BUREAU OF MINERAL RESOURCES, GEOLOGY AND GEOPHYSICS

RECORD

BMR Record No. 1987/ 34

LEARMONTH GEOMAGNETIC OBSERVATORY INSTALLATION NOVEMBER 1986

by

P.A. Hopgood

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Contents

CHAPTER 1: **INTRODUCTION**

The long-term plan to expand the Bureau of Mineral Resources' (BMR) geomagnetic observatory network to more uniformly cover the Australian continent, included the establishment of a station in north-western Australia.

Following a request in 1981 by the Ionospheric Prediction Service (IPS) for BMR's collaboration in the installation of a sensor to monitor variations in a single geomagnetic element at the Learmonth Solar Observatory (LSO), it was mutually decided to locate the magnetic observatory planned for the region on this site.
The magnetic observatory would thus be guaranteed: a secure environment; availability of technical expertise; operation by interested and appropriately qualified personnel; a magnetically stable environment; a (fairly) dependable power supply.

Learmonth is situated on Australia's North West Cape, overlooking the Exmouth Gulf to the east, Cape Range to the west and is about 35 km. south of the town of Exmouth. A locality diagram is given in Figure 1.

The Learmonth Solar Observatory was established in 1977 and is operated jointly by IPS of the Australian Department of Science and the United States Air Force personnel. The solar observatory's telescopes operate every day during daylight hours, monitoring the sun's output and watching for signs of activity capable of affecting radio communications. This is an ideal environment to locate a geomagnetic observatory, the data gained complementing that from the solar observatory.

A proton precession magnetometer was loaned to IPS and operated at Learmonth from October 1983 whilst preparations were made for the installation of the complete magnetic observatory, which took place in late November 1986.

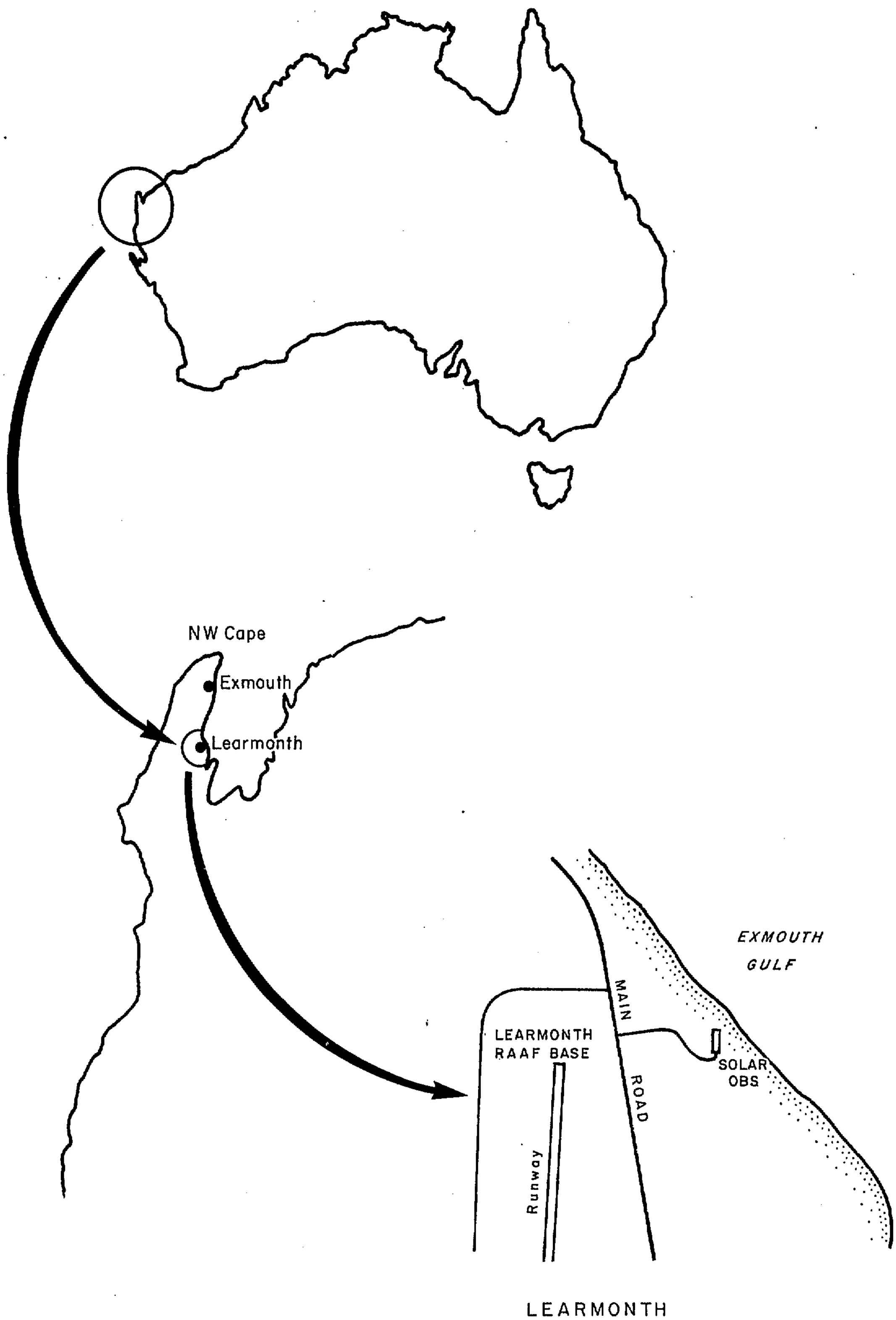

Fig.1 Location of Learmonth Solar Observatory

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CHAPTER 2: **EQUIPMENT**

The Learmonth Magnetic Observatory (LRMMO) consists of components located at three separate but neighbouring sites: the variometer sensor heads; the electronics associated with the sensors; and the absolute observation site.

There are two variometer sensor heads: one of a 3-component fluxgate variometer, the other of a proton precession magnetometer. The fluxgate sensor head is situated in a concrete vaultlet located within the perimeter of the solar observatory grounds approximately 50 metres to the east of the buildings. The vault is sunk into the ground by about two-thirds of its depth and has a thick concrete lid for temperature stability. Further temperature stability was gained by covering the vaultlet with sand when installation was completed. A PVC conduit carrying cables runs underground from the vaultlet to the electronics console.

The proton magnetometer head is located about 10 metres from the fluxgate head vault, on a wooden pole about 2 metres in height. The pole is embedded in concrete and was encased in PVC tubing during the LRMMO installation. Another underground PVC conduit carrying a cable runs from the PPM head to the electronics console.

The electronics console is located within the central or Radio Solar Telescope Network (RSTN) building of the solar observatory. The single rack and teletype are situated towards the south-eastern corner of the building.

The site selected for absolute observations is about 200 metres south of the solar observatory and situated on Royal Australian Air Force land. It consists of a concrete plinth beneath a shelter with brick walls on two sides to the same height of the plinth. Proton magnetometer surveys were performed in the vicinity of the site both before and after the erection of the shelter and pier. The results of these surveys are given in Tables 1a and 1b.

An overview of the relative locations of the magnetic observatory components is shown in Figure 2.

2.1 Instrumentation

The instrumentation employed to monitor the geomagnetic variations at the LRMMO consists of a 3-component EDA model FM-105B fluxgate magnetometer aligned to monitor the geomagnetic elements X, Y and Z, and an Elsec model 595 proton precession magnetometer (PPM) to monitor the total field intensity, F.

Because the fluxgate sensors are sensitive to temperature changes, it is necessary to also monitor the temperature, T, in the vicinity of the latter. This is achieved with a Doric series 410A Trendicator digital thermometer, with its sensor within the fluxgate sensor head casing.

Variations in the five parameters: X, Y, Z, F and T are recorded on both a Linseis analogue chart recorder and digitally on an EDAS-2 cassette tape recorder. Digital readings are taken each minute.

A digital clock is used in conjunction with the analogue recorder to place hour marks on the chart record. The EDAS-2 has its own internal clock and time is recorded every minute with each digital record.

The EDAS2 recorder is programmed by means of a teleprinter (TTY model 43). When required, data can be printed in parallel with the EDAS2.

Details of the operation of the instrumentation are given in the separate "Learmonth Geomagnetic Observatory Manual".

Table 1a

PPM survey of proposed Absolute Observation site at Learmonth

Distance from pier (metres)	East	West	South	North
3	0	0	0	0
6	0	-1	3	-1
9	3	0	-1	0
12	3	-2	0	0
15	2	-4	-2	2
18	-2	-3	-1	1
21	-2	-4	0	3
24	0	-6	0	4
27	-1	-6		4
30				6
33				7
36				5
39				7
42				9

Distance from pier (feet)				
3	1	0	1	1
6	1	-1	0	0
9	2	0	3	0
12	1	0	0	0

Observations: M.W. McMullan, February 1984

Reference : Proposed pier centre, 53251 nT.

Table 1b

PPM Survey of Absolute Pier & Shelter Site After Construction

Values given are means of two readings at the pier height of 1.2 metres and relative to an intensity level of 53327 nT.

Distance from Pier (metres)		East (0325 UT)	West (0330 UT)	South (0334 UT)	North (0338 UT)
0.0		+0.5	-0.5	0.0	0.0
1.8		-7.0	-7.5	-4.5	+4.0
3.6		-5.5	-8.0	-5.5	-7.5
5.4		-3.5	-9.5	-7.5	-6.0
7.2		-4.5	-10.0	-8.5	-4.5
9.0		-3.5	-9.5	-10.0	-2.5
18.0		-2.0	-14.5	-10.5	-2.0
0.0	at	0341 UT	+0.5		

Pier Check performed at 0345 UT

Location on Pier	Height above Pier	53320 nT plus
Centre	0.2 m	0.0
NW	0.2 m	+2.0
NE	0.2 m	+2.0
SE	0.2 m	0.0
SW	0.2 m	0.0
Centre	0.0	+5.5

Observers: P.J. Gregson & B.J. Page

Date of observation: 26 June 1986

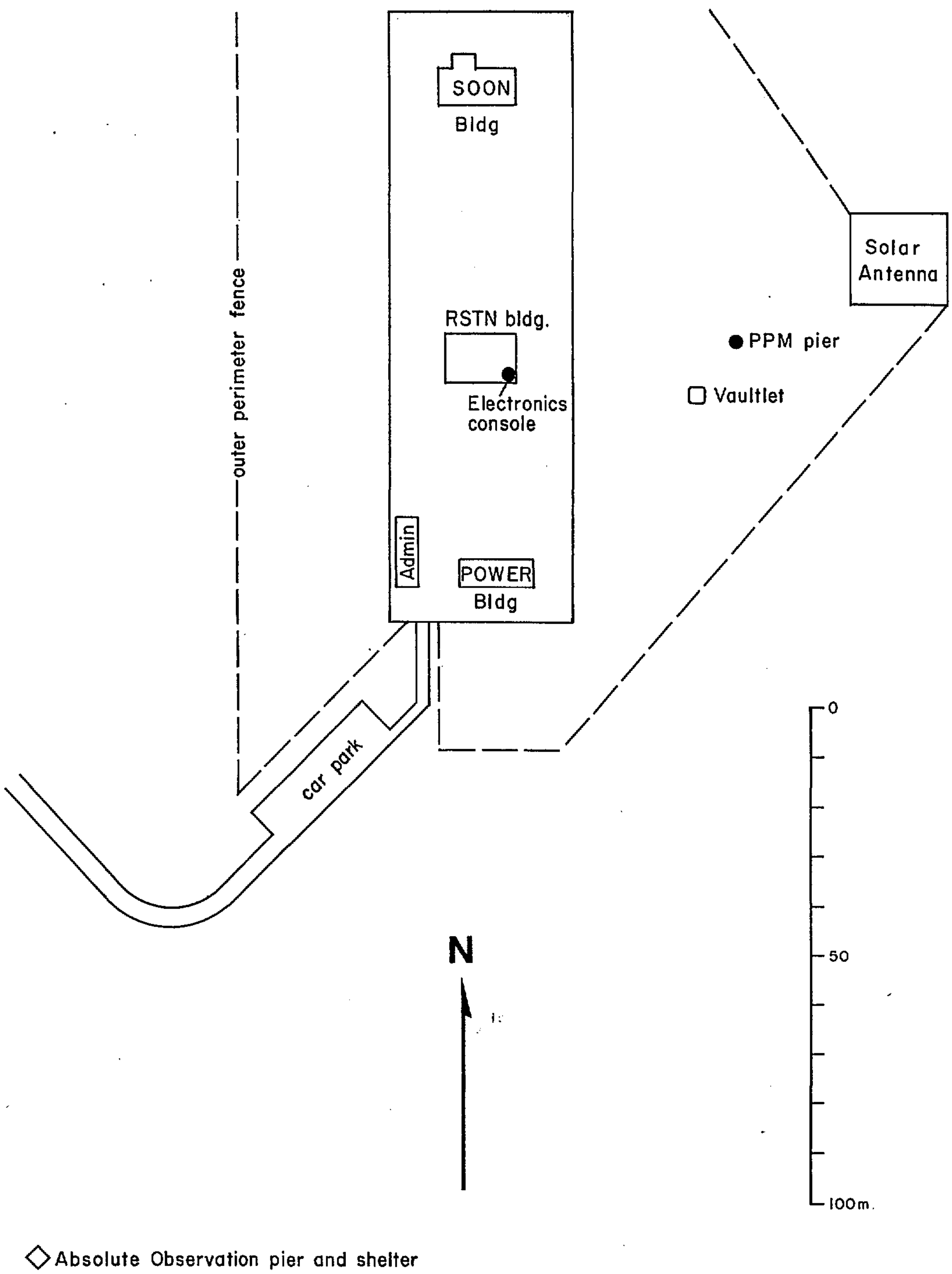

Fig 2 Overview of magnetic observatory components within Learmonth Solar Observatory compound

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CHAPTER 3: **CALIBRATION of SCALE VALUES**

Installed within the fluxgate sensor head is a small solenoid, oriented such that when a direct-current flows through the windings, a magnetic field is produced which has a component in each of the X, Y and Z directions. This 'scale-value' (SV) coil has been calibrated at the Canberra Magnetic Observatory to determine the X,Y & Z bias components produced per milliampere of current flowing.

