Bureau of Mineral Resources, Geology & Geophysics

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MAWSON GEOPHYSICAL OBSERVATORY

ANNUAL REPORT, 1989

BY
PETER CROSTHWAITE
GEOPHYSICAL OBSERVATORIES AND MAPPING BRANCH

DEPARTMENT OF PRIMARY INDUSTRIES AND ENERGY

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GEOLOGY AND GEOPHYSICS**

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Summary

The Bureau of Mineral Resources, Geology and Geophysics contributes to the Australian National Antarctic Research Expeditions by operating geomagnetic and seismological observatories at Mawson and Macquarie Island, operating a seismological observatory at Casey, providing an observer for the Mawson observatories, assisting in the operation and calibration of the Antarctic Division geomagnetic monitoring programs at Davis and Casey, and by performing geophysical and geological field work in Antarctica.

This report describes the operation of the Mawson geomagnetic and seismological observatories from 23rd December 1988 until 2nd January 1990. It also describes a brief visit to Davis to perform calibrations on the local geomagnetic instruments in March 1990. It includes an analysis of Mawson geomagnetic data from 1st January 1989 UTC until 31st December 1989 UTC (inclusive).

The geomagnetic field at Mawson was continuously monitored using a three component PhotoElectronic Magnetometer (aligned geographic North, East and Vertical) and a proton precession magnetometer. The data were recorded initially on magnetic cassette tape, later on remote computers at the Australian Seismic Centre via ANARESAT telemetry lines and eventually on disc on a local personal computer. The personal computer recording system allowed for the first time immediate local access to the variometer data in digital form where consistency checking of the 4-channel data was straightforward. As a spare computer for the variometer recording system was available as an analysis tool, the PEM system could be more thoroughly investigated than ever before. Along with access to the ASC computers and recording of telemetered data at ASC, this was one of the most significant leaps forward in operation, data quality control and data processing in the history the magnetic observatory.

Seismic activity was monitored by two independent systems. One consisted of a Benioff short period vertical seismometer and a Press Ewing long period vertical seismometer; these data were recorded locally on hot pen helicorders. The other consisted of three Guralp wide band seismometers (aligned North, East and Vertical); these data were telemetered in real time via ANARESAT telemetry lines to the Australian Seismological Centre.

Preliminary magnetic data (K indices and Monthly Mean Field values) were forwarded monthly to the Geomagnetism Section at BMR. Seismic data derived from scaling the locally recorded visual seismograms were distributed via the Global Telecommunications System on approximately a weekly basis.

The author also performed geomagnetic field observations in Kemp Land (Depot Island and Fold Island) during October 1989, and in the Prince Charles Mountains during January and February 1990. Those observations are described in a separate report (Crosthwaite, in prep).

Contents

Introduction

Mawson Geophysical Observatory is operated by the Geophysical Observatories and Mapping Branch, Bureau of Mineral Resources, Geology and Geophysics (**BMR**) as part of the Australian National Antarctic Research Expeditions (**ANARE**). Logistic support is provided by the Antarctic Division, Department of Arts, Sport, the Environment, Tourism and Territories.

The observatory commenced operation in 1955 with the installation of a three component La Cour magnetograph from Heard Island (Oldham, 1957). The history of geomagnetic and seismological instrumentation changes from 1955 until 1989 appears in Appendix A. Station details appear in Table 1. A map of Mawson showing the location of the geophysical buildings and cable paths appears in previous observatory reports (Kelsey, 1987).

The author arrived at Mawson aboard a helicopter from the Lady Franklin on 22nd December 1988 and assumed responsibility for the running of the observatory following the departure of the previous observer, Rodney Hutchinson, on 23rd December 1988. Geomagnetic instrument comparisons were performed by the author in December 1988 and January 1989 (Table 4).

On 2nd January 1990, the following observer, Andrew Lewis arrived aboard a helicopter from the Ice Bird. He assumed responsibility for the observatory on 3rd January 1990. Geomagnetic instrument comparisons were performed by Andrew Lewis in January and February 1990.

The author remained at Mawson until 11th January awaiting favourable flying conditions for departure to Dovers summer retreat to begin a field program of geomagnetic observations in the Prince Charles Mountains. He returned to Mawson on 16th February 1990, and finally boarded the Ice Bird on 26th February. The Ice Bird left Mawson Harbour after the abatement of a blizzard on 27th February.

The author performed geomagnetic instrument comparisons and examined the geomagnetic monitoring equipment at Davis from 1st to 2nd March, and arrived in Australia on 13th March 1990.[1]

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[1]Note: All errors quoted in this report are ± 1 one standard deviation.

The geomagnetic field was continuously monitored by a four-component variometer which consisted of a three-component photo-electronic magnetometer (**PEM**) aligned magnetic North (X), East (Y) and Vertical (down, Z) and a proton precession magnetometer (**PPM**) . The temperature of the sensor equipment was monitored using a single electronic thermometer (a Doric device) located in the sensor room near the Y component PEM. These sensors and the controlling electronics were all located in the New Variometer Building. A data cable carried the analogue signals to the Science Building.

The analogue data were recorded in the Science Building on a multipen W&W ink chart recorder, and also digitised on a minute basis and recorded on various computer-readable media. The local digitising and recording instruments were an EDAS data logger utilising a cassette tape unit (which was removed from the system at 09:00 UTC 17th May 1989) and a personal computer (which began operation at 09:46 UTC 21st May 1989) utilising a hard disc drive.

From 10th January 1989, digital data from both the EDAS and computer systems were recorded reasonably reliably on the Australian Seismic Centre's computers via the ANARESAT satellite telemetry link.

The variometer was calibrated on a regular basis by making absolute observations on the standard absolute pier A in the Absolute Hut.

Three new declination azimuth marks visible from the absolute pier A were installed (Table 3).

A summary of the Geomagnetic Log is included in Appendix B. A block diagram of the final instrument layout and connections is shown in Figure 5.

Currently, there is no remote secondary reference pier which is regularly monitored to check and in case of corruption to the magnetic environment of the Absolute Hut. It would be worth while establishing such a reference, possibly over the azimuth mark LEE, located 1.5km from the Absolute Hut on Lee Island, well clear of the effects of the station.

Absolute Instruments

The primary instruments used for variometer calibrations were:

QHM 300, Thermometer 1650, Askania Glass Circle 611665 for **H**
Declinometer 630332, Askania Glass Circle 611665 for **D**
PPM Elsec 770/199 (used in the Bolts Up orientation) for **F**

In addition, the following secondary instruments were used:

QHM 300, Thermometer 1650, Askania Glass Circle 611665 for **D**
QHM 301, Thermometer 1416, Askania Glass Circle 611665 for **H** and **D**
QHM 302, Thermometer 1401, Askania Glass Circle 611665 for **H** and **D**
PPM Elsec 770/206 (used in the Bolts Up and Down orientations) for **F**
DIM Elsec 810/213, Theodolite 311542 for **D** and **I** (and surveying)

The following comparison instruments were used in December 1988 and January 1989:

QHM 172, Thermometer 619, Askania Glass Circle 611665 for **H**
HTM 704 , Thermometer (unlabelled), Askania Glass Circle 611665 for **H**
Declinometer 640505, Askania Metal Circle 508813 for **D**
PPM Elsec770/188 (used in the Bolts Up Orientation) for **F**

The instrument constants used for these magnetometers are listed in Table 2.

No instrument corrections have been applied to any instrument observations or derived baselines or data in this report.
The preliminary instrument corrections to the standard instruments, and therefore preliminary corrections to all baselines and magnetic field summaries, are:
-5nT for H (QHM 300), **-3.4nT for F** (PPM 199 Bolts Up) and **+0.3' for D** (Declinometer 630332)
and therefore:
-0.7nT for X, +5.2nT for Y, +1.7nT for Z and **-0.3' for I.**

These preliminary corrections are based on comparisons performed during the 88/89, 89/90 and 90/91 summers, and are in the sense
preliminary corrected value = instrumental value + preliminary instrument correction

All absolute observations for variometer calibration and instrument comparison were performed on Pier A in the Absolute Hut. Mark **SOH** near the Old Variometer Building was used for all declination references. The adopted azimuth of mark SOH from pier A in this report is 274°15.0'. All instrument comparisons were performed through baselines.

All QHM observations were performed using the standard 9 minute (2,2,1,2,2 minute delay between 0,+,-,-,+,0 readings) schedule. All QHMs were used in 2π mode at Mawson.

When QHMs were used as declinometers on an Askania Circle (which was always the case; QHM circles were never used), the mark was viewed without the QHM mounted on the circle, exactly as for a declinometer.

The standard PPM 770/199 was used in the "bolts up" orientation for variometer calibrations throughout the year. Comparisons were performed in both "bolts up" and "bolts down" orientation. It was realised too late that the manufacturers recommend the "bolts down" orientation.

When using the DIM to measure D, the vertical circle was set to 90 or 270 immediately prior to every horizontal circle reading even when a rotation from "Vertical Circle North" to "South" (for example) would not be expected to alter the vertical circle reading. This was done as the theodolites used with the DIMs are gimballed devices, and the vertical circle reading may change during a rotation in the horizontal plane if the alidade is not level. The DIM observations were sometimes "full sheet" and sometimes "half sheet" observations.

Variometer Sensor Description and Modifications

The variometer system was housed in the New Variometer Building in East Bay, about 80 meters north of the Absolute Hut. As mentioned above, it consisted of a three component PEM and an Elsec 820 PPM. A Doric temperature device was installed with the sensor near the Y PEM (Kelsey, 1987). The variometer sensors were kept in a temperature stable environment using a short cycle time room heater - except during temperature coefficient testing and power failures, the sensor room was maintained at 10°C (±1°C). A long, shielded cable (containing 10 twisted pairs) connected the variometer building to the Science Building; it was used to send analogue and digital data to the Science Building, and to receive digital data and timing and scale value test initiating pulses from the Science Building.

On the author's arrival, the electronics control units for the PEM, PPM and Doric were located just outside the sensor room in a wooden cupboard in the anteroom, only about 2 meters from the X PEM (Kelsey, 1987). A battery charger and battery were located nearby. The undesirable proximity of the control equipment to the sensors was clearly necessitated by the restricted lengths of cables supplied with the PEMs.

The PEM system produces analogue voltages from two recorder sockets. The PPM produces both an analogue voltage output and an RS232 digital output; it can be configured to cycle automatically at specified intervals or on command from an RS232 device. The Doric produces an analogue voltage output. The recording of these outputs is described below under "Recording Systems".

No alterations to the variometers were made until 09:00 17 May 1989 UTC. At that time, it was intended to make the following changes to the system:

1. Replace the LED in the Y PEM. (The performance of the LED appeared to be near the lower limits of acceptability. The LEDs of all PEMs require regular replacement.)
2. Replace the PEM cables with ones long enough to reach the furthermost corner of the building from the sensors. Reroute the PEM, PPM and Doric cables along the walls at a height above the doors to keep them distinct from power cables, and install box conduit to contain all data cables in the anteroom and recorder room.
3. Reterminate the long cable from the science building in the recorder room.

4. Remove any nonpower cable terminations and equipment from the power switchboard cupboard.
5. Shift all of the non sensor electronics from the anteroom to the recorder room of the building and mount them in a new nonmagnetic desk/equipment rack built by the maintenance carpenter. (Increasing the distance between the equipment and the nearest magnetic sensor (the X PEM) to 5 meters.)
6. Install the computer acquisition system to replace the error prone EDAS magnetic cassette recording system.
7. Install a cable between the absolute hut and the variometer building to record fiducial marks.
8. Remove the battery and battery charger and install an SPS1000 backup power supply.
9. Modify the PEM to extend the range of magnetic field variations measurable from ±1000nT to ±2000nT according to instructions from Canberra.

The technical advice from Canberra to achieve 9 was incorrect, and testing in Canberra was inadequate to detect the error. Although the set up procedure described in the manual for the original PEM boards was not appropriate for the modified boards, an attempt to modify the X PEM revealed that the specified modifications halved the measurable range of field variation - exactly the opposite to the desired effect. The system was inoperative while advice from Canberra to correct the problem was sought. Timely advice was not forthcoming, and blizzard conditions prevented return to the variometer building until 21st May, when the original X PEM board was reinstalled and the recording was restarted. (Only the X PEM modifications were attempted.) However, for the loss of several days of data, 2 to 8 from the above list were achieved. Notably, the EDAS system was replaced by the PC system, and the variometer sensors and recording system in the variometer building became independent from the outside world unaffected by cable damage and power failures for periods of up to at least one hour. Furthermore, the system could be left to run without operator intervention for several months except for calibrations and abnormal circumstances (e.g. in 1990, Andrew Lewis reported that static discharge apparently halted the system during a blizzard).

The new recording system allowed, for the first time, immediate local access to the variometer data in digital form where consistency checking of the 4 channel data was straightforward. As a spare PC for the variometer recording system was available as an analysis tool, the PEM system could be more thoroughly investigated than ever before. Along with access to the ASC computers and recording of telemetered data at ASC, this was one of the most significant leaps forward in operation, data quality control and data processing in the history the observatory.

One of the most notable discoveries of the PEM system was found by monitoring the difference between the value of F as measured by the X, Y and Z PEMs and the PPM. During "rapid" temperature fluctuations (of perhaps 1 or 2 °C/hour) the measured F difference varied enormously. This situation arose when the sensor temperature was altered to measure the instrument temperature coefficients and whenever there was a mains power failure and loss of heating. The reason for the malfunction was attributed to the Z PEM. One set of absolutes performed during a period of malfunction appeared self consistent and confirmed the expected X and Y baselines, but indicated a 17nT shift in the Z baseline, and F consistency checks indicated variations of up to 30nT. It appears that the X and Y instruments can cope with temperature fluctuations because their magnets are thermally connected to the air mass containing the temperature sensors through the metallic QHM materials. (There are two types of temperature sensors - the Doric which measures the "variometer temperature" and the PEM sensors used to reduce the PEM temperature coefficients.) The Z PEM magnet, on the other hand, is insulated from the air mass by a perspex container. As the native temperature coefficient of the Z PEM is about -14nT/°C (Kelsey, 1987), a temperature differential of a little more than a degree between the inside of the Z PEM magnet container and the outside air mass would cause the apparent baseline shift.

The above observations indicate that the PEM system should be left as undisturbed as possible. The door to the sensor room should be left closed whenever the system is checked, either the air in the sensor room should be undisturbed or homogeneously mixed and that the heating system should not cause rapid changes in temperature. Fortunately, the heater controller in the sensor room is excellent, with very stable temperature control and a cycle time of the order of a second, and under normal operation the air in the sensor room is undisturbed.

For future temperature sensitive variometer installations, each sensor should have a small thermal cover to reduce rates of temperature change, each sensor should be monitored by its own temperature device (a single Doric for the 3 PEMs is not ideal), and the temperature devices should have adequate thermal connection to the critical sensor components.

On 22nd August, with new advice about the ±2000nT modifications to the PEMs and new manual entries for installation, work commenced on installing new boards. The X installation appeared satisfactory using a modified spare board. The Y installation using another modified spare board resulted in intolerable noise problems (up to 15nT scatter in the 10 second sampling was noted during a quiet field). The third spare board available was found to be unserviceable. Brief blizzard conditions delayed return to the variometer, then the original Y board was modified and installed in the Y PEM with unacceptable noise problems. The original X board was modified and installed in the Y PEM and proved to be acceptable. Apparently, the suggested modifications pushed the design of the PEM to its limits and induced internal noise.

With this poor success rate, the Z PEM electronics were not modified. While the system was in a state of turmoil, the Y PEM LED was replaced and the lid of the Z PEM was replaced with a brass lid to try and increase the thermal connection between the magnet and the surrounding air mass. The system was operational again by 24th August, although without temperature compensation adjustments on the X and Y PEMs. Temperature compensation adjustments were made on 26th, 28th and 29th August. No further alterations were made to the variometer sensor equipment during the year.

The difficulty in modifying the PEMs indicates a problem with small scale production of in house designed and built devices. Over the years, considerable effort has been put into the design and modification of the PEMs, and the result has been quite a respectable device which unfortunately requires a fair amount of maintenance and training (- the only operational PEM installations are in remote Antarctic sites, where there is an annual turnover of personnel), and which is still subject to operational difficulties only slowly being discovered. The departure from BMR of the designing engineer and the loss of the full time services of the technical officer most involved with the development of the PEMs has left inadequate support for development and maintenance. Furthermore, the installation of PEMs requires a rather expensive nonmagnetic large thermally insulated building, whereas other sensors can adequately be installed in a small hole in the ground. In retrospect, the PEMs have been an expensive alternative to off the shelf commercially available products.

The Elsec 820 PPM frequently showed spikes on the analogue charts. It appeared that these spikes were accompanied by bad digital data as displayed on the PPM readout and sent down the digital data line. The spikes were particularly prevalent during mains power outages when the PPM was powered from a DC power supply which was in turn powered by the SPS1000 backup power supply. (The SPS1000 has a very nonsinusoidal output, and appeared to cause stresses on much of the electronics.) The problem of spikes was partially overcome by filtering the digital data. Unfortunately, during power outages there is loss of heating causing major temperature fluctuations and the previously referred to problems with the Z PEM data, and it is then that the F data is of most value. To make best use of the F data, it is best to either use a single channel digital filter or to filter the redundant four channel data using consistency criteria.

Recording Systems

All digital recording systems used during 1989 recorded one minute data. The acquisition minute commenced 30 seconds before the minute and ended 30 seconds after the minute.

The recording system from 1988 was left intact until 17th May 1989. This system consisted of an EDAS analogue to digital converter with an audio sized digital cassette drive installed in the Science Building. Analogue data was received from the variometer via the long cable from the variometer building and consisted of X, Y, Z, F and temperature channels. The timing for the EDAS derived data was from the internal EDAS clock, which drifted less than a second a day. The timing was set a few seconds fast each tape change (about every 8 days) and drifted a few seconds slow by the end of the tape. Hutchinson (1989) describes considerable data loss due to the inability to read data from the digital cassettes from this system during 1988. The data loss from the cassettes was even more severe in 1989, and for many days was near total. The EDAS recording system was decommissioned at 09:00UTC 17th May 1989.

Fortunately, for most of the period of operation of the EDAS system, an alternative recording media was in use. From 10th January 1989, RS232 digital data from the EDAS was sent via a modem to the ANARESAT telemetry link to Australia. In Broadway, Sydney, the geomagnetic data were merged through a statistical multiplexor with digital seismic data and sent to the Australian Seismic Centre (ASC) where it was recorded on their Unix network. The RS232 data from the EDAS was always reliable and readable, and the telemetry and recording systems at the ASC were reasonably reliable. (There were some days of nonrecorded data at ASC, and occasional blocks of data lost through the unavailability of the computer, and some satellite problems, but on the whole, recording was far more reliable than on the EDAS cassettes, and data integrity was excellent. The ASC system was able to be interrogated through a terminal connection from Mawson enabling the Mawson observer to pin-point problems quickly.)

The data finally transferred to the Data General computer for archival and production of data for the World Data Centre for the period of operation of the EDAS system consisted of the telemetered data from ASC, with as many holes as possible filled in with data from the EDAS cassettes. Data loss ran at about 10% until the telemetry system was operational, and then at much less than 1% when the satellite and ASC systems were functioning, although there was still some significant data loss on some days. The total data loss for the months January to April, and 1st to 17th May from the combined data sets were 3.2%, 3.2%, 0.8%, 4.9%, 1.8%.

On 21st May 1989, the NEC PowerMate 1 Personal Computer system was commissioned. The system was very similar to the one installed at Macquarie Island the previous summer, with some minor hardware additions and some software modifications. There were no data losses due to the lack of performance of the recording system for the rest of the year (all data losses were due to deliberate interference with the system to perform variometer sensor upgrades, perform system tests, or lack of performance of the sensors e.g. clipping during magnetic storms.) The final hardware configuration for this system is shown in Figure 5. The schematics and circuit diagrams for the Macquarie Island installation of the same system are relevant to Mawson also (Maplestone, 1990). Data from this system were available at any time and the real time performance of the system was displayed at the variometer hut and could be interrogated from the Science Building. Data from the PC system continued to be telemetered to Canberra and recorded at ASC, although there was never any need to use the ASC data as the locally recorded data was completely reliable. The most significant advantage of the telemetered data was that the system was able to be monitored from Canberra during the absence of the observer during field work - if any problems had been encountered during such times, the stand-in geomagician at Mawson (Mike Dymond) could have been swiftly advised.

The data from the PC system transferred to the Data General was modified slightly in order to preserve current file formats - the F channel, which in the original PC data was the measured F value from the variometer PC, was transformed using : $F_{DG} = (F_{PC} - 49000.0) * 10$. That is, the Data General files record F in tenths of nT relative to a 49000nT baseline (in addition to the normal corrections that must be applied to calculate F at the standard pier from F measured by the variometer). The timing for the PC data was taken from the PC DOS clock, which, initially, was regularly automatically synchronised to the Real Time clock in the computer. The Real Time clock drifted by about 1 second per day and was frequently corrected manually. From the 1st September 1989, the DOS clock was synchronised to the seismic GED clock from which minute pulses were taken and transmitted over the long cable from the Science Building to the variometer building. The GED clock had a drift of only milliseconds per day and was maintained throughout the year to well within 50ms of UTC. A description of the acquisition program (and other programs) and modifications made throughout the year is given in Appendix C.

A W&W multipen chart recorder recorded the analogue X, Y, Z, F and temperature traces for the entire year. The digital baselines were applied to the analogue records directly; the scale values of the analogue records were measured independently from the digital data for December 1988 only. The preliminary monthly means were derived from the analogue records for that month only. K indices were derived from the analogue charts until July 1989. From August 1989 (the analogue scale values changed significantly with the installation of ±2000nT boards in the X and Y PEMs on the 24th August), K indices were derived from digital records, and the analogue charts were used only as a visual check on the field and as an ultimate backup - otherwise they were not used.

Variometer Calibrations

Calibrations performed on the variometer were base line calibrations, scale value calibrations, null offset calibrations, orientation calibrations and temperature calibrations.

There were seven periods when the variometer parameters were apparently constant. Each discontinuity was caused by intentional alterations to the system. There were no accidents and no inexplicable irregularities in the data. The results of baseline, scale value and temperature calibrations are given in Appendix D. Offset and orientation calibration results are given below.

