Rapport nr. 88.171

Petrophysics and Palaeomagnetism initial report of the Norwegian Geological Survey Laboratory

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RAPPORT

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Sammendrag:

In this account we describe a modern Petrophysical and Palaeomagnetic Laboratory in terms of construction details, software and applications. The Norwegian Geological Survey Laboratory allows definite measurements of magnetic susceptibility, weight, volume, density and the natural remanent magnetization (NRM). These parameters are of crucial importance in the regional interpretation of aeromagnetic and gravity data.

The stability of NRM is tested by means of thermal and alternating field demagnetization, thus allowing carefully planned palaeomagnetic studies. Such studies provide a method in dating of rocks or orogenic/hydrothermal events, azimuthal orientation of borecores and assists tectonic modelling on a variety of crustal scales.

Emneord	Petrofysikk	Paleomagnetisme
EDB	Laboratoriemåling	
Geofysikk		Brukerdokumentasjon

PETROPHYSICS AND PALAEOMAGNETISM
INITIAL REPORT OF THE NORWEGIAN GEOLOGICAL SURVEY LABORATORY

by
Trond H. Torsvik and Odleiv Olesen
Norwegian Geological Survey
(1988)

BACKGROUND

Magnetic **susceptibility, remanence** and **density** are crucial petrophysical parameters in the interpretation of aeromagnetic and gravity data. Routine measurements of these parameters have been carried out in the Norwegian Geological Survey (NGU) since the 1960's, but in 1980 it was concluded to construct a new and modernized petrophysical laboratory with the following principal aims:

(1) Build an automatic laboratory with digital recording of:

-volume and density
-magnetic susceptibility
-remanence, both handsamples and cores
-gamma radiation

(2) Develop integrated software for automatic interpretation and presentation of data.

(3) Implement palaeomagnetic equipment and techniques, i.e. thermal and alternating field demagnetization to test the stability of the natural remanent magnetization (NRM)

In this account we describe the hardware and software developed for the petrophysical and palaeomagnetic laboratory at NGU. In the course of constructing the laboratory the work of Kåre Kirkeby and Oddvar Blokkum are greatly appreciated. We also thank the Director Henrik Håbrekke for almost unlimited financial support.

Trondheim, November 1988
Trond H. Torsvik
Odleiv Olesen

W A R N I N G

IT HAS BEEN NOTICED WITH SOME SURPRISE THAT NUMEROUS GEOLOGISTS AND GEOPHYSICISTS IN THE GEOLOGICAL SURVEY USE A 400^{O} COMPASS TO COPE WITH THEIR GEOMETRICAL PROBLEMS - ALL ORIENTATION OF SAMPLES SHOULD BE DONE WITH A 360^{O} COMPASS

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APPENDIXES

1. SOFTWARE

All software have been written for IBM PC/AT compatible computers. The data-base format for petrophysical data, however, is identical to the data-base format used by PETBA on mainframe HP3000 (cf. NGU report no. 85.166). Thus, petrophysical data can be typed in the traditional manner on HP3000 and later transferred to PC/AT, or visa versa.

1.1. PROGRAMS AND DATA-BASE STRUCTURE

Main-Programs

The following programs have been developed for the petrophysical and palaeomagnetic laboratory:

PETROFYS This is the main program in the analysis of petrophysical data, and includes e.g.:
- Storing, retrieving and editing of data
- Search & filtering facilities
- Output to printer, plotter or HP3000
- Statistics
- Graphics

CONPETRO Convert mainframe HP3000 files to PETROFYS format. Use FILECONV on HP3000 before using this program.

PETROLAB Laboratory instrument control program
Controls and store the following data:
- susceptibility
- remanence
- density
- volume

Additionally, the following programs are used for analysis of palaeomagnetic data (Torsvik, 1985 and manuscript in prep):

IAPD2 Interactive Analysis of Palaeomagnetic data
Automatic interpretation and presentation of palaeomagnetic data.

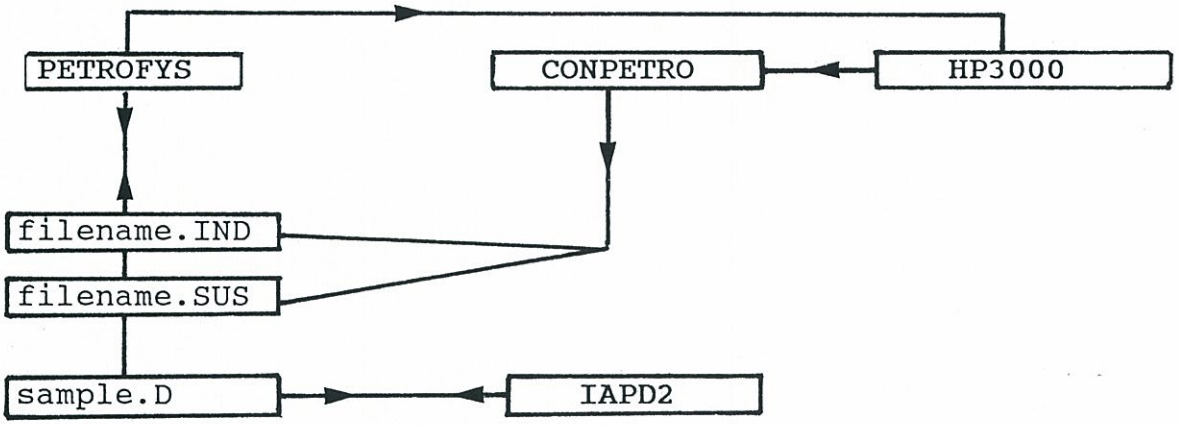
PALSTAT Statistical analysis and distributional testing of palaeomagnetic data

AMS2/KLY2 Software for calculation of strain-ellipsoids based on measurements of anisotropy of magnetic susceptibility

Data-files

The data-base structure in PETROFYS-PETROLAB is divided into three file types:

- Filename.sus — RANDOM ACCESS FILES
  These are the major files, and data are stored in RECORDS
- Filename.ind — SEQUENTIAL INDEX FILES
  (pointer index to RANDOM files)
- Sample.d — SEQUENTIAL DEMAGNETIZATION FILES
  (Cf. PETROLAB manual)
  These files are analyzed with IAPD2



System files

These files are loaded during bootup, and are exclusively system or configuration files:

- Petro.sys — System file for PETROFYS
- Lab.sys — System file for PETROLAB
- BIB.m — IEEE handle routine for PETROLAB
- Cfg.sys — System file for IAPD2

1.2. DATA-BASE LIMITATION

The maximum number of samples in one file is approximately 700 (RECORDS). If more samples are to be analyzed, the secondary file option in mode FILTER (PETROFYS) must be invoked. In demagnetization files, space for 25 heating steps have been allocated.

1.3. SYSTEM REQUIREMENT

Computer

- IBM compatible PC/XT/AT computer
- Minimum 640Kbyte RAM.
- 20 Mb HardDisk
- 1 Diskdrive
- Extra Serial RS232C port (Com2)
- IEEE 488 interface card

Most programs are compiled with mathematical co-processor option (8087 or 208087), but will perform a software emulation if co-processor is not percent.

Graphic card

CGA, EGA or ATT400 (Olivetti SHR).
VGA, PS/2 or HERCULES graphic card can be invoked in the program.

Plotter

HP-GL compatible plotter, e.g. HP7074, HP7574, ROLAND 800 and 900 series.

Printer

Epson/IBM compatible dot-matrix printer or Laser Jet

2. DESCRIPTION OF PETROFYS PROGRAM

- Turn computer ON

  During boot-up the HP-VECTRA and the OLIVEETTI 240/290 activate a special menu-driven program called PAM and OLISOFT respectively

- Select PETROFYS in OLISOFT or PAM by using the cursors, followed by <ENTER>

PETROFYS is executed from sub-directory c:\PETRO, and during initialization PETROFYS search for a system file which is named PETRO.SYS. The most important information in this file is:

- screen mode (CGA & EGA)

  Note : OLIVETTI M240 (PC) uses CGA
  OLIVETTI M290 (AT) and HP-VECTRA uses EGA

- port plotter (LPT1: & LPT2:)

  Note : HP-PLOTTER connected with HP-VECTRA in the computing center uses LPT2:

PETRO.SYS can be altered using a standard EDITOR, or can be changed after PETROFYS has been executed (see later - configuration).

2.1 MAIN MENU

After program execution the main menu is displayed. Keys with arrows are used to move the cursor to a desired mode ('box') which is subsequently selected by pressing RETURN/ENTER. Most sub-menus uses popscreen menus.

The options in the main menu are:

OPTION	EFFECT
READ	READ INDEX FILE AND OPEN RANDOM ACCESS FILE
INPUT	INPUT PETROPHYSICAL DATA
SEARCH	SEARCH FOR A ROCK NUMBER OR RECORD
FILTER	SET FILTER & SEARCH ARGUMENTS
OUTPUT	OUTPUT TO PRINTER, DISC OR SCREEN
CONFIGURE	CONFIGURATION OF THE SYSTEM
BACKUP	COPY FILES FROM HARD-DISK TO DISKETTE
PLOT-STAT	PLOT OR STATISTICAL FACILITIES
CREATE FILE	CREATE A NEW FILE
QUIT	QUIT PROGRAM

WARNING - PLEASE READ THIS

To achieve maximum speed data-files are always left 'OPEN' during program execution, and files are only CLOSED in case of an error or when leaving (QUIT) the program. You must therefore always QUIT PETROFYS before turning off the computer. If not, data would not be properly stored.

2.2 READ

You must always start to READ the file index or alternatively CREATE a file (see later). Simply type in file-name. Typing error would result in an error report.

2.3 INPUT

In INPUT mode the following information is demanded:

- Sample no.
- Map-Sheet no.
- UTM zone
- UTM co-ordinates EAST (10 m)
- UTM co-ordinates NORTH (10 m)
- Lithological code (cf. Appendix 3)
- Metamorphic code (cf. Appendix 4)
- Stratigraphic code (cf. Appendix 5)
- Rock name (do not use ⌟ in this field)

The input mode is ended by typing END or simply pressing ENTER/CR when SAMPLE NO. is demanded.

NOTE:

Apart from sample no., other inputs can be repeated by just pressing ENTER/CR when the specific input fields are prompted. The proceeding values will be printed during input.

The input data-format and codes are similar to the DATA-BASE on HP3000 (see Appendix 2). Input-fields exceeding the format will be truncated.

2.4 SEARCH

After selecting SEARCH in the main menu the program demands for sample number. Alternatively you can specify RECORD by typing RECORD*. The following information is displayed:

-Sample no.
-Map-sheet no.
-UTM zone
-UTM co-ordinates EAST
-UTM co-ordinates NORTH
-Lithological code
-Metamorphic code
-Stratigraphic code
-Rock name
-Density
-Susceptibility
-Radiometric
-Volume
-NRM intensity Q-VALUE (Field=0.5)*
-NRM DEC, INC & a_{95}
-IN-SITU Susceptibility

*The Q-VALUE depends on the total earths magnetic field - Based on the map-sheet number the program automatically find the correct field-value (see Appendix 6). If map-sheet number is not present and/or map-sheet number does not exist, a field value of 50000 gamma (0.50e) will be substituted in the formulae for Q.

Options available in SEARCH mode are:

OPTION	EFFECT
EDIT	EDIT DATA -Press ENTER/CR in input field if value is OK, else type new value (all characters)
PLOT	PLOT OF IN-SITU SUSCEPTIBILITY VALUES IF MEASURED
INSUS	INPUT OF IN-SITU SUSCEPTIBILITY DATA -data are inputted in 10^{-5} SI units -end data input with 999
EDSUS	EDIT IN-SITU SUSCEPTIBILITY -Select code-number, and type new value
FORW	FORWARD SPOOLING IN DATA-BASE -steps one RECORD forward
BACK	BACKWARD SPOOLING IN DATA-BASE -steps one RECORD backward
QUIT	QUIT TO MAIN MENU

INPUT OF IN-SITU SUSCEPTIBILITY DATA
-end input with 999

2.5 FILTER

The filter option serve two purposes. The most important is to set constraints to what is to be displayed in SEARCH, PLOT-STAT and OUTPUT, but also to invoke a SECONDARY file in case of large files.

The following filter/search arguments are implemented:

MODE	EFFECT
1	Sample no. or *last character Example: *b would search for all samples like 102b, 167b etc.
2	Map-Sheet no.
3	Lithological code or *last character (see 1)
12	Alternative Lith. code
4	Metamorphic code
13	Alternative Met. code
5	Stratigraphical code
14	Alternative Strat. code
6	DENSITY (define minimum value to be included)
9	DENSITY (define maximum value to be included)
7	SUSCEPTIBILITY (minimum value)
10	SUSCEPTIBILITY (maximum value)
8	RADIOMETRIC (minimum)
11	RADIOMETRIC (maximum)
15	SECONDARY FILE
16	a95 (minimum value)
17	a95 (maximum value)
18	NRM intensity (minimum value)
19	NRM intensity (maximum value)

Type in SEARCH/FILTER argument after selecting MODE 1-19.

2.6 OUTPUT

The mode OUTPUT is designed to output data to PRINTER, DISC (Hard-disc) or SCREEN.

-Select output P(printer),D(Diskette) or S(screen)

ALL or a SELECTED part of the data-base can be outputted.
-Type y (yes) on each data-field you want to output.

-write heading or file-name and confirm if output is OK

Note:
Output to DISC create a HP3000 compatible file, which later can be transferred to mainframe. Note that <y> on data-fields are ignored in DISC sub-mode.

2.7 CONFIGURE

This mode controls plotter and screen modes. The following options are implemented:

OPTION	EFFECT
PORT PLOTTER	SELECT LPT1: or LPT2: LPT2: is configuration for HP-PLOTTER working against HP-VECTRA in the computing center.
PLOT SPEED	Select a value between 1-80 (max speed)
PLOT FORMAT	Select 4 (A4) or 3 (A3)
ACTIVE PEN	Select pen 1-8
SCREEN MODE	Select cga or ega A computer with HERCULES card would also work in cga mode
SAVE CHANGES	PETRO.SYS will be permanently saved, thus during boot-up of PETROFYS your edited changes will be taken into account.
QUIT	QUIT TO MAIN MENU

2.8 BACKUP

It is advised that your Data-file is saved on DISKETTE in case of break-down on hard-disc. Follow the instructions in BACKUP mode for copying your files.

2.9 PLOT-STAT

This mode is used for graphic displays, but also calculates mean-values and standard deviation. The following options are implemented:

OPTION	EFFECT
SUSCEPTIBILITY LAB	DISPLAY LABORATORY SUSCEPTIBILITIES IN A HISTOGRAM (LOG-SCALE)
DENSITY	DISPLAY DENSITY IN A HISTOGRAM
RADIOMETRIC	DISPLAY GAMMA-RADIATION IN A HISTOGRAM
IN-SITU SUSCEPTIBILITY	DISPLAY IN-SITU SUSCEPTIBILITY IN A HISTOGRAM (LOG-SCALE)
COMBINED IN-SITU & LAB	DISPLAY BOTH IN-SITU AND LABORATORY SUSCEPTIBILITY MEASUREMENTS IN A HISTOGRAM (LOG-SCALE)
NRM-INTENSITY	DISPLAY NRM-INTENSITIES IN HISTOGRAM
PLOT DEC & INC NRM	DISPLAY DEC & INC IN A STEREOGRAM
Q-VALUES	DISPLAY Q-VALUES IN A HISTOGRAM
QUIT	RETURN TO MAIN MENU

<u>SUSCEPTIBILITY HISTOGRAMS</u>

-Logarithmic horizontal axes (Fig. 1)
-Vertical axis equals frequency
-Mean susceptibility and plot-values given in 10^{-5} SI values
-N=number of samples
-A=Tick axis (logarithmic). Automatic fitting during start-up
This value can be changed to any value.

The following sub-options are available in <u>all</u> histograms:

X (Xmax)	Select max X-value on horizontal axis
Y (Ymax)	Select max Y-value (frequency) on vertical axis
A (A-Tick)	Select tick (box) length in histogram
T (Text)	Insert a TEXT which will be outputted on plotter
H (Hp-Plot)	Copy to HP compatible plotter

NOTE:

If you execute GRAPHICS in OLIMENU before starting PETROFYS, you can get an image of the screen on an ordinary dot-matrix printer by pressing <PRINT SCREEN>

Q (Quit) Return to PLOT-STAT menu

DENSITY HISTOGRAMS

Conventions as susceptibility plots, but horizontal axes is not logarithmic. Minimum X-value is set to 2500 (Fig. 2).

NRM INTENSITY HISTOGRAMS

Conventions as density plots. No minimum value set for NRM (Fig. 3).

DEC & INC STEREOGRAMS

Nrm directions are displayed in a stereogram, and mean values of DEC and INC are printed on the screen. Also the 95% confidence circle and precision-parameter (K) is listed (Fig. 4).

Downward pointing inclinations (positive) are shown as filled symbols. Negative inclinations shown with open symbols.

Hardcopy to plotter is achieved by pressing <H>.