3.1 Calibration of scale-value coil

The calibration of the SV-coil at CMO was achieved as follows:

- Level the Proton Vector Magnetometer (PVM) coils and align H coils in the magnetic meridian.
- Place EDA fluxgate head centrally within PVM coils and level.
- With PVM coils in the 0 degrees dowelled position (H coils in magnetic meridian) and all Baseline potentiometers on the EDA console set to the Lo position and wound back to zero, rotate the fluxgate sensor head so the meter reads zero when switched to the Y position. This sets the X fluxgate sensor parallel to magnetic north.
- Switch the meter to X and bring the needle to the zero (centre) position with the X Baseline potentiometer.
- Introduce a current into the SV-coil in the fluxgate sensor head. This deflects the EDA meter needle from the zero position.
- Return the needle to the zero position by introducing a DC current into the PVM H-coil.
- Monitor the currents applied to SV-coil and PVM-coil for zero needle deflection to calibrate the X component SV-coil bias.
- Perform a similar procedure to calibrate Y component; and also using the Vertical PVM-coil, the Z component.

The SV-calibration results are given in Table 2 and graphed in Figure 3.

Since the coil constants of the PVM are known: Horizontal coil is 153.5 nT/mA; Vertical coil is 153.4 nT/mA; the slopes of the lines in Figure 3 give the constants of the SV-coil in the fluxgate sensor head:

X is 8.954 nT/mA; Y is 10.471 nT/mA; Z is 22.754 nT/mA.

3.2 Magnetograph Calibrator

A 'Magnetograph Calibrator' unit is installed in the electronics rack at LRMMO. This is a constant current supply designed to power the SV-coil in

Table 2

Calibration of Scale-Value Coil (within Fluxgate Sensor Head)

X: SV-coil current (mA)	X: PVM Helmholtz coils mA.	Y: SV-coil current (mA)	Y: PVM Helmholtz coils mA.	Z: SV-coil current (mA)	Z: PVM Helmholtz coils mA.
Reverse	Reverse	Reverse	Reverse	Normal	Reverse
0.0	0.0	0.0	0.0	(0.0	0.0)
2.25	-0.14	2.0	-0.11	-1.512	0.18
5.0	-0.29	4.0	-0.24	-2.34	0.315
7.3	-0.40	5.9	-0.32	-4.52	0.65
9.9	-0.575	8.0	-0.49	-6.75	0.99
12.5	-0.71	10.1	-0.63	-9.27	1.36
14.9	-0.84	12.9	-0.78	-11.6	1.70
18.5	-1.03	17.1	-1.06	-13.02	1.90
22.0	-1.26	21.1	-1.34	-15.34	2.21
26.6	-1.55	26.0	-1.66	-17.07	2.50
30.3	-1.76	30.1	-1.97	-20.0	2.95
34.0	-1.97	38.2	-2.55	-24.9	3.67
40.9	-2.39	49.2	-3.29	-29.9	4.43
50.0	-2.89	59.5	-3.98	-34.9	5.15
60.0	-3.47	69.9	-4.73	0.0	0.0
0.0	0.0	0.0	+0.10		

(0532 UT)

X: SV-coil current (mA)	X: PVM Helmholtz coils mA.	Y: SV-coil current (mA)	Y: PVM Helmholtz coils mA.	Z: SV-coil current (mA)	Z: PVM Helmholtz coils mA.
Normal	Normal	Normal	Normal	Reverse	Normal
-50.0	2.91	-69.7	4.78	35.1	-5.22
-40.0	2.33	-60.1	4.14	30.6	-4.55
-35.1	2.04	-50.0	3.39	25.0	-3.71
-30.1	1.78	-45.0	3.06	20.0	-2.99
-26.9	1.58	-39.9	2.72	15.1	-2.25
-23.1	1.37	-34.9	2.40	10.0	-1.50
-20.0	1.15	-30.0	2.03	7.5	-1.11
-17.1	1.01	-26.9	1.84	5.9	-0.89
-15.0	0.89	-23.7	1.61	4.0	-0.61
-13.2	0.79	-20.0	1.38	2.1	-0.33
-11.0	0.67	-16.8	1.18	1.05	-0.16
-9.1	0.56	-13.1	0.88	0.5	-0.11
-7.0	0.40	-9.9	0.68	0.0	0.0
-5.1	0.30	-7.0	0.47		
-3.0	0.19	-5.0	0.35	(0445 UT)	
-0.9	0.04	-3.5	0.22		
0.0	0.0	-1.5	0.10		
		0.0	0.0		

(0550 UT)

Observations: 24 March 1986 by PAH & TS.
Location: Canberra Magnetic Observatory, Pier AE
Ammeters: Calibration coil - AWA; PVM coil - Fluke.

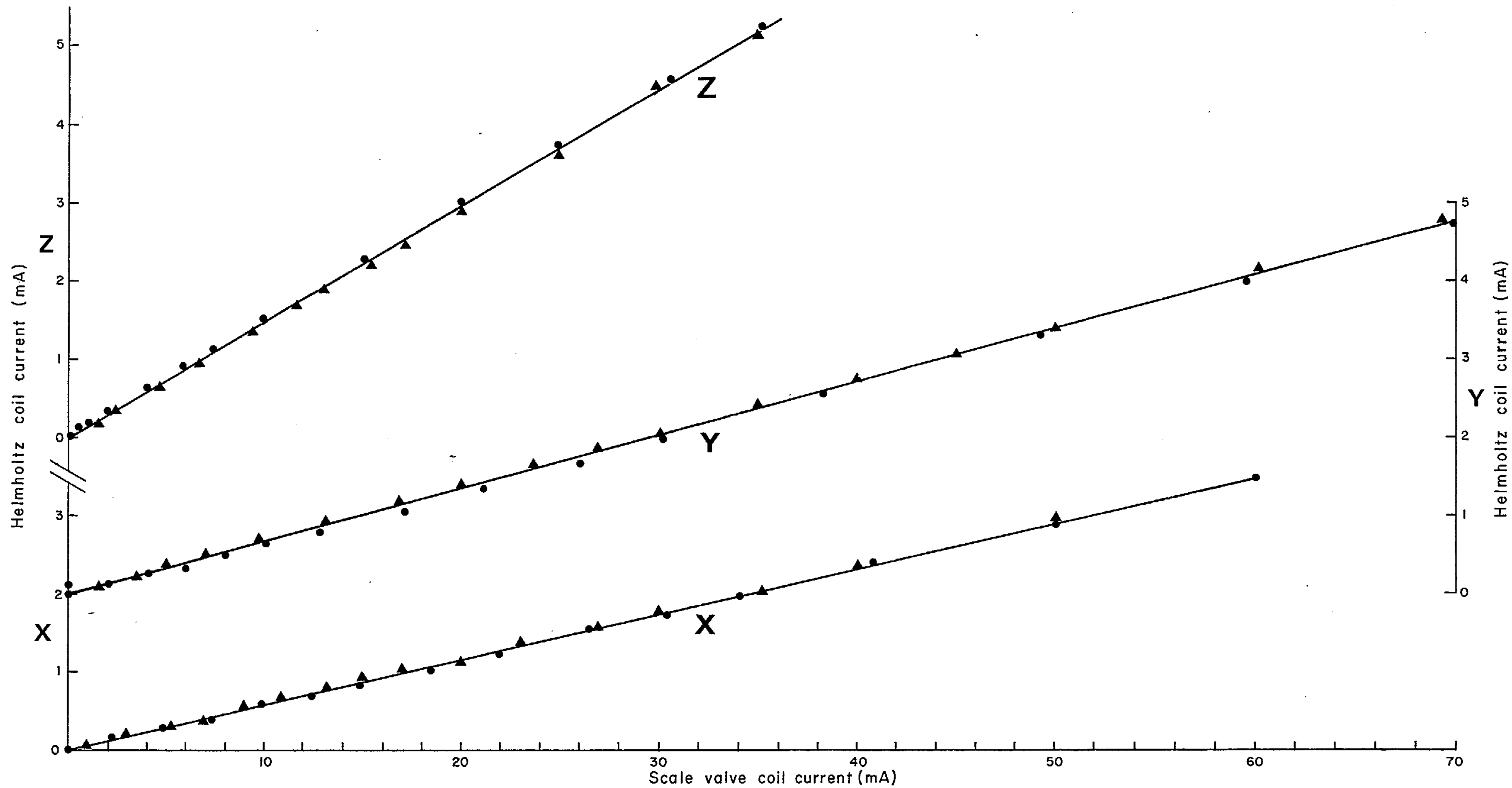

Fig.3 Calibration of scale-value coil in fluxgate sensor head

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Table 3

Calibration of Magnetograph Calibrator Meter

Meter mA.	True mA.
0.66	0.83
1.47	1.65
3.15	3.33
6.42	6.61
13.0	13.20
25.8	26.02
49.9	50.2

Least-squares straight line of best fit:

True-mA = 1.0025 x Meter-mA + 0.1705

Calibration performed by ESU/BMR

the EDA fluxgate sensor head when a scale-value (SV) determination is required.

Although the Magnetograph Calibrator unit is normally switched on, unless a SV determination is actually being performed, it will be switched to 'Dummy' position. This will direct the current through a 14 ohm resistor, a resistance approximately equal to that of the SV-coil at 5 ohm plus the cable resistance to the coil and back from the unit at 9 ohm.

On the front panel of the Magnetograph Calibrator is a digital readout of the current flowing. The current shown on this meter is not exact. The meter has been calibrated by BMR, the results of which are shown in Table 3.

The least squares straight line to the data in Table 3 is:

$$\text{True mA} = 1.0025 \times \text{mA (on meter)} + 0.1705$$

Hence at current setting #5, yielding approximately 12.66 mA, a current considered appropriate by which to calibrate the system giving a bias field ~ 100 nT on all three components, a correction of 0.20 mA is to be added to the observed meter reading.

By applying a known current to the SV-coil in the fluxgate head, the scale-values for the system's output may be determined.

When SV-tests are performed, three applications of the current are required: each successive current in the opposite direction to that previous, ie +, -, +. For each current application, the current must flow continuously for the duration of the EDAS-2 sampling interval of one minute.

Whilst the X,Y,Z scale-value tests are performed, F(100nT), F(0nT), F(100nT) are performed concurrently, as well as a reading of the Doric digital thermometer readout.

3.3 Preliminary scale-value determinations

EDAS-2 digital outputs during routine calibrations performed from November 22-26 are given in Table 4.

