PMG1

Proton magnetometer and gradiometer

Operation manual

Version 2007

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1. Introduction

The proton magnetometer PMG1 is a portable instrument which can be powered by an internal battery or by an external source. It is intended for ground measuring of the absolute value of the magnetic induction vector of the Earth´s magnetic field by measuring the frequency of the precession of protons in hydrogen nuclei. The magnetic induction vector is also called the magnetic field vector.

The magnetometer PMG1 allows the Earth´s magnetic field to be measured in three modes:

SINGLE mode is used in a profile magnetic survey with one sensor. It detects the absolute value of the magnetic field in the location of the sensor. The sensor is connected to the ‘Up sensor’ connector, see Fig. 4.

GRAD mode uses two sensors. The absolute values of the magnetic induction vector in the locations of both sensors are measured simultaneously. The horizontal or vertical gradient of the magnetic field between the two sensors is determined by subtraction: The value of the field measured in the location of the sensor connected to the ‘Up sensor’ connector minus the value of the field measured in the location of the sensor connected to the ‘Down sensor’ connector. The gradient measurement removes to some extent the undesirable influence of disturbing fields, compensates for the influence of the regional field and does not depend on diurnal variations in the Earth´s magnetic field.

AUTO mode allows repeated measurements with one sensor in set time intervals. Both the starting time and the length of the intervals can be set prior to the measurements. This mode is used for measuring diurnal variations in the Earth´s magnetic field.

The results of the measurements can be stored in an internal protected memory. The recorded data is not lost when the instrument is switched off or when the battery is removed. The data can be transmitted to a computer through a standard serial interface RS-232C using the communication program PMG1tr.EXE which is supplied with the instrument. The program running under Windows 95 or later transmits the data from the instrument to a PC and saves the data in a text file of the external computer.

The magnetometer PMG1 is delivered with a power supply, which is a built-in lead acid battery. The non-magnetic rechargeable battery does not contribute enough to the magnetic moment of the instrument to affect measured values. A battery charger is also supplied with the instrument.

All functions of the magnetometer PMG1 are controlled by an internal microprocessor. This internal microprocessor allows an operator to communicate with the instrument via a keyboard and LDC display, controls the measurement process and transmits the acquired data to an external computer through the serial interface RS-232C.

The proton magnetometer automatically checks correctness of the measurement and of the activities of the operator. If a failure is detected, the operator is warned with an audible signal and with an error message on the display.

2. Specifications

Measuring range	20 000 to 100 000 nT
Resolution	0.1 nT
Absolute accuracy	±1 nT
Maximum gradient value	5 000 nT/m
Measuring cycle	ca 2 s
Triggering	- manual
	- automatic in AUTO mode
	- external, through serial interface RS-232C
Internal clock	day, month, year, hours, minutes and seconds, independent of battery condition
Data memory	27 000 readings

Serial interface RS-232C:

Use	data transmission to a computer, remote control of the magnetometer via a computer
Baud rate	optional from 300 to 19 200 Bd
Format	10 bits, 1 start, 8 data, 1 stop (without parity)

Power supply	internal lead acid battery 12 V / 3.4 Ah,
Battery lifetime	5 000 readings on average in GRAD mode

Processing unit:

Dimensions	240 x 90 x 170 mm
Weight	3.2 kg including battery

Sensor

Dimensions	dia 80 x 200 mm
Weight	0.7 kg

Operating temperature range	- 10 to 60 °C
Storage temperature range	- 20 to 70 °C

3. Description

The proton magnetometer PMG1 consists of a processing unit, measuring sensors and a post.

3.1 Measuring sensor with accessories

The measuring sensor contains two coils properly arranged to suppress an external disturbing field. The coils are placed in a laminated cylinder container filled with a liquid rich in hydrocarbons.

North and south are marked on the container of the sensor. The ‘north’ mark should point to the geographical north. The orientation of the sensor does not affect the value of the measured magnetic field, but it does affects the intensity of the signal from the sensor and thus the size of error of the measurement.

