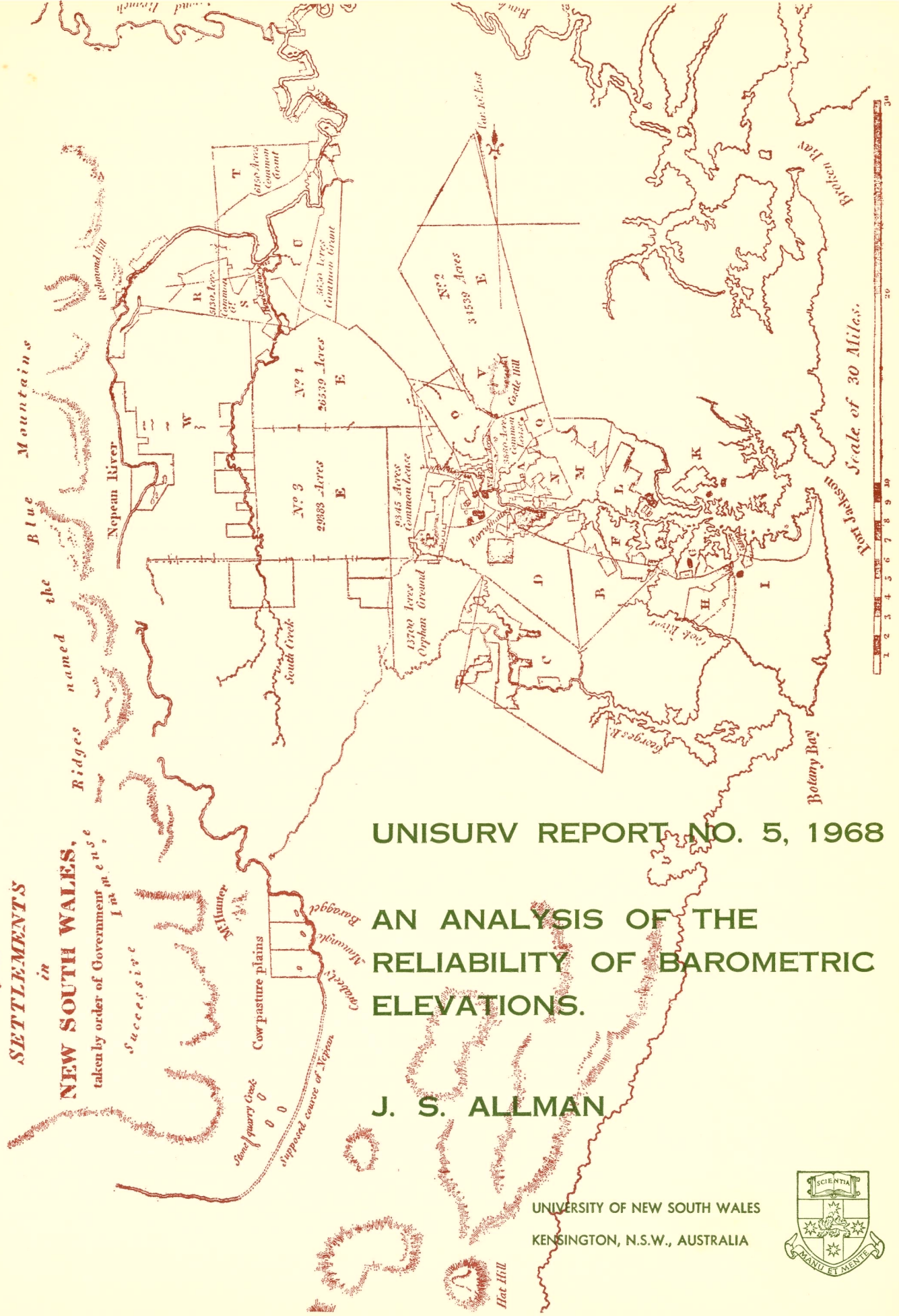


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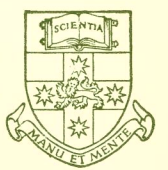


**UNISURV REPORT NO. 5, 1968**

**AN ANALYSIS OF THE  
 RELIABILITY OF BAROMETRIC  
 ELEVATIONS.**

**J. S. ALLMAN**

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



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- B Liberty Plains
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AN ANALYSIS OF THE RELIABILITY

OF BAROMETRIC ELEVATIONS

by

J.S. ALLMAN



## CONTENTS

Introduction	1
1. History of Barometric Surveying	5
2. Examination of the Surveying Aneroid	16
2.1 Askania Microbarometer	18
2.2 Wallace and Tiernan Surveying Aneroid	20
2.3 The American Paulin System	20
2.4 The Baromec Barometer	22
2.5 The Barometric Comparator	26
2.6 Test Results	47
2.6.1 Reading Tests	47
2.6.2 Graduation Errors	48
2.6.3 Drift of the Index Values	54
2.6.4 Hysteresis	57
2.6.5 Error due to Temperature	57
2.7 Conclusions	58
3. Investigation of the Pressure/Height Relationship in a Vertical Column	59
3.1 Equipment	59
3.2 Results	72

4.	Field Techniques and the Isobaric Surface	77
4.1	Diurnal Curve Method	78
4.2	Single Base Method	80
4.3	The Leap-frog Method	80
4.4	The Two Base Method	81
4.5	The Multiple Base Method	83
4.6	The Isobaric Surface Investigation	84
4.7	Conclusions.	89
5.	Field Traverses	100
5.1	Multiple Base Method	103
5.2	Leap-frog Method	104
5.3	Two Base Method	106
5.4	Conclusions	107
6.	The Methods of Computation of the Results	123
6.1	Standard Atmosphere Tables	123
6.2	Single Base Reductions	123
6.3	Multiple Base Reductions	125
6.4	Nomogram for the Determination of Tilt	129
6.5	Computer Programmes	131
6.5.1	Temperature Correction	134
6.5.2	Humidity Correction	134
6.5.3	Tilt of the Isobaric Surface	138

6.5.4	Standard Atmosphere Programme SVY 12.	142
6.5.5	Isobaric Surface Investigation Programme SVY 14.	143
6.5.6	Barometer Traverse Reduction Programme SVY 19.	145
6.5.7	Tower Reading Reduction Programme SVY 24	147
6.5.8	Automatic Graphing Programme SVY 16	149
6.5.9	Analysis of Summaries Programme SVY 26	151
6.5.10	Two Base Barometer Reduction Programme SVY 42	151
6.5.11	Leap-frog Reduction Programme SVY 53	154
6.5.12	Analysis of Summaries Programme SVY 46	154
7.	Conclusions	159
	Bibliography	162
	Appendices	
I	Assumed Standard Atmosphere (ASA)	169
II	Isobaric Surface Reductions	177

III	Barometer Traverse Reductions	228
IV	Leap-frog Reductions	268
V	Two Base Reductions	272
VI	Computer Programmes	287
VII	Analysis of Summaries	319.

## INTRODUCTION

The problem of obtaining accurate elevations using barometric methods has vexed many investigators since Pascal and Perrier experimented in France in 1648.<sup>12</sup> 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  $1 \times 10^{-4}$  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.<sup>4</sup> This standard states (page 8):

"2. Apart from the basic unit of pressure viz. the dyne per square centimeter ( $\text{dyne/cm}^2$ ), 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  $1000 \text{ dyne/cm}^2$ .

- b. The millimeter of mercury at  $0^{\circ}$  C and standard gravity  $980.665 \text{ cm/s}^2$ .
- c. The inch of mercury at  $0^{\circ}$  C and standard gravity  $980.665 \text{ cm/s}^2$ .

By 'mercury at  $0^{\circ}$  C' is meant a hypothetical fluid having an invariable density of exactly  $13.5951 \text{ g/cm}^3$ ."

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 computer 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 verified 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.<sup>12</sup> 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

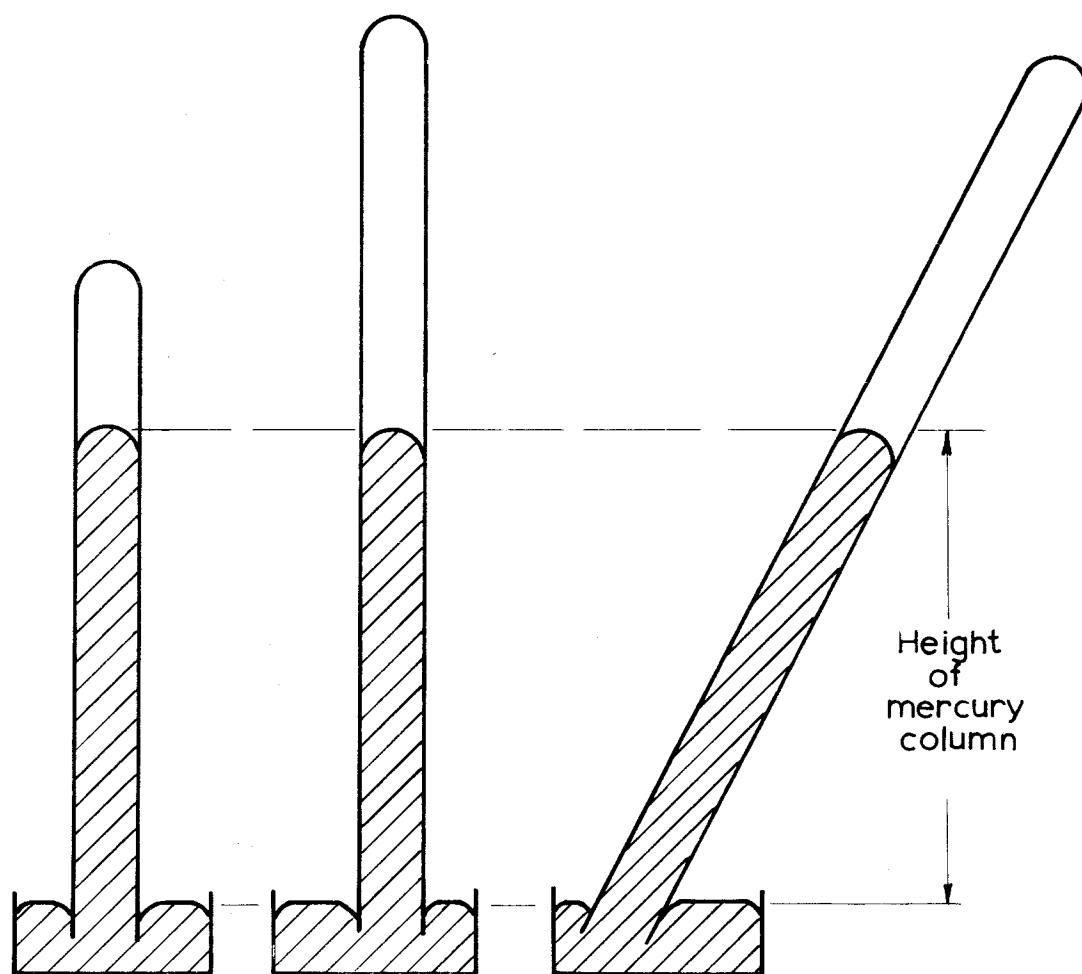


FIG. 1.1. PRINCIPLE OF THE MERCURY BAROMETER.

be linear.

In 1686, Halley put forward the relationship

$$\Delta H = k \cdot \log \frac{P_0}{P_1}$$

where

$\Delta H$  is the difference in height

$P_0$ ,  $P_1$  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.<sup>12</sup>

Laplace then put forward his theoretical approach to the problem which integrated the hydrostatic equation.<sup>5</sup> 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:

$$dP = - g \cdot \rho \cdot dH \quad \dots \dots (1)$$

where  $g$  is the acceleration due to gravity

and  $\rho$  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:

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

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

Now for the same mass of gas

$$V \cdot \rho = V_s \cdot \rho_s$$

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

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

Substituting in (1)

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

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



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

$$\Delta H = - \int \frac{P_s \cdot T \cdot dP}{g \cdot \rho_s \cdot T_s \cdot P}$$

between the upper and lower pressures.

$$\text{Thus } \Delta H = - \frac{P_s \cdot T}{g \cdot \rho_s \cdot T_s} \{ \text{Ln } P_1 - \text{Ln } P_2 \}$$

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

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

where  $\varphi$  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

$$\begin{aligned} \frac{T}{T_s} &= \frac{t - 32 + T_s}{T_s} \\ &= 1 + \frac{t - 32}{T_s} \end{aligned}$$

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

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

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).<sup>2</sup> The final formula thus becomes<sup>2, 5</sup>

$$\Delta H = 60370 (\log P_1 - \log P_2) \cdot (1 + 0.002695 \cos 2\varphi) \cdot \left(1 + \frac{t_1 + t_2 - 64}{900}\right).$$

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

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

Average humidity is defined as 50% relative humidity at 50° F.<sup>8</sup>

The effect of the gravity term varies from 0.27% at the equator to zero at latitude 45°.<sup>14</sup> 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.<sup>3, 9, 15, 27</sup> This is

called the Lapse Rate and has been found empirically to be  $6.5^{\circ}$  C per kilometer ( $3.56^{\circ}$  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.<sup>9</sup>

Denoting the Lapse Rate as  $\gamma$ ,  
 the sea level temperature as  $T_0$ ,  
 and the elevation as H

then 
$$T = T_0 - \gamma \cdot H$$

and the Hydrostatic equation<sup>3</sup>

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

may be expressed as

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

where R is the Gas constant.

Integrating this relationship gives:

$$\int_{P_0}^P \frac{dP}{P} = \int_0^H \frac{g}{R \cdot (T_0 - \gamma \cdot H)} \cdot dH$$

$$\ln \frac{P}{P_0} = \frac{g}{R \cdot \gamma} \ln \left( \frac{T_0 - \gamma \cdot H}{T_0} \right)$$

$$\frac{P}{P_0} = \left( \frac{T_0 - \gamma \cdot H}{T_0} \right)^{\frac{g}{R \cdot \gamma}}$$

$$\text{whence } H = \frac{T_0}{\gamma} \left( 1 - \left( \frac{P}{P_0} \right)^{\frac{R \cdot \gamma}{g}} \right)$$

This may be expressed as:

$$H = C_1 \cdot \left( 1 - \left( \frac{P}{P_0} \right)^{C_2} \right)$$

$$\text{where } C_1 = \frac{T_0}{\gamma}$$

$$\text{and } C_2 = \frac{R \cdot \gamma}{g}$$

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.<sup>3, 9, 14, 15.</sup>

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  $15^{\circ}$  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

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

5. For altitudes above 11,000 m, the temperature of the air is constant and equal to  $-56.5^{\circ}$  C.

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

U.S. STANDARD ATMOSPHERE (or N.A.C.A. Standard Atmosphere).<sup>3, 14.</sup>

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 =  $15^{\circ}$  C.

4. The lapse rate  $0.0065^{\circ}$  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  $-55^{\circ}$  C.

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

I.C.A.O. STANDARD ATMOSPHERE<sup>11, 14.</sup>

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<sup>5</sup>

1. The air is dry, isothermal and homogeneous.
2. The value of gravity at latitude  $45^\circ$  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  $32^\circ$  F.
5. The constant  $\frac{P_s}{g \cdot s}$  is 60370.

AIRY'S STANDARD ATMOSPHERE<sup>5</sup>

1. The air is isothermal and homogeneous.
2. The humidity is "average".
3. The value of gravity at latitude  $45^\circ$  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  $50^\circ$  F.
6. The constant including the humidity correction is 62759.

AIRY'S MODIFIED STANDARD ATMOSPHERE<sup>5</sup>

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<sup>o</sup> 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.<sup>35</sup> 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.<sup>5</sup> 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.<sup>21</sup> 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

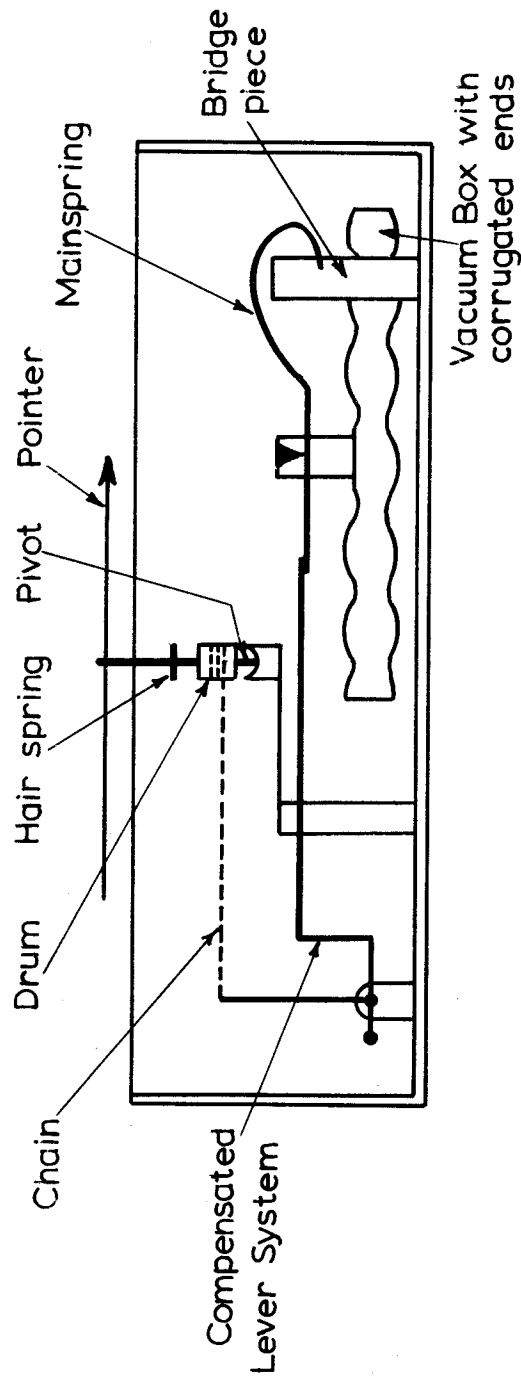


FIG. 2.1. ANEROID BAROMETER MECHANISM.

unreliable and have errors up to 50 feet or more.<sup>5</sup>

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,<sup>2, 5, 12, 44, 50, 53</sup> 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<sup>44, 50</sup>

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.

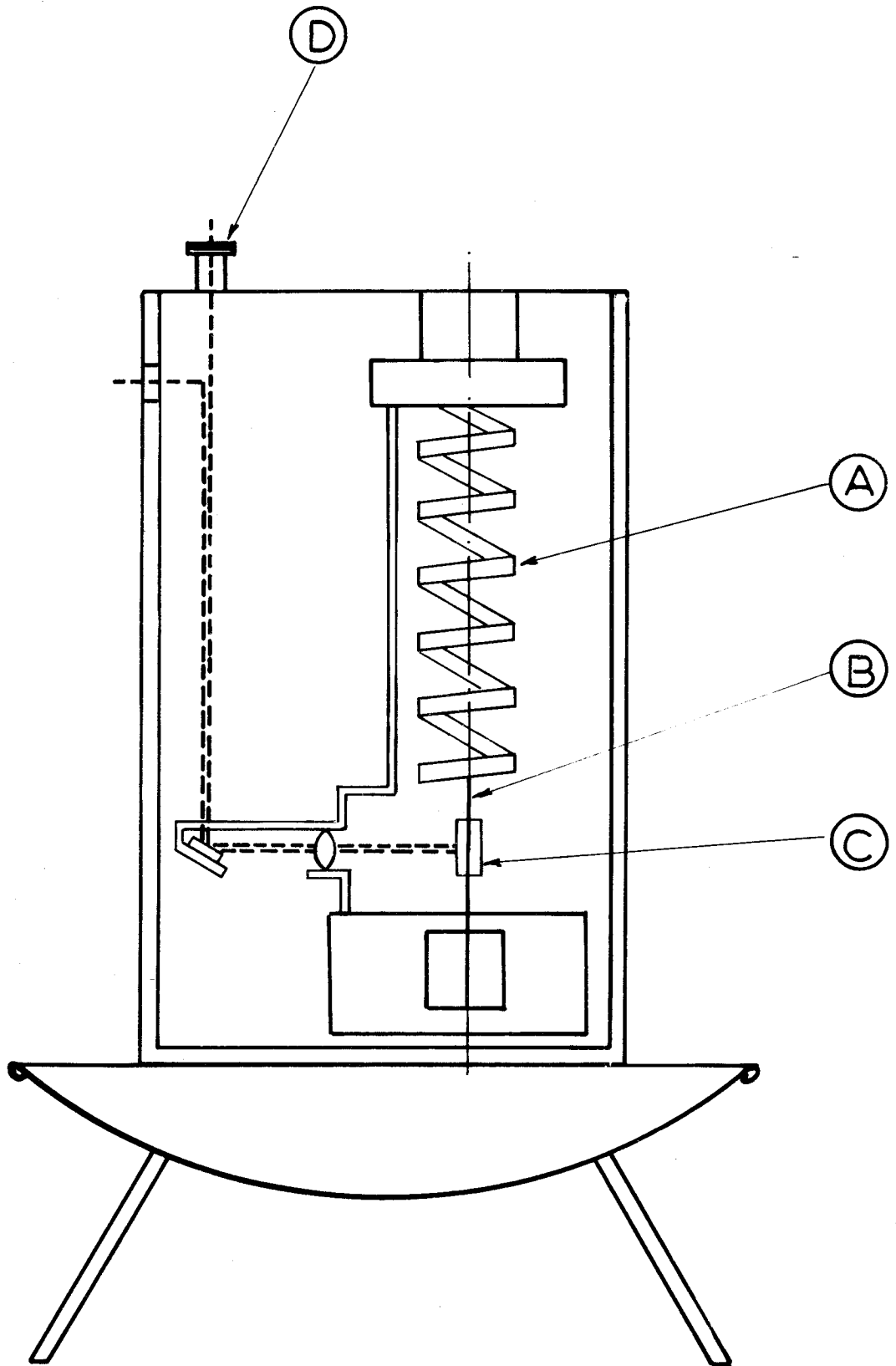


FIG. 2.2 SCHEMATIC SECTION OF THE ASKANIA MICROBAROMETER.

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<sup>5, 50, 53</sup>

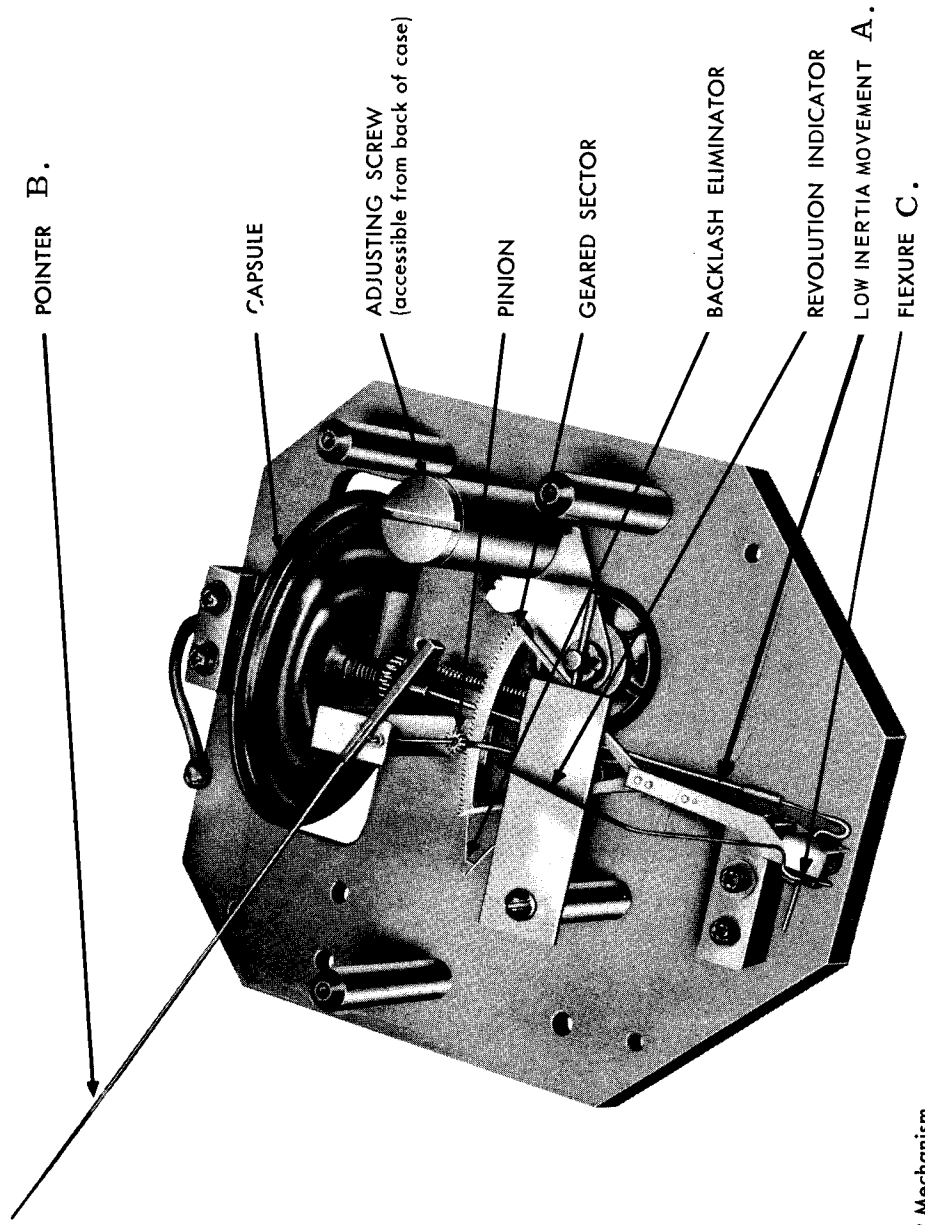
This barometer consists essentially of a precision aneroid mechanism shock mounted in its case. The mechanism includes a low-inertia movement (A), a balances pointer (B), flexure pivots (C), a backlash eliminator and jewelled bearings to ensure sensitivity (see figure 2.3). Before reading it is advisable 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<sup>5, 50</sup>

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.





FA-129 Mechanism

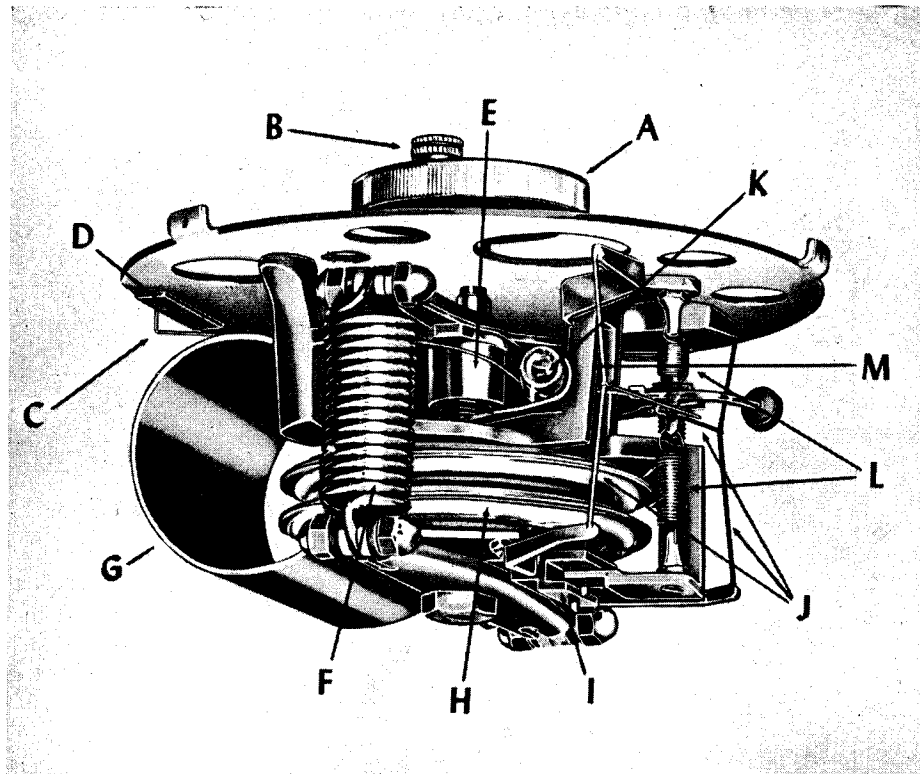
FIGURE 2.3 THE WALLACE AND TIERNAN BAROMETER.

A change of air pressure will cause contraction or expansion of the diaphragms (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 diaphragms (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 BAROMECH BAROMETER (see Figure 2.5)<sup>5</sup>

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.

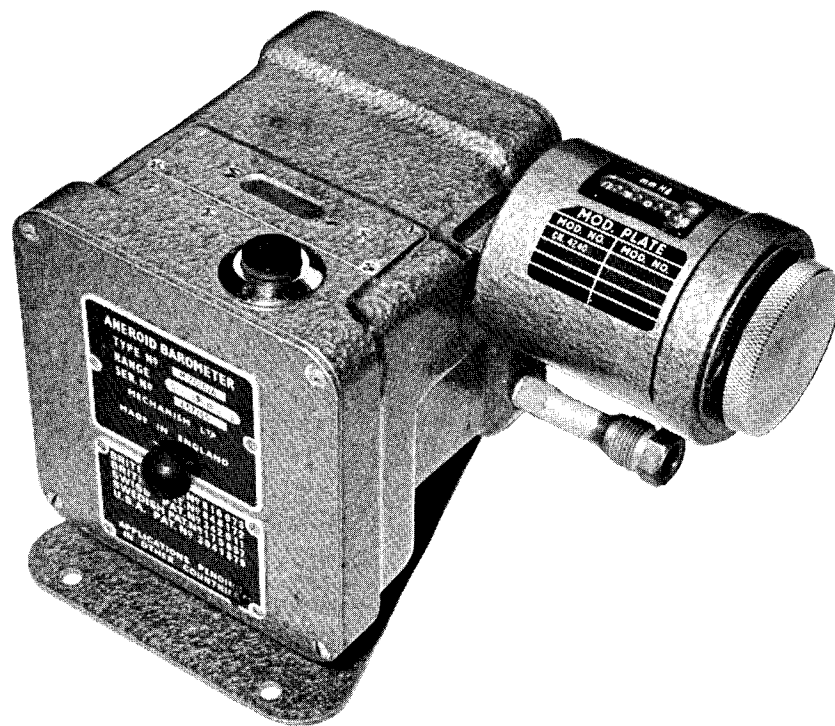


FIGURE 2.5 THE BAROMEC BAROMETER.

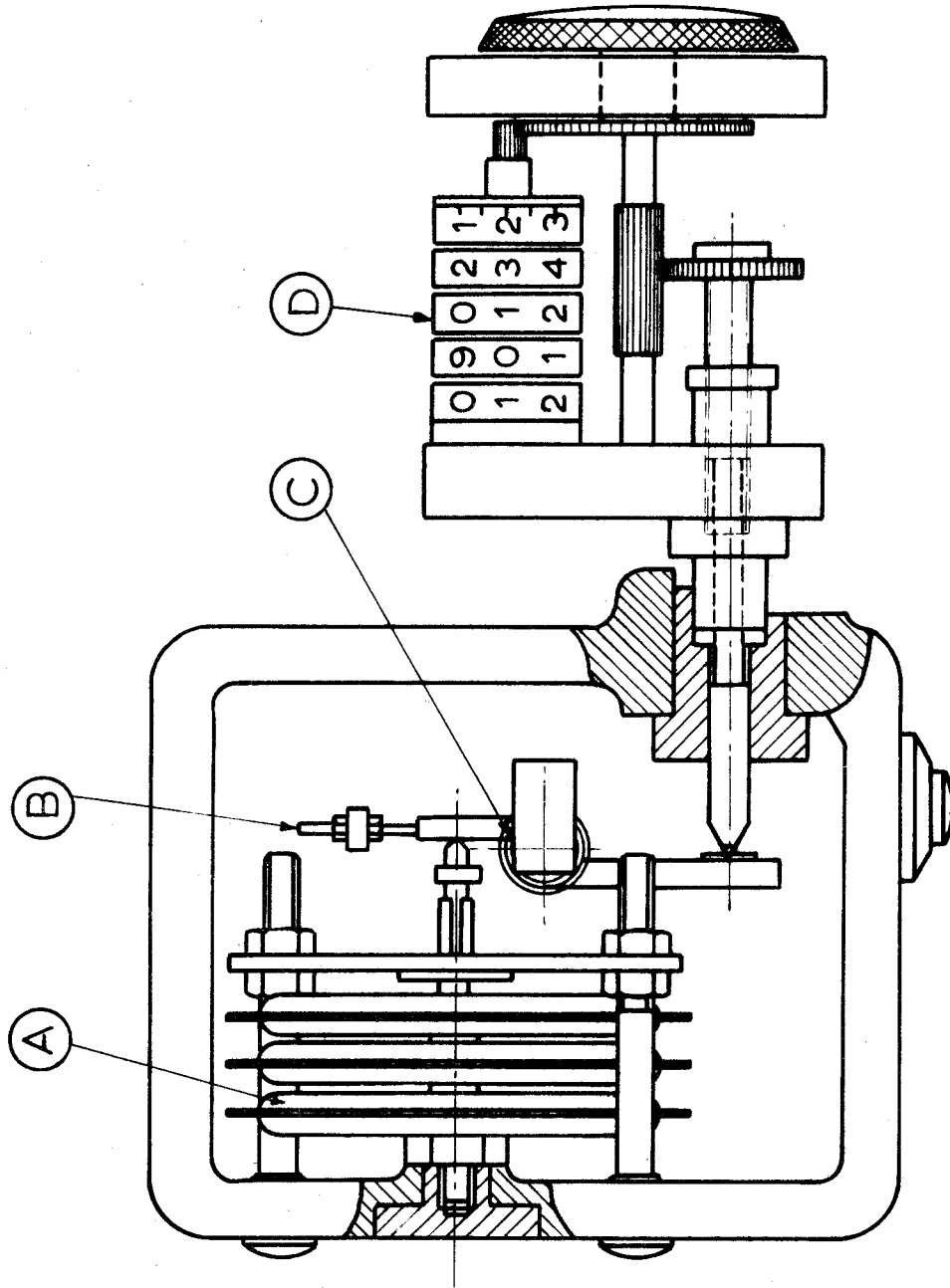


FIG. 2.6 BAROMEC BAROMETER

of indicating contact is capable of a precision of  $1 \times 10^{-5}$  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<sup>18</sup>

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. Systematic Errors (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

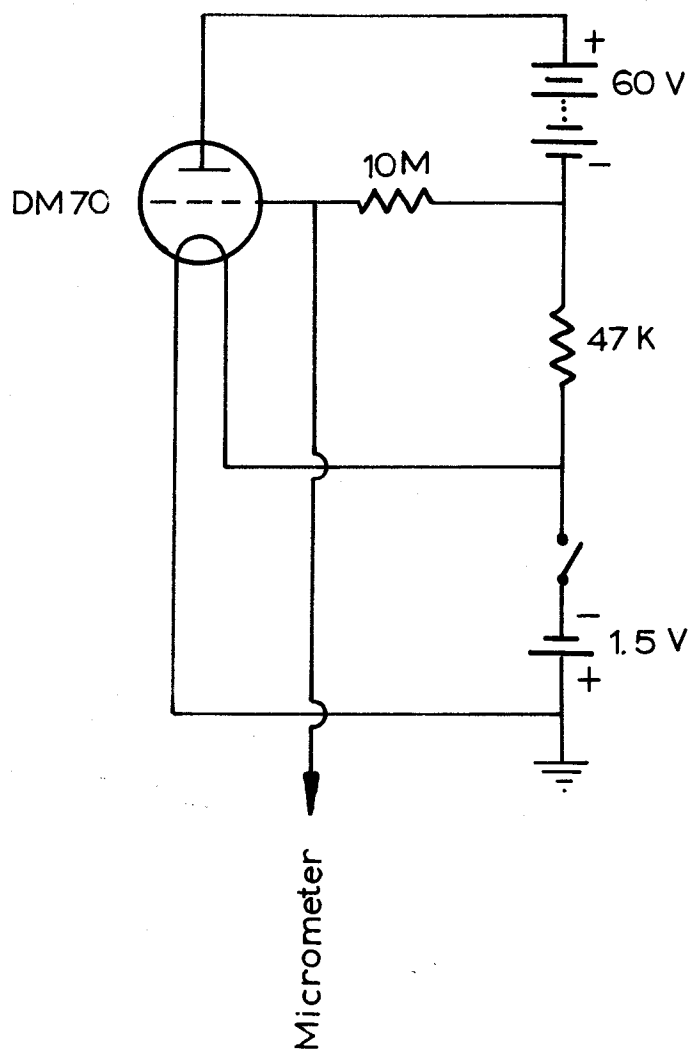
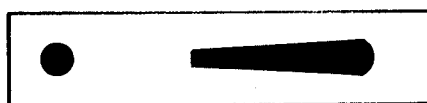
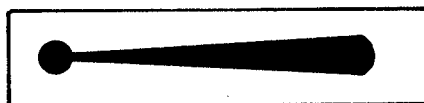


FIG. 2.7 CONTACT INDICATOR CIRCUIT



(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<sup>1</sup> has a number of novel features (see figures 2.9, 2.10).<sup>18</sup> 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.<sup>38, 47</sup> 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.

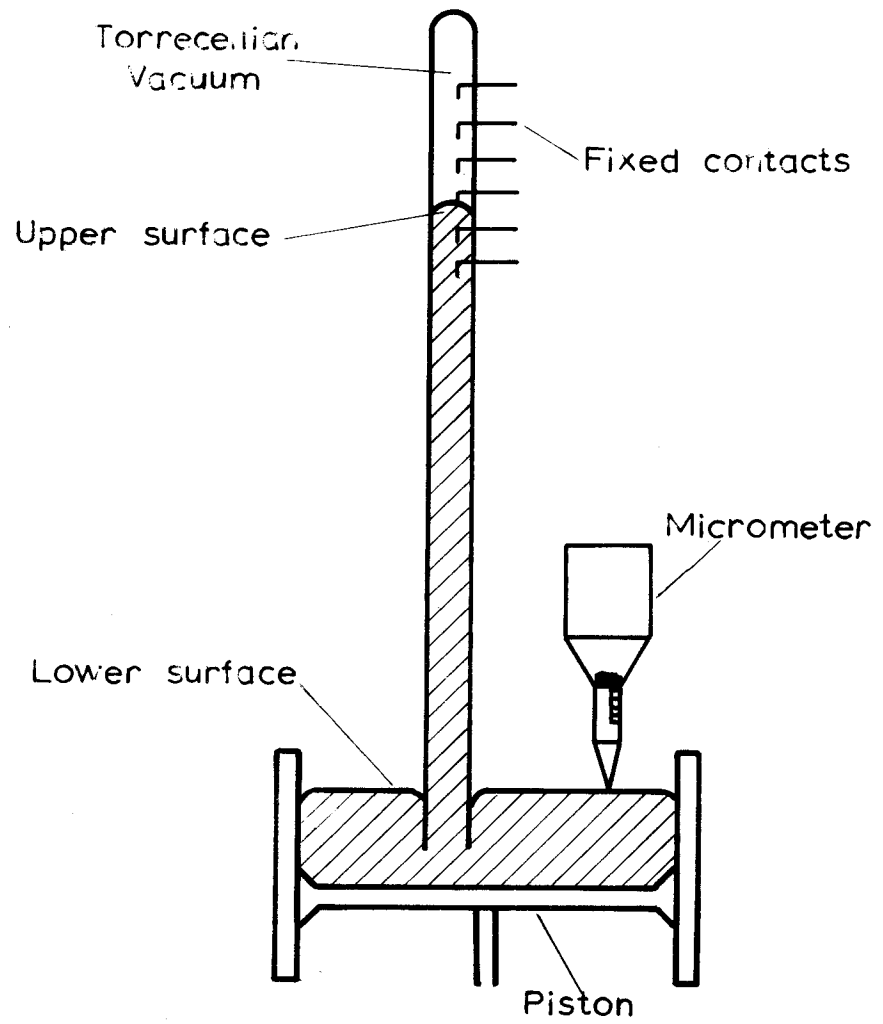
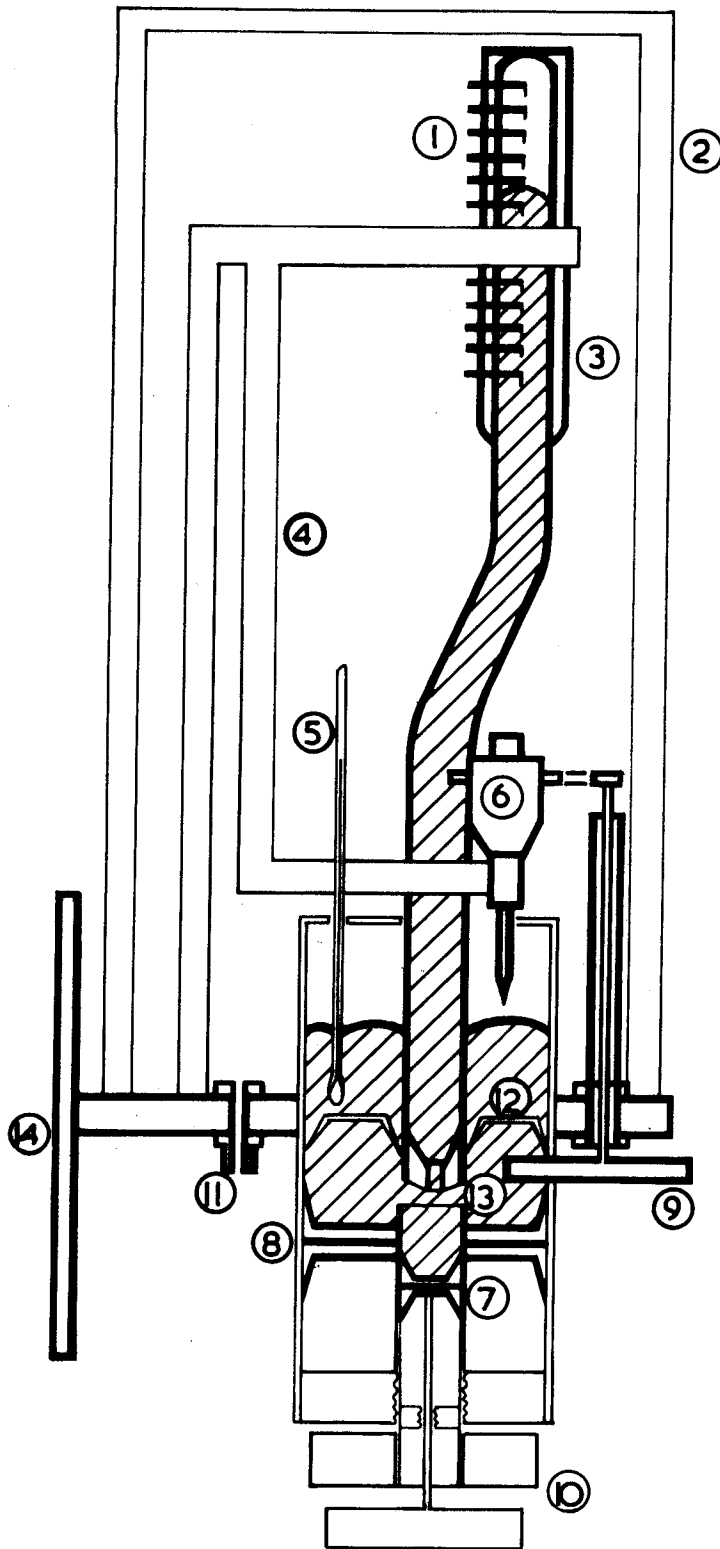


FIG. 2.9 SCHEMATIC DIAGRAM SHOWING BASIC DESIGN.



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 servo 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

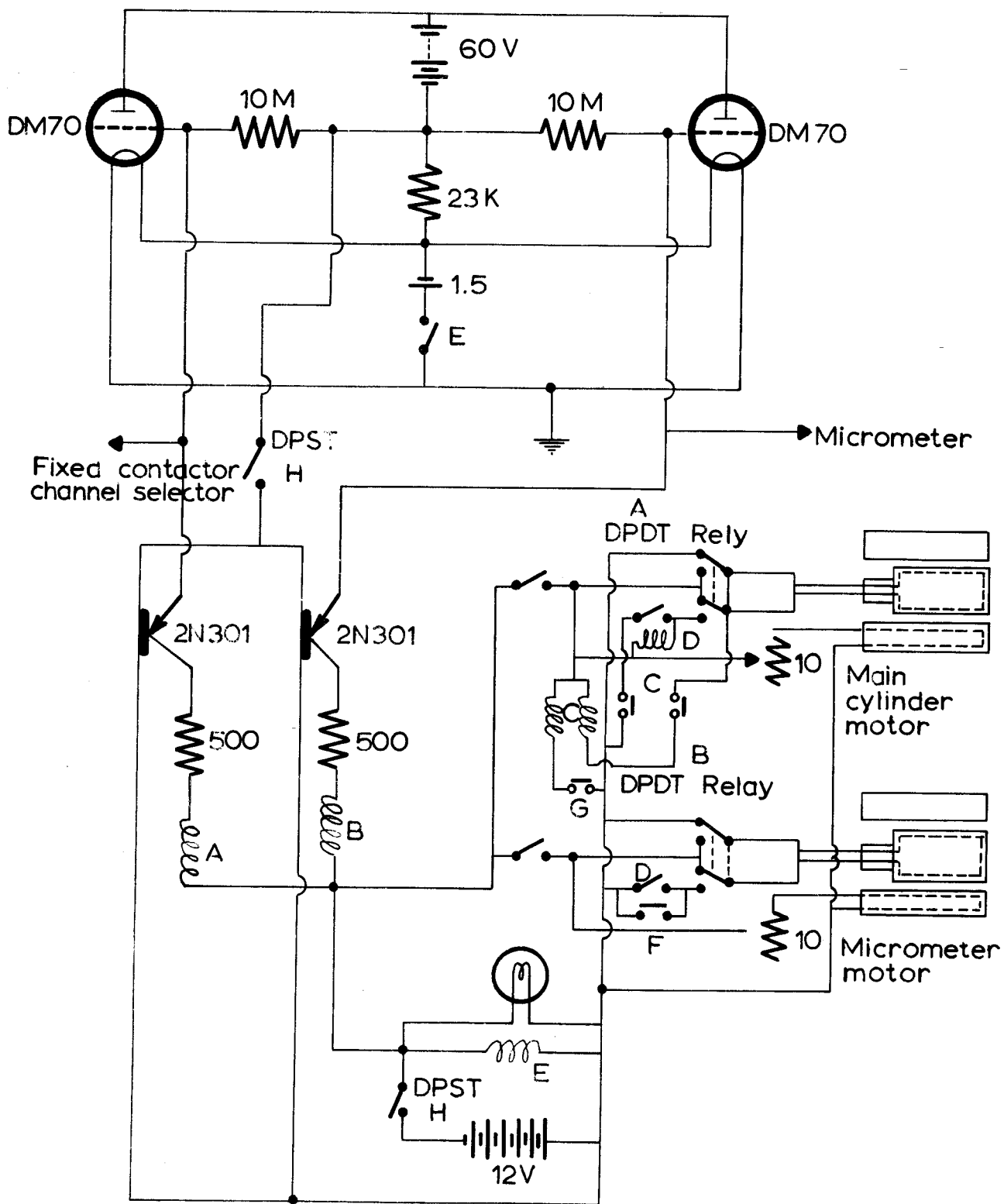


FIG. 2.11 CIRCUIT DIAGRAM OF SERVO CONTROL.

