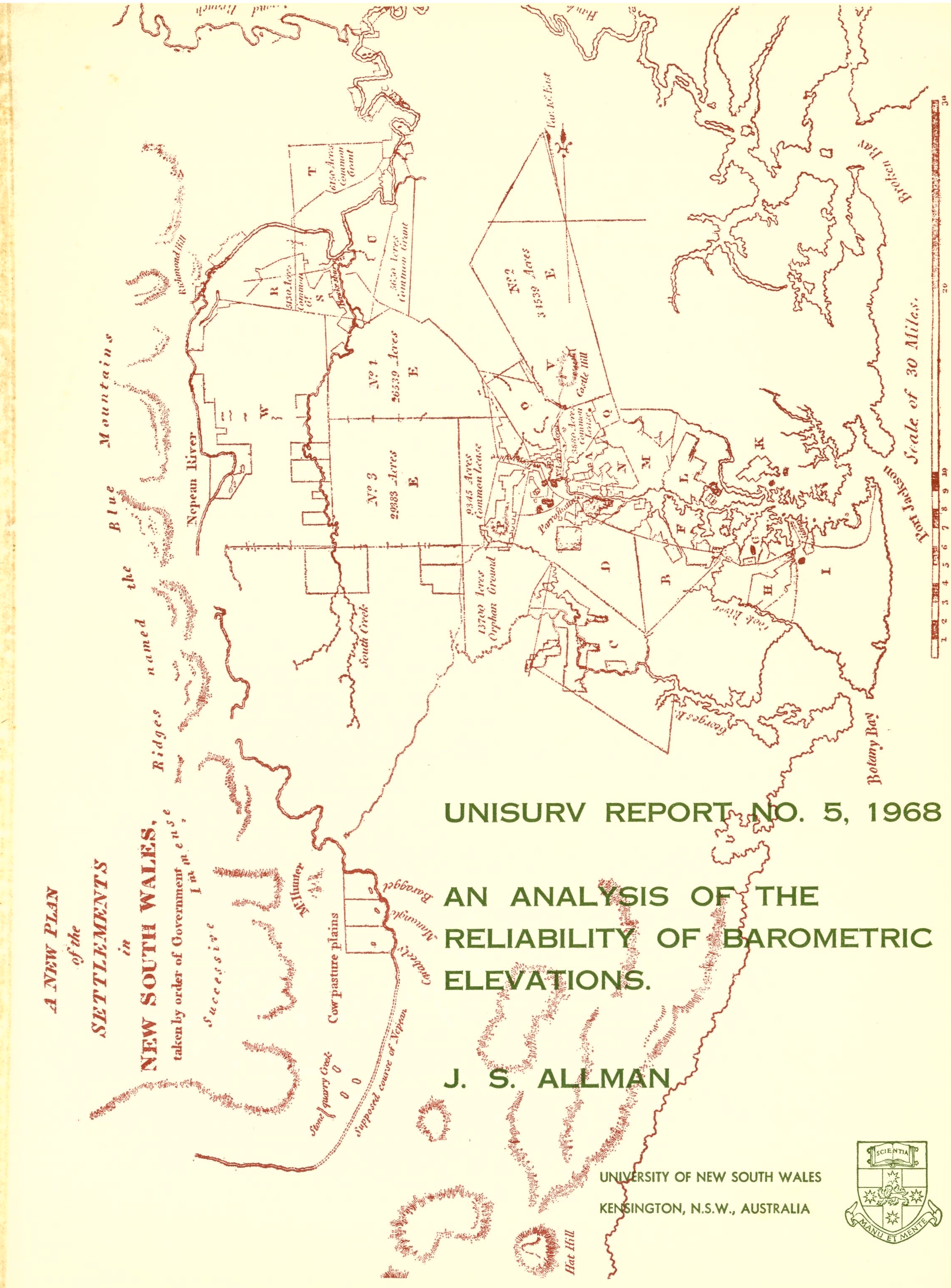


UNISURV REPORT NO. 5, 1968

AN ANALYSIS OF THE RELIABILITY OF BAROMETRIC ELEVATIONS.

J. S. ALLMAN

UNIVERSITY OF NEW SOUTH WALES
KENSINGTON, N.S.W., AUSTRALIA

Reference to Districts.

A	Northern Boundaries
B	Liberty Plains
C	Banks Town
D	Parramatta
EEEE	Ground reserved for Govt. purposes
F	Concord
G	Petersham
H	Bulanaming
I	Sydney
K	Hunters Hills
L	Eastern Farms
M	Field of Mars
N	Ponds
O	Toongabbey
P	Prospect
Q	
R	Richmond Hill
S	Green Hills
T	Phillip
U	Nelson
V	Castle Hill
W	Evan

The cover map is a reproduction in part of a map noted as follows:

London: Published by John Booth, Duke Street, Portland Place, July 20th, 1810

Reproduced here by courtesy of The Mitchell Library, Sydney

THE UNIVERSITY OF NEW SOUTH WALES

DECLARATION RELATING TO DISPOSITION OF REPORT

In the light of the provisions of the Copyright Act (1912-1950) I declare that I wish to retain my full privileges of copyright in this report and request that neither the whole nor any portion of the report may be published and I further declare that this preservation of my copyright privileges in the report shall lapse from the 1st day of January, 1978, unless it shall previously have been extended or revoked in writing over my hand.

Signature.......JS Allman.......

Witness.......P. V. Angus-Leppan.......

Date.......3rd November 1967.......

AN ANALYSIS OF THE RELIABILITY OF BAROMETRIC ELEVATIONS

by

J.S. ALLMAN

CONTENTS

Appendices

INTRODUCTION

The problem of obtaining accurate elevations using barometric methods has vexed many investigators since Pascal and Perrier experimented in France in 1648.[12] Methods have been suggested from time to time with exaggerated claims as to their efficiency. Each method generally gives acceptable results provided that the technique is restricted to the particular limitations of the basic assumptions. However there may be occasional pressure readings which result in errors of fifty or more feet. The occurrence of these errors can only be detected by repeating the field measurements or by the determination of the elevation by some other means. Some of these errors may be attributed to reading errors (i.e. mistakes) but the remainder must be due to some weakness in the fundamental hypothesis. The reading error may be readily detected by using a battery of two or more barometers for each field reading and comparing the resultant readings. The remaining sources of error are more difficult to isolate and are the subject of the present investigation.

The investigation falls naturally into a number of discrete sections which were each examined in turn. These sections are:

1. Historical and Theoretical Review.
2. Examination of the Surveying Aneroid.
3. Investigation of the Pressure/Height relationship in a vertical column.

4. The Isobaric Surface.
5. Field Traverses.
6. Methods of computation of the results.
7. Analysis of the experimental results.

The examination of the Surveying Aneroid led the writer to the development of a laboratory standard barometer which was operated impersonally and had a precision of 1×10^{-4} inches of mercury. This instrument was used to test a number of types of Aneroid Barometer.

It was shown that the better class of modern barometer in fact reads atmospheric pressure more accurately than the various mathematical models fit the known data. The errors then must significantly be due to irregularities in the atmosphere. These irregularities form the limiting condition and so improvements in the instruments will not have any significant effect on the results.

The next section was the testing of the accepted formulae for the pressure/height relationship. Barometers were positioned at various levels on a free standing television tower and simultaneous readings of pressure taken on a number of occasions.

The standard atmospheres were shown to be unsatisfactory in the vicinity of the ground. This led to the development of new standard atmosphere which was designated as ASA (Assumed Standard Atmosphere).

This atmosphere and the standard I.C.A.N. atmosphere were tested against field readings and the results compared.

The precision of the elevation of a field station was shown to be a complex function of the tilt of the apparent isobaric plane and the distances between the base stations.

This led naturally into an investigation of the limits between which it is feasible to assume that the isobaric surface approximates a plane surface. Pressure readings were taken at five points of known position and elevation. From these readings the degree of tilting of the surface and the deviation from a plane were deduced.

A number of field traverses were then calculated on the basis of the conclusions formed in the foregoing. This completed the experiments and allowed a statistical study of the results to be made.

There are a number of standard conventions used in measuring atmospheric pressure. This led to some confusion when reducing the readings. Accordingly, the conventions specified by British Standard No. 2520; 1954 have been used throughout.[4] This standard states (page 8):

"2. Apart from the basic unit of pressure viz. the dyne per square centimeter (dyne/cm^2), the following pressure units only shall be recognized for barometric purposes. They are given in order of preference, the millibar being strongly recommended:-

a. The millibar, equal to 1000 dyne/cm^2.

b. The millimeter of mercury at 0° C and standard gravity 980.665 cm/s^2.

c. The inch of mercury at 0° C and standard gravity 980.665 cm/s^2.

By 'mercury at 0° C' is meant a hypothetical fluid having an invariable density of exactly 13.5951 g/cm^3."

Further it is stated on the same page that the three basic units may be denoted by the abbreviations mb, mmHg and inHg.

Since the instruments used for this project were graduated in either inches or millimetres, the appropriate units as defined above have been adopted throughout. The Askania instruments which were calibrated in Torr. have been converted to inches of Mercury.

Finally, I would like to acknowledge the assistance of my supervisor, Professor P. Angus-Leppan for his helpful suggestions, T.C.N. Channel 9 for the use of their Television Tower, Mr. R. Degotardi of Technicomps for the use of his electronic computor and also the many people who generously came to my assistance.

CHAPTER 1

HISTORY OF BAROMETRIC SURVEYING

The concept that air has weight was theorised by Anaxagoras and Empedocles some 2400 years ago to explain the lifting power of pumps. Aristotle dismissed this idea and it remained to Galileo to show that air has mass.

This was vertified by his pupil Torricelli who in 1643 discovered that when a tube filled with mercury was inverted with the open end in a bowl of mercury, the difference in height between the two mercury surfaces was independent of the length or inclination of the tube (see Figure 1.1).

When this was repeated with fluids of different density the same effect was observed, the height of column being inversely proportional to the specific gravity of each fluid. From this he deduced that the weight of the column of fluid was supported by the weight of the atmosphere.

The first demonstration that the weight of the atmosphere could be used to determine elevations was carried out by Pascal and Perrier on 19th September, 1648 near Clermon-Ferrand, Auvergne, France. Readings of the height of the mercury column were taken at the base and summit of Puy de Dome.[12] From the readings it was seen that there was a relationship between pressure and height. Pascall proposed that the atmosphere was compressible and therefore that the relationship would not

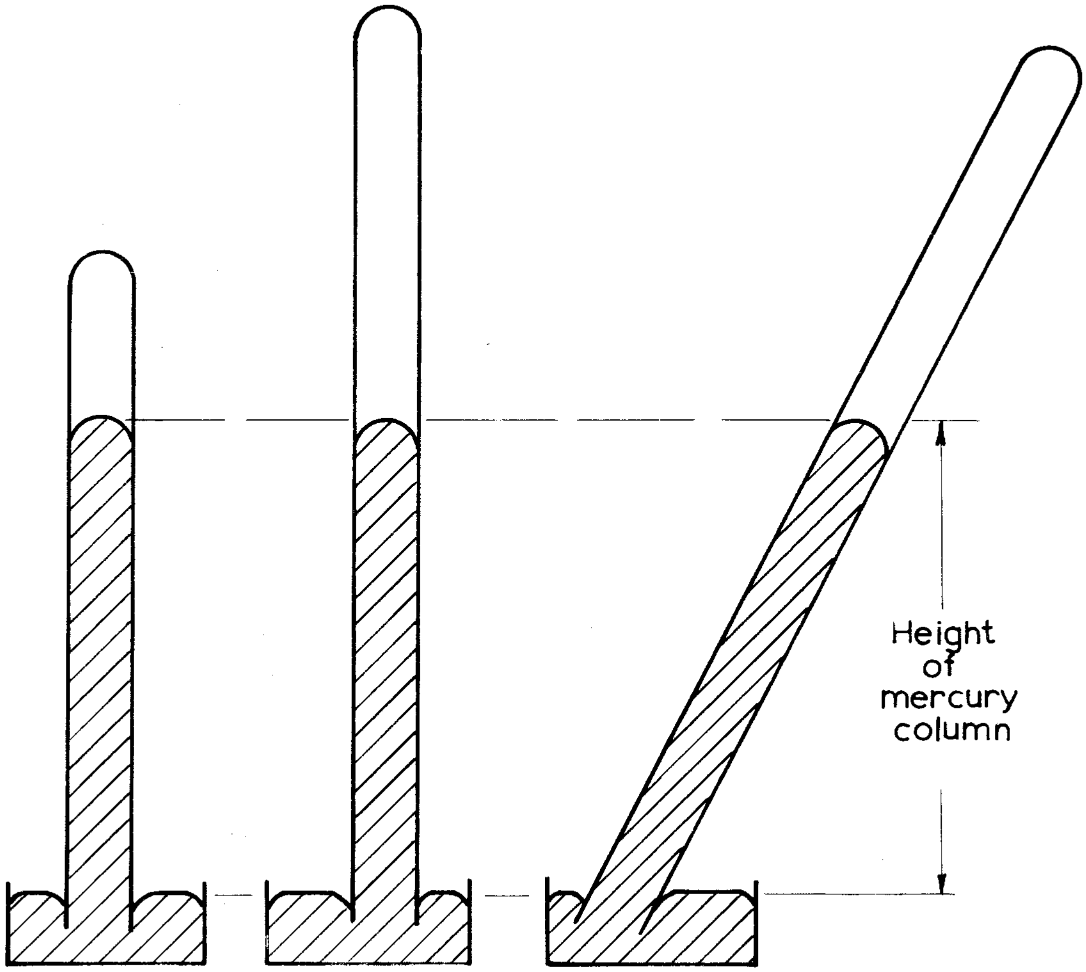


FIG. 1.1. PRINCIPLE OF THE MERCURY BAROMETER.

be linear.

In 1686, Halley put forward the relationship

$$\Delta H = k.\log\frac{P_o}{P_1}$$

where

ΔH is the difference in height

P_o, P_1 are atmosphere pressures

k is a constant.

Numerous experiments were undertaken to find the value of the constant k but as a number of variables such as temperature,humidity and gravity were ignored, the results were disappointing. In 1771, Deluc published in the Philosophical Transactions a method which introduced a temperature correction. This was followed in 1777 by a similar approach proposed by Shuckburg.[12]

Laplace then put forward his theoretical approach to the problem which integrated the hydrostatic equation.[5] He took a column of air of unit cross-sectional area and showed that the pressure change dP for a change in elevation dH is given by:

$$dP = - g.\rho.\ dH \qquad \ldots\ldots (1)$$

where g is the acceleration due to gravity

and ρ is the density of air at pressure P

and absolute temperature T.

But if some standard atmosphere is taken which is denoted by a suffix s, then from the Universal Gas Law:

$$\frac{P.V}{T} = \frac{P_s . V_s}{T_s}$$

or $$V = \frac{P_s . T . V_s}{P . T_s} .$$

Now for the same mass of gas

$$V . \rho = V_s . \rho_s$$

whence $$\rho = \frac{V_s . \rho_s}{V}$$

$$= \frac{P}{P_s} . \rho_s . \frac{T_s}{T} .$$

Substituting in (1)

$$dP = - gP . \frac{\rho_s}{P_s} . \frac{T_s}{T} . dH$$

$$dH = - \frac{P_s}{g . \rho_s} . \frac{T}{T_s} . \frac{dP}{P} .$$

If the temperature T is constant throughout the vertical column, then

$$\Delta H = - \int \frac{P_s . T. dP}{g. \,_s . T_s . P}$$

between the upper and lower pressures.

$$\text{Thus} \quad \Delta H = - \frac{P_s . T}{g. \rho_s . T_s} \left\{ \text{Ln } P_1 - \text{Ln } P_2 \right\}$$

and substituting standard values for $\frac{P_s}{g. \rho_s}$

$$\Delta H = 60370 (\log P_1 - \log P_2) \quad (1+0.002695 \cos 2 \varphi \quad). \frac{T}{T_s}$$

where φ is the latitude.

The factor $\frac{T}{T_s}$ when the temperature t is expressed in degrees Fahrenheit and T_s is taken as the freezing point in degree absolute becomes

$$\frac{T}{T_s} = \frac{t - 32 + T_s}{T_s}$$

$$= 1 + \frac{t - 32}{T_s}$$

$$= 1 + \frac{t_1 + t_2 - 64}{2\,T_s}$$

$$= 1 + \frac{t_1 + t_2 - 64}{982}$$

where t_1 and t_2 are the two measured Field temperatures in degrees Fahrenheit.

The value 982 is generally reduced to 900 to make an approximate correction for average humidity (see section 6.5.2).[2] The final formula thus becomes [2, 5]

$$\Delta H = 60370\,(\log P_1 - \log P_2)\,.\,(1+0.002695\ \text{Cos}\ 2\varphi).(1+\frac{t_1+t_2-64}{900}).$$

Sir G. B. Airy[5] derived his constants for an atmospheric temperature of 50° F with average humidity which modified the formula to

$$\Delta H = 62579\,(\log P_1 - \log P_2)\,(1+0.002695\ \cos\ 2\varphi)\,(1 + \frac{t_1 + t_2 - 100}{1000})$$

Average humidity is defined as 50°/o relative humidity at 50° F.[8]

The effect of the gravity term varies from 0.27°/o at the equator to zero at latitude 45°.[14] Since other errors have a much larger effect it may safely be neglected.

In the foregoing, it was assumed that the atmosphere is at a constant temperature. This has been shown to be incorrect for there is a general fall in temperature with an increase in elevation.[3, 9, 15, 27] This is called the Lapse Rate and has been found empirically to be 6.5° C per kilometer (3.56° F per 1000 ft.). Incorporation of this Lapse Rate into the derivation gives rise to the Lapse Rate Formula proposed by the International Commission for Aerial Navigation in 1924.[9]

Denoting the Lapse Rate as γ,
the sea level temperature as T_o,
and the elevation as H

then $$T = T_o - \gamma . H$$

and the Hydrostatic equation[3]

$$\rho = \frac{P}{RT}$$

may be expressed as

$$dP = - \frac{P.g.}{R.T.} \, dH$$

where R is the Gas constant.

Integrating this relationship gives:

$$\int_{P_o}^{P} \frac{dP}{P} = \int_{o}^{H} \frac{g}{R.(T_o - \gamma.H)} . dH$$

$$\ln \frac{P}{P_o} = \frac{g}{R.\gamma} \ln \left(\frac{T_o - \;.H}{T_o}\right)$$

$$\frac{P}{P_o} = \left(\frac{T_o - \gamma.H}{T_o}\right)^{\frac{g}{R.H}}$$

whence $$H = \frac{T_o}{\gamma} \left(1 - \left(\frac{P}{P_o}\right)^{\frac{R\gamma}{g}}\right)$$

This may be expressed as:

$$H = C_1 \;.\; \left(1 - \left(\frac{P}{P_o}\right)^{C2}\right)$$

where $$C_1 = \frac{T_o}{\gamma}$$

and $$C_2 = \frac{R.\gamma}{g}$$

With the advent of the aneroid barometer, it became feasible to graduate the instruments in both pressure readings and the corresponding elevation according to some standard atmosphere. A number of these standard atmospheres have been adopted in various countries. The most common are listed below.

INTERNATIONAL STANDARD ATMOSPHERE - I.C.A.N.[3, 9, 14, 15.]

1. The air is dry and its chemical composition is the same at all altitudes.

2. The value of gravity is uniform and equal to 980.62 cm per sec per sec.

3. The Temperature and pressure at M.S.L. (Mean Sea Level) are 15° C and 1013.2 mb.

4. At any altitude z (metres) measured above M.S.L. and between 0 and 11,000 m. the temperature of the air is given by

$$T = 15 - 0.0065 z \ 0^{\circ} C.$$

5. For altitudes above 11,000 m, the temperature of the air is constant and equal to -56.5° C.

(Hence $C_1 = 145367.59$ and $C_2 = 0.19023$)

U.S. STANDARD ATMOSPHERE (or N.A.C.A. Standard Atmosphere).[3, 14.]

This atmosphere is similar to the I.C.A.N. but uses slightly different constants.

1. Gravity = 980.665 cm per sec per sec.

2. M.S.L. pressure = 760 mmHg = 1013.25 mb.

3. M.S.L. Temperature = 15° C.

4. The lapse rate 0.0065° C per metre applies to elevations up to 10,769 m.

5. Altitudes above 10.769 m, the temperature of the air is constant and equal to -55° C.

(Hence $C_1 = 145367.59$ and $C_2 = 0.190284$)

I.C.A.O. STANDARD ATMOSPHERE[11, 14]

This atmosphere is identical to the I.C.A.N. Standard Atmosphere except that the M.S.L. pressure is 1013.250 mb (=760 mm Hg.). (Hence $C_1 = 145367.59$ and $C_2 = 0.19023$)

LAPLACE STANDARD ATMOSPHERE[5]

1. The air is dry, isothermal and homogeneous.
2. The value of gravity at latitude 45° is 980.665 cm per sec per sec.
3. The Mean Sea Level (M.S.L.) pressure is 760. mm Hg.
4. The Mean Sea Level temperature is 32° F.
5. The constant $\frac{P_s}{g.\rho s}$ is 60370.

AIRY'S STANDARD ATMOSPHERE[5]

1. The air is isothermal and homogeneous.
2. The humidity is "average".
3. The value of gravity at latitude 45° is 980.665 cm per sec. per sec.
4. The M.S.L. Pressure is 31.00 inHg.
5. The M.S.L. Temperature is 50° F.
6. The constant including the humidity correction is 62759.

AIRY'S MODIFIED STANDARD ATMOSPHERE[5]

This atmosphere is similar to the usual Airy's Atmosphere but is taken with dry air.

The constant then becomes 62580.

ASSUMED STANDARD ATMOSPHERE (See Chapter 3)

1. The air is dry and its chemical composition is the same at all altitudes.
2. The M.S.L. pressure is 760 mmHg = 1013.25 mb.
3. The M.S.L. Temperature is 15° C.
4. The constant C_1 is 143831.87.
5. The constant C_2 is 0.18910.

The use of a Standard Atmosphere to graduate the barometer scale greatly simplifies the reduction of the readings as the more tedious part of the calculation has already been carried out. The difference in height is obtained by subtracting the two readings and then applying the appropriate temperature correction.

In practice, the choice of standard atmosphere is largely a personal choice as the variation in the computed difference in elevation using the values as indicated is insignificant.

However, in Chapter 3 it has been shown, at least for the coastal region in the vicinity of Sydney, Australia that the adoption of any of the above Standard Atmospheres will lead to somewhat larger errors than would be the case if the new standard atmosphere designated as the Assumed Standard Atmosphere (A.S.A.) had been used.

CHAPTER 2

EXAMINATION OF THE SURVEYING ANEROID

The mercury barometer although simple in concept and use is not sufficiently robust or sufficiently compact for general use in the field. This led to the development of the "Mountain Barometer" which can be used in the field but is somewhat inconvenient. In this instrument the glass tube has been encased in a metal sleeve in an attempt to overcome the inherent fragility of the instrument.[35] In a parallel development, the principle that a partially evacuated chamber, with the sides forced apart by a spring, would tend to dilate or contract according to the atmospheric pressure, was utilised to construct the aneroid barometer. Since the movement of the chamber is small the linkage by which the movement is translated into a pressure reading must incorporate a high degree of magnification.[5] As the forces are small, this magnification linkage must be of minimum size and low inertia. It must use jewelled bearings and rely on precision workmanship comparable with that used in small watches (see figure 2.1). Even so the earlier instruments require a light vibration before reading to ensure that the linkage has completed its movement.[21] This vibration may be generated by tapping the instrument lightly on the glass face with a finger or pencil.

When the instrument is not vibrated the readings may be

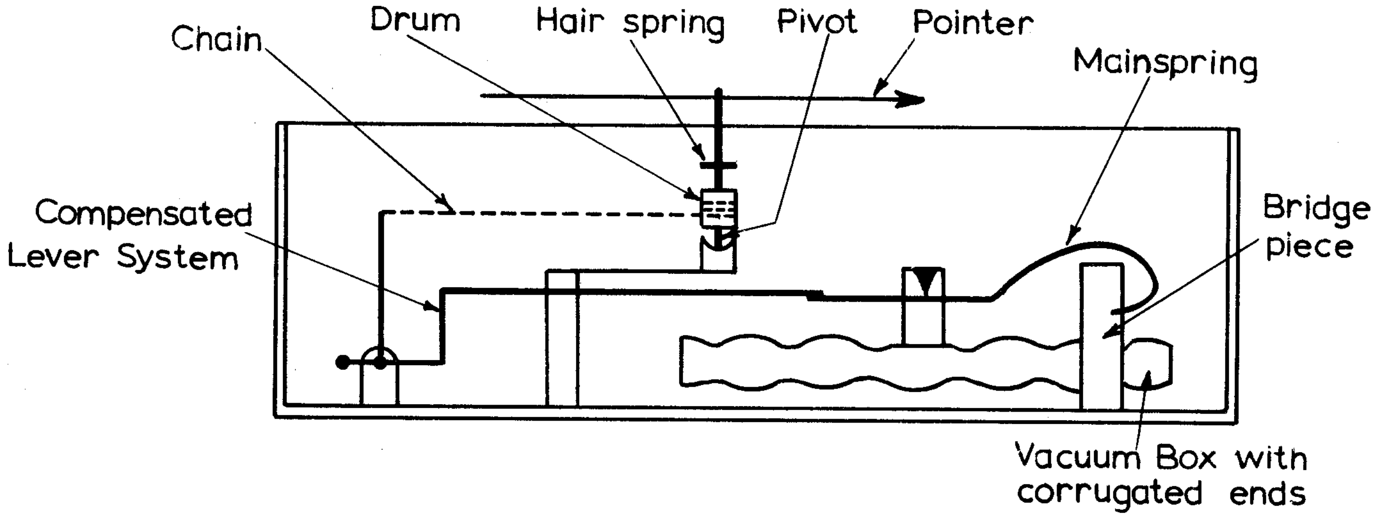


FIG. 2.1. ANEROID BAROMETER MECHANISM.

unreliable and have errors up to 50 feet or more.[5]

More recently the so called micro-barometers have entered the field with radically new approaches to the problem of translating the movement of the pressure chamber to the reading scale. Since these instruments have been described in a number of places,[2, 5, 12, 44, 50, 53] they will not be described in detail here. It will suffice to mention only the principle by which in the better instruments the movement is translated.

2.1 ASKANIA MICROBAROMETER[44, 50]

A Bourdon tube (A) in the form of an evacuated helical spring is utilized as the pressure-sensing element. The upper end of the tube is firmly clamped and the lower end is attached to a fine wire torsion bar (B). A mirror (C) is fixed to the torsion bar (see figure 2.2). Pressure changes cause a rotational movement of the Bourdon tube which is in turn transferred to the torsion bar. This causes the mirror to rotate slightly. The mirror is viewed through an autocollimating telescope (D). The image of one of a series of index lines engraved on the mirror appears on an eyepiece scale. The reading is made by recording the scale reading of the index line on the eyepiece. The instrument is extremely sensitive and a small pressure change (approximately 9.5 mm. Hg.) will cause an index line to move across the entire scale. For this reason four index lines are provided extending the range to approximately 38 mm.Hg. Pressure variations beyond this range may be measured by rotating the top of the Bourdon tube to another one of a number of predetermined positions. This causes the image of the index lines to be brought back into the field of view.

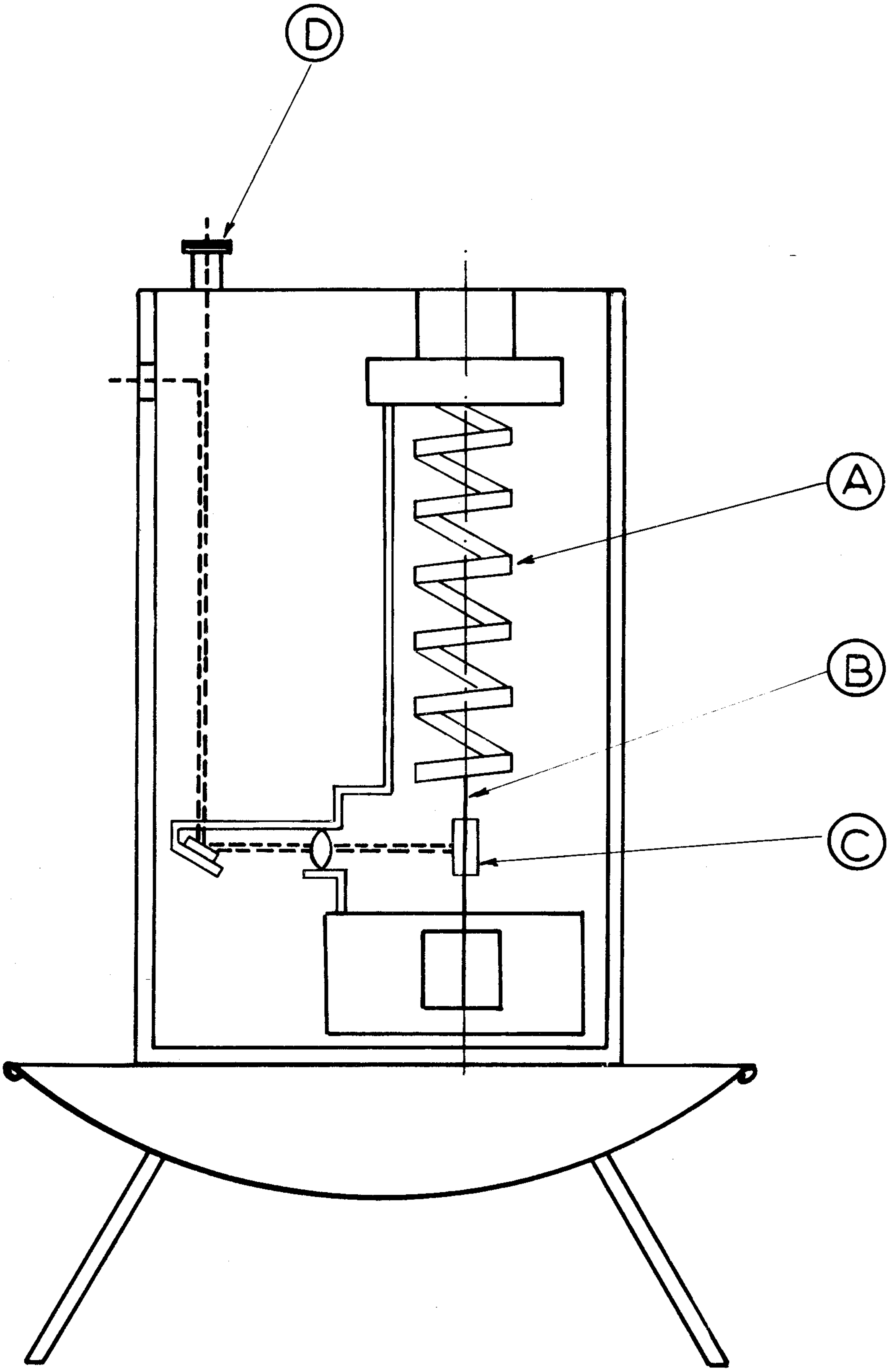


FIG. 2.2 SCHEMATIC SECTION OF THE ASKANIA MICROBAROMETER.

The instrument is extremely sensitive to temperature. For this reason a "built in" thermometer is provided and the instrument is surrounded with a leather case filled insulating material for thermal insulation.

While the instrument is extremely sensitive for small relative changes of pressure, the lack of sensitivity in setting the upper clamp to the predetermined position makes difficult an effective use of this instrument for field barometer traverses due to the possibility that vibrations during transport may cause a slight shift in the setting which would be difficult to detect.

2.2 WALLACE AND TIERNAN SURVEYING ANEROID[5, 50, 53]

This barometer consists essentially of a precision aneroid mechanism shock mounted in its case. The mechanism includes a low-inertia movement (A), a balances pointer (B), flexure pivots (C), a backlash eliminator and jewelled bearings to ensure sensitivity (see figure 2.3). Before reading it is advisable to lightly vibrate the movement.

The reading scale is graduated to 10 foot intervals according to the Smithsonian Meteorological Table No. 51 Standard Atmosphere (identical to the U.S. Standard Atmosphere). This scale may be interpolated to one foot.

2.3 THE AMERICAN PAULIN SYSTEM[5, 50]

The basic principle of this instrument is the use of a null reading as an indication of matching tensions in the evacuated chamber and the balance spring.

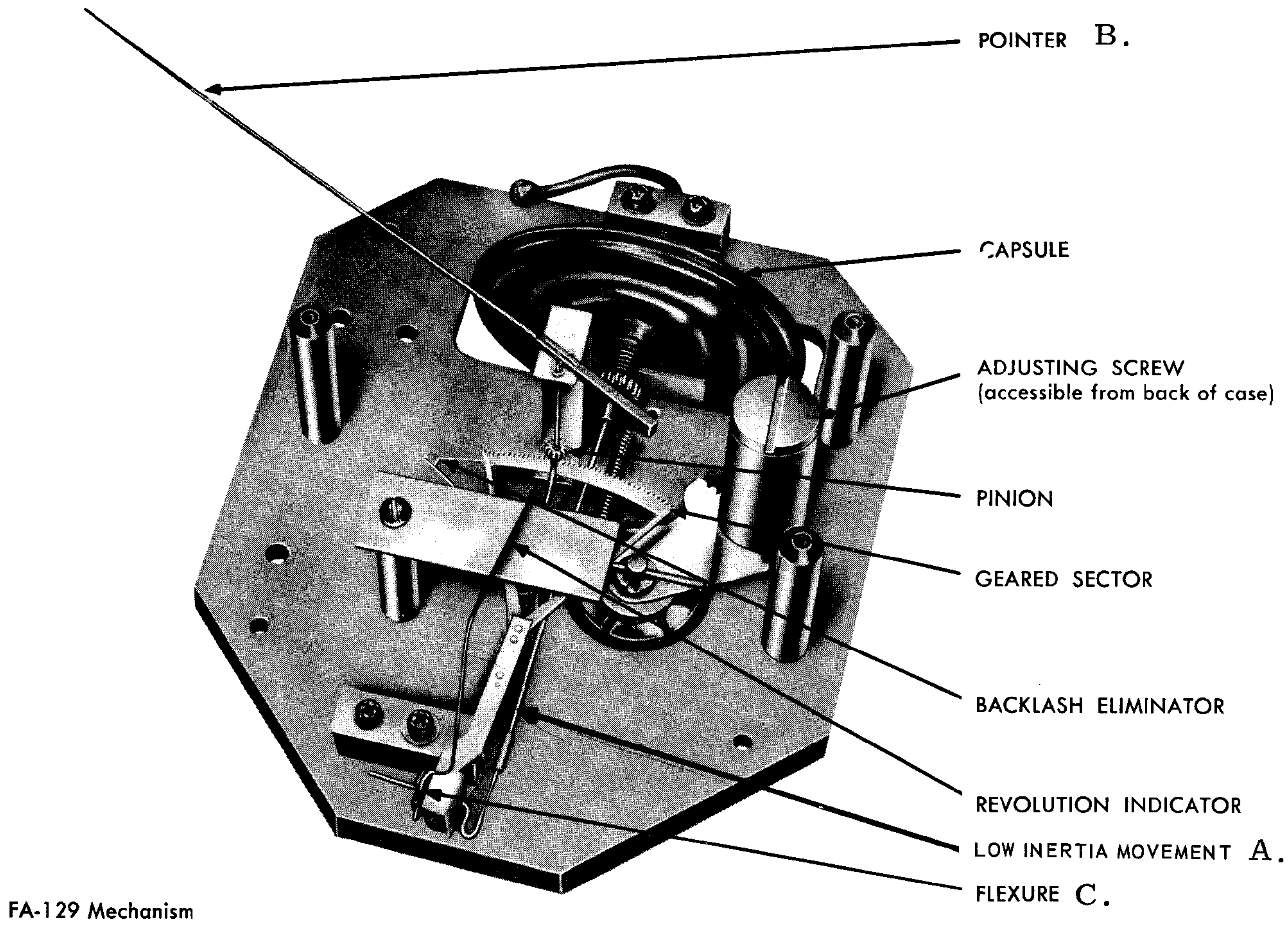


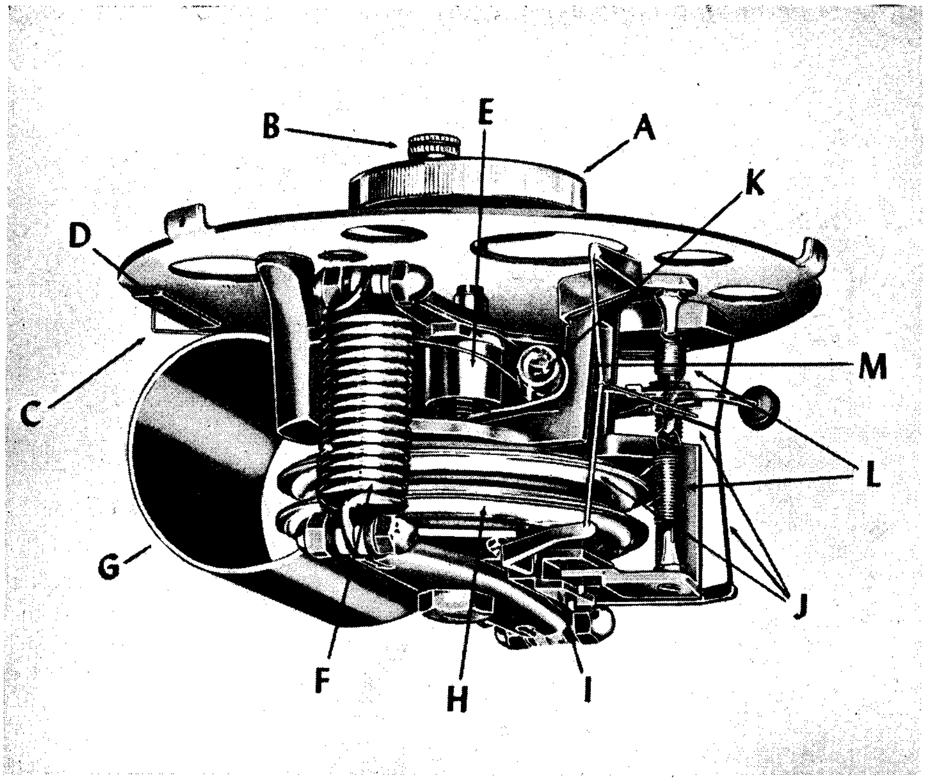
FIGURE 2.3 THE WALLACE AND TIERNAN BAROMETER.

A change of air pressure will cause contraction or expansion of the diaphrams (H) (see figure 2.4). This causes a change in the sensitive bands (J) in such a manner that the balance indicator pointer (C) will move from its zero point. Rotation of the control knob (A) will turn the precision-ground micrometer screw (E). This will directly change the tension of the balance spring (F) across the diaphrams (H). This will also cause the bands to return the balance indicator pointer (C) to its zero point.

The pressure may then be read directly on the graduated scale by means of the pointer which is integral with the control knob (A).

2.4 THE BAROMEC BAROMETER (see Figure 2.5)[5]

In this instrument the pressure chamber is not required to actuate a complex mechanical linkage. Instead movements of the pressure chamber (A) are followed by a simple lever (B) which is held against the pressure chamber by a hair spring (see figure 2.6). The position of this lever is then measured by a micrometer (D) utilizing an electronic contact. The circuit for the electronic contact indicator is given in figure 2.7. The valve (DM70) displays two different configurations depending on the potential across the valve grid. When the potential is negative the display takes the form illustrated in figure 2.8 (a). When the potential is positive, the display is changed to the form illustrated in figure 2.8(b). From the circuit diagram (Figure 2. 7), it will be seen that when the contacts are open the potential on the grid will be negative. When the contacts close the potential becomes positive. Tests have shown that this method



A	Control Knob.	I	Diaphragm Limiting Device.
B	Reset Knob.	J	Bands, to operate balance indicator pointer.
C	Balance Indicator Pointer.	K	Damper, reducing vibration of balance indicator pointer.
D	Mirror.	L	Balance Indicator Suspension Springs.
E	Micrometer Screw.	M	Precision Frame Casting.
F	Balance Spring.		
G	Diaphragm Spring.		
H	Diaphragms.		

FIGURE 2.4 CONSTRUCTION OF THE PAULIN BAROMETER.

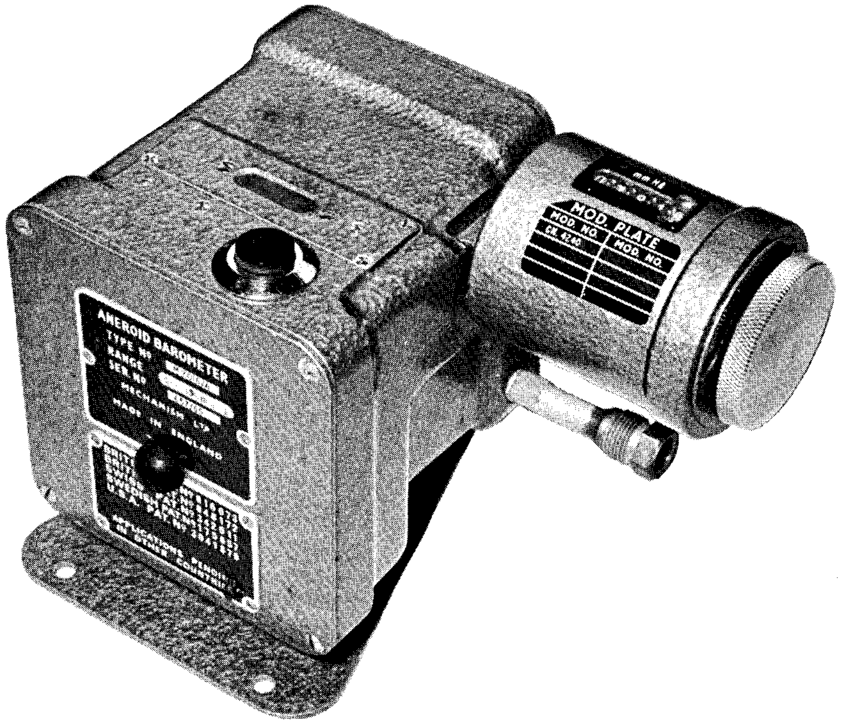


FIGURE 2.5 THE BAROMEC BAROMETER.

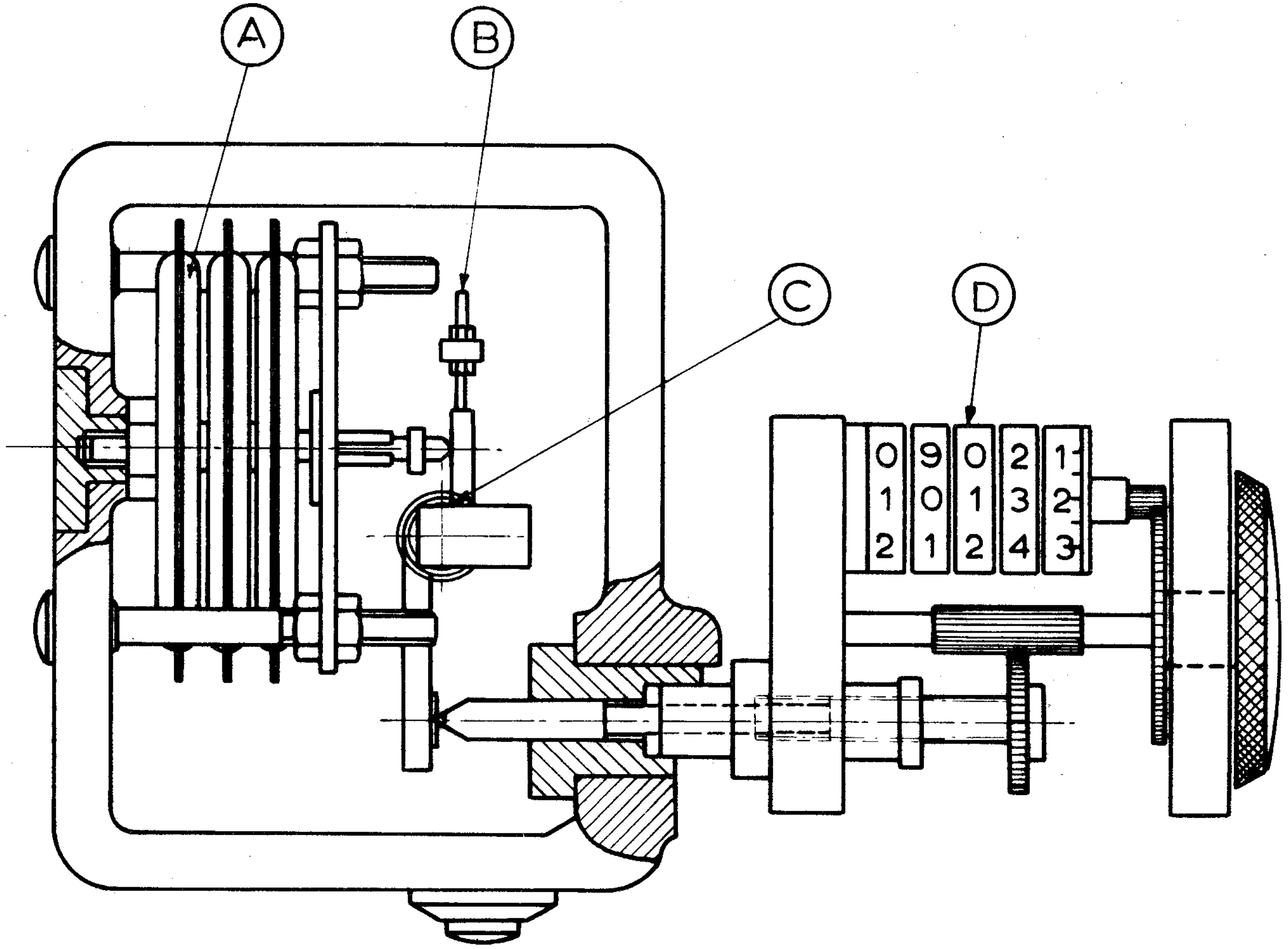


FIG. 2.6 BAROMEC BAROMETER

of indicating contact is capable of a precision of 1×10^{-5} inch.

To read the instrument, the micrometer knob is rotated until the position is reached where the contacts just close. The micrometer which may have conventional scales or take the form of a digital read-out is then ready for reading.

Tests have shown this instrument to be extremely robust and not subject to a significant hysteresis or drift.

2.5 THE BAROMETRIC COMPARATOR[18]

For this report, the main concern was to establish the reliability of the barometric instruments. Before this could be investigated, it was necessary to construct a reliable standard instrument against which the individual instruments could be tested in the laboratory for errors from a variety of sources. These errors were loosely grouped together as systematic and random errors, viz.

1. Random Errors in the linkage and in reading.
2. SystematicErrors (a) Graduation Errors.
   (b) Drift with respect to time.
   (c) Hysteresis.
   (d) Error due to Temperature.

Thus the standard instrument had to be capable of giving reliable readings which were more accurate than the instruments under investigation (.01 mm of mercury pressure) and incorporate a pressure chamber to allow the pressure to be varied at will. Obviously, although

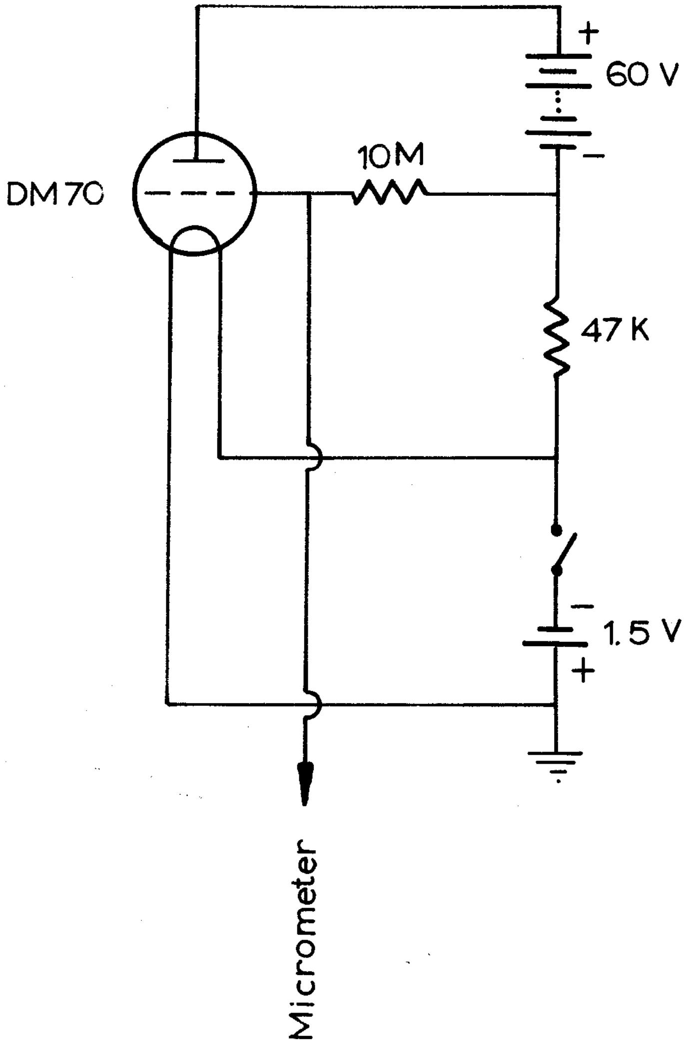
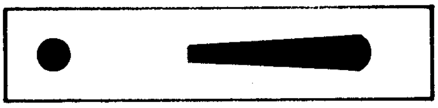
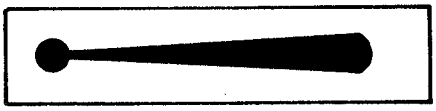


FIG. 2.7 CONTACT INDICATOR CIRCUIT



(a) Contact not made — Decrease Reading



(b) Contact made — Increase Reading

FIG. 2.8 CONTACT INDICATOR FOR BAROMEC BAROMETER.

it would have been ideal if the standard barometer had given absolute measurements, this was not necessary since a small index error would not have any significant effects. The manipulation is actually in relative readings or reading difference.

Accordingly, the barometric comparator was designed and constructed. This instrument although fundamentally a normal mercury barometer of the Fortin type[1] has a number of novel features (see figures 2.9, 2.10).[18] In the first place, it would have been extremely difficult if not impossible to achieve the required precision of the reading by relying on optical settings of the reading scales within a small pressure chamber. This led to the use of electronic contact indicators.[38, 47] Since it is impossible to move a contact within the Torricellian Vacuum, the fixed contacts were placed in the top of the tube. Readings were obtained by raising the piston and hence both mercury levels until contact was made at the fixed contact and then reading the level of the lower surface by means of a moveable contact (see figure 2.9).

Since electronic circuits had already been installed, it was then a simple matter to use these circuits to control the two servo motors required to operate both the piston for setting the upper contact and the moveable contact. Inclusion of a latching relay made the readings impersonal and extremely simple.

In practice, to obtain a reading it was only necessary to press one button-switch.

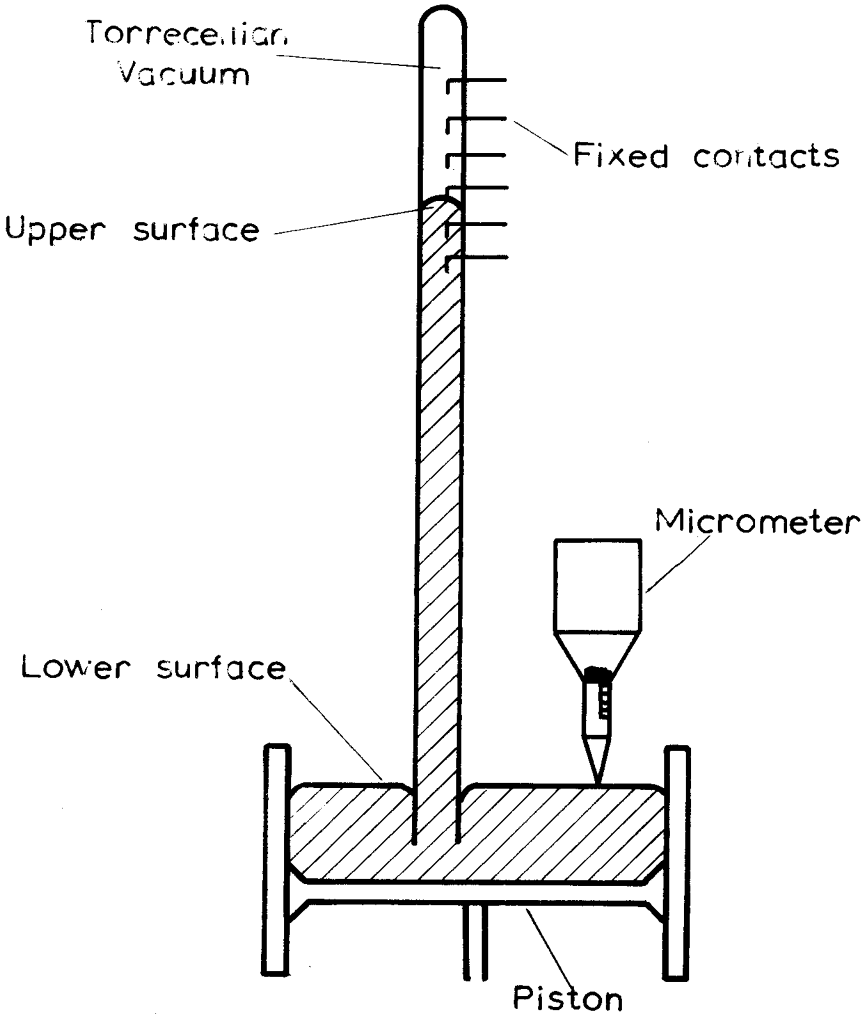
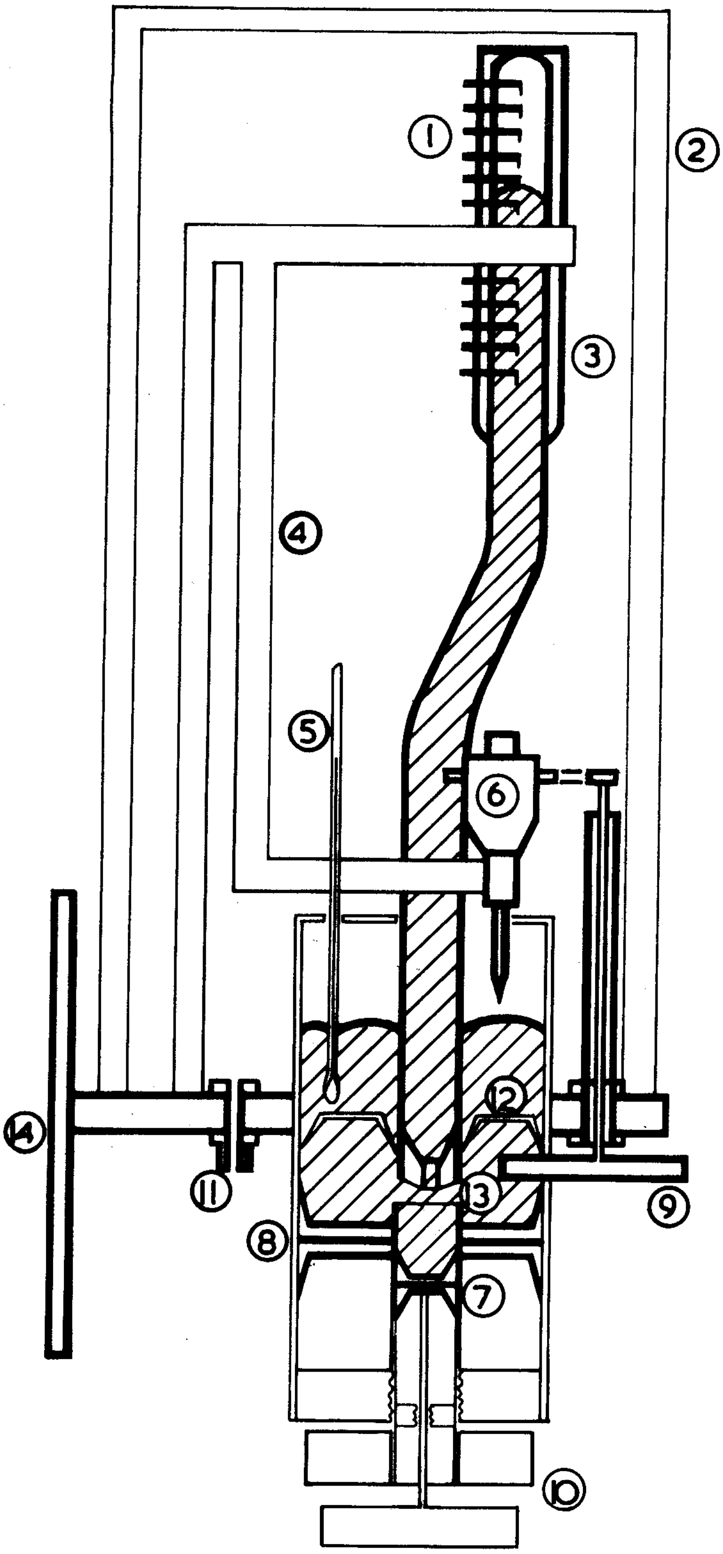


FIG. 2.9 SCHEMATIC DIAGRAM SHOWING BASIC DESIGN.



1. Upper contacts.
2. Pressure chamber.
3. Shell Epicote Resin casting.
4. Independant micrometer mounting.
5. Thermometer.
6. Micrometer.
7. Fine adjustment piston
8. Coarse adjustment piston.
9. Micrometer control.
10. Piston control.
11. Pressure inlet.
12. Sludge trap.
13. Choke.
14. Wall mounting bracket.

Figure. 2.10 SCHEMATIC DESIGN OF THE BAROMETRIC COMPARATOR.

When this switch (G) was pressed the latching relay (C) was closed (see figure 2.11). At the same time the main relay (A) for the piston servo motor closed causing the motor to turn in the direction required to lower the piston. This in turn caused the upper and lower mercury surfaces to be lowered.

The motor continued turning in this direction until the upper fixed contact left the mercury. Due to capillary action the mercury tended to cling to the sharpened contact and hence when the circuit was broken, the mercury surface was approximately .1 mm below the contact. The main relay then opened causing the latching relay (C) to open and the motor to turn in the opposite direction. The motor continued to turn until contact was made. The main relay then closed but since the latching relay (C) was open, the piston servo motor did not turn.

Simultaneously, the serve motor for the moveable contact followed a similar procedure except that the latching relay (D) remained closed until the piston servo motor had ceased to operate. The moveable contact thus hunted about the mercury surface until the fixed contact had been set. When the latching switch (D) opened, the servo motor for the moveable piston stopped immediately on making contact.

A reset button switch was provided, so that the moveable contact could be reset without actuating the piston servo motor.

The drive motors were mounted externally to prevent any possibility of the heat generated disturbing the stability of the instrument. The pressure chamber, which was constructed of a one piece Pyrex glass tube

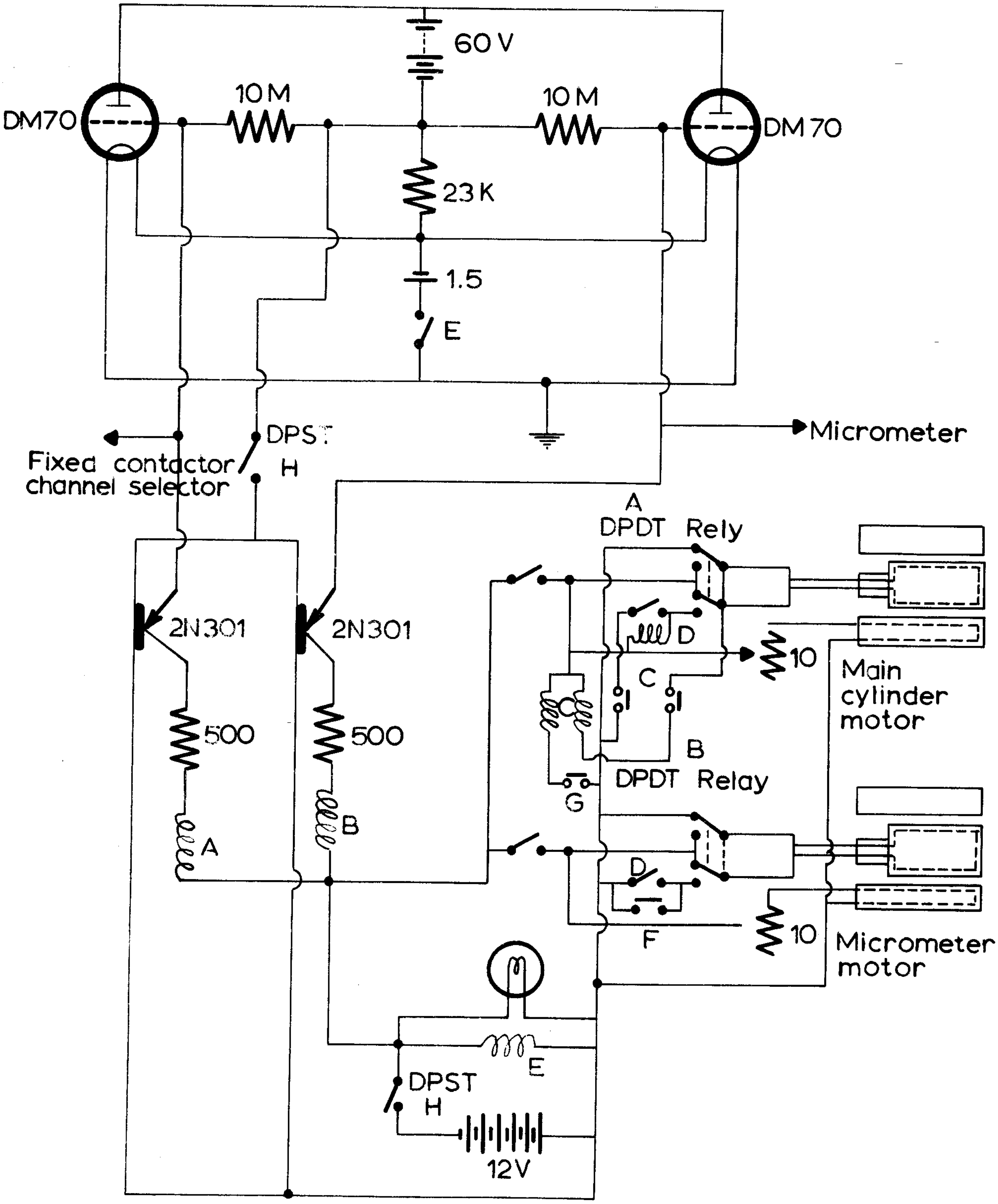


FIG. 2.11 CIRCUIT DIAGRAM OF SERVO CONTROL.

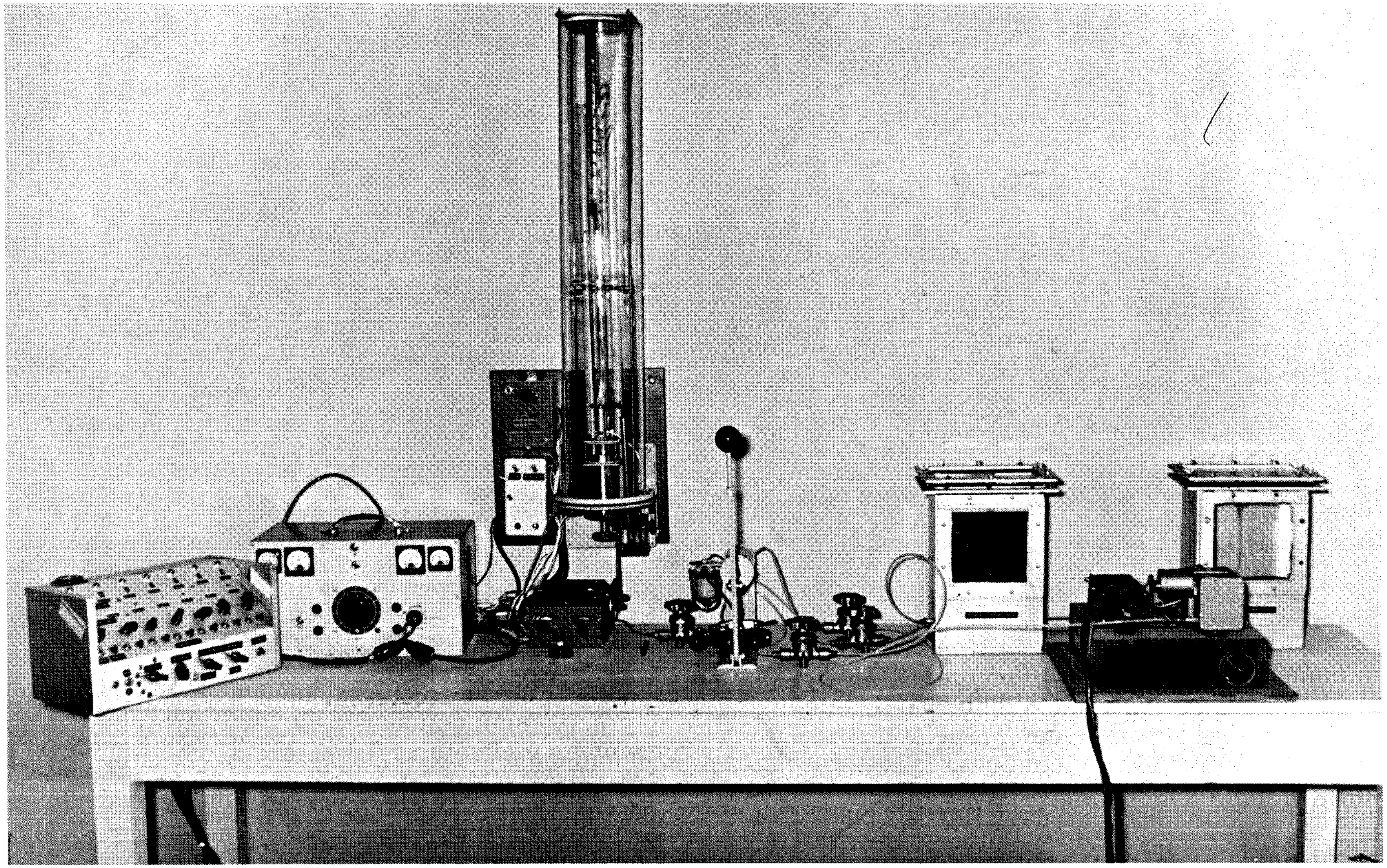


FIGURE 2.12 THE BAROMETRIC COMPARATOR.

with 1/4 inch wall thickness, was placed over the barometer but left the lower side of the reservoir piston exposed (see Figure 2.10).

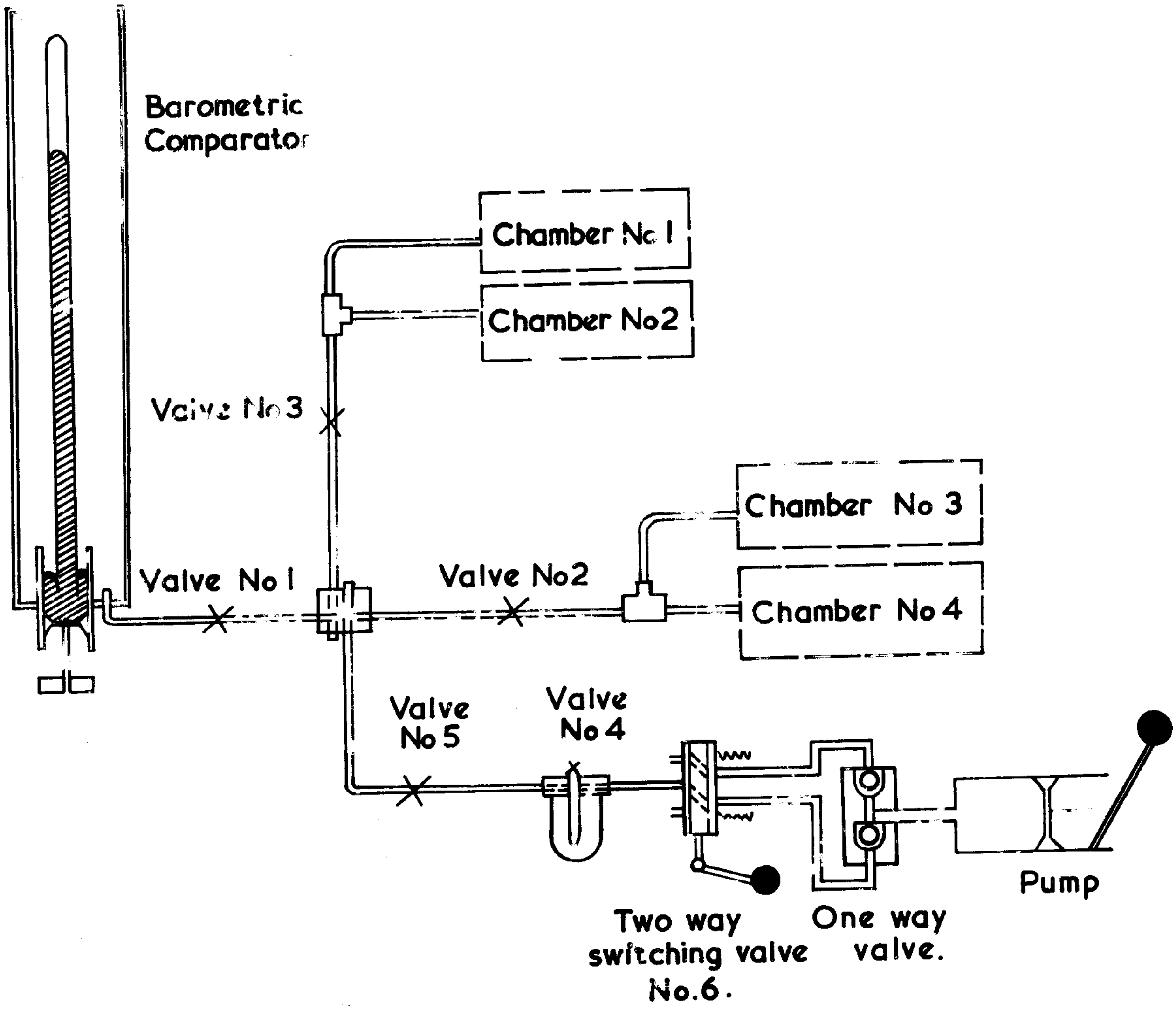
As there was not sufficient room within the pressure chamber for the instruments which were to be tested, these were placed in auxilliary chambers connected to the main chamber by pressure hoses. The inclusion of a pump to vary the pressure and a number of valve cocks to shut off the various sections completed the equipment (see Figure 2.13).

Some difficulty was experienced in cleaning the mercury before installation but this was overcome by passing the mercury through a purifying tube filled with 0.05N Nitric Acid.[7] The mercury was then washed and dried. To prevent any possible effect on the readings due to oxides floating on the lower mercury surface a sludge trap was incorporated in the reservoir and the surface was periodically lowered beneath the trap and then raised, leaving oxides beneath the trap (see Figure 2.14).

The level of water vapour in the system was controlled by placing a reservoir of Silica Gel in the pressure hose adjacent to the pump.

To extend the range of the instrument twelve fixed contacts were placed in the upper tube. These contacts were spaced at approximately 0.9 inch apart to allow for calibration within the range of the moveable contact (1 inch). This gave a total range of approximately 11 inches.

The contacts were formed by L shaped pieces of platinum wire firmly fixed into the wall of the soda glass tube. The pressure difference on the wall of the tube caused leakage past the platinum wire.



CALIBRATION OF ANEROID BAROMETERS BY THE BAROMETRIC-COMPARATOR.

FIG. 2.13

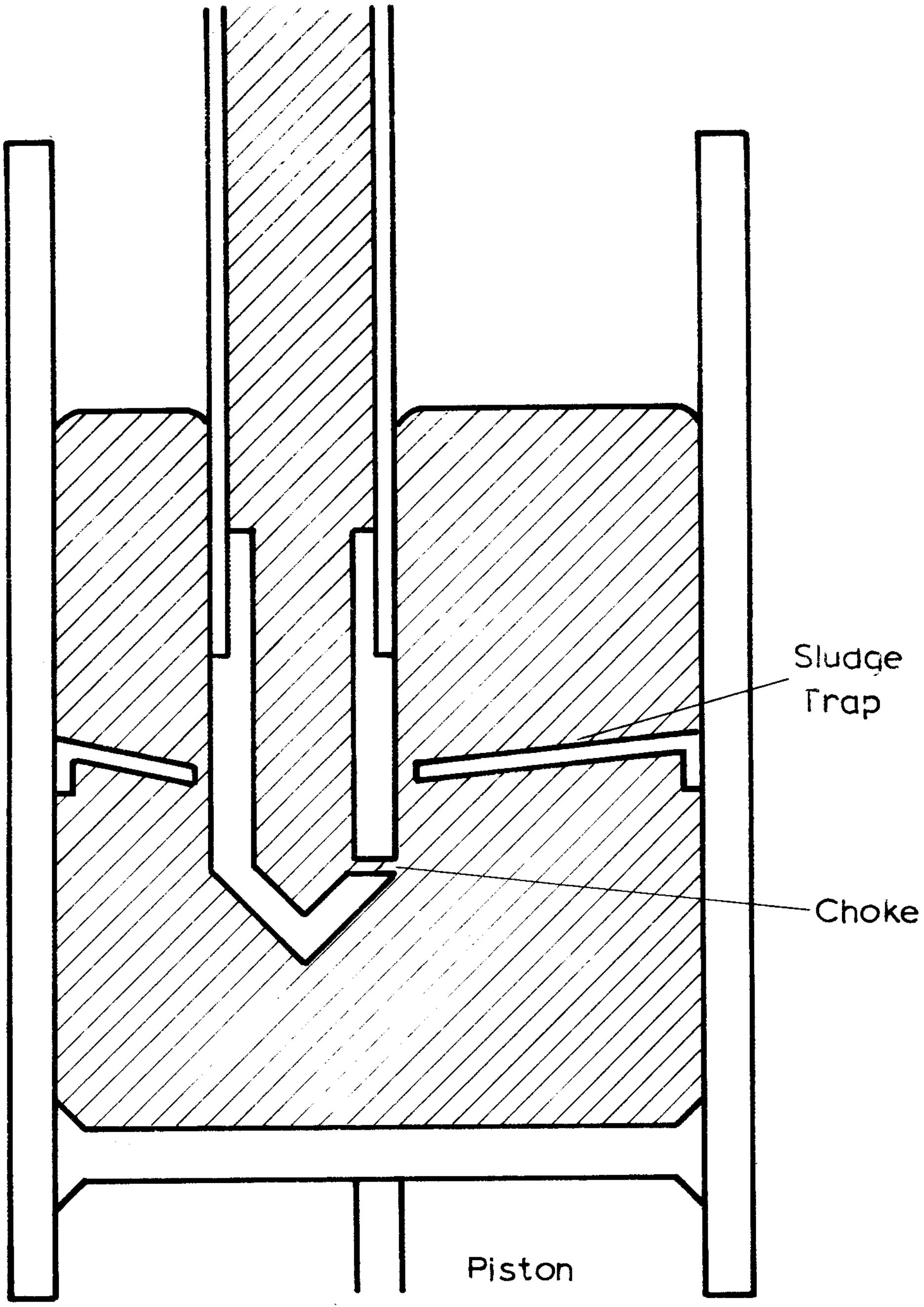


FIG. 2.14 DETAILS OF SLUDGE TRAP AND CHOKE

To overcome this a thin layer of Shell Epicote Resin was run down the inside of the tube to seal the joints. This appeared to give a satisfactory bond but on final setting some shrinkage occurred in the Resin. This set up high stresses in the glass and finally caused a longitudinal crack in the tube. This was overcome by casting a solid block of the Resin around the outside of the tube. This block completely covered the portion of the tubing containing the contacts.

The possibility of arcing between the contacts and the mercury surfaces was most unlikely since the voltage across the contacts was 1.5 volts and the current 1×10^{-6} amp.

Initially, the mercury showed signs of surging while the levels were being changed and so a choke was placed in the lower end of the Torricellian Tube (see Figure 2.14). The choice of diameter of the choke was extremely critical. If too large, then surging took place. If too small, then the excessive damping caused hysteresis when the pressure in the chamber was varied.

While endeavouring to obtain the optimium choke diameter the bottom of the glass tube was cracked. This was repaired by cutting off the bottom two inches of the tube and inserting a two inch long perspex rod drilled out to match the glass tube and incorporating the choke. This rod was cemented in place with an acrylic cement. It was decided to leave the choke diameter at the previous value (0.075" diameter) and to design the experimental procedures to overcome the resultant hysterisis.

Since atmospheric pressure is measured in terms of the height of a mercury column at standard density, a thermometer was incorporated within the reservoir. The connection between the fixed and moveable contacts was manufactured from a mild steel rod and the expansion of this rod taken into account when applying the temperature correction (see figure 2. 15). Further the position of the contact within the glass tube in relation to the support had to be considered.

The temperature correction was thus determined as a function of the mercury column height which must be reduced to standard temperature (32^{o} F) and the length of the mild steel rod and glass reduced to the standard operating temperature (68^{o}) (see figure 2. 16).

Denoting:

C_o as the length of mild steel rod from the support to the zero of the micrometer at 68^{o} F,

C_1 as the length of the column between a particular contact and the micrometer zero at 68^{o},

C_2 as the length of the glass tube from the support to the same contact at 68^{o} F,

μ_1 as the coefficient of volume expansion of mercury (1.010×10^{-4} cubic units/^{o} F),

μ_2 as the coefficient of linear expansion of mild steel (0.65×10^{-5} units/^{o} F),

μ_3 as the coefficient of linear expansion of glass (0.47×10^{-5} units/^{o} F),

R the micrometer reading (inches),

T the temperature (degrees Fahrenheit),

then the corrected reading in terms of the height to which a mercury column at 68° F would rise is given by:

$$H_{68} = (T-68).\left\{(C_o - R).\ \mu_2 + C_2.\ \mu_3\right\} + (C_1 - R).$$

When this formula is reduced to give the height at 32° F:

$$H_{32} = (1 - \mu_1\ .\ (T - 32)).\left\{(T - 68) . \left[(C_o - R).\ \mu_2 + C_2.\ \mu_3\right] + (C_1 - R)\right\}$$

The correction C_T to a reading is given by:

$$C_T = H_{32} - C_1 + R$$

$$= (1 - \mu_1 . (T-32)).\left\{(T-68).\left[(C_o - R).\ \mu_2 + C_2.\ \mu_3\right] + (C_1 - R)\right\}$$

$$\text{x} \left\{(1 - \mu_1)\ (T - 32) - 1\right\}$$

which reduces to

$$C_T = K_2 - K_1 - R.K_3$$

where

$$K_1 = C_1 . \mu_1 . (T - 32)$$

$$K_2 = (1 - \mu_1 . (T - 32)). \ (T - 68). \ (C_o . \mu_2 + C_2 . \mu_3)$$

$$K_3 = (1 - \mu_1 . (T - 32)). \left\{(T - 68). \mu_2 - \mu_1 . (T - 32)\right\}$$

In this form the three variates "K" were found to be functions of one variable only, i.e., T. This made it feasible to construct a nomogram for each contact. For convenience the nomogram was divided into two parts ($K_2 - K_1$) and K_3. The micrometer reading could then be used as an argument for the second nomogram giving the value RK_3 directly. As an example the nomograms for contact No. 3 are given herein (see figure 2.16).

