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THE AUSTRALIAN GEODETIC SURVEY
AN INTERIM REPORT ON THE UTILISATION OF ELECTRONIC DISTANCE MEASURING EQUIPMENT

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INTRODUCTION:

In Australia the amount of fundamental geodetic survey required is large, and the resources available to do it are comparatively small. In addition, much of Central Australia is flat desert, or semi desert, country and the cost of triangulation, with its attendant tower work is likely to be very high. Until the invention of the Tellurometer the geodetic survey made slow progress, and geodetic triangulation was generally confined to the more populated and hilly areas of the south east.

By 1957, 250,000 square miles had been covered by primary triangulation in which the base lines had been measured either with invar tapes or with Geodimeters, but since the advent of the Tellurometer in 1957, progress has been rapid, and control in the form of geodetic traverse now covers the entire continent - (see Appendix 1).

In much of Central Australia, meteorological conditions are remarkably uniform, both in time and space, and are very suitable for use of the Tellurometer. In the flat areas, the cost of traversing on towers is very much less than the cost of tower triangulation. Moreover, in 1957, commercial helicopters became available in Australia at an economic price, which enabled traverses to be run into very remote areas.

THE SURVEY:

Basically, the fundamental survey now consists of loops of pure traverse only. At the beginning of 1963, some of these loops were still very large, exceeding 100 lines and 2,000 miles in length. It is hoped that by 1965 few loops will exceed 50 lines or 1,000 miles. Where geodetic triangulation already exists, a continuous traverse of Tellurometer lines is being run through it.

At the end of March 1963, 28 individual loops had been closed. These loops are made up of 1200 sides and the overall length measured with the Tellurometer totals approximately 22,000 miles. Azimuth control along the traverses is provided by 214 Laplace Stations.

Observations for the fundamental geodetic survey have been made by no less than ten different agencies :
Division of National Mapping,
Royal Australian Survey Corps,
The six State Lands Departments,
The Northern Territory Administration,
The Department of Interior.

The work of all agencies is coordinated by the National Mapping Council, who lay down specifications for the work, but slight differences in emphasis in interpreting the specifications do exist.

Specifications have tightened several times in the light of experience but much of the work done in 1958 and 1959, with specifications now considered to be out of date, will be included in the adjustment, possibly with some additional azimuth control. The present loop closures are a result of work done to various specifications over the past 5 years. If all work had been done to the 1963 specifications (summarised in Appendix 2) loop closures would presumably have been smaller.

A feature of this "tightening" has been emphasis on additional azimuth control in order to reduce the statistical double summation of lateral displacement errors. These result from the accumulated effects of random errors in angular observation. An empirical investigation has indicated that these displacement errors are directly related to the accuracy of the angular observations and that a reduction in spacing of azimuth control from 8 to 4 stations apart introduces an improvement factor of approximately 2.

PRECISION OF SURVEY:

The precision of the survey may be judged from the data on linear measurements, angular measurements and loop closures tabulated in Appendices 3, 4 and 5 respectively.

The vector distance misclosure between the adopted origin of each traverse and its computed position at the end of the traverse has fairly consistently averaged about 2 parts in 10^6 of the total length of a loop.

COMPUTATION AND ADJUSTMENT OF THE SURVEY:

A preliminary adjustment is planned for mid-1963 to provide preliminary coordinates of high accuracy for use on the final adjustment, and to provide temporary, homogenous coordinates on a single spheroid for current use in International geodetic surveys, as the basis of National Mapping and for control of survey operations generally. The plan is to make the final adjustment and publish a definitive list of coordinates in 1966.

The methods employed for the National Geodetic Adjustment can be considered under four headings :

(a) tabulation of basic data - azimuths, angles and distances;
(b) computation of traverses by Clarke^{t}s formula to obtain the loop closures;
(c) the adjustment of the loop closures to obtain fixed values for the junction points;
(d) the adjustment of traverses between the junction points.

Tabulation of Data: Extreme care has been taken to obtain data for the adjustment which is free from blunders and copying errors. Some agencies make all observations at satellite stations, which require special care. All data which is to be incorporated in the adjustment has been tabulated on special forms direct from the field books and is certified free from copying errors by a responsible officer. One copying error in a Tellurometer distance and one in an angle have been discovered so far; four "clockwise angles" have been entered anti-clockwise; and two "D" crystal errors have been found in distances. It would be a bold person who asserted that no small copying errors of the order of 1 second or 1 foot remain in the data, but very stringent precautions have been taken.