Base Line Calibrations

Until the end of March 1989, the variometers were calibrated using the previously adopted absolute observation schedule: PPM 199, Declinometer 332, QHM 300, Declinometer 332, PPM 199 (with temperature and scale value observations). These observations were made about twice per week. On a monthly basis, QHMs 301 and 302 were included in this sequence (breaking the time symmetry in the FDHDF measurements). The theory behind the symmetry of such observations is presumably based on the assumption of a linearly varying field - averaging the pairs of F and D measurements would hopefully give the value of F and D at the mid-point of the H observation, or if not then the errors arising from imperfect knowledge of the variometer parameters would at least tend to cancel and produce a reasonable FDH field measurement for a given variometer output. In the author's view, it is not necessary to perform symmetrical observations when each part of each observation can be corrected simply using digital data and a computerised reduction method which can be recursively applied with minimal human effort. Furthermore, the assumption of linearity is completely invalid at high latitude observatories. Absolute observations should be made over as broad a range of field values as possible in order to achieve reliable calibrations for the full range of data. The major source of variation at Mawson is storm activity. The period of variations from storms is shorter than the time taken to perform a set of absolute observations, and so the linearity assumption fails in most instances.

From April 1989 onwards, the absolute observation schedule was reduced to a single F, D and H observation in no particular order, and the number of observations was increased to about 16 per month. QHMs 301 and 302 were still included once per month, and from June onwards, the DIM was frequently included (and for the same reasons as the FDH symmetry was abandoned, the symmetry of the DIM DIID or "full sheet" schedule was often abandoned in favour of a DI or "half sheet" schedule). The QHMs were used to measure D as well as H during 1989. There was a great advantage in measuring redundant components of the field (extra D measurements from the QHM and extra D and I measurements using the DIM). It enabled curious results from the observations to be attributed reliably to the observations or to a previously unknown malfunction in the variometer or some other part of the system. Furthermore, it enabled calibration of nonstandard instruments in the case of standard instrument loss, and comparison of the reliability of different instruments (see "Absolute Instrument Performance" below and Table 4).

The absolute observations were performed during both quiet fields and moderately noisy fields (within the limits of the absolute instruments and tracking ability of the variometer system). Generally, the monthly range in field values over which absolutes were made were about 100 to 300nT for X, 50 to 150nT for Y, 50 to 300nT for Z and 100 to 200nT for F. About 2/3 of the K indices for Mawson are K4 or less, and the upper limit for K4 is 210nT. Hence the variometer parameters could be taken as reasonably valid for the majority of the field values. There would be some doubt concerning the validity of the parameters during large storms where the variations may exceed 1500nT. A faster tracking variometer (with a higher sampling rate and a shorter time constant) would allow a greater range of fields to be measured if more accuracy during stormy fields is required.

Software to reduce observations and calculate variometer parameters (baselines etc.) was developed progressively during 1989. The final software is described in Appendix C.

The model for the deriving the magnetic field vector from the variometer data is assumed to be a linear relationship:

$$\begin{pmatrix} X \\ Y \\ Z \end{pmatrix} = \begin{pmatrix} b_x \\ b_y \\ b_z \end{pmatrix} + \begin{pmatrix} d_x \\ d_y \\ d_z \end{pmatrix}.(\text{Time-Time}_0) + \begin{pmatrix} s_{xx} & s_{xy} & s_{xz} \\ s_{yx} & s_{yy} & s_{yz} \\ s_{zx} & s_{zy} & s_{zz} \end{pmatrix} . \left(\begin{pmatrix} x \\ y \\ z \end{pmatrix} - \begin{pmatrix} x_0 \\ y_0 \\ z_0 \end{pmatrix} \right) + \begin{pmatrix} q_x \\ q_y \\ q_z \end{pmatrix}.(\text{temp-temp}_s)$$

This equation could be described using the classical terminology:

X,Y and Z are the geomagnetic field components

b_x, b_y and b_z are baselines at standard temperature $temp_s$ and at time $Time_0$

d_x, d_y and d_z are drift rates

(s_{ij}) is a "scale value" matrix , the diagonal elements approximating "scale values", and the off diagonal elements representing exorientation factors for imperfect variometer alignment

q_x, q_y and q_z are temperature coefficients

x,y, z, temp are the digital ordinates from the variometer

x_0, y_0 and z_0 are digital data reference levels (at which the baselines are measured - for the EDAS XYZ data this is 5000 for example, approximately the 0 output from the PEMs)

$Time_0$ is a reference time

$temp_s$ is the standard temperature for the variometer

Note however that the baselines, drift rates, "scale values" and temperature coefficients are not those of the actual instruments, but rather linear combinations dependent on the alignment of all of the PEMs. Inversion of this matrix equation to produce the actual instrument alignments, baselines, etc is given in Appendix F.

Additional equations for the 4 component system are:

$$\text{temperature} = B_t + S_t.(t-t_0)$$

where:

temperature is the true temperature of the variometer

B_t is the true temperature baseline at the digital temperature reference level t_0

S_t is the true temperature scale value

t is the digital temperature ordinate from the variometer

t_0 is the digital data reference level

$$\boxed{F_{variometer\ pier} = B_f + S_f.(f-f_0)}$$

where:

B_f is the F baseline at the digital F variometer reference level f_0. For the PC data where f is the value measured by a PPM, B_f is the PPM instrument correction and S_f is unity.

S_f is the true F scale value

f is the digital F ordinate from the variometer

f_0 is the digital data reference level

(This equation does not apply to EDAS data where the data represent only the least significant two digits of the field, and hence require an adjustment of an unknown number of hundreds of nanteslas.)

$$\boxed{\underline{\mathbf{F}}_{variometer\ pier} = \underline{\mathbf{F}}_{absolute\ pier} + \begin{pmatrix} p_x \\ p_y \\ p_z \end{pmatrix}}$$

where:

p_x, p_y and p_z represent the vector pier difference

$\underline{\mathbf{F}}_{?\ pier}$ are the magnetic field vectors at the given pier. Unless specifically measured at variometer installation and modification, this pier difference can only be derived from looking at the variation of $F_{variometer\ pier} - F_{absolute\ pier}$ (using the XYZ data) with variations in X, Y and Z. It is often assumed that the F pier difference is a scalar value. However, for the magnitude of field variations common at Mawson, this is not valid. It was observed that the "F scalar pier difference" on 22nd October, for example, (when the K indices were 6775 3335) was 26nT ±4nT over 1427 samples during the day (the other 13 samples being rejected due to PPM misbehaviour during large storms).

In practice, the variometer PPM F instrument corrections were not known, and other variations clouded the vector pier difference. Consequently, the parameters for these final equations have not been determined. Instead, a reasonable "F scalar pier difference" for quiet fields was calculated.

It appeared that the F scalar pier difference was constant for the duration of the PC acquisition system and from June and September local quiet days that this value was +27±1nT. This value can be used as the correction to the variometer F data to derive F at pier A as measured by standard instruments *without corrections.*

The derived parameters specified in Appendix D were derived from linear regression analysis of the absolute measurements of field values versus the variometer digital data. This method is described by Crosthwaite (1986). No instrument corrections have been applied in the reduction of observations used to derive these parameters. See also the section below "Variometer Performance" for comments on the reliability of these parameters.

The above model and regression techniques assume that all data channels are functional. An analysis of Macquarie Island data by Stewart Dennis indicated that the Z data were unreliable, possibly because of inadequate temperature stabilisation and associated problems with the Z PEM. It may therefore be better to invert the above model and determine the system parameters by using the absolute X, Y and Z measurements as the independent regression variables and the variometer data as the dependent variables. (See Appendix F.) This would characterise each channel by its true scale value, temperature coefficient, alignment etc. - regression of absolute results could be applied to each channel independently and hence not require that all channels were functional (but instead require that all absolutes measure the complete vector field). Once the geometry of the system is known, formulae for deriving true X, Y and Z (etc.) from two of the nominal X, Y and Z variometer channels and F could be derived.

The expected error in absolute observations of:
H using QHM 300 is 1.4nT due to an error in the measurement of ϕ of 0.4'
D using any instrument on the Askania Circle is 0.4'
F using an Elsec 770 PPM is 1nT
D using a DIM is 0.2'
I using the DIM is 0.2'

The dependence of **X**, **Y** and **Z** baselines on **H**, **D** and **F** measurements is dX/dH=-0.4, dX/dD=4.8, dX/dF=0, dY/dH=0.9, dY/dD=2.3, dY/dF=0, dZ/dH=-0.4, dZ/dD=0, dZ/dF=-1.1 (fields in nT, angles in minutes).

The expected errors in baseline determinations from HDF observations would therefore be **2.5nT for X**, **2.2nT for Y** and **1.7nT for Z.**

The dependence of **X**, **Y** and **Z** baselines on **D**, **I** and **F** measurements in the Mawson field is dX/dD=4.8, dX/dI=5.8, dX/dF=0.2, dY/dD=2.3, dY/dI=-12.1, dY/dF=-0.3, dZ/dD=0, dZ/dI=5.4, dZ/dF=-0.9 (fields in nT, angles in minutes). The expected errors in baseline determinations from DIF observations would therefore be **2.2nT for X**, **3.3nT for Y** and **2.0nT for Z.**

It is probably reasonable to halve the above errors as most absolute instrument observation schedules are based on at least 4 of the basic measurements (F or angles), bringing all of the expected errors down to about 1nT.

Additional sources of error for baseline determinations arise from noise within the variometer system, instability of the variometer system, cross interference between sensors, lack of exact synchronisation between absolute observations and variometer sampling, different time responses of the absolute and variometer instruments to variations in the field, imperfect knowledge of the variometer parameters, an imperfect variometer model (e.g. nonlinearity, A/D electronics temperature compensations), difficulties in observing the azimuth mark during poor weather conditions, variometer pier creep, absolute pier creep (the absolute pier is a very old wooden pillar - the levelling bubbles of the absolute instruments can be observed to wander during strong winds) etc.. It is surprising that the baseline standard deviations are of the order of 1nT for all components for either HDF or DIF observations.

Appendix F gives the inversion of the first matrix equation in this model for different data periods and instruments. The deduced orientation implications for the variometers are discussed below under Orientation Calibrations.

Scale Value Calibrations

Scale value tests were performed on the X, Y and Z PEM channels by injecting a current into the scale value Helmholtz coils using the current generator in the PEM control unit. There are two ways of doing this. Either using an automatic scale value sequence, which takes a little longer than 6 minutes (a positive signal for about 2 minutes, then a 2-minute negative signal, followed by a 2-minute positive signal), or manually by selecting the current value and timing via switches on the PEM control unit. The current generator in the control unit was not stable and the tests were only useful when the current was monitored. Inaccuracies in the results of the scale value tests may result from inaccurate geometry in positioning the sensor in the Helmholtz coils, inaccurate coil constants and inaccuracies in the current measurement (the multimeter used was compared to a similar unit and differed from it by 0.2%). Furthermore, scale value tests are of less value during magnetically active periods.

Automatic scale value calibrations were performed at about 00:05 UTC daily until 17th May 1989. These scale value tests served to mark the 00 UTC hour mark of the analogue charts, but were never used for any other purpose. They corrupted at least 8 minutes of data every day. There was no guarantee that the calibrations would occur during a reasonably magnetically quiet period and the current was not monitored. They were therefore discontinued.

Automatic scale value calibrations were also performed during most absolute observations until the end of March 1989. From then until August, they were only performed during very quiet magnetic fields, usually during absolute observations.

From August 1989, automatic scale value sequences were abandoned in favour of manual sequences. The manual method used a 0,+,0,-,0,+,0 sequence of currents separated in time just long enough to allow the PEM to settle (about 30 seconds). This gave extra 0 data points to use in a regression to calculate scale values, and also allowed enough good data points during the observation to be able to edit the 10-second data and produce meaningful 1-minute data, thus losing no data during the observation (as the observations were only performed during quiet periods, any sample during a minute was a reasonable estimate of the minute average.)

Following the installation of the PC acquisition system (21st May), the scale values could be calculated using 10 second data rather than the 1-minute data.

The results of the tests are given in Appendix D. It is interesting to note that the automatic scale value tests using EDAS 1-minute data from Data Period I have a consistency of about 1% on all channels, and differ from scale values derived from regression of absolute measurements of the field values against variometer counts by up to 2.3%, whereas manual scale value tests using PC 10-second data from Data Period VII have a consistency of 0.1% and differ from scale values derived from regression results by up to 0.8%. (The regression results have a standard deviation of about 0.3% for Data Period I and 0.2% for Data Period VII.) Note that the difference in scale values derived from the direct and regression methods is very much smaller than the values of up to 9% reported by Hutchinson (1989).

Null Offset Calibrations

The Null Offset for the EDAS recording system was measured by shorting the analogue inputs on 20th March 1989, 28th March 1989 and 21st April 1989. The values for X, Y, Z, F and temperature channels were 4993±1, 4992±1, 4995±1, 0000±0, 4995±0. This is a null error of about 1 to 2 nT. As the null was constant, there is no need to account for it when interpreting the digital data. A small error will result if the digital baselines are transferred to the analogue records, as in the preliminary data report for December 1988 (all subsequent reports were based on digital data). In this record, all EDAS "baselines" are derived at the variometer counts of 5000, 5000, 5000, 0, 5000.

The Null Offset for the DT2805/5716A A/D board, the heart of the PC system, was very small (only a few counts - equivalent to 0.1nT for ±1000nT PEMs, and 0.2nT for ±2000nT PEMs). As the A/D board multiplexes the analogue channels, the offset is the same for all channels, although possibly different if different scaling ranges are used. In any case, the acquisition routine was programmed to measure a Null channel (whose input was permanently shorted) on every conversion and automatically adjust the recorded data by the Null Offset. (Initially, this caused a problem because adjustments to data at or near saturation of the A/D board made saturated readings apparently only nearly saturated, and near saturated data appear saturated - this only happened during severe storms and was corrected at 15:33UTC 21st September 1989.)

Orientation Calibrations

The orientations of the variometers were derived from a regression analysis of the absolute observations against the variometer data. See below. A single orientation test was performed on 10th December 1989. This was done by injecting a current into the orientation coils of the PEMs using the PEM controller. The effect is to measure the difference in alignment of the PEM magnets and the PEM orientation coils, which were aligned at the PEM installation in 1985 (Kelsey, 1987). Neither the X nor Y PEMs showed any misorientation (as expected, as this is part of the set-up procedure for the PEMs). It is known that the Z magnet is not horizontal and will show some misorientation. Assuming an orientation coil constant of 96.36nT/mA, a measured orientation current of ±29.5mA and a measured ordinate change of -49nT (for a positive current) and +46nT (for a negative current), the misorientation of the Z magnet with respect to the orientation coils is about 1.0°.

Appendix F gives the orientation matrix U for data periods I, III and VII as deduced from standard instrument observations and data periods III and VII as deduced from DIM/F observations. From the orientation matrix , the following angular orientations can be deduced:

Using standard instruments, for data periods I, III and VII:
The X PEM is aligned -0.4°, 0.0° and 0.1° from true North, and 0.1°, 0.0° and 0.0° downwards.
The Y PEM is aligned -0.3°, -0.4° and 0.0° from true East, and -0.2°, 0.0° and 0.0° downwards.
The Z PEM is aligned 134.0°, 130.9° and 112.6° from true North, and 1.6°, 1.2° and 1.6° from the vertical.

Using the DIM/F instruments, for data periods III and VII:
The X PEM is aligned 0.2° and 0.0° from true North, and 0.0° and 0.3° downwards.
The Y PEM is aligned -0.6° and 0.0° from true East, and 0.2° and -0.1° downwards.
The Z PEM is aligned 170.7° and 121.6° from true North, and 1.1° and 1.7° from the vertical.

Temperature Calibrations

The temperature according to the digital readout of the Doric was noted and compared to the temperature counts on the digital records at the beginning and/or the end of each set of absolute calibrations. This allowed a temperature scale value to be derived. This scale value is an intermediate figure which is of no real value, as the digital readout is uncalibrated. This is of no consequence however, as it is only necessary to assume that the variometer outputs are dependent upon the temperature counts, whatever the units may be. The results are given in Appendix D.

Variometer Performance

Appendix D gives the variometer models throughout 1989. Certain results are doubtful, such as the dependence of X and Y on the z variometer data, variable drift rates during different parts of the year (-4,+7,+1 nT/year for X,Y and Z during data period I, -7,+2 and +14 during data period III and -12, +13 and 0 during data period VII), and changing alignment of the Z magnet during different data periods. However, in the author's opinion, inclusion of the parameters as specified will not introduce serious errors into the data provided the data are interpreted with the specified standard deviations.

Figure 4 shows the residual differences between the variometer models and absolute observations throughout 1989. From this information it seems that the PEM system does not conform to the basic linear model discussed above under "Base Line Calibrations". From the 1989 observations, and more clearly from the 1989 observations combined with the 1990 observations (Lewis, 1991), the PEM system (mostly the Z component) shows departures from the model which are not purely random and have various periods from days to months (any higher frequency departures would not be apparent from absolute observations). Possible explanations for the departures are:

Random and systematic walking of the Z PEM magnet on its agate
Random fluctuations in individual component values in the electronics
Exclusion of an essential component from the variometer model such as A/D converter temperature

The presence of such departures from the variometer model, of the order of a few nanoteslas, has considerable impact on the derivation of small parameters such as temperature coefficients and drift rates - it is not surprising that such parameters seem to vary depending on the data period being analysed.

If there are small mismatches between the 1989 data and adjacent data periods, a linear baseline splicing function could be used to make the minute data values continuous. To merge the XYZ data to 1990 data, the author suggests that splicing function be applied from days of year 362, 362 and 355 respectively (see Figure 4 and the comments in Appendix D for merging Data Period VII to 1990 data). To merge the XYZ data to 1988 data, the suggested days are 3, 4 and 10, however because of the large differences between the variometer parameters in Appendix D and in Hutchinson's Tables 6 and 7 (1989), it is unlikely that the 1988 and 1989 data merging will be meaningful.

Data Losses

Spurious data losses occurred due to EDAS tape recording problems, remote recording problems in Canberra, PPM misbehaviour and clipping of X, Y and Z channels during magnetic storms. (See "Recording Systems" above.)

Total data loss occurred from
09:01 17th May 1989 to 09:45 21st May 1989 UTC during system modifications
and
13:55 22nd August 1989 to 20:59 24th August 1989 UTC also during system modifications.
This amounts to 6.3 days of complete data loss.

K Indices

Until the end of July 1989, while the PEMs were all ±1000nT variometers, the K indices were scaled from the analogue W&W chart records. From the beginning of August , K indices were derived from the digital data. In effect, the K indices were Range Indices - that is, the index produced was a quantised measure of the total range in field values over each 3 hour period. Precautions were taken to ensure that data spikes did not cause high indices. (All bad data where the 4 components measured, XYZF, were inconsistent, were examined and the offending channels of data nulled. In addition, any number of the highest and lowest field values could be displayed to make sure they were not isolated spikes.) Hence, throughout the year, it was assumed that there was no diurnal variation. This is consistent with the practice adopted by most, but not all, observers at Mawson throughout the 1980s.

Mean hourly value graphs (Crosthwaite, in prep) show that there are characteristic daily variation patterns which persist for days or weeks, although the characteristics of the patterns change, and the magnitude of the variations vary enormously. See Figure 3 for magnetograms on the two quietest days of the year.

The K indices were forwarded monthly with the preliminary monthly reports.

Hutchinson (1989) notes that the K index distribution for 1988 indicated an incorrect choice for the K9 level at Mawson (he too assumed that there was no diurnal variation). The K index distribution varies throughout the solar cycle and it is difficult to deduce a proper K9 level from a single year of data. Figure 1 shows a comparison of the 1988 and 1989 distributions. Figure 2 shows the activity during 1989 as measured by the K index. Table 7 shows the K index distribution for 1988, 1989 and for each month during 1989. At Mawson, the adopted value for K9 is 1500nT.

Preliminary Data Reports

The primary content of the monthly data reports (generally forwarded on the 1st of the following month) was the K indices and mean monthly quiet field values for X Y and Z. The reports contained the following preliminary corrections derived from standard instrument corrections:

December 1988	to February 1989:	X -3.7nT, Y +7.5nT, Z -2.2nT
March 1989	to December 1989:	X -2.3nT, Y +14.5nT, Z -4.5nT

In June 1990, the new preliminary corrections given to Andrew Lewis were:

X +1.5nT, Y +6.8nT, Z -2.2nT.

The preliminary corrections for March 1989 until May 1990 were significantly incorrect, particularly in the Y component, due to the adoption of an unlikely correction for QHM 300.

The December 1988 and January 1989 reports used Rod Hutchinson's reduction software to calculate baselines. Subsequent reports used alternative software developed during 1989. Details are given in Appendix C. The December 1988 report's average field values were derived from scalings of analogue records. Magnetic field data for the 1989 reports until 17th May were derived from digital data recorded at ASC using software developed from Mawson on the ASC network. Average field data from 21st May were derived from locally recorded digital data. The derivation of K index data is described above under "K indices".

The monthly and annual average quiet magnetic fields are given in Table 5. The monthly and annual average fields are given in Table 6. The data in neither of these tables has had instrument corrections applied. Both tables use the variometer parameters given in Appendix D, and therefore have not had instrumental corrections applied. The table of annual means often given in observatory annual reports is omitted from this report as the discontinuity in instrument corrections from year to year may give a misleading impression of magnetic variation.

Surveyed Declination Marks

During 1989, three new marks were installed. **BMR89/1** and **BMR89/2** were installed in the vicinity of the variometer hut over 100 m from pier A. **LEE** was installed on Lee Island, 1561m from the absolute hut. A peep hole was installed to view BMR89/2. BMR89/1 and LEE are visible through the opened door.

Several sunshots were made to ascertain the azimuth of LEE by the author and AUSLIG surveyors, Peter Murphy and Trevor Forgan, and several rounds of angles were made. Table 3 shows the adopted azimuths of the marks with a description of each, and its history. The results of the rounds of angles are implicit in the adopted azimuths, all of which are relative to the adopted value for LEE.

Mark SOH was used throughout the year for all declination observations. Although SOH is apparently Oldham's Mark C (Oldham, 1957), installed at the beginnings of the observatory, its longevity is suspect due to its proximity to the quarry. It is less useful than it once was as the power for its light comes from the now unused Old Variometer Building, and it subtends a significant angle which is perhaps a little large for the higher achievable optical resolutions of modern magnetometers such as the DIM. The author recommended that mark BMR89/2 be used as the standard reference mark post 1989, and that a light drawing its power from the external power supply of the New Variometer Building be installed to illuminate the mark (rather than the light being the mark, as for SOH) for use during winter. Although BMR89/2 was positioned in a drift free area in 1989, it was at times obscured by a low drift between it and the absolute hut - this problem was easily maintained. BMR89/2 has the advantages that it is close to the absolute and variometer buildings, is in a stable location, has a shape suitable for instruments of various optical qualities, it is less than 2° from the horizontal plane through pier A (not quite as good as SOH), and is visible through a small peep hole in the absolute hut wall (sitings through the open door are not appropriate during winter when the temperature differential may exceed 40°C). LEE is an excellent mark for use as a sunshot mark and round of angle reference but is not appropriate as an everyday mark due to its remoteness.