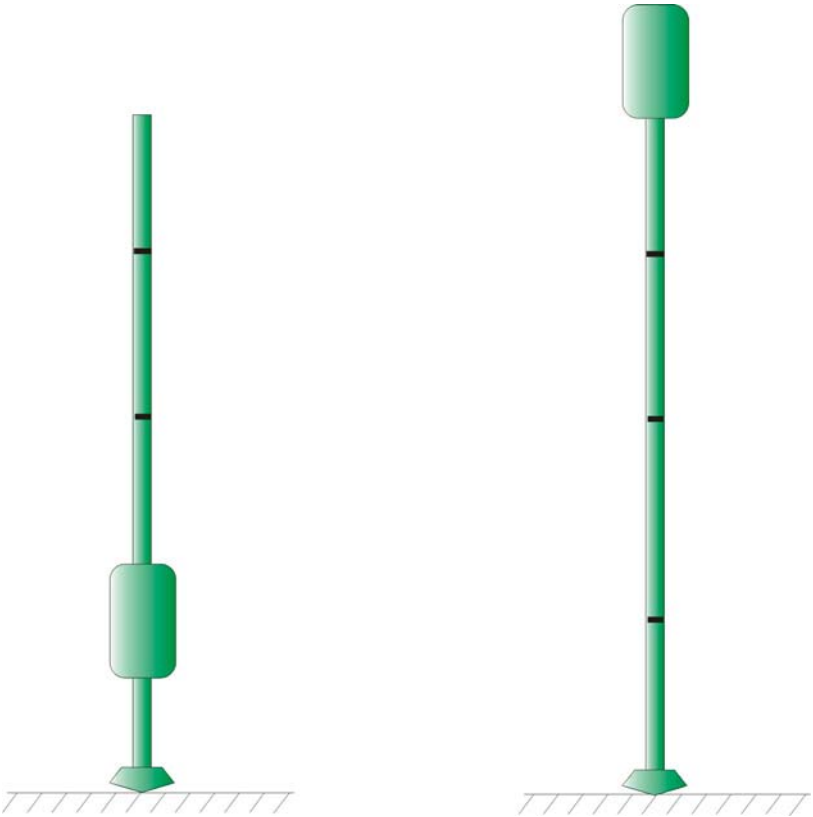

Fig. 1: Post assembly for line measurement

For measurements the sensor is mounted on a post which is assembled using up to five half meter long sticks joined with screw coupling. In this way the sensor can be set to various heights above the ground - see Fig. 1. For gradient measurement an extension (gradient stick) is used to keep both sensors 0.5 or 1 m apart - see Fig. 2. The gradient stick allows the position of the sensors to be set so that the orientation of both sensors to the Earth´s magnetic field may be the same. For AUTO mode measurements (diurnal variations) an anchor ring with ropes and pins is supplied to hold the post in place.

The measuring sensors and the processing unit are connected via 2.5 m long cables.

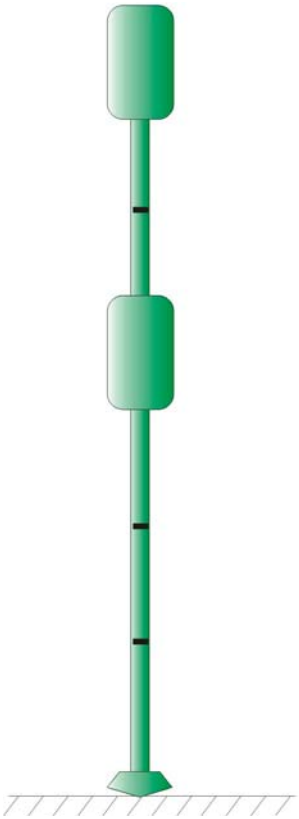

Fig. 2: Post assembly for gradient measurement

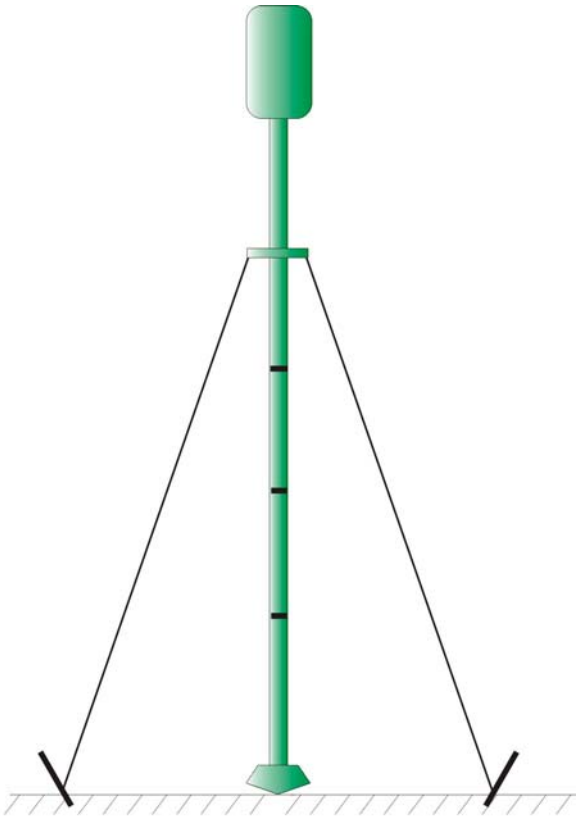

Fig. 3: Post assembly for magnetic variation measurement

3.2 Processing unit

The processing unit allows for communication with an operator via a keyboard and a two row alphanumeric LCD display. It contains circuits for processing and analyzing the measured signal: tuning circuits, low-noise amplifier, filter and shaping amplifier.

The processing unit is placed in a duralumin box. Two bayonet watertight connectors for connecting the sensors are located on the top of the box. In SINGLE and AUTO modes only the upper left connector is used, ‘Up sensor’ - see Fig. 4. In GRAD mode, the connector is used for the upper sensor. The gradient is determined by subtraction: The value of the field measured in the location of the sensor connected to the ‘Up sensor’ connector minus the value of the field measured in the location of the sensor connected to the ‘Down sensor’ connector.

There are two connectors on the right side of the instrument box. A 9 - pole trapezoid connector serves for connecting an external computer through the serial interface RS-232C. A coaxial connector for charging of the internal battery is located in the lower part of the instrument. The connector can also be used for an external power supply after removing the internal battery.

The lead acid battery is placed in the bottom part of the unit and is accessible by unscrewing the four bolts in the bottom cover. The battery compartment is hermetically separated from the electronics.

All controls are concentrated on the top side of the unit - see Fig. 4. The keyboard contains 17 watertight membrane push-buttons with audible indication.

The instrument is delivered with a harness to fasten it on the chest of an operator.

Fig. 3: Instrument panel

3.3 Functions

The measurement of the magnetic field is conducted in two steps. In the first measuring step the polarization current feeds the sensor and causes uniform orientation of magnetic moments of hydrogen nuclei contained in the liquid in the sensor. The time of polarization is automatically increased according to the decreasing source voltage so that the precession signal gained from the sensor may remain constant. During the polarization cycle the sensor and the low-noise amplifier are disconnected. The first step of the measuring sequention is terminated by switching the polarization current off.