Within the Division of National Mapping, satellite corrections, trigonometrical and tellurometer reductions are now computed electronically. This enables all available human effort to be put in the careful tabulation and checking of the data; and it has been found that the data sheets for the electronic computer form a very valuable permanent abstract of the observation.

All Laplace observations are being uniformly reduced to bring them so far as is possible into terms of the FK4 catalogue, the BIH mean pole of epoch, and the BIM "Greenwich" meridian of 1962.0.

Appendix 6 is an example of the new Laplace station summary form. Electronic computation is employed for the calculation of azimuths from Sigma Octantis, for precise star coordinates, and for three small computations associated with meridian transit longitude observations. Astronomical observations with geodetic theodolites (Almucantar longitudes and Circum-meridian latitudes) are also predicted and computed electronically.

Computations to Close Loops: Computations are currently being carried out on the "165" Spheroid :
$A = 6\ 378\ 165$ metres $1/f = 298.3$

The present "Maurice" origin is based on 54 isostatically reduced Laplace stations along the vicinity of the 32° parallel between Sydney and Perth. Prior to the 1963 preliminary adjustment, it is planned to introduce a new datum based on about 200 isostatically reduced Laplace stations distributed throughout Australia.

Initially, observed angles were adjusted by equal increments between successive Laplace azimuths, the latter being held fixed. The loop closures listed in Appendix 5 were computed in this way. Not all the Laplace azimuths used had been properly reduced in accordance with para 15 above. As soon as all the definite Laplace azimuths are available, angles will be re-adjusted as follows :

(a) At each junction point, the azimuth of one line will be determined, and held fixed, being the weighted mean of the azimuth derived from the nearest Laplace station on each of the radiating traverses;
(b) observed angles and Laplace azimuths in each section between fixed azimuths at the junction points will then be adjusted by least squares, an observed angle and an observed azimuth being given equal weight.

It is hoped that the revised loop closures obtained with angles adjusted in this way will be available for distribution at the Conference.

Observed distances have not yet been adjusted in any way, but before the 1966 adjustment, they are likely to be adjusted as follows :

(a) To allow for the change in height of the terminals due to adjustments to improved levelling data;
(b) for the index correction; at present half the agencies in Australia apply an index error of about -0.2 feet, and half do not. This matter is currently being investigated and no decision has been reached;
(c) curvature of radio waves. Most agencies now assume the radio path is straight; but a correction to allow for the curvature of the radio path and the dip of the ray into a region of greater refractive index is likely to be incorporated.

Although some geoid survey has been made in Australia, it seems unlikely that by 1965 it will be possible to reduce many tellurometer distances to the spheroid rather than to the geoid. However, with a modern spheroid oriented on 200 Laplace stations, it is thought that this omission is unlikely to lead to serious inaccuracy.

Traverse computations are done by Clarke's formula on the Sirius electronic computer. It is necessary to feed in the coordinates and an opening azimuth of one or more junction points, and the names, angles and distances for any number of sections of traverse between junction points. The computer then computes each section in turn and prints out for each station :

	Angle GA Distance	Latitude Forward Azimuth	Longitude Reverse Azimuth
J1 SUNDOWN	098 51 03.840 180 03 52.890 96240.50	-31 54 01.6-67 336 35 57.608	141 26 54.003 156 39 50.498
2 ROBE	229 14 58.330 179 53 44.274 142838.52	-31 39 27.410 25 54 48.828	141 19 31.789 205 48 33.103

The end station of each section is stored as a new junction point. The coordinates of all the junction points and the loop closures are listed separately at the end. 500 lines have been computed in an hour, but unless one is very confident of the data, it is better to compute in smaller batches, and inspect the output before proceeding. The cost is £2, plus 2/- per line.

Adjustment of Loop Closures: Loops will be closed separately in latitude and longitude, as for the Bowie method (USC & GS Sp. Pub. 159). An electronic least squares programme which will solve up to 150 observation equations for 100 unknowns in about 3 minutes is available.

Adjustment between Junction Points: For the 1966 adjustment, this is likely to be done by variation of coordinates on the spheroid. The variation of coordinates programme will make use of all the data that is available. The relative weights to allocate to azimuths, angles and distances will be investigated, but at present there is no evidence to favour weighting them other than equally. For the 1963 adjustment, no variation of coordinates programme is available. Traverses will, when necessary, be adjusted between junction points by Jolly's method, on the Transverse Mercator projection (ESR No. 28, 339, 1937), for which a programme is available.