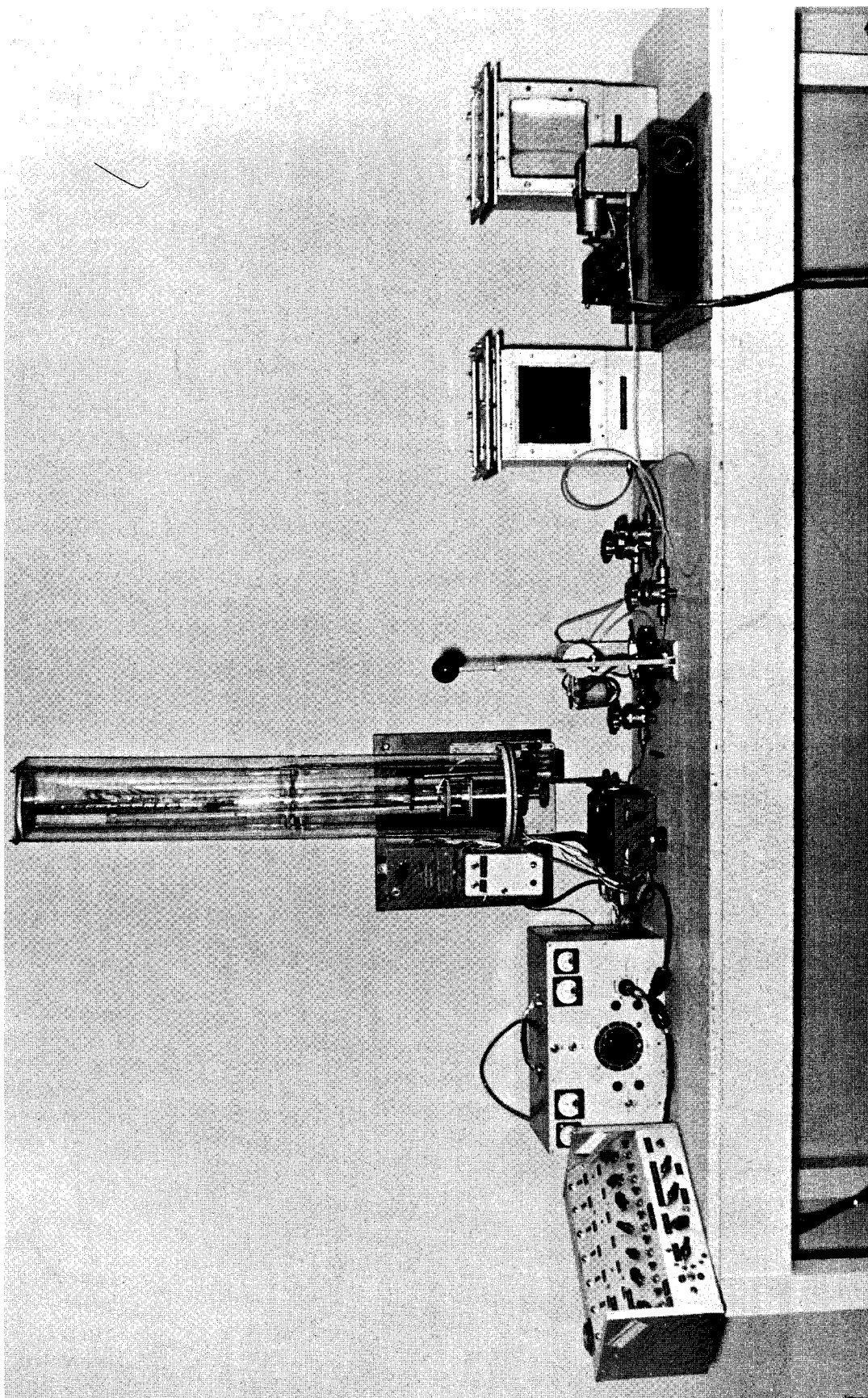


FIGURE 2.12 THE BAROMETRIC COMPARATOR.

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).

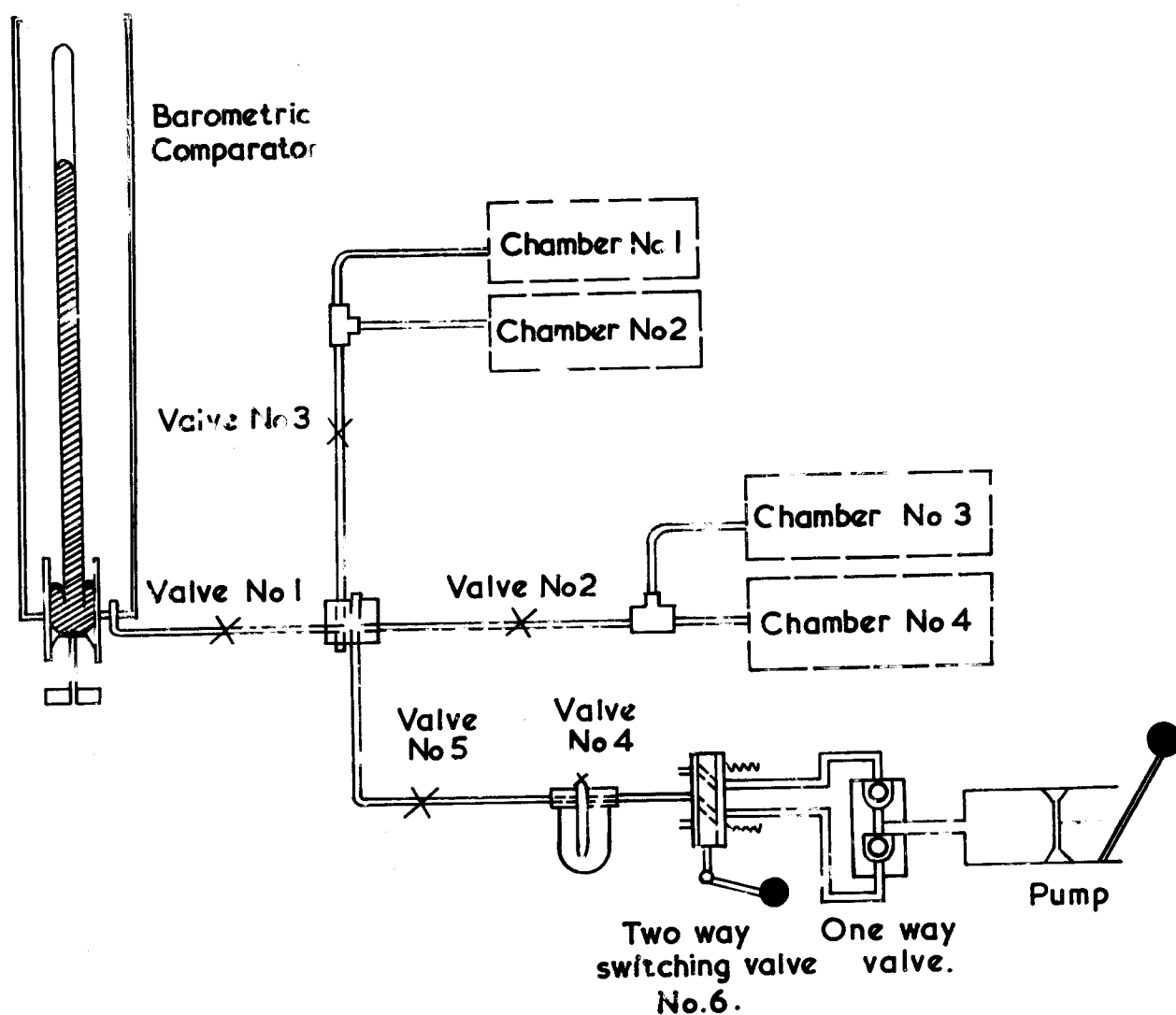
As there was not sufficient room within the pressure chamber for the instruments which were to be tested, these were placed in auxiliary chambers connected to the main chamber by pressure hoses. The inclusion of a pump to vary the pressure and a number of valve cocks to shut off the various sections 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.<sup>7</sup> 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



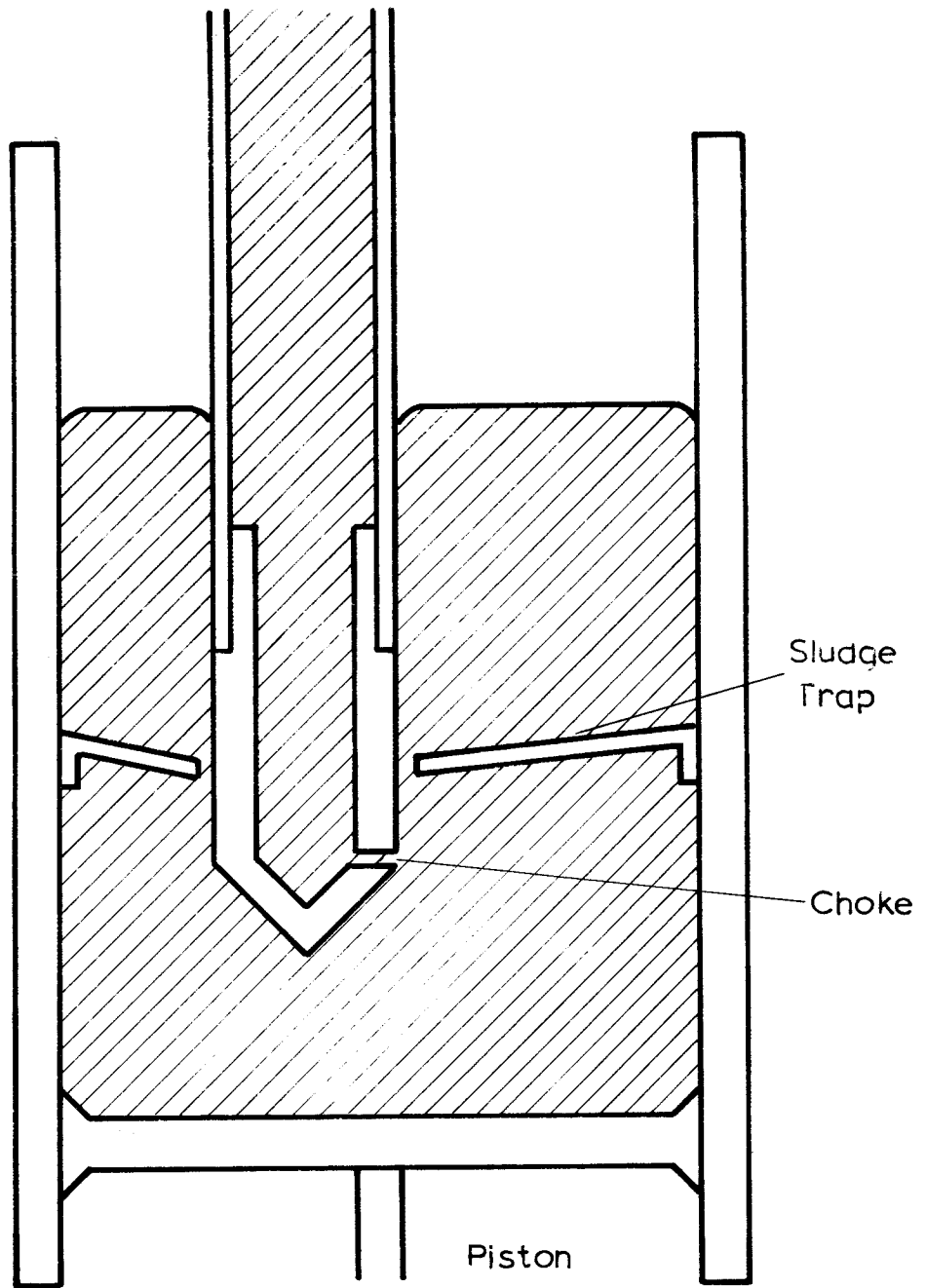


FIG. 2.14 DETAILS OF SLUDGE TRAP AND CHOKE

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  $1 \times 10^{-6}$  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 optimum 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 hysteresis.

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 ( $32^{\circ}$  F) and the length of the mild steel rod and glass reduced to the standard operating temperature ( $68^{\circ}$ ) (see figure 2.16).

Denoting:

- $C_0$  as the length of mild steel rod from the support to the zero of the micrometer at  $68^{\circ}$  F,
- $C_1$  as the length of the column between a particular contact and the micrometer zero at  $68^{\circ}$ ,
- $C_2$  as the length of the glass tube from the support to the same contact at  $68^{\circ}$  F,
- $\mu_1$  as the coefficient of volume expansion of mercury ( $1.010 \times 10^{-4}$  cubic units/ $^{\circ}$  F),
- $\mu_2$  as the coefficient of linear expansion of mild steel ( $0.65 \times 10^{-5}$  units/ $^{\circ}$  F),
- $\mu_3$  as the coefficient of linear expansion of glass ( $0.47 \times 10^{-5}$  units/ $^{\circ}$  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:

$$H_{68} = (T-68) \cdot \left\{ (C_0 - R) \cdot \mu_2 + C_2 \cdot \mu_3 \right\} + (C_1 - R).$$

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

$$H_{32} = (1 - \mu_1 \cdot (T - 32)) \cdot \left\{ (T - 68) \cdot \left[ (C_0 - R) \cdot \mu_2 + C_2 \cdot \mu_3 \right] + (C_1 - R) \right\}$$

The correction  $C_T$  to a reading is given by:

$$\begin{aligned} C_T &= H_{32} - C_1 + R \\ &= (1 - \mu_1 \cdot (T - 32)) \cdot \left\{ (T - 68) \cdot \left[ (C_0 - R) \cdot \mu_2 + C_2 \cdot \mu_3 \right] + (C_1 - R) \right\} \\ &\quad \times \left\{ (1 - \mu_1) (T - 32) - 1 \right\} \end{aligned}$$

which reduces to

$$C_T = K_2 - K_1 - R \cdot K_3$$

where

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

$$K_2 = (1 - \mu_1 \cdot (T - 32)) \cdot (T - 68) \cdot (C_0 \cdot \mu_2 + C_2 \cdot \mu_3)$$

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

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<sup>10</sup>

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

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

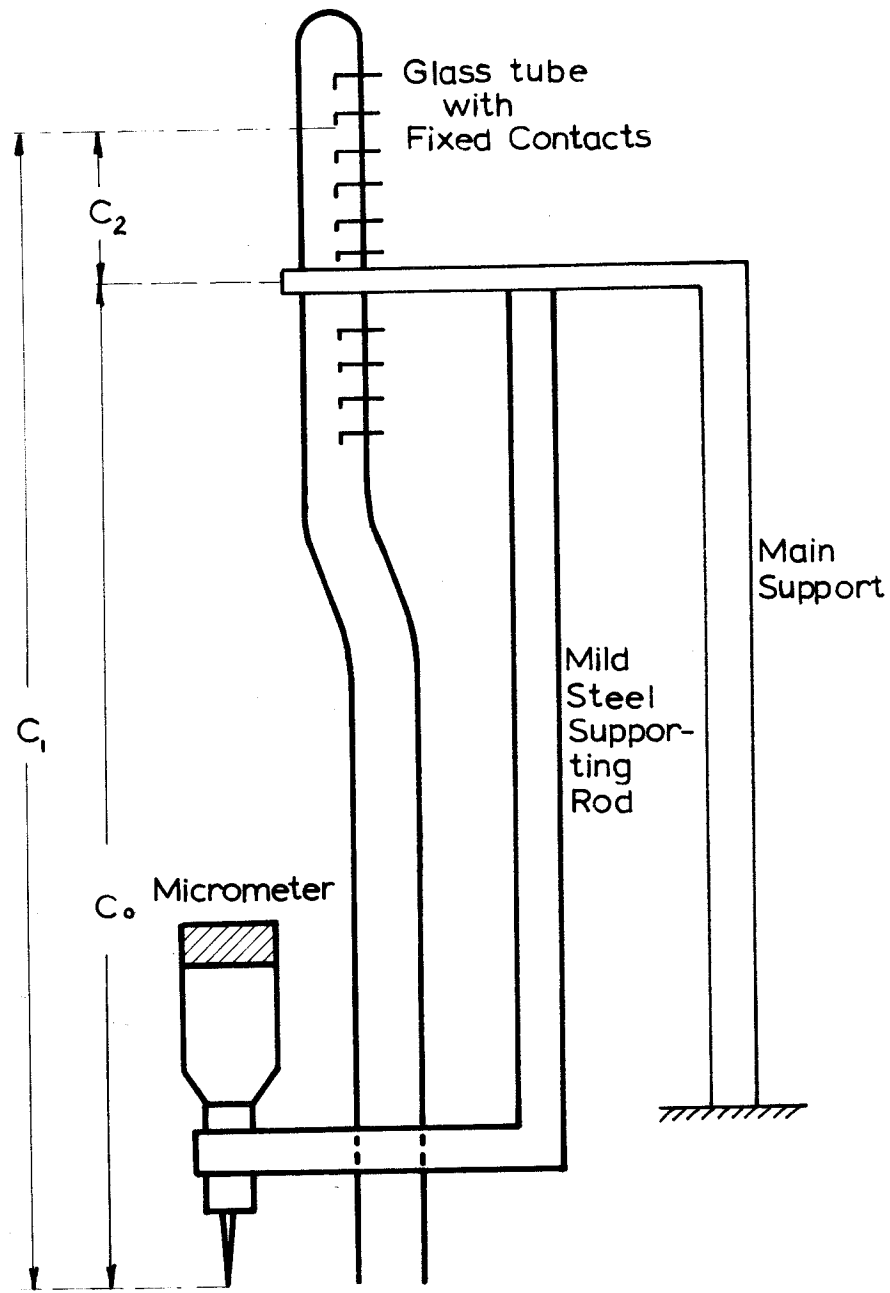


FIG. 2.15 INDEPENDENT SUSPENSION SYSTEM

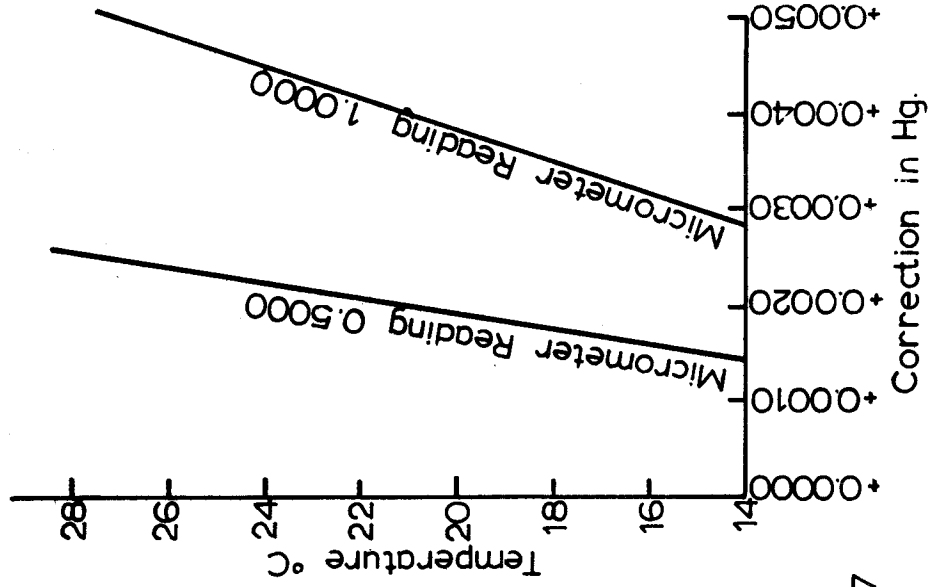
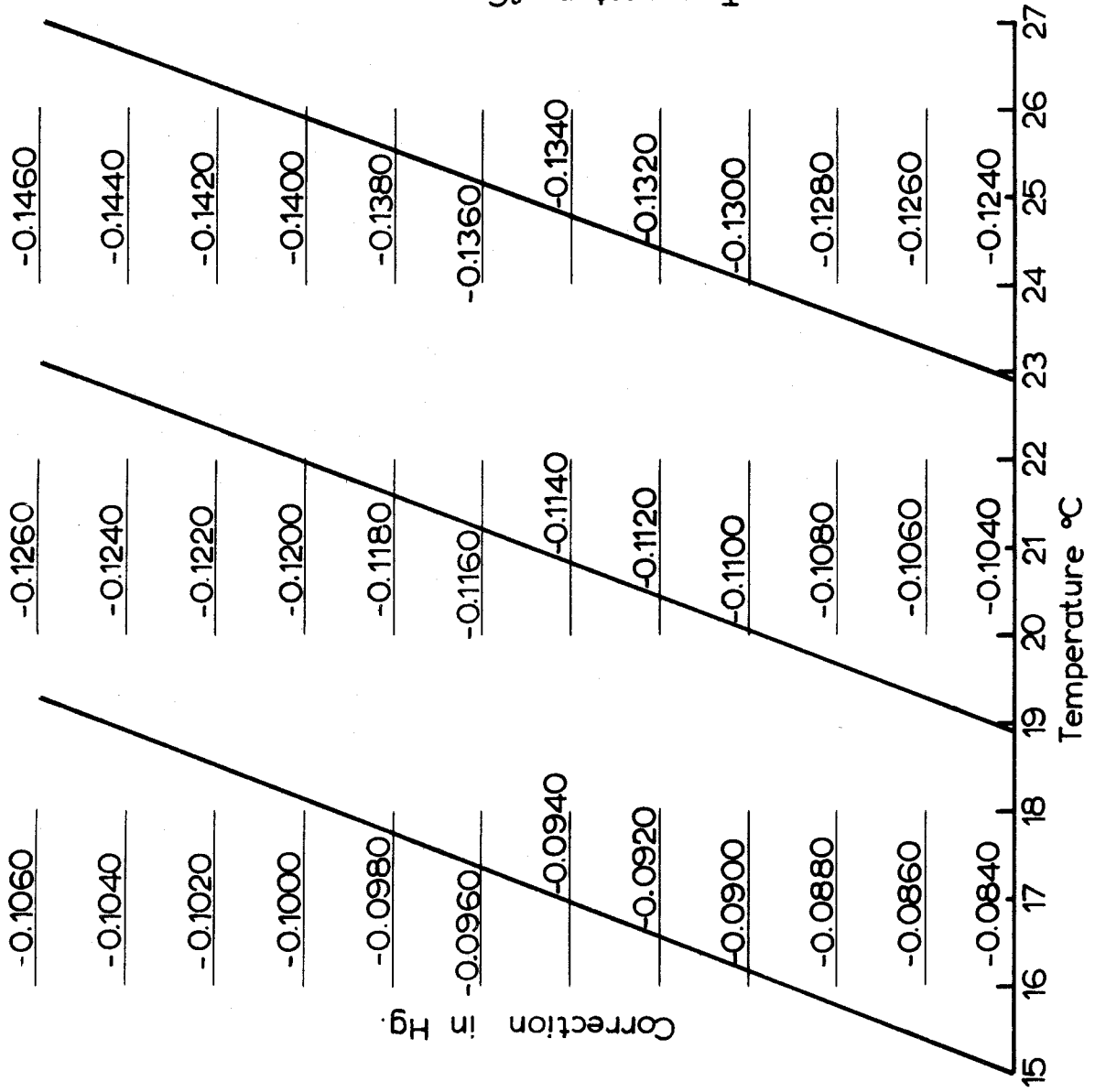


FIG. 2.16 NOMOGRAM FOR TEMPERATURE CORRECTIONS TO COMPARATOR PRESSURES.

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  $0.7 \times 10^{-3}$  mm and at 25° C only  $1.7 \times 10^{-3}$  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  $1 \times 10^{-4}$  inches of mercury pressure (.002 mmHg). A typical set of readings at a constant pressure is given in Table 2.2.



TABLE 2.1CONTACT 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 2.2COMPARATOR READINGS AT A CONSTANT PRESSURE

Contact No. 3

Date: 11/12/63

<u>Temperature</u>	<u>Reading</u>
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
	<hr/>
	Mean 0.2907

Standard Deviation  $1 \times 10^{-4}$  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 2.3READING TEST BAROMEK BAROMETER 657/65

Comparator Pressure mmHg	Baromek 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 2.4READING TEST WALLACE AND TIERNANBAROMETER 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 2.5READING TEST ASKANIA BAROMETER 530530

Comparator Pressure inHg	Scale Units	Askania inHg	Index 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 2.6TEST 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 consistent 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% 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.

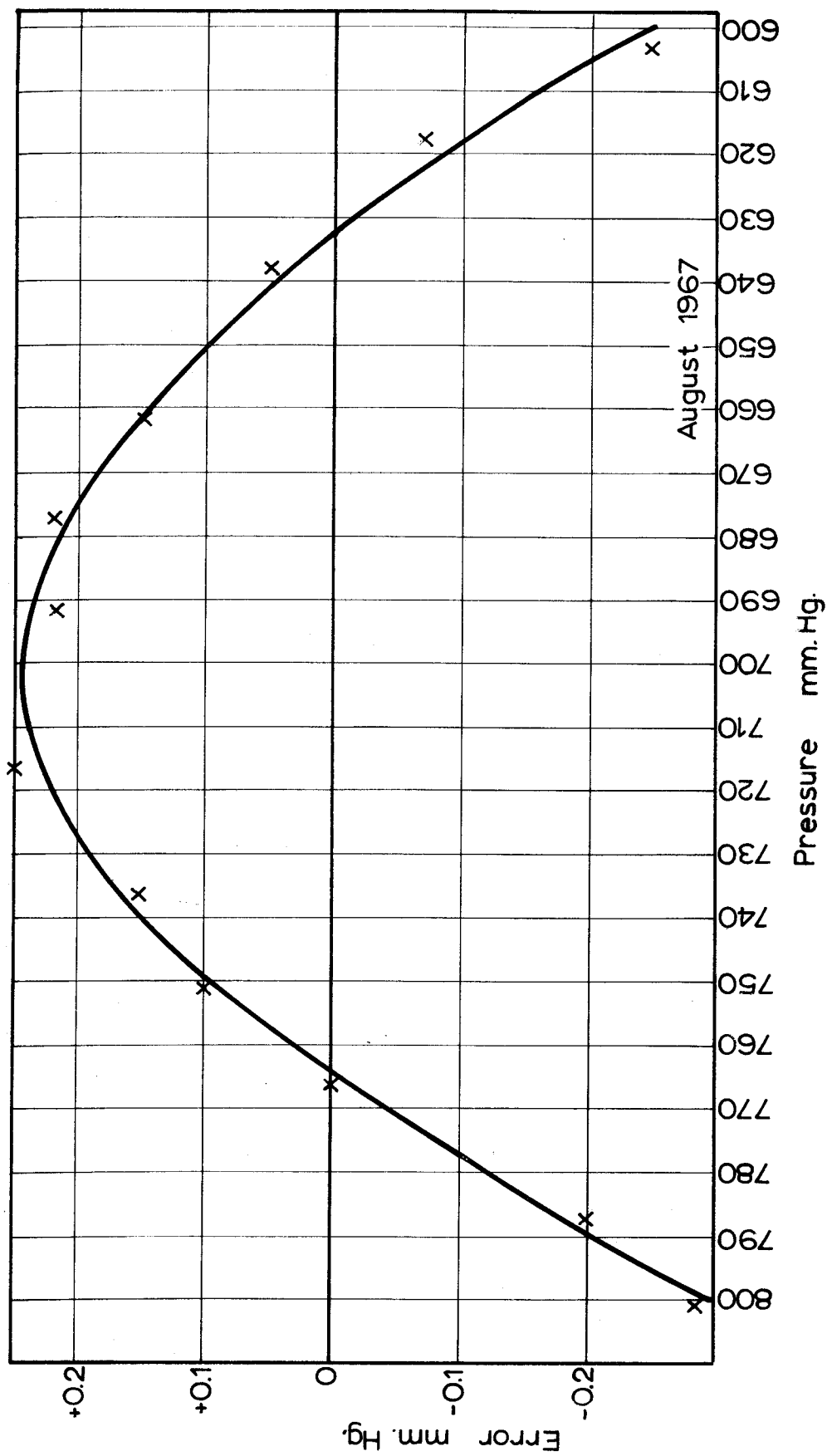


FIG. 2. 17. GRADUATION ERROR BAROMEC BAROMETER N° 302/62



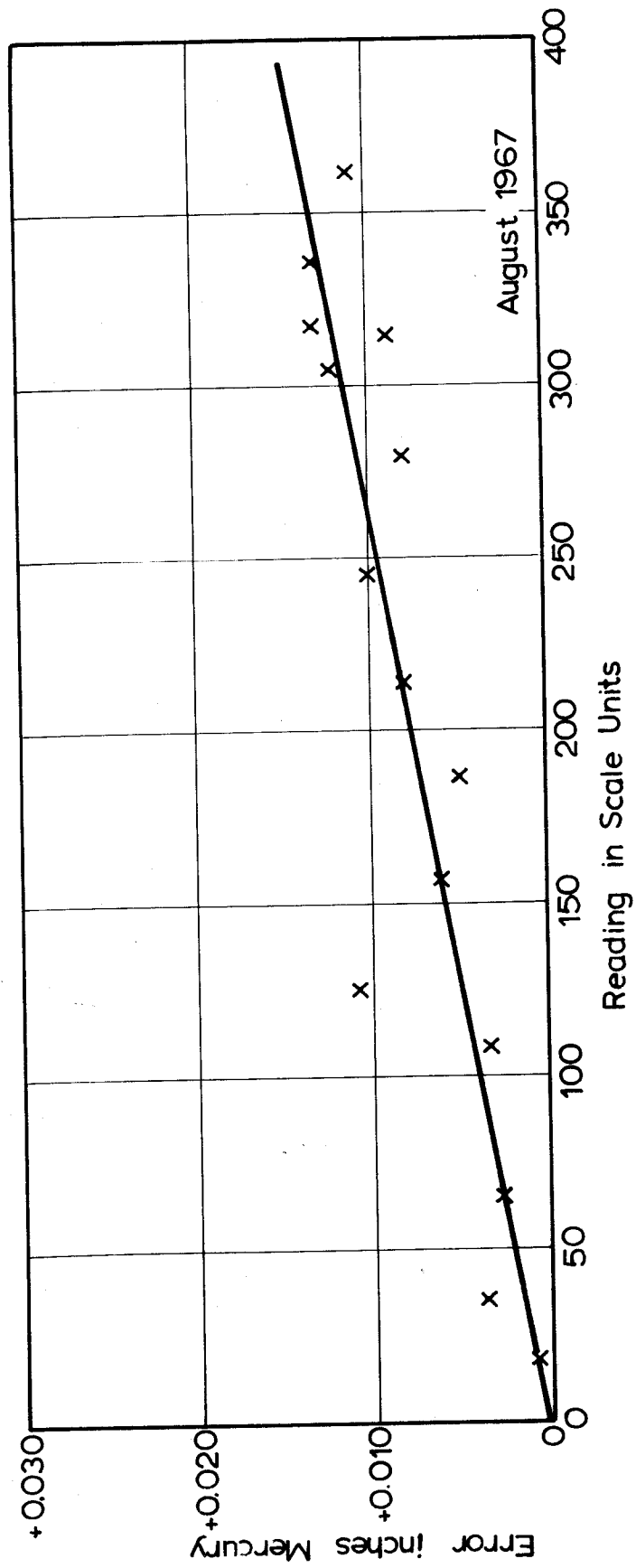


FIG. 2.18. RECALIBRATION OF SCALE CONSTANT ASKANIA BAROMETER N° 530530

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

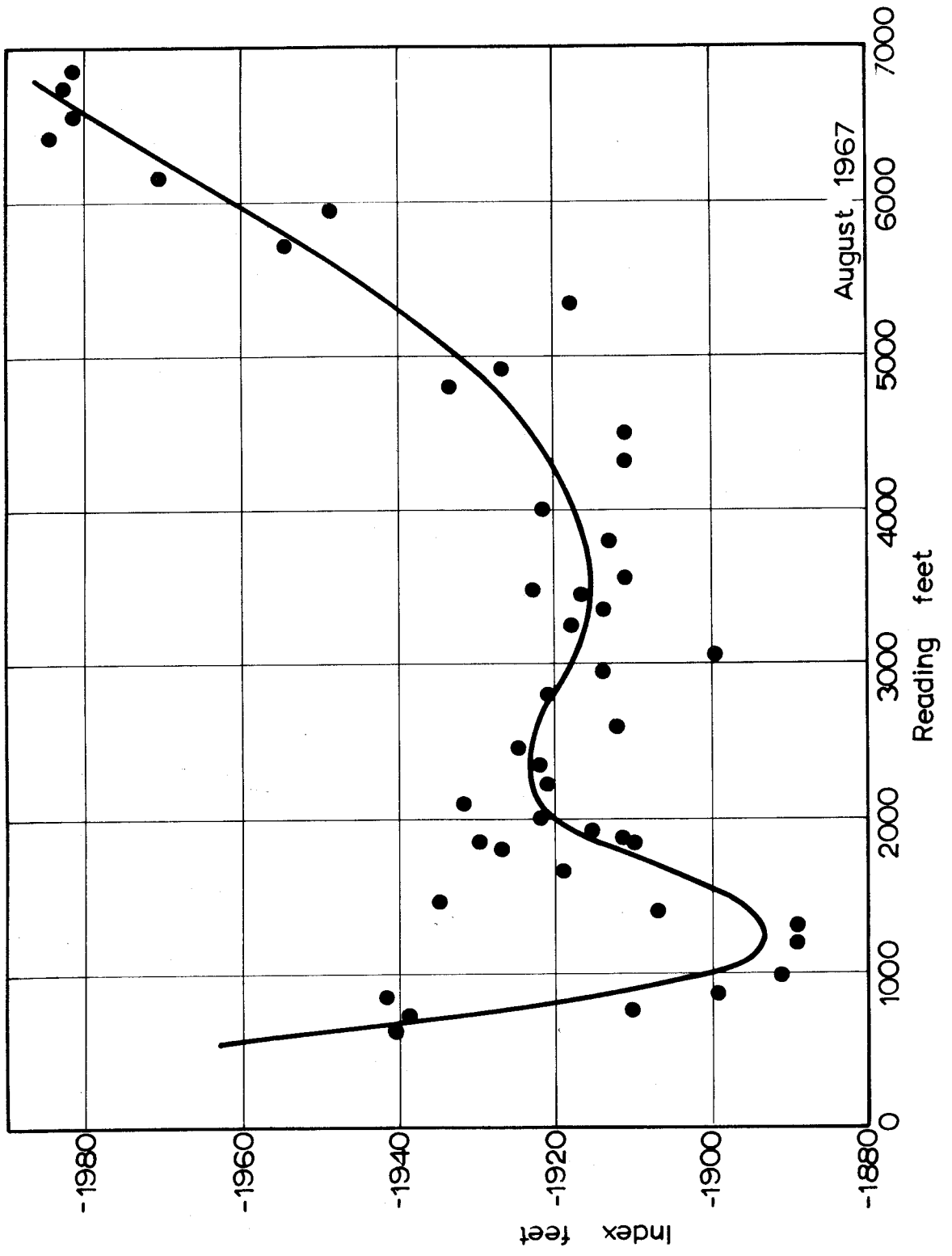


FIG. 2.19 GRADUATION TEST WALLACE AND TIERNAN BAROMETER N° 55423

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<sup>o</sup>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<sup>o</sup> F to 95<sup>o</sup> 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 consistency 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).<sup>3, 50, 21</sup> 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 (see Figure 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 (see Figure 3.2). This made it possible to undertake the design and fitting of a servo

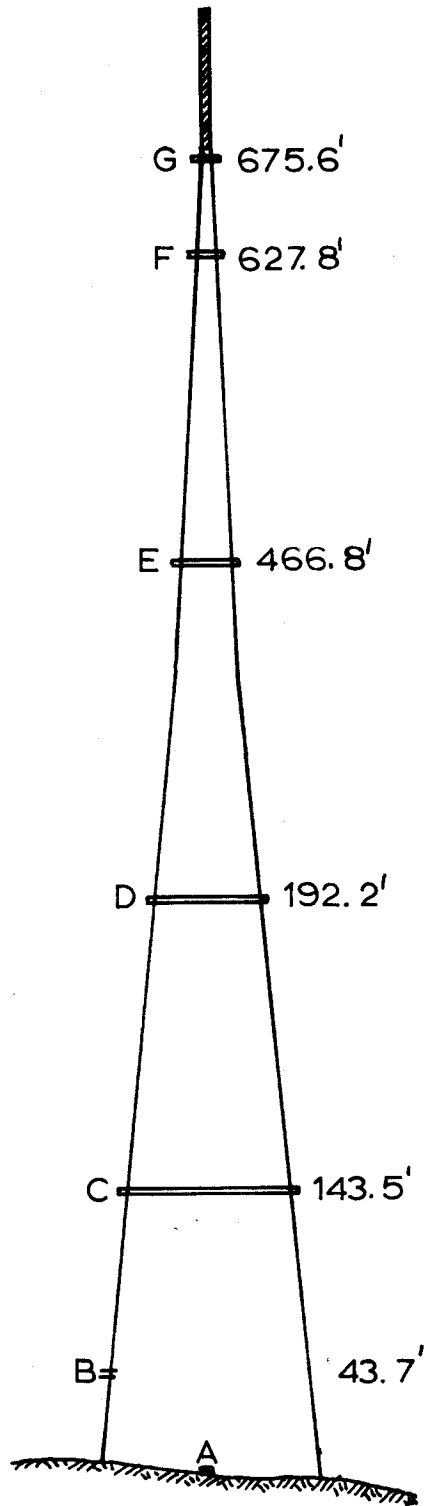


FIG. 3.1. TCN 9 TELEVISION TOWER SHOWING THE BAROMETER POSITIONS.



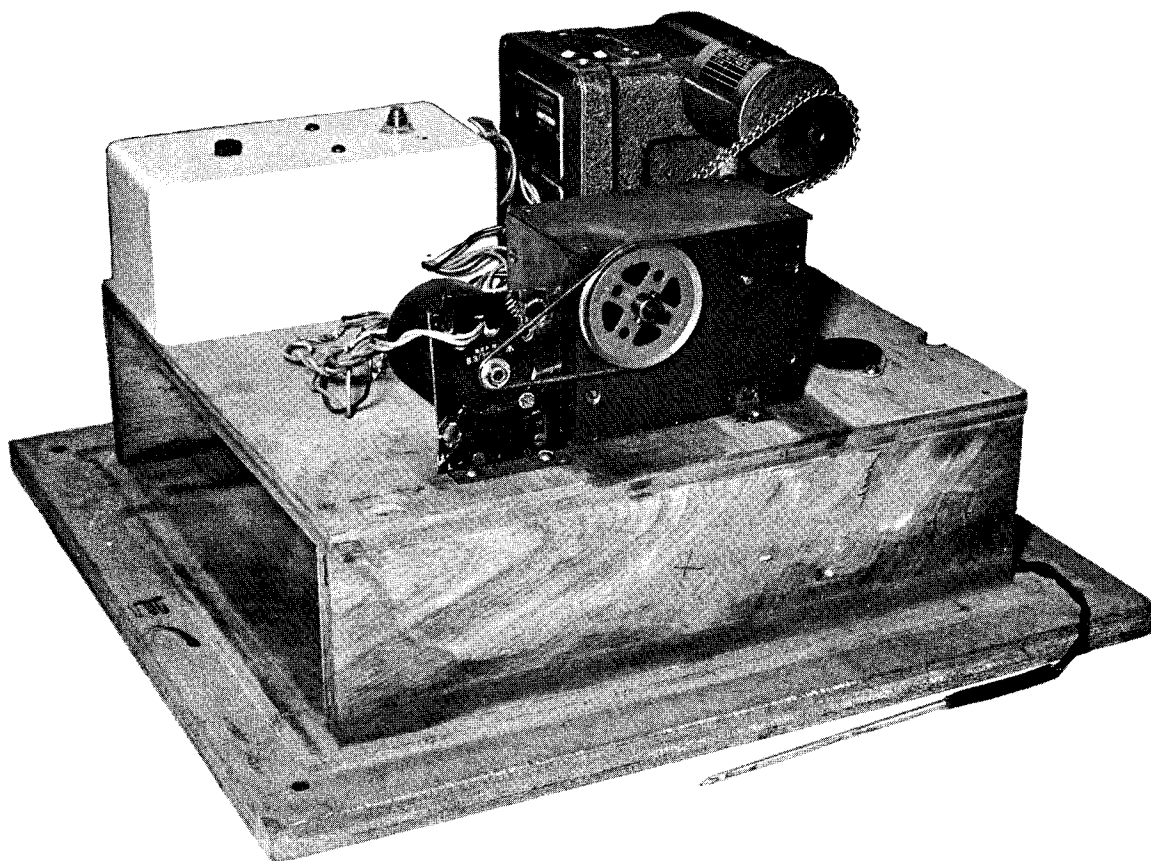


FIGURE 3.2 A REMOTE UNIT WITH THE COVER REMOVED.

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 consistent 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-ammeter. 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).

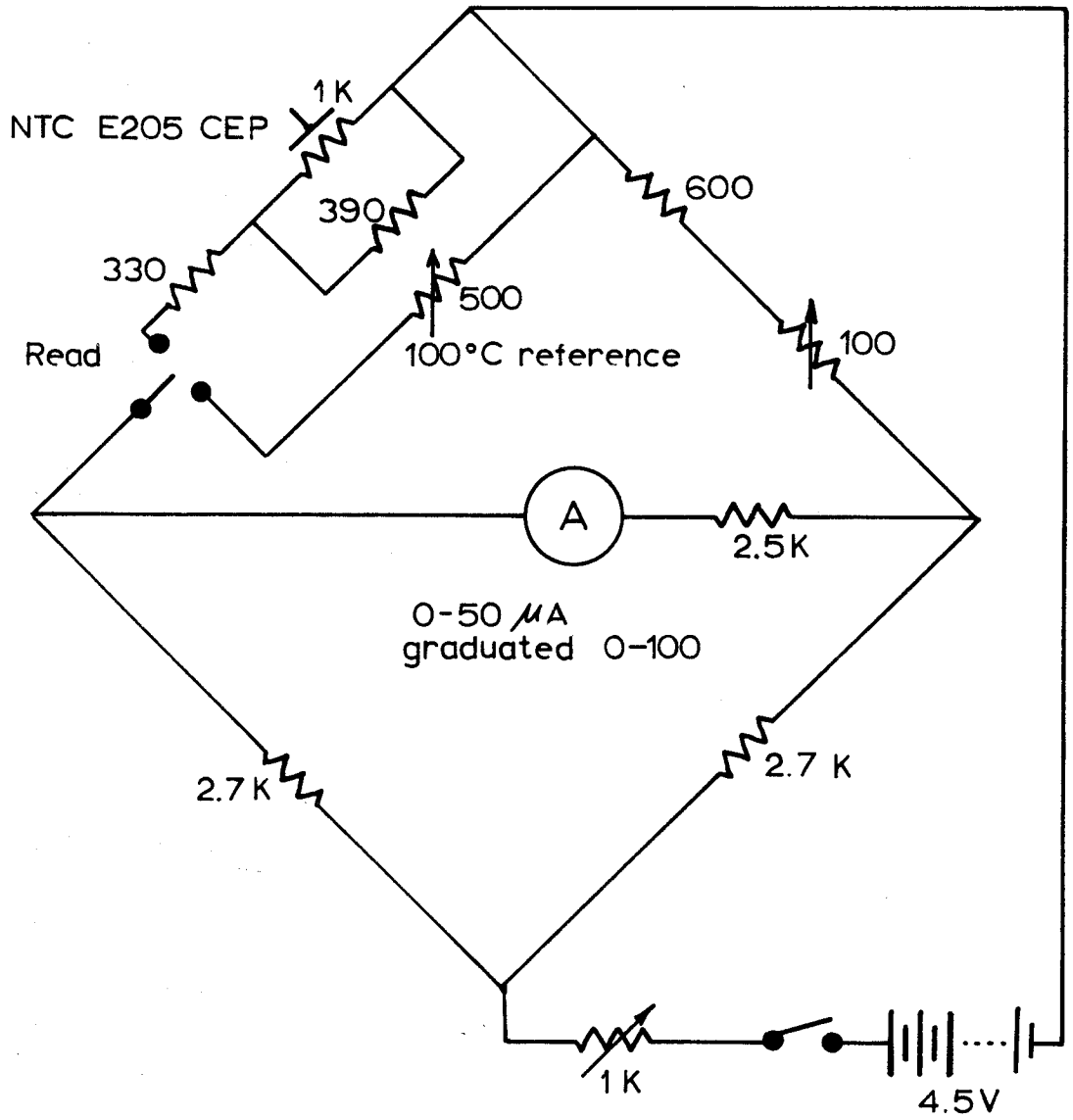
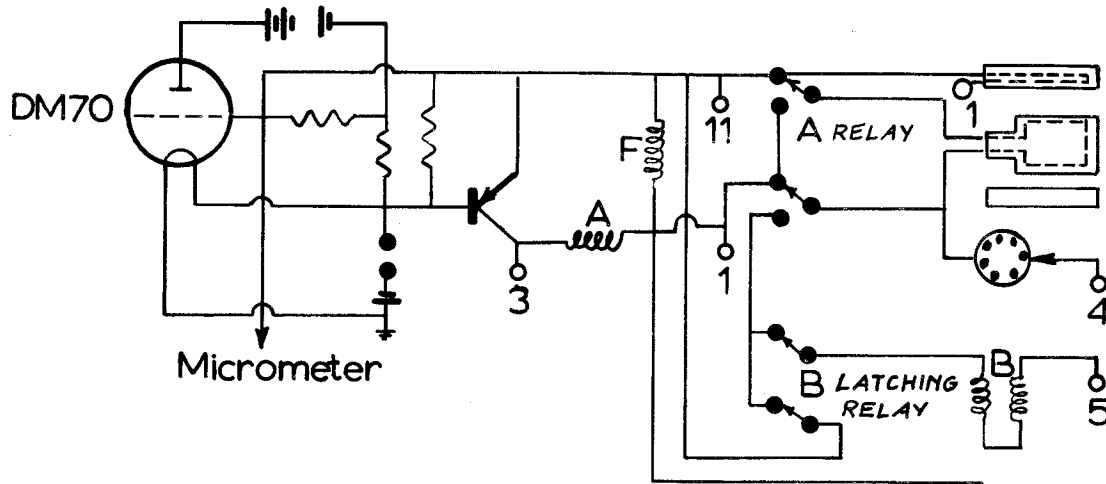
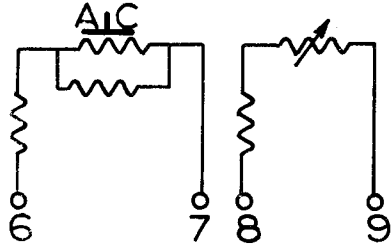


FIG. 3.3 BASIC CIRCUIT DIAGRAM FOR THERMISTOR CIRCUITS.

### Remote Barometer and Servo Control Circuit



### Thermister Circuit



### Control Unit Circuits

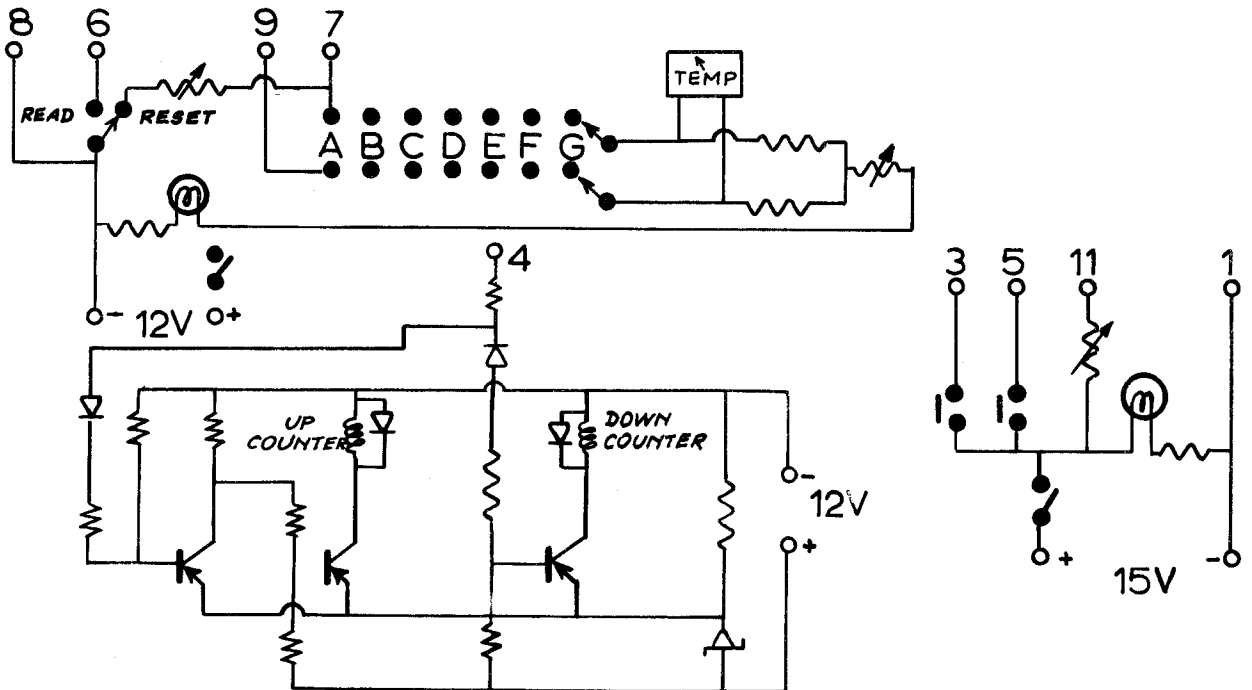


FIG. 3.4 CIRCUIT DIAGRAMS FOR THE REMOTE BAROMETER UNITS, THERMISTERS AND CONTROL UNITS.

