SECTION 3

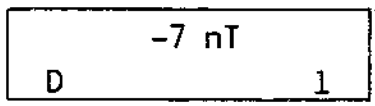
OPERATING INSTRUCTIONS

3-1 Introduction

This section starts off by briefly introducing the user to the main display and operating modes. This is followed by a more detailed look at the keyboard functions and logging procedures, instructions on how to align the fluxgate sensors, charge the battery pack and take care of the gradiometer. Instructions and advice on how best to use the gradiometer in the field are given in section 4. It is advisable to read section 2-2, which describes the physical layout, before reading this section.

3-2 Switching on for the first time

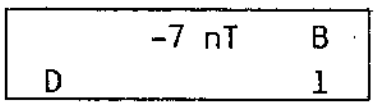
Before switching on for the first time make sure the battery pack has been given a full charge - see section 3-9 for charging instructions. To switch the gradiometer on, rotate the On/Off/Charge switch clockwise. A beep of about 1 second duration will be heard and the Liquid Crystal Display (LCD) will look something like this :



This is known as the Digital Display mode and the gradiometer will always start up in this mode. (If at any time you want to switch the gradiometer off then on again wait about 5s before doing so.) There are in fact three basic display modes (2 only for the FM9) : Digital, Analogue and Logging Modes. These are introduced below, with more detail given in the following section, 3-3(1) and (2), which deals with the key functions in depth.

(1) Digital Display Mode

Apart from displaying the gradiometer reading in digital form, this mode also indicates the current display resolution, the status of the Log Drift facility and the battery status.



The reading may be either positive or negative, with maximum value of 204.7 nT, 2047 nT or 20470 nT depending on whether 0.1, 1, or 10 nT resolution is selected. The current resolution is shown in the bottom right hand corner as the figure 0.1, 1, or 10. Log Drift status is indicated in the bottom left hand corner - the presence of a D indicates that it has been selected, an absence of any character indicates it has not been selected. A low battery is indicated, as in all the display modes, by a flashing B in the top right hand

corner. If this is showing you should refer to section 3-9 for charging instructions and advice on operational time left.

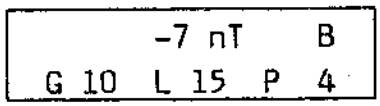
(2) Analogue Display Mode

To enter the Analogue Display Mode press the DISPLAY MODE key situated at the bottom left hand side of the keyboard once. This mode uses a moving bar to indicate the sign and magnitude of a reading, rather like the needle indicator of a conventional moving coil meter. The particular range selected is shown on the scale at the bottom of the display.

If the reading is too strong for the range selected the bar will be replaced by an arrow at the end of the scale, pointing left or right, depending on whether the reading was positive or negative. The analogue mode is useful for preliminary scanning over an area to locate areas of interest before the digital or logging mode is used for the more detailed survey. Press the DISPLAY MODE key again to return to the digital display.

(3) Logging Display Mode (FM18 and FM36 only)

If you have an FM18 or FM36 then press the ENABLE LOG key on the bottom right hand corner of the keyboard to bring up the Logging Display mode. In this mode the resolution and Log Drift status information is replaced by a sequence of letters and numbers which are used to indicate the position reached on a survey. The letters G, L, and P and the numbers to the right of each letter indicate, respectively, the current grid, the current survey line in a grid, and the next reading position to be logged.



As the readings are logged into memory P, L, and G will increment to help you keep track of survey position. They will also change if some of the other logging function keys such as DELETE, FINISH LINE, DUMMY LOG etc. are pressed. Readings can only be logged or data memory altered whilst the Logging display mode is selected. Press the LOG ENABLE key once again to return to the digital display mode.

The function and operation of these display modes and the remainder of the key positions are described in much greater detail in the following section, whilst advice on their use in the field is given in section 4.

3-3 Keyboard Operations

The keyboard layouts of the FM9 and FM36 are shown in figure 3-1 (the FM18 layout is identical to that of the FM36). The key functions may be split into two groups as shown in Table 3-1. All instruments have the six Basic Key Functions in common, whilst the FM18 and FM36 have additional Logging Key Functions. The MENU key, END MENU key and the associated left and right "arrow" keys provide in effect an extra set of options which are used to configure the gradiometer for use.

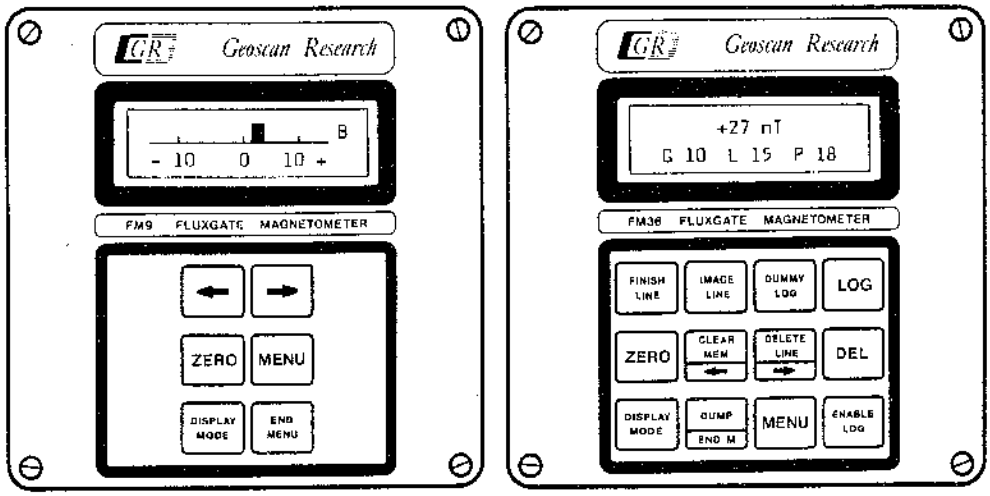


Figure 3-1. Keyboard layouts for the FM9 and FM36.

Only light pressure will be needed to activate a key so if you find you need to press hard you may not be directly over the centre. You are more likely to hit the key centre if you use the pad of the finger rather than the tip since this will give a larger pressure area. Note that the actual position of the top row of keys is displaced slightly above the marked position so press nearer the LCD display than would normally be the case. Remember that the logging function keys will only operate when the Logging Display is selected.

Each key press is accompanied by a "beep" for feedback. The other principle sound used is a "Warble" which **ONLY** occurs when the LOG, DUMMY LOG or hand-held external LOG key is pressed. There are also other sequences of "beeps" used for various key functions and status indications. The type of sound associated with each key function is fully described at each appropriate point.

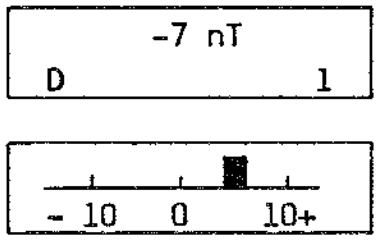
There follows a detailed description of each key function, starting first of all with the basic key functions common to all the gradiometers, followed by the logging key functions of the FM18 and FM36. An index to the page on which each key function is described is shown in Table 3-1.