EXTENSION OF THE SURVEY:

It is hoped that after the 1966 adjustment accurate and definite values will be available along loops of survey enclosing areas smaller than 200 miles square in the less developed areas and 100 miles square in the more developed areas. In the more developed areas, it is likely that the loops will be filled in with intensive networks of first order Tellurometer traverses and in the less developed areas, with networks of Aerodist trilateration. It is likely that these "fill in" surveys will be subjected to block adjustment techniques within the framework of primary geodetic traverses.

The Royal Australian Survey Corps has commenced a Tellurometer traverse around the coastline of that portion of New Guinea which is under Australian Administration, while the Division of National Mapping and the Administration's Division of Surveys have commenced a combination of traverse and triangulation along the central mountains.

These surveys will be tied together on one datum and will be correlated with a HIRAN survey at present being undertaken by the U.S. Air Force over the Territories of Papua and New Guinea and extending to north Eastern Australia where numerous connections will be made between HIRAN stations and the stations of the Australian National Geodetic Survey.

CONCLUSIONS:

There is good evidence that a very sound primary geodetic survey can be carried out by means of Tellurometer traversing if frequent Laplace azimuth control is provided.

Appendix 2.

EXTRACTS FROM NATIONAL SPECIFICATIONS FOR CONTROL SURVEYS

EXPLANATION:
The National Specifications are accompanied by Schedules setting out Recommended Survey Practices.

SPECIFICATIONS:
Extract from Specification for Horizontal Control Surveys.

"General Description:

Special High Precision surveys will normally be of very limited extent and be specifically undertaken for purposes where the utmost precision is required.

First Order Surveys are carried out to the highest accuracy that is economically reasonable and surveys shall normally be executed along lines of Primary Control as approved from time to time by the National Mapping Council. First order surveys may also be used in conjunction with second order surveys to provide a fundamental geodetic network over any particular area.

Second Order surveys shall normally be used to subdivide the area between first order control for the purpose of providing a fundamental geodetic network of first and second order stations over the entire area to be controlled.

Third Order surveys shall normally be used to subdivide the area between first and second order stations for the purpose of providing a network of third or higher order stations over the entire area to be controlled, at distances apart of approximately 5 to 10 miles.

Fourth Order surveys shall be used to connect the control of higher grades of surveys with mapping operations in a region.

Accuracy.

Horizontal control surveys shall conform to the following standards of accuracy :

Class of Survey	Random errors of final values of lines joining adjacent stations not to exceed					
	length (parts in 10^6)			azimuth (seconds)		
	Probable (50%)	Standard (68%)	Limiting (95%)	Probable (50%)	Standard (68%)	Limiting (95%)
Special high precision	Substantially lower than required for first order					
First	5	7.5	15	1	1.5	3
Second	10	15	30	2	3	6
Third	20	30	60	4	6	12
Fourth	A plottable amount at scale of mapping					

and fundamental geodetic networks shall conform to the standards of accuracy approved by the International Union of Geodesy as set out in Resolution No. 4 (XII Assembly 1960).

Elevations.
The elevations of horizontal control stations shall be determined to such a degree of accuracy as is necessary for the purpose for which the station is being established."

RECOMMENDED SURVEY PRACTICES

Extract from Schedule 3;

"ANGULAR OBSERVATIONS
First Order Horizontal

One round of observations should consist of a face right pointing to each station in turn proceeding clockwise reversing on the last station, and a face left pointing on each station in turn proceeding anticlockwise. The means should then be deduced. The closing of the horizon is optional.

One set of horizontal Observations should consist of six rounds on six different zeroes so chosen as to divide the main circle and the micrometer drum into equal parts.

All classifications - Acceptance Criteria for horizontal angles.

Recommended ranges and standards of accuracy for classifications for horizontal angular observations are shown below in tabulated form. Geodetic instruments being used for special High Precision and First Order angular work, and approved 1" instruments for Second and Third Order work.

Special High Precision

As specified by requirements of the project.

First Second and Third Order

	First	Second	Third
Range within each set of 6 Zeros should seldom exceed (a)	6"	6"	6"
Range within each set of 6 zeros not to exceed	8	10	12
Residual from mean of any direction should seldom exceed (a)	3	3	3
Residual from mean of any direction not to exceed	4	5	6
Minimum number of sets each of 6 zeros	6(b)	2	1
Range between sets no to exceed.	4	4	(not specified)

Notes

(a) Where these ranges are exceeded it is essential that additional observations be made.

