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Port Stanley Observatory Service Report 6 – 11 September 2004

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Looking towards Mount William and Tumbledown from Sapper Hill.

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Foreword

This report details repairs made to the equipment operating at the Port Stanley Magnetic Observatory in the Falkland Islands during September 2004. Port Stanley is one of three overseas magnetic observatories maintained and operated by the British Geological Survey in addition to three in the UK. Measurements are collated in Edinburgh and are primarily used to model the main magnetic field of the Earth.

Acknowledgements

Simon Flower of BGS, who is jointly responsible for the operation and maintenance of the Port Stanley observatory and has developed much of the recording equipment and software, provided valuable help and advice prior to the visit. The visit and work carried out thereafter would not have been possible without the considerable assistance provided by Nigel Bishop and David McLeod of Cable and Wireless, Port Stanley.

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Summary

This report describes repairs and upgrades made to the Port Stanley Magnetic Observatory during a visit to the Falkland Islands in September 2004. Damage caused by a lightning strike in March of this year stopped the automated magnetic data recordings up to the time of the visit. The work undertaken during the visit and documented in this report was sufficient to restart the recordings. Since the report is intended as a technical reference for observatory operation, the instruments, computing equipment, software and cabling have been described in detail.

1 Introduction

In February 1994, the British Geological Survey (BGS) installed an automated observatory to monitor changes in the geomagnetic field vector at Sapper Hill, near Port Stanley in the Falkland Islands. The observatory was upgraded in February 2002 (Turbitt & Flower, 2002) using instruments less prone to temperature and humidity variations, and using recording equipment capable of communicating the data in near real-time to Edinburgh in the UK. Flower and Harris (2003) document the installation of a second data logger to capture readings from a number of meteorological instruments installed close to the magnetic observatory site. A severe lightning strike close to the observatory on 14th March 2004 stopped the automatic recordings as well as damaging some of the magnetic and meteorological instruments. Despite efforts by BGS and local Cable & Wireless staff, it became obvious that the most efficient way to restart the observatory was to ship a complete set of replacement equipment from the UK and visit the site in person. This report describes a visit to the observatory between 7th and 10th September 2004, documenting the damage found, work undertaken to repair the observatory and some of the additional precautions taken to minimise the risk of future lightning damage.

At the time of the lightning strike, the observatory was running a BGS GDAS observatory system with a DMI FGE fluxgate magnetometer and a Geomag SM90R Overhauser proton precession magnetometer (PPM). The three magnetic and one temperature channel of the fluxgate magnetometer were sampled at 1 Hz via a pair of Advantech ADAM-4017 modules, while the PPM was sampled at 0.1 Hz. All data were synchronised to UTC using a Garmin GPS35-HVS receiver and the data were transmitted via an Internet connection every five minutes to Edinburgh for processing. Monthly manual absolute magnetic measurements were provided by Alex Blake (of the Falkland Islands Department of Mineral Resources) in order to quantify and correct for any instabilities in the vector variometer data from the fluxgate magnetometer.

2 Observatory Equipment

The lightning strike was not a direct hit on any of the observatory installations, but rather the damage was thought to have been caused by large, transient, induced currents in the cables connecting components of the observatory instrumentation. This means that the Cable & Wireless hut (which houses the data recorders), the fluxgate magnetometer hut, the absolute hut and the PPM enclosure were undamaged and continue to offer good protection to the instruments.

The remainder of this section describes the damage done and repairs made to the observatory components in detail.

2.1 GDAS DATA LOGGER

On arrival, the GDAS PC was found to be unresponsive to telnet or ftp access requests and would not react to keyboard input. The PC recovered after a power down and it may be that the keyboard problem was a consequence of the keyboard having been unplugged and re-plugged during tests by Cable & Wireless. Since the PC was powered down, either this or previous incorrectly sequenced shutdowns had caused the file system to become corrupt. Boot sequence checks detected an error in the /home/sdas/data directory and this directory was marked as corrupt (using the QNX zap utility). The disk integrity was then rechecked (using chkfsys) and the SDAS acquisition restarted. Following the restart, data were recorded in a relocated

/home/sdas/data directory on the disk and the previously recorded data are no longer accessible locally, although they have been transmitted to Edinburgh.

The current PC (S/N GMAG-QPC.03-025) was installed in April 2004, replacing the original PC (S/N GMAG-QPC.02-016), which had been severely damaged by the lightning strike to the extent that the main processor board and the connector breakout board were beyond repair. Once the acquisition had been started, it became evident that the serial port connected to the proton precession magnetometer (COM4) of the replacement PC was not transmitting or receiving. This fault was traced to a missing link on the serial port printed circuit board, which meant that the serial port ground was not connected to the main processor board. This was a fault in manufacturing and was repaired on site.