From these results, preliminary SV's in units of nT per EDAS-2 count have been calculated:

SV(X) = 0.1973; SV(Y) = 0.1998; SV(Z) = -0.1956; SV(F) = 0.02164

To demonstrate how these SV's have been calculated the X scale-value is derived in detail:

Mean Magnetograph Calibrator current readout is = 12.65 mA

So the true current is 12.65 + 0.20 (corr'n) = 12.85 mA

The X-component bias produced by SV-coil is 8.954 nT/mA

So the X bias is 8.954 x 12.85 = 115.06 nT

The difference in EDAS-2 output counts between both (+) and (-) current directions is 1166.1 counts

Table 4

Preliminary scale-value tests

Date in 1986:	22 Nov.	23 Nov.	24 Nov.	25 Nov.	26 Nov.	Means
U.T. :	0616	0446	0633	0816	0203	
Temp. °C:	43.14	32.12	33.11	30.44	31.06	
Current (mA):	12.625	12.64	12.65	12.66	12.66	12.65
EDAS2 counts:						
mean X(+)	5641	5591	5492	5132.5	5271.5	
X(-)	4476	4424	4324	3970	4107	
X(+) - X(-)	1165	1167	1168	1162.5	1164.5	1166.1
mean Y(+)	5328.5	5232	5258	5317	5132	
Y(-)	3982	3884	3911	4015	3786	
Y(+) - Y(-)	1346.5	1348	1347	1302	1346	1346.9
mean Z(+)	3603	3590	3715.5	3767.5	3696	
Z(-)	6594	6581	6704	6757	6688	
Z(-) - Z(+)	2991	2991	2988.5	2989.5	2992	2990.4
mean F(100)	4774.5	4734.5	4735	4692	4682.5	
F(OnT)	0169	0113	0122	0071	0062	
F(100) - F(0)	4605.5	4621.5	4613	4621	4620.5	4621
Zero counts:						
X					5001	
Y					4975	
Z					5000	

Hence the SV(X) = 115.06 x 2 / 1166.1 = 0.1973 nT/count

3.4 Temperature

The least squares linear fit to the temperature calibrations for the same days ie November 22-26, 1986 is:

$$\text{Temperature (deg. C)} = 0.019924 \times \text{EDAS-2 counts} - 0.176$$

Hence the temperature scale-value, ST, is 0.019924 and the temperature baseline, BT, is -0.176 degrees. So that:

$$T\ (^\circ C) = BT + ST \times \text{EDAS2-counts}$$

CHAPTER 4: **CONSTRUCTION DETAILS**

The vaultlet to house the fluxgate head and the absolute pier & shelter were constructed by the Geraldton Building Co. during June and July 1984.

4.1 Vaultlet

The vaultlet (see Figure 4 and Plate 1) is constructed of 100mm thick concrete on a foundation of approximately 400mm. It is of square section of inside dimension 600mm wide. It is 800mm deep approximately two-thirds of which is below ground level.

A conduit to the electronics console enters the western side of the vaultlet at about ground level. A vent pipe is connected to this conduit.

A 100mm thick concrete lid which overlaps the top by about 50mm all around was provided.

4.2 Absolute Pier & Shelter

The Absolute observation pier and shelter are shown in Figure 5 and Plate 2. This consists of a concrete plinth 1200mm in height from the floor, of square cross-section with side 380mm. The floor of the shelter is a 3-metre square concrete slab approximately 150mm thick. The roof is the same size as the floor. The NE and NW sides of the shelter have a wall to the same height as the pier.

Because the absolute shelter is accessible to sheep in the area, it is considered worthwhile to construct additional barriers on the two sides without walls to keep the floor area clean. A few courses of bricks would probably be adequate.

Three brass foot-pads were fixed to the top of the absolute pier at 120 degrees spacing with one towards the north.

Visible from the pier and used as azimuth reference marks are (see Figure 5):

i To the north: Western-most (left) edge of the northern-most (far) Solar Observatory building (the SOON building). This is the **NTH** mark of true azimuth 17.9256 degrees.

ii To the west: Wind-sock at the airport. The **WST** mark has a true azimuth of 283.0383 degrees.

iii To the south: The eastern-most (left) of the two aerial masts, between which is a small square building. This is the **STH** mark with true azimuth 195.8692 degrees.

The geographic co-ordinates of the absolute pier are 22° 13' 19" S (22.2219) latitude; 114° 06' 03" E (114.1008) longitude; with elevation of 3.9 metres above sea-level.

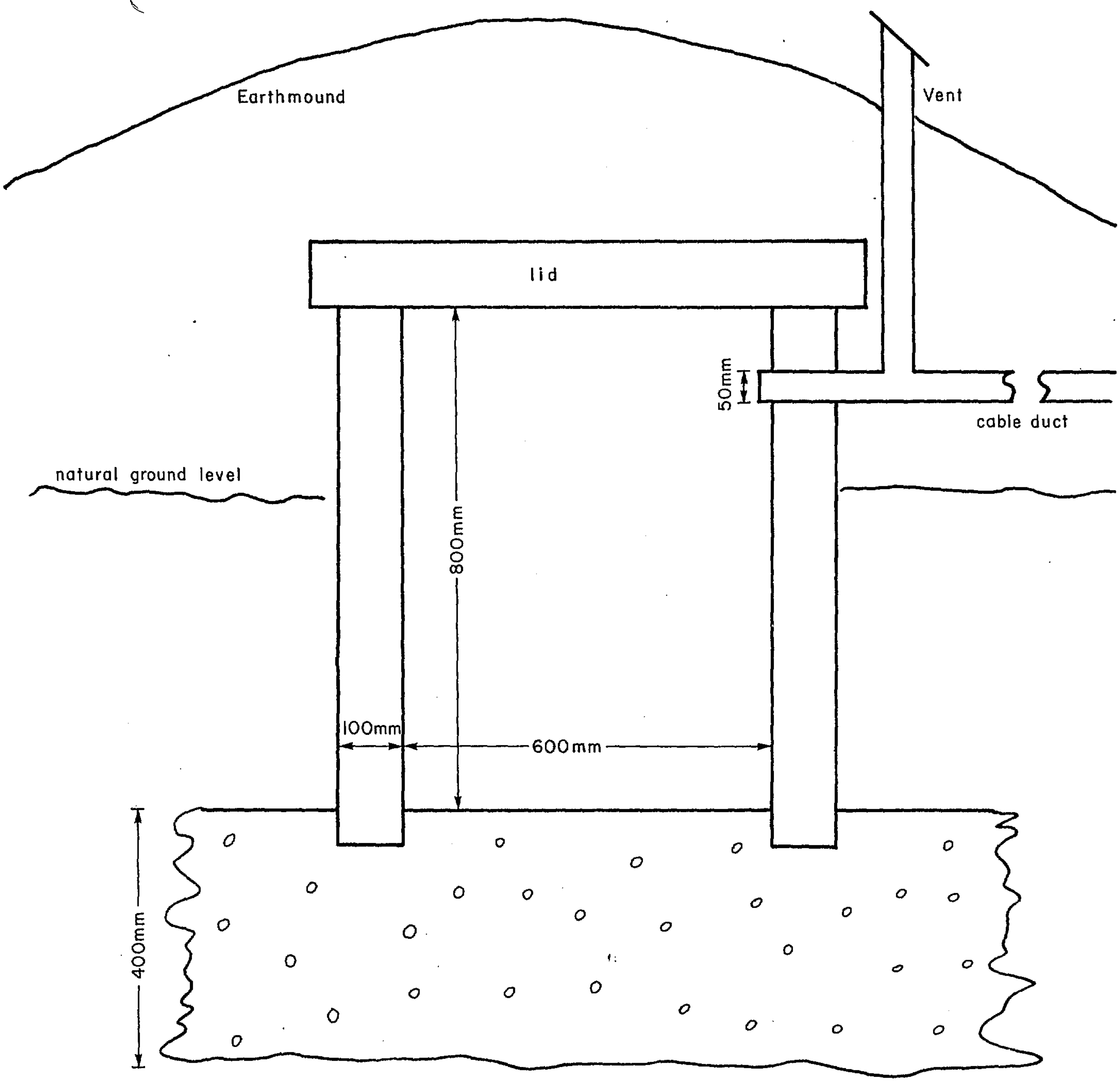

Fig. 4 LRMMO Vaultlet Schematic

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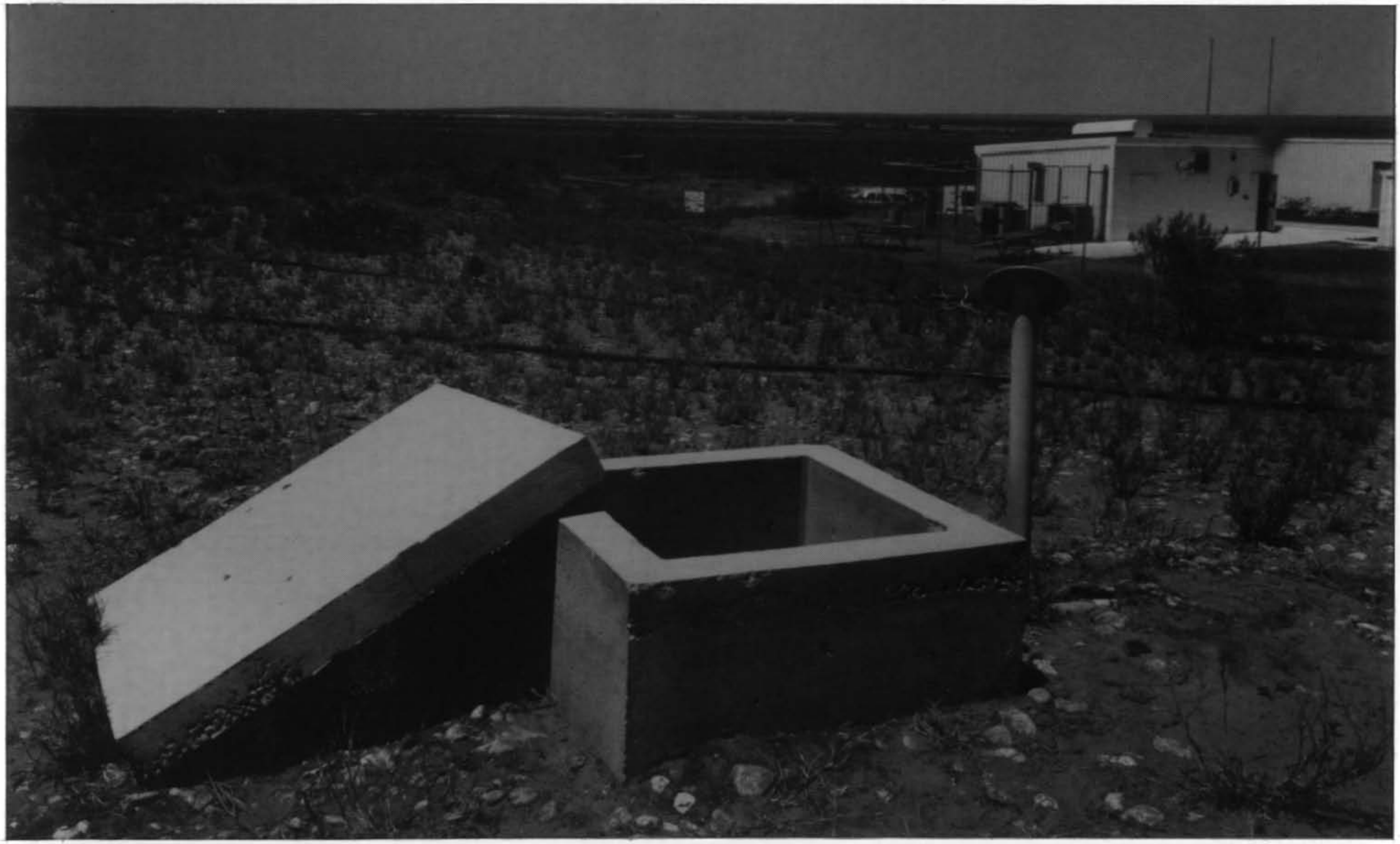

Plate 1. Vaultlet to house fluxgate variometer sensors at Learmonth.