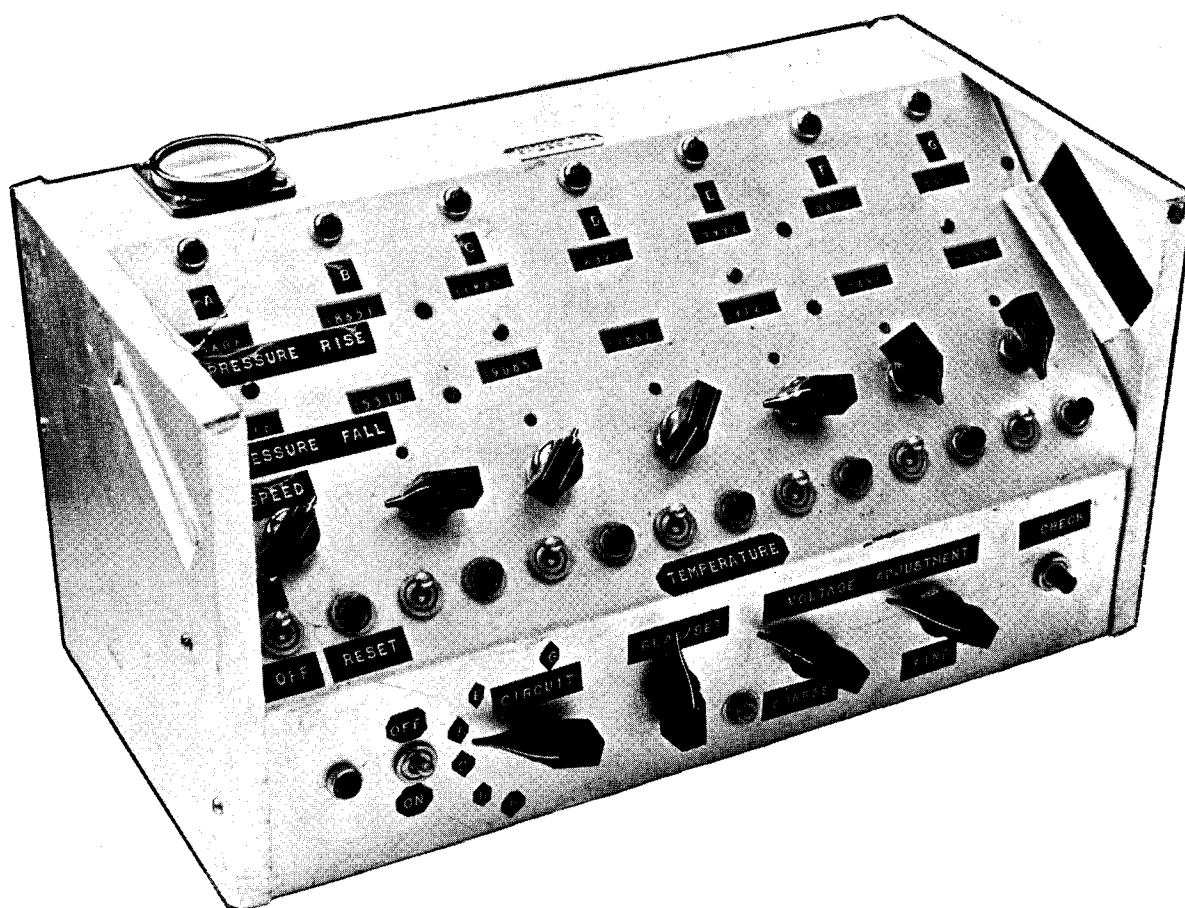


FIGURE 3.5 THE CONTROL UNIT.

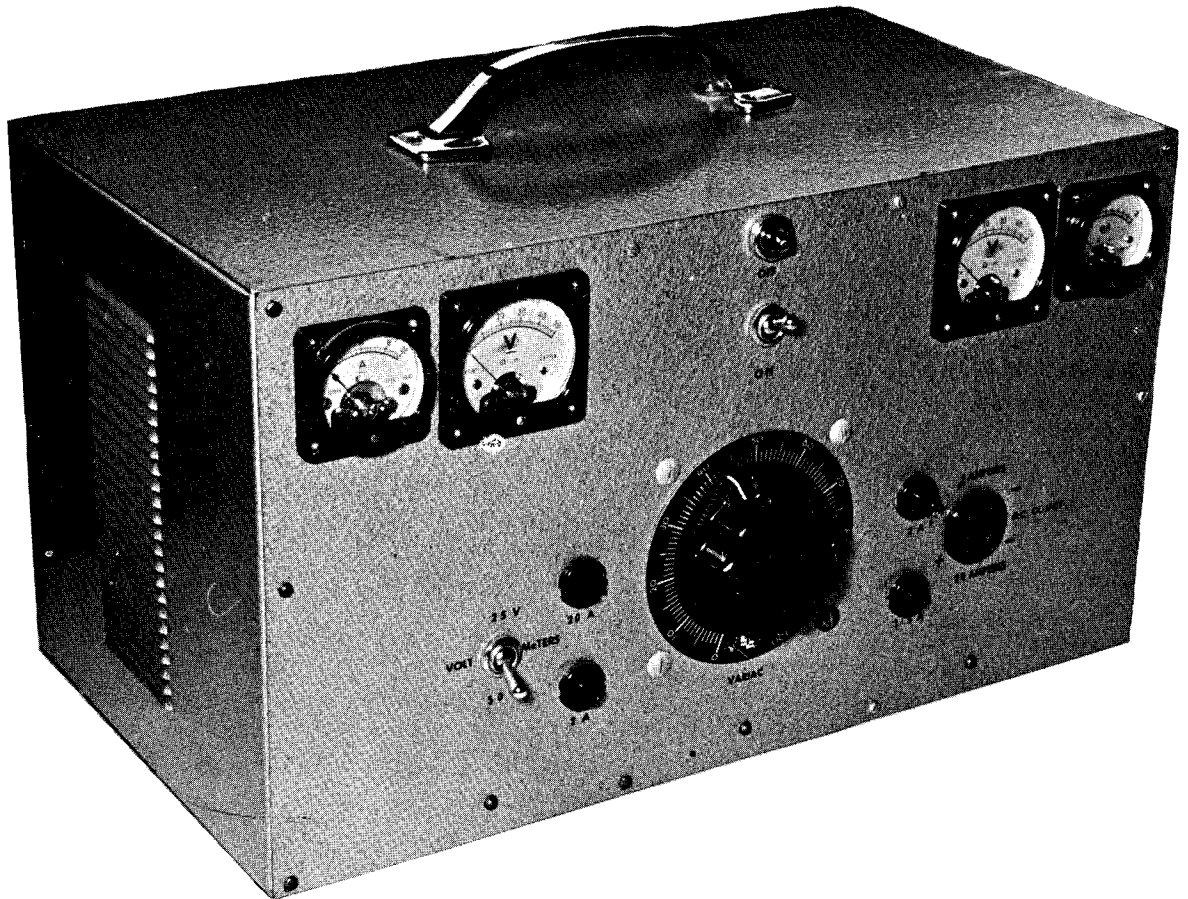


FIGURE 3.6 POWER SUPPLY FOR THE TOWER PROJECT



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 direction. 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  $\Delta P_i$   
the difference in counter readings as  $\Delta R_i$   
and the constant as C.

Then the parametric equations are:

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

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

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

which give the normal equation as:

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

or

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

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	37273	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	+0.007
699.54	-94.91	33378	45287	88091	-14830	-94.903	+0.002
683.48	-110.97	33378	47798	85580	-17341	-110.972	-0.002
672.07	-117.44	33378	48809	84569	-17352	-117.442	-0.002
673.14	-121.31	33378	49581	83797	-18124	-121.313	-0.003
683.18	-121.27	34944	50980	83964	-18957	-121.273	-0.003
696.25	-118.20	37606	52073	85533	-17388	-118.273	-0.003
705.95	-88.50	39959	52382	87577	-15344	-88.510	+0.008
714.05	-80.40	42295	53205	89090	-13831	-80.596	+0.010
724.26	-70.19	44083	53725	90358	-12563	-70.201	+0.004
731.32	-63.13	46206	54255	91951	-10970	-63.136	-0.011
739.54	-54.91	48481	55426	93455	-8566	-54.913	-0.006
765.06	-29.39	50602	56262	94340	-4581	-29.413	-0.003
793.68	-0.77	55590	57265	98325	-4596	-0.412	-0.002
		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 computer 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  $2.41^{\circ}$  F which according to the Lapse Rate of  $3.56^{\circ}$  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.<sup>49</sup> 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:

$$h = C_1 \left( \frac{P_1}{P_0} \right)^{C_2} \quad (1 + \text{Temperature Correction})$$

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

NO	CALCULATED ELEVATION ERRORS						
	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

NO	CALCULATED ELEVATION ERRORS						
	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		-4.89	5.03	0.00
C2	4.56	5.20	-1.99	-0.76	-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	-1.17	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	13.04	-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. <sup>5, 31</sup>

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. <sup>50, 41, 17, 34</sup>

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.<sup>5, 50, 56</sup>

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

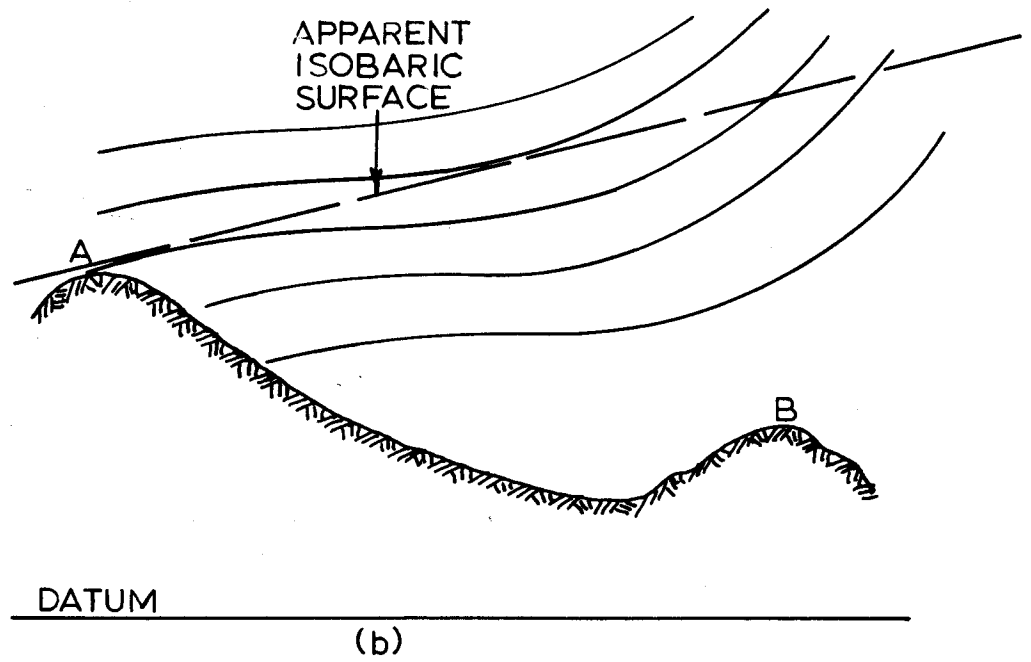
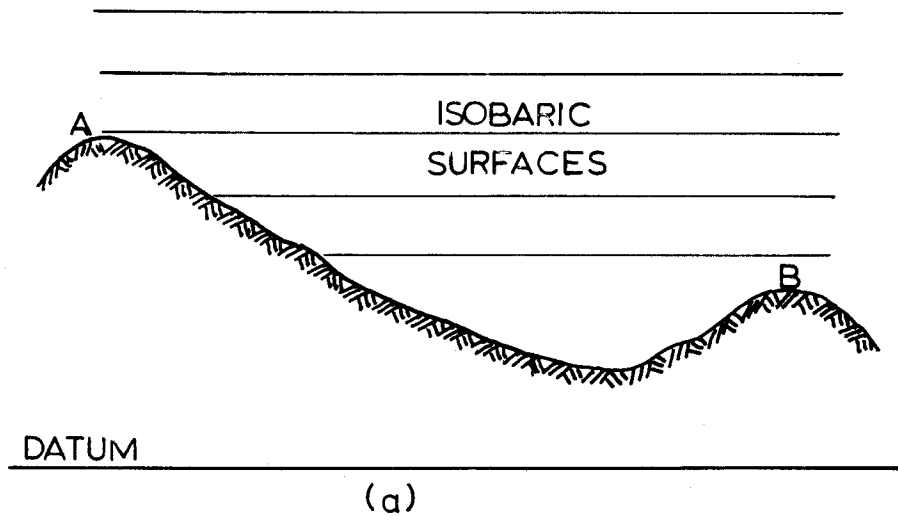


FIG. 4.1 ISOBARIC SURFACES

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.<sup>13</sup>

#### 4.2 SINGLE BASE METHOD<sup>5, 28, 42, 43, 44, 50, 56.</sup>

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<sup>5, 23, 29, 43, 44, 50, 56</sup>

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.<sup>17</sup> 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<sup>5,29,39,42,44,50,52,53,56</sup>

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:

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

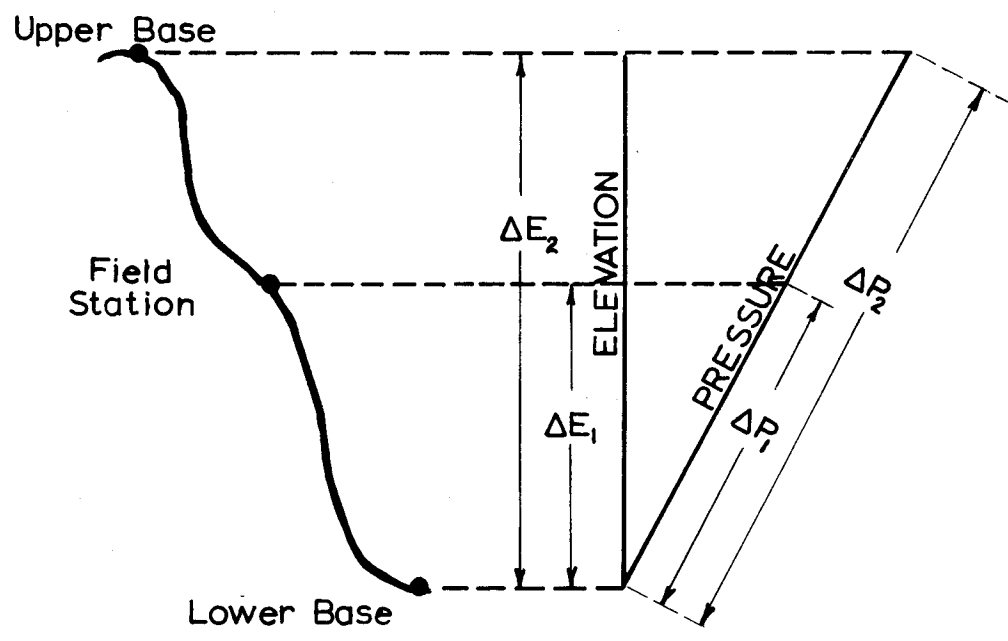


FIG. 4. 2. THE TWO BASE METHOD



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<sup>37, 41, 44, 45, 50, 55</sup>

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.<sup>45</sup> The corrections for field readings may then be interpolated.

A simpler 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

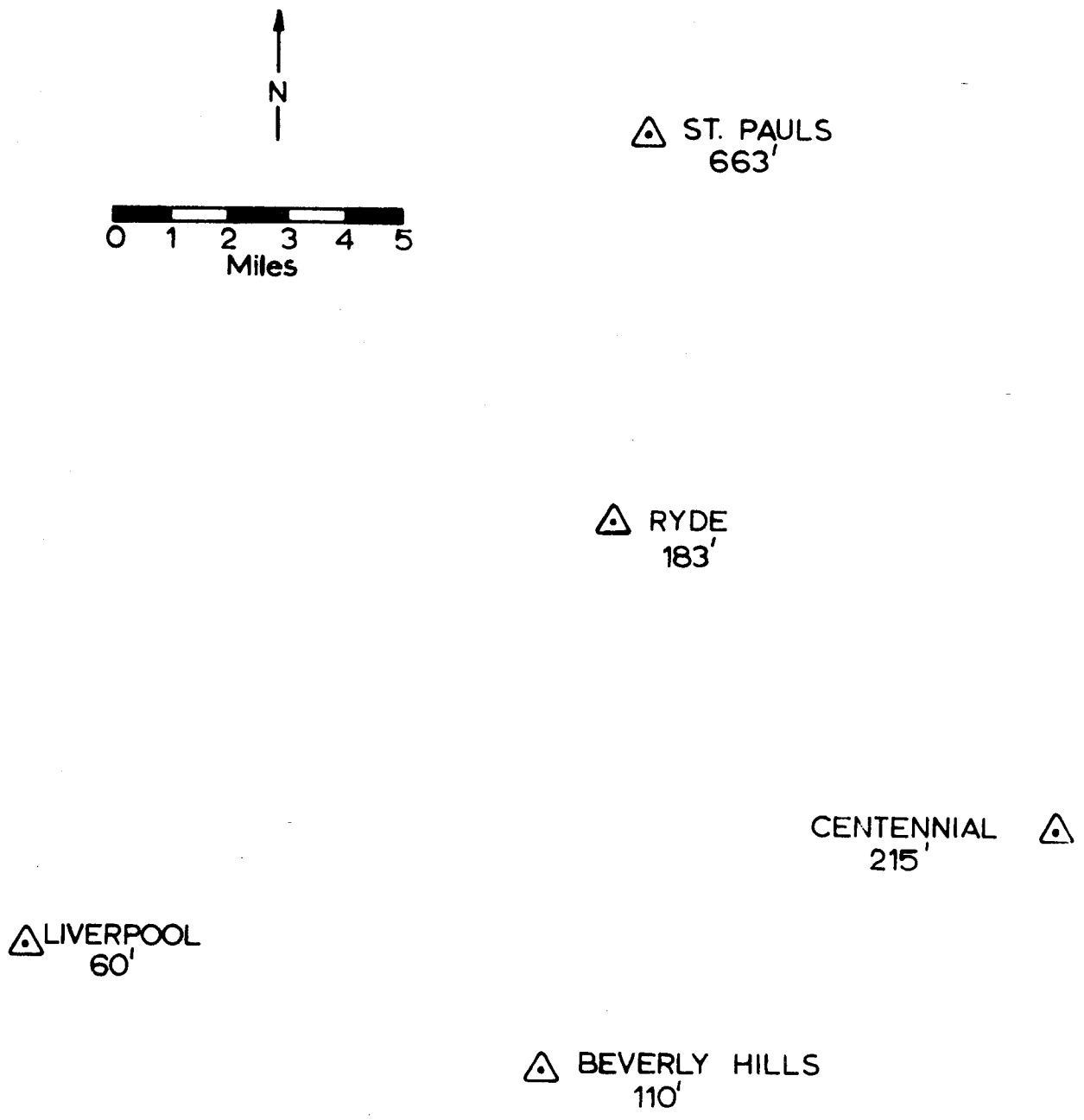
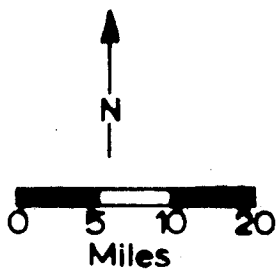


FIG. 4.3 CITY TEST AREA



△ QUANDIALLA  
817'

86

MONTEAGLE △  
1627'

△ YEO YEO  
1124'

△ HAREFIELD  
833'

△ PETTITS  
797'

△ WAGGA  
609'

△ BATLOW  
2544'

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 CITY AREA 26 MAY 1959

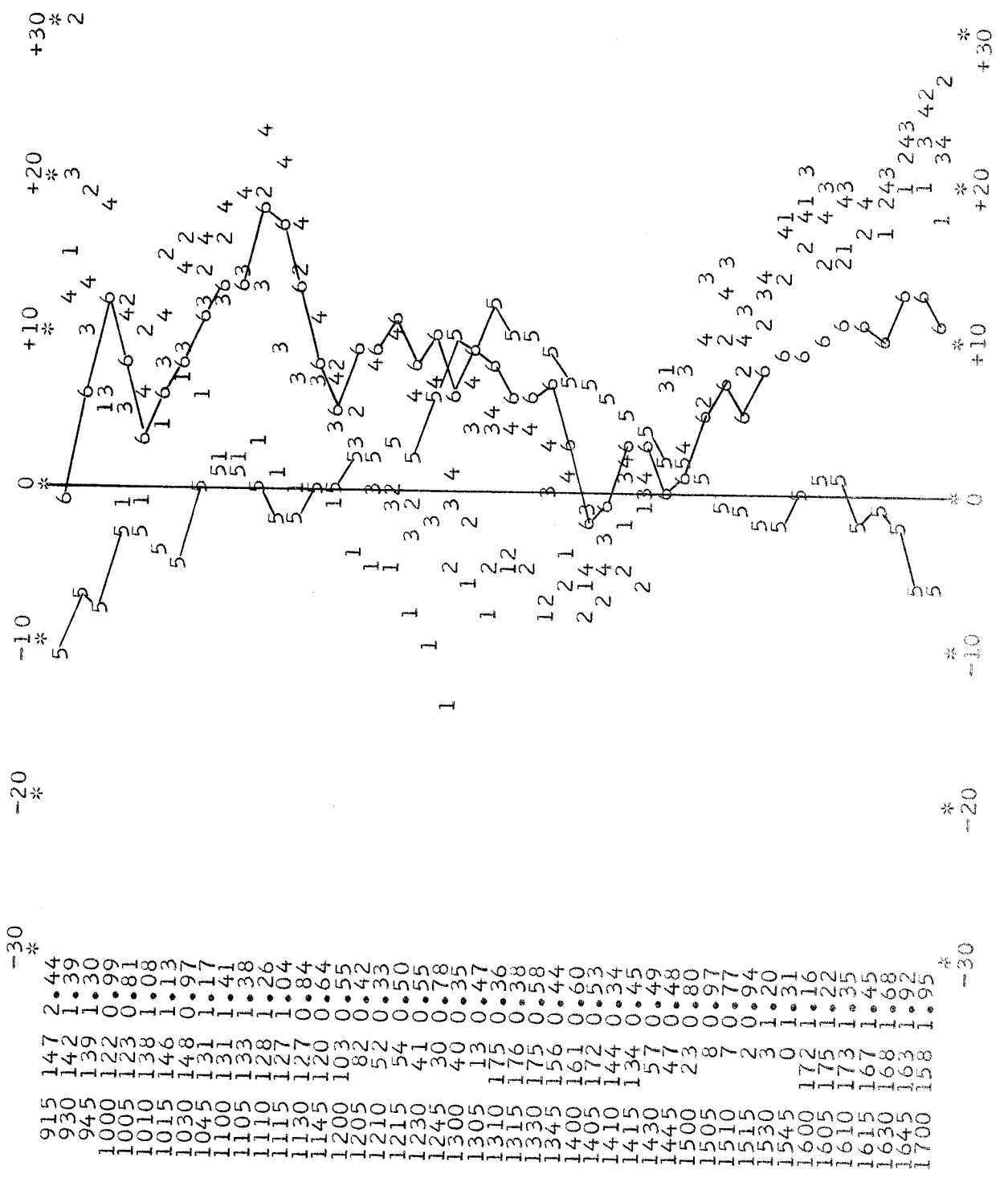




TABLE 4.3 SINGLE AND MULTIPLE BASE ERRORS USING THE ASSUMED STANDARD ATMOSPHERE COOTAMUNDRA AREA 28 FEBRUARY 1966

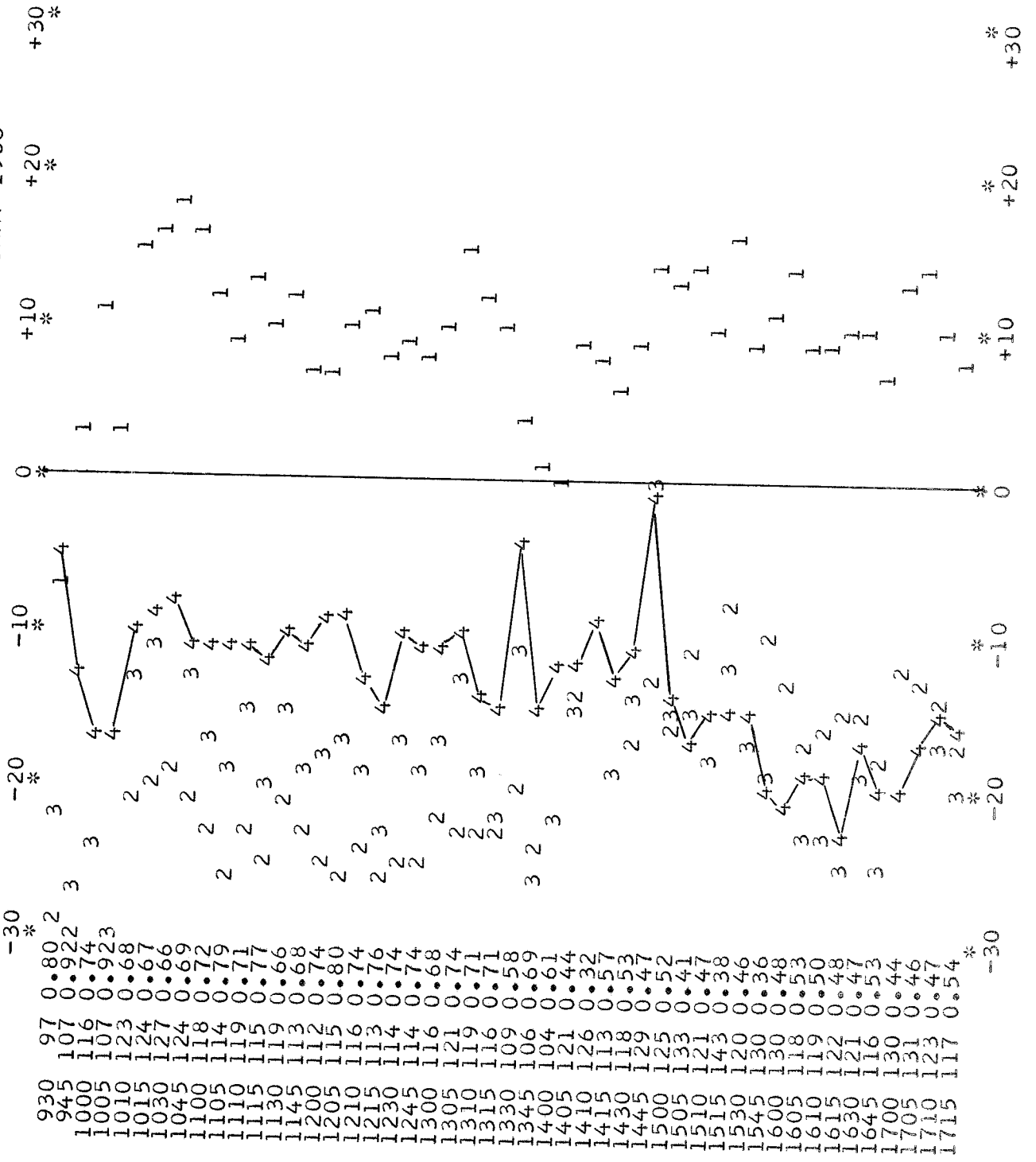


TABLE 4.4 SINGLE AND MULTIPLE BASE ERRORS USING THE ASSUMED STANDARD ATMOSPHERE COOTAMUNDRA AREA 1 MARCH 1966

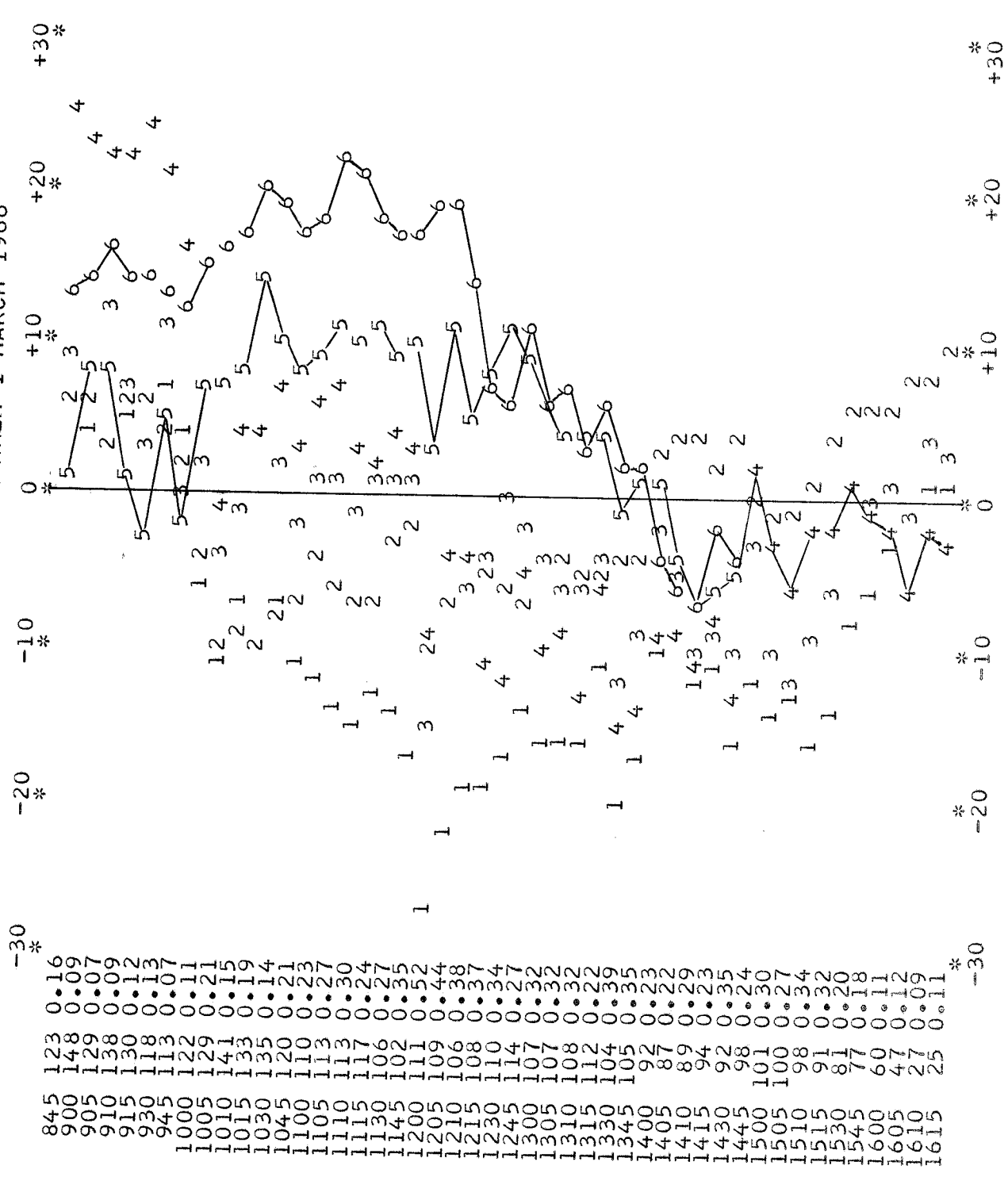
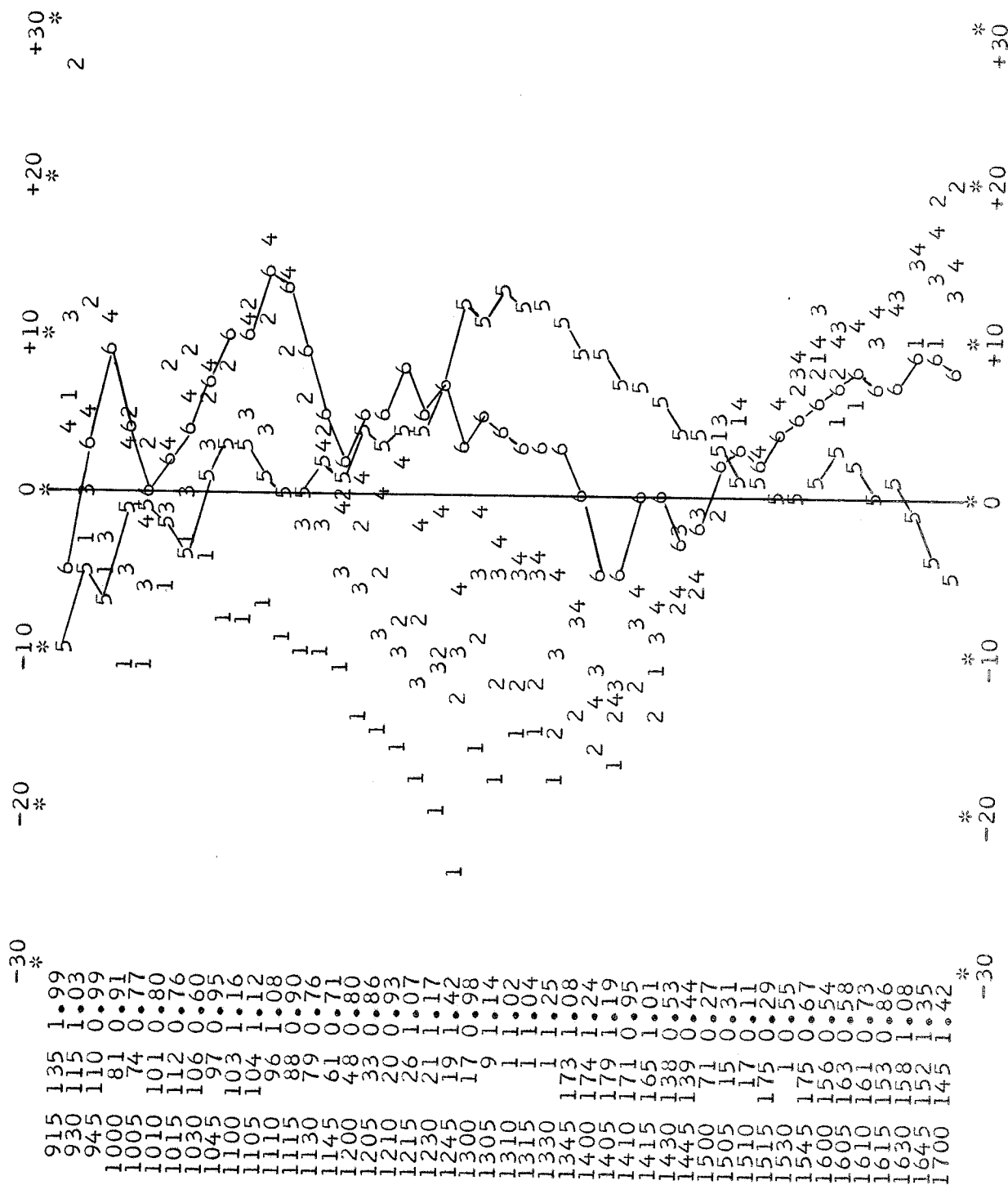


TABLE 4.5  
 SINGLE AND MULTIPLE BASE ERRORS USING THE ICAN ATMOSPHERE  
 CITY AREA 26 MAY 1959



\*-30  
 \* -20  
 \* -10  
 \* 0  
 \* +10  
 \* +20  
 \* +30

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

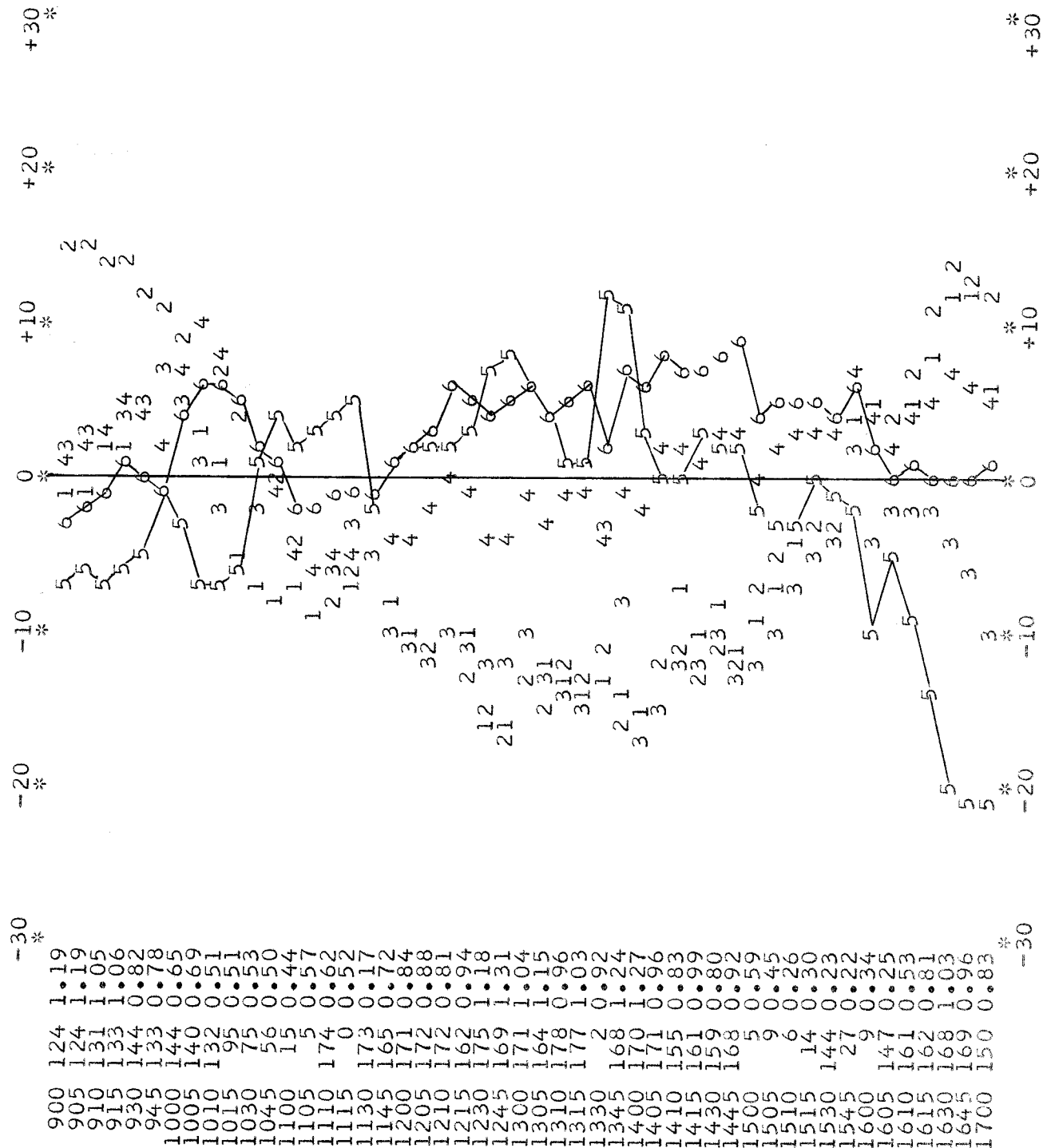


TABLE 4.7 SINGLE AND MULTIPLE BASE ERRORS USING THE ICAN ATMOSPHERE  
COOTAMUNDRA AREA 28 FEBRUARY 1966

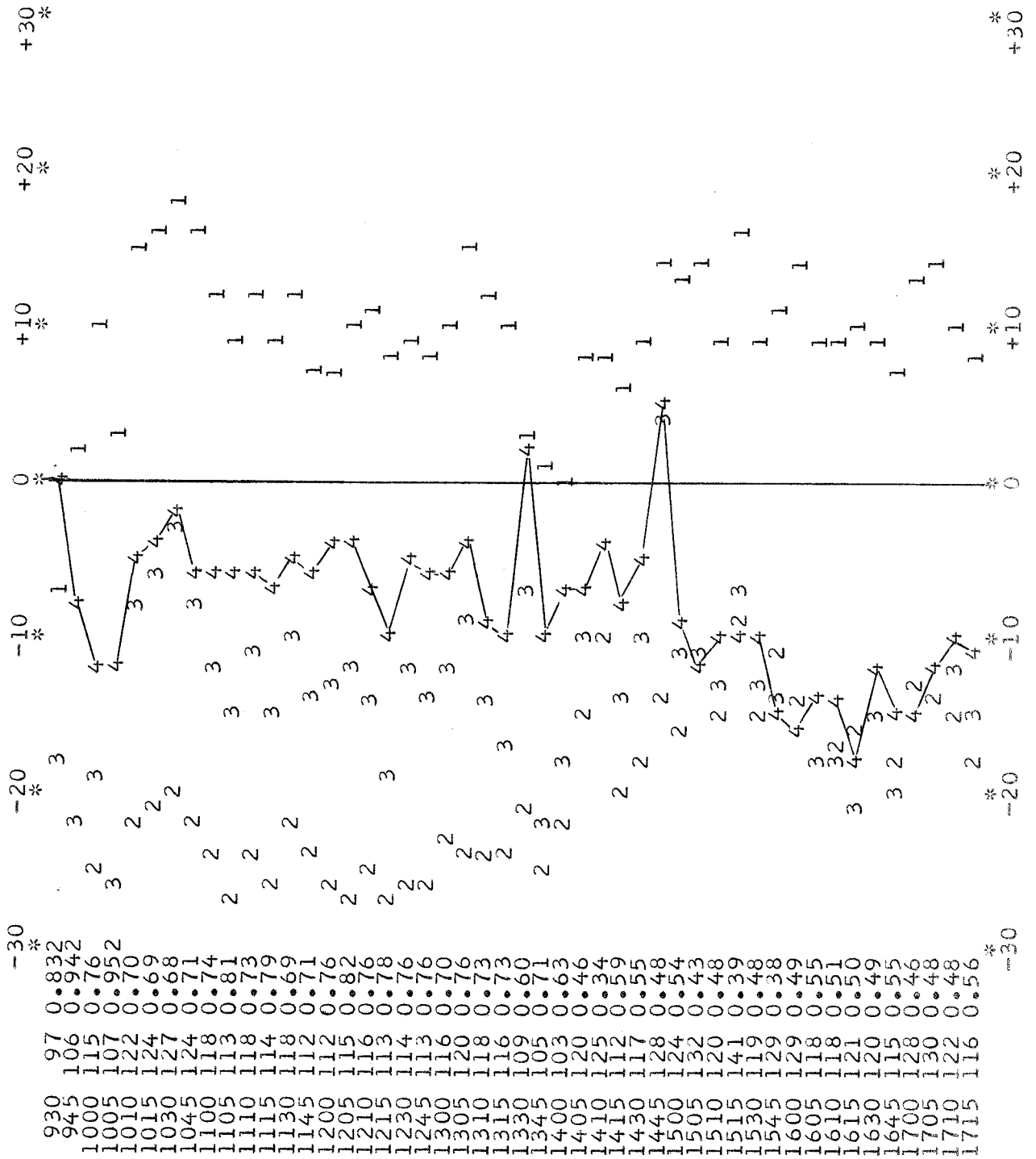
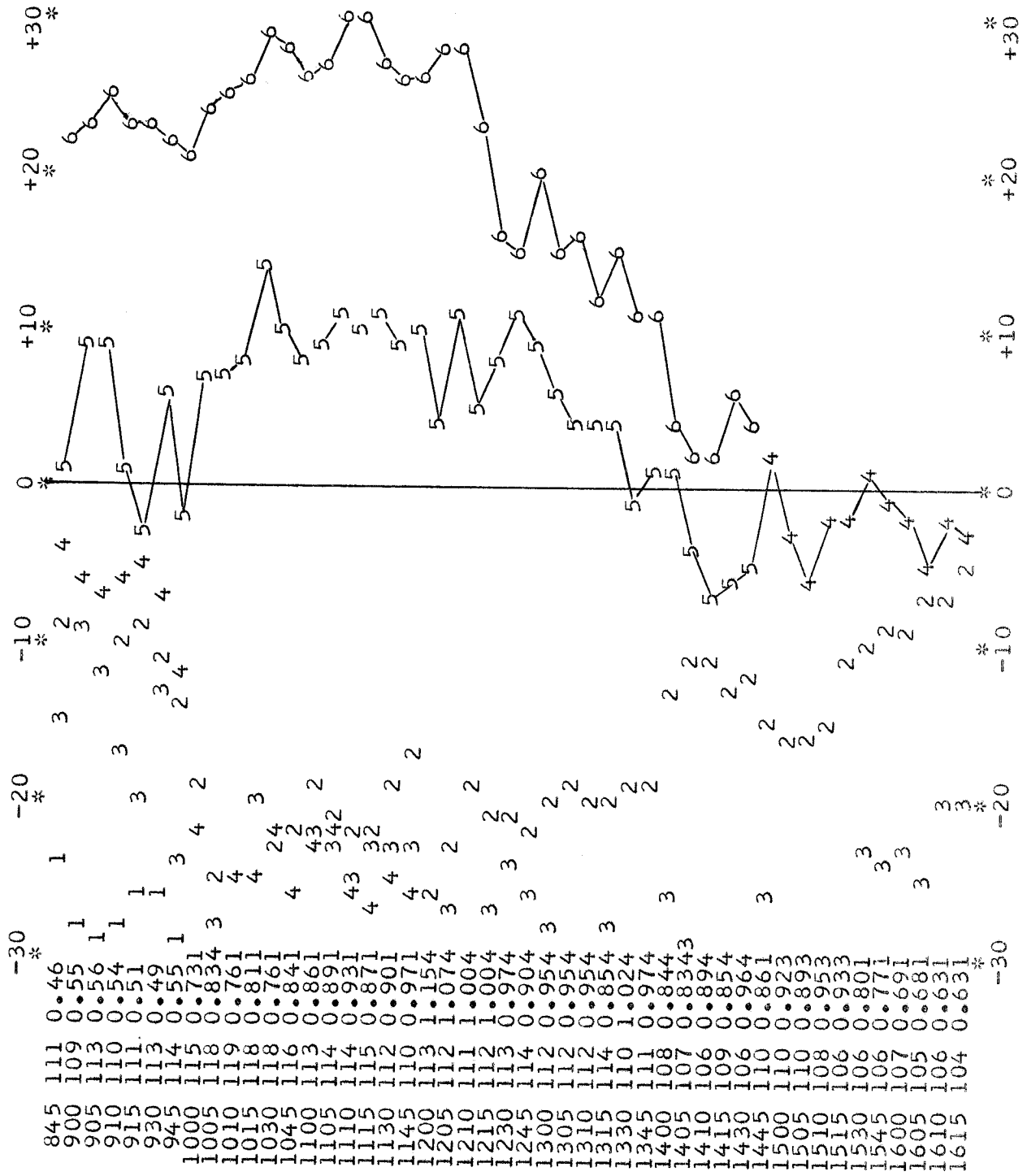