2.2 PROTON PRECESSION MAGNETOMETER

Following the lightning strike, the proton precession magnetometer installed in the sensor hut (Geomag SM90R S/N 13158) was still responding to serial port commands and it calibrated correctly but it continually gave field readings of C0000000, suggesting that the polarising circuit had been damaged. There appeared to be some heat damage to two of the integrated circuits on the RF board of the magnetometer. This PPM was returned to the UK for repair and was replaced with a Gem Systems GSM90 V6 (S/N 4051375). The sensor bottle was not replaced.

The cable between the PPM electronics and the sensor bottle was shortened to approximately 10 metres from a length of 25 metres by pulling the excess cable through to the sensor enclosure, then cutting the excess and fitting a new BNC connector. The connector was fitted to the sensor end since the tri-axial cable has an additional ground connection at the end connected to the electronics.

There were three reasons for shortening the cable:

- A shorter cable is less susceptible to the transient, induced currents generated by a lightning strike close to the sensor hut - assumed to be the cause of the damage to the magnetometer.
- Shortening the cable reduces the sensitivity of the magnetometer to externally generated radio signals. The observatory is close to a number of communication antennas, broadcasting at high power over a wide range of frequencies. Radio frequency interference has previously been the cause of poor quality magnetic recordings. Following the modification, the signal-to-noise ratio indicated by the PPM with each reading is consistently very high (‘99’).
- Excess cable had previously been coiled in the sensor hut, within a metre of the fluxgate magnetometer sensor. The polarisation current in the cable generated a +3 nT step in the H- and D-components of the fluxgate one-second data; lasting for around two seconds every ten seconds. This cross-contamination between the magnetometers was eliminated by routing the cable directly from the sensor hut to the proton sensor enclosure.

It is worth noting that the PPM signal strength was reduced when the PPM was sampled using a PC other than the GDAS PC, which may be attributed to a grounding problem. The PPM power and signal grounds are connected together inside the PPM electronics, but are brought separately to the power and the data connectors.

The PPM was calibrated to verify that the changes made did not have a significant effect on the operation of the instrument. The calibration is listed in detail in Appendix B.

2.3 FLUXGATE MAGNETOMETER

The only damage caused by the lightning strike to the fluxgate magnetometer electronics (DMI Rev. FGE98G S/N E0262) was on the DC-DC converter used to condition the input power supply voltage to ±15 VDC. The Ericsson PKV3325 PI was replaced with a Traco Power TEN 3-1223 converter. Subsequent tests and calibrations confirmed that there was no further damage to the electronics or the fluxgate magnetometer sensor.

As a precaution, the aluminium foil was removed from the fluxgate electronics and the digitiser box to reduce the risk of future lightning damage. The aluminium foil had been added during a previous service visit to provide a Faraday shield against the high-power RF signal generated by the communications systems close to the sensor hut. The foil was also connected to an earth spike, which meant that the GDAS power supply DC 0V was grounded via the aluminium case of the fluxgate electronics and the long cable between the recording hut and the sensor hut. Although the 0V is not connected directly to ground at the recording hut, it is indirectly connected via the transformer and the DC-DC converter in the GDAS power supply. The foil was removed to isolate the 0V from earth and therefore reduce the risk of another lightning-induced transient from damaging either the transformer or the DC-DC converters of the power supply or the fluxgate magnetometer.

Due to the structure of the fluxgate magnetometer sensor, it is more likely to be susceptible to RF interference than the electronics and since the foil added to the sensor is electrically isolated from the sensor by the thermal insulation, the foil was left in place around the sensor.

Component	H	D	Z
Calibration (µV/0.1nT)	249.88	250.07	246.36
SDAS Values (µV/0.1nT)	251.00	249.65	252.13
Difference (%)	0.45	-0.17	2.34

Table 1 Fluxgate Calibration Values

Table 1 lists the fluxgate magnetometer calibration values obtained during the visit (Appendix B) and those recorded in the SDAS configuration file. Since the SDAS values are derived from calibrations made on previous service visits, the difference between these sets of values suggests that the fluxgate magnetometer scale constants have changed significantly since February. The cause of this change is not known, but is likely due to the voltage regulator change described earlier. The SDAS configuration was updated to reflect these new calibration values.

2.4 GDAS POWER SUPPLY

There was no detectable damage to the GDAS power supply by the lightning strike, but the mains electricity supply to the Cable & Wireless hut may have been the source of the transient current which damaged the other GDAS components. A Furse ESP 240 M1 lightning suppressor was added to the 220 VAC mains supply in the recording hut, as a precaution against future strikes. The lightning suppressor was grounded via the hut earth point and was fitted with a four-way distribution board, into which the uninterruptible power supply (UPS), the GDAS power supply, the GDAS display and the environmental monitoring PC were connected. The UPS provides a reserve power supply to the network hub, router, the meteorological instruments and the GDAS modem.