The actual physical mark known as SOH or C has been altered over the years, but the basic pipe is apparently as installed by Oldham. There have been various adoptions for the azimuth of this mark. Oldham indicated the mark azimuth was 274°13.6'. Kirton (1960) reports discarding unsatisfactory results and adopting the results of star observations made by a surveyor in 1958. He does not quote the result, and the 1958 report could not be located. Towson (1968) and Smith (1971) report using 274°14.4' for a post mark, no doubt SOH. Major (1971) reported using 274°14.4', although he measured it as 274°15.0'. Cechet (1984) reports using 274°14.4' for a light he installed on the "pipe" at the same azimuth as the pipe. Crosthwaite (1986) measured and adopted an azimuth of 274°14.8'. Hutchinson (1987) measured azimuths of 274°15.1' and 274°15.2'. Hutchinson (1989) adopted 274°14.8' but reported the results of an AUSLIG surveyor as 274°15.1'. The same surveyor later measured the azimuth of LEE as 357°04.9' and through rounds of angles, the azimuth of SOH would be 274°14.9'. In the 1989/90 summer, both the author and another AUSLIG surveyor measured the azimuth of LEE. There were several irregularities in the results, but it appeared that the best estimate for the azimuth of LEE was 357°05.0', and that the derived azimuth of SOH was 274°15.0'. This azimuth was adopted.

The range of azimuths of 1.6' is rather large. Several observations have been discarded (and not quoted by value) by previous observers presumably because the results did not agree with the adopted value. Oldham reported difficulties associated with horizontal refraction from cold down drafts from the plateau. The author observed serious problems in maintaining a level over the course of an observation on a rock platform in 1989 (although no similar problem on a concrete platform in 1985), perhaps due to the fact that the observing platform surface was subject to thermal distortions (unlike the soil platforms normal in Australia). The same problem was frequently encountered during field work. His solution was to perform a very brief observing schedule to avoid levelling changes. Additional sources of scatter in the results of astronomical observations come from the various almanacs used. The Nautical Almanac only guarantees GHA of the Sun to 0.2', producing an error of about the same order in the derived azimuth. AUSLIG use a software almanac whose method is unknown to the author. Hutchinson used an approximate almanac routine from the Astronomical Almanac, although that reference fails to make fine distinctions in the meaning of parameters quoted on an annual basis and similar parameters quoted on a multidecade basis. The author used an almanac routine from an article in the Australian Surveyor, September 1980, Vol. 30, No. 3 (G.C.Bennett) which was valid for decades and included planetary and lunar perturbation effects. Given that the level of accuracy required in geomagnetism is 0.1', the use of the Nautical Almanac should probably be abandoned for final results, particularly at high latitudes. The use of computer almanacs allows a more accurate and error detecting method to be applied in any case.

Absolute Instrument Performance

Each instrument used is discussed. The standard instruments are compared to the variometer in order to ascertain the variance that can be expected due to irregularities in both. (Note that the variometer parameters have been chosen so that the average difference between the instruments and the variometer is 0). The nonstandard instruments are compared both to the standards and to the variometer. *The comparisons are made without the application of any instrument corrections.* A summary of the comparison results is given in Table 4.

QHM 300 was used to test fibre relaxation in QHMs. The QHM was left in the $+2\pi$ position and monitored for 20 minutes. The circle reading was corrected for temperature and field variations during the test, and the results showed that the circle reading was constant within the expected scatter, casting doubt on the need to comply with the standard 9 minute schedule.

Declinometer 630332

No problems were encountered with the declinometer. No adjustments were made during the year. The readings from the hanging weight were scattered (readings of the erect and inverted weight from August to November were +9.4±3.7 and +6.1±3.2 divisions of the Askania telescope scale) but showed a definite asymmetry. No instruction to adjust the declinometer was received.

The value of the Erect-Inverted magnetic readings for data periods I, III and VII (69, 47 and 55 observations) were 13.6'±0.2', 13.6'±0.2' and 13.7'±0.3'. The scatter in the difference between the expected D from the variometer and the measured D using the declinometer during these same three data periods was 0.2' in each case.

QHM 300

No problems were encountered with the QHM. There were no mishaps to alter its calibration.

The value of α corrected to H=18500nT for periods I, III and VII (45, 47 and 54 observations) were 12.0'±0.3', 11.9'±0.2' and 12.0'±0.3'. The scatter in the difference between the expected H from the variometer and the measured H using the QHM during these same three data periods was 0.9nT, 0.9nT and 1.0nT.

The correction to the 150 QHM D measurements which needs to be applied to make them agree with the declinometer 630332 D measurements throughout the year was -2.4'±0.4'.

QHM 301

No problems were encountered with the QHM. There were no mishaps to alter its calibration.

The value of α corrected to H=18500nT for periods I, III and VII (4, 2 and 4 observations) were -17.7'±0.3', -17.9'±0.0' and -18.0'±0.3'. The corrections to the QHM H measurements which need to be applied to make them agree with the expected H from the variometer during these same three data periods were +5.1±1.8nT, +5.3±0.1nT and +6.3±0.2nT.

The correction to the 10 QHM D measurements which needs to be applied to make them agree with the declinometer 630332 D measurements throughout the year was +0.2'±0.2'. The correction to the 10 QHM H measurements which needs to be applied to make them agree with the QHM 300 H measurements throughout the year was +5.5±1.0nT.

QHM 302

No problems were encountered with the QHM. There were no mishaps to alter its calibration.

The value of α corrected to H=18500nT for periods I, III and VII (5,2 and 4 observations) were -1.0'±0.4', -1.0'±0.3' and -1.0'±0.6'. The corrections to the QHM H measurements which need to be applied to make them agree with the expected H from the variometer during these same three data periods were -0.2±1.7nT, 0.0±1.2nT and -0.2±1.4nT.

The correction to the 11 QHM D measurements which needs to be applied to make them agree with the declinometer 630332 D measurements throughout the year was -0.5'±0.3'. The correction to the 11 QHM H measurements which needs to be applied to make them agree with the QHM 300 H measurements throughout the year was -0.3±1.6nT.

Declinometer Inclination Magnetometer 213/Theodolite 311542

The DIM was not used until June. The only point to mention about its use is the need to use the screw mount from the DIM tripod to firmly attach the DIM to the pier to reduce the movement of the tribrach in the pier grooves. It proved to be an excellent instrument for use in the observatory, and with a longer more flexible sensor cable and better solder connections in the sensor, would have been equally as good and reliable in the field (at temperatures of -20°C and above, without the use of shelters or heaters). No adjustments were made throughout the year (to the sensor alignment, for example); the instrument was in good adjustment (the magnetic axis was within 5' of the optical axis) and remained stable in observatory and field use. Appendix E lists variometer parameters for data periods III and VII derived using only DIM and PPM observations for comparison with Appendix D which lists the variometer parameters derived using QHM, Declinometer and PPM observations.

The corrections to the DIM measurements which need to be applied to make them agree with the expected D and I from the variometer during data period III (28 observations) are -1.0'±0.3' and -0.1'±0.1'. For data period VII (23 observations), these corrections are -1.0'±0.2' and 0.0'±0.1'.

The corrections to the DIM measurements which need to be applied to make them agree with the measured values of D and I using the standard instruments during data period III (28 observations) are -1.0'±0.4' and -0.0'±0.1'. For data period VII (23 observations), these corrections are -1.1'±0.3' and 0.0'±0.1'.

PPM 199

No problems were encountered with the PPM. The PPM was used in the bolts UP mode for standard observations. The manufacturers suggest the bolts DOWN mode. The scatter in the difference between the expected F from the variometer and the measured F using the PPM during data periods I, III and VII (44, 48 and 54 observations) was 1.2nT, 1.3nT and 1.0nT.

PPM 206

No problems were encountered with the PPM in either the observatory or the field. The only point of interest is that the PPM used three sets of batteries over four weeks operating in the field under cold conditions. The PPM was used in the bolts UP mode for the Kemp Land field work, and the bolts DOWN mode for the Prince Charles Mountains field work.

The correction to the PPM/UP mode measurements which needs to be applied to make them agree with the expected F from the variometer during data period VII (6 observations) is -0.6±0.5nT. For the DOWN mode, (8 observations), the correction is -0.0±0.4nT.

The correction to the PPM/UP measurements which need to be applied to make them agree with the measured values of F using the standard instruments during data period VII (6 observations) is -0.4±0.3nT. For the DOWN mode (5 observations), the correction is -0.3±0.4nT.

Instrument Comparisons

The author made comparisons between the travelling standard instruments and the Mawson standards in December 1988 and January 1989. The travelling standards were:

QHM 172, Thermometer 619, Askania Glass Circle 611665 for **H**
HTM 704, Thermometer (704), Askania Glass Circle 611665 for **H**
Declinometer 640505, Askania Metal Circle 508813 for **D**
PPM Elsec 770/188 (used in the Bolts Up orientation) for **F**

The QHM and thermometer constants used are listed in Table 2. In all, 6 observations each of declinometers 640505 and 630332 on the 9th January 1989 were used, and 6 observations each of QHM 300 and HTM 704, and 5 of QHM 172 on the 30th December 1988 and 2nd January 1989. QHM and Declinometer observations were corrected through baselines using the PEM and EDAS system. Numerous PPM comparisons were made on the 26th, 27th and 29th December 1988. PPM observations were corrected by noting simultaneous readings by hand from the variometer PPM. PPM 199 was compared in the BOLTS DOWN mode (as it was used in 1988) and in the BOLTS UP mode (as it was used in 1989).

The comparison results, along with the comparisons of the local instruments accumulated throughout 1989, are listed in Table 4. It should be noted that the D comparisons quoted by Crosthwaite (1986) are for declination West, and use the opposite sign convention to the normal declination East as used in this and most other reports.

UAP Magnet Calibration

The Upper Atmospheric Physicists requested calibration of a bar magnet (used in micropulsation calibrations) on 11th November 1989. Magnets 31 and 32 were measured.

The procedure for using a BMZ is outlined in BMR instructions. The author has used a QHM for calibration of BMR orientation magnets in the past. On this occasion it was decided to use a DIM for the calibration using the following technique:

The DIM was located on Pier A with the optical axis horizontal in a magnetic East West alignment (to make sure the fluxgate was not saturated) and the magnet was placed on a tripod in a holder about 1.6m away. The theodolite was used to align the magnet holder with the DIM optical axis (and by measuring the displacement of the optical and magnetic axes, at the same height as the fluxgate sensor). The magnet was then placed in the magnet holder and reversed several times. Assuming that the scale reading on the DIM is accurate, then the magnetic field of the magnet can be directly read from the DIM. The reversals remove any offset effects from small misalignment from east-west. The procedure is so quick that in a reasonable field there is no need to account for natural field variations in the calculations (a pair of readings takes only 10 seconds). Using the formula $H = 2M\cos\theta / r^3$, the measured values of M(31) and M(32) were 672.5 and 726.7nT.m^3. Later, when the DIM was aligned with a magnetic field of 49.7μT and set to the μT range, the DIM measured 51.2μT. If the same scale value applied uniformly to all fields on both the μT and nT ranges, then the measured values supplied to UAP should be derated by 2.9%. (Aside: the measurement of F using the DIM is a quick way to find the initial setting for a PPM when measuring F accurately in a previously unexplored area where F is unknown.)

Davis Geomagnetic Installation Inspection

The Davis geomagnetic monitoring equipment was examined and comparisons were performed on 1st and 2nd March 1990. The UAP physicist Mike Hesse assisted in familiarisation and simultaneous comparisons of the F absolute instrument and the travelling standard.

The Absolute Hut and the variometer sensors are both in the vicinity of the UAP building and the helipads. The variometer sensors are protected from traffic at each corner by a galvanised metal pipe. F pier differences at opposite corners of the Absolute Hut were of the order of 45nT. The field gradients in the hut seem rather large. There is a possibility of magnetic interference in the absolute hut and to a greater extent at the variometer sensor site.

Absolute Instruments

The primary instruments used for variometer calibrations at Davis were:

QHM 494, Thermometer 2385, QHM Circle 73 for **H** and **D**
PPM Elsec 770/194 (used in the Bolts Down orientation) for **F**

The following travelling comparison instruments were used:

QHM 174, Thermometer N151, QHM Circle 14 for **H** and **D**
PPM Geometrics G816/1025 for **F**

F comparisons were performed by simultaneous observations using temporary piers in opposite corners of the absolute hut (a wooden tripod and the DIM tripod). The Elsec PPM gave erratic results for a while before settling down.

It was intended to compare QHM 494 for H and D to PPM G816/1025 and DIM Elsec810/206 with Theodolite 312714. However it was not possible to fit the theodolite legs into the pier grooves, and it was not possible to firmly attach the DIM to the pier top due to the thickness of the pier and the lack of a suitable screw attachment as was used at Mawson on a thinner pier top. Also, the QHM circle would not fit onto the DIM tripod and so not even an auxiliary pier could be established for the comparisons. A further attempt to use the DIM simply resting on the pier top was abandoned when it was discovered that the DIM was malfunctioning. The only other instruments accessible were the ex-89/90 Lambert Glacier Traverse field instruments - a QHM and QHM circle.

The F comparisons were acceptable, with G816/1025 - Elsec770/194 = -1.9 ± 1.3nT (PPMs used in the BOLTS DOWN mode).

The QHM comparisons were unusable without the use of variometer data due to the normal high level of field activity: D varied by 40' and H by 200nT during the comparisons. The Antarctic Division provided variometer data for the duration of the comparisons and preliminary variometer parameters. Using this data, the two variometer corrected QHM 174 measurements differed by 0.8nT in H, 2.0' in D and 1.4' in α (H differed by 50nT, D by 19' between the observations); the two variometer corrected QHM 494 measurements differed by 3.0nT in H, 3.1' in D and 0.0' in α (H differed by 110nT, D by 20' between the observations).

The instrument constants used are listed in Table 2.

The comparison results are listed in Table 4.

The variometer data was interpreted using the formulae:

$$X = +3702 - 0.52826.(x - 0)$$
$$Y = -16006 + 0.46756.(y - 8)$$
$$Z = -52160 + 0.47094.(z + 2)$$

Seismological activity was continuously monitored by two independent systems. One was a short and long period vertical locally recorded visual system. The other was a three component wide band digital system whose data was telemetered in real time via ANARESAT to the Australian Seismological Centre in Canberra. Scaled data from the visual system was reported approximately weekly via the Global Telecommunication System. The telemetered data was processed in Canberra.

Access to the ASC Unix network via a terminal line allowed examination of quick epicentre determination files etc., and interrogation of the Mawson data files to ensure the data pathway between Mawson and Canberra was operational.

Visually Locally Recorded System

The sensors for this system were a Benioff short period vertical seismometer and a Press Ewing long period vertical seismometer. The seismometer details for this system are listed in Table 8. The seismometer signals are preamplified by TAM5 units and transmitted over a long shielded 10 twisted pair cable to the Science Building to Teledyne AR320 amplifiers and recorded on two separate helicorders, each record containing 24 hours of data.

Several noise problems were observed on the records, primarily due to radio interference (and frequently directly connected with particular radio skeds), particularly in summer during ship and helicopter operations. These same problems have been reported for some years, and the solution would be either to shift the recorders to the Cosray Building closer to the sensors, or to remove the analogue seismometers and use the digital data (either directly or rerecorded in analogue form) from the wide band system.

The helicorders provided problems at virtually every record change, and at other times, for some time after changeover before several problems (mostly with the clutch and pen drive mechanisms) were either rectified (after many attempts) or simply accepted as part of the individual nature of the instrumentation that makes seismology such a soul building and rewarding enterprise.

Apart from power supply alterations mentioned below, no changes were made to the system. The only adjustments required were occasional corrections to the LPZ mass position.

Calibrations

The SPZ seismometer was calibrated on 27th July 1989. The calibration results are listed in Table 9 and depicted in Figure 6. The LPZ seismometer was calibrated on 30th July 1989. The calibration results are listed in Table 10 and depicted in Figure 7. The LPZ calibration assumes a value of 370mm from the pivot to the centre of mass of the mass boom system. The actual value of this distance is unknown.

Masses for the weight lift tests were made from thin copper wire and aluminium foil and were weighed on the balances in the surgery. They were found to be much easier to use than the certified masses as there was no need to tie cotton to the masses - they could instead be hooked off with light cotton. The 6db steps on the preamplifier gains and attenuations, and the recorder attenuations were tested and shown to indeed produce factors of 2 change in the traces within the limitations of measurement (verifying the more rigourous measurements by Cechet (1984) and Crosthwaite (1986)).

Wide Band Telemetered System

The sensors for this system are three (north, east and vertical) Guralp wide band seismometers. The data is not accessible locally. Hutchinson (1989) noted that the previously installed short period Benioff seismometers were installed 30° west of the correct azimuths, and that the North-South reference line in the vault was correct. If the wide band system is aligned according to the same reference line, then this statement may need checking. The original NS reference line installed by Kelsey and Crosthwaite in 1985 was aligned relative to the Cosmic Ray telescope rails - their alignment was quoted as 240° and 270° by different sources. The horizontal seismometers were installed according to one source of information, and then reinstalled according to an apparently more reliable source at a 30° rotation. It is possible therefore that the NS line and/or Hutchinson's verification of the line are incorrect. This may have implications for the interpretation of the wide band data.

The only input by the author to the day to day running of the wide band system was to make sure it was operational, restart it if not, track down telecommunication problems if possible, maintain an accurate time reference and fix any hardware problems that arose.

The telecommunication problems usually led to hangups on the data line. There is a complicated line of equipment between Mawson and Canberra including modems, multiplexors, satellites and earth stations. Many of the pieces of equipment are subject to control locally and remotely. On at least occasion it was almost certain that a problem was due to a Mawson data line being modified by mistake rather than a data line from another Antarctic station. Mostly, though, the problems could not be explained. The only hardware problem was the failure of wiring connections in the equipment rack.

Early in the year, new memory and disc drive controller boards and a hard disc drive were installed in the PDP computer so that it could be used as a normal system to implement system changes and be accessible from Canberra for interrogation and modification. The modifications failed and the drive was returned to Canberra, although the new boards were left installed.

Calibrations

On 7th July 1989 calibration currents were injected into the seismometers to contribute to an intercontinental system calibration exercise. The results were processed from the telemetered data in Canberra.

Control Equipment

Power Supplies

Several changes were made to the power supplies to comply with suggestions made by a BMR technical officer who visited the observatory the previous summer.

Science Building

All of the trickle charged lead acid batteries and related inverters were removed. An Invertech low power rating 50Hz UPS model UPS-100-FF-P was installed to drive the helicorders and one clock, a Precision Power Standby Power System model SPS1000 was installed to supply all other essential equipment and a 24V DC dry cell battery pack was installed to backup the primary clock. An earth leakage protected distribution board was installed to power several pieces of equipment. The installation of the equipment increased the safety and tidiness of the observatory considerably. The power backup system was tested for 30 to 45 minutes each month to cycle the batteries - the helicorder inverter had the habit of stopping about 15 minutes after cycling if the period of cycling was too long.

Power Supply	Equipment
Invertech UPS	2 Helicorders
	1 GED Clock (Backup unit)
SPS/1000+Earth Leakage Protection	AR320 seismic amplifiers
	Modem to ANARESAT
	9V DC adaptor for RS232/485 converter
	RS232 splitter box
	W+W chart recorder
	1 GED Clock (Primary unit) - also uses 24V DC backup
12V output from GED clock	Time Mark Relay Driver
	Time Mark TX for Geomag Timing
Mains Supply	Terminal and modem connection to ANARESAT

New Variometer Building

The trickle charged sealed battery backup for the variometer was removed, and an SPS1000 backup power supply was installed to power all essential equipment (in fact, everything excluding the lights, heating and video screen). The power backup system was tested for about 45 minutes each month, and appeared to have a capacity exceeding one hour. The SPS1000 appeared to cause stresses on the electronics - this stress appeared to reduce when the load became more resistive and less reactive. The SPS1000 output (during backup phase) is very nonsinusoidal - it cannot, for example, light a fluorescent tube.

Power Supply	Equipment
SPS/1000	NEC acquisition computer
	PEM Control Unit
	9V DC adaptor for RS232/485 converter
	Doric
	Statronics 53/3B PPM power supply
	Statronics 53/3B power supply for Fiducial Latch, Time Mark Receiver Latch and analogue buffers
Mains Supply	Computer Display

Cosray Building

No changes were made to the Cosray power supplies. A BMR standby power supply feeds the PDP computer rack, and a low voltage DC supply, courtesy of the Cosmic Ray Observatory, feeds the equipment in the vault.

Timing

The primary time reference for all seismological and geomagnetic monitoring was distributed from the Science Building. Occasionally, the same time signal was distributed over the phone lines to the Upper Atmospheric Physics laboratory to maintain a time reference during UAP equipment maintenance. *The time reference requires an adjustment of -90ms prior to 19:18 UTC 1st January 1989* for an unknown period (see below). After that time, the clock was maintained to within the 50ms tolerance required by seismic monitoring.

Initially the system as described by Hutchinson (1989) was employed. The time was maintained by one primary and one secondary GED crystal oven clock. After the resupply in February 1989, each clock was powered by a separate inverter and the primary clock was also supplied with a 24V dry cell battery supply. The one second pulse from one clock was fed into the other and the inbuilt clock comparators enabled the relative drift rates of the clocks to be monitored and the actual adjustment of the clocks during time checks to be measured. This also enabled sudden and dramatic changes in performance of either clock to be quickly detected.

A portable Sony ICF2001D radio receiver was installed to receive time signals. This receiver proved inferior to the Collins radio belonging to the Antarctic Division that was already in use and the latter was used throughout the year. A makeshift aerial was repaired frequently during the year and proved to be inadequate, but with uncertainty about the future intentions regarding the timing equipment at the observatory, no long term solution was made. Instead, during poor radio conditions the local radio operators broadcast the WWV and WWV-H over the local FM station. (Mawson is in a notoriously bad location for radio reception. The Sony receiver proved to be extremely useful and essential during field work away from Mawson using a simple long wire aerial.)