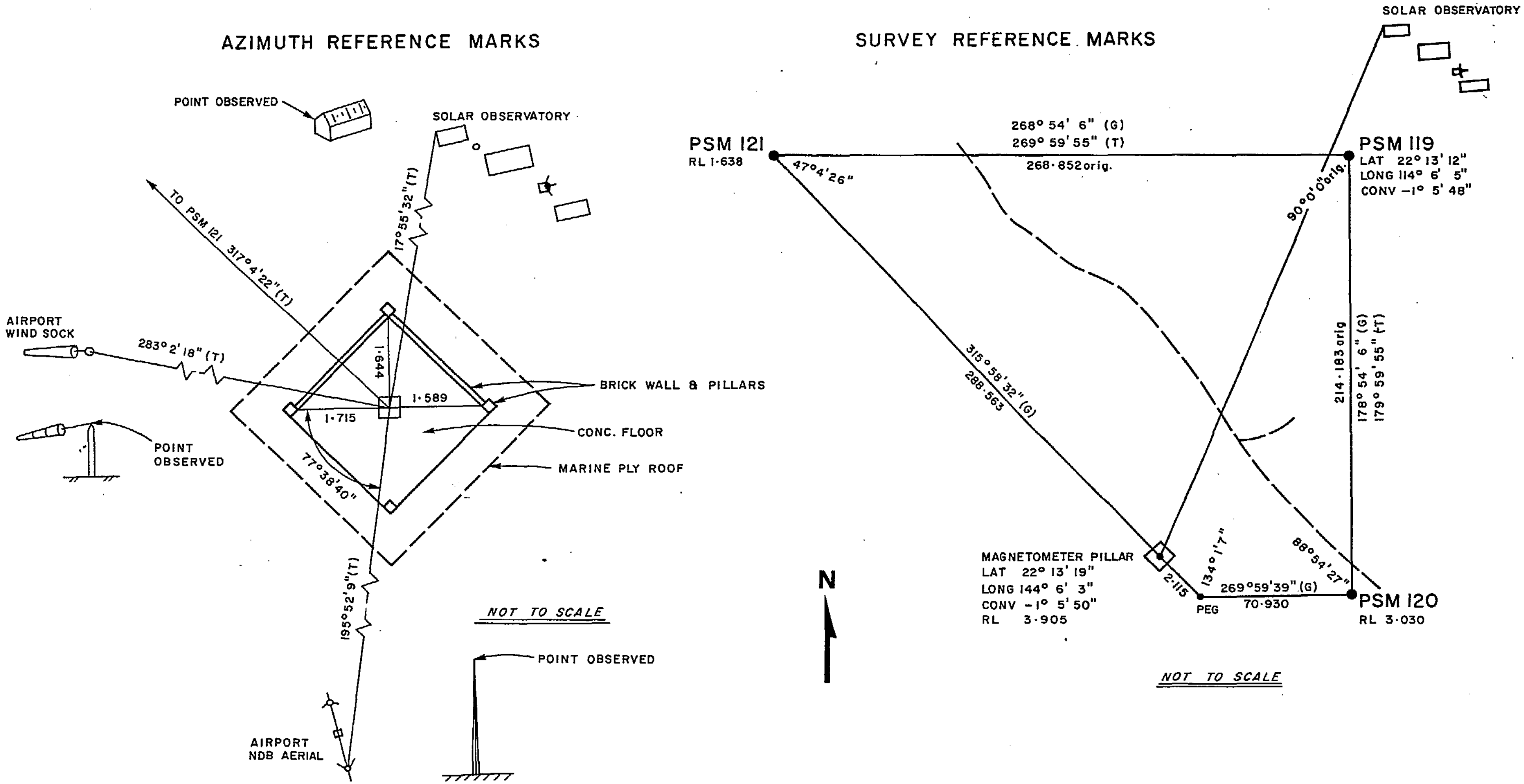

Fig.5 Azimuth Reference marks for Learmonth Magnetic Observatory

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Plate 2. Absolute Pier and Shelter at Learmonth.

CHAPTER 5: **INSTALLATION**

The LRMMO equipment was installed by BMR personnel from Mundaring, WA and Canberra ACT, from November 20 to 24, 1986
Appendix A lists the personnel involved in the installation.

5.1 Electronics console

The electronics rack and teletype were located in a small area towards the south-eastern corner of the Radio Solar Telescope Network (RSTN) building. This is the central building within the solar observatory complex. The location of the electronics is shown in Figure 2.

The respective distances of the vaultlet and PPM-pier from the conduit entry to the RSTN building are approximately 40 metres and 45 metres. The respective cable lengths of the EDA-fluxgate and Elsec-PPM are approximately 55 metres and 60 metres.

The cables from the PPM and Fluxgate heads enter the RSTN building at the eastern wall, go up 2.5 metres to an airconditioner duct and along this 2.5 metres, then along 4 metres and down an I-beam to the console.

5.2 Proton Magnetometer

The sensor head of the PPM already in operation at LRM prior to November 1986 was left on the pier near the vaultlet, but another electronics unit was installed. For protection, the pier (including the PPM head) was encased in PVC tubing and covered at the top.

Details of the PPM pier are:

- The wooden pier is 2 metres in height and 200 mm in diameter
- The pier is encased in Vinidex PVC tubing with ID 205 mm
- The PPM head is the round toroidal type (Elsec 595)
- The pier is located 10 metres to the NE of the vaultlet
- The Head cable to plug is 1.5 meters
- The cable from the PPM head is approximately 60 metres long and runs through a PVC pipe directly to the RSTN building.
- The distance from the PPM-pier to the RSTN building is about 45 metres.
- The PVC pipe is 44mm OD, 38mm ID
- The PPM tuning is: course - 50,000; fine - E

5.3 Fluxgate Magnetometers

Three brass footpads were located at 120 degree spacing on the floor of the vaultlet with one of them towards the south. This enabled the EDA-Fluxgate head to be firmly located, since the head base plate had been fitted with three threaded feet. Levelling was also much easier and more accurate and stable because of these feet.

With the 'baseline' potentiometers on the EDA FM-105B console all set to zero in the Lo switch position, the fluxgate head was rotated until the needle was centred (zero) on the meter on the console when switched to monitor the Y-component. The sensor-head base was then re-levelled and fine tuned to give zero on the meter. The X and Z outputs were then backed off to zero with their respective potentiometers.

In this orientation the X-component sensor is aligned with the magnetic meridian and so monitors variations in the Horizontal or H-component, whilst the Y-sensor monitors magnetic Declination or D. Since at Learmonth the magnetic Declination is very close to zero (approximately 0.6 degrees West) variations in H and D are virtually identical to those in the magnetic elements X and Y respectively. The fluxgate head was therefore left in the H/D configuration to monitor variations in X and Y.

In the above configuration the EDA FM-105B console 'baseline' potentiometers were:

X = 648.1 Y = 000.1 Z = 226.6

Figure 6 shows the EDA fluxgate head in the vaultlet.

For temperature stability a cardboard carton was carefully placed over the fluxgate head in the vaultlet and plastic bags full of polystyrene foam beads packed all around it to completely fill the vaultlet to the top. The concrete cover was then hauled on top and the vaultlet covered with sand.

The effect of the insulation was dramatic: Prior to insulation the diurnal temperature range was up to 10° C; afterwards it was virtually nil.

5.4 Chart Recorder

A Linseis LD-12 12-channel analogue chart recorder was installed at the LRMMO. This monitors variations in the magnetic elements X, Y, Z and F, as well as Temperature. Time marks are put on the chart every hour on the hour using an NDS-1 digital clock. The configuration in which the Linseis was set up is given in Table 5.

5.5 Back-up power

When the LRMMO equipment was assembled at BMR it was believed that in the event of a 240 volt mains power failure at Learmonth, emergency power supplies would become operational within 40 seconds. Since the loss of one or two minutes data is inconsequential, and in view of the EDAS-2 cassette recorder having its own internal batteries, the only back-up actually

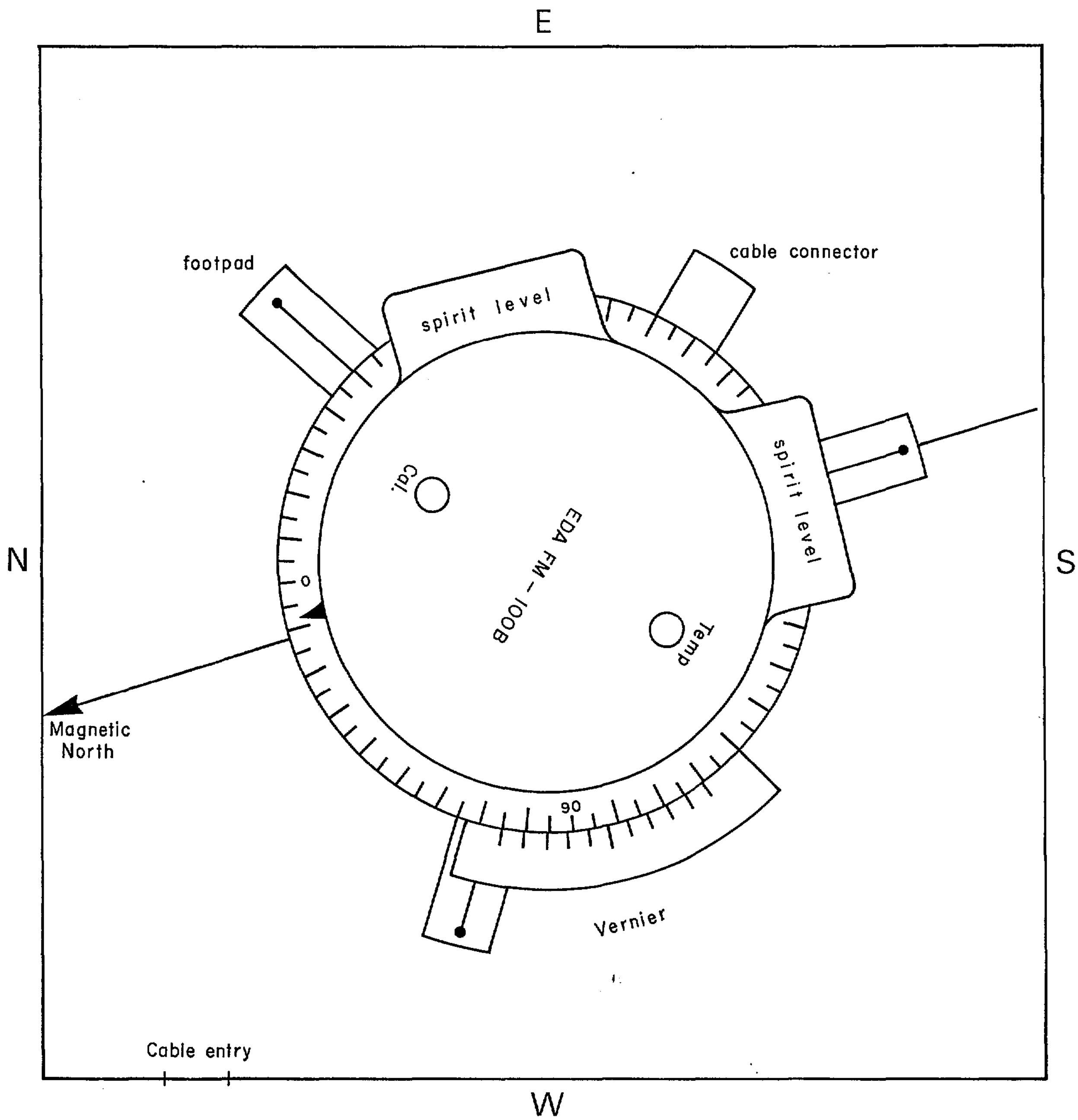

Fig.6 Orientation of fluxgate sensor in vaultlet at LRMMO

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Table 5

Linseis analogue Chart-Recorder settings

Channel	Input	Sensit -ivity	Variable Span	Input Polarity	Zero-level from Left	Nominal Scale
1 or 7	X	5 volts	Yes	Reversed	2.0	3 nT/mm
2 or 8	Y	5 volts	Yes	Reversed	3.0	3 nT/mm
3 or 9	Z	5 volts	Yes	Reversed	5.5	3 nT/mm
4 or 10	Temp.	1 volt	No	Reversed	8.0	0.4 /mm
5 or 11	F	5 volts	Yes	Reversed	9.5	3 nT/mm
6 or 12	Time	200 volts	No	Normal	7.5	-

provided at installation at Learmonth was a 12 volt dry cell to maintain the digital clock (for time marks on the chart) and Magnetograph Calibrator.

During installation it was discovered that any mains power failures which might occur at night-time (when the solar observatory cannot lose data) could continue for many hours. A back-up source is therefore being planned.

CHAPTER 6: **ABSOLUTE OBSERVATIONS**

Absolute observations at Learmonth (LRM) will be performed regularly on the Absolute pier by IPS personnel. The magnetometers used will be a Declination & Inclination Magnetometer (DIM): Elsec model 810 single channel fluxgate sensor (s/n 210) mounted on a Zeiss 020B (non-magnetic) theodolite (s/n 311847); and an Elsec model 770 Proton Precession Magnetometer (PPM) (s/n 189).