Table 3-1. Index to Keyboard functions

(1) BASIC KEY FUNCTIONS - FM9, FM18, FM36

DISPLAY MODE

The DISPLAY MODE key is used to switch between the digital and analogue display modes. Each press of the key switches the gradiometer into the other display mode and is accompanied by a single "beep". These modes have already been introduced in section 3-2 but are shown again below, digital display first followed by the analogue display.

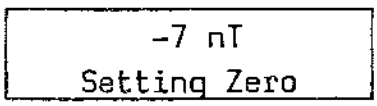


The reading will be updated three times a second for the digital display mode, and nine times a second for the analogue display mode, providing the digital average mode is not selected. If it is selected then the update rate, for both analogue and digital display, will depend on the average period selected and update period will vary from 0.6s to 4.8s typically - see 3-4 for further details.

Note that the internal gain of the gradiometer is altered when the **RESOLUTION** of the digital display is changed, whereas the internal gain associated with the analogue display remains the same, no matter which **RANGE** is selected - see the MENU key for details of changing resolution and range. The internal gain of the analogue display is the same as that for 1nT resolution on the digital display. Therefore when swopping between the two modes there will be a discrepancy in the reading if any resolution other than 1nT is used. In practise this will not usually be noticable since 1nT resolution will be most often used.

ZERO

The ZERO key is used to set the reading and analogue output to zero when the gradiometer is over a survey reference point. The key must be kept depressed for four "beeps" during which time the LCD will display a warning message :



After the four "beeps" there will be a short pause of between one and six seconds during which time the gradiometer nulls the reading and analogue output with an internal offset voltage. The offset voltage is stored in the non-volatile memory for recall at power-up. If the key is not kept depressed continually for four "beeps" the zeroing operation will be aborted and the display and internal offset voltage will revert to its former value, thereby preventing accidental shift of the zero. The gradiometer ZERO key can

provide null adjustment of +/-45nT, +/-450nT and +/-4500nT with 0.1nT, 1nT and 10nT resolution respectively on the digital display, and +/-450nT for the analogue display, regardless of range selected. If the reading and analogue output is outside these limits then the gradiometer will try its best to zero the display but gives the warning :

-7 nT
Balance

This situation will only occur if the balance control has been set well off its correct position or if batteries have been installed that are very magnetic, though this is very rare in practice. To remedy the latter situation first remove the zero adjustment by setting the CHECK OFFSET option to ON in the MENU sequence (see below). The resulting reading will be a measure of the residual magnetic effect. Try rotating each battery in turn until the the reading is well below the ZERO adjustment range. If this does not work you will have to replace the offending batteries.

The ZERO key will operate on all the display modes but as pointed out in DISPLAY MODE key entry the gradiometer internal gain depends on the resolution selected. Therefore when swopping between the analogue and digital display modes there will be a discrepancy in the reading if any resolution other than 1nT is used.

MENU and END MENU

The MENU key, in association with END MENU (or END M. for FM18/36) and the two left and right arrow keys, is used to configure the gradiometer for field use. The menu sequence may be entered from any of the three display modes. Each press of the MENU key steps through a list of parameters and their current values or status. The menu parameters available depend on the gradiometer type and are summarised in table 3-2, listed in the order in which they appear in the menu sequence. An index is also shown for the section(s) where they are described more fully or where advice is given for the optimum value for each parameter. The description here only discusses how to examine or change the current parameter value.

	Parameter	Values	Section
	Resolution (digital display)	0.1, 1, 10 nT	3-3(MENU),4-4
	Range (analogue display)	+/- 5, 10,20,40,80,160,320,640 nT	3-3(MENU),4-3
	Reading Average	ON / OFF	3-4,4-8
*	Log Zero Drift	ON / OFF	3-3(LOG),4-8
*	Log Interval	0.25, 0.5, 1 m	3-3(LOG),4-4
*	Grid size	10, 20, 30 m	4-4
	Average Period	16,32,64,128 readings	3-4
*	Baud rate	600,1200,2400 baud	3-7
*	External trigger type	Manual / Encoder	3-6
	Check offset	ON / OFF	3-3(ZERO)

Table 3-2. Index to Menu Parameters (* FM18, FM36 only)

Each parameter may be changed, if desired, by using one of the two arrowed keys. Pressing either the left or right arrow key will, respectively, decrease or increase the current value to one of those shown in table 3-2, for example :

Baud Rate
1200

Press the right hand arrow key to increase the baud rate :

Baud Rate
2400

Where only the status of a parameter can be changed, each press of either left or right arrow key will cause the bottom line of the display to alternate between ON and OFF (or Manual and Encoder in the case of External Trigger type).

Note that if the gradiometer is in the digital display mode then the first press of the MENU key will recall the current **RESOLUTION** :

Resolution
1 nT

Alternatively, if the gradiometer is in the analogue display mode then the first press of the menu key will recall the current **RANGE** :

Range
20 nT

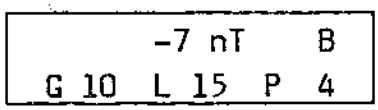
Whether resolution or range is displayed, both may be changed by using either the left or right arrow keys to, respectively, decrease or increase the current value to one of those shown in table 3-2.

As soon as they are changed **ALL** settings are immediately stored in the non-volatile memory ready for recall at power-up. You can exit from the menu sequence at any time by pressing the END MENU key and this will return you to the display mode in operation before the MENU key was pressed. In any case, once all the parameters have been stepped through, the display will revert back to either the digital or analogue mode. If the gradiometer was in the logging mode before entering the menu sequence it will return back to the digital display mode, and not the logging display mode.

(2) LOGGING KEY FUNCTIONS - FM18, FM36 ONLY

ENABLE LOG

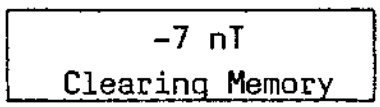
The ENABLE LOG key is used to enter the Logging Display mode which is the only display mode which allows readings to be logged or the data memory to be altered. It can only be entered from the Digital Display Mode - the ENABLE LOG key has no effect if the gradiomter is in the Analogue Display Mode. The display shows a sequence of letters and numbers which are used to indicate the position reached on a survey. The letters G, L, and P and the numbers to the right of each letter indicate, respectively, the current grid, the current survey line in a grid, and the next reading position to be logged.



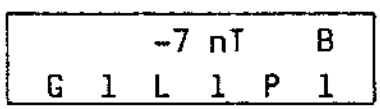
As the readings are logged into memory P, L, and G will increment to help you keep track of survey position. They will also change if some of the other logging function keys such as DELETE, FINISH LINE, DUMMY LOG etc. are pressed. Readings can only be logged or data memory altered whilst the Logging Display Mode is selected. The ENABLE LOG key itself does not log a reading but rather is a mode change key - pressing LOG ENABLE whilst in the Logging Display Mode will cause the display to return back to the Digital Display Mode. A single "beep" is given when this key is pressed.