TABLE 4.8 SINGLE AND MULTIPLE BASE ERRORS USING THE ICAN ATMOSPHERE  
COOTAMUNDRA AREA 1 MARCH 1966



## 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.

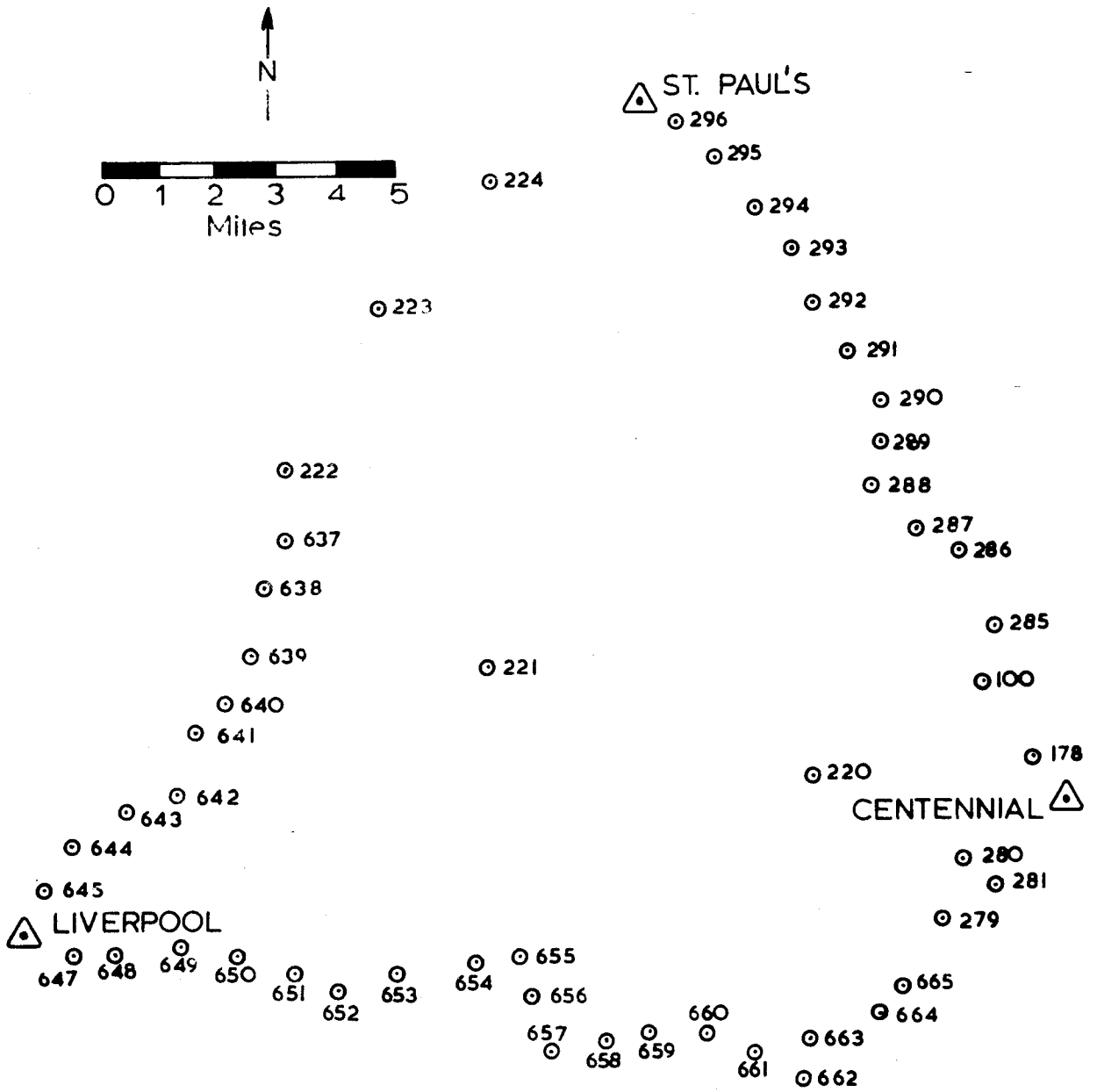


FIG. 5.1 BAROMETER TRAVERSE STATIONS — CITY AREA

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

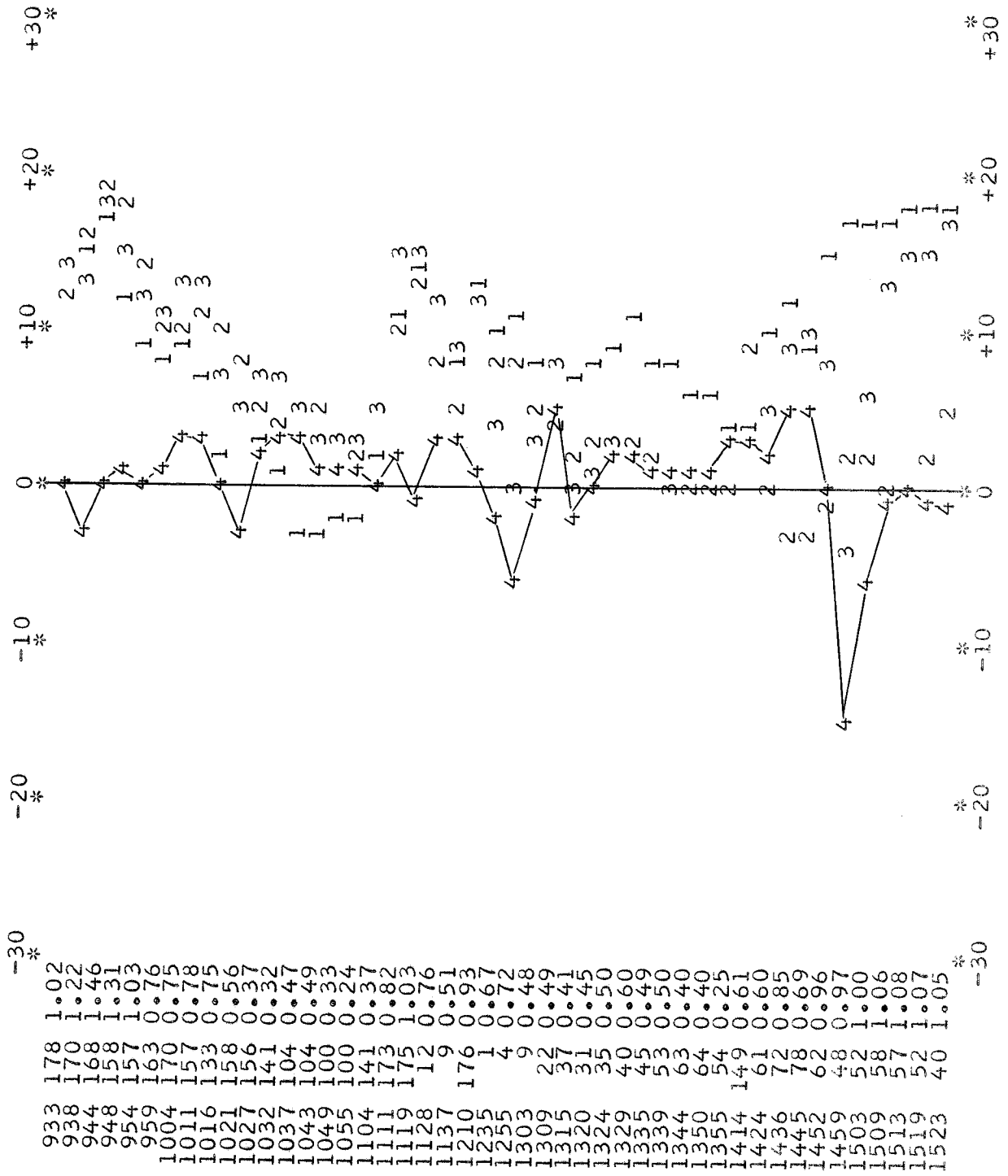


TABLE 5.3 SINGLE AND MULTIPLE BASE ERRORS USING THE ASSUMED STANDARD CITY TRAVERSE 6 DECEMBER 1955

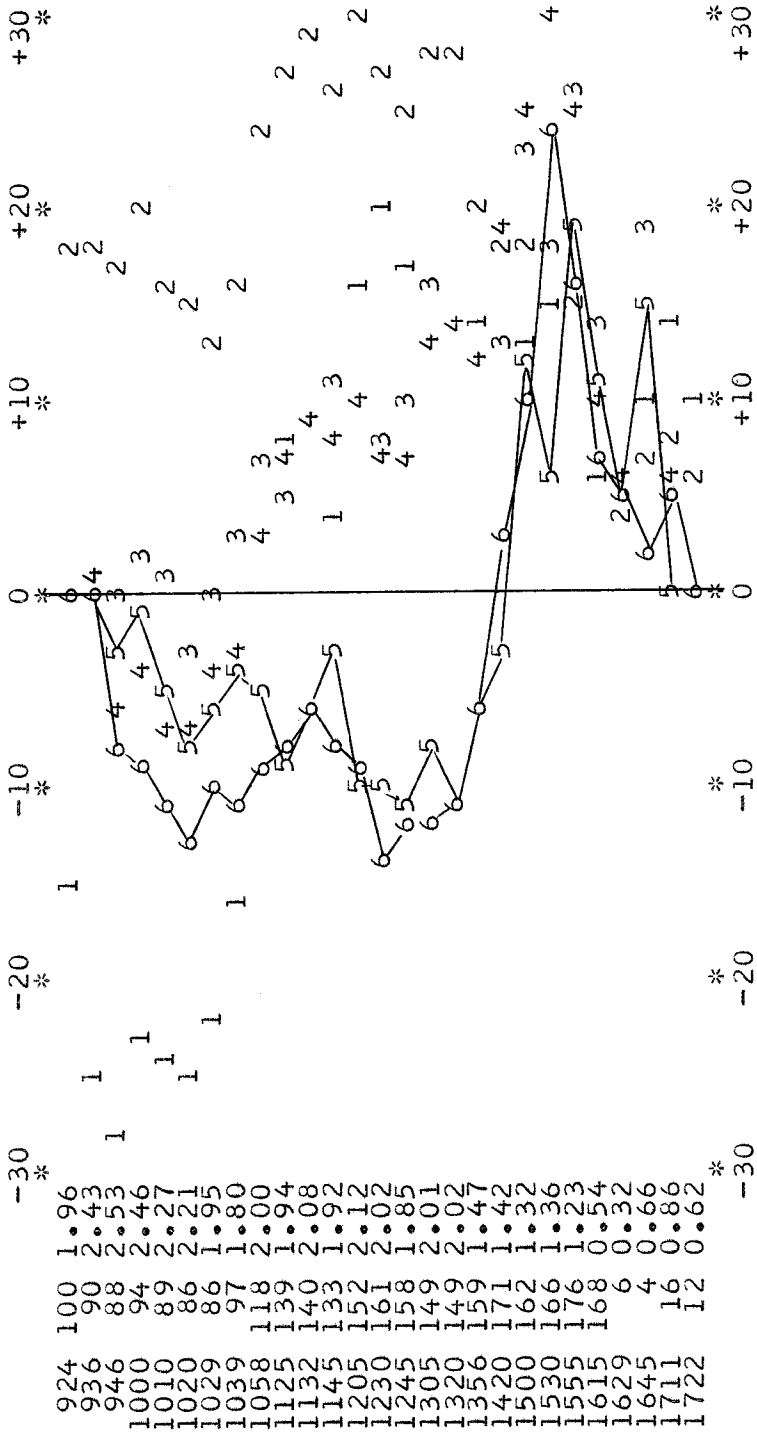


TABLE 5.4 SINGLE AND MULTIPLE BASE ERRORS USING THE ASSUMED STANDARD CITY TRAVERSE 7 DECEMBER 1955

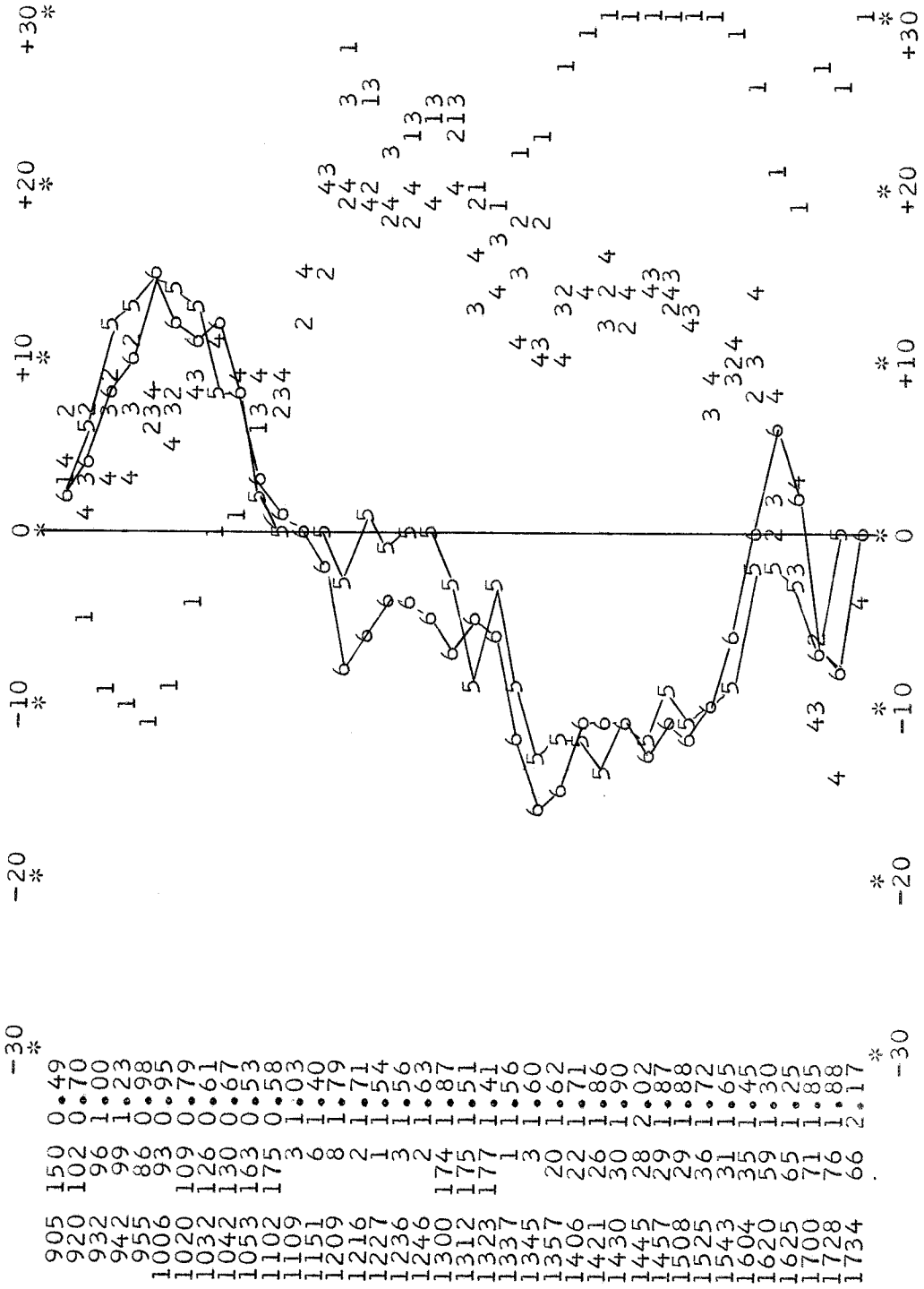


TABLE 5.5 SINGLE AND MULTIPLE BASE ERRORS USING THE ICAN ATMOSPHERE CITY TRAVERSE 22 MAY 1956

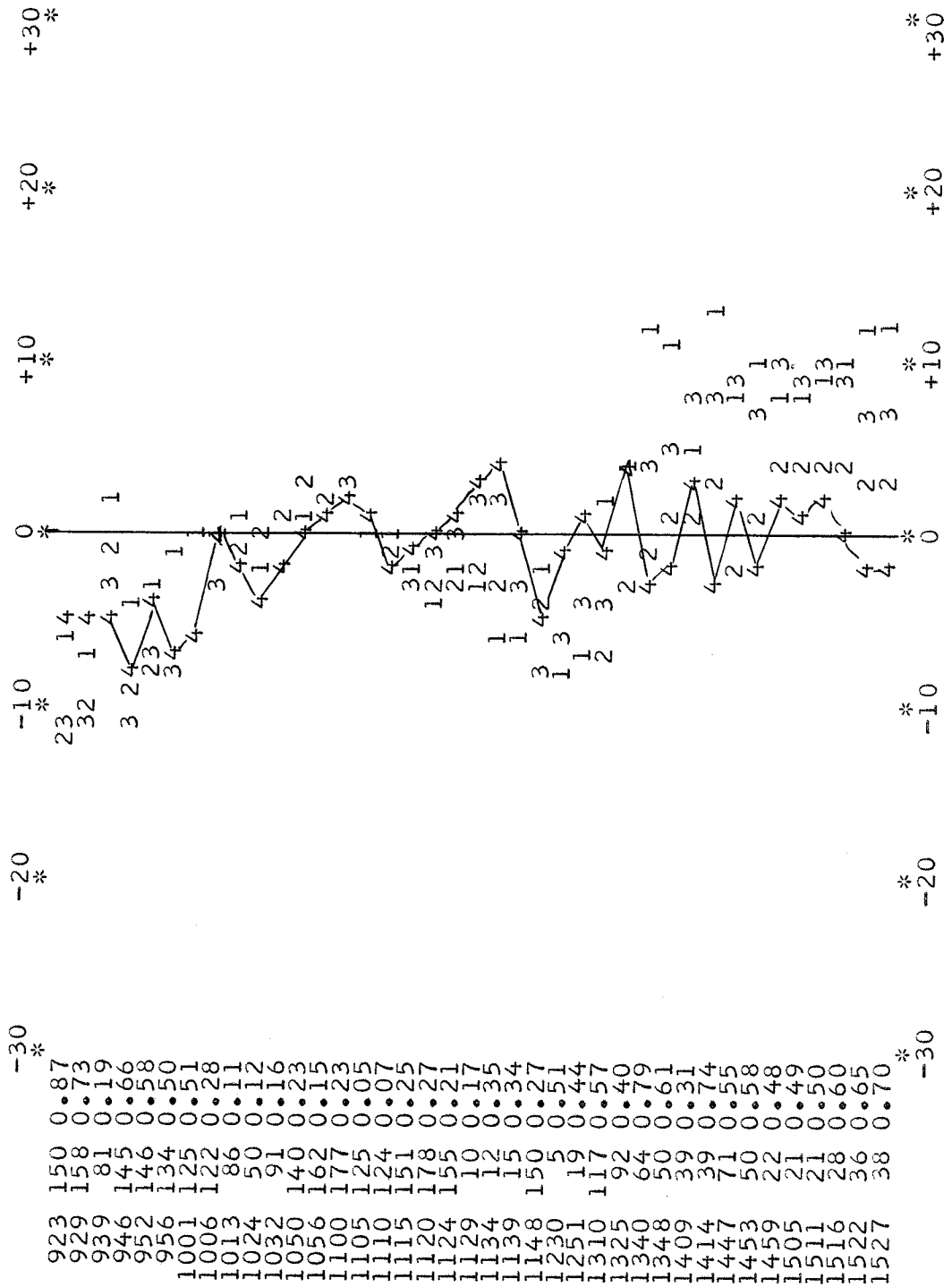


TABLE 5.6 SINGLE AND MULTIPLE BASE ERRORS USING THE ICAN ATMOSPHERE  
CITY TRAVERSE 23 MAY 1956

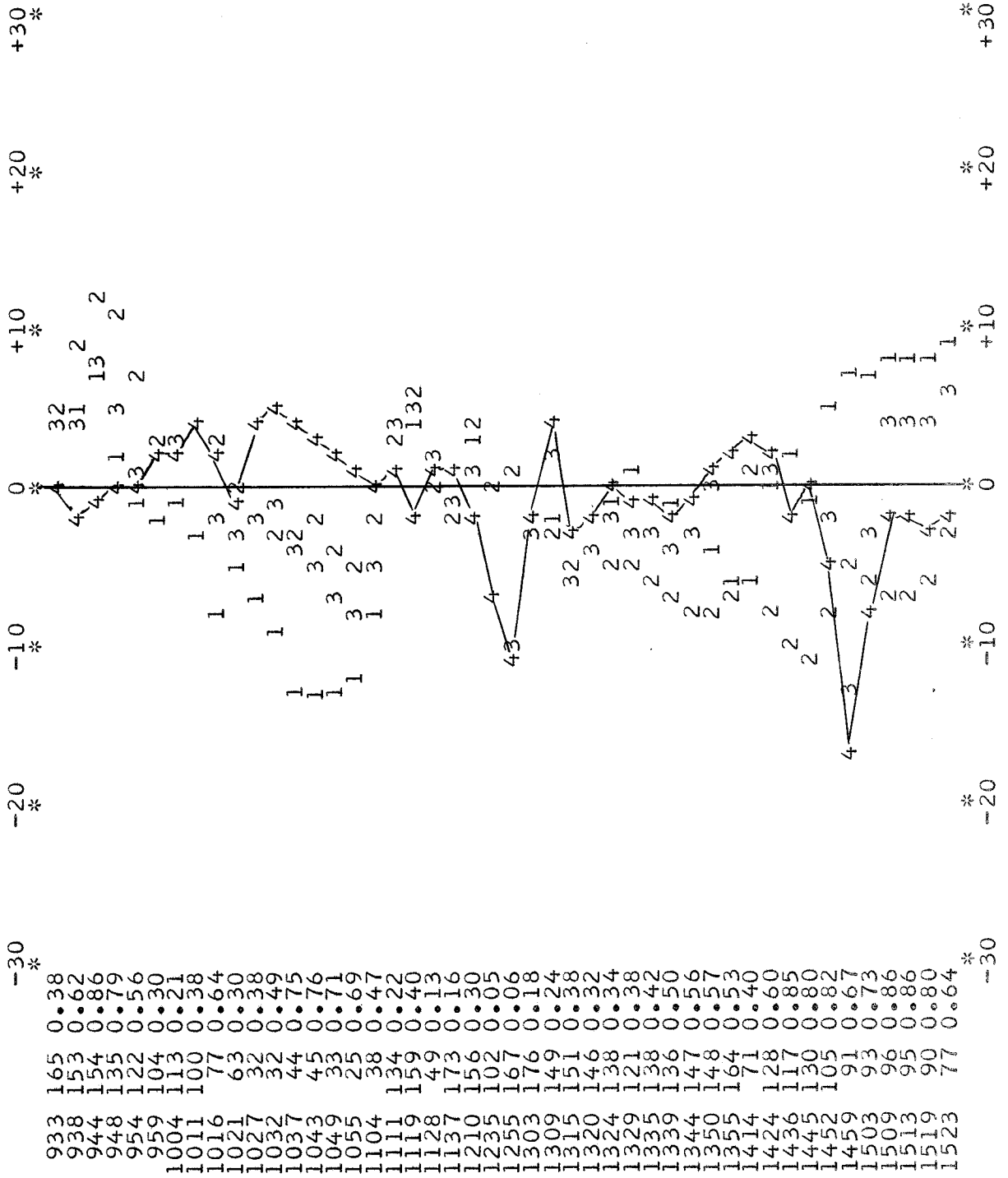




TABLE 5.7 SINGLE AND MULTIPLE BASE ERRORS USING THE ICAN ATMOSPHERE  
CITY TRAVERSE 6 DECEMBER 1955

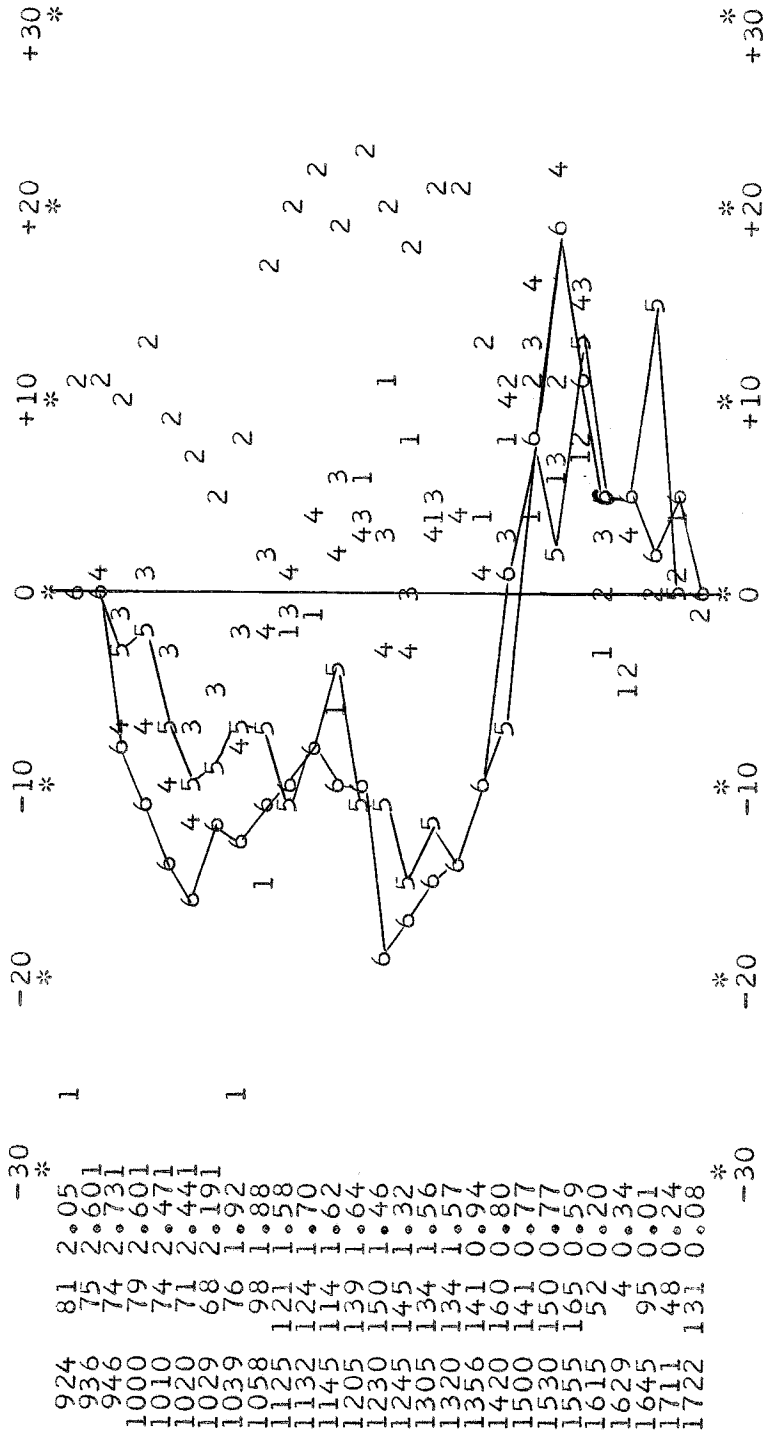


TABLE 5.8 SINGLE AND MULTIPLE BASE ERRORS USING THE ICAN ATMOSPHERE CITY TRAVERSE 7 DECEMBER 1955

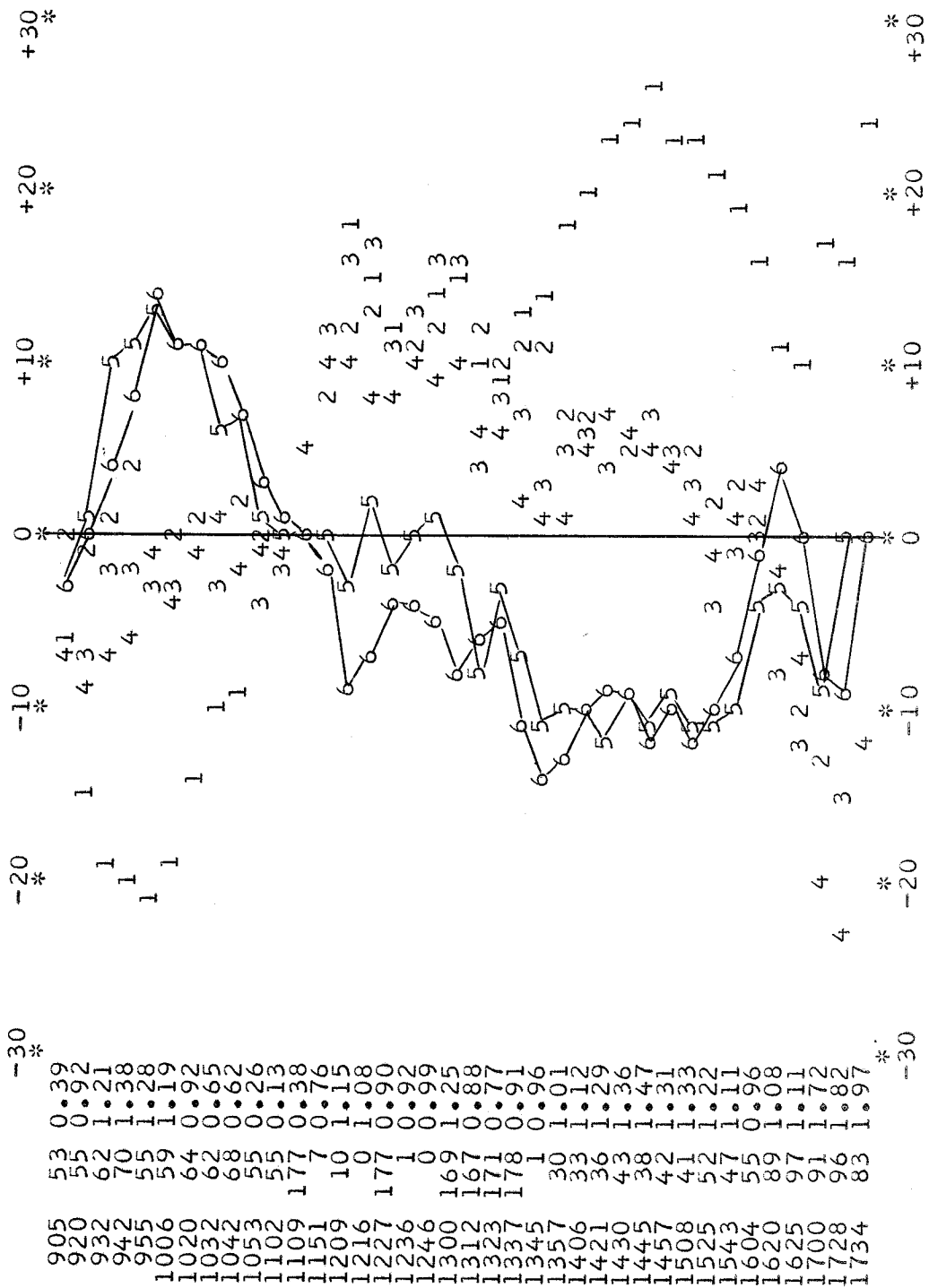


TABLE 5.9. LEAP FROG METHOD ERRORS USING THE ASSUMED STANDARD ATMOSPHERE  
 CITY TRAVERSE AREA 6 DECEMBER 1955

	-30*	-20*	-10*	0*	+10*	+20*	+30*
936							
946							
1000				1	1		
1010				1			
1020					1		
1029				1	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 5.11 2 BASE ERRORS 22 MAY 1956

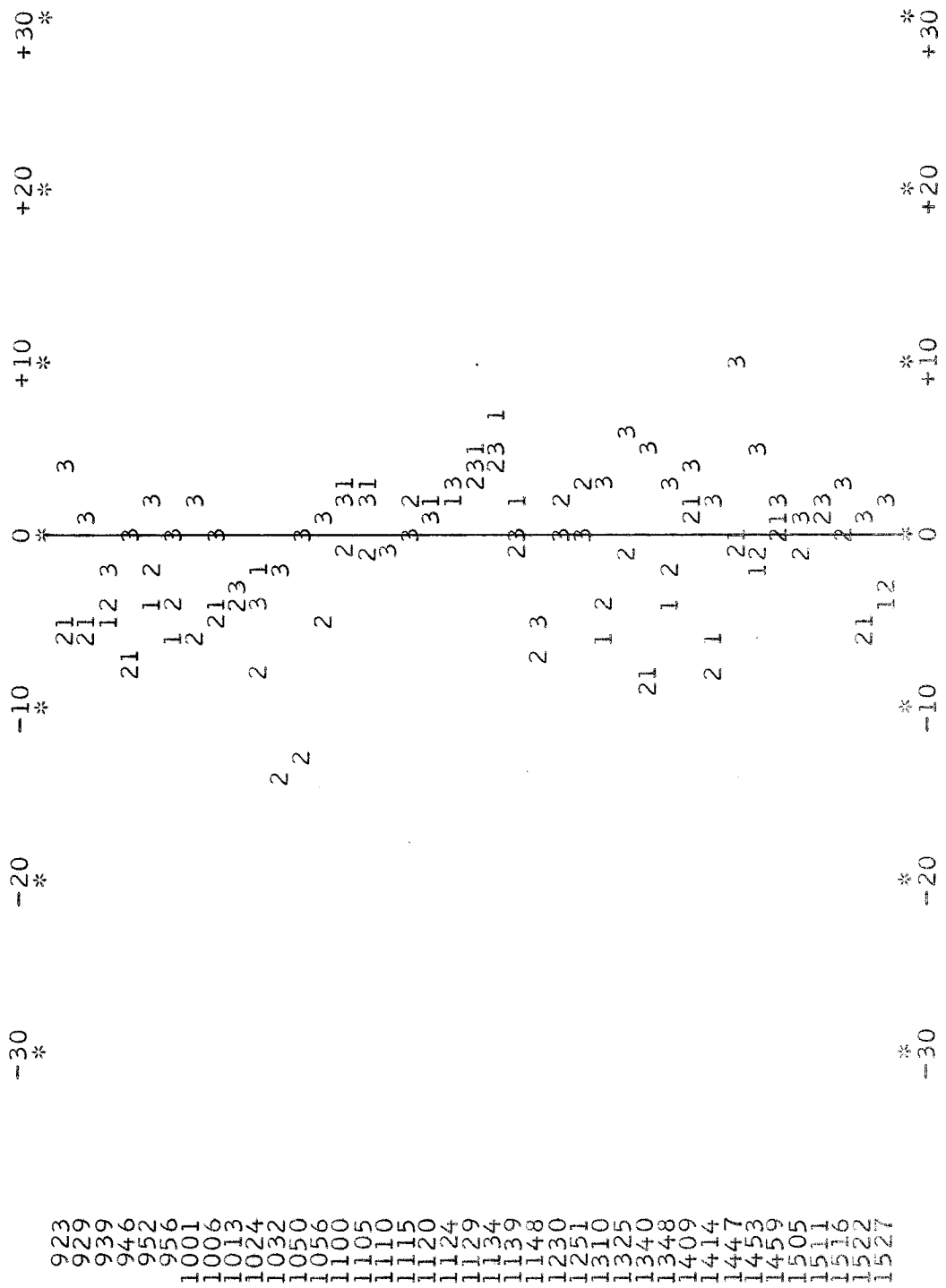


TABLE 5.12 2 BASE ERRORS 23 MAY 1956

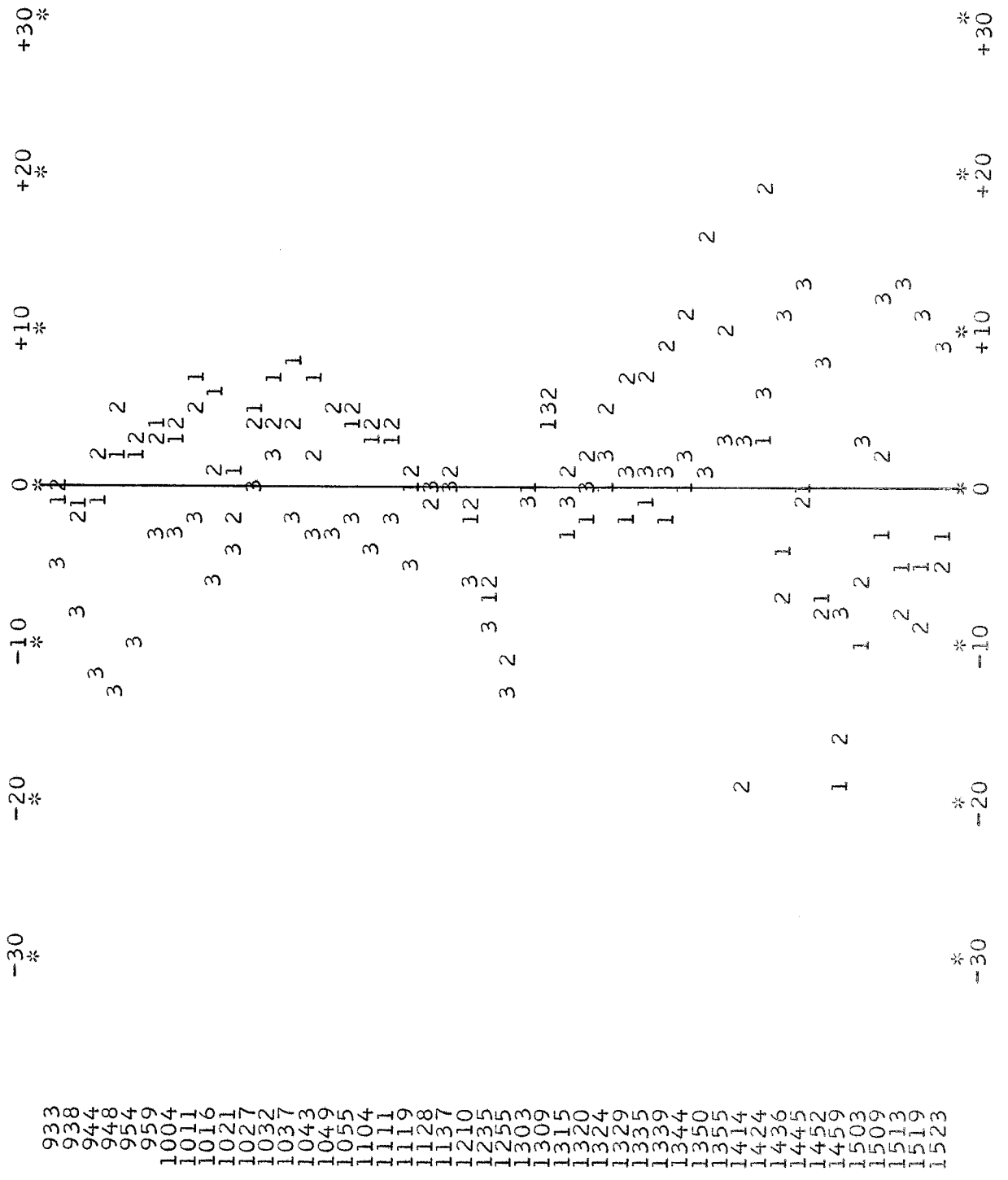


TABLE 5.10. LEAP FROG METHOD ERRORS USING THE ASSUMED STANDARD ATMOSPHERE  
 CITY TRAVERSE AREA 7 DECEMBER 1955

	-30*	-20*	-10*	0*	+10*	+20*	+30*
920							
932							
942							
955							
1006							
1020							
1032							
1042							
1053							
1115							
1120							
1121							
1127							
1123							
1124							
1126							
1130							
1131							
1132							
1133							
1134							
1135							
1137							
1145							
1146							
1147							
1148							
1150							
1152							
1153							
1154							
1160							
1162							
1165							
1170							

TABLE 5.11 2 BASE ERRORS 22 MAY 1956

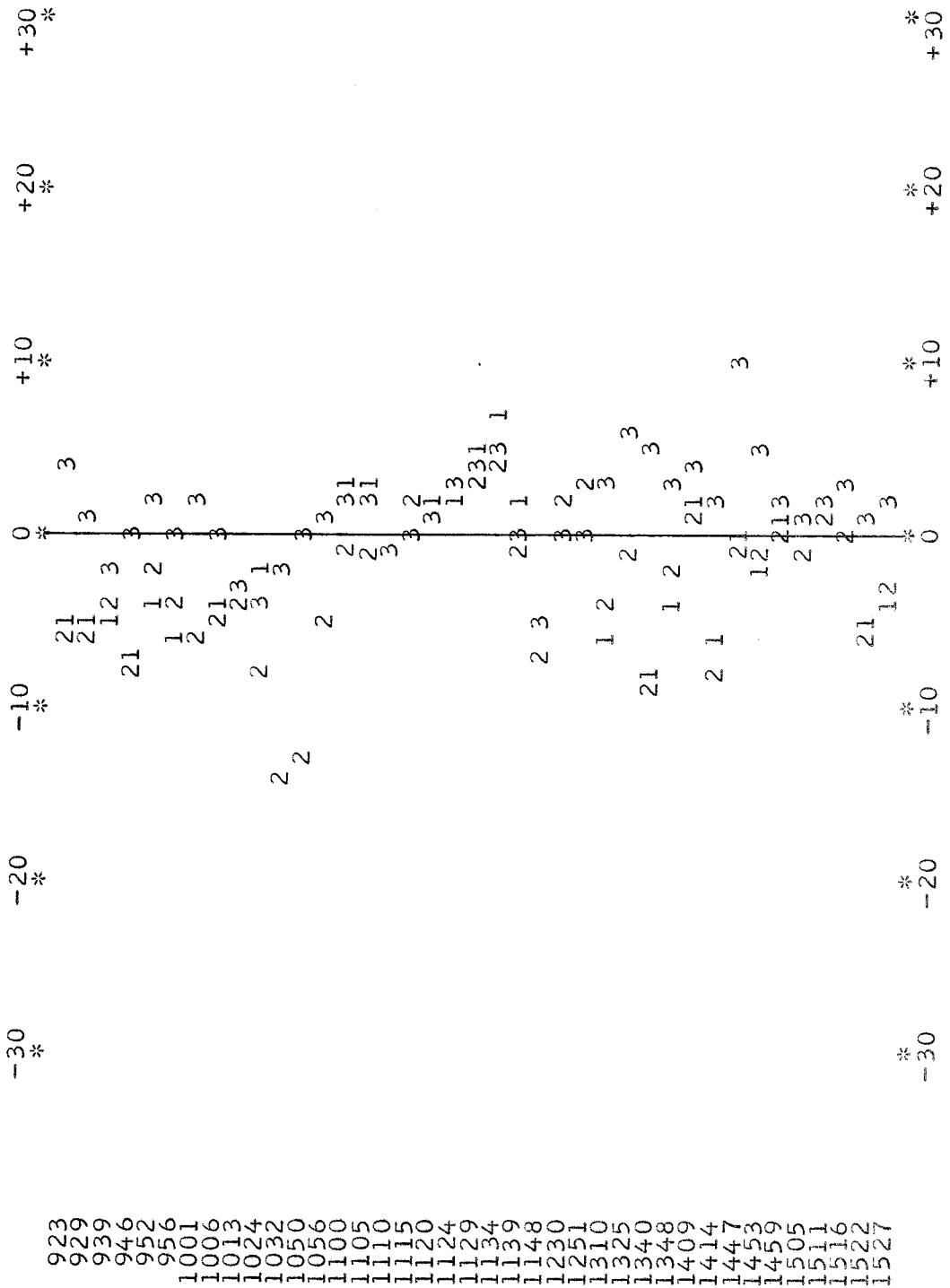




TABLE 5.12 2 BASE ERRORS 23 MAY 1956

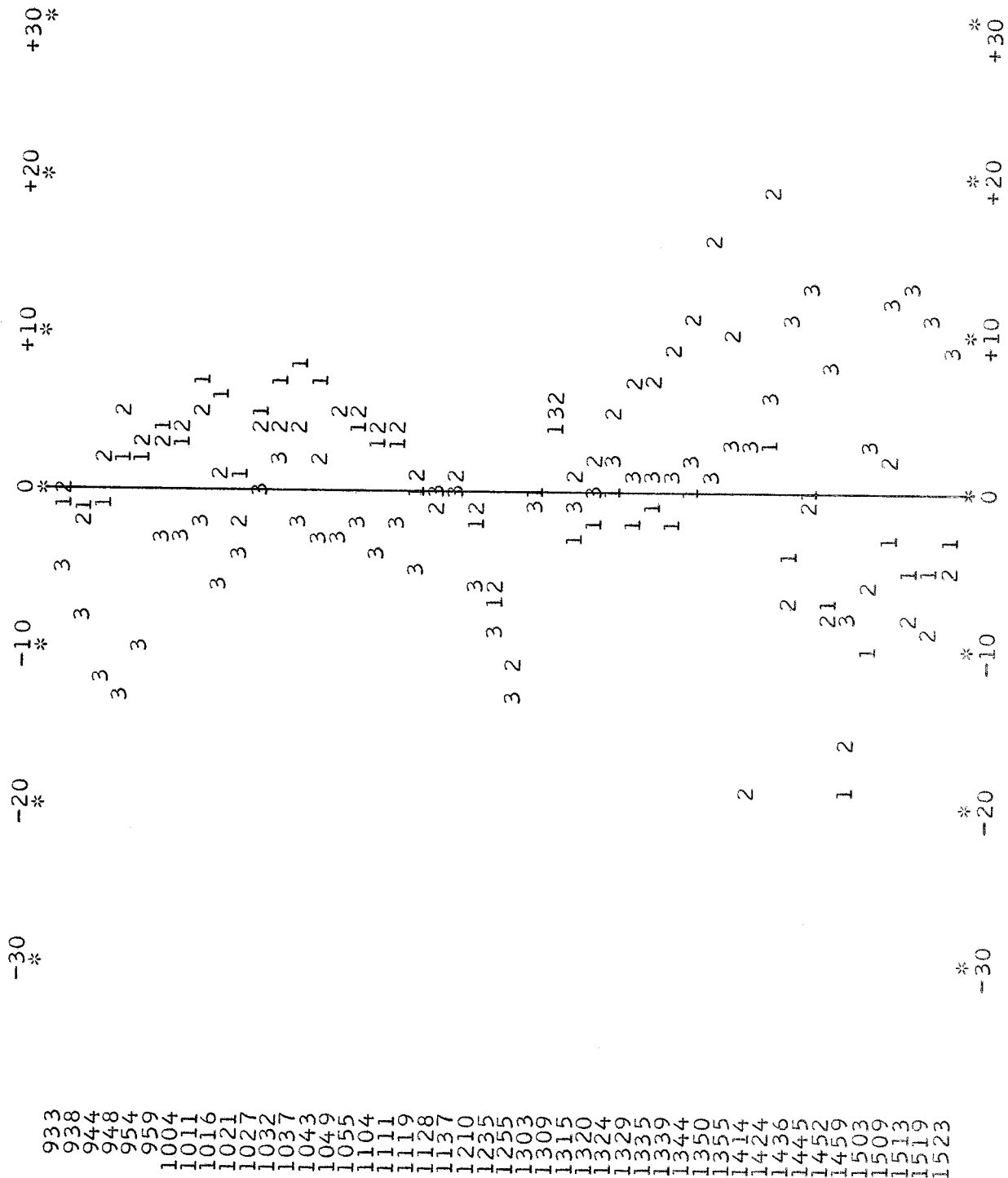
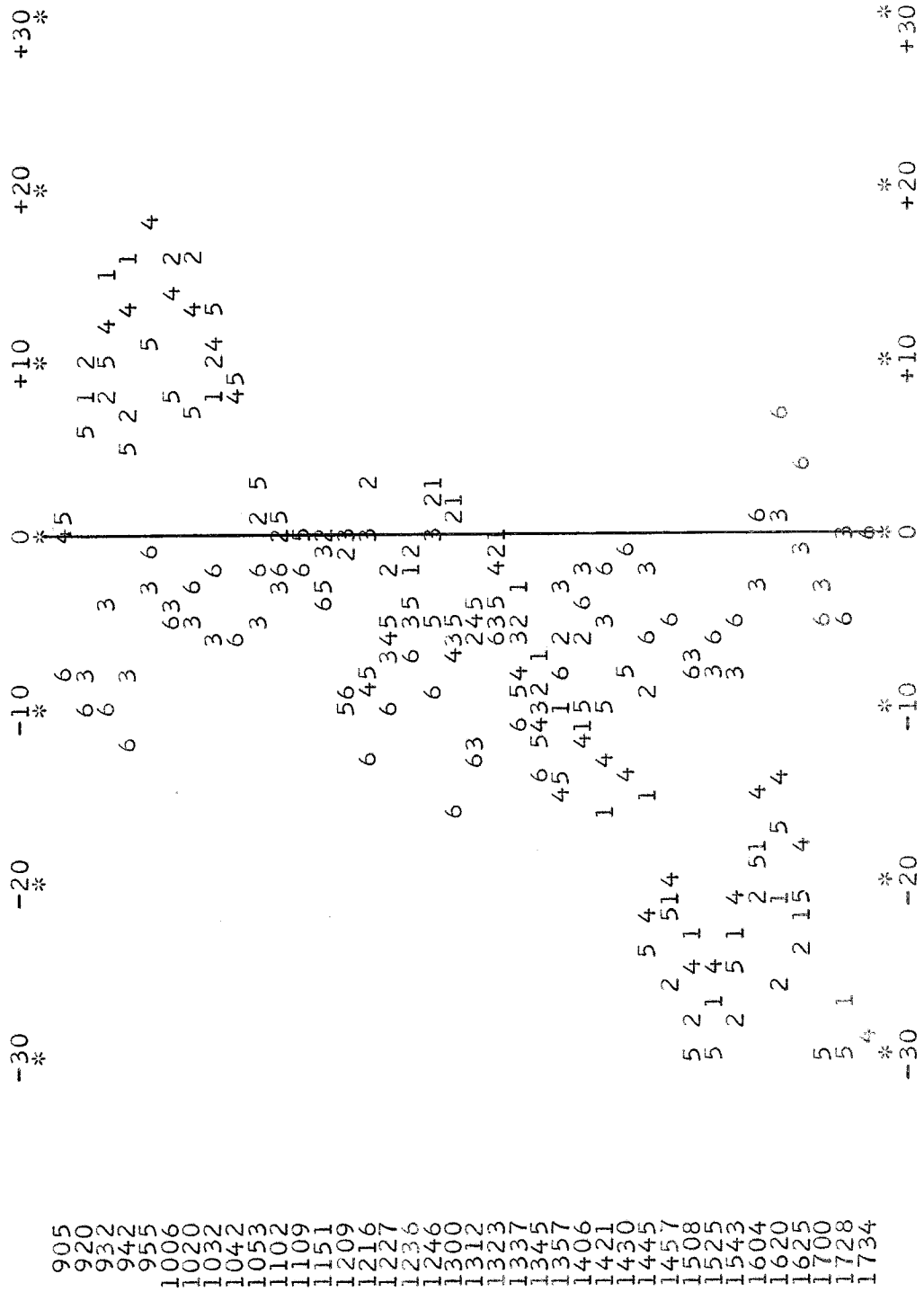


TABLE 5.13 2 BASE ERRORS 6 DECEMBER 1955

	-30*	-20*	-10*	0*	+10*	+20*	+30*
924							
936							
946							
1000							
1010							
1020							
1029							
1039							
1058							
1113							
1125							
1132							
1145							
1205							
1230							
1245							
1320							
1356							
1420							
1530							
1555							
1619							
1629							
1645							
1711							
1722							

924  
 936  
 946  
 1000  
 1010  
 1020  
 1029  
 1039  
 1058  
 1113  
 1125  
 1132  
 1145  
 1205  
 1230  
 1245  
 1320  
 1356  
 1420  
 1530  
 1555  
 1619  
 1629  
 1645  
 1711  
 1722

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.

$$\Delta H_{\text{calc}} = \Delta H_{\text{approx.}} \left( 1 + \frac{T_{\text{F}} + T_{\text{B}} - 2 T_{\text{SA}}}{1000} \right)$$

where

$T_{\text{F}}$  is the Temperature in Fahrenheit at the Traverse Station

$T_{\text{B}}$  is the Temperature in Fahrenheit at the Base Station

$T_{\text{SA}}$  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 transcription 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.<sup>16</sup> This can be established visually, with an interpolating frame<sup>50</sup> 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 6.1BASE 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
$\Delta'$ 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
$\Delta$ 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 <sup>o</sup>	250 <sup>o</sup>	N.A.	180 <sup>o</sup>
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  $+ 90^{\circ}$  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 semicircle 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.

