5·2	4·0	
L	150 02 56·6	240 34 18·5	32 12	32 11·6		5·0	5·1	
L	57·9	34 22·8	32 43	32 42·5		4·9	5·2	
	2) 223·1	2) 52·3		4) 126 08·9		20·2	18·4	
	330 03 51·55	60 34 26·15		19 31 32·2				
		−330 03 51·55		−09 30 16·9				
	00° 00′ 00″	90° 30′ 34·60″	GMT	10h 01m 15·3s	16°32′	E 1·8		

Reduced: H W Robertson Checked: R H Langdon

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Station NM/G/216 △ Reference Object NM/G/218 △ (Light)

Day & Date Friday 16 Sept 1966 Initial Data on Page 16 Star: σ Octantis

No of Zero	Horizontal Circle		Time		Vertical Circle	Level		Chord to Arc
	Reference Object	Star	Approximate	Stopwatch		E	W	
L	90 05 30	180 34 39	19 24 43	24 43·3	73° 29′	0·9	2·1	
L	05 29	34 52	25 39	25 39·3		1·0	2·0	
R	270 05 30	00 35 04	26 45	26 44·6		2·1	1·9	
R	05 31	35 08	27 22	27 21·8		2·2	1·8	
	4) 120	4) 223		4) 104 29·0		6·2	7·8	
	90 05 30	180 34 55·8		19 26 07·2				
		− 90 05 30·0		−09 30 16·9				
	00° 00′ 00″	90° 29′ 25·8″	GMT	09h 55m 50·3s	16°31′	W 1·6		
R	330 08 51	60 39 05	19 30 00	30 00·4	286°32′	2·1	1·1	
R	08 50	39 20	31 14	31 14·4		2·2	1·0	
L	150 08 50	240 39 33	32 12	32 11·6		2·0	2·1	
L	08 51	39 42	32 43	32 42·5		1·9	2·2	
	4) 202	4) 100		4) 126 08·9		8·2	6·4	
	50·5	60 39 25·0		19 31 32·2				
		−330 08 50·5		−09 30 16·9				
	00° 00′ 00″	90° 30′ 34·5″	GMT	10h 01m 15·3s	16°32′	E 1·8		

Reduced: H W Robertson Checked: R H Langdon

6. Access Notes

6.1. The Contractor shall supply sufficient access information to enable the traverse station to be readily located by others doing mapping work in the area at a later date. Generally, the Director of National Mapping will supply the Contractor with complete air photo coverage along the proposed route of the traverse and, where available, a photo mosaic at 1:100,000 or larger scale. The Contractor, where such information is supplied, shall:-

6.1.1. by inspection of detail, identify on the photo the position of each traverse station.

6.1.2. annotate in ink on the photo or mosaic, the access route to the station from a prominent object, preferably a homestead or other well known landmark. In undeveloped country it may be necessary to show the access route commencing at the adjacent traverse station.

6.2. In lieu of sub-para 6.1.2. wherel:250,000 maps are available the access route will be shown in ink to the correct scale and in proper relation to salient and recognisable features depicted on the map. Vehicle mileages, recorded to one-tenth of a mile, to features such as creek crossings, gates, fences, cattle grids, signposts, tanks, dams, windmills, homesteads, airstrips, road junctions, bridges, etc., shall be accurately and carefully recorded on these maps.

6.3. Notwithstanding the requirements of sub-paras 6.1. or 6.2. a concise, accurate description of the feature on which the traverse station is situated shall be written in the fieldbook (on pages 31 and 32) which shall be supplied by the Director of National Mapping.

6.4. Where 1:250,000 maps are not available or the air photos or available photo mosaics do not reveal sufficient detail to locate, accurately, the access route, the Contractor shall submit a detailed sketch showing the information outlined in sub-para 6.2. plotted at a convenient approximate scale, with magnetic bearings showing the direction of tracks. The North Point shall be shown to the top of the page.

7. Field Computation - Latitude, Longitude & Reverse Azimuth using Gauss Mid Latitude Formulae

where

$$\text{diff Azimuth } (Z) = \text{diff Longitude X Sin mid Latitude}$$

$$\text{diff Latitude} = \frac{\text{Distance (S) Cos mid Azimuth (Zm)}}{\text{p Sin 1"}}$$

$$\text{diff Longitude} = \frac{\text{Distance (S) Sin mid Azimuth (Zm) Sec mid Latitude}}{\text{v Sin 1"}}$$

where p Sin 1" and v Sin 1" are Radii of Curvature along the Meridian and perpendicular to the Meridian - see attached Tables.

These calculations may be carried out in a series of approximations. However, for 2nd Order Traversing in low Latitudes, mainly for accurate plotting of position and for carrying forward Azimuth to find Sigma Octantis, the following methods are suggested, using a factor K - see attached Tables.

Note that in this field form South Latitude is Positive and East Longitude is Positive.