FIG 1
Example of susceptibility plot

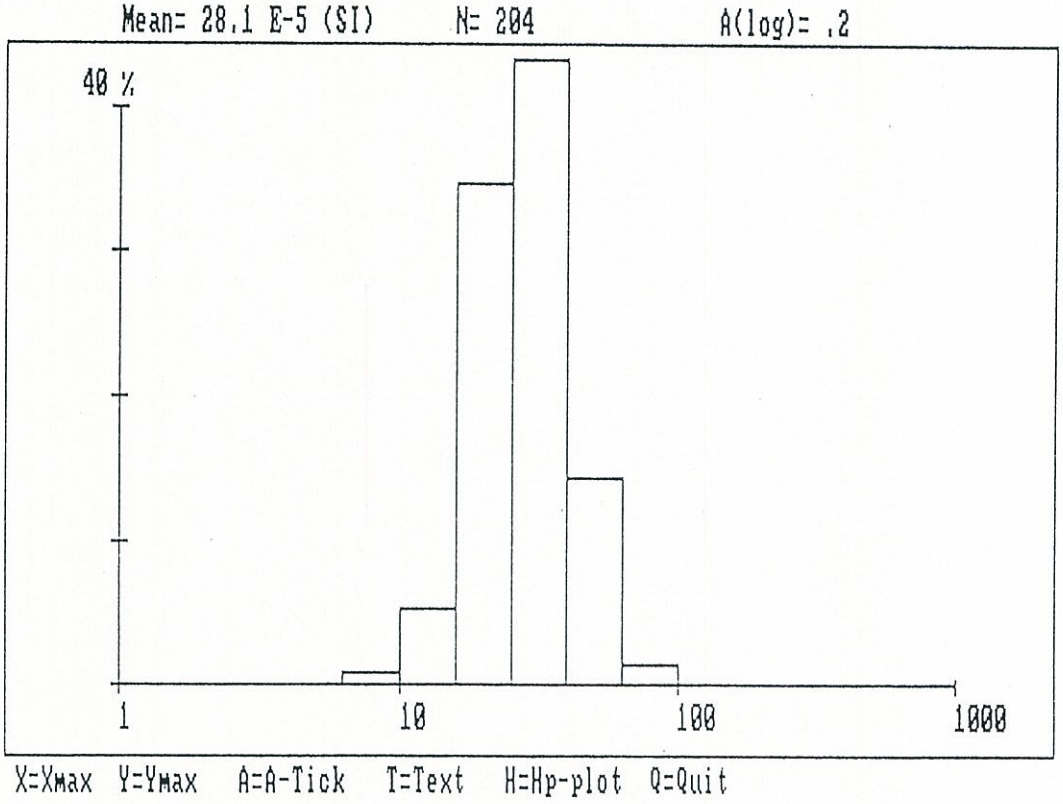


FIG 2
Example of density plot

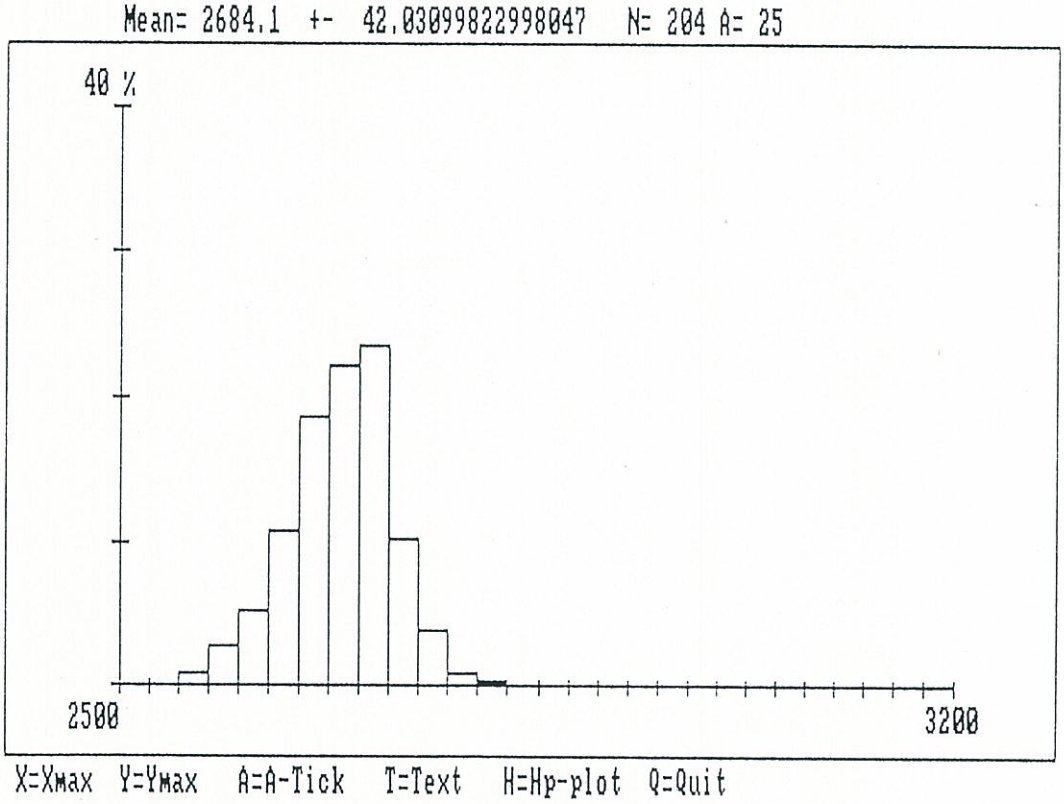


FIG 3
Example of NRM intensity plot

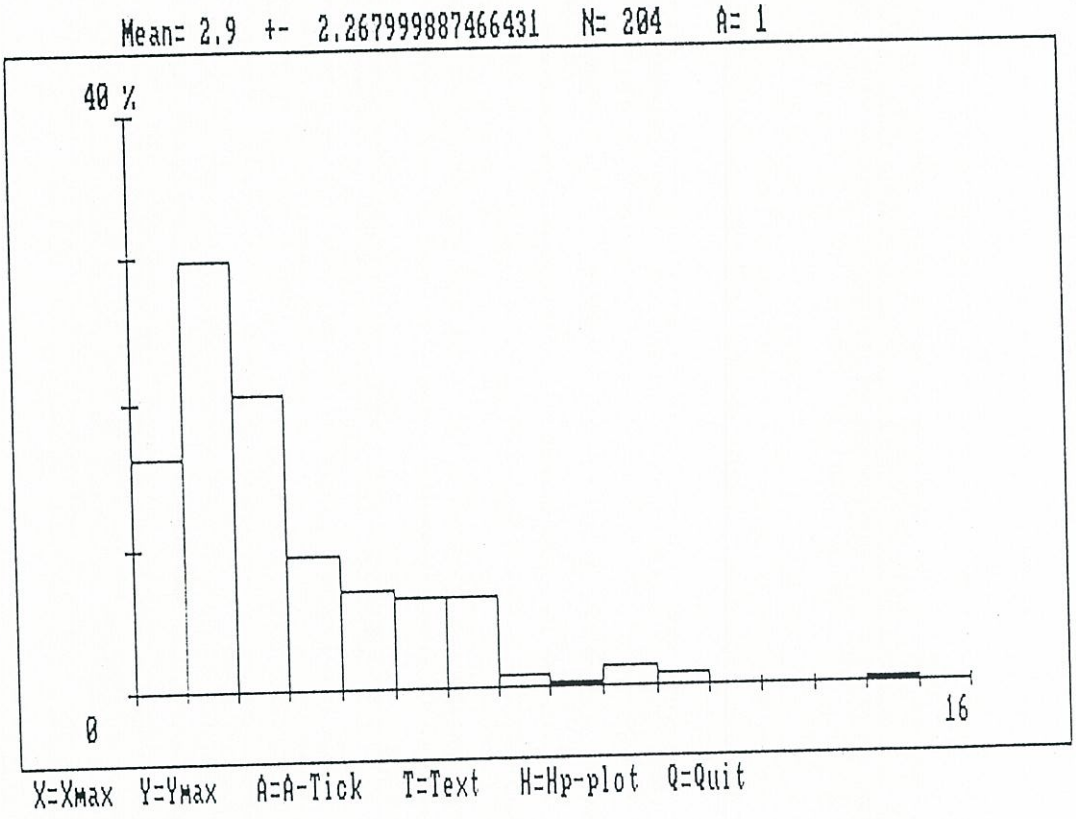
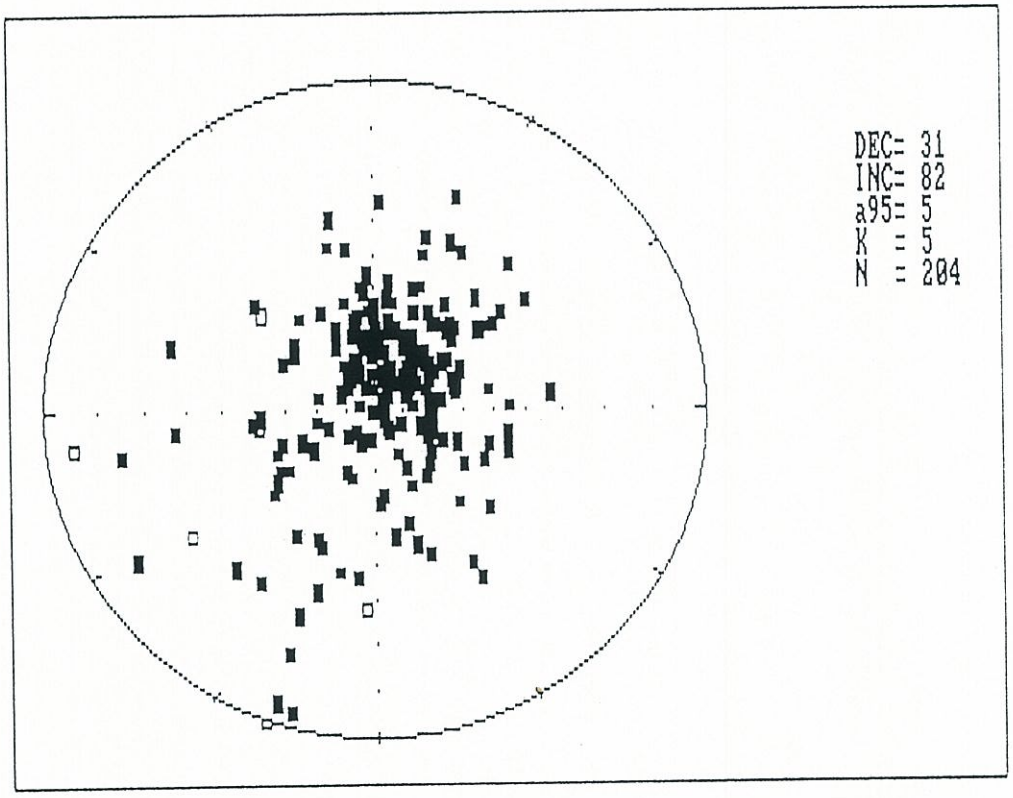


FIG 4
Example of stereoplot of declination and inclination



2.10 CREATE FILE

Create a new file-name. A list of used file-names will be displayed on the screen. Name should be given **without** file-extensions (.sus). Never use a name that appear on the list.

2.11 QUIT

Quit from PETROFYS

MUST ALWAYS BE DONE IF YOU HAVE INPUTTED or EDITED DATA IN THE DATA-BASE.

3. DESCRIPTION OF PETROLAB PROGRAM

Preparation:

1. Turn on weight
2. Turn on Philips Frequency Counter
   - set mode to PER A (Period A)
3. Turn on frequency-oscillator
4. Turn on Spinner magnetometer
5. Turn on Schonstedt magnetometer
   -Set GAIN to 20
6. Turn on Digital Voltmeter

- Turn computer ON
- Select PETROLAB in OLISOFT menu

PETROLAB is executed from sub-directory c:\PETRO. Note that this program uses OLIVETTI super-high resolution graphics (640x400), but can be modified to run under EGA/CGA graphics.

During start-up two files are automatically read from PETROLAB, i.e. LAB.SYS (configuration file) and BIB.M, a machine code language routine which handles IEEE communication.

Details in the preparation of samples and sampling conventions are given in Appendixes 7 and 8.

3.1 MAIN MENU

After program execution the main menu is displayed, and the following options are implemented:

OPTION	EFFECT
READ FILE	READ INDEX FILE AND OPEN RANDOM ACCESS FILE
LOG-SEARCH	LOGGING OF PETROPHYSICAL-PALAEOMAGNETIC DATA
CONFIGURE	SYSTEM CONFIGURATION
QUIT	END PROGRAM

3.2 READ FILE

Always start to READ the file index. Note that creation of a file and input of data (not measured data) must be done in PETROFYS.

-Simply type the file-name. Typing error would result in an error report.

3.3 LOG-SEARCH

This is the principal option in PETROLAB which controls all the instruments in the laboratory. Select LOG-SEARCH in main menu, and subsequently type the sample name of the sample which you want to measure or display the data for.

The following sub-options are implemented in this mode:

OPTION	EFFECT
FORW	Forward spooling in data-base
BACK	Backward spooling in data-base
WEIGHT	Measurement of dry and wet-weight
SUS	Measurement of magnetic susceptibility
REM	Measurement of remanence for hand-samples
MSPIN	Measurement of remanence for cores (spinner-magnetometer)
GET	Get a new sample - Type sample-name

NOTE

If you attempt to log/measure a specific parameter, and that parameter is already in the file, a warning is displayed. Confirm with y if you want to remeasure.

3.4 WEIGHT (Fig. 5)

Preparation

-samples must be water-saturated, i.e. kept in water for at least one day before measurements.
-surface of samples should be dry before measurement

Operation

- select **W** in LOG-SEARCH mode
- place sample at weight for dry-weight measurement
- press **M** (measure)

- place sample at weight for wet-weight measurements
- wait until weight-holder is stable
- press **W** (Wet-Weight)
- press **M** (Measure)

Volume and density will now be calculated

- press **Q** to Quit or alternatively **R** to repeat whole procedure
- type **Y** for SAVING data

DATA will now be stored at the designated sample-number.

FIG 5
Example of measurement of dry and wet weight

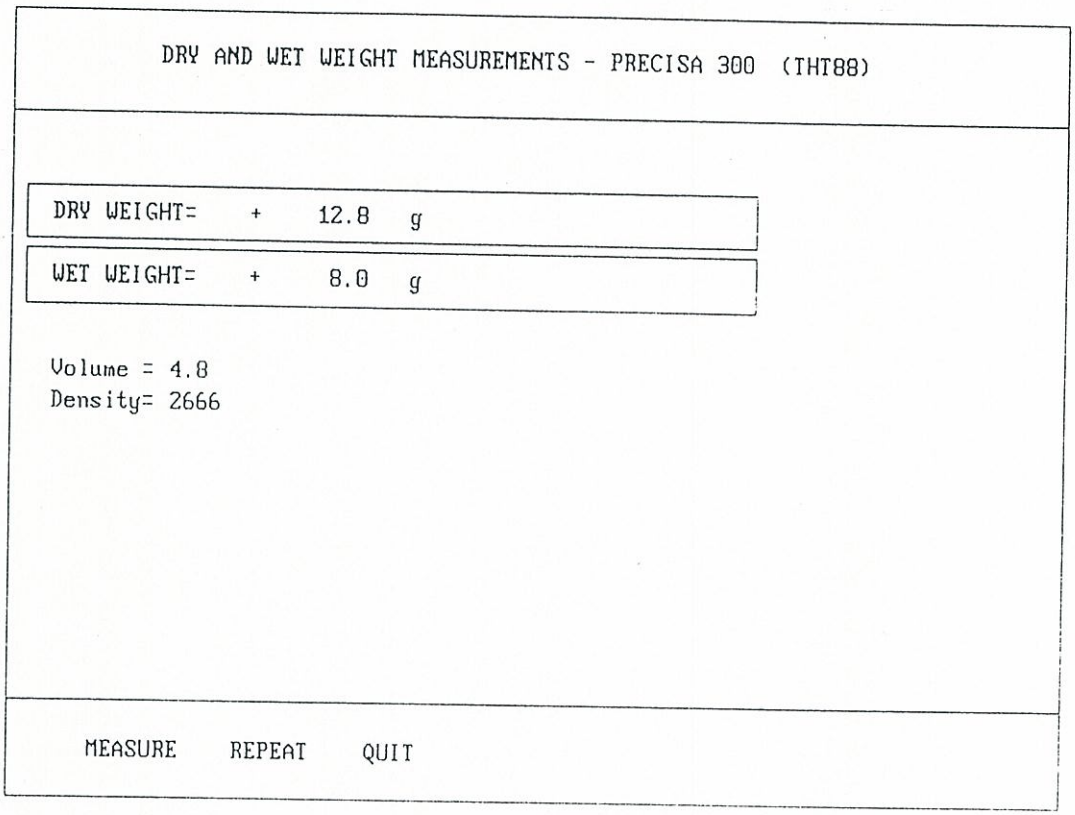
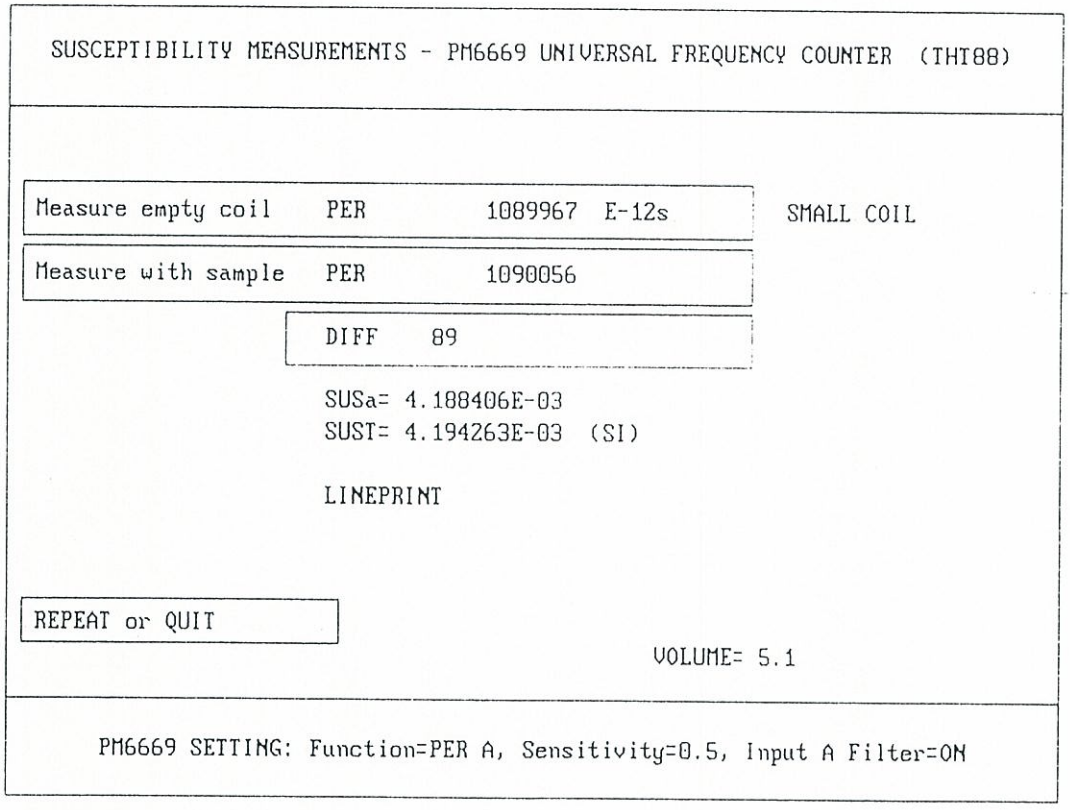


FIG 6
Example of susceptibility measurement



3.5 SUSCEPTIBILITY (Fig. 6)

Preparation

- check that function-select is set to PER A (period A)
- select the smallest possible recording-coil (1-3)
- set the corresponding recording-coil switch to 1,2 or 3 on frequency-oscillator (see Chapter 5)
- check that frequency-counter show stable readings, i.e. not drifting

Operation

- select **S** (SUS) in LOG-SEARCH mode
- press **M** (measure) to measure empty coil
- insert sample in coil as fast as possible to avoid drift, and
- press **M** (measure) to measure with sample inserted in coil

After measurement the volume of the sample is scanned from the data-base, and the susceptibility is calculated (10^{-5} SI-units).

- press **Q** (quit)
- type **Y** to SAVE data

Susceptibility is now stored in the data-base. In the data-base susceptibility data are stored as 'true' SI (VOL) susceptibility values.

3.6 SPINNER MAGNETOMETER (Fig. 8)

Preparation

-Calibrate MOLSPIN before operation (see Chapter 5)

Operation

-Select **M** (MSPIN) in LOG-SEARCH mode

Parameters such as spin-time (S or L), volume (from data-base) and range (1,10,100,1000) are passed to the molspin routine. Short spin-time and range 1 is standard set-up, and if you have to change range this has to be done in the CONFIGURATION mode, or alternatively press **C** after a measurement to change range. Measurement will then resume from the beginning.

TEMP/FIELD

Input of TEMP/FIELD. A negative argument would force you out of spinner magnetometer routine. If no file-data exist concerning the current sample enter a treatment of 0 or <CR>, followed by Strike and Dip. Strike/dip conventions are outlined in Appendix 7.

MEASUREMENT PROCEDURE

-Insert the specimen in position 1 **before** you have ended TEMP/FIELD or strike/dip data.

-6 spins are required following the measurement procedure seen in Fig. 7.

-After each spin, press <ENTER> or:

R to repeat a measurement
N to start with a new sample-input (i.e. cancel measurement)
C to change range
B to break (emergency break back to LOG/SEARCH mode)

DISPLAY OF RESULTS

-After each spin the NORTH and EAST component from the magnetometer is displayed (see later). Spin 1&3, 2&4 and 5&6 represent opposite measurements, thus the control value which is displayed should be close to 180 degrees.

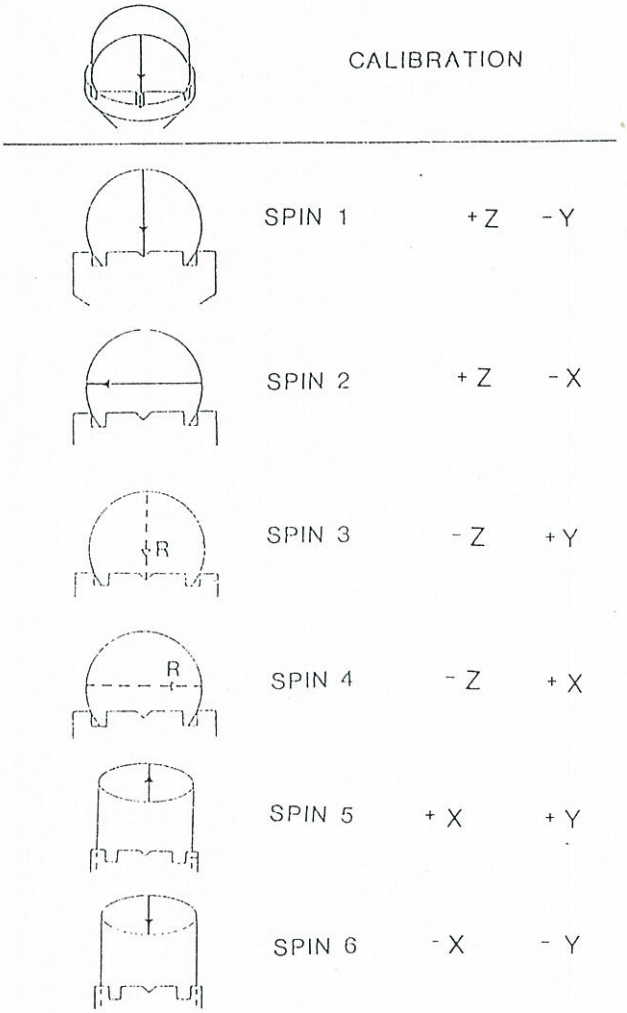
-Press RETURN after the last spin, and declination, inclination, intensity, a95 (cf. Briden and Arthur, 1981) and standard deviation of the intensity (U.INT) are displayed (Fig. 8). The result is shown in core sampling co-ordinates and geographic co-ordinates.

-Confirm SAVE DATA by pressing RETURN.

Note:

If sample-data already exist, file-data information (strike & dip) would immediately be displayed after the selected TEMP/FIELD. Also the last 7 demagnetization steps will be listed on the screen (starting from the bottom of the screen)

FIG 7
Calibration and spin-positions



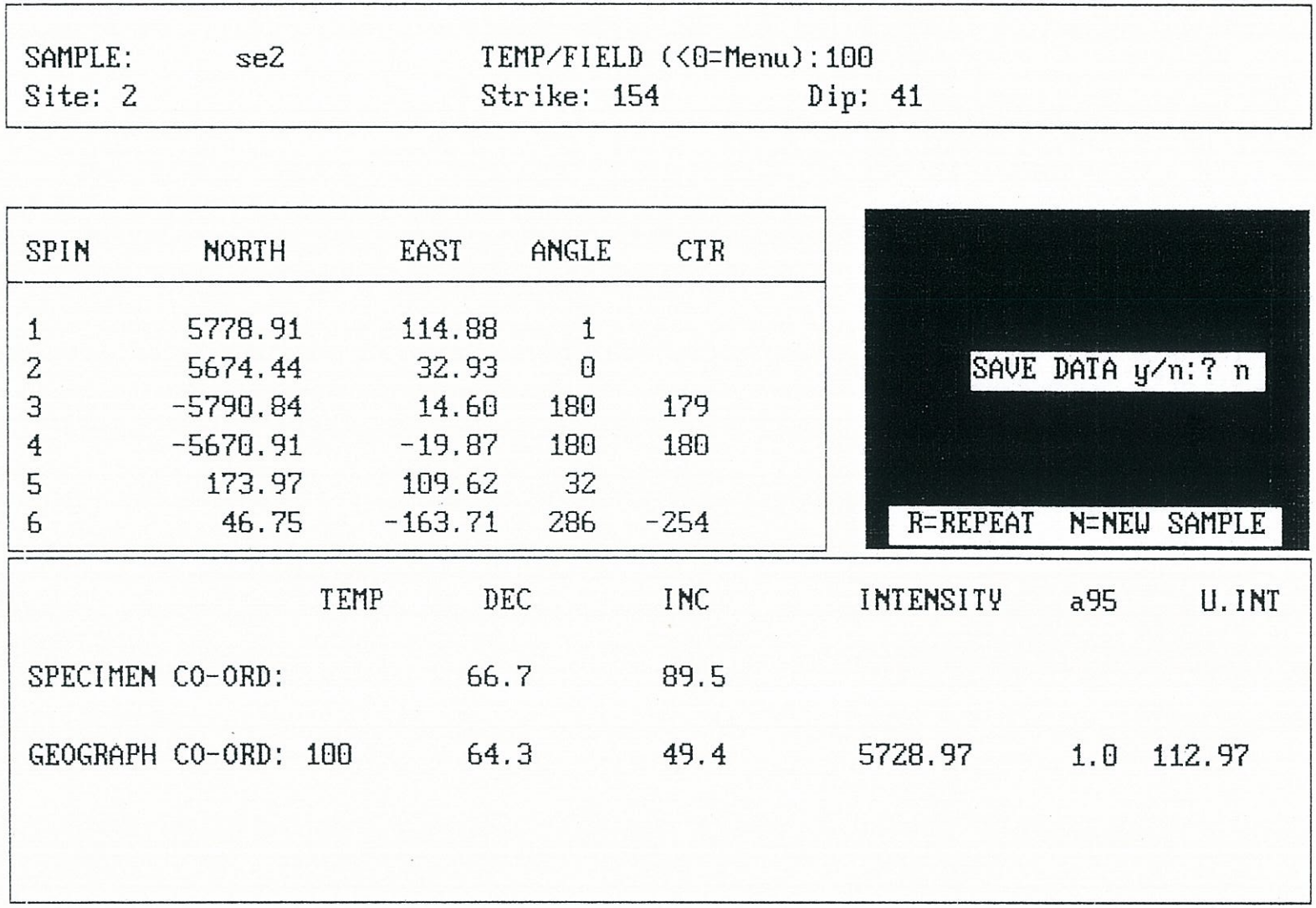


FIG 8
Example of spinner magnetometer measurement

3.7 REMANENCE HANDSAMPLES (Fig. 10)

- Select R (REM) in LOG-SEARCH mode

- Measure empty holder (TOM)

- Insert hand-sample in position 1

- Press <ENTER> after each new position 1-6
  Note to check that the digital voltmeter show stable readings before pressing <ENTER>

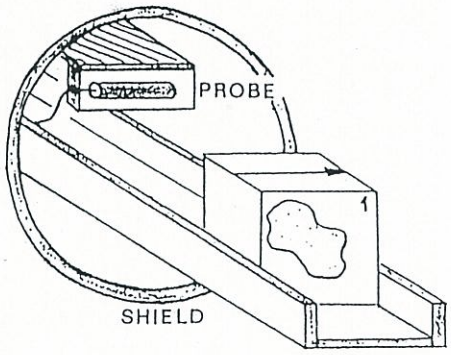
  (cf. sampling positions in Fig. 9)

After measurement the declination, inclination, intensity, intensity-uncertainty and a_{95} is displayed for a specimen in geographic co-ordinates. Strike and dip is demanded after specimen co-ordinates. Type 0,0 if no strike/dip measurements exists.

