Instruction Manual

FLUXGATE GRADIOMETER

FM9 FM18 FM36

Instruction Manual Version 1.4

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Addendum

For the FM9, FM18 and FM36 Instruction Manual

The following notes replace or supplement advice given in the instruction manual for the FM9, FM18 and FM36 Fluxgate gradiometers. *Even if you have used an FM9, FM18 or FM36 before you should read the following information.*

Optimum Instrument Heading Directions

When you tilt a gradiometer a small change in reading will occur even when properly aligned and balanced – this is known as a tilt error and will introduce in effect a small amount of noise to the observed or logged readings. Operators try to minimise this error by holding the gradiometer tube as vertical as possible. However, the magnitude of the tilt error is dependant on the direction or heading in which the gradiometer is pointed, with respect to magnetic north (heading direction is defined as the direction in which the electronics housing and handle axis is pointed). Since each instrument behaves differently in this respect there are unique optimum headings for each instrument that will minimise these tilt errors. You should ideally survey with the instrument pointing in one of these directions for lowest tilt error. Take care to remember that optimum heading direction refers to the direction in which the instrument is pointing – this may not necessarily be the same as the traverse direction, since it depends on the instrument holding technique you use.

The optimum heading will vary depending on your geomagnetic latitude. You can find the optimum headings at your latitude as follows:

1. Align and zero the instrument normally over a high quality alignment and balance / zero reference station.
2. Hold the instrument about 1m above the ground.
3. Observe the shift in reading as the instrument is tilted about 10 degrees from vertical in all four directions, with it facing in turn North, South, East and West.
4. The optimum directions are those that show the smallest change in reading.

In normal use you should be able to hold the instrument steady to about +/- 2.5 degrees from vertical so the observed tilt errors during a survey should be lower than just observed.

Section 1-6. Typical Specifications

The rechargeable battery type now supplied is Nickel Metal Hydride with a capacity of 2300mAh, replacing the Nickel Cadmium battery with 500mAh capacity. Therefore, in the Gradiometer section, Power Supply, replace “Nickel-Cadmium” with “Nickel Metal Hydride”. In the Gradiometer section, Battery life, replace “12.5 hours, Nickel-Cadmium” with 57 hours, Nickel Metal Hydride. In the Charger section, “Charge time for full capacity”, replace 10 hours with 46 hours. Section 3-9, Charging the Battery Pack, has also been revised – see that section for further information on charge time and capacity.

Section 2-2 (7). New Gradiometer Construction

A new style of housing for the sensors in the FM9, FM18, FM36 Fluxgate Gradiometers has been introduced, along with much smoother adjustment of the sensor alignment. This a more rugged construction in which the apertures needed to give access to the sensor adjustment controls are sealed against dust and dirt ingress, whilst the outer sealing caps maintain full waterproofing. Sensor alignment is now geared to give very fine angular adjustment via a control knob, replacing the earlier, coarser, edge adjustment wheel.

Figure 2-1. Spare sealing cap

The spare sealing cap (item 3) is no longer provided as standard but may be ordered as a spare part.

Section 2-3 (1). Battery Types - Rechargeable

The rechargeable battery type now supplied is Nickel Metal Hydride with a capacity of 2300mAh. The I.E.C. designation for the battery size is IEC HR6. Section 3-9, Charging the Battery Pack, has also been revised – see below.

Section 3-3 (1). Zero Key

If you obtain the "Balance" warning when trying to zero on the 0.1nT range and changing or rotating the batteries does not improve matters whilst in the field then, until less magnetic batteries can be obtained, adopt the following procedure. Step through the menu and set Check Offset to "On" to remove the effect of the zero control. Do not attempt to use the Zero control in future but accept an arbitrary zero. Also do NOT use Log Zero Drift. After the data is dumped subtract the mean from the data to obtain bipolar data (or use the Zero Mean Grid or Zero Mean Traverse process functions in Geoplot).

Section 3-5 (3). Alignment

The procedure for aligning the sensors remains the same. However, with the extra fine adjustment you have much more control. One rotation of the control knob will adjust the observed reading by about 1nT. However, you will observe a "dead" zone of about half a revolution in which rotation of the control knob will produce no change in reading - this is the backlash zone associated with the teeth of the gears.

It is advisable, when using the control knob, to rotate the required number of turns then rotate back slightly about one third of a turn until the control knob is back into the dead zone.

You should not press against the tube as you make adjustments, especially when aligning North-South, since this will bend the tube and can produce a change in reading of up to 5nT. Instead, make sure your hand just turns the control knob, ensuring you do not push it at the same time, whilst taking care not to rest your hand on the tube.

You should always make final alignment adjustments on the range you intend to use for a survey, rather than, for example, aligning on the 1nT range then switching to the 0.1nT range for the survey. Whilst aligning on the 0.1nT range you will find it much easier to gauge the correct control knob position if you switch Averaging to "On" with Averaging = 16 readings. Switch off just prior to the survey (unless you intend to use averaging for the survey as well).