A power reserve of up to 24 hours to the GDAS PC, fluxgate magnetometer, proton precession magnetometer and GPS receiver is provided by a 12 V, 38 Ah battery. As shown in Table 2, switching off the mains supply to the GDAS system for two hours between 17:38 and 19:39 on 8 September successfully tested this reserve.

Expected voltages	Measured voltages: Mains supply switched on	Immediately after mains supply switched off	Two hours after mains supply switched off
+13.8 V	+13.80 V	+13.27 V	+12.39 V
+15.0 V	+14.96 V	+14.96 V	+14.96 V

Table 2 Power Supply Voltages

The 15 VDC of the power supply was measured as 13.3 V at the sensor hut, while under the load of the fluxgate magnetometer and the digitiser box. This drop in voltage is due to the resistance of the cable between the two huts and the current drawn by the magnetometer and digitiser.

2.5 METEOROLOGICAL DATA LOGGER

On arrival, the PC used to record the meteorological data did not have an active login user shell and would not recognise either *sdas* or *root* user logins. Neither was it possible to login via telnet. Although the PC was still recording data in this state, it was rebooted and returned to full function. The time on the PC was 01 hours and 07 minutes slow at 13:30 on 7 September and the clock was set.

2.6 METEOROLOGICAL SENSORS

The meteorological station - providing wind speed, wind direction, temperature and humidity measurements - has no apparent damage resulting from the lightning strike. The separately mounted rain gauge, however, was not operational at the time of the visit. The tilting bucket of the gauge temporarily interrupts a 5 VDC signal from the rain gauge electronics located in the recording hut. This negative going pulse is fed via a Schmitt-trigger inverter to pin 10 of the parallel port of the environmental monitoring PC, providing an interrupt to the rain gauge software driver. The rain gauge electronics contains a DC-DC converter to condition the 12 VDC supply to the 5 VDC required by the gauge and this converter was tested and found to be working, as was the external sensor, but the inverter IC (a CD 4093 BCN) has been damaged such that the pulse generated by the sensor is not output to the PC. In addition, the software driver did not detect an artificial pulse generated on pin 10 of the PC's parallel port, suggesting that the PC may have also been damaged. It was not possible to repair either the rain gauge inverter or the PC during the visit and both are currently in need of repair or replacement.

3 Temperature Data

The Tinytalk temperature data recorder (S/N 26851) in the sensor hut was stopped and the data offloaded at 18:32 on 8 September. Data recorded between 29 February and 8 September 2004 have been plotted in Appendix D. The statistics on the temperature variations over this period are:

Maximum temperature: 20.9 °C

Minimum temperature: -2.7 °C

Average temperature: 4.6 °C

The Tinytalk battery was replaced as a precaution and the logger restarted, sampling every 1.5 hours and giving a capacity of 493 days.

4 Absolute Observations

Once the magnetometers and recording equipment were repaired and normal observatory operations resumed, a set of five manual absolute magnetic measurements were made over two days. These absolute measurements are essential to establish the offset (or baseline) values of the fluxgate magnetometer, particularly in light of the modifications made to the magnetometer and the resulting change in the calibration values described in Section 2.3. The measurements are listed in detail in Appendix A, along with the derivation of the baseline values. The baseline values have also been summarised in Table 3, including the mean of the March 2004 observations to highlight the changes resulting from the magnetometer repairs.

Observation	Declination	Horizontal Component	Vertical Component
March 2004	4° 08' 39"	19176.9 nT	-22084.2 nT
1	4° 06' 14"	19175.7 nT	-22097.5 nT
2	4° 06' 17"	19175.7 nT	-22097.5 nT
3	4° 06' 08"	19175.3 nT	-22097.4 nT
4	4° 06' 24"	19175.4 nT	-22097.2 nT
5	4° 06' 09"	19175.0 nT	-22097.7 nT
Mean	**4° 06' 14"**	**19175.4 nT**	**-22097.5 nT**

Table 3 Fluxgate Magnetometer Baselines

4.1 TRUE NORTH REFERENCE BEARINGS

Although the declination angle is referenced to the direction of true north, it is not common practice to determine the direction of true north for each observation. Rather, true north is initially determined with respect to a permanent mark and subsequent declination measurements are made with reference to that mark. Riddick (1999) determined that the bearing of the memorial cross on Tumbledown Mountain from the absolute observation position is 281° 31' 01" from true north, so the five declination measurements described above were made using sightings on the memorial cross fixed mark.

This primary fixed mark is sufficiently well defined to reduce the likelihood of sighting errors and is distant enough from the observing position such that any locating error of the theodolite on the tripod doesn't introduce a significant error in declination. Frequently, however, the memorial cross is obscured by fog or precipitation and there is a need for a closer fixed mark. Riddick (2001) describes an auxiliary mark on the escarpment to the north of the absolute observing position – this is the left-hand edge of the visible metal peg protruding from the concrete base of a former gun emplacement. The true north bearing of this mark was established in 2001 as 001° 46' 45". Measurements during subsequent visits estimated the bearing to be 1° 43' 57" (Turbitt, 2002) and 001° 46' 15" (Flower, 2004)

This auxiliary mark is approximately 20 metres from the absolute pillar and such a short baseline probably accounts for the large scatter in the measured bearings, as the bearing is very sensitive to the theodolite position on the tripod.