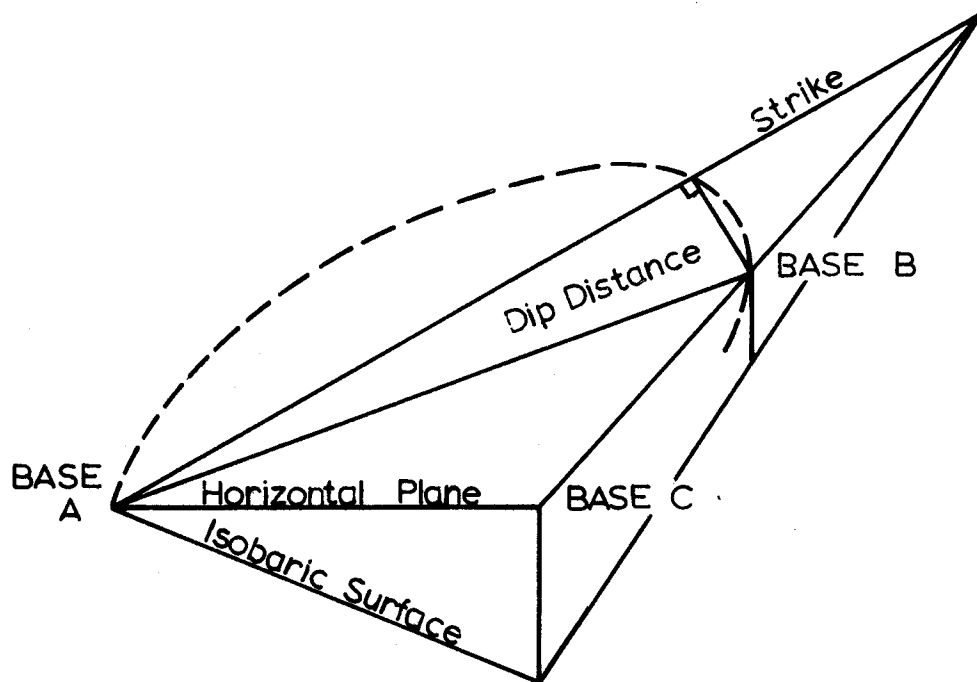


FIG. 6.1 TILT OF THE ISOBARIC SURFACE

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.

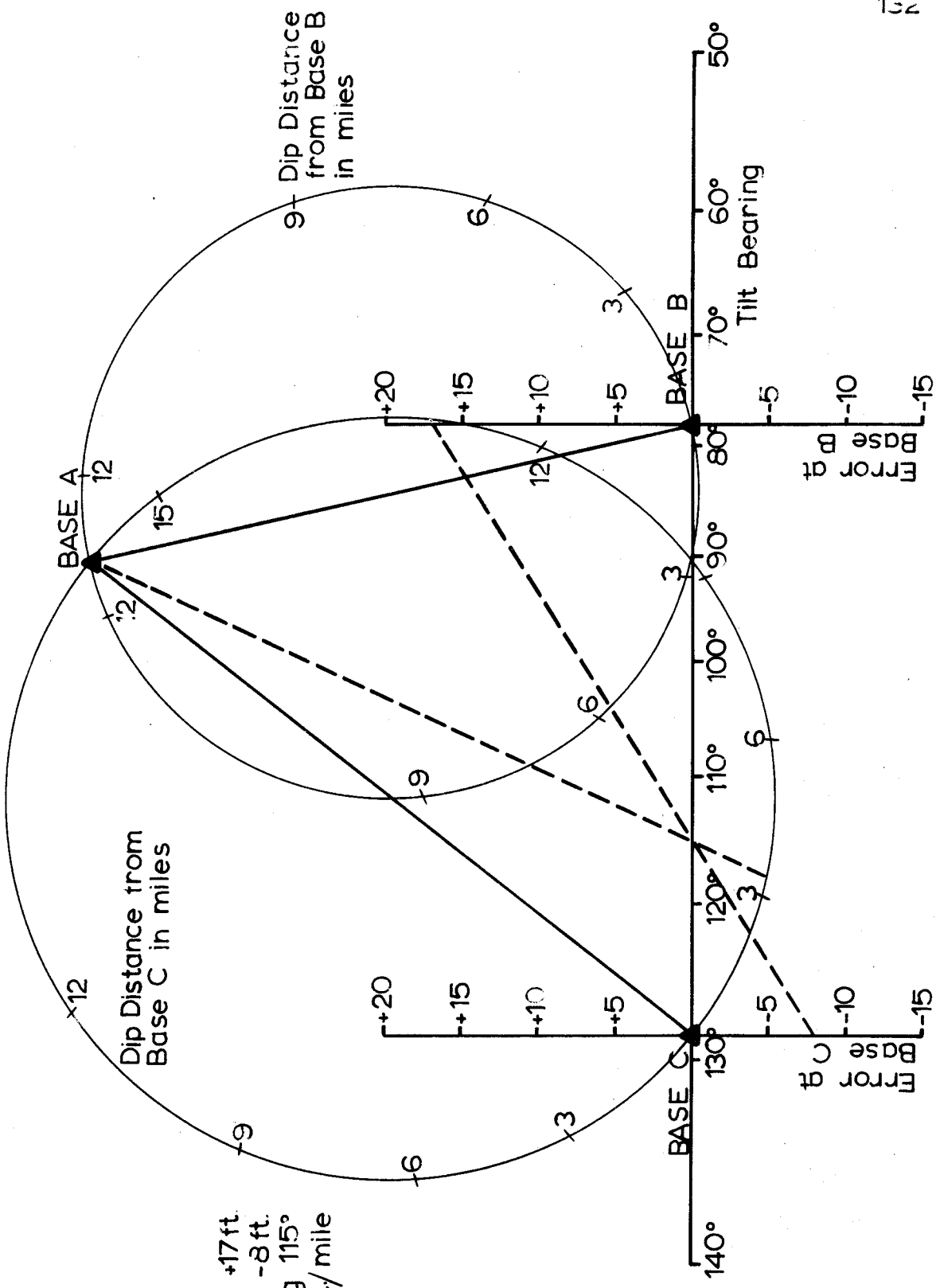
A  $360^{\circ}$  Protractor is then placed over station A with its zero east. The  $10^{\circ}$  Divisions are then projected onto the line BC giving the tilt bearing. An auxiliary scale is then drawn to divide the error by the tilt distance to give the tilt in feet per mile.

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<sup>5</sup>

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.<sup>24, 51</sup> 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,<sup>24</sup> is:

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

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<sup>3, 5, 32</sup>

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.<sup>3,56</sup> 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:

$$\begin{aligned} R &= \frac{M_a R_a + M_{wv} R_{wv}}{M_a + M_{wv}} \\ &= \frac{R_a + R_{wv} \cdot \omega}{1 + \omega} \end{aligned}$$

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

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



The Equation of State may also be written as:

$$PV = R_a T_v$$

where  $T_v$  is the virtual temperature.

Thus

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

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

$$\text{but } \frac{R_{wv}}{R_a} = \frac{M_{wv}}{M_a} = \frac{28.97}{18.02} \doteq 1.61$$

whence

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

$$\doteq T (t + 0.61 \omega) \text{ since } \omega < 0.03$$

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

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

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

If the increase in temperature is denoted as  $\Delta T$  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<sup>32</sup> that the saturation vapour pressure in millibars may be calculated using the formula.

$$\begin{aligned} \log P_w = & - 7.90298 \left( \frac{T}{T_s} - 1 \right) + 5.02808 \log \frac{T}{T_s} \\ & - 1.3816 \times 10^{-7} \left( 10^{11.344 (1 - T/T_s)} - 1 \right) \\ & + 8.1328 \times 10^{-3} \left( 10^{-3.49149 (T_s/T - 1)} - 1 \right) \\ & + \log 1013.246. \end{aligned}$$

### 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

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

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.

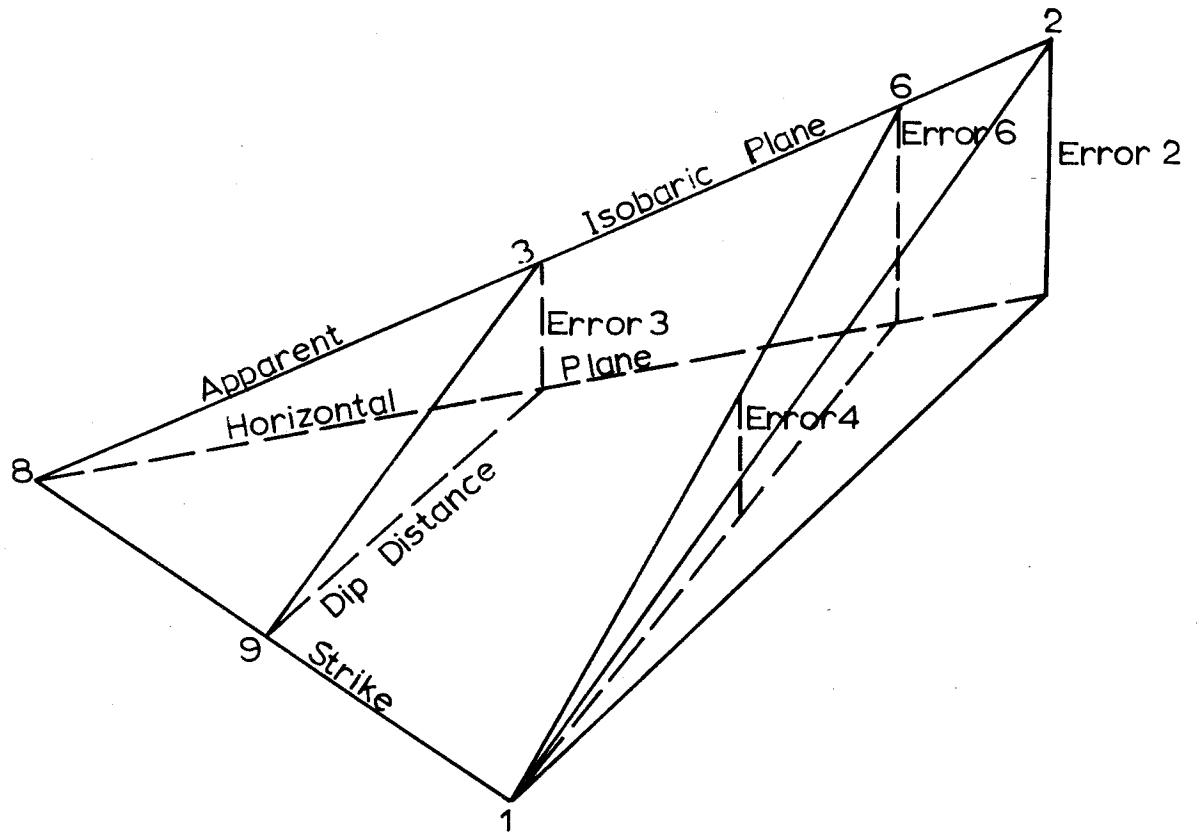


FIG. 6.3 GEOMETRIC RELATIONSHIP OF APPARENT ISOBARIC PLANE TO HORIZONTAL PLANE.

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

whence

$$X_6 = \frac{BX_2 - Y_2}{B - A} \quad \dots\dots\dots (2)$$

$$\text{and } Y_6 = AX_6$$

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

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

denoting the RHS as E, then

$$\text{Error 6} = \text{Error 2} - E32.E.$$

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.

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

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

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

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.

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

whence

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

and

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

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

$$\begin{aligned} \text{Dip Distance} &= \frac{X_3 \frac{Y_8}{X_8} - Y_3}{\sqrt{1 + \left(\frac{Y_8}{X_8}\right)^2}} \\ &= \frac{\omega X_3 - Y_3}{1 + \omega^2} \quad \dots\dots\dots (5) \end{aligned}$$

where

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

The tilt per mile is then given by:

$$\text{Tilt} = \frac{\text{Error 3}}{\text{Distance}} \quad \dots\dots\dots (6)$$

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  $C_2$ ,



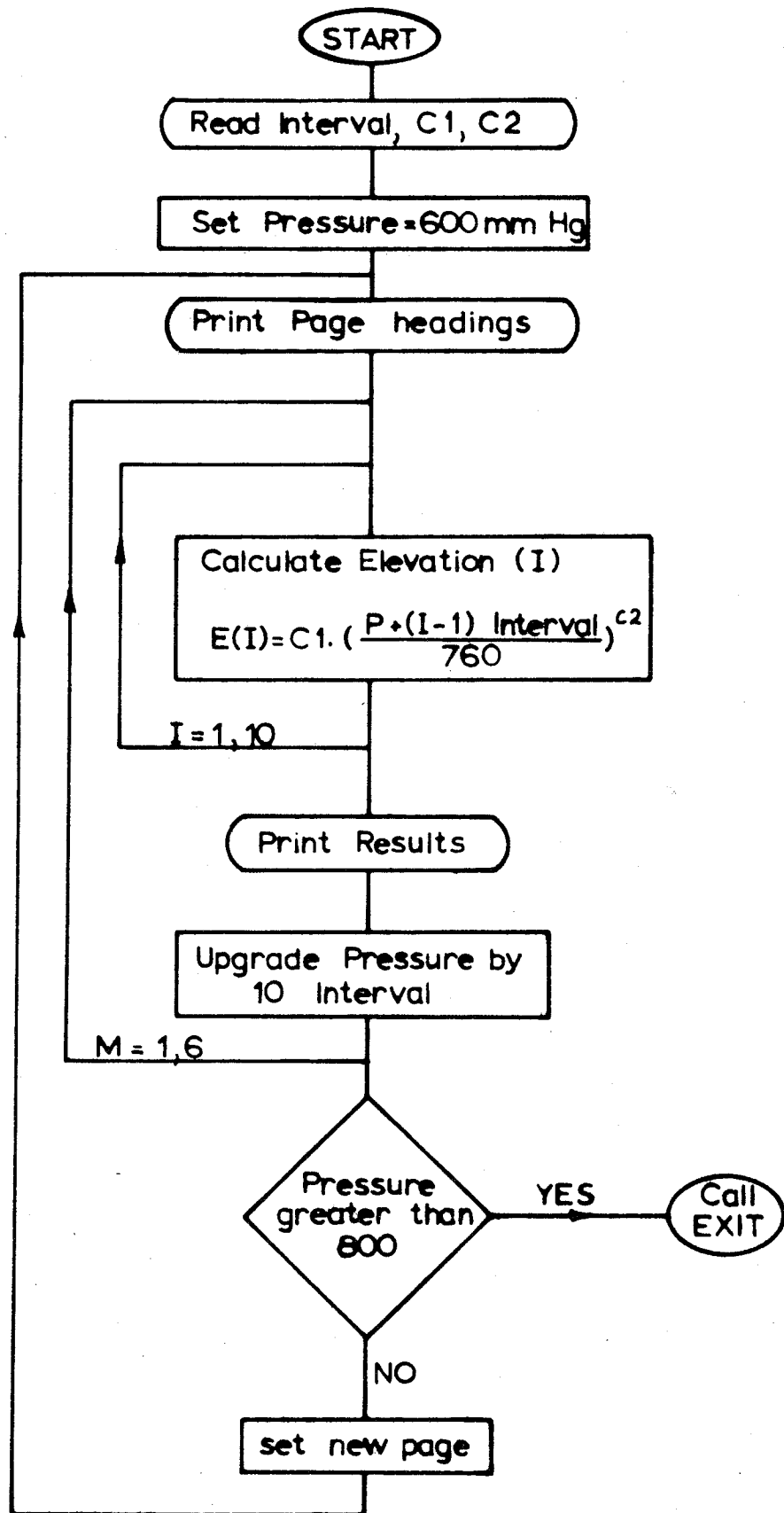


FIG. 6.4 FLOW CHART FOR SVY 12 STANDARD ATMOSPHERE PROGRAMME.

- (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.

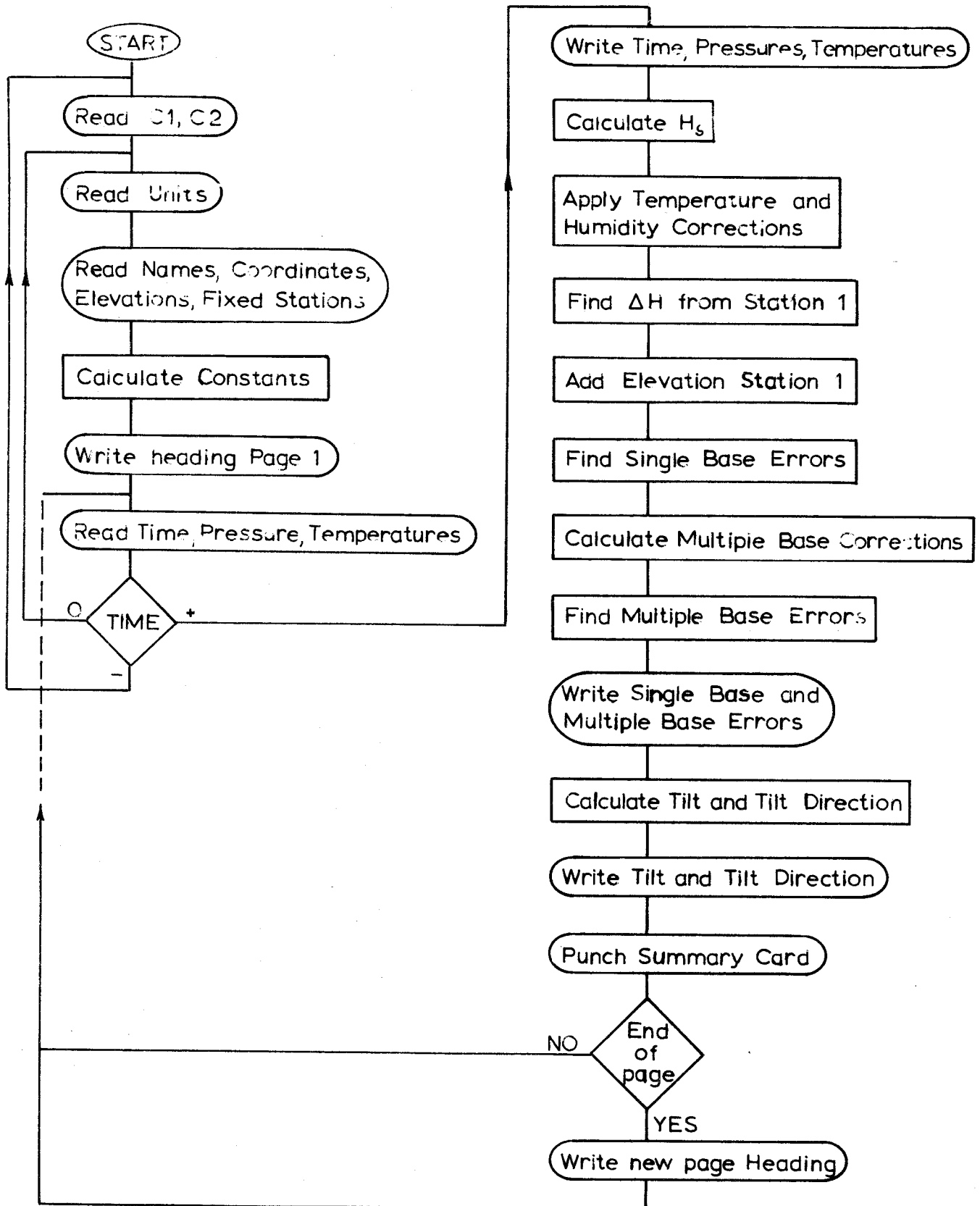


FIG. 6.5 FLOW CHART FOR SVY 14 - ISOBARIC SURFACE INVESTIGATION PROGRAMME.

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

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

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

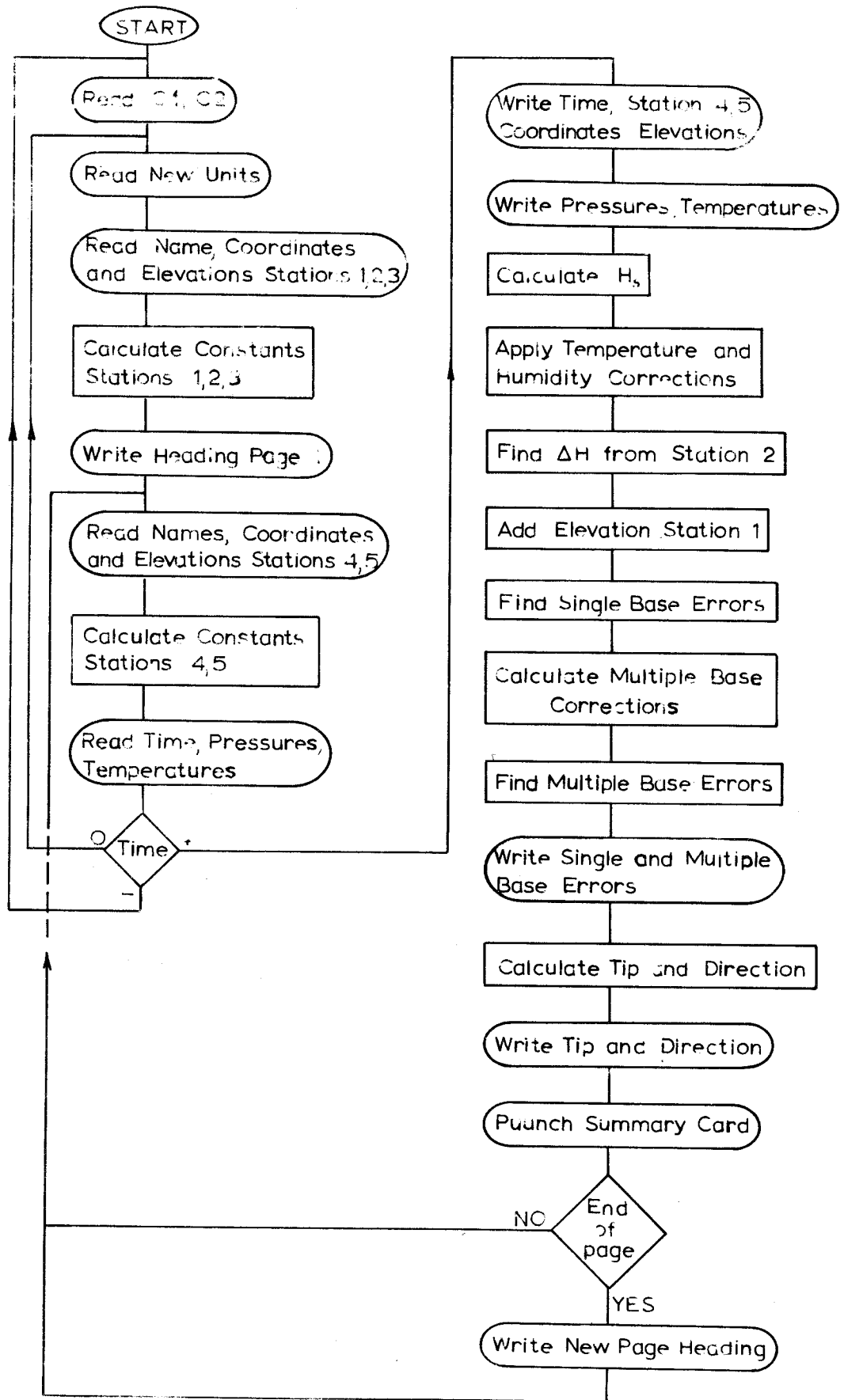


FIG. 5.6 FLOW CHART FOR SVY 19 BAROMETER TRAVERSE REDUCTION PROGRAM.ME.

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 optimum 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.

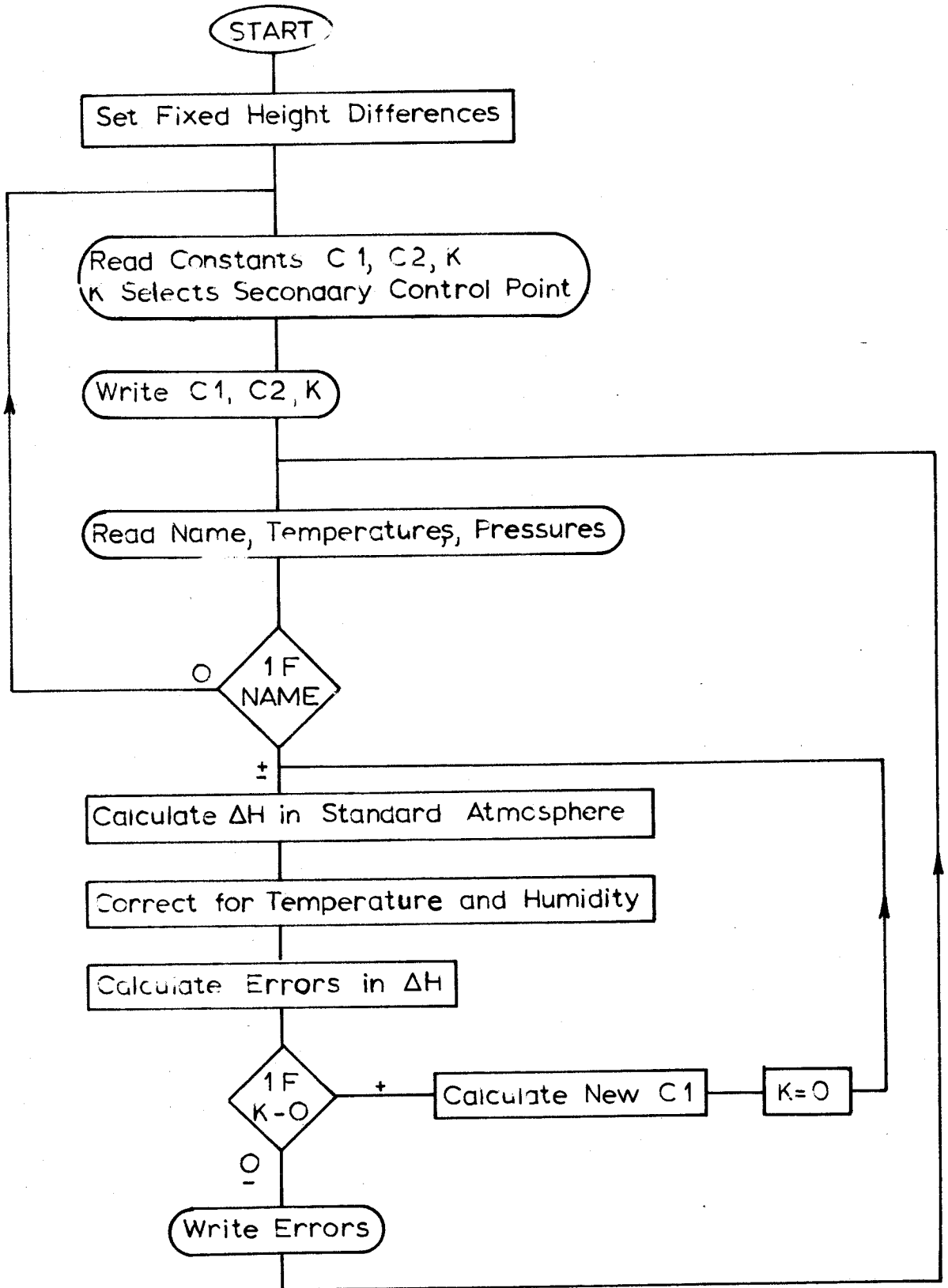


FIG.6.7 FLOW CHART FOR SVY 24 TOWER REDUCTION PROGRAMME

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.<sup>6</sup>

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



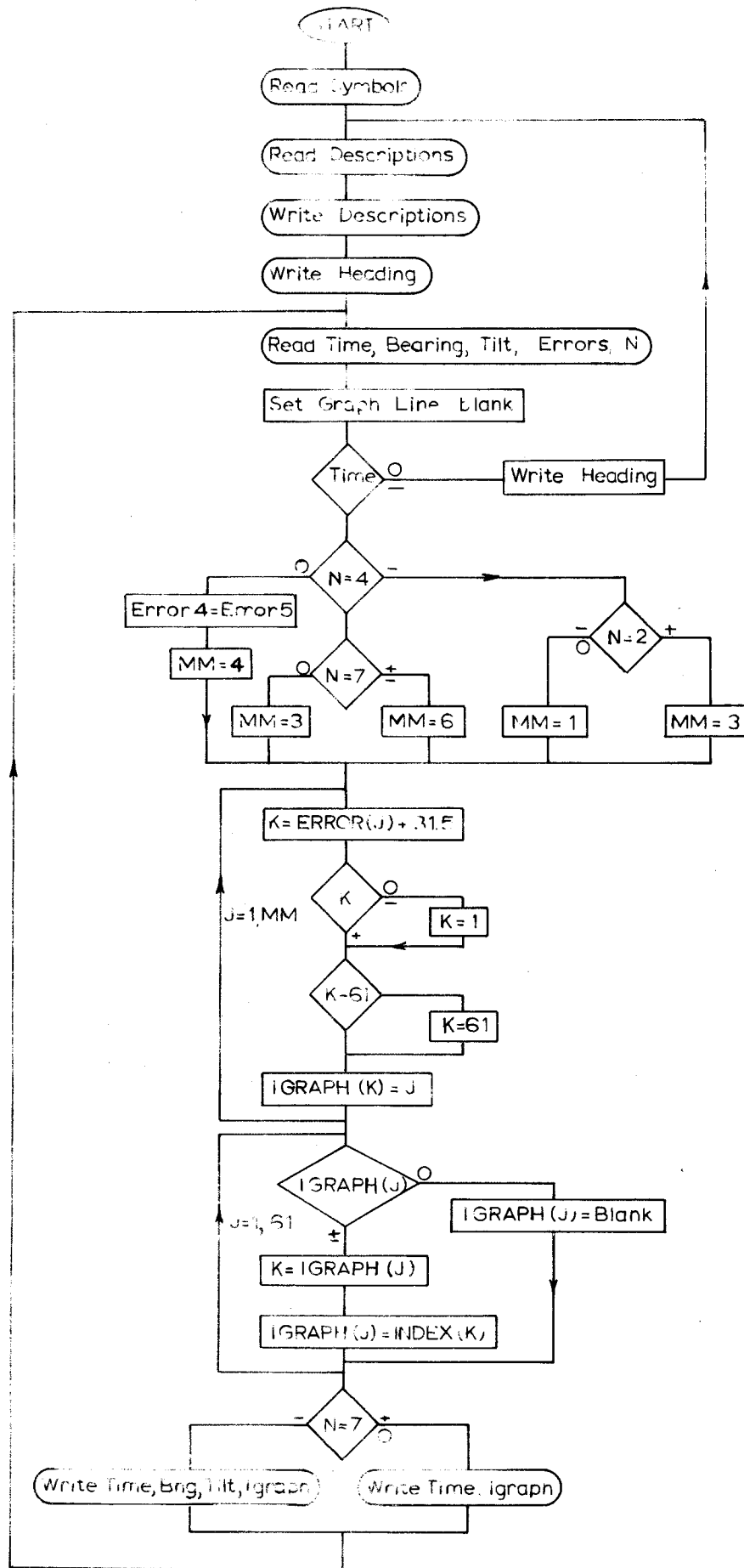


FIG 5.8 FLOW CHART FOR SVY 16 AUTOMATIC GRAPHING PROGRAMME

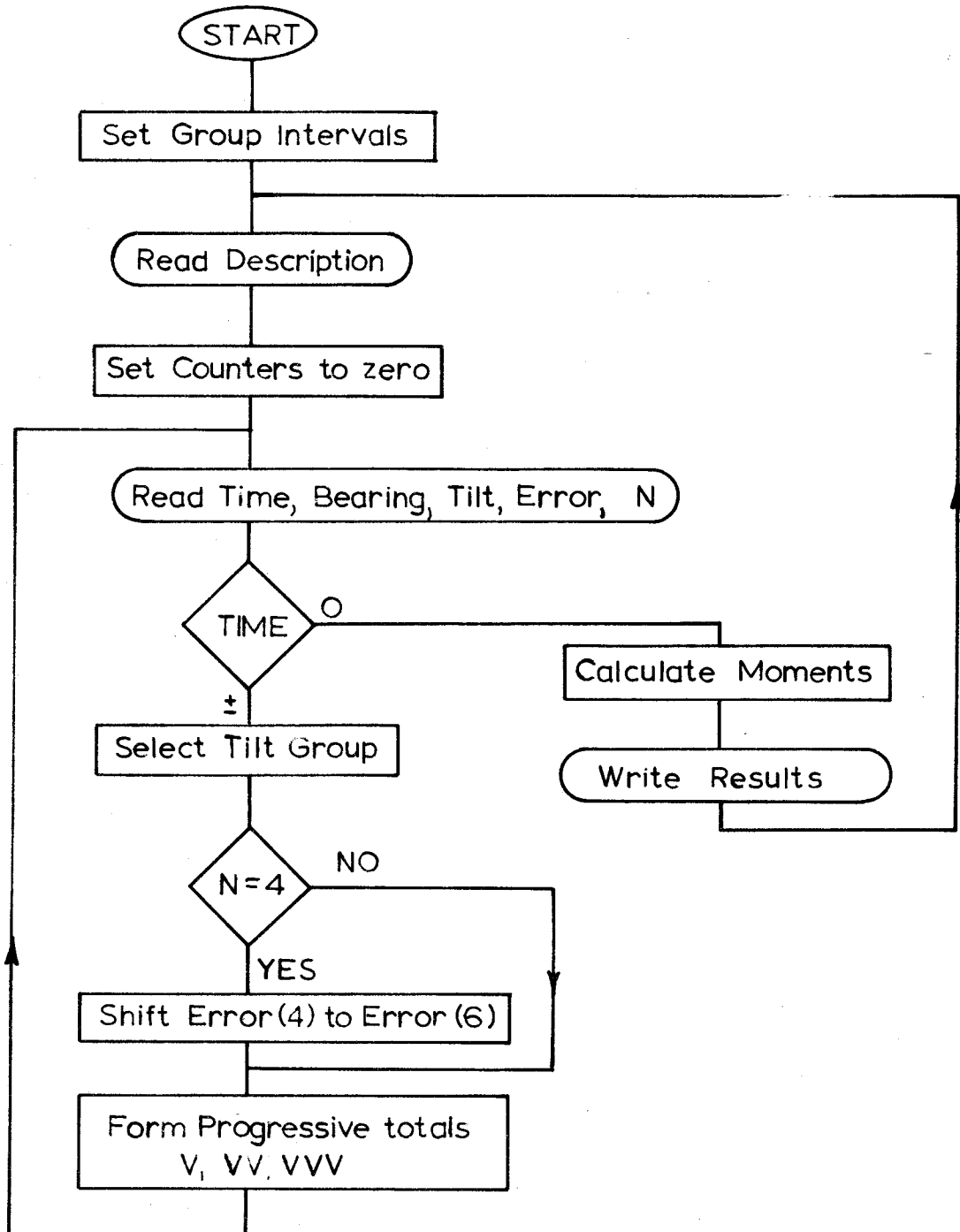


FIG. 6.9 FLOW CHART FOR SVY 26 ANALYSIS OF SUMMARIES PROGRAMME.

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

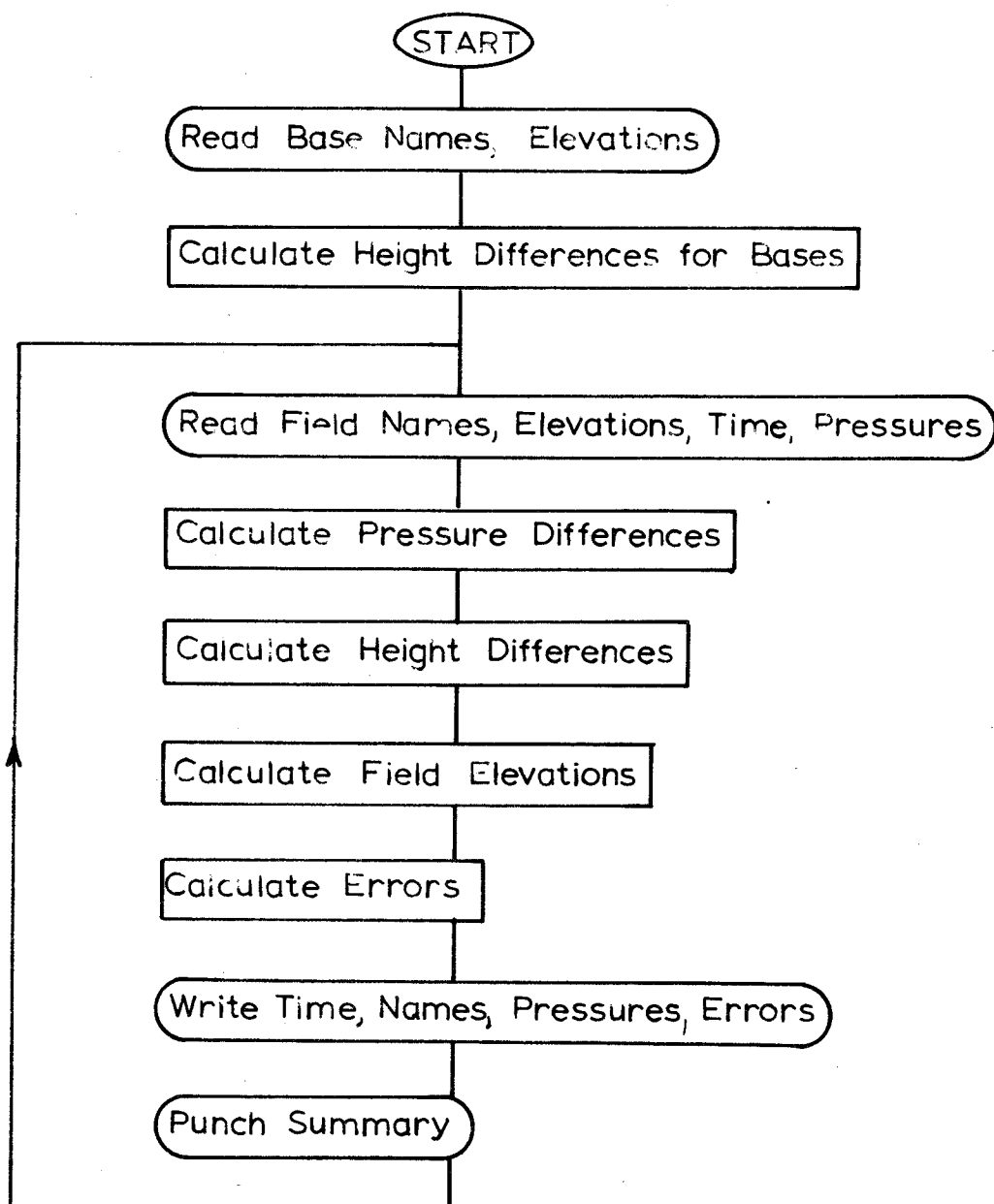


FIG. 6.10 FLOW CHART FOR SVY 42  
TWO BASE BAROMETER REDUCTION  
PROGRAMME.

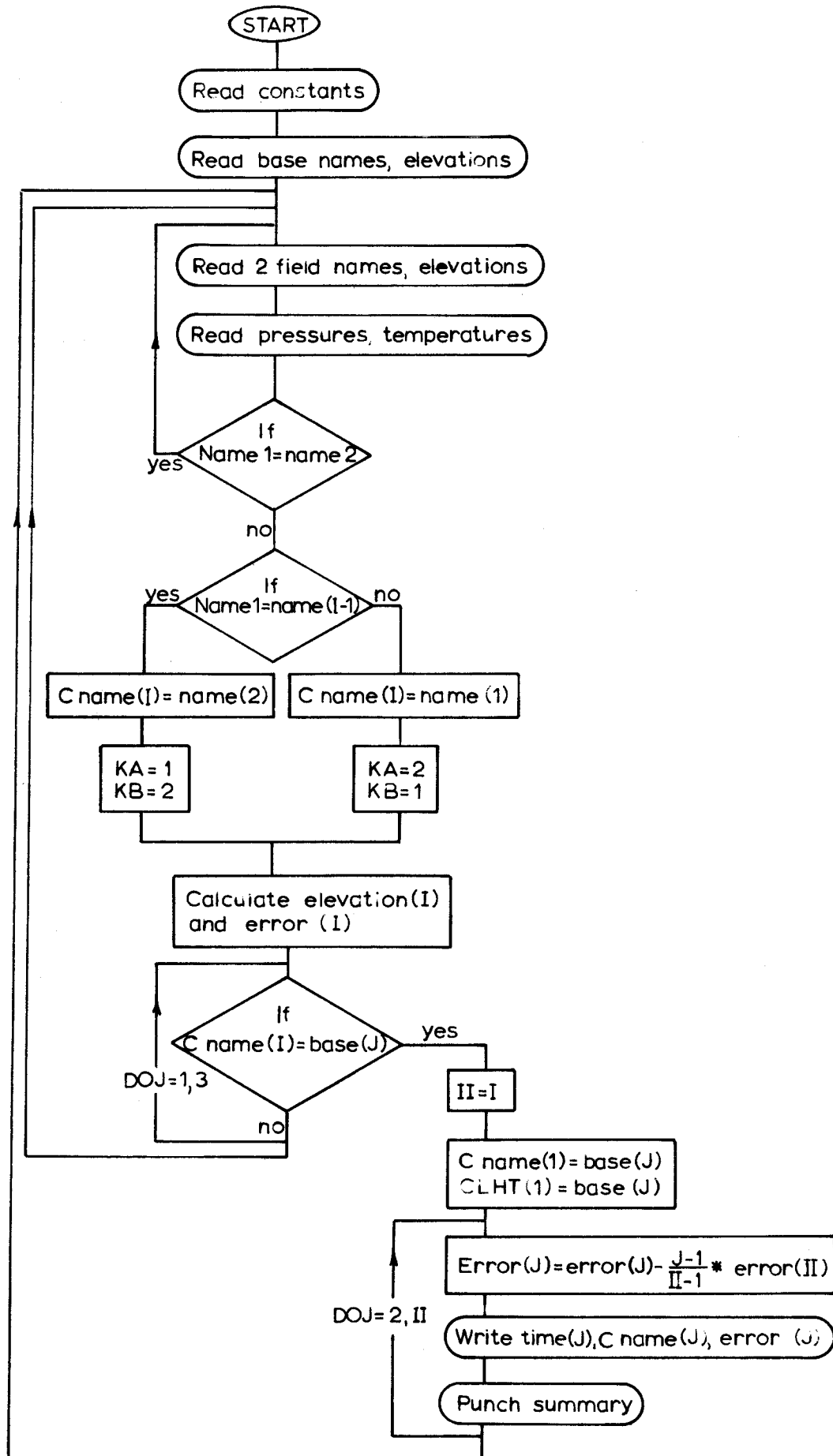


FIG. 6.11 FLOW CHART FOR SVY 43 LEAP FROG REDUCTION PROGRAMME.

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.