The clock and radio pips were compared using a CRO to display the radio signal. Initially, the timing monitoring settings were used as found - the CRO was triggered by the clock and the clock was adjusted so that the time pip arrived at the appropriate propagation delay time. It was discovered however that the CRO was being triggered on the trailing edge of the clock pulse, and hence the clock was being adjusted relative to a reference which was 90ms fast. From 19:18 on the 1st January 1989 UTC, the entire "second" pulse from the clock and the radio pips were simultaneously displayed (using a delayed trigger circuit (Crosthwaite, 1986)) and the timing error was corrected.

The various time marks to the PDP seismic computer in Cosray, the variometer PC in the New Variometer Building, the W&W chart recorder and the helicorders were distributed through a relay driver box (Crosthwaite, 1986). The only modification made to this box was to convert the old LaCour output to a 1 minute output for the new PC variometer system, and to install a 10K resistor and 0.12mF capacitor across the signal pair transmitting the time signal (the box was designed as a relay driver and thus to operate a low resistance device, not a high impedance electronic switch). A line driver was installed to carry the signal to a receiver which worked in cooperation with the variometer PC system. There was no line driver used on the long line to the PDP seismic system in Cosray.

The only useful radio time services during the year were WWV and WWV-H.

Geophysical Buildings Report

The real estate belonging to the geophysical observatories consists of a share in the Science Building, known as Wombat, the New Variometer Building, the Absolute Hut, a small share in the Cosmic Ray Observatory building (Cosray) along with one side of the underground vault. Buildings which were in use for seismology and geomagnetism but which are of little use any longer and have not been reassigned for other purposes are the Old Seismic Vault and the Old Variometer Building.

A large amount of damaged and superseded cables have accumulated about the observatory both within and between buildings over the years. Several boxes of such BMR and IPS cables, switches and relays were removed.

The Science Building is in good shape and needs little work other than a superficial beautifying treatment. The work room and instrument room provide ample work space for the operation of the observatory.

The New Variometer Building is a well constructed, stable and thermally efficient structure which provides a comfortable working environment. However certain deficiencies should be pointed out which may be of value in the design of similar buildings in the future:

1. Although a great effort was made to produce a structurally nonmagnetic building, magnetic material was introduced in the electrical switchboard apparatus and the fire extinguishers. Both of these magnetic items were centrally located in the building so that it was not possible to choose a "most distant" point for the magnetic sensors. The fire extinguishers in fact could not have been any closer to the X and F sensors without being in the same room.

2. The wiring paths within the building were suitable for power supplies, but there was no provision for the installation of data cables. (The wiring of the observatory was criticised in a technical report carried out in the 87/88 summer season. Part of the criticisms involved the mixing of power and low voltage and signal cabling.)

3. The only provision for entry of cables into the building was through an unnecessarily difficult long doglegged path under the building which in the end emerged at an external wall. This cable path made it difficult to install cables and had the serious problem that the entrances to the conduits were located in a seasonal pond created by the damming effect of the stairs. Water from the pond flowed into the conduit (whose gradient draws water into the conduit making it impossible to drain) in summer and froze, making it very difficult to rearrange any wiring. (The successful solution to this icing problem was suggested by the ACS electrician - lengths of heat trace were inserted into the conduit from both ends, and over the period of one to two weeks were pushed further into the conduit as they melted the ends of the ice cylinder until the entire contents of the conduit were melted and the cables could be moved.) This problem could have been avoided if only a simple, short and obvious cable entry had been provided.

The building has no bliz line, no fire alarm, no phone and no windows to monitor the weather during long periods of installation work and so care must be taken not to be caught in bad weather. A supply of food and water in the hut would be a good idea.

The Absolute Hut is a very old structure and adequate for the humble use that is made of it. It seems that there is some question over the future of the building in the minds of observers, given the direction of the Antarctic rebuilding program, and hence some reluctance to put a big effort into maintenance. One of the peep hole covers remained in poor repair for some years and allowed snow to thaw and freeze in the walls of the building causing some damage - this was replaced during the year. Drift frequently enters the building and melts/refreezes causing damage. The building requires painting again. A third peep hole with internal and external covers to view a new mark was installed in the north east wall. A minor problem is the stability of the absolute pier A, which moves in response to wind gusts and vibrates in high winds. A clear statement of the future of the building should be made so that the appropriate vigour can be put into maintenance.

BMR is a minor tenant in the Cosray building which is inspected and maintained by others, and is fortunate to have access to some low voltage power supplies in the building.

The Old Variometer Building is used as a store and still has power junctions for the Absolute Hut and SOH azimuth marker light. It still contains some materials (e.g. pier tops) which may be of use in future installations. The power supplies should be rationalised, and this building, which dates back to Heard Island and the first years of Mawson, should be declared historical and put to other use or removed.

The Old Seismic Vault is of no use to BMR and has more or less been handed over for other purposes.

References

Almond, R.,1975	Mawson Geophysical Observatory Annual Report, 1973. BMR Record 1975/140
Black, I.E., 1965	Mawson Geophysical Observatory Annual Report, 1963. BMR Record 1965/185
Cechet, R.P., 1984	Mawson Geophysical Observatory Annual Report, 1983. BMR Record 1984/36
Crosthwaite, P., 1986	Mawson Geophysical Observatory Annual Report, 1984. BMR Record 1986/12
Crosthwaite, P., in prep	Mawson Geomagnetic Observatory Magnetic Results, 1989. BMR Record.
Crosthwaite, P., in prep	Third Order Regional Magnetic Survey in Kemp Land and Prince Charles Mountains, 1989/1990. BMR Record.
Dent, V., 1971	Mawson Geophysical Observatory Annual Report, 1967. BMR Record 1971/9
Hill, P.J., 1978	Mawson Geophysical Observatory Annual Report, 1975. BMR Record 1978/59
Hutchinson, R., 1987	Mawson Geophysical Observatory Annual Report, 1986. BMR Record 1987/46
Hutchinson, R., 1989	Mawson Geophysical Observatory Annual Report, 1988. BMR Record 1989/25
Kelsey, P.J., 1987	Mawson Geophysical Observatory Annual Report, 1985. BMR Record 1987/29
Kirton, M., 1960	Mawson Geophysical Observatory Annual Report, 1959. BMR Record 1960/115
Lewis, A.M., 1991	Mawson Geophysical Observatory Annual Report, 1990. BMR Record 1991/59
Major, J.A., 1971	Mawson Geophysical Observatory Annual Report, 1969. BMR Record 1971/92
Maplestone, B. 1990	Macquarie Island Geomagnetic Installation Schematics, 21-2-90.
Merrick, R.W., 1961	Mawson Geophysical Observatory Annual Report, 1960. BMR Record 1961/118
Oldham, W.H., 1957	Mawson Geophysical Observatory Annual Report, 1955/56. BMR Record 1957/79
Petrovic, J.J., 1973	Mawson Geophysical Observatory Annual Report, 1971. BMR Record 1973/149
Pinn, J.D., 1961	Mawson Geophysical Observatory Annual Report, 1957. BMR Record 1961/27
Robertson, M.J.M., 1972	Mawson Geophysical Observatory Annual Report, 1970. BMR Record 1972/44
Silberstein, R.P., 1984	Mawson Geophysical Observatory Annual Report, 1982. BMR Record 1984/35
Smith, R.S., 1971	Mawson Geophysical Observatory Annual Report, 1968. BMR Record 1971/10
Towson, P., 1968	Mawson Geophysical Observatory Annual Report, 1966. BMR Record 1968/113

Other Duties

Each member of the station community is required to perform his/her share in the day to day running of the station. This involves kitchen hand duties, cooking, night watch and Saturday afternoon council duties on a regular basis, ad hoc assistance during the summer activities and resupply, and assistance with other station tasks such as drumline maintenance. Assistance in calibration and surveying was provided to the physicists. Field assistance during the testing of satellite navigation equipment was provided to the 1989/90 Lambert Glacier Basin Traverse party. The author was joint sea ice observer with Dave Grant.

In addition the author had the extreme pleasure of being "dogman". This was a time consuming and sometimes tiring position which nevertheless provided the most fulfilling experiences during the year.

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The author wishes to express his thanks to all fellow expeditioners (the 1989 wintering party, and also the 1988/89 and 1989/90 wintering and summering parties) for their assistance, cooperation and friendship during his 15 month residence on the continent. Every member of the station community made a significant contribution to the preparation and execution of the field work in Kemp Land and the Prince Charles Mountains, and contributed substantially to the operation of the observatory.

Assistance from Murray Hotchin, Mike Dymond, Dave Grant and Diana Patterson allowed the author to enjoy several short field trips during the year and kept the observatories operational during extended absence for field work. Graeme Small provided assistance beyond the call of duty in establishing and maintaining the telemetry links to the benefit of all of BMR's projects at Mawson.

The author also wishes to express his sincere gratitude to the Antarctic Division for the provision and support of the few dozen or so huskies and sledging equipment which provided the ability to enjoy the earth's greatest wilderness in intimacy. Particular thanks also to the huskies themselves for the unrewarded effort they gave during the Kemp Land field work, for the pleasure they provided throughout the year and for the wonderful memories.

Appendix A History of Instrumentation 1955 - 1989

A brief history of equipment changes at the Mawson Geophysical Observatory.

Date	Geomagnetic Observatory
May 1955	Absolute instruments used for regular observations of H,D and Z (Oldham, 1957)
July 1955	Continuous recording commenced by a three component Normal La Cour Magnetograph (Oldham, 1957)
1957	Bar-fluxmeter Magnetograph installed (Pinn, 1961)
January 1961	Three component Insensitive La Cour Magnetograph installed and recording commenced (Merrick, 1961)
December 1967	Bar-fluxmeter Magnetograph withdrawn (Dent, 1971)
September 1968	Insensitive La Cour Magnetograph converted to medium sensitivity and renamed Normal Magnetograph (Smith, 1971)
February 1975	15 mm/hr normal recorder replaced by 20 mm/hr recorder (Hill,1978)
December 1975	15mm/hr sensitive recorder replaced by 20mm/hr recorder (Hill,1978)
March 1981	MNS2 proton precession magnetometer installed for absolute measurements
August 1982	Sensitive recorder removed (Silberstein, 1984)
July 1983	Photo-electric magnetometer (PEM) X and Y components installed (Cechet, 1984)
July 1983	MNS2 proton precession magnetometer ceased operation (Cechet, 1984)
May 1984	Digital recording of PEM X and Y component data commenced (Crosthwaite, 1986)
December 1985	La Cour Normal Magnetograph ceased operation. X, Y and Z PEMs commenced operation (Kelsey, 1987)
March 1986	X, Y and Z PEMs temperature compensated to less than 1nT/°C (Hutchinson, 1987)
January 1988	DIM magnetometer introduced for testing as an absolute and field survey instrument (Hutchinson, 1989)
February 1988	MNS2 proton precession magnetometer replaced with Elsec 820 in variometer hut to continuously record F (Hutchinson,1989)
January 1989	Independent recording of geomagnetic data in Australia via ANARESAT commenced (this report)
May 1989	Local recording of all variometer data on a personal computer commenced (this report)
August 1989	X and Y PEMs converted to ±2000nT range (this report)

	Seismological Observatory
July 1956	Three component Leet Blumberg seismograph (Pen and Ink recorder) installed
1960	Three component seismograph installed consisting of Benioff seismometers (free period 1.0s) and three channel BMR single drum recorder. Z galvanometer 0.2s free period, horizontal galvanometers free period 70s (Merrick, 1961)
February 1963	BMR recorder replaced by Benioff 60 mm/min three channel recorder. 14s free period galvanometers installed (Black, 1965)
September 1970	14s free period horizontal galvanometers replaced by short period (0.2s) galvanometers (Robertson, 1972)
December 1973	Z seismometer transferred to Cosray vault (Almond, 1975)
April 1977	Transfer of Geophysics office, including power and timing to Wombat (Science Block)
1978	Recording of SP-N Benioff seismometer discontinued (Petrovic, 1973)
July 1981	Helicorder hot pen recorder installed for SP-Z and LP-Z, and SP-N Benioff restored
March 1983	Cosray vault fully concreted in readiness for movement of SP-N and SP-E. Thermostatically controlled heating installed to stabilise LPZ (Cechet, 1984)
August 1983	Four Teledyne Geotech seismic amplifiers (AR320) installed for connection to two twin hot pen recorders (Cechet,1984)
May 1984	Horizontal seismometers and the Benioff photographic recorder disconnected (Crosthwaite, 1986)
February 1985	Horizontal seismometers connected to visual hot pen recorders after reinstallation in Cosray vault and conversion of recorders to dual channel (Crosthwaite, 1986 & Kelsey, 1987)
February 1986	SPZ Rectilinear Pen Helicorder installed. Two Pen Helicorder for SP horizontals (Hutchinson, 1987)
January 1988	Guralp wide band seismic system installed in Cosray vault (Hutchinson, 1989)
January 1988	Short period horizontal seismometers removed from Cosray Vault (Hutchinson, 1989)

Appendix B Summary of Geophysical Log (23 December 1988 - 2 January 1990)

Date/Time (UTC)	GENERAL LOG
1988	
22 December	Peter Crosthwaite flew into Mawson from the Lady Franklin.
23 December	Rodney Hutchinson departed Mawson. Peter Crosthwaite assumed responsibility for the geophysical observatories.
1989	
1 January, 19:18	Method of correcting clock using radio pips corrected.
8 January	Terminal connection to ASC Unix system established.
14-18 February	IceBird Voyage 6 delivered major resupply.
20 February	Replaced the Lead Acid based inverter system in Wombat with new sealed gel cell Invertech 50Hz UPS and SPS 1000 backup power supply. Also installed an Earth Leakage Protection distribution board.
2 March	Changed AR320 power supply from DC to AC completing the phasing out of the Lead Acid/trickle charge power supply system.
25 March	IceBird departed Mawson after final voyage of 88/89 season.
26 September	Mandy becomes first Mawson husky to communicate via ANARESAT terminal link (Unix "mail" facility) from Wombat to BMR.
6 October	Departed Mawson for Kemp Land field work.
1 November	Returned to Mawson from Kemp Land field work.
17 November	Flyoff; first voyage of 89/90 season.
1990	
2 January	Andrew Lewis flew in to Mawson from the IceBird.
3 January	Andrew Lewis assumed responsibility for the geophysical observatories.
11 January	Peter Crosthwaite departed Mawson for Prince Charles Mountains survey.
16 February	Peter Crosthwaite returned to Mawson from Prince Charles Mountains.
26 February	Peter Crosthwaite boarded the IceBird for RTA via Davis.
1 March	Arrived at Davis for comparisons etc.
2 March	Departed Davis.
13 March	Arrived in Hobart.

	GEOMAGNETISM LOG
1989	
4 January	Installed a 6 conductor cable between Absolute and Variometer Buildings.
10 January	Recording of telemetered geomagnetic data on the ASC computers via and independent data line commenced.
20 January	Installed a fiducial button in the Absolute Hut, and removed the old fiducial circuitry connected to the Old Variometer Hut (light bulb, switch, terminal block etc.). The new equipment was tested and was much less magnetic than both the old equipment and the "magnetic (QHM observation) cork".
31 January	Installed azimuth marks BMR 89/1, 89/2 and LEE.
3 April	Commenced abbreviated absolute observation routine (a single F D and H observation in random order rather than a symmetrical FDHDF observation routine in fixed order).
11 May	Vehicle near variometer building
12 May 08:31-08:33	Replaced X PEM cable with new cable
12 May 15:45	Replaced new cable with old cable again. Also had to drill holes in the variometer building walls and move around the equipment rack a little to provide a new cable route to the electronics room.
17 May 11:30-11:45	Vehicle near variometer building to transport computer, screen and SPS1000 power supply to the electronics room.
17 May 09:00	Started shifting equipment around to install modified ±2000nT PEM boards and new acquisition system (NEC PC+MAGACQ). **END OF EDAS SYSTEM and DATA.**
21 May 09:46	The old ±1000nT boards were returned to the PEMs after failing to get the ±2000nT boards working. However, all new cabling and the NEC PC system (without external time pip reception) were installed. **START OF PC SYSTEM and DATA.**
3 August	Replaced the SOH azimuth globe.
10 August	Checked the Z PEM lid.
15 August	Installed new peep hole and peep hole covers in the Absolute Hut.
21 August	Repaired SOH azimuth globe.

22 August 04:30-06:00	Ladder in the variometer hut (and tools left in the hut furthermost from the sensors).
22 August 13:54	End of PEM ±1000nT system. Commenced installing ±2000nT boards.
23 August	Replaced Z PEM lid with a brass lid to increase thermal connectivity to room air mass.
24 August 21:00	Finished ±2000nT modifications for X and Y PEMs and system operational again.
26 August 11:22:30	Modified X and Y PEM temperature coefficients.
28 August 11:16:30	Modified X and Y PEM temperature coefficients.
29 August 14:30:30	Modified X and Y PEM temperature coefficients.
31 August 06:00:44	Switched to new MAGACQ program with modified ENQ remote command, 300 baud RS232 for the PPM, filtering of PPM data to reject bad values, checking for out of range analogue data, filtering analogue data to reject noise, and individual control over analogue channel scale values on the graphic display.
1 September	Time mark pulses from the seismic clock used to correct the MAGACQ system.
2 September	Replaced the covers on the X and Y PEMs, and removed some junk from the Variometer Hut.
8 September 10:39:40	Switched to new MAGACQ program with tighter F and time mark checking.
21 September 15:32:39	Switched to new MAGACQ program with correction to null value corrections to out of range analogue data.
5 November	Replaced the SOH azimuth globe.
11 November	Calibrated the UAP micropulsation calibration magnets.
29 November	Checked out the PCM survey tent for magnetism - ok except for the pegs.

SEISMIC LOG

1989	
19 February	Installed extra memory and hard disc drive in the seismic PDP computer to upgrade the system to a disc based system; the upgrade failed as the computer could not *boot* from disc.
7 July	Guralp Wide Band system calibrations performed in consultation with ASC.
27 July	SPZ seismometer calibrations performed.
30 July	LPZ seismometer calibrations performed.
5 November	Arthur Wilkinson reported feeling the San Francisco earthquake in the Met office.
30 November	Wide Band Z component failed; repairs made to wiring connections.

Appendix C - Acquisition and Processing Software

A Personal Computer based acquisition system developed in 1988 prior to departure for Mawson by the author was installed at Macquarie Island by Stewart Dennis in October 1988 and by the author at Mawson in May 1989. The system was based on a prototype developed by Kevin Seers built around a Data Translation DT2805/5716A analogue to digital conversion board with a GW Basic controlling and recording program.

In addition to the acquisition computer, an identical backup computer was sent to both Macquarie Island and Mawson observatories. A substantial amount of software for data quality control and data processing and analysis was developed during 1989 on the spare PC. Other processing software was developed on the ASC Unix network, but as that software fell into disuse following the installation of the PC acquisition system, it will not be described in this report.

This appendix is not a detailed description of the software. It is only intended to inform the reader of the scope of the software and to provide a basis for the development of specifications for a part of a set of software applicable to all BMR geomagnetic observatories and field surveys.

The Acquisition Program - MAGACQ

Prior to the deployment of the PC, the Mawson and Macquarie systems consisted of a three component PEM magnetometer (which can be considered a passive three component voltage output device), a Doric temperature device (which can be considered a passive single component voltage output device), an Elsec 820 PPM (which can be considered as either a passive single component voltage output device or a triggered digital device communicating through an RS232 data line), and an EDAS data logger which digitised the analogue voltages from the 5 data channels and recorded the information on audio sized magnetic cassettes. The EDAS logger had an RS232 output enabling any recorded data to be telemetered to a remote site for logging. This output was sent to a printer as the only form of local access to the digital data for producing digital baselines. In January 1989, it was also sent via ANARESAT to the Australian Seismic Centre for remote recording and a terminal connection allowed remote access from Mawson to the ASC digital data.

Kevin Seers developed a GW Basic program to record the data using the PC and DT2805 board - this program acquired the data according to a fixed time schedule and made the data unavailable until the program was halted and control was returned to the operating system.

It was highly desirable to develop a more flexible acquisition program with the added requirements:

1. It should utilise an external clock for its timing.
2. It should be able to record fiducial information to synchronise absolute measurements.
3. It should be able to record data at a rate comparable to the frequency response of the sensors (about 6 seconds for a PPM, and 10 to 20 seconds for a PEM).
4. It should be able to telemeter data, initially in real time, but eventually on request from a remote recording device (at Canberra head office). Furthermore, the remote device should be able to control to some extent the functioning of the system.
5. It should be able to deal with external device failure (such as the PPM not responding or not being present, lost or erratic timing pulses, etc).
6. It should provide feedback to the operator to guarantee that any malfunction is detectable.
7. It should give a graphical view of the current status of the magnetic field to aid the operator in calibrations.
8. It must be possible to adjust the system (set the clock, free file space, control the telemetry system, control the recording of fiducial information, etc.) and extract data without halting the system and with minimum impact on the data acquisition.
9. The program should be designed so that any non time critical routine processing code can be modified without the possibility of interfering with time critical data acquisition code.

The time frame for developing the system was restricted by the need to have it ready for Macquarie Island early in the season. At the time, the author had no experience with PCs or with the Basic language. Consequently, many of the objectives could not be achieved in the first version, although the system was designed so that solutions to all the objectives could be implemented without major redesign. The developed system had to be written in a language in common use with other members of the Geomagnetism Section (either Fortran or Basic). The only examples of drivers for the Data Translation board (either in the product documentation or Kevin Seers programs) were written in GW Basic. Specifications for Microsoft's Quick Basic Version 4 made it clear that it was superior to GW Basic from a software engineering and practical point of view (inbuilt communications drivers, good program structuring methods, etc). Quick Basic was the chosen development platform. In retrospect, this was not the ideal decision. Some of the claims of Quick Basic regarding its Event Driven capabilities and RS232 drivers were wrong.

(This almost caused a setback of 6 weeks during the Macquarie countdown. With considerable hacking, the development effort was saved.) As all software is eventually modified to the point where it is no longer of value, and as all expectations of computer systems eventually outgrow the original design limitations, MAGACQ of course has a limited life. In the next development, either an operating system capable of multitasking or if absolutely necessary, then a system easily driven by the DOS interrupts, should be considered before Quick Basic. The DOS possibilities known at the writing of this report are Zortech C++ and Blaise software products which assist in the programming of DOS Terminate and Stay Resident tasks. A UNIX system such as QNX would be a more versatile but expensive option.