In the second step due to an interruption of the polarization current in the sensor the transient field is dumped and then the low-noise amplifier is connected to the sensor. The signal induced in the sensor is amplified, filtered and shaped to suit the processing in numeric circuits.
In the sampling circuit of the microprocessor the frequency of attenuated oscillations of the precession motion of the hydrogen nuclei is evaluated. The frequency is directly proportional to the measured magnetic field.

The entire measuring cycle is controlled by a microprocessor which computes the measured magnetic field and statistical error of the measurement from the value of the frequency of the precession. Both values are displayed and optionally stored in the data memory.

During the second step, the amplitude of the precession signal and the time constant of the decay are determined. The supplementary values are also stored in the data memory.

3.4 Operating controls

[ON / OFF]	switching on and off
[ENTER]	start of measurement or other selected procedures, setting validity of modified parameters or data, storing measured data in the memory
[ESC]	termination of any going-on procedure without storing data
[FUNC]	selection of function, transfer to functions in the upper part of push-buttons. A function can be selected by pressing [v] or [^] or directly by the numeric push-buttons [0] to [9].
[NEXT]	next item
[0] to [9]	loading digits
[v]	scanning series of consecutive data towards higher ordinal numbers
[^]	scanning series of consecutive data towards lower ordinal numbers

Functions initialized after pressing [FUNC]

[+ / -]	changing the sign of the entered data
[TIME]	displays the time and date of the inner clock
[TUNE]	displays the current tuning of the instrument, displays the automatic tuning identifier
[LCD]	setting of the contrast and backlight of the display
[MODE]	displays the selected mode
[OFF]	displays the time interval for the instrument switch off if there are no activities on keyboard or serial channel. The function protects the battery.
[NOTE]	displays a comment about the measurement

[POS]	displays the current profile, position and spacing in SINGLE or GRAD modes, in AUTO mode also time interval and time of starting measurement
[BAT]	displays voltage of power supply
[MEMORY]	recalls and displays measured data stored in the data memory
[BAUD]	displays the rate of transmission through the serial interface RS-232C
[REMOTE]	transfers control of the instrument to an external computer

3.5 Display

A liquid crystal display (LCD) is used in the processing unit allowing display of two rows of 16 ASCII characters. A backlight can be used to make the display readable in worse conditions, but the power consumption is considerable. Therefore the option should be used for the shortest time possible.

The contrast of the display is automatically adjusted according to the temperature, however it also depends on lighting. That is why the contrast and the backlight can be set by the function LCD, see chapter 5.3.

4. Operation

4.1 Power supply

The instrument is delivered with a built-in hermetically closed lead acid battery 12V / 3.4Ah. The magnetometer can also be powered from an external source, for example a 12 V car battery, but the internal battery must first be removed. The battery compartment is accessible from the bottom part of the box by unscrewing the four bolts fastening the bottom cover of the instrument.

The internal battery can be charged directly in the instrument with the delivered with the instrument. The charger ALCS 2-24 is designed to match the optimum charge mode of the used battery. The use of the charger is described in chapter 9.2.

4.2 Switch on/off

The first check of the instrument function can be performed with the processing unit without connecting the sensor. The instrument is switched on by pressing [ON / OFF]. A notice appears on the display giving the type of the instrument, serial number and current measurement mode, for example:

```
PMG1  S/N:2613
Mode SINGLE<
```

After pressing any key the information is added about the number of readings that can be stored in the data memory, for example:

```
FreeMem =  09898
Mode SINGLE<
```

In the case of a faulty power supply an error message is displayed.

If the battery is deeply discharged, the instrument automatically switches off.

Also, the instrument automatically switches off if the time interval set by the OFF function elapses and there are no activities of the operator on the keyboard or through the serial interface RS-232C.

If the instrument does not display the above mentioned information even after repeatedly pressing [ON /OFF], it means there is an instrument failure. It is recommended to contact the distributor or the manufacturer.

4.3 Battery condition check

The battery condition check is performed automatically each second after the instrument is switched on. The voltage levels for error messages about the battery discharge were set from the discharge characteristics according to the power consumption at the time of the check. If an error message about the battery discharge is displayed, it is necessary to charge the battery or to replace it with a charged one. The software does not allow operation of the instrument if the battery is deeply discharged and switches it off automatically. Thus erroneous operation and damage of the battery are prevented.

If the instrument is not used for a long time, the battery should be checked and charged at least twice a year.

The battery voltage can be measured by a built-in digital voltmeter using the BAT function - see chapter 5.7.

4.4 Battery for data retention after the instrument is switched off

The battery in the instrument is used to power the data memory even after the instrument is switched off. If the error message about low voltage of the battery is displayed, an immediate transmission of measured data to a computer is recommended, otherwise the data may be lost. The measured data are lost when the battery is removed.

The battery voltage can be checked by a built-in digital voltmeter using the function BAT - see chapter 5.7.

5. Basic setting

All functions of the instrument are controlled by a microcomputer that retains the current setting of parameters after the instrument is switched off. After the instrument is switched on or after the termination of a selected procedure the control switches to MONITOR, i. e. a mode in which further commands from the keyboard or from an external computer through the serial interface RS-232C are awaited. The mode is indicated on the display by the prompt > and usually also by a notice of the next measurement position point. [ESC] terminates any procedure and transfers control to the MONITOR mode.