Capillary effects within the glass tube were constant for a given contact as[10]

$$H = -\frac{2 . \gamma . \cos \theta}{a . \rho . g}$$

where h is the height of the capillary,

a is the radius of the tube,

and $\theta = 145^{\circ}$ for mercury.

Since differential pressures only were required this correction could be taken as included in the values of the constants "C_1". The

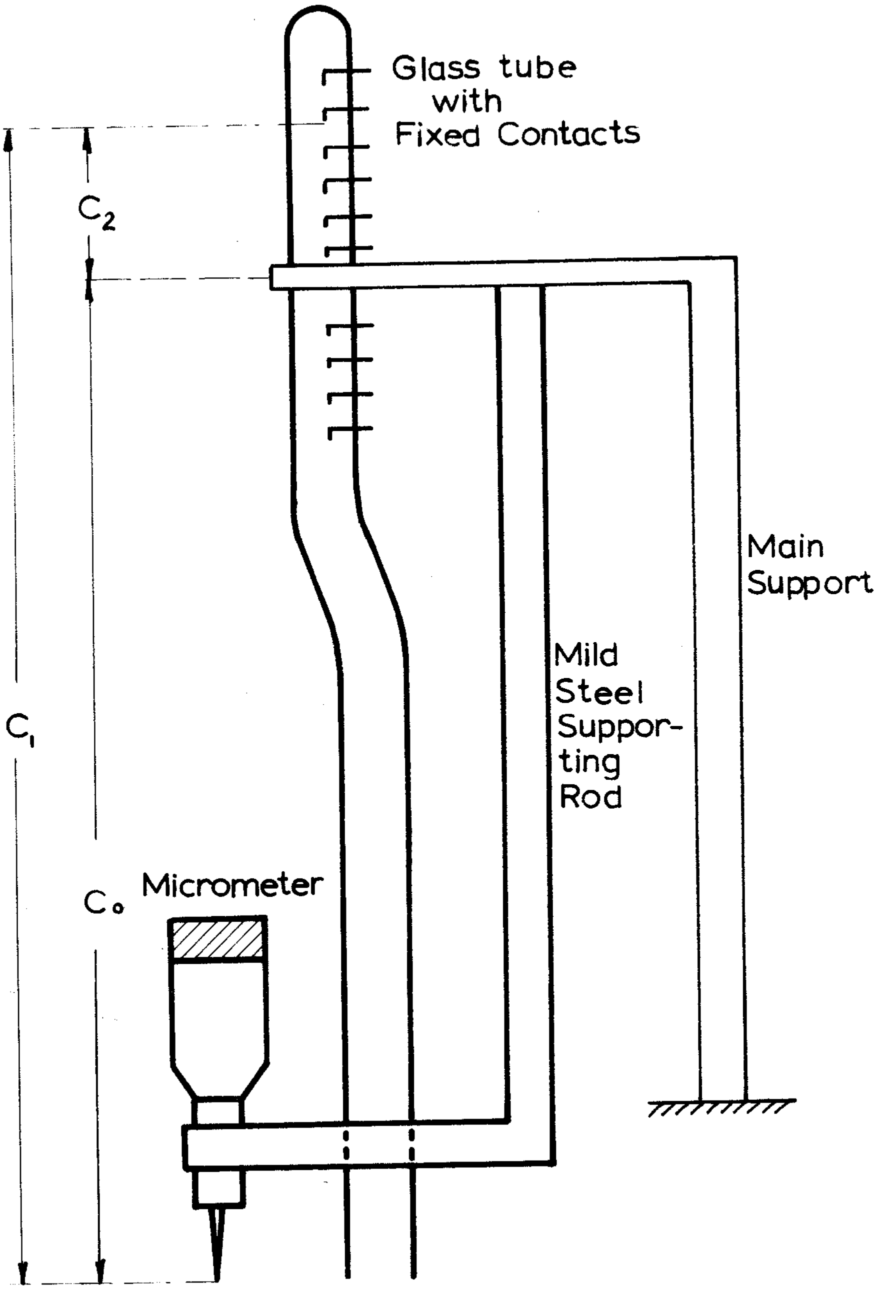


FIG. 2.15 INDEPENDENT SUSPENSION SYSTEM

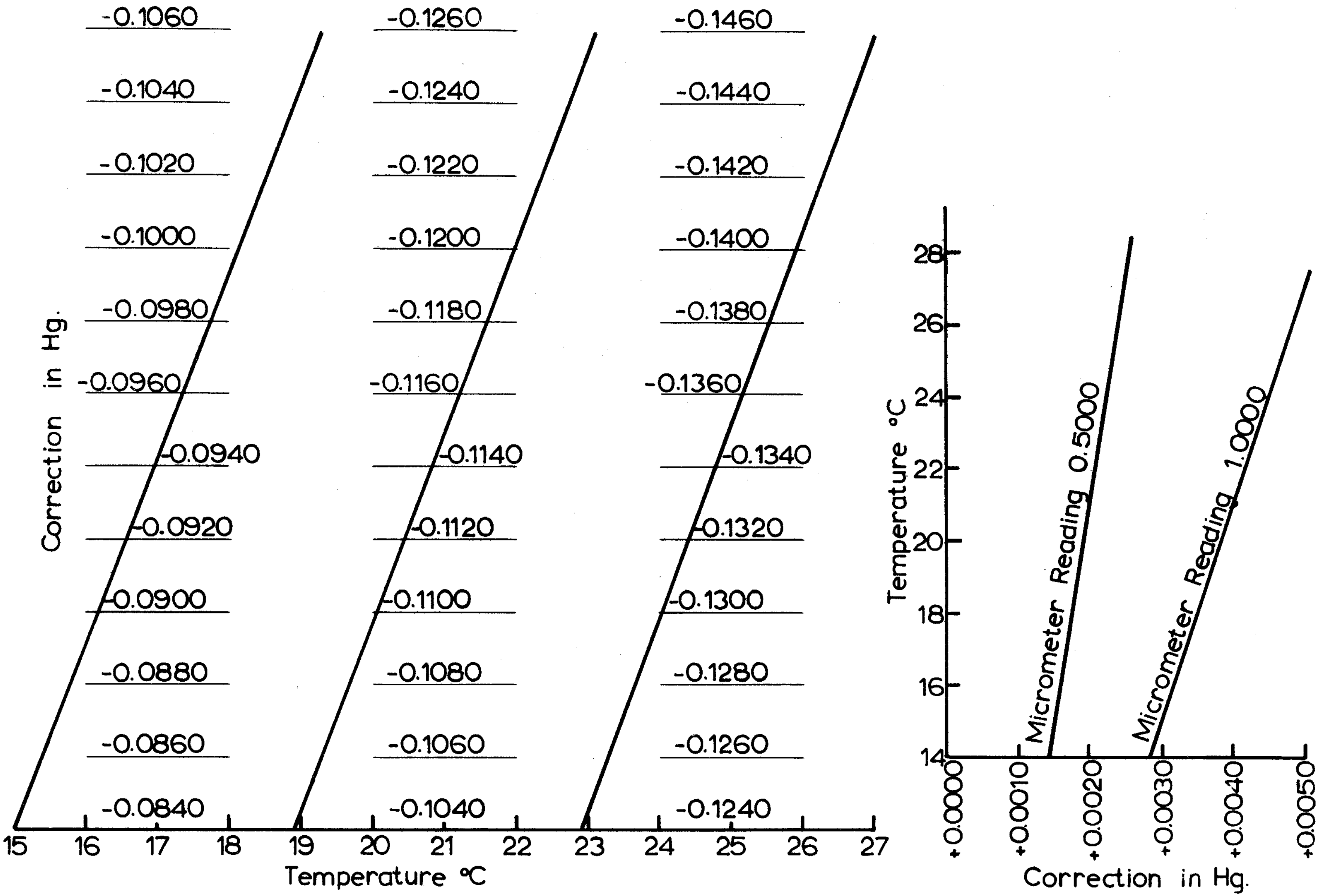


FIG. 2.16 NOMOGRAM FOR TEMPERATURE CORRECTIONS TO COMPARATOR PRESSURES.

correction amounted to + 0.2mm for a tube with a diameter of 1 cm. and would have to be applied when absolute values were required. For relative Readings this systematic error is cancelled due to the method of calibration.

The effect of Vapour Pressure in the Torricellian Vacuum depressed the height of the mercury column by an insignificant amount for the experimental range. For example at 15° C the depression was 0.7×10^{-3} mm and at 25° C only 1.7×10^{-3} mm.

The effect of a variation of gravity from standard gravity at latitude 45° upon the density of the mercury (and thus upon the height of the column) was a systematic error which was disregarded as the pressures were differential.

To calibrate the instrument, the distance between contact No. 3 and the zero of the micrometer was measured as accurately as possible. This distance was adopted as the standard column height at 68° F to which all subsequent readings were referred. The adopted value was 30.2440 inches. Using a "bootstrap" technique, the other contacts were then calibrated using overlapping readings. The results were as given in Table 2.1.

The instrument was then ready for the testing of the aneroid barometers.

In practice, the instrument proved very satisfactory and readings had a repeatability of 1×10^{-4} inches of mercury pressure (.002 mmHg). A typical set of readings at a constant pressure is given in Table 2.2.

TABLE 2.1

CONTACT CALIBRATION CONSTANTS

Contact No.	Pressure in Hg	Estimated Standard Deviation in Hg
1	32.3457	0.0003
2	31.1910	0.0002
3	30.2440	-
4	29.3228	0.0002
5	28.4654	0.0003
6	27.5550	0.0003
7	26.6003	0.0004
8	25.6620	0.0004
9	24.7299	0.0005
10	23.7854	0.0005
11	NOT USED.	
12	NOT USED.	

TABLE 2.2

COMPARATOR READINGS AT A CONSTANT PRESSURE

Contact No. 3 Date: 11/12/63

Temperature	Reading
16.7°C	0.2907 inch
16.7	0.2907
16.7	0.2908
16.7	0.2908
16.7	0.2908
16.7	0.2905
16.7	0.2908
16.7	0.2908
16.7	0.2906
16.7	0.2906
16.7	0.2907
Mean	0.2907

Standard Deviation 1×10^{-4} inch.

2.6 TEST RESULTS

The comparator was then used to test the Baromec, Wallace and Tiernan and Askania barometers. The tests were designed to give the magnitude of random and systematic errors in the instruments. The errors were given as reading differences and were confined to those likely to be of significance to the surveyor.

2.6.1 Reading Tests

The first test was designed to find the magnitude of the random errors in the mechanical linkages and in the readings of the barometers. The instruments were placed in pressure chambers and the chambers were partially evacuated (equivalent to a rise in elevation of 6000 ft). The pressure in the chambers was then allowed to return to atmospheric pressure. After five to ten minutes to allow any hysteresis to be taken up, the instruments were lightly vibrated and read. At the same time, a reading was taken on the barometric comparator. A comparison of the readings gave an index value.

This sequence was repeated a number of times to allow a statistical study to be made of the index. Typical results of this test are given in Tables 2.3 to 2.5.

For the Askania Barometer it was necessary to also test the accuracy of resetting the scale index. The result of this test is given in Table 2.6. This standard deviation was combined with that found in Table 2.5 to give the composite standard deviation for a single reading.

The Wallace and Tiernan instrument gave large residuals on two readings (see Nos. 1 and 4, Table 2.4). These would seem to be due to friction in the mechanical linkage. In practice, this could be minimised by using a battery of three barometers and repeating or rejecting any doubtful readings. The accuracy of the instrument quoted below assumes that this will be the case. These doubtful readings occurred in all tests on the Wallace and Tiernan barometers.

From the results of this test, the standard deviations for readings of the various instruments were converted to feet of elevation in a standard atmosphere to allow a comparison to be made. The converted values of the standard deviations are:

Baromec Barometer	1.6 feet.
Askania Barometer	3.4 feet.
Wallace and Tiernan	5.5 feet.

2.6.2 Graduation Errors

To test the various types of barometer for errors in graduation, an extended series of readings was taken throughout the working pressure range (600 to 800 mmHg). These readings were then compared with those of the barometric comparator.

The difference between the barometer reading and the comparator reading was taken as an index and the variation of this index throughout

TABLE 2.3

READING TEST BAROMEC BAROMETER 657/65

Comparator Pressure mmHg	Baromec Reading mmHg	Index mmHg
757.02	757.13	-0.11
756.53	756.50	+0.03
756.67	756.63	+0.04
756.06	756.06	0.0
756.89	756.92	-0.03
757.57	757.63	-0.06
757.08	757.13	-0.05
757.56	757.62	-0.06
757.54	757.60	-0.06
757.44	757.48	-0.04

Standard Deviation 0.045 mmHg.

TABLE 2.4

READING TEST WALLACE AND TIERNAN

BAROMETER 55423

No.	Comparator Pressure Feet	Wallace and Tiernan Feet	Index Feet
1	108	938	-830
2	126	980	-854
3	122	975	-853
4	144	1020	-876
5	113	960	-847
6	89	929	-840
7	106	958	-852
8	90	940	-850
9	90	948	-858
10	94	942	-848

Standard Deviation 11.6 feet.

Deleting readings 1 and 4 Standard Deviation 5.5 feet.

TABLE 2.5

READING TEST ASKANIA BAROMETER 530530

Comparator Pressure inHg	Askania			Index inHg
	Scale Units		inHg	
29.8037	15	276.0	30.061	-0.257
29.7846	15	269.0	30.034	-0.249
29.7900	15	270.5	30.039	-0.249
29.7660	15	265.8	30.021	-0.255
29.7993	15	274.9	30.057	-0.258
29.8257	15	280.8	30.080	-0.254
29.8065	15	276.2	30.062	-0.256
29.8254	15	280.2	30.077	-0.252
29.8243	15	280.2	30.077	-0.253
29.8205	15	279.4	30.074	-0.254

Standard Deviation 0.003 inHg.

TABLE 2.6

TEST FOR INDEX RESET ASKANIA BAROMETER 530530

Constant Pressure.

Index No.	Reading Units	Temperature
15	280.2	16.1°C
15	280.1	16.1
15	280.5	16.1
15	280.6	16.1
15	281.3	16.1
15	281.0	16.1
15	280.2	16.1
15	280.8	16.1
15	281.0	16.1
15	281.0	16.1

Standard Deviation 0.41 Units (=0.002 inHg).

the pressure range was plotted for the various instruments.

The graph for the Baromec Barometer is given in Figure 2.17 and is significantly consistant with the curve obtained three years before. The stability of the curve meant that corrections for the graduation error could be applied. When the reduction is by means of an electronic computer, this correction could be incorporated within the programme.

The testing of the Askania barometer had to be divided into two sections. The first of these consisted of a set of readings taken throughout the range of one particular scale setting. This was then repeated on a number of other scales. These readings when compared with the comparator readings gave index values. The index values for each scale were then individually plotted. The results showed that the calibration constant had changed by approximately 1°/o in 3 years (see Figure 2.18). The relevant values were for instrument number 530530.

1964	0.003913 inHg/unit reading.
1967	0.003875.

The second test for the Askania barometer consisted of a series of readings for each scale setting to determine the appropriate scale constants. These also had varied in the 3 year period. The results for instrument number 530530 are given in Table 2.7.

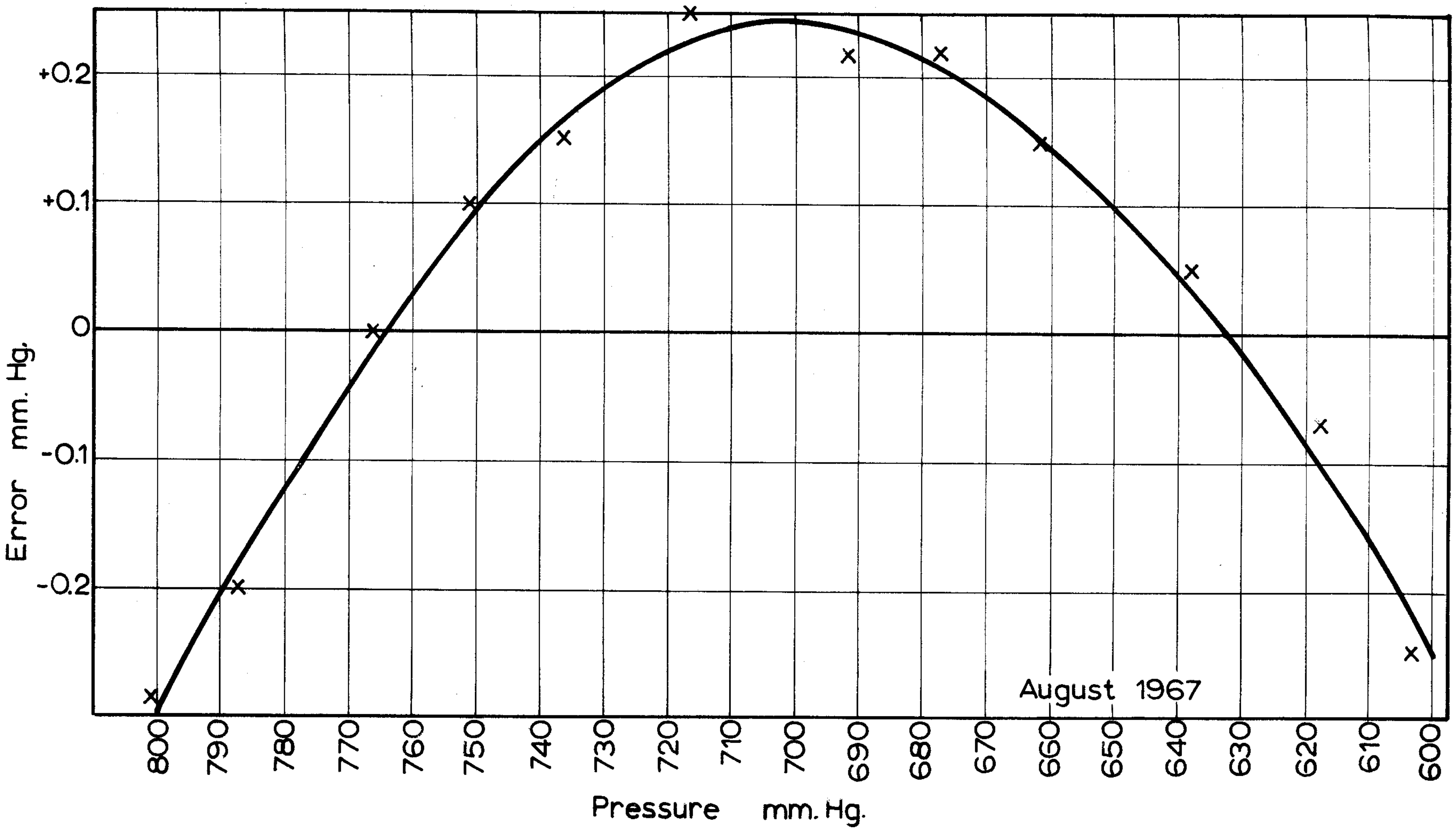


FIG. 2.17. GRADUATION ERROR BAROMEC BAROMETER N° 302/62

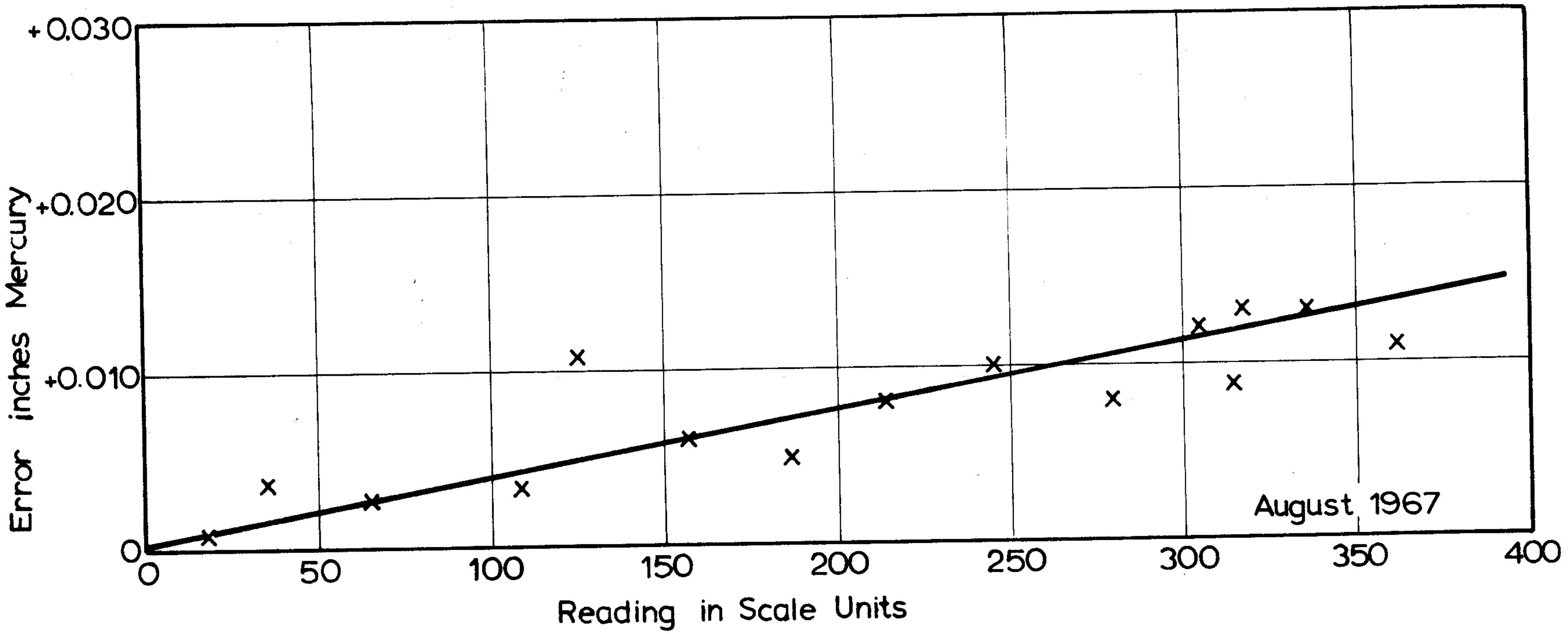


FIG. 2.18. RECALIBRATION OF SCALE CONSTANT ASKANIA BAROMETER N° 530530

With the revised constants, the readings of the instrument were linear and did not require a correction for graduation error.

TABLE 2.7

SCALE CONSTANTS ASKANIA NO. 530530

Scale	Constant (inHg)		
	1964	1967	Difference
15	28.979	29.935	+ 0.956
14	28.168	29.115	+0.947
13	27.357	28.292	+0.935
12	26.544	27.473	+0.929
11	25.731	26.655	+0.924
10	24.919	25.846	+0.927
9	24.107	25.040	+0.933
8	23.294	24.228	+0.934

The Wallace and Tiernan Barometers gave a polynomial curve (see Figure 2.19). The variation within the readings themselves however indicates that application of a correction to the readings would not significantly improve readings in the middle range. Some improvement however could be expected with readings towards the edges of the scale.

2.6.3 Drift of the Index Values

Drift of the index values may be subdivided into short and long term variations. All the instruments tested exhibited some

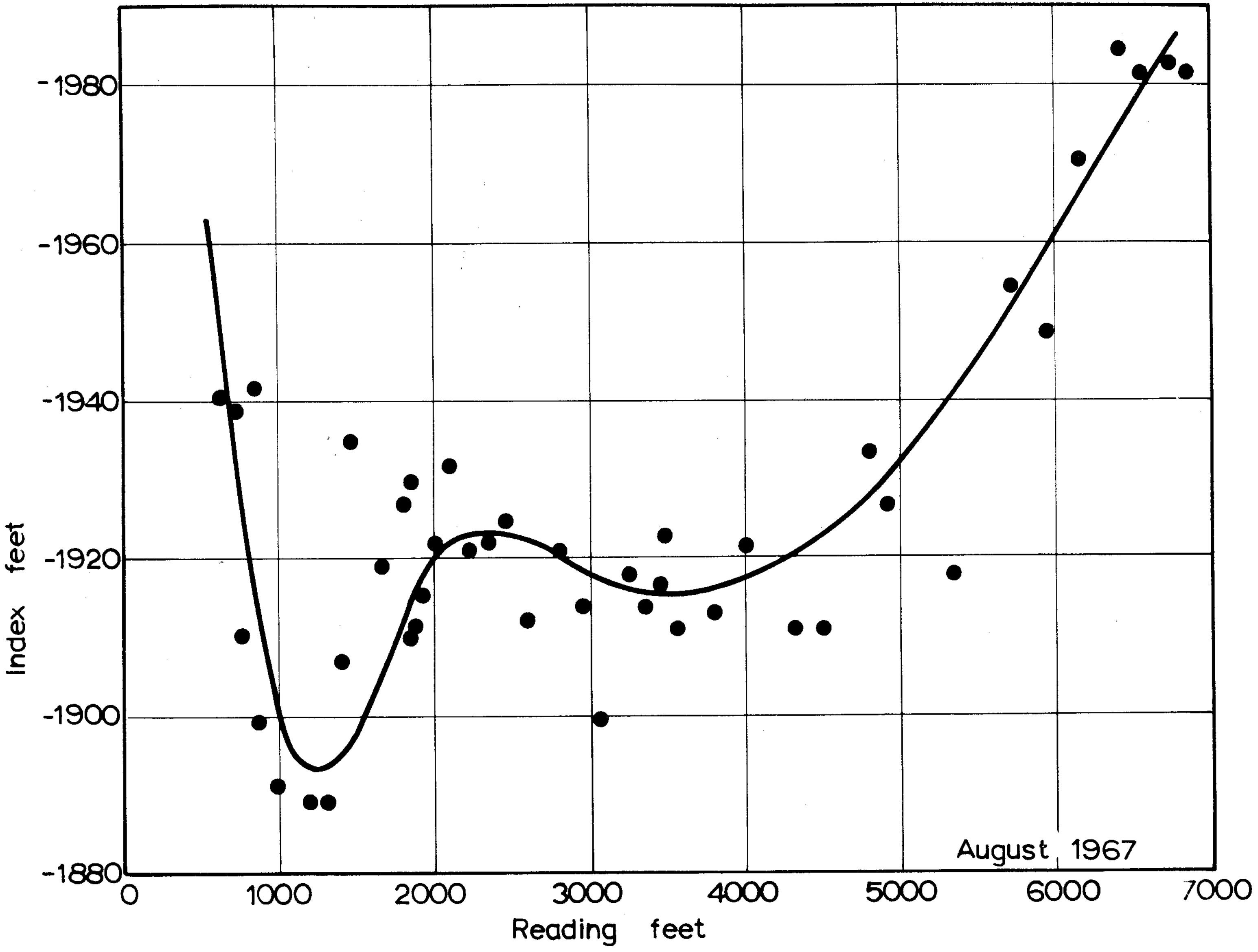


FIG. 2.19 GRADUATION TEST WALLACE AND TIERNAN BAROMETER Nº 55423

long term variation. The effect with the Wallace and Tiernan and the Askania barometers was to vary the differential pressures. The Baromec barometer however retained significantly the same differential reading.

The surveyor when determining elevations by barometer uses differential pressure over a short period of time. Accordingly, when using Wallace and Tiernan or Askania barometers, the instruments should be recalibrated at frequent intervals (say every 3 months). The Baromec should, of course, also be tested but it is not likely that any serious change will be found.

The short term drift is caused by handling the instruments. To test the magnitude of this variation, the comparison readings of the barometers were inspected for a number of field traverses. In addition the barometers were examined before and after student exercises. The apparent differences in all cases were quite small and certainly a large part of the difference could be attributed to random errors of reading. However, there still remained a portion due to drift, and the whole difference was applied as an index correction. The magnitude of the apparent diurnal drift was similar for the three types of instrument and had an average value of 0.010 inHg. The maximum value found was 0.027 inHg.

2.6.4 Hysteresis

To test the parameters for hysteresis, the barometers were placed in the pressure chambers and the pressure lowered to approximately 600 mmHg. The pressure was then suddenly allowed to return to atmospheric. The barometers and the comparator were then read at frequent intervals and the readings compared. The minimum time to take a reading on the comparator was 20 seconds. It was found that all barometers had settled to the point where no significant hysteresis remained after the 20 seconds.

2.6.5 Error due to Temperature

The Askania barometer is extremely sensitive to temperature and is covered by a thick layer of thermal insulating material. In addition a thermometer is built into the instrument to allow the temperature of the instrument to be measured. A temperature correction may then be applied when reducing the readings.

The Wallace and Tiernan barometer whilst not as sensitive as the Askania, is supplied with a temperature correction nomogram. As there is not a thermometer within the instrument, the ambient temperature of the air must be used as the argument for the nomogram.

The Baromec barometer has a high degree of temperature compensation and corrections are not applied for instrumental temperature. This is only valid for temperature changes of up to

5°C within the duration of the traverse.

The experimental facilities did not permit a complete test of temperature effects on the barometers. However, readings under extreme temperature conditions (35° F to 95° F) were inspected to see whether any systematic effect could be detected. No error was found which could be attributed to temperature. However it is recommended that when using barometers in the field the instruments should be shielded from direct sunlight and should be well ventilated.

2.7 CONCLUSIONS

Of the barometers tested, the Baromec barometer proved the most reliable. The instrument was more robust and well suited to the type of handling encountered in barometer traversing. The consistancy of readings of this type of barometer (standard deviation 0.045 mmHg) is much better than the mathematical model for the atmosphere.

CHAPTER 3

INVESTIGATION OF THE PRESSURE/HEIGHT RELATIONSHIP IN A VERTICAL COLUMN

The Pressure/Height relationship between atmospheric pressure and elevation has been examined many times (see Chapter 1).[3,50,21] The isothermal approach was used in the derivations of Laplace and Airy. More recently, the Lapse-Rate derivation has been used. Both methods yield significantly the same results and these have been empirically verified using rockets and balloons over large elevation differences. These relationships may be valid for a free standing column of air, but as the surveyor is interested in the layers of atmosphere adjacent to the ground, it was felt that a study should be carried out with a static column close to the ground.

A television tower which gave a vertical column of 677 ft. was chosen and pressure units were placed at various levels to determine the pressure profile (seeFigure 3.1). Readings were then taken on a number of occasions to see whether the profile varied.

3.1 EQUIPMENT

The Baromec Barometer having proved to be the most reliable of the aneroids tested, was selected as the basic unit (seeFigure 3.2). This made it possible to undertake the design and fitting of a servo

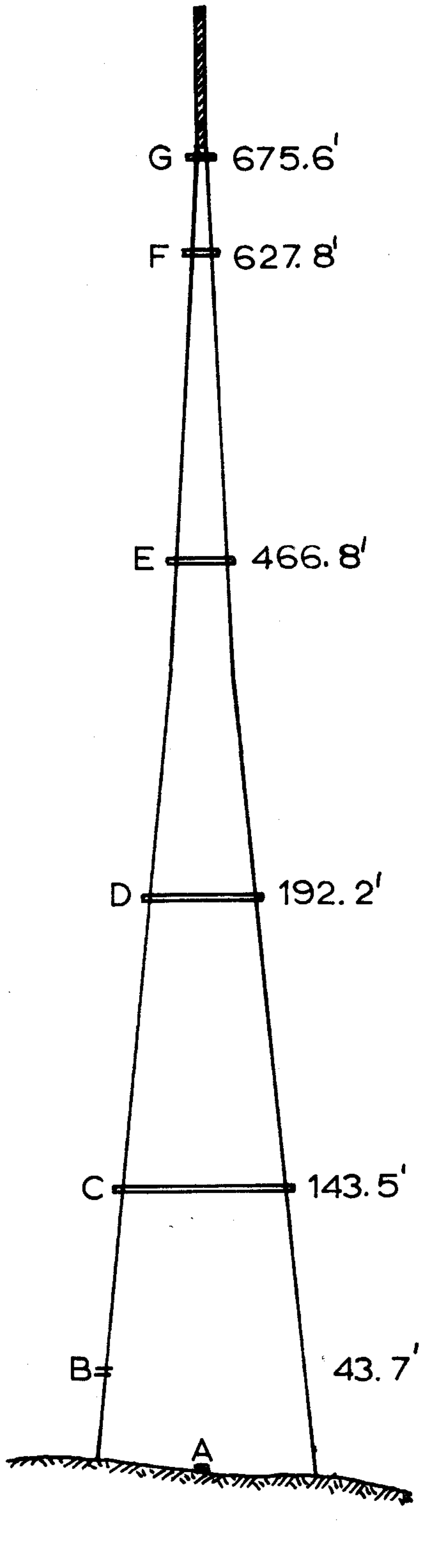


FIG. 3.1. TCN 9 TELEVISION TOWER SHOWING THE BAROMETER POSITIONS.

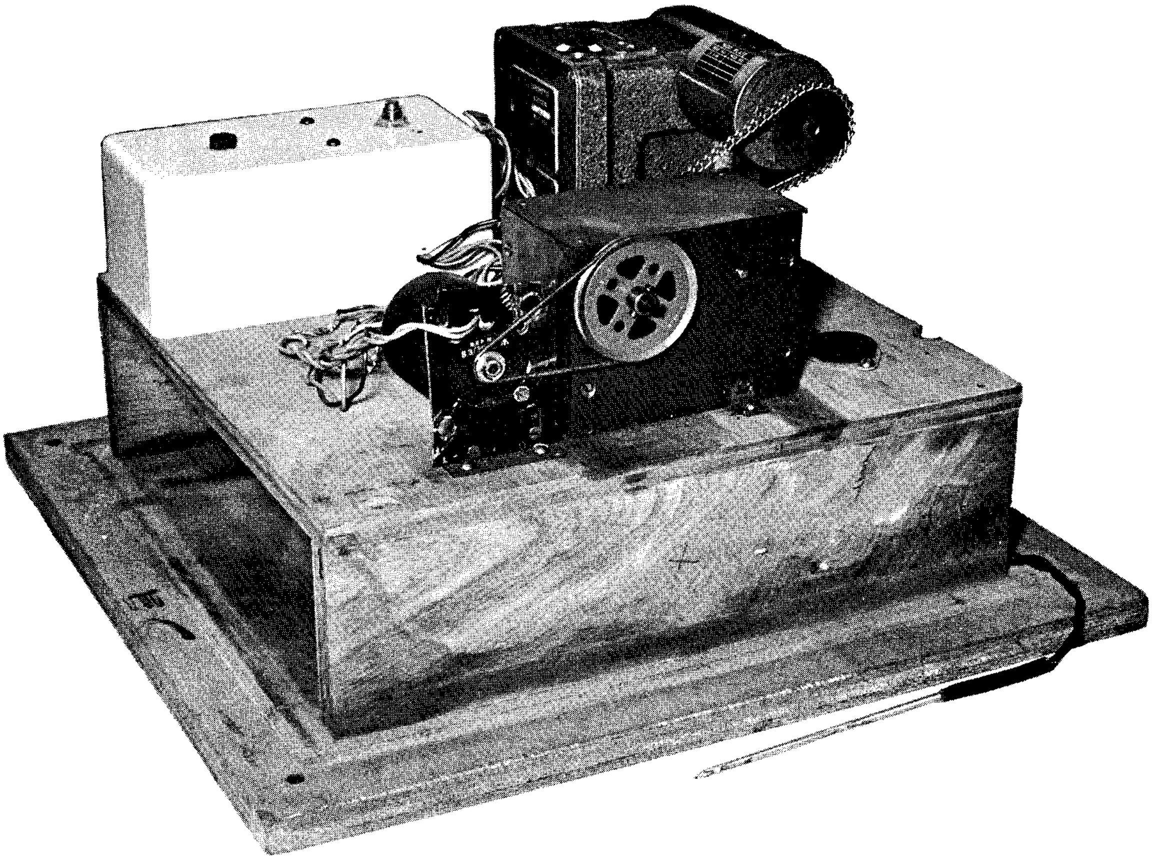


FIGURE 3.2 A REMOTE UNIT WITH THE COVER REMOVED.

control for remote reading on the ground.

Since the Baromec Barometer relies on an electronic contact to indicate the atmospheric pressure, it was possible to use this circuit as the control for the servo motors. To obtain a reading it was thus necessary to complete the electronic circuit and then switch off the motor. This was achieved by placing a latching relay in the control circuit which, when closed, allowed the motor to drive the equipment until the contact was broken, thus releasing the latching relay and reversing the direction of motor drive. The motor then continued to operate until contact was established, at which stage, as the relay was open, the drive came to rest. The readings of the instrument were thus quite impersonal and proved in laboratory tests to be more consistant than hand readings.

A typical laboratory test with the instruments on a bench and hence subject to atmospheric pressure changes is given in Table 3.1. The pressures recorded in the table are the actual readings to which the following index corrections must be applied.

Unit A	+0.31 mm Hg.
B	+0.45
C	-0.60
D	+3.11
E	-0.02
F	-0.06
G	+0.45

TABLE 3.1 TEST OF THE ACCURACY OF IMPERSONAL READING SYSTEM 18/8/65

TIME	UNIT A	UNIT B	UNIT C	UNIT D	UNIT E	UNIT F	UNIT G
1005	760.06	759.78	760.71	757.14	760.22	760.17	759.75
1020	759.98	759.78	760.74	757.07	760.25	760.25	759.81
1025	759.99	759.76	760.84	757.07	760.22	760.25	759.75
1030	760.00	759.78	760.88	757.17	760.25	760.35	759.79
1045	759.90	759.77	760.65	757.15	760.25	760.25	759.80
1050	759.94	759.77	760.86	757.05	760.25	760.24	759.77
1110	759.68	759.70	760.77	757.08	760.17	760.33	759.70
1115	759.74	759.60	760.72	756.98	760.10	760.15	759.60
1125	759.69	759.55	760.72	756.95	760.05	760.15	759.55
1130	759.54	759.55	760.64	756.86	760.07	760.02	759.55
MEAN	759.85	759.70	760.75	757.05	760.18	760.22	759.71

PRESSURES IN MILLIMETRES OF MERCURY

These readings show a standard deviation of 0.06 mm Hg which corresponds to approximately 2 feet of elevation. It should be noted that if the mean of several readings was taken, then the results is significantly improved. Accordingly, in the tower tests, multiple readings were taken to increase the accuracy.

Relaying the readings to the ground proved to be a problem when seven units were employed. A number of possible solutions were tried but generally interference with the remote readings of adjacent units was detected. The final solution isolated each unit and proved quite satisfactory in the laboratory and in the field. The method employed a segmented wheel in the primary drive of each unit with carbon brushes picking up signed pulses and relaying these to the Control Unit by a single-wire signalling technique.

Each remote unit included a thermister circuit to measure the temperature. By balancing the lengths of the leads, the temperature could be read directly from the scale of a micro-ampmeter. The basic circuit is given in Figure 3.3.

The readings of the barometers were deduced from the differences of the two counters for each unit - one measuring the increases in the micrometer readings and the other the decreases.

The Control Unit contained the necessary circuits to control the seven Remote Units and to record the change in readings (see Figures 3.4 to 3.6).

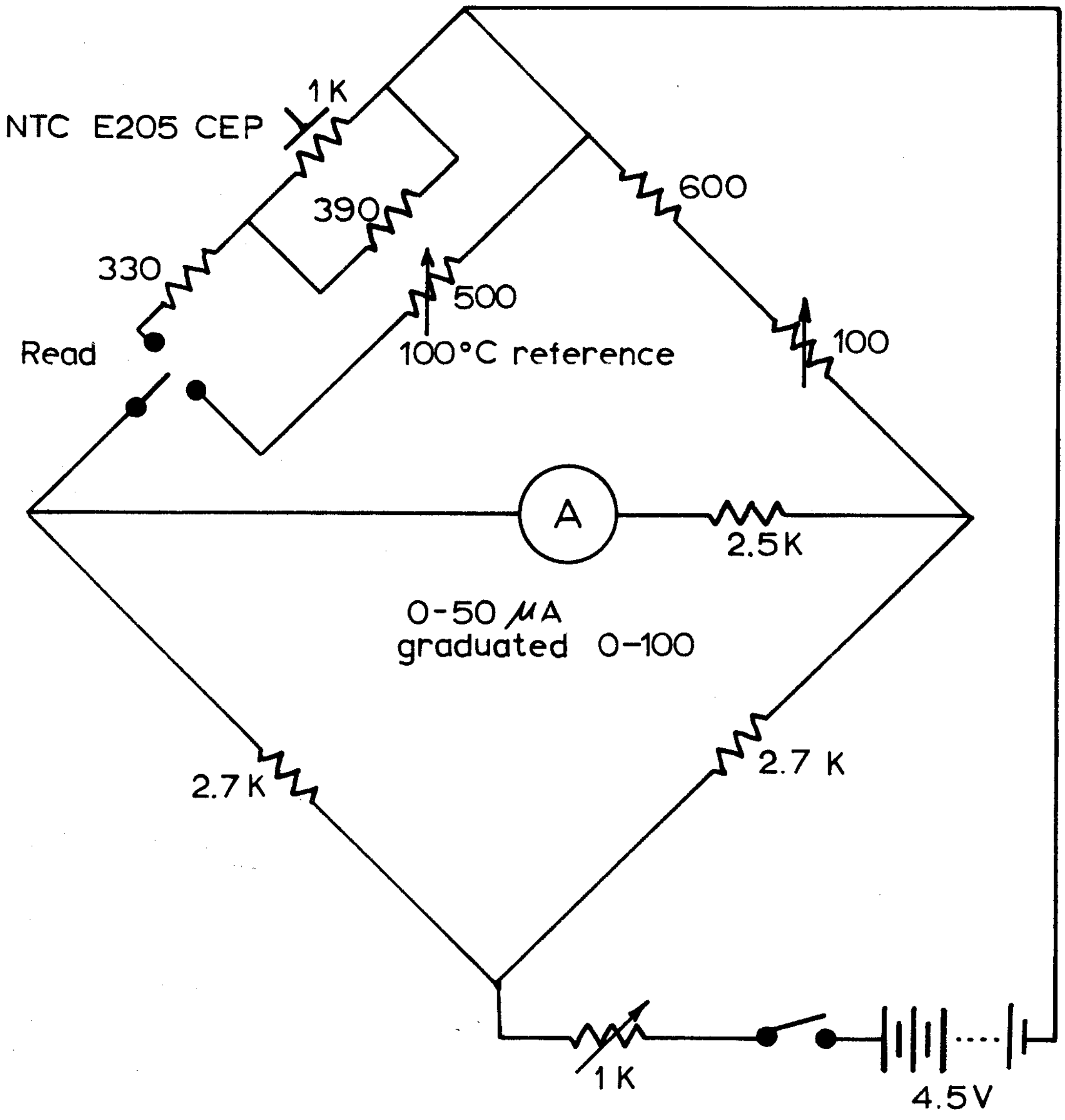
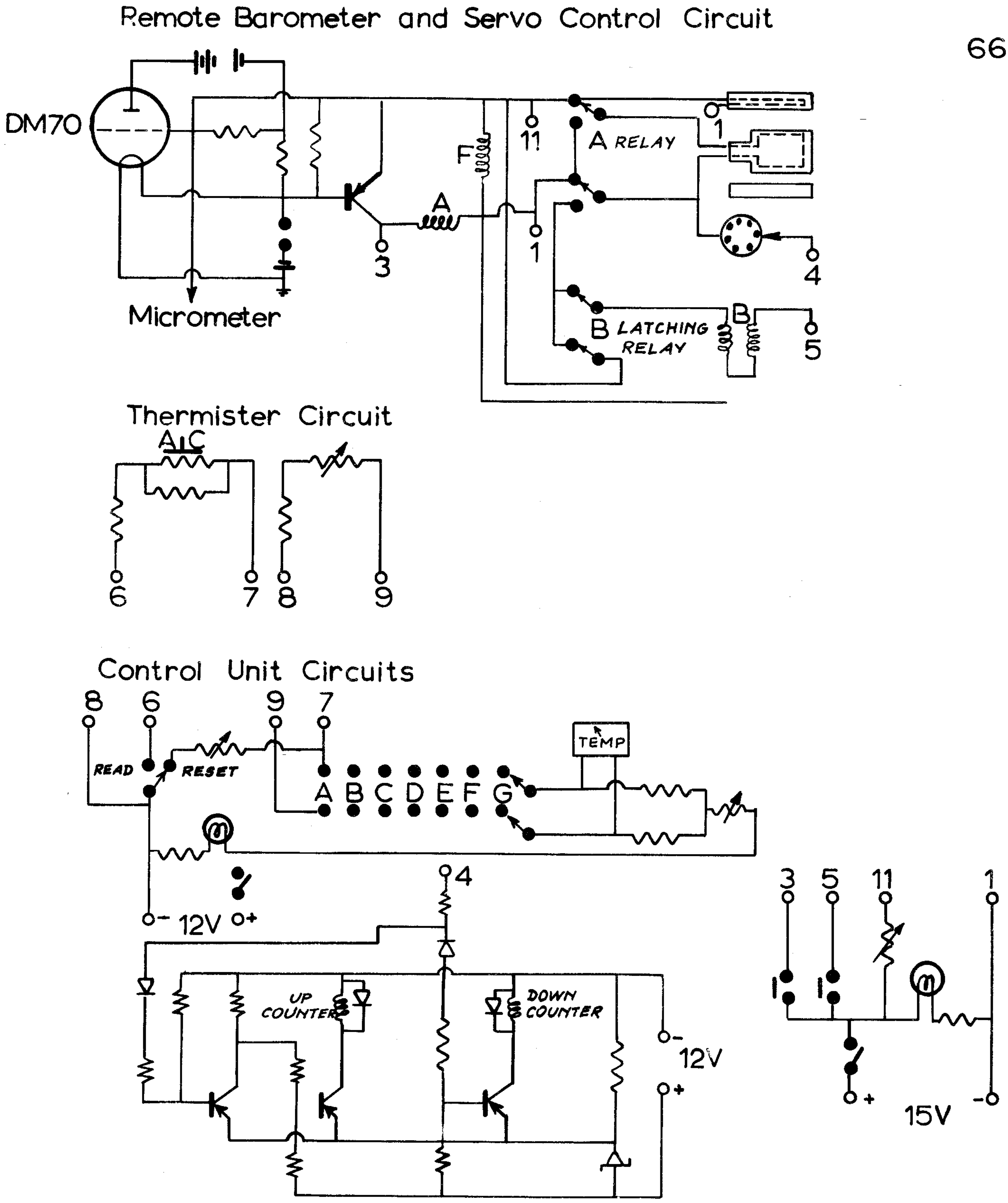


FIG. 3.3 BASIC CIRCUIT DIAGRAM FOR THERMISTER CIRCUITS.



Remote Barometer and Servo Control Circuit

Thermister Circuit

Control Unit Circuits

FIG. 3.4 CIRCUIT DIAGRAMS FOR THE REMOTE BAROMETER UNITS, THERMISTERS AND CONTROL UNITS.

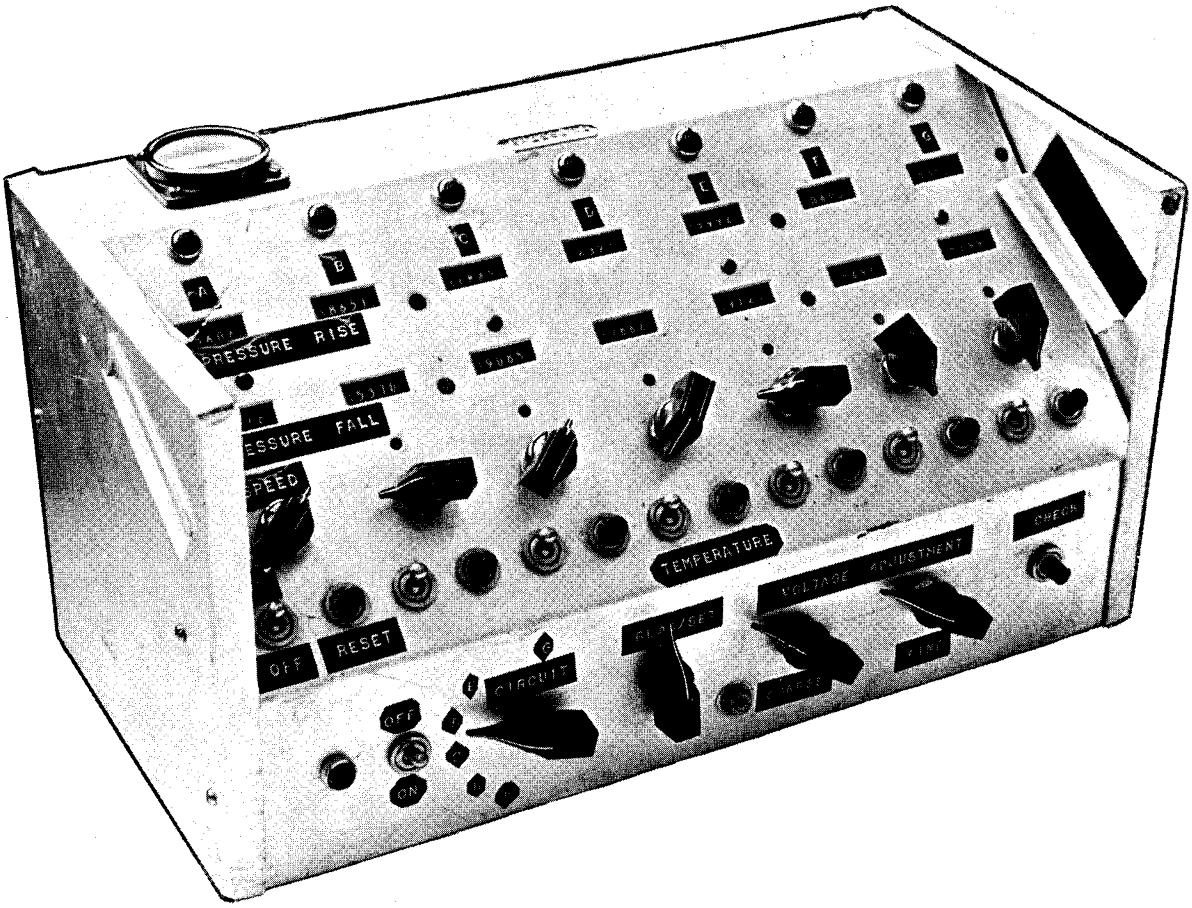


FIGURE 3.5 THE CONTROL UNIT.

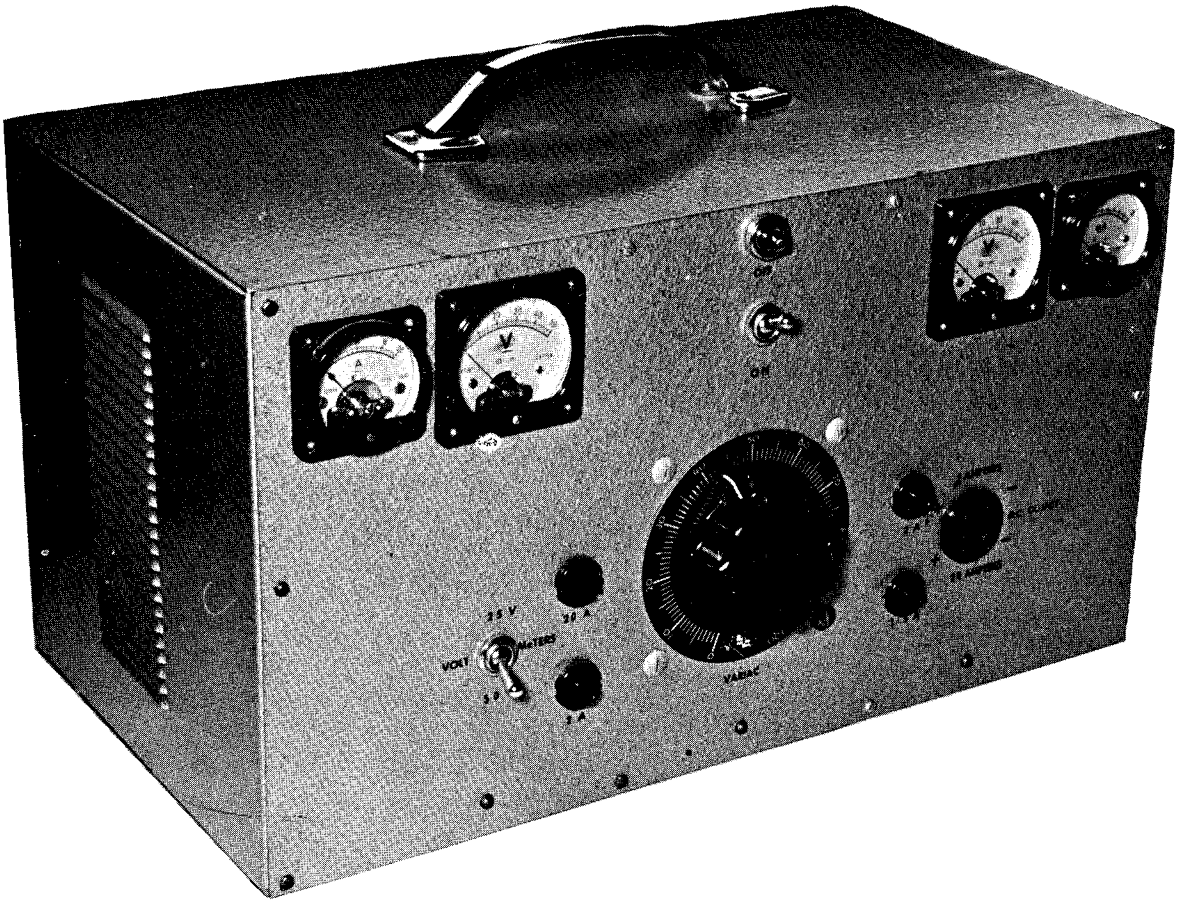


FIGURE 3.6 POWER SUPPLY FOR THE TOWER PROJECT

Due to the meccano gearing and chain drive incorporated in the gear box, there was a small amount of slackness within the system. This was overcome by taking the final motion before reading always in the same direftion. The gear ratio could not be directly calculated and so each unit was calibrated to obtain the constant multiplier required to convert the differences of counter readings into differences of pressures. This was carried out by reading the barometer and the counters at different pressures. The pressures were changed between readings until the counters had varied by approximately 60, 000 units. The constants were then deduced by a least squares method.

Denoting the difference in Barometer reading as ΔP_i
the difference in counter readings as ΔR_i
and the constant as C.

Then the parametric equations are:

$$\Delta R_1 . C - \Delta P_1 = 0$$

$$\Delta R_2 . C - \Delta P_2 = 0$$

$$\Delta R_n . C - \Delta P_n = 0$$

which give the normal equation as:

$$[\Delta R^2] . C - [\Delta R . \Delta P] = 0$$

or

$$C = \frac{[\Delta R . \Delta P]}{[\Delta R^2]}$$

and the variance of the constant as

$$\sigma^2 = \frac{[vv]}{[\Delta R^2] (n - 2)} .$$

A typical set of readings for the evaluation of the constant is given in Table 3.2 for which the constant was evaluated as 0.006 3994 with a standard deviation of 0.000 0003. This was repeated using each of the seven instruments and gave a final value of the constant as 0.006 3995 with a standard deviation of 0.000 0003.

This constant was used throughout the field tests and proved to be extremely reliable.

Although quite satisfactory for the three months of field service, it is felt that some minor modifications would give a longer and more reliable experimental life. The main improvement would be to replace the segmented wheel by a wheel incorporating a number of small bar magnets which when revolved would actuate a proximity reed switch.

TABLE 3.2 CALIBRATION OF UNIT G, 4 AUGUST 1965

A	B	C	D	E	F	G	H
794.45	0.00	33378	30457	02921	0	0.000	0.000
780.34	-14.11	33378	32657	00721	-2200	-14.079	+0.031
763.00	-31.45	33378	35366	98012	-4909	-31.415	+0.035
747.94	-46.51	33378	37723	95655	-7266	-46.498	+0.012
734.15	-60.30	33378	39879	93499	-9422	-60.295	+0.005
715.65	-78.80	33378	42771	90607	-12314	-78.802	-0.002
699.54	-94.91	33378	45287	88091	-14830	-94.903	+0.007
683.48	-110.97	33378	47798	85580	-17341	-110.972	-0.002
677.01	-117.44	33378	48809	84569	-18352	-117.442	-0.002
672.07	-122.38	33378	49581	83797	-19124	-122.382	-0.002
673.14	-121.31	34944	50980	83964	-18957	-121.313	-0.003
683.18	-111.27	37606	52073	85533	-17388	-111.273	-0.003
696.25	-98.20	39959	52382	87577	-15344	-98.192	+0.008
705.95	-88.50	42295	53205	89090	-13831	-88.510	-0.010
714.05	-80.40	44083	53725	90358	-12563	-80.396	+0.004
724.26	-70.19	46206	54255	91951	-10970	-70.201	-0.011
731.32	-63.13	48481	55426	93055	-9866	-63.136	-0.006
739.54	-54.91	50602	56262	94340	-8581	-54.913	-0.003
765.06	-29.39	55590	57265	98325	-4596	-29.412	-0.022
793.68	-0.77	60357	57559	02798	-123	-0.787	-0.017

COLUMN A BAROMETER READING MMHG
B DIFFERENCE FROM INITIAL READING
C READING ON UP COUNTER
D READING ON DOWN COUNTER
E DIFFERENCE OF COUNTER READINGS
F DIFFERENCE FROM INITIAL VALUE
G CALCULATED DIFFERENCE OF PRESSURE MMHG
H ERROR MMHG

3.2 RESULTS

Readings were obtained on seven different occasions thus providing sufficient data for a statistical analysis. The actual pressures obtained are given in Table 3.3. To facilitate the reductions a computor programme (SVY 24) was written and the field readings were then processed.

The basis of reduction was to adopt the highest point G as a fixed base and deduce the resultant errors in the other positions by 3 different formulae, viz

1. ICAN
2. Laplace
3. Airy

As the field temperatures were read on the ground (i.e. at station A), these were reduced by 2.41° F which according to the Lapse Rate of 3.56° F/1000 ft. should give the temperatures at Station G. This was verified using the thermister circuits which were incorporated in each of the tower units.

The resultant height values indicated that the ICAN, Laplace and Airy Formulae all gave consistent results, but these did not agree with the known height differences. This seemed improbable and so a check was made on the height differences.

A point was chosen from which all the tower stations were visible and the distance from this point to the tower was measured using a Tellurometer. The vertical angles to the tower stations were then measured and the height differences calculated (see Table 3.4).

TABLE 3.3 TOWER PROJECT PRESSURE READINGS

NO	TEMP	A	B	C	D	E	F	G
A1	69.060.5	750.47	749.60	747.09			734.20	732.75
A2	63.059.5	750.18	749.35	746.77			733.80	732.42
A3	64.059.0	750.19	749.26	746.77			733.75	732.38
B1	79.065.0	759.93	758.61	756.30			743.88	742.40
C1	83.064.0	758.94	757.89	755.47	751.54	747.04	742.55	741.43
C2	84.065.0	759.13	757.95	755.49	751.52	747.12	742.49	741.43
C3	85.066.0	759.25	758.09	755.45	751.48	746.97	742.56	741.44
D1	68.062.0	761.07	760.29	757.79	753.33	748.69	744.23	743.12
D2	67.061.5	761.06	760.36	757.71	753.22	748.59	744.14	742.91
D3	68.062.0	760.94	760.03	757.57	753.12	748.39	744.00	742.84
D4	67.061.0	761.00	759.77	757.45	753.03	748.19	743.80	742.71
D5	65.560.5	760.53	759.64	757.31	752.90	748.14	743.84	742.60
E1	68.062.0	759.19	758.25	755.95	751.52	746.94	742.42	741.31
E2	67.561.5	759.31	758.26	755.80	751.55	746.93	742.47	741.26
E3	68.062.0	759.13	758.21	755.78	751.48	746.84	742.46	741.23
E4	69.063.0	759.16	758.17	755.80	751.51	746.81	742.39	741.20
E5	70.063.0	759.15	758.22	755.75	751.51	746.72	742.37	741.18
F1	75.067.5	757.21	756.38	754.08	750.01	745.29	741.09	739.80
F2	75.068.0	757.73	756.43	754.07	749.97	745.35	741.20	739.89
F3	75.068.0	757.99	756.44	754.08	749.91	745.39	741.18	739.88
F4	75.068.0	757.94	756.51	754.03	749.87	745.43	741.16	739.85
G1	81.070.0	751.90	750.52		744.24			734.17
G2	81.070.0	751.86	750.47		744.21			734.10
G3	83.071.0	751.81	750.43		744.17			734.08

TABLE 3.4

Station	Vertical Angle	Height Difference From G
A	-0° 16' 09".5	-675.6 Ft.
B	-0 03 03	-631.9
C	+0 26 53.5	-532.1
D	+1 11 50	-383.4
E	+2 04 12	-208.8
F	+2 52 47	-47.8
G	+3 07 08.5	0.0
DISTANCE	3 4789.0 metres	

These heights agreed with those scaled off the construction plans for the tower and were adopted.

The differences of height calculated from the barometer readings were then inspected. They showed a general tendency in spite of the scatter but the tendency was reversed in the 100 feet closest to the ground. This reversal is due to the presence of non-uniform conditions in this region viz. rapidly changing temperature and humidity profiles.[49] Accordingly the readings at A and B were not used for the subsequent redetermination of the constants for the Standard Atmosphere. In practice, since the field readings must be within this band of atmosphere within 100 ft. of the ground, the assumption must be made that similar temperature and humidity profiles are applicable to all field readings at a given instant. This will give an equal systematic error in the elevations of all points at that instant and hence a reasonable height difference.

Returning to the readings of stations C to G, the tendency to deviate from the known values when the height differences were determined from the ICAN Standard Atmosphere appeared to follow a curved line. Since the ICAN Formula is basically:

$$h = C_1 \left(\frac{P_1}{P_o}\right)^{C_2} \qquad (1 + \text{Temperature Correction})$$

where

$$C_1 = 145\,367.59$$

$$C_2 = 0.19023$$

it was realized that the results could be improved by varying the values of the two constants. This was carried out by modifying the computer programme SVY 24 to allow for the variation of the constants. The mean pressures for day D were then used to establish the line of best fit which was then tested against the mean pressure for day E. This line of best fit gave the new constants as:

$$C_1 = 143831.87$$

$$C_2 = 0.18910$$

Once the values of the constants had been determined these were used to recalculate the errors in the heights for all pressure readings. These are calculated for the ICAN Standard Atmosphere in Table 3.5. The new constants which determine the New Standard Atmosphere (to avoid confusion this has been called the Assumed Standard Atmosphere (ASA) were used to give the results in Table 3.6.

The ICAN results have a standard deviation of 8.0 Ft. while the ASA results have a standard deviation of 4.7 Ft. This reduction was significant enough to warrant the recalculation of all the field readings in the latter Chapters using the Assumed Standard Atmosphere.

TABLE 3.5 TOWER RESULTS USING THE ICAN ATMOSPHERE

CALCULATED ELEVATION ERRORS

NO	A	B	C	D	E	F	G
	145367.59	0.19023	0				
A1	3.65	-7.35	-12.67			-7.67	0.00
A2	9.52	-3.33	-7.08			-4.42	0.00
A3	6.34	-2.72	-9.64			-4.15	0.00
B1	6.89	13.10	0.82			-9.15	0.00
C1	1.80	-1.84	-9.18	-7.20	-8.47	4.31	0.00
C2	-6.68	-5.31	-10.95	-7.15	-11.97	6.56	0.00
C3	-12.15	-11.45	-10.02	-5.94	-6.18	4.15	0.00
D1	5.69	-9.16	-16.35	0.76	-0.46	5.99	0.00
D2	-0.60	-18.46	-20.28	-2.33	-4.24	1.55	0.00
D3	-0.10	-10.14	-18.79	-1.99	0.20	4.09	0.00
D4	-5.94	-4.23	-18.21	-2.81	3.17	6.80	0.00
D5	9.15	-1.76	-15.60	-1.02	1.50	1.29	0.00
E1	6.66	-2.18	-16.57	-0.16	-3.23	5.89	0.00
E2	0.96	-3.84	-12.37	-2.81	-4.54	2.15	0.00
E3	5.85	-3.73	-13.28	-1.70	-2.50	1.36	0.00
E4	2.32	-4.59	-16.20	-4.69	-2.91	2.78	0.00
E5	0.66	-8.43	-16.14	-6.19	-0.68	2.69	0.00
F1	14.08	1.63	-11.40	-6.06	-1.15	-1.64	0.00
F2	-2.01	3.21	-7.56	-1.08	0.00	-2.41	0.00
F3	-12.18	2.45	-8.33	0.80	-1.89	-2.02	0.00
F4	-11.45	-1.32	-7.59	1.17	-4.57	-2.40	0.00
G1	-10.70	-1.46		-8.04			0.00
G2	-11.92	-2.29		-9.62			0.00
G3	-13.33	-3.89		-10.31			0.00

TABLE 3.6 TOWER RESULTS USING THE ASSUMED STANDARD ATMOSPHERE

CALCULATED ELEVATION ERRORS

NO	A	B	C	D	E	F	G
	143831.87	0.18910	0				
A1	14.76	3.20	-3.67			-6.76	0.00
A2	20.52	7.15	1.82			-3.56	0.00
A3	17.40	7.75	-0.69			-3.29	0.00
B1	17.92	23.31	9.58			-8.21	0.00
C1	12.92	8.61	-0.25	-0.76	-4.89	5.03	0.00
C2	4.56	5.20	-1.99	-0.71	-8.33	7.24	0.00
C3	-0.80	-0.84	-1.08	0.47	-2.63	4.87	0.00
D1	16.74	1.41	-7.31	7.07	2.98	6.68	0.00
D2	10.55	-7.73	-11.17	4.02	-0.73	2.31	0.00
D3	11.04	0.44	-9.70	4.36	3.64	4.81	0.00
D4	5.29	6.26	-9.13	3.55	6.57	7.47	0.00
D5	20.14	8.68	-6.57	5.32	4.92	2.05	0.00
E1	17.70	8.27	-7.52	6.16	0.26	6.58	0.00
E2	12.09	6.64	-3.39	3.55	-1.02	2.90	0.00
E3	16.91	6.75	-4.28	4.65	0.98	2.12	0.00
E4	13.44	5.90	-7.15	1.70	0.57	3.52	0.00
E5	11.80	2.13	-7.09	0.23	2.76	3.43	0.00
F1	25.00	12.04	-2.43	0.36	2.30	-0.83	0.00
F2	9.16	13.59	1.33	5.25	3.45	-1.58	0.00
F3	-0.83	12.84	0.58	7.11	1.57	-1.20	0.00
F4	-0.11	9.12	1.31	7.47	-1.05	-1.58	0.00
G1	0.63	8.99		-1.57			0.00
G2	-0.56	8.18		-3.13			0.00
G3	-1.95	6.60		-3.81			0.00

CHAPTER 4

FIELD TECHNIQUES AND ISOBARIC SURFACE

So far, the application of the pressure/height relationship has been restricted to a vertical column. When the two points have a lateral separation, a most important assumption must be made and this is that the surface of equal pressure or Isobaric Surface is a plane parallel to the datum plane. In practice this surface is neither plane nor parallel to datum.[5,31]

The surface is in fact similar to any other equipotential surface in that when the surface lies close to horizontal it will approximate a plane. When tilted the surface tends to buckle and finally becomes very irregular. This is analogous to the surface of a lake and a swiftly flowing mountain stream. The extent of the buckling depends on the tilt of the surface and the determination of the apparent tilt is most important when more precise results are required.[50,41,17,34]

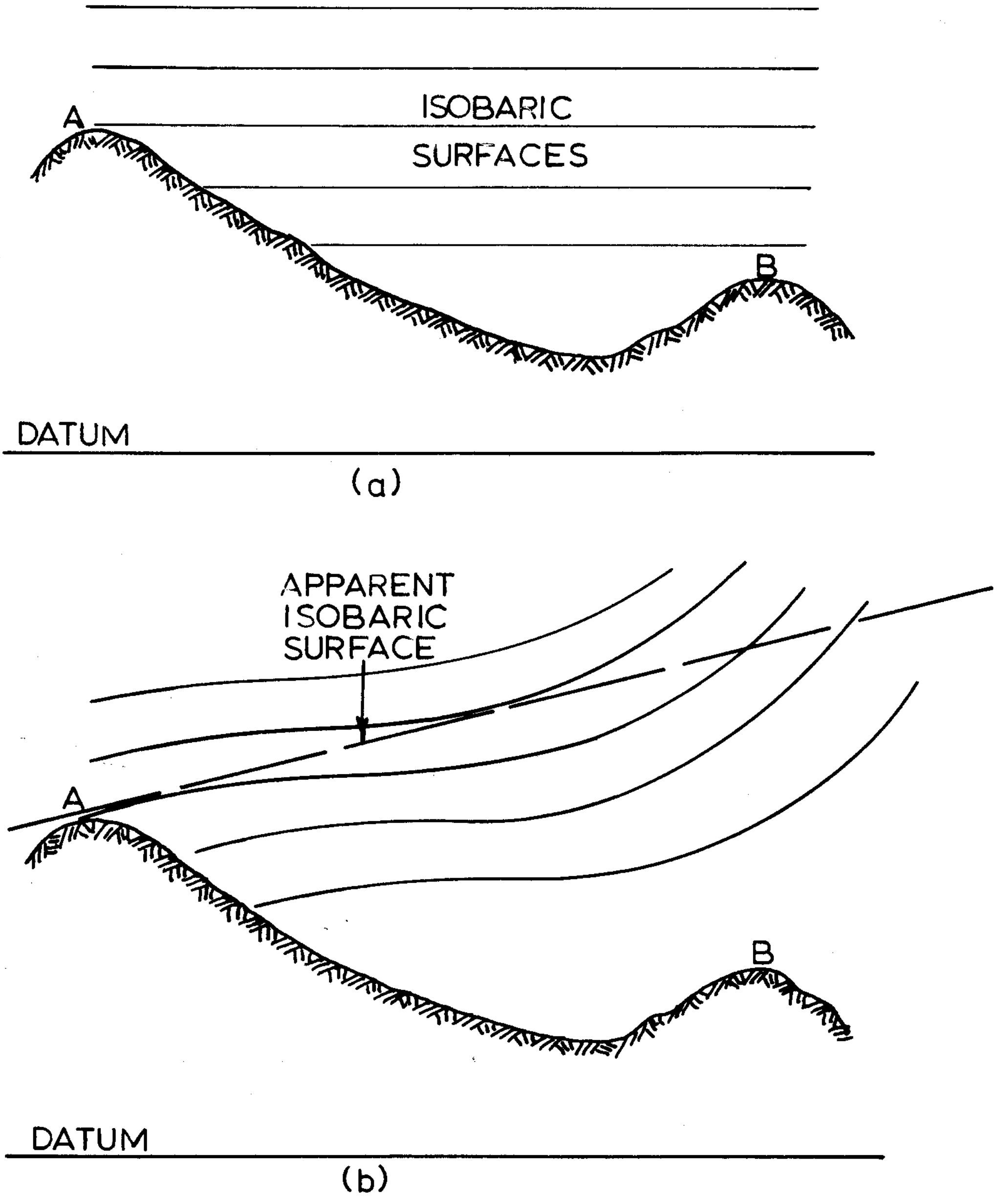
The tilt may be determined if pressure readings are obtained simultaneously at three points of known elevation.

The elevation for the pressure reading at each point may then be calculated using a standard atmosphere. The known differences in elevation together with the known lateral displacements allows the apparent tilt of the surface to be calculated. For convenience, this is generally expressed in feet of tilt/mile. The actual calculations are described in Chapter 6. The two dimensional case is shown in Figure 4.1 in which the elevations of two points A and B are known. From the pressure readings the elevation of the Isobaric Surface which passes through A is determined for the vicinity of point B. In Figure 4.1 (a) the surface has equal elevations near A and B and so the surface closely approximates a plane, parallel to the datum plane. In Figure 4.1 (b) the surface is much higher at the vicinity of B and thus the Isobaric Surface departs from the plane.

A number of field techniques have been devised which attempt to obtain elevations for laterally displaced points and it is advisable that the limitations of each technique to be examined in order that misleading results can be avoided. The techniques may be summarized into groups.

4.1. DIURNAL CURVE METHOD.[5, 50, 56]

This method is frequently used in the tropics or well inland for large continents. Repeat readings at one station show that the variation of pressure throughout the day follows a predictable pattern called the Diurnal Curve. Once the Diurnal Curve has been established, a single barometer may be read at a point of known elevation or base station and then taken to a number of field stations. The pressure reading for the particular instant of time is then inferred for the base station and the



(a)

(b)

FIG. 4.1 ISOBARIC SURFACES

difference in elevation calculated. This method suffers from two major defects.

a) The Isobaric Surface uncertainties,

b) There is no way of detecting the passage across the area of an atmospheric disturbance.[13]

4.2 SINGLE BASE METHOD[5, 28, 42, 43, 44, 50, 56].

This method is probably the most frequently used in practice. Two barometers are used, one of which remains at the base while the other is moved around the field stations. Inspection of the base readings will disclose any major atmosphere disturbance (and hence the rejection of field readings near that time) but small disturbances may be masked by the Diurnal Curve and hence be difficult to detect. The method assumes that the Isobaric Surface will be plane and parallel to Mean Sea Level. It has been shown that tilts of the surface of up to 3 ft./mile are fairly common and this should be remembered in assessing the reliability of the computed elevations for distant field stations. To make the method more economic a number of field barometers may use the same base barometer.

4.3 THE LEAP-FROG METHOD[5, 23, 29, 43, 44, 50, 56]

In this method two barometers are used with one remaining stationary whilst the other "leap-frogs" over it. Thus the stationary barometer may be used as a local single base during the calculation of the elevation of the forward station. The traverse should start at a point of known elevation, and pass through other known points as often as possible. The misclose in elevation at each of these points is adjusted by a straight forward linear interpolation.

By keeping the distance between barometers to a minimum, the possibility of a differential effect from a pressure disturbance is reduced but the effect of the tilt of the Isobaric Surface remains. It has been shown that this tilt although varying in magnitude may lie in a particular direction for several days.[17] This will cause a systematic drift in the calculated elevations. Further, should there be a differential effect from a pressure disturbance or a simple reading error at one field station, this error will be carried into all subsequent elevations.

Since the method is slow in the field in that one barometer is always stationary and in view of the above remarks, this method is not recommended (see Chapter 5).

4.4 THE TWO BASE METHOD[5,29,39,42,44,50,52,53,56]

In an attempt to compensate for the tilt of the isobaric surface, two base stations are chosen such that one is above and the other below the heights of the required field stations. Only the pressure and time is recorded at the base and field stations and the calculation is carried out by simple proportions. This is illustrated in figure 4.2. The proportions may be expressed mathematically by the formula:

$$\Delta E_2 = \frac{\Delta P_2}{\Delta P_1} \cdot \Delta E_1 .$$

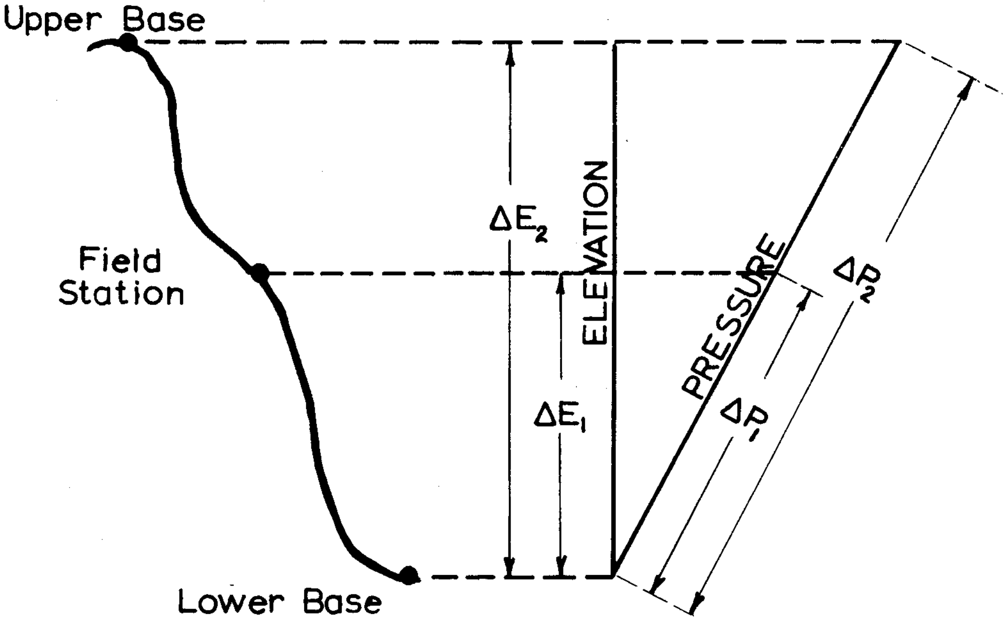


FIG. 4. 2. THE TWO BASE METHOD

The method has the advantages of simplicity of field readings and calculation and does not rely on a Standard Atmosphere. The disadvantages are that there is no attempt to remove the effects of tilt of the Isobaric Surface since the formula does not take into account the horizontal position of the points. Even when the field station lies directly between the base stations the systematic error will not be removed since points of equal elevation along the line joining the base stations will have different pressure readings dependant on position.

4.5 THE MULTIPLE BASE METHOD[37,41,44,45,50,55]

For this method, a barometer is placed at each of three points of known elevation and co-ordinates. Simultaneous readings of the barometers will then allow the tilt of the apparant Isobaric Surface to be determined. Corrections for this tilt may then be applied to the calculated elevations of field stations which rely on pressures recorded at that time.

The tilt of the Isobaric Surface may be determined by increasing the base readings by an amount dependent on their differences in elevation from sea level or a selected pivot station. Comparison of these "reduced level" readings will indicate the magnitude and direction of the tilt.[45] The corrections for field readings may then be interpolated.

A simplier approach is to use one of the three bases as the main base and reduce all readings including the field reading by the Single Base Method using this base. The differences between the known and calculated elevations of the bases give the necessary data to deduce the tilt magnitude and its direction.

Since this technique was used as the basis of the study of the isobaric surface, further description will be deferred (see Section 4.6).

4.6 ISOBARIC SURFACE INVESTIGATION

Since any assessment of possible accuracy must be dependent on the fluctuations of the Isobaric Surface, it was decided to position five barometers on points of known elevation and to take a series of readings to determine the nature of these fluctuations. This was carried out on four different days in two different locations namely Sydney and Cootamundra.

In the Sydney Test, which was called the City Traverse Area, the stations St. Paul's, Centennial, Liverpool, Ryde and Beverly Hills were placed to encompass an area slightly in excess of 100 square miles (see Figure 4.3). For the Cootmunundra tests two different patterns were used. On the 28th February, 1966, the stations Harefield, Qandialla, Pettits and Yeo Yeo encompassed 1,000 square miles whilst on 1st March, 1966, the stations Batlow, Wagga, Monteagle, Yeo Yeo and Quandialla were chosen to enclose some 3,000 square miles (see Figure 4.4).