(b) A minimum of 3 sets should be taken on each of two days.

Vertical Angles

Where it is not possible to determine the elevation of a geodetic survey station by differential leveling such elevation may be determined by vertical angle observations.

Reciprocal vertical angles should be observed under conditions of minimum refraction. These conditions normally occur between 1400 hours and 1600 hours. L.M.T.

Vertical angles should be observed with an approved 1 second or geodetic theodolite.

At least one set of 3 or more pairs (Face Left and Face Right) should be observed at each terminal.

Where the Range between the 3 pairs exceeds 8 seconds, sufficient additional pairs should be observed to obtain further comparisons and to improve the accuracy of the set.

Where the line is not included in a closed trigonometrical figure, such as a Tellurometer traverse, two such sets of vertical angles should be observed during the hours prescribed but separated by at least 15 minutes of time.

Within the prescribed time conditions it is desirable that reciprocal vertical angles be observed simultaneously. When observations are taken at any other time it is essential they be observed simultaneously.

When the stations are occupied on a second day it is desirable that additional sets be observed.

DISTANCE MEASUREMENT

First Order Tellurometer Traverses

Two separate measurements should be made for each line determined - it being desirable that the measurements be separated by a reasonable time interval, but not necessarily on different days.

It is desirable, but not essential that the two separate measurements be effected in opposite directions.

First order measurements should not be undertaken when meteorological conditions are unfavourable.

When the two measurements differ by more than 1/150,000, further series of 2 measurements should be made until satisfactory agreement is reached.

Coarse readings should be checked and reduced in the field to show they are not ambiguous -

with model MRA1 the check should be made by reading a coarse, set in the reverse position.

with model MRA2 an independent coarse reading will be made from either end.

A full range of cavities must be used when taking fine readings. The number of cavities read depends on the characteristics of the line under measurement.

The desirable number of cavities in a set of fine readings, under average conditions, should not be less than 20.

Should the graph exhibit a cyclic tendency, a full cycle is to be completed if possible.

The range of the fine readings should seldom exceed 5 m.u.s. The amplitude of swing can usually be kept within this limit by resiting of stations. Not more than 5% of lines shall have a range of more than 8 m.u.s.

Careful meteorological readings are as equally important as a good set of fine readings.

Barometers and thermometers should be calibrated and index error of barometers frequently checked.

At each station three or four sets of meteorological readings ore to be taken at equal intervals covering the period of the fine readings.

Temperatures are read or estimated to 0.1 F and pressures read to 0.01 inch of mercury.

The vapour pressure will be calculated in the field - any change in the dew point in excess of 20ºF or 0.05 inch of vapour pressure at a station during observation should be suspect.

Psychrometers should be operated at no less than five feet from the ground level, preferably in the shade.

Thermometers should be of the mercury type graduated in intervals of at least 1° F.