6.1 Initial Absolute Observations at Learmonth

Following the installation of the variometers at the LRMMO, a series of absolute observations were performed on the absolute pier. Sets of observations were performed alternately with the DIM/PPM instruments and the classical QHM/Declinometer/PPM equipment.

The instruments used were:

DIM - Elsec 810/201; Zeiss 020B/311847

PPM - Geometrics 816/1024

QHM - Askania 462 with thermometer 1289 on Askania circle 508810
Constants used: C1 = 4.33168   C2 = 18.4x10**-5   C3 = 40x10**-10
Thermom. 1289 corrections: 20°C = 0.0   30°C = 0.05   40°C = -0.05
2 pi torsion used throughout.

Declinometer - Askania 640506 on Askania circle 508810
Torsion head setting: coarse - 99+ ; fine 41

Azimuth reference used throughout was the windsock to the west with true azimuth of 283.03833 degrees.

The purpose of the absolute observations was threefold:

- To compare the DIM with the classical instruments
- To determine preliminary temperature coefficients for the EDA fluxgate components
- To determine preliminary Baseline values for the fluxgate variometers

The results of the Absolute observations are given in Table 6.

The temperatures shown in Table 6 were calculated from the preliminary expression (see Section 3.4):

$$\text{Temp } (^{\circ}C) = 0.019924 \times \text{EDAS2-counts} - 0.176$$

The 'pseudo-baselines' in Table 6 were gained by computing a 'pseudo-ordinate' in the observed element using the relevant formula in Appendix B, and subtracting this from the observed value. The X, Y and Z baselines were then calculated directly from the pseudo-baselines.

Table 6

Absolute observations at Learmonth: November 22-26, 1986

Instr	Elt	Obsvr	Date:UT	Observ'n	Pseudo-BLV	XYZ-Baselines	Temp.
PPM	F	PAH	22:2248-2249	53338.2	53283.3		27.44
DEC	D		2307-2312	-00.5937	-00.3968	X: 29486.8	27.56
QHM	H		2329-2336	29494.6	29488.2	Y: -203.6	27.80
QHM	H		2344-2349	29492.4	29486.8	Z:-44376.5	27.96
DEC	D		2359-0004	-00.6082	-00.3944	(mean T=27.86)	28.13
PPM	F		23:0009-0010	53341.4	53283.8		28.24
PPM	F	PAH	23:0013-0014	53340.9	53284.2	X: 29485.6	28.24
DIM	D		0035-0104	-00.6442	-00.4198	Y: -216.0	28.69
"	I		"	-56.4340	-56.4008	Z:-44381.8	"
PPM	F		0109-0110	53335.2	53284.0	(mean T=28.69)	28.94
PPM	F	PAH	23:0120-0121	53334.7	53284.7	X: 29485.6	29.13
DIM	D		0128-0150	-00.6422	-00.4221	Y: -217.2	29.41
"	I		"	-56.4337	-56.4013	Z:-44382.7	"
PPM	F		0153-0154	53330.8	53285.0	(mean T=29.41)	29.65
PPM	F	PAH	23:0254-0255	53313.8	53279.1		30.55
DEC	D		0308-0313	-00.6132	-00.3925	X: 29491.3	30.81
QHM	H		0332-0339	29493.6	29491.6	Y: -201.1	31.18
QHM	H		0348-0354	29494.9	29492.2	Z:-44374.4	31.40
DEC	D		0402-0406	-00.5755	-00.3888	(mean T=31.24)	31.60
PPM	F		0415-0416	53304.4	53282.8		31.74
PPM	F	PAH	23:2215-2216	53323.0	53283.8		27.03
DEC	D		2226-2230	-00.5972	-00.3943	X: 29484.4	26.96
QHM	H		2244-2252	29461.0	29483.7	Y: -202.7	26.96
QHM	H		2303-2309	29450.7	29486.5	Z:-44382.4	26.96
DEC	D		2318-2322	-00.5855	-00.3936	(mean T=26.96)	27.02
PPM	F		2326-2327	53329.9	53284.0		27.06
PPM	F	PAH	23:2328-2330	53329.3	53283.7	X: 29483.5	27.09
DIM	D		2339-2357	-00.5912	-00.4124	Y: -212.2	27.27
"	I		"	-56.4402	-56.4035	Z:-44383.2	"
PPM	F		24:0000-0002	53327.8	53284.2	(mean T=27.27)	27.36
PPM	F	PAH	24:0006-0008	53330.0	53284.4	X: 29484.3	27.46
DIM	D		0012-0029	-00.6098	-00.4151	Y: -213.6	27.58
"	I		"	-56.4457	-56.4025	Z:-44382.8	"
PPM	F		0033-0035	53331.4	53284.0	(mean T=27.58)	27.76

table continued . . .

Table 6 (continued) . . .

Instr	Elt	Obsvr	Date:UT	Observ'n	Pseudo-BLV	XYZ-Baselines	Temp.
PPM	F	PAH	24:0038-0040	53332.9	53284.3		27.76
DEC	D		0052-0057	-00.6047	-00.3901	X: 29492.0	27.96
QHM	H		0111-0118	29485.0	29492.5	Y: -200.1	28.23
QHM	H		0126-0134	29484.7	29492.8	Z:-44378.3	28.44
DEC	D		0142-0147	-00.5993	-00.3873	(mean T=28.33)	28.65
PPM	F		0151-0153	53339.4	53285.0		28.75
PPM	F	PAH	24:0301-0303	53322.5	53285.4	X: 29485.3	29.75
DIM	D		0310-0329	-00.6150	-00.4165	Y: -214.3	30.02
"	I		"	-56.4407	-56.4022	Z:-44383.9	"
PPM	F		0333-0335	53317.0	53286.0	(mean T=30.02)	30.25
PPM	F	PAH	24:0338-0340	53308.4	53285.4		30.29
DEC	D		0349-0353	-00.5683	-00.3872	X: 29490.8	30.46
QHM	H		0407-0413	29455.0	29492.0	Y: -199.6	30.74
QHM	H		0422-0429	29444.7	29490.9	Z:-44380.7	30.94
DEC	D		0437-0441	-00.5673	-00.3883	(mean T=30.80)	31.11
PPM	F		0447-0449	53295.3	53286.4		31.24
PPM	F	PAH	24:0535-0537	53321.0	53291.3	X: 29487.3	34.65
DIM	D		0545-0600	-00.5707	-00.4121	Y: -212.1	33.86
"	I		"	-56.4407	-56.4016	Z:-44385.8	"
PPM	F		0603-0605	53307.9	53285.3	(mean T=33.86)	33.48
PPM	F	PAH	24:2250-2252	53289.1	53281.9		25.55
DEC	D		2301-2305	-00.5882	-00.3909	X: 29487.4	25.57
QHM	H		2316-2321	29450.3	29486.8	Y: -199.7	25.65
QHM	H		2330-2335	29449.1	29489.3	Z:-44378.5	25.72
DEC	D		2341-2345	-00.5782	-00.3852	(mean T=25.69)	25.77
PPM	F		2348-2350	53281.9	53282.5		25.86
PPM	F	PAH	24:2354-2356	53282.4	53282.5	X: 29482.8	25.86
DIM	D		25:0009-0026	-00.5810	-00.4113	Y: -211.6	26.10
"	I		"	-56.4615	-56.4031	Z:-44381.5	"
PPM	F		0029-0031	53278.5	53282.0	(mean T=26.10)	26.26
PPM	F	PJG	25:0033-0035	53281.1	53282.5	X: 29484.0	26.26
DIM	D		0041-0102	-00.5902	-00.4132	Y: -212.7	26.45
"	I		"	-56.4667	-56.4021	Z:-44381.7	"
PPM	F		0105-0107	53281.7	53283.6	(mean T=26.45)	26.64

table continued . . .

Table 6 (continued) . . .

Instr	Elt	Obsvr	Date:UT	Observ'n	Pseudo-BLV	XYZ-Baselines	Temp.
PPM	F	PJG	25:0110-0112	53282.8	53283.7		26.66
DEC	D		0120-0124	-00.5583	-00.3810	X: 29490.3	26.82
QHM	H		0142-0148	29431.7	29489.8	Y: -198.3	27.08
QHM	H		0156-0202	29434.8	29491.9	Z:-44378.7	27.26
DEC	D		0208-0212	-00.5557	-00.3894	(mean T=27.17)	27.38
PPM	F		0216-0218	53277.5	53284.1		27.46
PPM	F	PAH	25:0325-0327	53283.2	53286.1		29.35
DEC	D		0335-0339	-00.5342	-00.3756	X: 29491.0	29.25
QHM	H		0352-0359	29437.4	29491.6	Y: -194.4	29.25
QHM	H		0406-0413	29440.1	29491.5	Z:-44380.8	29.30
DEC	D		0422-0425	-00.5142	-00.3795	(mean T=29.28)	29.38
PPM	F		0430-0432	53276.8	53285.9		29.45
PPM	F	PAH	25:0601-0602	53279.8	53286.5	X: 29487.4	31.46
DIM	D		0646-0702	-00.5330	-00.4086	Y: -210.3	30.95
"	I		"	-56.4925	-56.4007	Z:-44384.5	"
PPM	F		0705-0707	53279.8	53288.2	(mean T=30.95)	30.65
PPM	F	PJG	25:0708-0710	53283.8	53290.0		30.65
DEC	D		0715-0718	-00.5085	-00.3833	X: 29492.4	30.65
QHM	H		0727-0732	29412.9	29492.4	Y: -197.3	30.55
QHM	H		0737-0742	29417.5	29493.6	Z:-44383.9	30.55
DEC	D		0746-0750	-00.5252	-00.3832	(mean T=30.55)	30.46
PPM	F		0753-0755	53292.9	53288.8		30.45
PPM	F	PAH	26:0000-0002	53278.1	53289.9	X: 29489.1	31.04
DIM	D		0010-0029	-00.6335	-00.4168	Y: -214.5	31.04
"	I		"	-56.4985	-56.4004	Z:-44386.5	"
PPM	F		0032-0034	53282.5	53289.9	(mean T=31.04)	31.04
PPM	F	PAH	26:0040-0042	53286.1	53289.7	X: 29489.3	31.04
DIM	D		0049-0106	-00.6290	-00.4172	Y: -214.7	31.04
"	I		"	-56.4897	-56.4000	Z:-44386.1	"
PPM	F		0110-0112	53289.1	53289.7	(mean T=31.04)	31.04

Note: Instruments used throughout were:

QHM 462 on circle 810,
Declinometer 506 on circle 810,
PPM G816/1024,
DIM E810/201.