When development of MAGACQ commenced, the majority of the hardware had already been acquired. In cooperation with the Engineering Support Unit (ESU), the additional hardware to support time marks and fiducial marks was designed and developed: the DT2805 board, in addition to its analogue input ports, has 16 digital IO ports (2 groups of 8, each group configurable as input or output); the time and fiducial mark electronics respond to an input pulse by setting a line on a DT2805 digital input port high, and remaining high until the computer sets corresponding line on a DT2805 output port high. This ensured that no single time or fiducial mark could be lost through timing delays in the software (although multiple marks could be lost - the queue was only 1 deep).

The hardware configuration of this system is shown in Figure 5.

Program Operation

The program is started from the DOS command line or the AUTOEXEC.BAT DOS startup file by the command:

MAGACQ r: sta PSV=p XSV=x YSV=y ZSV=z TSV=t FMIN=min FMAX=max TELEMETRY=ts

where

r: is the disk to be used for recording, default C:

sta is a three letter code for the observatory, default @@@ (e.g. MAW or MCQ)

p,x,y,z,t are the scale values (counts per pixel) used to display the digital data for F,X,Y,Z, and temperature on the screen (they have no effect on the recorded data).

FMIN and FMAX are limits on the PPM data for data editing, defaults are 10000 and 80000. Data outside of these limits are discarded by the system.

ts is the startup real time telemetry status, and may be OFF, ON or DEFER.

Once the program starts up, the acquisition of data commences immediately in 10 second cycles in a background mode, and display, recording and control of the program begins to operate in the foreground. There are two logical displays selectable using an F1 function key toggle.

The first visible screen consists of two text windows. The top large window is a text description of all of the activities of the background acquisition process and the activities of the foreground processes.

The background messages include:

Event mark messages, mainly indicating the receipt of Time Marks or Fiducial Marks

Acquisition timing and activity. Each acquisition cycle starts at a 10 second time or as soon after as possible. If there may be enough time to do a PPM reading, the PPM is triggered; if not, the PPM is not triggered. When the PPM polarising and sampling are complete (to prevent PPM interference with the PEMs), the PEM channels and temperature channel are sampled, and Null channels are sampled to check on the 0 levels for PEM and temperature data separately. Each action and response from the instruments is listed, including PPM timeouts. The PEM message includes the results of the A/D conversion relative to the Null level, which is listed in brackets for information so that any wild Nulls indicating A/D failure can be detected.

The foreground messages include:

Startup messages: echoing the startup parameters as specified or the defaults, giving clock corrections and port configurations.

Help messages in response to an incorrectly specified local command.

Responses from local commands.

Warnings about lost data due to incorrect recording settings or full buffers.

Receipt of remote commands and illegal characters.

The second window of this first screen is a single line at the bottom. It echoes any local commands entered from the keyboard. Following a carriage return, the command is absorbed into the messages window for foreground processing.

The second logical display consists of another two windows. The top window is a graph of the data from all channels with 1 and 3 hour time grids. This graph scrolls left across the screen. The bottom window is a text window showing the status of the buffers in the program, the flow of acquired data to the normal and fiducial data buffer areas, the flow from those buffers to the recording disk and telemetry lines, telemetry status, the current acquisition time and the current remote command being processed (if any). To understand these descriptions, a knowledge of the program buffering is required.

The data from 10 second cycles is accumulated in a circular buffer called the Acquisition Buffer. This is long enough for a few hours of data to be held. Space in the buffer is freed when data is transferred to the circular Summary or Fiducial Buffers (two independent ways of being "free"). The Summary Buffer consists of the 1 minute summary of the 10 second data. The most recent data entered into the Summary Buffer is displayed in characters and on the graph. Space is freed when data is Recorded to disc and when it is Telemetered. The Fiducial Buffer consists of 10 second data complete with Event Mark information - the minute before and after any fiducial event is stored in the buffer along with the minute containing the fiducial mark. Space is freed when data is recorded to disc. Data passes between buffers in the foreground. The process can be held up by other foreground processes (such as long file transfers) or disk problems or telemetry problems (being Xoff'ed for a long time). This may be detectable from the information on the graphics screen (which itself is updated in the foreground and so may not be current) e.g. the Xon/Xoff status display may show Xoff, the free space in one of the buffers may be heading to 0 (if telemetry is deferred, say, the Telemetry Free space in the Summary Buffer will diminish).

There is an attempt to save as much data as possible by some means. So, for example, if the Telemetry Free space in the Summary Buffer falls to 0, but data can be recorded to disc, then the telemetry will be sacrificed to save data which can at least be retrieved from the disc. Fiducial data is a low priority, and basic recording will not suffer from lack of fiducial space, and so on.

There are 2 telemetry status variables: one is the Xon/Xoff status, and the other is a logical status which may be ON, OFF, DEFER or DELAY. ON causes data to be telemetered in near real time. OFF sends all telemetered data to the bit bucket. DEFER causes telemetry to be deferred until locally or remotely CONTINUEd. DELAY is a software state set when there are buffer problems or the like.

Data in the summary buffer can be accessed remotely in non real time using the remote SEND command. Binary or text data can be retrieved from disc remotely using the remote TELEMETER command. Data in the fiducial buffer can be accessed locally using the local DUMP command. Data on disc can be accessed locally by temporarily suspending acquisition and utilising any DOS command (that does not upset the colour tables and screen configuration) using the local SHELL command. The DOS system can be accessed locally or remotely using the local and remote SHELL commands.

The following local commands are available from the keyboard:
SHELL dos command
to suspend acquisition and invoke the DOS COMMAND processor. (If 'dos command' is not specified, then you must 'exit' DOS when finished.).
SIMULATE FIDUCIAL {ON|OFF}
to cause every minute to be processed as if it contained a fiducial mark - useful if the fiducial hardware is not functional.
FIDUCIAL {OFF|ON filename {[IN] {TEXT|BINARY}}}
to cause fiducials to be recorded onto a file.
DUMP FIDUCIAL [TO] filename [[IN] {TEXT|BINARY}]
to cause the entire fiducial buffer to be recorded to a file.
TELEMETRY {XON|XOFF|ON|OFF|DEFER|CONTINUE}
to deliberately fiddle the Xon/Xoff status if there are telemetry problems, or to control the mode of data telemetry.
SYNC
to inform the system that the clock status is correct. See notes on *Timing* below.

Certain restricted character editing is available from the keyboard: *Backspace* key rubs out the last character, *Delete* rubs out the entire line, *Up-arrow* recalls the last command, *Enter* completes a command. The following Function keys are defined: *F1* toggles between screen displays, *F2* simulates a time mark pulse, *F3* simulates a fiducial mark pulse, *F10* halts the program immediately.

The following remote commands are available from the COM2 communication port:
SHELL dos command
to suspend acquisition and invoke the DOS COMMAND processor ('dos command' must be specified. It is possible to hang the system if a command requiring a keyboard response is required).
TELEMETRY {XON|XOFF|ON|OFF|DEFER|CONTINUE}

to deliberately fiddle the Xon/Xoff status if there are telemetry problems, or to control the mode of data telemetry. In addition, the Xon/Xoff status is adjusted automatically: the Xoff state will timeout under program control to prevent MAGACQ hangups, although possibly causing other problems; a *Bel* character will function as an *Xon*; if no data is received by MAGACQ then the program will periodically issue an *Xon* character.

TELEMETER filename {TEXT|BINARY} {startcharacter {endcharacter}}

to telemeter a file (or file portion) in either TEXT mode (non ASCII characters are replaced with ASCII characters) or BINARY mode (each character is transferred as two hexadecimal (ASCII) characters).

The file contents are preceded by a *STX* character and terminated by an *ETX* character.

SYNC

to inform the system that the clock status is correct. See Timing below.

ENQ

to send a status report to the remote end including current time, buffer status, telemetry status, and last synchronisation to an external or internal clock pulse.

SEND {fromday fromminute {today tominute}}

to telemeter data in the summary buffer in the specified exclusive time period in "real time" format

The following non text keys are accepted: *Xon*, *Xof* and *Bel* (equivalent to *Xon*) are processed as usual; *Enq* will cause a response of *Ack* if the program is ready for a remote command and *Nak* if not (in which case all other characters are ignored); *Tab* will recall the previous command for editing; *Can* will interrupt the currently executing remote command at the next convenient time; *Del* will clear the current command buffer; *LF* is ignored; *CR* completes the command in the buffer. All printable characters are entered in the command buffer, and nonprintable characters not already mentioned are ignored.

Timing in the system is a complicated misfortune arising from the history of development. The running clock is the DOS system clock. It is very inaccurate. When information about using the IBM compatible AT Real Time or CMOS clock became available, it was used to correct the DOS system clock about once an hour. The Real Time clock is better than the DOS clock, but still is in error by about 1 second per day. The actual Real Time clock time is not used, but rather the rate of the clock is used - hence the time difference between the two clocks is maintained in the absence of a better (external) clock. The value of the time difference is taken as the value at start up or when a SYNC command is received or when an acceptable external time mark is received. If external time marks (either real pulses or simulated pulses) are present, then the DOS clock is adjusted whenever the difference exceeds 1 second. An external time mark is acceptable if it falls within an expected window (±15 seconds) of the accepted time and is consistent with the previous 2 time marks.

An auxiliary program TMX (accessible from DOS) allows the DOS and Real Time clocks to be manipulated without the need for keyboard intervention (compared to the DOS TIME command which could hang the system if issued remotely). The date and time of either clock can be examined or set to a given value or to the other clock, with keyboard synchronisation if required. TMX/glookyooka (alternatively, try TMX/help) will display the parameters and usage on the screen.

A remote program ACQTELE communicates with the MAGACQ program from a remote computer and transfers data to the remote disc. Ad hoc remote interrogation can be done manually from any remote terminal.

During 1989 and 1990, several inadequacies of the system as installed at Macquarie Island were found. The following list of modifications were made to the initial system :

1. Modified the timing system to use the internal Real Time Clock in the event of an External Clock failure (the Real Time clock is more accurate than the DOS system clock).
2. Added the binary format feature to recorded fiducial data files to make it easier to interface to an automatic fiducial editor.
3. Added the monitoring of a Null channel to keep track of the Null drift of the A/D board and correct the data accordingly.
4. Inserted the hooks for receiving remote commands on the COM2 port, and install implement the ENQ command to enable checking the system remotely.
5. Reduce the PPM data rate from 1200 baud to 300 baud to reduce data errors.
6. Add a digital filter (using a 'clustering' algorithm) to allow for the rejection of many incorrect PPM values (which appear as spikes on analogue data).
7. Increase the number of samples of analogue channels at each 10 second cycle and apply a clustering type filter to reject data spikes to try and reduce the noise from the ±2000nT PEM boards.
8. Correct the treatment of minutes of data where some of the data is out of range of the A/D board or the PEM.
9. Allow individual control of the PEM graphic display scale values following the mixing of ±1000 and ±2000nT PEM boards.
10. Allow system clock corrections from external time marks as small as 1 second - the initial version only made corrections when the external time marks indicated greater than 2 seconds difference. As the time resolution of

recognising an event is only 1 second in the Basic system, it was thought that corrections of 1 second may cause unjustifiable changes.
11. Correct the Null adjustments to out of range data.
12. Implement substantial remote control facilities via the COM port, including non real time telemetry and file transfers, remote access to operating system functions to interrogate and modify the disk system and clocks.

The Processing Programs

The history of previous Mawson software has been that each new observer created his or her own software (this is recent history; the resources to do this have only been available since 1985 in Canberra, and since 1986 at Mawson) which was discarded at their departure. The author expected the same fate to await the software described here. It was written early in 1989 in a preliminary form under the pressure of urgent need, and modified and added to throughout the year and beyond. It suffers from being developed in haste to produce reports and without a clear view of the generality required to be applicable to a wide range of geomagnetic activities, and was done without the benefit of discussion with other members of the Geomagnetism Section who would have been able to contribute a great deal to the software specifications (but at least with a previous year's experience in operating the Mawson observatory, even if only during the predigital photographic era). Apart from satisfying the author's needs, it was hoped to at least provide an example of a few different approaches to some problems.

It would be highly desirable to merge the specifications of this software with the Canberra software to produce an integrated system applicable to all observatories and field work.

The consequences of the expectation of doom for the programs was undocumented software. The programs have since been used more generally and it is fortunate that Andrew Lewis took the time to write excellent documentation on the use of the programs early in 1990. That documentation should be referred to for a detailed description of program operation.

The "different" approaches mentioned in many cases simply mean discarding the "log table" approach to calculations. Many of the computerised techniques applied in the many versions of the reduction software available directly employ the methods established 40 years previously, before even calculators were available. In that era every calculation was time consuming, multiplications were performed using log tables etc., and there was never any question of reworking any data. Recent programs using powerful computers have converted all calculations to the same logarithm formulae, a method great for humans but burdensome for computers. Furthermore, they use "delta formulae" for deriving changes in dependent parameters from changes in independent parameters, again great for humans, but needlessly inaccurate and awkward to specify when using computers. In general small computers are underutilised, and there is no penalty for using exact procedures in preference to approximations, and there is little effort involved in reworking data. It is therefore straightforward to use methods which operate on each detail of an observation, say, and thus remove a level of inaccuracy associated with averaging parts of an observation and performing "bulk" calculations, and to provide feedback to the operator to indicate possible errors in the original data or its transcription.

The programs worth describing are REDUCE, COMPARE, REGRESS7, PLOTV, SUMMARYP, EXAMINE, REDUCES, FIDUCIAL and KINDEX.

Reduce

REDUCE reduces absolute observations to field components, and produces an output file suitable for input to COMPARE with auxiliary information on instrument characteristics (e.g. α.H for a QHM, E-I for a declinometer). Variometer data, if available, can be given either in the observation data file or in a separate variation file. Output can optionally be directed to a reduction file. To facilitate remote observation comparison to variometer data, corrections can be suppressed with the /CORRECT=NO option, allowing remote pier differences to be approximated.

The input observations for REDUCE can be fairly flexible; no standard observation schedule is expected. There is therefore no difficulty in using DIMs with "full" or "half" sheet observations, or declinometers with just one erect and inverted reading, or QHMs with $-\pi$ rotations before $+\pi$ etc. Also, for nonsymmetrical observations, most REDUCE routines will apply known constants if they are available e.g. if a declinometer is used with just an erect reading, and no inverted reading, then a known E-I value for the declinometer will be applied to derive the value of D. REDUCE can easily be extended to handle instruments outside the current list (QHM, declinometer, DIM and PPM, as well as Scale Value and Temperature variometer tests). Most of the instrument reductions follow normal methods, with the exception that if variometer data is given, all parts of each observation are corrected to the mean field during the observation to make each part of the observation comparable to other parts (e.g. to make both erect readings of a declinometer refer to the same field and therefore, all being well, the same), and to reduce the scatter in instrument auxiliary data (e.g. α.H for a QHM). The reductions for a QHM follow the methods described by

Crosthwaite (1986) to reduce the parts of the observation to a given field and to derive the value of H (and D if mark readings are supplied). The "odd π" correction for the angle between the front and back mirrors has not been implemented. The formula used for H is:

$H = (K . n) / ((1 - k1 . t).(1 + k2 . H . \cos \varphi) . \sin \varphi . \cos b)$
where:
φ = average of φ_+ and φ_- (φ_+, φ_- are the $+\pi$ and $-\pi$ circle deviations from the 0π reading)
$b = \alpha + (\varphi_+ + \varphi_-)/2$
$\tan \alpha = (\sin \varphi_+ - \sin \varphi_-) / (2 - (\cos \varphi_+ + \cos \varphi_-))$
n = 1,2,3... (note that in some expressions of this formula, n is .5, 1, 1.5...).

and the formula for D is

$D = C_0$ + Mark Azimuth - $C_M - \alpha + c$ + D correction
where:
C_0 = average circle reading of the QHM is the 0π position
C_M = average circle reading of the mark
c = QHM collimation angle as specified in the instrument calibrations
D correction = additional correction deduced from comparisons (a refinement to c)

Compare

COMPARE accepts the output of the REDUCE program and compares the field components measured by a variometer or standard instruments on a standard pier to other instruments on other piers or a variometer. It can therefore be used to derive variometer corrections and for instrument comparisons. To facilitate comparisons between remote stations and a variometer, actual variometer corrections to individual observations can be suppressed using the /CORRECT=NO option.

Corrections to the predicted value of any standard component (XYZHFDI) using variometer data and variometer parameters may be requested whether or not that component is one of the primary components of the variometer (e.g. for an XYZ variometer, the correction to D as predicted by the variometer can be determined). Up to 3 standard instruments,the components they measure and the pier they are used on (as standards) can be specified. (A QHM could be specified twice for both D and H, and so on) . Station and Pier parameters must specify the standard pier. All observations are corrected to a representative field value using any available variometer information.

The output of COMPARE can be used as input to REGRESS7.

Regress7

REGRESS7 is a small improvement on a program called REGRESSV. It calculates the average and standard deviation of any standard component (XYZDHFI) variometer correction and measured scale value in a .BLV file produced by COMPARE. In addition it performs ordinary linear regression of the variometer correction for standard linear components (XYZ and temperature) on the variometer xyz and temperature ordinates and time. This enables refinements to variometer parameters for XYZ type variometers to be made. An alternative to the use of REGRESS7 would be spread sheet programs which have built in statistical functions. Borland's QUATTRO and Microsoft's EXCEL, for example, have multilinear and ordinary regression analysis (and means, standard deviations etc) functions. The use of multilinear regression should remove most of the iterations in the refinement procedure for the variometer parameters and remove the need for good initial guesses at the parameters.

Examine

EXAMINE is a versatile way of browsing through small volumes of data (up to a week or so) and producing reports about data loss, data consistency, data statistics and for deriving real field elements from variometer data. The major deficiency in the current version is the lack of a graphical display facility to view the data, and the lack of a graphical interface to derive K indices from the data by accepting pointing device inputs to define the quiet day curves. Much of EXAMINE was structured to be independent of the source of the data (absolute data or variometer data from various types of variometers for example), although most of the code actually implemented is specific to the data it is currently used with.

The first step in using EXAMINE is to GET a data file (in EDAS format, MAGACQ text or binary format currently) into memory in a common format. Variometer data is automatically associated with the variometer parameters from the constants file valid for that data period. Once in memory, all operations are fairly quick, and browsing through different parts of the data is easy. There are a few commands to FREE data space for more data, and to SHOW details of all data currently in memory.

The useful commands are:
LIST to list the data.
DATACHECK to check for holes in the data and out of range data.
FCHECK (specific to XYZF and temperature variometers) to compare XYZ and F data, rejecting and reporting data outside a specified window of acceptability, and reporting the average results.
AVERAGE to average data
RINDEX to derive a "Range Index" for data, and to display peak data values for data checking. This can be used to produce pseudo K indices if the diurnal is ignored. Ultimately, real K indices could be produced by graphically entering the diurnal curve and the deriving a range index on the difference between the original data and the diurnal
DERIVE to convert variometer data to absolute data
PUT to put the data to a file, possibly in a different format to the original (for binary to text conversions perhaps)
CORRECT to correct data from a valid data set. This is used to Null bad data or to replace corrupted data (say, scale value test data) with edited good data (derived from data recorded at a higher sampling rate than the normal data)
EXTRACT to extract variometer data corresponding to absolute observations in an input file for REDUCE for use in the REDUCE program.

The commands have the option to select portions of the data, report on intervals as well as the whole data period, split reports at changes in variometer parameters, report to files or the screen etc. There should be editing commands to merge data sets, delete data, modify times, modify data, subtract data sets and so on. The interface to the program is character based (with no prompting, although help is available), and so it is moderately transportable to other computers, but not as quick or delightful to use as a GUI.

Fiducial

FIDUCIAL provides a quick way of going through a binary fiducial file from MAGACQ and interpolating data at the fiducial marks from the 10 second samples. This can be done in "auto" mode, although it may be useful to go through the file to check for data spikes and generally browse through the fiducial file manually. Sometimes interpolation is not the correct technique, as in the case of scale value tests where a pure sample is needed. This possibility is allowed for. False fiducial marks can be ignored. Also, the fiducial file can be edited to remove invalid data (say data corrupted by scale value pulses) and produce a cleaned 1 minute data file which can be used to correct the corrupted one minute data files output by MAGACQ.

Kindex

Primarily, KINDEX is a program to format K indices entered from the terminal. It has an input format flexible enough to accept brief data from the terminal or its own more elaborate output format as input. Hence, there is no need to maintain a raw and processed data file. Any changes to the X index, say, can be made in the single data file, which can then be run through the program to correct the K index and K sum, and create a list of days sorted by K sum and a new K index distribution table. A similar program exists on the Data General, and a common program could no doubt be made.

Plotv

PLOTV takes the output of COMPARE and produces a list of XYZ baseline corrections with the corresponding variometer data and time. All data items are separated by commas. This file is therefore readable by many spreadsheet packages and can be used to quickly graph the baseline changes.

Summaryp

SUMMARYP is a small variation to a program called SUMMARYL, which was overshadowed by Examine. It provides a quick graph of one day's binary data from the MAGACQ program. Ideally, the functionality should be transferred to EXAMINE.

Reduces

REDUCES accepts a file of sunshot observations and produces a list of 'corrections to the theodolite horizontal circle readings to give true azimuth' based on each part of each sun observation. To do this, it uses an almanac program and the known latitude and longitude (and pressure and temperature if available to calculate refraction) to locate the sun in apparent local azimuth and altitude coordinates, and then calculates the apparent azimuth of the appropriate limb of the sun and derives the circle correction. This allows consistency of each part of the sun observation to be examined, and takes out the first level of errors that are produced by nonlinearity when the entire observation is averaged for a single calculation by hand.

"Azimuth by hour angle" and "azimuth by altitude" methods are implemented.

One common aspect of REDUCE, COMPARE and EXAMINE is the use of a common constants file for geomagnetic items. This includes all absolute instruments, variometers, observatories and the like. Each program uses the same file by default, although a specific file for a specific purpose can be used. In addition, each program can use an overriding constants file to specify constants for a particular item (say a test set of variometer parameters) without modifying a more widely used reliable constants file. Each set of constants is timestamped, and the same item can have constants for different time periods in the files.

It proved extremely useful and convenient to save all of the raw data observations on computer media (from all types of tests including absolute observations, orientation and scale value tests, temperature calibrations, sun shots, rounds of angles etc). It has not been common practice in Canberra to retain these files, but for cyclic processing, and for data quality control and reprocessing to derive instrument performance or following instrument correction updates etc., it is essential.