A number of methods for the analysis of the readings were considered before deciding on the method finally adopted in this thesis. The method has the advantage that it may be used for this investigation and also for the reduction of normal field traverses. Basically, the method

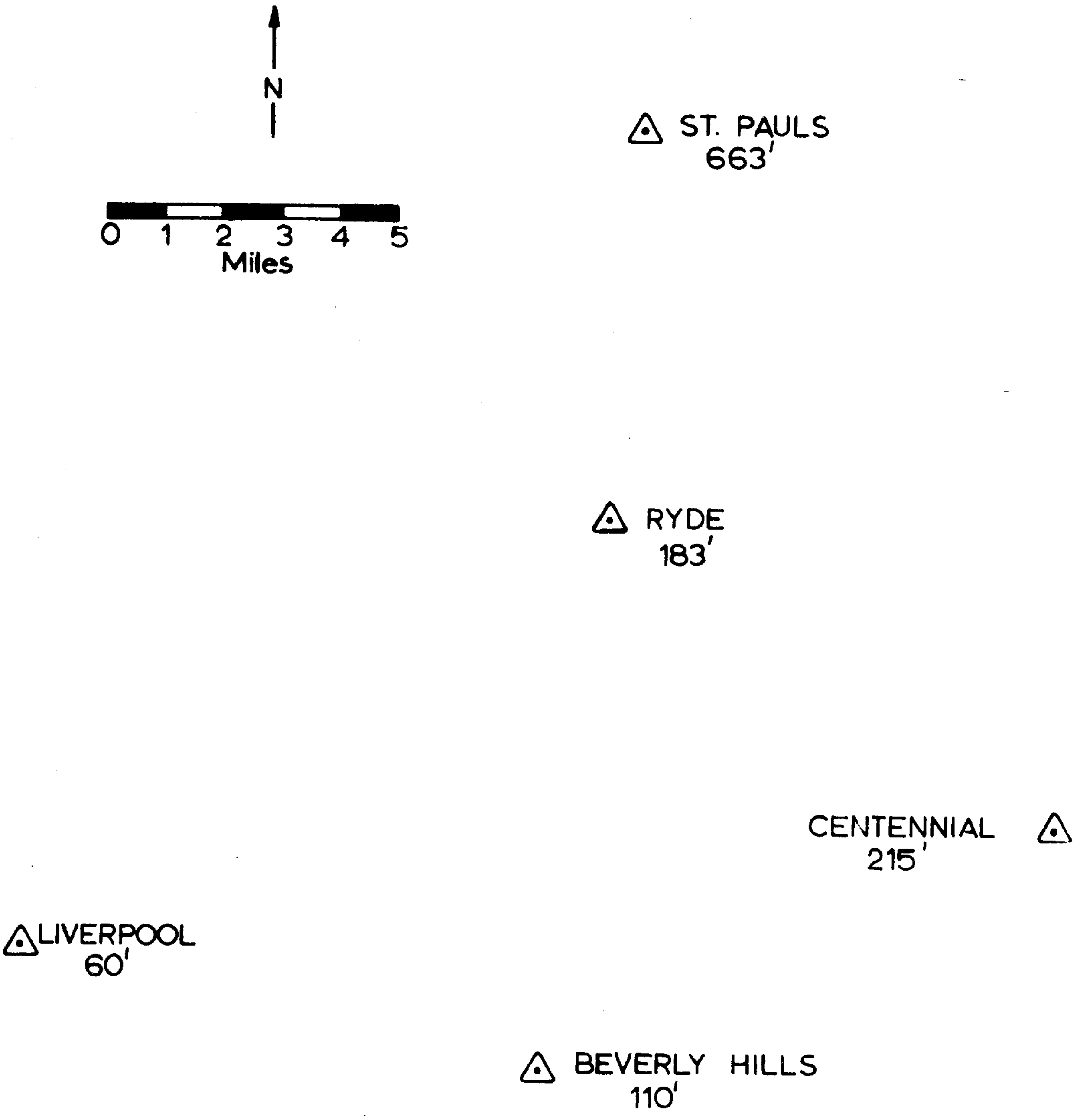


FIG. 4.3 CITY TEST AREA

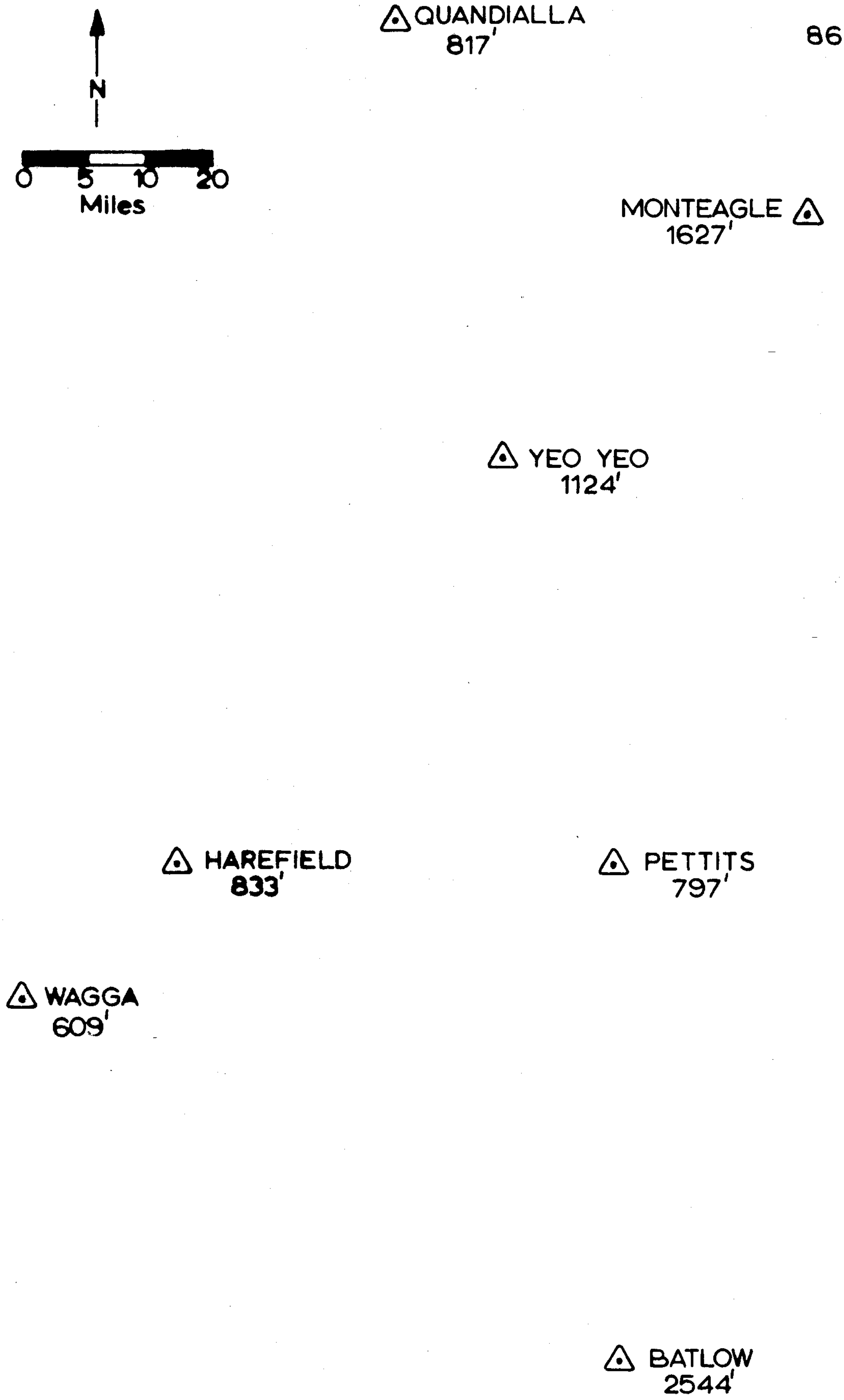


FIG. 4.4 COOTAMUNDRA TEST STATIONS.

takes one station as Base A and then calculates the single base elevation for the remaining stations. Comparison of these values with the known elevations gives the Single Base Errors. When two of these stations are selected as base B and base C, the tilt of the apparent Isobaric Surface and the direction of this tilt may be calculated. From these values, corrections to the calculated elevations of the remaining points may be deduced. The final elevation is then compared with the known elevation to give the Multiple Base Error. A statistical study of these Multiple Base Errors gives the resultant error due to both instrumental errors and the divergence of the Isobaric Surface from the apparent Isobaric Plane. Since this error must be directly related to the errors obtained during a field traverse, its magnitude is of prime importance.

The number of results involved necessitated the use of some mechanical method of processing. To this end a computer programme SVY 16 was prepared which automatically plotted the Single Base Errors and the Multiple Base Errors.

Each graph was obtained by joining the appropriate number by lines. It should be noted that the smaller numbers may be overwritten by a higher number. The plot also gives the time of the reading together with the tilt direction in degrees and the tilt in feet per mile.

The computation of the field readings using the Assumed Standard Atmosphere has been tabulated in Appendix II and the graphical summaries are shown in Tables 4.2 to 4.4. For comparison the results using the ICAN Standard Atmosphere are given in Tables 4.5 to 4.8.

Tables 4.1, 4.2, 4.5 and 4.6 give the results for the City Area for the 26th and 28th May, 1959. Graphs 1, 2, 3 and 4 are the Single Base Errors at Liverpool, Centennial, Beverly Hills and Ryde respectively with the base at St. Paul's. Graphs 5 and 6 are the Multiple Base Errors at Beverly Hills and Ryde.

Tables 4.3 and 4.7 show the results obtained for the 1,000 square mile area at Cootmunundra. Graphs 1, 2 and 3 give the Single Base Errors at Quandialla, Pettits and Yeo Yeo based on Harefield. Graph 4 gives the Multiple Base Error at Yeo Yeo.

Tables 4.4 and 4.8 show the results for the 3000 square mile area at Cootamundra. Graphs 1, 2, 3 and 4 give the Single Base Errors at Wagga, Monteagle, Yeo Yeo and Quandialla respectively based at Batlow. Graphs 5 and 6 give the Multiple Base Errors at Yeo Yeo and Quandialla.

The graphs clearly illustrate the fact that for small tilts the Multiple Base Errors will tend to be small. For large tilts, the errors will tend to be large and when the tilt is changing, the errors will tend to be large and when the tilt is changing, the errors will tend to fluctuate. It will also be seen that the atmosphere is somewhat unstable at two periods of the day. These periods (at approximately 10 a.m. and 4 p.m.) correspond to the periods at which temperature inversions will be applicable and indicate a general instability of the atmospheric structure. Accordingly, it is recommended that field readings should not be taken at these times.

Further, the correlation between the two Multiple Base Errors, indicates that in fact at least four bases should be employed in order to obtain an accurate determination of the Isobaric Surface for the reduction of field traverses.

It is also quite instructive to contrast the results of Table 4.1 to 4.4 with Tables 4.5 to 4.8 which is the same data computed with the ICAN Standard Atmosphere. It will be seen that such comparison completely justifies the adoption of the new Standard Atmosphere. This has been the case whenever the comparison has been made.

4.7 CONCLUSIONS

Pressure readings taken with a stationary barometer will tend to be more reliable than those taken with a barometer subjected to the vibrations and shocks of normal field transport. Conclusions based on the foregoing results will thus give an estimate of the results of field traverses. The computer programme SVY 26 was used to obtain the first, second and third moments of the results. The results for these calculations are given in Appendix VII. Obviously the results on any given day are subject to systematic errors and this was borne out by the large values of the third moments. The significant reduction in the third moments for graphs 5 and 6 however, indicates that the systematic errors have been greatly reduced by the Multiple Base method.

The presence of these systematic errors made doubtful the use of a normal statistical approach. Instead, the average and the maximum error were estimated for each class interval of tilt using the computer programme SVY 46. These values are also given in Appendix VII.

The mean errors for the Multiple Base Method for the days of 26th and 28th May, 1959 give an indication of a trend related to the tilt of the Isobaric Surface. This trend shows that the minimum value of the mean error occurs with tilts of the Isobaric Surface less than 1 foot/mile. Once the tilt exceeds this value, the mean error increases. The results of the 28th February and 1st March, 1966 show the same tendency. Further the distance of the field stations from the base stations has a definite correlation with the magnitude of the mean error.

When these errors were analysed the mean error for the Multiple Base Method was found to conform to the formula:

$$\text{Mean Error} = C_1 + .3 \times D_1 + .2 \times T^2 \times D_1$$

where C_1 is the standard deviation of reading for the particular make of barometer (ft.),

D_1 is the distance of the field station from the nearest base station (miles),

and T is the tilt of the Isobaric Surface (ft/mile).

The values of C_1 for several types of barometer are given in Chapter 2.

The maximum error for the Multiple Base method due to fluctuations of the Isobaric surface cannot be determined. However, an estimate of the value can be made for days on which pressure abnormalities are not apparent. This estimate is twice the calculated mean error.

TABLE 4.1 SINGLE AND MULTIPLE BASE ERRORS USING THE ASSUMED STANDARD ATMOSPHERE CITY AREA 26 MAY 1959

915	147	2.44
930	142	1.39
945	139	1.30
1000	122	0.99
1005	123	0.81
1010	138	1.08
1015	146	1.13
1030	148	0.97
1045	131	1.17
1100	131	1.41
1105	133	1.38
1110	128	1.26
1115	127	1.04
1130	127	0.84
1145	120	0.64
1200	103	0.55
1205	82	0.42
1210	52	0.33
1215	54	0.50
1230	41	0.55
1245	30	0.78
1300	40	0.35
1305	13	0.47
1310	175	0.36
1315	176	0.38
1330	175	0.58
1345	156	0.44
1400	161	0.60
1405	172	0.53
1410	144	0.34
1415	134	0.45
1430	57	0.49
1445	47	0.48
1500	23	0.80
1505	8	0.97
1510	7	0.77
1515	2	0.94
1530	3	1.20
1545	0	1.31
1600	172	1.16
1605	175	1.22
1610	173	1.35
1615	167	1.45
1630	168	1.68
1645	163	1.92
1700	158	1.95

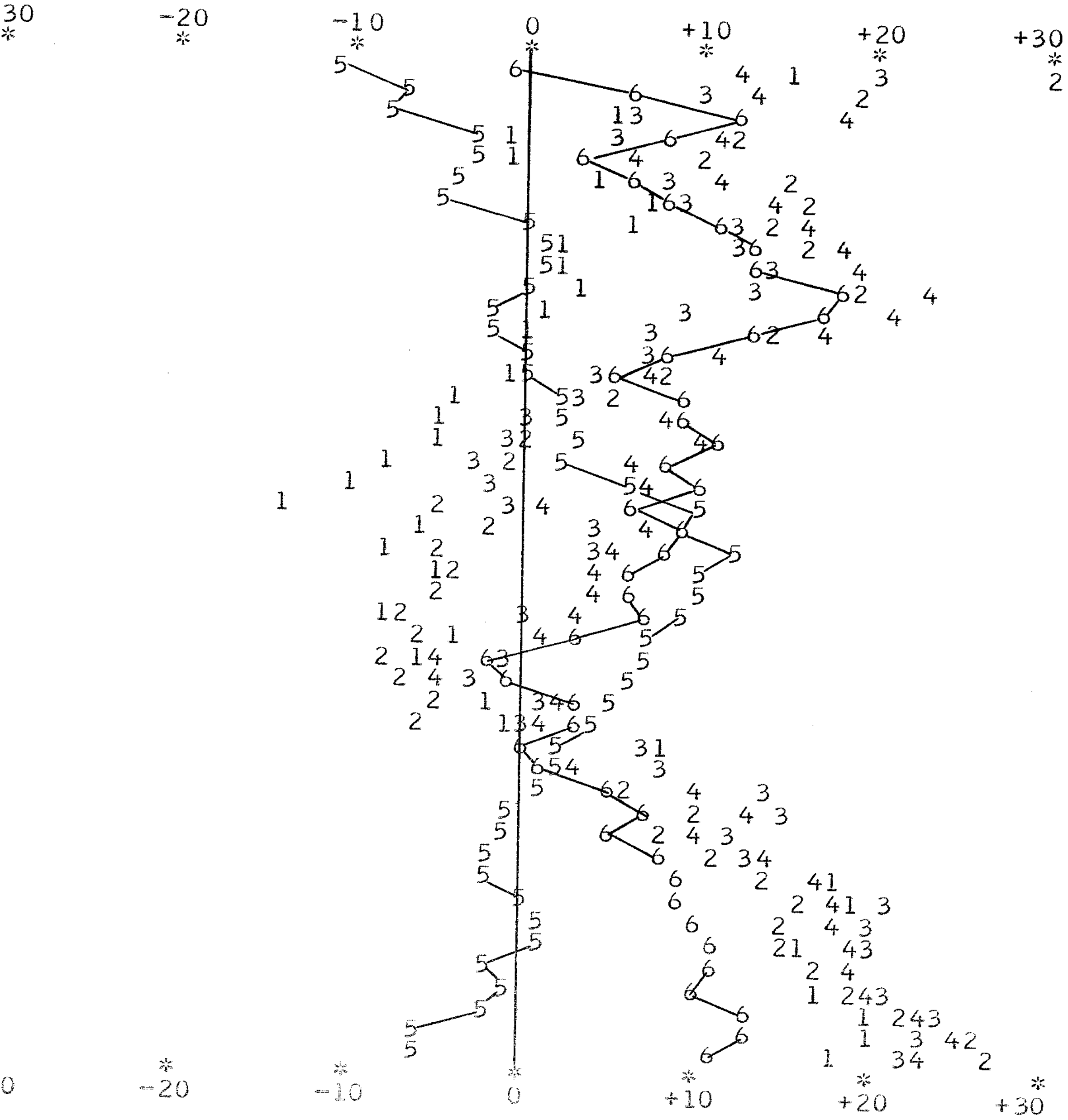


TABLE 4.2 SINGLE AND MULTIPLE BASE ERRORS USING THE ASSUMED STANDARD ATMOSPHERE CITY AREA 28 MAY 1959

900	145	1.60
905	145	1.60
910	152	1.52
915	153	1.54
930	162	1.38
945	157	1.29
1000	165	1.22
1005	162	1.24
1010	162	1.05
1015	148	0.83
1030	139	0.69
1045	136	0.52
1100	165	0.24
1105	5	0.09
1110	71	0.13
1115	24	0.15
1130	10	0.50
1145	100	0.24
1200	132	0.25
1205	139	0.28
1210	129	0.22
1215	124	0.42
1230	163	0.53
1245	154	0.68
1300	150	0.42
1305	139	0.57
1310	161	0.31
1315	164	0.38
1330	176	0.26
1345	149	0.63
1400	154	0.65
1405	145	0.35
1410	103	0.41
1415	126	0.46
1430	102	0.35
1445	133	0.35
1500	2	0.07
1505	176	0.22
1510	4	0.40
1515	177	0.37
1530	22	0.51
1545	11	0.87
1600	6	1.01
1605	175	0.87
1610	174	1.16
1615	173	1.43
1630	175	1.67
1645	176	1.60
1700	166	1.41

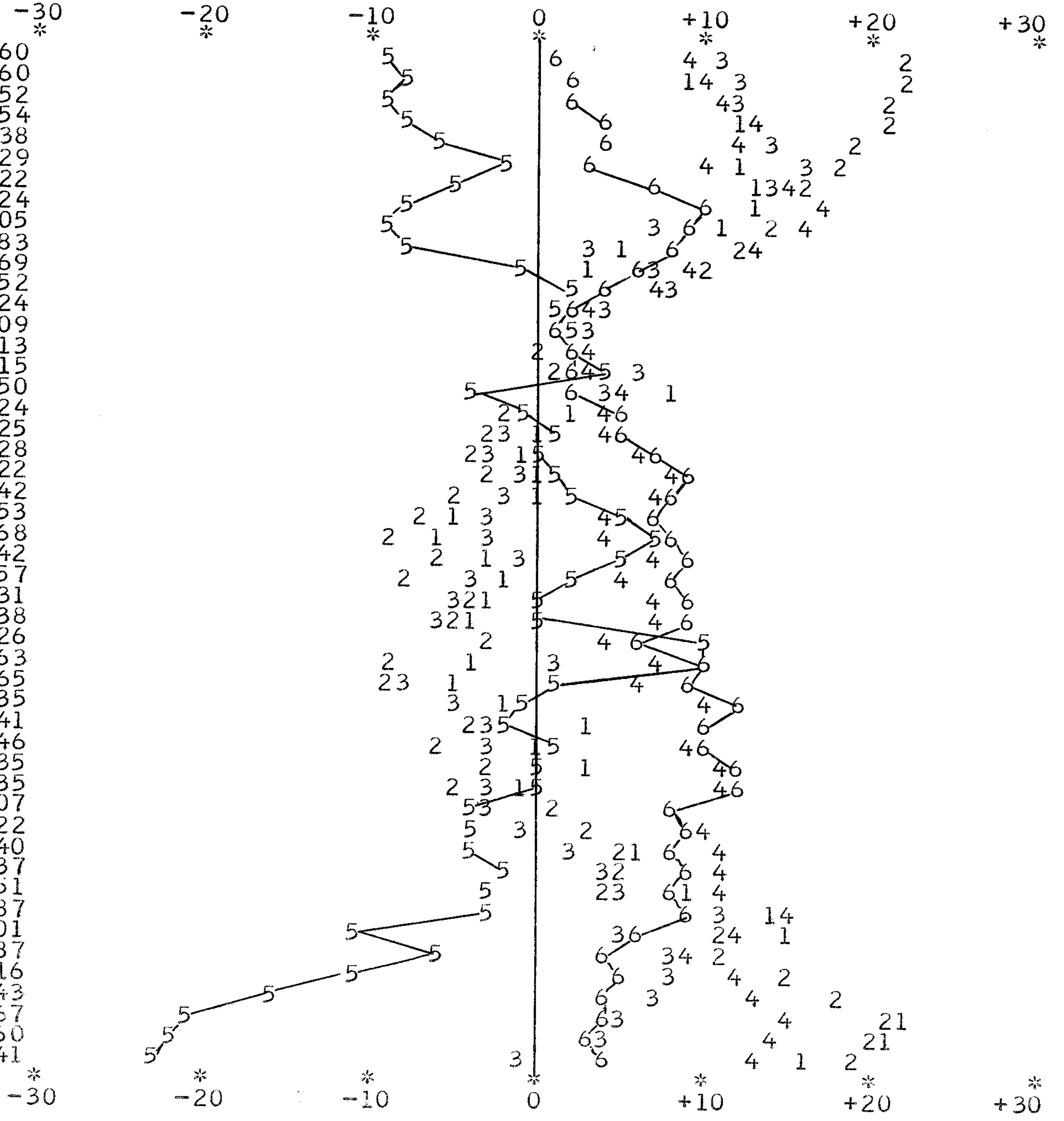


TABLE 4.3 SINGLE AND MULTIPLE BASE ERRORS USING THE ASSUMED STANDARD ATMOSPHERE COOTAMUNDRA AREA 28 FEBRUARY 1966

930	97	0.80
945	107	0.922
1000	116	0.74
1005	107	0.923
1010	123	0.68
1015	124	0.67
1030	127	0.66
1045	124	0.69
1100	118	0.72
1105	114	0.79
1110	119	0.71
1115	115	0.77
1130	119	0.66
1145	113	0.68
1200	112	0.74
1205	115	0.80
1210	116	0.74
1215	113	0.76
1230	114	0.74
1245	114	0.74
1300	116	0.68
1305	121	0.74
1310	119	0.71
1315	116	0.71
1330	109	0.58
1345	106	0.69
1400	104	0.61
1405	121	0.44
1410	126	0.32
1415	113	0.57
1430	118	0.53
1445	129	0.47
1500	125	0.52
1505	133	0.41
1510	121	0.47
1515	143	0.38
1530	120	0.46
1545	130	0.36
1600	130	0.48
1605	118	0.53
1610	119	0.50
1615	122	0.48
1630	121	0.47
1645	116	0.53
1700	130	0.44
1705	131	0.46
1710	123	0.47
1715	117	0.54

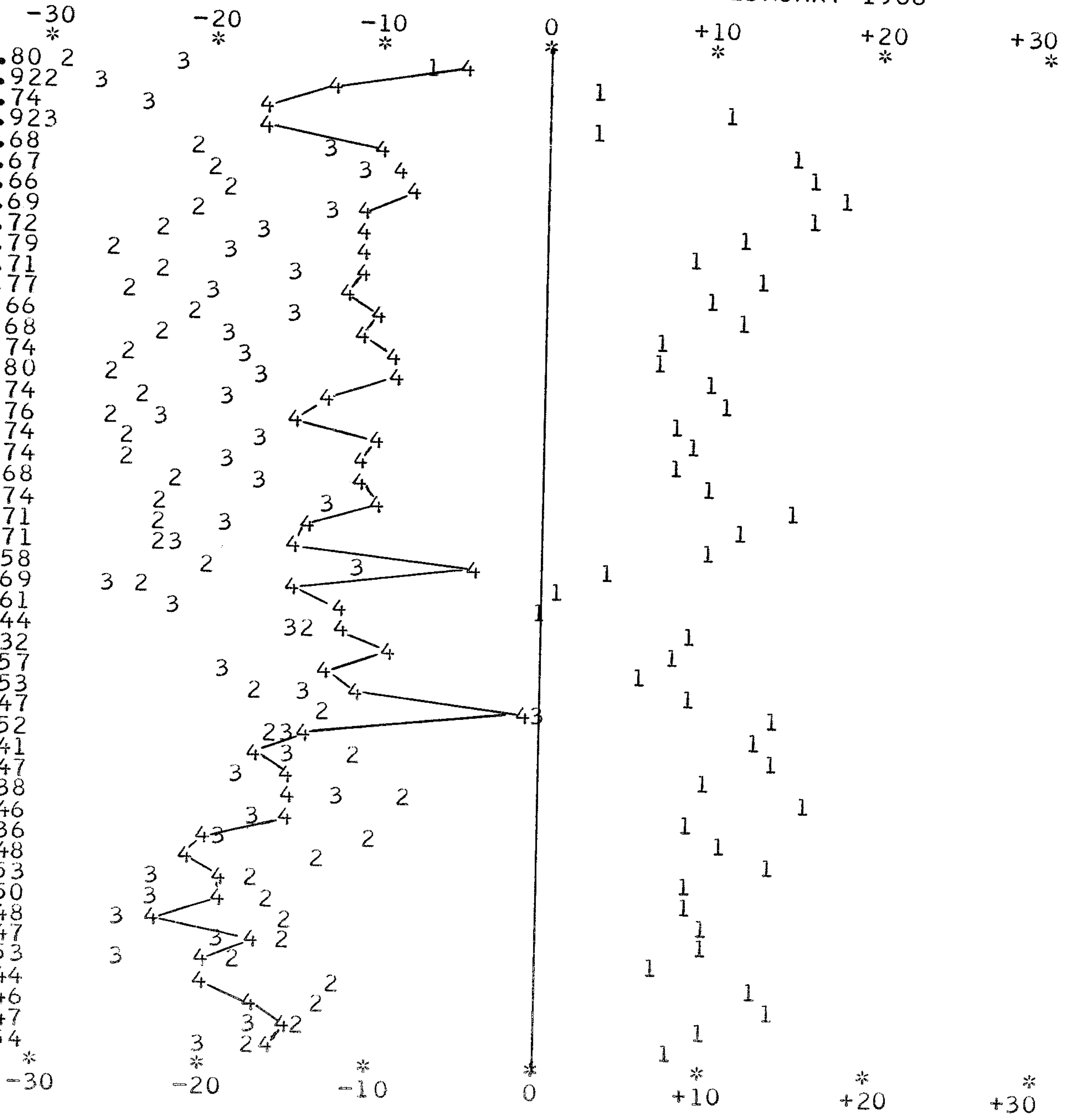


TABLE 4.4 SINGLE AND MULTIPLE BASE ERRORS USING THE ASSUMED STANDARD ATMOSPHERE COOTAMUNDRA AREA 1 MARCH 1966

845	123	0.16
900	148	0.09
905	129	0.07
910	138	0.09
915	130	0.12
930	118	0.13
945	113	0.07
1000	122	0.11
1005	129	0.21
1010	141	0.15
1015	133	0.19
1030	135	0.14
1045	120	0.21
1100	110	0.23
1105	113	0.27
1110	113	0.30
1115	117	0.24
1130	106	0.27
1145	102	0.35
1200	111	0.52
1205	109	0.44
1210	106	0.38
1215	108	0.37
1230	110	0.34
1245	114	0.27
1300	107	0.32
1305	107	0.32
1310	108	0.32
1315	112	0.22
1330	104	0.39
1345	105	0.35
1400	92	0.23
1405	87	0.22
1410	89	0.29
1415	94	0.23
1430	92	0.35
1445	98	0.24
1500	101	0.30
1505	100	0.27
1510	98	0.34
1515	91	0.32
1530	81	0.20
1545	77	0.18
1600	60	0.11
1605	47	0.12
1610	27	0.09
1615	25	0.11

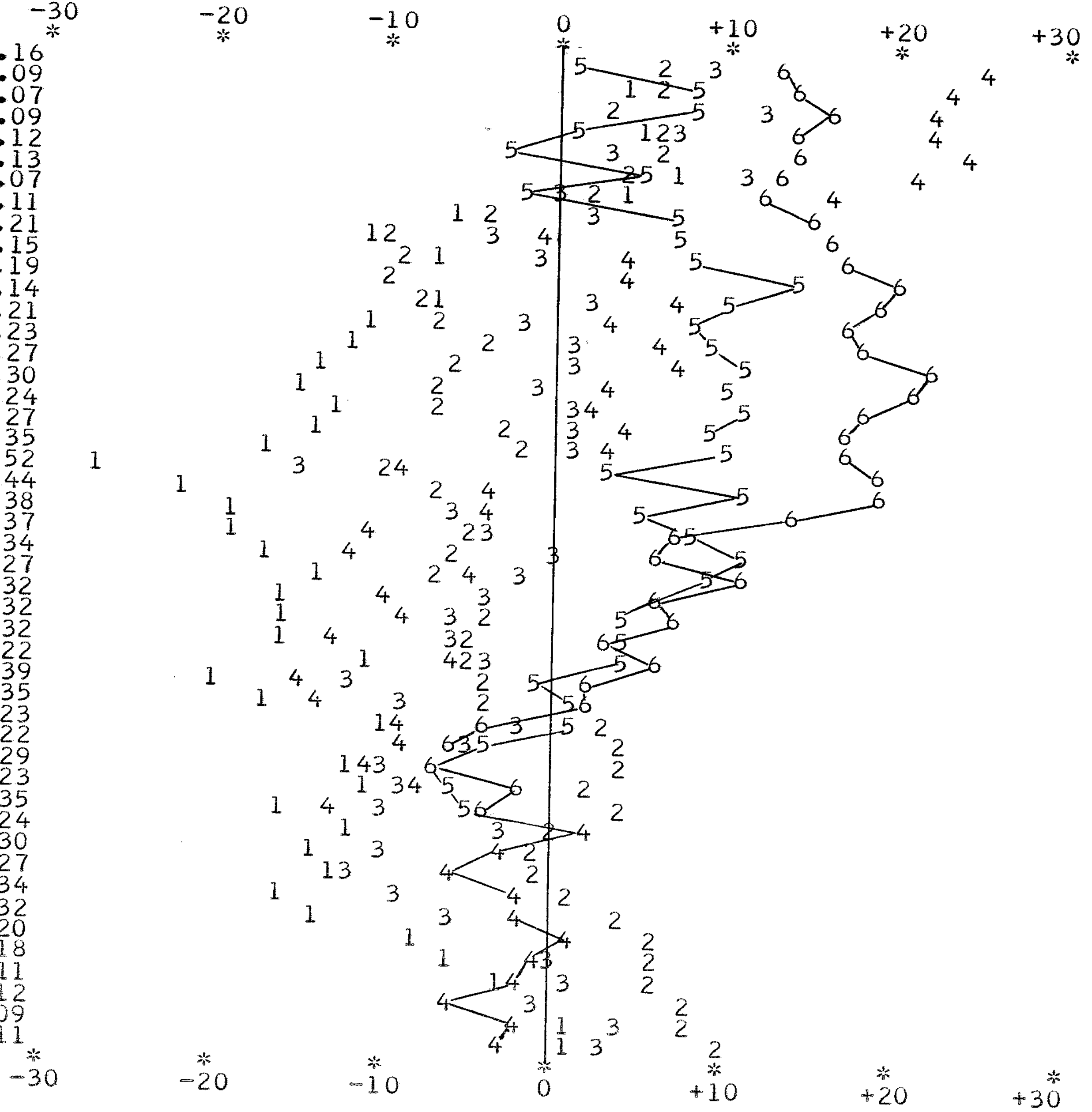


TABLE 4.5 SINGLE AND MULTIPLE BASE ERRORS USING THE ICAN ATMOSPHERE
CITY AREA 26 MAY 1959

915	135	1.99
930	115	1.03
945	110	0.99
1000	81	0.91
1005	74	0.77
1010	101	0.80
1015	112	0.76
1030	106	0.60
1045	97	0.95
1100	103	1.16
1105	104	1.12
1110	96	1.08
1115	88	0.90
1130	79	0.76
1145	61	0.71
1200	48	0.80
1205	33	0.86
1210	20	0.93
1215	26	1.07
1230	21	1.17
1245	19	1.42
1300	17	0.98
1305	9	1.14
1310	1	1.02
1315	1	1.04
1330	1	1.25
1345	173	1.08
1400	174	1.24
1405	179	1.19
1410	171	0.95
1415	165	1.01
1430	138	0.53
1445	139	0.44
1500	71	0.27
1505	15	0.31
1510	17	0.11
1515	175	0.29
1530	1	0.55
1545	175	0.67
1600	156	0.54
1605	163	0.58
1610	161	0.73
1615	153	0.86
1630	158	1.08
1645	152	1.35
1700	145	1.42

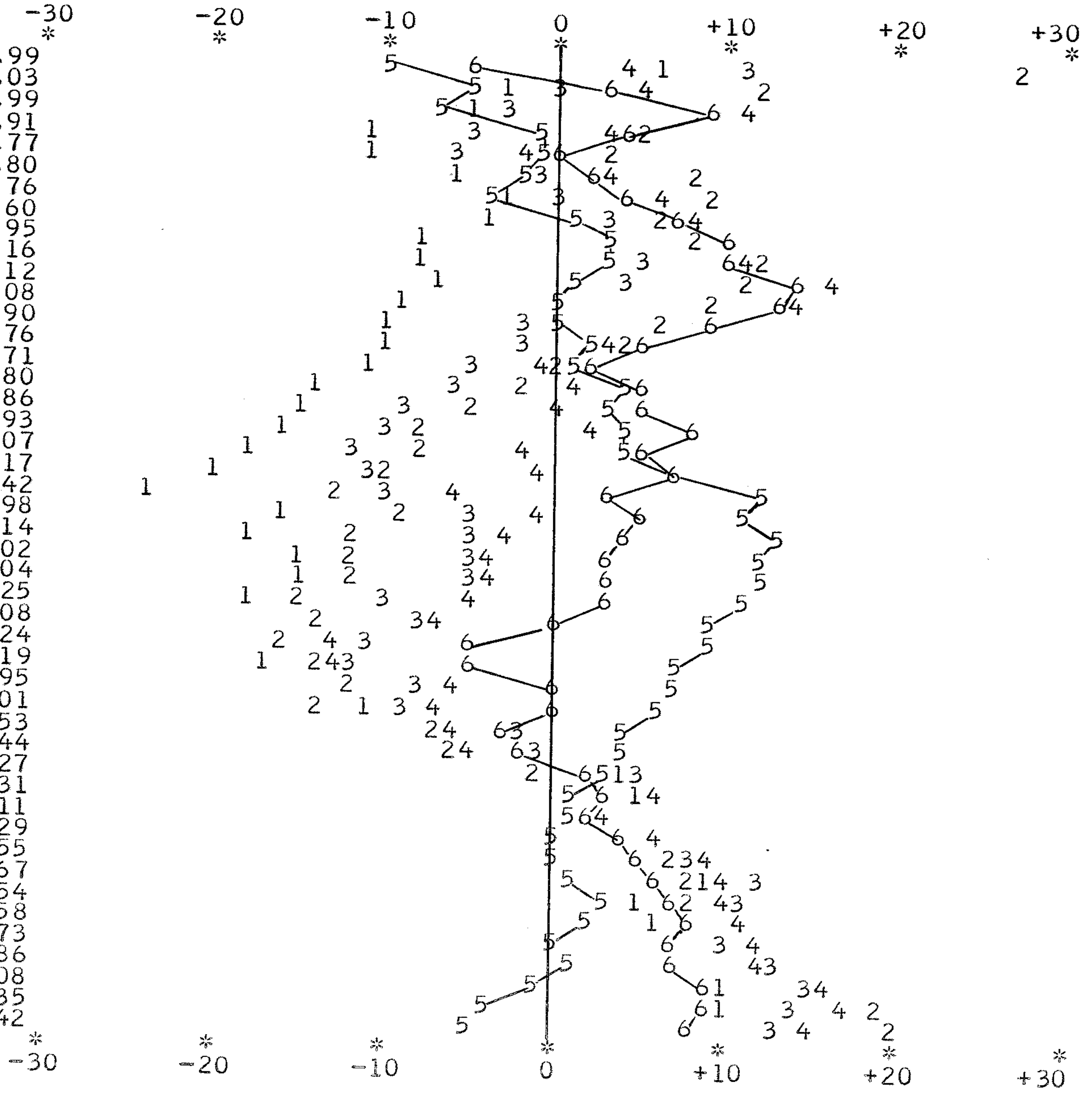


TABLE 4.6 SINGLE AND MULTIPLE BASE ERRORS USING THE ICAN ATMOSPHERE
CITY AREA 28 MAY 1959

900	124	1.19
905	124	1.19
910	131	1.05
915	133	1.06
930	144	0.82
945	133	0.78
1000	144	0.65
1005	140	0.69
1010	132	0.51
1015	95	0.51
1030	75	0.53
1045	56	0.50
1100	15	0.44
1105	5	0.57
1110	174	0.62
1115	0	0.52
1130	173	0.17
1145	165	0.72
1200	171	0.84
1205	172	0.88
1210	172	0.81
1215	162	0.94
1230	175	1.18
1245	169	1.31
1300	171	1.04
1305	164	1.15
1310	178	0.96
1315	177	1.03
1330	2	0.92
1345	168	1.24
1400	170	1.27
1405	171	0.96
1410	155	0.83
1415	161	0.99
1430	159	0.80
1445	168	0.92
1500	5	0.59
1505	9	0.45
1510	6	0.26
1515	14	0.30
1530	144	0.23
1545	27	0.22
1600	9	0.34
1605	147	0.25
1610	161	0.53
1615	162	0.81
1630	168	1.03
1645	169	0.96
1700	150	0.83

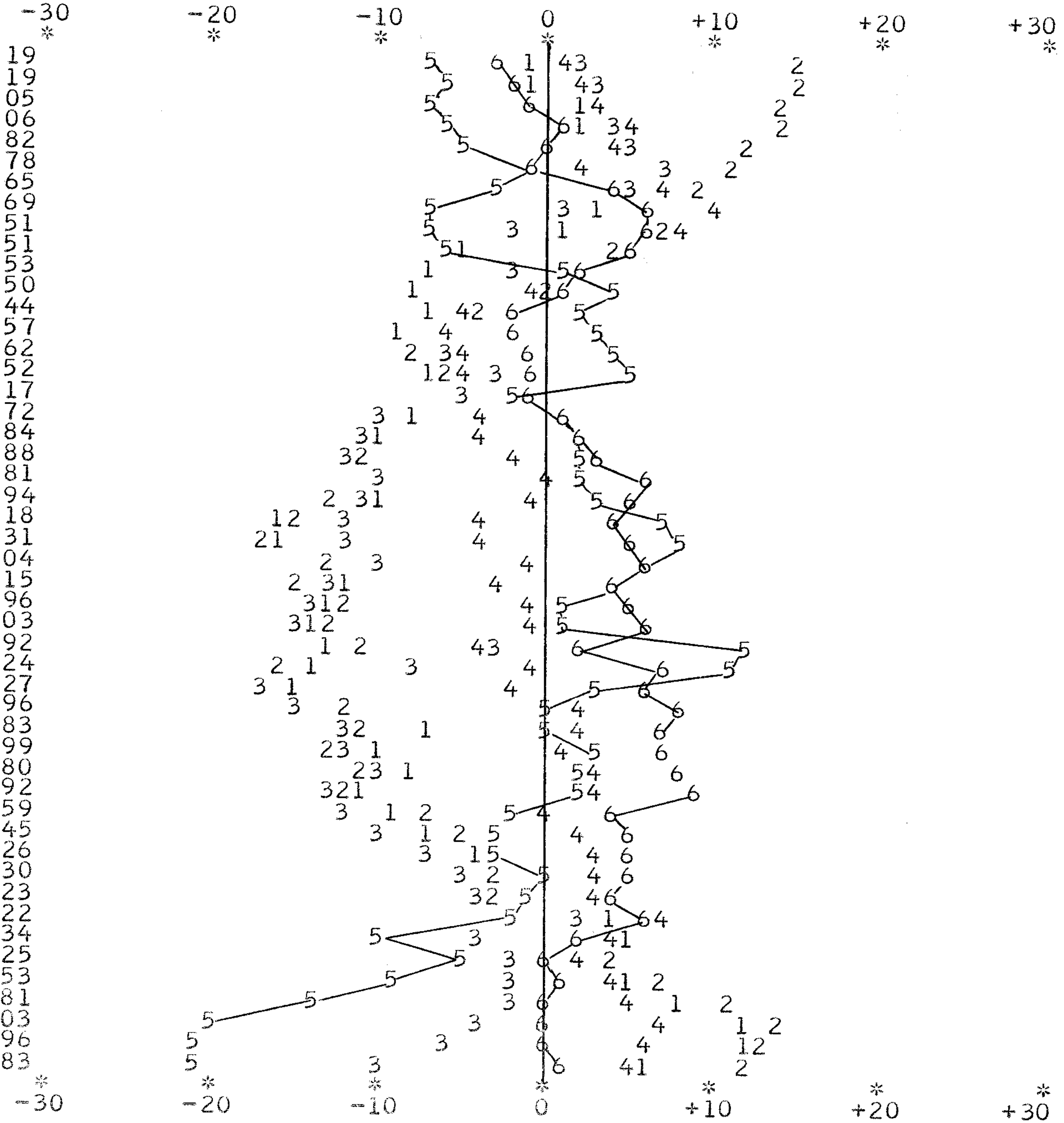


TABLE 4.7 SINGLE AND MULTIPLE BASE ERRORS USING THE ICAN ATMOSPHERE
COOTAMUNDRA AREA 28 FEBRUARY 1966

930	97	0.832
945	106	0.942
1000	115	0.76
1005	107	0.952
1010	122	0.70
1015	124	0.69
1030	127	0.68
1045	124	0.71
1100	118	0.74
1105	113	0.81
1110	118	0.73
1115	114	0.79
1130	118	0.69
1145	112	0.71
1200	112	0.76
1205	115	0.82
1210	116	0.76
1215	113	0.78
1230	114	0.76
1245	113	0.76
1300	116	0.70
1305	120	0.76
1310	118	0.73
1315	116	0.73
1330	109	0.60
1345	105	0.71
1400	103	0.63
1405	120	0.46
1410	125	0.34
1415	112	0.59
1430	117	0.55
1445	128	0.48
1500	124	0.54
1505	132	0.43
1510	120	0.48
1515	141	0.39
1530	119	0.48
1545	129	0.38
1600	129	0.49
1605	118	0.55
1610	118	0.51
1615	121	0.50
1630	120	0.49
1645	115	0.55
1700	128	0.46
1705	130	0.48
1710	122	0.48
1715	116	0.56

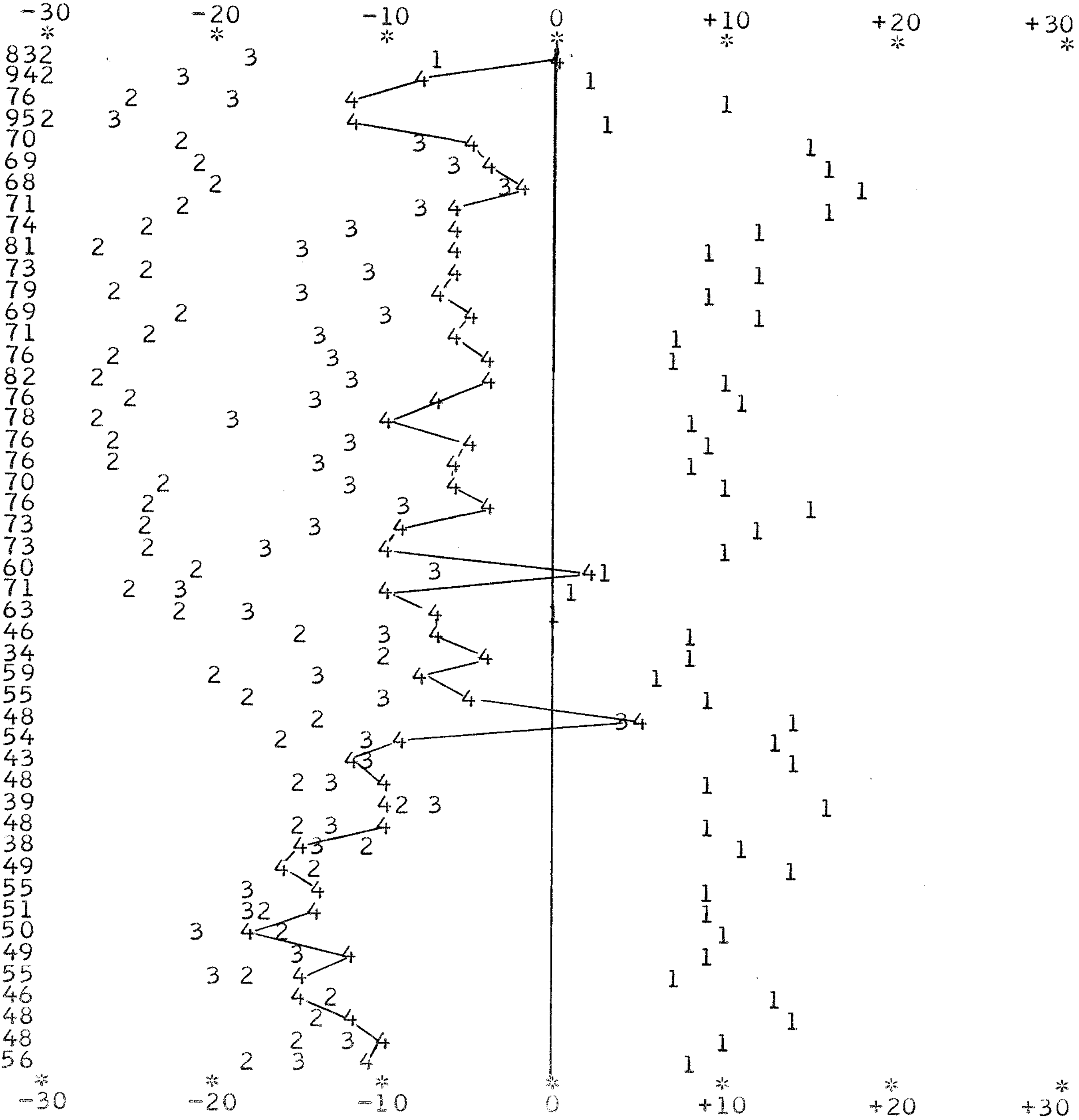
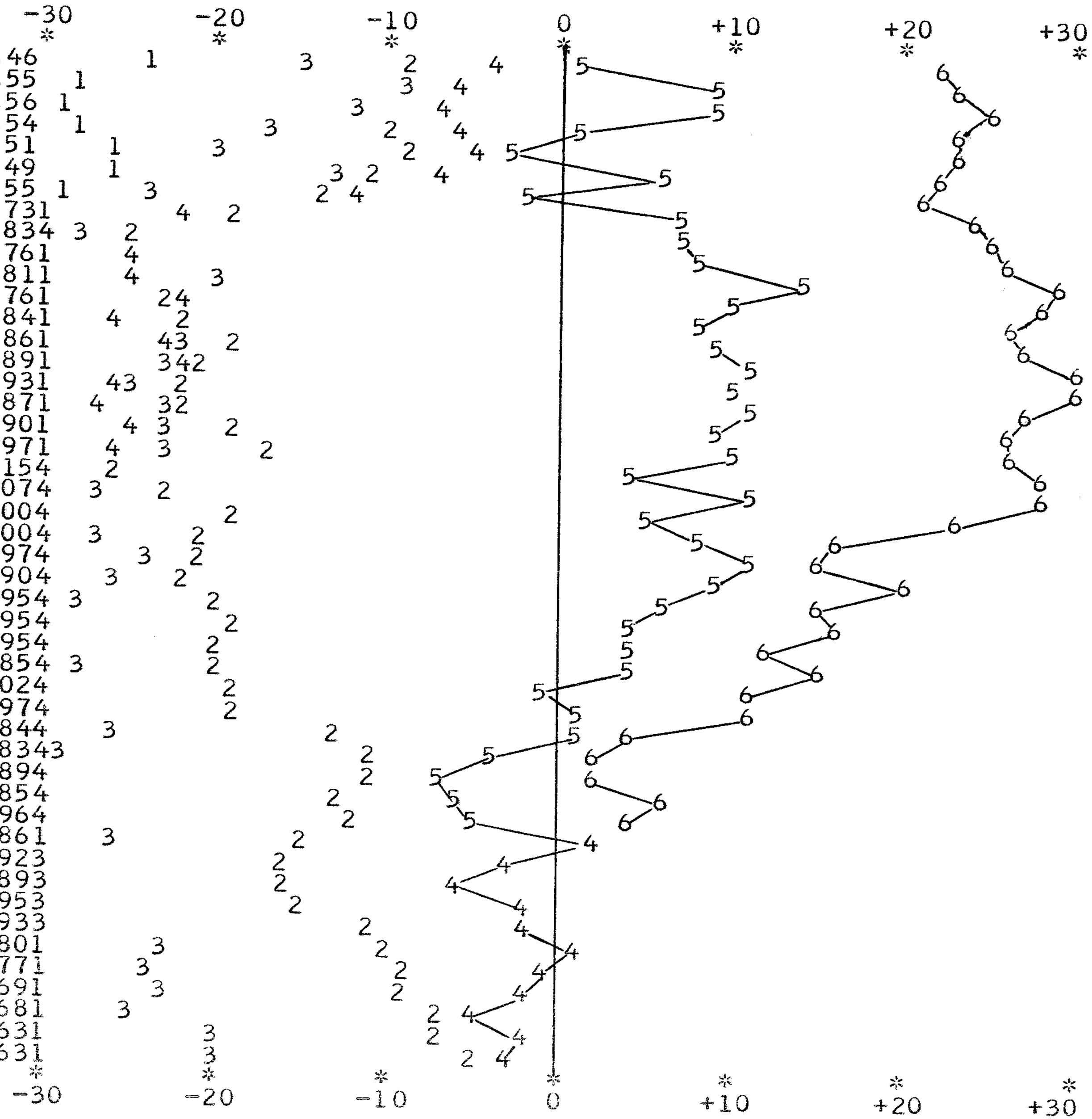


TABLE 4.8 SINGLE AND MULTIPLE BASE ERRORS USING THE ICAN ATMOSPHERE
COOTAMUNDRA AREA 1 MARCH 1966

845	111	0.46
900	109	0.55
905	113	0.56
910	110	0.54
915	111	0.51
930	113	0.49
945	114	0.55
1000	115	0.731
1005	118	0.834
1010	119	0.761
1015	118	0.811
1030	118	0.761
1045	116	0.841
1100	113	0.861
1105	114	0.891
1110	114	0.931
1115	115	0.871
1130	112	0.901
1145	110	0.971
1200	113	1.154
1205	112	1.074
1210	111	1.004
1215	112	1.004
1230	113	0.974
1245	114	0.904
1300	112	0.954
1305	112	0.954
1310	112	0.954
1315	114	0.854
1330	110	1.024
1345	111	0.974
1400	108	0.844
1405	107	0.834
1410	106	0.894
1415	109	0.854
1430	106	0.964
1445	110	0.861
1500	110	0.923
1505	110	0.893
1510	108	0.953
1515	106	0.933
1530	106	0.801
1545	106	0.771
1600	107	0.691
1605	105	0.681
1610	106	0.631
1615	104	0.631



CHAPTER 5

FIELD TRAVERSES

Four traverses were made in the Sydney Area in order to assess the accuracy to be expected in a barometer traverse. Three base stations and a number of field stations of known elevation were utilized for the traverses. The field stations were permanent marks placed by the Survey Co-ordination Branch of the New South Wales Department of Lands as part of the First Order Levelling around the city of Sydney. The marks are at one to two mile intervals and generally follow main arterial roads. This made them ideal stations for the traverses as it greatly simplified the problems of transport. For barometric heighting, however, they were not always ideal as the local topography and buildings in the immediate vicinity could have caused significant local turbulences. This effect was not apparent in the results as the errors from other causes were far more significant.

The area of the traverses was approximately 100 square miles and the positions of the field stations were as indicated in Figure 5.1.

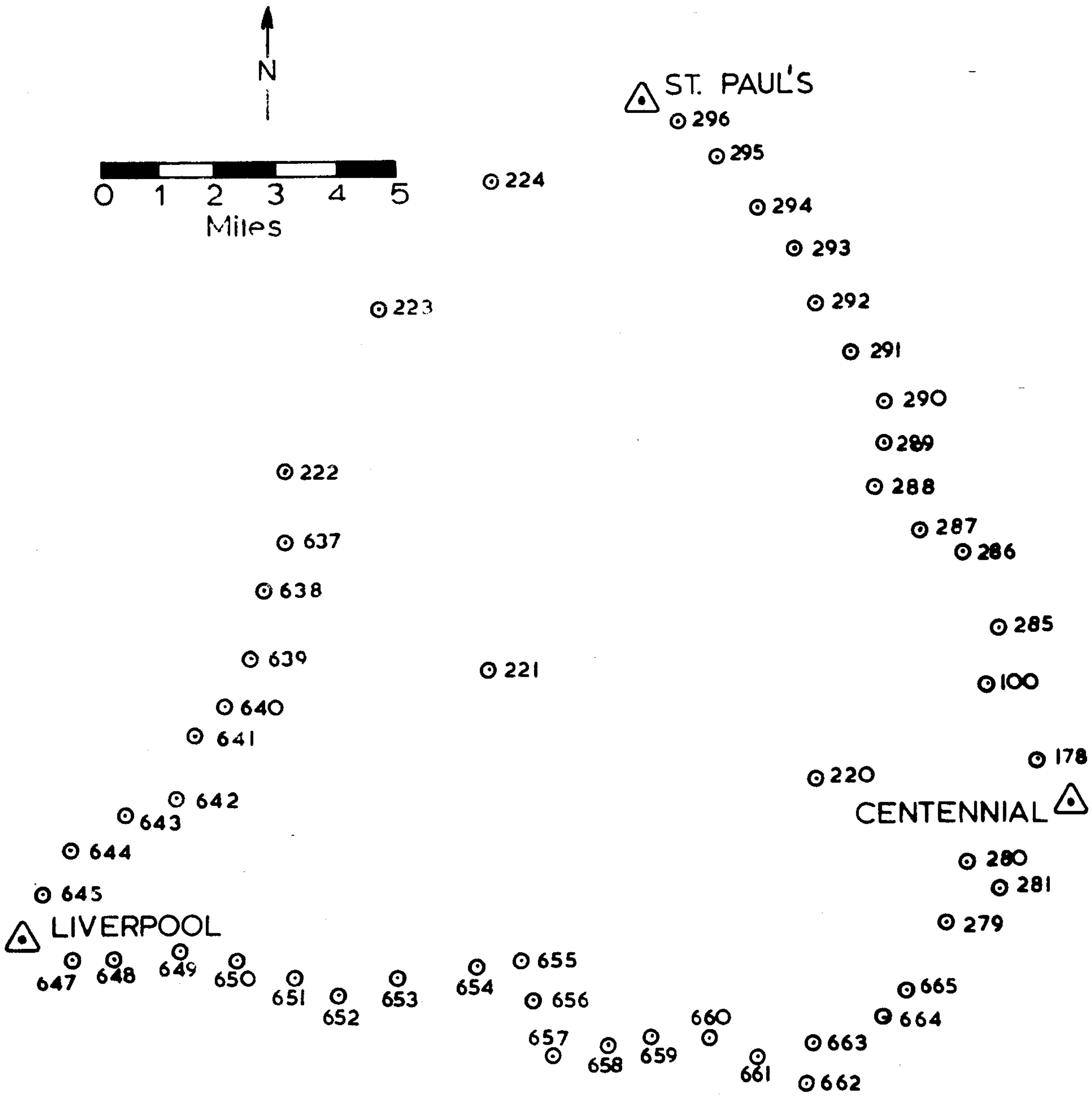


FIG. 5.1 BAROMETER TRAVERSE STATIONS — CITY AREA

For some twenty years, many authors have advocated the use of either the Two Base or the Leap-frog method.[5, 23, 29, 39, 42, 43, 44, 50, 52, 53, 56.]

Accordingly the field work was designed to allow a comparison to be made between these methods and the Multiple Base Method. Thus on the 6th and 7th of December, 1955, two field barometers were used in the Leap-frog manner. At the same time, three base stations were also occupied. This allowed the barometer reading to be reduced by each of the three methods.

In addition the Multiple Base traverse of the 22nd and 23rd of May, 1956 was reduced by both the Multiple Base and Two Base methods.

The field procedure adopted was to compare all barometers simultaneously to obtain index corrections. One barometer was then sent to each of the base stations (St. Paul's, Liverpool and Centennial) and read at quarter-hourly intervals. The remaining barometers were then traversed around the field stations with index checks against a base instrument when in the vicinity of that base. At the end of the day's traverse, the barometers were again compared to give new indices. Any drift in the index was apportioned linearly throughout the readings.

The reading of the base instrument at the instant of a field reading was then deduced by linear interpolation between the relevant base readings.

The reduced readings thus had been corrected for index and drift prior to entry into the computation.

The reduced readings of pressure, together with the time,station name, co-ordinates, known elevation and temperatures were then punched into computer cards for input into the appropriate programme. The basis of computation and a description of the computer programmes are given in Chapter 6.

5.1 MULTIPLE BASE TRAVERSE

The traverses of the 22nd and 23rd May, 1956 and 6th and 7th of December, 1955 were calculated using the Multiple Base Method (Computer Programme SVY 19). Both the ICAN and ASA Standard Atmospheres were used to allow a further comparison to be drawn between them. The results for the ASA Standard Atmosphere are given in Appendix III and summaries for both atmospheres are given in graphical form in the following Tables.

Tables 5.1 and 5.2 give the results for the traverses of the 22nd and 23rd May respectively using the ASA Atmosphere. Tables 5.5 and 5.6 give the results from the same data using the ICAN atmosphere. The base stations were St. Paul's, Liverpool and Centennial. Graphs 1, 2 and 3 give the errors resulting from Single Base Computations based on St. Paul's for Liverpool, Centennial and the field station respectively. Graph 4 shows the error for the field station when the Multiple Base method is applied.

Tables 5.3, 5.4, 5.7 and 5.8 show the results for the traverses of the 6th and 7th December using both Standard Atmospheres. The base stations were again St. Paul's, Liverpool and Centennial. Graphs 1, 2, 3 and 4 give the Single Base errors based on St. Paul's for Liverpool, Centennial and the two field stations. Graphs 5 and 6 give the resulting errors for the field stations when the Multiple Base method is applied.

5.2 LEAP-FROG METHOD

The readings for the 6th and 7th of December, 1955, were then reduced using the Leap-frog method (computer programme SVY 43) and the ASA atmosphere. The results for this calculation are given in Appendix IV and are summarised in graphical form in Tables 5.9 and 5.10.

In practice, the only check on the reliability of the calculated field elevations is given by the difference between the known elevation and the calculated elevation of any fixed station included in the traverse. This difference is called the misclose and if it is sufficiently small the traverse is assumed to be reliable and the misclose is then applied in a linear manner to the intermediate field elevations. The output from SVY 43, consists of the known station, the number of stations and the misclose. This is then followed by the field results in the form:

time, station, error in adjusted field elevation.

On the 7th of December, the two miscloses (0.9 and -7.5 feet) were quite small and indicated that the field elevations should be quite precise. This conclusion was borne out by an analysis of the errors which gave the following results:

Average error	3.3 feet.
Maximum error	7.8 feet.

These figures are of the same magnitude as those found by other investigators.

On the 6th December, the misclose was -0.4 and it thus appeared that the results would be of the same precision as the 7th December results. This however, was not the case as indicated by the results:

Average error	9.6 feet.
Maximum error	26.0 feet.

Within the field readings themselves there is no indication that the results are not reliable. The only conclusion that may be drawn therefore is that the Leap-frog method may only be used when an average error of up to 10 feet with a maximum error of up to 30 feet may be tolerated.

It is most instructive to contrast these results with those obtained by the Multiple Base method. In the latter the high degree of tilt and its variability immediately indicate that the results will be unreliable.

Since small atmospheric disturbances which are not readily detected in the field readings are quite common, it was felt that the method should not be recommended. Further, the field procedure is quite slow as one field barometer must always remain stationary.

5.3 TWO BASE METHOD

The readings for the 22nd and 23rd May, 1956 and the 6th and 7th of December, 1955 were also reduced by the Two Base method (computer programme SVY 42). The results of this calculation are given in Appendix V and are summarised in graphical form in the Tables 5.11 to 5.14 respectively. In each Table graph 1 gives the result of the calculation using St. Paul's and Liverpool as the two bases. Graphs 2 and 3 give the results using Liverpool/Centennial and Centennial/St. Paul's respectively as the two bases.

As with the Leap-frog method the average errors and the maximum errors are generally within acceptable limits. However on one day, 6th December, a number of errors are in excess of 100 feet. As before, from the readings there is no indication in the method of calculation of the unreliability of the results. Admittedly, the stations at which these larger errors occurred were some fifteen miles from the direct line joining the two base stations and also at elevations some 400 feet in excess of the higher base giving a field to base difference in elevation of 3 to 1. However, since these conditions are frequently encountered in practice, it was felt that the method suffered from serious limitations and could not be recommended for general use.

5.4 CONCLUSIONS

The Multiple Base errors were examined to see whether they conformed to the hypothesis suggested in Section 4.7. As the field barometers were moved from station to station between readings, it follows that the distances from the field station to the nearest base station varied. This made the analysis difficult and so a random sampling of the results was made. The errors examined in this way conformed to the hypothesis.

The expected error (or mean error) for a typical field station may thus be determined by the application of the formula in Section 4.7.

To determine the reliability of a series of elevations for field stations surrounding the base stations, the errors were again examined by the programme SVY 46. The mean error for the Multiple Base method was found to conform to the formula:

$$\text{Mean Error} = C_1 + .3 \times D_2 + .2 \times T^2 \times D_2$$

where C_1 is the standard deviation of reading for the particular make of barometer,

T is the tilt of the Isobaric surface,

and D_2 is the mean distance in miles of the field stations from the nearest base stations.

The maximum error for the Multiple Base method is estimated as double the calculated mean error.

The Leap-frog method is not recommended and the Two Base method should be restricted to special cases in which the topography has a uniform slope from one base station to the other. When a more reliable result is required, temperatures may be recorded and the Multiple Base method of reduction modified by assuming that base B and C are the same station.

TABLE 5.1 SINGLE AND MULTIPLE BASE ERRORS USING THE ASSUMED STANDARD ATMOSPHERE
CITY TRAVERSE 22 MAY 1956

923	100	0.50
929	92	0.33
939	20	0.73
946	75	0.45
952	64	0.42
956	53	0.52
1001	52	0.60
1006	30	0.59
1013	14	0.68
1024	176	0.58
1032	171	0.67
1050	174	0.84
1056	1	0.80
1100	3	0.89
1105	2	0.69
1110	11	0.63
1115	22	0.47
1120	10	0.39
1124	18	0.49
1129	3	0.49
1139	175	0.33
1148	24	0.46
1230	7	0.16
1251	161	0.26
1310	54	0.69
1325	36	0.79
1340	37	1.25
1348	26	1.17
1409	16	0.93
1414	23	1.33
1447	35	1.01
1453	26	1.14
1459	12	1.13
1505	12	1.13
1511	12	1.14
1516	16	1.23
1522	21	1.25
1527	22	1.29

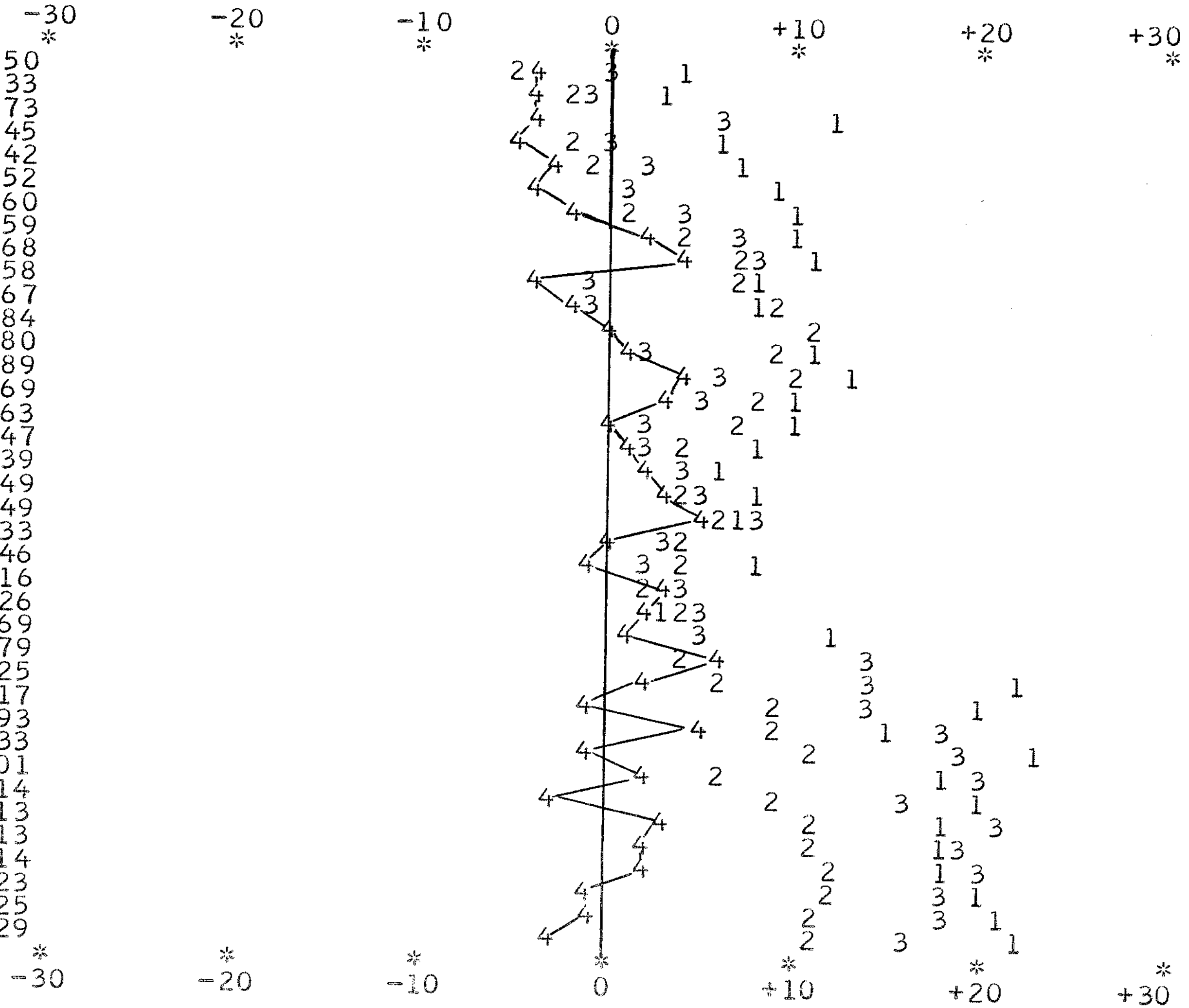


TABLE 5.2 SINGLE AND MULTIPLE BASE ERRORS USING THE ASSUMED STANDARD ATMOSPHERE CITY TRAVERSE 23 MAY 1956

933	178	1.02
938	170	1.22
944	168	1.46
948	158	1.31
954	157	1.03
959	163	0.76
1004	170	0.75
1011	157	0.78
1016	133	0.75
1021	158	0.56
1027	156	0.37
1032	141	0.32
1037	104	0.47
1043	104	0.49
1049	100	0.33
1055	100	0.24
1104	141	0.37
1111	173	0.82
1119	175	1.03
1128	12	0.76
1137	9	0.51
1210	176	0.93
1235	1	0.67
1255	4	0.72
1303	9	0.48
1309	22	0.49
1315	37	0.41
1320	31	0.45
1324	35	0.50
1329	40	0.60
1335	45	0.49
1339	53	0.50
1344	63	0.40
1350	64	0.40
1355	54	0.25
1414	149	0.61
1424	61	0.60
1436	72	0.85
1445	78	0.69
1452	62	0.96
1459	48	0.97
1503	52	1.00
1509	58	1.06
1513	57	1.08
1519	52	1.07
1523	40	1.05

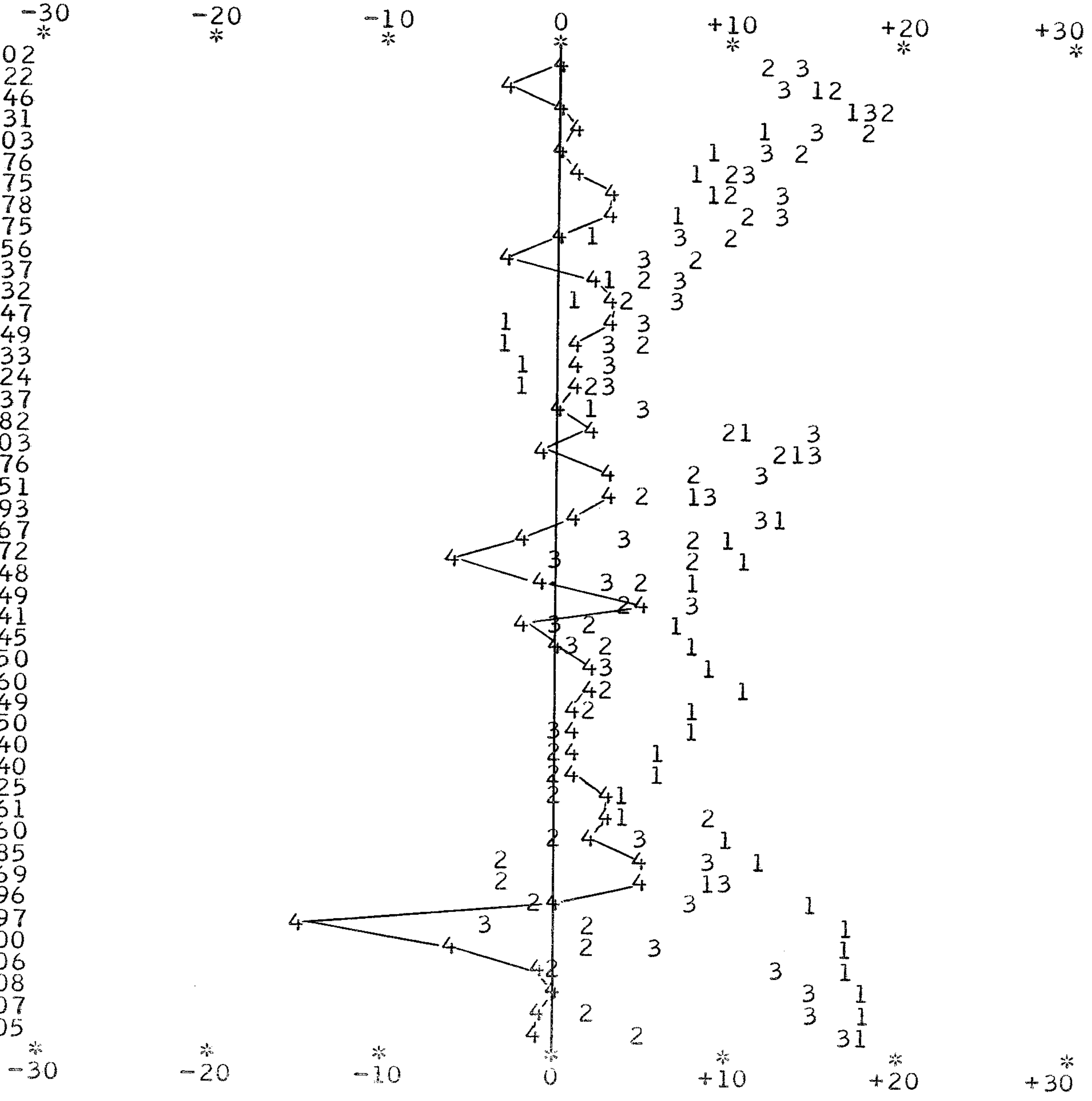


TABLE 5.3 SINGLE AND MULTIPLE BASE ERRORS USING THE ASSUMED STANDARD ATMOSPHERE CITY TRAVERSE 6 DECEMBER 1955

924	100	1.96
936	90	2.43
946	88	2.53
1000	94	2.46
1010	89	2.27
1020	86	2.21
1029	86	1.95
1039	97	1.80
1058	118	2.00
1125	139	1.94
1132	140	2.08
1145	133	1.92
1205	152	2.12
1230	161	2.02
1245	158	1.85
1305	149	2.01
1320	149	2.02
1356	159	1.47
1420	171	1.42
1500	162	1.32
1530	166	1.36
1555	176	1.23
1615	168	0.54
1629	6	0.32
1645	4	0.66
1711	16	0.86
1722	12	0.62

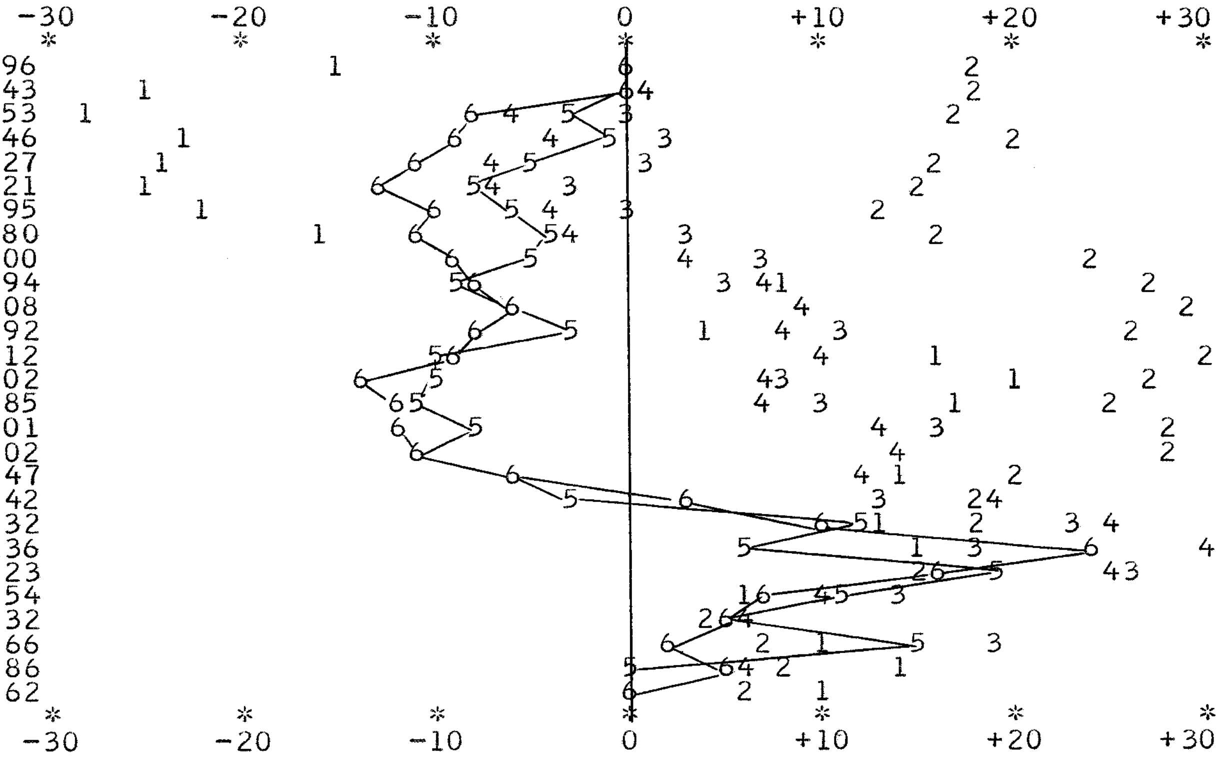


TABLE 5.4 SINGLE AND MULTIPLE BASE ERRORS USING THE ASSUMED STANDARD ATMOSPHERE

CITY TRAVERSE 7 DECEMBER 1955

905	150	0.49
920	102	0.70
932	96	1.00
942	99	1.23
955	86	0.98
1006	93	0.95
1020	109	0.79
1032	126	0.61
1042	130	0.67
1053	163	0.53
1102	175	0.58
1109	3	1.03
1151	6	1.40
1209	8	1.79
1216	2	1.71
1227	1	1.54
1236	3	1.56
1246	2	1.63
1300	174	1.87
1312	175	1.51
1323	177	1.41
1337	1	1.56
1345	3	1.60
1357	20	1.62
1406	22	1.71
1421	26	1.86
1430	30	1.90
1445	28	2.02
1457	29	1.87
1508	29	1.88
1525	36	1.72
1543	31	1.65
1604	35	1.45
1620	59	1.30
1625	65	1.25
1700	71	1.85
1728	76	1.88
1734	66	2.17