To solve this problem, another, more distant, mark was established (Figure 1). A two-metre section of angled steel post was mounted vertically in concrete, approximately sixty metres to the west of the absolute hut where it is clearly visible through the observation hatch of the absolute hut.

Figure 1 Auxiliary Fixed Mark

Table 4 lists the circle readings of sightings on both the primary and auxiliary marks and also the true north bearing of the auxiliary mark derived from these readings.

Mark	Circle Reading	Mean Difference	True North Bearing
Memorial Cross, Tumbledown	CR 279° 36' 12"	000° 20' 39"	281° 31' 01"
	CL 099° 36' 10"		
New Auxiliary Mark	CR 279° 15' 33"		281° 10' 22"
	CL 099° 15' 31"		

Table 4 Fixed mark true north bearings

The bearing of the auxiliary fixed mark relative to the primary fixed mark should be measured as part of the normal service routine during future visits. Outwith service visits, Alex Blake of the Falkland Islands Government Department of Mineral Resources makes absolute measurements once per month and he has been instructed to use the new auxiliary mark when the primary mark is not visible.

4.2 SITE DIFFERENCES

The difference in the field magnitude between the absolute pillar and the GDAS PPM site was measured by running a second Proton Precession magnetometer (GSM-19 S/N 701595) concurrently with the GDAS PPM.

5850 ten-second, total field samples were taken from 20:40:20 on the 8 September 2004, with the average difference ($F_{ABSOLUTE} - F_{GDAS}$) equal to -30.2 nT (standard deviation 0.2nT). This compares favourably with all of the site difference value measured following the PPM relocation in February 2004 (-30.7 nT), indicating that there has been no significant magnetic contamination introduced to the site that may have affected the absolute observations and derived baselines.

A value of –30.2 nT has been added to the GDAS PPM data at the time of the absolute observations performed during the visit. The corrected total field readings are then used to reduce the absolute inclination measurements to horizontal and vertical field components and to determine the fluxgate magnetometer baselines.

In previous years, the site difference has changed significantly between the annual service visits, although the cause has never been determined. So that any future variations can be closely monitored, the GSM-19 PPM has been left with Alex Blake so that he can measure the total field site difference each time he makes an absolute observation.

5 Conclusions and Recommendations

Although the lightning strike in March 2004 damaged a number of components of the magnetic and meteorological observatory at Port Stanley, work completed during the visit in September 2004 was sufficient to restart the automated recordings of all but the rain gauge. Some precautions were taken to minimise the risk of further damage by lightning, but despite this, the recordings were stopped again in November 2004 by another strike. Having discussed the need to maintain reliable recordings at this very vulnerable site, we have come to the following conclusions:

1. The lightning suppression barriers in place in the Cable & Wireless hut are not adequately protecting the long data and power lines between the Cable & Wireless hut and the sensor hut. The connection between the lightning suppression box and earth needs to be checked and possibly improved. Further lightning protection needs to be added to the power lines of the fluxgate magnetometer/digitiser and the GPS receiver in the sensor hut.
2. The GPS, PPM and digitiser data lines between the sensor hut and the Cable & Wireless hut should be electrically isolated, possibly using fibre optic links to eliminate the risk of induced transient currents.
3. Cable & Wireless should keep a set of pre-configured, plug-in spares for as much of the observatory system as provision will allow.

As described in Section 2.6, the rain gauge was not repairable during the visit and the gauge's inverter (and possibly the recording PC) will need to be either repaired or replaced during the next service visit. All future service visits should confirm the true north bearing of the auxiliary fixed mark by measuring the difference in circle reading between the auxiliary and primary marks.

Shortly after the visit, and despite the interruption to the recordings, the data being recorded at Port Stanley magnetic observatory was deemed of sufficiently high quality that the observatory has been accepted as an INTERMAGNET observatory (IMO). The observatory's isolated location means that Port Stanley data are of particular importance to those studying the geomagnetic main field and ionospheric current systems in the Polar Regions, and so it is important that the observatory continues to provide reliable, quality data. One recommendation of the INTERMAGNET committee on accepting the observatory as an IMO was that the frequency of the absolute measurements is increased from one per month to at least one per fortnight and this is to be discussed with Alex Blake.

Glossary

ADC Analog-to-digital converter – Used to convert the analog output of an instrument to a digital record for recording and transmission.

Fluxgate Abbreviation of fluxgate magnetometer – a vector magnetometer, here composed of three orthogonally mounted elements.