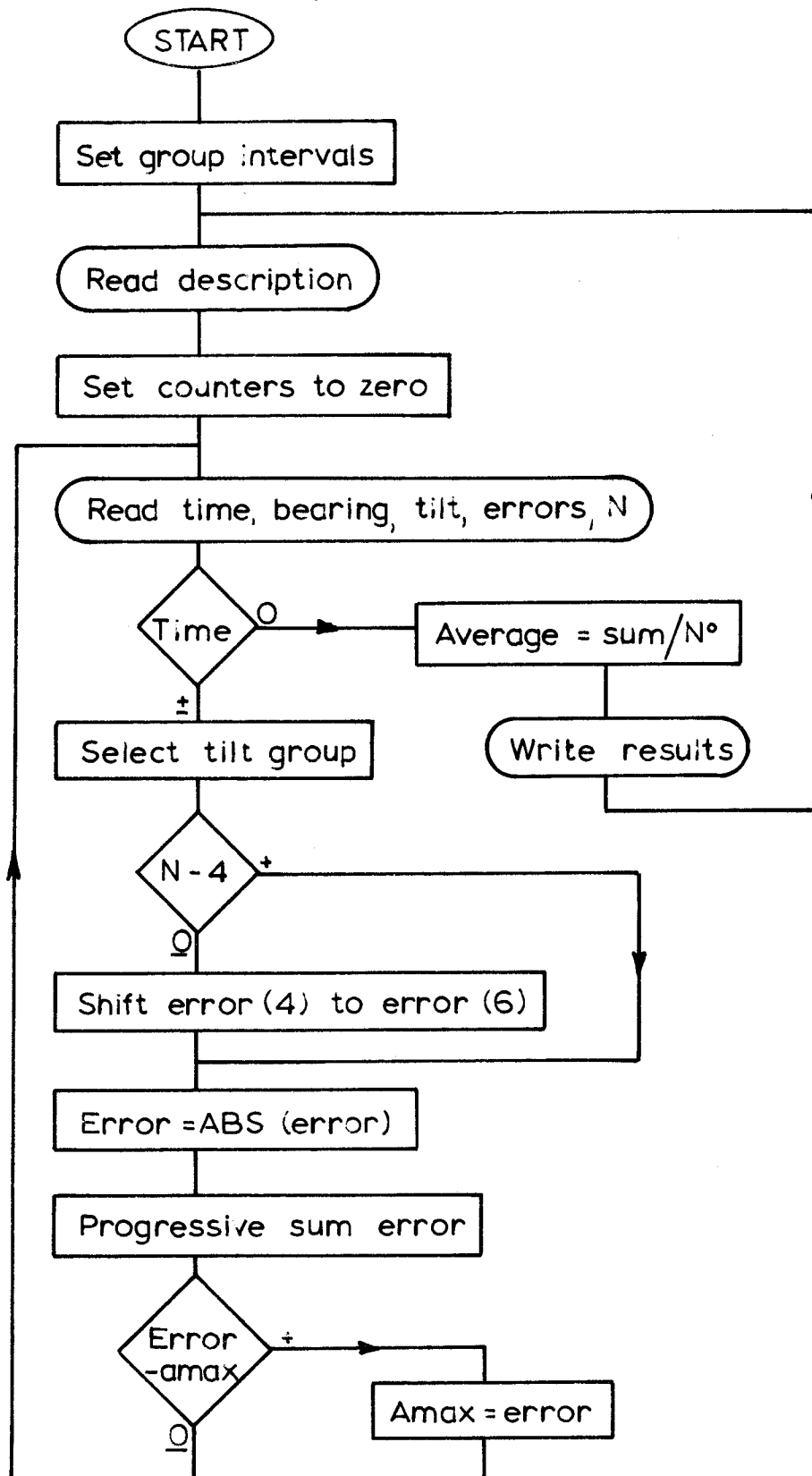


FIG. 6.12 ANALYSIS OF SUMMARIES PROGRAMME 2, SVY 46

## 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.

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APPENDIX I

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

MM PRES	E L E V A T I O N									A.S.A.		
	.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	6253.3	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.	5601.3	5597.1	5593.0	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 PRES	E L E V A T I O N									A.S.A.		
	.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	4443.0	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	4096.8	4092.8	4088.8	4084.7	4080.7	4076.6	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	3846.6	3842.6	3838.6	3834.5	3830.5		
659.	3826.6	3822.6	3818.6	3814.6	3810.5	3806.5	3802.5	3798.5	3794.5	3790.5		

MM PRES	°0	°1	°2	°3	E L E V A T I O N °4	°5	°6	°7	°8	A.S.A. °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	3738.4	3734.4	3730.4	3726.4	3722.4	3718.4	3714.4	3710.4
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	3622.3	3618.3	3614.3	3610.3	3606.3	3602.3	3598.3	3594.3	3590.3
665	3586.4	3582.4	3578.4	3574.4	3570.4	3566.4	3562.4	3558.4	3554.4	3550.4
666	3546.6	3542.6	3538.6	3534.6	3530.6	3526.6	3522.6	3518.6	3514.6	3510.6
667	3506.8	3502.8	3498.8	3494.8	3490.8	3486.8	3482.8	3478.8	3474.8	3470.8
668	3467.0	3463.0	3459.0	3455.0	3451.0	3447.0	3443.0	3439.0	3435.0	3431.0
669	3427.3	3423.3	3419.3	3415.3	3411.3	3407.3	3403.3	3399.3	3395.3	3391.3
670	3387.6	3383.6	3379.6	3375.6	3371.6	3367.6	3363.6	3359.6	3355.6	3351.6
671	3348.5	3344.5	3340.5	3336.5	3332.5	3328.5	3324.5	3320.5	3316.5	3312.5
672	3308.9	3304.9	3300.9	3296.9	3292.9	3288.9	3284.9	3280.9	3276.9	3272.9
673	3268.5	3264.5	3260.5	3256.5	3252.5	3248.5	3244.5	3240.5	3236.5	3232.5
674	3229.5	3225.5	3221.5	3217.5	3213.5	3209.5	3205.5	3201.5	3197.5	3193.5
675	3190.0	3186.0	3182.0	3178.0	3174.0	3170.0	3166.0	3162.0	3158.0	3154.0
676	3150.7	3146.7	3142.7	3138.7	3134.7	3130.7	3127.7	3123.7	3119.7	3115.7
677	3111.3	3107.3	3103.3	3099.3	3095.3	3091.3	3087.3	3083.3	3079.3	3075.3
678	3072.1	3068.1	3064.1	3060.1	3056.1	3052.1	3048.1	3044.1	3040.1	3036.1
679	3032.8	3028.8	3025.8	3021.8	3017.8	3013.8	3009.8	3005.8	3001.8	2997.8
680	2993.6	2989.6	2985.6	2981.6	2978.6	2974.6	2970.6	2966.6	2962.6	2958.6
681	2954.5	2950.5	2946.5	2942.5	2938.5	2935.5	2931.5	2927.5	2923.5	2919.5
682	2915.4	2911.4	2907.4	2903.4	2899.4	2895.4	2892.4	2888.4	2884.4	2880.4
683	2876.3	2872.3	2868.3	2864.3	2860.3	2856.3	2853.3	2849.3	2845.3	2841.3
684	2837.3	2833.3	2829.3	2825.3	2821.3	2817.3	2814.3	2810.3	2806.3	2802.3
685	2798.4	2794.4	2790.4	2786.4	2782.4	2778.4	2775.4	2771.4	2767.4	2763.4
686	2759.5	2755.5	2751.5	2747.5	2743.5	2740.5	2736.5	2732.5	2728.5	2724.5
687	2720.6	2716.6	2712.6	2708.6	2705.6	2701.6	2697.6	2693.6	2689.6	2685.6
688	2681.7	2677.7	2673.7	2670.7	2666.7	2662.7	2658.7	2654.7	2650.7	2646.7
689	2643.0	2639.0	2635.0	2631.0	2627.0	2623.0	2619.0	2615.0	2611.0	2608.0

MM PRES	.0	.1	.2	.3	.4	E L E V A T I O N				.6	.7	.8	A.S.A.	.9
690.	2604.3	2600.4	2596.5	2592.7	2588.8	2584.9	2581.1	2577.2	2573.3	2569.5	2565.6	2561.7	2557.8	2553.9
691.	2565.6	2561.8	2557.9	2554.0	2550.2	2546.3	2542.4	2538.6	2534.7	2530.8	2526.9	2523.0	2519.1	2515.2
692.	2488.0	2484.1	2480.3	2476.4	2472.5	2468.6	2464.7	2460.8	2456.9	2453.0	2449.1	2445.2	2441.3	2437.4
693.	2449.8	2446.0	2442.1	2438.3	2434.4	2430.6	2426.7	2422.9	2419.0	2415.2	2411.3	2407.4	2403.5	2399.6
694.	2411.3	2407.5	2403.6	2399.8	2395.9	2392.1	2388.3	2384.4	2380.6	2376.7	2372.8	2368.9	2365.0	2361.1
695.	2372.9	2369.0	2365.2	2361.4	2357.5	2353.6	2349.8	2346.0	2342.1	2338.2	2334.3	2330.4	2326.5	2322.6
696.	2334.5	2330.6	2326.8	2323.0	2319.1	2315.2	2311.3	2307.4	2303.5	2299.6	2295.7	2291.8	2287.9	2284.0
697.	2296.1	2292.3	2288.4	2284.6	2280.8	2276.9	2273.1	2269.3	2265.4	2261.5	2257.6	2253.7	2249.8	2245.9
698.	2257.8	2254.0	2250.1	2246.3	2242.4	2238.5	2234.6	2230.7	2226.8	2222.9	2219.0	2215.1	2211.2	2207.3
699.	2219.5	2215.7	2211.9	2208.0	2204.2	2200.4	2196.6	2192.7	2188.9	2185.1	2181.2	2177.3	2173.4	2169.5
700.	2181.3	2177.5	2173.6	2169.8	2166.0	2162.2	2158.4	2154.5	2150.7	2146.8	2142.9	2139.0	2135.1	2131.2
701.	2143.1	2139.3	2135.5	2131.6	2127.8	2124.0	2120.2	2116.4	2112.5	2108.7	2104.8	2101.0	2097.1	2093.2
702.	2104.9	2101.1	2097.3	2093.5	2089.7	2085.9	2082.1	2078.3	2074.4	2070.6	2066.7	2062.8	2059.0	2055.1
703.	2066.8	2063.0	2059.2	2055.4	2051.6	2047.8	2044.0	2040.2	2036.3	2032.4	2028.5	2024.6	2020.7	2016.8
704.	2028.8	2025.0	2021.2	2017.4	2013.6	2009.8	2006.0	2002.2	1998.4	1994.6	1990.7	1986.8	1983.0	1979.1
705.	1990.8	1987.0	1983.2	1979.4	1975.6	1971.8	1968.0	1964.2	1960.4	1956.6	1952.7	1948.8	1945.0	1941.1
706.	1952.9	1949.1	1945.3	1941.5	1937.7	1933.9	1930.1	1926.3	1922.5	1918.7	1914.8	1911.0	1907.1	1903.2
707.	1914.0	1911.2	1907.4	1903.6	1899.8	1895.9	1892.1	1888.3	1884.5	1880.7	1876.8	1873.0	1869.1	1865.2
708.	1877.0	1873.2	1869.4	1865.6	1861.8	1857.9	1854.1	1850.3	1846.5	1842.7	1838.8	1835.0	1831.1	1827.2
709.	1839.1	1835.4	1831.6	1827.8	1824.0	1820.2	1816.4	1812.6	1808.8	1805.0	1801.1	1797.2	1793.3	1789.4
710.	1801.3	1797.6	1793.8	1790.0	1786.2	1782.4	1778.6	1774.8	1771.0	1767.2	1763.3	1759.4	1755.5	1751.6
711.	1763.6	1759.8	1756.0	1752.2	1748.4	1744.6	1740.8	1737.0	1733.2	1729.3	1725.4	1721.5	1717.6	1713.7
712.	1725.9	1722.1	1718.3	1714.5	1710.7	1706.9	1703.1	1699.3	1695.5	1691.7	1687.8	1684.0	1680.1	1676.2
713.	1688.2	1684.4	1680.6	1676.8	1673.0	1669.2	1665.4	1661.6	1657.8	1654.0	1650.1	1646.2	1642.3	1638.4
714.	1650.6	1646.8	1643.0	1639.2	1635.4	1631.6	1627.8	1624.0	1620.2	1616.4	1612.6	1608.8	1605.0	1601.1
715.	1613.0	1609.2	1605.4	1601.6	1597.8	1594.0	1590.2	1586.4	1582.6	1578.8	1575.0	1571.2	1567.4	1563.6
716.	1575.5	1571.7	1567.9	1564.1	1560.3	1556.5	1552.7	1548.9	1545.1	1541.3	1537.5	1533.7	1529.9	1526.1
717.	1538.0	1534.2	1530.4	1526.6	1522.8	1519.0	1515.2	1511.4	1507.6	1503.8	1499.9	1496.1	1492.3	1488.5
718.	1500.5	1496.7	1492.9	1489.1	1485.3	1481.5	1477.7	1473.9	1470.1	1466.3	1462.5	1458.7	1454.9	1451.1
719.	1463.0	1459.2	1455.4	1451.6	1447.8	1444.0	1440.2	1436.4	1432.6	1428.8	1425.0	1421.2	1417.4	1413.6

MM PRES	.0	.1	.2	.3	.4	E L E V A T I O N	.5	.6	.7	.8	.9
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.	1313.3	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	1043.2	1039.5	1035.8	1032.1	1028.4	1024.7	1021.0	
732.	1017.4	1013.7	1010.0	1006.3	1002.6	998.9	995.2	991.5	987.8	984.1	
733.	980.5	976.8	973.1	969.4	965.7	962.0	958.3	954.6	951.0	947.3	
734.	943.7	940.0	936.3	932.6	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.	870.5	866.8	862.1	858.4	854.7	851.0	847.3	843.6	840.0	836.3	
737.	833.8	829.1	825.4	821.7	818.0	814.3	810.6	807.0	803.3	799.6	
738.	796.2	792.5	788.8	785.1	781.4	777.7	774.1	770.4	766.7	763.0	
739.	760.2	756.5	752.8	749.1	745.4	741.7	738.0	734.3	730.6	727.0	
740.	723.6	719.9	716.2	712.5	708.8	705.1	701.4	697.7	694.0	690.3	
741.	687.0	683.3	679.6	676.0	672.3	668.6	665.0	661.3	657.6	654.0	
742.	650.5	646.8	643.1	639.4	635.7	632.0	628.3	624.6	621.0	617.3	
743.	614.0	610.3	606.6	603.0	599.3	595.6	592.0	588.3	584.6	581.0	
744.	577.6	574.0	570.3	566.6	563.0	559.3	555.6	552.0	548.3	544.6	
745.	541.2	537.6	533.9	530.3	526.7	523.0	519.4	515.8	512.1	508.5	
746.	504.5	501.2	497.6	494.0	490.3	486.7	483.1	479.4	475.8	472.2	
747.	468.3	464.7	461.3	457.7	454.0	450.4	446.8	443.2	439.5	435.9	
748.	432.0	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	

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	323.0	320.0	316.5	312.9	309.2	305.6	302.0	298.4	294.8	291.2
752	287.5	284.0	280.4	276.8	273.1	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	125.5	122.0	118.4	114.8	111.2
757	107.6	104.0	100.4	96.8	93.2	89.6	86.0	82.4	78.8	75.2
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	25.0	28.6	32.2
761	35.5	39.1	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	214.6	217.3	221.0	224.3	228.3	231.7	235.0	239.0	242.8	246.5
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	306.5	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	472.8	476.4	479.9	483.5	487.0	490.6	494.1
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	585.5	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	631.1	634.6
778	638.2	641.6	645.2	648.7	652.1	655.7	659.1	662.7	666.1	669.7
779	673.3	676.6	680.0	683.3	687.7	691.1	694.4	697.8	701.1	704.8



MM 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.	-743.3	-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	-806.3	-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.	-952.0	-955.6	-959.1	-962.6	-966.1	-970.0	-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.	-1126.8	-1130.2	-1133.6	-1137.1	-1140.5	-1143.9	-1147.3	-1150.7	-1154.1	-1157.5
793.	-1160.8	-1164.2	-1167.6	-1171.1	-1174.6	-1178.1	-1181.5	-1184.9	-1188.3	-1191.7
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	-1624.4	-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.

26th May, 1959	178.
28th May, 1959	190.
28th February, 1966	203.
1st March, 1966	216.

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

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

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

CITY TRAVERSE REDUCTION 26 MAY 1959 ASA

ST PAULS	LIVERPOOL	CENTENNIAL	BEVERLY HILL	RYDE
TIME 1000	29.883	30.362	30.487	30.399
PRESSURE	60.0	60.0	72.0	0.0
TEMP DRY	60.0	60.0	72.0	0.0
SINGLE BASE	12.3	10.9	MULTIPLE	BASE
ERRORS	4.5	TILT/MILE	-2.6	ERRORS
DIP BEARING	122.2 DEG	0.99 FEET		7.8
TIME 1005	29.883	30.364	30.488	30.404
PRESSURE	60.0	60.0	72.0	0.0
TEMP DRY	60.0	60.0	72.0	0.0
SINGLE BASE	10.3	6.1	MULTIPLE	BASE
ERRORS	3.3	TILT/MILE	-3.0	ERRORS
DIP BEARING	123.9 DEG	0.81 FEET		3.4
TIME 1010	29.888	30.364	30.488	30.404
PRESSURE	60.0	61.0	70.0	0.0
TEMP DRY	60.0	61.0	70.0	0.0
SINGLE BASE	14.9	10.7	MULTIPLE	BASE
ERRORS	7.9	TILT/MILE	-4.1	ERRORS
DIP BEARING	138.5 DEG	1.08 FEET		5.7
TIME 1015	29.890	30.365	30.489	30.403
PRESSURE	60.0	61.0	70.0	0.0
TEMP DRY	60.0	61.0	70.0	0.0
SINGLE BASE	15.7	13.5	MULTIPLE	BASE
ERRORS	8.9	TILT/MILE	-5.2	ERRORS
DIP BEARING	146.0 DEG	1.13 FEET		7.6

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 13.5			MULTIPLE BASE	ERRORS 10.5
DIP BEARING 148.4 DEG	12.0	15.7	-0.5	
		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 15.6			MULTIPLE BASE	ERRORS 13.0
DIP BEARING 131.6 DEG	12.1	17.7	1.0	
		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 18.7			MULTIPLE BASE	ERRORS 13.3
DIP BEARING 131.3 DEG	14.4	18.9	1.0	
		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 18.5			MULTIPLE BASE	ERRORS 17.5
DIP BEARING 133.1 DEG	13.1	23.3	-0.5	
		TILT/MILE 1.38 FEET		

CITY TRAVERSE REDUCTION 26 MAY 1959 ASA

ST PAULS	LIVERPOOL	CENTENNIAL	BEVERLY HILL	RYDE
TIME 1110	29.884	30.546	30.481	30.387
PRESSURE	61.0	65.0	72.0	0.0
TEMP DRY	ERRORS	9.2	MULTIPLE BASE	ERRORS
SINGLE BASE	16.5	21.2	-1.8	16.5
0.6		TILT/MILE		
DIP BEARING	128.2 DEG	1.26 FEET		

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

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

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

CITY TRAVERSE REDUCTION 26 MAY 1959 ASA

ST PAULS	LIVERPOOL	CENTENNIAL	BEVERLY HILL	RYDE
TIME 1200	29.873	30.357	30.475	30.388
PRESSURE	62.0	63.0	72.0	0.0
TEMP DRY	ERRORS 5.3		MULTIPLE BASE	ERRORS 8.6
SINGLE BASE	-3.8	9.2	2.0	
DIP BEARING	103.3 DEG	TILT/MILE 0.55 FEET		

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

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

TIME 1215	29.868	30.357	30.475	30.385
PRESSURE	63.0	64.0	76.0	0.0
TEMP DRY	ERRORS -0.6		MULTIPLE BASE	ERRORS 8.0
SINGLE BASE	-8.4	5.8	2.4	
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	29.864	30.535	30.471	30.381
PRESSURE	63.0	62.0	72.0	0.0
TEMP DRY				
SINGLE BASE	-9.6	7.0	MULTIPLE	BASE
DIP BEARING	-2.3	TILT/MILE 0.55	FEET	5.5
	41.0 DEG			10.0
				ERRORS
				10.0
TIME 1245	29.860	30.534	30.465	30.382
PRESSURE	63.0	62.0	76.0	0.0
TEMP DRY				
SINGLE BASE	-13.7	1.4	MULTIPLE	BASE
DIP BEARING	-5.1	TILT/MILE 0.78	FEET	10.4
	30.9 DEG			6.1
				ERRORS
				6.1
TIME 1300	29.859	30.526	30.459	30.376
PRESSURE	62.0	63.0	75.0	0.0
TEMP DRY				
SINGLE BASE	-6.2	4.4	MULTIPLE	BASE
DIP BEARING	-1.6	TILT/MILE 0.35	FEET	9.2
	40.3 DEG			8.7
				ERRORS
				8.7
TIME 1305	29.857	30.525	30.457	30.376
PRESSURE	62.0	63.0	76.0	0.0
TEMP DRY				
SINGLE BASE	-7.7	4.0	MULTIPLE	BASE
DIP BEARING	-4.7	TILT/MILE 0.47	FEET	11.6
	13.8 DEG			7.7
				ERRORS
				7.7



CITY TRAVERSE REDUCTION 26 MAY 1959 ASA

ST PAULS	LIVERPOOL	CENTENNIAL	BEVERLY HILL	RYDE
TIME 1310	29.857	30.522	30.457	30.377
PRESSURE	62.0	63.0	75.0	0.0
TEMP DRY	ERRORS			
SINGLE BASE	-4.5	3.9		
DIP BEARING	175.6 DEG	TILT/MILE 0.36 FEET		
			MULTIPLE BASE	10.0
				ERRORS 6.3

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

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

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

CITY TRAVERSE REDUCTION 26 MAY 1959 ASA

ST PAULS	LIVERPOOL	CENTENNIAL	BEVERLY HILL	RYDE
TIME 1400	29.851	30.348	30.456	30.380
PRESSURE	62.0	63.0	78.0	0.0
TEMP DRY	ERRORS		MULTIPLE	BASE
SINGLE BASE	-8.1	-5.3	7.4	ERRORS
-6.0				-1.6
DIP BEARING 161.9 DEG	1.5	TILT/MILE 0.60 FEET		
TIME 1405	29.851	30.346	30.457	30.379
PRESSURE	64.0	63.0	78.0	0.0
TEMP DRY	ERRORS		MULTIPLE	BASE
SINGLE BASE	-6.7	-4.8	5.5	ERRORS
-6.6				-1.4
DIP BEARING 172.4 DEG	2.8	TILT/MILE 0.53 FEET		
TIME 1410	29.855	30.348	30.457	30.376
PRESSURE	64.0	63.0	78.5	0.0
TEMP DRY	ERRORS		MULTIPLE	BASE
SINGLE BASE	-4.7	1.7	5.1	ERRORS
-1.8				3.4
DIP BEARING 144.2 DEG	1.0	TILT/MILE 0.34 FEET		
TIME 1415	29.855	30.350	30.459	30.377
PRESSURE	63.0	62.0	78.0	0.0
TEMP DRY	ERRORS		MULTIPLE	BASE
SINGLE BASE	-6.1	1.4	4.3	ERRORS
-1.1				3.3
DIP BEARING 134.4 DEG	0.3	TILT/MILE 0.45 FEET		

CITY TRAVERSE REDUCTION 26 MAY 1959 ASA

ST PAULS	LIVERPOOL	CENTENNIAL	BEVERLY HILL	RYDE
TIME 1430				
PRESSURE 29.862		30.351	30.459	30.384
TEMP DRY 62.0		62.0	77.0	0.0
SINGLE BASE ERRORS 0.2			MULTIPLE BASE	ERRORS 0.2
DIP BEARING 8.1		7.0	2.1	2.0
		TILT/MILE 0.49	FEET	

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

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

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

CITY TRAVERSE REDUCTION 26 MAY 1959 ASA

ST PAULS	LIVERPOOL	CENTENNIAL	BEVERLY HILL	RYDE
TIME 1510	29.869	30.516	30.461	30.382
PRESSURE	64.0	66.0	75.0	0.0
TEMP DRY				
SINGLE BASE				
11.7	8.4	10.4		
DIP BEARING	7.1 DEG	TILT/MILE 0.77 FEET	MULTIPLE BASE	ERRORS 5.3
			-0.9	
TIME 1515	29.870	30.516	30.461	30.380
PRESSURE	64.0	65.5	72.0	0.0
TEMP DRY				
SINGLE BASE				
13.6	11.0	13.4		
DIP BEARING	2.0 DEG	TILT/MILE 0.94 FEET	MULTIPLE BASE	ERRORS 7.6
			-1.9	
TIME 1530	29.872	30.515	30.460	30.380
PRESSURE	63.0	63.0	72.0	0.0
TEMP DRY				
SINGLE BASE				
17.7	13.8	17.4		
DIP BEARING	3.5 DEG	TILT/MILE 1.20 FEET	MULTIPLE BASE	ERRORS 8.7
			-2.1	
TIME 1545	29.873	30.515	30.457	30.380
PRESSURE	62.0	64.0	71.0	0.0
TEMP DRY				
SINGLE BASE				
18.6	15.5	21.1		
DIP BEARING	0.6 DEG	TILT/MILE 1.31 FEET	MULTIPLE BASE	ERRORS 8.9
			-0.1	

CITY TRAVERSE REDUCTION 26 MAY 1959 ASA

ST PAULS	LIVERPOOL	CENTENNIAL	BEVERLY HILL	RYDE
TIME 1600	29.870	30.518	30.346	30.378
PRESSURE	61.0	64.0	61.0	68.0
TEMP DRY	ERRORS			
SINGLE BASE	14.8	19.6	17.8	MULTIPLE BASE
DIP BEARING	172.3 DEG		TILT/MILE 1.16 FEET	1.3
				ERRORS
				10.3

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

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

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

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 22.0	23.7	23.4	MULTIPLE BASE	ERRORS 12.6
DIP BEARING 168.8 DEG		TILT/MILE 1.68 FEET	-2.4	
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 26.0	23.2	24.6	MULTIPLE BASE	ERRORS 12.6
DIP BEARING 163.3 DEG		TILT/MILE 1.92 FEET	-5.7	
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 26.8	21.7	22.9	MULTIPLE BASE	ERRORS 11.3
DIP BEARING 158.3 DEG		TILT/MILE 1.95 FEET	-6.4	

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

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

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

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 21.4	13.2	12.9	MULTIPLE BASE	0.0
DIP BEARING 153.5 DEG		TILT/MILE 1.54 FEET	-8.0	ERRORS 4.1
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 14.2	14.3	12.1	MULTIPLE BASE	0.0
DIP BEARING 162.6 DEG		TILT/MILE 1.38 FEET	-6.3	ERRORS 3.6
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 11.5	16.0	10.3	MULTIPLE BASE	0.0
DIP BEARING 157.2 DEG		TILT/MILE 1.29 FEET	-2.3	ERRORS 2.7
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 13.4	13.6	15.1	MULTIPLE BASE	0.0
DIP BEARING 165.4 DEG		TILT/MILE 1.22 FEET	-5.0	ERRORS 7.4



CITY TRAVERSE REDUCTION 28 MAY 1959 ASA

ST PAULS	LIVERPOOL	CENTENNIAL	BEVERLY HILL	RYDE
TIME 1005	29.788	30.441	30.388	30.299
PRESSURE	0.0	0.0	64.0	0.0
TEMP DRY	ERRORS	56.0	MULTIPLE BASE	ERRORS
SINGLE BASE	16.7	17.3	-8.1	9.7
DIP BEARING	162.9 DEG	10.4	TILT/MILE	1.24 FEET

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

TIME 1015	29.784	30.264	30.390	30.298
PRESSURE	0.0	58.0	66.0	0.0
TEMP DRY	ERRORS	12.8	MULTIPLE BASE	ERRORS
SINGLE BASE	11.5	3.0	-7.6	8.4
DIP BEARING	148.0 DEG	10.3	TILT/MILE	0.83 FEET

TIME 1030	29.779	30.260	30.379	30.296
PRESSURE	0.0	59.0	68.0	0.0
TEMP DRY	ERRORS	8.9	MULTIPLE BASE	ERRORS
SINGLE BASE	9.5	6.9	-0.9	5.7
DIP BEARING	139.6 DEG	12.7	TILT/MILE	0.69 FEET

CITY TRAVERSE REDUCTION 28 MAY 1959 ASA

ST PAULS	LIVERPOOL	CENTENNIAL	BEVERLY HILL	RYDE
TIME 1045	29.776	30.435	30.373	30.294
PRESSURE	0.0	59.0	71.0	0.0
TEMP DRY	7.1	6.5	MULTIPLE	BASE
SINGLE BASE	1.6	7.8	2.2	4.1
DIP BEARING	136.7 DEG	TILT/MILE 0.52 FEET		ERRORS
TIME 1100	29.768	30.424	30.367	30.288
PRESSURE	0.0	60.0	73.0	0.0
TEMP DRY	3.2	4.4	MULTIPLE	BASE
SINGLE BASE	2.6	3.3	0.8	1.8
DIP BEARING	165.9 DEG	TILT/MILE 0.24 FEET		ERRORS
TIME 1105	29.765	30.422	30.365	30.286
PRESSURE	0.0	60.0	73.0	0.0
TEMP DRY	1.0	3.1	MULTIPLE	BASE
SINGLE BASE	1.4	2.0	1.7	1.4
DIP BEARING	5.9 DEG	TILT/MILE 0.09 FEET		ERRORS
TIME 1110	29.762	30.419	30.363	30.283
PRESSURE	0.0	60.0	72.0	0.0
TEMP DRY	0.4	2.7	MULTIPLE	BASE
SINGLE BASE	1.9	2.5	1.8	2.1
DIP BEARING	71.0 DEG	TILT/MILE 0.13 FEET		ERRORS

CITY TRAVERSE REDUCTION 28 MAY 1959 ASA

ST PAULS	LIVERPOOL	CENTENNIAL	BEVERLY HILL	RYDE
TIME 1115	29.760	30.247	30.357	30.280
PRESSURE	0.0	60.0	72.0	0.0
TEMP DRY	2.6	3.1	MULTIPLE	BASE
SINGLE	1.2	TILT/MILE	3.8	ERRORS
BASE	24.6 DEG	0.15 FEET		2.1
DIP BEARING				

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

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

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

CITY TRAVERSE REDUCTION 28 MAY 1959 ASA

ST PAULS	LIVERPOOL	CENTENNIAL	BEVERLY HILL	RYDE
TIME 1205	29.725	30.219	30.334	30.244
PRESSURE	0.0	62.0	66.0	0.0
TEMP DRY	ERRORS	5.5	MULTIPLE	BASE
SINGLE	-1.1	TILT/MILE	-0.0	ERRORS
BASE	-3.8	0.28	FEET	6.8
DIP BEARING	139.6 DEG			
TIME 1210	29.723	30.216	30.330	30.239
PRESSURE	0.0	62.0	66.0	0.0
TEMP DRY	ERRORS	8.3	MULTIPLE	BASE
SINGLE	-0.2	TILT/MILE	0.7	ERRORS
BASE	-2.9	0.22	FEET	9.1
DIP BEARING	129.2 DEG			
TIME 1215	29.719	30.215	30.327	30.237
PRESSURE	0.0	62.0	65.0	0.0
TEMP DRY	ERRORS	6.8	MULTIPLE	BASE
SINGLE	0.3	TILT/MILE	1.5	ERRORS
BASE	-5.3	0.42	FEET	8.2
DIP BEARING	124.3 DEG			
TIME 1230	29.709	30.206	30.317	30.229
PRESSURE	0.0	63.0	66.0	0.0
TEMP DRY	ERRORS	3.9	MULTIPLE	BASE
SINGLE	-5.5	TILT/MILE	4.9	ERRORS
BASE	-7.1	0.53	FEET	7.1
DIP BEARING	163.3 DEG			

CITY TRAVERSE REDUCTION 28 MAY 1959 ASA

ST PAULS	LIVERPOOL	CENTENNIAL	BEVERLY HILL	RYDE	
TIME 1245	29.702	30.366	30.308	30.220	
PRESSURE	0.0	0.0	67.0	0.0	
TEMP DRY					
SINGLE BASE	ERRORS		MULTIPLE	BASE	ERRORS
-5.6	-9.5		6.6	8.3	
DIP BEARING	154.4 DEG				
		4.3			
		TILT/MILE	0.68	FEET	

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

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

TIME 1310	29.694	30.355	30.302	30.209	
PRESSURE	0.0	0.0	68.0	0.0	
TEMP DRY					
SINGLE BASE	ERRORS		MULTIPLE	BASE	ERRORS
-3.0	-4.2		-0.4	8.7	
DIP BEARING	161.1 DEG				
		6.9			
		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	-4.1	-5.8	6.8	MULTIPLE	0.0
DIP BEARING	164.6 DEG	164.6 DEG	TILT/MILE 0.38 FEET	-0.1	9.2
					ERRORS
					9.2
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	-3.4	5.8	4.1	MULTIPLE	0.0
DIP BEARING	176.2 DEG	176.2 DEG	TILT/MILE 0.26 FEET	9.9	5.8
					ERRORS
					5.8
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	-4.3	1.3	6.8	MULTIPLE	0.0
DIP BEARING	149.5 DEG	149.5 DEG	TILT/MILE 0.63 FEET	9.5	10.3
					ERRORS
					10.3
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	-5.2	-7.9	5.7	MULTIPLE	0.0
DIP BEARING	154.1 DEG	154.1 DEG	TILT/MILE 0.65 FEET	1.0	9.4
					ERRORS
					9.4

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 -4.9	-5.5	9.8	MULTIPLE BASE -1.2	ERRORS 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 -4.0	-2.7	9.8	MULTIPLE BASE -1.8	ERRORS 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 -5.9	-2.9	8.8	MULTIPLE BASE 0.9	ERRORS 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 -3.4	-0.3	11.3	MULTIPLE BASE 0.4	ERRORS 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	29.674	30.333	30.281	30.185
PRESSURE	0.0	68.0	67.0	0.0
TEMP DRY	ERRORS	61.0	MULTIPLE	BASE
SINGLE	-0.7	-3.5	10.9	0.0
BASE	133.5 DEG	TILT/MILE	0.35	FEET
DIP BEARING				ERRORS
				12.4
TIME 1500	29.678	30.335	30.284	30.192
PRESSURE	66.0	66.0	66.8	0.0
TEMP DRY	ERRORS	61.0	MULTIPLE	BASE
SINGLE	1.1	-2.7	8.2	-3.8
BASE	2.5 DEG	TILT/MILE	0.07	FEET
DIP BEARING				ERRORS
				7.7
TIME 1505	29.680	30.335	30.284	30.192
PRESSURE	66.0	0.0	67.0	0.0
TEMP DRY	ERRORS	61.0	MULTIPLE	BASE
SINGLE	3.0	-0.8	10.1	-4.3
BASE	176.3 DEG	TILT/MILE	0.22	FEET
DIP BEARING				ERRORS
				8.6
TIME 1510	29.681	30.334	30.283	30.193
PRESSURE	64.0	0.0	66.0	0.0
TEMP DRY	ERRORS	61.0	MULTIPLE	BASE
SINGLE	5.9	2.2	10.9	-4.2
BASE	4.1 DEG	TILT/MILE	0.40	FEET
DIP BEARING				ERRORS
				8.3



CITY TRAVERSE REDUCTION 28 MAY 1959 ASA

ST PAULS	LIVERPOOL	CENTENNIAL	BEVERLY HILL	RYDE
TIME 1515	29.681	30.335	30.165	30.281
PRESSURE	64.0	0.0	61.0	65.8
TEMP DRY	ERRORS	4.1	11.0	MULTIPLE BASE
SINGLE BASE	5.1	4.6	TILT/MILE	-1.9
DIP BEARING	177.7 DEG		0.37 FEET	ERRORS 8.5
TIME 1530	29.681	30.332	30.166	30.281
PRESSURE	60.0	63.0	63.5	65.8
TEMP DRY	ERRORS	4.9	10.8	MULTIPLE BASE
SINGLE BASE	8.7	4.2	TILT/MILE	-3.1
DIP BEARING	22.4 DEG		0.51 FEET	ERRORS 7.6
TIME 1545	29.686	30.333	30.167	30.281
PRESSURE	61.0	64.0	60.0	0.0
TEMP DRY	ERRORS	10.7	14.6	MULTIPLE BASE
SINGLE BASE	13.8	8.9	TILT/MILE	-3.3
DIP BEARING	11.3 DEG		0.87 FEET	ERRORS 8.9
TIME 1600	29.685	30.332	30.165	30.288
PRESSURE	60.0	61.0	60.0	0.0
TEMP DRY	ERRORS	4.9	12.3	MULTIPLE BASE
SINGLE BASE	15.3	11.1	TILT/MILE	-11.4
DIP BEARING	6.8 DEG		1.01 FEET	ERRORS 5.6

CITY TRAVERSE REDUCTION 28 MAY 1959 ASA

ST PAULS	LIVERPOOL	CENTENNIAL	BEVERLY HILL	RYDE
TIME 1605	29.683	30.163	30.283	30.200
PRESSURE	60.0	60.0	0.0	0.0
TEMP DRY	ERRORS		MULTIPLE BASE	ERRORS
SINGLE BASE	11.4	9.4	-6.4	3.6
DIP BEARING	175.0 DEG	7.5 TILT/MILE	0.87 FEET	
TIME 1610	29.686	30.162	30.286	30.200
PRESSURE	60.0	60.0	0.0	0.0
TEMP DRY	ERRORS		MULTIPLE BASE	ERRORS
SINGLE BASE	15.2	12.1	-10.9	4.5
DIP BEARING	174.9 DEG	7.5 TILT/MILE	1.16 FEET	
TIME 1615	29.686	30.159	30.288	30.200
PRESSURE	58.0	60.0	0.0	0.0
TEMP DRY	ERRORS		MULTIPLE BASE	ERRORS
SINGLE BASE	18.2	13.1	-15.8	3.8
DIP BEARING	173.1 DEG	6.9 TILT/MILE	1.43 FEET	
TIME 1630	29.685	30.156	30.290	30.198
PRESSURE	57.0	59.0	0.0	0.0
TEMP DRY	ERRORS		MULTIPLE BASE	ERRORS
SINGLE BASE	22.0	14.9	-21.4	3.9
DIP BEARING	175.3 DEG	5.2 TILT/MILE	1.67 FEET	

CITY TRAVERSE REDUCTION 28 MAY 1959 ASA

ST PAULS	LIVERPOOL	CENTENNIAL	BEVERLY HILL	RYDE
TIME 1645	29.683	30.327	30.291	30.198
PRESSURE	56.0	58.0	0.0	0.0
TEMP DRY	19.8	14.0	0.0	0.0
SINGLE BASE ERRORS	3.5	3.5	0.0	0.0
DIP BEARING 176.0 DEG	TILT/MILE 1.60 FEET		MULTIPLE BASE ERRORS 3.4	

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

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

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

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

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	25.0
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	982.67	984.63	973.17	
TEMP DRY	28.0	28.0	26.6	
TEMP WET	23.5	20.8	0.0	
SINGLE BASE ERRORS				MULTIPLE BASE ERRORS
16.3				-11.1
DIP BEARING 124.9 DEG	-13.0	TILT/MILE 0.69 FEET		
TIME 1100				
PRESSURE	982.59	984.48	973.09	
TEMP DRY	28.5	28.0	26.6	
TEMP WET	23.1	23.1	0.0	
SINGLE BASE ERRORS				MULTIPLE BASE ERRORS
11.9				-11.4
DIP BEARING 118.6 DEG	-16.6	TILT/MILE 0.72 FEET		
TIME 1105				
PRESSURE	982.52	984.42	973.01	
TEMP DRY	27.9	28.3	27.2	
TEMP WET	22.2	23.1	0.0	
SINGLE BASE ERRORS				MULTIPLE BASE ERRORS
9.0				-11.2
DIP BEARING 114.2 DEG	-19.3	TILT/MILE 0.79 FEET		
TIME 1110				
PRESSURE	982.47	984.36	972.96	
TEMP DRY	28.0	28.6	27.8	
TEMP WET	22.2	23.1	0.0	
SINGLE BASE ERRORS				MULTIPLE BASE ERRORS
12.5				-10.7
DIP BEARING 119.5 DEG	-15.4	TILT/MILE 0.71 FEET		

REDUCTION OF FIELD READINGS COOTAMUNDRA 28/2/66 ASA

HAREFIELD	QUANDIALLA	PETTITS	YEO	YEO
TIME 1115	982.19	984.30	972.94	
PRESSURE	26.8	28.9	27.2	
TEMP DRY	17.6	23.1	0.0	
TEMP WET	ERRORS			MULTIPLE BASE ERRORS
SINGLE BASE	-25.5			-12.5
9.6				
DIP BEARING 115.1 DEG	-20.0	TILT/MILE 0.77 FEET		
TIME 1130	982.49	984.30	972.94	
PRESSURE	27.9	29.5	27.8	
TEMP DRY	19.1	22.8	0.0	
TEMP WET	ERRORS			MULTIPLE BASE ERRORS
SINGLE BASE	-21.3			-10.3
11.6				
DIP BEARING 119.4 DEG	-14.7	TILT/MILE 0.66 FEET		
TIME 1145	982.48	984.20	972.92	
PRESSURE	29.7	27.5	27.8	
TEMP DRY	19.3	18.9	0.0	
TEMP WET	ERRORS			MULTIPLE BASE ERRORS
SINGLE BASE	-23.1			-11.4
7.2				
DIP BEARING 113.4 DEG	-18.8	TILT/MILE 0.68 FEET		
TIME 1200	982.45	984.23	972.89	
PRESSURE	31.0	29.0	27.8	
TEMP DRY	20.3	19.6	0.0	
TEMP WET	ERRORS			MULTIPLE BASE ERRORS
SINGLE BASE	-25.1			-9.4
7.2				
DIP BEARING 112.7 DEG	-17.8	TILT/MILE 0.74 FEET		

REDUCTION OF FIELD READINGS COOTAMUNDRA 28/2/66 ASA

HAREFIELD	QUANDIALLA	PETTITS	YEO	YEO
TIME 1205				
PRESSURE	982.13	984.26	972.82	
TEMP DRY	30.0	29.0	27.8	
TEMP WET	19.0	20.0	0.0	
SINGLE BASE ERRORS				MULTIPLE BASE ERRORS
10.4				-9.4
DIP BEARING 115.6 DEG	-16.9	TILT/MILE 0.80 FEET		
TIME 1210				
PRESSURE	982.12	984.17	972.89	
TEMP DRY	30.8	29.5	28.4	
TEMP WET	19.7	19.8	0.0	
SINGLE BASE ERRORS				MULTIPLE BASE ERRORS
10.7				-12.6
DIP BEARING 116.8 DEG	-18.8	TILT/MILE 0.74 FEET		
TIME 1215				
PRESSURE	982.01	984.11	972.92	
TEMP DRY	30.4	29.7	28.4	
TEMP WET	19.3	19.7	0.0	
SINGLE BASE ERRORS				MULTIPLE BASE ERRORS
8.4				-15.1
DIP BEARING 113.8 DEG	-23.1	TILT/MILE 0.76 FEET		
TIME 1230				
PRESSURE	981.84	983.91	972.55	
TEMP DRY	28.8	30.0	29.4	
TEMP WET	18.6	19.9	0.0	
SINGLE BASE ERRORS				MULTIPLE BASE ERRORS
9.0				-9.8
DIP BEARING 114.7 DEG	-17.1	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			-11.3
DIP BEARING	114.0 DEG	-19.0	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				-15.5
DIP BEARING 116.6 DEG	-21.6		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				-3.7
DIP BEARING 109.7 DEG	-11.4		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				-15.3
DIP BEARING 106.0 DEG	-24.2		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				-12.0
DIP BEARING 104.1 DEG	-21.6		TILT/MILE 0.61 FEET	

REDUCTION OF FIELD READINGS COOTAMUNDRA 28/2/66 ASA

HAREFIELD	QUANDIALLA	PETTITS	YEO	YEO
TIME 1405	980.74	980.99	982.43	971.44
PRESSURE	32.2	31.5	30.3	31.1
TEMP DRY	20.0	25.2	19.2	0.0
TEMP WET	ERRORS	-14.8		MULTIPLE BASE ERRORS
SINGLE BASE	-14.0			-12.4
8.6				
DIP BEARING	121.1 DEG		TILT/MILE 0.44 FEET	
TIME 1410	980.78	981.04	982.32	971.29
PRESSURE	32.3	32.1	30.5	30.0
TEMP DRY	19.3	25.0	19.5	0.0
TEMP WET	ERRORS	-9.2		MULTIPLE BASE ERRORS
SINGLE BASE	-9.5			-8.8
8.3				
DIP BEARING	126.8 DEG		TILT/MILE 0.32 FEET	
TIME 1415	980.44	980.78	982.31	971.29
PRESSURE	33.0	32.5	30.5	30.0
TEMP DRY	19.8	25.1	19.0	0.0
TEMP WET	ERRORS	-19.1		MULTIPLE BASE ERRORS
SINGLE BASE	-19.3			-12.8
5.9				
DIP BEARING	113.3 DEG		TILT/MILE 0.57 FEET	
TIME 1430	980.35	980.59	982.14	971.07
PRESSURE	32.9	33.1	32.2	30.6
TEMP DRY	19.8	25.9	19.9	0.0
TEMP WET	ERRORS	-14.4		MULTIPLE BASE ERRORS
SINGLE BASE	-17.1			-10.7
8.9				
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	980.34	980.42	982.00	970.58
PRESSURE	33.0	31.9	31.6	31.1
TEMP DRY	19.5	25.1	19.2	0.0
TEMP WET	ERRORS			MULTIPLE BASE ERRORS
SINGLE BASE	-13.2	-0.4		-0.8
DIP BEARING	129.9 DEG		TILT/MILE 0.47 FEET	
TIME 1500	980.10	980.21	981.84	970.86
PRESSURE	34.0	33.0	31.1	31.1
TEMP DRY	19.5	27.0	18.9	0.0
TEMP WET	ERRORS			MULTIPLE BASE ERRORS
SINGLE BASE	-15.6	-15.5		-14.2
DIP BEARING	125.5 DEG		TILT/MILE 0.52 FEET	
TIME 1505	980.16	980.24	981.75	970.89
PRESSURE	33.0	33.1	30.0	30.6
TEMP DRY	20.3	21.5	19.0	0.0
TEMP WET	ERRORS			MULTIPLE BASE ERRORS
SINGLE BASE	-11.1	-15.4		-16.8
DIP BEARING	133.5 DEG		TILT/MILE 0.41 FEET	
TIME 1510	979.99	980.21	981.70	970.80
PRESSURE	33.0	33.6	29.7	30.0
TEMP DRY	20.2	21.2	19.0	0.0
TEMP WET	ERRORS			MULTIPLE BASE ERRORS
SINGLE BASE	-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	980.16	980.15	981.66	970.77
PRESSURE	32.6	32.0	32.1	31.1
TEMP DRY	19.9	20.1	19.8	0.0
TEMP WET	ERRORS			MULTIPLE BASE ERRORS
SINGLE BASE	-8.4			-15.5
DIP BEARING	143.4 DEG	-11.6	TILT/MILE 0.38 FEET	
TIME 1530	979.94	980.18	981.65	970.74
PRESSURE	32.0	32.0	31.0	31.1
TEMP DRY	19.9	23.2	18.8	0.0
TEMP WET	ERRORS			MULTIPLE BASE ERRORS
SINGLE BASE	-14.6	-17.4		-14.9
DIP BEARING	120.9 DEG		TILT/MILE 0.46 FEET	
TIME 1545	979.93	980.10	981.49	970.79
PRESSURE	32.5	32.2	32.0	30.6
TEMP DRY	20.0	19.5	20.0	0.0
TEMP WET	ERRORS			MULTIPLE BASE ERRORS
SINGLE BASE	-10.2	-19.1		-19.6
DIP BEARING	130.7 DEG		TILT/MILE 0.36 FEET	
TIME 1600	979.79	979.85	981.46	970.71
PRESSURE	33.8	32.1	30.5	30.6
TEMP DRY	20.8	20.9	19.5	0.0
TEMP WET	ERRORS			MULTIPLE BASE ERRORS
SINGLE BASE	-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	979.70	981.49	970.69	
PRESSURE	33.5	31.5	30.6	
TEMP DRY	20.7	19.0	0.0	
TEMP WET	ERRORS			MULTIPLE BASE ERRORS
SINGLE BASE	-17.0			-19.1
DIP BEARING 8.9	118.8 DEG			
		TILT/MILE 0.53	FEET	
TIME 1610	979.96	981.47	970.70	
PRESSURE	32.1	30.8	31.1	
TEMP DRY	20.1	18.7	0.0	
TEMP WET	ERRORS			MULTIPLE BASE ERRORS
SINGLE BASE	-22.6			-19.4
DIP BEARING 8.9	119.8 DEG			
		TILT/MILE 0.50	FEET	
TIME 1615	979.96	981.48	970.84	
PRESSURE	32.1	32.1	30.6	
TEMP DRY	20.1	19.5	0.0	
TEMP WET	ERRORS			MULTIPLE BASE ERRORS
SINGLE BASE	-25.4			-23.2
DIP BEARING 10.1	122.4 DEG			
		TILT/MILE 0.48	FEET	
TIME 1630	980.00	981.49	970.66	
PRESSURE	32.1	31.9	31.1	
TEMP DRY	19.1	19.3	0.0	
TEMP WET	ERRORS			MULTIPLE BASE ERRORS
SINGLE BASE	-19.5			-17.2
DIP BEARING 9.5	121.8 DEG			
		TILT/MILE 0.47	FEET	

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

HAREFIELD	QUANDIALLA	PETTITS	YEO	YEO
TIME 1645	979.69	979.98	981.50	970.74
PRESSURE	33.2	31.9	31.6	30.6
TEMP DRY	20.2	20.9	20.1	0.0
TEMP WET	ERRORS			MULTIPLE BASE ERRORS
SINGLE BASE	-17.6			-19.9
DIP BEARING	116.3 DEG	-24.7	TILT/MILE 0.53 FEET	
TIME 1700	979.91	980.01	981.55	970.79
PRESSURE	32.8	31.8	30.6	31.1
TEMP DRY	19.9	19.9	18.7	0.0
TEMP WET	ERRORS			MULTIPLE BASE ERRORS
SINGLE BASE	-12.5			-20.4
DIP BEARING	130.1 DEG	-20.0	TILT/MILE 0.44 FEET	
TIME 1705	979.93	979.99	981.58	970.70
PRESSURE	32.6	31.9	31.3	30.6
TEMP DRY	19.6	19.9	19.6	0.0
TEMP WET	ERRORS			MULTIPLE BASE ERRORS
SINGLE BASE	-12.8			-17.5
DIP BEARING	131.3 DEG	-16.7	TILT/MILE 0.46 FEET	
TIME 1710	979.89	980.08	981.59	970.66
PRESSURE	32.3	31.9	31.2	30.6
TEMP DRY	19.6	0.0	18.8	0.0
TEMP WET	ERRORS			MULTIPLE BASE ERRORS
SINGLE BASE	-14.3			-15.1
DIP BEARING	123.6 DEG	-16.8	TILT/MILE 0.47 FEET	

REDUCTION OF FIELD READINGS COOTAMUNDRA 28/2/66 ASA

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



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

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

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

REDUCTION OF FIELD READINGS COOTAMUNDRA 1/3/66 ASA

BATLOW	WAGGA	MONTEAGLE	YEO YEO	QUANDIALLA
TIME 910	927.56	958.16	975.36	985.46
PRESSURE	23.5	22.5	0.0	0.0
TEMP DRY	16.2	17.4	0.0	0.0
TEMP WET	ERRORS			
SINGLE BASE	5.5			
BEARING	138.3 DEG	22.1		
		TILT/MILE	0.09 FEET	
				MULTIPLE BASE
				0.9
				ERRORS
				13.6
TIME 915	927.56	958.17	975.50	985.45
PRESSURE	23.0	23.0	0.0	0.0
TEMP DRY	16.0	17.7	0.0	0.0
TEMP WET	ERRORS			
SINGLE BASE	5.7			
BEARING	130.5 DEG	23.5		
		TILT/MILE	0.12 FEET	
				MULTIPLE BASE
				-3.1
				ERRORS
				13.6
TIME 930	927.53	958.18	975.18	985.45
PRESSURE	23.0	23.0	0.0	0.0
TEMP DRY	16.5	17.6	0.0	0.0
TEMP WET	ERRORS			
SINGLE BASE	3.9			
BEARING	118.9 DEG	21.4		
		TILT/MILE	0.13 FEET	
				MULTIPLE BASE
				5.4
				ERRORS
				13.0
TIME 945	927.50	958.15	975.39	985.45
PRESSURE	23.5	23.3	0.0	0.0
TEMP DRY	17.0	17.7	0.0	0.0
TEMP WET	ERRORS			
SINGLE BASE	3.7			
BEARING	113.1 DEG	16.2		
		TILT/MILE	0.07 FEET	
				MULTIPLE BASE
				-2.4
				ERRORS
				12.1

REDUCTION OF FIELD READINGS COOTAMUNDRA 1/3/66 ASA

BATLOW	WAGGA	MONTEAGLE	YEO	YEO	QUANDIALLA
TIME 1000					
PRESSURE	927.52	958.16	975.04	985.42	
TEMP DRY	23.5	25.0	28.5	0.0	
TEMP WET	17.0	18.2	0.0	0.0	
SINGLE BASE ERRORS	-3.8				14.7
DIP BEARING	122.0 DEG	2.2 TILT/MILE 0.11 FEET		7.1 MULTIPLE BASE ERRORS	14.7
TIME 1005					
PRESSURE	927.46	958.24	975.09	985.51	
TEMP DRY	24.0	26.3	28.8	0.0	
TEMP WET	17.0	19.9	0.0	0.0	
SINGLE BASE ERRORS	-9.9				16.4
DIP BEARING	129.6 DEG	-4.0 TILT/MILE 0.21 FEET		7.2 MULTIPLE BASE ERRORS	16.4
TIME 1010					
PRESSURE	927.48	958.27	975.08	985.45	
TEMP DRY	24.0	26.7	26.8	0.0	
TEMP WET	17.5	20.6	0.0	0.0	
SINGLE BASE ERRORS	-9.0				17.3
DIP BEARING	141.6 DEG	-1.3 TILT/MILE 0.15 FEET		7.7 MULTIPLE BASE ERRORS	17.3
TIME 1015					
PRESSURE	927.52	958.27	974.86	985.38	
TEMP DRY	23.5	27.0	28.8	0.0	
TEMP WET	17.0	20.3	0.0	0.0	
SINGLE BASE ERRORS	-9.6				19.5
DIP BEARING	133.0 DEG	3.6 TILT/MILE 0.19 FEET		14.1 MULTIPLE BASE ERRORS	19.5