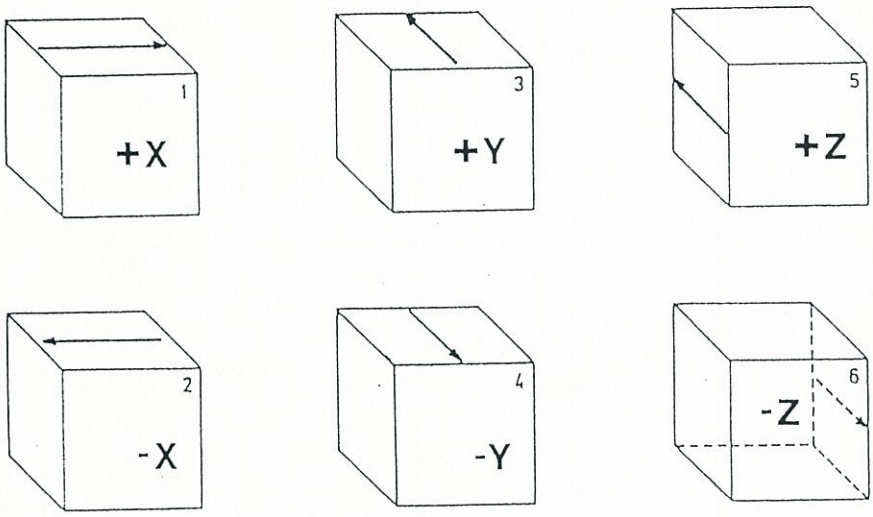
- End measurement by typing Q (quit) or R to repeat measurement

- Confirm with y (yes) if you want to save data

REMANENCE MEASURING DESIGN

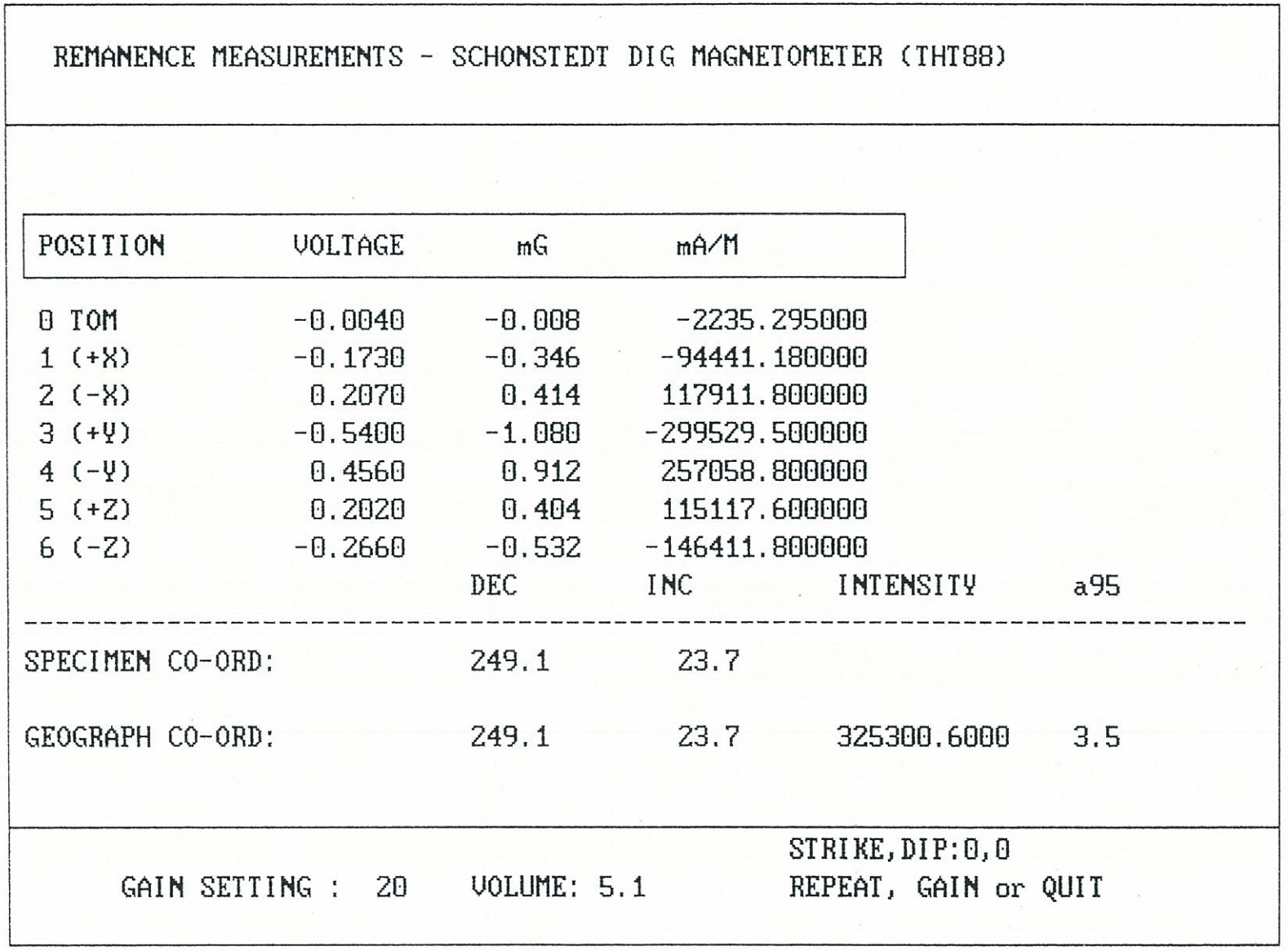


ROCK BOULDER IN SENSOR UNIT



SAMPLE HOLDER POSITIONS

FIG 9
Conventions for remanence measurements of handsamples



REMANENCE MEASUREMENTS - SCHONSTEDT DIG MAGNETOMETER (THT88)

POSITION	VOLTAGE	mG	mA/M
0 TOM	-0.0040	-0.008	-2235.295000
1 (+X)	-0.1730	-0.346	-94441.180000
2 (-X)	0.2070	0.414	117911.800000
3 (+Y)	-0.5400	-1.080	-299529.500000
4 (-Y)	0.4560	0.912	257058.800000
5 (+Z)	0.2020	0.404	115117.600000
6 (-Z)	-0.2660	-0.532	-146411.800000

	DEC	INC	INTENSITY	a95
SPECIMEN CO-ORD:	249.1	23.7		
GEOGRAPH CO-ORD:	249.1	23.7	325300.6000	3.5

GAIN SETTING : 20 VOLUME: 5.1

STRIKE,DIP:0,0
REPEAT, GAIN or QUIT

FIG 10
Example of remanence measurement of an handsample

3.8 CONFIGURATION

This mode is accessed in the Main menu, and a number of parameters can be changed and permanently saved on the hard-disk (file = lab.sys).

Printer ON/OFF (Default=on)

ON/OFF setting of printer
ON=all logging results are automatically printed

Logic Spinner (Default=+1)

Logic should show +1, and is only changed to -1 if the fluxgate has been turned through 180 degrees e.g. associated with repair of the Molspin.

Calibration remanence (Default=1425)

Intensity calibration of remanence measurements for handsamples. The instrument is calibrated to 1425.

Delay spinner (Default=50)

A "delay spinner" value handshakes the MOLSPIN magnetometer properly. If this value is set too low, a warning is displayed during measurement (P-ERROR; possible error). Delay spinner value depends on computer used. A value of 50 work with almost all computers since it is calibrated for an 8086 INTEL, 10 MHz processor. For the IBM AT compatible this value must be set as high as 150 or 200, whereas for PC's running on a 4MHz clock the value may be lowered to ca. 30. If a P-ERROR occurs during measurement and delay spinner value is properly set, turn off/on the Molspin (spinner) and Repeat measurement. If still not working, check all connections.

Spin-Time (s or l) (Default=s)

Setting of S (short) or L (long) spin-time.

Spinn-Range (1-1000) (Default=1)

Change spin-range on Molspin
See Hardware section for typical range areas.

4. FILE-CONVERTING PC/AT AND HP3000

File-converting is somewhat complicated, but this procedure will be done automatically when the PC at the laboratory will be connected to the PC-NET.

The following programs are needed for file-converting:

PC/MS-DOS PROGRAMS	HP3000 PROGRAMS
PETROFYS	FILECONV
CONPETRO	
FILETRAN	

4.1 CONVERT FROM PC/AT TO HP3000

PROBLEM

Data is typed, measured and stored on OLIVETTI M240 in sub-directory C:\PETRO. We want to transfer data to HP3000 for processing

PROCEDURE IN LABORATORY

1. Turn on computer (Olivetti M240)
2. Insert a diskette in DRIVE A

Only if you have a non-formatted disk:

3. Press <ESC> in OLIMENU to leave the menu-driver
   confirm with Y (yes)
4. Type FORMAT A:
5. Type OLM to activate OLIMENU program

---

6. Select PETROFYS in OLIMENU
7. Select READ FILE in PETROFYS
8. Select BACKUP and confirm with Y (yes) twice
9. QUIT
10. Turn OFF OLIVETTI M240
11. Bring your DISK from DRIVE A to an HP/OLIVETTI M290
    which is linked with the mainframe (PC-NET)

PROCEDURE PC-NET

1. Turn on computer
2. Select MS-DOS command in PAM or ESC in OLIMENU
   Insert your disk in drive A
3. Type COPY A:**filename.*** c:\petro
   Copies two files to hard-disk
4. Type EXIT to return to PAM or OLM to activate OLIMENU
5. Select PETROFYS in PAM/OLIMENU
6. Select READ FILE in PETROFYS
7. Select OUTPUT and answer with **D** (disk output)
   type file-name and data will be transformed into a
   HP3000 compatible file-format.
8. QUIT
9. Select START NET in PAM
10. Select MS-DOS command in PAM
11. Type COPY **c:\petro filename g:**
    Filename refers to point 7
    HP3000 compatible file will be copied to **G** disk on mainframe.

NOTE
To assure that Scandinavian characters (æøå) will be placed properly at HP3000 the following must be done. Thus, ignore point 11.

- Type C:\FILETRAN\FILETRAN C:\PETRO\ **filename**, G:**filename**/N49

---

12. EXIT
13. Select STOP NET in PAM
14. Turn off computer

Your file is now placed on **G:\FELLES**, and it has to be converted to MPE format by using the program FILECONV. This is recommended to be done on an ordinary TERMINAL, and the procedure is as follows:

CONVERTING TO MPE-FORMAT:

```
<Datamaskin/system ? >a,g                    'select system

:hello tht248,mgr.geof,petfys                'log on
:fileconv                                    'start FILECONV
```

F1 - CURRENT CONNECTS

write g and felles

F1 - ADD CONNECT
F8 - FILECONMAIN
F3 - CONVERT TO MPE

-write filename of MS-DOS file in first field
use TAB to change field
-write filename of MPE file in next field
use TAB to change field
-write 99 in record length field (VERY IMPORTANT)

NOTE
If FILETRAN has been used for translating Scandinavian characters FILE-TYPE must be changed from STANDARD ASCII to EXTENDED ASCII

F2 - NEXT FILETYPE

F1 - START CONVERT
F8 - FILECONVMAIN
F8 - EXIT FILECONV

4.2 CONVERT FROM HP3000 TO PC/AT

PROBLEM

Data is typed and stored on HP3000. We want to transfer data to PC/AT from HP3000 for processing and measurement/logging in the laboratory

PROCEDURE ON TERMINAL

Your file is placed at geof.petfys and the aim is to translate this file from MPE to MS-DOS format and copy it to G:\FELLES.

CONVERTING FROM MPE-FORMAT TO MS-DOS:

```
<Datamaskin/system ? >a,g                    'select system

:hello tht248,mgr.geof,petfys                'log on
:fileconv                                    'start FILECONV
```

F1 - CURRENT CONNECTS

write g and felles

F1 - ADD CONNECT
F8 - FILECONMAIN

F4 - CONVERT **FROM** MPE

-write filename of MPE file in 1. field (from geof.petfys)
use TAB to change field
-write filename of MS-DOS file in next field (to g:\felles)

F1 - START CONVERT
F8 - FILECONVMAIN
F8 - EXIT FILECONV

PROCEDURE ON PC-NET (HP-VECTRA)

1. Turn on computer
2. Select START NET in PAM menu
3. Select MS-DOS command in PAM
4. Type COPY G:**filename.*** c:\petro
   Copies file to hard-disk on HP Vectra from g:\felles

NOTE
To assure that Scandinavian characters (æøå) will be placed properly at PC/AT the following must be done. Thus, ignore point 4.

- Type C:\FILETRAN\FILETRAN G:**filename**, C:\PETRO**filename**/N12

---

5. Type EXIT to return to PAM
6. Select CONPETRO in PAM
   -Select **L** (les fil) in CONPETRO
   -Type filename
   -Select **P** (punched) of **D** (data-base) data format form HP3000
   -Select **A** (avslutt) in CONPETRO

THE FILE IS NOW TRANSLATED TO PETROFYS FORMAT

7. Select MS-DOS command in PAM
8. Insert a disk in drive A
9. Type copy c:\petro**filename.*** a:
   Copy files (2) to disk
10. Type EXIT to return to PAM
11. Select STOPP NET in PAM
12. Turn off computer

PROCEDURE IN THE LABORATORY

1. Turn on computer
2. Press <ESC> to leave OLIMENU
3. Insert data-disk in drive A
4. Type COPY A:**filename.*** c:\petro
5. Type OLM to activate OLIMENU
6. Select PETROFYS to see that file is OK.
7. Turn off computer

FINAL COMMENT

Complicated, not at all, ask the computer center in case of problems ! - Good Luck

5. HARDWARE

As yet the laboratory consist of equipment to measure and calculate the magnetic susceptibility, volume & density, remanence (both cores and hand-samples). Furthermore, the stability of NRM can be tested by means of stepwise thermal and AF demagnetization, and the various instruments are described below.

5.1 LABORATORY COMPUTER AND PERIPHERALS (Fig. 11)

- OLIVETTI M240 IBM compatible PC
- 8086 (10MHz) + 8087 (10MHZ) co-processor
- ATT400/CGA/EGA graphic card (EGA needs seperate monitor)
- 20 Mbyte Harddisk
- 5 3/4 & 3 1/2 Disk
- 2 serial RS232C ports (COM1, COM1)
- 1 parallel port (LPT1)
- 1 IEEE 488 interface card
- 1 Olivetti DM40 dot-matrix printer (LPT1)

5.2 INSTRUMENT INTERFACING

Molspin magnetometer

Serial RS232C - Communication port 1 (COM1)
No parity, 8 data-bit, 1 stop bit and binary data-transmission

Line configuration:

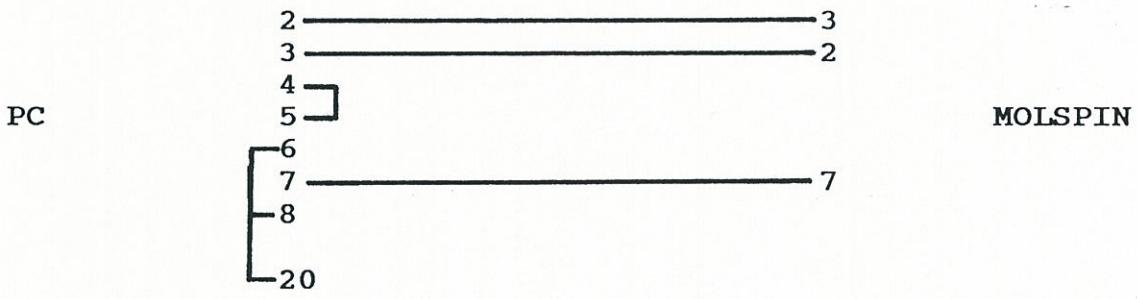
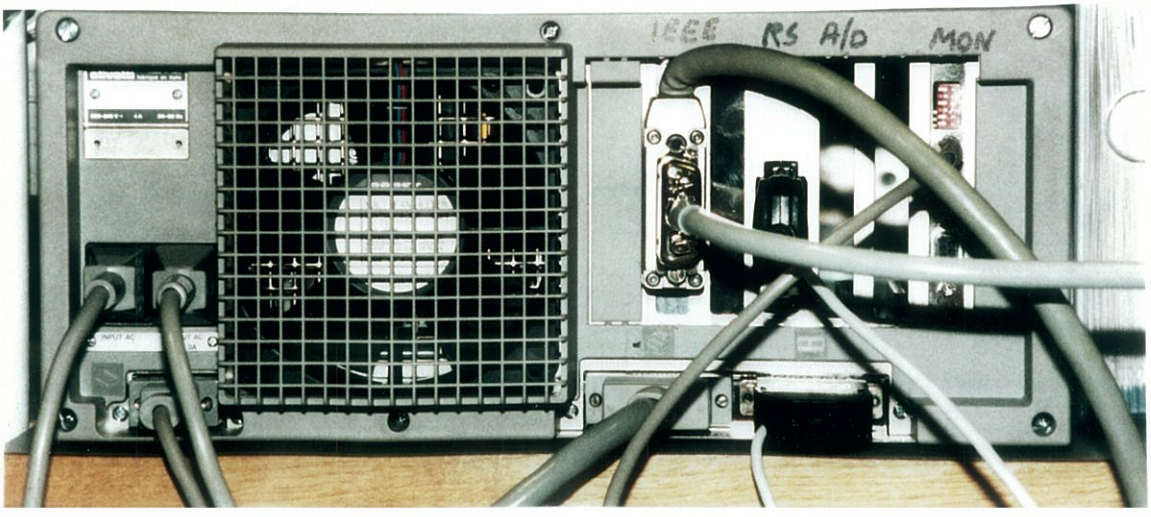


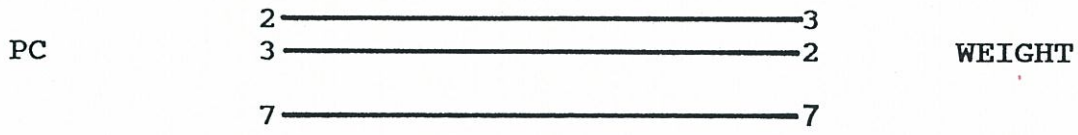
FIG .11



Precisa Weight

Serial RS232C - Communication port 2 (COM2)
Odd parity, 7 Data-bit, 1 stop-bit and binary data-transmission

Line configuration:



Remanence handsamples

-An analog signal (+/- 10V) from the Schonstedt Digital Magnetometer is logged by a Digital Voltmeter
-IEEE communication between PC and Digital Voltmeter

Susceptibility measurements

-IEEE communication between PC and Phillips Frequency Counter

5.3 SPINNER MAGNETOMETER (MOLSPIN)

The Molspin spinner magnetometer is capable of measuring NRM intensities down to approximately 0.1-0.2 mA/M, i.e. approximately 1000 times more sensitive than measurements of NRM on hand-samples. The sample is spinned in 6 positions within a u-metal shield (typically field<100 j). The measured values are as follows:

Spin	North	EAST
1	+Z1	-Y1
2	+Z2	-X1
3	-Z3	+Y2
4	-Z4	+X2
5	+X3	+Y3
6	-X4	-Y4

Total remanence, declination and inclination are calculated from the following formulae:

$$\text{TOTAL REMANENCE} = (Xm^2+Ym^2+Zm^2)^{1/2}$$

where:

$Xm=(X2+X3-X1-X4)/4$, $Ym=(Y2+Y3-Y1-Y4)/4$ and $Zm=(Z1+Z2-Z3-Z4)/4$

$$\text{DECLINATION} = \text{ATN}(Ym/Xm)$$

$$\text{INCLINATION} = \text{ATN}(Zm/(Xm^2+Ym^2)^{1/2})$$

Operating control (Fig. 12)

(a) LCD display

5 digit display of remanent intensity (true intensity in mA/m if volume=12.87). After measurement :

- NORTH component of sample magnetization is displayed.
- Press EAST to display the EAST component.
  The +/- indicator shows the sign of the component.

(b) SHORT/LONG switch

Selects the number of revolutions for which the signal is integrated. SHORT = 24 spins (6 seconds), LONG = 120 spins (24 seconds)

Short spin time is always recommended. Long spin time is only used with samples having intensities below 0.5 mA/m. However, long spin-time may introduce a "rotational" VRM since the residual field is in the order of 20-100j. Thus a cryogenic magnetometer is recommended for low sample intensities.

c) SET ATTENUATION (RANGE)

Four range settings: Typical range maxima (V=12.87) :	1	<	3000 mA/M
	10	<	30000 ma/M
	100	<	300000 mA/M
	1000	<	3000000 mA/M

Exceeding the range is detected by an almost instant stop during measurement.