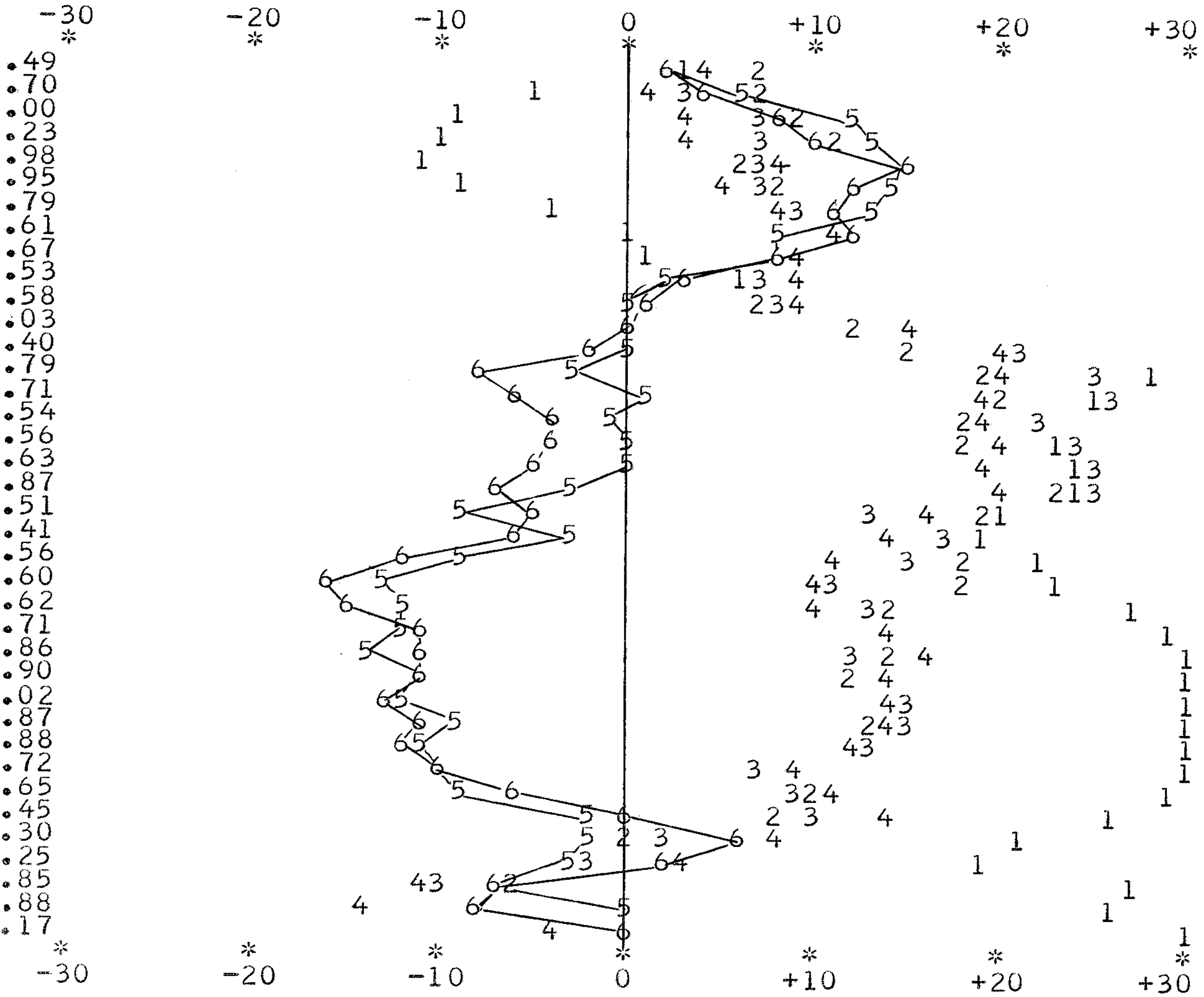


TABLE 5.5 SINGLE AND MULTIPLE BASE ERRORS USING THE ICAN ATMOSPHERE
CITY TRAVERSE 22 MAY 1956

923	150	0.87
929	158	0.73
939	81	0.19
946	145	0.66
952	146	0.58
956	134	0.50
1001	125	0.51
1006	122	0.28
1013	86	0.11
1024	50	0.12
1032	91	0.16
1050	140	0.23
1056	162	0.15
1100	177	0.23
1105	125	0.05
1110	124	0.07
1115	151	0.25
1120	178	0.27
1124	155	0.21
1129	10	0.17
1134	12	0.35
1139	15	0.34
1148	150	0.27
1230	5	0.51
1251	19	0.44
1310	117	0.57
1325	92	0.40
1340	64	0.79
1348	50	0.61
1409	39	0.31
1414	39	0.74
1447	71	0.55
1453	50	0.58
1459	22	0.48
1505	21	0.49
1511	21	0.50
1516	28	0.60
1522	36	0.65
1527	38	0.70

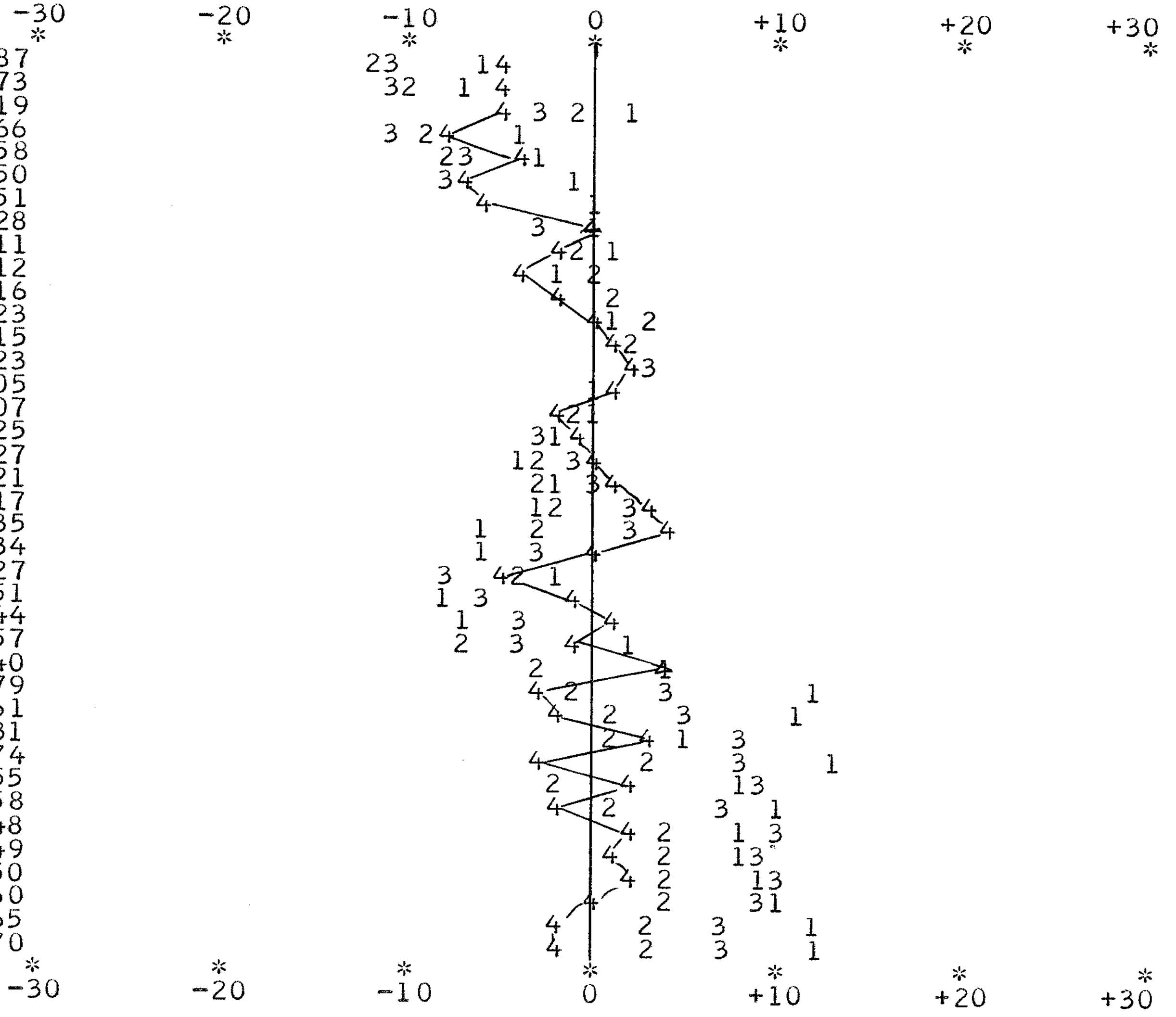


TABLE 5.6 SINGLE AND MULTIPLE BASE ERRORS USING THE ICAN ATMOSPHERE
CITY TRAVERSE 23 MAY 1956

933	165	0.38
938	153	0.62
944	154	0.86
948	135	0.79
954	122	0.56
959	104	0.30
1004	113	0.21
1011	100	0.38
1016	77	0.64
1021	63	0.30
1027	32	0.38
1032	32	0.49
1037	44	0.75
1043	45	0.76
1049	33	0.71
1055	25	0.69
1104	38	0.47
1111	134	0.22
1119	159	0.40
1128	49	0.13
1137	173	0.16
1210	156	0.30
1235	102	0.05
1255	167	0.06
1303	176	0.18
1309	149	0.24
1315	151	0.38
1320	146	0.32
1324	138	0.34
1329	121	0.38
1335	138	0.42
1339	136	0.50
1344	147	0.56
1350	148	0.57
1355	164	0.53
1414	71	0.40
1424	128	0.60
1436	117	0.85
1445	130	0.80
1452	105	0.82
1459	91	0.67
1503	93	0.73
1509	96	0.86
1513	95	0.86
1519	90	0.80
1523	77	0.64

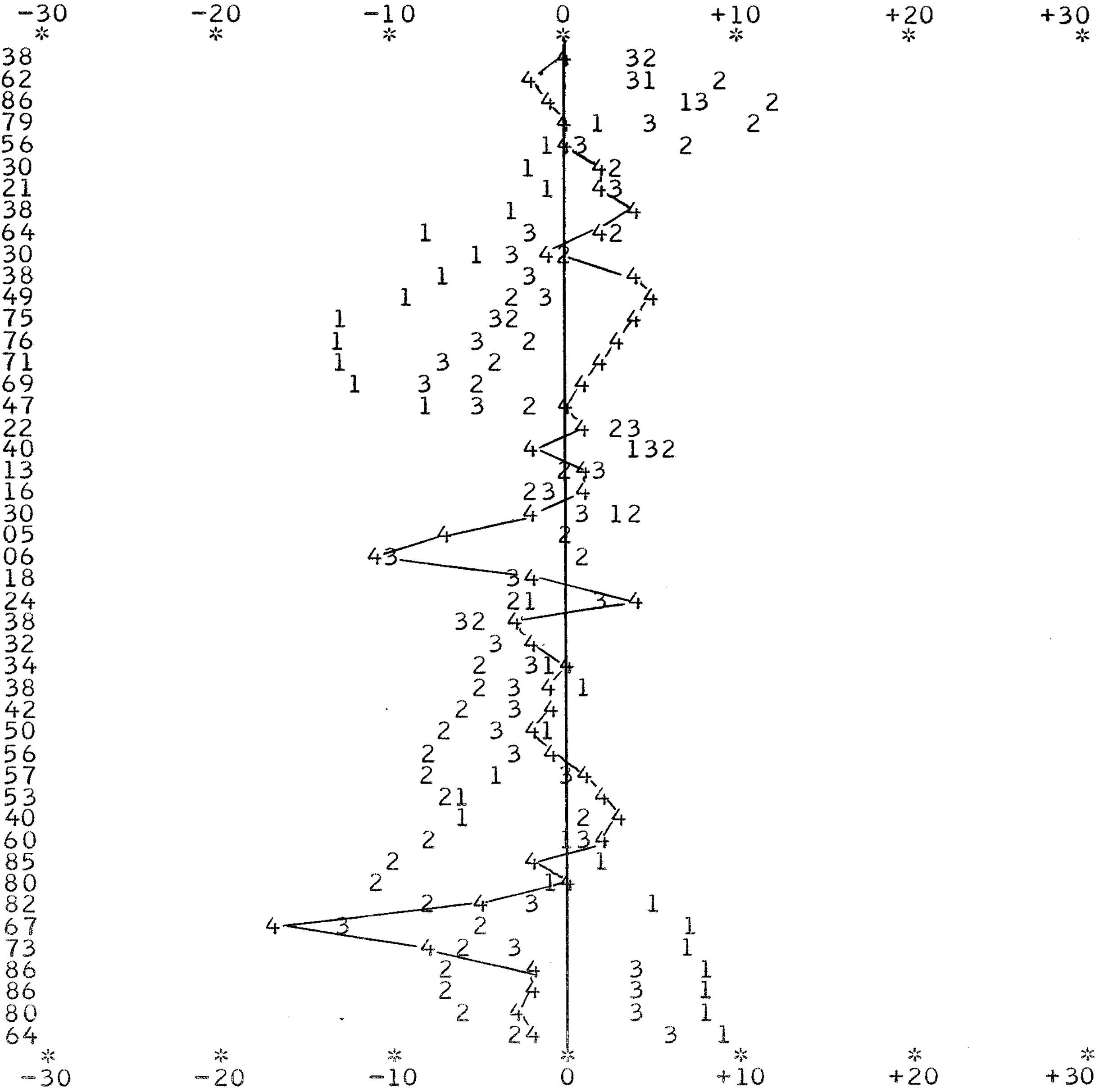


TABLE 5.7 SINGLE AND MULTIPLE BASE ERRORS USING THE ICAN ATMOSPHERE
CITY TRAVERSE 6 DECEMBER 1955

924	81	2.05
936	75	2.601
946	74	2.731
1000	79	2.601
1010	74	2.471
1020	71	2.441
1029	68	2.191
1039	76	1.92
1058	98	1.88
1125	121	1.58
1132	124	1.70
1145	114	1.62
1205	139	1.64
1230	150	1.46
1245	145	1.32
1305	134	1.56
1320	134	1.57
1356	141	0.94
1420	160	0.80
1500	141	0.77
1530	150	0.77
1555	165	0.59
1615	52	0.20
1629	4	0.34
1645	95	0.01
1711	48	0.24
1722	131	0.08

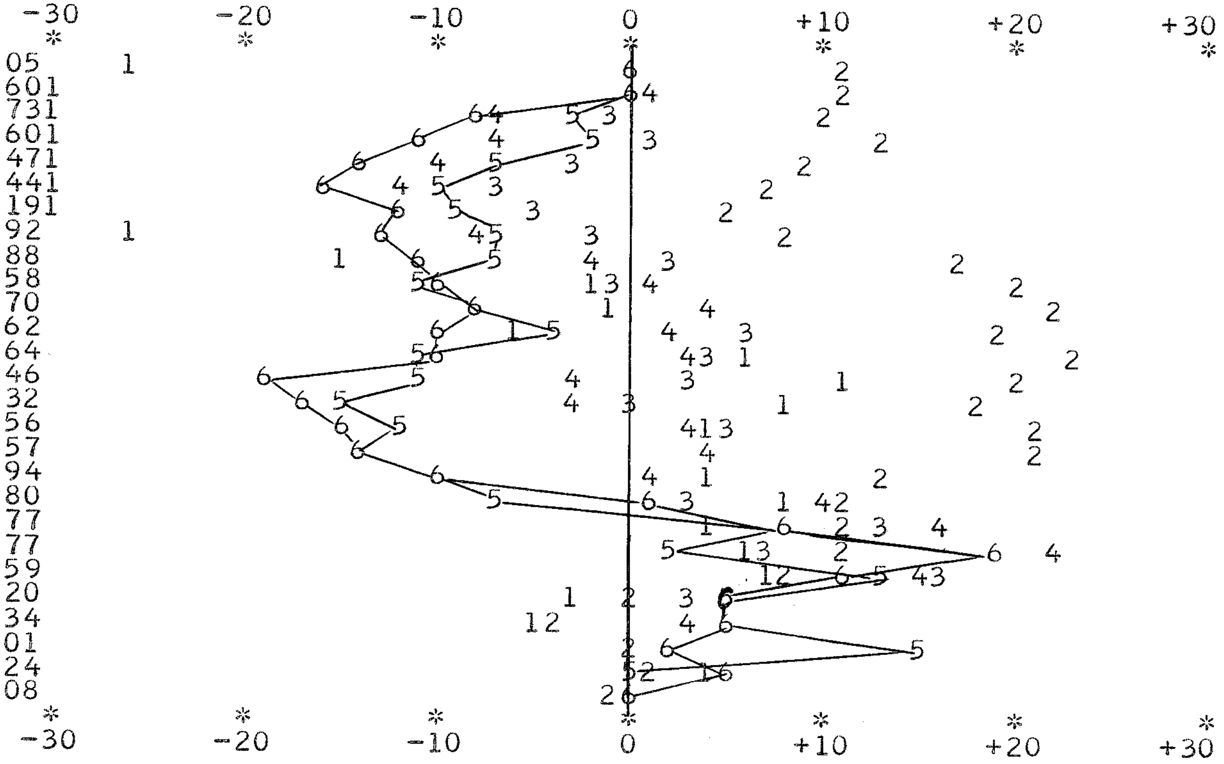
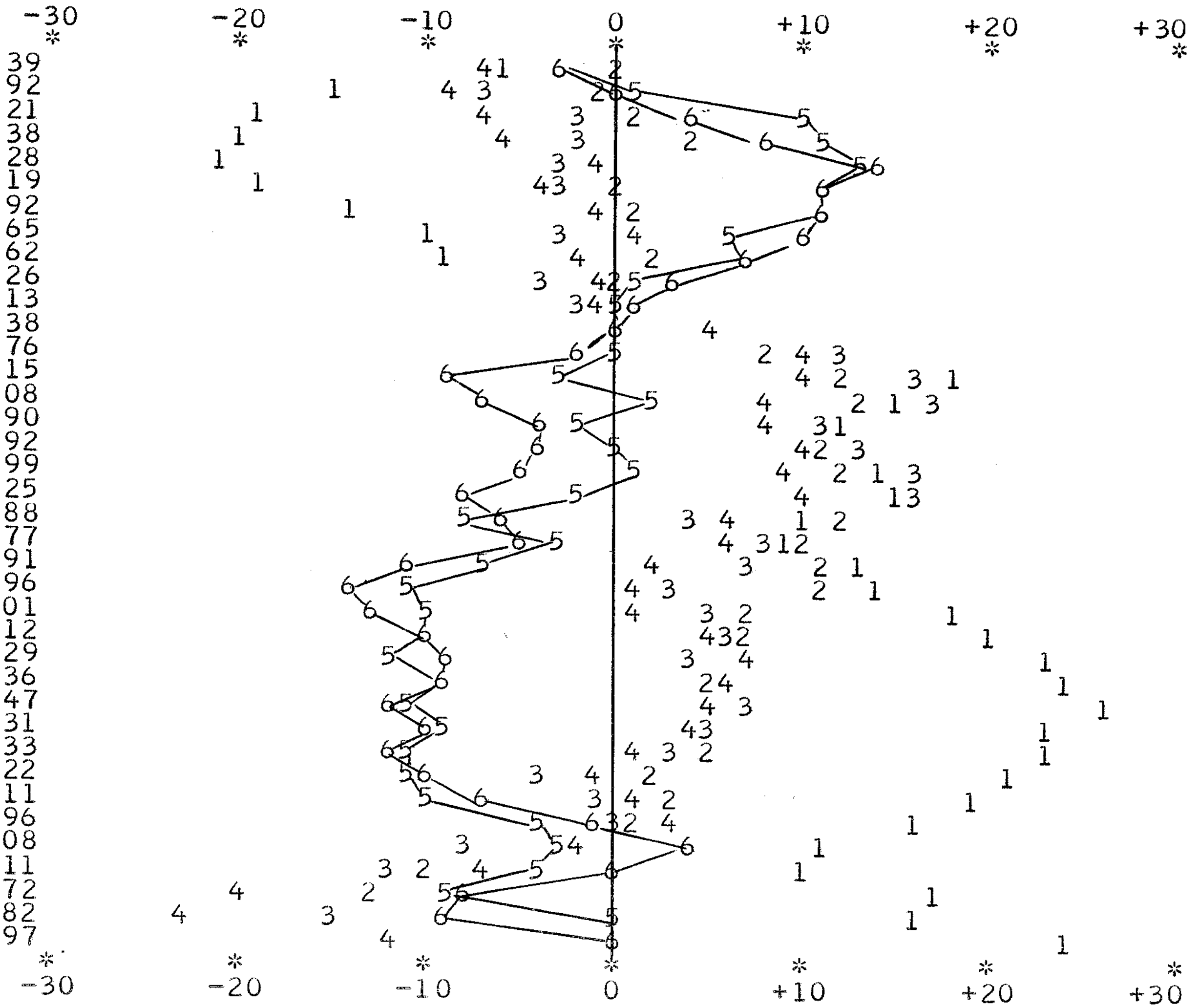


TABLE 5.8 SINGLE AND MULTIPLE BASE ERRORS USING THE ICAN ATMOSPHERE
CITY TRAVERSE 7 DECEMBER 1955

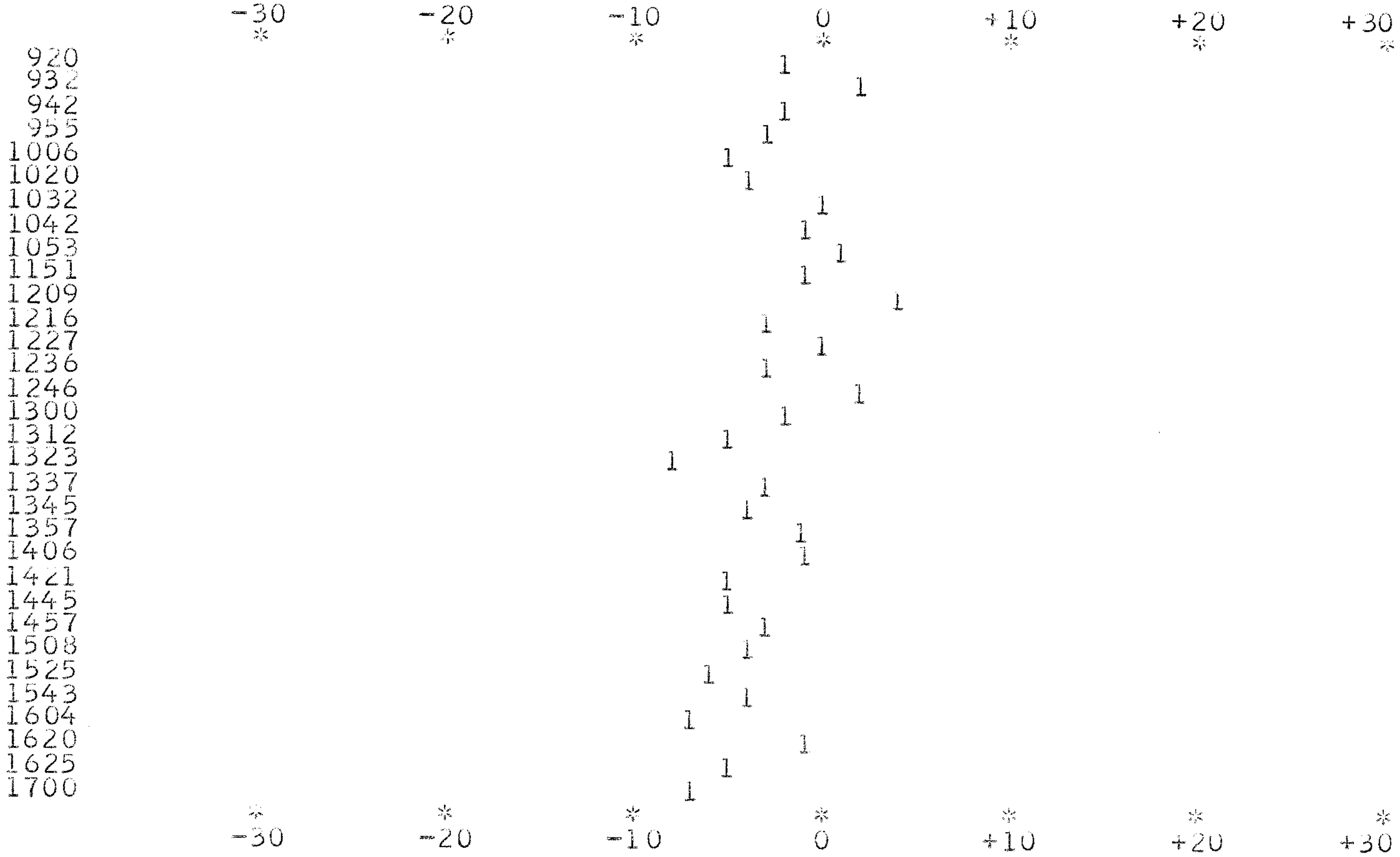
905	53	0.39
920	55	0.92
932	62	1.21
942	70	1.38
955	55	1.28
1006	59	1.19
1020	64	0.92
1032	62	0.65
1042	68	0.62
1053	55	0.26
1102	55	0.13
1109	177	0.38
1151	7	0.76
1209	10	1.15
1216	0	1.08
1227	177	0.90
1236	1	0.92
1246	0	0.99
1300	169	1.25
1312	167	0.88
1323	171	0.77
1337	178	0.91
1345	1	0.96
1357	30	1.01
1406	33	1.12
1421	36	1.29
1430	43	1.36
1445	38	1.47
1457	42	1.31
1508	41	1.33
1525	52	1.22
1543	47	1.11
1604	55	0.96
1620	89	1.08
1625	97	1.11
1700	91	1.72
1728	96	1.82
1734	83	1.97



```
TABLE 5.9  LEAP FROG METHOD ERRORS USING THE ASSUMED STANDARD ATMOSPHERE
CITY TRAVERSE AREA  6 DECEMBER 1955

         -30       -20       -10        0        +10       +20       +30
          *         *         *         *         *         *         *
 936                                     1
 946                                            1
1000                                      1
1010                                              1
1020                                         1
1029                                              1
1039                                        1
1058                                            1
1125                                              1
1145                                           1
1205                                           1
1230                                          1
1245                                             1
1305                                          1
1420                                                1
1500                                              1
1530                                                            1
1555                                                              1
1615                                                          1
1645                                          1
          *         *         *         *         *         *         *
         -30       -20       -10        0        +10       +20       +30
```

TABLE 5.10 LEAP FROG METHOD ERRORS USING THE ASSUMED STANDARD ATMOSPHERE
CITY TRAVERSE AREA 7 DECEMBER 1955



```
TABLE 5.11   2 BASE ERRORS   22 MAY 1956

            -30       -20       -10        0        +10       +20       +30
             *         *         *         *         *         *         *
 923                                 21    |   3
 929                                 21    |3
 939                                  12 3 |
 946                               21      3
 952                                   1 2 | 3
 956                                 1 2   3
1001                                 2     | 3
1006                                  21   3
1013                                   23  |
1024                               2   3 1 |
1032                         2           3 |
1050                          2            3
1056                                  2    |3
1100                                      2| 31
1105                                      2| 31
1110                                      3|
1115                                       3 2
1120                                       |31
1124                                       | 13
1129                                       |  231
1134                                       |   23 1
1139                                      23 1
1148                                2 3    |
1230                                       3 2
1251                                       3  2
1310                                 1 2   |  3
1325                                      2|     3
1340                              21       |    3
1348                                   1 2 |  3
1409                                       |21 3
1414                               2 1     | 3
1447                                      21         3
1453                                     12|    3
1459                                       213
1505                                      2|3
1511                                       |23
1516                                       2  3
1522                                 21    |3
1527                                   12  | 3
             *         *         *         *         *         *         *
            -30       -20       -10        0        +10       +20       +30
```

TABLE 5.12   2 BASE ERRORS   23 MAY 1956

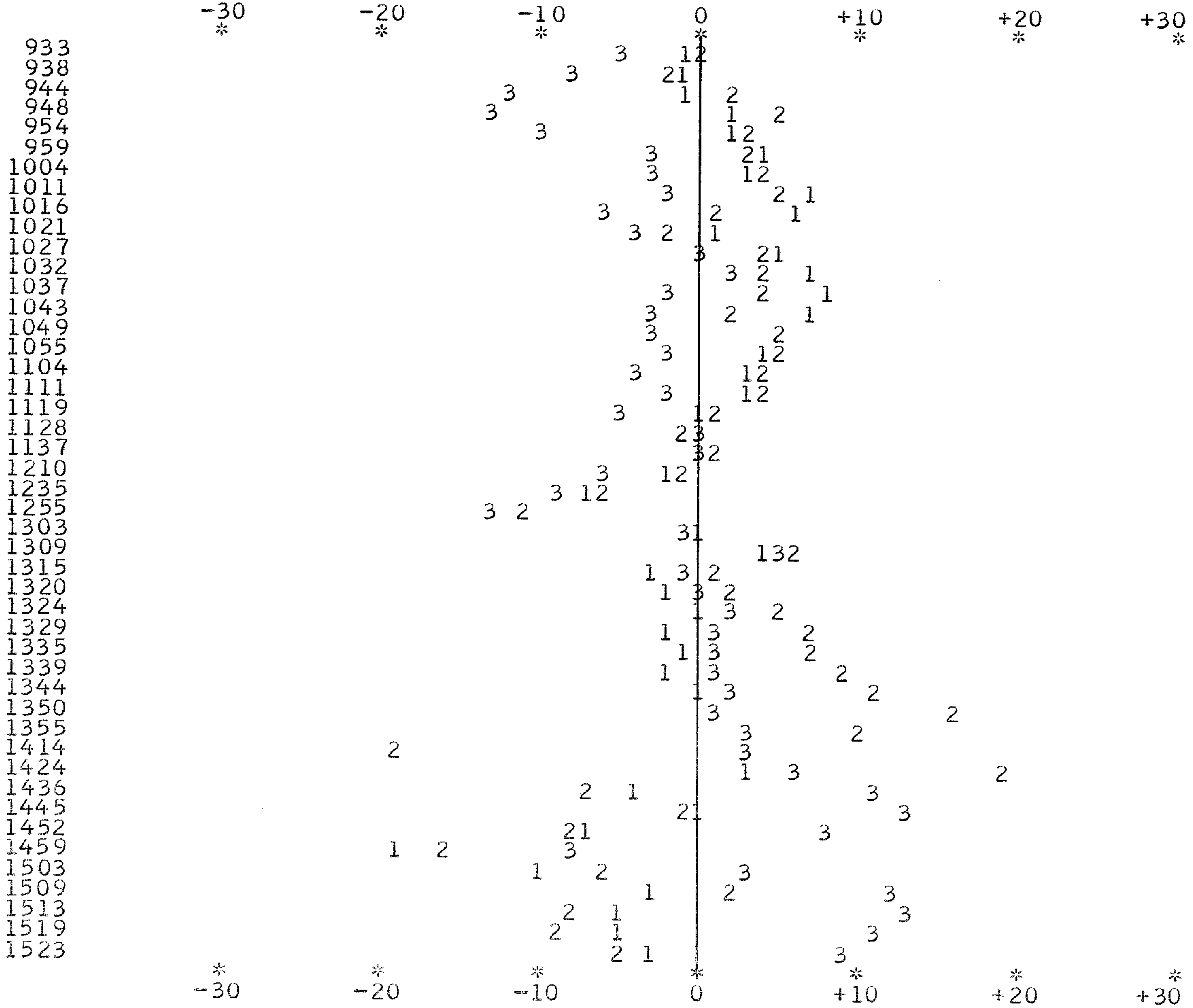


TABLE 5.10 LEAP FROG METHOD ERRORS USING THE ASSUMED STANDARD ATMOSPHERE
CITY TRAVERSE AREA 7 DECEMBER 1955

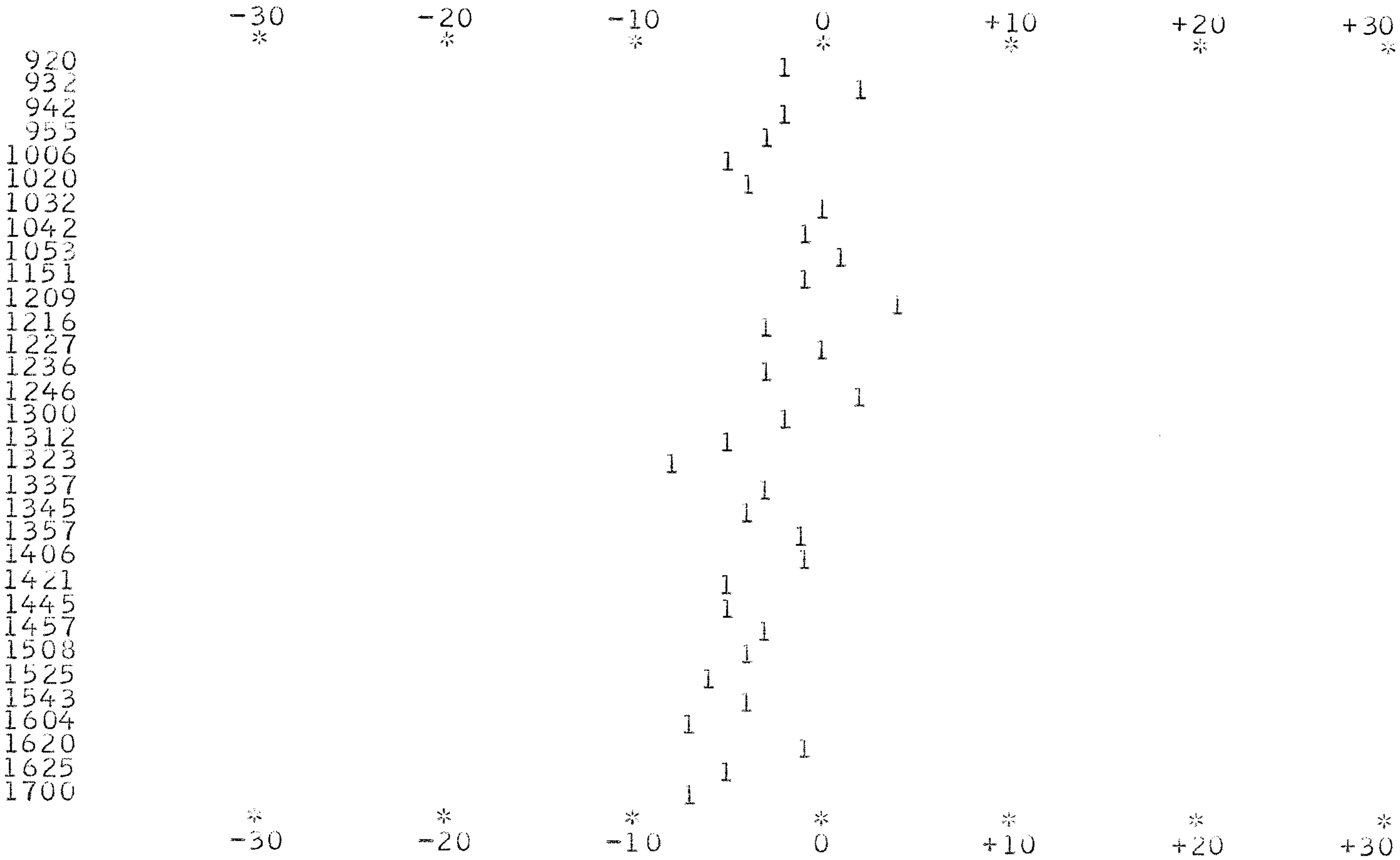


TABLE 5.11 2 BASE ERRORS 22 MAY 1956

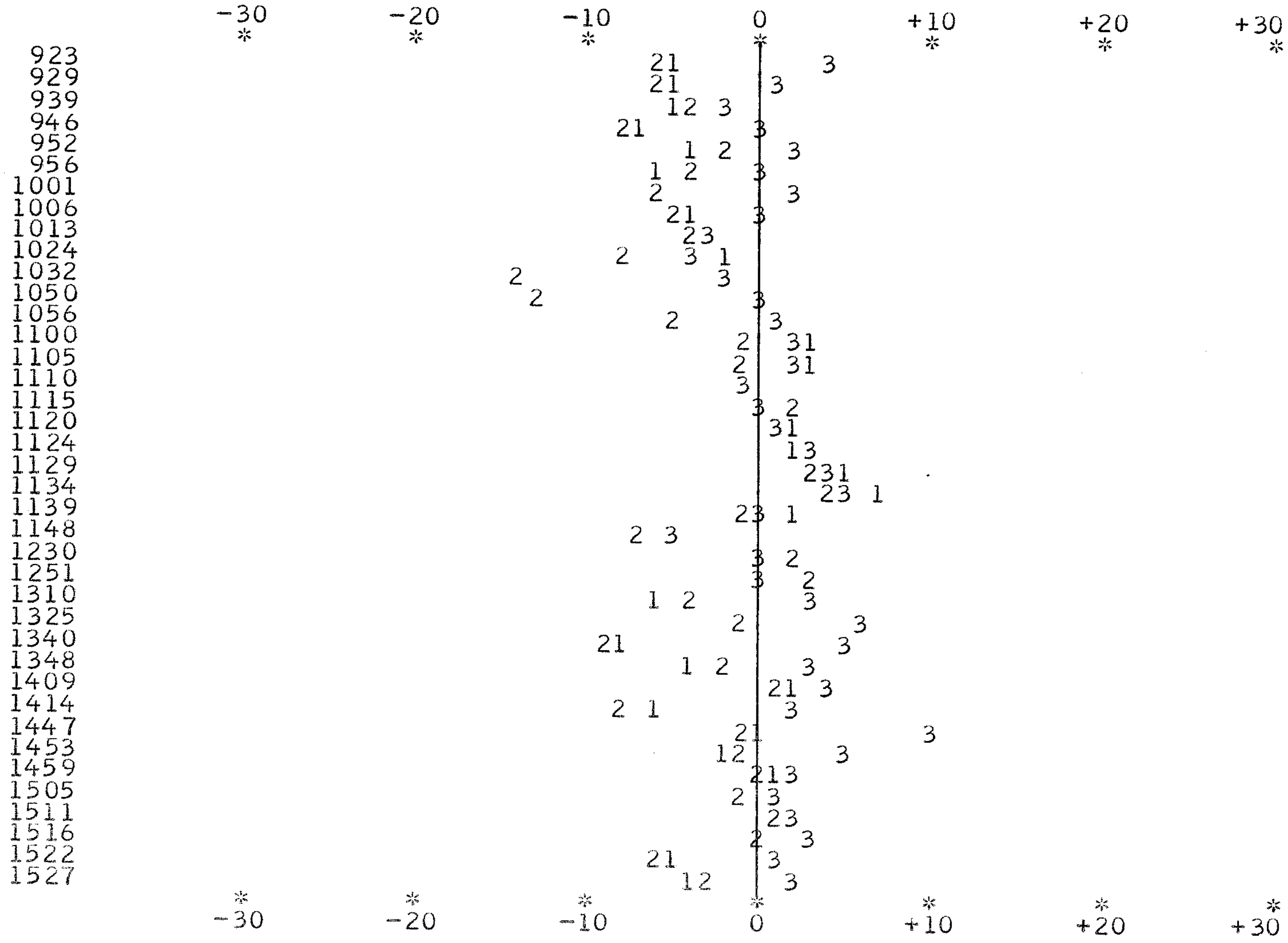


TABLE 5.12 2 BASE ERRORS 23 MAY 1956

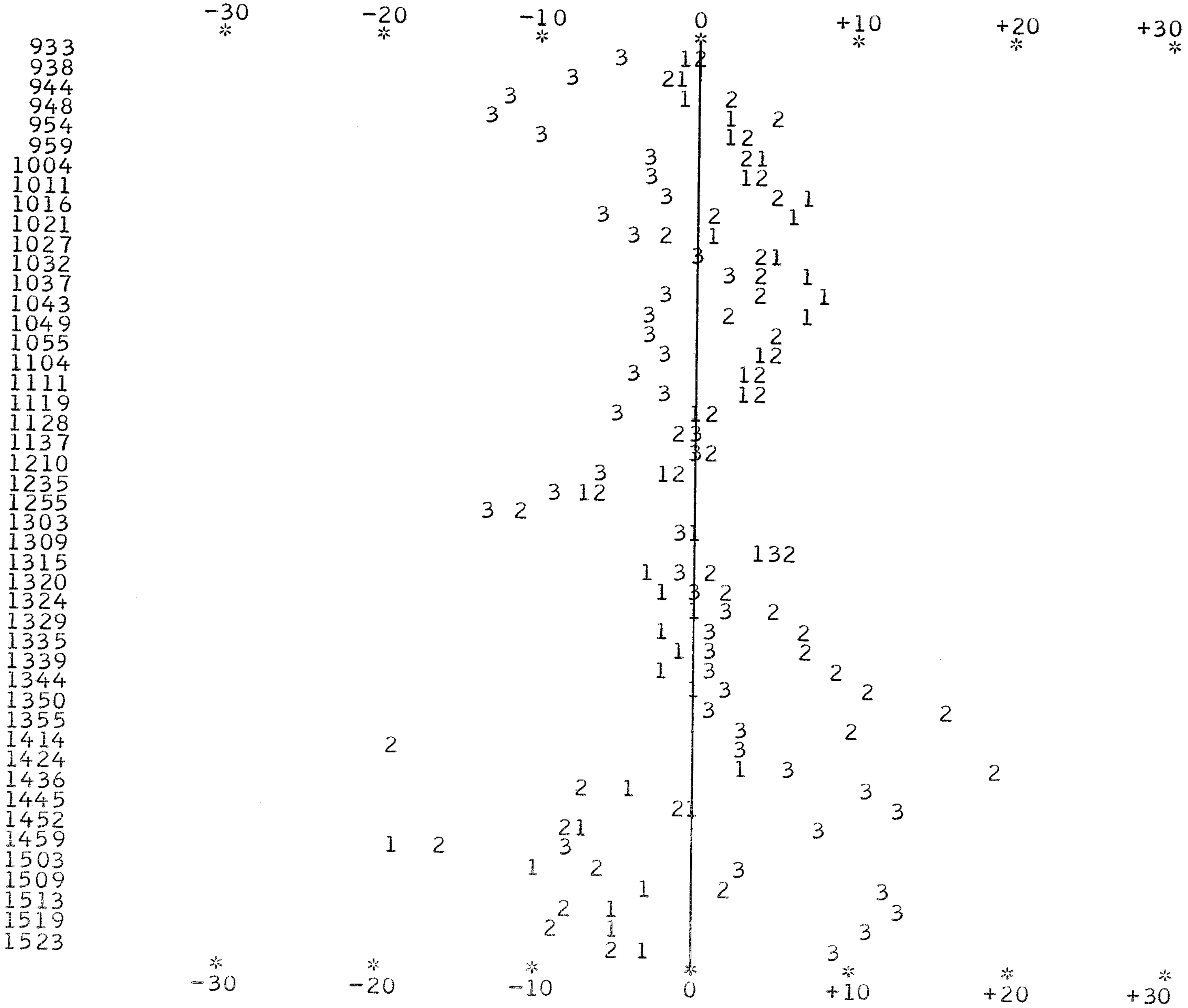


TABLE 5.13   2 BASE ERRORS   6 DECEMBER 1955

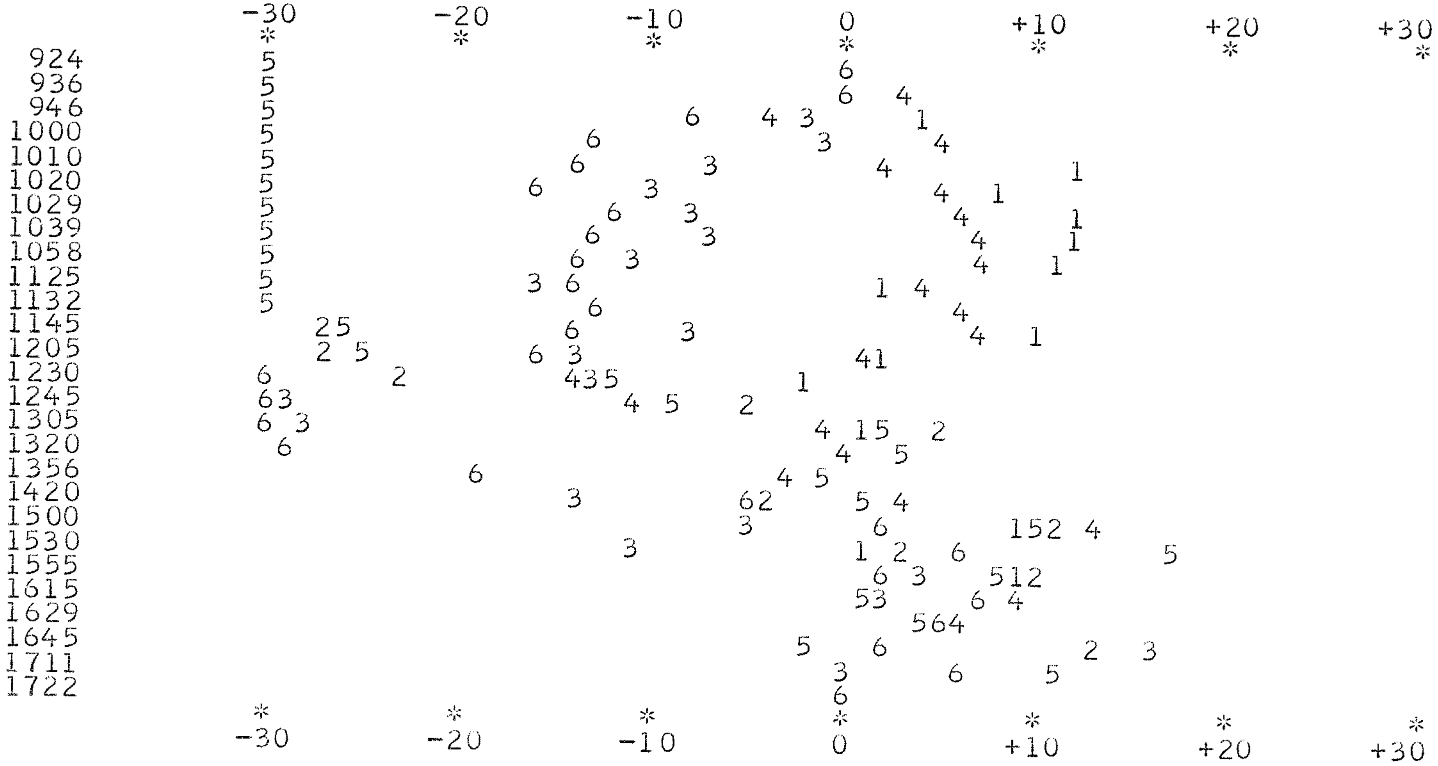
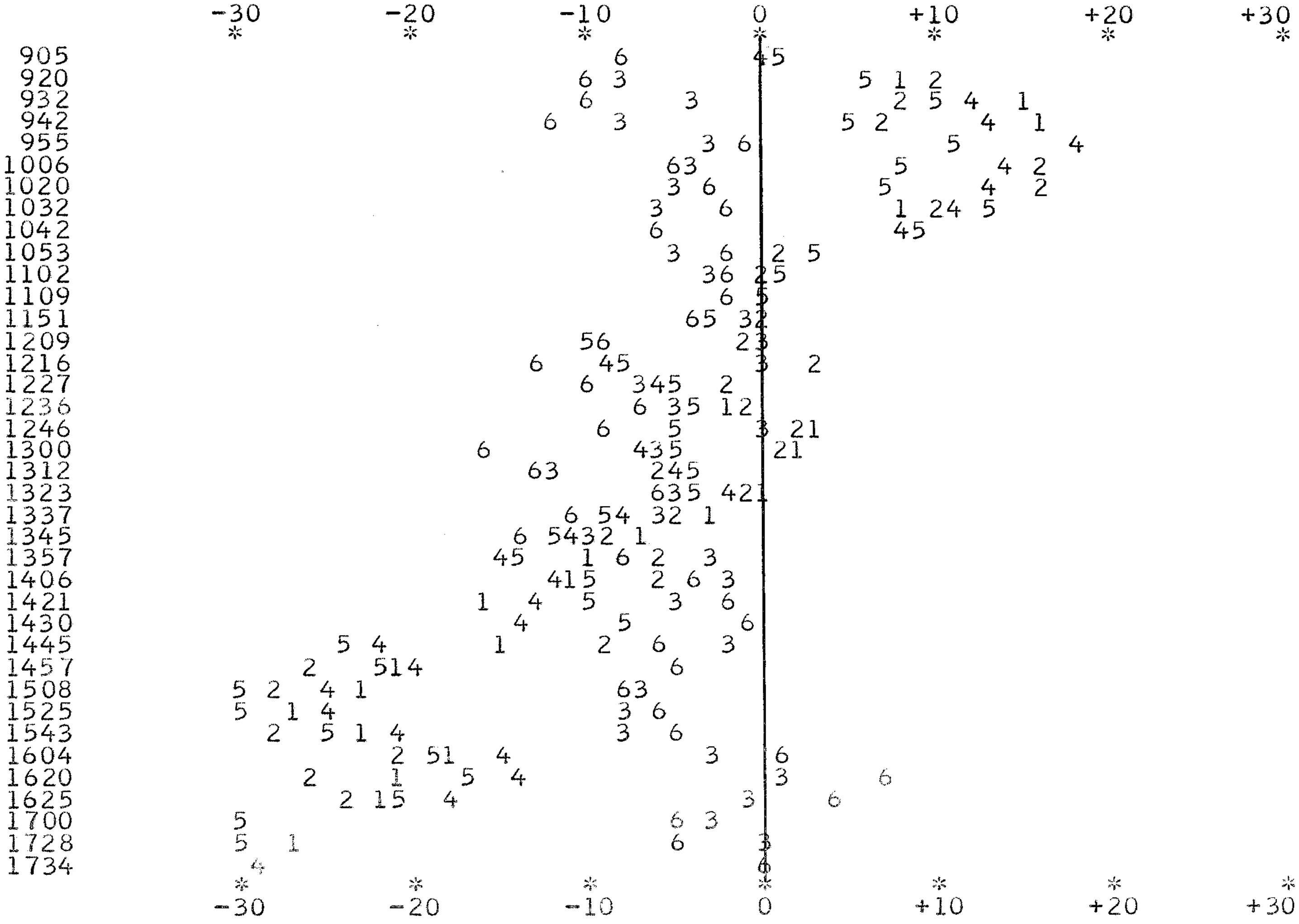


TABLE 5.14 2 BASE ERRORS 7 DECEMBER 1955



CHAPTER 6

THE METHODS OF COMPUTATION OF RESULTS

To facilitate the computation of results from the field readings a number of methods were used. These range from specially prepared tables to nomograms and electronic computer programmes. Each method has its limitations and these must be appreciated before the choice of reduction method for a particular case is made.

6.1 STANDARD ATMOSPHERE TABLES

Various people and organisations have at different times proposed relationships for the decrease of pressure with elevation. However it has been shown (see Chapter 3) that these do not give satisfactory results in the region of importance to surveyors. Instead the new atmosphere (Assumed Standard Atmosphere) has been used throughout. A computer programme was developed to give a table of standard elevations for the range of 600 mm to 800 mm of mercury by 0.1 mm steps (see Appendix 1).

6.2 SINGLE BASE REDUCTIONS

The field readings are reduced for any index drift and instrumental correction and the elevation in the Standard Atmosphere interpolated from the above tables. The difference in elevations from this Standard Atmosphere between the traverse station and the base station gives the approximate difference in elevation between the two stations. A temperature correction (calculated using a slide rule) is then applied to this difference to give the calculated difference in elevation.

$$\Delta H_{calc} = \Delta H_{approx.} \left(1 + \frac{T_F + T_B - 2\,T_{SA}}{1000}\right)$$

where

T_F is the Temperature in Fahrenheit at the Traverse Station
T_B is the Temperature in Fahrenheit at the Base Station
T_{SA} is the Temperature at the mean elevation in the Standard Atmosphere.

This formula, although not rigorous, gives a sufficiently close approximation for small differences in height (say up to 1000 ft.).

A better approximation was used as the formula for the computer programme but it was felt that for the differences in elevation usually involved, the simplicity of the above formula should be utilised for hand calculations.

The resultant difference in elevation is then applied to the known elevation of the base station giving the calculated elevation of the traverse station and is the result for the Single Base Computation. Comparison of this value with the known elevation gives the Single Base Error.

A typical example of this type of calculation is given in Tables 6.1 and 6.2. It is recommended that the field readings should be entered directly onto a proforma such as those in the tables. This eliminates the chance of a transciption error and saves a lot of time at the calculation stage. The example given shows the field barometer stationary as these readings were part of an isobaric gradient determination and hence the elevations of both stations were known. The same proformas may be used for a normal field traverse. When the traverse reaches a point of known elevation the calculation proceeds as before giving an error at that station. The error is then apportioned linearly as a correction back to the last known elevation.

6.3 MULTIPLE BASE REDUCTIONS

One of the three bases is designated as the main base and the other bases together with the field readings are reduced by the Single Base Method as outlined above. The resulting errors of the bases thus calculated allows the tilt of the isobaric plane and its direction at a given time to be determined.[16] This can be established visually, with an interpolating frame[50] or by means of the nomogram (vide next Section). The correction to the field station is then deduced and applied to give the final Reduced Levels in Table 6.3. The determination of the tilt in feet/mile is of prime importance as this gives an indication of the reliability of the final Reduced Levels (vide Chapter 7).

TABLE 6.1

BASE READINGS

Instrument	Mechanisms 307/62	Observer	B. Humphries.	
Date	12.10.64	Weather	Mild	
Time	0900	0910	0920	0930
Station	Base A	Base A	Base A	Base A
Temp. Dry	67.9	67.4	67.5	69.0
Reading	753.52	753.41	753.43	753.34
Index	+0.28	+0.28	+0.28	+0.28
Corr. Read.	753.80	753.69	753.71	753.62
Elev. St. Atmos.	222.7	226.7	225.9	229.2

TABLE 6.2

FIELD TRAVERSE READINGS

Instrument	Mechanisms 308/62		Observer	A. Spence
Date	12.10.64		Weather	Mild
Time	0900	0910	0920	0930
Station	STN 1	STN 1	STN 1	STN 1
Temp. Dry	64.5	63.0	63.0	67.0
Reading	735.31	735.33	735.22	735.24
Index	+0.66	+0.65	+0.65	+0.64
Corr. Read.	735.97	735.98	735.87	735.88
Elev. St. Atmos.	871.3	870.9	874.9	874.5
Base Elev. S.A.	222.6	226.6	225.8	229.1
Δ' Elev.	+648.7	+644.3	+649.1	+645.4
Base Temp.	67.9	67.4	67.5	69.0
Temp. St. Atmos.	57.2	57.2	57.2	57.2
Temp. Corr.	+11.7	+10.4	+10.5	+14.0
Δ Elev.	660.4	654.7	659.6	659.4
Base R.L.	76.0	76.0	76.0	76.0
Field R.L.	736.4	730.7	735.6	735.4
Corrn.	–	–	–	–
Final R.L.	–	–	–	–
Known R.L.	741	741	741	741
Error	-4.6	-10.3	-5.4	-5.6

TABLE 6.3

MULTIPLE BASE REDUCTION

Time	1445	1500	1505	1510
Field Stn.	Beverly Hills	Bev. Hills	Bev. Hills	Bev. Hills
Field Stn. Elev.	106	111	112	109
Base B. Error	-6	-1	-1	-2
Base C. Error	-9	-4	0	-2
Tilt Ft/Mile	0.8	0.3	0.0	0.2
Direction	340°	250°	N.A.	180°
Correction	+10	+3	0	+2
Final Elevation	116	114	112	111

6.4 NOMOGRAM FOR THE DETERMINATION OF TILT

Since the same field stations were used on a number of occasions, a nomogram was designed to facilitate the calculation of the Tilt of the Isobaric Surface in feet/mile and the bearing of the tilt. The nomogram is quite simple to construct and is recommended for larger areas where visual interpolation is rendered extremely difficult by the numerically larger errors involved.

The principle of the nomogram is the graphical determination of the intersection of the horizontal plane with the isobaric plane. This may be found by graphically (Figure 6.1) determining the point on the line from Base B to Base C at which there will be no correction. This point when joined to Base A gives the intersection of the two planes. The bearing of the line + 90^{o} gives the bearing of the tilt. It is then a simple matter to measure the perpendicular distance from the line of intersection to either Base B or C and knowing the error at that point, to deduce the rate of tilting. This may also be carried out on the nomogram by constructing two circles each with a diameter of Base A to the other Bases. Since the angle in a semicricle must be a right angle, the intersection of the strike or line of intersection of the two planes with either circle gives the foot of the perpendicular from the relevant base. The circles are then graduated with distances from the bases and the tilt distance directly read off.

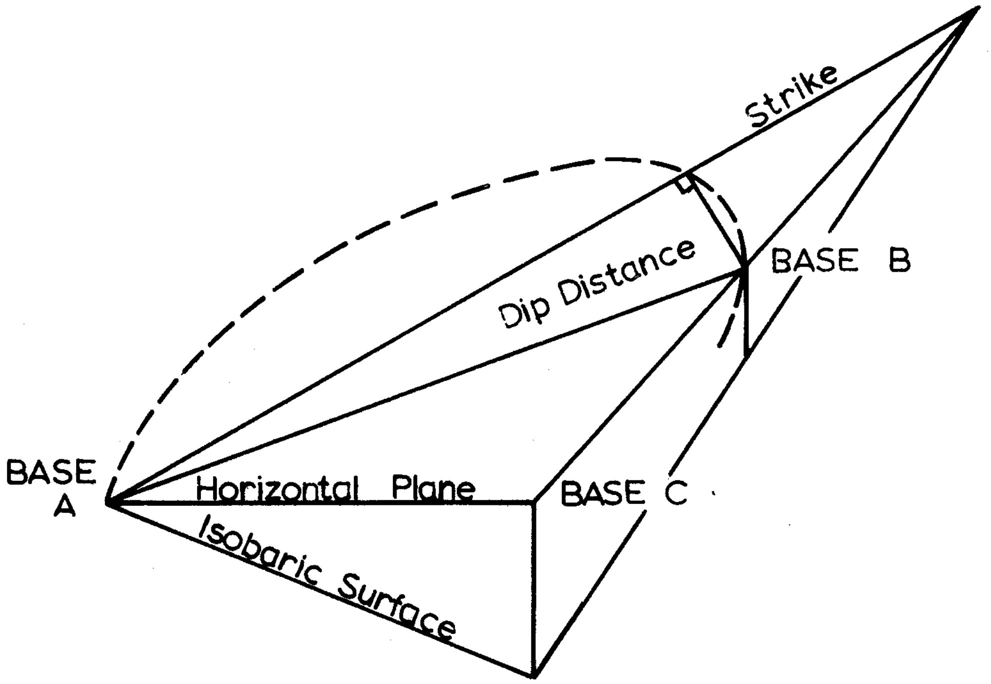


FIG. 6.1 TILT OF THE ISOBARIC SURFACE

To construct the nomogram, the base stations are plotted according to their co-ordinates and the lines joining the three stations drawn (see Figure 6.2). At right angles to the line joining Base B and Base C suitably graduated lines are drawn through each point to represent the errors. Circles are then drawn with AB and AC as diameters and the distances marked in miles from each station to points on their circumferences. Lines are then drawn from A through each of these marks to line BC where the appropriate distance graduation is noted.

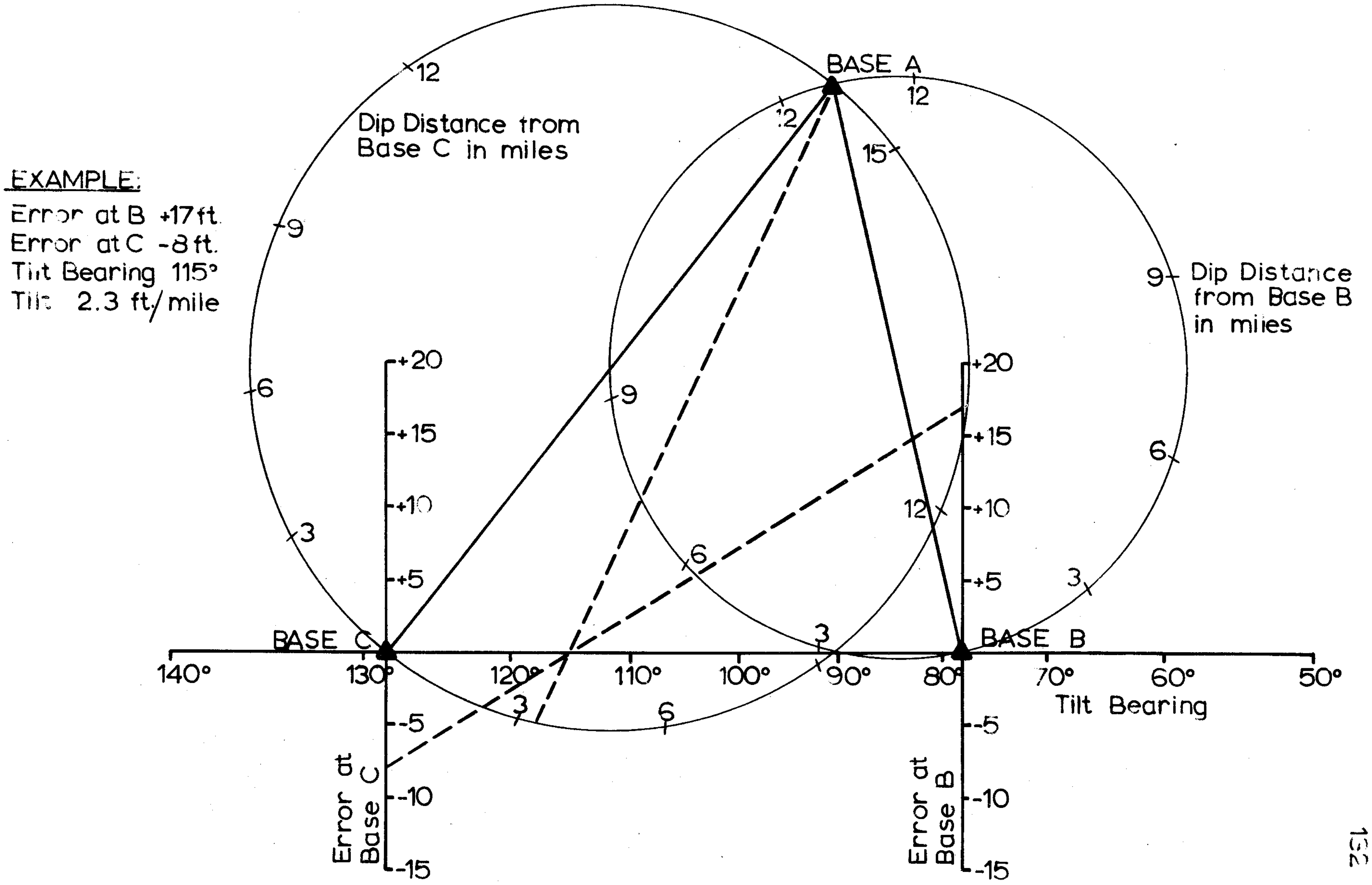
A 360^{o} Protractor is then placed over station A with its zero east. The 10^{o} Divisions are then projected onto the line BC giving the tilt bearing. An auxiliary scale is then drawn to divide the error by the tilt distance to give the tilt in feet per mile.

To use the nomogram, it is simply a matter of placing a straight edge on the error graduations at B and C and reading off the tilt bearing and distance. The straight edge is then moved to the auxiliary scale to give the tilt/mile.

When the field barometers are stationary, it is a simple matter to construct an additional scale on the main nomogram to give the correction to be applied at that particular station.

6.5 COMPUTER PROGRAMMES

The vast amount of repetitive calculation required for the reduction of the field readings necessitated the use of some computing device. The availability of electronic digital computers solved the



EXAMPLE:

Error at B +17 ft.
Error at C -8 ft.
Tilt Bearing 115°
Tilt 2.3 ft/mile

FIG. 6.2 NOMOGRAM FOR THE DETERMINATION OF THE TILT OF THE ISOBARIC SURFACE.

problem and so extensive use has been made of these machines. Programmes were written for the following calculations.

a)	A Standard Atmosphere.	SVY 12
b)	Isobaric Surface Investigation.	SVY 14
c)	Barometer Traverse Reduction.	SVY 19 SVY 42 SVY 43
d)	Tower Readings Reduction.	SVY 24
e)	Automatic Graphing.	SVY 16
f)	Analysis of Summaries.	SVY 26, SVY 44

In each of these programmes, corrections were applied for temperature and humidity as indicated in Sections 6.5.1 and 6.5.2.

Each programme was written in FORTRAN for one or more of the following computers.

1. The Institute of Highway and Traffic Computer. This is an I B M 1620 Computer with 20 K digits memory, card input and disc storage.
2. The D.U.C.H.E.S.S. Computer. This is an I B M 1620 computer with 40 K digits memory, card input, a fast line printer and disc storage.
3. Technicomps Computer. An I B M 1130 computer with paper tape input and disc storage.
4. The Computations Laboratory, U.N.S.W. An I B M 360-50 computer with all the appropriate ancillaries.

The coded programmes are listed in Appendix VI.

6.5.1 TEMPERATURE CORRECTION[5]

When using the Lapse-Rate Formulae, the temperature correction takes the form of a series expansion. Until recently only the first term of the expansion was applied.[24,51] Colonel D. R. Crone has shown that the second term cannot be neglected for precise work as its effect is significant. The formula for temperature correction, as given by Crone,[24] is:

$$H - H_s = \frac{H_s (T_u - T_{su})}{518.4} \left\{ 1 + 3.44 \times 10^{-6} . H + 1.6 \times 10^{-11} . H^2 + \ldots \right\}$$

where

H is the Standard Elevation corrected for Temperature

H_s is the uncorrected Standard Elevation

T_u is the virtual temperature at the station (see Humidity Correction 6.5.2).

T_{su} is the standard temperature at elevation H_s.

This formula has been incorporated into the computer programmes by applying a temperature correction to each standard elevation as deduced from the Lapse Rate Formula.

6.5.2 HUMIDITY CORRECTION[3,5,32]

It was shown in Chapter 1 that the constants for the pressure/ height relationship were evaluated for dry air. The density of moist air is less than dry air and so the constants must be re-evaluated or a suitable correction applied. The simplest approach is to apply a correction by replacing the measured temperatures with virtual temperatures.[3,56] These virtual temperatures are deduced by relating the difference in density to the apparent reduction in the height of the air column. This may then be corrected by increasing the temperature correction using an increase in the measured temperature.

The derivation of the virtual temperature follows.

For a mixture of dry air and water vapour the Equation of State is:

$$PV = RT$$

where the gas constant R for the mixture is given by:

$$R = \frac{M_a R_a + M_{wv} R_{wv}}{M_a + M_{wv}}$$

$$= \frac{R_a + R_{wv} . \omega}{1 + \omega}$$

in which M_a and M_{wv} are the masses of dry air and water vapour respectively, R_a and R_{wv} are the gas constants and

ω is the mixing ratio $\frac{M_{wv}}{M_a}$.

The Equation of State may also be written as:

$$PV = R_a T_v$$

where T_v is the virtual temperature.

Thus

$$R_a T_v = T \frac{(R_a + \omega . R_{wv})}{1 + \omega}$$

or

$$T_v = T \frac{(1 + \omega \frac{R_{wv}}{R_a})}{1 + \omega}$$

but

$$\frac{R_{wv}}{R_a} = \frac{M_{wv}}{M_a} = \frac{28.97}{18.02} \doteqdot 1.61$$

whence

$$T_v = T \frac{(1 + 1.61 . \omega)}{1 + \omega}$$

$\doteqdot T\ (t + 0.61\quad)$ since $\omega < 0.03$

but

$$\omega = \frac{P}{P_m}$$

where P is the mean pressure of aqueous vapour at temperature T_m and P_m is the mean pressure of the air between the two stations.

whence

$$T_v = T\,(1 + 0.61.\ \frac{P}{P_m}\ ).$$

If the increase in temperature is denoted as ΔT such that

$$\Delta T = T_v - T$$

then $$\Delta T = 0.61\ \frac{TP}{P_m}$$

in which $$P = P_w - 0.000367\ P_m\,(T_d - T_w)$$

where T_d is the dry temperature

T_w is the wet bulb temperature

and P_w is the saturation vapour pressure.

J. A. Goff and S. Gratch have shown[32] that the saturation vapour pressure in millibars may be calculated using the formula.

$$\log P_w = -\,7.90298\,(\frac{T_s}{T} - 1) + 5.02808\ \log \frac{T_s}{T}$$

$$-\ 1.3816 \times 10^{-7}\,(10^{\,11.344\,(1 - T/T_s)} - 1)$$

$$+\ 8.1328 \times 10^{-3}\,(10^{-3.49149(T_s/T - 1)} - 1)$$

$$+\ \log 1013.246.$$

6.5.3 TILT OF THE ISOBARIC SURFACE

To simplify the calculation of the tilt and Bearing of the Apparent Isobaric Surface, the geometric properties used in Section 6.4 are expressed in terms of co-ordinates.

The origin is translated to Station 1 and hence the following equations give the necessary relationships (see Figure 6.3):

$$\frac{X_8 - X_3}{X_3 - X_2} = \frac{Y_8 - Y_3}{Y_3 - Y_2} = \frac{\text{Error } 3}{\text{Error } 2 - \text{Error } 3} \quad \text{(by similar triangles)}$$

denoting

$$E32 = \text{Error } 2 - \text{Error } 3$$

then

$$X_8 = \frac{X_3 \text{ Error } 2 - X_2 \text{ Error } 3}{E32} \quad \ldots\ldots\ldots\ldots (1)$$

and

$$Y_8 = \frac{Y_3 \text{ Error } 2 - Y_2 \text{ Error } 3}{E32}$$

The co-ordinates of Point 6 are given by the interaction of the lines 2, 3 and 1, 4.

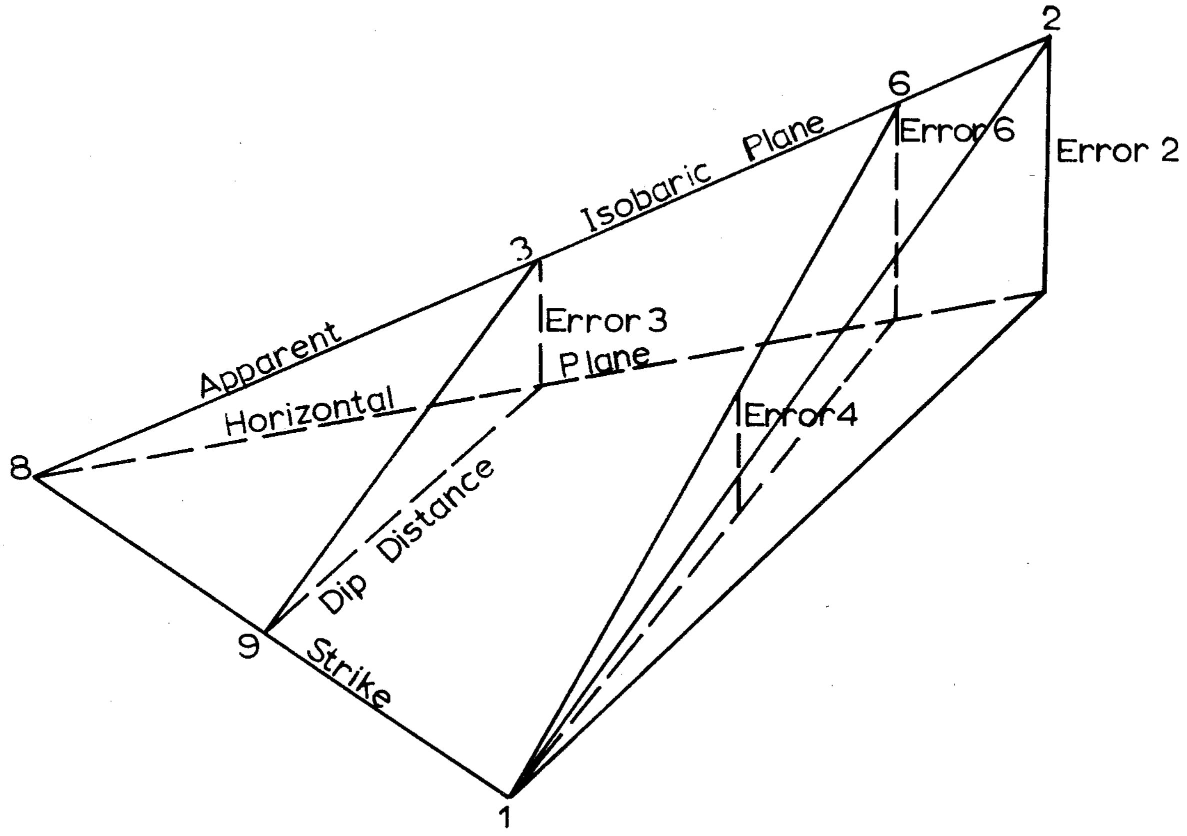


FIG. 6.3 GEOMETRIC RELATIONSHIP OF APPARENT ISOBARIC PLANE TO HORIZONTAL PLANE.

i.e. $$\frac{Y - Y_2}{Y_3 - Y_2} = \frac{X - X_2}{X_3 - X_2} \quad \text{and} \quad \frac{Y}{Y_4} = \frac{X}{X_4}.$$

whence

$$X_6 = \frac{BX_2 - Y_2}{B - A} \qquad \text{.......... (2)}$$

and $$Y_6 = AX_6$$

in which

$$A = \frac{Y_4}{X_4}$$

$$B = \frac{Y_3 - Y_2}{X_3 - X_2}$$

The Error at Point 6 is found by similar triangles

$$\frac{\text{Error 6 - Error 2}}{\text{Error 3 - Error 2}} = \sqrt{\frac{(X_2 - X_6)^2 + (Y_2 - Y_6)^2}{(X_2 - X_3)^2 + (Y_2 - Y_3)^2}}$$

denoting the RHS as E, then

Error 6 = Error 2 - E32.E.

In a similar manner the value of Error 4 may be found:

$$\frac{\text{Error } 4}{\text{Error } 6} = \sqrt{\frac{X_4^2 + Y_4^2}{X_6^2 + Y_6^2}}$$

denoting the RHS as D

then Error 4 = D. Error 6

which leads directly to the correction to be applied to a calculated elevation at 4 for the apparent tilt of the isobaric surface 1, 2, 3.

$$\text{Corr } 4 = D\ (\text{E.E32} - \text{Error } 2) \qquad \dots\dots\dots\dots (3)$$

The bearing of the Dip of the Isobaric Surface is given by:

$$\text{Bearing} = 90^{\circ} + \tan^{-1} \frac{Y_8}{X_8} \qquad \dots\dots\dots\dots (4).$$

The co-ordinates of Point 9 are given by the intersection of the line 1, 8 and the line through 3 with the above bearing.

i.e. $$Y = \frac{Y_8}{X_8} . X \text{ and } Y - Y_3 = -\frac{X_8}{Y_8} (X - X_3)$$

whence

$$X_9 = \frac{(X_8 X_3 + Y_3 Y_8)}{Y_8^2 + X_8^2} \quad X_8$$

and

$$Y_9 = \frac{(X_8 X_3 + Y_3 Y_8)}{Y_8^2 + X_8^2} \quad Y_8.$$

From the co-ordinates of 9 and 3, the dip distance to point 3 may be found.

$$\text{Dip Distance} = \frac{X_3 \quad \frac{Y_8}{X_8} - Y_3}{\sqrt{1 + \left(\frac{Y_8}{X_8}\right)^2}}$$

$$= \frac{\omega X_3 - Y_3}{1 + \omega^2} \qquad \text{.......... (5)}$$

where

$$\omega = \frac{Y_8}{X_8} \quad = \text{tangent of strike bearing.}$$

The tilt per mile is then given by:

$$\text{Tilt} = \frac{\text{Error 3}}{\text{Distance}} \qquad \text{.......... (6)}$$

The numbered formulae above are used in the Computer Programmes SVY 14 and SVY 19.

6.5.4 STANDARD ATMOSPHERE PROGRAMME SVY 12

This programme calculates the elevation in a Standard atmosphere for pressures from 600 to 800 mm Hg by selected increments.

The basic formula is:

$$H = C_1 \left(\frac{P}{760}\right)^{C_2}$$

in which the constants C_1 and C_2 are read into the computer.

The flow chart for the programme is given in Figure 6.4.

The output is a tabulated pressure/height relationship.

6.5.5 ISOBARIC SURFACE INVESTIGATION PROGRAMME SVY 14

This programme was written to reduce the simultaneous pressure readings taken throughout the day at five fixed points.

The basic formula is:

$$H_s = C_1 \left(\frac{P}{760}\right)^{C_2}$$

corrected for temperature and humidity.

The results are reduced as a Single Base calculation using Station 1 as the base. The tilt of the apparent Isobaric Surface is then determined using stations 2 and 3. The Multiple Base corrections are deduced for Stations 4 and 5.

The input for the programme is divided into two sections.

1. Basic information,
   (a) The constants C_1 and C_2,

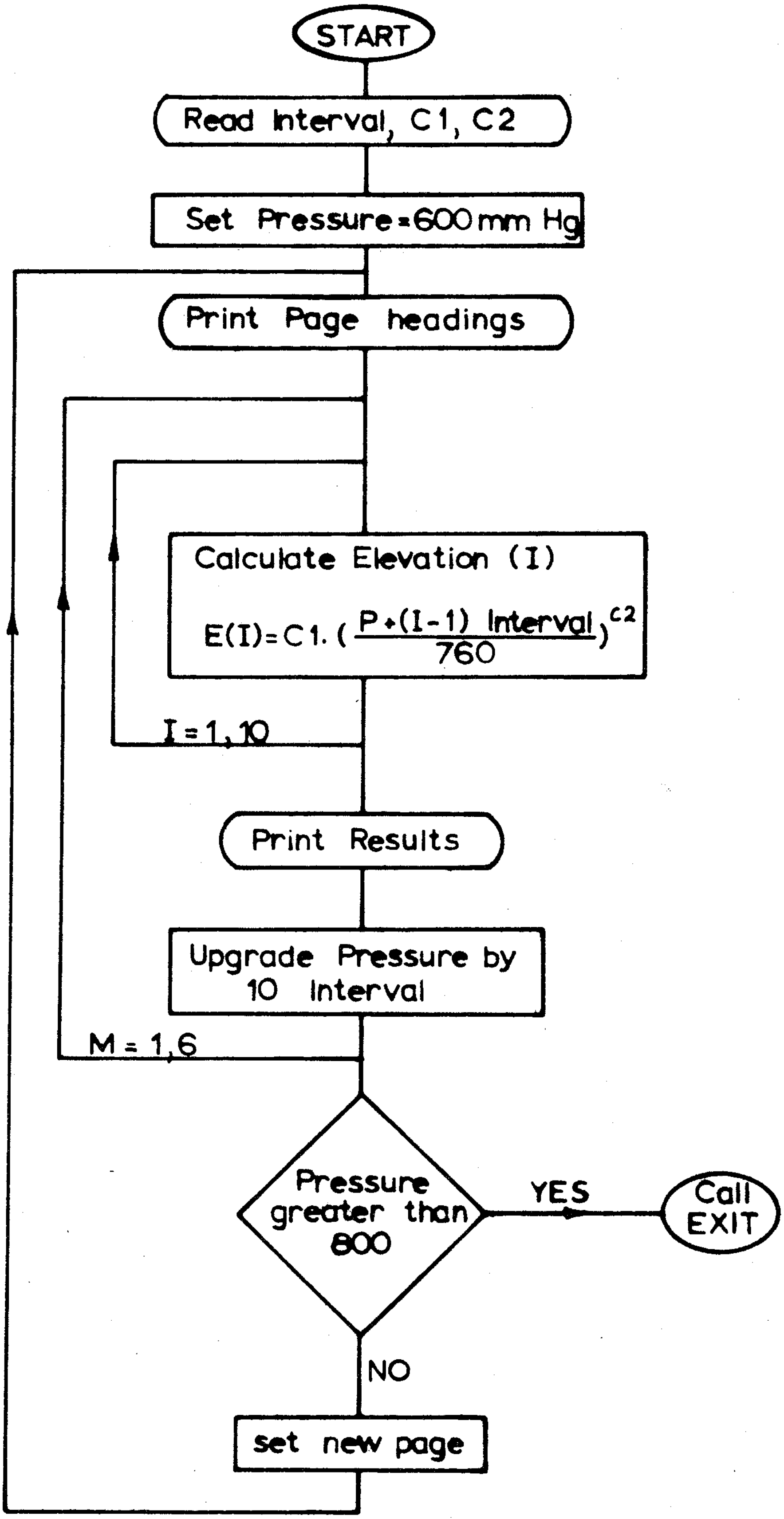


FIG. 6.4 FLOW CHART FOR SVY 12 STANDARD ATMOSPHERE PROGRAMME.

   - (b) The units for pressures, temperatures, co-ordinates,
   - (c) The co-ordinates and known elevations of the fixed stations.

2. Readings,
   - (a) Identifying time,
   - (b) Pressure, dry temperature, wet-bulb temperature at each of the five stations.

The output tabulates the identifying time, pressures and temperatures, together with the resultant Single Base and Multiple Base Errors. The direction and tilt/mile of the apparent Isobaric Surface is also given. A card is punched giving a summary of the results.

The flow chart for the programme is given in Figure 6.5.

6.5.6 BAROMETER TRAVERSE REDUCTION PROGRAMME SVY 19

This programme is similar to SVY 14 but the barometers No. 4 and 5 are moved to new field stations between each observation.

The input for the programme is divided into two sections:

1. Basic information,
   - a) The constants C_1 and C_2,
   - b) The units for pressures, temperatures and co-ordinates,
   - c) The co-ordinates and elevations of Stations 1, 2 and 3.