GDAS Geomagnetic Data Acquisition System – The proprietary data recording system of the British Geological Survey, developed specifically for operation at unmanned observatories. This system supersedes the FLARE *Plus* data logger.

GPS Global Positioning System – A system consisting of an array of satellites, base stations and remote receivers which has been designed to give accurate position and time.

PC Personal Computer – a term used to describe a computer capable of operating independently of other computers, typically based on the Intel 8086 chipset.

PPM Proton Precession Magnetometer – a scalar, full-field instrument, capable of giving a quasi-absolute measurement of the magnetic field.

PSU Power Supply Unit – A device for providing electrical power to another device or instrument, usually by conditioning another electrical power source.

UTC Coordinated Universal Time – a global time reference, used to relate observations between observatories.

Variometer An instrument which only measures variations of a natural element with respect to an arbitrary offset value, rather than measuring the true (absolute) value.

References

Most of the references listed below are held in the Library of the British Geological Survey at Keyworth, Nottingham. Copies of the references may be purchased from the Library subject to the current copyright legislation.

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Appendix A Absolute Observations

The following entries list the manual measurements made at the Port Stanley observatory absolute observing site using a fluxgate theodolite magnetometer. These null-method measurements are used to determine a precise vector measurement of the magnetic field to estimate the offsets, or baselines, of the vector variometer instrument.

ABSOLUTE OBSERVATION 1

```
Observatory: Port Stanley
Logger: fkqa
Observer: Turbitt
Date: 09 Sep 2004
Site Difference:    -30.2
Theodolite serial number: 160332
Fluxgate serial number: 0754H

FIXED MARK READING

        CR 1:          279°  36'  09"
        CL 1:          099°  36'  04"
        CR 2:          279°  36'  09"
        CL 2:          099°  36'  12"
        Mean:          189°  36'  09"

     FM True:          281°  31'  01"
   TN Circle:          178°  05'  08"

DECLINATION OBSERVATION
                                                             VarD(nT)
          WU: 13:30   091°  45'  32"    91.7589°               -122.3
          ED: 13:33   091°  42'  32"    91.7089°               -122.0
          WD: 13:25   271°  53'  49"   271.8969°               -123.0
          EU: 13:27   271°  55'  15"   271.9208°               -122.7
        Mean: 13:28   181°  49'  17"

 Declination: 13:28   003°  44'  09"     3.7359°

INCLINATION OBSERVATION
                                                    PPMF(nT) VarH(nT) VarZ(nT)
          NU: 13:38   131°  01'  29"   -48.9753°    29123.4   -106.0    125.7
          SD: 13:40   311°  02'  31"   -48.9581°    29123.3   -106.2    125.7
          ND: 13:43   229°  07'  57"   -49.1325°    29123.2   -106.2    125.7
          SU: 13:46   049°  06'  53"   -49.1147°    29122.7   -106.9    125.8

 Inclination: 13:41  -049°  02'  43"   -49.0451°

BASELINES

          Absolute      GDAS  Baseline
F (nT):    29093.0   29123.2     -30.2
D(deg):     3.7359   -0.3681    4.1040  004°  06'  14"
H (nT):    19069.4    -106.3   19175.7
Z (nT):   -21971.8     125.7  -22097.5
I (deg):  -49.0451

COLLIMATION ERRORS

Declination Delta:      000° -01'  06"
Declination Epsilon:    000° -04'  33"
Declination Zo (nT):  -2.2
Inclination Epsilon:    000° -04'  42"
Inclination Zo (nT):   4.4
```

ABSOLUTE OBSERVATION 2

Observatory: Port Stanley
Logger: fkqa
Observer: Turbitt
Date: 09 Sep 2004
Site Difference: -30.2
Theodolite serial number: 160332
Fluxgate serial number: 0754H

FIXED MARK READING

CR 1:	279°	36'	09"
CL 1:	099°	36'	04"
CR 2:	279°	36'	09"
CL 2:	099°	36'	12"
Mean:	189°	36'	09"
FM True:	281°	31'	01"
TN Circle:	178°	05'	08"

DECLINATION OBSERVATION

						VarD(nT)
WU:	13:50	091°	46'	04"	91.7678°	-120.2
ED:	13:53	091°	42'	54"	91.7150°	-120.0
WD:	13:56	271°	54'	28"	271.9078°	-119.6
EU:	13:59	271°	55'	46"	271.9294°	-119.4
Mean:	13:54	181°	49'	48"		
Declination:	13:54	003°	44'	40"	3.7445°	

INCLINATION OBSERVATION

						PPMF(nT)	VarH(nT)	VarZ(nT)
NU:	14:05	131°	00'	40"	-48.9889°	29120.6	-112.0	124.2
SD:	14:08	311°	01'	48"	-48.9700°	29120.6	-112.4	123.7
ND:	14:11	229°	08'	41"	-49.1447°	29120.4	-113.5	123.1
SU:	14:13	049°	07'	42"	-49.1283°	29120.5	-113.9	122.6
Inclination:	14:09	-049°	03'	29"	-49.0580°			