The 'M' Table :

Knowing the Latitude of Station A and the Azimuth (forward) at 'A', it is possible by means of the Correction to Latitude Table M to find an approximate mean Latitude to the nearest minute. The M table is worked out for every 10° of Azimuth in each quadrant, using a line of length 10 miles as a basis for the computation. The table is based on the formula

$$\text{diff Latitude} = \frac{\text{Distance (S) Cos mid Azimuth (Zm)}}{\text{p Sin 1}''}$$

and is suitable for Latitudes 0° to about 34° since p Sin 1" is changing slowly.

The correction 'M' is obtained thus

$$\tfrac{1}{2}\text{ diff Latitude} = \frac{\text{Distance (S) Cos Azimuth (Za)}}{\text{2 p Sin 1}''}$$

Thus by applying this correction to Latitude A (to nearest tenth of a minute) we arrive at an approximate value for the mid Latitude of the line. If the line is approximately x miles long, then the correction to the Latitude is found by multiplying the correction in the table by $\frac{\text{x miles}}{10}$. With this approximate mean Latitude, the factor K can then be looked up from the table, corresponding to the approx, mean Latitude. This K table is based on the following.

$$\text{diff Z} = \text{diff Longitude x Sin mid Latitude} \qquad (1)$$

$$\text{diff Long} = \frac{\text{Distance (S) Sin Zm Sec mid Latitude}}{\text{v Sin 1}''} \qquad (2)$$

Substituting (2) in (1)

$$\text{diff Z} = \frac{\text{Distance (S) Sin Zm Tan mid Latitude}}{\text{v Sin 1}''} \qquad (3)$$

Now for various mid-Latitudes the ratio $\frac{\text{Tan mid Latitude}}{\text{v Sin 1}''}$ can be found, which is the factor K.

Determination Approximate Difference in Azimuth :

The formula (3) can now be written

diff Z = S Sin Za . K

where Za is Azimuth at Station A

K is factor from table

S is distance reduced to Sea Level.

Halving this and applying with correct sign to Azimuth at A will give approx. mid Azimuth, Zm.

Using Cos Zm in the Latitude formula will give diff Latitude and thus Latitude B.

Using Sin Zm and Sec mid Latitude in the Longitude formula, will give diff. Longitude and thus Longitude B.

Finally this diff. Longitude multiplied by Sin mid Latitude will give diff. Azimuth, which with $\pm$ 180° plus Azimuth at A will give reverse Azimuth B.

This result of diff. Azimuth for lines 15 to 20 miles long in these latitudes should be within about 1" of the initial approx. result using the K factor. (In worked example 392".78 as against 393".25).

As a final approx. graphic check, the Latitude and Longitude of point B should be plotted on the best available map (probably 1:250,000 series) and the scaled true bearing and distance compared with the known distance and bearing.

<u>The Final result of Δ Z should be within 00° 00' 01" of the initial result from $\Delta Z = S \sin Za\ K$.</u>

<u>Summary</u> :

(1) Reduce distance to sea level.

(2) With approx. forward azimuth and length of line obtain approximate mid Latitude by using table M.

(3) Using approx. mid Latitude read off factor K.

(4) Compute diff. in Azimuth.

(5) Compute mid Azimuth.

(6) Compute latitude difference, then Latitude B then mid Latitude.

(7) Compute Longitude difference, then Longitude B.

(8) Compute accurate Azimuth difference hence Reverse Az.

(9) Plot calculated Latitude and Longitude and compare scaled distance and bearing with known values.

EXAMPLE | Naturals

LATITUDE LONGITUDE AND REVERSE AZIMUTH

GAUSS MID LATITUDE FORMULAE

Figure of the Earth used: A.N.S.

Field Books: NM 1768

Computed by: H. Jones

Date: Frid. 5th August 1966

To Find First Approximate Mid-Latitude

Approximate Distance = 18.8 Miles

Value from Table for Fwd Azimuth A = 0'.8

Correction = 0.8 x 18.8 Miles / 10 = 1'.50

Approximate Mid-Latitude = 22° 13' 10"

Back Azimuth at A	300° 17' 15".20
Obs. Angle at A	159° 32' 12".80
Fwd. Azimuth at A	99° 49' 28".00
Lat of A	22° 11' 40".45
Long of A	134° 01' 25".56
Mean Altitude A & B	1340'
Dist A to B	99 166.4
Sea Level Corr'n	0.999 9359
Dist S	99 160.0'

S	99 160.0	
K (from Table)	0.00 402	
Sin (Azimuth at A)	0.985 3352	
Diff in Azimuth (1)= -392".78	- 06' 32".78	
½ of (1)	- 03' 16".39	
Fwd. Az. at A	99° 49' 28".00	
Mid Az. (Zm)	99° 46' 11".61	
S	99 160.0	
Cos Zm	0.169 6916	
$\frac{1}{p \sin 1''}$	0.009 9092	
Diff in Latitude (2)= +166".74	+ 02' 46".74	
Latitude of A	22° 11' 40".45	
Latitude of B	22° 14' 27".19	
Mean (Mid Latitude)	22° 13' 03".82	
S	99 160.0	
Sin Zm	0.985 4972	
Sec (Mid Lat)	1.080 2009	
$\frac{1}{v \sin 1''}$	0.009 8523	
Diff in Longitude (3)= +1040".00	+ 17' 20".00	
Longitude of A	134° 01' 25".56	
Longitude of B	134° 18' 45".56	
Sin (Mid Lat)	0.378 1272	
(Sin Mid Lat X (3) (= Diff Azimuth (4)= -393".25	- 06' 33".25	
Azimuth A ± 180°	279° 49' 28".00	
Reverse Azimuth	279° 42' 54".75	
From Plot:		
(Latitude of B)	22° 14' 27"	
(Longitude of B)	134° 18' 46"	