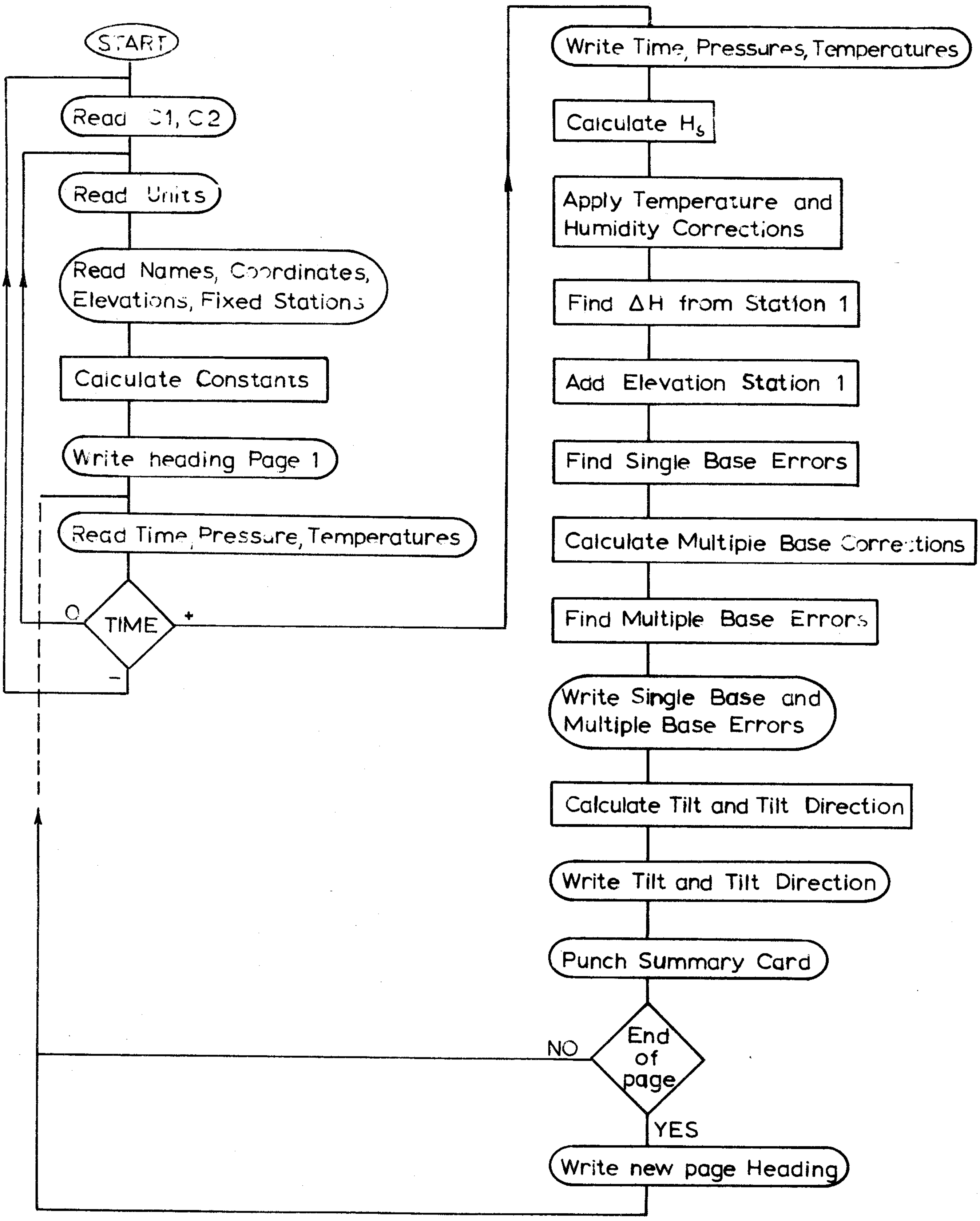


FIG. 6.5 FLOW CHART FOR SVY 14 – ISOBARIC SURFACE INVESTIGATION PROGRAMME.

2. Readings,
   - a) Identifying time,
   - b) The co-ordinates and elevations of Stations 4 and 5,
   - c) Pressure, dry and wet bulb temperature at each of the five stations.

The output tabulates the identifying time, Stations 4 and 5, the pressures and temperatures together with the resultant Single and Multiple Base Errors. The direction and Tilt/Mile of the apparent isobaric surface is also given. A card is punched giving a summary of the results.

The flow chart for the programme is given in Figure 6.6

This programme reduces the field readings for a barometer traverse in which the elevations of all stations are known. This, of course, was required in this project where the precision of various methods was under investigation. A simple modification however will make this programme suitable for the reduction of normal field traverses in which the elevations of Stations 4 and 5 are unknown.

6.5.7 TOWER READING REDUCTION PROGRAMME SVY 24

This programme takes the pressures measured at the different levels in the tower and calculates the error for each level in the assumed pressure/height relationship. This assumed relationship takes the form of the Lapse Rate formula

$$H = C_1 \left(\frac{P}{760}\right)^{C2}$$

where the parameters C_1 and C_2 are part of the input.

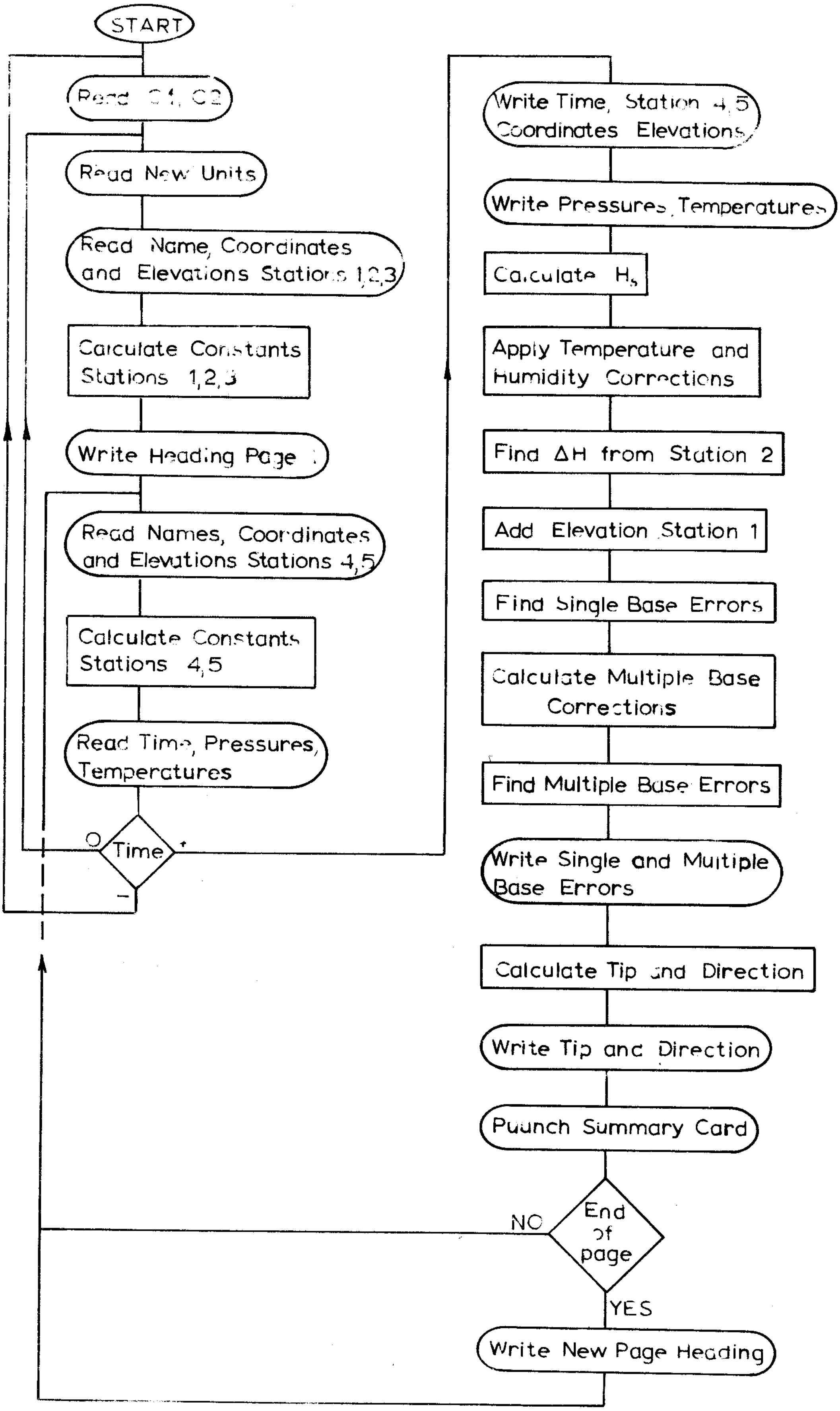


FIG. 5.6 FLOW CHART FOR SVY 19 BAROMETER TRAVERSE REDUCTION PROGRAMME.

The third parameter indicates the tower position to which a new value of C_1 is to be calculated. The heights are then recalculated and then resulting errors are printed out.

By running the programme with different values of C_2 the optimium set of values for C_1 and C_2 may be selected.

The flow chart for the programme is given in Figure 6.7.

6.5.8 AUTOMATIC GRAPHING PROGRAMME SVY 16

This programme prepares a series of graphs from the summary of the output from SVY 14 and SVY 19. Six symbols are read in and are placed in the appropriate position for each of the six different errors to be plotted. It should be noted that the lower order errors are overwritten by a higher order error of the same magnitude. The range of error that may be plotted is from - 30 ft. to + 30 ft. by 1 foot steps, with errors outside this range being set to the appropriate limit. The sequence of input is as follows:

a) A card containing the six symbols (e.g. 1, 2, 3, 4, 5 and 6).
b) A description of the particular summary set.
c) A series of summary cards.
d) A blank card.

when the blank card is reached the programme re-writes the heading and loops back to read a new description and a series of summary cards.

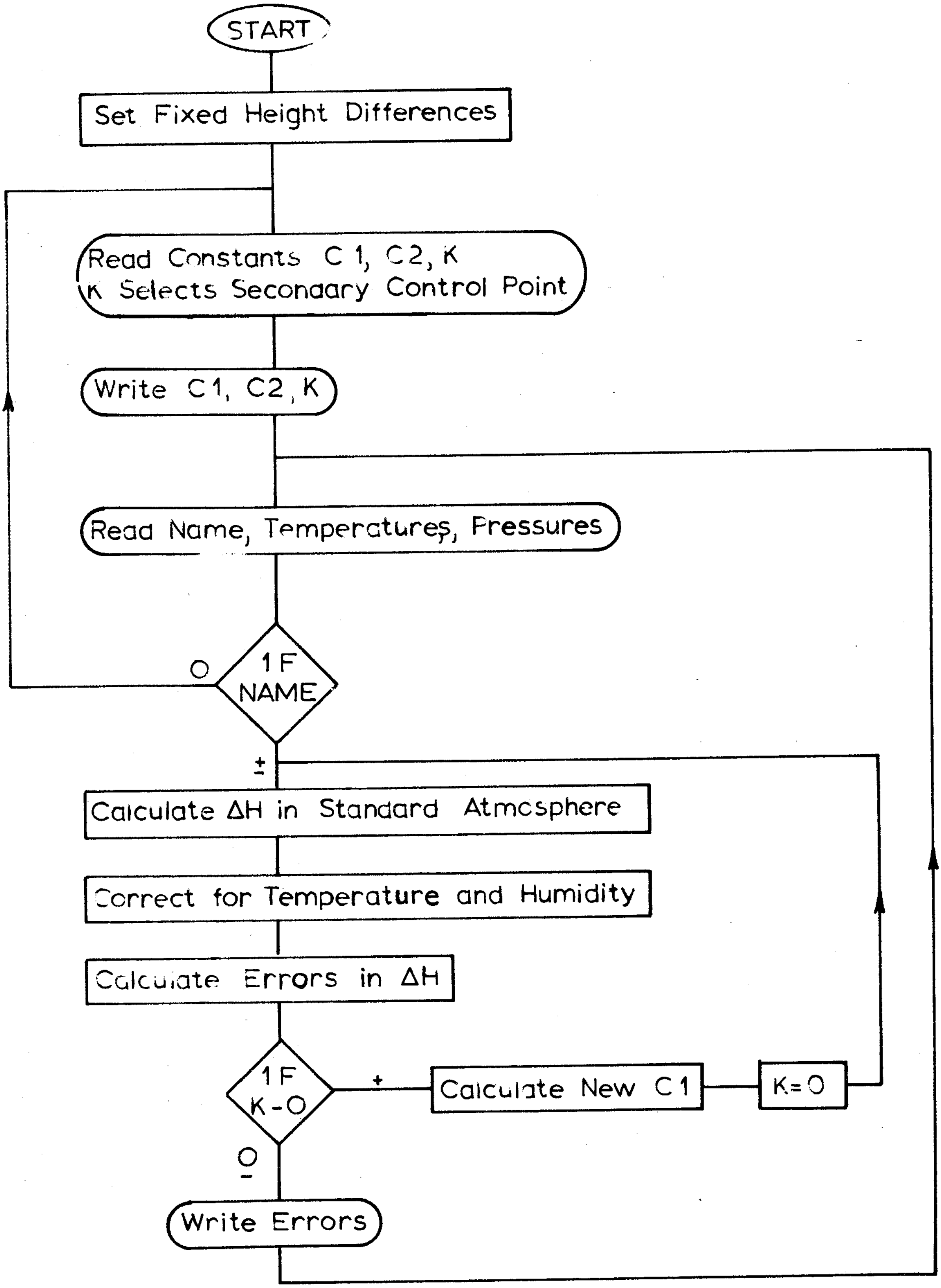


FIG.6.7 FLOW CHART FOR SVY 24 TOWER REDUCTION PROGRAMME

The output is six graphs superimposed on the one plot.

The flow chart for the programme is given in Figure 6.8.

6.5.9 ANALYSIS OF SUMMARIES PROGRAMME SVY 26

This programme takes the Summary cards from SVY 14 and SVY 19 and separates the errors into class intervals of tilt of the Isobaric Surface. The first, second and third moment is then calculated for each class interval.[6]

The input is as follows:

a) A description of the particular summary set.

b) A series of summary cards.

When the programme reaches a blank summary card the moments are printed and the programme returns to read a new description card.

The output is the print out of the tilt intervals with the mean, second moment, third moment and the number of readings for the errors at each station in turn.

The flow chart for the programme is given in Figure 6.9.

6.5.10 TWO BASE BAROMETER REDUCTION PROGRAMME SVY 42

Data punched for the Barometer Traverse programme SVY 19 is recalculated as a Two Base calculation (see Section 4.4) using each pair of the three base stations as the fixed bases. The output is a tabulation of the time of observation together with the three calculated errors in elevation. Where two field barometers were employed, each is

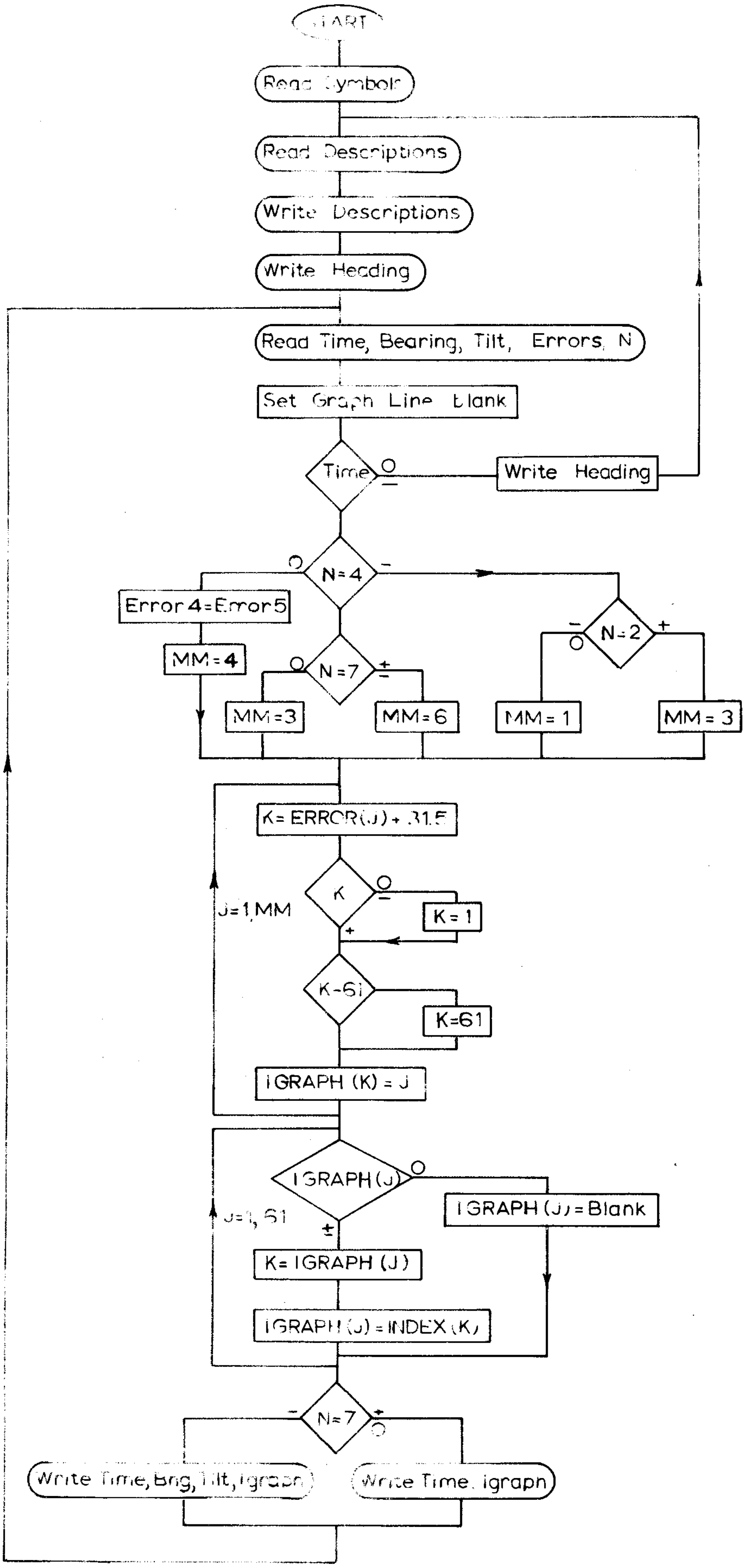


FIG 6.8 FLOW CHART FOR SVY 16 AUTOMATIC GRAPHING PROGRAMME

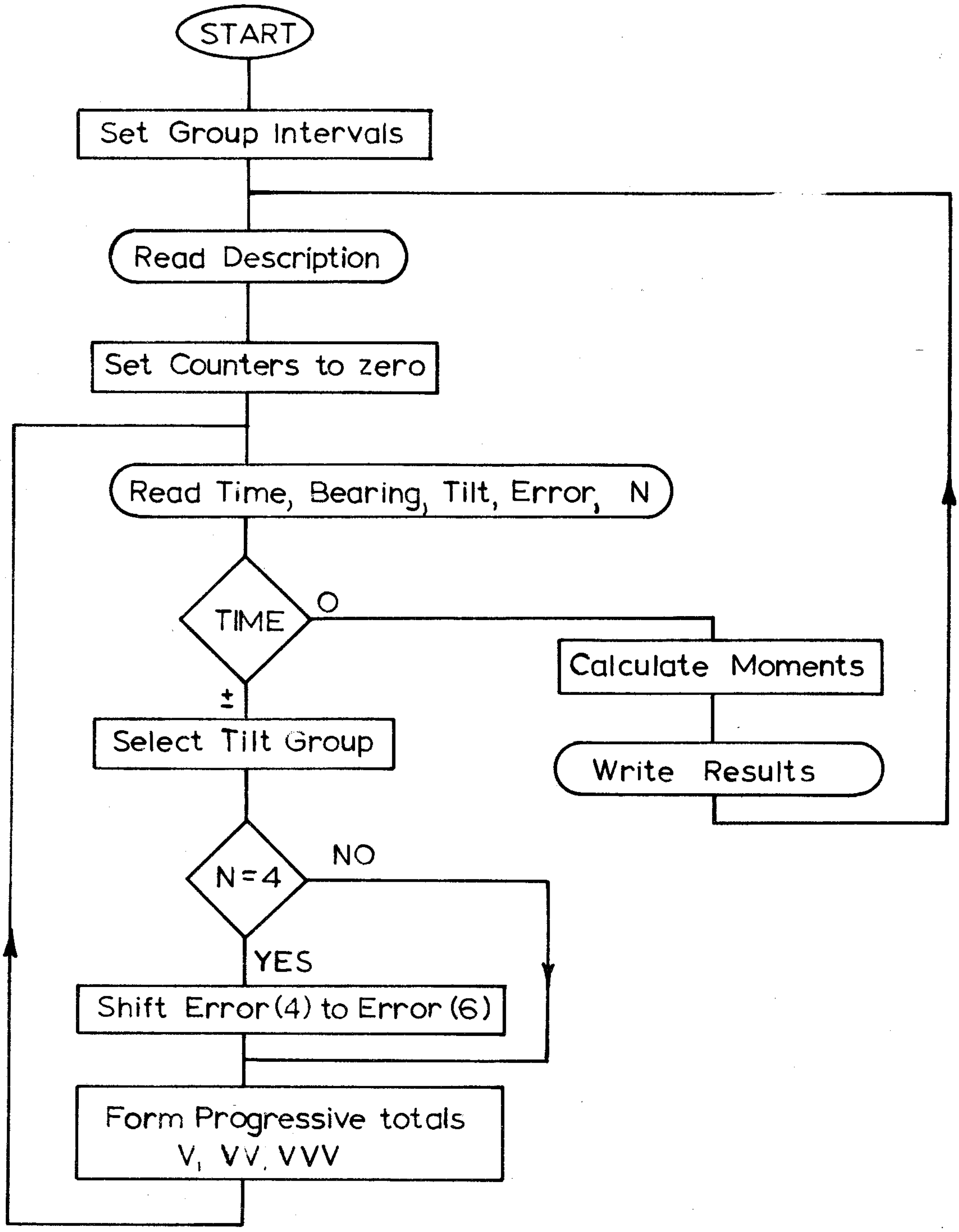


FIG. 6.9 FLOW CHART FOR SVY 26 ANALYSIS OF SUMMARIES PROGRAMME.

calculated in turn.

The flow chart for the programme is given in Figure 6.10.

6.5.11 LEAP-FROG REDUCTION PROGRAMME SVY 43

Data punched for the Barometer Traverse programme which had been observed using the Leap-frog method, is recalculated using the latter method. The programme automatically closes the results onto the three fixed bases and proportions the misclose linearly back to the previous fixed point.

The output is a tabulation of the identifying time, the name of the station and the error in elevation.

The flow chart for the programme is given in Figure 6.11.

This, and the previous programme, were written to confirm previous hand calculations. These calculations had indicated that the methods were inferior to the multiple base approach. Accordingly, when writing these programmes, use has been made of existing programmes and a number of refinements which could have been made, have been omitted.

6.5.12 ANALYSIS OF SUMMARIES PROGRAMME 2, SVY 46

This programme takes the summary cards punched using the previous programmes and separates the errors into class intervals of the tilt of the Isobaric Surface. The errors are made absolute and

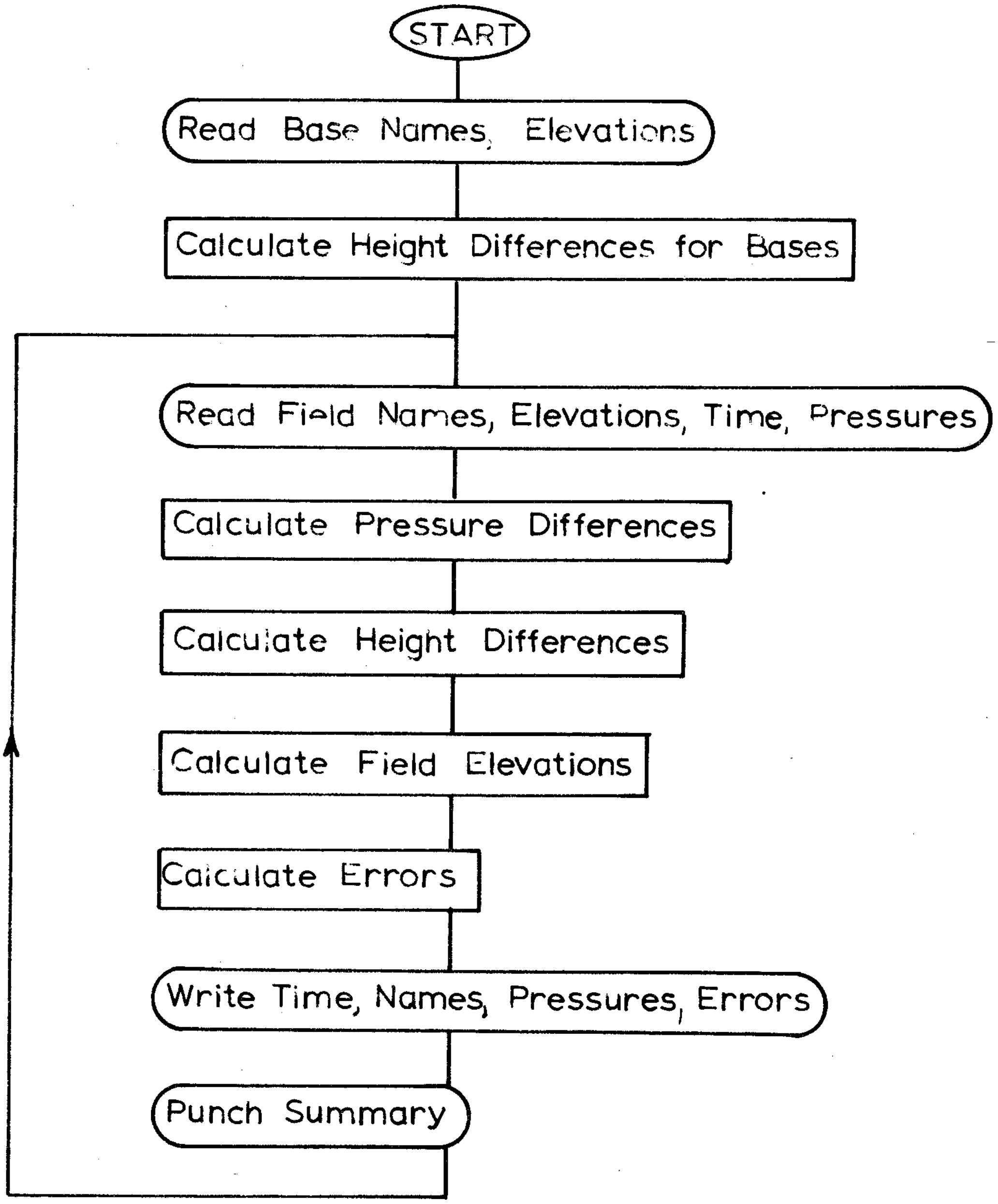


FIG. 6.10 FLOW CHART FOR SVY 42
TWO BASE BAROMETER REDUCTION
PROGRAMME.

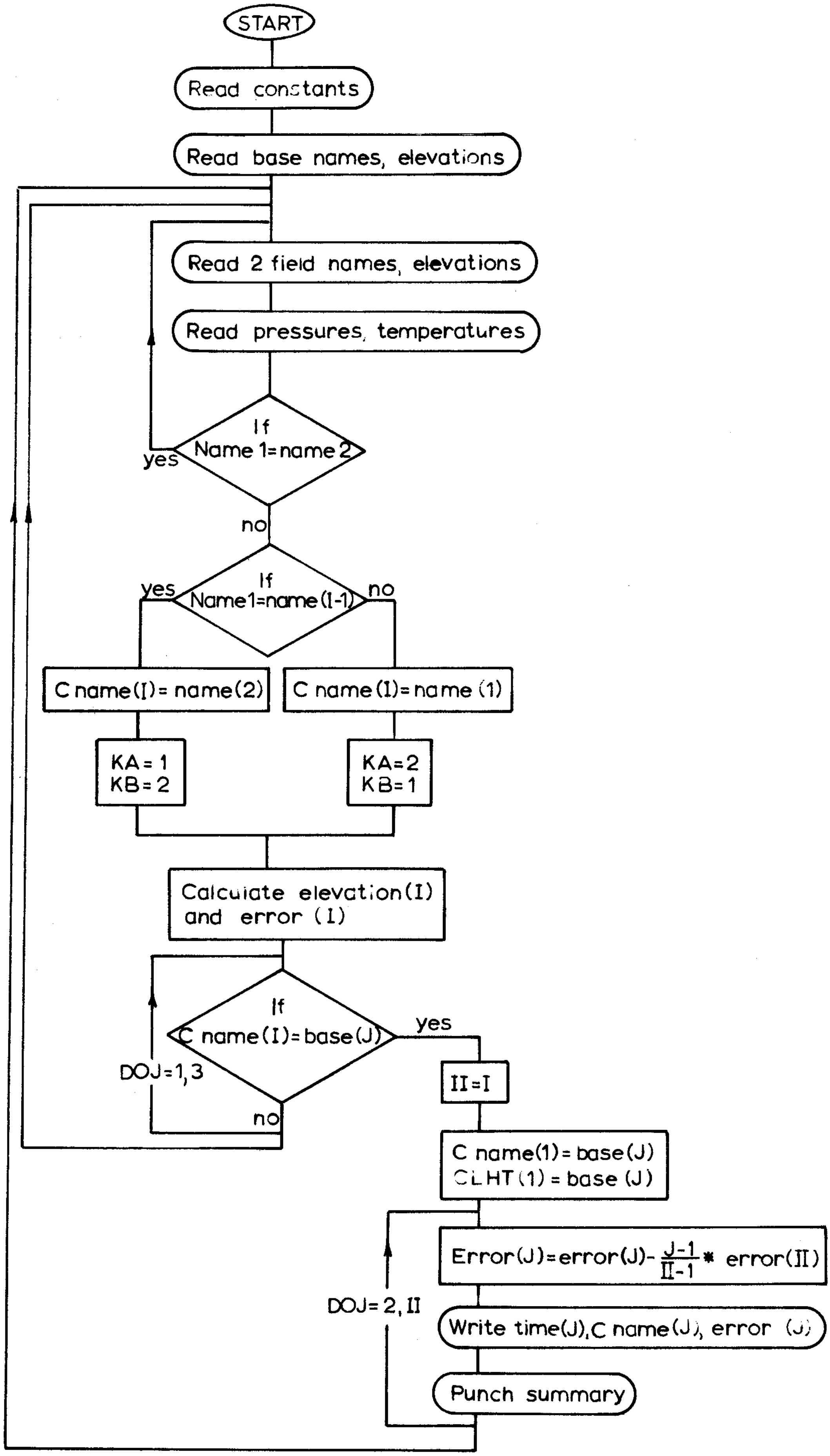


FIG. 6.11 FLOW CHART FOR SVY 43 LEAP FROG REDUCTION PROGRAMME.

then the average and maximum errors are calculated for each class interval.

The input is as follows:

a) A description of the particular summary set,
b) A series of summary cards.

When the programme reaches a blank summary card the results are printed out and the programme returns to the start.

The output is the print out of the tilt intervals, the average error, the maximum error and the number of results for the errors at each station in turn.

The flow chart for the programme is given in Figure 6.12.

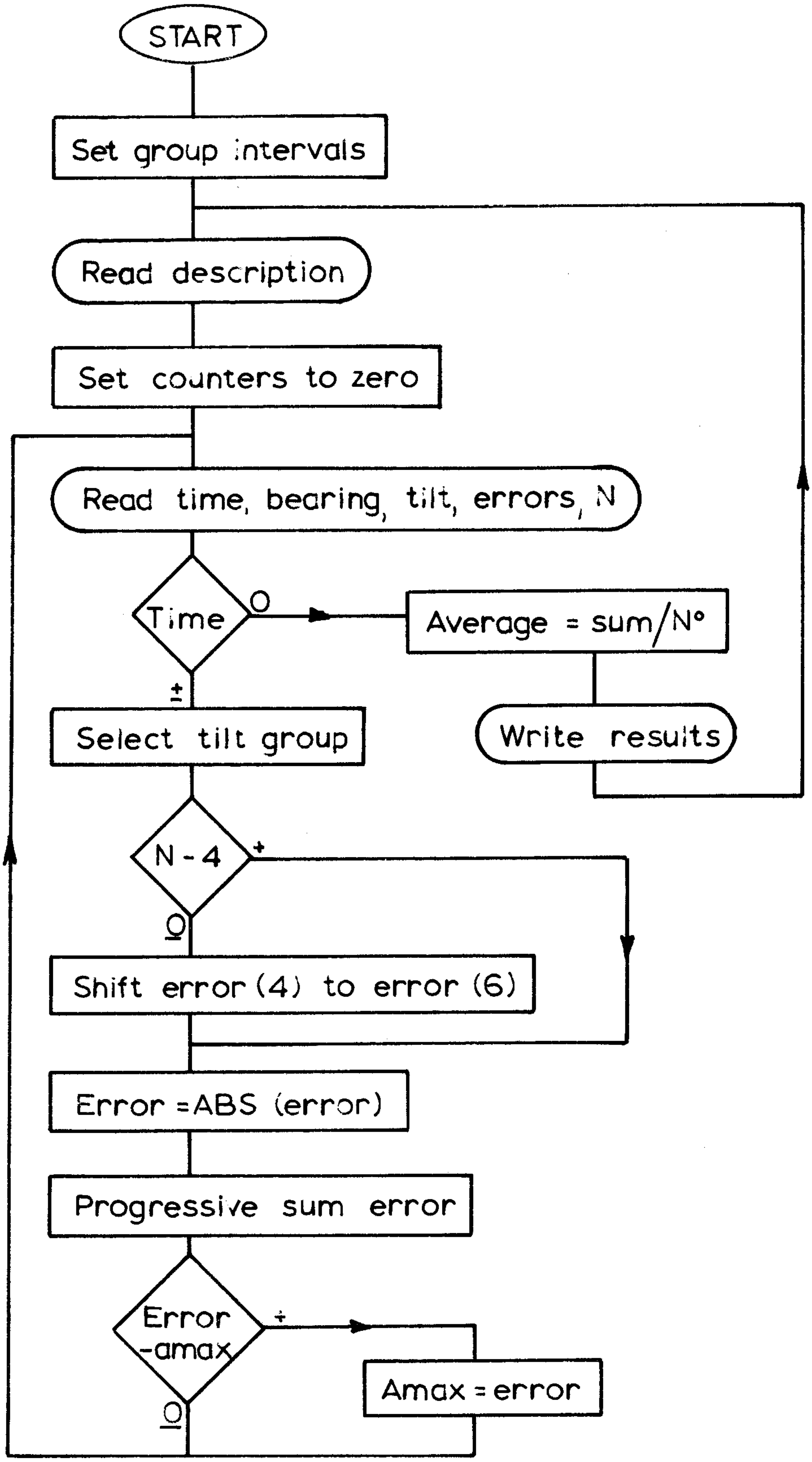


FIG. 6.12 ANALYSIS OF SUMMARIES PROGRAMME 2, SVY 46

CHAPTER 7

CONCLUSIONS

From the results achieved it would appear that barometric methods of determining elevations may certainly be used for lower order height control. For large scale engineering and similar projects the speed of obtaining the results make the methods invaluable at the reconnaissance stage. The instability of the mathematical model for the atmosphere however, precludes any attempt to obtain a higher order of accuracy. Some improvement in the model is obtained by using the Assumed Standard Atmosphere (ASA) in preference to the accepted atmospheres. This atmosphere is defined on page 15. The limitations of the barometric elevations then depend on the method used.

When the best results are not required a Single Base Method may be adopted provided that the possibility of a systematic error of up to approximately 3 feet per mile may be tolerated. The maximum error in a Single Base Elevation that occurred in this investigation was 32.2 feet which occurred at 1530 on the traverse for the 6th December, 1955. A larger error (34.0 feet) occurred at 0915 on the 26th May, 1959 but since the base pressures at that time were fluctuating excessively, the readings should be rejected. The Isobaric Surface around 1530 on the 6th December was fluctuating.

quite rapidly and indicated that a pressure front was travelling through the area. This front was masked by the diurnal variation and other local fluctuations and was impossible to detect by using the readings on just one base.

On the other hand, the elevation determined using the Multiple Base technique shows a distinct improvement. Even more significant, the fluctuation of the Isobaric Surface enables the surveyor to reject any readings taken about this period. This criterion of rejection is perhaps the most significant contribution that this thesis makes to this subject. Previously, readings could only be rejected if the fluctuation of the surface caused a significant jump in the readings at one of the base stations. It has been shown however that small jumps will tend to be masked and hence unreliable readings are carried into the results.

When the criterion is applied, all readings taken at times when the tilt exceeds 1 ft. per mile should be regarded as doubtful and only adopted if the Isobaric Surface tends to retain a constant tilt. The mean error and the maximum error for the elevations of the traverse stations may then be estimated by the formulae:

$$\text{Mean Error} = C_1 + .3 \times D_2 + .2 \times T^3 \times D_2$$

and

$$\text{Maximum Error} = 2 \times \text{Mean Error},$$

where C_1 is the standard deviation of reading the particular type of barometer (ft.),

D_2 is the mean distance of the field stations from the nearest base station (miles),

and T is the tilt of the Isobaric Surface (ft/mile).

The Leap-frog method should not be used as it will not give results as reliable as the Multiple Base method. Further the method is slower in the field.

The Two Base method should be restricted to special cases in which the topography has a more or less uniform slope from one base to the other. When this is not the case, the simplicity of the reduction and the slight saving in field work (temperatures are not recorded) do not warrant the risk of unreliable results.

BIBLIOGRAPHY

TEXTBOOKS

1. Australian Meteorological Observers' Handbook. Bureau of Meteorology, Australia. 1954.
2. Bannister and Raymond. Surveying. Pitman, London, 1959.
3. Berry, Wallace and Beers. Handbook of Meteorology. McGraw-Hill, New York, 1945.
4. British Standard 2520 Barometer Conventions and Tables. British Standards Institution, London, 1954.
5. Clark. Plane and Geodetic Surveying, Volume 2. 5th Edition. Constable and Co. London, 1963.
6. Croxton and Cowden. Applied General Statistics. Pitman, London, 1950.
7. Harrison, G.A. Chemical Methods in Clinical Medicine. J. and A Churchill Ltd., London, 1957.
8. Higgins, A.L. Higher Surveying. MacMillan, London, 1944.
9. International Commission for Air Navigation. Official Bulletin No. 26. Resolution No. 1053, December, 1938.

10. Martin and Connor. Basic Physics, Part 1. Whitcombe and Tombs, 1945.

11. National Advisory Committee for Aeronautics. Standard Atmosphere - Tables and Date for Altitudes to 65,800 feet. Report No. 1235, 1955.

12. O'Connor, D.C. Improved Methods of Ground Control for Photogrammetric Work in Australia. M.E. Thesis, U.N.S.W. 1959.

13. R.A.A.F. Manual of Meteorology. R.A.A.F. No. 153 Air Force Headquarters, Australia, 1943.

14. Saucier, W.J. Principles of Meteorological Analysis. University of Chicago Press, Chicago, 1955.

15. Smithsonian Meteorological Tables, Sixth Revised Edition. Smithsonian Institution, Washington, 1958.

PERIODICALS

16. Allman, J.S. Elevation by Microbarometer Cartography, Vol. 2, No. 3, 1958, p. 101-104.

17. Allman, J.S. The Adjustment of Barometric Level Networks. Cartography, Vol. 4, No. 4, Sept., 1962, p. 139-142.

18. Allman, J.S. A Comparator for the accurate measurement of differential Barometric Pressure. U.N.I.C.I.V. Report No. D3, October, 1963, University of N.S.W.

19. Bellamy, J.C. The Use of Pressure Altitude and Altimeter Corrections. Journal of Meteorology 11, 1945. 179.

20. Bowker, O.W. New Surveying Altimeter Announced. Surveying and Mapping, 1951, p. 164-165.

21. Brombacher. Altitude by Measurement of Air Pressures and Temperatures. Washington Academy of Sciences, Vol. 34, No. 9, Sept. 1944, p. 277-299.

22. Buckmaster, J.L. and A.H. Mears. Instrumental Improvements in Altimetry. Geological Survey Circular 405, Washington, 1958.

23. Cravat, H.R. Leap-frog Barometric Levelling. Photogrammetric Engineering, Vol. 23, No. 2, 1957, p. 328-330.

24. Crone, Col. D.R. Reduction of Aneroid Readings. ESR. J.14, No. 105, July, 1957, p. 141-143.

25. Crone, Col. D.R. Heights by Aneroid Barometer. ESR. Vol. 9, No. 69, July, 1948.

26. Crone, Col. D.R. Notes on Terrestrial Altimetry. ESR. Vol. 16, No. 122, Oct. 1961.

27. Crone, Col. D.R. Aneroid Heights - A Correction for The Exponential Lapse rate. ESR. Vol. 14, No. 110, Oct. 1958, p. 377-380.

28. Crone, Col. D.R. The Height of Lake Tana, Ethiopia. ESR. Vol. 13, No. 99, Jan. 1956, p. 220-228.

29. Demler, L.E. Altimetry - Its present day Techniques. Surveying and Mapping, 1951, p. 254-260.

30. Diehl, W.S. Standard Atmosphere - Tables and Data. N.A.C.A. Report No. 218, 1925.

31. Dixon, J.A. An Investigation into the Nature of the Isobaric Surface in Kenya. ESR. Vol. 19, No. 143, Jan. 1967. p. 19-21.

32. Goff, J.A. and Gratch, S. Low Pressure Properties of Water. Transactions American Society Heat and Ventilation Engineers. Vol. 52, 1946, p. 95.

33. Gold, E. Origin of the Lapse Rate Formula. ESR. Vol. 3, No. 17, p. 184 -186.

34. Green, A. The Adjustment of Miscloses in Networks with special reference to Microbarograph Surveys. Cartography Vol. 4, No. 1, March, 1961, p. 36-40.

35. Fowler, T.W. The Determination of Heights by Barometric Methods. Australian Assoc. Adv. Sc. Vol. II, 1898.

36. Hamilton, R.A., Biddle, C.A. and Sparks, B.W. Surveying Aneroids - Their uses and Limitations. Geographical Journal, Vol. 123, Pt. 4, Oct. 1957.

37. Haring, W.F. Improving the Accuracy of Altimetry. Surveying and Mapping, Vol. XV, No. 3, July, 1955, p. 359-364.

38. Harrison, E.R. A Mercury Surface Height Indicator Australian Journal of Applied Science, 1960, Vol. 2, No. 1, p. 198.

39. Hartog, P. Field Tests with Wallace and Tiernan Altimeters near Moshi, Tanganyika. ESR. Vol. 15, No. 113, July, 1959, p. 117-128.

40. Heimbrod, G. Topographic Surveying. The Surveyor, Aug. 1900, p. 162-165, 184-195.

41. Jenks, Instructions for the Use of the Surveying Aneroid and the Paulin Altimeter. N.S. Surveyor, 1959. p. 473-489.

42. Kissam, Prof. P. Precision Altimetry. Photogrammetric Engineering, Jan. - March, 1944.

43. Koeman, C. Analyse Van een Bartometrische hootemetin. Kadaster and Landmeetkunde, Vol. 74, No. 2, 1958, p. 58-70.

44. Koeman, C. Welke Nauwkeurigheid geeft de Barometrische Hooglemeting. K. and L., Vol. 74, No. 1, Feb, 1958.

45. Mears, A.H. and Haring, W.F. Multiple Base Altimetry. Photogrammetric Engineering, 1954, p. 814-822.

46. Miller, Barometric Levelling. Australian Surveyor, Dec. 1935, p. 458-465.

47. Mills, B. A Sensitive Contact Indicator. Review of Scientific Instruments, 1941, 12, p. 105.

48. McGraw, G.T. New Aneroid Tables. ESR. Vol. 3, No. 16, April, 1935, p. 85-98.

49. O'Connor, D.C. Microclimatology and its Effects on The Accuracy of Surveying Aneroids. ESR. Vol. 15, No. 118, Oct. 1960, p. 364.

50. O'Connor, D.C. The Use of Sensitive Pressure Devices in Surveying. ESR. Vol. 14, No's 103-107, 1957.

51. Rangen, J. Reduction of Aneroid Readings, ESR. Vol. 14, No. 103, Jan. 1957, p. 20-23.

52. Robertson, Col. R.R. Altimeters as used by the 30th Engineers for Mapping.
Photogrammetric Engineering, Dec, 1952, p. 839-845.

53. Sharp, H.O. and Palmer, R.K. Faster and Cheaper Surveys. Engineering News Record, Sept. 1948, Wallace and Tiernan Products, U.S.A.

54. Sparks, B.W. Effects of Weather on the Determination of Heights by Aneroid Barometer in Great Britain. Geographical Journal, 1953, Pt. 1, p. 73-80.

55. Wilson, G.U. Barometric Determinations of Elevation. ESR. Vol 15, No. 118, Oct. 1960, p. 350-364.

PAMPHLETS

56. Biddle, Lt.Col. C.A. Heights by Aneroid Barometer. Tellurometer (U.K.) Ltd., London.

APPENDIX I

Pressure/Height relationship in the Assumed Standard Atmosphere from 600 to 800 mm of mercury pressure by 0.1 mm intervals.

MM					ELEVATION				A.S.A.	
PRES	.0	.1	.2	.3	.4	.5	.6	.7	.8	.9
600.	6287.9	6283.6	6279.2	6274.9	6270.6	6266.2	6261.9	6257.6	6253.2	6248.9
601.	6244.6	6240.3	6235.9	6231.6	6227.3	6222.9	6218.6	6214.3	6210.0	6205.6
602.	6201.3	6197.0	6192.7	6188.4	6184.0	6179.7	6175.4	6171.1	6166.8	6162.4
603.	6158.1	6153.8	6149.5	6145.2	6140.9	6136.6	6132.2	6127.9	6123.6	6119.3
604.	6115.0	6110.7	6106.3	6102.0	6097.7	6093.4	6089.1	6084.8	6080.5	6076.2
605.	6071.9	6067.6	6063.3	6059.0	6054.7	6050.4	6046.1	6041.7	6037.5	6033.2
606.	6028.8	6024.6	6020.3	6016.0	6011.7	6007.4	6003.1	5998.8	5994.5	5990.2
607.	5985.9	5981.6	5977.3	5973.0	5968.7	5964.4	5960.1	5955.8	5951.6	5947.3
608.	5943.0	5938.7	5934.4	5930.1	5925.8	5921.5	5917.2	5913.0	5908.7	5904.4
609.	5900.1	5895.8	5891.5	5887.3	5883.0	5878.7	5874.4	5870.1	5865.9	5861.6
610.	5857.3	5853.0	5848.7	5844.5	5840.2	5835.9	5831.6	5827.4	5823.1	5818.8
611.	5814.6	5810.3	5806.0	5801.8	5797.5	5793.2	5788.9	5784.7	5780.4	5776.1
612.	5771.9	5767.6	5763.3	5759.1	5754.8	5750.6	5746.3	5742.0	5737.8	5733.5
613.	5729.2	5725.0	5720.7	5716.5	5712.2	5708.0	5703.7	5699.4	5695.2	5690.9
614.	5686.7	5682.4	5678.2	5673.9	5669.7	5665.4	5661.2	5656.9	5652.7	5648.4
615.	5644.1	5639.9	5635.7	5631.4	5627.2	5622.9	5618.7	5614.4	5610.2	5605.9
616.	5601.7	5597.5	5593.2	5589.0	5584.7	5580.5	5576.2	5572.0	5567.8	5563.5
617.	5559.3	5555.1	5550.8	5546.6	5542.3	5538.1	5533.9	5529.6	5525.4	5521.2
618.	5516.9	5512.7	5508.5	5504.3	5500.0	5495.8	5491.6	5487.3	5483.1	5478.9
619.	5474.6	5470.4	5466.2	5462.0	5457.7	5453.5	5449.3	5445.1	5440.9	5436.6
620.	5432.4	5428.2	5423.9	5419.7	5415.5	5411.3	5407.1	5402.9	5398.6	5394.4
621.	5390.2	5386.0	5381.8	5377.6	5373.4	5369.2	5364.9	5360.7	5356.5	5352.3
622.	5348.1	5343.9	5339.7	5335.5	5331.3	5327.1	5322.8	5318.6	5314.4	5310.2
623.	5306.0	5301.8	5297.6	5293.4	5289.2	5285.0	5280.8	5276.6	5272.4	5268.2
624.	5264.0	5259.8	5255.6	5251.4	5247.2	5243.0	5238.8	5234.6	5230.4	5226.2
625.	5222.0	5217.8	5213.6	5209.5	5205.3	5201.1	5196.9	5192.7	5188.5	5184.3
626.	5180.1	5175.9	5171.7	5167.6	5163.4	5159.2	5155.0	5150.8	5146.6	5142.4
627.	5138.3	5134.1	5129.9	5125.7	5121.5	5117.4	5113.2	5109.0	5104.8	5100.6
628.	5096.5	5092.3	5088.1	5083.9	5079.8	5075.6	5071.4	5067.2	5063.1	5058.9
629.	5054.7	5050.5	5046.4	5042.2	5038.0	5033.9	5029.7	5025.5	5021.4	5017.2

MM				ELEVATION					A.S.A.	
PRES	.0	.1	.2	.3	.4	.5	.6	.7	.8	.9
630.	5013.0	5008.8	5004.7	5000.5	4996.3	4992.2	4988.0	4983.9	4979.7	4975.5
631.	4971.4	4967.2	4963.1	4958.9	4954.7	4950.6	4946.4	4942.3	4938.1	4933.9
632.	4929.8	4925.6	4921.5	4917.3	4913.2	4909.0	4904.9	4900.7	4896.6	4892.4
633.	4888.3	4884.1	4880.0	4875.8	4871.7	4867.5	4863.4	4859.2	4855.1	4850.9
634.	4846.8	4842.6	4838.5	4834.3	4830.2	4826.1	4821.9	4817.8	4813.6	4809.5
635.	4805.3	4801.2	4797.1	4792.9	4788.8	4784.6	4780.5	4776.4	4772.2	4768.1
636.	4764.0	4759.8	4755.7	4751.6	4747.4	4743.3	4739.2	4735.0	4730.9	4726.8
637.	4722.6	4718.5	4714.4	4710.3	4706.1	4702.0	4697.9	4693.8	4689.6	4685.5
638.	4681.4	4677.3	4673.1	4669.0	4664.9	4660.8	4656.6	4652.5	4648.4	4644.3
639.	4640.2	4636.1	4631.9	4627.8	4623.7	4619.6	4615.5	4611.3	4607.2	4603.1
640.	4599.0	4594.9	4590.8	4586.7	4582.5	4578.4	4574.3	4570.2	4566.1	4562.0
641.	4557.9	4553.8	4549.7	4545.6	4541.5	4537.4	4533.2	4529.1	4525.0	4520.9
642.	4516.8	4512.7	4508.6	4504.5	4500.4	4496.3	4492.2	4488.1	4484.0	4479.9
643.	4475.8	4471.7	4467.6	4463.5	4459.4	4455.3	4451.2	4447.1	4443.1	4438.9
644.	4434.9	4430.8	4426.7	4422.6	4418.5	4414.4	4410.3	4406.2	4402.1	4398.0
645.	4393.9	4389.9	4385.8	4381.7	4377.6	4373.5	4369.4	4365.3	4361.3	4357.2
646.	4353.1	4349.0	4344.9	4340.9	4336.8	4332.7	4328.6	4324.5	4320.5	4316.4
647.	4312.3	4308.2	4304.1	4300.1	4296.0	4291.9	4287.8	4283.8	4279.7	4275.6
648.	4271.5	4267.5	4263.4	4259.3	4255.3	4251.2	4247.1	4243.0	4239.0	4234.9
649.	4230.8	4226.8	4222.7	4218.6	4214.6	4210.5	4206.4	4202.4	4198.3	4194.3
650.	4190.2	4186.1	4182.1	4178.0	4173.9	4169.9	4165.8	4161.8	4157.7	4153.6
651.	4149.6	4145.5	4141.5	4137.4	4133.4	4129.3	4125.3	4121.2	4117.2	4113.1
652.	4109.0	4105.0	4100.9	4096.9	4092.8	4088.8	4084.7	4080.7	4076.7	4072.6
653.	4068.5	4064.5	4060.5	4056.4	4052.4	4048.3	4044.3	4040.2	4036.2	4032.1
654.	4028.1	4024.1	4020.0	4016.0	4011.9	4007.9	4003.9	3999.8	3995.8	3991.7
655.	3987.7	3983.7	3979.6	3975.6	3971.5	3967.5	3963.5	3959.4	3955.4	3951.4
656.	3947.4	3943.3	3939.3	3935.3	3931.2	3927.2	3923.2	3919.1	3915.1	3911.1
657.	3907.1	3903.0	3899.0	3895.0	3890.9	3886.9	3882.9	3878.9	3874.9	3870.8
658.	3866.8	3862.8	3858.8	3854.7	3850.7	3846.7	3842.7	3838.7	3834.7	3830.6
659.	3826.6	3822.6	3818.6	3814.6	3810.5	3806.5	3802.5	3798.5	3794.5	3790.5

MM	ELEVATION A.S.A.									
PRES	.0	.1	.2	.3	.4	.5	.6	.7	.8	.9
660.	3786.4	3782.4	3778.4	3774.4	3770.4	3766.4	3762.4	3758.4	3754.4	3750.4
661.	3746.4	3742.4	3738.3	3734.3	3730.3	3726.3	3722.3	3718.3	3714.3	3710.3
662.	3706.3	3702.3	3698.3	3694.3	3690.3	3686.3	3682.3	3678.3	3674.3	3670.3
663.	3666.3	3662.3	3658.3	3654.3	3650.3	3646.3	3642.3	3638.3	3634.3	3630.3
664.	3626.3	3622.4	3618.4	3614.4	3610.4	3606.4	3602.4	3598.4	3594.4	3590.4
665.	3586.4	3582.4	3578.5	3574.5	3570.5	3566.5	3562.5	3558.5	3554.6	3550.6
666.	3546.6	3542.6	3538.6	3534.6	3530.7	3526.7	3522.7	3518.7	3514.7	3510.8
667.	3506.8	3502.8	3498.8	3494.9	3490.9	3486.9	3482.9	3478.9	3475.0	3471.0
668.	3467.0	3463.1	3459.1	3455.1	3451.1	3447.2	3443.2	3439.2	3435.3	3431.3
669.	3427.3	3423.3	3419.4	3415.4	3411.4	3407.5	3403.5	3399.5	3395.6	3391.6
670.	3387.6	3383.7	3379.7	3375.8	3371.8	3367.8	3363.9	3359.9	3355.9	3352.0
671.	3348.0	3344.1	3340.1	3336.2	3332.2	3328.3	3324.3	3320.3	3316.4	3312.4
672.	3308.5	3304.5	3300.6	3296.6	3292.7	3288.7	3284.8	3280.8	3276.9	3272.9
673.	3268.9	3265.0	3261.1	3257.1	3253.2	3249.2	3245.3	3241.3	3237.4	3233.4
674.	3229.5	3225.5	3221.6	3217.6	3213.7	3209.8	3205.8	3201.9	3197.9	3194.0
675.	3190.0	3186.1	3182.2	3178.2	3174.3	3170.4	3166.4	3162.5	3158.5	3154.6
676.	3150.7	3146.7	3142.8	3138.9	3134.9	3131.0	3127.1	3123.1	3119.2	3115.3
677.	3111.3	3107.4	3103.5	3099.6	3095.6	3091.7	3087.8	3083.8	3079.9	3076.0
678.	3072.1	3068.1	3064.2	3060.3	3056.4	3052.4	3048.5	3044.6	3040.7	3036.7
679.	3032.8	3028.9	3025.0	3021.1	3017.2	3013.2	3009.3	3005.4	3001.5	2997.6
680.	2993.6	2989.7	2985.8	2981.9	2978.0	2974.1	2970.1	2966.2	2962.3	2958.4
681.	2954.5	2950.6	2946.7	2942.8	2938.9	2935.0	2931.0	2927.1	2923.2	2919.3
682.	2915.4	2911.5	2907.6	2903.7	2899.8	2895.9	2892.0	2888.1	2884.2	2880.3
683.	2876.3	2872.5	2868.5	2864.7	2860.7	2856.9	2853.0	2849.0	2845.2	2841.2
684.	2837.3	2833.5	2829.6	2825.7	2821.8	2817.9	2814.0	2810.1	2806.2	2802.3
685.	2798.4	2794.5	2790.6	2786.7	2782.8	2778.9	2775.0	2771.1	2767.3	2763.4
686.	2759.5	2755.6	2751.7	2747.8	2743.9	2740.1	2736.2	2732.3	2728.4	2724.5
687.	2720.6	2716.7	2712.9	2709.0	2705.1	2701.2	2697.3	2693.4	2689.6	2685.7
688.	2681.8	2677.9	2674.0	2670.2	2666.3	2662.4	2658.5	2654.7	2650.8	2646.9
689.	2643.0	2639.2	2635.3	2631.4	2627.5	2623.7	2619.8	2615.9	2612.0	2608.2

MM				ELEVATION					A.S.A.	
PRES	.0	.1	.2	.3	.4	.5	.6	.7	.8	.9
690.	2604.3	2600.4	2596.5	2592.7	2588.8	2584.9	2581.1	2577.2	2573.3	2569.5
691.	2565.6	2561.8	2557.9	2554.0	2550.2	2546.3	2542.4	2538.6	2534.7	2530.8
692.	2527.0	2523.1	2519.3	2515.4	2511.5	2507.7	2503.8	2500.0	2496.1	2492.2
693.	2488.4	2484.5	2480.7	2476.8	2473.0	2469.1	2465.3	2461.4	2457.6	2453.7
694.	2449.8	2446.0	2442.1	2438.3	2434.4	2430.6	2426.7	2422.9	2419.0	2415.2
695.	2411.3	2407.5	2403.6	2399.8	2395.9	2392.1	2388.3	2384.4	2380.6	2376.7
696.	2372.9	2369.0	2365.2	2361.4	2357.5	2353.7	2349.8	2346.0	2342.2	2338.3
697.	2334.5	2330.6	2326.8	2323.0	2319.1	2315.3	2311.5	2307.6	2303.8	2299.9
698.	2296.1	2292.3	2288.4	2284.6	2280.8	2276.9	2273.1	2269.3	2265.4	2261.6
699.	2257.8	2254.0	2250.1	2246.3	2242.5	2238.7	2234.8	2231.0	2227.2	2223.3
700.	2219.5	2215.7	2211.9	2208.0	2204.2	2200.4	2196.6	2192.7	2188.9	2185.1
701.	2181.3	2177.5	2173.6	2169.8	2166.0	2162.2	2158.4	2154.5	2150.7	2146.9
702.	2143.1	2139.3	2135.5	2131.6	2127.8	2124.0	2120.2	2116.4	2112.6	2108.8
703.	2104.9	2101.1	2097.3	2093.5	2089.7	2085.9	2082.1	2078.3	2074.5	2070.7
704.	2066.8	2063.0	2059.2	2055.4	2051.6	2047.8	2044.0	2040.2	2036.4	2032.6
705.	2028.8	2025.0	2021.2	2017.4	2013.6	2009.8	2006.0	2002.2	1998.4	1994.6
706.	1990.8	1987.0	1983.2	1979.4	1975.6	1971.8	1968.0	1964.2	1960.4	1956.6
707.	1952.8	1949.0	1945.2	1941.4	1937.6	1933.8	1930.0	1926.2	1922.5	1918.7
708.	1914.9	1911.1	1907.3	1903.5	1899.7	1895.9	1892.1	1888.3	1884.6	1880.8
709.	1877.0	1873.2	1869.4	1865.6	1861.8	1858.1	1854.3	1850.5	1846.7	1842.9
710.	1839.1	1835.4	1831.6	1827.8	1824.0	1820.2	1816.5	1812.7	1808.9	1805.1
711.	1801.3	1797.6	1793.8	1790.0	1786.3	1782.5	1778.7	1774.9	1771.2	1767.4
712.	1763.6	1759.8	1756.1	1752.3	1748.5	1744.7	1741.0	1737.2	1733.4	1729.7
713.	1725.9	1722.1	1718.4	1714.6	1710.8	1707.1	1703.3	1699.5	1695.8	1692.0
714.	1688.2	1684.5	1680.7	1676.9	1673.2	1669.4	1665.6	1661.9	1658.1	1654.4
715.	1650.6	1646.8	1643.1	1639.3	1635.6	1631.8	1628.0	1624.3	1620.5	1616.8
716.	1613.0	1609.3	1605.5	1601.8	1598.0	1594.2	1590.5	1586.7	1583.0	1579.2
717.	1575.5	1571.7	1568.0	1564.2	1560.5	1556.7	1553.0	1549.2	1545.5	1541.7
718.	1538.0	1534.2	1530.5	1526.7	1523.0	1519.3	1515.5	1511.8	1508.0	1504.3
719.	1500.5	1496.8	1493.0	1489.3	1485.6	1481.8	1478.1	1474.3	1470.6	1466.9

MM PRES	.0	.1	.2	.3	.4	.5	.6	.7	.8	.9
				E L E V A T I O N					A.S.A.	
720.	1463.1	1459.4	1455.6	1451.9	1448.2	1444.4	1440.7	1436.9	1433.2	1429.5
721.	1425.7	1422.0	1418.3	1414.5	1410.8	1407.1	1403.3	1399.6	1395.9	1392.1
722.	1388.4	1384.7	1381.0	1377.2	1373.5	1369.8	1366.0	1362.3	1358.6	1354.9
723.	1351.1	1347.4	1343.7	1340.0	1336.2	1332.5	1328.8	1325.0	1321.3	1317.6
724.	1313.9	1310.2	1306.4	1302.7	1299.0	1295.3	1291.6	1287.8	1284.1	1280.4
725.	1276.7	1273.0	1269.2	1265.5	1261.8	1258.1	1254.4	1250.7	1246.9	1243.2
726.	1239.5	1235.8	1232.1	1228.4	1224.7	1221.0	1217.2	1213.5	1209.8	1206.1
727.	1202.4	1198.7	1195.0	1191.3	1187.6	1183.9	1180.1	1176.4	1172.7	1169.0
728.	1165.3	1161.6	1157.9	1154.2	1150.5	1146.8	1143.1	1139.4	1135.7	1132.0
729.	1128.3	1124.6	1120.9	1117.2	1113.5	1109.8	1106.1	1102.4	1098.7	1095.0
730.	1091.3	1087.6	1083.9	1080.2	1076.5	1072.8	1069.1	1065.4	1061.7	1058.0
731.	1054.3	1050.6	1046.9	1043.3	1039.6	1035.9	1032.2	1028.5	1024.8	1021.1
732.	1017.4	1013.7	1010.0	1006.4	1002.7	999.0	995.3	991.6	987.9	984.2
733.	980.5	976.9	973.2	969.5	965.8	962.1	958.4	954.8	951.1	947.4
734.	943.7	940.0	936.3	932.7	929.0	925.3	921.6	917.9	914.3	910.6
735.	906.9	903.2	899.6	895.9	892.2	888.5	884.9	881.2	877.5	873.8
736.	870.2	866.5	862.8	859.2	855.5	851.8	848.1	844.5	840.8	837.1
737.	833.5	829.8	826.1	822.5	818.8	815.1	811.5	807.8	804.1	800.5
738.	796.8	793.1	789.5	785.8	782.1	778.5	774.8	771.1	767.5	763.8
739.	760.2	756.5	752.8	749.2	745.5	741.9	738.2	734.5	730.9	727.2
740.	723.6	719.9	716.2	712.6	708.9	705.3	701.6	698.0	694.3	690.7
741.	687.0	683.4	679.7	676.1	672.4	668.8	665.1	661.5	657.8	654.2
742.	650.5	646.9	643.2	639.6	635.9	632.3	628.6	625.0	621.3	617.7
743.	614.0	610.4	606.7	603.1	599.5	595.8	592.2	588.5	584.9	581.3
744.	577.6	574.0	570.3	566.7	563.0	559.4	555.8	552.1	548.5	544.8
745.	541.2	537.6	533.9	530.3	526.7	523.0	519.4	515.8	512.1	508.5
746.	504.9	501.2	497.6	494.0	490.3	486.7	483.1	479.4	475.8	472.2
747.	468.5	464.9	461.3	457.7	454.0	450.4	446.8	443.2	439.5	435.9
748.	432.3	428.7	425.0	421.4	417.8	414.2	410.5	406.9	403.3	399.7
749.	396.0	392.4	388.8	385.2	381.6	377.9	374.3	370.7	367.1	363.5

ELEVATION A.S.A.

MM PRES	.0	.1	.2	.3	.4	.5	.6	.7	.8	.9
750.	359.8	356.2	352.6	349.0	345.4	341.8	338.2	334.5	330.9	327.3
751.	323.7	320.1	316.5	312.9	309.2	305.6	302.0	298.4	294.8	291.2
752.	287.6	284.0	280.4	276.8	273.2	269.5	265.9	262.3	258.7	255.1
753.	251.5	247.9	244.3	240.7	237.1	233.5	229.9	226.3	222.7	219.1
754.	215.5	211.9	208.3	204.7	201.1	197.5	193.9	190.3	186.7	183.1
755.	179.5	175.9	172.3	168.7	165.1	161.5	157.9	154.3	150.7	147.1
756.	143.5	139.9	136.3	132.7	129.1	125.6	122.0	118.4	114.8	111.2
757.	107.6	104.0	100.4	96.8	93.2	89.6	86.1	82.5	78.9	75.3
758.	71.7	68.1	64.5	61.0	57.4	53.8	50.2	46.6	43.0	39.4
759.	35.9	32.3	28.7	25.1	21.5	18.0	14.4	10.8	7.2	3.6
760.	-0.0	-3.6	-7.2	-10.7	-14.3	-17.9	-21.4	-25.2	-28.6	-32.3
761.	-35.9	-39.4	-43.0	-46.6	-50.1	-53.7	-57.2	-60.8	-64.4	-67.9
762.	-71.5	-75.1	-78.6	-82.2	-85.8	-89.3	-92.9	-96.5	-100.0	-103.6
763.	-107.2	-110.7	-114.3	-117.9	-121.4	-125.0	-128.6	-132.1	-135.7	-139.3
764.	-142.8	-146.4	-150.0	-153.5	-157.1	-160.7	-164.2	-167.8	-171.4	-174.9
765.	-178.5	-182.1	-185.6	-189.2	-192.8	-196.3	-199.9	-203.5	-207.0	-210.5
766.	-214.0	-217.6	-221.2	-224.7	-228.3	-231.9	-235.4	-239.0	-242.6	-246.0
767.	-249.6	-253.1	-256.7	-260.3	-263.8	-267.4	-271.0	-274.5	-278.1	-281.5
768.	-285.1	-288.7	-292.2	-295.8	-299.4	-302.9	-306.3	-309.9	-313.5	-317.0
769.	-320.6	-324.2	-327.7	-331.2	-334.7	-338.3	-341.9	-345.4	-348.9	-352.4
770.	-356.0	-359.6	-363.1	-366.7	-370.1	-373.7	-377.3	-380.8	-384.3	-387.8
771.	-391.4	-395.0	-398.5	-402.0	-405.5	-409.1	-412.7	-416.2	-419.6	-423.2
772.	-426.8	-430.3	-433.8	-437.3	-440.9	-444.3	-447.9	-451.5	-455.0	-458.6
773.	-462.0	-465.6	-469.2	-472.6	-476.2	-479.7	-483.3	-486.7	-490.3	-493.9
774.	-497.3	-500.9	-504.4	-508.0	-511.4	-515.0	-518.5	-522.0	-525.5	-529.1
775.	-532.5	-536.1	-539.7	-543.2	-546.7	-550.2	-553.8	-557.2	-560.8	-564.4
776.	-567.8	-571.4	-574.9	-578.4	-581.9	-585.3	-588.9	-592.5	-595.9	-599.5
777.	-602.9	-606.5	-610.0	-613.5	-617.0	-620.6	-624.0	-627.6	-631.0	-634.6
778.	-638.2	-641.6	-645.2	-648.6	-652.1	-655.7	-659.1	-662.7	-666.1	-669.7
779.	-673.3	-676.7	-680.3	-683.7	-687.3	-690.7	-694.3	-697.8	-701.3	-704.8

```
 MM                                 E L E V A T I O N                     A.S.A.
 PRES    .0      .1      .2      .3      .4          .5      .6      .7      .8      .9
---------------------------------------------------------------------------------------------
780.   -708.3  -711.8  -715.2  -718.8  -722.2      -725.8  -729.2  -732.8  -736.2  -739.8
781.   -743.2  -746.8  -750.2  -753.8  -757.4      -760.8  -764.4  -767.8  -771.3  -774.8
782.   -778.3  -781.8  -785.3  -788.8  -792.3      -795.8  -799.2  -802.8  -806.2  -809.8
783.   -813.2  -816.8  -820.2  -823.7  -827.2      -830.7  -834.2  -837.6  -841.2  -844.6
784.   -848.2  -851.6  -855.2  -858.6  -862.2      -865.6  -869.0  -872.6  -876.0  -879.6


785.   -883.0  -886.6  -890.0  -893.4  -897.0      -900.4  -904.0  -907.4  -910.8  -914.4
786.   -917.8  -921.4  -924.8  -928.3  -931.8      -935.3  -938.7  -942.3  -945.7  -949.1
787.   -952.7  -956.1  -959.7  -963.1  -966.5      -970.1  -973.5  -977.0  -980.5  -984.0
788.   -987.4  -991.0  -994.4  -997.8-1001.4     -1004.8-1008.2-1011.8-1015.2-1018.7
789.  -1022.2-1025.7-1029.1-1032.7-1036.1     -1039.5-1042.9-1046.5-1049.9-1053.4


790.  -1056.9-1060.4-1063.8-1067.4-1070.8     -1074.2-1077.6-1081.2-1084.6-1088.1
791.  -1091.5-1095.1-1098.5-1101.9-1105.4     -1108.9-1112.4-1115.8-1119.2-1122.8
792.  -1126.2-1129.6-1133.1-1136.5-1140.1     -1143.5-1146.9-1150.3-1153.9-1157.3
793.  -1160.8-1164.2-1167.6-1171.1-1174.6     -1178.1-1181.5-1184.9-1188.3-1191.9
794.  -1195.3-1198.8-1202.2-1205.6-1209.2     -1212.6-1216.0-1219.5-1222.9-1226.3


795.  -1229.9-1233.3-1236.8-1240.2-1243.6     -1247.0-1250.5-1254.0-1257.5-1260.9
796.  -1264.3-1267.8-1271.2-1274.6-1278.2     -1281.5-1285.0-1288.5-1291.9-1295.3
797.  -1298.8-1302.2-1305.6-1309.1-1312.5     -1316.0-1319.5-1322.9-1326.3-1329.8
798.  -1333.2-1336.6-1340.1-1343.5-1346.9     -1350.3-1353.8-1357.3-1360.8-1364.2
799.  -1367.6-1371.1-1374.5-1377.9-1381.3     -1384.8-1388.2-1391.6-1395.1-1398.5


800.  -1401.9-1405.3-1408.8-1412.2-1415.6     -1419.1-1422.5-1425.9-1429.3-1432.8
801.  -1436.2-1439.6-1443.1-1446.5-1449.9     -1453.4-1456.8-1460.2-1463.6-1467.1
802.  -1470.5-1473.9-1477.4-1480.8-1484.2     -1487.6-1491.1-1494.5-1497.9-1501.4
803.  -1504.8-1508.2-1511.6-1515.1-1518.5     -1521.8-1525.2-1528.7-1532.1-1535.5
804.  -1538.9-1542.4-1545.8-1549.2-1552.7     -1556.1-1559.5-1562.9-1566.2-1569.7


805.  -1573.1-1576.5-1580.0-1583.4-1586.8     -1590.2-1593.7-1597.1-1600.4-1603.8
806.  -1607.3-1610.7-1614.1-1617.5-1621.0     -1624.3-1627.7-1631.1-1634.6-1638.0
807.  -1641.4-1644.8-1648.3-1651.6-1655.0     -1658.4-1661.8-1665.3-1668.7-1672.0
808.  -1675.4-1678.9-1682.3-1685.7-1689.0     -1692.4-1695.9-1699.3-1702.7-1706.2
809.  -1709.4-1712.9-1716.3-1719.7-1723.2     -1726.5-1729.9-1733.3-1736.7-1740.2
```