After the instrument is switched on the information of the serial number of the instrument and the current measurement mode is displayed. After pressing any key the information of free data memory is added, it is the number of readings that can be stored in the data memory (the remaining capacity of the data memory). After pressing another key the instrument switches to the MONITOR mode and the message about the position of the next awaited measurement is displayed,
for example:

> Next position:
L= 0010 P= 0080

The instrument setting parameters can be checked or set in the MONITOR mode. They are:
- time and date of the internal clock
- tuning of input circuits of the magnetometer
- contrast of the display
- measurement mode
- time interval to switch off
- position of the measurement
- voltage of the power supply
- contents of the data memory
- rate of transmission through the serial interface RS-232C

The modified parameters are retained in the memory even after the instrument is switched off until next modification. Only if the battery is low, are the set parameters lost and replaced by default values.

5.1 Checking and setting the internal clock - TIME

The function for the internal clock control is called by consecutively pressing [FUNC] and [TIME]. The current value of real time and date is displayed:

```
7. Time hh:mm:ss
Date dd.mm.yyyy
```

hh stands for hours, mm minutes, ss seconds, dd day in month, mm month and yyyy year. The data can be modified by pressing [ENTER], which causes it to enter the edit mode. A cursor indicates the place to be modified by numeric push-buttons. The cursor is moved by pressing [v] and [^]. The push-button [NEXT] moves the cursor to the date that can be modified similarly.

To store the modified data in the memory it is necessary to press [ENTER] after the modification. The procedure can be terminated without changing data by pressing [ESC]. The control returns to the MONITOR mode.

5.2 Tuning of the magnetometer - TUNE

Considering the character of the signal processed by the analog part of the instrument it is necessary to tune input circuits at least approximately to the measured magnetic field. To display the current tuning interval [FUNC] and [TUNE] are consecutively pressed (in the MONITOR mode). For the SINGLE and AUTO modes the display shows for example:

```
8. Tune Off
45500 - 48000<
```

The tuning procedure is entered by pressing [ENTER]. The display shows for example:

```
Tune Off
45500 - 48000<
```

The word On/Off indicates if the function of the automatic tuning of input circuits is on or off. The automatic tuning can be switched on or off by pressing [NEXT]. The interval of the magnetic field can be selected by pressing [v] and [^] according to the awaited value.

The tuning intervals are:

1. 20 000 - 21 000 nT
2. 20 900 - 22 000 nT
3. 21 900 - 23 000 nT
4. 22 900 - 24 100 nT
5. 24 000 - 25 200 nT
6. 25 100 - 26 400 nT
7. 26 300 - 27 700 nT
8. 27 500 - 29 000 nT
9. 28 800 - 30 400 nT
10. 30 200 - 31 800 nT
11. 31 600 - 33 300 nT
12. 33 100 - 34 800 nT
13. 34 600 - 36 400 nT
14. 36 200 - 38 200 nT
15. 38 000 - 40 000 nT
16. 39 700 - 41 800 nT
17. 41 600 - 43 800 nT
18. 43 500 - 45 800 nT
19. 45 500 - 48 000 nT
20. 47 700 - 50 200 nT
21. 49 900 - 52 600 nT
22. 52 300 - 55 100 nT
23. 54 800 - 57 700 nT
24. 57 400 - 60 400 nT
25. 60 100 - 63 200 nT
26. 62 900 - 66 200 nT
27. 65 900 - 69 300 nT
28. 69 000 - 72 600 nT
29. 72 300 - 76 000 nT
30. 75 700 - 79 600 nT
31. 79 300 - 83 300 nT
32. 82 900 - 87 300 nT
33. 86 800 - 91 400 nT
34. 90 900 - 95 700 nT
35. 95 300 - 99 999 nT

Preliminary approximate setting of the tuning point is performed on the basis of a magnetic field map - see Fig. 5 in dependence on the geographic coordinates of the point of measurement. An error message indicates if the measured value of the magnetic field is not within the tuning interval. If the automatic tuning is on, the input circuits will be automatically tuned at the next measurement.

The modified tuning interval is stored in the memory after pressing [ENTER]. By pressing [ESC] the tuning procedure is terminated without changing the interval.

For the GRAD mode after pressing [FUNC] and [TUNE], the tuning interval of the ‘Up sensor’ (number 1) is displayed. After pressing [ENTER]

Tune 1 or 2 ?

is displayed, because the tuning should be repeated twice, for each sensor separately. After pressing [1] or [2] the procedure, it is setting the tuning interval and the automatic tuning, is identical to the one in the SINGLE mode. The automatic tuning (On/Off) is the same for both sensors.