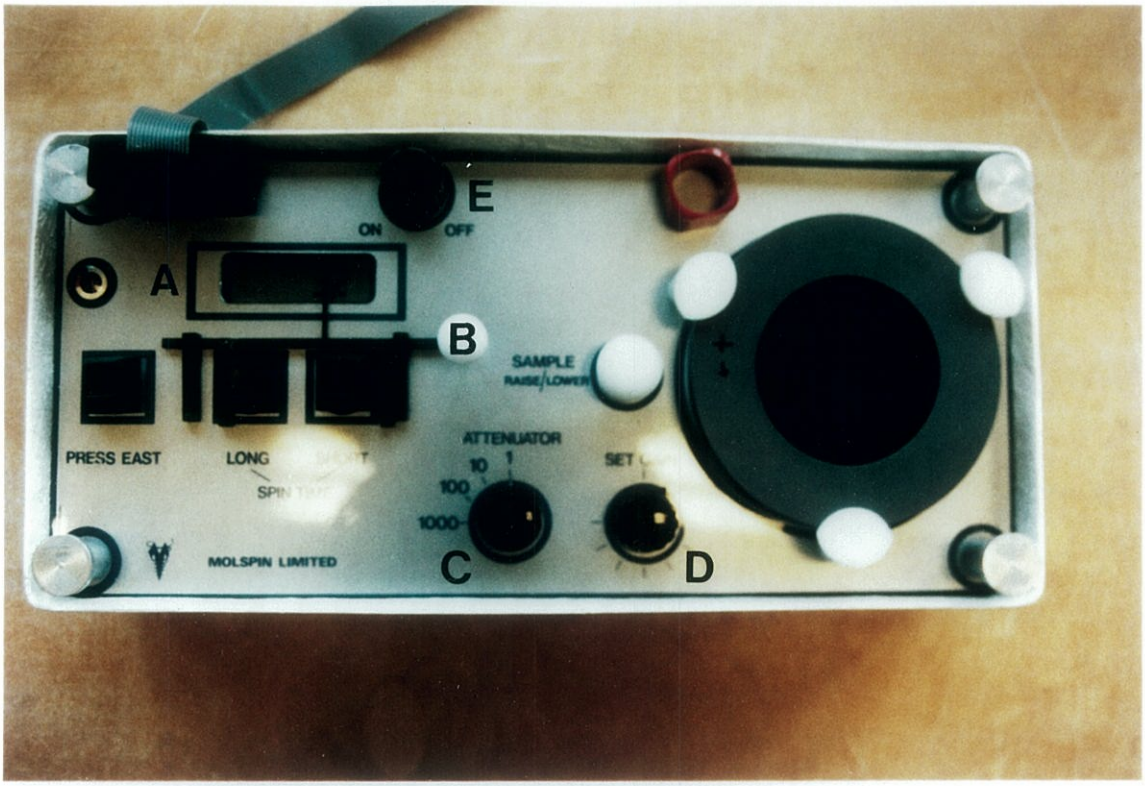
d) SET GAIN

Calibration of intensity
Should be adjusted until Calibration sample show 815 (mA/M)

e) ON/OFF

Switches instrument ON/OFF.
Note that if the molspin is working properly, a value of 32 should be displayed on the LCD panel.

FIG 12


E
ON
OFF
A
B
SAMPLE
RAISE/LOWER
PRESS EAST
LONG
ATTENUATOR
10
1
100
1000
SET
MOLSPIN LIMITED
C
D

THE MONITOR SOCKET (Fig. 13)

The monitor socket provides connections for charging the battery, checking voltage levels (NB), and interfacing the spinner with computers.

a) BAT SWITCH

Show voltage of the internal 5V supply. When the instrument is ON, the reading should be close to 5V on the 10 unit scale. On charge it varies between 6 and 7V. If Molspin is not working properly, i.e. not rotating, check voltage. If voltage is low press charger ON (in BAT switch position), and wait a minute before voltage level increases to 5 or higher.

b) 5V SWITCH

Should read 5V if voltage is OK.

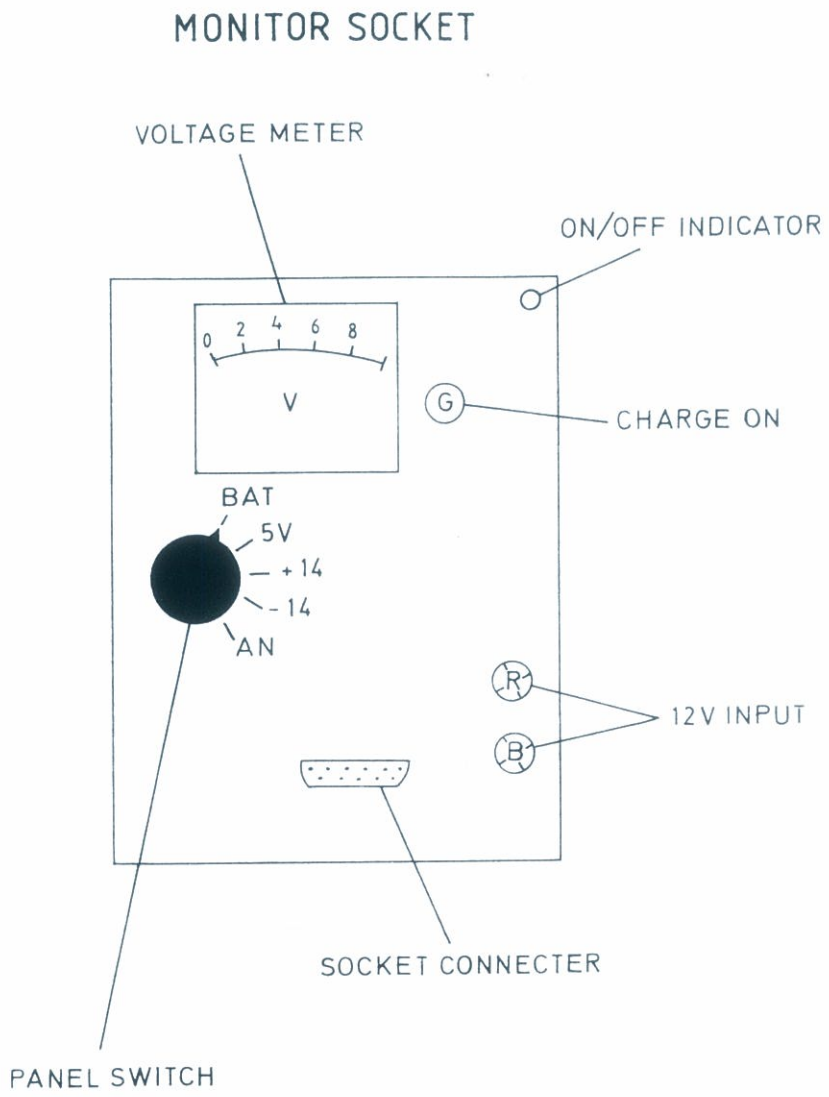
c) Battery charging procedure

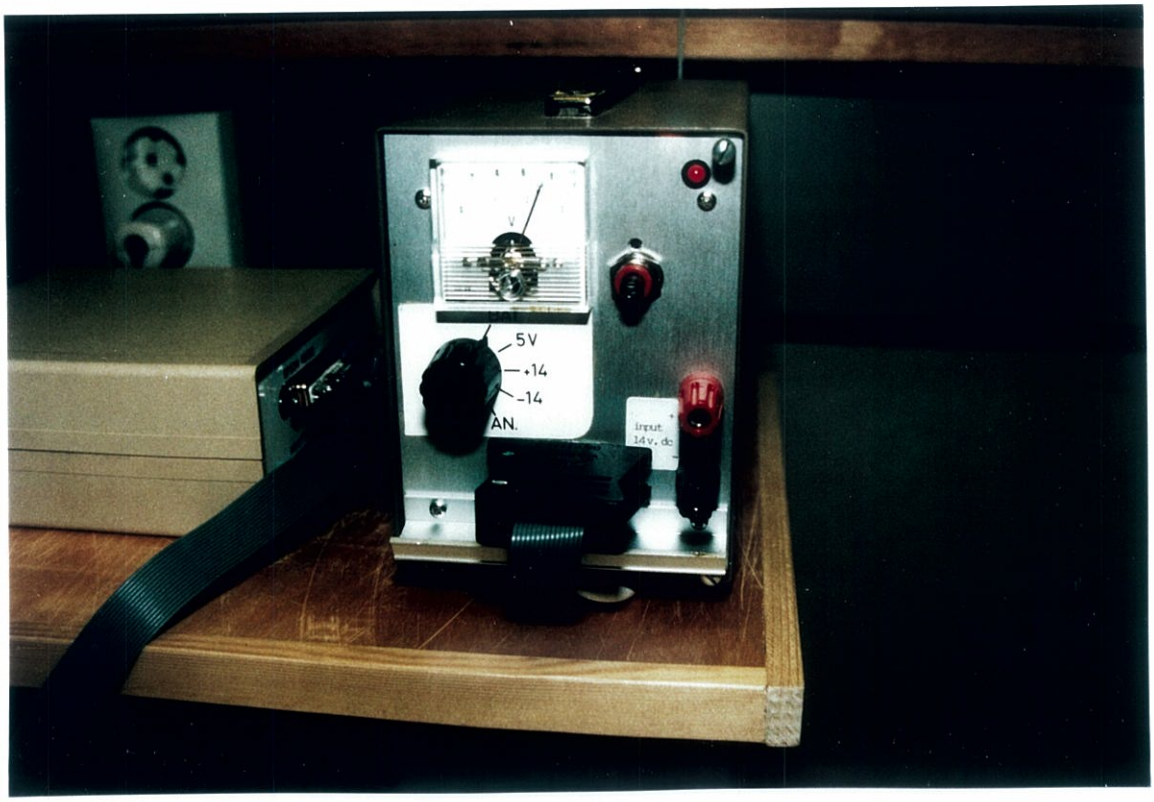
Generally charge battery for 12 hours (switch in BAT position), then use instrument for ca. 12 hours and repeat the procedure. If the battery is low the instrument can be used with charger ON (switch in BAT position), but total charging time becomes much longer.

NOTE:

It is important <u>not</u> to over charge the battery (say leaving it on charge for a week), because this will eventually damage the battery. To avoid damage check therefore that charging is switched off when the battery is fully loaded (i.e. around 5V).

FIG 13
The monitor socket





START-UP AND CALIBRATION

Switch the power on. The motor will start to run, and 32 should be displayed on the LCD. Check battery status. If voltage is low, press the RED button on the monitor socket to activate charger. A red light will appear during charging - Set switch to BAT position.

When the molspin is "cold", the calibration procedure must be repeated after 5-10 samples during the first hour of operation.

a) Intensity Calibration

Insert calibration sample in holder as shown in Fig. 7. Set spin-time selector SHORT. Press SHORT and read NORTH value. Adjust gain and re-measure until the NORTH value is close to 815mA/m (+/- 5 acceptable).

b) Declination Calibration

Declination calibration is performed by reading the EAST value. This value should be close to 0 (+/-10). To reduce this value it is necessary to rotate the fluxgate and shield assembly and re-measure. If EAST is positive (negative) rotate the fluxgate clockwise (anticlockwise).

TROUBLE-SHOOTING

It has been noted that during measurement that the Molspin can be 'locked' and POS-ERR is shown on the SCREEN. Turn Molspin ON/OFF to proceed. If this happen during measurement, you have to press **N** (new measurement) to remeasure the sample. Alternatively press **B** to break out of the molspin handling routine.

5.4. REMANENCE HANDSAMPLES (SCHONSTEDT)

Remanence measurements for handsamples are done with a fixed Schonstedt flux-gate which is positioned within a two-layered u-metal shield (see Fig. 14). The sensitivity depends on the volume of the sample (i.i. total moment), typically being ca. 50-100 mA/m for 200cm^3 samples. The construction of the magnetometer is detailed in Puranen and Sulkanen (1985).

The background field in the probe direction is typically below 1-2 gamma. The background field-value is first measured, and a sample is inserted at a distance of 10 cm (center of sample) from the probe. The change in field-value is proportional to the sample remanence in the probe direction, and this component is related from the following formula:

$$\text{REMANENCE} = \frac{\text{CALIBRATION COEFFICIENT} * \text{CHANGE IN FLUXGATE OUTPUT}}{\text{VOLUME}}$$

The calibration coefficient has been found to be ca. 1425 based on calibration against the spinner magnetometer.

The sample is measured in six positions:

POS 1 Sample remanence in +X direction (X1)
2 Sample remanence in -X direction (X2)
3 Sample remanence in +Y direction (Y1)
4 Sample remanence in -Y direction (Y2)
5 Sample remanence in +Z direction (Z1)
6 Sample remanence in -Z direction (Z2)

The total sample remanence is calculated from:

$$\text{Total Remanence} = (Xm^2+Ym^2+Zm^2)^{1/2} \text{ , where}$$

$$Xm=\frac{X1-X2}{2} \qquad Ym=\frac{Y1-Y2}{2} \qquad Zm=\frac{Z1-Z2}{2}$$

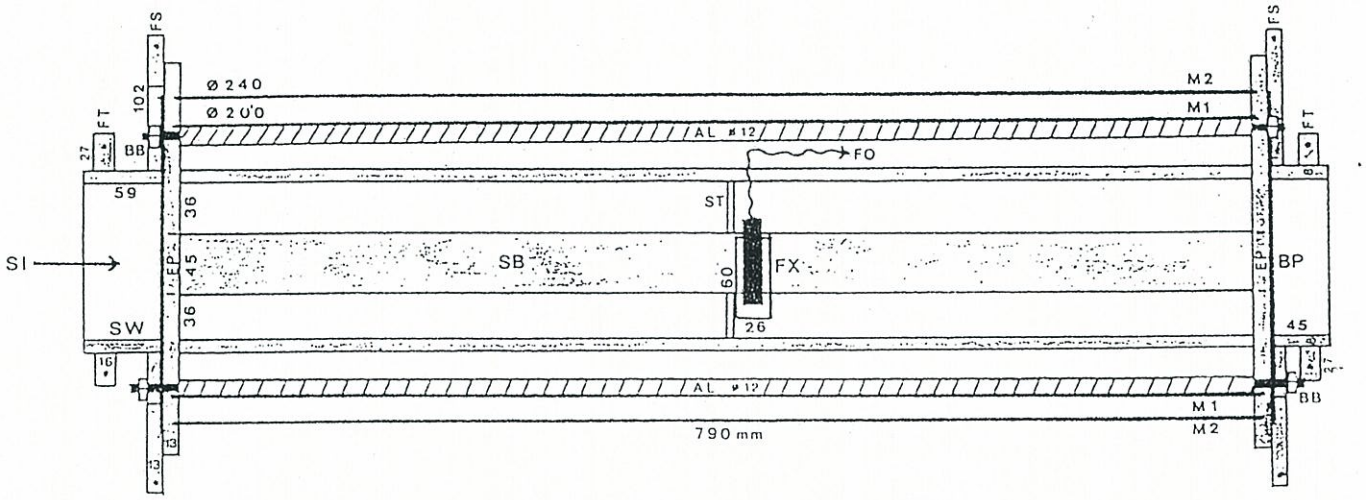
The declination and inclination of remanence is calculated from:

$$\text{Declination} = ATN(Ym/XM)$$

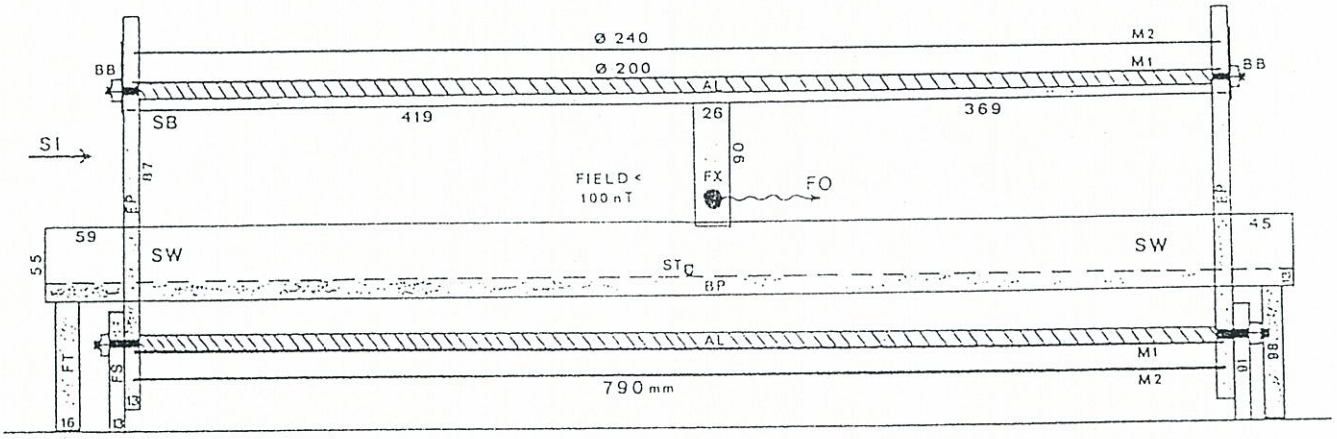
$$\text{Inclination} = ATN(Zm/(Xm^2+Ym^2)^{1/2})$$

FIG 14
Constructing details for handsample magnetometer

TOP VIEW OF REMANENCE SENSOR UNIT



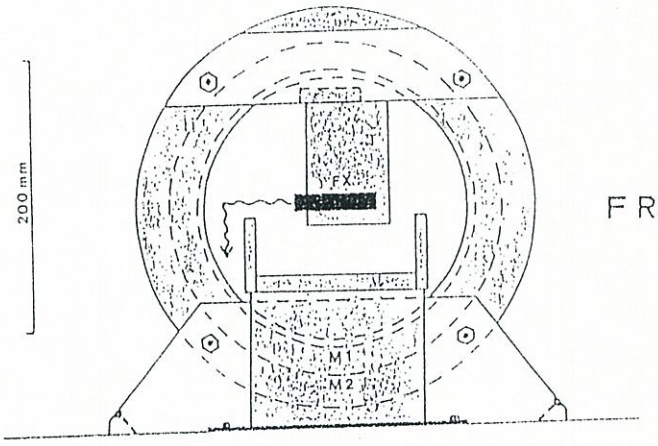
SIDE VIEW OF REMANENCE SENSOR UNIT



SI = sample insertion direction
ST = sample stop slab of ACRYL
SW = sample track walls of PVC
BP = track bottom plate of PVC
FT = track foot plates of PVC

FX = fluxgate probe in ACRYL holder
SB = probe suspension bar of ACRYL
M1 = mumetal shielding tube no. 1
M2 = mumetal shielding tube no. 2

FO = fluxgate output signal
EP = shield end plates of PVC
FS = shield foot plates of PVC
AL = aluminum tie rods of shield
BB = brass bolts of tie rods



FRONT VIEW

Fundamentals (Fig. 15)

The flux-gate probe is monitored from the Schonstedt Digital magnetometer, and an analog signal is transferred to a Digital Voltmeter which is logged by the PC. The relation of fluxgate reading and output voltage is given below:

Fluxgate (mg)	Voltmeter Reading (Vdc)
19	9.5
16	8.0
12	6.0
8	4.0
4	2.0
0	0.0

Operation (Fig 15-16)

- Turn ON Schonstedt magnetometer
- Set RANGE to 20
- Turn on Digital Voltmeter
- Select R (REM) in PETROLAB