When aligning it is VITALLY important that you are pointing in the correct magnetic direction otherwise you will not be able to align the instrument correctly. In fact if you are 90 degrees out from the correct direction (not unknown, even for experienced users!) then any adjustments will actually make alignment worse and eventually the instrument will become unusable.

Section 3-7. Data Output to a Computer

When dumping data make sure you set the software parameters to match those of the instrument - in particular grid size, sample and traverse interval, and Log Zero Drift status. Getting the latter parameter correct is perhaps the most important since if you set it wrong the data may be scrambled.

Section 3-9. Charging the Battery Pack

Charging Instructions. The rechargeable battery type now supplied is Nickel Metal Hydride with a capacity of 2300mAh, replacing the Nickel Cadmium battery with 500mAh capacity discussed in the manual.

The charger output remains the same at 25V, 70mA constant current. At this charge rate, full capacity will be achieved in 46 hours and the instrument will operate for 57 hours. Unlike Nickel Cadmium batteries, you should not experience any noticable "memory" effects with Nickel Metal Hydride batteries. This means you can top up the charge whenever you wish though it is advisable to avoid prolonged overcharge.

If you are operating the instrument daily, a typical overnight charge of 10 hours will power the instrument for 17 hours, that is approximately 2 days at 8.5 hours per day. In this case you might wish to charge the batteries every other day. In addition you will have in reserve 36 hours of charge from the initial 46 hour charge, though over time (a month or two) this extra charge will be lost through natural leakage. Therefore, if you wish to maintain this power reserve you should do a full 46 hour charge every month or two, instead of a normal 10 hour charge.

General safety information. Nickel Metal Hydride cells are broadly similar to Nickel Cadmium cells in many ways but are less tolerant of abuse. Particular hazards are electrolyte leakage and gassing. The electrolyte used is potassium hydroxide. Under certain conditions NiMH cells may vent hydrogen. Remove electrolyte with water. If electrolyte comes into contact with skin or clothing, wash off with plenty of water. If a skin reaction occurs, contact a physician. If electrolyte enters the eye, flush immediately with copious amounts of water, holding the eyelids open and rolling the eye. Seek immediate medical help. Hydrogen gas may form an explosive mixture with air. If venting is suspected, ventilate immediately. Avoid sparks or naked flame.

Section 4-2 (3). Sensor Alignment and Stability

Optimum sensor stability will be achieved if the instrument is kept powered up as continuously as possible, with minimal switching on and off (of course the instrument has to be switched off and on after data has been dumped). Stability can also be improved if the instrument is supported vertically during breaks in a survey, such as during a mid-day break. This may be achieved by the construction of a simple wooden stand.

Stability is best if you survey as many grids as possible without stopping (checking alignment and balance every 1 or 2 grids though). However, inexperienced users may at first find it beneficial to dump data every grid or two grids to make sure the survey is going well and that survey technique or instrument settings do not need modifying.

Section 4-4 (2). Grid Size

You must not change grid size or sample interval part way through a survey - always dump data first. Data will be scrambled otherwise.

In order to survey a 20m grid with a traverse interval of 0.5m, divide the grid into two halves of 20m by 10m and treat these as two separate grids. The Table on page 23 indicates the number of grids possible - these figures should be modified if sample interval is not 1m.

Section 4-3 (3). Reading Interval

Most users of the FM18 and FM36 opt to use the ST1 Sample Trigger which allows you to increase sampling interval from 1/m up to 8/m without increasing the survey time. A popular survey pattern is to use a 1m traverse interval with 4 samples per metre. Higher sampling densities give coherence to any weak signals enabling them to be more easily detected.

Section 4-4 (5). Resolution

Most surveys made over archaeological sites are now made using the 0.1nT range, rather than the 1nT range. Some users prefer not to use the Log Zero Drift facility on this range.

Section 4-7. Setting up a Zero Reference Point

It is vital that a good zero reference point is chosen for correct alignment of the instrument. It may be advisable to check your data after one or two grids and if the majority of readings are not centered around zero then you know that the reference point is not as quiet as it should be. You should then try and locate a better point. Always zero the instrument in the direction of the first traverse.

Section 4-8. Doing an Area Survey

When walking it is the sensor tube that should always be aligned with tape markers, not the centre of instrument (handle). This is especially important for weak signals - a coherent signal can then be built up. Zig-zag surveying makes this harder to do but can nearly double the ground coverage for a given survey time, compared to parallel traverses. Although there is a Destagger process function in Geoplot to correct for sensor mispositioning, you will obtain better final results if you perfect your surveying technique. Destagger cannot fully compensate for poor marker alignment, leading to subsequent loss of signal.

Making sure that the sensor tube is vertical at all times will lead to the best survey results - get an observer to be critical of your surveying stance so that you can improve your results.