CLEAR MEMORY

The CLEAR MEMORY key is used to erase the entire data memory contents. It also initialises the survey tracking function when a new set of grids is to be started. The key only operates in the Logging Display Mode and must be kept depressed for four "beeps" during which time the LCD will display a warning message :



After the four "beeps" there will be a short pause of about 7 s (28 s, FM36) during which time the data memory will be erased and survey position initialised. G, L, and P will all be reset to one :



If the key is not kept depressed continually for four "beeps" the erasing operation will not be started and the reading and survey position will revert to their former values, thereby preventing accidental loss of data or position.

LOG

The LOG key is used to store the current reading in the data memory. The external hand-held LOG key has exactly the same operation but is more convenient to use. Details on how to physically connect the external hand-held LOG are given in section 3-6. (Section 3-6 also gives details on the use of an external distance encoder for logging and the ways in which it differs from use of the standard LOG key. The following discussion is limited to use of the standard LOG key.)

Readings may only be logged in the Logging Display Mode which shows, as well as the reading, a sequence of letters and numbers indicating the position reached on a survey. The letters G, L, and P and the numbers to the right of each letter indicate, respectively, the **CURRENT** grid, the **CURRENT** survey line in a grid, and the **NEXT** reading position to be logged. With the memory cleared G, L, and P will all equal 1. Each time LOG is pressed the buzzer will give a "warble" sound to indicate that the reading has been stored and P will increment by one. Note that P indicates where the next reading is to be logged and not the current position. Thus on a 20m grid, with logging interval of 1m, P = 20 when there is only one more reading to go before the end of the line. The equivalent display for the other logging intervals is P = 40 for a 0.5m interval, and P = 80 for a 0.25m interval.

When the last reading of a line is logged the buzzer will sound a single "beep" instead of a "warble" and L will increment by one whilst P will be reset to one.

When the last reading of a grid is logged the buzzer will sound two "beeps" instead of a "warble" and G will increment by one whilst L and P will both be reset to one. However, the sequence at the end of a grid is slightly different if Log Zero Drift is enabled. Two "beeps" will be given as before but, before the display shows G incremented by one and L and P reset to one, the display will show :

-7 nT
Log Zero Drift

This is a prompt to take the next reading over the survey zero reference point and a "warble" will be sounded when this reading is logged (the procedure is described further in Section 4). The display will then show G incremented by one and L and P reset to one ready for the next grid.

Once the memory is full with complete grids, the usual "warble" sound will be replaced by three "beeps" on the last reading to signify a full memory. Attempts to log any more readings will result in the three "beeps" being repeated. You will however be prompted to log the zero drift if that mode is enabled.

Note that although the logging interval may be varied, line separation is always 1m. Thus L will always increment in 1m intervals and can have a maximum value equal to the grid size. However, other line separations can be accommadated simply by logging into the memory normally reserved for the next grid(s). For example a line separation of 0.5m will require the memory reserved for two grids and a line separation of 0.25m will require the memory reserved for four grids.

If the gradiometer is in the Digital Average mode the survey position tracking operates in exactly the same way but the sequence of sounds differs. Details of operation may be found in Section 3-4.

In the manual mode readings can be stored at a maximum rate of one every 0.75s (as opposed to ten per second in the encoder mode), though in practise storage rate is not

that fast since time must also be added for movement between reading positions. Although the readings are only displayed with a resolution of 0.1nT, 1nT and 10nT, they are in fact stored with a resolution of 0.05nT, 0.5nT and 5nT.

Table 3-3 shows how the memory can be partitioned up in terms of grid size and logging interval, for a line separation of 1m.

FM18 Gradiometer *

Logging Interval	10 m grid	20 m grid	30 m grid
1 m	40	8	4
0.5 m	20	4	2
0.25 m	10	2	1

FM36 Gradiometer *

Logging Interval	10 m grid	20 m grid	30 m grid
1 m	160	40	16
0.5 m	80	20	8
0.25 m	40	10	4

* Divide the number of grids by 2 for 0.5 m line separation and by 4 for 0.25 m line separation. Only complete grids are allowed.

Table 3-3. Maximum number of grids that can be stored in the FM18 and FM36 memories.

The current survey position and data will be remembered by the gradiometer even if it is switched off. Therefore incomplete grids can be resumed after a break.

DEL

The DEL key is used to delete the last reading logged. When the key is pressed the buzzer will sound a single "beep" and P will be decremented by 1. If the survey position is at the beginning of a new line or grid, then DEL will delete the last reading of the previous line or grid (or zero drift if enabled). The key may be pressed as many times as required.

DELETE LINE

The DELETE LINE key is used to delete the current line of readings. The key must be kept depressed for four "beeps" during which time the LCD will display a warning message :

```
-7 nT
Deleting Line
```

After the four "beeps" there will be a pause of about one second during which time the current line of data will be erased, the survey line position L will remain the same and P will be reset to one.

If the key is not kept depressed continually for four "beeps" the deleting operation will not be started and the reading and survey position will revert to their former values, thereby preventing accidental loss of data or position.

If a line of readings has just been completed, but the first reading of the next line has not been logged then DELETE LINE will delete the **PREVIOUS** line of readings. In this case L will be decremented by one and, as before, P reset to one. If a line of readings has already been started then only those readings will be deleted.

If the survey is at the start of a grid DELETE LINE will have no effect. In order to delete the previous line DEL must first be pressed to delete the last reading of the previous grid (and an extra press of DEL to erase the zero drift if enabled) and then DELETE LINE.

DUMMY LOG

The DUMMY LOG key is used to enter a dummy reading in situations where a reading cannot be taken - for example there may be a physical obstruction in the way. In these cases a dummy reading equivalent to the maximum possible reading for the chosen resolution is displayed and stored : +20,470 nT, +2047 nT, or 204.7 nT for resolutions of 10nT, 1nT or 0.1nT respectively. Each time DUMMY LOG is pressed the buzzer will give a "warble" sound to indicate that the reading has been stored and P will increment by one, just as for the LOG key. Computer software may be used to recognise this as a dummy reading and represent it with a special symbol for data presentation plots - see Appendix B for more details.

FINISH LINE

The FINISH LINE key is used to complete the rest of a line with dummy readings. When FINISH LINE is pressed the display will show the dummy reading appropriate to the resolution - see DUMMY LOG - and the buzzer will give a single "beep". L will be incremented by 1 and P reset to 1. The gradiometer will keep track of survey position in just the same way as for the LOG command. For example when the grid is completed with FINISH LINE the buzzer will sound two "beeps" and G will increment by one whilst L and P will both be reset to one. See Section 4 for further applications of the FINISH LINE command.

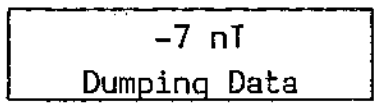
IMAGE LINE

The IMAGE LINE key may be used after a FINISH LINE instruction to create a mirror image of dummy readings at the start of the next line. The same number of dummy readings are inserted as for the previous FINISH LINE. It is **ONLY** used for zig-zag surveying - see Section 4 - and can **ONLY** be used after the previous line has been completed with a FINISH LINE instruction.