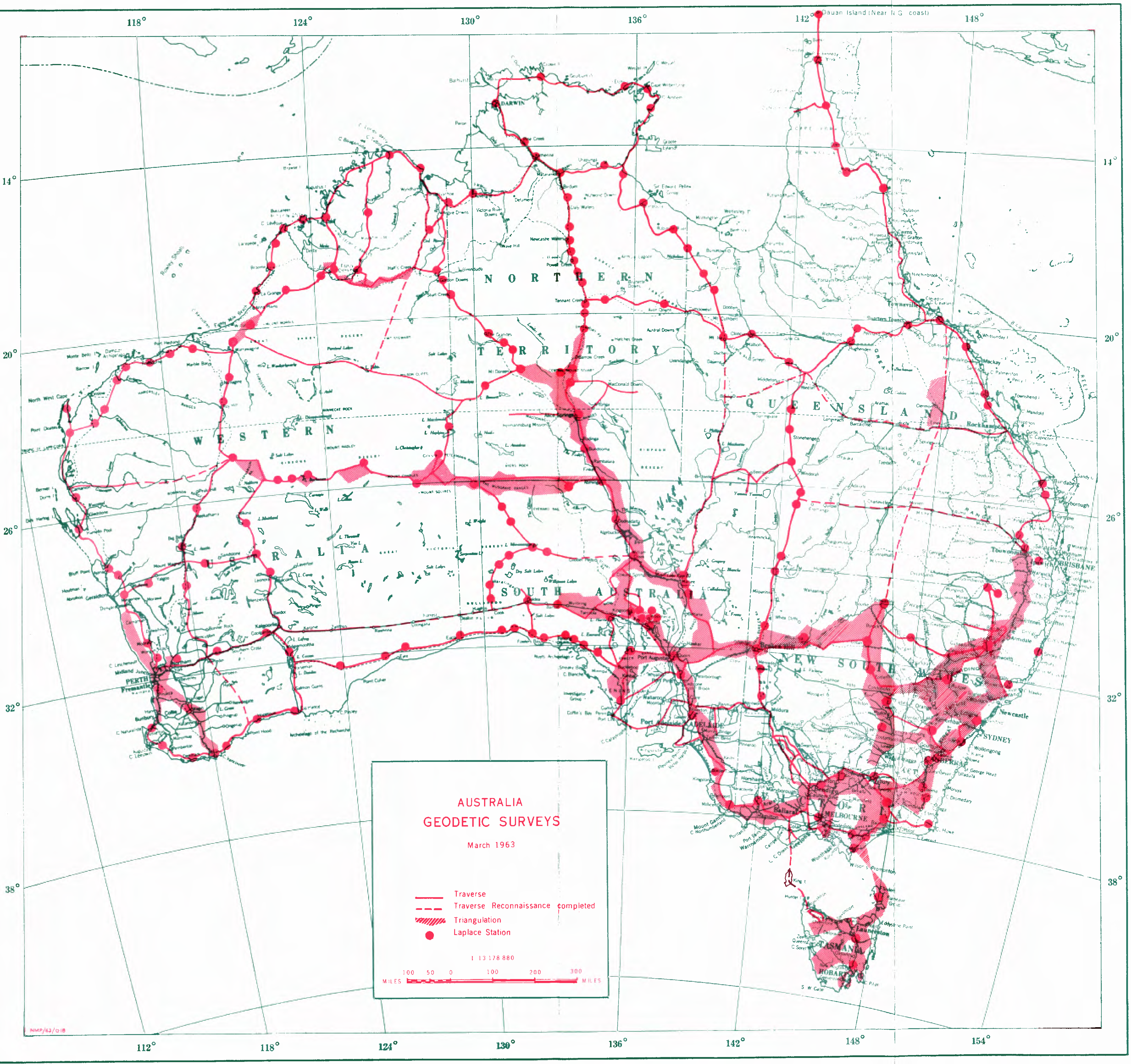
All four crystals should be recalibrated at least once per year.

ASTRONOMICAL OBSERVATIONS

Laplace stations should normally be observed with special astronomical theodolites at intervals of 4 to 6 geodetic stations apart but where ever there is evidence of excessive horizontal refraction pairs of Laplace stations should be observed at ends of common azimuth lines.

Individual Laplace azimuths should be observed with an accuracy represented by a standard deviation not in excess of ±0.4.

All observations at Laplace stations are to be reduced in accordance with Division of National Mapping Technical Report No. 1. "Small corrections to Astronomic Observations".


AUSTRALIA
GEODETIC SURVEYS
March 1963
Traverse
Traverse Reconnaissance completed
Triangulation
Laplace Station
1 : 13 178 880
MILES 100 50 0 100 200 300 MILES
NORTHERN TERRITORY
WESTERN AUSTRALIA
SOUTH AUSTRALIA
QUEENSLAND
NEW SOUTH WALES
VICTORIA
TASMANIA
DARWIN
PERTH
Fremantle
ADELAIDE
MELBOURNE
SYDNEY
BRISBANE
HOBART
Launceston
Newcastle
Townsville
Rockhampton
Port Augusta
Kalgoorlie
Dauan Island (Near N.G. coast)
NMP/63/018

APPENDIX 3

Some statistics on Tellurometer measurements in Australia

1. Total number of lines measured from 1957-1962 which are part of the National Geodetic network.

	= 1202	

2.

Total Distance measured	= 22,100	Miles
Average length of line	= 18	"
Longest line	78	"
Shortest line	0.8	"

3. Lines measured by the Division of National Mapping in 1962 have been analysed to show typical results.

	Total number of lines measured	157	
	Total number of miles measured	2770	Miles
	Average length of lines	18	"
	Longest line	40	"
*	Longest line internal accuracy	$1.3/10^6$	
	Shortest line	0.8	"
*	Shortest line internal accuracy	$4/10^6$	

* Summary of lines and their internal accuracies

Grouping of lines	Standard deviations
5 mile lines (14)	± 2.4 (part in 10^6)
10 " " (39)	± 1.5 " " "
15 " " (35)	± 1.3 " " "
20 " " (24)	± 0.9 " " "
25 " " (20)	± 0.9 " " "
30 " " (8)	± 0.7 " " "
35 " " (9)	± 1.0 " " "
40 " " (6)	± 0.7 " " "

(Internal Accuracies:

The values for internal accuracies (standard deviations) are derived by taking the average ratio dL/L for the number of lines considered and multiplying by 0.63 (dL difference in pair of measurements and L = length of line).