If you use an ST1 Sample Trigger take great care when you flick the ST1 Start switch that you do not tilt the instrument or change your posture. Only a very small tilt may be sufficient to generate a small change in reading which, on very quiet sites, may be observed as a systematic increase or decrease in reading at the start of every traverse of a grid. This has the appearance of a band running perpendicular to the traverse direction, typically of strength 1nT. Starting to walk a metre or more before the start point can help reduce this problem. Likewise, you should also continue to walk at the end of a traverse past the tape, so as to not induce any slight tilt as you relax at the end of the traverse. This sort of error or defect is difficult to remove by software techniques (see below).

Do not set the ST1 sample rate too fast otherwise, in the presence of strong signals, especially iron spikes, this can lead to missing data points being logged. This arises because the internal Analogue to Digital converter takes longer to log a strong signal. You will hear when this happens - the logging "click" does not appear until after a short delay. You may be able to momentarily slow down your walking pace to allow for this time delay.

In section (1) Basic Procedure, step 10 : “When all of the traverses have been completed return to the zero reference point and Log Zero Drift if enabled.” The following text should be added : “To Log Zero Drift either press the Log key or, if using the ST1, flick the Start switch On then Off. If you are in encoder mode and press the Log key you may find several readings are logged. If this is the case use the Delete key to step back through the survey tracking until you reach position P1. It is usually easier to use the ST1 switch.”

Data Collection Defects

There are several data collection defects that can arise in a fluxgate gradiometer survey. These include : slope in the grid data, discontinuities at the edges of grids, traverse striping, traverse staggering and periodic errors. Most of these errors can be corrected for by using software process functions specifically tailored to tackle each problem such as those provided in Geoscan Research's Geoplot program.

Slope errors in grid data show as a very small and slow drift in the average data value throughout a grid, leading to a small difference in the background levels between the first and last traverses. However, it is essentially constant during the time required to scan an individual traverse. Using the FM18/36 Log Zero Drift correction facility can usually help reduce this effect, but even then, if the 0.1nT range is used, and/or the zero reference point is not truly a magnetic zero, there may still be a slight slope in the data.

Grid edge discontinuities arise due to improper choice of the zero reference point, incorrect zeroing at the reference point, or failure to regularily re-zero the instrument between grids.

Traverse striping is where alternate traverses have a slightly different background level. They show up in graphics plots as a series of stripes orientated in the traverse direction, and are especially noticable if the plotting parameters are set to look at very weak features. They often occur because of instrument tilt, usually due to improper alignment, failure to regularily check alignment or inattention of the operator to carrying angle. High walking speeds, failure to maintain the instrument at the same height on alternate traverses or a tendancy to twist the body slightly for each traverse (in order to view a marker tape) can also give rise to traverse striping. It can be particularily noticable with zig-zag traverses. When it occurs the typical strength is 1nT but can be up to 5nT in extreme cases.

Stagger defects arise due to a simple mis-positioning of the instrument along the traverse when a reading was recorded. For example, a linear anomaly running perpendicular to the traverse direction shows, not as a clean linear response, but as a chevron type pattern, with the maximum of the response being displaced first forward and then backwards in each alternate traverse. It usually occurs when zig-zag traverses are being used at a rapid walking pace and small sample interval.

Periodic errors (periodic modulation of the data) show up as a series of linear bands perpendicular to the traverse direction, with a period usually approximately equal to one or two walking paces (1 c/m or 0.5 c/m). They usually arise because the operator changes his stance or elevation slightly whenever the left or right foot is placed on the ground, or he launches himself forward for the next pace. It is more likely to be a problem if the speed of walking is high, the ground has a higher than normal magnetic susceptibility, the terrain is uneven eg ploughed, if the alignment of the gradiometer sensors are not checked often enough, or any combination of these factors. It is also most likely to be noticable if you are setting plotting parameters to look at very weak responses. When it occurs the typical strength is 1nT but can be up to 5nT in extreme cases.

Other factors that can cause periodic errors include the following :

(1) "Regimental" style of walking
(2) "Bouncy" style of walking
(3) Magnetic wellington boots - although usually non-magnetic one user reported a very small residual magnetic effect sufficient to cause periodic errors. Changing boots cured the problem.
(4) Very slightly magnetic clothing. It is probably worth double checking every piece of clothing for small items of metal - suspect everything unless proved otherwise.
(5) Some of the new coins have been found to be EXTREMELY magnetic. This applies to 2p, 1p etc coins - the older coins have not proved a problem (also makes alignment very difficult)
(6) A tendency to change the traverse direction or angle of the body from that direction adopted when zeroing the instrument at the reference point.
(7) High susceptibility soils and/or rough terrain, with mud sticking to boots causing an effect as each foot moves past the bottom sensor.
(8) The trimmer tool is slightly magnetic and should not be carried on the person.
(9) Poor choice of zero reference point leads to improper alignment, and non-zero background level. Improper alignment means any tilt errors or walking patterns will be exacerbated.