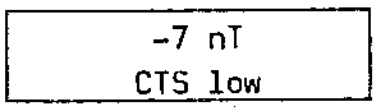
When IMAGE LINE is pressed the display will show the dummy reading appropriate to the resolution - see DUMMY LOG - and the buzzer will give a "warble" sound. L will be incremented by 1 and P set to the number of dummy readings inserted by FINISH LINE plus one. For example, on a 10 m grid with logging at 1 m intervals, if after the first 3 readings have been logged (P=4), FINISH LINE is pressed then L increments and P=1, and 7 dummy readings will have been inserted. If IMAGE LINE is pressed then 7 dummy readings will also be inserted, and, since the gradiometer is waiting for the eighth reading, P will equal eight and there will be three more readings required to complete the line.

DUMP

The DUMP key is used to start transmission of the memory contents, via the RS232 link, to another device such as a portable computer. The key may be used in any display mode. When DUMP is pressed the buzzer sounds a single "beep" and the bottom line of the LCD displays the message "Dumping Data" :



If CTS and RTS are not set up correctly (see Section 3-7 and Appendix A) then transmission will stop and the LCD will display the message :



This message will also momentarily appear as CTS is toggled by the external device. Once the entire memory contents have been output a "beep" signifies the end of transmission and the normal display will return. See section 3-7 for full details on outputting data to a portable computer.

3-4 Digital Averaging Mode

(1) Introduction

The DIGITAL AVERAGING MODE may be to reduce system noise and, possibly more importantly, also to smooth out tilt errors. This is especially useful on the 0.1nT range, where, for example, buffeting by the wind may cause unavoidable tilting of the instrument, subsequently seen as noise in the normally logged reading. Averaging, however, will considerably reduce this uncertainty. In this mode the instrument cycles through the average period, updating the display and sounding a very short "beep" at the end of each average period until (in the case of the FM18/36) a LOG command over-rides and restarts the cycle.

(2) Operating Instructions

The Digital Averaging Mode is controlled by two of the MENU parameters - see page 19 - and operates in all of the three display modes. It is turned ON and OFF by stepping through the MENU sequence until "Reading Average" is reached, and the status altered using the two arrow keys. The Average Period may be checked or altered by stepping further down the menu until "Average Period" is reached. The bottom line of the display will show the current period in terms of the number of readings that make up one period. Again this number may be altered using the two arrow keys and END MENU pressed to return to normal operation.

On return to the normal reading display mode there will be a short pause, depending on the period selected, before the buzzer sounds a very short "beep", almost a "click", to signify the end of the average period, and the reading will be updated. This reading will be frozen and the next cycle started, followed again by a "click" and a new reading displayed. The gradiometer will continue to cycle in this way until the average mode is switched off, using the MENU sequence, or the gradiometer itself is switched off (when the gradiometer is switched on it always starts off with average mode off). Note that the first reading after the menu sequence is always meaningless - only after the first "click" is the reading meaningful. Note also that the averaging mode only operates on the displayed (and logged reading) and **NOT** on the analogue output. Therefore it is not possible to use the FM9/DL10 combination to store averaged readings but instead they must be recorded manually.

If the gradiometer is in the Logging Display Mode then each press of the LOG key will cause the buzzer to give a "beep" instead of the usual "warble" sound, and it will over-ride the current average cycle and start a new one. Only on completion of the cycle will a "warble" sound and the averaged reading will be stored. A new average cycle can then be started using the LOG key or the gradiometer can be left to cycle through as before, sounding a "click" at the end of each period.

There is a choice of four Reading Average Periods, 16, 32, 64 or 128 readings. The number refers to the number of A/D conversions the mean of which go up to form the averaged reading - Table 3-4.

Number of Conversions	Reading average period
16	0.6 - 1.2 s
32	1.2 - 2.4 s
64	2.4 - 4.8 s
128	4.8 - 9.6 s

Table 3-4. Reading average period versus number of conversions.

It can be seen from Table 3-4 that there is a considerable difference in the time it takes for an averaged reading. It ranges from typically 0.6s to 4.8s, though these times will increase or even be doubled if there is a strong anomally present. The choice of period is determined by the trade off between time and performance required and is discussed below.

(3) Performance

Figures 3-2 and 3-3 illustrate the typical noise reduction that can be achieved using Digital Averaging. The runs were taken with the gradiometer fixed in position.

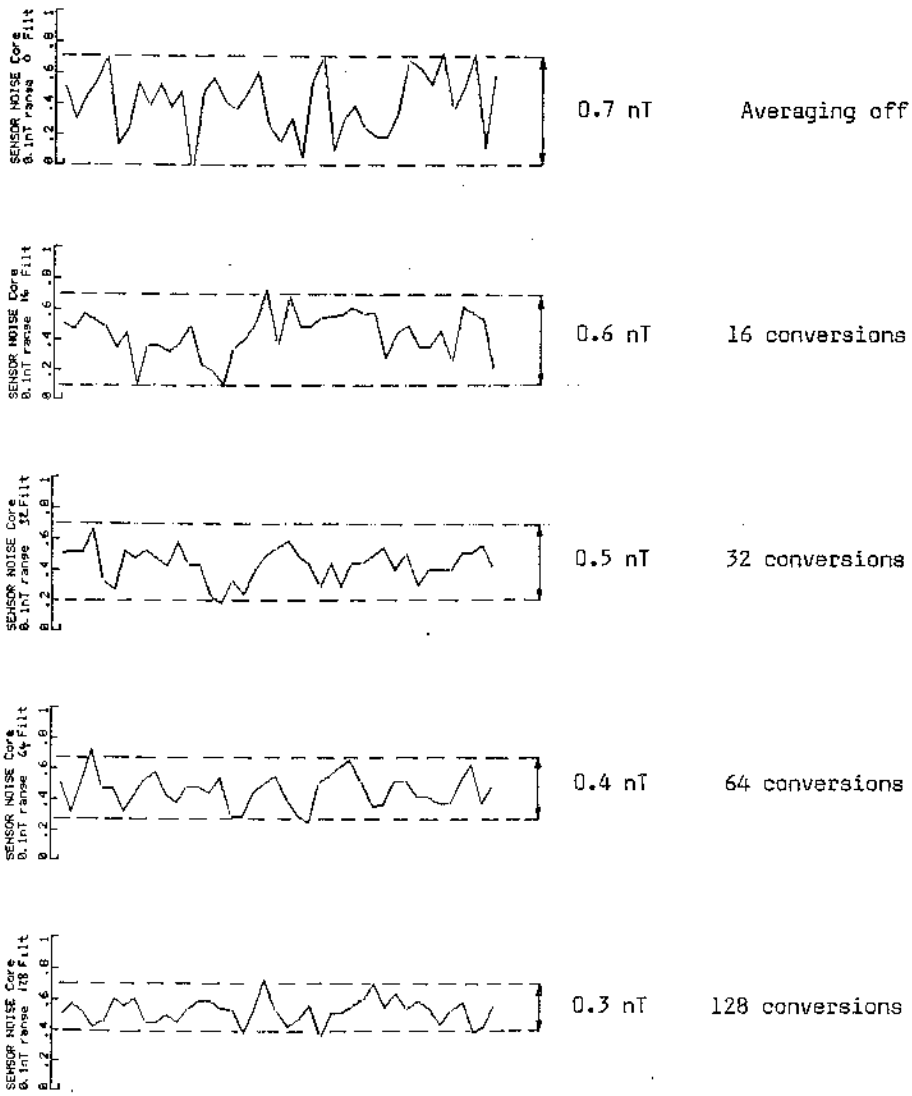


Figure 3-2. Noise reduction with Digital Averaging on the 0.1 nT range. This does not include the effects of tilt "noise".