When estimating external (actual) accuracies it is desirable to multiply the internal accuracies by a factor of 2 or 3).

All these measurements were made with the MRA1 CW type of Tellurometer.

All measurements were made twice or more in the same direction along each line.

A most important consideration is that each pair of measurements along a line were made from two different points on each hill in almost every case; i.e. from Trig. to Trig. for one measurement, then from the Eccentric on one hill to a Reference Mark on the other hill. The comparison is formed after the Eccentrics are corrected to centre; this ensures correct identification and connection of the points occupied; the pattern of the coarse readings is also substantially changed providing an extra check against errors in interpreting B, C, and D crystal readings; however the most important effect of this method is that the development of the wave front throughout the line, both out and back is entirely changed and any anomalies due to abnormal reflection from reflecting surfaces in the vicinity of or directly behind the instrument, or along the line will cause disagreement between the measurements to appear. Only one such case has been recorded when the Tellurometer was set close to, and on line from, a smoothly finished pillar.

APPENDIX 4

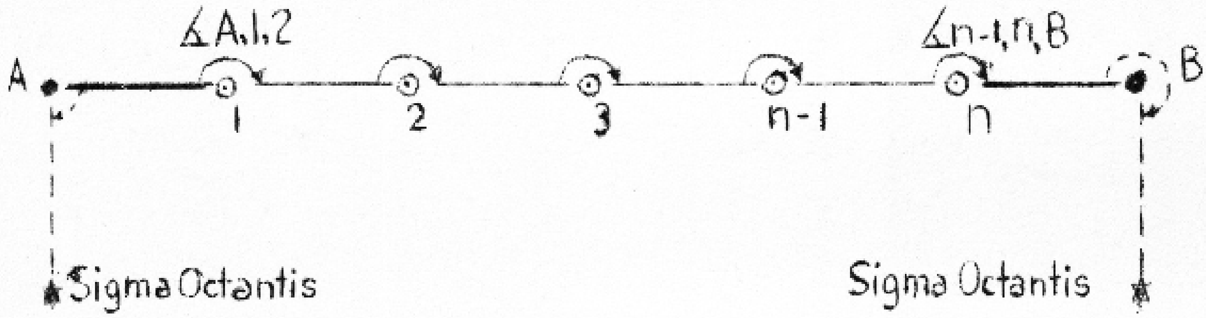
Statistics on angular misclosures between Laplace Stations

Introduction

An arbitrary rule has been adopted to the effect that where the distribution of the sectional closing azimuth error exceeds 1" per station the work needs further investigation. In all, 160 sections were considered and 13 eliminated for this reason.

This analysis deals with the remaining 147 sections of pure traverse with Laplace azimuths at either end.

Explanation



● = Laplace station ●——— = Laplace azimuth

Az(A,1) = Laplace azimuth from A to 1

Az(B,n) = Laplace azimuth from B to n

$$\Delta Az_{n-1,n} = \text{meridian convergence} = (\ n - n-1)\sin \frac{\phi n + \phi n-1}{2}$$

$$\text{Misclosure of section AB} = \left[Az(A,1) + \measuredangle A,1,2 \ldots + \measuredangle n-1,n,B + \Delta Az_{A,1} \ldots + \Delta Az_{n,B} + n \times 180^{\circ} \right] - Az\,(B,n)$$

$$\text{Correction per angle} = -\frac{\text{misclosure}}{n}$$

$$\text{Standard deviation of one observed angle, s.d.} = \pm \frac{\text{misclosure}}{\sqrt{n+2}}$$

4. <u>Distribution of Corrections</u>

Maximum number of traverse lines per section = 16

Minimum number of traverse lines per section = 3

Average number of traverse lines per section = 7

Maximum correction per traverse angle = 0"99

Minimum correction per traverse angle = 0"01

Average correction per traverse angle = 0"38

Distribution of corrections in per cent of the total number of sections

Corrections from - to	No. of sections having this correction		Percentage of section with this correction	
0"00 - 0"12	23	53	15.6%	36.0%
0.12 - 0.25	30		20.4	
0.25 - 0.38	27	46	18.4	31.3%
0.38 - 0.50	19		12.9	
0.50 - 0.75	30		20.4	
0.75 - 1.00	18		12.3	