Sign Convention	Z =	0°-90°	90°-180°	180°-270°	270°-360°
Lat. is positive	(1) & (4)	-	-	+	+
	(2)	-	+	+	-
	(3)	+	+	-	-

EXAMPLE *Logarithms.*

LATITUDE LONGITUDE AND REVERSE AZIMUTH

GAUSS MID LATITUDE FORMULAE

Figure of the Earth used: *A.N.S.*

Field Books: *N.M. 1768*

Computed by: *H. Jones*

Date: *Frid. 5th August 1966*

Back Azimuth at A	300° 17' 15".20
Obs. Angle at A	159° 32' 12".80
Fwd. Azimuth at A	99° 49' 28".00
Lat of A	22° 11' 40".45
Long of A	134° 01' 25".56
Mean Altitude A & B	1340'
Dist A to B	4.996 3646
Sea Level Corr'n	9.999 9722
Dist S	4.996 3368

To Find First Approximate Mid-Latitude

Approximate Distance = *18.8* Miles

Value from Table for Fwd Azimuth A = *0.8'*

Correction = *0.8* x $\frac{18.8 \text{ Miles}}{10}$ = *1'.50*

Approximate Mid-Latitude = *22° 13' 10"*

S	4.996 3368	
K (from Table)	7.604 2261	
Sin (Azimuth at A)	9.993 5840	
Diff in Azimuth (1) = *-392".78*	2.594 1469	-06' 32".78
½ of (1)	-03' 16".39	
Fwd. Az. at A	99° 49' 28".00	
Mid Az. (Zm)	99° 46' 11".61	
S	4.996 3368	
Cos Zm	9.229 6605	
$\frac{1}{p \sin 1''}$	7.996 0379 2.222 0352	
Diff in Latitude (2) = *+166".74*	+02' 46".74	
Latitude of A	22° 11' 40".45	
Latitude of B	22° 14' 27".19	
Mean (Mid Latitude)	22° 13' 03".82	
S	4.996 3368	
Sin Zm	9.993 6554	
Sec (Mid Lat)	10.033 5044	
$\frac{1}{v \sin 1''}$	7.993 5366 3.017 0332	
Diff in Longitude (3) = *+1040".00*	+17' 20".00	
Longitude of A	134° 01' 25".56	
Longitude of B	134° 18' 45".56	
Sin (Mid Lat)	9.577 6380	
(Sin Mid Lat X (3) (= Diff Azimuth (4) = *-393".25*	3.017 0332 2.594 6712	-06' 33".25
Azimuth A ± 180°		279° 49' 28".00
Reverse Azimuth		279° 42' 54".75
From Plot:		
(Latitude of B)	22° 14' 27"	
(Longitude of B)	134° 18' 46"	

Sign Convention	Z =	0°-90°	90°-180°	180°-270°	270°-360°
Lat. is positive	(1) & (4)	+	-	+	+
	(2)	-	+	+	-
	(3)	+	+	-	-

'M' TABLE TO OBTAIN CORRECTION TO LATITUDE OF 'A' TO FIND THE APPROXIMATE MEAN LATITUDE

To obtain correction for Line of X miles Multiply factor in Table by $\frac{X}{10}$

Azimuth	Corr. to be applied to Lat. A to obtain Mid-Latitude for K Tables	Azimuth
10 + 190	04'.3	170 + 350
20 + 200	04'.1	160 + 340
30 + 210	03'.8	150 + 330
40 + 220	03'.3	140 + 320
50 + 230	02'.8	130 + 310
60 + 240	02'.2	120 + 300
70 + 250	01'.5	110 + 290
80 + 260	00'.8	100 + 280

Sign Convention	Z =	$0^\circ - 90^\circ$	$90^\circ - 180^\circ$	$180^\circ - 270^\circ$	$270^\circ - 360^\circ$
Correction	=	-	+	+	-
(Where Latitude positive)					

'K' TABLE FOR USE WITH MID LATITUDE FORMULA (FIELD COMP)

Mean Latitude	K	Mean Latitude	K
14°	00.00 246	24° 30'	00.00 449
14° 30'	255	25	459
15	264	25 30	470
15 30	273	26	480
16	283	26 30	491
16 30	292	27	502
17	301	27 30	513
17 30	311	28	524
18	320	28 30	535
18 30	330	29	546
19	339	29 30	557
19 30	349	30	569
20	359	30 30	580
20 30	368	31	592
21	378	31 30	603
21 30	388	32	615
22	398	32 30	627
22 30	408	33	639
23	418	33 30	652
23 30	428	34	664
24	439		