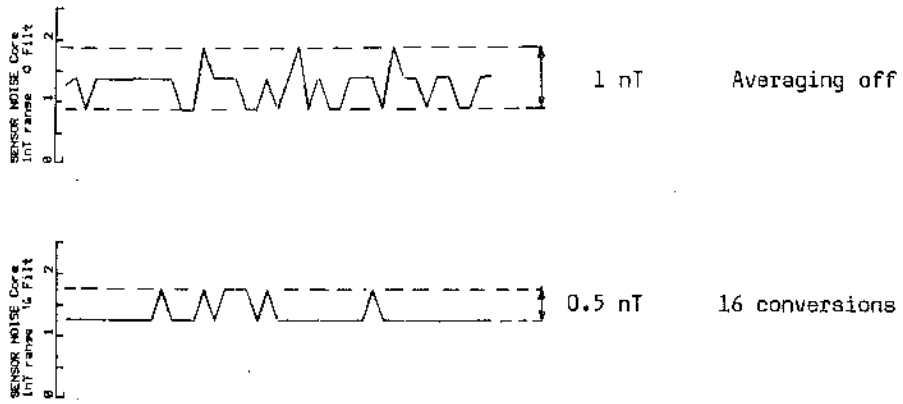


Figure 3-3. Noise reduction with Digital Averaging on the 1 nT range.

Figure 3-2 shows that noise can be reduced to about 0.3 nT peak to peak on the 0.1 nT range. There will be an additional noise due to tilting error but in practise, with such a long averaging period, the overall resulting uncertainty is typically 0.4 nT. As the averaging period is reduced both tilt effects and system noise become more noticable. However, the 4.8s cycle time for 128 conversions may be unacceptably long and reading uncertainty will be only marginally increased if 64 conversions are used instead, but with the benefit of a reduction in cycle time to 2.4s. It is not recommended that the number of conversions is reduced below 64 on the 0.1 nT range, since tilt errors will become much more noticable.

Figure 3-3 shows that a worthwhile reduction in reading uncertainty can be achieved even on the 1 nT range. A 16 conversion average period can reduce the occasional excursions from 1 nT to 0.5 nT though no further improvement can be achieved by using longer average periods, nor would it be worthwhile. Use of the 16 conversion average period on the 1 nT range can provide a useful compromise on quiet sites where time does not permit a survey on the 0.1 nT range yet some improvement over the reading uncertainty on the 1 nT range is required. In everyday use, however, there is no need for the Digital Averaging Mode to be used, since the resulting benefits of much greater speed and flexibility far outweigh potential noise reduction for most sites. Indeed, "soil noise", which averaging cannot remove, will on many sites exceed the gradiometer system noise.

3-5 Fluxgate Sensor Alignment

(1) Introduction

If the gradiometer sensors were always perfectly aligned then, no matter which direction the gradiometer was facing or tilted with respect to the earths magnetic field, the reading would always be the same. In practise it is not possible for this to be achieved, but it is possible to approach this ideal state for moderate periods of time, providing the sensor alignment is trimmed at the start of each day and checked periodically, depending on the precision required.

Setting the gradiometer up for good sensor alignment is vital to getting the best possible results. Although the procedure described below sounds complicated it is in fact very quick in practice, usually 2-3 minutes to set up at the start of the day, and less than 1 minute to trim once or twice during the day. There is little drift of alignment from day to day.

The alignment process is of even more importance if you plan to use the 0.1nT range, since one is trying to achieve and maintain alignment of the sensors to 0.0015 degrees just to keep errors below 1nT. The gradiometer should therefore be treated with great respect and banging or jarring should be avoided.

Although this section is headed sensor alignment, the balance control also plays an integral part in the alignment process as will be seen in the following procedures.

(2) Precautions

It is vital that you have no magnetic items in, or on your clothing. Items to avoid are watches, keys, belts, spectacles, zips and studs in trousers, studs in waterproof nylon anoraks, credit cards, studs in boots or even eylets in lace up shoes, etc. If on occassion you have no choice but to wear clothes with a magnetic effect then this may be minimised by holding the gradiometer at a constant distance and oriention to your clothes. However this is not really recommended and should only be attempted by experienced operators who know when this is acceptable. It cannot be stressed too strongly that you will have problems aligning the sensors satisfactorily if your clothing is magnetic.

As well as the gradiometer you will require the trimmer tool provided and a compass if you do not know in which direction magnetic north lies. The trimmer tool itself is slightly magnetic but if kept, for example, in your back pocket furthest away from the gradiometer it will have no effect during the alignment process. Nevertheless, it is best stored back in the carrying case after aligning the sensors. The compass on the other hand will, by its very nature, be magnetic so once you have located magnetic north make a mental note of the direction and store the compass well away before attempting to align the sensors.

(3) Alignment and Balance procedure

1 Select the Digital Display mode and 1nT range. Make sure the reading average mode is not operating. (If the sensor alignment has been meddled with you may have to select the 10nT range to start off with to bring the reading on scale though this will not normally be neccessary.) Remove the protective waterproof caps over the alignment controls and keep them in a safe place.

2 Move to a region where there are no localised changes observable. You can check this by scanning over the ground, taking care to hold the gradiometer vertical and at a constant orientation with respect to magnetic north. (Holding the gradiometer like this is needed to minimise tilt and orientation errors, since the sensors are not aligned at this stage). Once you have located such a region you can confirm that there are no local anomalies by

lowering the gradiometer nearer to the ground - the reading should change by only 2-3nT. If the changes are much greater then it is likely that there is a magnetic object buried nearby and you should try another location. (Note, however, that some soils, which are uneven and have a high magnetic susceptibility, may give a larger change as the gradiometer is lowered even though there is no buried magnetic object, and due allowance should be made for this.) Mark the region with a peg (non-magnetic) for future reference. This can serve not only as a region for aligning the sensors but also as a zero reference point - see section 4.