5. <u>Distribution of Standard deviations of observed angles</u>

Maximum standard deviation = ± 2"73

Minimum standard deviation = ± 0.01

Mean standard deviation of 147 sections = ± 1"02

Distribution of the standard deviation of 147 sections in multiples of the mean s.d. = 1"02 = m

Class interval	No. of s.d.s in interval	Percentage: Actual	Percentage: Theoretical
0 to 0.5 m	53	36.1%	38.3%
0 to 1.0 m	100	68.0	68.3
0 to 1.5 m	128	86.9	86.6
0 to 2.0 m	139	94.5	95.4
0 to 2.5 m	145	98.6	98.8
0 to 3.0 m	147	100.0	99.7

APPENDIX 6

LAPLACE STATION SUMMARY

GEODETIC SURVEY OF AUSTRALIA

ESTABLISHED BY:

Observer: ________________ Instrument: ______________ State: ______________________________ Height of Station: ______________ Station: ________________________

Recorder: ________________ Number: ________________ Sheet No and Name: __________________ Height of RO: ________________ RO: ________________________

LATITUDE
Observing Method:
Dates of Observations:
Standard Deviation of ____ pairs $=\sqrt{\Sigma v^2/(n-1)}$:
Standard Error of Mean $=\sqrt{\Sigma v^2/n\,(n-1)}$:
LONGITUDE
Observing Method:
Dates of Observations:
Standard Deviation of ____ pairs $=\sqrt{\Sigma v^2/(n-1)}$:
Standard Error of mean $=\sqrt{\Sigma v^2/n\,(n-1)}$:
AZIMUTH
Observing Method:
Dates of Observations:
Standard Deviation of ____ zeros $=\sqrt{\Sigma v^2/(n-1)}$:
Standard Error of Mean $=\sqrt{\Sigma v^2/n\,(n-1)}$:
TIME SIGNALS
Chronometer:
Chronograph:
Time Signal Origin:
Quality of Reception:
ECCENTRICITY DIAGRAM

		LATITUDE CORRECTIONS			
		Preliminary Latitude (+N, −S)	−		
1	+	Eccentricity Correction			
2	+	Correction to Mean Pole, $\Delta\phi_p$			
3	+	Correction to Sea Level, $\Delta\phi_H$	+		
4	+	Correction to FK4 (if applicable)			
		FK4 ASTRONOMIC LATITUDE (+N, −S), ϕ_A	−		

		LONGITUDE CORRECTIONS (all in Time)			
		Preliminary Longitude (+W, −E)	−		
5	+	Eccentricity Correction in Time			
6	+	$\Delta t = (t_m - t_0)$ in UT2			
7	−	ΔT_S = UT2 − UT1, (ΔT_S =)			
8	−	$\Delta\lambda_f$, Correction to Mean Pole, ($\Delta\lambda_f$ =)			
9	+	$\Delta\lambda_{MS'}$, (prior to 1956·0 only)			
10	+	TF, Transmission Time to Field Station	+		
11	−	TM, Transmission Time to Mt Stromlo, (TM =)	−		
12	+	Lag in Audio Filter	+		
13	+	Correction to Greenwich (prior to 1962·0 only)	−		
14	+	Personal Equation (Almucantars only)	−		
15	+	Diurnal Aberration (Almucantars only)	−		
16	+	Correction to FK4 (1961 observations only)			
		FK4 - GREENWICH ASTRONOMIC LONG. IN TIME (+W, −E)	−		
		FK4 - GREENWICH ASTRONOMIC LONG. IN ARC (+W, −E) λ_A	−		

		AZIMUTH CORRECTIONS			
		Preliminary Azimuth			
17	+	Eccentricity Correction			
18	+	Convergence			
19	+	Correction to Mean Pole, ΔA_p			
20	+	Correction for Diurnal Aberration			
21	+	Correction for Skew Normals			
		ASTRONOMIC AZIMUTH, A_A			

LAPLACE CORRECTION & DEVIATION OF VERTICA[L]			
Spheroid:			
Origin; Station:			
Latitude (+N, −S)	−		
Longitude (+W, −E)	−		
Geodetic Latitude (+N, −S), ϕ_G	−		
Geodetic Longitude (+W, −E), λ_G	−		
$\xi = \phi_A - \phi_G$			
$\lambda_A - \lambda_G$			
$\eta = (\lambda_A - \lambda_G)\cos\phi$			
$\zeta = \xi\sin A + \eta\cos A$			
Elevation Angle to RO, E ±			
Astronomic Azimuth, A_A			
$+(-\zeta\tan E)$ ±			
$+(\lambda_A - \lambda_G)\sin\phi$ ±			
LAPLACE AZIMUTH			

REMARKS

Certified free from copying errors: ________________

Approved by: ________________

Date: ____________

AHQ/MISC/2845

Note: See back of Summary for reference to correction numbers.