FIG 15
Operating contol Schonstedt magnetometer and Digital voltmeter

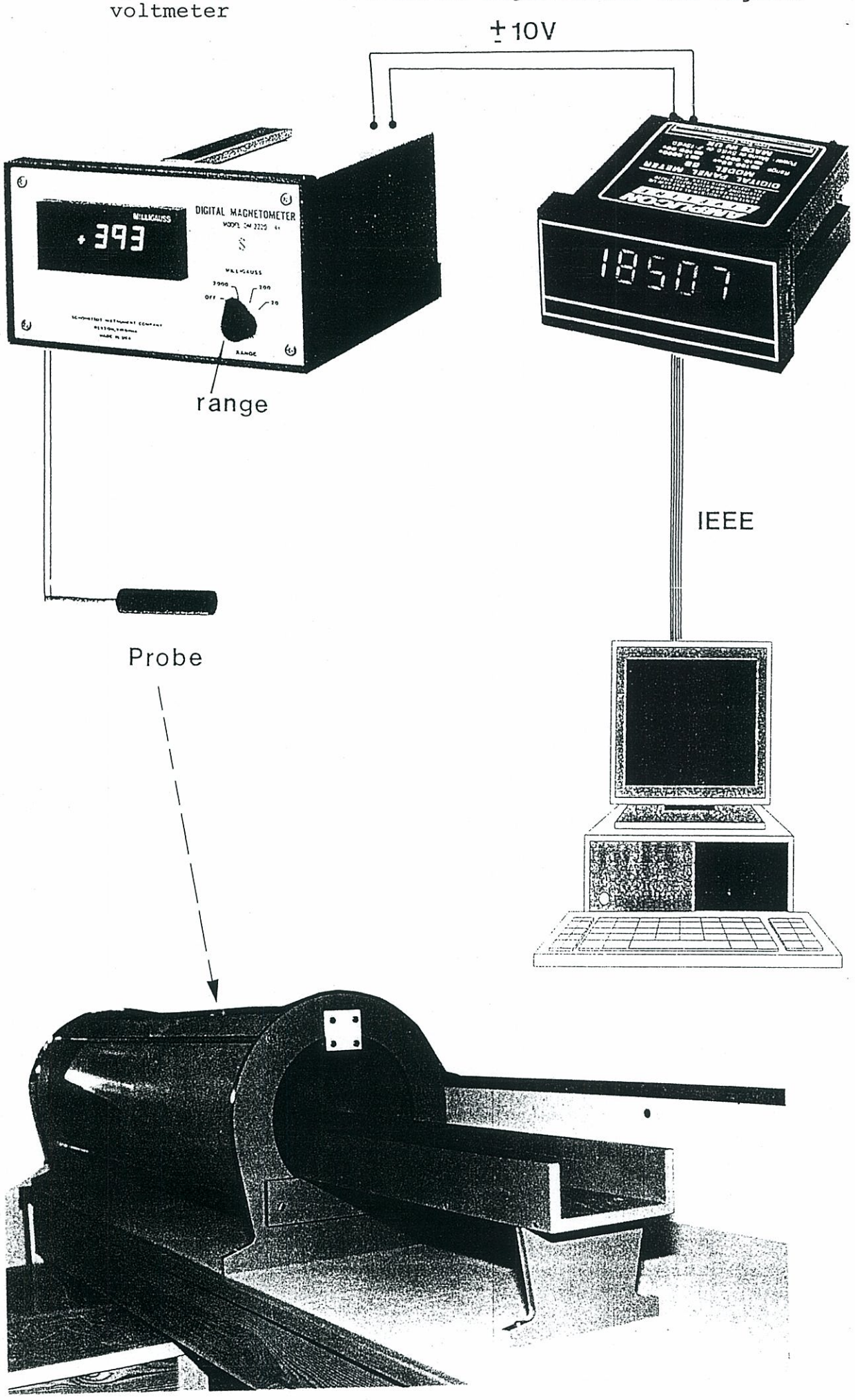
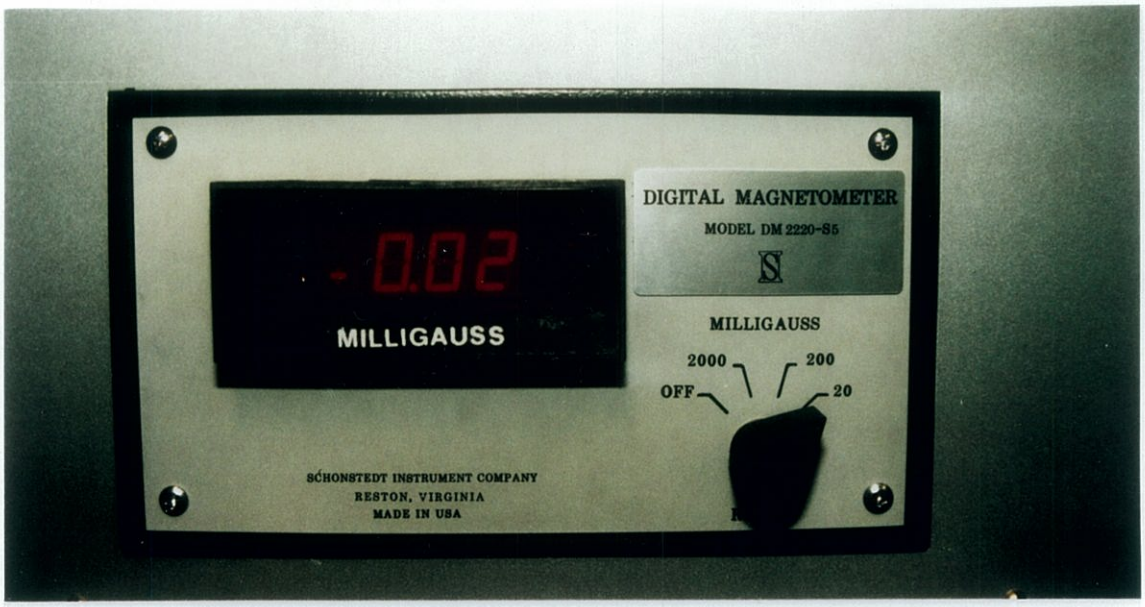
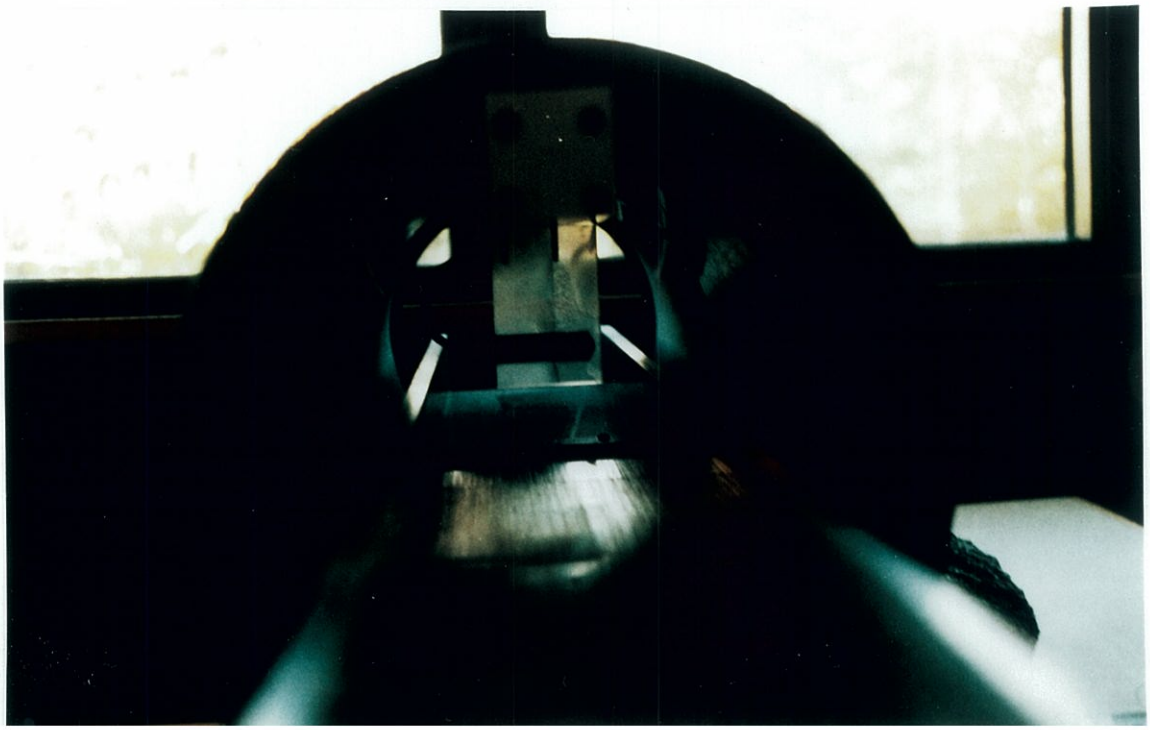


FIG 16


- 0.02
MILLIGAUSS
DIGITAL MAGNETOMETER
MODEL DM 2220-S5
MILLIGAUSS
2000
200
OFF
20
SCHONSTEDT INSTRUMENT COMPANY
RESTON, VIRGINIA
MADE IN USA



5.5. SUSCEPTIBILITY

Susceptibility measurements include the following equipment (Fig. 17):

1 - Frequency-oscillator
2 - Phillips PM6669 Frequency Counter (IEEE interface)
3 - Pick-up coils (1-3)

The pick-up coils (empty) have the following characteristics:

COIL	DIA(mm)	FREQ(Hz)	PER(ms)	RES(Ohm)	N	DIM(mm)	CFAC
1	32	917.470	1.089960	17.80	1400	0.5	0.00024
2	62	758.066	1.319030	21.50	-	0.5	0.000671
3	103	730.800	1.368444	24.8	-	0.5	0.00226

DIA=Inner diameter coil; FREQ=Frequency; PER=Periode; RES=Resistance; N=coil turns; DIM=wire diameter; CFAC=coil constant.

Susceptibility measurements are carried out by using a frequency-oscillator (Fig. 18) and a frequency counter (Fig. 19). The susceptibility of a sample can be calculated from the frequency difference between empty coil and coil with an inserted sample. The period of the coil rather than the frequency is monitored, and the susceptibility is calculated from the following formulae:

$$\text{APPARENT SUSCEPTIBILITY} = SUS_a = CFAC*(T1/T0)^{1/2}*(T1-T0/VOLUME)$$

where,

T0 = Period empty coil and T1=Period sample in coil

Corrected for demagnetization factor:

$$\text{TRUE SUSCEPTIBILITY} = SUS_a*4*3.14159/(4*3.14159-4.19*SUS_a)$$

Operation

- Turn on frequency oscillator
- Select coil 1-3 on oscillator
- Check that voltage is OK (>10 V)

- Turn on Frequency Counter
- Set FUNCTION to PER A (period)
- Select S (SUS) in PETROLAB

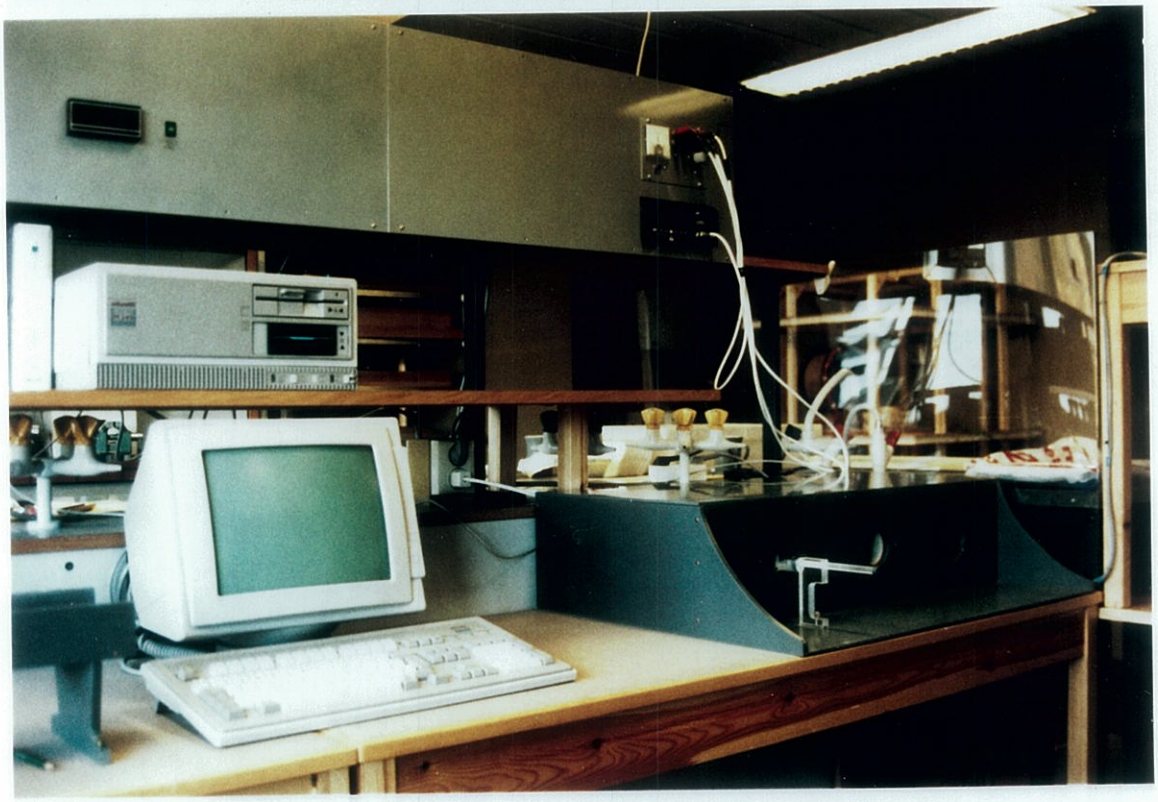
NOTE:

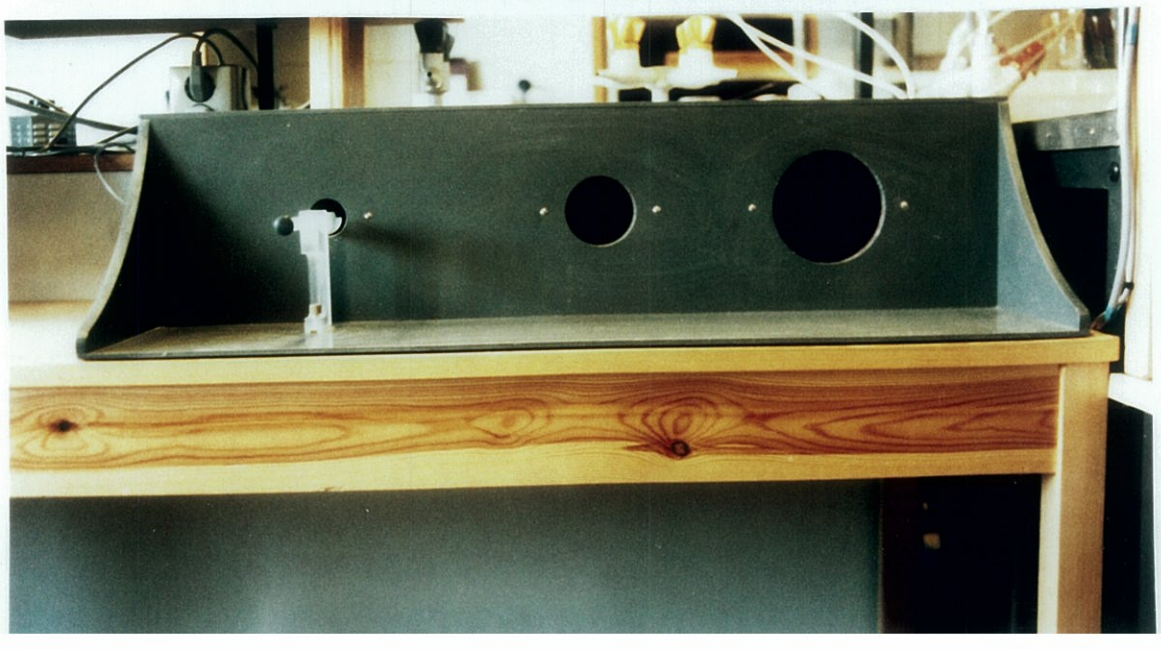
- Sensitivity knob should always be set to 10mV and maximum sensitivity (i.e. knob pressed and turned maximum clockwise)
- Filter <50 KHz always pressed (Fig. 19)

Test of susceptibility equipment

Samples have been tested against a low-field induction bridge KLY-2 (BERGEN) which is probably the best susceptibility instrument available. The results are displayed in Fig. 20. The calculated regression coefficient is better than 0.99, thus the NGU susceptibility system compares well with the KLY-2 bridge. The test was performed with coil 1. The sensitivity of the NGU susceptibility meter is approximately $1*10^{-5}$ SI.

FIG 17





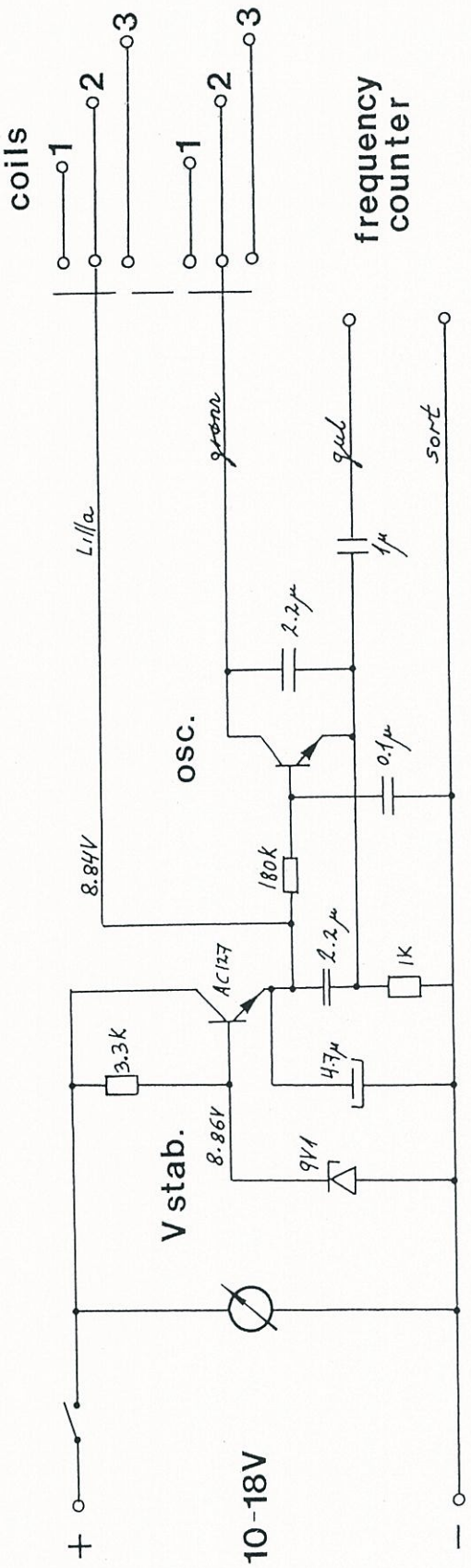
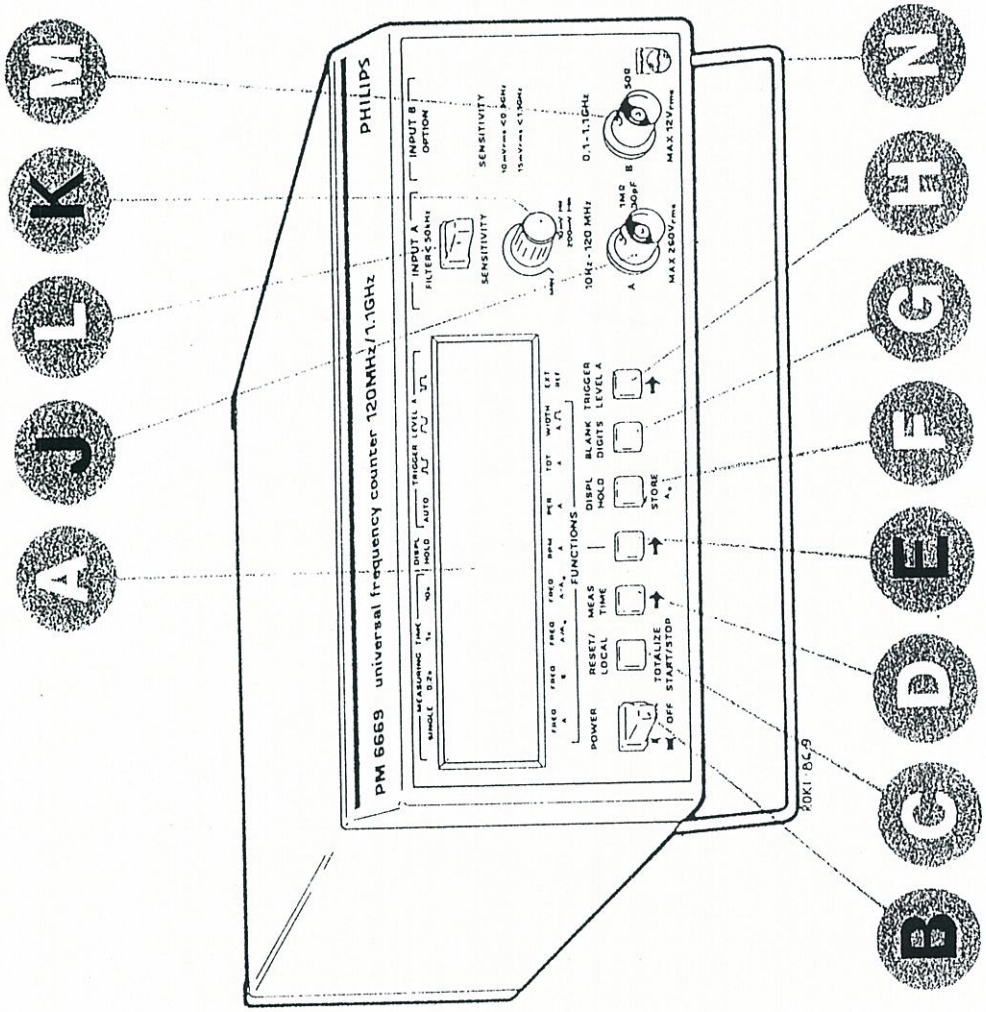


FIG 18
Signal oscillator circuit

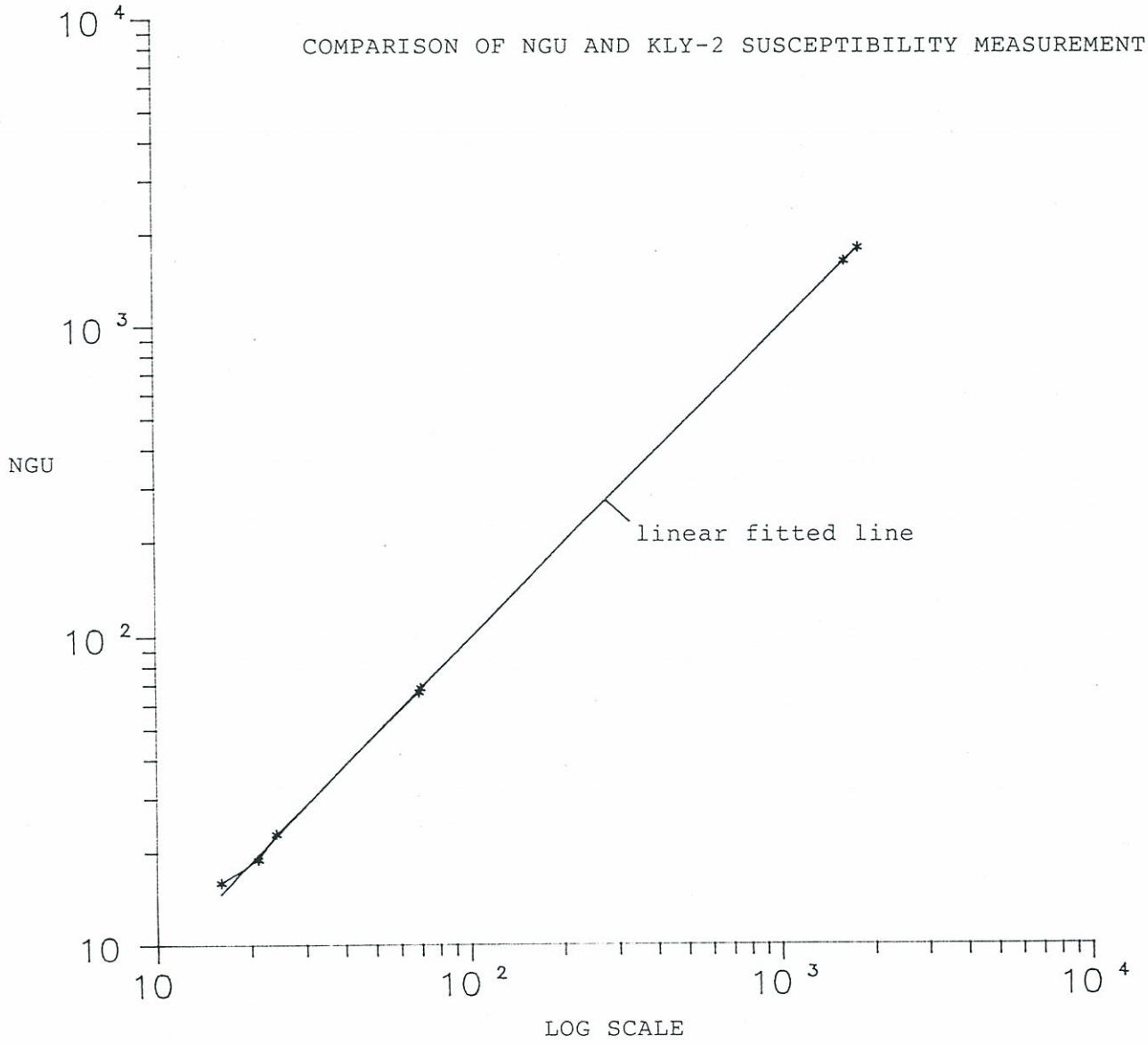
FIG 19
Operation of susceptibility equipment



Front view

A) Large LCD-display
B) Power switch
C) Reset button, doubles as local button if the counter is equipped with an GPIB interface. Starts and stops counting if the TOT A function is selected.
D) Measuring time selector-button. *
E) Function-selector button. *
F) Display-hold button. Freezes the display. The button is also used for storing A_0.
G) Blank-digits button. Blanks out one digit for each depression of the button, from the right to the left of the display. (No rounding off.)
H) Trigger-level setting-button. *
J) Input-A BNC-connector.
K) Sensitivity-control with dual-range push-in/pull-out switch.
L) 50 kHz filter-switch.
M) Input-B BNC-connector (optional).
N) Tilting support.