3 The balance control is adjusted first. (You should always check the balance before adjusting the alignment controls, except if the alignment has been meddled with, and the 10nT range is required or the difference in the two balance positions is more than 40nT.) Orientate yourself so that the gradiometer handle is aligned N-S and you are facing northwards. Hold the gradiometer as depicted in the first illustration of figure 3-3 and note the reading and its polarity. Take care to hold it vertically.

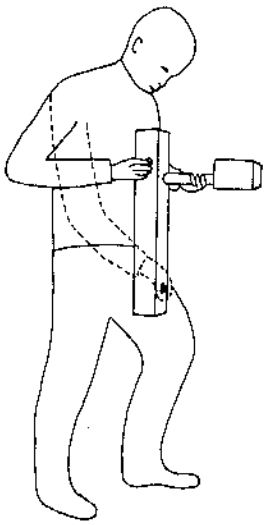
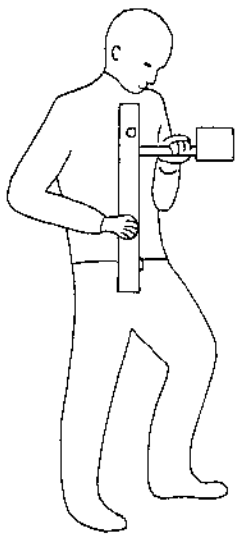


Figure 3-2.

Aligning the top and bottom fluxgate sensors



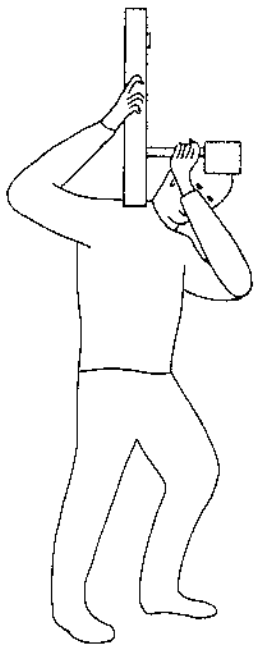


Figure 3-3. Checking the fluxgate sensor balance.

4 Invert the gradiometer as depicted in the second illustration of figure 3-3. The gradiometer is pivoted about its handle by the right hand which swings the sensor support tube into a vertical position. This method of inversion ensures that the gradiometer is always facing the same direction, a requirement if the balance control is to be properly adjusted. Again, take care to hold the sensor tube vertical and note the reading and polarity.

5 Return the gradiometer to its non-inverted position and with the trimmer tool adjust the balance control until the reading lies midway between that observed for the inverted and non inverted positions (take care to insert the trimmer tool in the balance control slot and not the sounder aperture otherwise you will puncture the waterproof membrain). For example if the two readings were -12nT and +4nT then adjust the reading to -4nT. Check that the gradiometer now produces the same reading for both the inverted and non-inverted position, and if not make any neccessary slight adjustments to the balance control to achieve this.

6 Hold the instrument vertically against your body as depicted in figure 3-2, making sure that you are still facing northwards. Position the gradiometer so that you have access to both the upper and lower adjustment openings and can also see the display. (If you have no choice but to make these adjustments whilst wearing clothing that is magnetic, for example a zip on trousers, then it is vitally important that when making the following alignment adjustments you hold the gradiometer in **EXACTLY** the same position with respect to your body for each pair of N-S and E-W adjustments).

7 Note the reading and its polarity. Rotate through 180 degrees to point south and note the reading again. If it is different then rotate the small aluminium wheel of the N-S alignment control, located at the bottom of the sensor tube, so that the reading lies midway between that observed for the two orientations. For example if the north readings was -4nT and the south reading +14nT then, whilst still facing southwards, adjust the reading to show +5nT. Rotate back through 180 degrees to face north again and check that the gradiometer now produces the same reading, ie +5nT in the above example. If not, make further slight adjustments to the N-S alignment control, again aiming for the mid-point reading each time, until the same reading is achieved when facing either north or south. Note that the control is very sensitive and only a very slight rotation will achieve an appreciable change in reading - 0.5 degree of rotation of the alignment control corresponds to about 1nT reading change. You may find it helps to rest thumb and middle finger on the rim of the alignment control opening whilst using the forefinger to make the adjustment. Make sure you do not alter the E-W alignment control when making N-S adjustments.

8 Rotate the gradiometer through 90 degrees so that it is now facing east and repeat procedure 7, except that adjustments are now carried out on an E-W alignment and using the E-W alignment control situated at the top of the sensor tube. Make sure you do not alter the N-S alignment control when making E-W adjustments.

9 The whole process is now repeated. First the balance control is adjusted as described in procedures 3,4 and 5 and this is then followed by the N-S and E-W alignment procedures of 6,7, and 8. The processes are repeated until 1nT or less change is observed for any of the above procedures. It is usual to finish with a final trim of the balance control.

You should now find that you can point the gradiometer in any direction and there will be 2nT or less change. More importantly, you should also find that the gradiometer can now be tilted from the vertical with little change in reading. You should aim for less than +/-2nT change with +/-20 degree change in tilt angle. In practise you will be able to maintain the gradiometer much nearer to the vertical than 10 degrees so you can be confident that any errors you introduce will be less than 1nT. Tilt errors howver will be more noticable on the 0.1nT range, so you should try to achieve the best possible sensor alignment and use the 128 reading averaging filter during surveying to smooth out tilt errors.

3-6 External LOG Triggering

(1) Introduction

Normally readings are logged in the FM18/FM36 by pressing the key of the external hand-held LOG key, or from the instrument keyboard. They may also be logged using pulses from an external distance encoder, such as a line together with hand held pulley/slotted wheel and optocoupler. This is especially useful if readings are required to be logged at 0.5m or 0.25m intervals at a walking pace.

(2) Selection of External Trigger Type

The type of External Trigger Device is selected by stepping through the MENU sequence - see page 19 - until "Ext. Trig. Type" is reached. The bottom line of the display will show the current trigger device : "manual" for LOG input via the external hand-held LOG key or keyboard, or "encoder" for an optocoupler type device. The device type may be altered using the two arrow keys and END MENU pressed to exit from the MENU. The Log Interval may be similarily set using the MENU keys to either 1m, 0.5m or 0.25m.

Operating instructions for the manual LOG input have already been given in Section 3-3, page 22 in detail, and physical connection of the external lead in Section 2-5, page 12. Operating instructions and interface details for an encoder type input are given below.

(3) External Distance Encoder

The gradiometers may be easily interfaced to external distance encoder systems and can log readings at rates of up to 10 readings per second. Appendix C gives details, including circuit diagram, of how a slotted wheel and optocoupler may be interfaced. Ensure that there are no ferrous or magnetic materials used either in the slotted wheel, line or the tripod system at either end, since they will be seen as unwanted anomalies.