FORMULAE FOR CORRECTIONS

Note: The International convention of λ=Longitude (+West,-East) and ϕ=Latitude (+North,-South) has been adopted.

All corrections are described in "Small Corrections to Astronomic Observations" published by the Division of National Mapping, to which paragraph numbers below refer.

LATITUDE:

1 Eccentricity Correction: If applicable. Diagram must be drawn in relevant space (see Para 10).

2 Correction to Mean Pole: $\Delta\phi_p = -(x \cos\lambda + y \sin\lambda)$, where x and y are interpolated from Mount Stromlo's "Preliminary Times of Emission" (see Para 14).

3 Correction to Sea Level: $\Delta\phi_H = -52''\times10^{-6} \times h \sin 2\phi$, where h=feet above sea level (see Para 15).

4 Correction to FK4: If applicable (see Para 16).

LONGITUDE:

5 Eccentricity Correction: Apply in time if applicable (see Para 10).

6 $\Delta t := t_m - t_o$ where t_m is the UT2 time of reception at Mount Stromlo of a signal sent out at a nominal time t_o. Issued in Time Service Bulletin B by Mt Stromlo (see Para 5).

7 ΔT_s :=UT2 - UT1, issued monthly by Mt Stromlo (see Para 5).

8 Correction to Mean Pole: $\Delta\lambda_f = \tan\phi\ (x \sin\lambda - y \cos\lambda)/15$ (see Para 5).

9 $\Delta\lambda_{MS}$:=correction to mean pole at Mt Stromlo; required before 1956·0 only (see Para 5).

10 TF, Transmission Time - Transmitter to Field Station: For short wave signals (WWVH, etc), calculate using Stoyko's Tables opposite (see Para 5).

11 TM, Transmission Time - Transmitter to Mt Stromlo: For WWVH the accepted distance Kihei to Mt Stromlo is 8559 km and the accepted delay 31 milliseconds (see Para 5).

12 Lag in Audio Filter: Correction positive if filter causes a delay as is usual (see Para 5).

13 Correction to Greenwich-Observations prior to 1962·0 only: Take value for year from Table opposite (see Para 7).

14 Personal Equation - Almucantars only. Where observer's Personal Equation is unknown, assume PE $= -0^s\!\cdot\!088$ (see Para 9b).

15 Diurnal Aberration - Almucantars only: $= -0^s\!\cdot\!0213 \sin E$ where E=Elevation of the Almucantar. For Meridian Transit Observations see Apparent Places, Table VII (see Para 4 and Para 9a), and make no entry here.

16 Correction to FK4 - 1961 Observations only: $= -\Sigma nF/N$, where F is the FK4 correction to a star's RA, n the number of times that star was observed, and N the total number of observations (see Para 6).

AZIMUTH:

17 Eccentricity Correction: If applicable (see Para 20).

18 Convergence: If applicable=($\Delta\lambda$ in secs of arc between Ecce and Trig)x sin ϕ (see Para 20).

19 Correction to Mean Pole: $\Delta A_p = (x \sin\lambda - y \cos\lambda) \sec\phi$ (see Para 21).

20 Diurnal Aberration: $= +0''\!\cdot\!32 \cos A \cos\phi \sec E$. For Sigma Octantis $= -0''\!\cdot\!32$ (see Para 22).

21 Skew normals, or elevation of RO: $= 33''\times10^{-6} \times h_2 \times \sin 2A \cos^2\phi$, where h_2 is height in feet above sea-level of the RO (see Para 23).

See paragraph 25e, for the recommended procedure when reciprocal azimuths have been observed at both ends of a line.

LAPLACE EQUATION AND DEVIATION OF THE VERTICAL

Note: The geodetic values in this section should only be inserted on the completion of the National Geodetic Adjustment of Australia, when the necessary entries will be computed electronically.

Corrections applicable to this section are dealt with comprehensively in paragraphs 25-29 inclusive of "Small Corrections to Astronomic Observations."