Where $K = \frac{\tan \phi m}{v \sin 1''}$

2ND ORDER TRAVERSING

FIELD COMPUTATIONS OF GEOGRAPHIC POSITIONS AND REVERSE AZIMUTH

TABLE FOR MID-LATITUDE FORMULA

NATURAL TABLES

Lat.	$\frac{1}{p \sin 1''}$	$\frac{1}{v \sin 1''}$	Lat.	$\frac{1}{p \sin 1''}$	$\frac{1}{v \sin 1''}$
14° 00'	0.0099 1760	0.0098 5507	22° 00'	0.0099 0945	0.0098 5237
10'	1746	5502	10'	0925	5230
20'	1732	5497	20'	0904	5223
30'	1718	5493	30'	0884	5217
40'	1704	5488	40'	0863	5210
50'	1690	5483	50'	0843	5203
15° 00'	0.0099 1676	0.0098 5479	23° 00'	0.0099 0822	0.0098 5196
10'	1661	5474	10'	0801	5189
20'	1646	5469	20'	0780	5182
30'	1631	5464	30'	0758	5175
40'	1616	5459	40'	0737	5168
50'	1601	5454	50'	0716	5161
16° 00'	0.0099 1586	0.0098 5449	24° 00'	0.0099 0695	0.0098 5154
10'	1570	5444	10'	0673	5147
20'	1554	5439	20'	0651	5140
30'	1539	5433	30'	0630	5132
40'	1523	5428	40'	0608	5125
50'	1507	5423	50'	0586	5118
17° 00'	0.0099 1491	0.0098 5418	25° 00'	0.0099 0564	0.0098 5110
10'	1474	5413	10'	0542	5103
20'	1458	5407	20'	0519	5096
30'	1441	5402	30'	0497	5088
40'	1425	5396	40'	0474	5081
50'	1408	5391	50'	0452	5074
18° 00'	0.0099 1391	0.0098 5385	26° 00'	0.0099 0429	0.0098 5066
10'	1374	5380	10'	0406	5058
20'	1357	5374	20'	0383	5050
30'	1339	5368	30'	0359	5043
40'	1322	5362	40'	0336	5035
50'	1305	5356	50'	0313	5027
19° 00'	0.0099 1287	0.0098 5350	27° 00'	0.0099 0290	0.0098 5020
10'	1269	5344	10'	0266	5012
20'	1251	5338	20'	0242	5004
30'	1233	5332	30'	0219	4996
40'	1215	5326	40'	0195	4988
50'	1197	5320	50'	0171	4980
20° 00'	0.0099 1178	0.0098 5314	28° 00'	0.0099 0148	0.0098 4972
10'	1159	5308	10'	0124	4964
20'	1140	5301	20'	0100	4956
30'	1121	5295	30'	0075	4948
40'	1102	5289	40'	0051	4940
50'	1083	5283	50'	0027	4932
21° 00'	0.0099 1064	0.0098 5276	29° 00'	0.0099 0002	0.0098 4924
10'	1044	5270	10'	0.0098 9977	4916
20'	1024	5263	20'	9952	4908
30'	1005	5257	30'	9928	4899
40'	0985	5250	40'	9903	4891
50'	0965	5244	50'	9878	4883

2ND ORDER TRAVERSING

FIELD COMPUTATIONS OF GEOGRAPHIC POSITIONS AND REVERSE AZIMUTH

TABLE FOR MID-LATITUDE FORMULA

NATURAL TABLES

Lat.	$\frac{1}{p \sin 1''}$	$\frac{1}{v \sin 1''}$	Lat.	$\frac{1}{p \sin 1''}$	$\frac{1}{v \sin 1''}$
30° 00'	0.0098 9853	0.0098 4875	32° 00'	0.0098 9546	0.0098 4773
10'	9828	4867	10'	9520	4764
20'	9802	4858	20'	9494	4756
30'	9777	4850	30'	9467	4747
40'	9752	4841	40'	9441	4738
50'	9726	4832	50'	9415	4730
31° 00'	0.0098 9701	0.0098 4824	33° 00'	0.0098 9389	0.0098 4721
10'	9675	4816	10'	9362	4712
20'	9649	4807	20'	9336	4703
30'	9624	4799	30'	9309	4695
40'	9598	4791	40'	9282	4686
50'	9572	4782	50'	9256	4677.
			34° 00'	0.0098 9229	0.0098 4668

TABLES FOR REDUCING DISTANCES TO SEA LEVEL

TO OBTAIN SEA LEVEL DISTANCE MULTIPLY MEASURED DISTANCE BY

SEA LEVEL FACTOR - NATURAL TABLES

Mid Altitude (feet)	Sea Level Factor	Mid Altitude (feet)	Sea Level Factor
500	.999 9761	1700	.999 9187
600	9713	1800	9139
700	9665	1900	9091
800	9617	2000	9043
900	9569	2100	8995
1000	9522	2200	8947
1100	9474	2300	8899
1200	9426	2400	8851
1300	9378	2500	8804
1400	9330	3000	8565
1500	9283	3500	8326
1600	.999 9235	4000	.999 8087