Readings may only be logged in the Logging Display Mode. Survey position tracking operates in exactly the same way as for the standard manual LOG input with the important exception that audible feedback given by the buzzer is restricted to only a short "click" every time a reading is logged - no end of line or grid "beeps" are given. This is to allow logging at rates of up to ten readings per second. The external encoder device must therefore be capable of giving the precise number of pulses per line required,, or be marked accordingly, though the position can also be checked visually at the end of a line. Note that if the encoder device is moved **VERY** slowly or stops on a slot, then there will be more than one trigger pulse and hence readings logged. The operator should therefore not stop once a traverse is started, though the ENABLE LOG key may be used to temporarily disable logging whilst the encoder device is set up at the start and end of a line. As with the LOG key the gradiometer can be switched off at any time and at power up the last survey position will be remembered.

Clearly the Digital Averaging Mode should not be selected since this will negate the speed advantages of using an external distance encoder. More importantly it would involve waiting at each reading station for the average cycle to end and there would be real danger of multiple triggering.

Since the settling time of the gradiometer is fast : 20 mS on 10 nT resolution, 40 mS on 1 nT and 120 mS on 0.1 nT resolution (step response settling time to within +/-5% of reading), this allows the magnetic profile to be accurately followed. The maximum trigger rate of 10 readings per second would allow the operator to walk at a rate of 2.5 m/S, logging at 0.25 m intervals, whilst still accurately following the magnetic profile at 1 nT resolution. In practise the walking pace is more likely to be between 1 and 1.5 m/S.

3-7 Data Output to a Computer

Once the survey has been completed the stored data may be output, via the RS232 link, to another device such as a portable computer. The FM18 and FM36 are supplied with a lead suitable for connecting from the gradiometer to either an Epson HX20 computer or an IBM compatable computer with 25 way sub-miniature D connector. Details of the RS232 link and pin connections are given in Appendix A for those wishing to make their own leads. The procedure for transfering the data is as follows.

1 Plug the black nylon connector of the lead into the gradiometer connector labelled as (3) in figure 2-2. The waterproof sealing caps must first be undone and this may most easily be achieved by gripping the strap and instrument/cable with one hand and gripping and turning the 'turret' extension of the cap with the other hand. The black nylon connector (flying socket) of the lead should then be inserted into the FM connector (plug) - there is a small locating pin inside the plug to ensure correct mating. Screw the outer retaining ring into place.

2 If the lead is for an HX20 computer then insert the 5 pin DIN nickel-plated connector at the other end of the lead into the **MIDDLE** socket of the HX20 labelled as RS232C - see Figure 3-5. If the lead is for an IBM compatible then insert the 25 way sub-miniature D connector into the serial socket of the computer.

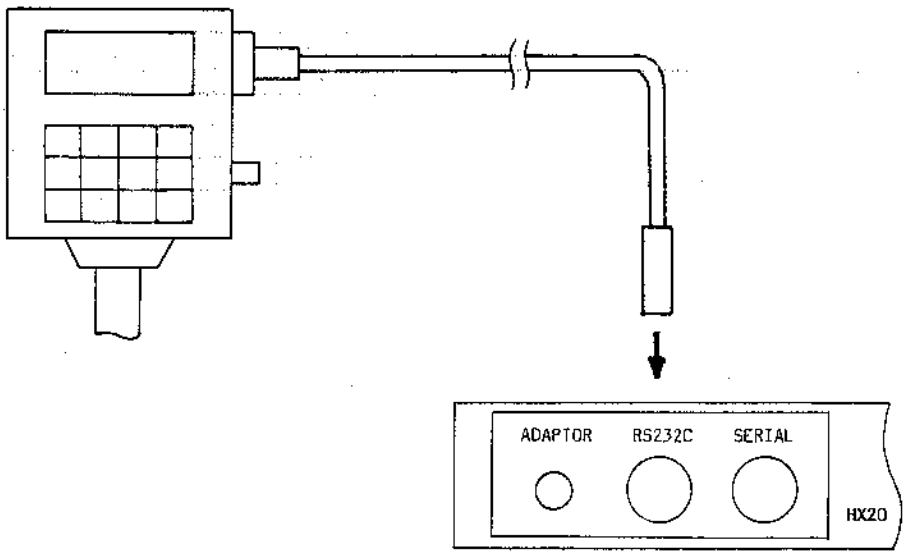


Figure 3-5. Connecting the FM18/36 to an HX20 computer for data transfer.

3 Switch both gradiometer and computer on.

4 Check that the gradiometer Baud rate is correct by using the MENU key. Step through the MENU sequence until "Baud Rate" is reached. A report of the current baud rate will be given on the bottom line and this may be changed using the arrowed keys. Normally Baud Rate will be set to the maximum possible of 2400 baud and this will be remembered when the gradiometer is next switched on.

5 Run the computer program to the point where it is awaiting transmission of the data from the gradiometer. This must be done before DUMP is pressed otherwise some of the data output from the gradiometer may be lost or corrupted. This sequence is discussed further in APPENDIX B, using input to the HX20 computer as an example. APPENDIX B also details the format in which data is stored and transmitted, together with sample software for receiving and reconstructing the data.

6 Press the DUMP key on the gradiometer to start transmission of the data - see Section 3-3, page 25, for details of the DUMP key and associated LCD messages. At 2400 baud it will take 5 minutes for the 4000 readings of the FM18 to be transferred and 20 minutes for the 16000 readings of the FM36 to be transferred. During this time the grid survey lines may be moved and set up for the next grids. At the end of transmission a "beep" will be sounded and the normal display will return. If at any point you wish to terminate transmission simply turn the gradiometer off.

If program GEOPLOT is being used full details of the dumping sequence is given in the manual, and the program itself will prompt the user.

3-8 Use of the Analogue Output

(1) Introduction

The analogue output may be used for either driving a chart recorder or for data logging purposes. In particular it is suitable for recording the readings from an FM9 with a DL10 Data Logger since the FM9 does not have a built-in logger

The analogue output is calibrated to give +/-2 V fsd for each range, equal to +/-20,000 nT, +/-2000 nT, or +/-200.0 nT. Thus 1mV equals 10 nT, 1 nT or 0.1 nT respectively. The analogue output follows the displayed reading exactly, having the same response time of 20 mS on 10 nT resolution, 40 mS on 1 nT and 120 mS on 0.1 nT resolution (step response settling time to within +/-5% of reading). Although the nominal analogue output is +/-2 V, to match the displayed reading, the actual swing can be between +4.4 V and -3.5 V, giving a much larger dynamic range than the displayed reading.

The output amplifier has a -3dB point of 200 Hz to limit high frequency noise, and has a response time of 4 mS. There is also an internal 50 Hz filter (60 Hz optional) to remove mains pickup. The output impedance of the analogue output is 220 ohm in parallel with 0.1 uF. External devices such as Data Loggers should therefore have an input impedance greater than 22 Kohm for less than 1% error.

(2) Output to the DL10 Data Logger

Section 2-5 (2) shows how the FM9 and DL10 should be connected together. It is recommended that the FM9 should be switched on first, followed by the DL10. When the survey is finished, switch off the DL10 first, followed by the FM9.