REDUCE and COMPARE together form a tool to derive the deviation of the field derived from sets of absolutes from the field predicted from a variometer - this is usually called "deriving baselines", but is in fact a more general procedure for deriving baselines and other variometer parameters when combined with some other processing routine. In the case of a rectilinear variometer, this other processing routine can be REGRESS7 which calculates a linear regression of the "deviations" verses the rectilinear variometer parameters (x,y,z and also temperature and time). Each of the two latter programs takes the output from the previous program as input. REGRESS7 does a few extra things, such as a regression of temperature against ordinates and some statistics on derived scale values. It should have the added functionality of producing some statistics on the performance of instruments using the parameters produced by the previous programs. It should be improved so that it can perform a multilinear regression using selected variables.

Although REDUCE and COMPARE are a team, they were written as two programs rather than one for reasons of utility and performance. REDUCE takes a file of sets of absolutes, each containing any number of field measurements (using QHMs, DIMs, PPMs, declinometers, and with the hooks to implement routines for other instruments) and variometer measurements (scale values, temperature measurements). Each part of each measurement is accompanied by the variometer data from the moment it was made. The program performs the reduction using the variometer data to correct each part of the observation to a representative field for the observation using the variometer data. REDUCE can then optionally represent the observation to the operator as if it had been made in a constant field (within the limitations of the variometer data). This is an extremely useful procedure for detecting mistyped data, misread instrument scales and observing mistakes. It makes large errors obvious before they are lost in the averaging process, and allows reliable corrections to common mistakes such as integral scale reading errors. This may lead to a cycle of corrections to the text input file of observations and REDUCE checking, without the extra time consuming step of actually deriving the deviations as such. Also, in some cases, REDUCE is all that is necessary; one of the results output by the program is the deviation of the absolute observation (say H and D from a QHM) from the variometer predicted result. Comparing two observations like this is equivalent to instrument comparison through baselines. If a processing cycle is used to refine variometer parameters, say, then it will seldom be necessary to include REDUCE in any but the first and last cycles; a simple cycle of parameter adjustment and COMPARE will show the most significant effects of a parameter change.

Appendix D - Adopted Variometer Parameters

The parameters listed in this appendix will allow the derivation of the magnetic field at Pier A in the Absolute Hut at Mawson as measured by the standard instruments ***without any instrument corrections*** and relative to the adopted azimuth of marker SOH from Pier A of 274° 15.0'.

Variometer parameters have been divided into 7 periods during 1989. Each period is bounded by specific events, and the variometer appeared to behave consistently within each period. The model for deriving the magnetic field is described in the report text under Variometer Calibrations, Base Line Calibrations and can be expressed as:
X = **b** + **d**.Δtime + **s**.Δx + **q**.Δtemperature

For the entire data period of this report, the nominal coil constants of the PEM system are assumed to be :
Scale Value for X Y and Z components: 8.03 nT/mA
Orientation for X Y and Z components : 96.36 nT/mA (assuming a 12 turn orientation coil)

In this appendix, geomagnetic field units are in nT, temperature is in degrees Centigrade, variometer units are in counts, currents are in mA and time is in days.

Period I 00:00 1 January 1989 to 19:00 12 May 1989 UTC and
Period II 19:00 12 May 1989 to 09:00 17 May 1989 UTC.

EDAS system continued unchanged from 1988.

$$\begin{pmatrix} X \\ Y \\ Z \end{pmatrix} = \begin{pmatrix} +\mathbf{8096.9}\pm1.0 \\ -\mathbf{16487.1}\pm0.9 \\ -\mathbf{46279.1}\pm1.4 \end{pmatrix} + \begin{pmatrix} -\mathbf{0.010}\pm.004 \\ +\mathbf{0.020}\pm.003 \\ +\mathbf{0.002}\pm.005 \end{pmatrix} .(\text{Time - 00:00 1 January 1989})$$

$$\ldots\ldots + \begin{pmatrix} +\mathbf{0.1864}\pm.0006 & +\mathbf{0.0016}\pm.0008 & -\mathbf{0.0002}\pm.0003 \\ -\mathbf{0.0010}\pm.0005 & +\mathbf{0.2072}\pm.0007 & +\mathbf{0.0008}\pm.0003 \\ +\mathbf{0.0037}\pm.0008 & -\mathbf{0.0042}\pm.0011 & +\mathbf{0.1975}\pm.0006 \end{pmatrix} .\left(\begin{pmatrix} x \\ y \\ z \end{pmatrix} - \begin{pmatrix} \mathbf{5000} \\ \mathbf{5000} \\ \mathbf{5000} \end{pmatrix} \right)$$

$$\ldots\ldots + \begin{pmatrix} -\mathbf{0.77}\pm.25 \\ -\mathbf{0.25}\pm.23 \\ -\mathbf{0.35}\pm.37 \end{pmatrix} .(\text{temp}-\mathbf{10})$$

with the exception of two data periods where the following baseline corrections apply (due to data corruption from the presence of a vehicle near the variometer building during the installation of new equipment and furniture):

11 May 1989 08:12 to 08:32 UTC $\begin{pmatrix} \mathbf{-25} \\ \mathbf{-20} \\ \mathbf{-19} \end{pmatrix}$

11 May 1989 09:08 to 09:14 UTC $\begin{pmatrix} \mathbf{-22} \\ \mathbf{-19} \\ \mathbf{-25} \end{pmatrix}$

temperature = +**0.58**±.04 +**0.01925**±.00022 .(t-**5000**)

Scale Values measured by classical (Helmholtz coil) techniques for X Y Z were:
SVx = +**0.1858**±.0018, SVy = +**0.2042**±.0014, SVz = +**0.1930**±.0027

(Period I constants are based on 45 HDF, 45 Temperature and 32 scale value observations. Period II constants were assumed to be the same as Period I - equipment rearrangements in the variometer building caused apparent baseline corrections of +0.1 +0.8 +3.7 -0.03 for X Y Z and T (based on 2 HDF and 2 Temperature observations). It is unlikely that these apparent changes are real, as the most likely instrument to be effected was the X PEM and the least likely Z.

The F variometer data are stepped, and so baselines are modulo 100nT. The difficulty in keeping track of the steps made it not worthwhile reducing the F data, and so no information about the F trace is available.

Period III 09:46 21 May 1989 to 13:54 22 August 1989 UTC.

NEC/PC recording system with ±1000nT PEM boards.

$$\begin{pmatrix} X \\ Y \\ Z \end{pmatrix} = \begin{pmatrix} +7965.7\pm1.0 \\ -16488.9\pm0.9 \\ -46292.6\pm1.2 \end{pmatrix} + \begin{pmatrix} -0.020\pm.006 \\ +0.006\pm.005 \\ +0.039\pm.007 \end{pmatrix} .(\text{Time - 09:46 21 May 1989})$$

$$\ldots\ldots + \begin{pmatrix} +0.02865\pm.00011 & +0.00000\pm.00021 & -0.00000\pm.00020 \\ -0.00020\pm.00009 & +0.03130\pm.00017 & +0.00000\pm.00016 \\ +0.00040\pm.00013 & -0.00050\pm.00025 & +0.03020\pm.00023 \end{pmatrix} .\left(\begin{pmatrix} x \\ y \\ z \end{pmatrix} - \begin{pmatrix} 0 \\ 0 \\ 0 \end{pmatrix} \right)$$

$$\ldots\ldots + \begin{pmatrix} -1.03\pm.09 \\ +0.56\pm.07 \\ +1.06\pm.10 \end{pmatrix} .(\text{temp}-10)$$

temperature = +0.24±.04 +0.003038±.000010 .(t-0)

Scale Values measured by classical (Helmholtz coil) techniques for X Y Z were:
SVx = +0.02837±.00004, SVy = +0.03114±.00016, SVz = +0.03010±.00006

(Period III constants are based on 47 HDF, 54 Temperature and 22 scale value observations.)

Period IV 21:00 24 August 1989 to 11:22 26 August 1989 UTC.

NEC/PC recording system with ±2000nT PEM boards; initial installation.

$$\begin{pmatrix} X \\ Y \\ Z \end{pmatrix} = \begin{pmatrix} +7964.9\pm0.1 \\ -16647.2\pm0.8 \\ -46267.8\pm1.1 \end{pmatrix} + \begin{pmatrix} -0.033\pm.004 \\ +0.037\pm.003 \\ +0.000\pm.003 \end{pmatrix} .(\text{Time - 21:00 24 August 1989})$$

$$\ldots\ldots + \begin{pmatrix} +0.05938\pm.00012 & -0.00010\pm.00018 & -0.00001\pm.00007 \\ -0.00003\pm.00011 & +0.06096\pm.00016 & -0.00002\pm.00006 \\ +0.00063\pm.00011 & -0.00155\pm.00017 & +0.03034\pm.00006 \end{pmatrix} .\left(\begin{pmatrix} x \\ y \\ z \end{pmatrix} - \begin{pmatrix} 0 \\ 0 \\ 0 \end{pmatrix} \right)$$

$$\ldots\ldots + \begin{pmatrix} +1.80\pm.03 \\ -7.60\pm.17 \\ +1.00\pm.28 \end{pmatrix} .(\text{temp}-10)$$

temperature = +0.24±.06 +0.003044±.000043 .(t-0)

Scale Values measured by classical (Helmholtz coil) techniques for X Y Z were:
SVx = +0.05950±.00014, SVy = +0.06078±.00002, SVz = +0.03007±.00004

(Period IV constants are based Period VII constants except for the X and Y baseline and temperature coefficient values which are based on 5 HDF , 4 Temperature and 6 scale value observations.)

Period V 11:23 26 August 1989 to 11:16 28 August 1989 UTC.

NEC/PC recording system with ±2000nT PEM boards; first temperature coefficient adjustment.

$$\begin{pmatrix}X\\Y\\Z\end{pmatrix} = \begin{pmatrix}+7964.8\pm0.2\\-16645.8\pm0.1\\-46267.8\pm1.1\end{pmatrix} + \begin{pmatrix}-0.033\pm.004\\+0.037\pm.003\\+0.000\pm.003\end{pmatrix}.(\text{Time - 11:23 26 August 1989})$$

$$\ldots\ldots + \begin{pmatrix}+0.05938\pm.00012 & -0.00010\pm.00018 & -0.00001\pm.00007\\-0.00003\pm.00011 & +0.06096\pm.00016 & -0.00002\pm.00006\\+0.00063\pm.00011 & -0.00155\pm.00017 & +0.03034\pm.00006\end{pmatrix}.\left(\begin{pmatrix}x\\y\\z\end{pmatrix}-\begin{pmatrix}0\\0\\0\end{pmatrix}\right)$$

$$\ldots\ldots + \begin{pmatrix}+1.00\pm.09\\+0.80\pm.04\\+1.00\pm.28\end{pmatrix}.(\text{temp-10})$$

temperature = +0.24±.06 +0.003044±.000043 .(t-0)

(Period V constants are based Period VII constants except for the X and Y baseline and temperature coefficient values which are based on 3 HDF and 3 Temperature observations.)

Period VI 11:17 28 August 1989 to 14:30 29 August 1989 UTC.

NEC/PC recording system with ±2000nT PEM boards; second temperature coefficient adjustment.

$$\begin{pmatrix}X\\Y\\Z\end{pmatrix} = \begin{pmatrix}+7963.7\pm0.2\\-16647.0\pm0.3\\-46267.8\pm1.1\end{pmatrix} + \begin{pmatrix}-0.033\pm.004\\+0.037\pm.003\\+0.000\pm.003\end{pmatrix}.(\text{Time - 11:17 28 August 1989})$$

$$\ldots\ldots + \begin{pmatrix}+0.05938\pm.00012 & -0.00010\pm.00018 & -0.00001\pm.00007\\-0.00003\pm.00011 & +0.06096\pm.00016 & -0.00002\pm.00006\\+0.00063\pm.00011 & -0.00155\pm.00017 & +0.03034\pm.00006\end{pmatrix}.\left(\begin{pmatrix}x\\y\\z\end{pmatrix}-\begin{pmatrix}0\\0\\0\end{pmatrix}\right)$$

$$\ldots\ldots + \begin{pmatrix}-0.59\pm.08\\-1.19\pm.17\\+1.00\pm.28\end{pmatrix}.(\text{temp-10})$$

temperature = +0.24±.06 +0.003044±.000043 .(t-0)

(Period VI constants are based Period VII constants except for the X and Y baseline and temperature coefficient values which are based on 3 HDF and 1 Temperature observations.)

Period VII 14:31 29 August 1989 to 24:00 31 December 1989 UTC.

NEC/PC recording system with ±2000nT PEM boards; third temperature coefficient adjustment - final configuration for 1989.

$$\begin{pmatrix} X \\ Y \\ Z \end{pmatrix} = \begin{pmatrix} +7963.1\pm1.1 \\ -16644.6\pm1.0 \\ -46267.8\pm1.1 \end{pmatrix} + \begin{pmatrix} -0.033\pm.004 \\ +0.037\pm.003 \\ +0.000\pm.003 \end{pmatrix} .(\text{Time - 14:31 29 August 1989})$$

$$\ldots\ldots + \begin{pmatrix} +0.05938\pm.00012 & -0.00010\pm.00018 & -0.00001\pm.00007 \\ -0.00003\pm.00011 & +0.06096\pm.00016 & -0.00002\pm.00006 \\ +0.00063\pm.00011 & -0.00155\pm.00017 & +0.03034\pm.00006 \end{pmatrix} .\left(\begin{pmatrix} x \\ y \\ z \end{pmatrix} - \begin{pmatrix} 0 \\ 0 \\ 0 \end{pmatrix} \right)$$

$$\ldots\ldots + \begin{pmatrix} -0.50\pm.30 \\ -1.10\pm.27 \\ +1.00\pm.28 \end{pmatrix} .(\text{temp}-10)$$

temperature = +**0.24**±.06 +**0.003044**±.000043 .(t-**0**)

Scale Values measured by classical (Helmholtz coil) techniques for X Y Z were:
SVx = +**0.05947**±.00005, SVy = +**0.06078**±.00006, SVz = +**0.03010**±.00004

(Period VII constants are based on 53 HDF, 58 Temperature and 32 scale value observations.)

See Figure 4 for a view of the baseline residuals for all absolute observations during 1989. Suggested times for implementing a splicing function to match the data covered by this report and subsequent data are at the last zero residual points from the graphs in Figure 4. For X and Y, this is day 362 (28th December 1989), and for Z this is day 355 (21st December 1989). The author suggests a linear adjustment (or "splicing function") from this time to the first zero residual point in the following data set which will make the derived field values for the transition period using the variometer parameters for Data Period VII and the 1990 parameters agree. The magnitude of the splicing funtion required is quite small for X and Y, and less than 10nT for Z. The Z adjustment appears to correspond to a real change in the drift rate of the Z PEM at the end of 1989 (Lewis, 1991).

Appendix E - DIM Variometer Parameters

The parameters listed in this appendix will allow the derivation of the magnetic field at Pier A in the Absolute Hut at Mawson as measured by the standard F instrument and the DIM ***without any instrument corrections*** and relative to the adopted azimuth of marker SOH from Pier A of 274° 15.0'. The parameters are for comparison with the Adopted Variometer Parameters derived using the standard instrument observations. They are not the adopted values.The model for deriving the magnetic field is described in the report text under Variometer Calibrations, Base Line Calibrations and can be expressed as:

X = b + d.Δtime **+ s.**Δx **+ q.**Δtemperature

Period III 09:46 21 May 1989 to 13:54 22 August 1989 UTC.

NEC/PC recording system with ±1000nT PEM boards.

$$\begin{pmatrix} X \\ Y \\ Z \end{pmatrix} = \begin{pmatrix} +7970.1 \pm 1.5 \\ -16489.9 \pm 1.1 \\ -46288.5 \pm 1.1 \end{pmatrix} + \begin{pmatrix} -0.003 \pm .016 \\ +0.040 \pm .011 \\ +0.028 \pm .012 \end{pmatrix} .(\text{Time - 09:46 21 May 1989})$$

$$\ldots\ldots + \begin{pmatrix} +0.02850 \pm .00019 & -0.00010 \pm .00045 & -0.00000 \pm .00044 \\ -0.00030 \pm .00014 & +0.03120 \pm .00032 & +0.00010 \pm .00031 \\ +0.00055 \pm .00015 & -0.00010 \pm .00034 & +0.03000 \pm .00034 \end{pmatrix} .\left(\begin{pmatrix} x \\ y \\ z \end{pmatrix} - \begin{pmatrix} 0 \\ 0 \\ 0 \end{pmatrix} \right)$$

$$\ldots\ldots + \begin{pmatrix} -1.80 \pm .56 \\ +0.20 \pm .40 \\ +0.95 \pm .43 \end{pmatrix} .(\text{temp-10})$$

(Period III constants are based on 29 DIF observations.)

Period VII 14:31 29 August 1989 to 24:00 31 December 1989 UTC.

NEC/PC recording system with ±2000nT PEM boards; third temperature coefficient adjustment - final configuration for 1989.

$$\begin{pmatrix} X \\ Y \\ Z \end{pmatrix} = \begin{pmatrix} +7967.0 \pm 0.8 \\ -16642.3 \pm 1.4 \\ -46268.2 \pm 1.1 \end{pmatrix} + \begin{pmatrix} -0.040 \pm .004 \\ +0.039 \pm .007 \\ +0.000 \pm .005 \end{pmatrix} .(\text{Time - 14:31 29 August 1989})$$

$$\ldots\ldots + \begin{pmatrix} +0.05951 \pm .00013 & -0.00006 \pm .00017 & +0.00015 \pm .00010 \\ +0.00003 \pm .00022 & +0.06085 \pm .00030 & -0.00004 \pm .00018 \\ +0.00090 \pm .00017 & -0.00150 \pm .00022 & +0.03030 \pm .00013 \end{pmatrix} .\left(\begin{pmatrix} x \\ y \\ z \end{pmatrix} - \begin{pmatrix} 0 \\ 0 \\ 0 \end{pmatrix} \right)$$

$$\ldots\ldots + \begin{pmatrix} +0.50 \pm .49 \\ -1.60 \pm .86 \\ +1.30 \pm .64 \end{pmatrix} .(\text{temp-10})$$

(Period VII constants are based on 23 DIF observations.)

Appendix F - Variometer Model Inversion

The variometer model used to reduce the data in this report can be expressed as

X = **b** + **d**.Δtime + **s**.Δ**x** + **q**.Δtemperature

where

X is the geomagnetic vector field

x is the variometer output vector (Δ**x** is the change from the standard variometer reference)

b, **d** and **q** are the pseudo baseline, drift rate and temperature coefficient vectors for the variometer (dependent on the variometer alignments)

s is a scale value/orientation matrix (also dependent on the variometer alignments)

If the inverse of the matrix **s** is expressed as

$$s^{-1} = S^{-1}U$$

where **U** has the property that its rows have unity norm and S^{-1} (and its inverse S) is a diagonal matrix, then

U.**X** = **U**.**b** + **U**.**d**.Δtime + **S**.Δ**x** + **U**.**q**.Δtemperature

In this form, the vectors **U**.**b**, **U**.**d** and **U**.**q** are the true instrument baseline, drift rate and temperature coefficient vectors, the rows of **U** representing the alignment of each channel of the variometer and **S** is the true (diagonal) scale value matrix of the variometers.

Inversion of the equations given in Appendix D (parameters deduced from standard instrument observations) for data periods I, III and VII give

S_I = Diag(0.18636, 0.20725, 0.19741)

S_{III} = Diag(0.028650, 0.031299, 0.030193)

S_{VII} = Diag(0.059380, 0.060961, 0.030326)

$$U_I = \begin{bmatrix} 0.999970 & -0.007699 & 0.001044 \\ 0.005446 & 0.999977 & -0.004046 \\ -0.019738 & 0.020411 & 0.999597 \end{bmatrix}$$

$$U_{III} = \begin{bmatrix} 1.000000 & 0.000000 & 0.000000 \\ 0.006981 & 0.999976 & 0.000000 \\ -0.013847 & 0.015971 & 0.999777 \end{bmatrix}$$

$$U_{VII} = \begin{bmatrix} 0.999999 & 0.001649 & 0.000331 \\ 0.000498 & 1.000000 & 0.000659 \\ -0.010593 & 0.025399 & 0.999621 \end{bmatrix}$$

Inversion of the equations given in Appendix E (parameters deduced from DIM/F instrument observations) for data periods III and VII give

S_{III} = Diag(0.028499, 0.031197, 0.029995)

S_{VII} = Diag(0.059505, 0.060848, 0.030284)

$$U_{III} = \begin{bmatrix} 0.999995 & 0.003205 & -0.000011 \\ 0.010590 & 0.999938 & -0.003333 \\ -0.019261 & 0.003143 & 0.999810 \end{bmatrix}$$

$$U_{VII} = \begin{bmatrix} 0.999987 & 0.000864 & -0.004949 \\ -0.000524 & 0.999999 & 0.001323 \\ -0.015130 & 0.024626 & 0.999582 \end{bmatrix}$$

The true scale values differ very little from the diagonal elements of the pseudo scale value matrix. The exorientation angles of the variometers can be derived from U, as the rows of **U** are the vector orientations of each PEM component and so, for example, the tangent of the angle of the X PEM from North is U_{12}/U_{11}. The derived orientation implications are discussed under Variometer Calibrations - Orientation Calibrations.

Table 1 - Station Data For Mawson

Magnetic Absolute Hut - Pier A (instrument level) (Hutchinson, 1989)

Geographic Coordinates	67° 36' 14.1" S	62° 52' 45.2" E	
Geomagnetic Coordinates*	73.20° S	107.57° E	Candidate IGRF 1990
Elevation	12 m		
Foundation	Mawson Charnockite		

Magnetic Variometer Building - Mark N1 (Crosthwaite, 1986)

Geographic Coordinates	67° 36' 11.4" S	62° 52' 44.5" E
Elevation	9m	
Foundation	Concrete on Mawson Charnockite	

Cosray Vault - Seismometer Platform (Crosthwaite, 1986)

Geographic Coordinates	67° 36' 16.6" S	62° 52' 16.6" E
Elevation	17 m	
Foundation	Concrete on Mawson Charnockite	

* The geomagnetic coordinates are the average of those for the USGS, USSR and US/UK candidate models for IGRF 1990.