BASELINES

	Absolute	GDAS	Baseline			
F (nT):	29090.3	29120.5	-30.2			
D(deg):	3.7445	-0.3601	4.1046	004°	06'	17"
H (nT):	19062.7	-112.9	19175.7			
Z (nT):	-21974.1	123.4	-22097.5			
I (deg):	-49.0580					

COLLIMATION ERRORS

Declination Delta:	000°	-01'	07"
Declination Epsilon:	000°	-04'	37"
Declination Zo (nT):	-2.6		
Inclination Epsilon:	000°	-04'	43"
Inclination Zo (nT):	4.5		

ABSOLUTE OBSERVATION 3

Observatory: Port Stanley
Logger: fkqa
Observer: Turbitt
Date: 09 Sep 2004
Site Difference: -30.2
Theodolite serial number: 160332
Fluxgate serial number: 0754H

FIXED MARK READING

CR 1:	279°	36'	16"
CL 1:	099°	36'	11"
CR 2:	279°	36'	13"
CL 2:	099°	36'	13"
Mean:	189°	36'	13"
FM True:	281°	31'	01"
TN Circle:	178°	05'	12"

DECLINATION OBSERVATION

						VarD(nT)
WU:	18:15	091°	55'	42"	91.9283°	-65.9
ED:	18:18	091°	53'	00"	91.8833°	-64.8
WD:	18:20	272°	04'	32"	272.0756°	-64.9
EU:	18:23	272°	05'	07"	272.0853°	-65.1
Mean:	18:19	181°	59'	35"		
Declination:	18:19	003°	54'	23"	3.9064°	

INCLINATION OBSERVATION

						PPMF(nT)	VarH(nT)	VarZ(nT)
NU:	18:36	131°	00'	12"	-48.9967°	29128.0	-110.5	115.4
SD:	18:38	311°	01'	16"	-48.9789°	29128.2	-110.0	115.2
ND:	18:31	229°	08'	58"	-49.1494°	29127.9	-110.6	115.3
SU:	18:33	049°	08'	10"	-49.1361°	29127.8	-110.7	115.3
Inclination:	18:34	-049°	03'	55"	-49.0653°			

BASELINES

	Absolute	GDAS	Baseline			
F (nT):	29097.8	29128.0	-30.2			
D(deg):	3.9064	-0.1959	4.1022	004°	06'	08"
H (nT):	19064.8	-110.4	19175.3			
Z (nT):	-21982.1	115.3	-22097.4			
I (deg):	-49.0653					

COLLIMATION ERRORS

Declination Delta:	000°	00'	-49"
Declination Epsilon:	000°	-04'	33"
Declination Zo (nT):	-2.9		
Inclination Epsilon:	000°	-04'	39"
Inclination Zo (nT):	3.9		

ABSOLUTE OBSERVATION 4

Observatory: Port Stanley
Logger: fkqa
Observer: Turbitt
Date: 10 Sep 2004
Site Difference: -30.2
Theodolite serial number: 160332
Fluxgate serial number: 0754H

FIXED MARK READING

CR 1:	279°	36'	12"
CL 1:	099°	36'	10"
CR 2:	279°	36'	12"
CL 2:	099°	36'	10"
Mean:	189°	36'	11"
FM True:	281°	31'	01"
TN Circle:	178°	05'	10"

DECLINATION OBSERVATION

						VarD(nT)
WU:	12:03	091°	49'	21"	91.8225°	-103.4
ED:	12:07	091°	45'	29"	91.7581°	-104.2
WD:	11:58	271°	58'	18"	271.9717°	-103.8
EU:	12:00	271°	58'	22"	271.9728°	-103.9
Mean:	12:02	181°	52'	53"		
Declination:	12:02	003°	47'	42"	3.7951°	

INCLINATION OBSERVATION

						PPMF(nT)	VarH(nT)	VarZ(nT)
NU:	12:13	131°	02'	58"	-48.9506°	29139.9	-81.8	124.3
SD:	12:15	311°	05'	21"	-48.9108°	29139.5	-81.9	124.8
ND:	12:35	229°	06'	16"	-49.1044°	29137.4	-82.3	127.1
SU:	12:37	049°	04'	13"	-49.0703°	29137.2	-82.5	127.2
Inclination:	12:25	-049°	00'	33"	-49.0090°			

BASELINES

	Absolute	GDAS	Baseline			
F (nT):	29108.3	29138.5	-30.2			
D(deg):	3.7951	-0.3116	4.1067	004°	06'	24"
H (nT):	19093.3	-82.1	19175.4			
Z (nT):	-21971.3	125.9	-22097.2			
I (deg):	-49.0090					