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

BATLOW	WAGGA	MONTEAGLE	YEO	YEO	QUANDIALLA
TIME 1030					
PRESSURE	927.54	958.22	974.93	985.28	
TEMP DRY	24.0	26.4	28.4	0.0	
TEMP WET	17.5	20.3	0.0	0.0	
SINGLE BASE ERRORS					MULTIPLE BASE ERRORS
-7.2	1.9	6.7		10.0	19.1
DIP BEARING 135.6 DEG		TILT/MILE 0.14 FEET			
TIME 1045					
PRESSURE	927.48	958.07	974.89	985.23	
TEMP DRY	24.0	27.8	29.1	0.0	
TEMP WET	17.3	20.0	0.0	0.0	
SINGLE BASE ERRORS					MULTIPLE BASE ERRORS
-11.2	-1.8	2.6		7.6	17.3
DIP BEARING 120.2 DEG		TILT/MILE 0.21 FEET			
TIME 1100					
PRESSURE	927.37	957.91	974.75	985.10	
TEMP DRY	23.5	25.9	29.9	0.0	
TEMP WET	17.5	18.2	0.0	0.0	
SINGLE BASE ERRORS					MULTIPLE BASE ERRORS
-11.9	1.3	6.0		9.1	18.3
DIP BEARING 110.2 DEG		TILT/MILE 0.23 FEET			
TIME 1105					
PRESSURE	927.32	957.88	974.65	984.95	
TEMP DRY	24.0	27.3	29.7	0.0	
TEMP WET	17.8	18.9	0.0	0.0	
SINGLE BASE ERRORS					MULTIPLE BASE ERRORS
-13.8	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	927.27	957.83	974.61	984.95
PRESSURE	24.5	28.0	29.7	0.0
TEMP DRY	18.0	19.5	0.0	0.0
TEMP WET	ERRORS			0.0
SINGLE BASE	-15.5	3.2		10.2
DIP BEARING	113.8 DEG	TILT/MILE 0.30 FEET		MULTIPLE BASE ERRORS 20.8
TIME 1115	927.26	957.85	974.58	985.03
PRESSURE	24.0	26.7	30.1	0.0
TEMP DRY	17.5	19.3	0.0	0.0
TEMP WET	ERRORS			0.0
SINGLE BASE	-12.7	2.1		10.8
DIP BEARING	117.7 DEG	TILT/MILE 0.24 FEET		MULTIPLE BASE ERRORS 17.8
TIME 1130	927.16	957.56	974.38	984.75
PRESSURE	24.5	26.8	31.4	0.0
TEMP DRY	18.0	17.7	0.0	0.0
TEMP WET	ERRORS			0.0
SINGLE BASE	-13.7	3.8		8.9
DIP BEARING	106.6 DEG	TILT/MILE 0.27 FEET		MULTIPLE BASE ERRORS 16.7
TIME 1145	927.15	957.38	974.18	984.55
PRESSURE	25.8	27.2	33.5	0.0
TEMP DRY	17.5	17.7	0.0	0.0
TEMP WET	ERRORS			0.0
SINGLE BASE	-17.0	2.9		9.5
DIP BEARING	102.1 DEG	TILT/MILE 0.35 FEET		MULTIPLE BASE ERRORS 16.6

REDUCTION OF FIELD READINGS COOTAMUNDRA 1/3/66 ASA

BATLOW	WAGGA	MONTEAGLE	YEO YEO	QUANDIALLA
TIME 1200				
PRESSURE	926.81	957.24	974.24	984.46
TEMP DRY	26.0	28.8	33.4	0.0
TEMP WET	18.0	18.4	0.0	0.0
SINGLE BASE ERRORS				MULTIPLE BASE ERRORS
-26.7	-10.3	-9.5		3.3
DIP BEARING 111.7 DEG		TILT/MILE 0.52 FEET		19.4
TIME 1205				
PRESSURE	926.78	957.18	973.94	984.39
TEMP DRY	26.2	28.8	31.4	0.0
TEMP WET	18.0	18.0	0.0	0.0
SINGLE BASE ERRORS				MULTIPLE BASE ERRORS
-22.3	-7.3	-4.4		10.7
DIP BEARING 109.7 DEG		TILT/MILE 0.44 FEET		18.5
TIME 1210				
PRESSURE	926.78	957.08	974.02	984.38
TEMP DRY	26.2	28.3	31.1	0.0
TEMP WET	18.0	18.2	0.0	0.0
SINGLE BASE ERRORS				MULTIPLE BASE ERRORS
-18.9	-4.1	-3.7		5.1
DIP BEARING 106.0 DEG		TILT/MILE 0.38 FEET		13.7
TIME 1215				
PRESSURE	926.76	957.09	973.92	984.60
TEMP DRY	26.2	28.5	31.4	0.0
TEMP WET	18.0	18.5	0.0	0.0
SINGLE BASE ERRORS				MULTIPLE BASE ERRORS
-18.9	-5.2	-11.2		7.8
DIP BEARING 108.0 DEG		TILT/MILE 0.37 FEET		7.3

REDUCTION OF FIELD READINGS COOTAMUNDRA 1/3/66 ASA

BATLOW	WAGGA	MONTEAGLE	YEO YEO	QUANDIALLA
TIME 1230				
PRESSURE	926.75	957.06	973.73	984.53
TEMP DRY	26.2	29.5	31.8	0.0
TEMP WET	18.0	17.8	0.0	0.0
SINGLE BASE ERRORS				MULTIPLE BASE ERRORS
-17.3				10.9
DIP BEARING 110.3 DEG	-0.4	-11.9		6.1
		TILT/MILE 0.34 FEET		
TIME 1245				
PRESSURE	926.68	957.02	973.72	984.24
TEMP DRY	27.0	28.5	32.1	0.0
TEMP WET	18.0	18.2	0.0	0.0
SINGLE BASE ERRORS				MULTIPLE BASE ERRORS
-14.3				8.5
DIP BEARING 114.9 DEG	-2.1	-5.4		11.3
		TILT/MILE 0.27 FEET		
TIME 1300				
PRESSURE	926.50	956.73	973.56	984.16
TEMP DRY	26.5	29.3	32.2	0.0
TEMP WET	18.0	18.2	0.0	0.0
SINGLE BASE ERRORS				MULTIPLE BASE ERRORS
-16.3				5.9
DIP BEARING 107.6 DEG	-3.9	-9.8		5.9
		TILT/MILE 0.32 FEET		
TIME 1305				
PRESSURE	926.45	956.69	973.61	984.11
TEMP DRY	26.5	29.0	31.9	0.0
TEMP WET	18.0	17.8	0.0	0.0
SINGLE BASE ERRORS				MULTIPLE BASE ERRORS
-16.4				3.6
DIP BEARING 107.1 DEG	-6.1	-8.8		6.7
		TILT/MILE 0.32 FEET		

REDUCTION OF FIELD READINGS COOTAMUNDRA 1/3/66 ASA

BATLOW	WAGGA	MONTEAGLE	YEO YEO	QUANDIALLA
TIME 1310	926.41	956.65	973.53	984.18
PRESSURE	27.0	29.0	32.1	0.0
TEMP DRY	18.0	18.0	0.0	0.0
TEMP WET	ERRORS		MULTIPLE BASE	ERRORS
SINGLE BASE	-4.7		4.2	2.8
DIP BEARING	108.5 DEG	TILT/MILE 0.32 FEET		
TIME 1315	926.38	956.72	973.59	984.10
PRESSURE	20.7	29.5	32.5	0.0
TEMP DRY	18.0	17.8	0.0	0.0
TEMP WET	ERRORS		MULTIPLE BASE	ERRORS
SINGLE BASE	-4.7		4.1	6.4
DIP BEARING	112.8 DEG	TILT/MILE 0.22 FEET		
TIME 1330	926.26	956.40	973.49	983.98
PRESSURE	27.5	29.9	32.3	0.0
TEMP DRY	17.5	18.1	0.0	0.0
TEMP WET	ERRORS		MULTIPLE BASE	ERRORS
SINGLE BASE	-3.6		-1.3	2.1
DIP BEARING	104.9 DEG	TILT/MILE 0.39 FEET		
TIME 1345	926.15	956.28	973.26	983.80
PRESSURE	27.5	30.5	32.8	0.0
TEMP DRY	17.0	18.1	0.0	0.0
TEMP WET	ERRORS		MULTIPLE BASE	ERRORS
SINGLE BASE	-3.7		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	926.14	956.05	972.98	983.61
PRESSURE	27.5	29.2	33.0	0.0
TEMP DRY	16.8	17.8	0.0	0.0
TEMP WET	ERRORS			
SINGLE BASE	2.5			
SINGLE BEARING	92.3 DEG			
DIP BEARING		TILT/MILE 0.23	FEET	1.1
				MULTIPLE BASE ERRORS -4.4
TIME 1405	926.12	955.96	973.06	983.56
PRESSURE	27.8	29.3	32.9	0.0
TEMP DRY	17.0	17.5	0.0	0.0
TEMP WET	ERRORS			
SINGLE BASE	4.3			
SINGLE BEARING	87.1 DEG			
DIP BEARING		TILT/MILE 0.22	FEET	-4.0
				MULTIPLE BASE ERRORS -6.5
TIME 1410	926.09	955.89	973.13	983.54
PRESSURE	28.0	30.8	32.8	0.0
TEMP DRY	17.0	18.0	0.0	0.0
TEMP WET	ERRORS			
SINGLE BASE	4.4			
SINGLE BEARING	89.4 DEG			
DIP BEARING		TILT/MILE 0.29	FEET	-7.4
				MULTIPLE BASE ERRORS -6.7
TIME 1415	926.05	955.95	973.09	983.42
PRESSURE	28.0	30.4	32.5	0.0
TEMP DRY	17.5	17.7	0.0	0.0
TEMP WET	ERRORS			
SINGLE BASE	1.9			
SINGLE BEARING	94.0 DEG			
DIP BEARING		TILT/MILE 0.23	FEET	-5.8
				MULTIPLE BASE ERRORS -2.4

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 3.5				MULTIPLE BASE ERRORS
DIP BEARING	92.8 DEG	-10.0	-12.6		-5.5
			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 0.4				MULTIPLE BASE ERRORS
DIP BEARING	98.1 DEG	-2.6			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 -0.9				MULTIPLE BASE ERRORS
DIP BEARING	101.1 DEG	-10.1			-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 -0.7				MULTIPLE BASE ERRORS
DIP BEARING	100.8 DEG	-12.5			-6.4
			TILT/MILE 0.27		FEET

REDUCTION OF FIELD READINGS COOTAMUNDRA 1/3/66 ASA

BATLOW	WAGGA	MONTEAGLE	YEO YEG	QUANDIALLA
TIME 1510	925.52	955.39	972.44	
PRESSURE	27.8	30.8	33.8	
TEMP DRY	17.0	18.1	0.0	
TEMP WET	ERRORS			MULTIPLE BASE ERRORS
SINGLE BASE	0.6			-2.5
DIP BEARING	98.1 DEG			
		TILT/MILE 0.34	FEET	
TIME 1515	925.61	955.36	972.40	
PRESSURE	28.0	31.3	33.8	
TEMP DRY	17.0	18.0	0.0	
TEMP WET	ERRORS			MULTIPLE BASE ERRORS
SINGLE BASE	3.8			-2.0
DIP BEARING	91.8 DEG			
		TILT/MILE 0.32	FEET	
TIME 1530	925.66	955.39	972.28	
PRESSURE	27.5	30.4	33.8	
TEMP DRY	16.5	17.6	0.0	
TEMP WET	ERRORS			MULTIPLE BASE ERRORS
SINGLE BASE	5.5			0.8
DIP BEARING	81.2 DEG			
		TILT/MILE 0.20	FEET	
TIME 1545	925.61	955.31	972.25	
PRESSURE	27.3	30.6	33.8	
TEMP DRY	16.0	17.8	0.0	
TEMP WET	ERRORS			MULTIPLE BASE ERRORS
SINGLE BASE	6.1			-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	925.54	955.29	972.24	
PRESSURE	27.0	29.7	33.2	
TEMP DRY	16.0	17.2	0.0	
TEMP WET	ERRORS			MULTIPLE BASE ERRORS
SINGLE BASE	6.2			-2.3
-2.6				
DIP BEARING	60.4 DEG	0.7	TILT/MILE 0.11 FEET	
TIME 1605	925.54	955.22	972.29	
PRESSURE	27.0	30.6	32.8	
TEMP DRY	16.0	17.8	0.0	
TEMP WET	ERRORS			MULTIPLE BASE ERRORS
SINGLE BASE	8.3			-5.6
-1.5				
DIP BEARING	47.5 DEG	-0.9	TILT/MILE 0.12 FEET	
TIME 1610	925.52	955.22	972.14	
PRESSURE	27.0	29.8	32.9	
TEMP DRY	15.5	18.0	0.0	
TEMP WET	ERRORS			MULTIPLE BASE ERRORS
SINGLE BASE	8.1			-1.9
0.5				
DIP BEARING	27.1 DEG	3.6	TILT/MILE 0.09 FEET	
TIME 1615	925.56	955.22	972.21	
PRESSURE	26.9	30.2	32.5	
TEMP DRY	15.0	17.6	0.0	
TEMP WET	ERRORS			MULTIPLE BASE ERRORS
SINGLE BASE	9.7			-3.3
0.8				
DIP BEARING	25.1 DEG	3.4	TILT/MILE 0.11 FEET	

APPENDIX III

## Barometer Traverse Reductions.

22nd May, 1956	229.
23rd May, 1956	239.
6th December, 1955	251.
7th December, 1955	258,

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	-4.6			MULTIPLE BASE ERRORS
DIP BEARING	100.2 DEG	-0.5		-4.2
				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	-2.5			MULTIPLE BASE ERRORS
DIP BEARING	92.0 DEG	-0.8		-3.7
				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	6.3			MULTIPLE BASE ERRORS
DIP BEARING	20.5 DEG	6.2		-3.9
				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 -1.8  
 DIP BEARING 6.2 75.3 DEG  
 -0.5 TILT/MILE 0.45 FEET  
 MULTIPLE BASE ERRORS -5.0

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 -0.6  
 DIP BEARING 6.5 64.7 DEG  
 1.8 TILT/MILE 0.42 FEET  
 MULTIPLE BASE ERRORS -2.7

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 0.7  
 DIP BEARING 8.8 53.6 DEG  
 1.3 TILT/MILE 0.52 FEET  
 MULTIPLE BASE ERRORS -4.4

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 0.9  
 DIP BEARING 10.1 52.5 DEG  
 4.1 TILT/MILE 0.60 FEET  
 MULTIPLE BASE ERRORS -1.7

CITY TRAVERSE REDUCTION 22 MAY 1956 ASA

ST PAULS LIVERPOOL CENTENNIAL

TIME 1006  
 FIELD STN 637 820800. 400500. 35.84  
 PRESSURE 29.389  
 TEMP DRY 0.0 30.027 29.866 30.057  
 SINGLE BASE ERRORS 0.0 0.0 0.0  
 10.3 MULTIPLE BASE ERRORS 1.7  
 DIP BEARING 30.9 DEG 6.9 TILT/MILE 0.59 FEET

TIME 1013  
 FIELD STN 222 822900. 400500. 30.61  
 PRESSURE 29.389  
 TEMP DRY 0.0 30.026 29.863 30.061  
 SINGLE BASE ERRORS 0.0 0.0 0.0  
 11.1 MULTIPLE BASE ERRORS 3.9  
 DIP BEARING 14.8 DEG 8.3 TILT/MILE 0.68 FEET

TIME 1024  
 FIELD STN 223 822900. 400500. 425.18  
 PRESSURE 29.386  
 TEMP DRY 0.0 30.026 29.859 29.641  
 SINGLE BASE ERRORS 0.0 0.0 0.0  
 7.8 MULTIPLE BASE ERRORS -3.9  
 DIP BEARING 176.7 DEG -0.6 TILT/MILE 0.58 FEET

TIME 1032  
 FIELD STN 224 831300. 406600. 621.34  
 PRESSURE 29.385  
 TEMP DRY 0.0 30.024 29.856 29.431  
 SINGLE BASE ERRORS 0.0 0.0 0.0  
 8.2 MULTIPLE BASE ERRORS -2.3  
 DIP BEARING 171.0 DEG -1.5 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  
 TEMP DRY 30.018 29.851 29.416  
 SINGLE BASE ERRORS 69.5 0.0  
 10.9 10.6 MULTIPLE BASE ERRORS  
 DIP BEARING 174.0 DEG 0.2 TILT/MILE 0.84 FEET -0.2

TIME 1056  
 FIELD STN 295 832050. 413350. 594.19  
 PRESSURE 29.382  
 TEMP DRY 30.016 29.851 29.453  
 SINGLE BASE ERRORS 69.8 0.0  
 11.4 9.4 MULTIPLE BASE ERRORS  
 DIP BEARING 1.1 DEG 2.1 TILT/MILE 0.80 FEET 1.2

TIME 1100  
 FIELD STN 294 830600. 414500. 460.81  
 PRESSURE 29.382  
 TEMP DRY 30.014 29.850 29.591  
 SINGLE BASE ERRORS 70.0 0.0  
 13.1 10.2 MULTIPLE BASE ERRORS  
 DIP BEARING 3.8 DEG 6.0 TILT/MILE 0.89 FEET 4.4

TIME 1105  
 FIELD STN 293 829300. 415500. 422.16  
 PRESSURE 29.379  
 TEMP DRY 30.014 29.849 29.630  
 SINGLE BASE ERRORS 70.3 0.0  
 10.0 8.0 MULTIPLE BASE ERRORS  
 DIP BEARING 2.2 DEG 5.2 TILT/MILE 0.69 FEET 3.4

CITY TRAVERSE REDUCTION 22 MAY 1956 ASA

ST PAULS LIVERPOOL CENTENNIAL

TIME 1110  
 FIELD STN 292 827700. 416250. 398.66  
 PRESSURE 29.376  
 TEMP DRY 30.010 29.847 29.655  
 SINGLE BASE ERRORS 71.0 0.0 0.0  
 DIP BEARING 10.0 2.1 TILT/MILE 0.63 FEET  
 11.3 DEG 6.5 MULTIPLE BASE ERRORS  
 0.3

TIME 1115  
 FIELD STN 291 826250. 417250. 359.53  
 PRESSURE 29.373  
 TEMP DRY 30.008 29.846 29.693  
 SINGLE BASE ERRORS 71.8 0.0 0.0  
 DIP BEARING 8.1 2.4 TILT/MILE 0.47 FEET  
 22.8 DEG 3.9 MULTIPLE BASE ERRORS  
 1.1

TIME 1120  
 FIELD STN 290 824900. 418250. 352.26  
 PRESSURE 29.372  
 TEMP DRY 30.008 29.844 29.698  
 SINGLE BASE ERRORS 72.6 0.0 0.0  
 DIP BEARING 6.2 3.5 TILT/MILE 0.39 FEET  
 10.3 DEG 4.1 MULTIPLE BASE ERRORS  
 1.8

TIME 1124  
 FIELD STN 289 823600. 418200. 330.20  
 PRESSURE 29.371  
 TEMP DRY 30.004 29.842 29.718  
 SINGLE BASE ERRORS 73.4 0.0 0.0  
 DIP BEARING 8.2 5.4 TILT/MILE 0.49 FEET  
 18.9 DEG 4.4 MULTIPLE BASE ERRORS  
 3.3

CITY TRAVERSE REDUCTION 22 MAY 1956 ASA

ST PAULS LIVERPOOL CENTENNIAL

TIME 1129  
 FIELD STN 288 822300. 417900. 325.39  
 PRESSURE 29.370  
 TEMP DRY 0.0 29.839 29.719  
 SINGLE BASE ERRORS 74.2 0.0  
 7.2 5.6 MULTIPLE BASE ERRORS  
 7.8 3.6 DEG 3.9 4.8  
 DIP BEARING 178.4 DEG TILT/MILE 0.49 FEET

TIME 1134  
 FIELD STN 287 821000. 419200. 291.72  
 PRESSURE 29.366  
 TEMP DRY 0.0 29.836 29.750  
 SINGLE BASE ERRORS 75.0 0.0  
 4.4 3.9 MULTIPLE BASE ERRORS  
 8.0 178.4 DEG 8.0 TILT/MILE 0.32 FEET

TIME 1139  
 FIELD STN 286 820300. 420500. 317.74  
 PRESSURE 29.363  
 TEMP DRY 0.0 29.832 29.724  
 SINGLE BASE ERRORS 75.8 0.0  
 4.3 4.1 MULTIPLE BASE ERRORS  
 3.1 175.0 DEG 3.1 TILT/MILE 0.33 FEET

TIME 1148  
 FIELD STN 285 818000. 421650. 39.70  
 PRESSURE 29.357  
 TEMP DRY 0.0 29.825 30.013  
 SINGLE BASE ERRORS 77.4 0.0  
 8.0 3.6 MULTIPLE BASE ERRORS  
 2.0 24.8 DEG 2.0 TILT/MILE 0.46 FEET  
 -0.6

CITY TRAVERSE REDUCTION 22 MAY 1956 ASA

ST PAULS LIVERPOOL CENTENNIAL

TIME 1230  
 FIELD STN 178 814150. 420250. 33.80  
 PRESSURE 29.331  
 TEMP DRY 0.0 29.965 29.801 29.991  
 SINGLE BASE ERRORS 0.0  
 MULTIPLE BASE ERRORS 2.5  
 DIP BEARING 2.4 7.2 DEG 4.2 TILT/MILE 0.16 FEET

TIME 1251  
 FIELD STN 220 813650. 413650. 97.52  
 PRESSURE 29.323  
 TEMP DRY 0.0 29.958 29.792 29.915  
 SINGLE BASE ERRORS 0.0  
 MULTIPLE BASE ERRORS 2.4  
 DIP BEARING 2.6 161.3 DEG 5.4 TILT/MILE 0.26 FEET

TIME 1310  
 FIELD STN 220 813650. 413650. 97.52  
 PRESSURE 29.317  
 TEMP DRY 0.0 29.945 29.791 29.912  
 SINGLE BASE ERRORS 0.0  
 MULTIPLE BASE ERRORS 1.1  
 DIP BEARING 11.5 54.9 DEG 4.9 TILT/MILE 0.69 FEET

TIME 1325  
 FIELD STN 221 817000. 407000. 52.95  
 PRESSURE 29.316  
 TEMP DRY 0.0 29.944 29.788 29.952  
 SINGLE BASE ERRORS 0.0  
 MULTIPLE BASE ERRORS 6.3  
 DIP BEARING 13.9 36.1 DEG 13.5 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 29.787 29.944  
 TEMP DRY 0.0 0.0 0.0  
 SINGLE BASE ERRORS  
 22.1 6.3 MULTIPLE BASE ERRORS  
 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 29.784 29.882  
 TEMP DRY 0.0 0.0 0.0  
 SINGLE BASE ERRORS  
 20.4 8.7 MULTIPLE BASE ERRORS  
 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 29.782 29.981  
 TEMP DRY 0.0 0.0 0.0  
 SINGLE BASE ERRORS  
 15.2 8.8 MULTIPLE BASE ERRORS  
 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 29.780 29.982  
 TEMP DRY 0.0 0.0 0.0  
 SINGLE BASE ERRORS  
 22.7 10.7 MULTIPLE BASE ERRORS  
 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  
 TEMP DRY 0.0 29.782 29.974  
 SINGLE BASE ERRORS 0.0  
 17.8 19.6 MULTIPLE BASE ERRORS 1.9  
 DIP BEARING 35.4 DEG TILT/MILE 1.01 FEET

TIME 1453  
 FIELD STN 648 808400. 395450. 96.47  
 PRESSURE 29.306  
 TEMP DRY 0.0 29.779 29.899  
 SINGLE BASE ERRORS 0.0  
 19.7 16.4 MULTIPLE BASE ERRORS -2.9  
 DIP BEARING 26.6 DEG TILT/MILE 1.14 FEET

TIME 1459  
 FIELD STN 649 808550. 397400. 7.72  
 PRESSURE 29.306  
 TEMP DRY 0.0 29.776 29.991  
 SINGLE BASE ERRORS 0.0  
 18.0 11.3 MULTIPLE BASE ERRORS 3.1  
 DIP BEARING 12.5 DEG TILT/MILE 1.13 FEET

TIME 1505  
 FIELD STN 650 808300. 399100. 12.18  
 PRESSURE 29.306  
 TEMP DRY 0.0 29.776 29.988  
 SINGLE BASE ERRORS 0.0  
 18.2 11.4 MULTIPLE BASE ERRORS 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  
 18.3 11.5 MULTIPLE BASE ERRORS  
 19.7 TILT/MILE 1.14 FEET 1.7

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  
 20.2 11.6 MULTIPLE BASE ERRORS  
 18.3 TILT/MILE 1.23 FEET -1.3

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  
 21.2 10.7 MULTIPLE BASE ERRORS  
 17.9 TILT/MILE 1.25 FEET -1.4

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  
 22.0 10.7 MULTIPLE BASE ERRORS  
 16.0 TILT/MILE 1.29 FEET -2.9

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	14.1	14.3			MULTIPLE BASE ERRORS
DIP BEARING	178.3 DEG				-0.2
					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	14.8	12.9			MULTIPLE BASE ERRORS
DIP BEARING	170.1 DEG				-2.7
					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	16.9	18.2			MULTIPLE BASE ERRORS
DIP BEARING	168.1 DEG				0.0
					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  
 TEMP DRY 0.0 29.786 30.011  
 SINGLE BASE ERRORS 61.7 0.0  
 MULTIPLE BASE ERRORS 15.1 0.7  
 DIP BEARING 158.4 DEG 1.31 TILT/MILE 1.31 FEET

TIME 954  
 FIELD STN 651 807700. 400750. 42.08  
 PRESSURE 29.317  
 TEMP DRY 0.0 29.787 29.979  
 SINGLE BASE ERRORS 9.2 0.0  
 MULTIPLE BASE ERRORS 14.2 -0.3  
 DIP BEARING 157.2 DEG 1.03 TILT/MILE 1.03 FEET

TIME 959  
 FIELD STN 652 807300. 402000. 97.75  
 PRESSURE 29.314  
 TEMP DRY 0.0 29.788 29.915  
 SINGLE BASE ERRORS 8.0 0.0  
 MULTIPLE BASE ERRORS 10.3 1.4  
 DIP BEARING 163.0 DEG 0.76 TILT/MILE 0.76 FEET

TIME 1004  
 FIELD STN 653 807750. 403700. 22.01  
 PRESSURE 29.313  
 TEMP DRY 0.0 29.787 29.994  
 SINGLE BASE ERRORS 9.1 0.0  
 MULTIPLE BASE ERRORS 9.8 2.8  
 DIP BEARING 170.0 DEG 0.75 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  
 TEMP DRY 0.0 29.785 29.907  
 SINGLE BASE ERRORS 63.6 0.0  
 7.0 10.8 MULTIPLE BASE ERRORS 3.0  
 DIP BEARING 157.2 DEG 12.7 TILT/MILE 0.78 FEET

TIME 1016  
 FIELD STN 655 808350. 407400. 147.50  
 PRESSURE 29.312  
 TEMP DRY 0.0 29.784 29.861  
 SINGLE BASE ERRORS 64.4 0.0  
 1.6 10.1 MULTIPLE BASE ERRORS 0.4  
 DIP BEARING 133.4 DEG 6.7 TILT/MILE 0.75 FEET

TIME 1021  
 FIELD STN 656 807000. 407750. 168.23  
 PRESSURE 29.311  
 TEMP DRY 0.0 29.785 29.839  
 SINGLE BASE ERRORS 65.1 0.0  
 5.2 7.7 MULTIPLE BASE ERRORS -2.9  
 DIP BEARING 158.6 DEG 4.6 TILT/MILE 0.56 FEET

TIME 1027  
 FIELD STN 657 805500. 408500. 112.12  
 PRESSURE 29.310  
 TEMP DRY 0.0 29.786 29.895  
 SINGLE BASE ERRORS 66.0 0.0  
 3.2 5.1 MULTIPLE BASE ERRORS 2.1  
 DIP BEARING 156.8 DEG 7.3 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 4.4  
 1.4  
 DIP BEARING 141.1 DEG 7.0 TILT/MILE 0.32 FEET  
 MULTIPLE BASE ERRORS 3.2

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 4.7  
 -3.1  
 DIP BEARING 104.5 DEG 4.7 TILT/MILE 0.47 FEET  
 MULTIPLE BASE ERRORS 2.7

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 4.8  
 -3.3  
 DIP BEARING 104.2 DEG 3.4 TILT/MILE 0.49 FEET  
 MULTIPLE BASE ERRORS 1.0

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 3.1  
 -2.5  
 DIP BEARING 100.9 DEG 2.6 TILT/MILE 0.33 FEET  
 MULTIPLE BASE ERRORS 1.0

CITY TRAVERSE REDUCTION 23 MAY 1956 ASA

ST PAULS LIVERPOOL CENTENNIAL

TIME 1055  
 FIELD STN 662 804600. 415900. 20.36  
 PRESSURE 29.298  
 TEMP DRY 0.0 29.944 29.773 29.982  
 SINGLE BASE ERRORS 70.3 0.0  
 MULTIPLE BASE ERRORS 1.1  
 DIP BEARING 100.2 DEG 2.5 TILT/MILE 0.24 FEET

TIME 1104  
 FIELD STN 663 805700. 416350. 24.00  
 PRESSURE 29.295  
 TEMP DRY 0.0 29.936 29.766 29.971  
 SINGLE BASE ERRORS 71.2 0.0  
 MULTIPLE BASE ERRORS 1.7 5.1  
 DIP BEARING 141.8 DEG 5.1 TILT/MILE 0.37 FEET

TIME 1111  
 FIELD STN 664 806600. 418100. 8.11  
 PRESSURE 29.294  
 TEMP DRY 0.0 29.925 29.759 29.976  
 SINGLE BASE ERRORS 10.5 10.3  
 MULTIPLE BASE ERRORS 2.0  
 DIP BEARING 173.7 DEG 14.9 TILT/MILE 0.82 FEET

TIME 1119  
 FIELD STN 665 807350. 418750. 20.35  
 PRESSURE 29.292  
 TEMP DRY 0.0 29.919 29.754 29.960  
 SINGLE BASE ERRORS 13.7 12.8  
 MULTIPLE BASE ERRORS -0.6  
 DIP BEARING 175.8 DEG 15.2 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  
 TEMP DRY 0.0 29.752 29.938  
 SINGLE BASE ERRORS 72.4 0.0  
 12.1 MULTIPLE BASE ERRORS 2.5  
 DIP BEARING 12.5 DEG 12.1 TILT/MILE 0.76 FEET

TIME 1137  
 FIELD STN 280 811250. 420600. 46.23  
 PRESSURE 29.281  
 TEMP DRY 0.0 29.750 29.927  
 SINGLE BASE ERRORS 72.8 0.0  
 7.9 MULTIPLE BASE ERRORS 2.6  
 DIP BEARING 9.1 DEG 8.6 TILT/MILE 0.51 FEET

TIME 1210  
 FIELD STN 178 814150. 420250. 33.80  
 PRESSURE 29.270  
 TEMP DRY 0.0 29.731 29.924  
 SINGLE BASE ERRORS 74.3 0.0  
 12.5 MULTIPLE BASE ERRORS 0.8  
 DIP BEARING 176.7 DEG 11.6 TILT/MILE 0.93 FEET

TIME 1235  
 FIELD STN 285 818000. 421650. 39.70  
 PRESSURE 29.265  
 TEMP DRY 0.0 29.729 29.920  
 SINGLE BASE ERRORS 75.2 0.0  
 9.6 MULTIPLE BASE ERRORS -2.3  
 DIP BEARING 1.3 DEG 3.6 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  
 TEMP DRY 0.0 29.721 29.916  
 SINGLE BASE ERRORS 75.8 0.0  
 10.6 MULTIPLE BASE ERRORS  
 DIP BEARING 4.0 DEG -0.1 TILT/MILE 0.72 FEET -6.2

TIME 1303  
 FIELD STN 286 820300. 420500. 317.74  
 PRESSURE 29.253  
 TEMP DRY 0.0 29.719 29.613  
 SINGLE BASE ERRORS 76.0 0.0  
 7.5 MULTIPLE BASE ERRORS  
 DIP BEARING 9.0 DEG 2.6 TILT/MILE 0.48 FEET -0.6

TIME 1309  
 FIELD STN 287 821000. 419200. 291.72  
 PRESSURE 29.250  
 TEMP DRY 0.0 29.717 29.632  
 SINGLE BASE ERRORS 8.3 4.1  
 DIP BEARING 22.0 DEG 7.7 TILT/MILE 0.49 FEET 5.3

TIME 1315  
 FIELD STN 288 822300. 417900. 325.39  
 PRESSURE 29.246  
 TEMP DRY 0.0 29.715 29.601  
 SINGLE BASE ERRORS 7.1 2.0  
 DIP BEARING 37.9 DEG -0.5 TILT/MILE 0.41 FEET -1.6

CITY TRAVERSE REDUCTION 23 MAY 1956 ASA

ST PAULS LIVERPOOL CENTENNIAL

TIME 1320 289 823600. 418200. 330.20  
 FIELD STN  
 PRESSURE 29.245  
 TEMP DRY 0.0 29.713 29.593  
 SINGLE BASE ERRORS 76.3 0.0  
 7.9 MULTIPLE BASE ERRORS  
 2.9 -0.0  
 DIP BEARING 31.9 DEG 1.3 TILT/MILE 0.45 FEET

TIME 1324 290 824900. 418250. 352.26  
 FIELD STN  
 PRESSURE 29.244  
 TEMP DRY 0.0 29.712 29.567  
 SINGLE BASE ERRORS 8.7 0.0  
 8.7 MULTIPLE BASE ERRORS  
 2.8 1.9  
 DIP BEARING 35.4 DEG 2.8 TILT/MILE 0.50 FEET

TIME 1329 291 826250. 417250. 359.53  
 FIELD STN  
 PRESSURE 29.242  
 TEMP DRY 0.0 29.710 29.558  
 SINGLE BASE ERRORS 10.5 0.0  
 10.5 MULTIPLE BASE ERRORS  
 2.6 1.5  
 DIP BEARING 40.3 DEG 2.1 TILT/MILE 0.60 FEET

TIME 1335 292 827700. 416250. 398.66  
 FIELD STN  
 PRESSURE 29.240  
 TEMP DRY 0.0 29.709 29.516  
 SINGLE BASE ERRORS 8.4 0.0  
 8.4 MULTIPLE BASE ERRORS  
 1.6 0.7  
 DIP BEARING 45.2 DEG 0.9 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  
 TEMP DRY 0.0 29.708 29.490  
 SINGLE BASE ERRORS 0.0 0.0 0.0  
 DIP BEARING 8.4 53.7 DEG 0.2 TILT/MILE 0.50 FEET 0.5 MULTIPLE BASE ERRORS

TIME 1344  
 FIELD STN 294 830600. 414500. 460.81  
 PRESSURE 29.236  
 TEMP DRY 0.0 29.707 29.447  
 SINGLE BASE ERRORS 0.0 0.0 0.0  
 DIP BEARING 6.4 63.2 DEG 0.6 TILT/MILE 0.40 FEET 0.9 MULTIPLE BASE ERRORS

TIME 1350  
 FIELD STN 295 832050. 413350. 594.19  
 PRESSURE 29.234  
 TEMP DRY 0.0 29.705 29.305  
 SINGLE BASE ERRORS 0.0 0.0 0.0  
 DIP BEARING 6.2 64.4 DEG 0.8 TILT/MILE 0.40 FEET 1.1 MULTIPLE BASE ERRORS

TIME 1355  
 FIELD STN 296 833100. 412100. 631.79  
 PRESSURE 29.232  
 TEMP DRY 0.0 29.702 29.262  
 SINGLE BASE ERRORS 0.0 0.0 0.0  
 DIP BEARING 4.2 54.2 DEG 2.5 TILT/MILE 0.25 FEET 2.5 MULTIPLE BASE ERRORS



CITY TRAVERSE REDUCTION 23 MAY 1956 ASA

ST PAULS LIVERPOOL CENTENNIAL

TIME 1414  
 FIELD STN 224 831300. 406600. 621.34  
 PRESSURE 29.228  
 TEMP DRY 0.0 29.690 29.268  
 SINGLE BASE ERRORS 0.0  
 4.2 MULTIPLE BASE ERRORS 2.6  
 8.5  
 DIP BEARING 149.6 DEG 3.4 TILT/MILE 0.61 FEET

TIME 1424  
 FIELD STN 223 822900. 400500. 425.18  
 PRESSURE 29.225  
 TEMP DRY 0.0 29.697 29.469  
 SINGLE BASE ERRORS 0.0  
 9.6 MULTIPLE BASE ERRORS 2.0  
 -0.4  
 DIP BEARING 61.4 DEG 5.3 TILT/MILE 0.60 FEET

TIME 1436  
 FIELD STN 222 822900. 400500. 30.61  
 PRESSURE 29.221  
 TEMP DRY 0.0 29.696 29.880  
 SINGLE BASE ERRORS 0.0  
 12.2 MULTIPLE BASE ERRORS 4.7  
 -2.7  
 DIP BEARING 72.0 DEG 8.7 TILT/MILE 0.85 FEET

TIME 1445  
 FIELD STN 637 820800. 400500. 35.84  
 PRESSURE 29.219  
 TEMP DRY 0.0 29.695 29.872  
 SINGLE BASE ERRORS 0.0  
 9.1 MULTIPLE BASE ERRORS 5.4  
 -3.1  
 DIP BEARING 78.0 DEG 9.8 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  
 TEMP DRY 0.0 29.841 29.847  
 SINGLE BASE ERRORS 73.5 0.0  
 15.2 -0.8 MULTIPLE BASE ERRORS  
 DIP BEARING 62.5 DEG 8.2 TILT/MILE 0.96 FEET -0.5

TIME 1459  
 FIELD STN 639 817300. 399500. 123.83  
 PRESSURE 29.220  
 TEMP DRY 0.0 29.691 29.795  
 SINGLE BASE ERRORS 73.0 0.0  
 16.7 2.4 MULTIPLE BASE ERRORS  
 DIP BEARING 48.6 DEG -4.0 TILT/MILE 0.97 FEET -14.9

TIME 1503  
 FIELD STN 640 815900. 398750. 119.13  
 PRESSURE 29.220  
 TEMP DRY 0.0 29.692 29.790  
 SINGLE BASE ERRORS 72.8 0.0  
 16.9 1.6 MULTIPLE BASE ERRORS  
 DIP BEARING 52.1 DEG 5.5 TILT/MILE 1.00 FEET -6.3

TIME 1509  
 FIELD STN 642 813150. 397350. 115.12  
 PRESSURE 29.220  
 TEMP DRY 0.0 29.694 29.787  
 SINGLE BASE ERRORS 72.4 0.0  
 17.4 0.1 MULTIPLE BASE ERRORS  
 DIP BEARING 58.5 DEG 12.8 TILT/MILE 1.06 FEET -0.9

CITY TRAVERSE REDUCTION 23 MAY 1956 ASA

ST PAULS LIVERPOOL CENTENNIAL

TIME 1513  
 FIELD STN 643 812700. 395800. 22.00  
 PRESSURE 29.841 29.694 29.885  
 TEMP DRY 72.1 0.0 0.0  
 SINGLE BASE ERRORS 17.7 0.3 MULTIPLE BASE ERRORS  
 DIP BEARING 57.5 DEG 14.6 TILT/MILE 1.08 FEET -0.3

TIME 1519  
 FIELD STN 644 811600. 394200. 20.60  
 PRESSURE 29.841 29.693 29.887  
 TEMP DRY 71.7 0.0 0.0  
 SINGLE BASE ERRORS 18.1 1.6 MULTIPLE BASE ERRORS  
 DIP BEARING 52.6 DEG 14.6 TILT/MILE 1.07 FEET -1.5

TIME 1523  
 FIELD STN 645 810300. 393300. 34.80  
 PRESSURE 29.841 29.690 29.870  
 TEMP DRY 71.5 0.0 0.0  
 SINGLE BASE ERRORS 18.4 4.6 MULTIPLE BASE ERRORS  
 DIP BEARING 40.5 DEG 16.5 TILT/MILE 1.05 FEET -0.9



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 30.285 30.071 29.684 29.833  
 TEMP DRY 70.0 0.0 0.0 0.0  
 TEMP WET 61.2 0.0 0.0 0.0  
 SINGLE BASE ERRORS 2.1 -4.1 -1.2 0.0  
 -23.1 20.0 MULTIPLE BASE ERRORS -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 30.285 30.074 29.868 29.835  
 TEMP DRY 70.0 0.0 0.0 0.0  
 TEMP WET 61.2 0.0 0.0 0.0  
 SINGLE BASE ERRORS 0.9 -6.9 -4.7 0.0  
 -24.1 16.2 MULTIPLE BASE ERRORS -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 30.285 30.075 29.871 29.901  
 TEMP DRY 69.9 0.0 0.0 0.0  
 TEMP WET 61.3 0.0 0.0 0.0  
 SINGLE BASE ERRORS -2.8 -7.3 -8.0 0.0  
 -24.9 14.5 MULTIPLE BASE ERRORS -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 30.281 30.076 29.934 29.897  
 TEMP DRY 69.9 0.0 0.0 0.0  
 TEMP WET 61.3 0.0 0.0 0.0  
 SINGLE BASE ERRORS 0.2 -4.5 -6.1 0.0  
 -22.2 12.6 MULTIPLE BASE ERRORS -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  
 PRESSURE 826250. 417250. 359.53  
 TEMP DRY 824900. 418250. 352.26  
 TEMP WET 30.278 30.077 29.935 29.949  
 SINGLE BASE ERRORS 69.9 0.0 0.0 0.0  
 -15.7 15.5 0.0 MULTIPLE BASE ERRORS  
 DIP BEARING 97.0 DEG 2.9 TILT/MILE 1.80 FEET -4.3 -11.1

TIME 1058  
 FIELD STN 289  
 PRESSURE 823600. 418200. 330.20  
 TEMP DRY 824900. 418250. 352.26  
 TEMP WET 30.274 30.075 29.969 29.950  
 SINGLE BASE ERRORS 69.8 0.0 0.0 0.0  
 -5.3 23.9 0.0 MULTIPLE BASE ERRORS  
 DIP BEARING 118.0 DEG 7.2 TILT/MILE 2.00 FEET -5.4 -9.1

TIME 1125  
 FIELD STN 289  
 PRESSURE 823600. 418200. 330.20  
 TEMP DRY 822300. 417900. 325.39  
 TEMP WET 30.259 30.071 29.971 29.974  
 SINGLE BASE ERRORS 69.7 0.0 0.0 0.0  
 7.6 26.7 0.0 MULTIPLE BASE ERRORS  
 DIP BEARING 139.5 DEG 4.5 TILT/MILE 1.94 FEET -9.2 -8.1

TIME 1132  
 FIELD STN 288  
 PRESSURE 822300. 417900. 325.39  
 TEMP DRY 822300. 417900. 325.39  
 TEMP WET 30.259 30.070 29.972 29.972  
 SINGLE BASE ERRORS 69.7 0.0 0.0 0.0  
 8.5 28.6 0.0 MULTIPLE BASE ERRORS  
 DIP BEARING 140.2 DEG 9.2 TILT/MILE 2.08 FEET -6.4 -6.4

## CITY TRAVERSE REDUCTION 6 DECEMBER 1955 ASA

ST PAULS LIVERPOOL CENTENNIAL

TIME 1145  
 FIELD STN 288 822300. 417900. 325.39  
 PRESSURE 287 821000. 419200. 291.72  
 TEMP DRY 29.614 30.066 29.963 30.003  
 TEMP WET 0.0 0.0 0.0 0.0  
 SINGLE BASE ERRORS 0.0 0.0 MULTIPLE BASE ERRORS  
 4.0 25.8 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  
 PRESSURE 287 821000. 419200. 291.72  
 TEMP DRY 29.615 30.063 29.974 30.002  
 TEMP WET 0.0 0.0 0.0 0.0  
 SINGLE BASE ERRORS 0.0 0.0 MULTIPLE BASE ERRORS  
 15.9 29.6 9.5 9.5 TILT/MILE 2.12 FEET  
 DIP BEARING 152.0 DEG -10.3 -8.8

TIME 1230  
 FIELD STN 286 820300. 420500. 317.74  
 PRESSURE 285 818000. 421650. 39.70  
 TEMP DRY 29.616 30.066 29.976 30.277  
 TEMP WET 0.0 0.0 0.0 0.0  
 SINGLE BASE ERRORS 0.0 0.0 MULTIPLE BASE ERRORS  
 20.3 27.4 8.4 7.3 TILT/MILE 2.02 FEET  
 DIP BEARING 161.7 DEG -9.8 -13.8

TIME 1245  
 FIELD STN 100 816300. 421200. 25.48  
 PRESSURE 285 818000. 421650. 39.70  
 TEMP DRY 29.615 30.067 30.288 30.276  
 TEMP WET 0.0 0.0 0.0 0.0  
 SINGLE BASE ERRORS 0.0 0.0 MULTIPLE BASE ERRORS  
 17.3 25.4 10.3 7.2 TILT/MILE 1.85 FEET  
 DIP BEARING 158.8 DEG -10.8 -12.4

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 30.064 30.282 30.276  
 TEMP DRY 0.0 0.0 0.0 0.0  
 TEMP WET 0.0 0.0 0.0 0.0  
 SINGLE BASE ERRORS 0.0 MULTIPLE BASE ERRORS  
 13.4 28.1 15.5 TILT/MILE 12.8 -7.7 -11.9  
 DIP BEARING 149.0 DEG

TIME 1320  
 FIELD STN 178 814150. 420250. 33.80  
 178 814150. 420250. 33.80  
 PRESSURE 29.615 30.064 30.275 30.275  
 TEMP DRY 0.0 0.0 0.0 0.0  
 TEMP WET 0.0 0.0 0.0 0.0  
 SINGLE BASE ERRORS 0.0 MULTIPLE BASE ERRORS  
 13.6 28.2 13.9 TILT/MILE 13.9 -11.0 -11.0  
 DIP BEARING 149.2 DEG

TIME 1356  
 FIELD STN 178 814150. 420250. 33.80  
 178 814150. 420250. 33.80  
 PRESSURE 29.615 30.073 30.278 30.278  
 TEMP DRY 0.0 0.0 0.0 0.0  
 TEMP WET 0.0 0.0 0.0 0.0  
 SINGLE BASE ERRORS 0.0 MULTIPLE BASE ERRORS  
 14.0 20.2 11.7 TILT/MILE 11.7 -6.5 -6.5  
 DIP BEARING 159.5 DEG

TIME 1420  
 FIELD STN 178 814150. 420250. 33.80  
 220 813650. 413650. 97.52  
 PRESSURE 29.615 30.075 30.276 30.201  
 TEMP DRY 0.0 0.0 0.0 0.0  
 TEMP WET 0.0 0.0 0.0 0.0  
 SINGLE BASE ERRORS 0.0 MULTIPLE BASE ERRORS  
 17.5 18.3 13.3 TILT/MILE 19.0 -3.5 2.5  
 DIP BEARING 171.4 DEG



CITY TRAVERSE REDUCTION 6 DECEMBER 1955 ASA  
 ST PAULS LIVERPOOL CENTENNIAL

TIME 1500  
 FIELD STN A 220 29.615 817000. 407000. 14.30  
 PRESSURE 813650. 413650. 97.52  
 TEMP DRY 30.247 30.075 30.286 30.194  
 TEMP WET 70.0 0.0 0.0 0.0  
 SINGLE BASE ERRORS 63.0 0.0 0.0 0.0  
 13.4 17.9 25.0 11.9  
 DIP BEARING 162.0 DEG 23.0 TILT/MILE 1.32 FEET MULTIPLE BASE ERRORS 10.0

TIME 1530  
 FIELD STN A 637 29.615 817000. 407000. 14.30  
 PRESSURE 820800. 400500. 35.84  
 TEMP DRY 30.245 30.075 30.292 30.253  
 TEMP WET 69.8 0.0 0.0 0.0  
 SINGLE BASE ERRORS 63.5 0.0 0.0 0.0  
 15.4 18.0 32.2 5.7  
 DIP BEARING 166.8 DEG 17.7 TILT/MILE 1.36 FEET MULTIPLE BASE ERRORS 24.1