2ND ORDER TRAVERSING

FIELD COMPUTATIONS OF GEOGRAPHIC POSITIONS AND REVERSE AZIMUTH

TABLE FOR MID-LATITUDE FORMULA

LOGARITHMIC TABLES

Lat.	Log. $\frac{1}{p \sin 1''}$	Log. $\frac{1}{v \sin 1''}$	Lat.	Log. $\frac{1}{p \sin 1''}$	Log. $\frac{1}{v \sin 1''}$
14° 00'	7.996 4066	7.993 6597	22° 00'	7.996 0496	7.993 5407
10'	4004	6575	10'	0408	5376
20'	3944	6553	20'	0316	5345
30'	3882	6535	30'	0229	5319
40'	3821	6513	40'	0136	5288
50'	3759	6491	50'	0048	5257
15° 00'	7.996 3698	7.993 6474	23° 00'	7.995 9957	7.993 5226
10'	3632	6452	10'	9864	5196
20'	3566	6430	20'	9772	5165
30'	3503	6408	30'	9676	5134
40'	3435	6386	40'	9584	5103
50'	3369	6364	50'	9491	5072
16° 00'	7.996 3304	7.993 6342	24° 00'	7.995 9400	7.993 5042
10'	3234	6320	10'	9303	5011
20'	3164	6298	20'	9206	4980
30'	3099	6271	30'	9115	4944
40'	3028	6249	40'	9018	4913
50'	2958	6227	50'	8922	4882
17° 00'	7.996 2887	7.993 6205	25° 00'	7.995 8826	7.993 4847
10'	2814	6183	10'	8729	4816
20'	2743	6157	20'	8629	4785
30'	2668	6135	30'	8532	4750
40'	2599	6108	40'	8431	4719
50'	2524	6086	50'	8335	4689
18° 00'	7.996 2449	7.993 6059	26° 00'	7.995 8234	7.993 4653
10'	2376	6037	10'	8132	4618
20'	2301	6011	20'	8032	4583
30'	2222	5984	30'	7927	4552
40'	2148	5958	40'	7825	4517
50'	2073	5931	50'	7725	4481
19° 00'	7.996 1994	7.993 5905	27° 00'	7.995 7624	7.993 4450
10'	1916	5879	10'	7518	4415
20'	1836	5852	20'	7414	4380
30'	1757	5826	30'	7313	4344
40'	1679	5799	40'	7207	4309
50'	1600	5773	50'	7102	4274
20° 00'	7.996 1516	7.993 5747	28° 00'	7.995 7001	7.993 4239
10'	1434	5720	10'	6896	4204
20'	1350	5689	20'	6791	4168
30'	1266	5663	30'	6681	4133
40'	1184	5637	40'	6575	4098
50'	1100	5610	50'	6471	4063
21° 00'	7.996 1017	7.993 5579	29° 00'	7.995 6361	7.993 4028
10'	0930	5553	10'	6251	3991
20'	0842	5522	20'	6142	3956
30'	0759	5495	30'	6036	3917
40'	0671	5464	40'	5926	3881
50'	0583	5438	50'	5817	3846

2ND ORDER TRAVERSING

FIELD COMPUTATIONS OF GEOGRAPHIC POSITIONS AND REVERSE AZIMUTH

TABLE FOR MID-LATITUDE FORMULA

LOGARITHMIC TABLES

Lat.	Log. $\frac{1}{p \sin 1''}$	Log. $\frac{1}{v \sin 1''}$	Lat.	Log. $\frac{1}{p \sin 1''}$	Log. $\frac{1}{v \sin 1''}$
30° 00'	7.995 5707	7.993 3811	32° 00'	7.995 4360	7.993 3361
10'	5597	3776	10'	4246	3322
20'	5483	3736	20'	4132	3286
30'	5374	3701	30'	4013	3247
40'	5264	3661	40'	3899	3207
50'	5149	3622	50'	3785	3172
31° 00'	7.995 5037	7.993 3587	33° 00'	7.995 3671	7.993 3132
10'	4926	3550	10'	3552	3092
20'	4812	3511	20'	3438	3052
30'	4703	3476	30'	3320	3017
40'	4588	3440	40'	3201	2977
50'	4474	3401	50'	3087	2940
			34 00'	7.995 2969	7.993 2898

TABLES FOR REDUCING DISTANCES TO SEA LEVEL

TO OBTAIN SEA LEVEL DISTANCE MULTIPLY MEASURED DISTANCE BY SEA LEVEL FACTOR

LOGARITHMIC TABLES $(X\ 10^{-10})$

Mid Altitude (feet)	Sea Level Factor	Mid Altitude (feet)	Sea Level Factor
500	9.999 9896	1700	9.999 9646
600	9876	1800	9626
700	9854	1900	9605
800	9833	2000	9584
900	9813	2100	9563
1000	9792	2200	9542
1100	9771	2300	9522
1200	9750	2400	9501
1300	9730	2500	9481
1400	9709	3000	9377
1500	9689	3500	9273
1600	9668	4000	9168