Always keep the DL10 well away from the gradiometer since it contains ferrous and magnetic parts which will be seen as anomalies if brought too close. This means you will require two operators - it is not possible for one man to operate the FM9 and DL10 together. It is recommended that the cable is supported at both ends by the operators to reduce cable strain. Field procedure using the FM9/DL10 combination is discussed further in Section 4.

If GEOPLOT is being used there is an option to read in data from the FM9/DL10 combination and the GEOPLOT manual should be consulted for further details. If GEOPLOT is not being used you should refer to the DL10 manual for details on data storage and output format.

(3) Output to Chart recorders

Since the settling time of the analogue output is fast this allows the magnetic profile to be accurately followed. However the bandwidth of the chart-recorder (typical -3dB point of 5 Hz, response time 200mS) will be the limiting factor in the response time. Thus the gradiometer should not be moved at speeds greater than, say 0.5m per second, less if possible, to minimise slewing of the profile and loss of amplitude.

Since the output impedance of the analogue output is 220 ohm the chart recorder should have an input impedance greater than 22 Kohm for less than 1% error.

3-9 Charging the Battery Pack

(1) Battery low warning

A full charge of the Nicad batteries should power the instrument for 12.5 hours continuous use. When the battery voltage drops below 9.3V a flashing "B" will appear in the top right hand corner of the display to warn that the battery voltage is dropping. As soon as you see this you have only a short time before the voltage drops to a dangerous level. If you are using Nicad batteries there is probably between 15 and 60 minutes operating time left - if temperatures are high and the batteries were not fully charged before use then there may be less than 15 minutes operating time left. If you are using primary cells there is probably about 2 hours operating time left. You are strongly advised to stop surveying as soon as possible after the "B" appears, since the battery voltage will drop rapidly after this point and if it is allowed to drop below 6.5V the gradiometer and batteries may be damaged. The life of the batteries will be much longer if you can avoid discharging them to the point where the battery low warning comes on, so it is prudent to make sure the batteries are properly charged before use.

WARNING

IF YOU USE THE BATTERIES AFTER THE LOW VOLTAGE WARNING APPEARS AND THE DISPLAY STARTS TO GO DIM - SWITCH OFF IMMEDIATELY !

(2) The Battery Charger

The gradiometer battery charger is supplied with voltage rating and mains input connector suitable for your country. Please check that the unit supplied is correct for your country before attempting to use. The three types available are :

(a) 240 V, 50/60 Hz, three pin connector moulded in the case, suitable for UK use
(b) 220 V, 50/60 Hz, two pin connector on flying lead, suitable for European use
(c) 120 V, 50/60 Hz, two pin connector moulded in the case, suitable for USA, Japan use

The charger is protected internally by a thermal cutout and is doubly insulated. The output is 25 V at a constant current of 70 mA.

If the charger does not operate correctly do **NOT** attempt to undo the four screws at the base of the charger since there are no user servicable parts. If the the unit appears to be faulty it should be returned to Geoscan Research for repair.

Unlike the gradiometer the battery charger is **NOT** waterproof. Since the charger is to be connected to the mains supply, do **NOT** expose it to wet or damp conditions - such as those encountered in the field.

(3) Charging Instructions

Position the charger in a cool position if possible and plug into the mains supply. Switch the ON/OFF switch of the gradiometer to the OFF/CHARGE position and insert the six-way flying socket on the battery charger into the six-way chassis plug of the gradiometer, labelled as (3) in figure 2-2. Note that the batteries will not charge if the gradiometer is switched to the ON position.

WARNING

ENSURE THAT THE GRADIOMETER IS FITTED WITH THE RECHARGEABLE NICAD BATTERY PACK BEFORE CONNECTING THE CHARGERS. UNDER NO CIRCUMSTANCES ATTEMPT TO CHARGE ANY OTHER SORT OF BATTERY WITH THE CHARGER.

An overnight charge of 10 hours will ensure that an uncharged battery pack is brought from an uncharged state to full charge. This charging period should not be greatly exceeded if at all possible, since prolonged overcharge will cause a progressive and irreversible decrease in charge capacity. If the battery pack is only partially discharged then the full charge time will not be required. In this case the charge time required is calculated from :

Charge time (hours) = number of hours the gradiometer has been used divided by 1.2

If the batteries are only partly discharged but you cannot leave the charger on for a period less than an overnight charge then this is permissible. Note that if the gradiometer has not been used for some time, capacity available will be reduced, depending on temperature and storage time as shown in figure 3-4. For example capacity of a fully charged battery stored at 20 C for 1 month is expected to be reduced to 70 %. Therefore the battery should be charged for 30 % of 10 hours = 3 hours to top up the battery to full capacity.

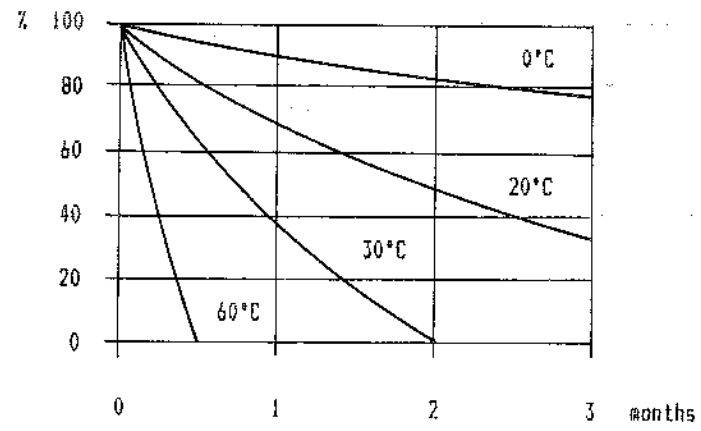


Figure 3-4. Capacity retention as a function of temperature and time

3-10 Care of the Instrument

1 Although the gradiometer and accessories have been designed to be waterproof and robust, they should still be treated as carefully as possible to maintain reliability. In particular, since the sensors must be aligned and maintained to 0.0015 degrees, the instrument should not be subjected to banging or jolting. You should at all times transport the gradiometer in the case provided.

2 There is a waterproof outer skin protecting the sensor tube, together with a silicone sealing system. Under this is a polystyrene and aluminium thermal jacket which contributes greatly to minimising drift effects. Great care should be taken to see that the outer skin is not punctured or the underlying poltstyrene dented. Keep well away from sharp objects in the field and always store in the carrying case when not in use.

3 If the front panel becomes dirty it is best cleaned with a very wet tissue soaked in tapwater. Wipe the panel in one direction only and leave to air dry.

4 If the gradiometer is used in wet conditions traces of damp in the air may enter via the sensor alignment apertures when the caps are removed for adjustment. It is then advisable to remove the caps when back in warm dry conditions to allow the moisture to escape. In severe cases blow warm air through the apertures using a hair dryer - do not place too close to avoid melting the outer plastic skin or polystyrene.

5 If the gradiometer is to be used in humid conditions then it may be prudent to insert a small bag of silica gel in the electronics housing to absorb moisture and thus minimise chances of corrosion.