Table 2 - Absolute Instrument Constants

QHM	K (nT)	k1 $*10^5$ (1/°C)	k2 $*10^{10}$ (1/nT)	alpha*H $*10^{-5}$ ('.nT)	odd π mis-alignment (')	collimation (')
300	7828.0	39.4	69.0	2.22	0.0	22.5
301	8230.5	39.7	90.0	-3.33	0.0	72.5
302	7690.1	42.0	90.0	-0.20	0.0	27.0
172	7938.5	39.1	46.1	0.00	0.0	47.2
704	6025.8	26.0	00.0	0.00	0.0	27.0
174	7765.87	39.1	46.1	0.00	0.0	249.9
494	3894.48	44.4	115.0	0.00	0.0	1.0

QHM	H correction (nT/nT)	H correction drift (1/day)
300	0.0	0.0
301	0.0	0.0
302	0.0	0.0
172	0.0	0.0
704	0.0	0.0
174	0.0	0.0
494	0.0	0.0

All constants are valid throughout all of 1989. Note that corrections may be needed to make the results in this report consistent with other reports using different instrument constants - in particular, the K and C QHM constants are not strictly interchangeable; the values of K and k1 equivalent to C and c1 depend on the temperature at which the observations are made due to different approximations to the temperature effect in the K and C formulae. QHM observations at Mawson were made almost always between 0°C and 13°C, but most commonly between 5°C and 10°C.

H is calculated using the formula: $H = (K . n) / ((1 - k1 . t).(1 + k2 . H . \cos\varphi) . \sin\varphi . \cos b)$ where:

φ = average of φ_+ and φ_- (φ_+, φ_- are the $+\pi$ and $-\pi$ circle deviations from the 0π reading)

$b = \alpha + (\varphi_+ + \varphi_-)/2$

$\tan\alpha = (\sin\varphi_+ - \sin\varphi_-) / (2 - (\cos\varphi_+ + \cos\varphi_-))$

n = 1,2,3... (note that in some expressions of this formula, n is .5, 1, 1.5... and consequently K is a factor of 2 greater than K quoted in this table).

For a detailed description of the technique used to reduce QHM observations, see Crosthwaite (1986).

Since the age of hand calculation of results is long past, and calculators/computers are designed to multiply far more effectively than add calculated logarithms, the author suggests the multiplicative "K" form of the equation be used in preference to the logarithmic "C" form in future to prevent arbitrary inconsistencies between data sets due to the reduction method employed.

Thermometer	-10°C	+0°C	+10°C	+20°C	+30°C	+40°C
1650	-0.10	+0.00	+0.05	+0.20	+0.10	+0.15
1416	-0.10	- 0.10	- 0.10	- 0.05	- 0.10	- 0.10
1401	+0.10	+0.10	+0.05	+0.00	- 0.50	+0.00
619		- 0.05	+0.00	- 0.05	- 0.10	- 0.10
(704 unlabelled)	+0.00					+0.00
144(N151)		+0.05	+0.00	- 0.15	- 0.05	- 0.05
2385	- 0.20	- 0.20	- 0.25	- 0.15	- 0.10	+0.00

All constants are valid throughout all of 1989.

No instrument corrections have been applied to any reductions of any instrument observations in any part of this report.

Table 3 - Azimuth Marks for Pier A, Absolute Hut

Name of Mark Adopted Azimuth Altitude Slope Distance Reference	Description and History
A 358° 35.4' -0°00.4' about 1500m Oldham, 1957	A natural feature on the eastern end of Lee Island which appears as the right hand side of an overhanging section of rock on the skyline. The feature is difficult to accurately sight as it is vertically asymmetrical. Visible through the doorway. Oldham used this as one of the original observatory marks in 1955 and installed the mark ShortPeg exactly in line with A to locate it.
B not measured not measured not measured (close) Oldham, 1957	A slit in a pipe illuminated by a light within the pipe. Very close to the hut and located on a large boulder at the edge of the ice sheet. Visible through a former peep hole in the northeast wall. Another of Oldham's original marks used for winter observations.
C or SOH 274° 15.0' +1°25.1' 101.55m Oldham, 1957	C is a 35mm diameter post near the Old Variometer Building with a light on top powered from the Old Variometer Building. The light has recently been referred to as SOH; it must be fiddled to repair the bulb.The light is masked with black tape leaving a 15mm gap to view the light bulb. A little imprecise to sight as the light bulb filament (summer mark) is not exactly aligned with the slit (winter mark), which is 0.6' wide. Visible through a peep hole in the northwest wall. C is another of Oldham's original marks. It seems to have been renamed SOH by 1975. It was frequently modified, most recently by Cechet (1984) with the installation of a light SOH at the same azimuth as the post.
BMR 85/2 241° 04.1' -0° 30.4' 59.82m Crosthwaite, 1986	A short hexagonal brass peg with a machined top. Frequently drifted over for much of the year. Visible through a peep hole in the southwest wall. Installed by Crosthwaite at a height for a particular QHM/circle combination.
BMR 89/1 350° 36.9' -1° 52.2' 112.37m this report	A short hexagonal brass peg with a machined top located near the New Variometer Building. Visible through the doorway.
BMR 89/2 019° 14.0' -1° 53.2' 104.56m this report	A short hexagonal brass peg with a machined top located near the New Variometer Building. Visible through a peephole in the northeast wall.
LEE 357° 05.0' +0° 10.5' 1561.25m this report	A short hexagonal brass peg with a machined top and an attached aluminium triangle located on Lee Island. Visible through the doorway just to the right and above the New Variometer Building on the skyline. The mark has a rock cairn nearby which can be used to locate the mark - take care not to confuse the cairn for the mark.
ShortPeg 358° 35.2' -2° 52.9' 34.68m Oldham, 1956	A short circular brass peg close to the absolute hut. It subtends 2.5' arc and leans 0.5' as viewed from Pier A. It is of little use except as a locator for Mark A. The mark was installed in line with Mark A.
TallPeg	A tall circular brass peg, now hidden from view from Pier A by the New Variometer Building.
MVLight 353° 46.8' not measured approx 80.5m this report	A screw in the external light fitting of the New Variometer Building. This is not a very reliable mark, but may be useful if a recent round of angles has been made because it is illuminated. It is the screw midway up the right hand side of the light fitting (near the upper part of the illuminating part). It is only visible through the doorway.

N1 353° 03.2' not measured 87.27m Crosthwaite, 1986	N1 is located in the Variometer Building sensor room. Together with R1, it provides a reference orientation for aligning instruments in the Variometer Building. Both N1 and R1 are hexagonal brass plugs set in the concrete floor. It is no longer visible from Pier A.
R1 not measured not measured not measured Crosthwaite, 1986	R1 is a reference mark for N1 located in the Variometer Building recorder room. It is used for alignment of apparatus in the sensor room. From rounds of angles in 1985 and the adopted azimuth of SOH from A, the azimuth of R1 from N1 can be adopted as 131°49.4'. It is no longer visible from Pier A.

Table 4 - Instrument Comparisons

This table lists the results of instrument comparisons through baselines. ***No instrument corrections have been applied*** to any calculations for any instrument in deriving this data.

Declination comparisons (Mawson)

Date	Instrument A	Instrument B	A-B
9th January 1989	Declinometer 640505 Circle 508813	Declinometer 630332 Circle 611665	0.9'±0.4'
1989	Declinometer 630332 Circle 611665	QHM 300 Circle 611665	-2.4'±0.4'
1989	Declinometer 630332 Circle 611665	QHM 301 Circle 611665	+0.2'±0.2'
1989	Declinometer 630332 Circle 611665	QHM 302 Circle 611665	-0.5'±0.3'
June-August 1989 August-December 1989	Declinometer 630332 Circle 611665	DIM 810/213 Theodolite 311542	-1.0'±0.4' -1.0'±0.3'

Horizontal Field Comparisons (Mawson)

Date	Instrument A	Instrument B	A-B at 18500nT
30th December 1988 2nd January 1989	HTM 704 Circle 611665	QHM 300 Circle 611665	-6.9±2nT -.00037±.00011H
30th December 1988 2nd January 1989	QHM 172 Circle 611665	QHM 300 Circle 611665	37.5±2nT +.00203±.00011H
1989	QHM 300 Circle 611665	QHM 301 Circle 611665	+5.5±1.0nT +.00030±.00005H
1989	QHM 300 Circle 611665	QHM 302 Circle 611665	-0.3±1.6nT -.00002±.00009H

Total Field Comparisons (Mawson)

Date	Instrument A	Instrument B	A-B
26th,27th and 29th January 1989	PPM Elsec 770/188 Bolts Up	PPM Elsec 770/199 Bolts Up	-4.9±2nT
26th,27th and 29th January 1989	PPM Elsec 770/188 Bolts Up	PPM Elsec 770/199 Bolts Down	-1.8±2nT
September 1989	PPM Elsec 770/199 Bolts Up	PPM Elsec 770/206 Bolts Up	-0.4±0.3nT
December 1989	PPM Elsec 770/199 Bolts Up	PPM Elsec 770/206 Bolts Down	-0.3±0.4nT

Inclination Comparisons (Mawson)

Date	Instrument A	Instrument B	A-B
June-August 1989 August-December 1989	PPM Elsec 770/199 Bolts Up & QHM 300	DIM 810/213 Theodolite 311542	0.0'±0.1' 0.0'±0.1'

Declination comparisons (Davis)

Date	Instrument A	Instrument B	A-B
2 March 1990	QHM 174 Circle 14	QHM 494 Circle 73	+4.7'±3.0'

Horizontal Field Comparisons (Davis)

Date	Instrument A	Instrument B	A-B at 16700nT
2 March 1990	QHM 174 Circle 14	QHM 494 Circle 73	+20.0±3.0nT +.00120±.00018H

Total Field Comparisons (Davis)

Date	Instrument A	Instrument B	A-B
1 March 1990	PPM Geometrics 816/1025	PPM Elsec 770/194 Bolts Down	-1.9±1.3nT

Table 5 - Average Uncorrected Quiet Magnetic Field by Month for 1989

1989	X	Y	Z	F	H	D	I
January	8070	-16644	-46122	49693	18497	-64°08.0'	-68°08.8'
February	8045	-16640	-46094	49662	18483	-64°11.9'	-68°09.0'
March	8051	-16638	-46126	49692	18483	-64°10.8'	-68°09.8'
April	8037	-16639	-46112	49676	18478	-64°13.1'	-68°09.8'
May	8039	-16648	-46112	49680	18487	-64°13.6'	-68°09.2'
June	8038	-16652	-46082	49653	18490	-64°14.0'	-68°08.2'
July	8036	-16651	-46079	49650	18489	-64°14.3'	-68°08.2'
August	8031	-16653	-46065	49637	18488	-64°15.3'	-68°07.9'
September	8020	-16650	-46089	49656	18481	-64°16.7'	-68°09.0'
October	8025	-16650	-46073	49643	18483	-64°16.0'	-68°08.4'
November	8040	-16668	-46060	49639	18506	-64°15.1'	-68°06.6'
December	8042	-16677	-46066	49648	18514	-64°15.4'	-68°06.3'
Year	8039	-16651	-46090	49661	18490	-64°13.7'	-68°08.4'

The Quiet Monthly fields were determined by averaging the field on the 5 International Quiet Days.

Table 6 - Average Uncorrected Magnetic Field by Month for 1989

1989	X	Y	Z	F	H	D	I
January	8074	-16637	-46117	49687	18493	-64°06.9'	-68°08.9'
February	8061	-16636	-46130	49697	18486	-64°09.0'	-68°09.7'
March	8025	-16613	-46156	49707	18450	-64°13.1'	-68°12.7'
April	8022	-16618	-46143	49697	18453	-64°14.0'	-68°12.2'
May	8022	-16627	-46117	49676	18461	-64°14.7'	-68°11.0'
June	8016	-16629	-46107	49666	18461	-64°15.9'	-68°10.7'
July	8030	-16644	-46074	49642	18480	-64°14.7'	-68°08.7'
August	8009	-16632	-46095	49655	18462	-64°17.1'	-68°10.2'
September	8019	-16641	-46093	49657	18473	-64°16.3'	-68°09.6'
October	8016	-16638	-46086	49650	18469	-64°16.6'	-68°09.6'
November	8047	-16663	-46090	49666	18505	-64°13.4'	-68°07.5'
December	8057	-16678	-46064	49649	18522	-64°12.9'	-68°05.7'
Year	8033	-16638	-46106	49671	18476	-64°13.7'	-68°09.7'

NOTE

Tables 5 and 6 above were derived using the variometer parameters in Appendix D which are based on the standard instruments without any instrument corrections applied.

Table 7 - K indices 1988, 1989

A list of the average K index and K index distribution (% of total measured 3 hourly intervals) for the years 1988 and 1989 and the months of 1989. The most common K index for each data period is highlighted. The low and high K index % are 0% if absent from the table.

	average K index	K0 %	K1 %	K2 %	K3 %	K4 %	K5 %	K6 %	K7 %	K8 %	K9 %
1988	3.1	9.0	10.4	19.2	**21.1**	17.7	13.9	6.9	1.6	0.2	
1989	3.73	3.0	6.5	14.4	**21.4**	20.6	18.5	11.4	3.2	0.6	0.2
January	4.23		0.8	6.0	22.2	**29.0**	27.0	12.1	2.8		
February	3.91	1.3	5.8	12.9	20.1	20.5	**23.2**	12.1	4.0		
March	4.69	0.8	3.2	3.2	14.1	**24.2**	**24.2**	19.4	5.6	4.0	1.2
April	3.94	1.7	7.5	15.4	**17.9**	15.8	18.3	16.7	6.3	0.4	
May	3.68	0.9	6.5	**21.9**	20.9	15.3	18.1	11.2	4.7	0.5	
June	3.10	6.3	11.7	18.8	**21.7**	20.4	14.6	5.8	0.4	0.4	
July	2.42	16.1	14.5	**22.6**	19.4	16.5	8.5	1.6	0.8		
August	3.41	3.9	10.5	19.2	**23.1**	13.5	15.7	9.6	2.6	1.3	0.4
September	3.20	3.3	9.6	22.5	**23.3**	22.5	10.0	6.3	2.5		
October	3.84	1.2	5.2	14.9	**25.4**	19.4	14.9	12.5	6.0	0.0	0.4
November	4.06		1.7	10.4	**26.3**	20.4	25.8	13.8	1.7		
December	4.21	0.4	1.2	6.5	23.0	**28.2**	22.2	16.1	1.6	0.8	

Table 8 - Seismograph Parameters

Component	SPZ	LPZ
Seismometer	Benioff (SN 55)	PressEwing SV282 (SN 11)
Free period (sec)	0.95	16.2
Mass (kg)	(107.5)	(6.9)
Coil Resistance (nominal)	1000Ω	500Ω
Damping Resistance	386.5Ω	5120Ω
Power Supply	PP2	PP2
Preamplifier	TAM5	TAM5
Bandpass filter (Hz)	1-5	0.01-0.2
Gain/Attenuation (db)	96/-12	96/-24
Recorder	Geotech RV-301	Geotech RV-301
Recorder Amplifier	Geotech AR320	Geotech AR320
Chart Rate (mm/min)	60	15
Polarity	Up/Up	Up/Up
Motor Constant G (N/A)	1.48	0.177
Calibrator Coil Resistance	(247Ω)	(3300Ω)

() bracketed values are taken from previous reports or instrument specifications.

Table 9 - SPZ Seismometer Calibration (27th July, 1989)

The calibrations were carried out with the following settings:
TAM5 Gain 96db, Attenuation -12db, bandpass 1-5 Hz
AR320 Attenuation -18db

G is measured as $g.(X_p/I_p)/(X_m/m)$.
X_p/I_p=13.12 mm/mA using currents of 1 and 2 mA.
X_m/m=86.97 mm/g using masses of 60 to 300 mg.
Hence G = 1.48 N/A

Free period measured as 0.948 seconds, Damping resistance = 386.5Ω

The calibration current was generated using a BWD Minilab function generator. The nominal period was taken from the function generator scale. The measured period was taken from the seismic records or measured directly using a stop watch. The peak to peak current was measured across a 1007Ω resistance using a peak voltmeter.

The Magnification at measured T was derived from the seismic charts. The Magnification at nominal T was interpolated from a log/log graph of the measured data.

Period (sec) (nominal)	Period (sec) (measured)	peak to peak current(mA)	Magnification at measured T	Magnification at nominal T
0.1	0.1	4.095	0	13,000
0.15	0.15		24,900	25,000
0.2	0.20		40,264	40,000
0.25	0.25		67,224	67,000
0.3	0.33		82,495	80,000
0.4	0.43	2.899	118,870	115,000
0.5	0.53	1.040	159,102	150,000
0.6	0.64		172,868	170,000
0.7	0.74		177,055	178,000
0.8	0.87		157,608	172,000
0.9	1.00		117,182	150,000
1.0	1.09		92,835	117,000
1.0	0.97		127,236	
1.1	1.06		100,193	87,000
1.2	1.15		75,939	65,000
1.3	1.24		59,261	52,000
1.5	1.44		35,723	33,000
2.0	1.93		12,751	10,100
3.0	2.92	1.620	2,735	2,500
4.0	3.53	0.986	1,095	800
5.0	4.88		404	380

Table 10 - LPZ Seismometer Calibration (30th July, 1989)

The calibrations were carried out with the following settings:
TAM5 Gain 96db, Attenuation -24db, bandpass 0.01-0.2 Hz
AR320 Attenuation -24db

G is measured as $D/B.g.(X_p/I_p)/(X_m/m)$. The test masses were placed at the nominal centre of mass of the boom/seismometer mass system. i.e. D=B=370mm.
X_p/I_p=8.207 mm/mA using currents of 4 mA.
X_m/m=454.1 mm/g using a mass of 60mg.
Hence G = 0.177 N/A

Free period measured as 16.2 seconds, Damping Resistance = 5120Ω.

The calibration current was generated using a BWD Minilab function generator. The nominal period was taken from the function generator scale. The measured period was taken from the seismic records or measured directly using a stop watch. The peak to peak current was measured across a 1007Ω resistance using a peak voltmeter.

The Magnification at measured T was derived from the seismic charts. The Magnification at nominal T was interpolated from a log/log graph of the measured data.

Period (sec) (nominal)	Period (sec) (measured)	peak to peak current(mA)	Magnification at measured T	Magnification at nominal T
1	0.97	1.063	-	-
2	1.92		511	520
3	2.94		636	630
4	3.83		621	630
5	4.79		631	600
6	5.69		586	570
7	6.63		553	530
8	7.58		504	490
9	8.73		474	460
10	9.74		446	430
10	11.83		396	
11	13.09		359	400
12	14.19		324	380
13	15.36		286	350
14	16.38		253	320
15	17.63		218	290
16	18.98		180	270
17	20.08		153	240
18	20.83		136	200
19	22.10		113	180
20	23.43		94	160
25	29.43		45	70
30	36.50		23	43
40	47.67		9	18
50	60.85		4	8
60	-	-	-	4