APPENDIX II

Isobaric Surface Reductions.

```
CITY TRAVERSE REDUCTION 26 MAY 1959 ASA

 PRESSURES IN INCHES
 TEMPERATURES IN FARENHEIT
 COORDINATES IN YARDS

CONSTANT 1 143831.81
CONSTANT 2   0.18910

 STATION         X          Y         HEIGHT
ST PAULS       833900.    411100.   663.00
LIVERPOOL      809100.    392600.    60.00
CENTENNIAL     812900.    423800.   215.00
BEVERLY HILL   805500.    408300.   110.00
RYDE           822200.    410200.   183.00

TIME    915
PRESSURE     29.884     30.533     30.340     30.472     30.400
TEMP DRY       57.0       60.0       62.0       70.0        0.0
SINGLE BASE ERRORS                                MULTIPLE BASE ERRORS
      15.4      34.0      20.2      11.9               -11.0      -1.1
DIP BEARING 147.7 DEG          TILT/MILE 2.44 FEET


TIME    930
PRESSURE     29.881     30.538     30.352     30.479     30.394
TEMP DRY       57.0       60.0       60.0       78.0        0.0
SINGLE BASE ERRORS                                MULTIPLE BASE ERRORS
       6.4      19.2        9.6       13.2               -6.7       6.4
DIP BEARING 142.0 DEG          TILT/MILE 1.39 FEET


TIME    945
PRESSURE     29.884     30.542     30.356     30.485     30.391
TEMP DRY       57.0       64.0       60.0       76.0        0.0
SINGLE BASE ERRORS                                MULTIPLE BASE ERRORS
       5.0      17.9        6.4       18.3               -8.2      12.1
DIP BEARING 139.3 DEG          TILT/MILE 1.30 FEET
```

```
 CITY TRAVERSE REDUCTION 26 MAY 1959 ASA
ST PAULS      LIVERPOOL     CENTENNIAL    BEVERLY HILL  RYDE

TIME   1000
PRESSURE     29.883     30.549     30.362     30.487     30.399
TEMP DRY       60.0       62.0       60.0       72.0        0.0
SINGLE BASE ERRORS                                MULTIPLE BASE ERRORS
      -1.4      12.3        4.5     10.9                -2.6       7.8
DIP BEARING 122.2 DEG         TILT/MILE 0.99 FEET


TIME   1005
PRESSURE     29.883     30.548     30.364     30.488     30.404
TEMP DRY       60.0       63.0       60.0       72.0        0.0
SINGLE BASE ERRORS                                MULTIPLE BASE ERRORS
      -0.7      10.3        3.3      6.1                -3.0       3.4
DIP BEARING 123.9 DEG         TILT/MILE 0.81 FEET


TIME   1010
PRESSURE     29.888     30.548     30.364     30.488     30.404
TEMP DRY       60.0       64.0       61.0       70.0        0.0
SINGLE BASE ERRORS                                MULTIPLE BASE ERRORS
       3.9      14.9        7.9     10.7                -4.1       5.7
DIP BEARING 138.5 DEG         TILT/MILE 1.08 FEET


TIME   1015
PRESSURE     29.890     30.547     30.365     30.489     30.403
TEMP DRY       60.0       64.0       61.0       70.0        0.0
SINGLE BASE ERRORS                                MULTIPLE BASE ERRORS
       6.5      15.7        8.9     13.5                -5.2       7.6
DIP BEARING 146.0 DEG         TILT/MILE 1.13 FEET
```

```
 CITY TRAVERSE REDUCTION 26 MAY 1959 ASA
ST PAULS      LIVERPOOL     CENTENNIAL    BEVERLY HILL  RYDE

TIME   1030
PRESSURE     29.890     30.548     30.368     30.486     30.401
TEMP DRY       62.0       65.0       60.0       66.0        0.0
SINGLE BASE ERRORS                                MULTIPLE BASE ERRORS
       6.3       13.5     12.0      15.7                 -0.5         10.5
DIP BEARING 148.4 DEG          TILT/MILE 0.97 FEET


TIME   1045
PRESSURE     29.889     30.551     30.364     30.484     30.397
TEMP DRY       62.0       66.0       60.0       68.0        0.0
SINGLE BASE ERRORS                                MULTIPLE BASE ERRORS
       1.8       15.6     12.1      17.7                  1.0         13.0
DIP BEARING 131.6 DEG          TILT/MILE 1.17 FEET


TIME   1100
PRESSURE     29.886     30.547     30.357     30.478     30.392
TEMP DRY       62.0       65.0       62.0       69.0        0.0
SINGLE BASE ERRORS                                MULTIPLE BASE ERRORS
       2.0       18.7     14.4      18.9                  1.0         13.3
DIP BEARING 131.3 DEG          TILT/MILE 1.41 FEET


TIME   1105
PRESSURE     29.886     30.546     30.357     30.479     30.387
TEMP DRY       62.0       65.0       62.0       70.0        0.0
SINGLE BASE ERRORS                                MULTIPLE BASE ERRORS
       2.7       18.5     13.1      23.3                 -0.5         17.5
DIP BEARING 133.1 DEG          TILT/MILE 1.38 FEET
```

```
 CITY TRAVERSE REDUCTION 26 MAY 1959 ASA

ST PAULS      LIVERPOOL     CENTENNIAL    BEVERLY HILL  RYDE

TIME   1110
PRESSURE     29.884     30.546     30.357     30.481     30.387
TEMP DRY       61.0       65.0       62.0       72.0         0.0
SINGLE BASE ERRORS                                MULTIPLE BASE ERRORS
       0.6      16.5       9.2      21.2                -1.8      16.5
DIP BEARING 128.2 DEG          TILT/MILE 1.26 FEET

TIME   1115
PRESSURE     29.882     30.544     30.358     30.481     30.390
TEMP DRY       62.0       65.0       62.0       72.0         0.0
SINGLE BASE ERRORS                                MULTIPLE BASE ERRORS
       0.2      13.5       7.1      16.5                -1.7      12.8
DIP BEARING 127.5 DEG          TILT/MILE 1.04 FEET

TIME   1130
PRESSURE     29.878     30.539     30.356     30.476     30.391
TEMP DRY       62.0       66.0       62.0       74.0         0.0
SINGLE BASE ERRORS                                MULTIPLE BASE ERRORS
       0.2      11.0       7.2      11.2                -0.0       8.1
DIP BEARING 127.7 DEG          TILT/MILE 0.84 FEET

TIME   1145
PRESSURE     29.875     30.537     30.356     30.476     30.392
TEMP DRY       62.0       67.0       62.0       75.0         0.0
SINGLE BASE ERRORS                                MULTIPLE BASE ERRORS
      -1.3       7.8       4.0       7.0                -0.3       5.2
DIP BEARING 120.2 DEG          TILT/MILE 0.64 FEET
```

```
 CITY TRAVERSE REDUCTION 26 MAY 1959 ASA
ST PAULS      LIVERPOOL     CENTENNIAL    BEVERLY HILL  RYDE

TIME   1200
PRESSURE     29.873     30.538     30.357     30.475     30.388
TEMP DRY       62.0       68.0       63.0       72.0        0.0
SINGLE BASE ERRORS                                MULTIPLE BASE ERRORS
      -3.8       5.3        3.2        9.2                  2.0         8.6
DIP BEARING 103.3 DEG              TILT/MILE 0.55 FEET


TIME   1205
PRESSURE     29.870     30.536     30.357     30.475     30.386
TEMP DRY       63.0       68.0       63.0       72.0        0.0
SINGLE BASE ERRORS                                MULTIPLE BASE ERRORS
      -5.1       2.4        0.2        8.0                  1.7         8.5
DIP BEARING  82.8 DEG              TILT/MILE 0.42 FEET


TIME   1210
PRESSURE     29.870     30.535     30.359     30.475     30.383
TEMP DRY       63.0       68.0       63.0       77.0        0.0
SINGLE BASE ERRORS                                MULTIPLE BASE ERRORS
      -5.5      -0.5       -1.1        9.5                  2.5        11.0
DIP BEARING  52.3 DEG              TILT/MILE 0.33 FEET


TIME   1215
PRESSURE     29.868     30.536     30.357     30.475     30.385
TEMP DRY       63.0       68.0       64.0       76.0        0.0
SINGLE BASE ERRORS                                MULTIPLE BASE ERRORS
      -8.4      -0.6       -3.0        5.8                  2.4         8.0
DIP BEARING  54.3 DEG              TILT/MILE 0.50 FEET
```

```
 CITY TRAVERSE REDUCTION 26 MAY 1959 ASA
ST PAULS      LIVERPOOL     CENTENNIAL    BEVERLY HILL  RYDE

TIME   1230
PRESSURE     29.864     30.535     30.356     30.471     30.381
TEMP DRY       63.0       69.0       62.0       72.0        0.0
SINGLE BASE ERRORS                                MULTIPLE BASE ERRORS
      -9.6       -2.3     -1.7       7.0                 5.5      10.0
DIP BEARING  41.0 DEG          TILT/MILE 0.55 FEET

TIME   1245
PRESSURE     29.860     30.534     30.354     30.465     30.382
TEMP DRY       63.0       69.0       62.0       76.0        0.0
SINGLE BASE ERRORS                                MULTIPLE BASE ERRORS
     -13.7       -5.1     -1.1       1.4                10.4       6.1
DIP BEARING  30.9 DEG          TILT/MILE 0.78 FEET

TIME   1300
PRESSURE     29.859     30.526     30.350     30.459     30.376
TEMP DRY       62.0       66.0       63.0       75.0        0.0
SINGLE BASE ERRORS                                MULTIPLE BASE ERRORS
      -6.2       -1.6      4.4       6.8                 9.2       8.7
DIP BEARING  40.3 DEG          TILT/MILE 0.35 FEET

TIME   1305
PRESSURE     29.857     30.525     30.351     30.457     30.376
TEMP DRY       62.0       67.0       63.0       76.0        0.0
SINGLE BASE ERRORS                                MULTIPLE BASE ERRORS
      -7.7       -4.7      4.0       4.5                11.6       7.7
DIP BEARING  13.8 DEG          TILT/MILE 0.47 FEET
```

```
 CITY TRAVERSE REDUCTION 26 MAY 1959 ASA
ST PAULS       LIVERPOOL      CENTENNIAL     BEVERLY HILL  RYDE


TIME    1310
PRESSURE       29.857        30.522       30.351       30.457       30.377
TEMP DRY         62.0          67.0         63.0         75.0          0.0
SINGLE BASE ERRORS                                        MULTIPLE BASE ERRORS
      -4.7         -4.5          4.3         3.9                10.0           6.3
DIP BEARING 175.6 DEG                  TILT/MILE 0.36 FEET


TIME    1315
PRESSURE       29.857        30.522       30.351       30.457       30.377
TEMP DRY         62.0          68.0         63.0         75.0          0.0
SINGLE BASE ERRORS                                        MULTIPLE BASE ERRORS
      -5.0         -4.7          4.0         3.7                10.1           6.2
DIP BEARING 176.1 DEG                  TILT/MILE 0.38 FEET


TIME    1330
PRESSURE       29.854        30.521       30.350       30.458       30.374
TEMP DRY         62.0          68.0         63.0         78.0          0.0
SINGLE BASE ERRORS                                        MULTIPLE BASE ERRORS
      -7.7         -7.3         -0.5         2.9                 8.8           6.7
DIP BEARING 175.5 DEG                  TILT/MILE 0.58 FEET


TIME    1345
PRESSURE       29.854        30.517       30.349       30.457       30.377
TEMP DRY         62.0          68.0         63.0         77.0          0.0
SINGLE BASE ERRORS                                        MULTIPLE BASE ERRORS
      -3.8         -6.1          0.7         0.5                 6.9           3.0
DIP BEARING 156.2 DEG                  TILT/MILE 0.44 FEET
```

```
 CITY TRAVERSE REDUCTION 26 MAY 1959 ASA
ST PAULS       LIVERPOOL      CENTENNIAL     BEVERLY HILL  RYDE

TIME   1400
PRESSURE      29.851     30.516     30.348     30.456     30.380
TEMP DRY        62.0       68.0       63.0       78.0        0.0
SINGLE BASE ERRORS                                  MULTIPLE BASE ERRORS
      -6.0      -8.1       -1.5       -5.3                   7.4       -1.6
DIP BEARING 161.9 DEG             TILT/MILE 0.60 FEET


TIME   1405
PRESSURE      29.851     30.516     30.346     30.457     30.379
TEMP DRY        64.0       68.0       63.0       78.0        0.0
SINGLE BASE ERRORS                                  MULTIPLE BASE ERRORS
      -6.6      -6.7       -2.8       -4.8                   5.5       -1.4
DIP BEARING 172.4 DEG             TILT/MILE 0.53 FEET


TIME   1410
PRESSURE      29.855     30.515     30.348     30.457     30.376
TEMP DRY        64.0       67.0       63.0       78.5        0.0
SINGLE BASE ERRORS                                  MULTIPLE BASE ERRORS
      -1.8      -4.7        1.0        1.7                   5.1        3.4
DIP BEARING 144.2 DEG             TILT/MILE 0.34 FEET


TIME   1415
PRESSURE      29.855     30.515     30.350     30.459     30.377
TEMP DRY        63.0       67.0       62.0       78.0        0.0
SINGLE BASE ERRORS                                  MULTIPLE BASE ERRORS
      -1.1      -6.1       -0.3        1.4                   4.3        3.3
DIP BEARING 134.4 DEG             TILT/MILE 0.45 FEET
```

```
CITY TRAVERSE REDUCTION 26 MAY 1959 ASA

ST PAULS       LIVERPOOL     CENTENNIAL    BEVERLY HILL  RYDE

TIME    1430
PRESSURE        29.862       30.513        30.351        30.459       30.384
TEMP DRY          62.0         66.0          62.0          77.0          0.0
SINGLE BASE  ERRORS                                            MULTIPLE BASE  ERRORS
       8.1         0.2          7.0           2.1                        2.0         0.2
DIP BEARING     57.6 DEG                 TILT/MILE 0.49 FEET

TIME    1445
PRESSURE        29.864       30.514        30.351        30.459       30.384
TEMP DRY          63.0         66.0          62.0          79.0          0.0
SINGLE BASE  ERRORS                                            MULTIPLE BASE  ERRORS
       8.2         1.4          8.0           3.3                        2.2         1.0
DIP BEARING     47.0 DEG                 TILT/MILE 0.48 FEET

TIME    1500
PRESSURE        29.867       30.513        30.350        30.458       30.381
TEMP DRY          65.0         66.0          62.0          70.0          0.0
SINGLE BASE  ERRORS                                            MULTIPLE BASE  ERRORS
      13.8         6.4         13.6          10.4                        1.2         5.4
DIP BEARING     23.9 DEG                 TILT/MILE 0.80 FEET

TIME    1505
PRESSURE        29.869       30.514        30.348        30.459       30.380
TEMP DRY          64.0         66.0          62.0          70.0          0.0
SINGLE BASE  ERRORS                                            MULTIPLE BASE  ERRORS
      15.1        10.4         14.7          13.3                       -1.1         6.9
DIP BEARING      8.6 DEG                 TILT/MILE 0.97 FEET
```

```
CITY TRAVERSE REDUCTION 26 MAY 1959 ASA

ST PAULS        LIVERPOOL      CENTENNIAL     BEVERLY HILL  RYDE

TIME    1510
PRESSURE      29.869      30.516      30.349      30.461      30.382
TEMP DRY        64.0        66.0        62.0        75.0         0.0
SINGLE BASE ERRORS                                   MULTIPLE BASE ERRORS
     11.7        8.4        11.6        10.4              -0.9          5.3
DIP BEARING    7.1 DEG              TILT/MILE 0.77 FEET


TIME    1515
PRESSURE      29.870      30.516      30.348      30.461      30.380
TEMP DRY        64.0        65.5        62.0        72.0         0.0
SINGLE BASE ERRORS                                   MULTIPLE BASE ERRORS
     13.6       11.0        13.4        13.9              -1.9          7.6
DIP BEARING    2.0 DEG              TILT/MILE 0.94 FEET


TIME    1530
PRESSURE      29.872      30.515      30.348      30.460      30.380
TEMP DRY        63.0        63.0        61.0        72.0         0.0
SINGLE BASE ERRORS                                   MULTIPLE BASE ERRORS
     17.7       13.8        17.4        16.8              -2.1          8.7
DIP BEARING    3.5 DEG              TILT/MILE 1.20 FEET


TIME    1545
PRESSURE      29.873      30.515      30.347      30.457      30.380
TEMP DRY        62.0        64.0        62.0        71.0         0.0
SINGLE BASE ERRORS                                   MULTIPLE BASE ERRORS
     18.6       15.5        21.1        17.7              -0.1          8.9
DIP BEARING    0.6 DEG              TILT/MILE 1.31 FEET
```

```
 CITY TRAVERSE REDUCTION 26 MAY 1959 ASA
ST PAULS       LIVERPOOL      CENTENNIAL     BEVERLY HILL  RYDE

TIME    1600
PRESSURE       29.870       30.518       30.346       30.457       30.378
TEMP DRY         61.0        64.0          61.0         68.0          0.0
SINGLE BASE  ERRORS                                          MULTIPLE BASE  ERRORS
     14.5         14.8        19.6          17.8                      1.3          10.3
DIP BEARING  172.3 DEG                  TILT/MILE 1.16 FEET


TIME    1605
PRESSURE       29.870       30.517       30.346       30.457       30.377
TEMP DRY         61.0        64.0          61.0         66.0          0.0
SINGLE BASE  ERRORS                                          MULTIPLE BASE  ERRORS
     16.0         15.2        20.1          19.2                      0.7          11.2
DIP BEARING  175.2 DEG                  TILT/MILE 1.22 FEET


TIME    1610
PRESSURE       29.870       30.516       30.344       30.458       30.377
TEMP DRY         62.0        63.0          60.0         66.0          0.0
SINGLE BASE  ERRORS                                          MULTIPLE BASE  ERRORS
     17.1         17.2        19.4          19.4                     -2.0          10.6
DIP BEARING  173.1 DEG                  TILT/MILE 1.35 FEET


TIME    1615
PRESSURE       29.870       30.517       30.342       30.456       30.377
TEMP DRY         61.0        63.0          60.0         66.0          0.0
SINGLE BASE  ERRORS                                          MULTIPLE BASE  ERRORS
     16.6         19.2        21.4          19.7                     -0.9          10.4
DIP BEARING  167.3 DEG                  TILT/MILE 1.45 FEET
```

```
 CITY TRAVERSE REDUCTION 26 MAY 1959 ASA
ST PAULS       LIVERPOOL     CENTENNIAL    BEVERLY HILL  RYDE

TIME   1630
PRESSURE      29.870       30.515      30.340      30.455      30.374
TEMP DRY        59.0         62.0        60.0        64.0         0.0
SINGLE BASE  ERRORS                                    MULTIPLE BASE  ERRORS
      19.8       22.0       23.7        23.4                 -2.4         12.6
DIP BEARING  168.8 DEG             TILT/MILE 1.68 FEET

TIME   1645
PRESSURE      29.871       30.516      30.337      30.457      30.374
TEMP DRY        58.0         60.5        60.0        65.0         0.0
SINGLE BASE  ERRORS                                    MULTIPLE BASE  ERRORS
      20.2       26.0       23.2        24.6                 -5.7         12.6
DIP BEARING  163.3 DEG             TILT/MILE 1.92 FEET

TIME   1700
PRESSURE      29.868       30.517      30.334      30.457      30.374
TEMP DRY        56.0         59.7        59.0        64.0         0.0
SINGLE BASE  ERRORS                                    MULTIPLE BASE  ERRORS
      18.0       26.8       21.7        22.9                 -6.4         11.3
DIP BEARING  158.3 DEG             TILT/MILE 1.95 FEET
```

```
CITY TRAVERSE REDUCTION 28 MAY 1959 ASA

 PRESSURES IN INCHES
 TEMPERATURES IN FARENHEIT
 COORDINATES IN YARDS

CONSTANT 1 143831.81
CONSTANT 2    0.18910

 STATION            X          Y       HEIGHT
ST PAULS         833900.    411100.   663.00
LIVERPOOL        809100.    392600.    60.00
CENTENNIAL       812900.    423800.   215.00
BEVERLY HILL     805500.    408300.   110.00
RYDE             822200.    410200.   183.00

TIME     900
PRESSURE       29.787      30.443      30.256      30.385      30.306
TEMP DRY         57.0         0.0        64.0        60.0         0.0
SINGLE BASE ERRORS                                    MULTIPLE BASE ERRORS
       9.1       22.3      11.1         9.3              -8.7          0.9
DIP BEARING 145.5 DEG          TILT/MILE 1.60 FEET


TIME     905
PRESSURE       29.787      30.443      30.256      30.384      30.305
TEMP DRY         57.0         0.0        64.0        60.0         0.0
SINGLE BASE ERRORS                                    MULTIPLE BASE ERRORS
       9.1       22.3      12.1        10.1              -7.8          1.8
DIP BEARING 145.5 DEG          TILT/MILE 1.60 FEET


TIME     910
PRESSURE       29.788      30.441      30.258      30.385      30.305
TEMP DRY         57.0         0.0        64.0        61.0         0.0
SINGLE BASE ERRORS                                    MULTIPLE BASE ERRORS
      11.4       21.2      11.7        10.7              -8.8          2.2
DIP BEARING 152.0 DEG          TILT/MILE 1.52 FEET
```

```
  CITY TRAVERSE REDUCTION 28 MAY 1959 ASA
 ST PAULS      LIVERPOOL     CENTENNIAL     BEVERLY HILL  RYDE

TIME     915
PRESSURE       29.788      30.442      30.259      30.385      30.304
TEMP DRY         57.0        56.0        64.0       61.0          0.0
SINGLE BASE ERRORS                                    MULTIPLE BASE ERRORS
      12.2       21.4        13.2        12.9              -8.0          4.1
DIP BEARING 153.5 DEG              TILT/MILE 1.54 FEET


TIME     930
PRESSURE       29.790      30.443      30.265      30.387      30.308
TEMP DRY         57.0        56.0        59.0       62.0          0.0
SINGLE BASE ERRORS                                    MULTIPLE BASE ERRORS
      14.2       18.7        14.3        12.1              -6.3          3.6
DIP BEARING 162.6 DEG              TILT/MILE 1.38 FEET


TIME     945
PRESSURE       29.790      30.446      30.266      30.385      30.310
TEMP DRY         57.0        59.0        56.0       62.0          0.0
SINGLE BASE ERRORS                                    MULTIPLE BASE ERRORS
      11.5       17.7        16.0        10.3              -2.3          2.7
DIP BEARING 157.2 DEG              TILT/MILE 1.29 FEET


TIME    1000
PRESSURE       29.788      30.441      30.265      30.385      30.302
TEMP DRY         57.0        59.5        56.0       64.0          0.0
SINGLE BASE ERRORS                                    MULTIPLE BASE ERRORS
      13.4       16.3        13.6        15.1              -5.0          7.4
DIP BEARING 165.4 DEG              TILT/MILE 1.22 FEET
```

```
 CITY TRAVERSE REDUCTION 28 MAY 1959 ASA
ST PAULS      LIVERPOOL     CENTENNIAL    BEVERLY HILL  RYDE

TIME   1005
PRESSURE     29.788     30.441     30.264     30.388     30.299
TEMP DRY        0.0        0.0       56.0       64.0        0.0
SINGLE BASE ERRORS
      12.8      16.7      10.4      17.3          MULTIPLE BASE ERRORS
DIP BEARING 162.9 DEG                                   -8.1          9.7
                               TILT/MILE 1.24 FEET

TIME   1010
PRESSURE     29.787     30.441     30.265     30.390     30.299
TEMP DRY        0.0        0.0       57.0       65.0        0.0
SINGLE BASE ERRORS
      10.8      14.2       6.7      15.5          MULTIPLE BASE ERRORS
DIP BEARING 162.7 DEG                                   -8.9          9.0
                               TILT/MILE 1.05 FEET

TIME   1015
PRESSURE     29.784     30.443     30.264     30.390     30.298
TEMP DRY        0.0       62.0       58.0       66.0        0.0
SINGLE BASE ERRORS
       5.3      11.5       3.0      12.8          MULTIPLE BASE ERRORS
DIP BEARING 148.0 DEG                                   -7.6          8.4
                               TILT/MILE 0.83 FEET

TIME   1030
PRESSURE     29.779     30.439     30.260     30.379     30.296
TEMP DRY        0.0       63.0       59.0       68.0        0.0
SINGLE BASE ERRORS
       2.7       9.5       6.9       8.9          MULTIPLE BASE ERRORS
DIP BEARING 139.6 DEG                                   -0.9          5.7
                               TILT/MILE 0.69 FEET
```

```
 CITY TRAVERSE REDUCTION 28 MAY 1959 ASA

ST PAULS      LIVERPOOL     CENTENNIAL    BEVERLY HILL  RYDE

TIME   1045
PRESSURE     29.776     30.435     30.258     30.373     30.294
TEMP DRY        0.0       65.0       59.0       71.0        0.0
SINGLE BASE ERRORS                                MULTIPLE BASE ERRORS
       1.6       7.1       7.8       6.5                 2.2       4.1
DIP BEARING 136.7 DEG          TILT/MILE 0.52 FEET


TIME   1100
PRESSURE     29.768     30.424     30.253     30.367     30.288
TEMP DRY        0.0       66.0       60.0       73.0        0.0
SINGLE BASE ERRORS                                MULTIPLE BASE ERRORS
       2.6       3.2       4.4       3.3                 0.8       1.8
DIP BEARING 165.9 DEG          TILT/MILE 0.24 FEET


TIME   1105
PRESSURE     29.765     30.422     30.252     30.365     30.286
TEMP DRY        0.0        0.0       60.0       73.0        0.0
SINGLE BASE ERRORS                                MULTIPLE BASE ERRORS
       1.4       1.0       3.1       2.0                 1.7       1.4
DIP BEARING   5.9 DEG          TILT/MILE 0.09 FEET


TIME   1110
PRESSURE     29.762     30.419     30.251     30.363     30.283
TEMP DRY        0.0        0.0       60.0       72.0        0.0
SINGLE BASE ERRORS                                MULTIPLE BASE ERRORS
       1.9      -0.4       2.7       2.5                 1.8       2.1
DIP BEARING  71.0 DEG          TILT/MILE 0.13 FEET
```

```
 CITY TRAVERSE REDUCTION 28 MAY 1959 ASA
ST PAULS       LIVERPOOL     CENTENNIAL    BEVERLY HILL  RYDE

TIME    1115
PRESSURE        29.760        30.416        30.247        30.357        30.280
TEMP DRY           0.0          67.0          60.0          72.0           0.0
SINGLE BASE ERRORS                                               MULTIPLE BASE ERRORS
       2.6         1.2           6.1           3.1                         3.8           2.1
DIP BEARING  24.6 DEG                    TILT/MILE 0.15 FEET


TIME    1130
PRESSURE        29.751        30.403        30.235        30.352        30.270
TEMP DRY           0.0          66.0          61.0          67.0           0.0
SINGLE BASE ERRORS                                               MULTIPLE BASE ERRORS
       7.9         5.2           4.0           5.4                        -4.1           2.1
DIP BEARING  10.7 DEG                    TILT/MILE 0.50 FEET


TIME    1145
PRESSURE        29.737        30.394        30.228        30.342        30.256
TEMP DRY           0.0          66.0          61.0          70.0           0.0
SINGLE BASE ERRORS                                               MULTIPLE BASE ERRORS
       1.9        -2.2          -0.9           4.3                        -0.6           4.5
DIP BEARING 100.2 DEG                    TILT/MILE 0.24 FEET


TIME    1200
PRESSURE        29.727        30.389        30.221        30.335        30.248
TEMP DRY           0.0           0.0          62.0          65.0           0.0
SINGLE BASE ERRORS                                               MULTIPLE BASE ERRORS
      -0.4        -3.3          -1.6           4.3                         0.8           5.3
DIP BEARING 132.6 DEG                    TILT/MILE 0.25 FEET
```

```
 CITY TRAVERSE REDUCTION 28 MAY 1959 ASA

ST PAULS        LIVERPOOL      CENTENNIAL     BEVERLY HILL  RYDE

TIME    1205
PRESSURE      29.725        30.387       30.219       30.334       30.244
TEMP DRY         0.0           0.0         62.0        66.0           0.0
SINGLE BASE  ERRORS                                        MULTIPLE BASE  ERRORS
       -1.1      -3.8         -3.1          5.5                 -0.0           6.8
DIP BEARING  139.6 DEG                TILT/MILE 0.28 FEET


TIME    1210
PRESSURE      29.723        30.384       30.216       30.330       30.239
TEMP DRY         0.0           0.0         62.0        66.0           0.0
SINGLE BASE  ERRORS                                        MULTIPLE BASE  ERRORS
       -0.2      -2.9         -1.2          8.3                  0.7           9.1
DIP BEARING  129.2 DEG                TILT/MILE 0.22 FEET


TIME    1215
PRESSURE      29.719        30.380       30.215       30.327       30.237
TEMP DRY         0.0           0.0         62.0        65.0           0.0
SINGLE BASE  ERRORS                                        MULTIPLE BASE  ERRORS
        0.3      -5.3         -1.8          6.8                  1.5           8.2
DIP BEARING  124.3 DEG                TILT/MILE 0.42 FEET


TIME    1230
PRESSURE      29.709        30.375       30.206       30.317       30.229
TEMP DRY         0.0           0.0         63.0        66.0           0.0
SINGLE BASE  ERRORS                                        MULTIPLE BASE  ERRORS
       -5.5      -7.1         -3.0          3.9                  4.9           7.1
DIP BEARING  163.3 DEG                TILT/MILE 0.53 FEET
```

```
 CITY TRAVERSE REDUCTION 28 MAY 1959 ASA
ST PAULS      LIVERPOOL     CENTENNIAL    BEVERLY HILL  RYDE

TIME   1245
PRESSURE     29.702     30.366     30.200     30.308     30.220
TEMP DRY        0.0        0.0       65.0       67.0        0.0
SINGLE BASE ERRORS                                MULTIPLE BASE ERRORS
      -5.6      -9.5      -2.9       4.3                 6.6       8.3
DIP BEARING 154.4 DEG          TILT/MILE 0.68 FEET


TIME   1300
PRESSURE     29.699     30.360     30.193     30.303     30.214
TEMP DRY        0.0        0.0       64.0       68.0        0.0
SINGLE BASE ERRORS                                MULTIPLE BASE ERRORS
      -3.0      -5.9      -1.1       6.9                 4.5       9.3
DIP BEARING 150.2 DEG          TILT/MILE 0.42 FEET


TIME   1305
PRESSURE     29.695     30.355     30.191     30.302     30.212
TEMP DRY        0.0        0.0       64.0       68.2        0.0
SINGLE BASE ERRORS                                MULTIPLE BASE ERRORS
      -2.2      -7.9      -4.1       4.9                 2.4       7.7
DIP BEARING 139.4 DEG          TILT/MILE 0.57 FEET


TIME   1310
PRESSURE     29.694     30.355     30.186     30.302     30.209
TEMP DRY        0.0        0.0       64.0       68.0        0.0
SINGLE BASE ERRORS                                MULTIPLE BASE ERRORS
      -3.0      -4.2      -4.9       6.9                -0.4       8.7
DIP BEARING 161.1 DEG          TILT/MILE 0.31 FEET
```

```
CITY TRAVERSE REDUCTION 28 MAY 1959 ASA
ST PAULS      LIVERPOOL      CENTENNIAL     BEVERLY HILL  RYDE

TIME   1315
PRESSURE     29.692     30.354     30.185     30.301     30.207
TEMP DRY        0.0        0.0       64.0       68.0        0.0
SINGLE BASE ERRORS                                MULTIPLE BASE ERRORS
      -4.1      -5.1      -5.8       6.8                -0.1       9.2
DIP BEARING 164.6 DEG         TILT/MILE 0.38 FEET

TIME   1330
PRESSURE     29.685     30.345     30.175     30.280     30.202
TEMP DRY        0.0       69.0       64.0       68.0        0.0
SINGLE BASE ERRORS                                MULTIPLE BASE ERRORS
      -3.4      -3.2       5.8       4.1                 9.9       5.8
DIP BEARING 176.2 DEG         TILT/MILE 0.26 FEET

TIME   1345
PRESSURE     29.678     30.339     30.174     30.278     30.192
TEMP DRY        0.0       70.0       63.0       67.8        0.0
SINGLE BASE ERRORS                                MULTIPLE BASE ERRORS
      -4.3      -8.8       1.3       6.8                 9.5      10.3
DIP BEARING 149.5 DEG         TILT/MILE 0.63 FEET

TIME   1400
PRESSURE     29.674     30.337     30.171     30.285     30.190
TEMP DRY        0.0        0.0       65.0       67.0        0.0
SINGLE BASE ERRORS                                MULTIPLE BASE ERRORS
      -5.2      -9.0      -7.9       5.7                 1.0       9.4
DIP BEARING 154.1 DEG         TILT/MILE 0.65 FEET
```

```
 CITY TRAVERSE REDUCTION 28 MAY 1959 ASA

ST PAULS      LIVERPOOL     CENTENNIAL    BEVERLY HILL  RYDE

TIME   1405
PRESSURE     29.676     30.336     30.169     30.285    30.188
TEMP DRY        0.0        0.0       64.0       67.0       0.0
SINGLE BASE ERRORS                                MULTIPLE BASE ERRORS
      -2.0      -4.9      -5.5       9.8               -1.2      11.6
DIP BEARING 145.3 DEG          TILT/MILE 0.35 FEET


TIME   1410
PRESSURE     29.676     30.332     30.169     30.283    30.189
TEMP DRY        0.0        0.0       63.0       66.0       0.0
SINGLE BASE ERRORS                                MULTIPLE BASE ERRORS
       2.9      -4.0      -2.7       9.8               -1.8      10.3
DIP BEARING 103.2 DEG          TILT/MILE 0.41 FEET


TIME   1415
PRESSURE     29.673     30.332     30.168     30.280    30.187
TEMP DRY        0.0       67.0       62.0       65.0       0.0
SINGLE BASE ERRORS                                MULTIPLE BASE ERRORS
       0.1      -5.9      -2.9       8.8                0.9      10.4
DIP BEARING 126.2 DEG          TILT/MILE 0.46 FEET


TIME   1430
PRESSURE     29.674     30.330     30.166     30.278    30.185
TEMP DRY        0.0       68.0       62.0       64.8       0.0
SINGLE BASE ERRORS                                MULTIPLE BASE ERRORS
       2.5      -3.4      -0.3      11.3                0.4      11.6
DIP BEARING 102.9 DEG          TILT/MILE 0.35 FEET
```

```
 CITY TRAVERSE REDUCTION 28 MAY 1959 ASA
ST PAULS      LIVERPOOL     CENTENNIAL    BEVERLY HILL  RYDE

TIME   1445
PRESSURE     29.674     30.333     30.167     30.281     30.185
TEMP DRY        0.0       68.0       61.0       67.0        0.0
SINGLE BASE ERRORS                                MULTIPLE BASE ERRORS
      -0.7      -4.7      -3.5      10.9                 0.0       12.4
DIP BEARING 133.5 DEG          TILT/MILE 0.35 FEET

TIME   1500
PRESSURE     29.678     30.335     30.165     30.284     30.192
TEMP DRY       66.0       66.0       61.0       66.8        0.0
SINGLE BASE ERRORS                                MULTIPLE BASE ERRORS
       1.1       0.8      -2.7       8.2                -3.8       7.7
DIP BEARING   2.5 DEG          TILT/MILE 0.07 FEET

TIME   1505
PRESSURE     29.680     30.335     30.165     30.284     30.192
TEMP DRY       66.0        0.0       61.0       67.0        0.0
SINGLE BASE ERRORS                                MULTIPLE BASE ERRORS
       3.0       2.7      -0.8      10.1                -4.3       8.6
DIP BEARING 176.3 DEG          TILT/MILE 0.22 FEET

TIME   1510
PRESSURE     29.681     30.334     30.165     30.283     30.193
TEMP DRY       64.0        0.0       61.0       66.0        0.0
SINGLE BASE ERRORS                                MULTIPLE BASE ERRORS
       5.9       4.5       2.2      10.9                -4.2       8.3
DIP BEARING   4.1 DEG          TILT/MILE 0.40 FEET
```

```
 CITY TRAVERSE REDUCTION 28 MAY 1959 ASA

ST PAULS      LIVERPOOL     CENTENNIAL    BEVERLY HILL  RYDE

TIME   1515
PRESSURE     29.681     30.335     30.165     30.281     30.193
TEMP DRY       64.0        0.0       61.0        65.8       0.0
SINGLE BASE ERRORS                                MULTIPLE BASE ERRORS
       5.1       4.6       4.1      11.0                -1.9       8.5
DIP BEARING 177.7 DEG          TILT/MILE 0.37 FEET


TIME   1530
PRESSURE     29.681     30.332     30.166     30.281     30.194
TEMP DRY       60.0       63.0       63.5        65.8       0.0
SINGLE BASE ERRORS                                MULTIPLE BASE ERRORS
       8.7       4.2       4.9      10.8                -3.1       7.6
DIP BEARING  22.4 DEG          TILT/MILE 0.51 FEET


TIME   1545
PRESSURE     29.686     30.333     30.167     30.281     30.196
TEMP DRY       61.0       64.0       60.0         0.0       0.0
SINGLE BASE ERRORS                                MULTIPLE BASE ERRORS
      13.8       8.9      10.7      14.6                -3.3       8.9
DIP BEARING  11.3 DEG          TILT/MILE 0.87 FEET


TIME   1600
PRESSURE     29.685     30.332     30.165     30.288     30.199
TEMP DRY       60.0       61.0       60.0         0.0       0.0
SINGLE BASE ERRORS                                MULTIPLE BASE ERRORS
      15.3      11.1       4.9      12.3               -11.4       5.6
DIP BEARING   6.8 DEG          TILT/MILE 1.01 FEET
```

```
 CITY TRAVERSE REDUCTION 28 MAY 1959 ASA

ST PAULS      LIVERPOOL     CENTENNIAL    BEVERLY HILL  RYDE


TIME   1605
PRESSURE     29.683       30.334      30.163      30.283      30.200
TEMP DRY       60.0          0.0        60.0        0.0         0.0
SINGLE BASE  ERRORS                                    MULTIPLE BASE  ERRORS
       11.4       10.9        7.5         9.4                 -6.4           3.6
DIP BEARING  175.0 DEG               TILT/MILE 0.87 FEET


TIME   1610
PRESSURE     29.686       30.333      30.162      30.286      30.200
TEMP DRY       60.0          0.0        60.0        0.0         0.0
SINGLE BASE  ERRORS                                    MULTIPLE BASE  ERRORS
       15.2       14.5        7.5        12.1                -10.9           4.5
DIP BEARING  174.9 DEG               TILT/MILE 1.16 FEET


TIME   1615
PRESSURE     29.686       30.331      30.159      30.288      30.200
TEMP DRY       58.0         60.0        60.0        0.0         0.0
SINGLE BASE  ERRORS                                    MULTIPLE BASE  ERRORS
       18.2       18.2        6.9        13.1                -15.8           3.8
DIP BEARING  173.1 DEG               TILT/MILE 1.43 FEET


TIME   1630
PRESSURE     29.685       30.327      30.156      30.290      30.198
TEMP DRY       57.0         59.0        59.0        0.0         0.0
SINGLE BASE  ERRORS                                    MULTIPLE BASE  ERRORS
       22.0       20.8        5.2        14.9                -21.4           3.9
DIP BEARING  175.3 DEG               TILT/MILE 1.67 FEET
```

```
 CITY TRAVERSE REDUCTION 28 MAY 1959 ASA

ST PAULS      LIVERPOOL     CENTENNIAL    BEVERLY HILL  RYDE

TIME   1645
PRESSURE     29.683     30.327     30.156     30.291     30.198
TEMP DRY       56.0       58.0       58.0        0.0        0.0
SINGLE BASE ERRORS                                MULTIPLE BASE ERRORS
      21.3      19.8       3.5      14.0               -22.0       3.4
DIP BEARING 176.0 DEG          TILT/MILE 1.60 FEET

TIME   1700
PRESSURE     29.679     30.329     30.153     30.292     30.195
TEMP DRY       56.0       59.0       57.0        0.0        0.0
SINGLE BASE ERRORS                                MULTIPLE BASE ERRORS
      15.8      18.7      -1.0      13.0               -22.6       4.1
DIP BEARING 166.4 DEG          TILT/MILE 1.41 FEET
```

```
 REDUCTION OF FIELD READINGS COOTAMUNDRA 28/2/66 ASA

 PRESSURES IN MILLIBARS
 TEMPERATURES IN CENTIGRADE
 COORDINATES IN YARDS

CONSTANT 1 143831.81
CONSTANT 2   0.18910

 STATION           X          Y       HEIGHT
HAREFIELD      682000.    551500.    833.00
QUANDIALLA     798000.    581500.    817.00
PETTITS        681500.    616000.    797.00
YEO YEO        738000.    596500.   1124.00
                    0.         0.      0.0

TIME    930
PRESSURE       982.56     983.35     984.82     973.29
TEMP DRY         25.0       25.5       24.5       24.5
TEMP WET         18.4       22.1       18.6        0.0
SINGLE BASE ERRORS                                  MULTIPLE BASE ERRORS
        -6.8      -29.2      -22.2                         -5.1
DIP BEARING  97.3 DEG             TILT/MILE 0.80 FEET

TIME    945
PRESSURE       982.41     982.87     984.77     973.32
TEMP DRY         25.4       27.5       25.0       24.5
TEMP WET         18.0       22.5       18.9        0.0
SINGLE BASE ERRORS                                  MULTIPLE BASE ERRORS
         2.7      -32.3      -26.8                        -12.9
DIP BEARING 107.0 DEG             TILT/MILE 0.92 FEET

TIME   1000
PRESSURE       982.66     982.85     984.75     973.47
TEMP DRY         25.3       27.2       25.0       25.0
TEMP WET         18.0       21.5       19.5        0.0
SINGLE BASE ERRORS                                  MULTIPLE BASE ERRORS
        10.5      -24.5      -23.9                        -17.5
DIP BEARING 116.5 DEG             TILT/MILE 0.74 FEET
```

```
  REDUCTION OF FIELD READINGS COOTAMUNDRA 28/2/66 ASA
HAREFIELD       QUANDIALLA     PETTITS        YEO YEO

TIME   1005
PRESSURE        982.39       982.83      984.75      973.44
TEMP DRY          26.8         27.7        25.3        24.5
TEMP WET          18.7         22.1        19.9         0.0
SINGLE BASE ERRORS                                         MULTIPLE BASE ERRORS
      3.2       -32.4        -30.4                            -16.7
DIP BEARING 107.5 DEG                 TILT/MILE 0.92 FEET

TIME   1010
PRESSURE        982.78       982.81      984.74      973.24
TEMP DRY          27.3         27.9        25.6        25.6
TEMP WET          18.8         22.5        20.3         0.0
SINGLE BASE ERRORS                                         MULTIPLE BASE ERRORS
     15.1       -20.9        -12.7                            -10.2
DIP BEARING 123.5 DEG                 TILT/MILE 0.68 FEET

TIME   1015
PRESSURE        982.80       982.80      984.74      973.22
TEMP DRY          27.4         28.2        25.8        26.1
TEMP WET          18.9         23.5        20.7         0.0
SINGLE BASE ERRORS                                         MULTIPLE BASE ERRORS
     16.0       -20.4        -11.2                             -9.4
DIP BEARING 124.9 DEG                 TILT/MILE 0.67 FEET

TIME   1030
PRESSURE        982.77       982.71      984.67      973.07
TEMP DRY          27.7         27.5        25.2        25.6
TEMP WET          18.9         22.5        21.6         0.0
SINGLE BASE ERRORS                                         MULTIPLE BASE ERRORS
     17.7       -19.2         -8.1                             -7.6
DIP BEARING 127.8 DEG                 TILT/MILE 0.66 FEET
```

```
  REDUCTION OF FIELD READINGS COOTAMUNDRA 28/2/66 ASA
HAREFIELD      QUANDIALLA    PETTITS        YEO YEO

TIME   1045
PRESSURE      982.68      982.67      984.63      973.17
TEMP DRY        26.3        28.0        28.0        26.6
TEMP WET        18.0        23.5        20.8         0.0
SINGLE BASE  ERRORS                                    MULTIPLE BASE ERRORS
     16.3      -20.7       -13.0                               -11.1
DIP BEARING 124.9 DEG              TILT/MILE 0.69 FEET

TIME   1100
PRESSURE      982.45      982.59      984.48      973.09
TEMP DRY        28.3        28.5        28.0        26.6
TEMP WET        18.8        23.1        23.1         0.0
SINGLE BASE  ERRORS                                    MULTIPLE BASE ERRORS
     11.9      -23.2       -16.6                               -11.4
DIP BEARING 118.6 DEG              TILT/MILE 0.72 FEET

TIME   1105
PRESSURE      982.28      982.52      984.42      973.01
TEMP DRY        27.7        27.9        28.3        27.2
TEMP WET        18.3        22.2        23.1         0.0
SINGLE BASE  ERRORS                                    MULTIPLE BASE ERRORS
      9.0      -26.4       -19.3                               -11.2
DIP BEARING 114.2 DEG              TILT/MILE 0.79 FEET

TIME   1110
PRESSURE      982.35      982.47      984.36      972.96
TEMP DRY        28.4        28.0        28.6        27.8
TEMP WET        18.5        22.2        23.1         0.0
SINGLE BASE  ERRORS                                    MULTIPLE BASE ERRORS
     12.5      -22.7       -15.4                               -10.7
DIP BEARING 119.5 DEG              TILT/MILE 0.71 FEET
```

```
  REDUCTION OF FIELD READINGS COOTAMUNDRA 28/2/66 ASA
HAREFIELD      QUANDIALLA     PETTITS       YEO YEO

TIME    1115
PRESSURE        982.19      982.41      984.30      972.94
TEMP DRY          26.8        28.0        28.9        27.2
TEMP WET          17.6        22.5        23.1         0.0
SINGLE BASE ERRORS                                        MULTIPLE BASE ERRORS
       9.6       -25.5       -20.0                             -12.5
DIP BEARING 115.1 DEG                TILT/MILE 0.77 FEET

TIME    1130
PRESSURE        982.34      982.49      984.30      972.94
TEMP DRY          29.3        27.9        29.5        27.8
TEMP WET          19.1        22.2        22.8         0.0
SINGLE BASE ERRORS                                        MULTIPLE BASE ERRORS
      11.6       -21.3       -14.7                             -10.3
DIP BEARING 119.4 DEG                TILT/MILE 0.66 FEET

TIME    1145
PRESSURE        982.18      982.48      984.20      972.92
TEMP DRY          30.0        29.7        27.5        27.8
TEMP WET          19.3        23.7        18.9         0.0
SINGLE BASE ERRORS                                        MULTIPLE BASE ERRORS
       7.2       -23.1       -18.8                             -11.4
DIP BEARING 113.4 DEG                TILT/MILE 0.68 FEET

TIME    1200
PRESSURE        982.15      982.45      984.23      972.89
TEMP DRY          31.5        31.0        29.0        27.8
TEMP WET          20.3        24.5        19.6         0.0
SINGLE BASE ERRORS                                        MULTIPLE BASE ERRORS
       7.2       -25.1       -17.8                              -9.4
DIP BEARING 112.7 DEG                TILT/MILE 0.74 FEET
```

```
  REDUCTION OF FIELD READINGS COOTAMUNDRA 28/2/66 ASA
HAREFIELD      QUANDIALLA    PETTITS       YEO YEO

TIME    1205
PRESSURE       982.13      982.32      984.26      972.82
TEMP DRY         30.0        30.2        29.0        27.8
TEMP WET         19.0        23.8        20.0         0.0
SINGLE BASE ERRORS                                    MULTIPLE BASE ERRORS
       10.4       -26.4      -16.9                          -9.4
DIP BEARING 115.6 DEG                TILT/MILE 0.80 FEET

TIME    1210
PRESSURE       982.12      982.30      984.17      972.89
TEMP DRY         30.8        30.2        29.5        28.4
TEMP WET         19.7        23.5        19.8         0.0
SINGLE BASE ERRORS                                    MULTIPLE BASE ERRORS
       10.7       -24.2      -18.8                         -12.6
DIP BEARING 116.8 DEG                TILT/MILE 0.74 FEET

TIME    1215
PRESSURE       982.01      982.27      984.11      972.92
TEMP DRY         30.4        29.5        29.7        28.4
TEMP WET         19.3        23.7        19.7         0.0
SINGLE BASE ERRORS                                    MULTIPLE BASE ERRORS
        8.4       -25.6      -23.1                         -15.1
DIP BEARING 113.8 DEG                TILT/MILE 0.76 FEET

TIME    1230
PRESSURE       981.84      982.08      983.91      972.55
TEMP DRY         28.8        30.0        30.0        29.4
TEMP WET         18.6        22.8        19.9         0.0
SINGLE BASE ERRORS                                    MULTIPLE BASE ERRORS
        9.0       -24.7      -17.1                          -9.8
DIP BEARING 114.7 DEG                TILT/MILE 0.74 FEET
```

```
  REDUCTION OF FIELD READINGS COOTAMUNDRA 28/2/66 ASA

HAREFIELD     QUANDIALLA    PETTITS       YEO YEO

TIME   1245
PRESSURE     981.66     981.92     983.73     972.46
TEMP DRY       30.7       29.8       30.7       30.0
TEMP WET       19.0       23.0       20.3        0.0
SINGLE BASE ERRORS                                MULTIPLE BASE ERRORS
       8.3     -24.9     -19.0                        -11.3
DIP BEARING 114.0 DEG          TILT/MILE 0.74 FEET

TIME   1300
PRESSURE     981.57     981.78     983.55     972.29
TEMP DRY       31.2       30.0       29.3       29.4
TEMP WET       20.1       22.2       19.4        0.0
SINGLE BASE ERRORS                                MULTIPLE BASE ERRORS
       9.8     -22.2     -16.9                        -11.2
DIP BEARING 116.8 DEG          TILT/MILE 0.68 FEET

TIME   1305
PRESSURE     981.44     981.48     983.45     972.06
TEMP DRY       31.0       30.5       31.3       29.4
TEMP WET       19.6       23.5       20.1        0.0
SINGLE BASE ERRORS                                MULTIPLE BASE ERRORS
      14.8     -23.2     -13.4                         -9.6
DIP BEARING 121.6 DEG          TILT/MILE 0.74 FEET

TIME   1310
PRESSURE     981.34     981.47     983.34     972.14
TEMP DRY       31.0       31.5       31.0       28.9
TEMP WET       19.7       24.0       19.9        0.0
SINGLE BASE ERRORS                                MULTIPLE BASE ERRORS
      12.2     -22.9     -18.7                        -13.7
DIP BEARING 119.0 DEG          TILT/MILE 0.71 FEET
```

```
  REDUCTION OF FIELD READINGS COOTAMUNDRA 28/2/66 ASA
HAREFIELD      QUANDIALLA     PETTITS        YEO YEO

TIME    1315
PRESSURE        981.27         981.47         983.28         972.17
TEMP DRY          31.8           31.9           29.3           29.4
TEMP WET          19.5           24.6           19.9            0.0
SINGLE BASE ERRORS                                             MULTIPLE BASE ERRORS
      10.1       -23.2          -21.6                                   -15.5
DIP BEARING 116.6 DEG                   TILT/MILE 0.71 FEET

TIME    1330
PRESSURE        981.14         981.56         983.04         971.72
TEMP DRY          32.0           32.1           30.2           30.0
TEMP WET          21.0           25.5           19.9            0.0
SINGLE BASE ERRORS                                             MULTIPLE BASE ERRORS
       3.6       -20.1          -11.4                                    -3.7
DIP BEARING 109.7 DEG                   TILT/MILE 0.58 FEET

TIME    1345
PRESSURE        980.87         981.37         982.91         971.94
TEMP DRY          32.6           32.0           30.0           29.4
TEMP WET          19.9           25.5           19.6            0.0
SINGLE BASE ERRORS                                             MULTIPLE BASE ERRORS
       1.2       -24.2          -26.1                                   -15.3
DIP BEARING 106.0 DEG                   TILT/MILE 0.69 FEET

TIME    1400
PRESSURE        980.74         981.29         982.69         971.69
TEMP DRY          32.3           31.3           31.0           30.0
TEMP WET          19.8           26.1           19.9            0.0
SINGLE BASE ERRORS                                             MULTIPLE BASE ERRORS
      -0.3       -21.6          -22.3                                   -12.0
DIP BEARING 104.1 DEG                   TILT/MILE 0.61 FEET
```

```
  REDUCTION OF FIELD READINGS COOTAMUNDRA 28/2/66 ASA
HAREFIELD     QUANDIALLA    PETTITS       YEO YEO

TIME   1405
PRESSURE     980.74     980.99     982.43     971.44
TEMP DRY       32.2       31.5       30.3       31.1
TEMP WET       20.0       25.2       19.2        0.0
SINGLE BASE ERRORS                                MULTIPLE BASE ERRORS
       8.6    -14.0     -14.8                         -12.4
DIP BEARING 121.1 DEG          TILT/MILE 0.44 FEET

TIME   1410
PRESSURE     980.78     981.04     982.32     971.29
TEMP DRY       32.3       32.1       30.5       30.0
TEMP WET       19.3       25.0       19.5        0.0
SINGLE BASE ERRORS                                MULTIPLE BASE ERRORS
       8.3     -9.5      -9.2                          -8.8
DIP BEARING 126.8 DEG          TILT/MILE 0.32 FEET

TIME   1415
PRESSURE     980.44     980.78     982.31     971.29
TEMP DRY       33.0       32.5       30.5       30.0
TEMP WET       19.8       25.1       19.0        0.0
SINGLE BASE ERRORS                                MULTIPLE BASE ERRORS
       5.9    -19.3     -19.1                         -12.8
DIP BEARING 113.3 DEG          TILT/MILE 0.57 FEET

TIME   1430
PRESSURE     980.35     980.59     982.14     971.07
TEMP DRY       32.9       33.1       32.2       30.6
TEMP WET       19.8       25.9       19.9        0.0
SINGLE BASE ERRORS                                MULTIPLE BASE ERRORS
       8.9    -17.1     -14.4                         -10.7
DIP BEARING 118.8 DEG          TILT/MILE 0.53 FEET
```

```
 REDUCTION OF FIELD READINGS COOTAMUNDRA 28/2/66 ASA
HAREFIELD     QUANDIALLA    PETTITS      YEO YEO


TIME   1445
PRESSURE      980.34       980.42      982.00      970.58
TEMP DRY        33.0         31.9        31.6        31.1
TEMP WET        19.5         25.1        19.2         0.0
SINGLE BASE ERRORS                                      MULTIPLE BASE ERRORS
       13.6    -13.2        -0.4                               -0.8
DIP BEARING 129.9 DEG             TILT/MILE 0.47 FEET

TIME   1500
PRESSURE      980.10       980.21      981.84      970.86
TEMP DRY        34.0         33.0        31.1        31.1
TEMP WET        19.5         27.0        18.9         0.0
SINGLE BASE ERRORS                                      MULTIPLE BASE ERRORS
       12.7    -15.6       -15.5                              -14.2
DIP BEARING 125.5 DEG             TILT/MILE 0.52 FEET

TIME   1505
PRESSURE      980.16       980.24      981.75      970.89
TEMP DRY        33.0         33.1        30.0        30.6
TEMP WET        20.3         21.5        19.0         0.0
SINGLE BASE ERRORS                                      MULTIPLE BASE ERRORS
       13.6    -11.1       -15.4                              -16.8
DIP BEARING 133.5 DEG             TILT/MILE 0.41 FEET

TIME   1510
PRESSURE      979.99       980.21      981.70      970.80
TEMP DRY        33.0         33.6        29.7        30.0
TEMP WET        20.2         21.2        19.0         0.0
SINGLE BASE ERRORS                                      MULTIPLE BASE ERRORS
        9.5    -14.6       -17.8                              -15.5
DIP BEARING 121.9 DEG             TILT/MILE 0.47 FEET
```

```
  REDUCTION OF FIELD READINGS COOTAMUNDRA 28/2/66 ASA
HAREFIELD      QUANDIALLA     PETTITS       YEO YEO

TIME    1515
PRESSURE        980.16       980.15       981.66       970.77
TEMP DRY          32.6         32.0         32.1         31.1
TEMP WET          19.9         20.1         19.8          0.0
SINGLE BASE ERRORS                                         MULTIPLE BASE ERRORS
        16.3       -8.4        -11.6                             -15.5
DIP BEARING 143.4 DEG                 TILT/MILE 0.38 FEET

TIME    1530
PRESSURE        979.94       980.18       981.65       970.74
TEMP DRY          32.0         32.0         31.0         31.1
TEMP WET          19.9         23.2         18.8          0.0
SINGLE BASE ERRORS                                         MULTIPLE BASE ERRORS
         8.9      -14.6        -17.4                             -14.9
DIP BEARING 120.9 DEG                 TILT/MILE 0.46 FEET

TIME    1545
PRESSURE        979.93       980.10       981.49       970.79
TEMP DRY          32.5         32.2         32.0         30.6
TEMP WET          20.0         19.5         20.0          0.0
SINGLE BASE ERRORS                                         MULTIPLE BASE ERRORS
        11.0      -10.2        -19.1                             -19.6
DIP BEARING 130.7 DEG                 TILT/MILE 0.36 FEET

TIME    1600
PRESSURE        979.79       979.85       981.46       970.71
TEMP DRY          33.8         32.1         30.5         30.6
TEMP WET          20.8         20.9         19.5          0.0
SINGLE BASE ERRORS                                         MULTIPLE BASE ERRORS
        14.2      -13.5        -20.9                             -21.4
DIP BEARING 130.4 DEG                 TILT/MILE 0.48 FEET
```

```
 REDUCTION OF FIELD READINGS COOTAMUNDRA 28/2/66 ASA
HAREFIELD      QUANDIALLA    PETTITS       YEO YEO

TIME   1605
PRESSURE      979.70      979.94      981.49      970.69
TEMP DRY        33.5        32.0        31.5        30.6
TEMP WET        20.7        20.1        19.0         0.0
SINGLE BASE ERRORS                                     MULTIPLE BASE ERRORS
       8.9     -17.0       -22.9                             -19.1
DIP BEARING 118.8 DEG              TILT/MILE 0.53 FEET

TIME   1610
PRESSURE      979.72      979.96      981.47      970.70
TEMP DRY        33.7        32.1        30.8        31.1
TEMP WET        20.3        20.1        18.7         0.0
SINGLE BASE ERRORS                                     MULTIPLE BASE ERRORS
       8.9     -15.8       -22.6                             -19.4
DIP BEARING 119.8 DEG              TILT/MILE 0.50 FEET

TIME   1615
PRESSURE      979.76      979.96      981.48      970.84
TEMP DRY        33.6        32.1        32.1        30.6
TEMP WET        20.6        20.1        19.5         0.0
SINGLE BASE ERRORS                                     MULTIPLE BASE ERRORS
      10.1     -15.0       -25.4                             -23.2
DIP BEARING 122.4 DEG              TILT/MILE 0.48 FEET

TIME   1630
PRESSURE      979.78      980.00      981.49      970.66
TEMP DRY        33.2        32.1        31.9        31.1
TEMP WET        20.3        19.1        19.3         0.0
SINGLE BASE ERRORS                                     MULTIPLE BASE ERRORS
       9.5     -14.7       -19.5                             -17.2
DIP BEARING 121.8 DEG              TILT/MILE 0.47 FEET
```

```
  REDUCTION OF FIELD READINGS COOTAMUNDRA 28/2/66 ASA
HAREFIELD     QUANDIALLA    PETTITS        YEO YEO

TIME   1645
PRESSURE     979.69     979.98     981.50     970.74
TEMP DRY       33.2       31.9       31.6       30.6
TEMP WET       20.2       20.9       20.1        0.0
SINGLE BASE ERRORS                                MULTIPLE BASE ERRORS
        7.4   -17.6      -24.7                          -19.9
DIP BEARING 116.3 DEG          TILT/MILE 0.53 FEET

TIME   1700
PRESSURE     979.91     980.01     981.55     970.79
TEMP DRY       32.8       31.8       30.6       31.1
TEMP WET       19.9       19.9       18.7        0.0
SINGLE BASE ERRORS                                MULTIPLE BASE ERRORS
       13.0   -12.5      -20.0                          -20.4
DIP BEARING 130.1 DEG          TILT/MILE 0.44 FEET

TIME   1705
PRESSURE     979.93     979.99     981.58     970.70
TEMP DRY       32.6       31.9       31.3       30.6
TEMP WET       19.6       19.9       19.6        0.0
SINGLE BASE ERRORS                                MULTIPLE BASE ERRORS
       14.2   -12.8      -16.7                          -17.5
DIP BEARING 131.3 DEG          TILT/MILE 0.46 FEET

TIME   1710
PRESSURE     979.89     980.08     981.59     970.66
TEMP DRY       32.3       31.9       31.2       30.6
TEMP WET       19.6        0.0       18.8        0.0
SINGLE BASE ERRORS                                MULTIPLE BASE ERRORS
       10.4   -14.3      -16.8                          -15.1
DIP BEARING 123.6 DEG          TILT/MILE 0.47 FEET
```

```
  REDUCTION OF FIELD READINGS COOTAMUNDRA 28/2/66 ASA
HAREFIELD      QUANDIALLA    PETTITS       YEO YEO

TIME   1715
PRESSURE       979.79     980.05     981.60     970.67
TEMP DRY         32.3       31.9       30.8       30.6
TEMP WET         19.6        0.0       19.7        0.0
SINGLE BASE ERRORS                                  MULTIPLE BASE ERRORS
       8.3     -17.5      -20.1                          -15.8
DIP BEARING 117.6 DEG              TILT/MILE 0.54 FEET
```

```
 REDUCTION OF FIELD READINGS COOTAMUNDRA 1/3/66 ASA

 PRESSURES IN MILLIBARS
 TEMPERATURES IN CENTIGRADE
 COORDINATES IN YARDS

CONSTANT 1 143831.81
CONSTANT 2    0.18910

 STATION            X          Y       HEIGHT
BATLOW          613000.    613000.   2544.00
WAGGA           663000.    535500.    609.00
MONTEAGLE       771500.    638500.   1627.00
YEO YEO         738000.    596500.   1124.00
QUANDIALLA      798000.    581500.    817.00

TIME     845
PRESSURE      927.30       993.32       958.05       975.30       985.44
TEMP DRY       22.3         22.0         20.3          0.0          0.0
TEMP WET       15.5         17.4         16.4          0.0          0.0
SINGLE BASE ERRORS                                      MULTIPLE BASE ERRORS
        8.6      6.2         8.7         24.9                1.0         12.9
DIP BEARING 123.8 DEG               TILT/MILE 0.16 FEET

TIME     900
PRESSURE      927.39       993.41       958.07       975.09       985.48
TEMP DRY       22.7         22.5         21.3          0.0          0.0
TEMP WET       16.0         17.8         16.8          0.0          0.0
SINGLE BASE ERRORS                                      MULTIPLE BASE ERRORS
        4.2      6.2        14.2         22.5                8.3         13.6
DIP BEARING 148.7 DEG               TILT/MILE 0.09 FEET

TIME     905
PRESSURE      927.45       993.35       958.17       975.13       985.44
TEMP DRY       23.0         23.0         22.3          0.0          0.0
TEMP WET       16.0         18.0         18.0          0.0          0.0
SINGLE BASE ERRORS                                      MULTIPLE BASE ERRORS
        3.4      3.0        11.7         21.6                8.2         16.3
DIP BEARING 129.6 DEG               TILT/MILE 0.07 FEET
```

```
  REDUCTION OF FIELD READINGS COOTAMUNDRA 1/3/66 ASA
BATLOW      WAGGA        MONTEAGLE    YEO YEO      QUANDIALLA

TIME   910
PRESSURE   927.56    993.33    958.16    975.36    985.46
TEMP DRY     23.5      23.5      22.5       0.0       0.0
TEMP WET     16.2      18.2      17.4       0.0       0.0
SINGLE BASE ERRORS                           MULTIPLE BASE ERRORS
      4.8      5.5      6.5      22.1              0.9     13.6
DIP BEARING 138.3 DEG       TILT/MILE 0.09 FEET

TIME   915
PRESSURE   927.56    993.32    958.17    975.50    985.45
TEMP DRY     23.0      23.0      23.0       0.0       0.0
TEMP WET     16.0      17.7      17.7       0.0       0.0
SINGLE BASE ERRORS                           MULTIPLE BASE ERRORS
      6.3      5.7      3.3      23.5             -3.1     13.6
DIP BEARING 130.5 DEG       TILT/MILE 0.12 FEET

TIME   930
PRESSURE   927.53    993.23    958.18    975.18    985.45
TEMP DRY     23.0      23.5      23.0       0.0       0.0
TEMP WET     16.5      18.0      17.6       0.0       0.0
SINGLE BASE ERRORS                           MULTIPLE BASE ERRORS
      6.6      3.9     10.7      21.4              5.4     13.0
DIP BEARING 118.9 DEG       TILT/MILE 0.13 FEET

TIME   945
PRESSURE   927.50    993.13    958.15    975.39    985.45
TEMP DRY     23.5      24.8      23.3       0.0       0.0
TEMP WET     17.0      18.3      17.7       0.0       0.0
SINGLE BASE ERRORS                           MULTIPLE BASE ERRORS
      3.7      1.6      0.2      16.2             -2.4     12.1
DIP BEARING 113.1 DEG       TILT/MILE 0.07 FEET
```

```
  REDUCTION OF FIELD READINGS COOTAMUNDRA 1/3/66 ASA
BATLOW        WAGGA         MONTEAGLE     YEO YEO       QUANDIALLA

TIME   1000
PRESSURE      927.52     993.06     958.16     975.04     985.42
TEMP DRY        23.5       26.0       25.0       28.5        0.0
TEMP WET        17.0       18.6       18.2        0.0        0.0
SINGLE BASE ERRORS                                 MULTIPLE BASE ERRORS
       -5.6      -3.8       2.2       7.1                 7.1       14.7
DIP BEARING 122.0 DEG           TILT/MILE 0.11 FEET

TIME   1005
PRESSURE      927.46     993.05     958.24     975.09     985.51
TEMP DRY        24.0       26.0       26.3       28.8        0.0
TEMP WET        17.0       18.8       19.9        0.0        0.0
SINGLE BASE ERRORS                                 MULTIPLE BASE ERRORS
      -11.1      -9.9     -4.0      -0.9                  7.2       16.4
DIP BEARING 129.6 DEG           TILT/MILE 0.21 FEET

TIME   1010
PRESSURE      927.48     993.02     958.27     975.08     985.45
TEMP DRY        24.0       26.2       26.7       26.8        0.0
TEMP WET        17.5       19.0       20.6        0.0        0.0
SINGLE BASE ERRORS                                 MULTIPLE BASE ERRORS
       -7.3      -9.0      -1.3       3.6                 7.7       17.3
DIP BEARING 141.6 DEG           TILT/MILE 0.15 FEET

TIME   1015
PRESSURE      927.52     993.02     958.27     974.86     985.38
TEMP DRY        23.5       26.5       27.0       28.8        0.0
TEMP WET        17.0       19.0       20.3        0.0        0.0
SINGLE BASE ERRORS                                 MULTIPLE BASE ERRORS
       -9.7      -9.6       3.6       3.6                14.1       19.5
DIP BEARING 133.0 DEG           TILT/MILE 0.19 FEET
```

```
  REDUCTION OF FIELD READINGS COOTAMUNDRA 1/3/66 ASA
BATLOW         WAGGA          MONTEAGLE     YEO YEO        QUANDIALLA

TIME    1030
PRESSURE        927.54        992.94        958.22        974.93        985.28
TEMP DRY          24.0          27.2          26.4          28.4           0.0
TEMP WET          17.5          19.3          20.3           0.0           0.0
SINGLE BASE ERRORS                                             MULTIPLE BASE ERRORS
     -7.2          -7.7           1.9           6.7                 10.0         19.1
DIP BEARING 135.6 DEG                   TILT/MILE 0.14 FEET

TIME    1045
PRESSURE        927.48        992.87        958.07        974.89        985.23
TEMP DRY          24.0          27.7          27.8          29.1           0.0
TEMP WET          17.3          19.5          20.0           0.0           0.0
SINGLE BASE ERRORS                                             MULTIPLE BASE ERRORS
    -11.2          -7.0          -1.8           2.6                  7.6         17.3
DIP BEARING 120.2 DEG                   TILT/MILE 0.21 FEET

TIME    1100
PRESSURE        927.37        992.89        957.91        974.75        985.10
TEMP DRY          23.5          27.4          25.9          29.9           0.0
TEMP WET          17.5          19.2          18.2           0.0           0.0
SINGLE BASE ERRORS                                             MULTIPLE BASE ERRORS
    -11.9          -4.1           1.3           6.0                  9.1         18.3
DIP BEARING 110.2 DEG                   TILT/MILE 0.23 FEET

TIME    1105
PRESSURE        927.32        992.82        957.88        974.65        984.95
TEMP DRY          24.0          27.1          27.3          29.7           0.0
TEMP WET          17.8          19.0          18.9           0.0           0.0
SINGLE BASE ERRORS                                             MULTIPLE BASE ERRORS
    -13.8          -5.8           1.0           6.7                 10.7         22.1
DIP BEARING 113.0 DEG                   TILT/MILE 0.27 FEET
```

```
  REDUCTION OF FIELD READINGS COOTAMUNDRA 1/3/66 ASA
BATLOW          WAGGA             MONTEAGLE     YEO YEO        QUANDIALLA

TIME    1110
PRESSURE        927.27          992.75        957.83        974.61        984.95
TEMP DRY          24.5            27.2          28.0          29.7          0.0
TEMP WET          18.0            18.9          19.5           0.0          0.0
SINGLE BASE ERRORS                                              MULTIPLE BASE ERRORS
        -15.5      -7.0          -1.0           3.2                  10.2        20.8
DIP BEARING 113.8 DEG                      TILT/MILE 0.30 FEET

TIME    1115
PRESSURE        927.26          992.70        957.85        974.58        985.03
TEMP DRY          24.0            27.5          26.7          30.1          0.0
TEMP WET          17.5            19.0          19.3           0.0          0.0
SINGLE BASE ERRORS                                              MULTIPLE BASE ERRORS
        -12.7      -7.0           0.8           2.1                  10.8        17.8
DIP BEARING 117.7 DEG                      TILT/MILE 0.24 FEET

TIME    1130
PRESSURE        927.16          992.50        957.56        974.38        984.75
TEMP DRY          24.5            28.0          26.8          31.4          0.0
TEMP WET          18.0            18.9          17.7           0.0          0.0
SINGLE BASE ERRORS                                              MULTIPLE BASE ERRORS
        -13.7      -3.2           0.9           3.8                   8.9        16.7
DIP BEARING 106.6 DEG                      TILT/MILE 0.27 FEET

TIME    1145
PRESSURE        927.15          992.35        957.38        974.18        984.55
TEMP DRY          25.8            28.6          27.2          33.5          0.0
TEMP WET          17.5            18.9          17.7           0.0          0.0
SINGLE BASE ERRORS                                              MULTIPLE BASE ERRORS
        -17.0      -1.6           1.1           2.9                   9.5        16.6
DIP BEARING 102.1 DEG                      TILT/MILE 0.35 FEET
```

```
  REDUCTION OF FIELD READINGS COOTAMUNDRA 1/3/66 ASA
BATLOW         WAGGA          MONTEAGLE      YEO YEO        QUANDIALLA

TIME    1200
PRESSURE       926.81         992.15         957.24         974.24         984.46
TEMP DRY         26.0           29.8           28.8           33.4           0.0
TEMP WET         18.0           19.5           18.4            0.0           0.0
SINGLE BASE ERRORS                                              MULTIPLE BASE ERRORS
      -26.7         -10.3          -14.9          -9.5                3.3           19.4
DIP BEARING 111.7 DEG                      TILT/MILE 0.52 FEET

TIME    1205
PRESSURE       926.78         992.12         957.18         973.94         984.39
TEMP DRY         26.2           29.2           28.8           31.4           0.0
TEMP WET         18.0           19.5           18.0            0.0           0.0
SINGLE BASE ERRORS                                              MULTIPLE BASE ERRORS
      -22.3          -7.3           -3.6          -4.4               10.7           18.5
DIP BEARING 109.7 DEG                      TILT/MILE 0.44 FEET

TIME    1210
PRESSURE       926.78         992.02         957.08         974.02         984.38
TEMP DRY         26.2           29.7           28.3           31.1           0.0
TEMP WET         18.0           19.6           18.2            0.0           0.0
SINGLE BASE ERRORS                                              MULTIPLE BASE ERRORS
      -18.9          -4.1           -5.7          -3.7                5.1           13.7
DIP BEARING 106.0 DEG                      TILT/MILE 0.38 FEET

TIME    1215
PRESSURE       926.76         991.98         957.09         973.92         984.60
TEMP DRY         26.2           29.4           28.5           31.4           0.0
TEMP WET         18.0           19.4           18.5            0.0           0.0
SINGLE BASE ERRORS                                              MULTIPLE BASE ERRORS
      -18.9          -5.2           -3.7         -11.2                7.8            7.3
DIP BEARING 108.0 DEG                      TILT/MILE 0.37 FEET
```

```
  REDUCTION OF FIELD READINGS COOTAMUNDRA 1/3/66 ASA
BATLOW          WAGGA            MONTEAGLE      YEO YEO        QUANDIALLA

TIME    1230
PRESSURE        926.75       991.82       957.06       973.73       984.53
TEMP DRY          26.2         30.0         29.5         31.8          0.0
TEMP WET          18.0         19.0         17.8          0.0          0.0
SINGLE BASE ERRORS                                      MULTIPLE BASE ERRORS
        -17.3       -6.0       -0.4        -11.9                10.9       6.1
DIP BEARING 110.3 DEG                  TILT/MILE 0.34 FEET

TIME    1245
PRESSURE        926.68       991.65       957.02       973.72       984.24
TEMP DRY          27.0         29.5         28.5         32.1          0.0
TEMP WET          18.0         19.2         18.2          0.0          0.0
SINGLE BASE ERRORS                                      MULTIPLE BASE ERRORS
        -14.3       -6.8       -2.1         -5.4                 8.5      11.3
DIP BEARING 114.9 DEG                  TILT/MILE 0.27 FEET

TIME    1300
PRESSURE        926.50       991.48       956.73       973.56       984.16
TEMP DRY          26.5         30.0         29.3         32.2          0.0
TEMP WET          18.0         19.0         18.2          0.0          0.0
SINGLE BASE ERRORS                                      MULTIPLE BASE ERRORS
        -16.3       -4.3       -3.9         -9.8                 5.9       5.9
DIP BEARING 107.6 DEG                  TILT/MILE 0.32 FEET

TIME    1305
PRESSURE        926.45       991.47       956.69       973.61       984.11
TEMP DRY          26.5         30.0         29.0         31.9          0.0
TEMP WET          18.0         18.9         17.8          0.0          0.0
SINGLE BASE ERRORS                                      MULTIPLE BASE ERRORS
        -16.4       -4.1       -6.1         -8.8                 3.6       6.7
DIP BEARING 107.1 DEG                  TILT/MILE 0.32 FEET
```

```
  REDUCTION OF FIELD READINGS COOTAMUNDRA 1/3/66 ASA
BATLOW       WAGGA       MONTEAGLE    YEO YEO      QUANDIALLA

TIME  1310
PRESSURE    926.41    991.38    956.65    973.53    984.18
TEMP DRY      27.0      30.0      29.0      32.1       0.0
TEMP WET      18.0      19.0      18.0       0.0       0.0
SINGLE BASE ERRORS                           MULTIPLE BASE ERRORS
    -16.2     -4.7      -5.9    -13.3              4.2      2.8
DIP BEARING 108.5 DEG       TILT/MILE 0.32 FEET

TIME  1315
PRESSURE    926.38    991.40    956.72    973.59    984.10
TEMP DRY      20.7      31.0      29.5      32.5       0.0
TEMP WET      18.0      19.8      17.8       0.0       0.0
SINGLE BASE ERRORS                           MULTIPLE BASE ERRORS
    -11.3     -4.7      -3.9     -6.1              4.1      6.4
DIP BEARING 112.8 DEG       TILT/MILE 0.22 FEET

TIME  1330
PRESSURE    926.26    991.21    956.40    973.49    983.98
TEMP DRY      27.5      30.8      29.9      32.3       0.0
TEMP WET      17.5      19.1      18.1       0.0       0.0
SINGLE BASE ERRORS                           MULTIPLE BASE ERRORS
    -19.6     -3.6     -12.0    -15.3             -1.3      2.1
DIP BEARING 104.9 DEG       TILT/MILE 0.39 FEET

TIME  1345
PRESSURE    926.15    991.00    956.28    973.26    983.80
TEMP DRY      27.5      30.1      30.5      32.8       0.0
TEMP WET      17.0      19.1      18.1       0.0       0.0
SINGLE BASE ERRORS                           MULTIPLE BASE ERRORS
    -17.5     -3.7      -9.1    -14.0              0.8      2.0
DIP BEARING 105.8 DEG       TILT/MILE 0.35 FEET
```

```
  REDUCTION OF FIELD READINGS COOTAMUNDRA 1/3/66 ASA
BATLOW        WAGGA         MONTEAGLE    YEO YEO      QUANDIALLA

TIME   1400
PRESSURE      926.14     990.72     956.05     972.98     983.61
TEMP DRY        27.5       31.8       29.2       33.0        0.0
TEMP WET        16.8       19.0       17.8        0.0        0.0
SINGLE BASE ERRORS                                 MULTIPLE BASE ERRORS
     -10.5       2.5       -1.7       -9.5                1.1       -4.4
DIP BEARING  92.3 DEG           TILT/MILE 0.23 FEET

TIME   1405
PRESSURE      926.12     990.64     955.96     973.06     983.56
TEMP DRY        27.8       32.0       29.3       32.9        0.0
TEMP WET        17.0       19.2       17.5        0.0        0.0
SINGLE BASE ERRORS                                 MULTIPLE BASE ERRORS
      -9.5       4.3       -5.3       -9.3               -4.0       -6.5
DIP BEARING  87.1 DEG           TILT/MILE 0.22 FEET

TIME   1410
PRESSURE      926.09     990.64     955.89     973.13     983.54
TEMP DRY        28.0       31.8       30.8       32.8        0.0
TEMP WET        17.0       18.8       18.0        0.0        0.0
SINGLE BASE ERRORS                                 MULTIPLE BASE ERRORS
     -12.5       4.4       -9.8      -11.5               -7.4       -6.7
DIP BEARING  89.4 DEG           TILT/MILE 0.29 FEET

TIME   1415
PRESSURE      926.05     990.57     955.95     973.09     983.42
TEMP DRY        28.0       31.8       30.4       32.5        0.0
TEMP WET        17.5       18.8       17.7        0.0        0.0
SINGLE BASE ERRORS                                 MULTIPLE BASE ERRORS
     -10.7       1.9       -9.1       -8.3               -5.8       -2.4
DIP BEARING  94.0 DEG           TILT/MILE 0.23 FEET
```

```
  REDUCTION OF FIELD READINGS COOTAMUNDRA 1/3/66 ASA
BATLOW        WAGGA         MONTEAGLE     YEO YEO       QUANDIALLA

TIME   1430
PRESSURE     925.88     990.37     955.63     972.80     983.21
TEMP DRY       27.3       33.0       31.7       34.0        0.0
TEMP WET       16.8       19.5       18.5        0.0        0.0
SINGLE BASE ERRORS
     -15.9       3.5    -10.0      -12.6                MULTIPLE BASE ERRORS
DIP BEARING  92.8 DEG                                  -5.5      -4.5
                               TILT/MILE 0.35 FEET

TIME   1445
PRESSURE     925.71     990.22     955.64     972.50
TEMP DRY       27.5       32.3       30.2       32.9
TEMP WET       17.2       19.2       17.9        0.0
SINGLE BASE ERRORS
     -11.6       0.4     -2.6                         MULTIPLE BASE ERRORS
DIP BEARING  98.1 DEG                                   2.1
                               TILT/MILE 0.24 FEET

TIME   1500
PRESSURE     925.60     990.07     955.51     972.54
TEMP DRY       28.2       32.2       31.0       33.6
TEMP WET       17.0       19.8       18.8        0.0
SINGLE BASE ERRORS
     -14.5      -0.9    -10.1                         MULTIPLE BASE ERRORS
DIP BEARING 101.1 DEG                                  -3.2
                               TILT/MILE 0.30 FEET

TIME   1505
PRESSURE     925.50     989.96     955.42     972.55
TEMP DRY       27.8       32.1       30.9       33.6
TEMP WET       16.5       19.7       18.2        0.0
SINGLE BASE ERRORS
     -13.1      -0.7    -12.5                         MULTIPLE BASE ERRORS
DIP BEARING 100.8 DEG                                  -6.4
                               TILT/MILE 0.27 FEET
```

```
  REDUCTION OF FIELD READINGS COOTAMUNDRA 1/3/66 ASA
BATLOW        WAGGA         MONTEAGLE     YEO YEO       QUANDIALLA

TIME   1510
PRESSURE     925.52     990.06     955.39     972.44
TEMP DRY       27.8       32.3       30.8       33.8
TEMP WET       17.0       19.3       18.1        0.0
SINGLE BASE ERRORS                                MULTIPLE BASE ERRORS
     -16.0      0.6      -9.0                          -2.5
DIP BEARING  98.1 DEG          TILT/MILE 0.34 FEET

TIME   1515
PRESSURE     925.61     990.07     955.36     972.40
TEMP DRY       28.0       32.3       31.3       33.8
TEMP WET       17.0       19.4       18.0        0.0
SINGLE BASE ERRORS                                MULTIPLE BASE ERRORS
     -14.5      3.8      -5.8                          -2.0
DIP BEARING  91.8 DEG          TILT/MILE 0.32 FEET

TIME   1530
PRESSURE     925.66     989.97     955.39     972.28
TEMP DRY       27.5       32.4       30.4       33.8
TEMP WET       16.5       19.2       17.6        0.0
SINGLE BASE ERRORS                                MULTIPLE BASE ERRORS
      -7.7      5.5       1.1                           0.8
DIP BEARING  81.2 DEG          TILT/MILE 0.20 FEET

TIME   1545
PRESSURE     925.61     989.85     955.31     972.25
TEMP DRY       27.3       33.0       30.6       33.8
TEMP WET       16.0       18.8       17.8        0.0
SINGLE BASE ERRORS                                MULTIPLE BASE ERRORS
      -6.4      6.1      -0.1                          -1.3
DIP BEARING  77.0 DEG          TILT/MILE 0.18 FEET
```

```
  REDUCTION OF FIELD READINGS COOTAMUNDRA 1/3/66 ASA
BATLOW          WAGGA            MONTEAGLE      YEO YEO        QUANDIALLA

TIME    1600
PRESSURE        925.54        989.77        955.29        972.24
TEMP DRY          27.0          32.5          29.7          33.2
TEMP WET          16.0          19.5          17.2           0.0
SINGLE BASE ERRORS                                              MULTIPLE BASE ERRORS
       -2.6         6.2          0.7                                 -2.3
DIP BEARING   60.4 DEG                 TILT/MILE 0.11 FEET

TIME    1605
PRESSURE        925.54        989.73        955.22        972.29
TEMP DRY          27.0          32.0          30.6          32.8
TEMP WET          16.0          19.5          17.8           0.0
SINGLE BASE ERRORS                                              MULTIPLE BASE ERRORS
       -1.5         8.3         -0.9                                 -5.6
DIP BEARING   47.5 DEG                 TILT/MILE 0.12 FEET

TIME    1610
PRESSURE        925.52        989.67        955.22        972.14
TEMP DRY          27.0          32.3          29.8          32.9
TEMP WET          15.5          18.8          18.0           0.0
SINGLE BASE ERRORS                                              MULTIPLE BASE ERRORS
        0.5         8.1          3.6                                 -1.9
DIP BEARING   27.1 DEG                 TILT/MILE 0.09 FEET

TIME    1615
PRESSURE        925.56        989.73        955.22        972.21
TEMP DRY          26.9          32.3          30.2          32.5
TEMP WET          15.0          18.0          17.6           0.0
SINGLE BASE ERRORS                                              MULTIPLE BASE ERRORS
        0.8         9.7          3.4                                 -3.3
DIP BEARING   25.1 DEG                 TILT/MILE 0.11 FEET
```