* The selected function is indicated on the display. A short press on the button moves the arrow one step to the right. A long press makes the arrow scroll.



DATA (10^{-5} SI UNITS)

NGU	KLY-2 (BERGEN)
16	16
21	19
24	23
69	66
70	68
1622	1606
1796	1774

REGRESSION COEF: 0.9999968

KLY-2

FIG 20
Comparison of NGU (coil 1) and KLY-2 measurements of magnetic susceptibility

5.6 WEIGHT

Volume and density calculations can be derived from measuring the dry and wet weight of a sample. Note, however, that a sample should be 'water saturated' before measurements. The petrophysical laboratory uses a PRECISA 3000D (Fig. 21) for routine measurements with a resolution power of 0.1gram.

Samples are firstly inserted on the top of the weight for dry-weight measurements (Fig. 22a), and subsequently put in the water-container for wet-weight measurement (underfloor weighting; Fig. 22b). See that the wet-weight holder is not oscillating during measurement (stabilize it).

Volume and density are calculated from the following formulae:

VOLUME = DRYWEIGHT - WETWEIGHT (cm^3)

DENSITY = (DRYWEIGTH/VOLUME)*1000 (kg/m^3)

Operation

-Turn on weight

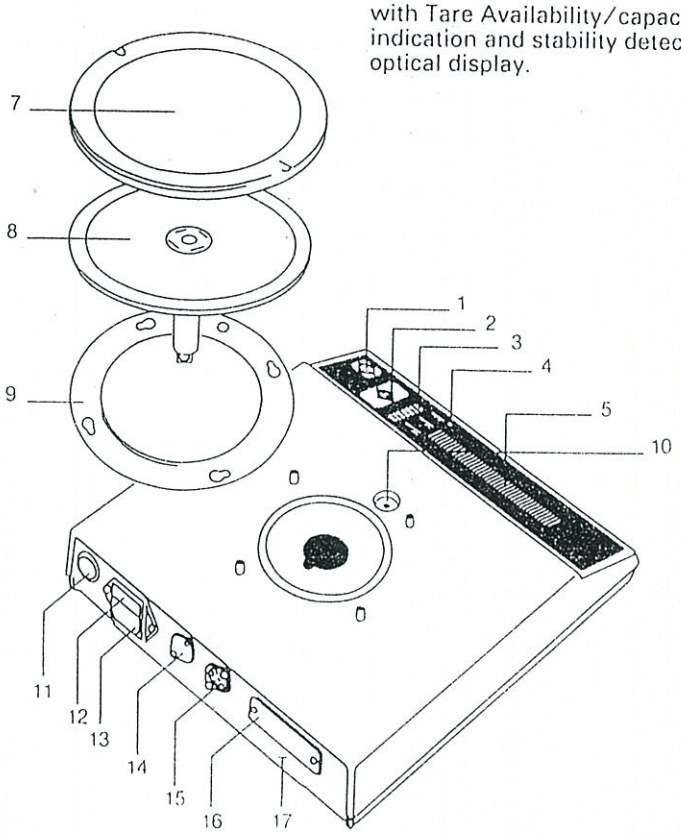
-Check that weight reads zero
If not use TARE or turn OFF/ON weight

-Select **W** (weight) in PETROLAB

FIG 21
Precisa 3000D weigth

Electronic Precision Balances

with Tare Availability/capacity indication and stability detector with optical display.



1 Stand-by switch
2 Taring button
3 Tare Availability/capacity indicator
4 Function diode
5 Digital weight readout with stability detector «g»
6 --
7 Weighing pan
8 Pan holder
9 Retention ring
10 Fixing screw
11 Voltage selector
12 Fuse
13 Mains connection
14 20 mA current loop/ Analogue data output
15 Plug for multi-function box
16 Digital data output
17 Name plate

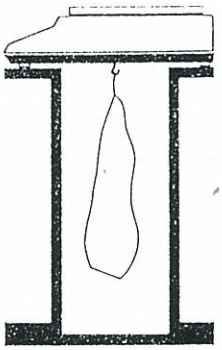
Weighing

1. Press the tare button. This zeroes the weight readout. Wait until the stability detector «g» lights up.

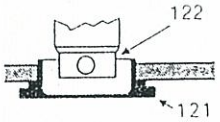
2. Place the object on the weighing pan. After the stability detector «g» lights up read the measured result.

3. If the weighing range is exceeded, the topmost segment of the weighing-in device shows a red light. The indicated weighing range can be exceeded.
The weighing-in device serves as a warning of overloading. With effective overloading the OL sign appears on display.

Underfloor weighing



Precisa balances are fitted with a device for underfloor weighing. Remove plug 121 from the bottom of the balance.

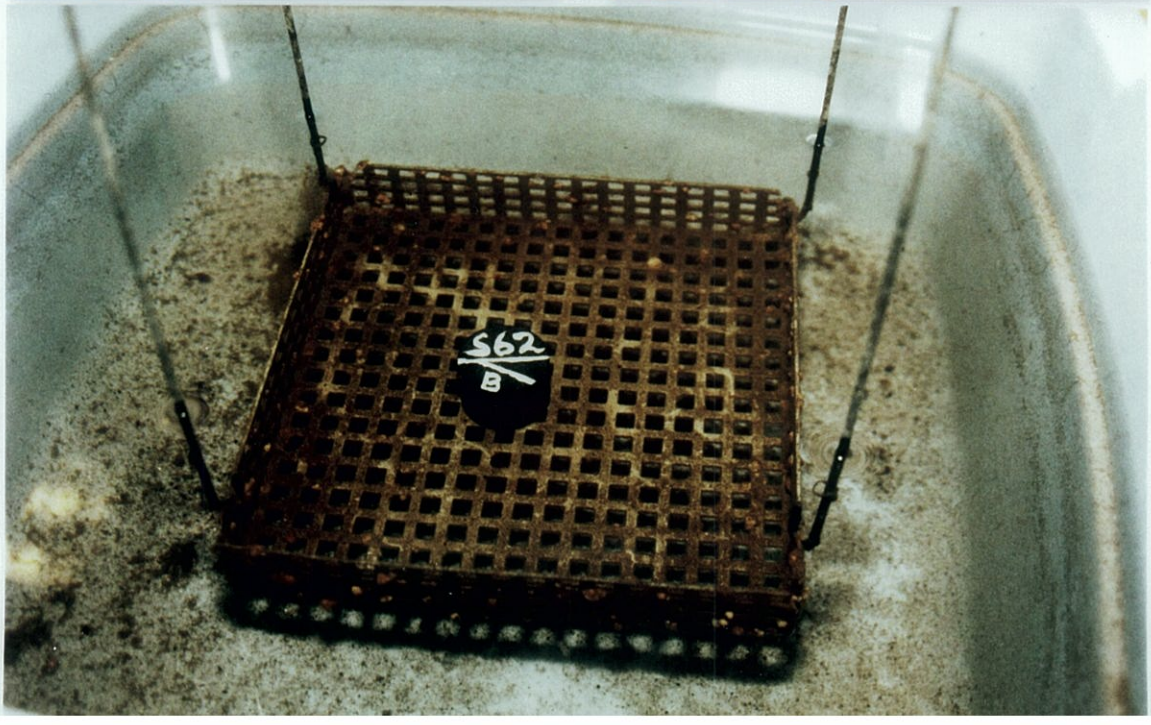


The object to be weighed is attached to the suspension device 122. The hooks must be made of antimagnetic material.

FIG 22

A

B



C

5.7 THERMAL DEMAGNETIZER

The laboratory utilize thermal and alternating field for magnetic cleaning of samples. The main object with magnetic cleaning is to remove unstable or secondary remanence components. Thermal demagnetization is the most widely used cleaning method in routine palaeomagnetic experiments. After measuring the NRM of a sample, the sample is heated to ca. 100°C, then cooled to room-temperature in **zero** magnetic field, and the NRM is re-measured. This process is repeated in 50-100°C steps until there is evidence that secondary NRM components have been removed. This may involve heating to within a few degrees below the Curie-point of the remanence carrying mineral, e.g. 580°C and 680°C for magnetite and haematite respectively. In general, heating steps of 100°C are used below 500°C, and then steps of 10-25°C are applied in the 500-680°C range.

The thermal demagnetizer is constructed in the Geological Survey, and comprises the following elements (Fig. 23):

Magnetic shielding and thermal isolation sylinders

- Double-layered outer u-metal shield (D=25/28cm, L=90/90cm)
  Residual magnetic field <20 j
- An inner water-cooled aluminum shield (D=11.5cm , L=120 cm)
  Isolated section between aluminum and u-metal shield
  See details in Fig. 23c.

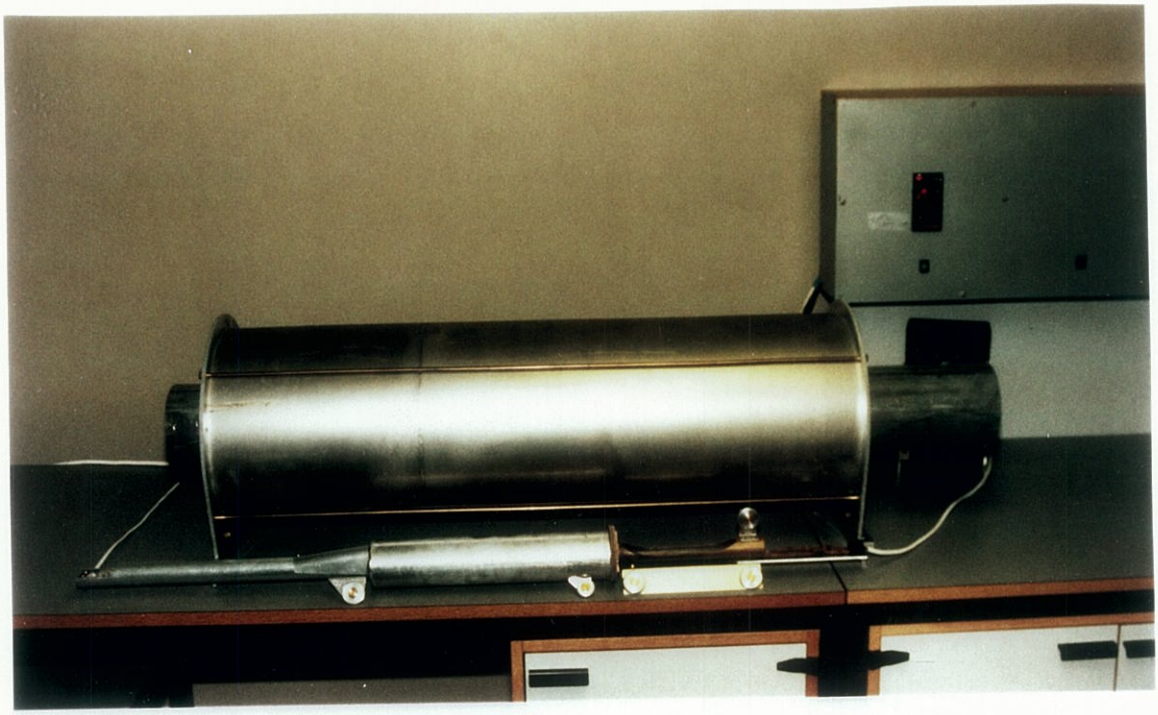
Heater element

- Non-Inductive Lindberg Furnace
  Enveloped with isolation/aluminum shield; closed one end.
  Resistance = 80 Ohm, Power = 605Watt (220V)
  See Fig. 23a.

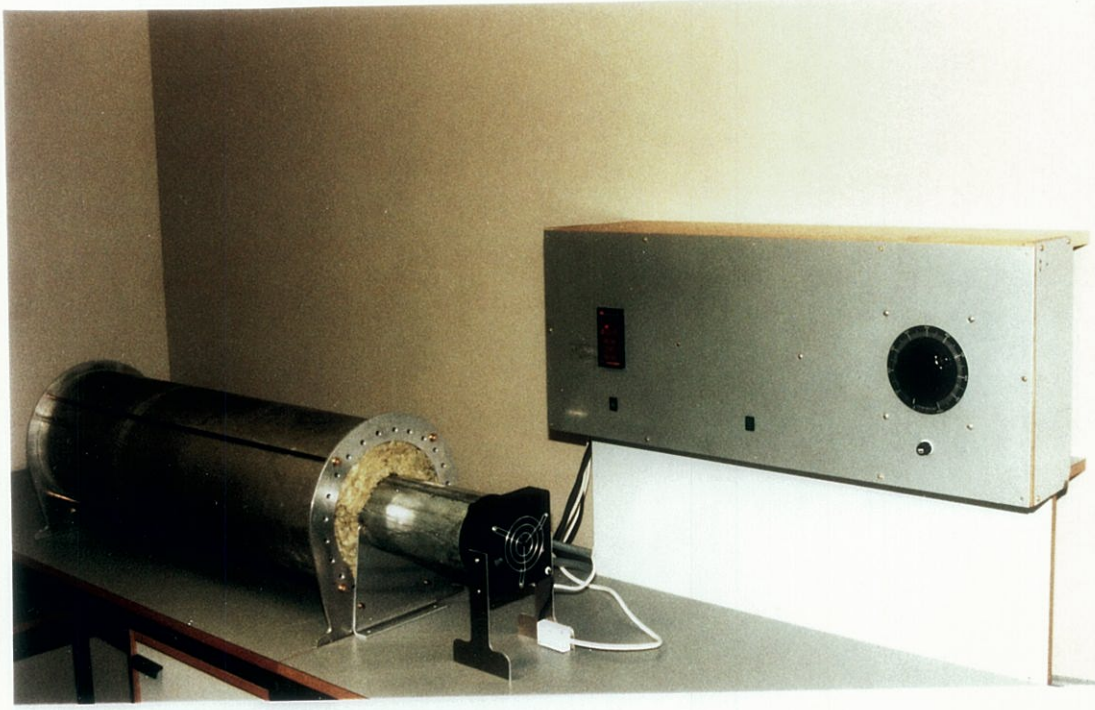
Sample holder

- Aluminum/quartz sample holder
  Sample capacity = 12
  See Fig. 23a.

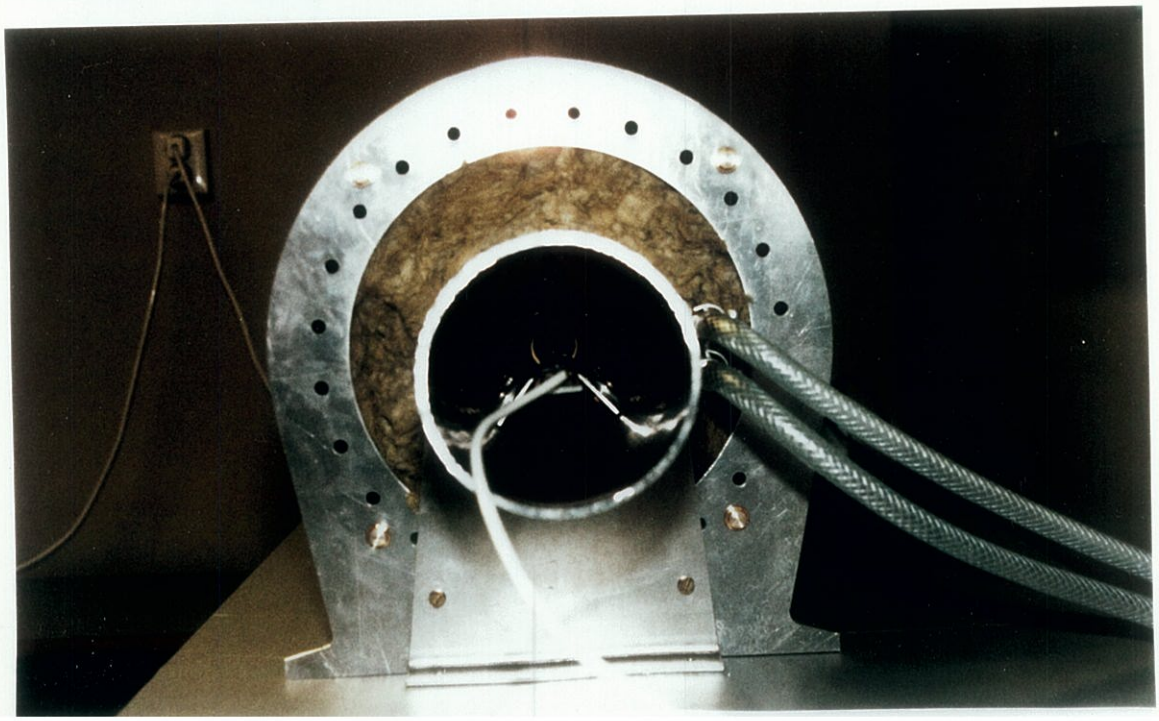
FIG 23



A



B



C

Temperature system controller

The temperature system consist of a Minicor temperature controller and a variac power supply (Fig. 24). Furnace power is controlled by a solid state relay. A NiCr-Ni thermoprobe (Type K) is situated in the center of the sample-holder. Explanation of the thermoprobe principle (seedbeck effect) and output-voltage (in mV) is given in fig. 25.

Operation

Preparation

1. Measure NRM of samples

Heating

1. Control that POWER-OUTPUT is set to 0%
2. Control that water-cooling is OK
3. Turn on temperature controller
4. Insert FURNACE in locked position
5. Insert SAMPLE-HOLDER in locked position
6. Press <F> on temperature controller
   <1> should appear in the left window
7. Set temperature by adjusting arrows (up - down)
8. Press <ENTER> on temperature controller
9. Set POWER OUTPUT to correct percentage (see Table below)

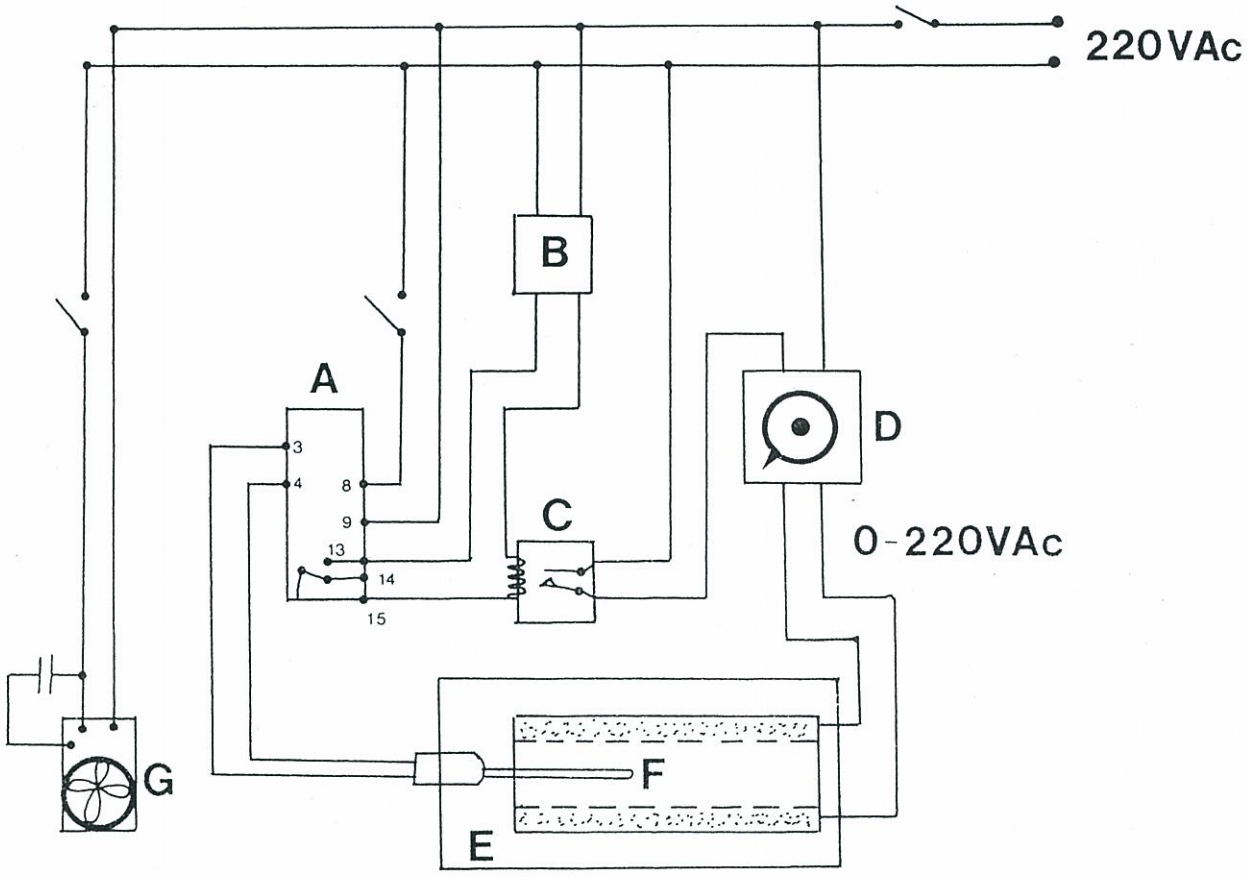
Cooling

1. Leave the furnace at the set temperature for ca. 15-30 min.
2. Turn POWER OUTPUT off (0 %)
3. Unlock FURNACE and pull it toward you
4. Insert FAN
5. Turn FAN on