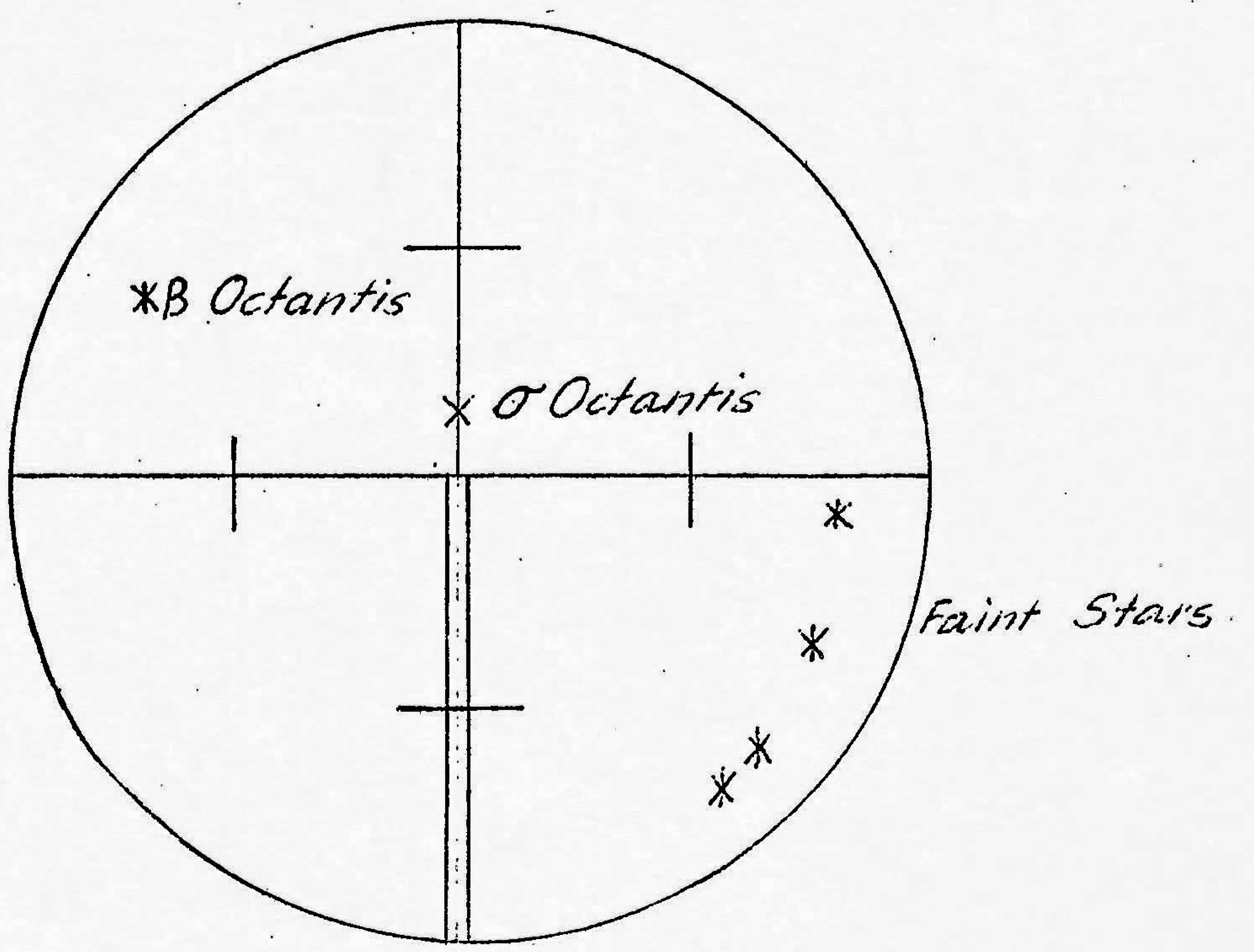
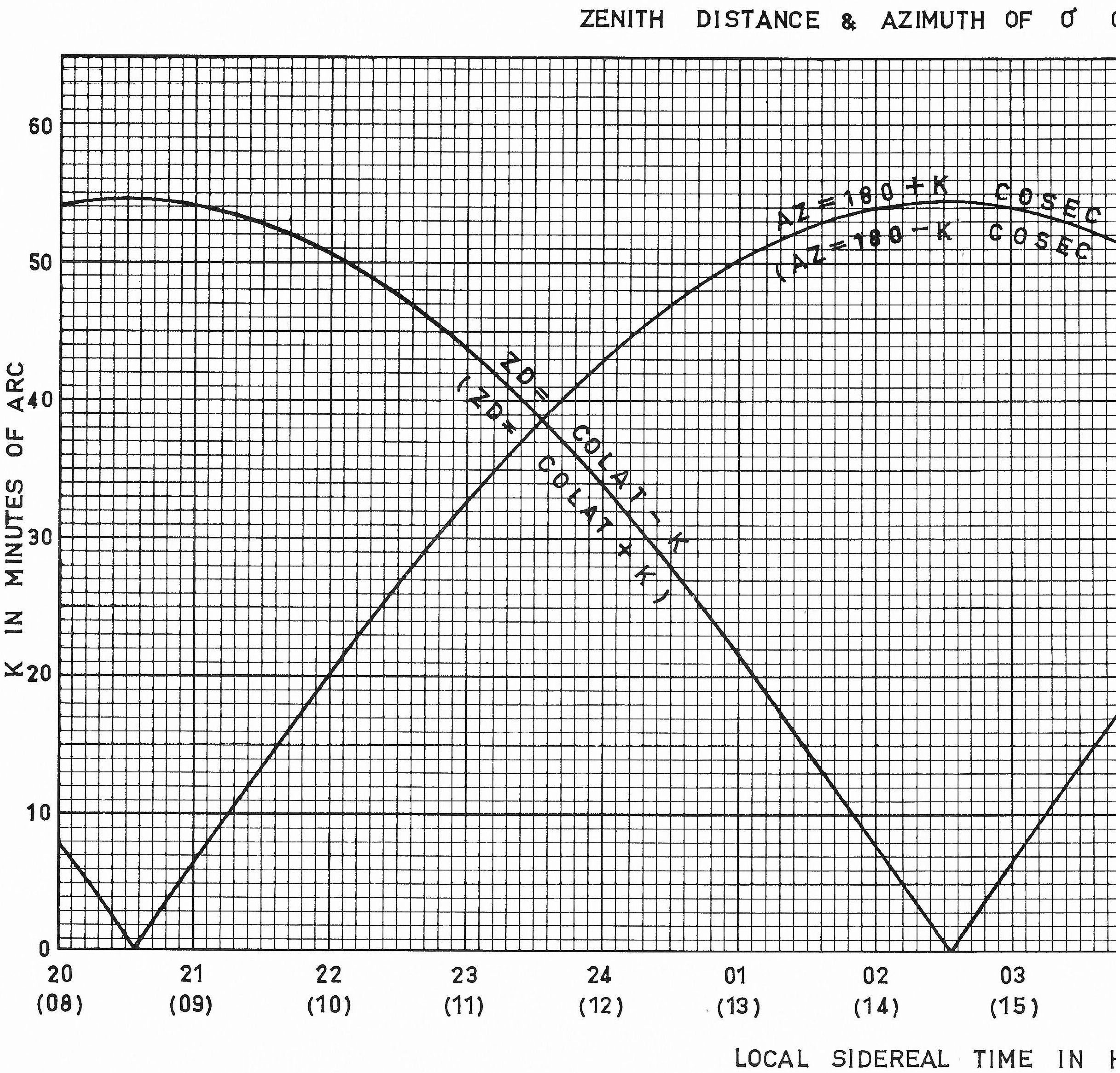