APPENDIX III

Barometer Traverse Reductions.

```
CITY TRAVERSE REDUCTION 22 MAY 1956   ASA


CONSTANT 1 143831.81
CONSTANT 2   0.18910
 PRESSURES IN INCHES
 TEMPERATURES IN FARENHEIT
 COORDINATES IN YARDS


 STATION         X         Y       HEIGHT
ST PAULS      833900.   411100.   663.00
LIVERPOOL     809100.   392600.    60.00
CENTENNIAL    812900.   423800.   215.00


TIME    923
FIELD STN   645           810300.     393300.     34.80

 PRESSURE    29.390     30.032     29.874     30.064
TEMP DRY       0.0       70.1        0.0        0.0
SINGLE BASE ERRORS                               MULTIPLE BASE ERRORS
       3.9     -4.6      -0.5                          -4.2
DIP BEARING 100.2 DEG         TILT/MILE 0.50 FEET


TIME    929
FIELD STN   644           811600.     394200.     20.60

 PRESSURE    29.389     30.032     29.871     30.079
TEMP DRY       0.0       69.8        0.0        0.0
SINGLE BASE ERRORS                               MULTIPLE BASE ERRORS
       3.3     -2.5      -0.8                          -3.7
DIP BEARING  92.0 DEG         TILT/MILE 0.33 FEET


TIME    939
FIELD STN   642           813150.     397350.    115.12

 PRESSURE    29.398     30.032     29.871     29.979
TEMP DRY       0.0       69.3        0.0        0.0
SINGLE BASE ERRORS                               MULTIPLE BASE ERRORS
      12.4      6.3       6.2                          -3.9
DIP BEARING  20.5 DEG         TILT/MILE 0.73 FEET
```

```
CITY TRAVERSE REDUCTION 22 MAY 1956   ASA

 ST PAULS      LIVERPOOL     CENTENNIAL

TIME    946
FIELD STN   641            815000.     397800.     46.39

 PRESSURE     29.389     30.030     29.871     30.052
TEMP DRY        0.0       68.9        0.0        0.0
SINGLE BASE ERRORS
       6.2      -1.8      -0.5                    MULTIPLE BASE ERRORS
                                                        -5.0
DIP BEARING  75.3 DEG         TILT/MILE 0.45 FEET


TIME    952
FIELD STN   640            815900.     398750.    119.13

 PRESSURE     29.389     30.030     29.870     29.971
TEMP DRY        0.0       68.6        0.0        0.0
SINGLE BASE ERRORS
       6.5      -0.6       1.8                    MULTIPLE BASE ERRORS
                                                        -2.7
DIP BEARING  64.7 DEG         TILT/MILE 0.42 FEET


TIME    956
FIELD STN   639            817300.     399500.    123.83

 PRESSURE     29.389     30.028     29.869     29.967
TEMP DRY        0.0       68.2        0.0        0.0
SINGLE BASE ERRORS
       8.8       0.7       1.3                    MULTIPLE BASE ERRORS
                                                        -4.4
DIP BEARING  53.6 DEG         TILT/MILE 0.52 FEET


TIME   1001
FIELD STN   638            819400.     399900.     61.40

 PRESSURE     29.389     30.027     29.869     30.032
TEMP DRY        0.0       67.9        0.0        0.0
SINGLE BASE ERRORS
      10.1       0.9       4.1                    MULTIPLE BASE ERRORS
                                                        -1.7
DIP BEARING  52.5 DEG         TILT/MILE 0.60 FEET
```

```
CITY TRAVERSE REDUCTION 22 MAY 1956   ASA
 ST PAULS      LIVERPOOL     CENTENNIAL

TIME   1006
FIELD STN   637             820800.     400500.     35.84

 PRESSURE     29.389     30.027     29.866     30.057
TEMP DRY        0.0       67.7        0.0        0.0
SINGLE BASE ERRORS                                  MULTIPLE BASE ERRORS
        10.3      3.9      6.9                               1.7
DIP BEARING  30.9 DEG          TILT/MILE 0.59 FEET


TIME   1013
FIELD STN   222             822900.     400500.     30.61

 PRESSURE     29.389     30.026     29.863     30.061
TEMP DRY        0.0       67.7        0.0        0.0
SINGLE BASE ERRORS                                  MULTIPLE BASE ERRORS
        11.1      6.6      8.3                               3.9
DIP BEARING  14.8 DEG          TILT/MILE 0.68 FEET


TIME   1024
FIELD STN   223             822900.     400500.    425.18

 PRESSURE     29.386     30.026     29.859     29.641
TEMP DRY        0.0       68.2        0.0        0.0
SINGLE BASE ERRORS                                  MULTIPLE BASE ERRORS
         7.8      7.1     -0.6                              -3.9
DIP BEARING 176.7 DEG          TILT/MILE 0.58 FEET


TIME   1032
FIELD STN   224             831300.     406600.    621.34

 PRESSURE     29.385     30.024     29.856     29.431
TEMP DRY        0.0       68.6        0.0        0.0
SINGLE BASE ERRORS                                  MULTIPLE BASE ERRORS
         8.2      8.6     -1.5                              -2.3
DIP BEARING 171.0 DEG          TILT/MILE 0.67 FEET
```

```
CITY TRAVERSE REDUCTION 22 MAY 1956   ASA
 ST PAULS       LIVERPOOL      CENTENNIAL

TIME    1050
FIELD STN    296               833100.      412100.     631.79

 PRESSURE      29.383       30.018       29.851       29.416
TEMP DRY          0.0        69.5          0.0          0.0
SINGLE BASE ERRORS                                       MULTIPLE BASE ERRORS
       10.9       10.6         0.2                                  -0.2
DIP BEARING 174.0 DEG                 TILT/MILE 0.84 FEET


TIME    1056
FIELD STN    295               832050.      413350.     594.19

 PRESSURE      29.382       30.016       29.851       29.453
TEMP DRY          0.0        69.8          0.0          0.0
SINGLE BASE ERRORS                                       MULTIPLE BASE ERRORS
       11.4        9.4         2.1                                   1.2
DIP BEARING   1.1 DEG                 TILT/MILE 0.80 FEET


TIME    1100
FIELD STN    294               830600.      414500.     460.81

 PRESSURE      29.382       30.014       29.850       29.591
TEMP DRY          0.0        70.0          0.0          0.0
SINGLE BASE ERRORS                                       MULTIPLE BASE ERRORS
       13.1       10.2         6.0                                   4.4
DIP BEARING   3.8 DEG                 TILT/MILE 0.89 FEET


TIME    1105
FIELD STN    293               829300.      415500.     422.16

 PRESSURE      29.379       30.014       29.849       29.630
TEMP DRY          0.0        70.3          0.0          0.0
SINGLE BASE ERRORS                                       MULTIPLE BASE ERRORS
       10.0        8.0         5.2                                   3.4
DIP BEARING   2.2 DEG                 TILT/MILE 0.69 FEET
```

```
CITY TRAVERSE REDUCTION 22 MAY 1956   ASA

 ST PAULS      LIVERPOOL     CENTENNIAL

TIME   1110
FIELD STN    292              827700.     416250.    398.66

 PRESSURE       29.376      30.010      29.847      29.655
TEMP DRY           0.0       71.0         0.0         0.0
SINGLE BASE ERRORS                                    MULTIPLE BASE ERRORS
        10.0        6.5       2.1                            0.3
DIP BEARING   11.3 DEG              TILT/MILE 0.63 FEET

TIME   1115
FIELD STN    291              826250.     417250.    359.53

 PRESSURE       29.373      30.008      29.846      29.693
TEMP DRY           0.0       71.8         0.0         0.0
SINGLE BASE ERRORS                                    MULTIPLE BASE ERRORS
         8.1        3.9       2.4                            1.1
DIP BEARING   22.8 DEG              TILT/MILE 0.47 FEET

TIME   1120
FIELD STN    290              824900.     418250.    352.26

 PRESSURE       29.372      30.008      29.844      29.698
TEMP DRY           0.0       72.6         0.0         0.0
SINGLE BASE ERRORS                                    MULTIPLE BASE ERRORS
         6.2        4.1       3.5                            1.8
DIP BEARING   10.3 DEG              TILT/MILE 0.39 FEET

TIME   1124
FIELD STN    289              823600.     418200.    330.20

 PRESSURE       29.371      30.004      29.842      29.718
TEMP DRY           0.0       73.4         0.0         0.0
SINGLE BASE ERRORS                                    MULTIPLE BASE ERRORS
         8.2        4.4       5.4                            3.3
DIP BEARING   18.9 DEG              TILT/MILE 0.49 FEET
```

```
CITY TRAVERSE REDUCTION 22 MAY 1956   ASA
 ST PAULS      LIVERPOOL     CENTENNIAL

TIME    1129
FIELD STN    288              822300.      417900.     325.39
 PRESSURE       29.370     30.003      29.839      29.719
TEMP DRY           0.0      74.2         0.0         0.0
SINGLE BASE  ERRORS                                      MULTIPLE BASE ERRORS
         7.2         5.6      7.8                                  4.8
DIP BEARING    3.6 DEG            TILT/MILE 0.49 FEET

TIME    1134
FIELD STN    287              821000.      419200.     291.72
 PRESSURE       29.366     30.001      29.836      29.750
TEMP DRY           0.0      75.0         0.0         0.0
SINGLE BASE  ERRORS                                      MULTIPLE BASE ERRORS
         4.4         3.9      8.0                                  5.6
DIP BEARING  178.4 DEG            TILT/MILE 0.32 FEET

TIME    1139
FIELD STN    286              820300.      420500.     317.74
 PRESSURE       29.363     29.997      29.832      29.724
TEMP DRY           0.0      75.8         0.0         0.0
SINGLE BASE  ERRORS                                      MULTIPLE BASE ERRORS
         4.3         4.1      3.1                                  0.4
DIP BEARING  175.0 DEG            TILT/MILE 0.33 FEET

TIME    1148
FIELD STN    285              818000.      421650.      39.70
 PRESSURE       29.357     29.985      29.825      30.013
TEMP DRY           0.0      77.4         0.0         0.0
SINGLE BASE  ERRORS                                      MULTIPLE BASE ERRORS
         8.0         3.6      2.0                                 -0.6
DIP BEARING   24.8 DEG            TILT/MILE 0.46 FEET
```

```
CITY TRAVERSE REDUCTION 22 MAY 1956   ASA

 ST PAULS      LIVERPOOL     CENTENNIAL

TIME   1230
FIELD STN   178            814150.     420250.     33.80

 PRESSURE     29.331     29.965     29.801     29.991
TEMP DRY        0.0       77.0        0.0        0.0
SINGLE BASE ERRORS                                MULTIPLE BASE ERRORS
       2.4       1.7       4.2                           2.5
DIP BEARING   7.2 DEG          TILT/MILE 0.16 FEET

TIME   1251
FIELD STN   220            813650.     413650.     97.52

 PRESSURE     29.323     29.958     29.792     29.915
TEMP DRY        0.0       75.8        0.0        0.0
SINGLE BASE ERRORS                                MULTIPLE BASE ERRORS
       2.6       3.5       5.4                           2.4
DIP BEARING 161.3 DEG          TILT/MILE 0.26 FEET

TIME   1310
FIELD STN   220            813650.     413650.     97.52

 PRESSURE     29.317     29.945     29.791     29.912
TEMP DRY        0.0       73.5        0.0        0.0
SINGLE BASE ERRORS                                MULTIPLE BASE ERRORS
      11.5       0.7       4.9                           1.1
DIP BEARING  54.9 DEG          TILT/MILE 0.69 FEET

TIME   1325
FIELD STN   221            817000.     407000.     52.95

 PRESSURE     29.316     29.944     29.788     29.952
TEMP DRY        0.0       71.4        0.0        0.0
SINGLE BASE ERRORS                                MULTIPLE BASE ERRORS
      13.9       4.3      13.5                           6.3
DIP BEARING  36.1 DEG          TILT/MILE 0.79 FEET
```

```
CITY TRAVERSE REDUCTION 22 MAY 1956   ASA
 ST PAULS      LIVERPOOL     CENTENNIAL

TIME   1340
FIELD STN   638             819400.     399900.     61.40

 PRESSURE      29.315      29.937      29.787      29.944
TEMP DRY          0.0       69.0         0.0         0.0
SINGLE BASE ERRORS                                    MULTIPLE BASE ERRORS
      22.1        6.3       14.2                                  1.6
DIP BEARING  37.9 DEG            TILT/MILE 1.25 FEET


TIME   1348
FIELD STN   640             815900.     398750.    119.13

 PRESSURE      29.313      29.939      29.784      29.882
TEMP DRY          0.0       67.2         0.0         0.0
SINGLE BASE ERRORS                                    MULTIPLE BASE ERRORS
      20.4        8.7       13.8                                 -0.6
DIP BEARING  26.9 DEG            TILT/MILE 1.17 FEET


TIME   1409
FIELD STN   643             812700.     395800.     22.00

 PRESSURE      29.310      29.943      29.782      29.981
TEMP DRY          0.0       65.9         0.0         0.0
SINGLE BASE ERRORS                                    MULTIPLE BASE ERRORS
      15.2        8.8       18.4                                  5.4
DIP BEARING  16.0 DEG            TILT/MILE 0.93 FEET


TIME   1414
FIELD STN   644             811600.     394200.     20.60

 PRESSURE      29.310      29.935      29.780      29.982
TEMP DRY          0.0       65.8         0.0         0.0
SINGLE BASE ERRORS                                    MULTIPLE BASE ERRORS
      22.7       10.7       18.9                                 -1.4
DIP BEARING  23.5 DEG            TILT/MILE 1.33 FEET
```

```
CITY TRAVERSE REDUCTION 22 MAY 1956   ASA
 ST PAULS       LIVERPOOL      CENTENNIAL

TIME   1447
FIELD STN   647               808300.      394250.      24.23

 PRESSURE       29.306      29.937      29.782      29.974
TEMP DRY           0.0       65.2         0.0          0.0
SINGLE BASE ERRORS                                      MULTIPLE BASE ERRORS
       17.8        5.6       19.6                              1.9
DIP BEARING   35.4 DEG            TILT/MILE 1.01 FEET

TIME   1453
FIELD STN   648               808400.      395450.      96.47

 PRESSURE       29.306      29.935      29.779      29.899
TEMP DRY           0.0       65.1         0.0          0.0
SINGLE BASE ERRORS                                      MULTIPLE BASE ERRORS
       19.7        8.5       16.4                             -2.9
DIP BEARING   26.6 DEG            TILT/MILE 1.14 FEET

TIME   1459
FIELD STN   649               808550.      397400.       7.72

 PRESSURE       29.306      29.937      29.776      29.991
TEMP DRY           0.0       65.0         0.0          0.0
SINGLE BASE ERRORS                                      MULTIPLE BASE ERRORS
       18.0       11.3       20.8                              3.1
DIP BEARING   12.5 DEG            TILT/MILE 1.13 FEET

TIME   1505
FIELD STN   650               808300.      399100.      12.18

 PRESSURE       29.306      29.937      29.776      29.988
TEMP DRY           0.0       64.9         0.0          0.0
SINGLE BASE ERRORS                                      MULTIPLE BASE ERRORS
       18.2       11.4       19.2                              1.5
DIP BEARING   12.5 DEG            TILT/MILE 1.13 FEET
```

```
CITY TRAVERSE REDUCTION 22 MAY 1956   ASA
 ST PAULS      LIVERPOOL     CENTENNIAL

TIME   1511
FIELD STN   651            807700.     400750.     42.08

 PRESSURE     29.306     29.937     29.776     29.955
TEMP DRY        0.0       64.8        0.0        0.0
SINGLE BASE ERRORS                                MULTIPLE BASE ERRORS
      18.3      11.5      19.7                           1.7
DIP BEARING  12.4 DEG               TILT/MILE 1.14 FEET


TIME   1516
FIELD STN   652            807300.     402000.     97.75

 PRESSURE     29.306     29.935     29.776     29.896
TEMP DRY        0.0       64.7        0.0        0.0
SINGLE BASE ERRORS                                MULTIPLE BASE ERRORS
      20.2      11.6      18.3                          -1.3
DIP BEARING  16.1 DEG               TILT/MILE 1.23 FEET


TIME   1522
FIELD STN   653            807750.     403700.     22.01

 PRESSURE     29.304     29.932     29.775     29.977
TEMP DRY        0.0       64.6        0.0        0.0
SINGLE BASE ERRORS                                MULTIPLE BASE ERRORS
      21.2      10.7      17.9                          -1.4
DIP BEARING  21.0 DEG               TILT/MILE 1.25 FEET


TIME   1527
FIELD STN   654            808050.     406150.    100.98

 PRESSURE     29.303     29.930     29.774     29.892
TEMP DRY        0.0       64.6        0.0        0.0
SINGLE BASE ERRORS                                MULTIPLE BASE ERRORS
      22.0      10.7      16.0                          -2.9
DIP BEARING  22.5 DEG               TILT/MILE 1.29 FEET
```

```
CITY TRAVERSE REDUCTION 23 MAY 1956   ASA


CONSTANT 1 143831.81
CONSTANT 2   0.18910
 PRESSURES IN INCHES
 TEMPERATURES IN FARENHEIT
 COORDINATES IN YARDS


 STATION          X           Y        HEIGHT
ST PAULS       833900.     411100.     663.00
LIVERPOOL      809100.     392600.      60.00
CENTENNIAL     812900.     423800.     215.00


TIME    933
FIELD STN   647            808300.     394250.     24.23

 PRESSURE     29.319     29.960     29.792     29.999
TEMP DRY        0.0      60.7         0.0        0.0
SINGLE BASE ERRORS                                MULTIPLE BASE ERRORS
      14.1      12.4      14.3                          -0.2
DIP BEARING 178.3 DEG          TILT/MILE 1.02 FEET


TIME    938
FIELD STN   648            808400.     395450.     96.47

 PRESSURE     29.320     29.960     29.789     29.922
TEMP DRY        0.0      60.9         0.0        0.0
SINGLE BASE ERRORS                                MULTIPLE BASE ERRORS
      14.8      15.9      12.9                          -2.7
DIP BEARING 170.1 DEG          TILT/MILE 1.22 FEET


TIME    944
FIELD STN   649            808550.     397400.      7.72

 PRESSURE     29.321     29.958     29.786     30.014
TEMP DRY        0.0      61.4         0.0        0.0
SINGLE BASE ERRORS                                MULTIPLE BASE ERRORS
      16.9      19.2      18.2                           0.0
DIP BEARING 168.1 DEG          TILT/MILE 1.46 FEET
```

```
CITY TRAVERSE REDUCTION 23 MAY 1956   ASA
 ST PAULS      LIVERPOOL     CENTENNIAL

TIME     948
FIELD STN    650            808300.     399100.     12.18

 PRESSURE      29.320      29.962      29.786      30.011
TEMP DRY         0.0       61.7          0.0         0.0
SINGLE BASE ERRORS                                    MULTIPLE BASE ERRORS
        12.1     18.0       15.1                              0.7
DIP BEARING 158.4 DEG             TILT/MILE 1.31 FEET


TIME     954
FIELD STN    651            807700.     400750.     42.08

 PRESSURE      29.317      29.962      29.787      29.979
TEMP DRY         0.0       61.8          0.0         0.0
SINGLE BASE ERRORS                                    MULTIPLE BASE ERRORS
         9.2     14.2       11.5                             -0.3
DIP BEARING 157.2 DEG             TILT/MILE 1.03 FEET


TIME     959
FIELD STN    652            807300.     402000.     97.75

 PRESSURE      29.314      29.960      29.788      29.915
TEMP DRY         0.0       62.0          0.0         0.0
SINGLE BASE ERRORS                                    MULTIPLE BASE ERRORS
         8.0     10.3       11.3                              1.4
DIP BEARING 163.0 DEG             TILT/MILE 0.76 FEET


TIME    1004
FIELD STN    653            807750.     403700.     22.01

 PRESSURE      29.313      29.957      29.787      29.994
TEMP DRY         0.0       62.6          0.0         0.0
SINGLE BASE ERRORS                                    MULTIPLE BASE ERRORS
         9.1      9.8       13.2                              2.8
DIP BEARING 170.0 DEG             TILT/MILE 0.75 FEET
```

```
CITY TRAVERSE REDUCTION 23 MAY 1956   ASA
 ST PAULS      LIVERPOOL     CENTENNIAL

TIME   1011
FIELD STN   654             808050.     406150.     100.98

 PRESSURE      29.313      29.958      29.785      29.907
TEMP DRY          0.0       63.6         0.0         0.0
SINGLE BASE ERRORS                                  MULTIPLE BASE ERRORS
        7.0      10.8      12.7                            3.0
DIP BEARING 157.2 DEG         TILT/MILE 0.78 FEET


TIME   1016
FIELD STN   655             808350.     407400.     147.50

 PRESSURE      29.312      29.962      29.784      29.861
TEMP DRY          0.0       64.4         0.0         0.0
SINGLE BASE ERRORS                                  MULTIPLE BASE ERRORS
        1.6      10.1       6.7                            0.4
DIP BEARING 133.4 DEG         TILT/MILE 0.75 FEET


TIME   1021
FIELD STN   656             807000.     407750.     168.23

 PRESSURE      29.311      29.956      29.785      29.839
TEMP DRY          0.0       65.1         0.0         0.0
SINGLE BASE ERRORS                                  MULTIPLE BASE ERRORS
        5.2       7.7       4.6                           -2.9
DIP BEARING 158.6 DEG         TILT/MILE 0.56 FEET


TIME   1027
FIELD STN   657             805500.     408500.     112.12

 PRESSURE      29.310      29.956      29.786      29.895
TEMP DRY          0.0       66.0         0.0         0.0
SINGLE BASE ERRORS                                  MULTIPLE BASE ERRORS
        3.2       5.1       7.3                            2.1
DIP BEARING 156.8 DEG         TILT/MILE 0.37 FEET
```

```
CITY TRAVERSE REDUCTION 23 MAY 1956   ASA

 ST PAULS      LIVERPOOL     CENTENNIAL

TIME   1032
FIELD STN    658             805800.      410000.     158.72

 PRESSURE       29.309      29.956       29.785      29.843
TEMP DRY           0.0       66.8          0.0         0.0
SINGLE BASE ERRORS                                       MULTIPLE BASE ERRORS
       1.4         4.4        7.0                                  3.2
DIP BEARING 141.1 DEG              TILT/MILE 0.32 FEET


TIME   1037
FIELD STN    659             806000.      411250.     123.38

 PRESSURE       29.308      29.959       29.783      29.882
TEMP DRY           0.0       67.5          0.0         0.0
SINGLE BASE ERRORS                                       MULTIPLE BASE ERRORS
      -3.1         4.7        4.7                                  2.7
DIP BEARING 104.5 DEG              TILT/MILE 0.47 FEET


TIME   1043
FIELD STN    660             806000.      413000.     154.27

 PRESSURE       29.306      29.956       29.780      29.847
TEMP DRY           0.0       68.4          0.0         0.0
SINGLE BASE ERRORS                                       MULTIPLE BASE ERRORS
      -3.3         4.8        3.4                                  1.0
DIP BEARING 104.2 DEG              TILT/MILE 0.49 FEET


TIME   1049
FIELD STN    661             805450.      414300.      57.64

 PRESSURE       29.302      29.950       29.777      29.947
TEMP DRY           0.0       69.3          0.0         0.0
SINGLE BASE ERRORS                                       MULTIPLE BASE ERRORS
      -2.5         3.1        2.6                                  1.0
DIP BEARING 100.9 DEG              TILT/MILE 0.33 FEET
```

```
CITY TRAVERSE REDUCTION 23 MAY 1956   ASA

 ST PAULS      LIVERPOOL     CENTENNIAL

TIME   1055
FIELD STN    662              804600.      415900.      20.36

 PRESSURE       29.298       29.944       29.773       29.982
TEMP DRY          0.0         70.3          0.0          0.0
SINGLE BASE ERRORS                                       MULTIPLE BASE ERRORS
      -1.9        2.2         2.5                                 1.1
DIP BEARING 100.2 DEG                  TILT/MILE 0.24 FEET


TIME   1104
FIELD STN    663              805700.      416350.      24.00

 PRESSURE       29.295       29.936       29.766       29.971
TEMP DRY          0.0         71.2          0.0          0.0
SINGLE BASE ERRORS                                       MULTIPLE BASE ERRORS
       1.7        5.1         5.1                                -0.2
DIP BEARING 141.8 DEG                  TILT/MILE 0.37 FEET


TIME   1111
FIELD STN    664              806600.      418100.       8.11

 PRESSURE       29.294       29.925       29.759       29.976
TEMP DRY          0.0         71.6          0.0          0.0
SINGLE BASE ERRORS                                       MULTIPLE BASE ERRORS
      10.5       10.3        14.9                                 2.0
DIP BEARING 173.7 DEG                  TILT/MILE 0.82 FEET


TIME   1119
FIELD STN    665              807350.      418750.      20.35

 PRESSURE       29.292       29.919       29.754       29.960
TEMP DRY          0.0         72.0          0.0          0.0
SINGLE BASE ERRORS                                       MULTIPLE BASE ERRORS
      13.7       12.8        15.2                                -0.6
DIP BEARING 175.8 DEG                  TILT/MILE 1.03 FEET
```

```
CITY TRAVERSE REDUCTION 23 MAY 1956   ASA
 ST PAULS      LIVERPOOL     CENTENNIAL

TIME   1128
FIELD STN   279              809300.     420000.     36.86

 PRESSURE      29.285      29.913      29.752      29.938
TEMP DRY          0.0       72.4         0.0         0.0
SINGLE BASE  ERRORS                                    MULTIPLE BASE ERRORS
       12.1       7.6      12.1                                 2.5
DIP BEARING  12.5 DEG              TILT/MILE 0.76 FEET


TIME   1137
FIELD STN   280              811250.     420600.     46.23

 PRESSURE      29.281      29.913      29.750      29.927
TEMP DRY          0.0       72.8         0.0         0.0
SINGLE BASE  ERRORS                                    MULTIPLE BASE ERRORS
        7.9       5.4       8.6                                 2.6
DIP BEARING   9.1 DEG              TILT/MILE 0.51 FEET


TIME   1210
FIELD STN   178              814150.     420250.     33.80

 PRESSURE      29.270      29.895      29.731      29.924
TEMP DRY          0.0       74.3         0.0         0.0
SINGLE BASE  ERRORS                                    MULTIPLE BASE ERRORS
       12.5      11.5      11.6                                 0.8
DIP BEARING 176.7 DEG              TILT/MILE 0.93 FEET


TIME   1235
FIELD STN   285              818000.     421650.     39.70

 PRESSURE      29.265      29.892      29.729      29.920
TEMP DRY          0.0       75.2         0.0         0.0
SINGLE BASE  ERRORS                                    MULTIPLE BASE ERRORS
        9.6       7.9       3.6                                -2.3
DIP BEARING   1.3 DEG              TILT/MILE 0.67 FEET
```

```
CITY TRAVERSE REDUCTION 23 MAY 1956   ASA
 ST PAULS      LIVERPOOL     CENTENNIAL

TIME   1255
FIELD STN   285            818000.     421650.     39.70
 PRESSURE     29.258     29.883     29.721     29.916
TEMP DRY        0.0       75.8        0.0        0.0
SINGLE BASE ERRORS                                MULTIPLE BASE ERRORS
      10.6       8.2      -0.1                           -6.2
DIP BEARING   4.0 DEG          TILT/MILE 0.72 FEET

TIME   1303
FIELD STN   286            820300.     420500.    317.74
 PRESSURE     29.253     29.881     29.719     29.613
TEMP DRY        0.0       76.0        0.0        0.0
SINGLE BASE ERRORS                                MULTIPLE BASE ERRORS
       7.5       5.1       2.6                           -0.6
DIP BEARING   9.0 DEG          TILT/MILE 0.48 FEET

TIME   1309
FIELD STN   287            821000.     419200.    291.72
 PRESSURE     29.250     29.877     29.717     29.632
TEMP DRY        0.0       76.1        0.0        0.0
SINGLE BASE ERRORS                                MULTIPLE BASE ERRORS
       8.3       4.1       7.7                            5.3
DIP BEARING  22.0 DEG          TILT/MILE 0.49 FEET

TIME   1315
FIELD STN   288            822300.     417900.    325.39
 PRESSURE     29.246     29.874     29.715     29.601
TEMP DRY        0.0       76.2        0.0        0.0
SINGLE BASE ERRORS                                MULTIPLE BASE ERRORS
       7.1       2.0      -0.5                           -1.6
DIP BEARING  37.9 DEG          TILT/MILE 0.41 FEET
```

```
CITY TRAVERSE REDUCTION 23 MAY 1956   ASA

 ST PAULS      LIVERPOOL     CENTENNIAL

TIME   1320
FIELD STN   289            823600.     418200.    330.20

 PRESSURE     29.245     29.872     29.713     29.593
TEMP DRY        0.0       76.3        0.0        0.0
SINGLE BASE ERRORS                                MULTIPLE BASE ERRORS
       7.9       2.9       1.3                          -0.0
DIP BEARING  31.9 DEG          TILT/MILE 0.45 FEET

TIME   1324
FIELD STN   290            824900.     418250.    352.26

 PRESSURE     29.244     29.870     29.712     29.567
TEMP DRY        0.0       76.4        0.0        0.0
SINGLE BASE ERRORS                                MULTIPLE BASE ERRORS
       8.7       2.8       2.8                           1.9
DIP BEARING  35.4 DEG          TILT/MILE 0.50 FEET

TIME   1329
FIELD STN   291            826250.     417250.    359.53

 PRESSURE     29.242     29.866     29.710     29.558
TEMP DRY        0.0       76.5        0.0        0.0
SINGLE BASE ERRORS                                MULTIPLE BASE ERRORS
      10.5       2.6       2.1                           1.5
DIP BEARING  40.3 DEG          TILT/MILE 0.60 FEET

TIME   1335
FIELD STN   292            827700.     416250.    398.66

 PRESSURE     29.240     29.866     29.709     29.516
TEMP DRY        0.0       76.6        0.0        0.0
SINGLE BASE ERRORS                                MULTIPLE BASE ERRORS
       8.4       1.6       0.9                           0.7
DIP BEARING  45.2 DEG          TILT/MILE 0.49 FEET
```

```
CITY TRAVERSE REDUCTION 23 MAY 1956   ASA

 ST PAULS      LIVERPOOL     CENTENNIAL

TIME   1339
FIELD STN   293             829300.     415500.    422.16

 PRESSURE     29.238      29.864      29.708      29.490
TEMP DRY         0.0       76.6         0.0         0.0
SINGLE BASE ERRORS                                   MULTIPLE BASE ERRORS
       8.4       0.6        0.2                               0.5
DIP BEARING  53.7 DEG            TILT/MILE 0.50 FEET


TIME   1344
FIELD STN   294             830600.     414500.    460.81

 PRESSURE     29.236      29.864      29.707      29.447
TEMP DRY         0.0       76.7         0.0         0.0
SINGLE BASE ERRORS                                   MULTIPLE BASE ERRORS
       6.4      -0.4        0.6                               0.9
DIP BEARING  63.2 DEG            TILT/MILE 0.40 FEET


TIME   1350
FIELD STN   295             832050.     413350.    594.19

 PRESSURE     29.234      29.862      29.705      29.305
TEMP DRY         0.0       76.8         0.0         0.0
SINGLE BASE ERRORS                                   MULTIPLE BASE ERRORS
       6.2      -0.5        0.8                               1.1
DIP BEARING  64.4 DEG            TILT/MILE 0.40 FEET


TIME   1355
FIELD STN   296             833100.     412100.    631.79

 PRESSURE     29.232      29.862      29.702      29.262
TEMP DRY         0.0       76.9         0.0         0.0
SINGLE BASE ERRORS                                   MULTIPLE BASE ERRORS
       4.2       0.3        2.5                               2.5
DIP BEARING  54.2 DEG            TILT/MILE 0.25 FEET
```

```
CITY TRAVERSE REDUCTION 23 MAY 1956   ASA
 ST PAULS      LIVERPOOL     CENTENNIAL

TIME   1414
FIELD STN   224            831300.     406600.    621.34

 PRESSURE      29.228     29.859     29.690     29.268
TEMP DRY         0.0       76.0        0.0        0.0
SINGLE BASE ERRORS                                 MULTIPLE BASE ERRORS
       4.2      8.5       3.4                             2.6
DIP BEARING 149.6 DEG          TILT/MILE 0.61 FEET


TIME   1424
FIELD STN   223            822900.     400500.    425.18

 PRESSURE      29.225     29.851     29.697     29.469
TEMP DRY         0.0       75.3        0.0        0.0
SINGLE BASE ERRORS                                 MULTIPLE BASE ERRORS
       9.6     -0.4       5.3                             2.0
DIP BEARING  61.4 DEG          TILT/MILE 0.60 FEET


TIME   1436
FIELD STN   222            822900.     400500.     30.61

 PRESSURE      29.221     29.845     29.696     29.880
TEMP DRY         0.0       74.6        0.0        0.0
SINGLE BASE ERRORS                                 MULTIPLE BASE ERRORS
      12.2     -2.7       8.7                             4.7
DIP BEARING  72.0 DEG          TILT/MILE 0.85 FEET


TIME   1445
FIELD STN   637            820800.     400500.     35.84

 PRESSURE      29.219     29.847     29.695     29.872
TEMP DRY         0.0       74.0        0.0        0.0
SINGLE BASE ERRORS                                 MULTIPLE BASE ERRORS
       9.1     -3.1       9.8                             5.4
DIP BEARING  78.0 DEG          TILT/MILE 0.69 FEET
```

```
CITY TRAVERSE REDUCTION 23 MAY 1956   ASA
 ST PAULS      LIVERPOOL     CENTENNIAL

TIME   1452
FIELD STN   638             819400.     399900.     61.40

 PRESSURE      29.219      29.841      29.693      29.847
TEMP DRY        0.0         73.5         0.0         0.0
SINGLE BASE ERRORS                                     MULTIPLE BASE ERRORS
       15.2     -0.8        8.2                             -0.5
DIP BEARING  62.5 DEG             TILT/MILE 0.96 FEET


TIME   1459
FIELD STN   639             817300.     399500.    123.83

 PRESSURE      29.220      29.841      29.691      29.795
TEMP DRY        0.0         73.0         0.0         0.0
SINGLE BASE ERRORS                                     MULTIPLE BASE ERRORS
       16.7      2.4       -4.0                            -14.9
DIP BEARING  48.6 DEG             TILT/MILE 0.97 FEET


TIME   1503
FIELD STN   640             815900.     398750.    119.13

 PRESSURE      29.220      29.841      29.692      29.790
TEMP DRY        0.0         72.8         0.0         0.0
SINGLE BASE ERRORS                                     MULTIPLE BASE ERRORS
       16.9      1.6        5.5                             -6.3
DIP BEARING  52.1 DEG             TILT/MILE 1.00 FEET


TIME   1509
FIELD STN   642             813150.     397350.    115.12

 PRESSURE      29.220      29.841      29.694      29.787
TEMP DRY        0.0         72.4         0.0         0.0
SINGLE BASE ERRORS                                     MULTIPLE BASE ERRORS
       17.4      0.1       12.8                             -0.9
DIP BEARING  58.5 DEG             TILT/MILE 1.06 FEET
```

```
CITY TRAVERSE REDUCTION 23 MAY 1956   ASA

 ST PAULS       LIVERPOOL     CENTENNIAL

TIME   1513
FIELD STN   643              812700.     395800.     22.00

 PRESSURE      29.220      29.841      29.694      29.885
TEMP DRY          0.0      72.1           0.0        0.0
SINGLE BASE ERRORS                                    MULTIPLE BASE ERRORS
      17.7        0.3      14.6                               -0.3
DIP BEARING  57.5 DEG              TILT/MILE 1.08 FEET


TIME   1519
FIELD STN   644              811600.     394200.     20.60

 PRESSURE      29.220      29.841      29.693      29.887
TEMP DRY          0.0      71.7           0.0        0.0
SINGLE BASE ERRORS                                    MULTIPLE BASE ERRORS
      18.1        1.6      14.6                               -1.5
DIP BEARING  52.6 DEG              TILT/MILE 1.07 FEET


TIME   1523
FIELD STN   645              810300.     393300.     34.80

 PRESSURE      29.220      29.841      29.690      29.870
TEMP DRY          0.0      71.5           0.0        0.0
SINGLE BASE ERRORS                                    MULTIPLE BASE ERRORS
      18.4        4.6      16.5                               -0.9
DIP BEARING  40.5 DEG              TILT/MILE 1.05 FEET
```

```
CITY TRAVERSE REDUCTION  6 DECEMBER 1955   ASA


CONSTANT 1 143831.81
CONSTANT 2   0.18910
 PRESSURES IN INCHES
 TEMPERATURES IN FARENHEIT
 COORDINATES IN YARDS


 STATION          X          Y       HEIGHT
ST PAULS        833900.    411100.   663.00
LIVERPOOL       809100.    392600.    60.00
CENTENNIAL      812900.    423800.   215.00


TIME    924
FIELD STN    ST PAULS       833900.     411100.    663.00
             ST PAULS       833900.     411100.    663.00
 PRESSURE     29.618       30.283      30.079    29.618     29.618
TEMP DRY         0.0       69.1          0.0       0.0        0.0
TEMP WET         0.0       60.7          0.0       0.0        0.0
SINGLE BASE  ERRORS                                 MULTIPLE BASE ERRORS
      -15.5     18.0        0.0        0.0                 0.0        0.0
DIP BEARING  100.0 DEG           TILT/MILE 1.96 FEET

TIME    936
FIELD STN    ST PAULS       833900.     411100.    663.00
             296            833100.     412100.    631.79
 PRESSURE     29.614       30.289      30.075    29.614     29.646
TEMP DRY         0.0       69.4          0.0       0.0        0.0
TEMP WET         0.0       60.8          0.0       0.0        0.0
SINGLE BASE  ERRORS                                 MULTIPLE BASE ERRORS
      -25.2     17.8        0.0        1.2                 0.0       -0.2
DIP BEARING   90.5 DEG           TILT/MILE 2.43 FEET

TIME    946
FIELD STN    295            832050.     413350.    594.19
             296            833100.     412100.    631.79
 PRESSURE     29.612       30.289      30.073    29.685     29.652
TEMP DRY         0.0       69.9          0.0       0.0        0.0
TEMP WET         0.0       61.0          0.0       0.0        0.0
SINGLE BASE  ERRORS                                 MULTIPLE BASE ERRORS
      -27.7     17.3        0.2       -6.4                -2.9       -7.8
DIP BEARING   88.2 DEG           TILT/MILE 2.53 FEET
```

```
CITY TRAVERSE REDUCTION  6 DECEMBER 1955   ASA

 ST PAULS      LIVERPOOL     CENTENNIAL

TIME   1000
FIELD STN    295             832050.      413350.     594.19
             294             830600.      414500.     460.81
 PRESSURE      29.613      30.285       30.071      29.684       29.833
TEMP DRY          0.0      70.0          0.0         0.0          0.0
TEMP WET          0.0      61.2          0.0         0.0          0.0
SINGLE BASE  ERRORS                                    MULTIPLE BASE  ERRORS
     -23.1        20.0       2.1        -4.1               -1.2          -9.2
DIP BEARING  94.4 DEG              TILT/MILE 2.46 FEET

TIME   1010
FIELD STN    293             829300.      415500.     422.16
             294             830600.      414500.     460.81
 PRESSURE      29.612      30.285       30.074      29.868       29.835
TEMP DRY          0.0      70.0          0.0         0.0          0.0
TEMP WET          0.0      61.2          0.0         0.0          0.0
SINGLE BASE  ERRORS                                    MULTIPLE BASE  ERRORS
     -24.1        16.2       0.9        -6.9               -4.7         -11.2
DIP BEARING  89.6 DEG              TILT/MILE 2.27 FEET

TIME   1020
FIELD STN    293             829300.      415500.     422.16
             292             827700.      416250.     398.66
 PRESSURE      29.611      30.285       30.075      29.871       29.901
TEMP DRY          0.0      69.9          0.0         0.0          0.0
TEMP WET          0.0      61.3          0.0         0.0          0.0
SINGLE BASE  ERRORS                                    MULTIPLE BASE  ERRORS
     -24.9        14.5      -2.8        -7.3               -8.0         -13.3
DIP BEARING  86.9 DEG              TILT/MILE 2.21 FEET

TIME   1029
FIELD STN    291             826250.      417250.     359.53
             292             827700.      416250.     398.66
 PRESSURE      29.610      30.281       30.076      29.934       29.897
TEMP DRY          0.0      69.9          0.0         0.0          0.0
TEMP WET          0.0      61.3          0.0         0.0          0.0
SINGLE BASE  ERRORS                                    MULTIPLE BASE  ERRORS
     -22.2        12.6       0.2        -4.5               -6.1          -9.8
DIP BEARING  86.3 DEG              TILT/MILE 1.95 FEET
```

```
CITY TRAVERSE REDUCTION  6 DECEMBER 1955   ASA
 ST PAULS      LIVERPOOL     CENTENNIAL

TIME   1039
FIELD STN   291            826250.     417250.    359.53
            290            824900.     418250.    352.26
 PRESSURE     29.614     30.278      30.077    29.935     29.949
TEMP DRY        0.0       69.9         0.0       0.0        0.0
TEMP WET        0.0       61.4         0.0       0.0        0.0
SINGLE BASE ERRORS                                MULTIPLE BASE ERRORS
     -15.7      15.5       2.9      -2.7              -4.3     -11.1
DIP BEARING  97.0 DEG          TILT/MILE 1.80 FEET

TIME   1058
FIELD STN   289            823600.     418200.    330.20
            290            824900.     418250.    352.26
 PRESSURE     29.621     30.274      30.075    29.969     29.950
TEMP DRY        0.0       69.8         0.0       0.0        0.0
TEMP WET        0.0       61.5         0.0       0.0        0.0
SINGLE BASE ERRORS                                MULTIPLE BASE ERRORS
      -5.3      23.9       7.2       2.9              -5.4      -9.1
DIP BEARING 118.0 DEG          TILT/MILE 2.00 FEET

TIME   1125
FIELD STN   289            823600.     418200.    330.20
            288            822300.     417900.    325.39
 PRESSURE     29.620     30.259      30.071    29.971     29.974
TEMP DRY        0.0       69.7         0.0       0.0        0.0
TEMP WET        0.0       61.5         0.0       0.0        0.0
SINGLE BASE ERRORS                                MULTIPLE BASE ERRORS
       7.6      26.7       4.5       6.5              -9.2      -8.1
DIP BEARING 139.5 DEG          TILT/MILE 1.94 FEET

TIME   1132
FIELD STN   288            822300.     417900.    325.39
            288            822300.     417900.    325.39
 PRESSURE     29.621     30.259      30.070    29.972     29.972
TEMP DRY        0.0       69.7         0.0       0.0        0.0
TEMP WET        0.0       61.6         0.0       0.0        0.0
SINGLE BASE ERRORS                                MULTIPLE BASE ERRORS
       8.5      28.6       9.2       9.2              -6.4      -6.4
DIP BEARING 140.2 DEG          TILT/MILE 2.08 FEET
```

```
CITY TRAVERSE REDUCTION  6 DECEMBER 1955   ASA

 ST PAULS      LIVERPOOL     CENTENNIAL

TIME    1145
FIELD STN    288               822300.      417900.     325.39
             287               821000.      419200.     291.72
 PRESSURE      29.614        30.257       30.066      29.963       30.003
TEMP DRY          0.0         69.6          0.0         0.0          0.0
TEMP WET          0.0         61.6          0.0         0.0          0.0
SINGLE BASE  ERRORS                                     MULTIPLE BASE ERRORS
        4.0       25.8         11.2         7.6              -2.9         -8.5
DIP BEARING  133.5 DEG             TILT/MILE 1.92 FEET

TIME    1205
FIELD STN    286               820300.      420500.     317.74
             287               821000.      419200.     291.72
 PRESSURE      29.615        30.245       30.063      29.974       30.002
TEMP DRY          0.0         69.5          0.0         0.0          0.0
TEMP WET          0.0         61.7          0.0         0.0          0.0
SINGLE BASE  ERRORS                                     MULTIPLE BASE ERRORS
       15.9       29.6          9.5         9.5             -10.3         -8.8
DIP BEARING  152.0 DEG             TILT/MILE 2.12 FEET

TIME    1230
FIELD STN    286               820300.      420500.     317.74
             285               818000.      421650.      39.70
 PRESSURE      29.616        30.241       30.066      29.976       30.277
TEMP DRY          0.0         69.8          0.0         0.0          0.0
TEMP WET          0.0         61.9          0.0         0.0          0.0
SINGLE BASE  ERRORS                                     MULTIPLE BASE ERRORS
       20.3       27.4          8.4         7.3              -9.8        -13.8
DIP BEARING  161.7 DEG             TILT/MILE 2.02 FEET

TIME    1245
FIELD STN    100               816300.      421200.      25.48
             285               818000.      421650.      39.70
 PRESSURE      29.615        30.243       30.067      30.288       30.276
TEMP DRY          0.0         69.9          0.0         0.0          0.0
TEMP WET          0.0         62.0          0.0         0.0          0.0
SINGLE BASE  ERRORS                                     MULTIPLE BASE ERRORS
       17.3       25.4         10.3         7.2             -10.8        -12.4
DIP BEARING  158.8 DEG             TILT/MILE 1.85 FEET
```

```
CITY TRAVERSE REDUCTION  6 DECEMBER 1955   ASA

 ST PAULS      LIVERPOOL     CENTENNIAL

TIME   1305
FIELD STN    100              816300.     421200.     25.48
             178              814150.     420250.     33.80
 PRESSURE      29.615       30.247      30.064     30.282      30.276
TEMP DRY          0.0        70.1         0.0        0.0          0.0
TEMP WET          0.0        62.2         0.0        0.0          0.0
SINGLE BASE  ERRORS                                  MULTIPLE BASE ERRORS
       13.4       28.1        15.5       12.8             -7.7        -11.9
DIP BEARING  149.0 DEG              TILT/MILE 2.01 FEET

TIME   1320
FIELD STN    178              814150.     420250.     33.80
             178              814150.     420250.     33.80
 PRESSURE      29.615       30.247      30.064     30.275      30.275
TEMP DRY          0.0        69.9         0.0        0.0          0.0
TEMP WET          0.0        62.3         0.0        0.0          0.0
SINGLE BASE  ERRORS                                  MULTIPLE BASE ERRORS
       13.6       28.2        13.9       13.9            -11.0        -11.0
DIP BEARING  149.2 DEG              TILT/MILE 2.02 FEET

TIME   1356
FIELD STN    178              814150.     420250.     33.80
             178              814150.     420250.     33.80
 PRESSURE      29.615       30.247      30.073     30.278      30.278
TEMP DRY          0.0        69.5         0.0        0.0          0.0
TEMP WET          0.0        62.5         0.0        0.0          0.0
SINGLE BASE  ERRORS                                  MULTIPLE BASE ERRORS
       14.0       20.2        11.7       11.7             -6.5         -6.5
DIP BEARING  159.5 DEG              TILT/MILE 1.47 FEET

TIME   1420
FIELD STN    178              814150.     420250.     33.80
             220              813650.     413650.     97.52
 PRESSURE      29.615       30.243      30.075     30.276      30.201
TEMP DRY          0.0        69.6         0.0        0.0          0.0
TEMP WET          0.0        62.7         0.0        0.0          0.0
SINGLE BASE  ERRORS                                  MULTIPLE BASE ERRORS
       17.5       18.3        13.3       19.0             -3.5          2.5
DIP BEARING  171.4 DEG              TILT/MILE 1.42 FEET
```

```
CITY TRAVERSE REDUCTION  6 DECEMBER 1955   ASA

 ST PAULS     LIVERPOOL    CENTENNIAL

TIME   1500
FIELD STN   A            817000.   407000.    14.30
            220          813650.   413650.    97.52
 PRESSURE     29.615    30.247    30.075    30.286    30.194
TEMP DRY        0.0      70.0       0.0       0.0       0.0
TEMP WET        0.0      63.0       0.0       0.0       0.0
SINGLE BASE ERRORS                           MULTIPLE BASE ERRORS
     13.4       17.9     23.0      25.0            11.9      10.0
DIP BEARING 162.0 DEG        TILT/MILE 1.32 FEET

TIME   1530
FIELD STN   A            817000.   407000.    14.30
            637          820800.   400500.    35.84
 PRESSURE     29.615    30.245    30.075    30.292    30.253
TEMP DRY        0.0      69.8       0.0       0.0       0.0
TEMP WET        0.0      63.5       0.0       0.0       0.0
SINGLE BASE ERRORS                           MULTIPLE BASE ERRORS
     15.4       18.0     17.7      32.2             5.7      24.1
DIP BEARING 166.8 DEG        TILT/MILE 1.36 FEET

TIME   1555
FIELD STN   222          822900.   400500.    30.61
            637          820800.   400500.    35.84
 PRESSURE     29.612    30.241    30.075    30.262    30.258
TEMP DRY        0.0      69.7       0.0       0.0       0.0
TEMP WET        0.0      64.0       0.0       0.0       0.0
SINGLE BASE ERRORS                           MULTIPLE BASE ERRORS
     16.4       15.2     26.3      24.8            19.4      16.2
DIP BEARING 176.1 DEG        TILT/MILE 1.23 FEET

TIME   1615
FIELD STN   222          822900.   400500.    30.61
            223          822900.   400500.   425.18
 PRESSURE     29.603    30.243    30.075    30.267    29.846
TEMP DRY        0.0      69.3       0.0       0.0       0.0
TEMP WET        0.0      64.1       0.0       0.0       0.0
SINGLE BASE ERRORS                           MULTIPLE BASE ERRORS
      6.4        7.1     13.7      10.1            10.9       7.3
DIP BEARING 168.8 DEG        TILT/MILE 0.54 FEET
```

```
CITY TRAVERSE REDUCTION  6 DECEMBER 1955   ASA

 ST PAULS      LIVERPOOL     CENTENNIAL

TIME   1629
FIELD STN   223            822900.     400500.    425.18
            223            822900.     400500.    425.18
 PRESSURE     29.599     30.241     30.075     29.846     29.846
TEMP DRY        0.0       69.0        0.0        0.0        0.0
TEMP WET        0.0       64.3        0.0        0.0        0.0
SINGLE BASE ERRORS                                MULTIPLE BASE ERRORS
       4.9       3.5       6.4       6.4                4.5       4.5
DIP BEARING   6.5 DEG          TILT/MILE 0.32 FEET

TIME   1645
FIELD STN   223            822900.     400500.    425.18
            224            831300.     406600.    621.34
 PRESSURE     29.602     30.239     30.074     29.836     29.644
TEMP DRY        0.0       68.7        0.0        0.0        0.0
TEMP WET        0.0       64.4        0.0        0.0        0.0
SINGLE BASE ERRORS                                MULTIPLE BASE ERRORS
       9.8       7.4      18.7       2.2               14.7       1.5
DIP BEARING   4.8 DEG          TILT/MILE 0.66 FEET

TIME   1711
FIELD STN   ST PAULS       833900.     411100.    663.00
            224            831300.     406600.    621.34
 PRESSURE     29.608     30.241     30.080     29.608     29.646
TEMP DRY        0.0       68.2        0.0        0.0        0.0
TEMP WET        0.0       64.5        0.0        0.0        0.0
SINGLE BASE ERRORS                                MULTIPLE BASE ERRORS
      14.2       8.0       0.0       6.0                0.0       5.3
DIP BEARING  16.9 DEG          TILT/MILE 0.86 FEET

TIME   1722
FIELD STN   ST PAULS       833900.     411100.    663.00
            ST PAULS       833900.     411100.    663.00
 PRESSURE     29.610     30.248     30.084     29.610     29.610
TEMP DRY        0.0       68.0        0.0        0.0        0.0
TEMP WET        0.0       64.5        0.0        0.0        0.0
SINGLE BASE ERRORS                                MULTIPLE BASE ERRORS
       9.8       6.2       0.0       0.0                0.0       0.0
DIP BEARING  12.1 DEG          TILT/MILE 0.62 FEET
```

```
CITY TRAVERSE REDUCTION  7 DECEMBER 1955   ASA

CONSTANT 1 143831.81
CONSTANT 2   0.18910
 PRESSURES IN INCHES
 TEMPERATURES IN FARENHEIT

 STATION          X          Y        HEIGHT
ST PAULS       833900.    411100.    663.00
LIVERPOOL      809100.    392600.     60.00
CENTENNIAL     812900.    423800.    215.00

TIME    905
FIELD STN    637          820800.      400500.      35.84
             637          820800.      400500.      35.84
 PRESSURE      29.772   30.415      30.244      30.441       30.441
TEMP DRY          0.0    72.6          0.0         0.0          0.0
TEMP WET          0.0    63.2          0.0         0.0          0.0
SINGLE BASE ERRORS                                 MULTIPLE BASE ERRORS
     3.4          6.9      3.6         3.6               1.7         1.7
DIP BEARING 150.0 DEG           TILT/MILE 0.49 FEET

TIME    920
FIELD STN    637          820800.      400500.      35.84
             638          819400.      399900.      61.40
 PRESSURE      29.772   30.424      30.244      30.441       30.416
TEMP DRY          0.0    72.7          0.0         0.0          0.0
TEMP WET          0.0    64.2          0.0         0.0          0.0
SINGLE BASE ERRORS                                 MULTIPLE BASE ERRORS
    -5.1          6.7      3.3         0.9               5.7         3.8
DIP BEARING 102.1 DEG           TILT/MILE 0.70 FEET

TIME    932
FIELD STN    639          817300.      399500.     123.83
             638          819400.      399900.      61.40
 PRESSURE      29.774   30.430      30.244      30.344       30.416
TEMP DRY          0.0    72.7          0.0         0.0          0.0
TEMP WET          0.0    64.8          0.0         0.0          0.0
SINGLE BASE ERRORS                                 MULTIPLE BASE ERRORS
    -8.9          8.5      6.9         2.8              12.4         7.7
DIP BEARING  96.5 DEG           TILT/MILE 1.00 FEET
```

```
CITY TRAVERSE REDUCTION  7 DECEMBER 1955   ASA

 ST PAULS      LIVERPOOL     CENTENNIAL

TIME    942
FIELD STN   639          817300.     399500.     123.83
            640          815900.     398750.     119.13
 PRESSURE      29.773   30.430      30.240      30.343      30.352
TEMP DRY        0.0     72.8         0.0         0.0         0.0
TEMP WET        0.0     65.3         0.0         0.0         0.0
SINGLE BASE ERRORS                              MULTIPLE BASE ERRORS
     -10.0     11.1      6.7         3.0                12.8        9.5
DIP BEARING  99.3 DEG          TILT/MILE 1.23 FEET

TIME    955
FIELD STN   641          815000.     397800.      46.39
            640          815900.     398750.     119.13
 PRESSURE      29.770   30.428      30.242      30.423      30.344
TEMP DRY        0.0     72.8         0.0         0.0         0.0
TEMP WET        0.0     66.0         0.0         0.0         0.0
SINGLE BASE ERRORS                              MULTIPLE BASE ERRORS
     -11.1      6.4      7.2         7.6                15.2       15.1
DIP BEARING  86.7 DEG          TILT/MILE 0.98 FEET

TIME   1006
FIELD STN   641          815000.     397800.      46.39
            642          813150.     397350.     115.12
 PRESSURE      29.770   30.426      30.241      30.423      30.351
TEMP DRY        0.0     72.7         0.0         0.0         0.0
TEMP WET        0.0     65.9         0.0         0.0         0.0
SINGLE BASE ERRORS                              MULTIPLE BASE ERRORS
      -9.1      7.5      7.3         5.2                13.8       11.9
DIP BEARING  93.4 DEG          TILT/MILE 0.95 FEET

TIME   1020
FIELD STN   B            812700.     395800.      17.00
            642          813150.     397350.     115.12
 PRESSURE      29.770   30.421      30.240      30.453      30.348
TEMP DRY        0.0     72.5         0.0         0.0         0.0
TEMP WET        0.0     65.7         0.0         0.0         0.0
SINGLE BASE ERRORS                              MULTIPLE BASE ERRORS
      -4.2      8.5      9.2         8.3                12.6       11.1
DIP BEARING 109.1 DEG          TILT/MILE 0.79 FEET
```

```
CITY TRAVERSE REDUCTION  7 DECEMBER 1955   ASA

 ST PAULS      LIVERPOOL     CENTENNIAL

TIME   1032
FIELD STN   B              812700.     395800.     17.00
            644            811600.     394200.     20.60
 PRESSURE     29.769     30.416      30.240      30.454      30.446
TEMP DRY        0.0       72.2        0.0        0.0        0.0
TEMP WET        0.0       65.5        0.0        0.0        0.0
SINGLE BASE ERRORS                                MULTIPLE BASE ERRORS
      -0.1        7.8      7.7      11.4                     7.6      11.5
DIP BEARING 126.0 DEG          TILT/MILE 0.61 FEET

TIME   1042
FIELD STN   645            810300.     393300.     34.80
            644            811600.     394200.     20.60
 PRESSURE     29.766     30.412      30.236      30.431      30.446
TEMP DRY        0.0       72.1        0.0        0.0        0.0
TEMP WET        0.0       65.4        0.0        0.0        0.0
SINGLE BASE ERRORS                                MULTIPLE BASE ERRORS
       0.8        8.9      8.5       8.7                     7.7       7.9
DIP BEARING 130.7 DEG          TILT/MILE 0.67 FEET

TIME   1053
FIELD STN   645            810300.     393300.     34.80
            646            808875.     392600.     66.12
 PRESSURE     29.766     30.407      30.238      30.433      30.397
TEMP DRY        0.0       71.9        0.0        0.0        0.0
TEMP WET        0.0       65.2        0.0        0.0        0.0
SINGLE BASE ERRORS                                MULTIPLE BASE ERRORS
       5.6        7.1      6.8       8.8                     1.5       3.1
DIP BEARING 163.9 DEG          TILT/MILE 0.53 FEET

TIME   1102
FIELD STN   LIVERPOOL      809100.     392600.     60.00
            646            808875.     392600.     66.12
 PRESSURE     29.767     30.406      30.239      30.406      30.398
TEMP DRY        0.0       71.8        0.0        0.0        0.0
TEMP WET        0.0       65.0        0.0        0.0        0.0
SINGLE BASE ERRORS                                MULTIPLE BASE ERRORS
       7.7        7.3      7.7       8.9                     0.0       1.1
DIP BEARING 175.1 DEG          TILT/MILE 0.58 FEET
```

```
CITY TRAVERSE REDUCTION  7 DECEMBER 1955   ASA

 ST PAULS      LIVERPOOL     CENTENNIAL

TIME   1109
FIELD STN   LIVERPOOL      809100.     392600.     60.00
            LIVERPOOL      809100.     392600.     60.00
 PRESSURE     29.771     30.402     30.238     30.402     30.402
TEMP DRY        0.0       71.9        0.0        0.0        0.0
TEMP WET        0.0       64.7        0.0        0.0        0.0
SINGLE BASE ERRORS                                MULTIPLE BASE ERRORS
      15.0      11.8      15.0      15.0                 0.0       0.0
DIP BEARING   3.0 DEG          TILT/MILE 1.03 FEET

TIME   1151
FIELD STN   LIVERPOOL      809100.     392600.     60.00
            647            808300.     394250.     24.23
 PRESSURE     29.766     30.390     30.229     30.390     30.430
TEMP DRY        0.0       72.1        0.0        0.0        0.0
TEMP WET        0.0       63.3        0.0        0.0        0.0
SINGLE BASE ERRORS                                MULTIPLE BASE ERRORS
      21.4      15.4      21.4      20.2                 0.0      -1.7
DIP BEARING   6.9 DEG          TILT/MILE 1.40 FEET

TIME   1209
FIELD STN   648            808400.     395450.     96.47
            647            808300.     394250.     24.23
 PRESSURE     29.766     30.383     30.225     30.347     30.430
TEMP DRY        0.0       72.2        0.0        0.0        0.0
TEMP WET        0.0       63.0        0.0        0.0        0.0
SINGLE BASE ERRORS                                MULTIPLE BASE ERRORS
      27.7      19.2      24.5      20.1                -3.4      -8.2
DIP BEARING   8.5 DEG          TILT/MILE 1.79 FEET

TIME   1216
FIELD STN   648            808400.     395450.     96.47
            649            808550.     397400.      7.72
 PRESSURE     29.766     30.386     30.224     30.345     30.449
TEMP DRY        0.0       72.3        0.0        0.0        0.0
TEMP WET        0.0       63.4        0.0        0.0        0.0
SINGLE BASE ERRORS                                MULTIPLE BASE ERRORS
      24.8      19.9      26.2      18.9                 0.8      -6.3
DIP BEARING   2.3 DEG          TILT/MILE 1.71 FEET
```

```
CITY TRAVERSE REDUCTION  7 DECEMBER 1955   ASA
 ST PAULS      LIVERPOOL     CENTENNIAL

TIME   1227
FIELD STN    650        808300.      399100.      12.18
             649        808550.      397400.       7.72
 PRESSURE     29.765   30.388      30.225      30.440      30.448
TEMP DRY       0.0      72.3         0.0         0.0         0.0
TEMP WET       0.0      63.7         0.0         0.0         0.0
SINGLE BASE  ERRORS                                MULTIPLE BASE ERRORS
     22.0      18.1     21.8        18.8                 -0.8        -3.6
DIP BEARING   1.3 DEG           TILT/MILE 1.54 FEET

TIME   1236
FIELD STN    650        808300.      399100.      12.18
             651        807700.      400750.      42.08
 PRESSURE     29.764   30.386      30.224      30.437      30.409
TEMP DRY       0.0      72.3         0.0         0.0         0.0
TEMP WET       0.0      63.9         0.0         0.0         0.0
SINGLE BASE  ERRORS                                MULTIPLE BASE ERRORS
     22.9      18.0     23.5        19.5                  0.2        -4.3
DIP BEARING   3.2 DEG           TILT/MILE 1.56 FEET

TIME   1246
FIELD STN    652        807300.      402000.      97.75
             651        807700.      400750.      42.08
 PRESSURE     29.763   30.384      30.222      30.342      30.408
TEMP DRY       0.0      72.4         0.0         0.0         0.0
TEMP WET       0.0      64.2         0.0         0.0         0.0
SINGLE BASE  ERRORS                                MULTIPLE BASE ERRORS
     23.6      18.9     24.7        19.3                 -0.2        -5.2
DIP BEARING   2.4 DEG           TILT/MILE 1.63 FEET

TIME   1300
FIELD STN    652        807300.      402000.      97.75
             653        807750.      403700.      22.01
 PRESSURE     29.764   30.384      30.218      30.343      30.430
TEMP DRY       0.0      72.5         0.0         0.0         0.0
TEMP WET       0.0      64.5         0.0         0.0         0.0
SINGLE BASE  ERRORS                                MULTIPLE BASE ERRORS
     24.4      23.4     24.6        19.8                 -2.7        -7.1
DIP BEARING 174.8 DEG           TILT/MILE 1.87 FEET
```

```
CITY TRAVERSE REDUCTION  7 DECEMBER 1955   ASA
 ST PAULS       LIVERPOOL     CENTENNIAL

TIME   1312
FIELD STN    654          808050.     406150.    100.98
             653          807750.     403700.     22.01
 PRESSURE     29.757    30.382      30.216     30.345      30.427
TEMP DRY        0.0      72.3         0.0        0.0         0.0
TEMP WET        0.0      64.2         0.0        0.0         0.0
SINGLE BASE  ERRORS                                MULTIPLE BASE  ERRORS
       19.9     18.8     13.1        16.4               -8.6         -5.5
DIP BEARING  175.4 DEG           TILT/MILE 1.51  FEET

TIME   1323
FIELD STN    654          808050.     406150.    100.98
             655          808350.     407400.    147.50
 PRESSURE     29.755    30.381      30.216     30.339      30.292
TEMP DRY        0.0      72.1         0.0        0.0         0.0
TEMP WET        0.0      64.0         0.0        0.0         0.0
SINGLE BASE  ERRORS                                MULTIPLE BASE  ERRORS
       19.3     17.1     17.1        14.1               -3.4         -6.2
DIP BEARING  177.9 DEG           TILT/MILE 1.41  FEET

TIME   1337
FIELD STN    656          807000.     407750.    168.23
             655          808350.     407400.    147.50
 PRESSURE     29.756    30.379      30.216     30.270      30.297
TEMP DRY        0.0      71.9         0.0        0.0         0.0
TEMP WET        0.0      63.6         0.0        0.0         0.0
SINGLE BASE  ERRORS                                MULTIPLE BASE  ERRORS
       22.3     18.3     14.9        10.7               -8.9        -12.0
DIP BEARING    1.4 DEG           TILT/MILE 1.56  FEET

TIME   1345
FIELD STN    656          807000.     407750.    168.23
             657          805500.     408500.    112.12
 PRESSURE     29.757    30.379      30.217     30.275      30.337
TEMP DRY        0.0      71.8         0.0        0.0         0.0
TEMP WET        0.0      63.1         0.0        0.0         0.0
SINGLE BASE  ERRORS                                MULTIPLE BASE  ERRORS
       23.4     18.4     11.3        10.1              -13.2        -15.7
DIP BEARING    3.3 DEG           TILT/MILE 1.60  FEET
```

```
CITY TRAVERSE REDUCTION  7 DECEMBER 1955   ASA
 ST PAULS      LIVERPOOL     CENTENNIAL

TIME   1357
FIELD STN   658            805800.     410000.    158.72
            657            805500.     408500.    112.12
 PRESSURE     29.756     30.374     30.221     30.283      30.336
TEMP DRY        0.0       71.6         0.0        0.0         0.0
TEMP WET        0.0       62.7         0.0        0.0         0.0
SINGLE BASE ERRORS                                 MULTIPLE BASE ERRORS
      27.3      13.9      12.8       10.3              -11.7     -14.9
DIP BEARING  20.6 DEG          TILT/MILE 1.62 FEET

TIME   1406
FIELD STN   658            805800.     410000.    158.72
            659            806000.     411250.    123.38
 PRESSURE     29.756     30.372     30.221     30.282      30.320
TEMP DRY        0.0       71.5         0.0        0.0         0.0
TEMP WET        0.0       62.8         0.0        0.0         0.0
SINGLE BASE ERRORS                                 MULTIPLE BASE ERRORS
      29.2      14.0      13.7       13.9              -11.9     -11.0
DIP BEARING  22.9 DEG          TILT/MILE 1.71 FEET

TIME   1421
FIELD STN   660            806000.     413000.    154.27
            659            806000.     411250.    123.38
 PRESSURE     29.756     30.369     30.221     30.289      30.318
TEMP DRY        0.0       71.4         0.0        0.0         0.0
TEMP WET        0.0       63.0         0.0        0.0         0.0
SINGLE BASE ERRORS                                 MULTIPLE BASE ERRORS
      32.1      14.1      11.7       15.8              -13.9     -10.6
DIP BEARING  26.0 DEG          TILT/MILE 1.86 FEET

TIME   1430
FIELD STN   660            806000.     413000.    154.27
            660            806000.     413000.    154.27
 PRESSURE     29.755     30.367     30.222     30.286      30.286
TEMP DRY        0.0       71.2         0.0        0.0         0.0
TEMP WET        0.0       63.2         0.0        0.0         0.0
SINGLE BASE ERRORS                                 MULTIPLE BASE ERRORS
      33.2      12.4      13.8       13.8              -11.0     -11.0
DIP BEARING  30.8 DEG          TILT/MILE 1.90 FEET
```

```
CITY TRAVERSE REDUCTION  7 DECEMBER 1955   ASA

 ST PAULS      LIVERPOOL     CENTENNIAL

TIME   1445
FIELD STN   660            806000.     413000.    154.27
            661            805450.     414300.     57.64
 PRESSURE     29.752     30.362     30.217     30.282      30.387
TEMP DRY        0.0       71.0        0.0        0.0         0.0
TEMP WET        0.0       63.4        0.0        0.0         0.0
SINGLE BASE ERRORS                               MULTIPLE BASE ERRORS
      35.2      14.2      14.8       14.4              -12.4     -12.6
DIP BEARING  28.5 DEG          TILT/MILE 2.02 FEET

TIME   1457
FIELD STN   662            804600.     415900.     20.36
            661            805450.     414300.     57.64
 PRESSURE     29.751     30.364     30.218     30.426      30.387
TEMP DRY        0.0       70.8        0.0        0.0         0.0
TEMP WET        0.0       63.6        0.0        0.0         0.0
SINGLE BASE ERRORS                               MULTIPLE BASE ERRORS
      32.6      12.6      15.0       13.7               -9.4     -10.8
DIP BEARING  29.9 DEG          TILT/MILE 1.87 FEET

TIME   1508
FIELD STN   662            804600.     415900.     20.36
            663            805700.     416350.     24.00
 PRESSURE     29.749     30.362     30.216     30.426      30.424
TEMP DRY        0.0       70.6        0.0        0.0         0.0
TEMP WET        0.0       63.7        0.0        0.0         0.0
SINGLE BASE ERRORS                               MULTIPLE BASE ERRORS
      32.7      12.7      13.4       11.6              -11.2     -11.8
DIP BEARING  29.8 DEG          TILT/MILE 1.88 FEET

TIME   1525
FIELD STN   C              806600.     418100.     19.70
            663            805700.     416350.     24.00
 PRESSURE     29.742     30.358     30.213     30.427      30.420
TEMP DRY        0.0       70.3        0.0        0.0         0.0
TEMP WET        0.0       63.2        0.0        0.0         0.0
SINGLE BASE ERRORS                               MULTIPLE BASE ERRORS
      30.2       9.2       7.0        9.1              -10.5     -10.2
DIP BEARING  36.1 DEG          TILT/MILE 1.72 FEET
```

```
CITY TRAVERSE REDUCTION  7 DECEMBER 1955   ASA

 ST PAULS      LIVERPOOL     CENTENNIAL

TIME   1543
FIELD STN   C              806600.     418100.     19.70
            665            807350.     418750.     20.35
 PRESSURE     29.740     30.358     30.210     30.423     30.420
TEMP DRY        0.0       69.9        0.0        0.0        0.0
TEMP WET        0.0       62.9        0.0        0.0        0.0
SINGLE BASE ERRORS                                MULTIPLE BASE ERRORS
      28.8      10.4       9.3       11.4                 -8.9      -6.0
DIP BEARING  31.8 DEG          TILT/MILE 1.65 FEET

TIME   1604
FIELD STN   279           809300.     420000.     36.86
            665            807350.     418750.     20.35
 PRESSURE     29.736     30.358     30.209     30.400     30.414
TEMP DRY        0.0       69.5        0.0        0.0        0.0
TEMP WET        0.0       62.5        0.0        0.0        0.0
SINGLE BASE ERRORS                                MULTIPLE BASE ERRORS
      25.6       8.0      10.1       13.8                 -2.2      -0.4
DIP BEARING  35.5 DEG          TILT/MILE 1.45 FEET

TIME   1620
FIELD STN   279            809300.     420000.     36.86
            280            811250.     420600.     46.23
 PRESSURE     29.729     30.356     30.211     30.402     30.385
TEMP DRY        0.0       69.3        0.0        0.0        0.0
TEMP WET        0.0       62.3        0.0        0.0        0.0
SINGLE BASE ERRORS                                MULTIPLE BASE ERRORS
      21.1      -0.2       1.9        8.2                 -1.7       5.7
DIP BEARING  59.4 DEG          TILT/MILE 1.30 FEET

TIME   1625
FIELD STN   181            810350.     421600.     67.96
            280            811250.     420600.     46.23
 PRESSURE     29.727     30.356     30.211     30.371     30.389
TEMP DRY        0.0       69.3        0.0        0.0        0.0
TEMP WET        0.0       62.1        0.0        0.0        0.0
SINGLE BASE ERRORS                                MULTIPLE BASE ERRORS
      19.2      -2.0      -2.5        2.7                 -2.6       2.1
DIP BEARING  65.5 DEG          TILT/MILE 1.25 FEET
```

```
CITY TRAVERSE REDUCTION  7 DECEMBER 1955   ASA

 ST PAULS      LIVERPOOL     CENTENNIAL

TIME   1700
FIELD STN   181            810350.     421600.     67.96
            X              810800.     422500.    122.80
 PRESSURE     29.719     30.340     30.207     30.371     30.313
TEMP DRY        0.0       69.0        0.0        0.0        0.0
TEMP WET        0.0       61.7        0.0        0.0        0.0
SINGLE BASE ERRORS                                MULTIPLE BASE ERRORS
      26.8      -5.6      -9.6     -11.1                -7.1      -7.5
DIP BEARING  71.3 DEG          TILT/MILE 1.85 FEET

TIME   1728
FIELD STN   CENTENNIAL     812900.     423800.    215.00
            X              810800.     422500.    122.80
 PRESSURE     29.717     30.340     30.208     30.208     30.315
TEMP DRY        0.0       68.5        0.0        0.0        0.0
TEMP WET        0.0       61.2        0.0        0.0        0.0
SINGLE BASE ERRORS                                MULTIPLE BASE ERRORS
      25.6      -7.8      -7.8     -14.2                 0.0      -8.3
DIP BEARING  76.2 DEG          TILT/MILE 1.88 FEET

TIME   1734
FIELD STN   CENTENNIAL     812900.     423800.    215.00
            CENTENNIAL     812900.     423800.    215.00
 PRESSURE     29.725     30.340     30.212     30.212     30.212
TEMP DRY        0.0       68.5        0.0        0.0        0.0
TEMP WET        0.0       61.2        0.0        0.0        0.0
SINGLE BASE ERRORS                                MULTIPLE BASE ERRORS
      33.0      -4.1      -4.1      -4.1                 0.0       0.0
DIP BEARING  66.7 DEG          TILT/MILE 2.17 FEET
```

APPENDIX IV

Leap-frog Reductions.

```
LEAP FROG METHOD
CITY TRAVERSE REDUCTION  6 DEC 1955

CONSTANT 1 143831.81
CONSTANT 2   0.18910
 PRESSURES IN INCHES
 TEMPERATURES IN FARENHEIT
 ST PAULS           663.00
 LIVERPOOL           60.00
 CENTENNIAL         215.00

 TIME   STATION         ERROR   FIXED HEIGHT

  924   ST PAULS                       663.00
                          NO OF STATIONS  22      MISCLOSE    -0.4

  936   296               1.2
  946   295               7.8
 1000   294               1.7
 1010   293               9.5
 1020   292               5.0
 1029   291               9.7
 1039   290               4.0
 1058   289               8.4
 1125   288              10.4
 1145   287               6.8
 1205   286               6.8
 1230   285               5.7
 1245   100               8.8
 1305   178               6.2
 1420   220              11.8
 1500   A                 9.9
 1530   637              24.4
 1555   222              26.0
 1615   223              22.4
 1645   224               6.0

 1711   ST PAULS                       663.00
```

```
LEAP FROG METHOD
CITY TRAVERSE REDUCTION 7 DEC 55

CONSTANT 1 143831.81
CONSTANT 2   0.18910
 PRESSURES IN INCHES
 TEMPERATURES IN FARENHEIT
 ST PAULS              663.00
 LIVERPOOL              60.00
 CENTENNIAL            215.00

 TIME   STATION           ERROR   FIXED HEIGHT


  905   637                                 35.84

                           NO OF STATIONS  11     MISCLOSE     0.9

  920   638                -2.5
  932   639                 1.6
  942   640                -2.1
  955   641                -2.6
 1006   642                -4.8
 1020   B                  -3.9
 1032   644                -0.3
 1042   645                -0.6
 1053   646                 1.3

 1102   LIVERPOOL                           60.00

                           NO OF STATIONS  25     MISCLOSE    -7.5

 1151   647                -0.9
 1209   648                 3.9
 1216   649                -3.2
 1227   650                 0.2
 1236   651                -3.5
 1246   652                 2.2
 1300   653                -2.2
 1312   654                -5.1
```

```
LEAP FROG METHOD
CITY TRAVERSE REDUCTION 7 DEC 55 CONTINUED
 1323   655              -7.8
 1337   656              -3.2
 1345   657              -4.1
 1357   658              -1.3
 1406   659              -0.8
 1421   660              -4.6
 1445   661              -4.6
 1457   662              -3.0
 1508   663              -4.5
 1525   C                -6.2
 1543   665              -3.8
 1604   279              -7.2
 1620   280              -0.7
 1625   181              -5.5
 1700   X                -6.7

 1728   CENTENNIAL                        215.00
```

APPENDIX V

Two Base Reductions

22nd May, 1956.

23rd May, 1956.

6th December, 1955.