*** * * COOLING * * * * * * * * * * * * * ***

6. Turn FAN off when temperature has dropped below 25-30^{o}C
7. Remove FAN
7. Unlock sample-holder and pull it out
8. Measure samples

FIG 24
Temperature controller circuit



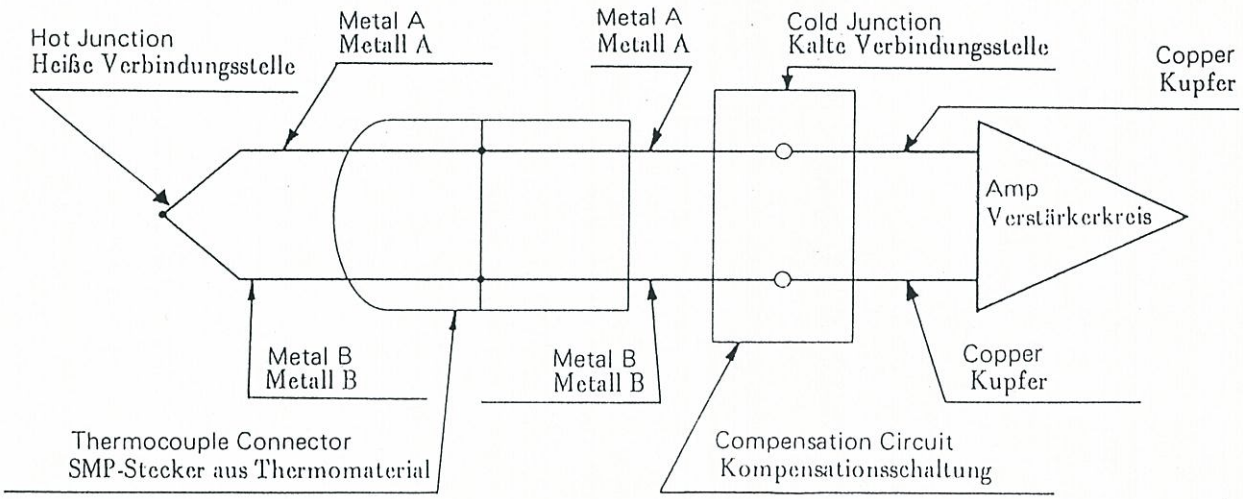
A	TEMPERATURE CONTROLLER	MINICOR 41 (Tormatic)
B	BATTERY ELIMINATOR 6-9 VDC	
C	SOLID STATE RELAY	(Tormatic)
D	VARIAC POWER SUPPLY 0-220 VAC - 7.5 A	
E	HEATER ELEMENT 220 VAC - 80 Ohm	(Lindberg)
F	THERMOCOUPLE NiCr-Ni	
G	COOLING FAN	

Table for POWER-OUTPUT

Temperature (^{o}C)	Ca. Power (%)
<100	60
<200	75
<300	80
<400	80
<500	90
>600	100

SEEBECK EFFECT

When two dissimilar metalic conductors are joined end to end and one of the ends is heated, produces a thermoelectric voltage in the circuit of which they form a part. Thomas Seebeck made this discovery in 1821.



TYPE: K (CA) Reference Junction at 0°C

°C	0	10	20	30	40	50	60	70	80	90	100	°C
-100	-3.553	-3.852	-4.138	-4.410	-4.669	-4.912	-5.141	-5.354	-5.550	-5.730	-5.891	-100
(-) 0	0	-0.392	-0.777	-1.156	-1.527	-1.889	-2.243	-2.586	-2.920	-3.242	-3.553	(-) 0
(+) 0	0	0.397	0.798	1.203	1.611	2.022	2.436	2.850	3.266	3.681	4.095	(+) 0
100	4.095	4.508	4.919	5.327	5.733	6.137	6.539	6.939	7.338	7.737	8.137	100
200	8.137	8.537	8.938	9.341	9.745	10.151	10.560	10.969	11.381	11.793	12.207	200
300	12.207	12.623	13.039	13.456	13.874	14.292	14.712	15.132	15.552	15.974	16.395	300
400	16.395	16.818	17.241	17.664	18.088	18.513	18.938	19.363	19.788	20.214	20.640	400
500	20.640	21.066	21.493	21.919	22.346	22.772	23.198	23.624	24.050	24.476	24.902	500
600	24.902	25.327	25.751	26.176	26.599	27.022	27.445	27.867	28.288	28.709	29.128	600
700	29.128	29.547	29.965	30.383	30.799	31.214	31.629	32.042	32.455	32.866	33.277	700
800	33.277	33.686	34.095	34.502	34.909	35.314	35.718	36.121	36.524	36.925	37.325	800
900	37.325	37.724	38.122	38.519	38.915	39.310	39.703	40.096	40.488	40.879	41.269	900
1000	41.269	41.657	42.045	42.432	42.817	43.202	43.585	43.968	44.349	44.729	45.108	1000
1100	45.108	45.486	45.863	46.238	46.612	46.985	47.356	47.726	48.095	48.462	48.828	1100
°C	0	10	20	30	40	50	60	70	80	90	100	°C

FIG 25
Explanation of thermoprobe principle, and the relation of temperature and output voltage (mA) for a NiCr-Ni (Type K) thermoprobe

5.8 ALTERNATING FIELD DEMAGNETIZER

The purpose with alternating field (AF) demagnetization is similar to thermal cleaning, but instead of using thermal energy, one uses an AF field to randomize the NRM. With increased AF fields, the magnetic moment of particles or domains of successively higher coercivities forces are randomized or demagnetized. Thus, remanence of differing stability can be distinguished in a sample. After measuring the initial NRM, a sample is rotated (2 or 3 axes) in a starting field of ca. 2-3 mT, and then the NRM is remeasured. This is repeated in steps of 2 mT below 10 mT (2,4,6,8,10 mT), and then in 3-5 mT steps above that field. Multidomain magnetite is typically randomized in fields of 5-15 mT (low coercivity), whereas single-pseudo-single domain magnetite may stand fields in the order of 50-80 mT. On the other hand, haematite (very high coercivity), may not be demagnetized in fields of several hundred mT.

Principal requirements for AF equipment are (Collinson, 1981):

(1) Coil and power-supply enabling a peak AF field of at least 100 mT.

(2) Stepwise and transient field reduction to zero of the coil current.

(3) Zero or low direct field of external origin.

Specifications Af demagnetizer

COIL

Field-strength/Current	38.2 mT/A_{eff}
Maximum field	150 mT
Maximum current	4 A_{eff}
Coil turns	3500
Diameter copper wire	1.5 mm
Ohms Resistance	19 Ohm ($20^{o}C$)
Self-inductance	1.1 Henry

AF HOMOGENEITY

Variation in field-strength in sample area	$\pm$ 4 %

DETERMINATION OF FIELD-STRENGTH

Uncertainty	$\pm$ 2 %

CAPACITORS

Type	Bosch
Capacitances	C=37.5 uF +/- 10 %
Nominal voltage	380 V

REGULATION OF FIELD

Maximum time for demagnetization	310 s

VARIAC TRANSFORMERS

Type	Phillips
Nominal secondary current	8.5 A

CAPACITY SAMPLE-HOLDER

Number of 19mm samples	4

MAGNETIC SHIELDING (Fig. 26)

3 orthogonal (squared) Helmholz-coils	single-layered
Power-control system for coil 1-3	< 5V, 1A output
220 VAC - 12 VDC transformer	max 5A output
Analog Voltmeter showing output to coils	5 V
Digital Voltmeter logging Oersted-meter	
Førster Oersted-meter	

Serious Warnings !

1. NEVER APPLY GREATER FIELD-STRENGTH THAN 1500 Oe (4 A)

The coil is not temperature secured, thus too much current would destroy the coil (4 A max)

Main fuse stands ca. 1900 Oe. If the fuse is blown and the Oersted-Meter is not functioning properly the operation-amplifier is destroyed, and has to be repaired.

2. DO NOT LEAVE CURRENT CONSTANT AT HIGH LEVEL FOR A LONG PERIOD

For example if you apply 1500 Oe for say 1/2 hour the coil will melt. The instrument is designed so that the field in the coil will start to reduce immediately after the set field is reached.

3. CHECK THAT AT LEAST ONE VARIAC IS SET TO ZERO VOLTAGE BEFORE TURNING THE INSTRUMENT ON/OFF

Voltage shook may damage the operation amplifier for the Oerstedmeter.

4. ALWAYS CHECK THAT FIELD WITHIN HELMHOLDZ COILS ARE ZERO CHECK VOLTAGE READING ON VOLTMETER

Magnetic Shielding operation (Fig. 27)

The power-control unit switch has four positions, **0=no current,** and position 1 to 3 is used to change the current in the various Helmholz coils.

1) Set switch to coil 1 (Vertical) in power control unit

2) Insert field-probe tool in center of Helmholz coils

3) Set Fluxgate Oersted-meter to range 1
-Turn on Digital Voltmeter

4) Position fluxgate-probes vertically

5) Turn knob 1 clockwise/anticlokwise until reading of Oersted-meter equals zero. Cf. reading on digital voltmeter if Oersted-meter is out of range.

6) Set switch to coil 2

7) Position fluxgate horizontally along coil 2

8) Regulate knob 2 until reading of Oersted-meter is zero

9) Set switch to coil 3

10) Position fluxgate-probes horxontallyalong coil 3

11) Regulate knob 3 until reading of Oersted-meter is zero

12) Test once more the vertical component 1, and remove field-probe tool after finishing.

13) Turn off Oersted-meter and Digital Voltmeter

NOTE

POWER CONTROL SWITCH MUST ALWAYS BE SET TO 1, or 3 DURING AF DEMAGNETIZATION (CHECK VOLTAGE INDICATOR)

CALIBRATION PROCEDURE MUST BE REPEATED 2-3 TIMES A DAY

SET SWITCH TO 0 WHEN FINISHING AF-DEMAGNETIZATION

NEVER TURN OFF VOLTAGE TRANSFORMER SINCE A 12VDC SIGNAL IS ALWAYS POWERING THE SUSCEPTIBILITY EQUIPMENT

Operation of Af demagnetizer

1) Check that both VARIACS are set to ZERO

2) Turn on main power-supply in controller box

3) Turn on digital voltmeter for field-control

4) Insert samples in holder

5) Turn on rotation sample ("rotasjon prøven")
Red arrow on motor should be set to 0.5 (ca. 400 r.p.m)

6) Select correct time for motor-driven variac
Time is given in minutes on green plastic-bits on the motor-variac.

Time-setting should be approximately:

Start-value AF field	<15	30	60	90	120	150
TIME (minutes)	1/4	1/2	1	1 1/2	2	2 1/2

7) Set non-motor driven VARIAC **carefully** to field-strength. Field-strength is converted from the digital ampere reading. **NEVER EXCEED 4 A (i.e. 150 mT)**

Field (mT)	Ampere	Field (mT)	Ampere
1	0.026	80	2.094
2	0.052	90	2.356
4	0.104	100	2.617
6	0.157	110	2.879
8	0.209	120	3.141
10	0.261	130	3.403
12	0.314	140	3.664
14	0.366	150	3.926
16	0.418		
18	0.471		
20	0.523		
25	0.654		
30	0.785		
35	0.916		
40	1.047		
50	1.308		
60	1.570		
70	1.832		

8) Push sample-holder into the coil

9) Turn ON motor variac ("motor variac")
Demagnetization is now fully automatic and a red-light will will be displayed above the Helmholz coils.

10) When motor-variac has stopped, pull sample-holder out off coil (Red light should be off).

Turn OFF rotation sample ("rotasjon prøven")
Turn OFF motor variac ("motor variac")

Take samples out off sample-holder

11) SET Voltage on non-motor driven variac to ZERO

12) Measure samples in magnetometer

13) Repeat procedure with increased AF field (point 4)

TURN OFF ALL SWITCHES BEFORE LEAVING THE INSTRUMENT

CHECK THAT VOLTAGE ON VARIAC IS SET TO ZERO

TURN OFF POWER-SUPPLY TO HELMHOLZ COILS

Suggested improvement of AF demagnetizer

Improvement in the AF demagnetization equipment has been undertaken and involve the following plans:

(1) The starting field for AF demagnetizing is now done manually. This will be done by reversing the motor.

(2) Make the AF demagnetizer completely automatic, i.e.

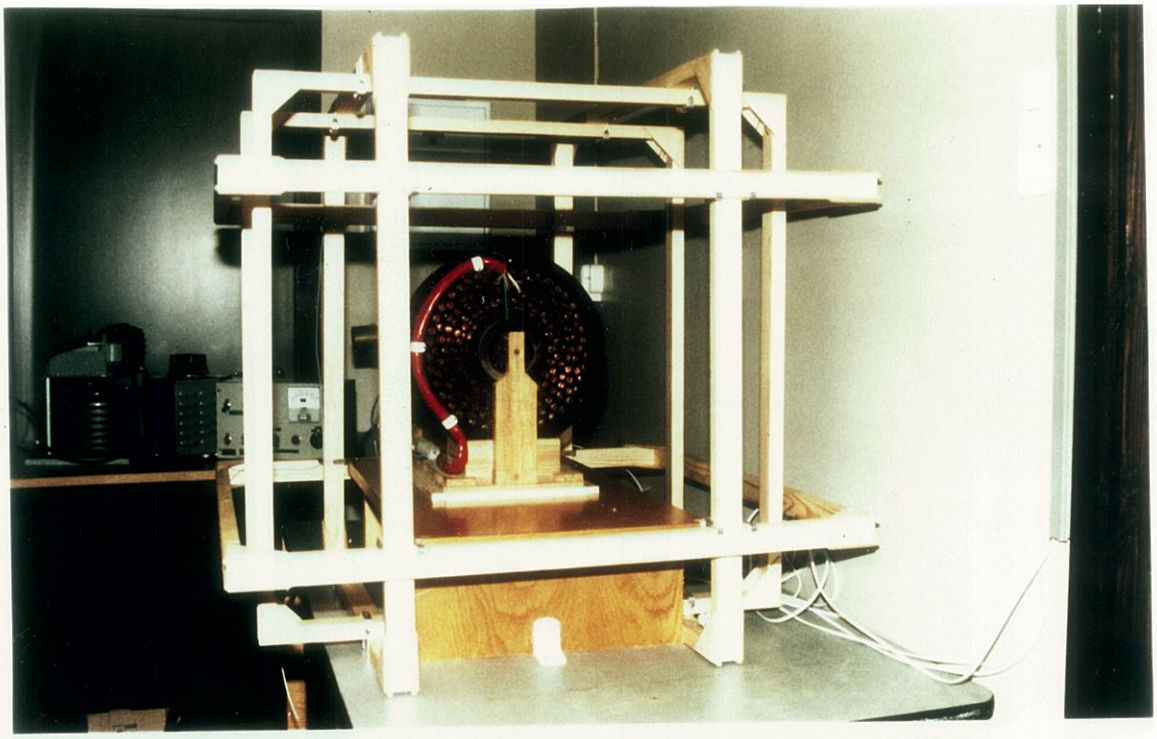
(a) Set field

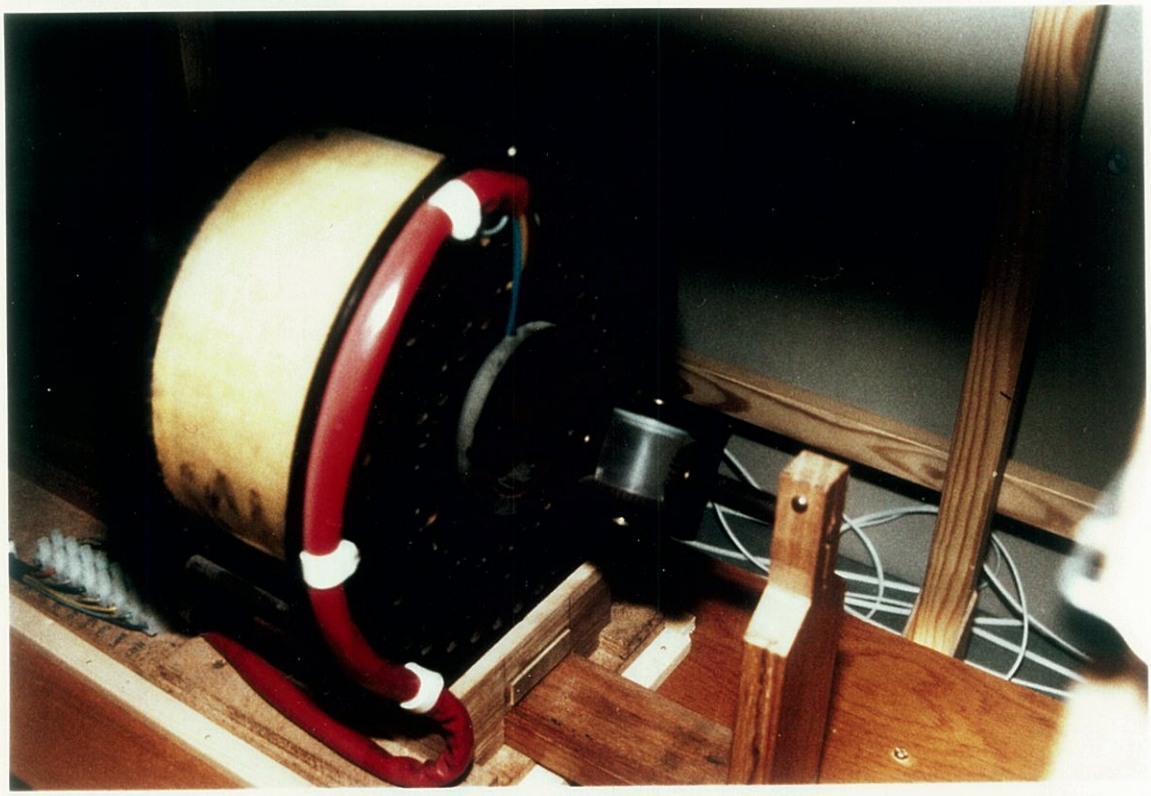
Insert sample and press one bottom and:

(b) motor start rotating
(c) field increases by the motor to the set field
(d) field automatically start decreasing at the set field
(e) motor automatically off after field reduced to zero