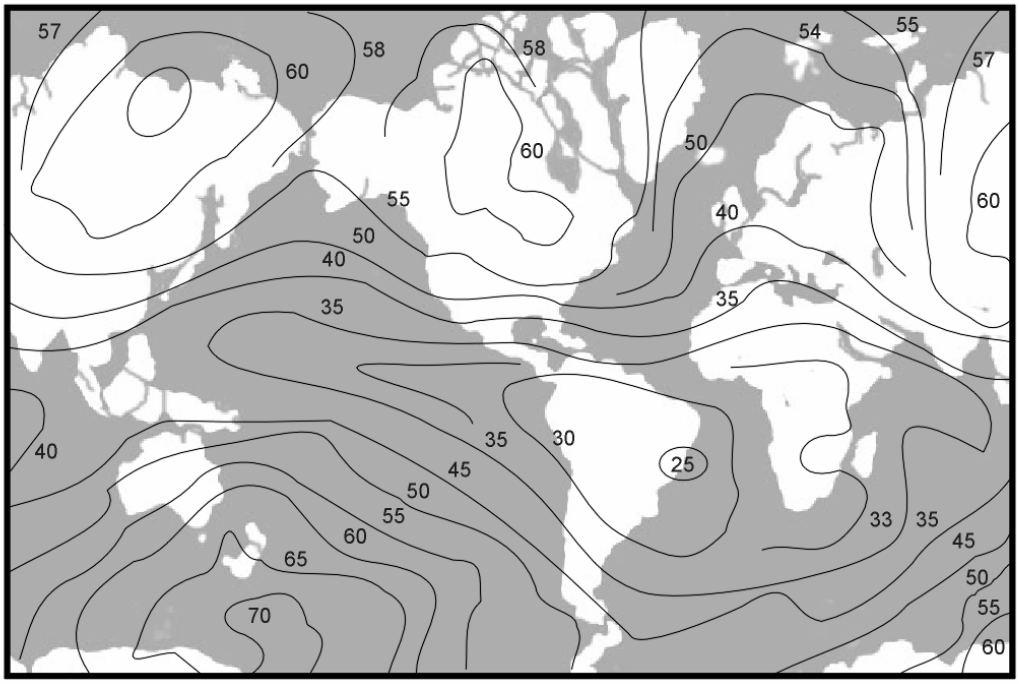

Fig. 5: Earth's magnetic field

5.3 Setting the display contrast - LCD

The LCD function is called by consecutively pressing [FUNC] and [LCD]. The current settings of the contrast and backlight are displayed.

9. Contrast 120
Backlight Off

The settings can be changed by pressing [ENTER] and entering the edit mode. The value of contrast is shown at the end of the first row. The letter A stands for automatic, the contrast is adjusted to the temperature. It can be modified by [v] and [^]. The backlight is switched on or off by pressing [NEXT]. The push-buttons [ENTER] and [ESC] have the same function as above. It is

to store the modified data or to terminate the LCD function without modifications. The contrast and backlight values are set to default after switching the instrument off.

5.4 Selection of the measurement mode - MODE

The MODE function allows the selection of one of the measurement modes: SINGLE, GRAD, AUTO. The currently selected mode is displayed after pressing [FUNC] and [MODE], for example:

```
4. Mode
    SINGLE<
```

After pressing [ENTER] the mode can be changed by repeatedly pressing [NEXT]. The pressing of the push-button [ENTER] asserts the selection, [ESC] terminates the procedure without changing the mode.

5.5 Setting the time interval to switch off - OFF

To protect the power supply, the lead acid battery, the instrument is automatically switched off after elapsing the set time interval after the last activities of the operator on the keyboard or through the serial interface. Thus the deep discharge and the damage of the battery are prevented even if the operator forgets to switch off the instrument. The default value is 20 min.

By consecutively pressing [FUNC] and [OFF] the time is displayed. After elapsing of the time the instrument is automatically switched off. The format is hh:mm:ss, where hh stands for hours, mm for minutes, ss for seconds. For example:

```
5. Time off
      00:20:00
```

After pressing [ENTER] the time can be modified. The cursor is moved by pressing [v] and [^], the digits are changed by numeric push-buttons. [ENTER] asserts the new value, [ESC] terminates the function without saving the changes.

5.6 Setting the position - POS

The POS function sets the position of the next measurement that will be conducted. The information is stored in the data memory together with the measured value. The position consists of the profile number ‘Line’, the position on the profile ‘Pos’ and the spacing ‘Step’, which is the increment or decrement of the next position ‘Pos’. If the ‘Step’ is positive, the value of the next ‘Pos’ stored with the measurement in the data memory is increased by the value of the ‘Step’, if the ‘Step’ is negative, the value of the next ‘Pos’ is decreased. This allows the operator to move to the end of the profile, to higher positions, and also back to the lower positions.

By consecutively pressing [FUNC], [POS] and [ENTER] the edit mode of the POS function items is entered. The items are: ‘Line’, ‘Pos’ and ‘Step’. The current value of the profile ‘Line’ is displayed, for example:

1.1. Line:
0001

A cursor appears at the place of the digit to be modified and can be moved by [v] and [^]. The value ‘Line’ can be set from -9999 to 9999. By pressing [NEXT] the second item, the current position on the profile ‘Pos’ is displayed, for example:

1.2. Pos:
0120

The value of ‘Pos’ can be also set from -9999 to 9999 the same way as with the profile. Another pressing of [NEXT] displays the current value of the ‘Step’, for example:

1.3. Step:
10

The value of the ‘Step’ can be set from -99 to 99 the same way as above. By [v] and [^] the digit to be modified is selected and by numeric push-buttons [0] to [9] it is changed.

[NEXT] is used for switching among the items ‘Line’, ‘Pos’ and ‘Step’. The modified data are stored in the memory by pressing [ENTER]. Pressing [ESC] terminates the function without storing the changes.

The previous description of the POS function refers to the SINGLE and GRAD modes. If the AUTO mode is selected, the items of the POS function are different. The items ‘Line’, ‘Pos’ and ‘Step’ identify the measurement. There are two more items: ‘Interval’ sets the time interval between measurements and ‘Start AUTO’ sets the time of the first measurement of the base station.

5.7 Checking of the battery condition - BAT

The BAT function is used to check the voltage of the power supply. The function is called by consecutively pressing [FUNC] and [BAT]. The voltage value of the batteries is displayed. For example:

```
2. Bat. = 12.1 V
```

5.8 Recalling stored data - MEMORY

The MEMORY function is used to display the data stored in the data memory.