Figure 1 - K index Distribution 1988/89

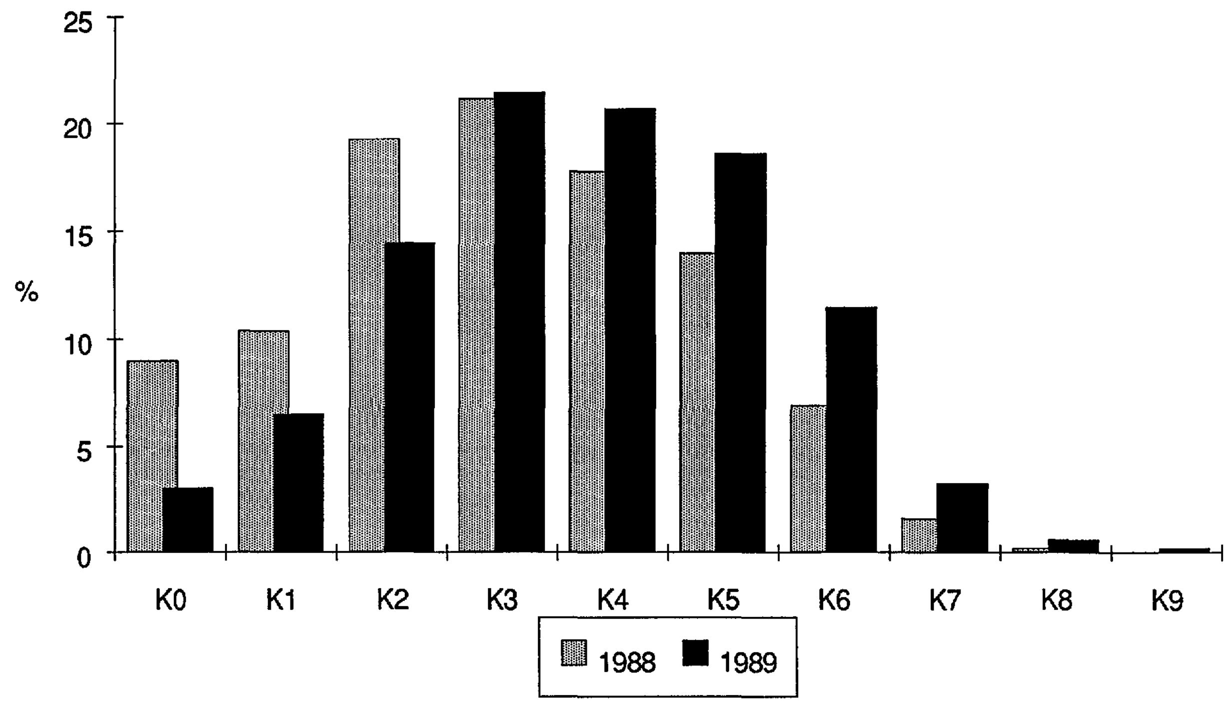
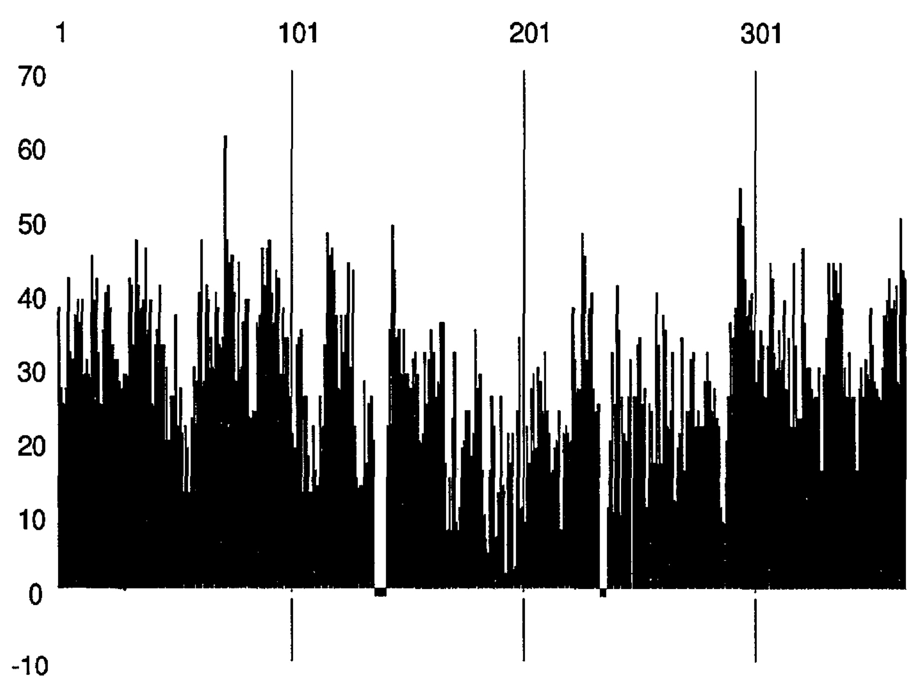
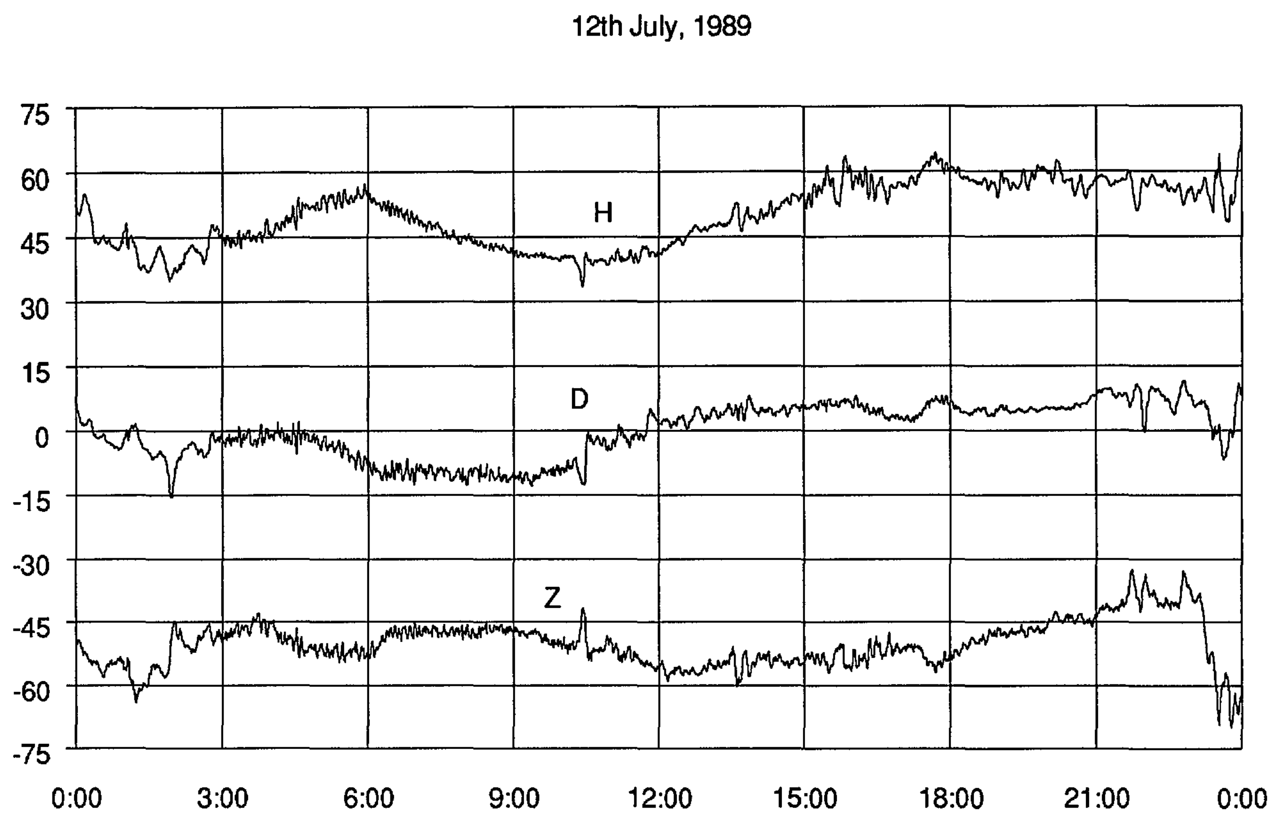


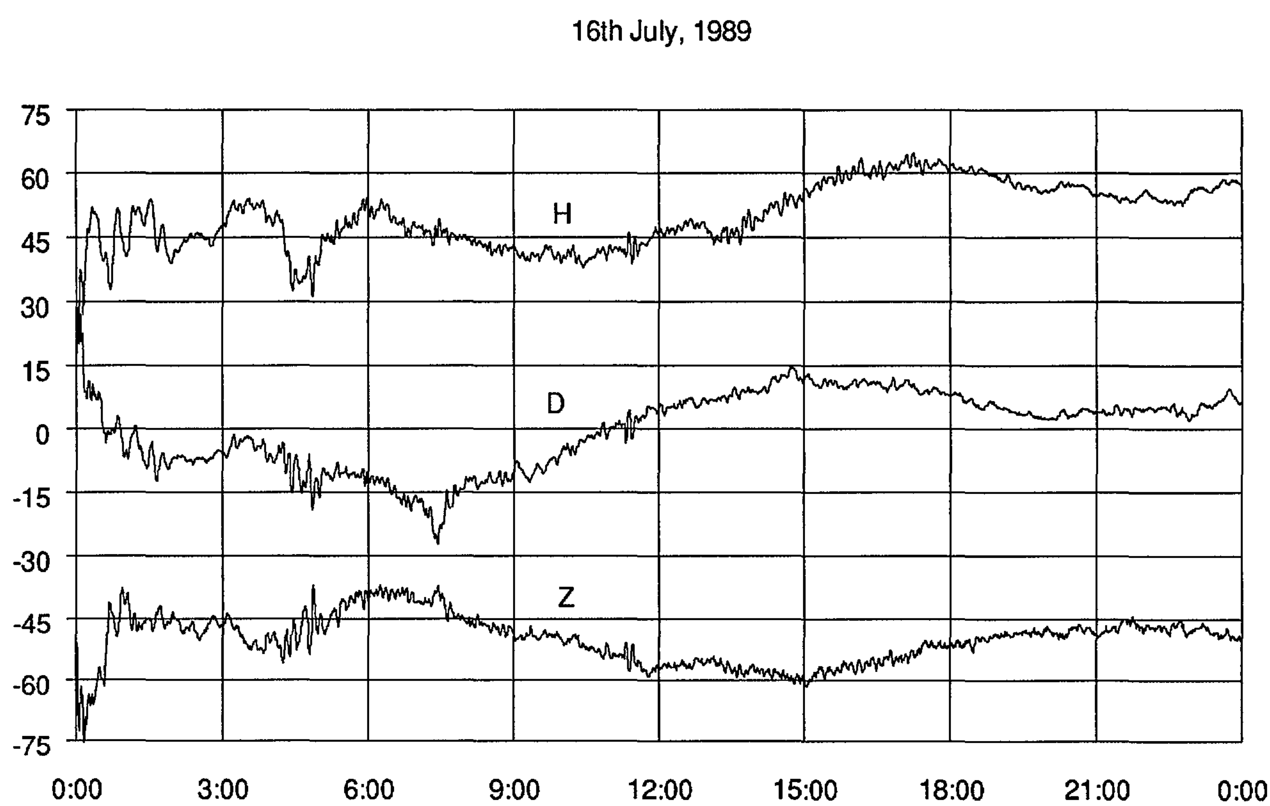
Figure 2 - Magnetic Activity (Daily K index sum) 1989



(Daily K sum versus Day of year; negative K sums represent missing data)

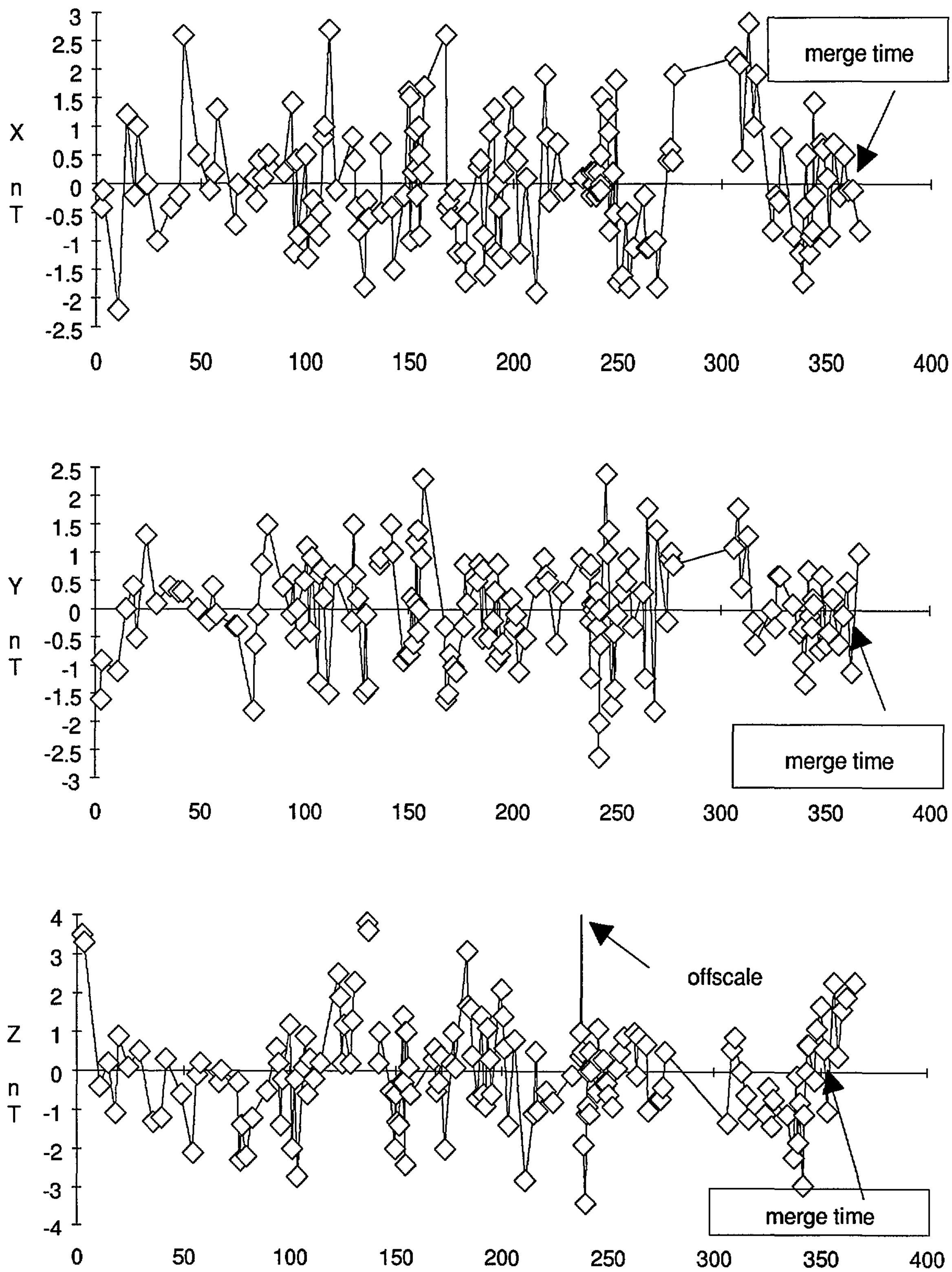
Figure 3 - Quiet Day Magnetograms





The two quietest UTC days of the year were Day 193, 12th July 1989 (K2) and Day 197, 16th July 1989 (K3).
The vertical scale increments are in units of K0=15nT, relative to an arbitrary baseline. The horizontal scale is UTC time. There is an apparent regularity in H, D and Z.

Figure 4 - XYZ Baseline Residuals 1989



The figures represent the difference between the measured value of the field through absolute observations and the value derived from the variometer parameters and data plotted against day of year (day 1 = 1st January 1989). The "merge times" are the suggested dates to be used for splicing functions to merge the 1989 data set and the 1990 data set.

Figure 5 - Geomagnetic Equipment Schematic

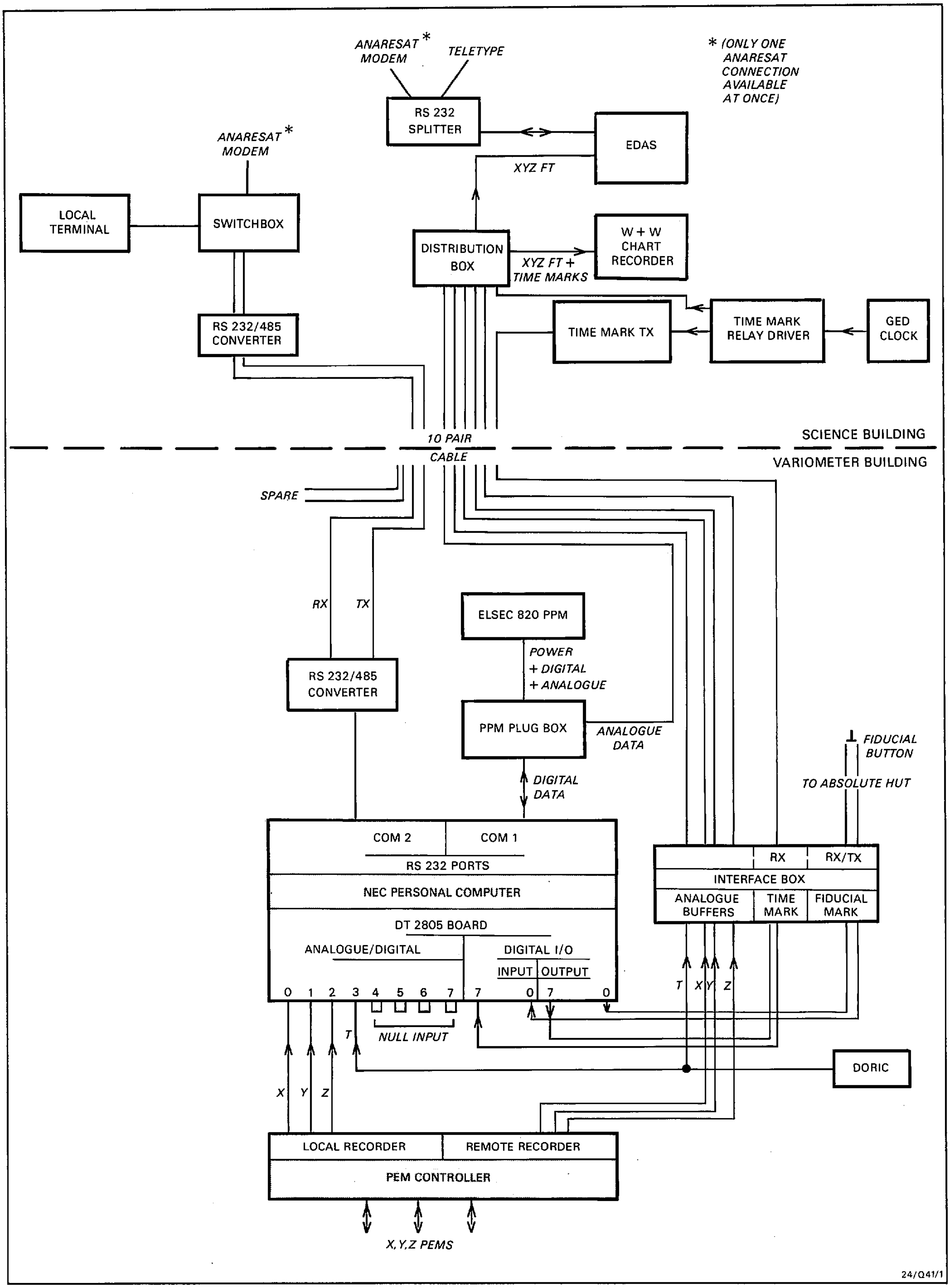
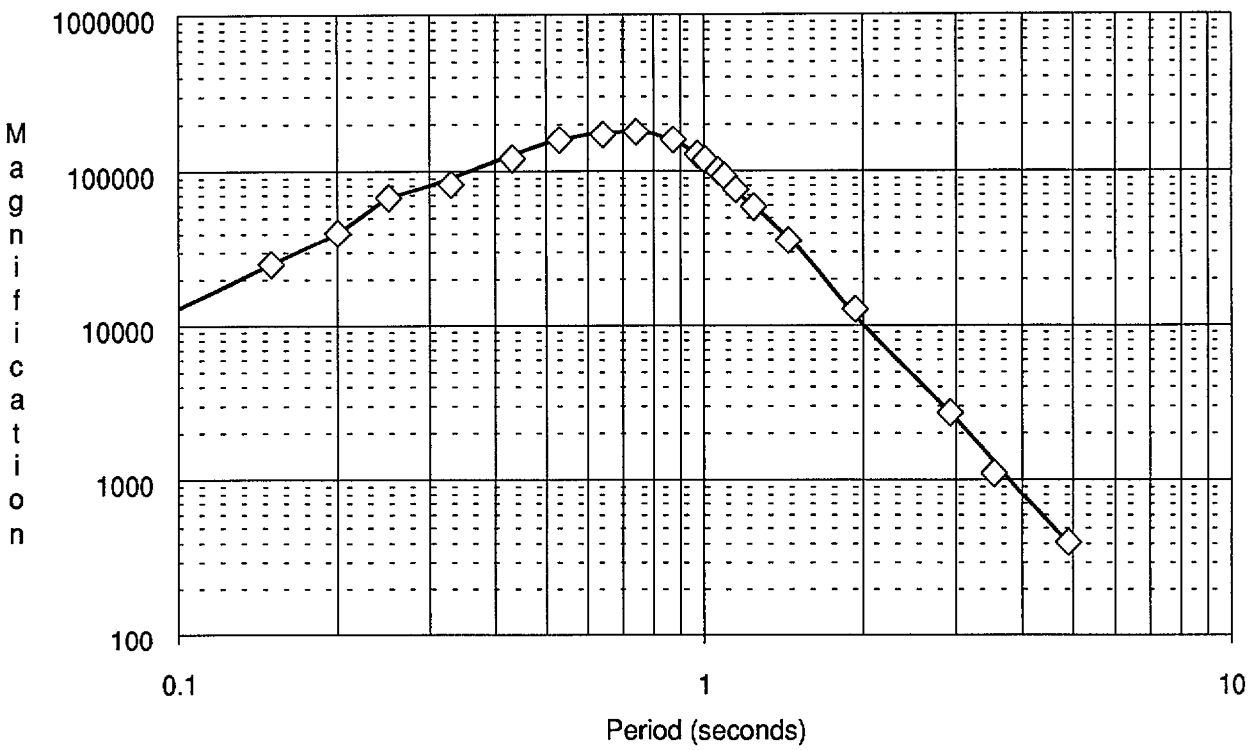
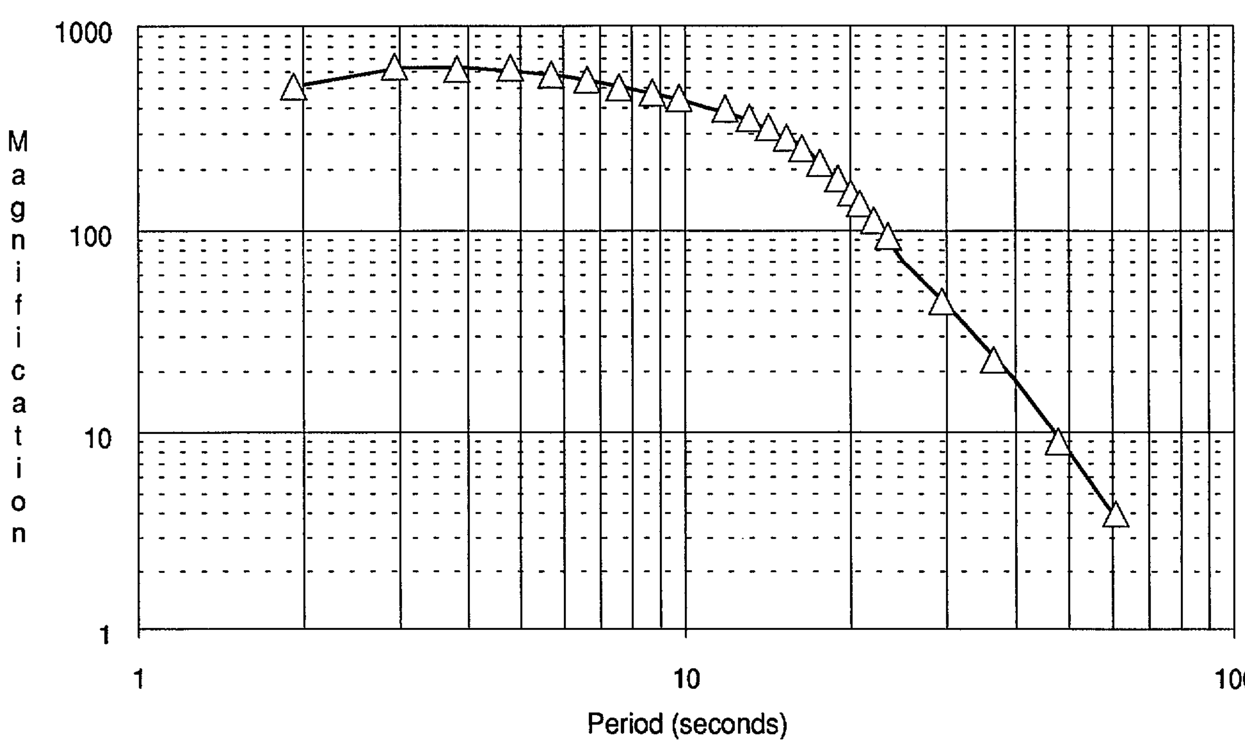


Figure 6 - SPZ Seismometer Calibration (27 July 1989)



The line represents the adopted magnifications at the nominal periods in Table 9. The diamonds represent the measured magnifications at the measured periods.

Figure 7 - LPZ Seismometer Calibration (30 July 1989)



The line represents the adopted magnifications at the nominal periods in Table 10. The diamonds represent the measured magnifications at the measured periods.