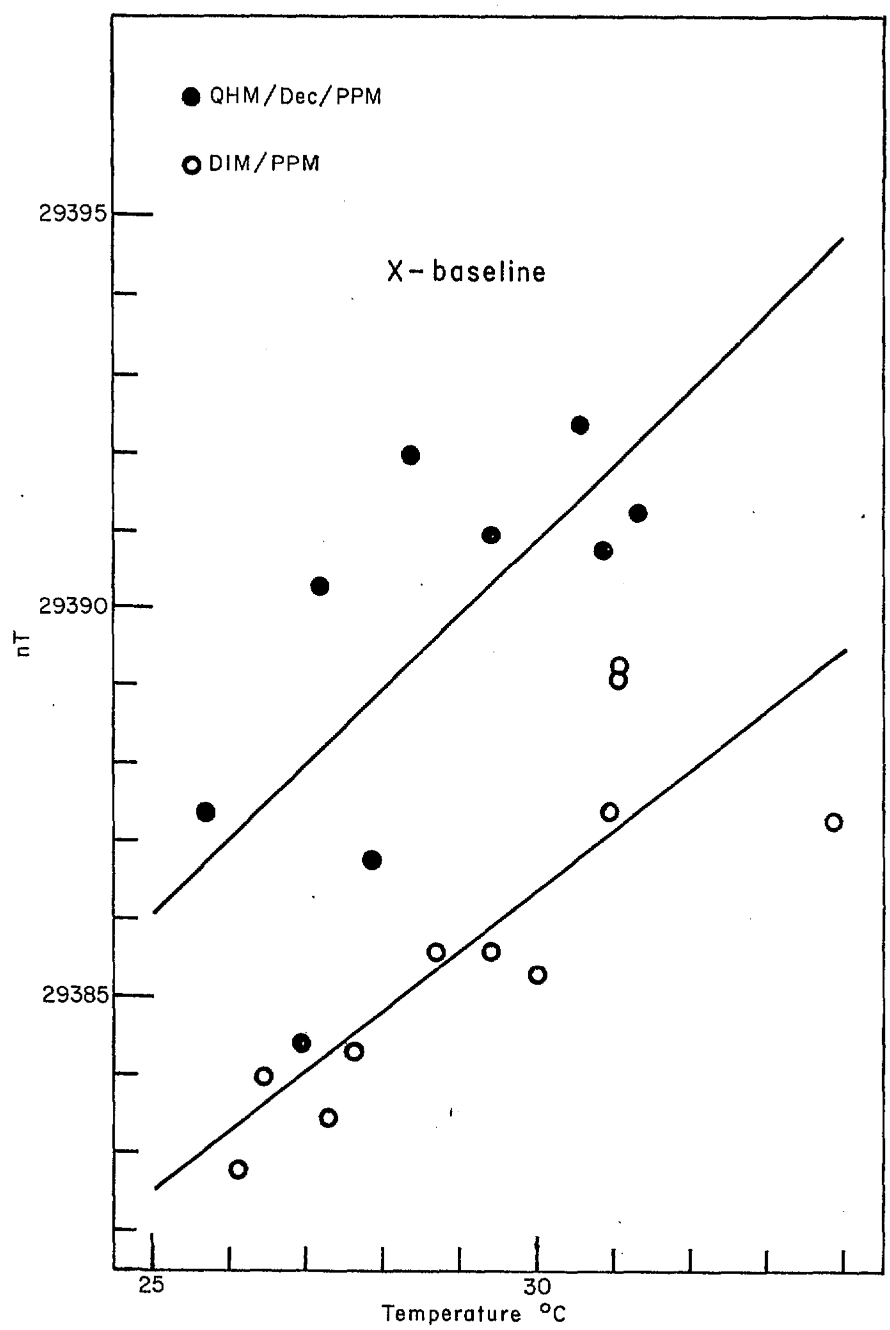

Fig. 7(a) LRMMO X- baseline vs temperature

24/F50-9/8

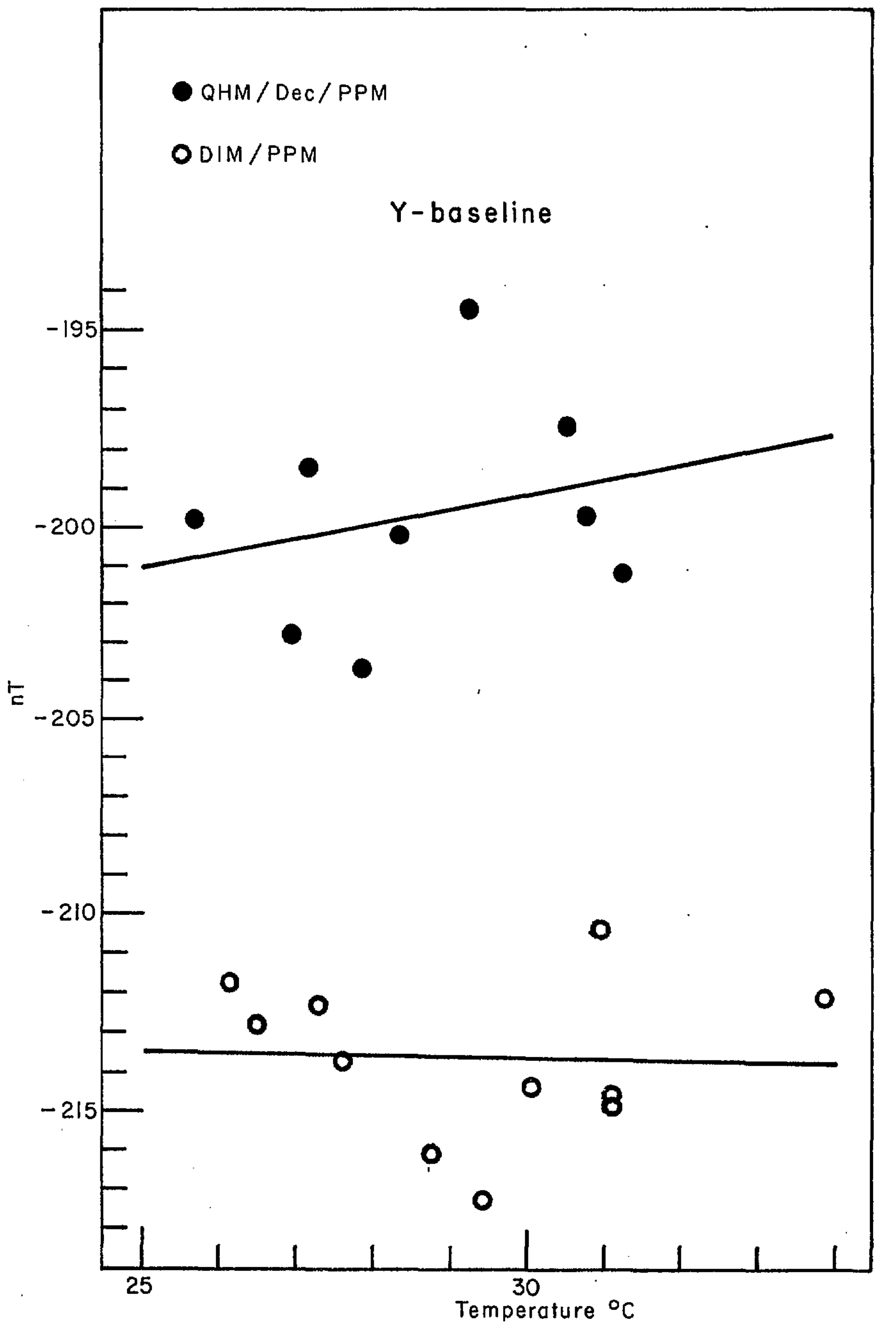

Fig. 7 (b) LRMMO Y-baseline vs temperature

24/F50-9/9

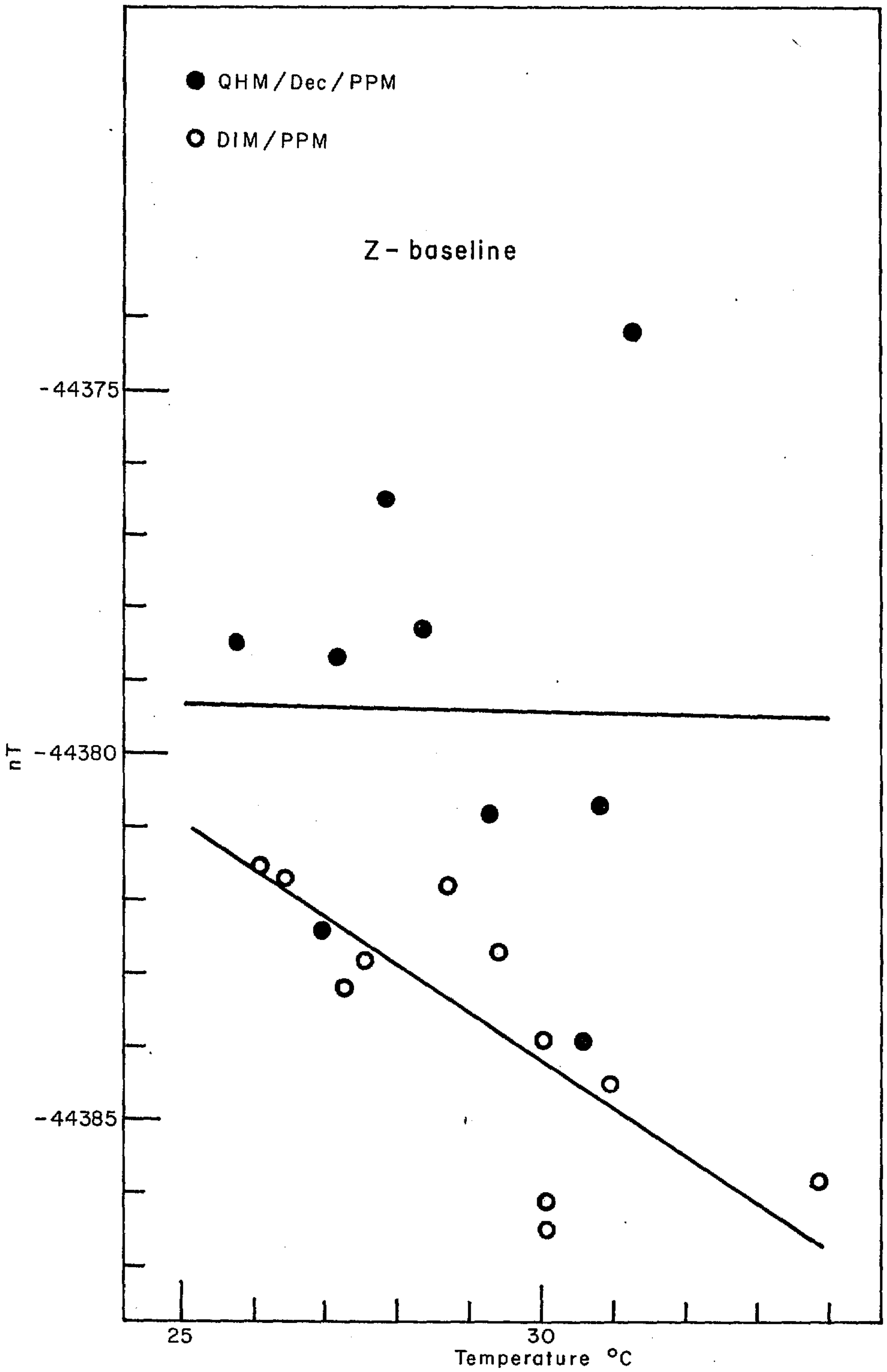

Fig. 7(c) LRMMO Z- baseline vs temperature

24/F50 - 9/10

(This was all performed by computer program EDABL).

The derived X, Y and Z baselines have been plotted as a function of the mean temperature during the absolute observation set. BLV's gained by the DIM/PPM magnetometers are indicated separately from those gained by the QHM/Declinometer/PPM magnetometers. The plots are given in Figures 7(a) to 7(c) for X, Y and Z respectively.

6.2 Temperature Coefficients

For each of the elements X, Y and Z, a straight line has been fitted (in a least squares sense) to BLV's derived by each of the magnetometer combinations. When plotted in this way, both preliminary temperature coefficients and instrument differences can be gained.

The X-baseline plot is fairly straightforward: Both absolute magnetometer sets give about the same temperature coefficient (slope) and so the BLV difference between the two instrument sets appears fairly constant with temperature.

The Y and Z baseline plots are not as neat since the results (particularly the Z-BLV's gained by the QHM/Declinometer/PPM absolute instrument set) show a greater degree of scatter.

To summarize the results, expressions for each of the linear regression lines are given:

BLV-X (QHM/Dec/PPM) = 0.9672 T + 29461.9 nT

BLV-Y (QHM/Dec/PPM) = 0.3588 T - 209.9 nT

BLV-Z (QHM/Dec/PPM) = -0.0179 T - 44378.8 nT

and

BLV-X (DIM/PPM) = 0.7694 T + 29463.3 nT

BLV-Y (DIM/PPM) = -0.0431 T - 212.3 nT

BLV-Z (DIM/PPM) = -0.6516 T - 44364.6 nT

In view of the larger scatter of the QHM/Dec/PPM determined baselines, it is reasonable to use the ones determined through the DIM & PPM to gain the temperature coefficients of the fluxgate sensors:

QX = 0.77 nT/°C
QY = -0.04 nT/°C
QZ = -0.65 nT/°C

ie BLV-E(T) = QE x T + BLV-E(T=0°C)

and BLV-E(Ts) = QE x Ts + BLV-E(T=0°C)

So BLV-E(Ts) = BLV-E(T) - QE x (T - Ts)

and BLV-E(T) = BLV-E(Ts) + QE x (T - Ts)

Now BLV-E(T) = E - SV-E x E-counts

so E = BLV-E(Ts) + SV-E x E-counts + QE x (T - Ts)

where E is any of the elements X, Y or Z
T is the ambient temperature
Ts is the standard temperature (say 25°C for LRM)
QE is the temperature coefficient for E variometer
BLV-E is the baseline value for E
E-counts is the EDAS2 counts at some epoch
SV-E is the scale value for the E variometer

6.3 Instrument Differences

Figures 7(a) - (c) clearly demonstrate instrument differences between the DIM/PPM and QHM/Declinometer/PPM combinations.