By consecutively pressing [FUNC], [MEMORY] and [ENTER] the last measurement is displayed. By pressing [v] or [^] the following or the previous measurement is displayed. By pressing [NEXT] next item of the selected measurement is displayed. The first item is

```
Date dd.mm.yyyy
Time hh:mm:ss
```

dd stands for day, mm month, yyyy year, hh hours, mm minutes and ss seconds. In the AUTO mode the first row is omitted. By pressing [v] or [^] the time of the following or the previous measurement is displayed. Pressing [NEXT] displays the next item of the recorded data.
In the SINGLE and AUTO modes the value of the magnetic field, error of the measurement, profile number and position number are all displayed. For example:

```
48059.2 ±0.1 nT
L 0000 P 0020
```

In the AUTO mode the second row is omitted.

Pressing [NEXT] another time displays the next item, containing signal intensity, time constant of the decay of the signal and mode, for example:

```
A=2    D=4.2s
     SINGLE
```

In the GRAD mode pressing [NEXT] displays first the gradient value, error of the measurement, profile number and position number. For example:

```
00400.6  ±00.1nT
L:0000 P 0020
```

Pressing [NEXT] another time displays the next item, containing values of the magnetic field measured in both locations

```
48459.8 ±00.1nT
48059.2 ±00.1nT
```

Pressing [NEXT] another time displays the next item, containing signal intensity, time constant of the decay of the signal and mode, for example:.

```
A=2  D=4.2s
     GRAD
```

5.9 Setting the rate of transmission - BAUD

The BAUD function is used to set the rate of transmission of the serial interface RS-232C. After consecutively pressing [FUNC] and [BAUD] the current value of the rate is displayed.
By pressing [v] or [^] one of the following values of the rate of transmission can be selected:

300 Bd
600 Bd
1200 Bd
2400 Bd
4800 Bd
9600 Bd
19200 Bd.

Pressing [ENTER] asserts the selected value, [ESC] terminates the function without storing changes.

5.10 Sign change +/-

The function changes the sign of the value of POS function items ‘Line’, ‘Pos’ and ‘Step’. The sign is changed during modification of the item by consecutively pressing [FUNC] and [+ / -].

6. Measurement

The instrument and its accessories are transported in a leather case. It must be assembled before operation.

The measured value of the magnetic field depends very much on the presence of metal objects near the sensor. The operator should remove all the metal objects prior to measuring.

6.1 Instrument set-up

Screw together the sensor and the sticks of the post to the desirable length - see Fig. 1. The processing unit can be attached to the harness and carried on the chest.

Connect the sensor to the processing unit by using the appropriate connectors. In the SINGLE and AUTO modes the connector ‘Up sensor’ is used, see Fig. 4. In the GRAD mode both sensors are used. The upper sensor should be connected to the ‘Up sensor’ connector, otherwise the sign of the gradient value is changed.

The instrument is ready for measurement.

Notice:

It is recommended to keep the sensor as far as possible from the processing unit to limit the influence of the magnetic moment of the instrument.

For the same reason it is recommended to keep the direction of the advance along the profile during the measurement on one area.

6.2 Sensor orientation

The measured value of the magnetic field does not depend on the sensor orientation. But with the changing orientation of the sensor towards the Earth’s magnetic field the signal from the sensor is changed and the statistical error of the measurement increases. To achieve the maximum signal the sensor must be oriented in the north - south direction, that is the ‘north’ mark on the sensor must point to the geographical north.

6.3 Tuning

Before measuring in a new area it is necessary to set or check the preliminary tuning of the instrument according to the map of the Earth's magnetic field, see Fig. 5. If the measurement is conducted with inaccurately tuned circuits, an error message is displayed. If the automatic tuning function is on, the tuning will occur automatically with regard to the measured value. The automatic tuning is not performed in the case of an enormous difference in which the value of the magnetic field is measured with a big statistical error. The tuning procedure is described in the chapter 5.

6.4 Measuring in SINGLE mode

By consecutively pressing [FUNC], [MODE] and [ENTER] the MODE function is entered in which the measurement mode can be modified. By repeated pressing [NEXT] the SINGLE mode is selected. The selection is asserted by [ENTER]. The instrument is prepared to measure the absolute value of the magnetic field vector. If the data memory should be used, the position of the first measurement must be set, which means setting the items 'Line', 'Pos' and 'Step' in the POS function. This is described in detail in the chapter 5. The measurement is started by pressing [ENTER]. After about 2 seconds the measured value of the magnetic field with the statistical error is displayed in the first row. In the second row the position of the measurement point 'Line' and 'Pos' is displayed, as well as the letter S and the blinking cursor indicating that the reading can be stored in the data memory. For example:

```
47239.1 ±00.2 nT
L 0000 P 0010 S?
```

Pressing [NEXT] displays additional information of the reading. In the first row the value A means the signal intensity and the value D expresses a time constant of the decay of the precession signal. In the second row the mode is displayed. The letter S with a cursor indicates the option to store
the reading in the data memory. For example:

```
A=6   D=3.2s
    SINGLE<S?
```

After another pressing [NEXT] the number of the readings that can still be stored is displayed.

```
FreeMem = 09795
```

6.5 Measuring in GRAD mode

The instrument measures the value of the magnetic field in both locations of the sensors simultaneously. The displayed value of the gradient is determined by subtracting of the value of the magnetic field of the sensor connected to the ‘Down sensor’ connector from the value of the magnetic field of the sensor connected to the ‘Up sensor’ connector. The procedure of measuring and storing data is identical to the SINGLE mode. The measurement is started by pressing [ENTER]. After about 2 seconds the measured value of the gradient with the statistical error is displayed in the first row. In the second row the position of the measurement point ‘Line’ and ‘Pos’ is displayed, and also the letter S and the blinking cursor indicating that the reading can be stored in the data memory.