COLLIMATION ERRORS

Declination Delta:	000°	00'	-59"
Declination Epsilon:	000°	-04'	45"
Declination Zo (nT):	-5.3		
Inclination Epsilon:	000°	-04'	42"
Inclination Zo (nT):	9.4		

ABSOLUTE OBSERVATION 5

Observatory: Port Stanley
Logger: fkqa
Observer: Turbitt
Date: 10 Sep 2004
Site Difference: -30.2
Theodolite serial number: 160332
Fluxgate serial number: 0754H

FIXED MARK READING

CR 1:	279°	36'	10"
CL 1:	099°	36'	08"
CR 2:	279°	36'	09"
CL 2:	099°	36'	07"
Mean:	189°	36'	09"
FM True:	281°	31'	01"
TN Circle:	178°	05'	08"

DECLINATION OBSERVATION

						VarD(nT)
WU:	12:21	091°	48'	04"	91.8011°	-109.1
ED:	12:23	091°	44'	09"	91.7358°	-109.8
WD:	12:25	271°	57'	09"	271.9525°	-109.9
EU:	12:27	271°	56'	42"	271.9450°	-110.0
Mean:	12:24	181°	51'	31"		
Declination:	12:24	003°	46'	23"	3.7732°	

INCLINATION OBSERVATION

						PPMF(nT)	VarH(nT)	VarZ(nT)
NU:	12:40	131°	03'	08"	-48.9478°	29136.8	-83.4	127.2
SD:	12:42	311°	05'	13"	-48.9131°	29136.6	-83.8	127.0
ND:	12:46	229°	06'	26"	-49.1072°	29136.0	-84.9	126.9
SU:	12:48	049°	04'	51"	-49.0808°	29135.8	-85.4	126.8
Inclination:	12:44	-049°	00'	44"	-49.0122°			

BASELINES

	Absolute	GDAS	Baseline			
F (nT):	29106.1	29136.3	-30.2			
D(deg):	3.7732	-0.3292	4.1024	004°	06'	09"
H (nT):	19090.6	-84.4	19175.0			
Z (nT):	-21970.7	127.0	-22097.7			
I (deg):	-49.0122					

COLLIMATION ERRORS

Declination Delta:	000°	00'	-52"
Declination Epsilon:	000°	-04'	42"
Declination Zo (nT):	-6.1		
Inclination Epsilon:	000°	-04'	54"
Inclination Zo (nT):	7.8		

Appendix B Instrument Calibrations

The following tables list the comparisons between portable calibrators taken to Port Stanley and the BGS standard calibrators. The standard calibrators are regularly verified against known UK national standards. The comparisons were carried out on 1st September 2004, prior to the Port Stanley service visit.

DVM Calibration	
FLUKE 45	FLUKE 87 III
6887022	85560294
Volts	Volts
0.13314	0.13308
-0.13307	-0.13302
0.21186	0.2118
-0.21192	-0.2116
1.1656	1.1655
-1.1659	-1.1653
2.1644	2.164
-2.1648	-2.164
4.0638	4.063
-4.0642	-4.063
8.1530	8.152
-8.1536	-8.150
Resistance	
Ohms	Ohms
1003.0	1000.5

PPM Calibrator Calibration	
19 S/N 810794	
CAL0	C2
nT	nT
19572.67	19572.78
23487.19	23487.24
39145.36	39145.69
46974.34	46974.60
58717.94	58718.29
78290.64	78291.08

The following table lists the fluxgate magnetometer and digitiser calibrations conducted on the Port Stanley GDAS system using the portable calibrators.

SDAS System	fkqa	**Observatory**	PST	**Date**	7-Sep-04		
Observer	CWT	**DVM Type**	Fluke 87III	**DVM S/N**	85560294		
Flux Elect. S/N	E0262	**Flux. Sensor S/N**	S0216				
Resistor S/N	FGAD.014	**Resistor Temp.**	3.0	**Resistor Value**	1000.6		
X-coil constant	38600						
Y-coil constant	38593						
Z-coil constant	38601						
Applied Voltage	**H**	**Resistor Voltage**	**D**	**Resistor Voltage**	**Z**	**Resistor Voltage**	
+	8.372	90.200	8.565	90.200	8.292	90.040	
0	-0.267	0	-0.1115	0	-0.2671	0	
-	-9.022	-90.240	-8.839	-90.240	-8.842	-90.240	
Output Range	17.394		17.404		17.134		
Resistor Current	0.180332		0.1803318		0.180172		
Generated Field	6960.808		6959.54519		6954.815		
Calibration	400.18	**nT/V**	399.88	**nT/V**	405.91	**nT/V**	
	249.88	**uV/0.1nT**	250.07	**uV/0.1nT**	246.36	**uV/0.1nT**	
GDAS Values	251.00		249.65		252.13		
% Error	0.45		-0.17		2.34		