7th December, 1955.

```
       TWO BASE METHOD
CITY TRAVERSE REDUCTION 22 MAY 1956

 STATION          X         Y      HEIGHT
ST PAULS       833900.   411100.   663.00

LIVERPOOL      809100.   392600.    60.00

CENTENNIAL     812900.   423800.   215.00
              923   645                      -4.9     -6.2      4.3

              929   644                      -4.7     -5.8      1.1

              939   642                      -4.7     -4.1     -2.4

              946   641                      -7.1     -7.8      0.4

              952   640                      -3.6     -2.0      1.8

              956   639                      -6.3     -4.4     -0.3

             1001   638                      -6.1     -6.3      1.5

             1006   637                      -4.2     -4.7     -0.2

             1013   222                      -3.7     -3.9     -2.7

             1024   223                      -2.4     -7.8     -3.7

             1032   224                      -1.8    -14.2     -2.1

             1050   296                      -0.1    -13.0     -0.4
```

```
      TWO BASE METHOD
CITY TRAVERSE REDUCTION 22 MAY 1956

ST PAULS        LIVERPOOL     CENTENNIAL
            1056    295                     1.3     -5.3      1.0

            1100    294                     2.8     -1.0      2.1

            1105    293                     2.5     -1.4      1.6

            1110    292                    -1.0     -1.1     -1.0

            1115    291                    -0.4      1.9      0.4

            1120    290                     1.7      0.7      1.3

            1124    289                     2.3      3.4      2.8

            1129    288                     5.1      3.0      4.2

            1134    287                     6.6      4.1      5.3

            1139    286                     1.9     -1.3      0.4

            1148    285                    -6.6     -6.8     -4.7

            1230    178                     1.5      1.6      0.1

            1251    220                     3.3      2.6     -0.0

            1310    220                    -5.8     -4.3      3.1
```

```
    TWO BASE METHOD
CITY TRAVERSE REDUCTION 22 MAY 1956

 ST PAULS       LIVERPOOL     CENTENNIAL
             1325   221                  -0.6    -0.9     6.4

             1340   638                  -8.2    -8.6     4.6

             1348   640                  -4.2    -2.1     2.7

             1409   643                   1.8     1.4     4.1

             1414   644                  -5.9    -7.6     1.9

             1447   647                   0.4    -1.2    10.1

             1453   648                  -1.9    -0.7     4.9

             1459   649                   0.7     0.3     2.3

             1505   650                  -0.9    -1.3     0.7

             1511   651                   0.7     0.6     2.3

             1516   652                  -0.4     0.3     2.9

             1522   653                  -5.2    -6.4     0.9

             1527   654                  -4.4    -3.2     1.8
```

```
     TWO BASE METHOD
CITY TRAVERSE REDUCTION 23 MAY 1956


 STATION           X          Y        HEIGHT
ST PAULS        833900.    411100.    663.00

LIVERPOOL       809100.    392600.     60.00

CENTENNIAL      812900.    423800.    215.00
                 933    647                     -0.9       -0.2       -5.3

                 938    648                     -0.7       -2.0       -8.5

                 944    649                     -0.7        1.8      -12.4

                 948    650                      1.8        4.7      -13.5

                 954    651                      2.0        2.9      -10.1

                 959    652                      4.3        2.8       -2.8

                1004    653                      3.3        4.3       -2.7

                1011    654                      6.7        4.7       -1.8

                1016    655                      6.2        0.5       -5.6

                1021    656                      1.2       -2.2       -4.3

                1027    657                      4.8        3.5        0.3

                1032    658                      6.6        3.7        1.7
```

```
        TWO BASE METHOD
CITY TRAVERSE REDUCTION 23 MAY 1956

 ST PAULS      LIVERPOOL     CENTENNIAL
              1037   659                        8.0      4.4     -1.8

              1043   660                        6.9      1.7     -2.6

              1049   661                        5.2      5.1     -3.0

              1055   662                        4.2      5.2     -2.5

              1104   663                        3.1      4.1     -4.0

              1111   664                        3.1      4.3     -2.2

              1119   665                        0.2      1.1     -5.1

              1128   279                       -0.9     -0.9     -0.3

              1137   280                        0.4      0.5     -0.3

              1210   178                       -1.8     -1.2     -6.4

              1235   285                       -6.6     -6.3     -9.1

              1255   285                      -11.5    -11.3    -13.4

              1303   286                       -0.4     -1.3     -0.8

              1309   287                        3.9      5.6      4.8
```

```
     TWO BASE METHOD
CITY TRAVERSE REDUCTION 23 MAY 1956

 ST PAULS        LIVERPOOL      CENTENNIAL
              1315   288                     -3.3      0.7     -1.5

              1320   289                     -1.9      1.8     -0.3

              1324   290                     -0.4      5.0      1.5

              1329   291                     -1.9      6.5      1.0

              1335   292                     -1.5      6.9      0.7

              1339   293                     -1.9      9.4      0.6

              1344   294                     -0.4     10.9      1.5

              1350   295                      0.6     15.7      1.3

              1355   296                      2.5      9.5      2.6

              1414   224                      3.4    -19.3      2.9

              1424   223                      2.8     19.3      6.2

              1436   222                     -4.4     -7.0     10.9

              1445   637                      0.1     -1.3     12.6

              1452   638                     -7.2     -7.7      8.1
```

```
      TWO BASE METHOD
CITY TRAVERSE REDUCTION 23 MAY 1956

ST PAULS       LIVERPOOL      CENTENNIAL
            1459   639                      -19.2    -16.3     -7.8

            1503   640                       -9.6     -6.1      2.8

            1509   642                       -2.7      1.8     12.0

            1513   643                       -4.7     -8.4     12.5

            1519   644                       -5.3     -8.8     10.7

            1523   645                       -3.0     -4.6      8.6
```

```
      TWO BASE METHOD
CITY TRAVERSE REDUCTION   6 DEC 1955


 STATION          X          Y       HEIGHT
ST PAULS       833900.    411100.    663.00

LIVERPOOL      809100.    392600.     60.00

CENTENNIAL     812900.    423800.    215.00
             924   ST PAULS                     0.0     -97.7      0.0
             924   ST PAULS                     0.0     -97.7      0.0

             936   ST PAULS                     0.0    -114.1      0.0
             936   296                          2.6    -106.0      0.1

             946   295                          3.8    -100.7     -2.1
             946   296                         -4.4    -114.7     -7.7

            1000   295                          5.1     -98.9     -0.6
            1000   294                          4.8     -73.4    -13.0

            1010   293                         11.5     -55.8     -7.4
            1010   294                          2.4     -70.2    -14.0

            1020   293                          8.2     -56.6    -10.2
            1020   292                          4.9     -55.2    -15.7

            1029   291                         12.3     -37.2     -8.0
            1029   292                          6.4     -48.3    -11.6

            1039   291                         12.0     -35.0     -7.1
            1039   290                          6.5     -38.6    -13.4

            1058   289                         11.4     -32.6    -10.6
            1058   290                          6.9     -39.9    -13.9
```

```
       TWO BASE METHOD
   CITY TRAVERSE REDUCTION  6 DEC 1955

 ST PAULS       LIVERPOOL     CENTENNIAL
             1125    289                          1.6     -32.7     -15.9
             1125    288                          3.5     -30.4     -14.0

             1132    288                          5.9     -30.0     -12.6
             1132    288                          5.9     -30.0     -12.6

             1145    288                         10.3     -26.8      -8.3
             1145    287                          6.5     -25.6     -14.3

             1205    286                          1.6     -27.0     -13.8
             1205    287                          0.9     -24.8     -15.7

             1230    286                         -2.1     -23.0     -13.1
             1230    285                        -14.4     -11.6     -34.8

             1245    100                         -8.7      -5.1     -29.5
             1245    285                        -11.4      -8.8     -31.9

             1305    100                          1.1       4.9     -28.0
             1305    178                         -1.5       1.6     -30.3

             1320    178                         -0.5       2.5     -29.3
             1320    178                         -0.5       2.5     -29.3

             1356    178                         -3.4      -1.4     -19.3
             1356    178                         -3.4      -1.4     -19.3

             1420    178                         -5.5      -4.2     -14.5
             1420    220                          2.8       1.2      -5.2

             1500    A                            8.5      10.6      -4.8
             1500    220                         13.1      10.3       1.6
```

```
       TWO BASE METHOD
 CITY TRAVERSE REDUCTION  6 DEC 1955

ST PAULS      LIVERPOOL    CENTENNIAL
              1530  A                        0.7      2.8    -10.6
              1530  637                     16.5     16.9      5.8

              1555  222                      9.3      9.8      3.5
              1555  637                      7.9      8.3      2.1

              1615  222                      6.8      7.2      2.2
              1615  223                      8.9      1.1      7.2

              1629  223                      5.8      3.6      5.4
              1629  223                      5.8      3.6      5.4

              1645  223                     16.3     13.4     15.7
              1645  224                      1.9     -2.4      1.8

              1711  ST PAULS                 0.0      6.4      0.0
              1711  224                      5.5     11.4      5.6

              1722  ST PAULS                 0.0      0.0      0.0
              1722  ST PAULS                 0.0      0.0      0.0
```

```
      TWO BASE METHOD
CITY TRAVERSE REDUCTION 7 DEC 1955


 STATION          X          Y       HEIGHT
ST PAULS       833900.    411100.    663.00

LIVERPOOL      809100.    392600.     60.00

CENTENNIAL     812900.    423800.    215.00

              905   637                       -0.2      0.6      -7.8
              905   637                       -0.2      0.6      -7.8

              920   637                        8.4      9.5      -7.8
              920   638                        6.0      5.5      -9.7

              932   639                       15.2      7.8      -4.2
              932   638                       11.5     10.3     -10.3

              942   639                       16.0      7.1      -7.6
              942   640                       12.5      4.5     -11.6

              955   641                       18.2     17.8      -3.2
              955   640                       17.8     10.9      -0.9

             1006   641                       16.4     16.1      -4.5
             1006   642                       13.8      7.7      -4.7

             1020   B                         13.4     15.6      -5.0
             1020   642                       12.5      7.4      -3.1

             1032   B                          7.6      9.5      -5.6
             1032   644                       11.4     13.0      -1.6

             1042   645                        7.5      8.5      -5.7
             1042   644                        7.7      9.4      -5.8
```

```
      TWO BASE METHOD
CITY TRAVERSE REDUCTION 7 DEC 1955

 ST PAULS       LIVERPOOL     CENTENNIAL
              1053   645                         0.7        1.4       -4.9
              1053   646                         3.3        3.1       -2.0

              1102   LIVERPOOL                   0.0        0.0       -3.5
              1102   646                         1.4        1.3       -2.0

              1109   LIVERPOOL                   0.0        0.0       -2.3
              1109   LIVERPOOL                   0.0        0.0       -2.3

              1151   LIVERPOOL                   0.0        0.0       -0.8
              1151   647                        -2.9       -2.7       -3.7

              1209   648                        -1.3       -1.1       -0.5
              1209   647                       -10.2      -10.3       -9.3

              1216   648                         3.4        2.8        0.2
              1216   649                        -9.0       -8.0      -12.8

              1227   650                        -2.5       -1.6       -6.6
              1227   649                        -5.8       -4.8       -9.9

              1236   650                        -1.6       -1.0       -4.6
              1236   651                        -4.4       -4.1       -7.2

              1246   652                         3.0        2.4        0.1
              1246   651                        -5.4       -5.0       -8.6

              1300   652                         2.1        0.5       -6.1
              1300   653                        -6.8       -5.0      -16.2

              1312   654                        -5.3       -6.4      -11.9
              1312   653                        -5.4       -4.0      -13.0
```

```
     TWO BASE METHOD
CITY TRAVERSE REDUCTION 7 DEC 1955

ST PAULS      LIVERPOOL     CENTENNIAL
             1323   654                   -0.5    -1.5    -5.5
             1323   655                   -1.8    -3.9    -6.4

             1337   656                   -2.7    -4.6    -5.8
             1337   655                   -8.1    -9.5   -11.4

             1345   656                   -7.4    -8.7    -9.7
             1345   657                  -11.4   -11.9   -14.0

             1357   658                   -9.9    -6.5    -3.5
             1357   657                  -15.0   -13.6    -7.9

             1406   658                  -10.6    -6.3    -2.5
             1406   659                  -12.5   -10.0    -3.8

             1421   660                  -15.6   -10.5    -4.8
             1421   659                  -13.2   -10.0    -1.8

             1430   660                  -14.5    -7.7    -0.7
             1430   660                  -14.5    -7.7    -0.7

             1445   660                  -15.2    -8.8    -1.9
             1445   661                  -22.3   -24.4    -6.4

             1457   662                  -21.3   -26.2    -4.9
             1457   661                  -20.3   -22.1    -4.8

             1508   662                  -23.3   -28.3    -6.8
             1508   663                  -25.0   -29.8    -8.5


             1525   C                    -27.2   -33.5    -8.2
             1525   663                  -24.7   -30.3    -5.9
```

TWO BASE METHOD

ST PAULS	LIVERPOOL	CENTENNIAL		
1543	C	-23.1	-27.8	-7.7
1543	665	-20.9	-25.3	-5.5
1604	279	-17.6	-20.6	-2.8
1604	665	-14.6	-18.6	0.5
1620	279	-21.1	-26.0	0.6
1620	280	-14.1	-17.2	7.1
1625	181	-22.3	-24.0	-1.0
1625	280	-17.9	-21.5	4.0
1700	181	-38.1	-44.1	-3.5
1700	X	-36.6	-31.3	-5.1
1728	CENTENNIAL	-27.2	0.0	0.0
1728	X	-38.6	-33.4	-5.4
1734	CENTENNIAL	-29.5	0.0	0.0
1734	CENTENNIAL	-29.5	0.0	0.0

APPENDIX VI

Computer Programmes.

```
C     THIS PROGRAMME IS UNSW SURVEY NO. 12
C     PREPARED BY J.S.ALLMAN, FEB,1966,MODIFIED FOR IBM 360,JAN 1967
C     THIS PROGRAMME PREPARES A TABLE OF ELEVATIONS FOR THE STANDARD
C      ATMOSPHERE FROM 600.0 TO800.0 MM BY .1 MM STEPS
C
      DIMENSION  TABLE(5,11),NAME(4)
      MMM=2
      IPAGE=8
C
C     READ PARAMETERS AND INTERVAL
  100 READ (1,50) CON1,CON2,NAME,AINT
   50 FORMAT (F9.2,F8.5,2X,4A2,F5.1)
C
C     SET INITIAL PRESSURE
      CONS=600.0
      DO 5 N=1,IPAGE
C
C     WRITE PAGE HEADING
      WRITE (MMM,55)NAME
      WRITE(3,99) AINT
      WRITE(3,98)
      DO 5 M=1,6
      WRITE(3,99) CONS
      DO 2 I=1,5
      A=I
      TABLE(I,1)=CONS+(A-1.)*10.0*AINT
      WRITE(3,99) A
      WRITE(3,99) TABLE (I,1)
C
C     CALCULATE ELEVATIONS
      DO 1 J=2,11
      B=J-1
      COST=TABLE(I,1)
      TABLE(I,J)=CON1*(1.-((COST+(B-1.)*AINT)/760.)**CON2)
      IF (TABLE(I,J))6,1,7
    6 TABLE(I,J)=TABLE(I,J) -0.05
      GO TO 1
    7 TABLE(I,J)=TABLE(I,J) +0.05
    1 CONTINUE
```

```
C     SURVEY NO 12 CONTINUED
C
C     WRITE RESULTS
      WRITE (MMM,3)(TABLE(I,J),J=1,11)
    2 CONTINUE
      WRITE (MMM,4)
      IF (CONS-800.0) 8,8,100
C
C     UPGRADE PRESSURES
    8 CONS =CONS+50.*AINT
    5 CONTINUE
    3 FORMAT(2X,F4.0,1X,5(F7.1),2X,5(F7.1))
    4 FORMAT(/)
   55 FORMAT(1H1/////3X,2HMM,27X,17HE L E V A T I O N,20X,4A2/3X,4HPRES,
     1       3X,     2H.0,5X,2H.1,5X,2H.2,5X,2H.3, 5X,2H.4,7X,2H.5,5X,
     2 2H.6,5X,2H.7,5X,2H.8,5X,2H.9 /3X,11(7H-------))
   99 FORMAT (1H ,F10.6)
   98 FORMAT (1H ,//)
      GO TO 100
      END
```

```
C     THIS PROGRAMME IS UNSW SURVEY NO. 14,360 VERSION
C     PREPARED BY J.S.ALLMAN, APRIL,1966 ,MODIFIED JANUARY 1967
C
C     ID1=1 PRESSURE IN MILLIBARS,=2 MILLIMETERS,=3 INCHES
C     ID2=1 TEMPERATURES IN FARENHEIT , =2 CENTIGRADE
C     ID3=1 COORDINATES IN YARDS,=2 FEET
C     M=2...PUNCH, M=3...PRINT
C     ITIME = 0 READ NEW BASES, = NEGATIVE READ NEW PARAMETERS
C
      DIMENSION DESC(18),A(5,6),RE(5,3),HSA(5),TEMPS(5),DIFFHT(5),
     1 CALHT(5),ERROR(7),B(5)
C
C     READ PARAMETERS
  200 READ(1,100)CON1,CON2,M
  100 FORMAT(F9.2,2X,F6.5,I3)
C
C     READ UNITS
   50 READ (1,1) ID1,ID2,ID3,DESC
    1 FORMAT(I1,I1,I1,5X,18A4)
      WRITE (M,20) DESC
   20 FORMAT(1H1,//////7X,18A4//)
      GO TO (21,22,23),ID1
   21 WRITE (M,11)
   11 FORMAT(8X,22HPRESSURES IN MILLIBARS)
      GO TO 24
   22 WRITE (M,12)
   12 FORMAT(8X,24HPRESSURES IN MILLIMETERS)
      GO TO 24
   23 WRITE (M,13)
   13 FORMAT (8X,19HPRESSURES IN INCHES)
   24 GO TO (25,26),ID2
   25 WRITE (M,14)
   14 FORMAT (8X,25HTEMPERATURES IN FARENHEIT)
      GO TO 27
   26 WRITE (M,15)
   15 FORMAT (8X,26HTEMPERATURES IN CENTIGRADE)
   27 GO TO (28,29),ID3
   28 CC=1760.
      WRITE (M,17)
   17 FORMAT(8X,20HCOORDINATES IN YARDS)
      GO TO 30
   29 CC=5280.
      WRITE (M,18)
   18 FORMAT(8X,19HCOORDINATES IN FEET)
```

```
C     SURVEY NO 14  CONTINUED
C
C     READ NAMES, COORDINATES AND ELEVATIONS OF FIXED STATIONS
   30 READ (1,2)((A(I,J),J=1,6),I=1,5)
    2 FORMAT( 3A4 , 2X,F10.0,1X,F10.0,1X,F8.2)
C
C     WRITE PAGE HEADING
      WRITE (M,201) CON1,CON2
  201 FORMAT (/7X,10HCONSTANT 1,F10.2/7X,10HCONSTANT 2,F10.5)
      WRITE (M,3)
    3 FORMAT (//7X,8H STATION,9X,1HX,10X,1HY,7X,6HHEIGHT)
      WRITE (M,4) ((A(I,J),J=1,6),I=1,5)
    4 FORMAT(7X, 3A4 , F10.0,1X,F10.0,1X,F8.2)
      DO 5 I=2,5
      DO 5 J=4,5
    5 A(I,J)=(A(I,J)-A(1,J))/CC
      A(1,4)=0.
      A(1,5)=0.
      CONA=A(4,5)/A(4,4)
      CONB=(A(3,5)-A(2,5))/(A(3,4)-A(2,4))
      X6=(CONB*A(2,4)-A(2,5))/(CONB-CONA)
      Y6=CONA*X6
      COND=SQRT((A(4,4)**2+A(4,5)**2)/(X6**2+Y6**2))
      CONE=SQRT(((A(2,4)-X6)**2+(A(2,5)-Y6)**2)/((A(2,4)-A(3,4))**2+
     1(A(2,5)-A(3,5))**2))
      IF(A(5,6))7,7,6
    6 CONC=A(5,5)/A(5,4)
      X7=(CONB*A(2,4)-A(2,5))/(CONB-CONC)
      Y7=CONC*X7
      CONF=SQRT((A(5,4)**2+A(5,5)**2)/(X7**2+Y7**2))
      CONG=SQRT(((A(2,4)-X7)**2+(A(2,5)-Y7)**2)/((A(2,4)-A(3,4))**2+
     1(A(2,5)-A(3,5))**2))
    7 CONTINUE
      MMM=3
      MM=0
C
C     READ TIME, PRESSURES AND TEMPERATURES
    8 READ (1,9)ITIME,((RE(I,J),J=1,3),I=1,5)
    9 FORMAT (I4,5(F7.2,2F4.0))
```

```
C     SURVEY NO 14  CONTINUED
C
C     TIME NEGATIVE..READ NEW PARAMETERS, ZERO..READ NEW UNITS,
C     POSITIVE..CARRY ON COMPUTATION
      IF (ITIME)200,50,31
   31 N=5
      IF (RE(5,1))10,10,35
   10 N=4
   35 DO 85 J=2,3
      DO 85 I=1,N
   85 RE(I,J)=RE(I,J)/10.
      IF (ID1-3)89,87,89
C
C     WRITE TIME,PRESSURES AND TEMPERATURES
   87 WRITE (M,88)ITIME,(RE(I,1),I=1,N)
   88 FORMAT(//7X,4HTIME,3X,I4/7X,8HPRESSURE,5(3X,F8.3))
      GO TO 90
   89 WRITE (M,36) ITIME,(RE(I,1),I=1,N)
   36 FORMAT(//7X,4HTIME,3X,I4/7X,8HPRESSURE,5(3X,F8.2))
   90 WRITE (M,37)  (RE(I,2),I=1,N)
C
C     IF WET THERMOMETER IS NOT RECORDED ..DO NOT PRINT
      K=1
      DO 32 I=1,N
      IF (RE(I,3))34,32,34
   32 CONTINUE
      K=0
      GO TO 33
   34 WRITE (M,38)  (RE(I,3) ,I=1,N)
   37 FORMAT(7X,8HTEMP DRY,5(5X,F6.1))
   38 FORMAT(7X,8HTEMP WET,5(5X,F6.1))
C
C     ID1=1 PRESSURE IN MILLIBARS,=2 MILLIMETERS,=3 INCHES
   33 GO TO (60,61,62),ID1
   61 CD=1013.25/760.
      GO TO 63
   62 CD=1013.25/29.921
   63 DO 64 J=1,N
   64 RE(J,1)=RE(J,1)*CD
```

```
C        SURVEY NO 14  CONTINUED
C
C        ID2=1 TEMPERATURES IN FARENHEIT , =2 CENTIGRADE
   60    GO TO (65,66),ID2
   66    DO 68 J=2,3
         DO 68 I=1,N
         IF (RE(I,J))68,68,67
   67    RE(I,J)=RE(I,J)*1.8+32.
   68    CONTINUE
C
C        CALCULATE HEIGHT IN A STANDARD ELEVATION
   65    DO 86 I=1,N
         HSA(I)=CON1*(1.-(RE(I,1)/1013.25)**CON2)
   86    TEMPS(I)=59.-0.003566*HSA(I)
         PM=0.
         DT=0.
         DTW=0.
         TM=0.
         ON=0.
         ONN=0.
         DO 70 I=1,N
         PM=PM+RE(I,1)
         IF (RE(I,2))80,80,71
   71    ON=ON+1.
         DT=DT+RE(I,2)-TEMPS(I)
         TM=TM+RE(I,2)
         IF (RE(I,3)) 80,80,72
   72    ONN=ONN+1.
         DTW=DTW+RE(I,2)-RE(I,3)
   80    CONTINUE
   70    CONTINUE
         AN=N
         PM=PM/AN
         TM=TM/ON
         DT=DT/ON
         IF (ONN) 73,73,74
   74    DTW=DTW/ONN
   55    TS=373.16
         T=273.16+((TM-DTW)-32.)*5./9.
         CA=TS/T
```

```
C      SURVEY NO 14  CONTINUED
C
       CB=(1.-T/TS)*11.344
       CC=-3.49149*(CA-1.)
       CD=-18.19731*(CA-1.)-.0031812*.0001*(10.**CB-1.)+.00187265*(10.**
      1 CC-1.)+6.9209182
       CE=5.02808*ALOG(CA)
       ALP=CD+CE
       PW=EXP(ALP)
       P=PW-0.000367*PW*DTW
       DT=DT+(459.8+TM)*0.734*P/(1013.25+PM)
C
C      APPLY TEMPERATURE AND HUMIDITY CORRECTIONS
    73 DO 16 I=1,N
       HSA(I)=HSA(I)+HSA(I)/518.4*DT*(1.+.00000344*HSA(I)
      1 +1.6*.000001*0.00001*HSA(I)**2)
    16 CONTINUE
C
C      CALCULATE ERRORS
       DO 47 I=2,N
       DIFFHT(I)=HSA(I)-HSA(1)
       CALHT(I)=A(1,6) +DIFFHT(I)
    47 ERROR(I)=CALHT(I)-A(I,6)
       E32=ERROR(2)-ERROR(3)
       ERROR(6)= (E32*CONE-ERROR(2))*COND+CALHT(4)-A(4,6)
C
C      WRITE RESULTS
       IF(N-4)19,19,48
    48 ERROR(7)= (E32*CONG-ERROR(2))*CONF+CALHT(5)-A(5,6)
       WRITE (M,46)
    46 FORMAT(7X,18HSINGLE BASE ERRORS ,32X,20HMULTIPLE BASE ERRORS)
       WRITE (M,81) (ERROR(I),I=2,7)
    81 FORMAT(7X,4F10.1,10X,2F10.1)
       GO TO 40
    19 WRITE (M,46)
       WRITE(M,82) (ERROR (I),I=2,4),ERROR(6)
    82 FORMAT (7X,3F10.1,20X,F10.1)
```

```
C     SURVEY NO 14  CONTINUED
C
C     CALCULATE TILT AND TILT DIRECTION
   40 IF(ABS( E32)-0.1)41,41,42
   41 W=(A(3,5)-A(2,5))/(A(3,4)-A(2,4))
      GO TO 49
   42 X8=(ERROR(2)*A(3,4)-ERROR(3)*A(2,4))/E32
      Y8=(ERROR(2)*A(3,5)-ERROR(3)*A(2,5))/E32
      W=Y8/X8
   49 BNG=90.+57.295780*ATAN(W)
      IF (ABS(ERROR(2))-ABS(ERROR(3)))51,51,43
   43 J=2
      GO TO 52
   51 J=3
   52 DIPDIS=ABS(A(J,4)*W-A(J,5))/SQRT(1.+W*W)
      TILT=ABS(ERROR(J)/DIPDIS)
      IF (M-3) 101,83,83
  101 IF (N-4) 39,39,44
C
C     PUNCH SUMMARY
   39 WRITE (M,45) ITIME,BNG,TILT,(ERROR(I),I=2,4),ERROR(6),N
   45 FORMAT(7X,I4,F6.1,F5.2,3F9.1,9X,F9.1,12X,I1)
      GO TO 83
   44 WRITE (M,56) ITIME,BNG,TILT,(ERROR(I),I=2,5),(ERROR(J),J=6,7),N
   56 FORMAT(7X,I4,F6.1,F5.2,6F9.1,3X,I1)
   83 WRITE (M,53) BNG,TILT
   53 FORMAT(7X,11HDIP BEARING,F6.1,4H DEG,10X,9HTILT/MILE,F5.2,5H FEET)
      IF (K) 78,78,79
   78 WRITE (M,98)
   98 FORMAT(1X,1H )
   79 MM=MM+1
C
C     CHECK FOR END OF PAGE
      IF(MM-MMM) 75,76,76
   75 GO TO 8
C
C     WRITE NEW PAGE HEADING
   76 MM=0
      WRITE (M,77) DESC,((A(I,J),J=1,3),I=1,5)
   77 FORMAT( 1H1,/////8X,18A4//7X,5(3A4,2X))
      MMM=4
      GO TO 8
      END
```

```
C     THIS PROGRAMME IS UNSW SURVEY NO. 19 IBM 360 VERSION
C     PREPARED BY J.S.ALLMAN, NOV. 1966,MODIFIED JANUARY 1967
C
C     ID1=1 PRESSURE IN MILLIBARS,=2 MILLIMETERS,=3 INCHES
C     ID2=1 TEMPERATURES IN FARENHEIT , =2 CENTIGRADE
C     ID3=1 COORDINATES IN YARDS,=2 FEET
C     M=2...PUNCH, M=3...PRINT
C     ITIME=0 READ NEW BASES, = NEGATIVE READ NEW CONSTANTS
C
      DIMENSION DESC(18),A(5,6),RE(5,3),HSA(5),TEMPS(5),DIFFHT(5),
     1 CALHT(5),ERROR(7),B(3,6)
C
C     READ PARAMETERS
  300 READ(1,350) CON1,CON2,M
  350 FORMAT(F9.2,2X,F6.5,I3)
C
C     READ UNITS
  250 READ (1,1)ID1,ID2,ID3,DESC
    1 FORMAT(I1,I1,I1,5X,18A4)
      WRITE(M,20) DESC
   20 FORMAT (1H1,//////7X,18A4//)
      WRITE (M,400) CON1,CON2
  400 FORMAT (/7X,10HCONSTANT 1,F10.2/7X,10HCONSTANT 2,F10.5)
      GO TO (21,22,23),ID1
   21 WRITE (M,11)
   11 FORMAT(8X,22HPRESSURES IN MILLIBARS)
      GO TO 24
   22 WRITE(M,12)
   12 FORMAT(8X,24HPRESSURES IN MILLIMETERS)
      GO TO 24
   23 WRITE(M,13)
   13 FORMAT (8X,19HPRESSURES IN INCHES)
   24 GO TO (25,26),ID2
   25 WRITE(M,14)
   14 FORMAT (8X,25HTEMPERATURES IN FARENHEIT)
      GO TO 27
   26 WRITE(M,15)
   15 FORMAT (8X,26HTEMPERATURES IN CENTIGRADE)
```

```
C     SURVEY NO 19  CONTINUED
C
   27 GO TO (28,29),ID3
      WRITE(M,17)
   17 FORMAT(8X,20HCOORDINATES IN YARDS)
   28 CC=1760.
      GO TO 30
   29 CC=5280.
      WRITE(M,18)
   18 FORMAT(8X,19HCOORDINATES IN FEET)
C
C     READ NAME,COORDINATES AND ELEVATIONS FOR STATIONS 1,2 AND 3
   30 READ (1,2)((A(I,J),J=1,6),I=1,3)
    2 FORMAT( 3A4 , 2X,F10.0,1X,F10.0,1X,F8.2)
      WRITE (M,3)
    3 FORMAT (//7X,8H STATION,9X,1HX,10X,1HY,7X,6HHEIGHT)
      WRITE(M,4)((A(I,J),J=1,6),I=1,3)
    4 FORMAT(7X, 3A4 , F10.0,1X,F10.0,1X,F8.2)
C
C     CALCULATE CONSTANTS
      DO 79 I=1,6
   79 B(3,I)=A(1,I)
      DO 5 I=2,3
      DO 5 J=4,5
    5 A(I,J)=(A(I,J)-A(1,J))/CC
      A(1,4)=0.
      A(1,5)=0.
      MMM=3
      MM=0
C
C     READ NAME,COORDINATES AND ELEVATIONS FOR STATIONS 4 AND 5
  150 READ (1,200)((A(I,J),J=1,6),I=4,5)
  200 FORMAT (2(3A4,F10.0,F10.0,F8.2))
C
C     CALCULATE CONSTANTS
      DO 8 MA=1,6
      DO 8K=1,2
      I=K+3
    8 B(K,MA)= A(I,MA)
```

```
C     SURVEY NO 19  CONTINUED
C
      DO 95 I=4,5
      DO 95 J=4,5
   95 A(I,J)=(A(I,J)-B(3,J))/CC
      CONA=A(4,5)/A(4,4)
      CONB=(A(3,5)-A(2,5))/(A(3,4)-A(2,4))
      X6=(CONB*A(2,4)-A(2,5))/(CONB-CONA)
      Y6=CONA*X6
      COND=SQRT((A(4,4)**2+A(4,5)**2)/(X6**2+Y6**2))
      CONE=SQRT(((A(2,4)-X6)**2+(A(2,5)-Y6)**2)/((A(2,4)-A(3,4))**2+
     1(A(2,5)-A(3,5))**2))
      IF(A(5,6))7,7,6
    6 CONC=A(5,5)/A(5,4)
      X7=(CONB*A(2,4)-A(2,5))/(CONB-CONC)
      Y7=CONC*X7
      CONF=SQRT((A(5,4)**2+A(5,5)**2)/(X7**2+Y7**2))
      CONG=SQRT(((A(2,4)-X7)**2+(A(2,5)-Y7)**2)/((A(2,4)-A(3,4))**2+
     1(A(2,5)-A(3,5))**2))
    7 CONTINUE
C
C     READ TIME, PRESSURES AND TEMPERATURES
   96 READ (1,9)ITIME,((RE(I,J),J=1,3),I=1,5)
    9 FORMAT (I4,5(F7.2,2F4.0))
C
C     TIME NEGATIVE..READ NEW PARAMETERS, ZERO..READ NEW UNITS,
C     POSITIVE..CARRY ON COMPUTATION
      IF (ITIME)300,250,31
   31 N=5
      IF (RE(5,1))10,10,44
   10 N=4
   44 DO 85 J=2,3
      DO 85 I=1,N
   85 RE(I,J)=RE(I,J)/10.
      MB=N-3
      WRITE(M,45)ITIME,((B(J,I),I=1,6),J=1,MB)
   45 FORMAT(//7X,4HTIME,3X,I4 /7X9HFIELD STN,3X3A4,F10.0,2XF10.0,2XF8.2
     1 /19X,3A4,F10.0,2X,F10.0,2X,F8.2)
      IF (ID1-3)89,87,89
   87 WRITE(M,88)(RE(J,1),J=1,N)
   88 FORMAT (1H ,7X,8HPRESSURE,5(3X,F8.3))
      GO TO 90
```

```
C         SURVEY NO 19  CONTINUED
C
     89  WRITE(M,91)(RE(J,1),J=1,N)
     91  FORMAT (1H ,7X,8HPRESSURE,5(3X,F8.2))
     90  WRITE(M,46)(RE(I,2),I=1,N)
C
C        IF WET THERMOMETER IS NOT RECORDED ..DO NOT PRINT
         K=1
         DO 57 I=1,N
         IF (RE(I,3))56,57,56
     57  CONTINUE
         K=0
         GO TO 58
     56  WRITE(M,47)(RE(I,3) ,I=1,N)
     46  FORMAT(7X,8HTEMP DRY,5(5X,F6.1))
     47  FORMAT(7X,8HTEMP WET,5(5X,F6.1))
C
C        ID1=1 PRESSURE IN MILLIBARS,=2 MILLIMETERS,=3 INCHES
     58  GO TO (60,61,62),ID1
     61  CD=1013.25/760.
         GO TO 63
     62  CD=1013.25/29.921
     63  DO 64 J=1,N
     64  RE(J,1)=RE(J,1)*CD
C
C        ID2=1 TEMPERATURES IN FARENHEIT , =2 CENTIGRADE
     60  GO TO (65,66),ID2
     66  DO 68 J=2,3
         DO 68 I=1,N
         IF (RE(I,J))68,68,67
     67  RE(I,J)=RE(I,J)*1.8+32.
     68  CONTINUE
C
C        CALCULATE HEIGHT IN A STANDARD ELEVATION
     65  DO 86 I=1,N
         HSA(I)=CON1*(1.-(RE(I,1)/1013.25)**CON2)
     86  TEMPS(I)=59.-0.003566*HSA(I)
         PM=0.
         DT=0.
         DTW=0.
         TM=0.
```

```
C     SURVEY NO 19  CONTINUED
C
      ON=0.
      ONN=0.
      DO 70 I=1,N
      PM=PM+RE(I,1)
      IF (RE(I,2))80,80,71
   71 ON=ON+1.
      DT=DT+RE(I,2)-TEMPS(I)
      TM=TM+RE(I,2)
      IF (RE(I,3)) 80,80,72
   72 ONN=ONN+1.
      DTW=DTW+RE(I,2)-RE(I,3)
   80 CONTINUE
   70 CONTINUE
      AN=N
      PM=PM/AN
      TM=TM/ON
      DT=DT/ON
      IF (ONN) 73,73,74
   74 DTW=DTW/ONN
   55 TS=373.16
      T=273.16+((TM-DTW)-32.)*5./9.
      CA=TS/T
      CB=(1.-T/TS)*11.344
      CF=-3.49149*(CA-1.)
      CD=-18.19731*(CA-1.)-.0031812*.0001*(10.**CB-1.)+.00187265*(10.**
     1 CF-1.)+6.9209182
      CE=5.02808*ALOG(CA)
      ALP=CD+CE
      PW=EXP(ALP)
      P=PW-0.000367*PW*DTW
      DT=DT+(459.8+TM)*0.734*P/(1013.25+PM)
C
C     APPLY TEMPERATURE AND HUMIDITY CORRECTIONS
   73 DO 16 I=1,N
      HSA(I)=HSA(I)+HSA(I)/518.4*DT*(1.+.00000344*HSA(I)
     1 +1.6*.000001*0.00001*HSA(I)**2)
   16 CONTINUE
```

```
C     SURVEY NO 19  CONTINUED
C
C     CALCULATE ERRORS
      DO 81 I=2,N
      DIFFHT(I)=HSA(I)-HSA(1)
      CALHT(I)=A(1,6) +DIFFHT(I)
   81 ERROR(I)=CALHT(I)-A(I,6)
      E32=ERROR(2)-ERROR(3)
      ERROR(6)= (E32*CONE-ERROR(2))*COND+CALHT(4)-A(4,6)
      IF(N-4)19,19,82
   82 ERROR(7)= (E32*CONG-ERROR(2))*CONF+CALHT(5)-A(5,6)
C
C     WRITE RESULTS
      WRITE(M,83)
   83 FORMAT(7X,18HSINGLE BASE ERRORS ,32X,20HMULTIPLE BASE ERRORS)
      WRITE(M,84)(ERROR(I),I=2,7)
   84 FORMAT(7X,4F10.1,10X,2F10.1)
      GO TO 40
   19 WRITE(M,83)
      WRITE(M,92)(ERROR (I),I=2,4),ERROR(6)
   92 FORMAT (7X,3F10.1,20X,F10.1)
C
C     CALCULATE TILT AND TILT DIRECTION
   40 IF(ABS( E32)-0.1)41,41,42
   41 W=(A(3,5)-A(2,5))/(A(3,4)-A(2,4))
      GO TO 49
   42 X8=(ERROR(2)*A(3,4)-ERROR(3)*A(2,4))/E32
      Y8=(ERROR(2)*A(3,5)-ERROR(3)*A(2,5))/E32
      W=Y8/X8
   49 BNG=90.+57.295780*ATAN(W)
      IF (ABS(ERROR(2))-ABS(ERROR(3)))51,51,50
   50 J=2
      GO TO 52
   51 J=3
   52 DIPDIS=ABS(A(J,4)*W-A(J,5))/SQRT(1.+W*W)
      TILT=ABS(ERROR(J)/DIPDIS)
      IF (M-3)37,38,38
   38 IF (N-4) 33,33,34
   33 WRITE(2,35)ITIME,BNG,TILT,(ERROR(I),I=2,4),ERROR(6),N
   35 FORMAT(7X,I4,F6.1,F5.2,3F9.1,9X,F9.1,12X,I1)
      GO TO 37
```

```
C      SURVEY NO 19  CONTINUED
C
C      PUNCH SUMMARY
   34 WRITE(2,36)ITIME,BNG,TILT,(ERROR(I),I=2,5),(ERROR(J),J=6,7),N
   36 FORMAT(7X,I4,F6.1,F5.2,6F9.1,3X,I1)
   37 WRITE(M,53)BNG,TILT
   53 FORMAT(7X,11HDIP BEARING,F6.1,4H DEG,10X,9HTILT/MILE,F5.2,5H FEET)
      IF (K) 78,78,69
   78 WRITE(M,98)
   98 FORMAT (1X,1H )
   69 MM=MM+1
C
C      CHECK FOR END OF PAGE
      IF(MM-MMM)75,76,76
   75 GO TO 150
C
C      WRITE NEW PAGE HEADING
   76 MM=0
      WRITE(M,77)DESC,((A(I,J),J=1,3),I=1,3)
   77 FORMAT(1H1,//////8X,18A4//8X,3(3A4,2X))
      MMM=4
      GO TO 150
      END
```

```
C     SVY 24 TOWER REDUCTION PROGRAMME, IBM 1130 VERSION
C     PREPARED BY J.S.ALLMAN, OCT.1966

      DIMENSION HT(7),FT(2),R(7),HSA(7),ERROR(7),HS(7)
      TS=373.16
      HT(1)= -675.6
      HT(2)= -631.9
      HT(3)= -532.1
      HT(4)= -383.4
      HT(5)= -208.8
      HT(6)= -47.8
      HT(7)= 0.0

C     K INDICATES SECONDARY CONTROL POINT
   90 READ (4,13) CON1,CON2,K
   13 FORMAT (F9.2,2X,F6.5,2X,I1)
      WRITE (1,14) CON1,CON2,K
   14 FORMAT (1H1,7X,F9.2,2X,F7.5,2X,I2/9X,8(1H-),3X,6(1H-))
  100 READ (4,1) ANAME,FT(1),FT(2),(R(I),I=1,7)
    1 FORMAT (A4,2F4.1,7F8.2)
      IF (ANAME-16448.) 12,90,12
   12 FT(1)=FT(1)-2.41
      FT(2)=FT(2)-2.41
  200 DO 2 I=1,7
    2 HSA(I)=145367.59*(1.-(R(I)/760.)**0.19023)
      TSTD=59.-0.003566*HSA(7)
      DTW=FT(1)-FT(2)
      DT=FT(1)-TSTD
      DDT=DT
      T=273.16+(FT(2)-32.)*5./9.
      CA=TS/T
      CB=(1.-T/TS)*11.344
      CF=-3.49149*(CA-1.)
      CD=-18.19731*(CA-1.)-.0031812*.0001*(10.**CB-1.)+.00187265*(10.**
     1 CF-1.)+6.9209182
      CE=5.02808*LOGF(CA)
      ALP=CD+CE
      PW=EXPF(ALP)
      P=PW-0.000367*PW*DTW
      DT=DT+(459.8+FT(1))*0.734*P/(1013.25+R(7)/760.*1013.25)
```

```
C     PROGRAMME SVY 24 CONTINUED

      DO 9 I=1,7
      IF (R(I))9,9,8
    8 HS (I)=HSA(I)+HSA(I)/518.4*DDT*(1.+.00000344*HSA(I)
     1 +1.6*.000001*0.00001*HSA(I)**2)
    9 CONTINUE
      DO 3 I=1,7
      IF (R(I)) 3,6,10
    6 ERROR(I)=99.99
      GO TO 3
   10 ERROR(I)=HSA(I)-HSA(7)-HT(I)
    3 CONTINUE
      IF (K) 99,50,51

C     CALCULATE NEW PARAMETER
   51 CON1=CON1*(1+ERROR(K)/(675.6-ERROR(K)))
      K=0
      WRITE (1,14) CON1,CON2,K
      GO TO 200

C     SWITCH 1 OFF PRINT...ON CALCULATE MINIMIUM
   50 CALL DATSW (1,M)
      GO TO (55,60),M
   55 SUM =0.0
      DO 65 I=3,6
   65 SUM=SUM+ERROR(I)**2
      WRITE (1,70) ANAME,(ERROR(I),I=1,7),SUM
   70 FORMAT (2X,A4,2X,8F9.2)
      GO TO 100
   60 WRITE (1,5) ANAME,(ERROR(I),I=1,7)
    5 FORMAT (5X,A4,2X,7F9.2)
      GO TO 100
   99 STOP
      END
```

```
C     THIS IS PROGRAMME SVY 16, 360 VERSION
C     PREPARED BY J.S.ALLMAN, JANUARY 1967
C
      DIMENSION IGRAPH(61),INDEX(6),ERROR(6),DESC(18)
      READ (1,200) M,INDEX
  200 FORMAT (I1,6A1)
  100 READ (1,35) DESC
      WRITE (M,400)
  400 FORMAT (1H1/////)
      WRITE (M,35) DESC
   35 FORMAT (7X,18A4)
      WRITE (M,30)
   30 FORMAT(18X,3H-30,7X,3H-20,7X,3H-10,8X,1H0,8X,3H+10,7X,3H+20,6X,
     1 3H+30/10X,7(9X,1H*))
   10 READ (1,25)II,ITIME,BNG,TILT,(ERROR(I),I=1,6),N
   25 FORMAT(6X,A1,I4,F6.1,F5.2,6F9.1,3X,I1)
      IBNG=BNG
C
C     IF DATA FOLLOWED BY A BLANK CARD HEADING REPEATED
      DO 46 K=1,61
   46 IGRAPH(K)=0.0
      IF (ITIME) 31,31,32
   32 IF (N-4) 1,2,3
    1 IF(N-2) 6,6,8

C     NO OF GRAPHS IS ONE
    6 MM=1
      GO TO 5

C     NO OF GRAPHS IS THREE
    8 MM=3
      GO TO 5

C     NUMBER OF STATIONS IS 4
    2 ERROR(4)=ERROR(5)
      MM=4
      GO TO 5

C     NUMBER OF STATIONS IS 5
    3 IF (N-7) 9,8,9
```

```
C     PROGRAMME SVY 16 CONTINUED
C     NO OF GRAPHS IS SIX
    9 MM=6
    5 DO 15 J=1,MM
      K=ERROR(J)+31.5
      IF (K) 27,27,28
   27 K=1
   28 IF (K-61) 29,45,45
   45 K=61
   29 CONTINUE
   15 IGRAPH(K)=J
      DO 16 J=1,61
      IF (IGRAPH(J)) 17,18,17
   18 IGRAPH(J)=II
      GO TO 16
   17 K=IGRAPH(J)
      IGRAPH(J)=INDEX(K)
   16 CONTINUE
      IF (N-7) 21,22,22
   22 WRITE (M,23) ITIME,(IGRAPH(J),J=1,61)
   23 FORMAT (6X,I4,9X,61A1)
      GO TO 10
   21 WRITE (M,19)ITIME,IBNG,TILT,(IGRAPH(J),J=1,61)
   19 FORMAT(6X,I4,I4,F5.2,61A1)
      GO TO 10
   31 WRITE (M,30)
      GO TO 100
      END
```

```
C     THIS IS PROGRAMME SVY26
C     ANALYSIS OF BAROMETER SUMMARIES
C     PREPARED BY J.S.ALLMAN FEB 1967 FOR IBM 360

      DIMENSION A(6),AN(6,6),B(2,6),V(6,6,6),DESC(18)
      MMM=2

C     SET TILT GROUP INTERVALS
      DO 1 I=1,2
      DO 1 J=1,6
      B(I,J)=0.5*(J-I+1)+0.01*(I-2)
    1 CONTINUE
  100 READ (1,5) DESC
    5 FORMAT (7X,18A4)

C     SET COUNTERS
      DO 2 K=1,6
      DO 2 I=1,6
      AN(I,K)=0.0
      DO 2 J=1,6
    2 V(I,J,K)=0.0
  200 READ (1,10) ITIME,BNG,TILT,A,N
   10 FORMAT (7X,I4,F6.1,F5.2,6F9.1,3X,I1)
C
C     IF TIME IS ZERO , RESULTS PRINTED AND NEW DATA READ
      IF (ITIME)20,300,20
   20 DO 30 IA=1,5
C
C     SELECT TILT GROUP
      I=IA
      IF (TILT-B(1,IA))50,50,40
   40 CONTINUE
   30 CONTINUE
      I=6
C
C     IF ONLY FOUR GRAPHS, SHIFT 4 TO 5
   50 CONTINUE
```

```
C       PROGRAMME SVY 26 CONTINUED
        IF (N-4)60,60,70
     60 AN(I,6)=AN(I,6)-1.0
        AN(I,4)=AN(I,4)-1.0
C
C       FORM PROGRESSIVE TOTALS OF V,VV,VVV
     70 DO 80 J=1,6
        AN(I,J)=AN(I,J)+1.0
        DO 80 K=1,3
     80 V(I,K,J)=V(I,K,J)+A(J)**K
        GO TO 200
C
C       CALCULATE MOMENTS 1,2,3
    300 DO 115 I=1,6
        DO 115 K=1,6
        DO 116 J=1,3
        JJ=J+3
        IF (AN(I,K))105,105,110
    105 V(I,JJ,K)=0.0
        GO TO 116
    110 V(I,JJ,K)=V(I,J,K)/ AN(I,K)
    116 CONTINUE
        V(I,5,K)= SQRT (V(I,5,K))
    115 CONTINUE
C
C       PRINT RESULTS
        DO 170 MM=1,2
        M=1+(MM-1)*3
        N=3+(MM-1)*3
        IF (MM-1) 118,118,119
    118 WRITE (MMM,120) DESC
    120 FORMAT (1H1/////7X,18A4//6X,4HTILT,7H  GRAPH,4X,6HSUM V ,5X,
      1 7HSUM VV ,4X,8HSUM VVV ,6X,2HNO/)
        GO TO 125
    119 WRITE (MMM,121) DESC
    121 FORMAT (1H1/////7X,18A4//6X,4HTILT,7H  GRAPH,6X,4HMEAN,6X,
      1 6HST DEV,5X,7H3RD MOM,6X,2HNO/)
```

```
C      PROGRAMME SVY 26 CONTINUED
  125 DO 170 J=1,6
      DO 150 I=1,6
      IF (AN(I,J))150,150,130
  130 WRITE (MMM,140) B(2,I),J,(V(I,K,J),K=M,N),AN(I,J)
      IF (MM-2) 150,145,145
  145 WRITE (2,140) B(2,I),J,(V(I,K,J),K=M,N),AN(I,J)
  140 FORMAT (5X,F5.2,1X,I4,2X,F10.2,2X,F10.2,2X,F10.2,4X,F5.0)
  150 CONTINUE
      WRITE (MMM,160)
  160 FORMAT (/)
  170 CONTINUE
      GO TO 100
      END
```

```
C        PROGRAMME SVY 42, TWO BASE BAROMETER REDUCTION
C        PREPARED BY J.S.ALLMAN, JULY 1967
         DIMENSION DESC(18),A(5,6),RE(5,3),ERROR(3,2),DP(5,3),DHT(3)
   300   READ (1,350) M
   350   FORMAT (17X,I3)
   250   READ (1,1) DESC
     1   FORMAT (8X,18A4)
         WRITE(M,20) DESC
    20   FORMAT (1H1//////7X,7X,15HTWO BASE METHOD/7X,18A4//)
         IF (M-2) 30,30,32
    32   WRITE(2,28) DESC
    28   FORMAT (1H1,6X,18A4)
    30   READ (1,2)((A(I,J),J=1,6),I=1,3)
     2   FORMAT( 3A4 , 2X,F10.0,1X,F10.0,1X,F8.2)
         WRITE (M,3)
     3   FORMAT (//7X,8H STATION,9X,1HX,10X,1HY,7X,6HHEIGHT)
         WRITE(M,4)((A(I,J),J=1,6),I=1,3)
     4   FORMAT(7X, 3A4 , F10.0,1X,F10.0,1X,F8.2//)
         NNN=6
         DHT(1)=-A(1,6)+A(2,6)
         DHT(3)=-A(3,6)+A(1,6)
         DHT(2)=-A(2,6)+A(3,6)
   100   READ (1,200)((A(I,J),J=1,6),I=4,5)
   200   FORMAT (2(3A4,F10.0,F10.0,F8.2))
    96   READ (1,9)ITIME,((RE(I,J),J=1,3),I=1,5)
     9   FORMAT (I4,5(F7.2,2F4.0))
         NN=3
         IF (ITIME)300,250,31
    31   N=5
         IF (RE(5,1))10,10,44
    10   N=4
    44   NN=NN+N
         DO 15 J=1,3
         DO 15 I=1,N
    15   DP(I,J)=RE(I,1)-RE(J,1)
         DO 19 K=4,N
         J=K-3
```

```
C     PROGRAMME SVY 42 CONTINUED
      DO 13 I=1,3
      II=I+1
      IF (II-3) 17,17,16
   16 II=II-3
   17 ERROR(I,J)=A(I,6)+DP(K,I)/DP(II,I)*DHT(I)-A(K,6)
   13 CONTINUE
      NNN=NNN+1
      WRITE (M,26) ITIME,(A(K,IA),IA=1,3),(ERROR(IB,J),IB=1,3)
   26 FORMAT (1H ,18X,I4,3X,3A4,5X,3F9.1)
   19 CONTINUE
      IF (M-2) 18,18,21
   21  JJ=1
      IF (N-5) 50,51,51
   51 JJ=2
   50 WRITE (2,22) ITIME,((ERROR(I,J),I=1,3),J=1,JJ),NN
   22 FORMAT (1H ,6X,I4,11X,6F9.1,3X,I1)
   18 CONTINUE
      WRITE (M,27)
   27 FORMAT(/)
      NNN=NNN+2
      IF (NNN-41) 23,24,24
C     SET NEW PAGE
   24 WRITE (M,20) DESC
      WRITE (M,25) ((A(I,J),J=1,3),I=1,3)
   25 FORMAT (1H ,7X,3(3A4,2X)/)
      NNN=0.
   23 GO TO 100
      END
```

```
C     PROGRAMME SVY 43, LEAP FROG REDUCTION OF BAROMETER READINGS
C     PREPARED BY J.S.ALLMAN, JULY 1967
C     IBM 360 VERSION
C
C     ID1=1 PRESSURE IN MILLIBARS,=2 MILLIMETERS,=3 INCHES
C     ID2=1 TEMPERATURES IN FARENHEIT , =2 CENTIGRADE
C     ID3=1 COORDINATES IN YARDS,=2 FEET
C     M=2...PUNCH, M=3...PRINT
C     ITIME=0 READ NEW BASES, = NEGATIVE READ NEW CONSTANTS

      DIMENSION A(2,4),C(25,3),CLHT(25),ERROR(25),BASE(3,4),RE(5,3),
     1 HSA(5),TEMPS(5),ITME(25),DESC(18)
  300 READ(1,350) CON1,CON2,M
  350 FORMAT(F9.2,2X,F6.5,I3)
  250 READ (1,1)ID1,ID2,ID3,DESC
    1 FORMAT(I1,I1,I1,5X,18A4)
      WRITE(M,20) DESC
   20 FORMAT (1H1,/////7X,16HLEAP FROG METHOD/7X,18A4)
      WRITE (M,400) CON1,CON2
  400 FORMAT (/7X,10HCONSTANT 1,F10.2/7X,10HCONSTANT 2,F10.5)
      GO TO (21,22,23),ID1
   21 WRITE (M,11)
   11 FORMAT(8X,22HPRESSURES IN MILLIBARS)
      GO TO 24
   22 WRITE(M,12)
   12 FORMAT(8X,24HPRESSURES IN MILLIMETERS)
      GO TO 24
   23 WRITE(M,13)
   13 FORMAT (8X,19HPRESSURES IN INCHES)
   24 GO TO (25,26),ID2
   25 WRITE(M,14)
   14 FORMAT (8X,25HTEMPERATURES IN FARENHEIT)
      GO TO 27
   26 WRITE(M,15)
   15 FORMAT (8X,26HTEMPERATURES IN CENTIGRADE)
   27 CONTINUE
   30 READ (1,2) ((BASE(J,I),I=1,4),J=1,3)
    2 FORMAT (3A4,23X,F8.2)
      WRITE (M,3)((BASE(J,I),I=1,4),J=1,3)
    3 FORMAT (8X,3A4,5X,F8.2)
```

```
C       PROGRAMME SVY 43 CONTINUED
        WRITE (M,420)
  420   FORMAT (1H /8X,4HTIME,3X,7HSTATION,9X,5HERROR,3X,12HFIXED HEIGHT/)
        IF (M-2) 423,422,423
  422   WRITE (M,421) (DESC(I),I=1,16)
  421   FORMAT (1H1,6X,9HSUMMARY   ,16A4)
  423   READ(1,200)((A(I,J),J=1,4),I=1,2)
  200   FORMAT (2(3A4,20X,F8.2))
        READ (1,9) ITIME,((RE(I,J),J=1,3),I=1,5)
        WRITE (M,997) ITIME ,(A(1,J),J=1,4)
  997   FORMAT (1H /8X,I4,3X,3A4,17X,F8.2/)
        DO 999 I=1,3
  999   C(1,I)=A(1,I)
        CLHT(1)=A(1,4)
        ERROR(1)=0.
  800   DO 100 II=2,25
  150   READ(1,200)((A(I,J),J=1,4),I=1,2)
   96   READ (1,9) ITIME,((RE(I,J),J=1,3),I=1,5)
    9   FORMAT (I4,5(F7.2,2F4.0))
        IB=II-1
        IF (ITIME)300,250,31
   31   N=5
        ITME(II)=ITIME
        IF(A(1,1)-A(2,1)) 151,150,151
  151   IF (A(1,1)-C(IB,1))153,152,153
  152   DO 154 J=1,3
  154   C(II,J)=A(2,J)
        KA=4
        KB=5
        GO TO 155
  153   IF(A(2,1)-C(IB,1)-171,170,171
  171   WRITE (3,172)
  172   FORMAT (1H ,10HCHECK DATA)
        CALL EXIT
  170   DO 156 J=1,3
  156   C(II,J)=A(1,J)
        KA=5
        KB=4
```

```
C      PROGRAMME SVY 43 CONTINUED
  155 IF (RE(5,1))10,10,44
   10 N=4
   44 DO 85 J=2,3
      DO 85 I=1,N
   85 RE(I,J)=RE(I,J)/10.
   58 GO TO (60,61,62),ID1
   61 CD=1013.25/760.
      GO TO 63
   62 CD=1013.25/29.921
   63 DO 64 J=1,N
   64 RE(J,1)=RE(J,1)*CD
C      ID2=1 TEMPERATURES IN FARENHEIT , =2 CENTIGRADE
   60 GO TO (65,66),ID2
   66 DO 68 J=2,3
      DO 68 I=1,N
      IF (RE(I,J))68,68,67
   67 RE(I,J)=RE(I,J)*1.8+32.
   68 CONTINUE
   65 DO 86 I=1,N
      HSA(I)=CON1*(1.-(RE(I,1)/1013.25)**CON2)
   86 TEMPS(I)=59.-0.003566*HSA(I)
      PM=0.
      DT=0.
      DTW=0.
      TM=0.
      ON=0.
      ONN=0.
      DO 70 I=1,N
      PM=PM+RE(I,1)
      IF (RE(I,2))80,80,71
   71 ON=ON+1.
      DT=DT+RE(I,2)-TEMPS(I)
      TM=TM+RE(I,2)
      IF (RE(I,3)) 80,80,72
   72 ONN=ONN+1.
      DTW=DTW+RE(I,2)-RE(I,3)
   80 CONTINUE
   70 CONTINUE
```

```
C     PROGRAMME SVY 43 CONTINUED
      AN=N
      PM=PM/AN
      TM=TM/ON
      DT=DT/ON
      IF (ONN) 73,73,74
   74 DTW=DTW/ONN
   55 TS=373.16
      T=273.16+((TM-DTW)-32.)*5./9.
      CA=TS/T
      CB=(1.-T/TS)*11.344
      CF=-3.49149*(CA-1.)
      CD=-18.19731*(CA-1.)-.0031812*.0001*(10.**CB-1.)+.00187265*(10.**
     1 CF-1.)+6.9209182
      CE=5.02808*ALOG(CA)
      ALP=CD+CE
      PW=EXP(ALP)
      P=PW-0.000367*PW*DTW
      DT=DT+(459.8+TM)*0.734*P/(1013.25+PM)
   73 DO 16 I=1,N
      HSA(I)=HSA(I)+HSA(I)/518.4*DT*(1.+.00000344*HSA(I)
     1 +1.6*.000001*0.00001*HSA(I)**2)
   16 CONTINUE
      DIFFHT=HSA(KB)-HSA(KA)
      CLHT(II)=CLHT(II-1)+DIFFHT
      ERROR(II)=CLHT(II)-A(KB-3,4)
      DO 157 J=1,3
      IF(C(II,1)-BASE(J,1)) 157,158,157
  157 CONTINUE
  100 CONTINUE
  158 IA=II
      CLHT(1)=BASE(J,4)
      WRITE (M,410) IA,ERROR(IA)
  410 FORMAT (1H ,32X,14HNO OF STATIONS,I4,5X,8HMISCLOSE,F8.1/)
      MI=IA-1
      DO 159 J=2,MI
      E=J-1
      EE=IA-1
      ERROR(J)=ERROR(J)-E/EE*ERROR(IA)
```

```
C      PROGRAMME SVY 43 CONTINUED
       WRITE(M,160) ITME(J),(C(J,I),I=1,3),ERROR(J)
  160  FORMAT (1H ,7X,I4,3X,3A4,F9.1)
       IF (M-2) 161,159,161
  161  WRITE (2,162) ITME(J),ERROR(J)
  162  FORMAT (7X,I4,11X,F9.1)
  159  CONTINUE
       DO 998 I=1,3
  998  C(1,I)=C(IA,I)
       WRITE( M,997) ITME(IA),(C(IA,I),I=1,3),CLHT(1)
       GO TO  800
       END
```

```
C     THIS IS PROGRAMME SVY46
C     ANALYSIS OF BAROMETER SUMMARIES
C     PREPARED BY J.S.ALLMAN AUG 1967 FOR IBM 360

      DIMENSION A(6),AN(6,6),B(2,6),V(6,2,6),DESC(18)
      MMM=2

C     SET TILT GROUP INTERVALS
      DO 1 I=1,2
      DO 1 J=1,6
      B(I,J)=0.5*(J-I+1)+0.01*(I-2)
    1 CONTINUE
  100 READ (1,5) DESC
    5 FORMAT (7X,18A4)

C     SET COUNTERS
      DO 2 K=1,6
      DO 2 I=1,6
      AN(I,K)=0.0
      DO 2 J=1,2
    2 V(I,J,K)=0.0
  200 READ (1,10) ITIME,BNG,TILT,A,N
   10 FORMAT (7X,I4,F6.1,F5.2,6F9.1,3X,I1)

C     IF TIME IS ZERO , RESULTS PRINTED AND NEW DATA READ
      IF (ITIME)20,300,20
   20 DO 30 IA=1,5

C     SELECT TILT GROUP
      I=IA
      IF (TILT-B(1,IA))50,50,40
   40 CONTINUE
   30 CONTINUE
      I=6

C     IF ONLY FOUR GRAPHS, SHIFT 4 TO 5
   50 CONTINUE
      IF (N-4)60,60,70
   60 AN(I,6)=AN(I,6)-1.0
      AN(I,4)=AN(I,4)-1.0
```

```
C     PROGRAMME SVY 46 CONTINUED
C     FORM PROGRESSIVE TOTAL  OF V
   70 DO 80 J=1,6
      A(J)=ABS(A(J))
      AN(I,J)=AN(I,J)+1.0
      V(I,1,J)=V(I,1,J)+A(J)
      IF (V(I,2,J)-A(J)) 71,80,80
   71 V(I,2,J)=A(J)
   80 CONTINUE
      GO TO 200
C     CALCULATE MEAN ERROR
  300 DO 115 I=1,6
      DO 115 J=1,6
      IF (AN(I,J))105,105,110
  105 V(I,1,J)=0.0
      GO TO 115
  110 V(I,1,J)=V(I,1,J)/AN(I,J)
  115 CONTINUE
C     PRINT RESULTS
  118 WRITE (MMM,120) DESC
  120 FORMAT (1H1/////7X,18A4//6X,4HTILT,7H  GRAPH,4X,7HAVERAGE,4X,
     1 8HMAXIMIUM,5X,2HNO/)
      DO 170 J=1,6
      DO 150 I=1,6
      IF (AN(I,J)) 150,150,130
  130 WRITE (MMM,140) B(2,I),J,(V(I,K,J),K=1,2),AN(I,J)
  140 FORMAT (5X,F5.2,1X,I4,2F12.2,F8.0)
  150 CONTINUE
      WRITE (MMM,160)
  160 FORMAT(2H  )
  170 CONTINUE
      GO TO 100
      END
```

APPENDIX VII

Analysis of Summaries.

26th May, 1959.
28th May, 1959.
28th February, 1966.
1st March, 1966.
22nd May, 1956.
23rd May, 1956.
6th December, 1955.
7th December, 1955.

```
 SUMMARY  CITY AREA  26 MAY 1959  ASA
 SINGLE AND MULTIPLE BASE ERRORS

TILT  GRAPH    AVERAGE    MAXIMIUM    NO

0.0      1        5.20        8.20    11.
0.50     1        7.49       15.10    16.
1.00     1        8.64       18.60    15.
1.50     1       19.33       20.20     3.
2.00     1       15.40       15.40     1.

0.0      2        3.35        6.10    11.
0.50     2        7.91       13.50    16.
1.00     2       16.41       19.20    15.
1.50     2       24.93       26.80     3.
2.00     2       34.00       34.00     1.

0.0      3        3.18        8.00    11.
0.50     3        6.13       14.70    16.
1.00     3       13.85       21.40    15.
1.50     3       22.87       23.70     3.
2.00     3       20.20       20.20     1.

0.0      4        4.13        9.50    11.
0.50     4        8.46       15.70    16.
1.00     4       17.59       23.30    15.
1.50     4       23.63       24.60     3.
2.00     4       11.90       11.90     1.

0.0      5        5.96       11.60    11.
0.50     5        3.34       10.40    16.
1.00     5        2.49        8.20    15.
1.50     5        4.83        6.40     3.
2.00     5       11.00       11.00     1.

0.0      6        5.39       11.00    11.
0.50     6        6.41       10.50    16.
1.00     6       11.00       17.50    15.
1.50     6       12.17       12.60     3.
2.00     6        1.10        1.10     1.
```

```
 SUMMARY  CITY AREA  28 MAY 1959  ASA
 SINGLE AND MULTIPLE BASE ERRORS

TILT   GRAPH     AVERAGE     MAXIMIUM      NO

0.0      1         2.24        5.90       22.
0.50     1         6.18       13.80       12.
1.00     1        14.13       18.20        9.
1.50     1        14.18       22.00        6.

0.0      2         3.51        5.90       22.
0.50     2         8.30       11.50       12.
1.00     2        16.23       18.70        9.
1.50     2        21.30       22.30        6.

0.0      3         3.05        6.10       22.
0.50     3         5.33       10.70       12.
1.00     3         9.03       16.00        9.
1.50     3         9.47       13.20        6.

0.0      4         7.07       11.30       22.
0.50     4         7.83       14.60       12.
1.00     4        13.42       17.30        9.
1.50     4        11.98       14.90        6.

0.0      5         2.05        9.90       22.
0.50     5         4.33        9.50       12.
1.00     5        10.14       22.60        9.
1.50     5        12.78       22.00        6.

0.0      6         7.44       12.40       22.
0.50     6         6.93       10.30       12.
1.00     6         5.60        9.70        9.
1.50     6         2.72        4.10        6.
```

```
 SUMMARY  COOTAMUNDRA AREA 28 FEBRUARY 1966  ASA
 SINGLE AND MULTIPLE BASE ERRORS

TILT  GRAPH    AVERAGE    MAXIMIUM     NO

0.0     1       11.51       16.30     14.
0.50    1        9.33       17.70     34.

0.0     2       12.74       15.00     14.
0.50    2       22.65       32.40     34.

0.0     3       16.07       25.40     14.
0.50    3       18.69       30.40     34.


0.0     5       15.65       23.20     14.
0.50    5       12.31       19.90     34.
```

```
SUMMARY  COOTAMUNDRA AREA 1 MARCH 1966  ASA
SINGLE AND MULTIPLE BASE ERRORS

TILT  GRAPH    AVERAGE    MAXIMIUM     NO

0.0     1       11.12      22.30      46.
0.50    1       26.70      26.70       1.

0.0     2        4.98       9.90      46.
0.50    2       10.30      10.30       1.

0.0     3        4.75      14.20      46.
0.50    3       14.90      14.90       1.

0.0     4       10.19      24.90      35.
0.50    4        9.50       9.50       1.

0.0     5        5.66      14.10      46.
0.50    5        3.30       3.30       1.

0.0     6       11.97      22.10      35.
0.50    6       19.40      19.40       1.
```

```
 SUMMARY CITY TRAVERSE 22 MAY 1956  ASA
 SINGLE AND MULTIPLE BASE ERRORS

TILT  GRAPH    AVERAGE     MAXIMIUM     NO

0.0     1        5.62        8.20      12.
0.50    1       10.54       15.20      16.
1.00    1       20.05       22.70      11.

0.0     2        3.31        5.60      12.
0.50    2        6.07       10.60      16.
1.00    2        9.73       11.60      11.

0.0     3        3.74        8.00      12.
0.50    3        5.11       18.40      16.
1.00    3       17.71       20.80      11.

0.0     5        2.82        5.60      12.
0.50    5        3.02        6.30      16.
1.00    5        1.85        3.10      11.
```

```
 SUMMARY CITY TRAVERSE 23 MAY 1956  ASA
 SINGLE AND MULTIPLE BASE ERRORS

TILT  GRAPH      AVERAGE     MAXIMIUM      NO

0.0     1          4.87         8.40      15.
0.50    1          9.43        16.70      20.
1.00    1         15.39        18.40      11.

0.0     2          3.09         5.10      15.
0.50    2          6.17        11.50      20.
1.00    2          9.15        19.20      11.

0.0     3          3.30         7.70      15.
0.50    3          7.19        14.90      20.
1.00    3         13.75        18.20      11.


0.0     5          1.60         5.30      15.
0.50    5          3.04        14.90      20.
1.00    5          1.31         6.30      11.
```

```
SUMMARY CITY TRAVERSE 6 DECEMBER 1955  ASA
SINGLE AND MULTIPLE BASE ERRORS

TILT   GRAPH    AVERAGE     MAXIMIUM     NO

0.0      1        4.90        4.90       1.
0.50     1       10.05       14.20       4.
1.00     1       15.34       17.50       5.
1.50     1       13.72       22.20       6.
2.00     1       17.43       25.20      10.
2.50     1       27.70       27.70       1.

0.0      2        3.50        3.50       1.
0.50     2        7.17        8.00       4.
1.00     2       17.92       20.20       5.
1.50     2       20.67       26.70       6.
2.00     2       23.43       29.60      10.
2.50     2       17.30       17.30       1.

0.0      3        6.40        6.40       1.
0.50     3        8.10       18.70       4.
1.00     3       18.40       26.30       5.
1.50     3        4.85       11.20       6.
2.00     3        6.95       15.50      10.
2.50     3        0.20        0.20       1.

0.0      4        6.40        6.40       1.
0.50     4        4.57       10.10       4.
1.00     4       22.54       32.20       5.
1.50     4        4.75        7.60       6.
2.00     4        7.51       13.90      10.
2.50     4        6.40        6.40       1.

0.0      5        4.50        4.50       1.
0.50     5        6.40       14.70       4.
1.00     5        9.40       19.40       5.
1.50     5        5.55       10.80       6.
2.00     5        6.45       11.00      10.
2.50     5        2.90        2.90       1.

0.0      6        4.50        4.50       1.
0.50     6        3.52        7.30       4.
1.00     6       11.86       24.10       5.
1.50     6        8.32       12.40       6.
2.00     6        9.49       13.80      10.
2.50     6        7.80        7.80       1.
```

SUMMARY CITY TRAVERSE 7 DEC 1955 ASA
SINGLE AND MULTIPLE BASE ERRORS

TILT	GRAPH	AVERAGE	MAXIMIUM	NO
0.0	1	3.40	3.40	1.
0.50	1	5.46	11.10	8.
1.00	1	17.56	25.60	8.
1.50	1	26.82	33.20	19.
2.00	1	34.10	35.20	2.
0.0	2	6.90	6.90	1.
0.50	2	7.52	8.90	8.
1.00	2	9.26	17.10	8.
1.50	2	15.04	23.40	19.
2.00	2	9.15	14.20	2.
0.0	3	3.60	3.60	1.
0.50	3	7.21	9.20	8.
1.00	3	10.20	21.40	8.
1.50	3	15.72	26.20	19.
2.00	3	9.45	14.80	2.
0.0	4	3.60	3.60	1.
0.50	4	7.47	11.40	8.
1.00	4	9.97	20.20	8.
1.50	4	14.66	20.10	19.
2.00	4	9.25	14.40	2.
0.0	5	1.70	1.70	1.
0.50	5	8.01	15.20	8.
1.00	5	4.39	12.80	8.
1.50	5	7.07	13.90	19.
2.00	5	6.20	12.40	2.
0.0	6	1.70	1.70	1.
0.50	6	8.19	15.10	8.
1.00	6	4.16	9.50	8.
1.50	6	8.95	15.70	19.
2.00	6	6.30	12.60	2.

```
SUMMARY   CITY AREA   26 MAY 1959   ASA
SINGLE AND MULTIPLE BASE ERRORS

TILT   GRAPH       MEAN      ST DEV     3RD MOM       NO

0.0      1         -2.24       5.66      -18.36       11.
0.50     1          0.09       8.97      335.57       16.
1.00     1          8.64      11.05     1963.60       15.
1.50     1         19.33      19.36     7278.92        3.
2.00     1         15.40      15.40     3652.26        1.

0.0      2         -2.63       3.95      -76.75       11.
0.50     2          4.14       8.61      582.05       16.
1.00     2         16.41      16.52     4592.17       15.
1.50     2         24.93      25.02    15824.27        3.
2.00     2         34.00      34.00    39304.00        1.

0.0      3          2.93       4.11      104.33       11.
0.50     3          4.81       7.87      745.33       16.
1.00     3         13.85      14.85     3860.06       15.
1.50     3         22.87      22.88    12005.83        3.
2.00     3         20.20      20.20     8242.40        1.

0.0      4          4.13       4.95      176.17       11.
0.50     4          7.19       9.33      969.52       16.
1.00     4         17.59      17.86     5935.39       15.
1.50     4         23.63      23.64    13236.26        3.
2.00     4         11.90      11.90     1685.16        1.

0.0      5          5.96       6.95      449.97       11.
0.50     5          2.06       4.57      157.14       16.
1.00     5         -1.95       3.42      -72.40       15.
1.50     5         -4.83       5.14     -153.72        3.
2.00     5        -11.00      11.00    -1331.00        1.

0.0      6          5.39       6.32      331.98       11.
0.50     6          6.04       6.90      380.39       16.
1.00     6         11.00      11.47     1688.88       15.
1.50     6         12.17      12.18     1814.55        3.
2.00     6         -1.10       1.10       -1.33        1.
```

```
SUMMARY  CITY AREA  28 MAY 1959  ASA
SINGLE AND MULTIPLE BASE ERRORS

TILT  GRAPH      MEAN      ST DEV     3RD MOM      NO

0.0     1        0.61       2.70       13.00      22.
0.50    1        2.38       7.12      405.09      12.
1.00    1       14.13      14.30     3023.71       9.
1.50    1       14.18      15.18     4186.02       6.

0.0     2       -1.87       3.85      -45.71      22.
0.50    2        1.25       8.55      152.67      12.
1.00    2       16.23      16.41     4546.66       9.
1.50    2       21.30      21.32     9711.46       6.

0.0     3       -0.47       3.51        0.30      22.
0.50    3        2.35       5.96      170.62      12.
1.00    3        8.81      10.15     1314.26       9.
1.50    3        9.47      10.17     1204.04       6.

0.0     4        7.07       7.68      538.67      22.
0.50    4        7.83       8.51      766.06      12.
1.00    4       13.42      13.57     2587.37       9.
1.50    4       11.98      12.16     1876.39       6.

0.0     5        0.39       3.04       41.34      22.
0.50    5        0.10       5.05       37.62      12.
1.00    5      -10.14      11.66    -2209.74       9.
1.50    5      -12.78      14.26    -3795.81       6.

0.0     6        7.44       8.12      629.44      22.
0.50    6        6.93       7.34      446.35      12.
1.00    6        5.60       6.08      278.20       9.
1.50    6        2.72       2.96       30.79       6.
```

```
SUMMARY  COOTAMUNDRA AREA  28 FEBRUARY 1966  ASA
SINGLE AND MULTIPLE BASE ERRORS

TILT  GRAPH      MEAN       ST DEV     3RD MOM       NO

0.0     1       11.51       11.78     1742.78       14.
0.50    1        8.91       10.19     1251.07       34.

0.0     2      -12.74       12.91    -2223.82       14.
0.50    2      -22.65       23.01   -12754.52       34.

0.0     3      -16.07       17.08    -5531.39       14.
0.50    3      -18.69       19.31    -7860.90       34.

0.0     5      -15.65       16.57    -5020.23       14.
0.50    5      -12.31       12.84    -2363.14       34.
```

```
SUMMARY   COOTAMUNDRA AREA   1 MARCH 1966   ASA
SINGLE AND MULTIPLE BASE ERRORS

TILT   GRAPH        MEAN        ST DEV       3RD MOM          NO

0.0      1         -9.43        12.39       -2276.46         46.
0.50     1        -26.70        26.70      -19034.15          1.

0.0      2         -0.75         5.55         -46.90         46.
0.50     2        -10.30        10.30       -1092.73          1.

0.0      3         -1.40         6.15         -72.94         46.
0.50     3        -14.90        14.90       -3307.95          1.

0.0      4          1.27        12.29        1613.44         35.
0.50     4         -9.50         9.50        -857.38          1.

0.0      5          3.14         6.63         332.48         46.
0.50     5          3.30         3.30          35.94          1.

0.0      6         10.57        13.39        2917.54         35.
0.50     6         19.40        19.40        7301.37          1.
```

```
SUMMARY  CITY AREA  22 MAY 1956  ASA
SINGLE AND MULTIPLE BASE ERRORS

TILT  GRAPH      MEAN       ST DEV      3RD MOM       NO

0.0      1        5.62        5.98       245.95      12.
0.50     1       10.54       10.85      1369.18      16.
1.00     1       20.05       20.13      8243.01      11.

0.0      2        2.49        3.57        49.17      12.
0.50     2        5.50        6.86       382.83      16.
1.00     2        9.73        9.94      1034.51      11.

0.0      3        3.52        4.44       122.94      12.
0.50     3        4.79        7.04       649.29      16.
1.00     3       17.71       17.85      5805.91      11.

0.0      5        0.82        3.27        13.61      12.
0.50     5        0.44        3.50        19.02      16.
1.00     5       -0.06        1.99        -0.70      11.
```

```
SUMMARY  CITY AREA  23 MAY 1956  ASA
SINGLE AND MULTIPLE BASE ERRORS

TILT  GRAPH      MEAN     ST DEV    3RD MOM       NO

0.0     1        3.43      5.48      197.61      15.
0.50    1        9.43     10.03     1165.53      20.
1.00    1       15.39     15.64     3981.15      11.

0.0     2        2.97      3.55       56.22      15.
0.50    2        5.47      7.23      482.63      20.
1.00    2        9.15     11.64     2172.92      11.

0.0     3        3.23      4.09      102.28      15.
0.50    3        6.78      8.44      790.94      20.
1.00    3       13.75     14.10     2959.54      11.

0.0     5        1.28      2.08       15.18      15.
0.50    5        0.36      4.35     -159.61      20.
1.00    5       -1.18      2.17      -24.95      11.
```

```
SUMMARY  CITY AREA  6 DECEMBER 1955  ASA
SINGLE AND MULTIPLE BASE ERRORS

TILT  GRAPH     MEAN     ST DEV     3RD MOM      NO

0.0     1       4.90      4.90      117.65       1.
0.50    1      10.05     10.42     1251.95       4.
1.00    1      15.34     15.41     3714.54       5.
1.50    1      -4.08     15.01    -2142.35       6.
2.00    1      -3.09     18.71    -3999.32      10.
2.50    1     -27.70     27.70   -21253.92       1.

0.0     2       3.50      3.50       42.88       1.
0.50    2       7.17      7.20      378.37       4.
1.00    2      17.92     17.99     5890.00       5.
1.50    2      20.67     21.40    10691.82       6.
2.00    2      23.43     24.06    14910.42      10.
2.50    2      17.30     17.30     5177.70       1.

0.0     3       6.40      6.40      262.14       1.
0.50    3       8.10     11.59     2277.64       4.
1.00    3      18.40     19.22     7971.57       5.
1.50    3       4.85      6.59      435.53       6.
2.00    3       6.39      8.62      899.95      10.
2.50    3       0.20      0.20        0.01       1.

0.0     4       6.40      6.40      262.14       1.
0.50    4       4.57      5.98      314.24       4.
1.00    4      22.54     23.56    14544.95       5.
1.50    4       2.35      5.47      162.67       6.
2.00    4       3.85      8.44      604.75      10.
2.50    4      -6.40      6.40     -262.14       1.

0.0     5       4.50      4.50       91.12       1.
0.50    5       6.40      9.15     1117.89       4.
1.00    5       5.40     11.00     1770.84       5.
1.50    5      -5.55      6.65     -394.88       6.
2.00    5      -6.45      7.35     -485.86      10.
2.50    5      -2.90      2.90      -24.39       1.

0.0     6       4.50      4.50       91.12       1.
0.50    6       3.52      4.57      135.32       4.
1.00    6       9.26     14.08     3798.00       5.
1.50    6      -8.32      9.23     -893.50       6.
2.00    6      -9.49     10.20    -1187.77      10.
2.50    6      -7.80      7.80     -474.55       1.
```

```
SUMMARY  CITY AREA  7 DECEMBER 1955  ASA
SINGLE AND MULTIPLE BASE ERRORS

TILT  GRAPH       MEAN       ST DEV      3RD MOM        NO

0.0     1         3.40        3.40        39.30         1.
0.50    1        -1.94        6.53      -211.91         8.
1.00    1        12.84       18.38      6488.55         8.
1.50    1        26.82       27.11     20557.93        19.
2.00    1        34.10       34.12     39775.59         2.

0.0     2         6.90        6.90       328.51         1.
0.50    2         7.52        7.57       440.67         8.
1.00    2         8.71       10.80      1597.65         8.
1.50    2        13.63       15.72      4248.86        19.
2.00    2         5.05       10.45      1397.18         2.

0.0     3         3.60        3.60        46.66         1.
0.50    3         7.21        7.40       427.31         8.
1.00    3         9.57       12.14      2478.29         8.
1.50    3        13.89       16.89      5655.31        19.
2.00    3         5.35       10.86      1586.44         2.

0.0     4         3.60        3.60        46.66         1.
0.50    4         7.47        8.04       584.82         8.
1.00    4         9.97       11.80      2208.59         8.
1.50    4        11.99       15.12      3317.69        19.
2.00    4         5.15       10.59      1458.53         2.

0.0     5         1.70        1.70         4.91         1.
0.50    5         8.01        9.57      1153.04         8.
1.00    5         1.91        6.55       491.42         8.
1.50    5        -6.97        8.57      -813.65        19.
2.00    5        -6.20        8.77      -953.31         2.

0.0     6         1.70        1.70         4.91         1.
0.50    6         8.19        9.44      1074.45         8.
1.00    6         2.09        5.34       158.13         8.
1.50    6        -8.95        9.55     -1027.63        19.
2.00    6         -6.30       8.91     -1000.19         2.
```

DEPARTMENT OF SURVEYING - UNIVERSITY OF NEW SOUTH WALES

Kensington, N.S.W. 2033.

Reports from the Department of Surveying, School of Civil Engineering.

1. The discrimination of radio time signals in Australia.
   G.G. BENNETT (UNICIV Report No. D-1)
2. A comparator for the accurate measurement of differential barometric pressure.
   J.S. ALLMAN (UNICIV Report No. D-3)
3. The establishment of geodetic gravity networks in South Australia.
   R.S. MATHER (UNICIV Report No. R-17)
4. The extension of the gravity field in South Australia.
   R.S. MATHER (UNICIV Report No. R-19)

UNISURV REPORTS.

5. An analysis of the reliability of Barometric elevations.
   J.S. ALLMAN (UNISURV Report No. 5)
6. The free air geoid in South Australia and its relation to the equipotential surfaces of the earth's gravitational field.
   R.S. MATHER (UNISURV Report No. 6)
7. Control for Mapping. (Proceedings of Conference, May 1967).
   P.V. ANGUS-LEPPAN, Editor. (UNISURV Report No. 7)
8. The teaching of field astronomy.
   G.G.BENNETT and J.G.FREISLICH (UNISURV Report No. 8)
9. Photogrammetric pointing accuracy as a function of properties of the visual image.
   J.C. TRINDER (UNISURV Report No. 9)
10. An experimental determination of refraction over an Icefield.
    P.V. ANGUS-LEPPAN (UNISURV Report No. 10)