By pressing [NEXT] the value of the magnetic field in the location of the sensor connected to the ‘Up sensor’ connector with the statistical error is displayed in the first row. In the second row the same information for the ‘Down sensor is displayed. After another pressing [NEXT] additional information appears. The value A means the signal intensity of the upper sensor and the value D expresses a time constant of the decay of the precession signal.

After another pressing [NEXT] the number of the readings that can still be stored is displayed.

By pressing [ENTER] the reading is stored in the data memory and the next position is displayed. By pressing [ESC] the measured data is erased and the current position is displayed.

6.6 Measuring in AUTO mode

By consecutively pressing [FUNC], [MODE] and [ENTER] the MODE function is entered in which the measurement mode can be modified. By repeated pressing [NEXT] the AUTO mode is selected. The selection is asserted by [ENTER]. The instrument is prepared to serve as a base station, and measure diurnal variations. The time of the first automatically started measurement is displayed, for example:

```
>Next start:
      10:00:00
```

The information is displayed until the time of the first measurement. After the measurement the measured value is displayed for about 1 s, and then the time of the next measurement. The start time and the time interval are set in the POS function as described in the chapter 5.

The results of the measurement in the AUTO mode are stored automatically in the data memory.

The AUTO mode is terminated by changing the measurement mode in the MODE function or by switching the instrument off.

7. Data memory

The instrument is equipped with a large memory where all readings and identifiers can be recorded. The capacity of the data memory is 27 000 readings. The readings obtained in various modes can be stored sequentially. The stored data can be recalled, displayed or transmitted to an external computer through the serial interface RS-232C.

It is useful before the beginning of the measuring in a new area to transmit data stored in the data memory to the external computer and to erase the data memory. Thus the data memory is set to maximum capacity.

7.1 Erasing and checking of the data memory

The stored data will be erased during the procedure, therefore it is necessary to transmit the data to an external computer through the serial interface RS-232C prior to the procedure. To prevent occasional erasing of the memory, the operator is repeatedly reminded of the danger of loosing the data.

The erasing procedure is called by selecting the ERASE function. By pressing [FUNC] the last selected function appears on the display. By pressing [v] or [^] the ERASE function is selected and by pressing [ENTER] the ERASE function is entered. The message is displayed:

Erase memory ?
OK=Enter

After pressing [ENTER] the following message is displayed:

Are you sure ?
OK=Next

Only after pressing [NEXT] will the data memory be erased. The ERASE function can be terminated by pressing [ESC] any time.

7.2 Data storage in the data memory

After a measurement the result is displayed as well as the profile number and the position on the profile of the measurement point. There is also the letter S and a cursor. To store the data,

the operator presses [ENTER], otherwise [ESC] (canceling the measured value), and the measurement on the point can be repeated. The position of the next measurement is displayed in both cases. The position can be changed in the POS function.

7.3 Note

The NOTE function adds a comment to the last stored measurement. By pressing [FUNC] the last selected function appears on the display. By pressing [NOTE] or [v] or [^] the NOTE function is selected and the last selected note is displayed, for example

6.NOTE 07
Clay

By pressing [ENTER] the NOTE function is entered and by pressing [v] or [^] a desired item of the note list is selected. After pressing [ENTER] the position of the last stored reading is displayed and the operator is asked to confirm ([ENTER]) or refuse ([ESC]) the note to be stored with the reading.
If the last reading is not stored and the operator makes an attempt to use the NOTE function, the message is displayed:

First Save
the Last Reading

The last measurement should be either stored ([ENTER]) or canceled ([ESC]).There are 39 items of the alphabetical note list. The note number 00 is empty.

7.4 Display of data stored in memory

The data stored in the data memory can be recalled, displayed or transmitted through the serial interface RS-232C in a computer.

The data is displayed in the MEMORY function. By pressing [FUNC], [MEMORY] the last stored data is displayed. By pressing [NEXT] the individual items of the reading can be scanned. Pressing [v] or [^] displays the following or the previous reading. Continually pressing [v] or [^] increases the speed of the scanning. A notice is displayed if the data memory is empty and when there is a beginning of the data memory.

7.5 Transmission of the stored data to a computer

Before transmission of the stored data to an external computer it is necessary to connect the instrument and the computer with a cable and to set the magnetometer to the REMOTE mode in which the instrument is controlled by the computer. By pressing [FUNC] the last selected function is displayed. By pressing [v] or [^] the REMOTE function is selected and by pressing [ENTER] it is entered. The message is displayed:

Remote

On the computer it is necessary to run the program PMG1tr.EXE which allows the data to be transmitted from the magnetometer to the computer and stored in a text file. The program runs under Windows 95 or later.
The format of the data is different for various measurement modes.

Format of the transmitted data

```
M Date       Time      Line  Pos   Field    Err  A D    Grad    Note
S 25.07.1995 09:32:16  0001  0000  48248.2  00.1 7 1.2
S 25.07.1995 09:32:30  0001  0002  48255.8  00.1 7 1.3
G 25.07.1995 09:32:58  0001  0004  48262.1  00.3 6 1.3 -00000.6 Bridg
G 25.07.1995 09:33:10  0001  0006  48272.2  00.3 6 1.2  00002.3
G 25.07.1995 09:33:24  0001  0008  48277.1  00.1 7 1.1  00002.5 Ravin
G 25.07.1995 09:33:36  0001  0010  48280.4  00.1 7 1.2  00002.0
G 25.07.1995 09:33:46  0001  0012  48283.1  00.0 6 1.4  00000.9
A 25.07.1995 09:34:01  0001  1111  48287.3  00.1 6 1.2
A 25.07.1995 09:34:21  0001  1111  48287.4  00.1 7 1.3
A 25.07.1995 09:34:41  0001  1111  48285.5  00.1 6 1.2
```

M is the measurement mode. The letter S stands for the SINGLE mode, G for the GRAD mode and A for the AUTO mode.
Date is the date of the measurement.
Time is the time of the start of the measurement.
Line is the profile number.
Pos is the position on the profile.
Field is the magnetic field value of the sensor connected to the ‘Up sensor’ connector.
Err is the statistical error of the measurement.