Temperature Probe	**Scale:**	0.005	**V/deg.C**
	Thermometer:	3	
	Voltage:	1.385	
	Offset:	1370100	**uV at 0 deg.C**

ADC #01

Applied Voltage	4.468	**%Error**	-4.467	**%Error**	0.0000
H	4.4736	-0.1253	-4.4731	-0.1366	0.0002
D	4.4694	-0.0313	-4.4688	-0.0403	0.0002
Z	4.4734	-0.1209	-4.4693	-0.0515	0.0002
T	4.4694	-0.0313	-4.4678	-0.0179	0.0002

ADC #02

Applied Voltage	8.273	**%Error**	-8.272	**%Error**	0.000
H	8.275	-0.0242	-8.275	-0.0363	0.000
D	8.272	0.0121	-8.273	-0.0121	0.000
Z	8.272	0.0121	-8.272	0.0000	0.000
T	8.272	0.0121	-8.272	0.0000	0.000

The following table lists the proton precession magnetometer calibrations conducted on the Port Stanley GDAS system using the portable calibrators.

PPM Sensor		**PPM Electronics**			
Serial Number		**Type**	GSM90	**S/N**	4051375
Cal Box	C2				
Proton Gyromagnetic Ratio			267515250	±40 T-1s-1	
Switch Setting	**Input Freq.**	**Cal Value**	**PPM Output**		**Error**
7	833.33333	19572.67	19572.63		0.04
9	1000	23487.20	23486.85		0.35
6	1666.6667	39145.34	39144.75		0.59
5	2000	46974.41	46973.66		0.75
4	2500	58718.01	58717.09		0.92
3	3333.3333	78290.68	78289.41		1.27

PPM Sensor		**PPM Electronics**			
Serial Number		**Type**	GSM19	**S/N**	701595
Cal Box	C2				
Proton Gyromagnetic Ratio			267515250	±40 T-1s-1	
Switch Setting	**Input Freq.**	**Cal Value**	**PPM Output**		**Error**
7	833.33333	19572.67	19572.50		0.17
9	1000	23487.20	23486.99		0.21
6	1666.6667	39145.34	39145.05		0.29
5	2000	46974.41	46974.09		0.32
4	2500	58718.01	58717.60		0.41
3	3333.3333	78290.68	78290.12		0.56

Appendix C SDAS Configuration File

The file listed below is the SDAS configuration file /home/sdas/current/config/channels.cfg. This file contains the magnetometer scale and offset derived from the calibrations made during the visit and described in Appendix B.

```
# channels.cfg - this database defines the channels that will be
#                  recorded - it is read by the ring buffer manager to
#                  map digitiser channels to SDAS channels - digitiser
channels
#                not mentioned in this file will be ignored by the ring-
buffer
#                manager and thus ignored
#
# field  | field         |
# number | name          | description
# -------+--------------+---------------------------------------------------
# 1      | sdas_chan     | unique index for the SDAS channel number - unless
#        |               | you have a good reason start at 0 and work up
#        |               | contiguously
# 2      | chan_name     | name for this SDAS channel
# 3      | chan_type     | a code for the type of channel
# 4      | units         | name of the physical units being used
# 5      | offset        | this gets subtracted from the channel data
#        |               | before it is stored
# 6      | scale         | the data is divided by this after the offset
#        |               | has been removed and before it is stored
# 7      | acquire.id    | acquire id (from acquire.cfg) for the acquisition
#        |               | process to which this channel spec. relates
# 8      | acq_type      | "main" or "aux" - many digitisers have two types
#        |               | of input - "main" inputs are the seismic data
inputs
#        |               | typically 24-bit 100Hz, "aux" inputs are much
slower
#        |               | and lower resolution, e.g. 8 bit, 1Hz
# 9      | acq_chan      | the channel number used by the digitiser driver
#        |               | typically 0-2 for "main" channels, 0-7 for "aux"
#        |               | channels

0    PST      "H"            "0.1nT"  0.0  249.88   0    main 0
1    PST      "D"            "0.1nT"  0.0  250.07   0    main 1
2    PST      "Z"            "0.1nT"  0.0 -246.36   0    main 2
3   PST     "T"              "0.1dg.C"  1370100  500.0   0 main    3
4   PST     "F"          "0.1nT"  0.0  10.0   1 main    0
5   PST     "H filter"   "0.1nT"  0.0  1.0   2 main    0
6   PST     "D filter"   "0.1nT"  0.0  1.0   3 main    0
7   PST     "Z filter"   "0.1nT"  0.0  1.0   4 main    0
8   PST     "T filter"   "0.1dg.C"  0.0  1.0   5 main    0
9   PST     "F filter"   "0.1nT"  0.0  1.0   6 main    0
10  PST     "Closing Err" "0.1nT" 0.0  1.0   7 main    0
```

Appendix D Fluxgate Magnetometer Hut Temperature