Evaluated at 29°C, ie around the median observation temperature, the baseline value differences between the two sets of absolute instruments, i.e.:

BLV (QHM/Dec/PPM) = BLV(DIM/PPM) + BLV-difference

are: BLV-X-difference = +4.3 nT
BLV-Y-difference = +14.0 nT
BLV-Z-difference = +4.1 nT

However, before considering any corrections to be applied to the DIM used at Learmonth, any corrections to the standardizing instruments ie QHM's 461 & 462, Declinometer 506 and PPM/1024 must be taken into consideration.

6.3.1 Standard Instruments

QHM's: The QHM's 461 and 462 are from BMR's standard set which is periodically sent to Rude Skov for calibration to the international standard. This was most recently performed in April 1983.

By linear extrapolation to November 1986, the logarithmic QHM constant C for QHM 462 would have decreased by 2.25 x 10**-5, resulting in a correction dH = H.ln10.dC of -1.23 nT at Canberra and -1.53 nT at Learmonth. Similarly for QHM 461, dC is -1.5 x 10**-5 resulting in a correction of -0.82 nT at Canberra.

Declinometer 506: Askania Declinometer 640506 on Askania (metal) circle 508810 was compared with the standard Ruska 4813 Declinometer (which itself was supplied with a correction of -0.3 minutes) on November 17/18 1986. This comparison was through baselines (for the Littlemore AMO) on pier AW at the Canberra Magnetic Observatory (CMO).

The results of the Declinometer comparison, given in Table 7 may be summarized by:

D:Ruska 4813 (corrected) = D:Askania 506/810 - 2.14'

Table 7

Comparison of Askania declinometer 640506

on circle 508810 vs. Ruska 4813

Instrument	Date : U.T.	Observ'n	AMO baseline D
Ruska 4813	17 Nov 1986 : 2339	12 20.56	12 00.62'
Ruska 4813	17 Nov 1986 : 2349	12 21.05'	12 00.82'
Askania 506	18 Nov 1986 : 0234	12 30.40'	12 02.55'
Askania 506	18 Nov 1986 : 0247	12 30.95'	12 02.66'
Askania 506	18 Nov 1986 : 0308	12 31.11'	12 02.52'
Askania 506	18 Nov 1986 : 0318	12 31.56'	12 02.53'
Ruska 4813	18 Nov 1986 : 0337	12 29.62'	12 00.78'
Ruska 4813	18 Nov 1986 : 0346	12 29.45'	12 00.66'

Mean Ruska D-baseline = 12° 00.72'
Ruska correction = -00.30'

Mean corrected Ruska BLV = 12° 00.42'

Mean Askania baseline = 12° 02.56'

Correction to Askania 506 = -02.14'

Site: CMO / pier AW

Ref. Azimuth: NW mark

Observer: PAH

PPM: The Geometrics 816 Proton Magnetometer #1024 was compared on 18 November 1986 at CMO to the MNS2.3/X PPM which is used as the Canberra standard. The results may be summarized:

F:MNS2.3/X = F:G816/1024 + 2.3 nT

DIM: The Declination & Inclination magnetometer destined for Learmonth was also compared with the BMR standards prior to dispatch. This was performed through baselines for the AMO during October and November 1986. The results are given in Table 8.

Since the Canberra AMO baselines (as determined by the routine instruments, ie Ruska 4813 Declinometer, Proton Vector Magnetometer PVM/A and Proton Magnetometer MNS2.3/X) were constant (and temperature independent) throughout the period of DIM comparisons at CMO, all similar baseline determinations have been averaged for instrument comparisons.

The mean AMO-baselines as determined by the various standard absolute magnetometers on CMO pier AW were:

D	: AMO/BLV/AW	: Ruska 4813	=	12 00.3'
F	: "	: PPM MNS2.3/X	=	58002.3 nT
H	: "	: QHM 461	=	23521.0 nT (uncorrected)
H	: "	: QHM 462	=	23520.8 nT (")

Application of the corrections appropriate for Canberra of -0.82 nT and -1.23 nT to respective results from QHM's 461 and 462, gives a mean corrected standardized H pseudo-baseline for the AMO, at pier AW

H : BLV/AW = 23519.8 nT

This, together with the F-baseline of 58002.3 nT gives the standard I-baseline of

I : BLV/AW = -66° 04.659'

Now the mean AMO D and I baselines determined by the DIM:E810/201 on CMO pier AW were:

D	: BLV/AW	: DIM/E810/201	=	12 00.75'
I	"	"	=	-66 04.804'

When the baselines determined through the DIM are compared with those determined through the corrected standard instruments, the corrections for the DIM can be calculated:

D-correction	: DIM E810/201	=	-0.45'
I-correction	: " "	=	+0.145'

These corrections will be compared to corresponding ones determined at the Learmonth Magnetic Observatory itself.

6.3.2 DIM vs QHM 462 & Declinometer 506 at Learmonth

As noted in Section 6.3 the differences between LRMMO X,Y and Z baselines gained through the 'standard' instruments of QHM/462, Declinometer 640506 and PPM G816/1024, and those gained by the DIM E810/201 and PPM/1024 are:

Table 8

Comparison of DIM vs. Ruska 4813, MNS2.3/X & QHM's 461, 462

Instrument	Elt.	Date & U.T.	Observation	AMO-baseline
DIM E810/201	D	23 Oct/0106-0133	12 24.39'	12 00.60'
" "	I	" "	-66 13.15'	-66 04.90'
DIM E810/201	D	23 Oct/0242-0308	12 27.39'	12 00.68'
" "	I	" "	-66 12.34'	-66 04.86'
DIM E810/201	D	23 Oct/0335-0359	12 28.65'	12 00.69'
" "	I	" "	-66 11.96'	-66 04.89'
QHM 462/042	H	28 Oct/0115-0120	23652.8	23519.2 *
" "	H	" 0127-0132	23656.0	23518.4 *
DIM E810/201	D	28 Oct/0229-0255	12 28.19'	12 00.79'
" "	I	" "	-66 14.16'	-66 04.75'
DIM E810/201	D	28 Oct/0305-0327	12 29.15'	12 00.74'
" "	I	" "	-66 14.04'	-66 04.81'
DIM E810/201	D	28 Oct/0336-0358	12 29.24'	12 00.86'
" "	I	" "	-66 12.66'	-66 04.71'
QHM 461/042	H	28 Oct/0417-0422	23690.9	23522.0 *
" "	H	" 0429-0434	23693.6	23521.5 *
Ruska 4813#	D	02 Nov/2303-2306	12 17.52'	12 00.39'
" "	D	" 2311-2315	12 17.72'	12 00.36'
PPM MNS2.3/X	F	02 Nov/2320-2321	58690.9	58002.5
" "	F	" 2343-2344	58689.1	58002.8
QHM 461/042	H	03 Nov/0003-0010	23667.0	23520.3 *
" "	H	" 0017-0022	23665.9	23520.0 *
PPM MNS2.3/X	F	03 Nov/0027-0028	58687.4	58001.8
DIM E810/201	D	03 Nov/0043-0107	12 22.72'	12 00.68'
" "	I	" "	-66 13.37'	-66 04.79'
DIM E810/201	D	03 Nov/0114-0134	12 24.26'	12 00.73'
" "	I	" "	-66 13.06'	-66 04.79'
PPM MNS2.3/X	F	03 Nov/0155-0156	58692.9	58001.9

table continued . . .

Table 8 continued . . .

Instrument	Elt.	Date & U.T.	Observation	AMO-baseline
PPM MNS2.3/X	F	03 Nov/0222-0223	58699.4	58002.2
DIM E810/201	D	03 Nov/0237-0258	12 29.06’	12 00.81’
" "	I	" "	-66 11.09’	-66 04.75’
DIM E810/201	D	03 Nov/0312-0333	12 30.77’	12 00.90’
" "	I	" "	-66 10.85’	-66 04.79’
PPM MNS2.3/X	F	03 Nov/0337-0338	58720.6	58001.9
QHM 462/042	H	03 Nov/0355-0401	23727.9	23521.9 *
" "	H	" 0409-0416	23718.2	23523.5 *
PPM MNS2.3/X	F	03 Nov/0421-0423	58718.2	58003.1

* pseudo-baselines (see formulae in Appendix B)
  with the QHM observations uncorrected.

routine weekly Ruska observations also taken into account
  with the Ruska observations corrected by -0.3’

All observations on pier AW at CMO during Oct/Nov 1986 by PAH.

Mean AMO baselines:				
	DIM E810/201	D	=	12° 00.75’
	" "	I	=	-66° 04.804’
	PPM MNS2.3/X	F	=	58002.3 nT
	QHM 461 *	H	=	23521.0 nT
	" 462 *	H	=	23520.8 nT
	Ruska 4813 #	D	=	12° 00.30’

X-baseline (standard instr.)	=	X-baseline (DIM etc)	+ 4.3 nT
Y " " "		Y " "	+ 14.1 nT
Z " " "		Z " "	+ 4.1 nT

where all differences are algebraic.

Using these baseline differences, instrument differences may be inferred.

Assuming for the moment that the QHM 462 and Declinometer 506 require no corrections themselves, then the corrections to the DIM would be simply the inferred instrument differences:

$$\tan(\text{D-difference}) = [X.dY - Y.dX] / [\ X.(X + dX) + Y.(Y + dY)\ ]$$

$$= 0.00048 \text{ rad.} = 0.0273 \text{ deg.} = 1.64'$$

and

$$\tan(\text{I-difference}) = [H.dZ - Z.dH] / [\ H.(H + dH) + Z.(Z + dZ)\ ]$$

where $dH = \sqrt{(X + dX)^2 + (Y + dY)^2} - \sqrt{(X^2 + Y^2)} = 4.23 \text{ nT}$

so I-difference = 0.00011 rad. = 0.00624 deg. = 0.375'

It is known however (see Section 6.3.1) that the 'standard' magnetometers used to calibrate the DIM at Learmonth need corrections to bring them to the BMR standard, viz.

D [std] : Ruska 4813 = D : Decl. 506/810 - 2.14'

F [std] : MNS2.3/X = F : G816/1024 + 2.3 nT

H [std] : QHM 462 (corrected) = H : QHM 462 - 1.53 nT (LRM)

When all these final corrections are applied to the instruments compared with the DIM at Learmonth, the complete corrections to the DIM may be determined:

Declination:

	D : Ruska 4813	=	D : Askania 506	- 2.14'
and	D : Askania 506	=	D : DIM E810/201	+ 1.64'
so	D : Ruska 4813	=	D : DIM E810/201	- 0.50'

The Ruska declinometer (corrected) is considered to be the standard.

Note that the D-correction to be applied to the DIM of -0.50' gained at Learmonth compares well with the value of -0.45' gained by direct comparison with the Ruska at Canberra (see Section 6.3.1).

Inclination:

It was found that through baselines at Learmonth the Inclination difference between the DIM and QHM 462 (uncorrected) & PPM G816/1024 was:

I (QHM/462 & PPM/1024) = I (DIM E810/201) + 0.375'

Now by use of the formula

$$dI = (dF/F - dH/H) / \tan I$$

and applying the corrections to the comparison instruments to bring them to the standard:

F (MNS2.3/X) [stnd] = F (PPM:G816/1024) + 2.3 nT

and H [stnd] = H (QHM/462) - 1.53 nT (LRM)

giving dI = -0.217'

so that I [stnd] = I (DIM E810/201) + 0.158'

This I-correction to the DIM can be compared with that gained at Canberra where the DIM was compared with both QHM's 461 & 462 and the PPM MNS2.3/X directly to find a I-correction of +0.145' (see Section 6.3.1).

6.3.3 Adopted DIM preliminary corrections

In view of there being less observational scatter, a more controlled environment and more direct comparison to the primary standards with regard to the comparisons performed at the Canberra Magnetic Observatory, the DIM corrections gained there will be adopted. Those gained at Learmonth serve as an excellent on-site verification.

The adopted DIM preliminary corrections are thus:

D = D (DIM E810/201) - 0.45'
I = I (" ") + 0.145'

where both corrections are applied algebraically.