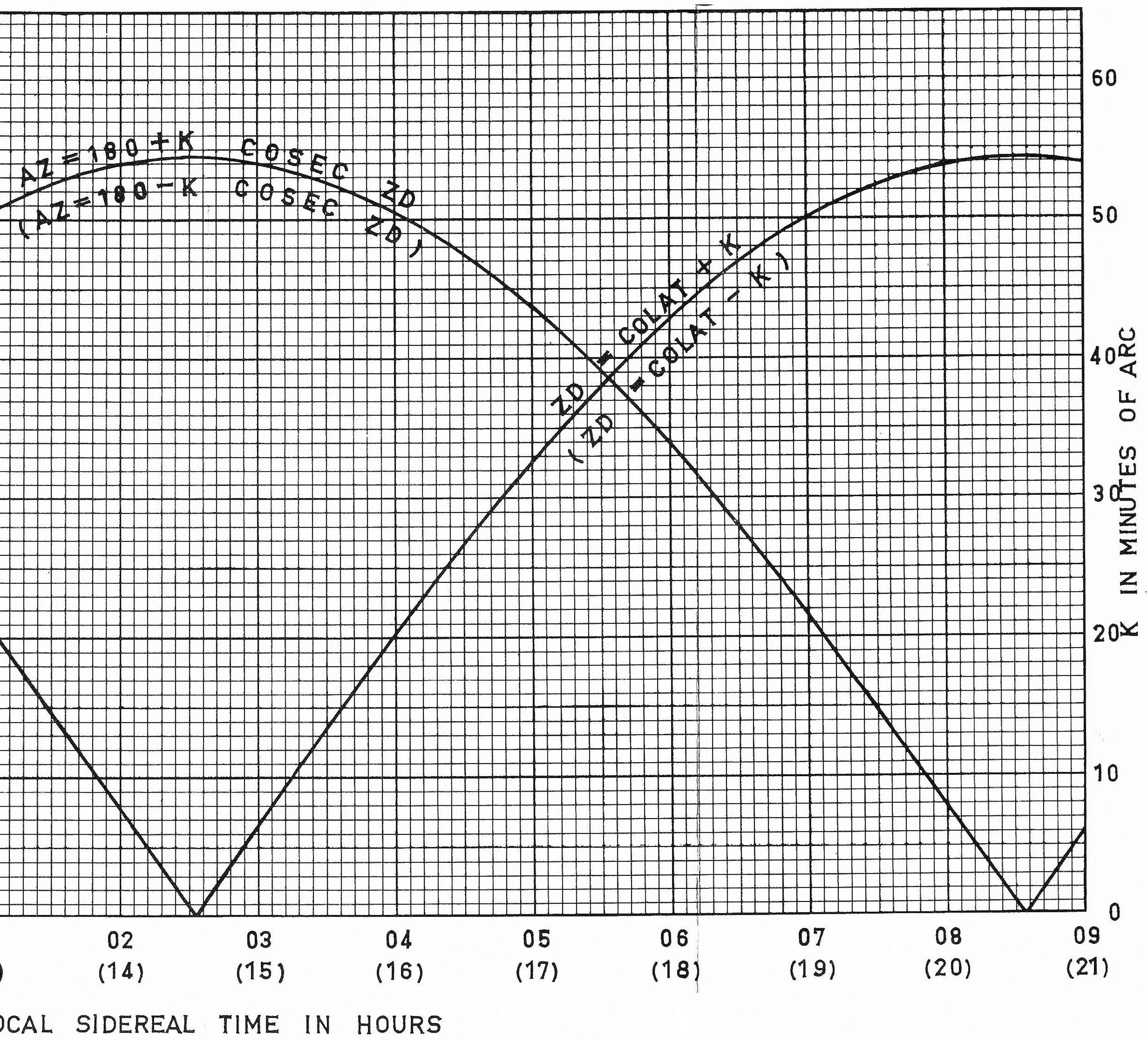