A is the signal intensity.

D is the time constant of the decay of the precession signal.

Grad is the value of the gradient.

Note is a comment about measurement.

In the AUTO mode the values of date, line and position are not valid because they are not used, they are not stored in the data memory with each individual reading.

8. Magnetometer control by an external computer

As explained in the previous chapter, when the instrument is set to the remote control mode, all function can be controlled only by an external computer through the serial interface RS-232C. On the keyboard of the instrument only the push-button [ESC] responds, terminating the REMOTE mode at any time.

The communication with the instrument is achieved by ASCII characters sent from the computer to the magnetometer. The pressing of push-buttons on the keyboard is substituted by sending the appropriate ASCII character through the serial interface RS-232C to the magnetometer.

Parameters of the interface:

Data flow control:	none
Number of stop bits:	1
Number of data bits:	8
Parity:	none
Rate of transmission:	300 Bd, 600 Bd, 1200 Bd, 2400 Bd, 4800 Bd, 9600 Bd, 19200 Bd

Equivalents of the magnetometer keyboard push-buttons on the remote control through the serial interface RS-232C:

Push-button PMG1	ASCII character	Decimal value
key Esc	BS	8
key Enter	CR	13
key Next	HT	9
key Func	!	33
key 1	1	49
key 2	2	50
key 3	3	51
key 4	4	52
key 5	5	53
key 6	6	54
key 7	7	55

key 8	8	56
key 9	9	57
key 0	0	48
key ♦	:	58
key ♦	;	59

Besides the above characters there are other ASCII characters which are commands for the instrument:

$ command for the magnetometer to send the contents of the data memory in the text form to the computer

? command for the magnetometer to send the current contents of the display of the instrument to the computer

command for the termination of the communication and the activation of the instrument keyboard. The communication can be also terminated by pressing [ESC] on the instrument.

Error messages are transmitted as text strings beginning with the character *.

9. Supplementary information

9.1 Serial interface RS232C

The magnetometer PMG1 can be directly connected with a computer through the serial interface RS-232C according to the EIA. The majority of currently used IBM PC computers have this standard interface. According to the standard the same types of connectors are used with the same pin positions and the same voltage for both logical signals.

To achieve the correct communication the interface of the computer must be set according to the parameters of the instrument. The rate of transmission and data format are described in the chapter 2.

The magnetometer is connected to the computer with the cable supplied by the manufacturer.

The program PMG1tr.EXE supplied with the instrument can be used to transmit data from the magnetometer to the external computer.

9.2 Charger

The charger ALCS 2-24 is delivered with the instrument, allowing careful and optimum charging of the built-in lead acid battery 12 V / 3.4 Ah, so as to use its full capacity and lifetime. The product is double insulated.

The charger automatically sets the optimum charging mode according to the condition of the battery and starts charging. The charging is indicated with the red LED. After finishing the charging (indicated with the red LED switching off) only a small current keeps going to the battery, thus the battery cannot be overcharged.

Operation:

1. Plug the coaxial connector of the charger cable in the connector on the lower left part of the instrument.
2. Switch on the charger by plugging it in. The connection to a power supply is indicated with the red LED.
3. When the battery is charged, the red LED is switched off and the charger operates in a keeping mode. There is no danger to damage of the battery from overcharging.

9.3 Maintenance and repair work

Under normal operating conditions the magnetometer requires no special maintenance. Only the built-in lead acid battery needs care. If the voltage drops under a certain level the battery might be damaged or the magnetometer might not operate correctly, so the instrument is switched off automatically. When the instrument is not used for a long time, it is still discharging and must be charged at least once a half-year.

Because of the complexity of the instrument it is strongly recommended not to make any interference into electronics.

In the case of a failure of the magnetometer the customer should contact the distributor or the manufacturer. The service will be performed as soon as possible, at a high quality level.

9.4 Storage and transportation

The packed instrument can be stored and transported in the range of temperatures -20° to 70°C and at the relative humidity of up to 90%.

The built-in lead acid battery should be checked and charged with the supplied charger at least once a half-year.

9.5 Warranty

The manufacturer provides a one year warranty after the purchase of the proton magnetometer PMG1. Other information relating to the warranty is given in the warranty certificate.

9.6 Accessories

1 processing unit
2 sensors
1 charger
1 diskette with the communication program
1 cable for connection to a computer
1 harness
1 bottom stick
4 middle sticks
1 gradient stick
1 anchor ring with ropes
3 pins

1 transportation case

1 manual

9.7 Connectors pins assignment

The sensor connector:

Pin	
	A - input
	B - input
	C - shielding
	D - shielding

The charger connector:

Inner contact - positive pole of the battery

Outer contact - negative pole of the battery

RS-232C connector, type DB9S

Pin	Signal
5	GND
2	data transmitted from PMG1
3	data received to PMG1

9.8 Interface cable connection

Connector DB25 (computer)		Connector DB9 (magnetometer)
Female		Male
1 - 7	----------	5
2	----------	3
3	----------	2
4 - 5		
6 - 20		