When combined with the correction to the PPM used:

F = F (G816/1024) + 2.3 nT

the adjustments to the baselines gained by these two instruments can be calculated:

Now the raw baselines gained by the DIM and PPM/1024 at LRM were:

X-baseline : DIM/PPM 1024 : 29°C = 29485.6 nT
Y " " " " = -213.6 nT
Z " " " " = -44383.5 nT

By application of the preliminary temperature coefficients (see Section 6.2) of 0.77, -0.04 and -0.65 nT/°C for QX, QY and QZ respectively using the formula:

$$BLV(Ts) = BLV(T) - Q \times (T - Ts)$$

the baselines at a standard temperature (Ts) of 25°C are:

X-baseline : DIM/PPM 1024 : 25°C = 29482.5 nT
Y " " " " = -213.4 nT

Z " " " " = -44380.9 nT

(These may also be scaled directly from Figures 7(a) - (c) or calculated from the regression formulae).

Pseudo-baselines calculated from these standard-temperature X, Y and Z baselines, then, are:

H-pseudo-BLV : DIM/PPM 1024 : $25^{\circ}C$	=	29483.3 nT
F " " " "	=	53281.6 nT
D " " " "	=	-004 24.88'
I " " " "	=	-564 24.177'

and hence the baseline adjustments are:

Z-BLV-ADJ = (F + dF).sin(I + dI) - Z = -0.7 nT
[H-BLV-ADJ = (F + dF).cos(I + dI) - H = +3.1 nT]
X-BLV-ADJ = (H + dH).cos(D + dD) - X = +3.1 nT
Y-BLV-ADJ = (H + dH).sin(D + dD) - Y = -3.9 nT

Application of these adjustments results in the preliminary corrected baselines at a standard temperature of $25^{\circ}C$ during the observation period.

Appendix D shows the preliminary baseline file based on the above results. This is in the correct format for input to the routine data processing computer programs.

6.4 Introduction of PPM: Elsec 770, s/n 189

Subsequent to the initial installation and calibration of LRMMO in late November 1986, the observatory was without a portable PPM for absolute observations for approximately a month. In late December 1986 the Elsec model 770 PPM with serial no. 189 was sent to Learmonth as the routine absolute PPM.

Prior to dispatch to Learmonth this instrument was compared at the Canberra Magnetic Observatory (17 December 1986) with the standard Proton magnetometer MNS2.3/X, the difference found being:

F (MNS2.3/X) = F (E770/189) - 0.9 nT

Incorporating this correction with those to be applied to the DIM E810/201 at Learmonth produces adjustments to be applied to the raw baselines gained through the two instruments:

X-baseline adjustment	=	+1.4 nT
Y " "	=	-3.8 nT
Z " "	=	+2.0 nT

where all adjustments are to be applied algebraically.

APPENDIX A: **Personnel in attendance during LRM-MO installation**

From Mundaring Geophysical Observatory, W.A.

P. J. Gregson

B. J. Page

From Geomagnetism Section, BMR, Canberra

P. A. Hopgood

From Learmonth Solar Observatory

M. W. Mc Mullan (IPS)

APPENDIX B: Formulae Relating Geomagnetic Elements

B.1 Horizontal Plane

$X = H.\cos D$ .... basic relation

$dD.\tan D = dH/H - dX/X$ .... differential form

$X + dX = (H + dH).\cos(D + dD)$ .... full variational forms

$\sin dD = [\ \cos D.\sqrt{(H + dH)^2 - (X + dX)^2} - (X + dX).\sin D\ ] / (H + dH)$

$Y = H.\sin D$ .... basic relation

$dD/\tan D = dY/Y - dH/H$ .... differential form

$Y + dY = (H + dH).\sin(D + dD)$ .... full variational forms

$\sin dD = [\ (Y + dY).\cos D - \sin D.\sqrt{(H + dH)^2 - (Y + dY)^2}\ ] / (H + dH)$

$H^2 = X^2 + Y^2$ .... basic relation

$H.dH = X.dX + Y.dY$ .... differential form

$dH = \sqrt{(X + dX)^2 + (Y + dY)^2} - H$ ..... full variational forms

$dY = \pm\sqrt{(H + dH)^2 - (X + dX)^2} - Y$

$dX = \pm\sqrt{(H + dH)^2 - (Y + dY)^2} - X$

$Y = X.\tan D$ .... basic relation

$dY/Y = dX/X + 2.dD/\sin 2D$ .... differential form

$Y + dY = (X + dX).\tan(D + dD)$ .... full variational forms

$\tan dD = [\ X.dY - Y.dX\ ] / [\ X.(X + dX) + Y.(Y + dY)\ ]$

B.2 Vertical Plane

$H = F.\cos I$ .... basic relation

$dI.\tan I = dF/F - dH/H$ .... differential form

$H + dH = (F + dF).\cos(I + dI)$ .... full variational forms

$\sin dI = [\cos I. \sqrt{(F + dF)^2 - (H + dH)^2} - (H + dH).\sin I] / (F + dF)$

$Z = F.\sin I$ .... basic relation

$dI/\tan I = dZ/Z - dF/F$ .... differential form

$Z + dZ = (F + dF).\sin(I + dI)$ .... full variational forms

$\sin dI = [(Z + dZ).\cos I - \sin I. \sqrt{(F + dF)^2 - (Z + dZ)^2}] / (F + dF)$

$F^2 = H^2 + Z^2$ .... basic relation

$F.dF = H.dH + Z.dZ$ .... differential form

$dF = \sqrt{(H + dH)^2 + (Z + dZ)^2} - F$ ..... full variational forms

$dZ = \pm\sqrt{(F + dF)^2 - (H + dH)^2} - Z$

$dH = \sqrt{(F + dF)^2 - (Z + dZ)^2} - H$

$Z = H.\tan I$ .... basic relation

$dZ/Z = dH/H + 2.dI/\sin 2I$ .... differential form

$Z + dZ = (H + dH).\tan(I + dI)$ .... full variational forms

$\tan dI = [H.dZ - Z.dH] / [H.(H + dH) + Z.(Z + dZ)]$

APPENDIX C: **Summary of Instrument Comparisons & Corrections**

C.1 At Canberra through D,F,I baselines of Littlemore AMO.

[std]	F : PPM-MNS2.3-X	=	F : G816/1024	+	2.3 nT
[std]	F : PPM-MNS2.3-X	=	F : E770/189	-	0.9 nT
[std]	D : Ruska 4813 (cor'd)	=	D : Askania 506/810	-	2.14'
[std]	D : Ruska 4813 (cor'd)	=	D : DIM-E810/201	-	0.45'
	I : QHM 461,462(uncor)/PPM-MNS2.3-X	=	I : DIM-E810/201	+	0.211'
[std]	I : QHM 461,462(cor'd)/PPM-MNS2.3-X	=	I : DIM-E810/201	+	0.145'

C.2 At Learmonth through X,Y,Z baselines of EDA Fluxgate Variometer.

D : Askania 506/810	=	D : DIM E810/201	+	1.64'
I : QHM 462(uncor)/PPM-G816-1024	=	I : DIM-E810/201	+	0.374'

Bringing these to the standard, viz. Ruska 4813 (corrected) for D; PPM-MNS2.3/X for F; and QHM-462 (corrected) for H gives:

D-standard = D : DIM-E810/201 - 0.50' and

I-standard = I : DIM-E810/201 + 0.158'

C.3 Preliminary baseline corrections

The adopted corrections for the ROUTINE absolute magnetometers at Learmonth, viz. DIM E810/201 and PPM E770/189 are:

F = F : PPM-E770/189 - 0.9 nT
D = D : DIM-E810/201 - 0.45'
I = I : DIM-E810/201 + 0.145'

leading to preliminary baseline value adjustments of:

X-adjustment = +1.4 nT
Y " = -3.8 nT
Z " = +2.0 nT

APPENDIX D: **Preliminary 1986 Learmonth Baseline (& etc) file**

<u>LM86BL:101:58</u>

```
Learmonth (LRM) baseline file for Nov. 1986
BLV's are as observed reduced to Ts
Prelim. Adjustments are in the file
OX,11,22,05,51,  5001.      Zero recording level for X (counts)
OY,11,22,05,51,  4975.       "       "        "    "  Y      "
OZ,11,22,05,51,  5000.       "       "        "    "  Z      "
SX,11,22,05,51, 0.1973      X scale-value in nT/count
SY,11,22,05,51, 0.1998      Y     "      "      "
SZ,11,22,05,51,-0.1956      Z     "      "      "
BX,11,22,05,51, 29482.5     Observed X-BLV (nT) reduced to Ts
BY,11,22,05,51,  -213.4        "     Y  "   "       "    "  "
BZ,11,22,05,51,-44380.9        "     Z  "   "       "    "  "
AX,11,22,05,51,     3.1     X-BLV Adj. due to instr. corrections
AY,11,22,05,51,    -3.9     Y  "    "    "   "   "          "
AZ,11,22,05,51,    -0.7     Z  "    "    "   "   "          "
TS,11,22,05,51,    25.      Standard temperature at LRMMO
BT,11,22,05,51,  -0.176     Temperature baseline in °C
ST,11,22,05,51, 0.019924    Temp. scale-value in °C/count
QX,11,22,05,51,   0.77      Temp. coeff for X sensor in nT/°C
QY,11,22,05,51,  -0.04        "     "    "  Y   "    "    "
QZ,11,22,05,51,  -0.65        "     "    "  Z   "    "    "

A2 I2 I2 I2 I2   F10.0      Required FORMAT of record.
```

```
Allowable parameters: OX,OY,OZ,OF,OT,  SX,SY,SZ,SF,ST,  BX,BY,BZ,BF,BT,
                      AX,AY,AZ,AF,AT,  QX,QY,QX,QF,     TS
```

Default values for parameters omitted from file is zero.

Embedded comments are allowed within the file.

APPENDIX E: **Indices of Activity**

K-Indices: Advice from Institut de Physique du Globe de Paris states the lower limit for a K-index of 9 is 350 nT at Learmonth.

This leads to the limits for K and ak indices as follows:

K-index	K-index limits	Equivalent ak
	0	
0		0
	3.5	
1		4.2
	7	
2		9.8
	14	
3		21
	28	
4		37.8
	49	
5		67.2
	84	
6		112
	140	
7		196
	231	
8		336
	350	
9		560

APPENDIX F: **Geomagnetic Equipment at Learmonth MO**

MAGNETOMETERS	CONSUMABLES
Declination & Inclination Magnetometer (DIM): - Elsec/810 Fluxgate Variometer s/n 201. - Zeiss 020B Theodolite (s/n 311847) (with handbooks)	* 1.5V D-cells x 12
Proton Precession Magnetometer (PPM): - Elsec/770 (s/n 189) (with handbook)	* 1.5V D-cells x 12
Digital stop-watch: - Micronta LCD Quartz Chronagraph catalogue no. 63-5009A	* alkaline button cells cat no. 23-115 x 2 (1.5 volt)

VARIOMETERS

Fluxgate Variometer, 3-component:
- EDA FM-105B Electronic console (s/n 196205)
- EDA FM-100B Sensor head (s/n 3181) with cables (& handbook)

Recording Proton Precession Magetometer
- Elsec 595 with head & cable (s/n 131)

Power-supply (18V) for Recording PPM
- Cole Electronics #2521 (Adaptor Box #5/1)

Thermometer, digital
- Doric Trendicator 410A (s/n 345749) with cable (& handbook)

NDS-1 Digital Clock

RECORDERS	
Digital Data Logger (EDAS-2) - Digital Electronics (s/n 028) Front key: Yale DC778 - Incl. 18V/600mA power supply Arlec plug pack AC adaptor	* Gel-cells 6V/2AH x 2 (eg Exide RE 6-4) * Head cleaner kit * Tape Cassettes (eg Verbatim 300NH) * Cassette labels
Chart Recorder - Linseis LD-12 s/n R2501/80 (with handbook)	* Z-fold chart paper * print heads (LO/52)

Teletype with RS232 cable
- Teletype Corp'n TTY model 43
  s/n 339097

* TTY paper
* TTY ribbon (430484)

Table on castors for TTY

OTHER APPARATUS

Magnetograph Calibrator
with cable to EDA head

Regulated Power-supply (+/- 12V)
- Statronics model 53/2 B
  s/n A 003387

Standby switch-box (12V / 1A)

* Lantern battery, 12V

Electronics rack on castors
Rear door key UNION FS900

Power distribution boards x 2

Learmonth ID stamp

* Stamp pad

* Magnetic Observation Forms

* Magnetograph Log sheets

* Pre-paid envelopes

* Padded Jiffy bags

* Pre-paid mailing stickers

* Syringe / ink