TIME 1555  
 FIELD STN 222 29.612 822900. 400500. 30.61  
 PRESSURE 820800. 400500. 35.84  
 TEMP DRY 30.241 30.075 30.262 30.258  
 TEMP WET 69.7 0.0 0.0 0.0  
 SINGLE BASE ERRORS 64.0 0.0 0.0 0.0  
 16.4 15.2 24.8 19.4  
 DIP BEARING 176.1 DEG 26.3 TILT/MILE 1.23 FEET MULTIPLE BASE ERRORS 16.2

TIME 1615  
 FIELD STN 222 29.603 822900. 400500. 30.61  
 PRESSURE 822900. 400500. 425.18  
 TEMP DRY 30.243 30.075 30.267 29.846  
 TEMP WET 69.3 0.0 0.0 0.0  
 SINGLE BASE ERRORS 64.1 0.0 0.0 0.0  
 6.4 7.1 10.1 10.9  
 DIP BEARING 168.8 DEG 13.7 TILT/MILE 0.54 FEET MULTIPLE BASE ERRORS 7.3

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 30.241 30.075 29.846  
 TEMP DRY 69.0 0.0 0.0  
 TEMP WET 64.3 0.0 0.0  
 SINGLE BASE ERRORS 3.5  
 4.9  
 DIP BEARING 6.5 DEG 6.4 TILT/MILE 0.32 FEET  
 6.4  
 MULTIPLE BASE ERRORS 4.5  
 4.5

TIME 1645  
 FIELD STN 223 822900. 400500. 425.18  
 224 831300. 406600. 621.34  
 PRESSURE 30.239 30.074 29.836  
 TEMP DRY 68.7 0.0 0.0  
 TEMP WET 64.4 0.0 0.0  
 SINGLE BASE ERRORS 7.4  
 9.8  
 DIP BEARING 4.8 DEG 18.7 TILT/MILE 2.2  
 14.7  
 MULTIPLE BASE ERRORS 1.5  
 1.5

TIME 1711  
 FIELD STN 224 833900. 411100. 663.00  
 ST PAULS 831300. 406600. 621.34  
 PRESSURE 30.241 30.080 29.608  
 TEMP DRY 68.2 0.0 0.0  
 TEMP WET 64.5 0.0 0.0  
 SINGLE BASE ERRORS 8.0  
 14.2  
 DIP BEARING 16.9 DEG 0.0 TILT/MILE 6.0  
 0.86 FEET  
 MULTIPLE BASE ERRORS 5.3  
 5.3

TIME 1722  
 FIELD STN 224 833900. 411100. 663.00  
 ST PAULS 833900. 411100. 663.00  
 PRESSURE 30.248 30.084 29.610  
 TEMP DRY 68.0 0.0 0.0  
 TEMP WET 64.5 0.0 0.0  
 SINGLE BASE ERRORS 6.2  
 9.8  
 DIP BEARING 12.1 DEG 0.0 TILT/MILE 0.62 FEET  
 0.62  
 MULTIPLE BASE ERRORS 0.0  
 0.0

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
PRESSURE	29.772
TEMP DRY	0.0
TEMP WET	0.0
SINGLE BASE ERRORS	6.9
DIP BEARING	150.0 DEG

820800.	400500.	35.84	
820800.	400500.	35.84	
30.415	30.244	30.441	30.441
72.6	0.0	0.0	0.0
63.2	0.0	0.0	0.0
3.6	3.6	1.7	1.7
	TILT/MILE	0.49	FEET
			MULTIPLE BASE ERRORS
			1.7

TIME	920
FIELD STN	637
PRESSURE	29.772
TEMP DRY	0.0
TEMP WET	0.0
SINGLE BASE ERRORS	6.7
DIP BEARING	102.1 DEG

820800.	400500.	35.84	
819400.	399900.	61.40	
30.424	30.244	30.441	30.416
72.7	0.0	0.0	0.0
64.2	0.0	0.0	0.0
3.3	0.9	5.7	3.8
	TILT/MILE	0.70	FEET
			MULTIPLE BASE ERRORS
			3.8

TIME	932
FIELD STN	639
PRESSURE	29.774
TEMP DRY	0.0
TEMP WET	0.0
SINGLE BASE ERRORS	8.5
DIP BEARING	96.5 DEG

817300.	399500.	123.83	
819400.	399900.	61.40	
30.430	30.244	30.344	30.416
72.7	0.0	0.0	0.0
64.8	0.0	0.0	0.0
6.9	2.8	12.4	7.7
	TILT/MILE	1.00	FEET
			MULTIPLE BASE ERRORS
			7.7

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 30.240 30.343 30.352  
 TEMP DRY 0.0 0.0 0.0 0.0  
 TEMP WET 0.0 0.0 0.0 0.0  
 SINGLE BASE ERRORS 65.3 0.0 0.0 0.0  
 -10.0 11.1 MULTIPLE BASE ERRORS 9.5  
 DIP BEARING 99.3 DEG 6.7 TILT/MILE 3.0 12.8  
 1.23 FEET

TIME 955  
 FIELD STN 641 815000. 397800. 46.39  
 640 815900. 398750. 119.13  
 PRESSURE 29.770 30.242 30.423 30.344  
 TEMP DRY 0.0 0.0 0.0 0.0  
 TEMP WET 0.0 0.0 0.0 0.0  
 SINGLE BASE ERRORS 66.0 0.0 0.0 0.0  
 -11.1 6.4 MULTIPLE BASE ERRORS 15.1  
 DIP BEARING 86.7 DEG 7.2 TILT/MILE 7.6 15.2  
 0.98 FEET

TIME 1006  
 FIELD STN 641 815000. 397800. 46.39  
 642 813150. 397350. 115.12  
 PRESSURE 29.770 30.241 30.423 30.351  
 TEMP DRY 0.0 0.0 0.0 0.0  
 TEMP WET 0.0 0.0 0.0 0.0  
 SINGLE BASE ERRORS 65.9 0.0 0.0 0.0  
 -9.1 7.5 MULTIPLE BASE ERRORS 11.9  
 DIP BEARING 93.4 DEG 7.3 TILT/MILE 5.2 13.8  
 0.95 FEET

TIME 1020  
 FIELD STN B 642 812700. 395800. 17.00  
 642 813150. 397350. 115.12  
 PRESSURE 29.770 30.240 30.453 30.348  
 TEMP DRY 0.0 0.0 0.0 0.0  
 TEMP WET 0.0 0.0 0.0 0.0  
 SINGLE BASE ERRORS 65.7 0.0 0.0 0.0  
 -4.2 8.5 MULTIPLE BASE ERRORS 11.1  
 DIP BEARING 109.1 DEG 9.2 TILT/MILE 8.3 12.6  
 0.79 FEET

CITY TRAVERSE REDUCTION 7 DECEMBER 1955 ASA  
 ST PAULS LIVERPOOL CENTENNIAL

TIME 1032  
 FIELD STN B 644 29.769 812700. 395800. 17.00  
 PRESSURE 811600. 394200. 20.60  
 TEMP DRY 30.416 30.240 30.454 30.446  
 TEMP WET 72.2 0.0 0.0 0.0  
 SINGLE BASE ERRORS 65.5 0.0 0.0 0.0  
 -0.1 7.8 7.7 11.4 MULTIPLE BASE ERRORS 11.5  
 DIP BEARING 126.0 DEG 7.8 TILT/MILE 0.61 FEET 7.6

TIME 1042  
 FIELD STN 645 29.766 810300. 393300. 34.80  
 PRESSURE 811600. 394200. 20.60  
 TEMP DRY 30.412 30.236 30.431 30.446  
 TEMP WET 72.1 0.0 0.0 0.0  
 SINGLE BASE ERRORS 65.4 0.0 0.0 0.0  
 0.8 8.9 8.5 TILT/MILE 0.67 FEET 7.9  
 DIP BEARING 130.7 DEG 8.9 MULTIPLE BASE ERRORS 7.9

TIME 1053  
 FIELD STN 645 29.766 810300. 393300. 34.80  
 PRESSURE 808875. 392600. 66.12  
 TEMP DRY 30.407 30.238 30.433 30.397  
 TEMP WET 71.9 0.0 0.0 0.0  
 SINGLE BASE ERRORS 65.2 0.0 0.0 0.0  
 5.6 7.1 6.8 TILT/MILE 0.53 FEET 1.5  
 DIP BEARING 163.9 DEG 7.1 MULTIPLE BASE ERRORS 3.1

TIME 1102  
 FIELD STN LIVERPOOL 646 29.767 809100. 392600. 60.00  
 PRESSURE 808875. 392600. 66.12  
 TEMP DRY 30.406 30.239 30.406 30.398  
 TEMP WET 71.8 0.0 0.0 0.0  
 SINGLE BASE ERRORS 65.0 0.0 0.0 0.0  
 7.7 8.9 7.7 TILT/MILE 0.58 FEET 0.0  
 DIP BEARING 175.1 DEG 7.3 MULTIPLE BASE ERRORS 1.1

CITY TRAVERSE REDUCTION 7 DECEMBER 1955 ASA

ST PAULS LIVERPOOL CENTENNIAL

TIME 1109  
 FIELD STN LIVERPOOL  
 PRESSURE 809100. 392600. 60.00  
 TEMP DRY 809100. 392600. 60.00  
 TEMP WET 30.402 30.402 30.402  
 SINGLE BASE 71.9 0.0 0.0  
 ERRORS 64.7 0.0 0.0  
 15.0 15.0 TILT/MILE 1.03 FEET  
 DIP BEARING 3.0 DEG MULTIPLE BASE ERRORS 0.0

TIME 1151  
 FIELD STN LIVERPOOL  
 PRESSURE 809100. 392600. 60.00  
 TEMP DRY 808300. 394250. 24.23  
 TEMP WET 30.390 30.229 30.390 30.430  
 SINGLE BASE 72.1 0.0 0.0  
 ERRORS 63.3 0.0 0.0  
 21.4 20.2 TILT/MILE 1.40 FEET  
 DIP BEARING 6.9 DEG MULTIPLE BASE ERRORS -1.7

TIME 1209  
 FIELD STN LIVERPOOL  
 PRESSURE 808400. 395450. 96.47  
 TEMP DRY 808300. 394250. 24.23  
 TEMP WET 30.383 30.225 30.347 30.430  
 SINGLE BASE 72.2 0.0 0.0  
 ERRORS 63.0 0.0 0.0  
 24.5 20.1 TILT/MILE 1.79 FEET  
 DIP BEARING 8.5 DEG MULTIPLE BASE ERRORS -8.2

TIME 1216  
 FIELD STN LIVERPOOL  
 PRESSURE 808400. 395450. 96.47  
 TEMP DRY 808550. 397400. 7.72  
 TEMP WET 30.386 30.224 30.345 30.449  
 SINGLE BASE 72.3 0.0 0.0  
 ERRORS 63.4 0.0 0.0  
 26.2 18.9 TILT/MILE 1.71 FEET  
 DIP BEARING 2.3 DEG MULTIPLE BASE ERRORS -6.3

CITY TRAVERSE REDUCTION 7 DECEMBER 1955 ASA  
 ST PAULS LIVERPOOL CENTENNIAL

TIME 1227  
 FIELD STN 650 808300. 399100. 12.18  
 649 808550. 397400. 17.72  
 PRESSURE 29.765 30.440 30.448  
 TEMP DRY 0.0 0.0 0.0  
 TEMP WET 0.0 0.0 0.0  
 SINGLE BASE ERRORS 0.0 MULTIPLE BASE ERRORS -3.6  
 22.0 18.1 18.8 TILT/MILE 1.54 FEET  
 DIP BEARING 1.3 DEG -0.8

TIME 1236  
 FIELD STN 650 808300. 399100. 12.18  
 651 807700. 400750. 42.08  
 PRESSURE 29.764 30.437 30.409  
 TEMP DRY 0.0 0.0 0.0  
 TEMP WET 0.0 0.0 0.0  
 SINGLE BASE ERRORS 0.0 MULTIPLE BASE ERRORS -4.3  
 22.9 18.0 19.5 TILT/MILE 1.56 FEET  
 DIP BEARING 3.2 DEG

TIME 1246  
 FIELD STN 652 807300. 402000. 97.75  
 651 807700. 400750. 42.08  
 PRESSURE 29.763 30.342 30.408  
 TEMP DRY 0.0 0.0 0.0  
 TEMP WET 0.0 0.0 0.0  
 SINGLE BASE ERRORS 0.0 MULTIPLE BASE ERRORS -5.2  
 23.6 18.9 19.3 TILT/MILE 1.63 FEET  
 DIP BEARING 2.4 DEG

TIME 1300  
 FIELD STN 652 807300. 402000. 97.75  
 653 807750. 403700. 22.01  
 PRESSURE 29.764 30.343 30.430  
 TEMP DRY 0.0 0.0 0.0  
 TEMP WET 0.0 0.0 0.0  
 SINGLE BASE ERRORS 0.0 MULTIPLE BASE ERRORS -7.1  
 24.4 23.4 19.8 TILT/MILE 1.87 FEET  
 DIP BEARING 174.8 DEG -2.7

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 30.216 30.345 30.427  
 TEMP DRY 0.0 0.0 0.0 0.0  
 TEMP WET 0.0 0.0 0.0 0.0  
 SINGLE BASE ERRORS 64.2 0.0 0.0 0.0  
 19.9 18.8 13.1 16.4  
 DIP BEARING 175.4 DEG 175.4 DEG 175.4 DEG 175.4 DEG  
 TILT/MILE 1.51 FEET  
 MULTIPLE BASE ERRORS -5.5  
 -8.6

TIME 1323  
 FIELD STN 654 808050. 406150. 100.98  
 655 808350. 407400. 147.50  
 PRESSURE 29.755 30.216 30.339 30.292  
 TEMP DRY 0.0 0.0 0.0 0.0  
 TEMP WET 0.0 0.0 0.0 0.0  
 SINGLE BASE ERRORS 72.1 0.0 0.0 0.0  
 19.3 17.1 17.1 14.1  
 DIP BEARING 177.9 DEG 177.9 DEG 177.9 DEG 177.9 DEG  
 TILT/MILE 1.41 FEET  
 MULTIPLE BASE ERRORS -6.2  
 -3.4

TIME 1337  
 FIELD STN 656 807000. 407750. 168.23  
 655 808350. 407400. 147.50  
 PRESSURE 29.756 30.216 30.270 30.297  
 TEMP DRY 0.0 0.0 0.0 0.0  
 TEMP WET 0.0 0.0 0.0 0.0  
 SINGLE BASE ERRORS 71.9 0.0 0.0 0.0  
 22.3 18.3 14.9 10.7  
 DIP BEARING 1.4 DEG 1.4 DEG 1.4 DEG 1.4 DEG  
 TILT/MILE 1.56 FEET  
 MULTIPLE BASE ERRORS -12.0  
 -8.9

TIME 1345  
 FIELD STN 656 807000. 407750. 168.23  
 657 805500. 408500. 112.12  
 PRESSURE 29.757 30.217 30.275 30.337  
 TEMP DRY 0.0 0.0 0.0 0.0  
 TEMP WET 0.0 0.0 0.0 0.0  
 SINGLE BASE ERRORS 71.8 0.0 0.0 0.0  
 23.4 18.4 11.3 10.1  
 DIP BEARING 3.3 DEG 3.3 DEG 3.3 DEG 3.3 DEG  
 TILT/MILE 1.60 FEET  
 MULTIPLE BASE ERRORS -15.7  
 -13.2



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 30.221 30.283 30.336  
 TEMP DRY 0.0 0.0 0.0 0.0  
 TEMP WET 0.0 0.0 0.0 0.0  
 SINGLE BASE ERRORS 13.9 10.3 MULTIPLE BASE ERRORS  
 27.3 13.9 -11.7 -14.9  
 DIP BEARING 20.6 DEG 12.8 TILT/MILE 1.62 FEET

TIME 1406  
 FIELD STN 658 805800. 410000. 158.72  
 659 806000. 411250. 123.38  
 PRESSURE 29.756 30.221 30.282 30.320  
 TEMP DRY 0.0 0.0 0.0 0.0  
 TEMP WET 0.0 0.0 0.0 0.0  
 SINGLE BASE ERRORS 14.0 13.9 MULTIPLE BASE ERRORS  
 29.2 14.0 -11.9 -11.0  
 DIP BEARING 22.9 DEG 13.7 TILT/MILE 1.71 FEET

TIME 1421  
 FIELD STN 660 806000. 413000. 154.27  
 659 806000. 411250. 123.38  
 PRESSURE 29.756 30.221 30.289 30.318  
 TEMP DRY 0.0 0.0 0.0 0.0  
 TEMP WET 0.0 0.0 0.0 0.0  
 SINGLE BASE ERRORS 14.1 15.8 MULTIPLE BASE ERRORS  
 32.1 14.1 -13.9 -10.6  
 DIP BEARING 26.0 DEG 11.7 TILT/MILE 1.86 FEET

TIME 1430  
 FIELD STN 660 806000. 413000. 154.27  
 660 806000. 413000. 154.27  
 PRESSURE 29.755 30.222 30.286 30.286  
 TEMP DRY 0.0 0.0 0.0 0.0  
 TEMP WET 0.0 0.0 0.0 0.0  
 SINGLE BASE ERRORS 12.4 13.8 MULTIPLE BASE ERRORS  
 33.2 12.4 -11.0 -11.0  
 DIP BEARING 30.8 DEG 13.8 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 30.217 30.282 30.387  
 TEMP DRY 0.0 0.0 0.0 0.0  
 TEMP WET 0.0 0.0 0.0 0.0  
 SINGLE BASE ERRORS 0.0 0.0 0.0 0.0  
 35.2 14.4 14.4 14.4  
 DIP BEARING 28.5 DEG 14.2 14.4 14.4 TILT/MILE 2.02 FEET  
 MULTIPLE BASE ERRORS -12.6

TIME 1457  
 FIELD STN 662 804600. 415900. 20.36  
 661 805450. 414300. 57.64  
 PRESSURE 29.751 30.218 30.426 30.387  
 TEMP DRY 0.0 0.0 0.0 0.0  
 TEMP WET 0.0 0.0 0.0 0.0  
 SINGLE BASE ERRORS 0.0 0.0 0.0 0.0  
 32.6 13.7 13.7 13.7  
 DIP BEARING 29.9 DEG 12.6 13.7 13.7 TILT/MILE 1.87 FEET  
 MULTIPLE BASE ERRORS -10.8

TIME 1508  
 FIELD STN 662 804600. 415900. 20.36  
 663 805700. 416350. 24.00  
 PRESSURE 29.749 30.216 30.426 30.424  
 TEMP DRY 0.0 0.0 0.0 0.0  
 TEMP WET 0.0 0.0 0.0 0.0  
 SINGLE BASE ERRORS 0.0 0.0 0.0 0.0  
 32.7 11.6 11.6 11.6  
 DIP BEARING 29.8 DEG 12.7 11.6 11.6 TILT/MILE 1.88 FEET  
 MULTIPLE BASE ERRORS -11.8

TIME 1525  
 FIELD STN C 663 806600. 418100. 19.70  
 663 805700. 416350. 24.00  
 PRESSURE 29.742 30.213 30.427 30.420  
 TEMP DRY 0.0 0.0 0.0 0.0  
 TEMP WET 0.0 0.0 0.0 0.0  
 SINGLE BASE ERRORS 0.0 0.0 0.0 0.0  
 30.2 9.1 9.1 9.1  
 DIP BEARING 36.1 DEG 9.2 9.1 9.1 TILT/MILE 1.72 FEET  
 MULTIPLE BASE ERRORS -10.2

CITY TRAVERSE REDUCTION 7 DECEMBER 1955 ASA

ST PAULS LIVERPOOL CENTENNIAL

TIME 1543  
 FIELD STN C 665 806600. 418100. 19.70  
 PRESSURE 807350. 418750. 20.35  
 TEMP DRY 29.740 30.210 30.423 30.420  
 TEMP WET 0.0 0.0 0.0 0.0  
 SINGLE BASE ERRORS 0.0 0.0 0.0 0.0  
 DIP BEARING 28.8 10.4 9.3 TILT/MILE 11.4 -8.9 MULTIPLE BASE ERRORS -6.0  
 31.8 DEG 1.65 FEET

TIME 1604  
 FIELD STN 279 809300. 420000. 36.86  
 PRESSURE 807350. 418750. 20.35  
 TEMP DRY 29.736 30.209 30.400 30.414  
 TEMP WET 0.0 0.0 0.0 0.0  
 SINGLE BASE ERRORS 0.0 0.0 0.0 0.0  
 DIP BEARING 25.6 8.0 10.1 TILT/MILE 13.8 -2.2 MULTIPLE BASE ERRORS -0.4  
 35.5 DEG 1.45 FEET

TIME 1620  
 FIELD STN 279 809300. 420000. 36.86  
 PRESSURE 811250. 420600. 46.23  
 TEMP DRY 29.729 30.211 30.402 30.385  
 TEMP WET 0.0 0.0 0.0 0.0  
 SINGLE BASE ERRORS 0.0 0.0 0.0 0.0  
 DIP BEARING 21.1 -0.2 1.9 TILT/MILE 8.2 -1.7 MULTIPLE BASE ERRORS 5.7  
 59.4 DEG 1.30 FEET

TIME 1625  
 FIELD STN 181 810350. 421600. 67.96  
 PRESSURE 811250. 420600. 46.23  
 TEMP DRY 29.727 30.211 30.371 30.389  
 TEMP WET 0.0 0.0 0.0 0.0  
 SINGLE BASE ERRORS 0.0 0.0 0.0 0.0  
 DIP BEARING 19.2 -2.0 -2.5 TILT/MILE 2.7 -2.6 MULTIPLE BASE ERRORS 2.1  
 65.5 DEG 1.25 FEET

CITY TRAVERSE REDUCTION 7 DECEMBER 1955 ASA

ST PAULS LIVERPOOL CENTENNIAL

TIME 1700  
 FIELD STN 181 X  
 PRESSURE 810350. 421600. 67.96  
 TEMP DRY 810800. 422500. 122.80  
 TEMP WET 30.340 30.207 30.371 30.313  
 SINGLE BASE 69.0 0.0 0.0 0.0  
 ERRORS 61.7 0.0 0.0 0.0  
 DIP BEARING 26.8 -9.6 TILT/MILE -11.1 MULTIPLE BASE ERRORS -7.5  
 71.3 DEG 1.85 FEET

TIME 1728  
 FIELD STN X  
 PRESSURE 812900. 423800. 215.00  
 TEMP DRY 810800. 422500. 122.80  
 TEMP WET 30.340 30.208 30.208 30.315  
 SINGLE BASE 68.5 0.0 0.0 0.0  
 ERRORS 61.2 0.0 0.0 0.0  
 DIP BEARING 25.6 -7.8 TILT/MILE -14.2 MULTIPLE BASE ERRORS -8.3  
 76.2 DEG 1.88 FEET

TIME 1734  
 FIELD STN X  
 PRESSURE 812900. 423800. 215.00  
 TEMP DRY 810800. 422500. 122.80  
 TEMP WET 30.340 30.212 30.212 30.212  
 SINGLE BASE 68.5 0.0 0.0 0.0  
 ERRORS 61.2 0.0 0.0 0.0  
 DIP BEARING 33.0 -4.1 TILT/MILE -4.1 MULTIPLE BASE ERRORS 0.0  
 66.7 DEG 2.17 FEET

APPENDIX IV

Leap-frog Reductions.

6th December, 1955	269.
7th December, 1955	270.

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	NO OF STATIONS	MISCLOSE
924	ST PAULS		663.00	22	-0.4
936	296	1.2			
946	295	7.8			
1000	294	1.7			
1010	293	19.5			
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	6.7			
1230	285	5.8			
1245	100	8.2			
1305	178	6.2			
1420	220	11.8			
1500	A	19.9			
1530	637	24.4			
1555	222	26.0			
1615	223	22.4			
1645	224	26.0			
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	NO OF STATIONS	MISCLOSE
905	637		35.84	11	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	25	-7.5
1151	647	-0.9			
1209	648	3.9			
1216	649	-3.2			
1227	650	0.2			
1236	651	-3.3			
1246	652	-2.2			
1300	653	-2.2			
1312	654	-5.1			

LEAP	FROG METHOD			
CITY	TRAVERSE	REDUCTION	7 DEC	55 CONTINUED
13233	655		-7.8	
13337	656		-3.2	
13455	657		-4.1	
13557	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

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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	0.0	-97.7	0.0
924 ST PAULS			0.0	0.0	-97.7	0.0
936 ST PAULS			0.0	0.0	-114.1	0.0
936 296			2.6	2.6	-106.0	0.1
946 295			3.8	3.8	-100.7	-2.1
946 296			-4.4	-4.4	-114.7	-7.7
1000 295			5.1	5.1	-98.9	-0.6
1000 294			4.8	4.8	-73.4	-13.0
1010 293			11.5	11.5	-55.8	-7.4
1010 294			2.4	2.4	-70.2	-14.0
1020 293			8.2	8.2	-56.6	-10.2
1020 292			4.9	4.9	-55.2	-15.7
1029 291			12.3	12.3	-37.2	-8.0
1029 292			6.4	6.4	-48.3	-11.6
1039 291			12.0	12.0	-35.0	-7.1
1039 290			6.5	6.5	-38.6	-13.4
1058 289			11.4	11.4	-32.6	-10.6
1058 290			6.9	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		9.0	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.

Standard Atmosphere	SVY 12	288.
Isobaric Surface Investigation	SVY 14	290.
Barometer Traverse Reduction	SVY 19	296.
Tower Readings Reduction	SVY 24	303.
Automatic Graphing	SVY 16	305.
Analysis of Summaries I	SVY 26	307.
Two Base Barometer Reduction	SVY 42	310.
Leap-frog Reduction	SVY 43	312.
Analysis of Summaries II	SVY 46	317.



```

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 TO 800.0 MM BY .1 MM STEPS

```

```

C DIMENSION TABLE(5,11),NAME(4)
C MMM=2
C IPAGE=8

```

```

C READ PARAMETERS AND INTERVAL
100 READ (1,50) CON1,CON2,NAME,AINT
50 FORMAT (F9.2,F8.5,2X,4A2,F5.1)

```

```

C SET INITIAL PRESSURE
C CONS=600.0
C DO 5 N=1,IPAGE

```

```

C WRITE PAGE HEADING
C WRITE (MMM,55)NAME
C WRITE(3,99) AINT
C WRITE(3,98)
C DO 5 M=1,6
C WRITE(3,99) CONS
C DO 2 I=1,5

```

```

C A=I
C TABLE(I,1)=CONS+(A-1.)*10.0*AINT
C WRITE(3,99) A
C WRITE (I,1)

```

```

C CALCULATE ELEVATIONS
C DO 1 J=2,11
C B=J-1
C COST=TABLE(I,1)
C TABLE(I,J)=CON1*(1.-((COST+(B-1.)*AINT)/760.))**CON2)
C IF (TABLE(I,J))6,1,7
6 TABLE(I,J)=TABLE(I,J) -0.05
7 GO TO 1
7 TABLE(I,J)=TABLE(I,J) +0.05
1 CONTINUE

```

```

C
C
C
SURVEY NO 12 CONTINUED
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 2H.6,5X,2H.7,5X,2H.8,5X,2H.9 /3X,11(7H-----))
2 2H.0,5X,2H.1,5X,2H.2,5X,2H.3,5X,2H.4,7X,2H.5,5X,
99 FORMAT(1H,/,)
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
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,I1,5X,18A4)
20 WRITE (M,20) DESC
FORMAT(1H1,///7X,18A4//)
GO TO (21,22,23),IDI
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
C SURVEY NO 14 CONTINUED
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
201 WRITE (M,201) CON1,CON2
FORMAT(/7X,10HCONSTANT 1,F10.2/7X,10HCONSTANT 2,F10.5)
3 WRITE (M,3)
FORMAT(/7X,8H STATION,9X,1HX,10X,1HY,7X,6HHEIGHT)
4 WRITE (M,4) ((A(I,J),J=1,6),I=1,5)
FORMAT(7X,3A4,F10.0,1X,F10.0,1X,F8.2)
5 DO 5 I=2,5
DO 5 J=4,5
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)/77.6)
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(14,5(F7.2,2F4.0))

```

```

C
C SURVEY NO 14 CONTINUED
C TIME NEGATIVE..READ NEW PARAMETERS, ZERO..READ NEW UNITS,
C POSITIVE..CARRY ON COMPUTATION
C IF (ITIME)200,50,31
31 N=5
10 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 (IDI-3)89,87,89
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 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 IDI=1 PRESSURE IN MILLIBARS,=2 MILLIMETERS,=3 INCHES
33 GO TO (60,61,62),IDI
61 CD=1013.25/760.
62 CD=1013.25/29.921
63 DO 64 J=1,N
64 RE(J,1)=RE(J,1)*CD

```

```

C
C
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
C SURVEY NO 14 CONTINUED
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.+0.0000344*HSA(I)
1 +1.6*.000001*.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)
ERROR(I)=CALHT(I)-A(1,6)
E32=ERROR(2)-ERROR(3)
ERROR(6)=(E32*CONE-ERROR(2))*COND+CALHT(4)-A(4,6)
C
C WRITE RESULTS
IF(N-4)I9,I9,48
ERROR(7)=(E32*CONG-ERROR(2))*CONF+CALHT(5)-A(5,6)
48 WRITE(M,46)
46 FORMAT(7X,18HSINGLE BASE ERRORS ,32X,20MULTIPLE BASE ERRORS)
81 WRITE(M,81) (ERROR(I),I=2,7)
FORMAT(7X,4F10.1,10X,2F10.1)
GO TO 40
19 WRITE(M,46)
82 WRITE(M,82) (ERROR(I),I=2,4),ERROR(6)
FORMAT(7X,3F10.1,20X,F10.1)

```

```

C
C
C
SURVEY NO 14 CONTINUED
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
75 IF (MM - MMM) 75, 76, 76
GO TO 8
C
C
WRITE NEW PAGE HEADING
MM = 0
76 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
C DIMENSION DESC(18),A(5,6),RE(5,3),HSA(5),TEMPS(5),DIFFHT(5),
C 1 CALHT(5),ERROR(7),B(3,6)
C
C READ PARAMETERS
C 300 READ(1,350) CON1,CON2,M
C 350 FORMAT(F9.2,2X,F6.5,I3)
C
C READ UNITS
C 250 READ (1,1) ID1, ID2, ID3, DESC
C 1 FORMAT(11,11,11,5X,18A4)
C WRITE(M,20) DESC
C 20 FORMAT (1H1, //7X,18A4//)
C 400 WRITE (M,400) CON1,CON2
C FORMAT (/7X,10HCONSTANT 1,F10.2/7X,10HCONSTANT 2,F10.5)
C GO TO (21,22,23), ID1
C 21 WRITE (M,11)
C 11 FORMAT(8X,22HPRESSURES IN MILLIBARS)
C GO TO 24
C 22 WRITE(M,12)
C 12 FORMAT(8X,24HPRESSURES IN MILLIMETERS)
C GO TO 24
C 23 WRITE(M,13)
C 13 FORMAT (8X,19HPRESSURES IN INCHES)
C 24 GO TO (25,26), ID2
C 25 WRITE(M,14)
C 14 FORMAT (8X,25HTEMPERATURES IN FARENHEIT)
C GO TO 27
C 26 WRITE(M,15)
C 15 FORMAT (8X,26HTEMPERATURES IN CENTIGRADE)

```

```

C
C SURVEY NO 19 CONTINUED
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
C      SURVEY NO 19 CONTINUED
C      DO 95 I=4,5
C      DO 95 J=4,5
C      A(I,J)=(A(I,I)-B(3,J))/CC
C      CONA=A(4,5)/A(4,4)
C      CONB=(A(3,5)-A(2,5))/(A(3,4)-A(2,4))
C      X6=(CONB*A(2,4)-A(2,5))/(CONB-CONA)
C      Y6=CONA*X6
C      COND=SQRT((A(4,4)**2+A(4,5)**2)/(X6**2+Y6**2))
C      CONE=SQRT((A(2,4)-X6)**2+(A(2,5)-Y6)**2)/((A(2,4)-A(3,4))**2+
1      1(A(2,5)-A(3,5))**2))
C      IF(A(5,6))7,7,6
C      6 CONCA=A(5,5)/A(5,4)
C      X7=(CONCA*A(2,4)-A(2,5))/(CONB-CONC)
C      Y7=CONC*X7
C      CONF=SQRT((A(5,4)**2+A(5,5)**2)/(X7**2+Y7**2))
C      CONG=SQRT((A(2,4)-X7)**2+(A(2,5)-Y7)**2)/((A(2,4)-A(3,4))**2+
1      1(A(2,5)-A(3,5))**2))
C      7 CONTINUE
C
C      READ TIME, PRESSURES AND TEMPERATURES
C      96 READ (1,9)ITIME,((RE(I,J),J=1,3),I=1,5)
C      99 FORMAT (I4,5(F7.2,2F4.0))
C
C      TIME NEGATIVE READ NEW PARAMETERS, ZERO READ NEW UNITS,
C      POSITIVE CARRY ON COMPUTATION
C      IF (ITIME)300,250,31
C      31 N=5
C      IF (RE(5,1))10,10,44
C      10 N=4
C      44 DO 85 J=2,3
C      DO 85 I=1,N
C      85 RE(I,J)=RE(I,J)/10.
C      MB=N-3
C      WRITE(M,45)ITIME,((B(J,I),I=1,6),J=1,MB)
C      45 FORMAT(/7X,4HTIME,3X,I4 /7X9HFIELD STN,3X3A4,F10.0,2XF10.0,2XF8.2
1      /19X,3A4,F10.0,2X,F8.2)
C      1 IF (IDI-3)89,87,89
C      87 WRITE(M,88)(RE(J,1),J=1,N)
C      88 FORMAT(1H ,7X,8HPRESSURE,5(3X,F8.3))
C      GO TO 90

```

```

C C SURVEY NO 19 CONTINUED
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.
62 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
DO 86 I=1,N
65 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.

```

## SURVEY NO 19 CONTINUED

```

ONN=0.
DO 70 I=1,N
PM=PM+RE(I,1)
IF (RE(I,2))80,80,71
71 ON=ON+I.
DT=DT+RE(I,2)-TEMPS(I)
TM=TM+RE(I,2)
IF (RE(I,3)) 80,80,72
72 ONN=ONN+I.
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.+0.00000344*HSA(I)
1 +1.6*.000001*0.00001*HSA(I)**2)
16 CONTINUE

```

```

C
C
C
SURVEY NO 19 CONTINUED
CALCULATE ERRORS
DO 81 I=2,N
DIFFHT(I)=HSA(I)-HSA(I)
CALHT(I)=A(I,6)+DIFFHT(I)
ERROR(I)=CALHT(I)-A(I,6)
E32=ERROR(2)-ERROR(3)
ERROR(6)=(E32*CONG-ERROR(2))*COND+CALHT(4)-A(4,6)
IF(N-4)19,19,82
ERROR(7)=(E32*CONG-ERROR(2))*CONF+CALHT(5)-A(5,6)
C
C
WRITE RESULTS
WRITE(M,83)
FORMAT(7X,18HSINGLE BASE ERRORS ,32X,20HMULTIPLE BASE ERRORS)
WRITE(M,84)(ERROR(I),I=2,7)
FORMAT(7X,4F10.1,10X,2F10.1)
GO TO 40
19 WRITE(M,83)
WRITE(M,92)(ERROR(I),I=2,4),ERROR(6)
FORMAT(7X,3F10.1,20X,F10.1)
C
C
CALCULATE TILT AND TILT DIRECTION
IF(ABS(E32)-0.1)41,41,42
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
BNG=90.+57.295780*ATAN(W)
IF (ABS(ERROR(2))-ABS(ERROR(3)))51,51,50
J=2 TO 52
GO TO 52
J=3
DIPDIS=ABS(A(J,4))*W-A(J,5))/SQRT(1.+W*W)
TILT=ABS(ERROR(J))/DIPDIS
IF (M-3)37,38,38
IF (M-4)33,33,34
38 IF (N-4)33,33,34
33 WRITE(2,35)TILT,BNG,TILT,(ERROR(I),I=2,4),ERROR(6),N
35 FORMAT(7X,14,F6.1,F5.2,3F9.1,9X,F9.1,12X,I1)
GO TO 37

```

```

C
C SURVEY NO 19 CONTINUED
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(N,53)BNG,TILT
53 FORMAT(7X,I11HDIP BEARING,F6.1,4H DEG,10X,9HTILT/MILE,F5.2,5H FEET)
78 IF (K) M=98
98 WRITE(M,98)
69 FORMAT(1X,1H )
MM=MM+1
C CHECK FOR END OF PAGE
75 IF(MM-MMM)75,76,76
GO TO 150
C WRITE NEW PAGE HEADING
76 MM=0
77 WRITE(N,77)DESC,((A(I),J),J=1,3),I=1,3)
FORMAT(1H,////8X,18A4//8X,3(3A4,2X))
MMM=4
GO TO 150
END

```

```

C
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
C K INDICATES SECONDARY CONTROL POINT
90 READ(4,13) CON1,CON2,K
13 FORMAT(F9.2,2X,F5.5,2X,I1)
14 WRITE(1,14) CON1,CON2,K
100 READ(4,11) ANAME,FT(1),FT(2),R(1),3X,6(1H-)
1 I FORMAT(A4,2F4.1,7F8.2)
12 IF (ANAME-16448.) 12,90,12
12 FT(1)=FT(1)-2.41
12 FT(2)=FT(2)-2.41
200 DO 2 1=1,145367.59*(1.-(R(1)/760.))**0.19023)
2 HSA(1)=145367.59*(1.-(R(1)/760.))**0.19023)
TSID=59.70.003566*HSA(7)
DTW=FT(1)-FT(2)
DT=FT(1)-TSTD
DDT=DT
I=273.16+(FT(2)-32.)*5./9.
CA=TS/T
Cb=(1.-T/TS)*11.344
CF=-3.49149*(CA-1.)
CDF=-18.19731*(CA-1.)-.0031812*.0001*(10.**CB-1.)+.00187265*(10.**
1 CF-1.)+6.9209182
1 CDE=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
      HS (I)=HSA(I)+HSA(I)/518.4*DDT*(1.+0.00000344*HSA(I)
1 +1.6*0.000001*0.00001*HSA(I)**2)
9 CONTINUE
      DO 3 I=1,7
      IF (R(I))3,6,10
      ERROR(I)=99.99
6 GO TO 3
10 ERROR(I)=HSA(I)-HSA(7)-HT(I)
3 CONTINUE
      IF (K) 99,50,51
C      CALCULATE NEW PARAMETER
      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 MINIMUM
      CALL DATSW (1,M)
      GO TO (55,60),M
      SUM=0.0
      DO 65 I=3,6
      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
      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)
200 READ (1,200) M, INDEX
100 FORMAT (11,6A1)
400 READ (1,35) DESC
WRITE (M,400)
FORMAT (1H1//)
35 WRITE (M,35) DESC
FORMAT (7X,18A4)
30 WRITE (M,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) I1, I1TIME, BNG, TILT, (ERROR(I), I=1,6), N
25 FORMAT(6X,A1, I4, F6.1, F5.2, 6F9.1, 3X, I1)
1 IBNG=BNG
C IF DATA FOLLOWED BY A BLANK CARD HEADING REPEATED
C DO 46 K=1,61
46 IGRAPH(K)=0.0
32 IF (I1TIME) 31,31,32
1 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
      MM=6
      DO 15 J=1,MM
      K=ERROR(J)+31.5
      IF (K) 27,27,28
      K=1
      IF (K-61) 29,45,45
      K=61
      CONTINUE
      IGRAPH(K)=J
      DO 16 J=1,61
      IF (IGRAPH(J)) 17,18,17
      IGRAPH(J)=II
      GO TO 16
      K=IGRAPH(J)
      IGRAPH(J)=INDEX(K)
      CONTINUE
      IF (N-7) 21,22,22
      WRITE (M,23) II,TIME,(IGRAPH(J),J=1,61)
      FORMAT (6X,14,9X,61A1)
      GO TO 10
      WRITE (M,19) II,TIME,IBNG,TILT,(IGRAPH(J),J=1,61)
      FORMAT (6X,14,14,F5.2,61A1)
      GO TO 10
      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
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
C 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

```

```

C      PROGRAMME SVY 26 CONTINUED
      IF (N-4)60,60,70
      AN(I,6)=AN(I,6)-1.0
      AN(I,4)=AN(I,4)-1.0
C      FORM PROGRESSIVE TOTALS OF V, VV, VVV
      DO 80 J=1,6
      AN(I, J)=AN(I, J)+1.0
      DO 80 K=1,3
      V(I, K, J)=V(I, K, J)+A(J)**K
      GO TO 200
C      CALCULATE MOMENTS 1,2,3
      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
      GO TO 116
      V(I, JJ, K)=V(I, J, K)/ AN(I, K)
      110 CONTINUE
      V(I, 5, K)= SQRT (V(I, 5, K))
      115 CONTINUE
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,
      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,F10.2,4X,F5.0)
150 CONTINUE
    WRITE (MMM,160)
160 FORMAT (/)
170 CONTINUE
    GO TO 100
    END
```

```

&      PROGRAMME SVY 42 TWO BASE BAROMETER REDUCTION
      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
      FORMAT (8X, 18A4)
      WRITE (M,20) DESC
20   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)
      FORMAT (3A4, 2X,F10.0,1X,F10.0,1X,F8.2)
2   WRITE (M,3)
3   FORMAT (//7X,8H STATION,9X,1HX,10X,1HY,7X,6HHEIGHT)
4   WRITE(M,4)((A(I,J),J=1,6),I=1,3)
      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
31   IF (ITIME)300,250,31
10   N=5
44   IF (RE(5,1))10,10,44
      N=4
      NN=NN+N
      DO 15 J=1,3
      DO 15 I=1,N
15   DP(I,J)=RE(I,1)-RE(J,1)
      DO 15 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
      II=II-3
      16 ERROR(I,J)=A(I,6)+DP(K,I)/DP(II,I)*DHT(I)-A(K,6)
      17 CONTINUE
      NNN=NNN+1
      26 WRITE (M,26) ITIME,(A(K,IA),IA=1,3),(ERROR(IB,J),IB=1,3)
      19 FORMAT (1H,18X,I4,3X,3A4,5X,3F9.1)
      21 IF (M-2) 18,18,21
      JJ=1
      51 IF (N-5) 50,51,51
      50 JJ=2
      50 WRITE (2,22) ITIME,((ERROR(I,J),I=1,3),J=1,3),NN
      22 FORMAT (1H,6X,I4,11X,6F9.1,3X,11)
      18 CONTINUE
      27 WRITE (M,27)
      27 FORMAT (/)
      NNN=NNN+2
      IF (NNN-41) 23,24,24
      C      SET NEW PAGE
      24 WRITE (M,20) DESC
      25 WRITE (M,25) ((A(I,J),J=1,3),I=1,3)
      25 FORMAT (1H,7X,3(3A4,2X)/)
      23 GO TO 100
      END

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C
PROGRAMME SVY 43, LEAP FROG REDUCTION OF BAROMETER READINGS
PREPARED BY J.S. ALLMAN, JULY 1967
IBM 360 VERSION

ID1=1 PRESSURE IN MILLIBARS,=2 MILLIMETERS,=3 INCHES
ID2=1 TEMPERATURES IN FARENHEIT, =2 CENTIGRADE
ID3=1 COORDINATES IN YARDS,=2 FEET
M=2...PUNCH, M=3...PRINT
ITIME=0 READ NEW BASES, = NEGATIVE READ NEW CONSTANTS

1 DIMENSION A(2,4),C(25,3),CLHT(25),ERROR(25),BASE(3,4),RE(5,3),
   HSA(5),TEMPS(5),ITIME(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(11,I1,11,5X,18A4)
20 WRITE(M,20) DESC
   FORMAT(1H1,7X,16HLEAP FROG METHOD/7X,18A4)
400 WRITE (M,400) CON1,CON2
   FORMAT (7X,10HCONSTANT 1,F10.2/7X,10HCONSTANT 2,F10.5)
21 GO TO (21,22,23),ID1
   WRITE (M,11)
11 FORMAT(8X,22HPRESSURES IN MILLIBARS)
22 WRITE(M,12)
12 FORMAT(8X,24HPRESSURES IN MILLIMETERS)
23 GO TO 24
   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)
26 GO TO 27
   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(1,3A4,23X,F8.2)
3 WRITE (M,3) ((BASE(J,I),I=1,4),J=1,3)
   FORMAT (8X,3A4,5X,F8.2)

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```

C      PROGRAMME SVY 43 CONTINUED
420 WRITE (M,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))
997 READ (1,9) ITIME,((RE(I,J),J=1,3),I=1,5)
    WRITE (M,997) ITIME, (A(1,J),J=1,4)
    FORMAT (1H/8X,14,3X,3A4,17X,F8.2/)
999 C(1,I)=A(1,I)
    CLH(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 (14,5(F7.2,2F4.0))
    IB=II-1
    IF (ITIME)300,250,31
31 N=5
    ITIME(II)=ITIME
    IF(A(1,1)-A(2,1)) 151,150,151
    IF (A(1,1)-C(IB,1))153,152,153
151 DO 154 J=1,3
152 C(II,J)=A(2,J)
154 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

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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
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
DTW=DTW/ONN
74 TS=373.16
55 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-.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.+0.00000344*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,I)-BASE(J,I)) 157,158,157
157 CONTINUE
100 CONTINUE
158 IA=II
CLHT(1)=BASE(J,4)
WRITE (M,410) IA,ERROR(IA)
410 FORMAT (I4,32X,14HNO OF STATIONS,I4,5X,8HMI SCLOSE,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
      C(1,I)=C(IA,I)
998  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
V(I,J,K)=0.0
200 READ (1,10) ITIME,BNG,IILI,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

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```

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 8HMAXIMUM,5X,2HNO7)
   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,14,2F12.2,F8.0)
150 CONTINUE
   WRITE (MMM,160)
160 FORMAT(2H )
170 CONTINUE
   GO TO 100
END

```

APPENDIX VII

## Analysis of Summaries.

Average and Maximum Errors	320.
First, Second and Third Moments	328.
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	MAXIMUM	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	MAXIMUM	NO
0.0	1	2.24	5.90	22.
0.50	1	6.18	13.80	12.
1.00	1	14.13	18.20	19.
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	19.
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	19.
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	19.
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	19.
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	19.
1.50	6	2.72	4.10	6.

SUMMARY COOTAMUNDRA AREA 28 FEBRUARY 1966 ASA  
 SINGLE AND MULTIPLE BASE ERRORS

TILT	GRAPH	AVERAGE	MAXIMUM	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	MAXIMUM	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	MAXIMUM	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	MAXIMUM	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	MAXIMUM	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	14.85	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	MAXIMUM	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	19.15	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	19.45	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	19.25	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	NU
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	18.40	11.59	2277.64	4.
1.00	3	18.85	19.22	7971.57	5.
1.50	3	4.39	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	117.89	4.
1.00	5	5.40	11.00	1770.84	5.
1.50	5	-5.55	16.65	-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	9.32	14.08	3793.50	5.
1.50	6	-8.23	19.23	-893.77	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	BRD	MUM	INC
0.0	1	3.40	3.40	59.30	1.8	1.8
0.50	1	-1.94	6.53	-211.91	8.8	8.8
1.00	1	12.84	18.38	6488.55	19.2	19.2
1.50	1	26.82	27.11	20557.93		
2.00	1	34.10	34.12	39775.59		
0.0	2	6.90	6.90	328.51	1.8	1.8
0.50	2	7.52	7.57	440.67	8.8	8.8
1.00	2	8.71	10.80	1597.65	19.2	19.2
1.50	2	13.63	15.72	4248.86		
2.00	2	15.05	10.45	1397.18		
0.0	3	3.60	3.60	46.66	1.8	1.8
0.50	3	7.21	7.40	427.31	8.8	8.8
1.00	3	9.57	12.14	2478.29	19.2	19.2
1.50	3	13.89	16.89	5655.51		
2.00	3	15.35	10.86	1586.44		
0.0	4	3.60	3.60	46.66	1.8	1.8
0.50	4	7.47	8.04	584.82	8.8	8.8
1.00	4	9.97	11.80	2208.59	19.2	19.2
1.50	4	11.99	15.12	3317.69		
2.00	4	15.15	10.59	1458.53		
0.0	5	1.70	1.70	4.91	1.8	1.8
0.50	5	18.01	9.57	1153.04	8.8	8.8
1.00	5	1.91	6.55	491.42	19.2	19.2
1.50	5	-6.97	8.57	-813.65		
2.00	5	-6.20	8.77	-953.31		
0.0	6	1.70	1.70	4.91	1.8	1.8
0.50	6	18.19	9.44	1074.45	8.8	8.8
1.00	6	2.09	5.34	158.13	19.2	19.2
1.50	6	-8.95	9.55	-1027.63		
2.00	6	-6.30	8.91	-1000.19		



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.  
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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.  
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7. Control for Mapping. (Proceedings of Conference, May 1967).  
P.V. ANGUS-LEPPAN, Editor. (UNISURV Report No. 7)
8. The teaching of field astronomy.  
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9. Photogrammetric pointing accuracy as a function of properties  
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