Diagram illustrating the position of Sigma Octantis with respect to adjacent stars as seen in the field of view of the telescope of a T2 theodolite.


ZENITH DISTANCE & AZIMUTH OF σ
K IN MINUTES OF ARC
60
50
40
30
20
10
0
AZ = 180 + K COSEC
(AZ = 180 − K COSEC
ZD = COLAT − K
(ZD = COLAT + K)
20 (08)
21 (09)
22 (10)
23 (11)
24 (12)
01 (13)
02 (14)
03 (15)
LOCAL SIDEREAL TIME IN

ANCE & AZIMUTH OF σ OCTANTIS AT EQUATOR



To find Altitude & True Bearing of Sigma Octantis at any given Latitude and Longitude by use of Sigma Octantis graph.

Preliminary computation.

Definition: ZD = Zenith Distance = 90° - Altitude
Colat = Co-Latitude = 90° - Latitude
LST = Local Siderial Time
C.A.T. = Central Australian Time
G.T.C. = Greenwich Time Correction (in W.A., G.T.C. = -08 hrs 00 mins
(in Central Aust., G.T.C. = -09 hrs 30 mins
(in Eastern States, G.T.C. = -10 hrs 00 mins

Example:-

Compute LST at 1900 hrs. Central Australiam Time on 1 March 1967 at NM/F/110 Moodini, Latitude 31° 54' 34"; Longitude 127° 16' 38".

	h	m	
Central Australian Time	19	00	
-09h 30 m East of Greenwich	-09	30	
G.M.T.	09	30	
Correction for Siderial Time	+	01.6	See page 433 Chambers Tables or 9.5X10 secs (approx.)
Siderial Time at 00 hrs 1 March 1967	10	32.5	See Star Almanac or FK4 Table.
Longitude in Time	08	29.1	Divide by 15 or p434 Chambers
	28	33.2	
Therefore LST	04	33.2	

At Moodini Latitude = 31° 55', Colat = 58° 05'.

Then to use graph: (Annexure A1).

(1) To find Altitude

Enter graph using LST (hours are divided to 6 minutes) and read up to ZD curve. In example, correction K to ZD for LST 4 hrs 33 m is 27', and since LST has no brackets around figures 04,

then ZD = 58° 05' + 27' = 58° 32'
Therefore Altitude = 31° 28'

Note: Where LST is in brackets, the correction K is minus, thus

ZD = 58° 05' - 27' = 57° 38'

(2) To find True Bearing

Using LST 04 hrs 33 m, read up to azimuth curve, in this example 47'. This value 47' is multiplied by Cosec Zenith Distance, thus 47' x Cosec 57° 38' = 47' X 1.18 = 55'.
Then True Bearing of Sigma Octantis is 180° + 55' = 180° 55'.

Where LST is in brackets, correction K is minus, thus True Bearing is 180° - 55' = 179° 05'.

Magnitude Sigma Octantis = 5.5 (See Annexure A illustrating the
Magnitude B Octantis = 6.5 relative star positions).