(e) Set input-field to zero

FIG 26





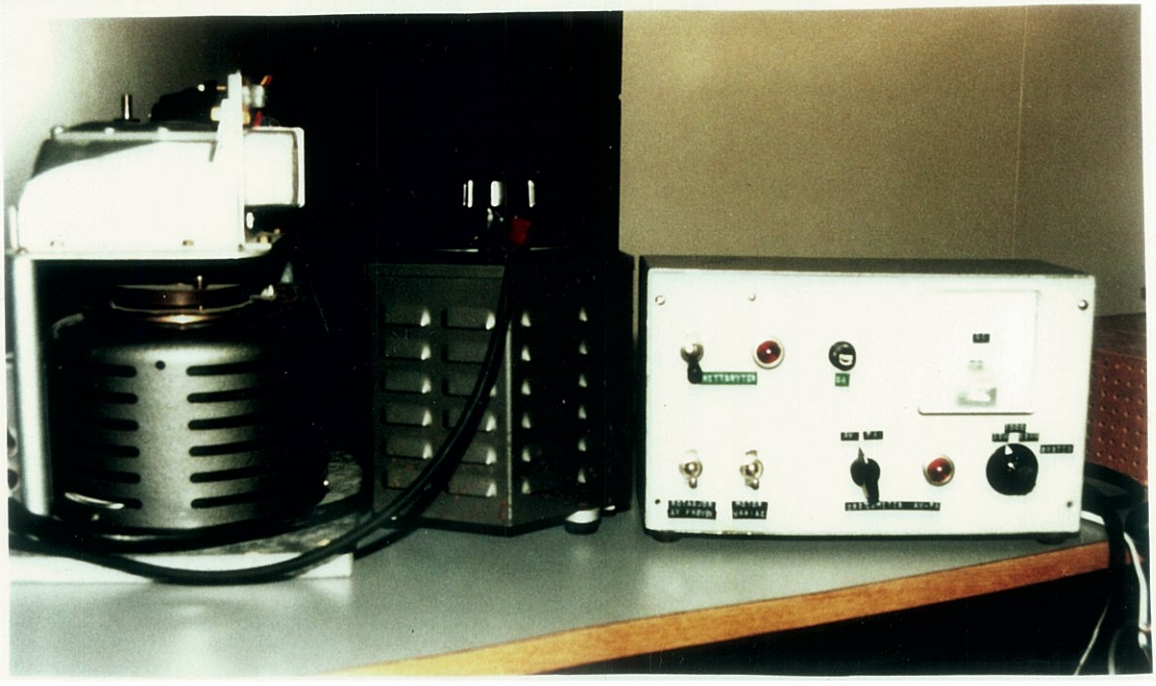
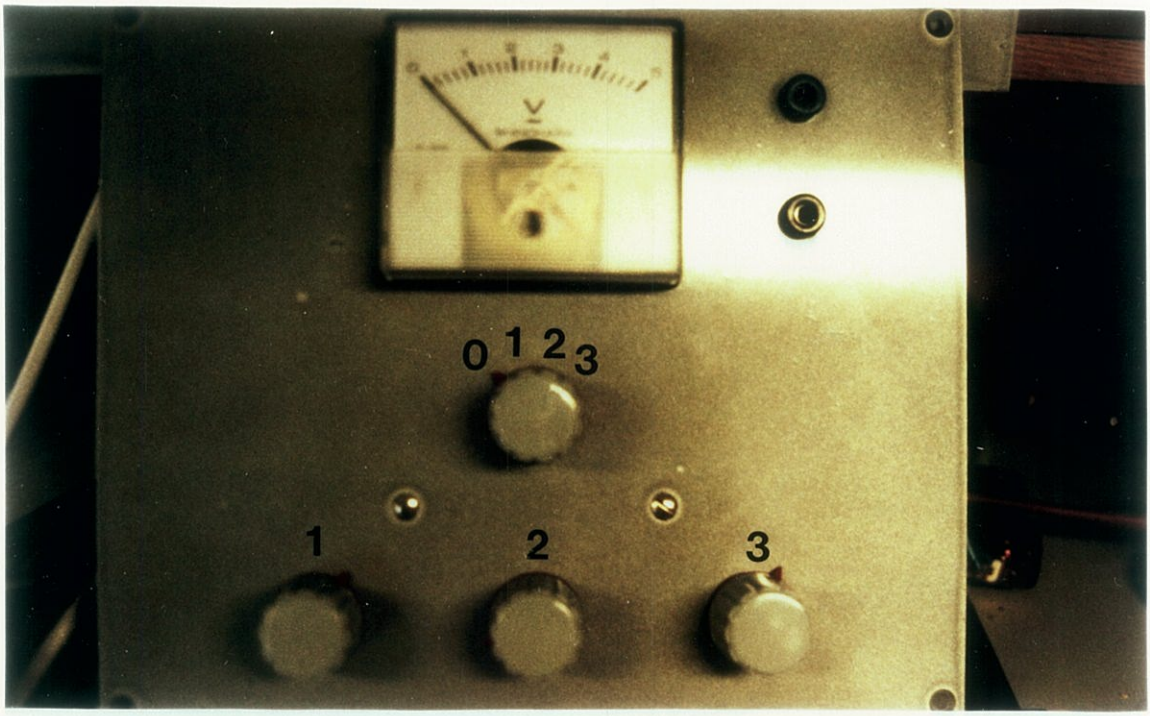
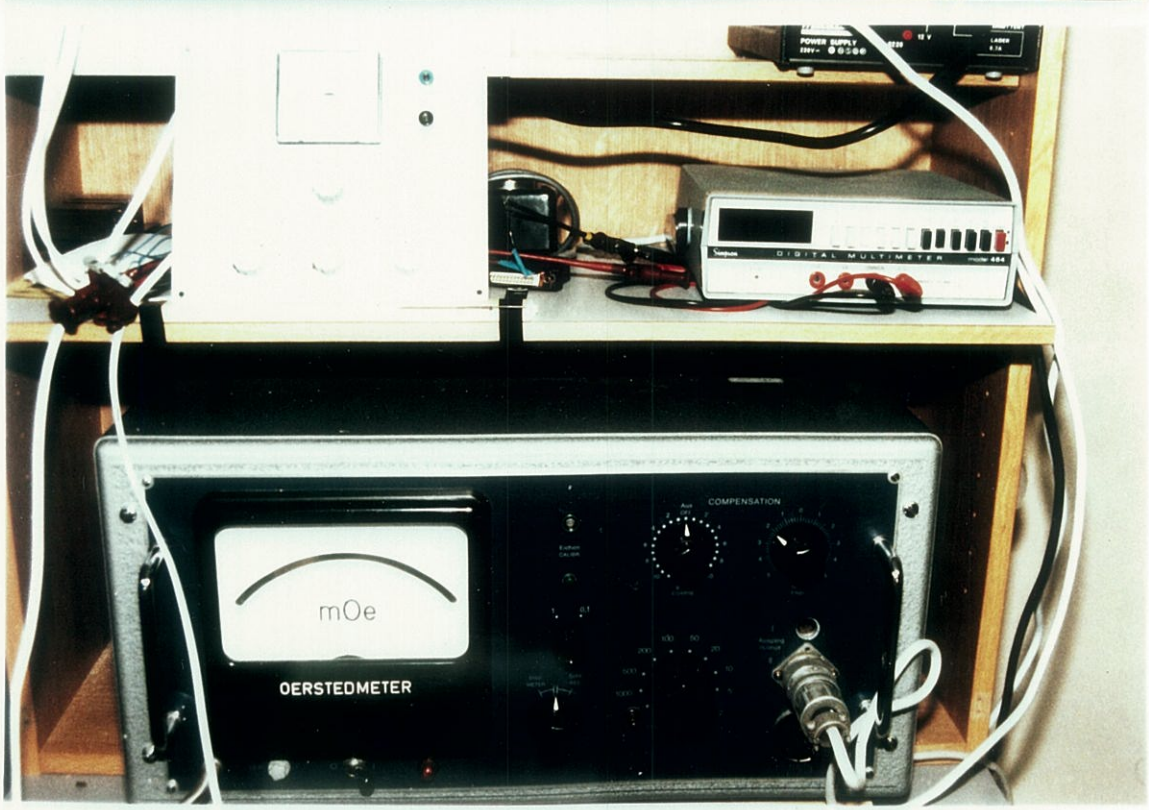
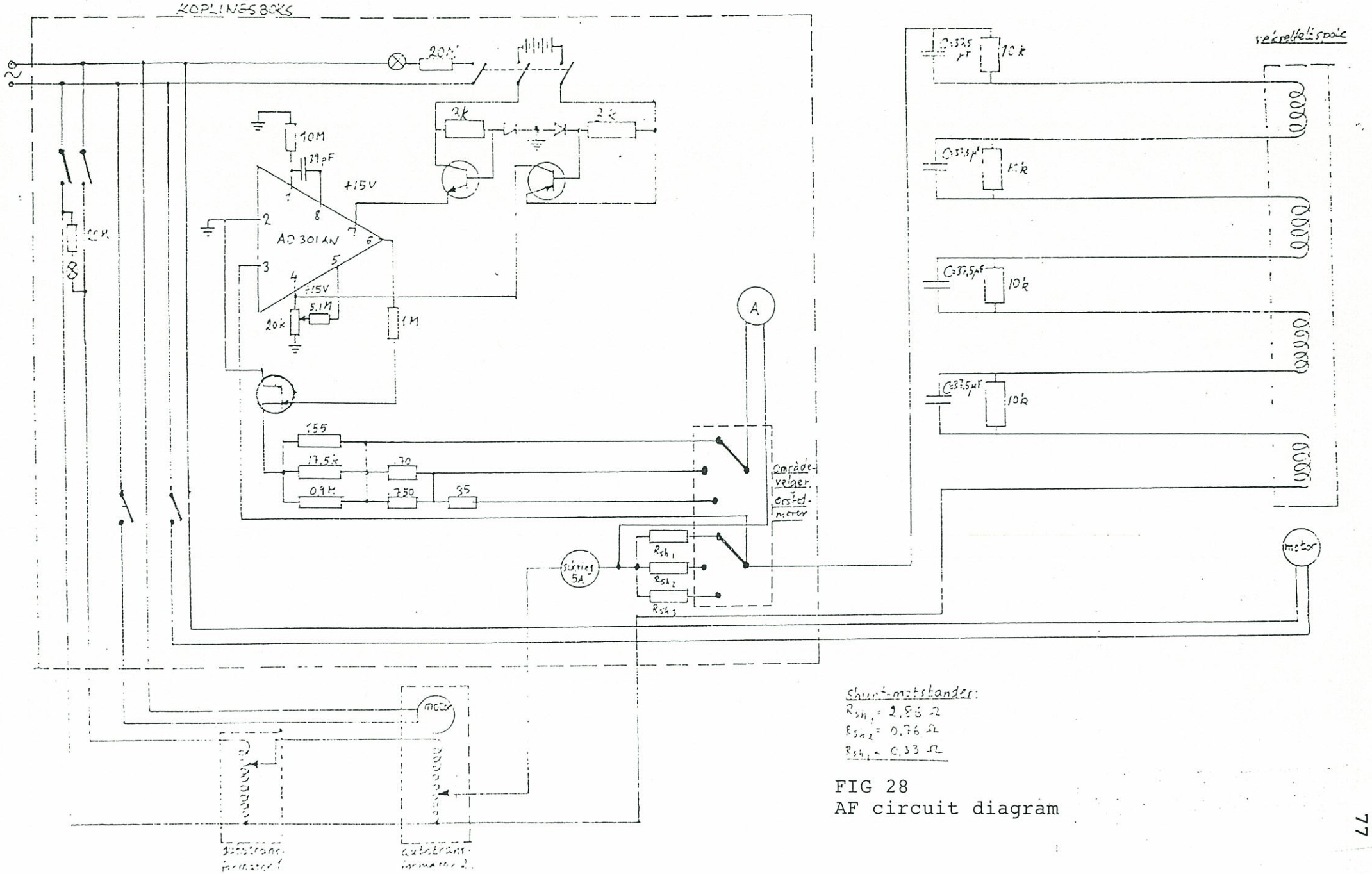


FIG 27


mOe
OERSTEDMETER
COMPENSATION
Aus OFF
grob COARSE
fein FINE
Eichen CALIB
Instr METER
Schr REC
START
Ausgang OUTPUT


0 1 2 3
1
2
3


POWER SUPPLY
DIGITAL MULTIMETER
mOe
OERSTEDMETER
COMPENSATION



Shunt-motstånder:
R_{sh_1} = 2,86 Ω
R_{sh_2} = 0,76 Ω
R_{sh_3} = 0,33 Ω

FIG 28
AF circuit diagram

6. CONCLUSIONS AND FUTURE RECOMMENDATIONS

The petrophysical-palaeomagnetic laboratory at the Geological Survey is now a modern and totally automatized laboratory, and the following principal physical properties are determined:

- Magnetic Susceptibility
- Density, Weight and Volume
- The direction and intensity of the Natural Remanent Magnetization (NRM) on both handsamples and cores

Sensitivity on measurements of susceptibility, weight and NRM intensity is $1*10^{-5}$ SI, 0.1 gram and approximately 0.1 mA/M respectively.

The stability of NRM are tested by means of THERMAL, AF and also CHEMICAL demagnetization. The latter is not described in this account (see e.g. Collinson, 1983).

All software enabling petrophysical and palaeomagnetic software have been developed, and data can be interchanged between IBM compatible computers and the HP3000 mainframe.

The petrophysical-palaeomagnetic laboratory serve a number of functions, and the most important applications of the measured physical properties are outlined below:

DENSITY

-Assists interpretations of gravity data
-Estimates of silicate-composition

SUSCEPTIBILITY

-Assists interpretation of aeromagnetic/magnetic data.

-Provide bulk-mineralogical information and grain 'domain' status together with other rock-magnetic methods

DEMAGNETIZATION STUDIES

-A method of dating rocks or orogenic/hydrothermal events.

-Assists interpretation of stratigraphy (Magneto-stratigraphy)

-Orientation of bore-cores from e.g. the North Sea.

-Tectonic modelling on micro to planetary scales.

-Provide bulk-magnetic information and thermal unblocking temperatures.

Future recommendations

(1)
It is recommended that the Geological Survey invest in a very sensitive susceptibility bridge (10^{-8} SI) or an anisotropy delineator in order to measure the anisotropy of magnetic susceptibility (AMS). The price of such equipment varies from 90.000 Nk (delineator) to ca. 200.000 N.Kr. (kappa-bridge). AMS studies would enable us to carry out detailed petro-fabric studies in order to determine:

-palaeoflow directions (lineations) in sediments or intrusive/ extrusive rocks

-principal strain axes, shape and magnitude of the 'strain' ellipse

Petrofabric mapping utilizing the anisotropy of magnetic susceptibility should be carried out as routine measurements in the Geological Survey, thus providing important sedimentological and structural information.

(2)
In order to investigate the magnetic properties it is recommended to invest in a pulse-magnetizer which provide essential bulk-magnetic information. Estimated price ca. 40.000 N.Kr.

(3)
The AF demagnetizer system is somewhat old-fashioned, and it would be of importance to construct a modern and fully automatic system. Such a system can be build by the University of Bergen (Geophysical Institute). Price in the order of 10-12.000 N.Kr.

(4)
A new gamma-spectrometer is recommended, since the original equipment which was intended to be used in the laboratory did not function properly. It is recommended to invest in a stationary PC spectrometer based system. Estimated cost approximately 120.000 N.Kr.

(5)
Finally, a second computer system is recommended in the laboratory, since one computer is now handling all operations. This implies that only one person can operate the laboratory.

APPENDIX 1 - BASIC MS-DOS 3.2

OPTION	EFFECT
DIR	List files on current directory
DIR /P	List files on directory page by page
DEL filename	Delete a file
CD\NAME	Change current directory to NAME
COPY A:filename C:	Copy from A to C (file=filename)
COPY A:*.* C:	Copy all files from A to C (Wildcard)
COPY A:filename C:\PETRO	Copy filename from A to C:\PETRO directory
FORMAT A:	Format a disk in drive A

Note:

If data are changed between OLIVETTI PC and HP-VECTRA always format the diskette with single-side (360Kb) option, i.e. use the command:

FORMAT A:/4	Format with switch 4 (360 Kb formatting)

APPENDIX 2 - DATA FORMAT PETROFYS & HP-3000

PETROFYS and PETROLAB employs a RANDOM ACCESS data-base structure in contrast to sequential files on HP3000. The data-formats, however, are broadly equivalent and are as follows:

Variable	Length	Format/Type
Sample No.	10	Character
<blank>	1	Character*
Map-Sheet No.	5	Integer
<blank>	1	Character*
UTM-ZONE	2	Integer
<blank>	1	Character*
UTM-EAST	6	Integer
UTM-NORTH	7	Integer
<blank>	1	Character*
LITHO. CODE	3	Character
METAM. CODE	1	Character
STRAT. CODE	3	Character
<blank>	1	Character*
Rock-name	20	Character
Density	5	Integer
Susceptibility	8	Real (8.5)
QVALUE	7	Real (7.2)*
NRM-DEC	4/5	Integer* / Real
NRM-INC	3/4	Integer* / Real

ONLY IN PETROFYS:

VOLUME
NRM-INTENSITY
a_{95}
I-S SUSCEPTIBILITY

APPENDIX 3 - LITHOLOGIC CODES

Code	Rock-name	COLOR Code	DENSITY Min	Max
I00	FELSIC PLUTONIC ROCKS	1200.	2500	2800
I01	ALKALI-FELDSP. GRANITE	21200.	2500	2800
I02	GRANITE	41200.	2500	2800
I03	GRANODIORITE	61200.	2500	2800
I04	TONALITE	81200.	2500	2800
I10	FELSIC HYPAB. ROCKS	121200.	2500	2800
I11	APLITE	101200.	2500	2800
I12	QUARTS-FELDSPAR PORPHYRITE	121200.	2500	2800
I13	PEGMATITE	141200.	2500	2800
I20	INTERMED. PLUTONIC-/HYPAB.R	81600.	2550	2850
I21	QUARTS ALKALI-FELTSP. SYENITE	41600.	2550	2850
I22	QUARTS SYENITE	21600.	2550	2850
I23	QUARTS MONZONITE	1600.	2550	2850
I24	QUARTS MONZODIROTE	1604.	2550	2850
I25	QUARTS DIORITE	1606.	2550	2850
I26	ALKALI-FELDSP. SYENITE	1608.	2550	2850
I27	SYENITE	1610.	2550	2850
I28	MONZONITE	1612.	2600	3100
I29	MONZODIRITE	1614.	2600	3100
I30	DIORITE	1616.	2600	3126
I40	FOID-BEAR. PLUTONIC-/HYPAB.	1604.	2500	3600
I41	NEPHELINE SYENITE	1608.	2500	3600
I50	MAFIC PLUTONIC ROCKS	161202.	2700	3500
I51	QUARTS MONZOGABBRO	161202.	2700	3500
I52	QUARTS GABBRO	161204.	2700	3500
I53	QUARTS NORITE	161204.	2700	3500
I54	MONZOGABBRO	161206.	2700	3500
I55	GABBRO	161206.	2700	3500
I56	NORITE	161208.	2700	3500
I60	MAFIC HYPAB. ROCKS	161212.	2700	3500
I61	ALBITE DIABASE	161210.	2700	3500
I62	DIABASE	161212.	2700	3500
I70	ULTRAMAFIC PLUTONIC-/HYPAB.	80808.	2800	3700
I71	HORNBLENDITE	101010.	2800	3700
I72	PYROXENITE	121212.	2800	3700
I73	PERIDOTITE	141414.	2800	3700
I74	DUNITE	161616.	2800	3700
I80	ANORTHOSITE	40000.	2600	3300
I81	CARBONATITE	40000.	2600	3300
I82	KIMBERLITE	60000.	2600	3300
S00	CONGLOMERATE/SED. BRECCIA	60000.	2500	2900
S01	CONGLOMERATE, PEBBLE SUPPORTED	80000.	2500	2900
S02	CONGLOMERATE, MATRIX SUPPORTED	80000.	2500	2900
S03	TILLITE	100000.	2500	2900
S10	PSAMMITIC ROCKS	100000.	2500	2900
S11	QUARTZITE	120000.	2480	2800

Code	Rock-name	COLOR Code	DENSITY Min	Max
S12	QUARTZ-SANDSTONE	120000.	2450	2800
S13	SANDSTONE, FELDSP.-BEARING	140000.	2400	2800
S14	ARKOSE	140000.	2480	2900
S15	GREYWACKE	160000.	2500	2840
S20	PELITIC ROCKS	160004	2600	2900
S21	MUDROCKS	160006.	2600	2900
S22	ARGILLITE	160008.	2600	2900
S23	PHYLLITE	160010.	2600	2900
S24	MICA-SCHIST	160012.	2490	2920
S25	GRAPHITIC SCHIST	160016.	2600	2900
S40	CARBONATE ROCKS	4.	2600	3000
S41	LIMESTONE	6.	2600	3000
S42	CALCITE MARBLE	8.	2600	3000
S43	DOLOMITE	10.	2600	3000
S44	DOLOMITE MARBLE	12.	2600	3000
S45	MARL	16.	2600	3000
S50	JASPER	416.	2500	5000
S51	CHERT	816.	2500	5000
S52	CHERT	1216.	2500	5000
S53	BANDED IRON FORM.	1616.	2500	5000
V00	ACID VOLCANITES	81600.	2500	2800
V01	RHYOLITE	101600.	2500	2800
V02	DACITE	121600.	2500	2800
V03	KERATOPHYRE/QUARTS KERATOPHYRE	141600.	2500	2800
V04	ACID TUFF/TUFFITE	161600.	2500	2800
V10	INTERMEDIATE VOLCANITES	81604.	2600	2900
V11	TRACHYTE	121604.	2600	2900
V12	ANDESITE	141604.	2600	2900
V13	INTERMEDIATE TUFF/TUFFITE	161604.	2600	2900
V20	BASIC VOLCANITES	160804.	2700	3500
V21	TRACHYTE	161006.	2700	3500
V22	GREENSTONE	161208.	2700	3500
V23	AMPHIBOLITE	161210.	2700	3500
V24	BASIC TUFF/TUFFITE	161212.	2700	3500
V25	METADIABASE	161414.	2700	3500
V30	ULTRABASIC VOLCANITES	101010.	2700	3700
V31	KOMATIITES	161616.	2700	3700
V40	NEPHELINE-RICH VOLCANICS	808.	2600	3100
V41	PHONOLITE	1010.	2600	3100
V42	TEFRITE	1010.	2600	3100
M00	GNEISS	80800.	2500	3500
M01	GRANITIC GNEISS	81200.	2500	3500
M02	GRANODIORIC GNEISS	81600.	2500	3500
M03	TONALITIC GNEISS	161600.	2500	3500
M04	GLIMMERGNEIS	160800.	2500	3500
M05	HORNBLENDE GNEISS	161204.	2500	3550
M06	BANDED GNEISS	121600.	2500	3500
M07	AUGEN GNEISS	141600.	2500	3500

Code	Rock-name	COLOR Code	DENSITY Min	Max
M08	MIGMATITE	161600.	2500	3500
M10	GREENSCHIST	160804.	2700	3500
M11	AMPHIBOLITE	161208.	2700	3500
M12	SERPENTINITE	121616.	2700	3500
M13	EKLOGITE	161616.	2700	3500
M20	SKARN	800.	2700	5000
M21	ALBITE-FELS./QUARTS ALB.FELS	1000.	2500	3000
M23	ALBITE-CARBONATE ROCKS	1200.	2500	3100
M30	MYLONITE/BRECCIA	120000.	2500	2900
M31	HYDROTHERMAL QUARTS	160000.	2500	2900
M40	MAGNETITE	1604.	2700	6500
M41	ORE UNDIFFERENTIATED	1608.	2700	6500

NAME OF LITHOLOGIC FILE ON HP3000:

-English version = PETBERGE.PETFYS.GEOF
-Norwegian version = PETBERGN.PETFYS.GEOF

APPENDIX 4 - METAMORPHIC CODES

CODE	METAMORPHIC GRADE
A	Non-metamorphic
B	Very low metamorphic grade
C	Very low metamorphic grade - low pressure
D	Very low metamorphic grade - high pressure
E	Low metamorphic grade
F	Low metamorphic grade - low pressure
G	Low metamorphic grade - high pressure
H	Medium metamorphic grade
K	Medium metamorphic grade - low pressure
L	Medium metamorphic grade - high pressure
M	High metamorphic grade
N	High metamorphic grade - low pressure
O	High metamorphic grade - high pressure
P	High metamorphic degree - granulite facies
R	High metamorphic degree - eclogite facies

NAME OF METAMORPHIC FILE ON HP3000:

-English version = PETMETE.PETFYS.GEOF
-Norwegian version = PETMETN.PETFYS.GEOF

APPENDIX 5 - STRATIGRAPHIC CODES

NJA NJALLAJAAKKAKOMPL.
RAS RAISÆDNO GNEISKOMPL.
AVZ AVZIFM.
BIK BIKKACAKKAFM.
CAS CASKEJJASFM.
CAR CARRAVARRIFM.
GÅL GAALDENVARRIFM.
LIK LIKCAFM.
MAS MASIFM.
SOL SUOLUVUOBMIFM.
STU STUORAJAV'RIFM.
VOM VUOMEGIELASFM.
SKU SKUVVANVARRIFM.
JER JER'GUL GNEISKOMPL.
GÅB GÅL'LEBAI'KEFM.
BAK BAKKILVARRIFM.
RAI RAI'TEGÅR'ZIFM.
IDD IDDJAJAV'RIGR.
GÅS TANAELV MIGMATITTKOMPL.
LEV LEVAJOK GRANULITTKOMPL.
POL POLMAK ERUPTIVKOMPL.
NEI NEIDEN GRANITTKOMPL.
BJV BJØRNEVANN GNEISKOMPL.
KGB KARASJOK GRØNNSTEINS BELTE
BAI BAISVARRI GNEISKOMPL.
ULV ULVERYGGFM.
NUS NUSSIRGR.
PRS PORSAGR.
BOS BOSSEKOPGR.
BOR BORRASGR.
SKO SKOADDUVARRIFM.
KVE KVENVIKFM.
STN STORVIKNESFM.
NAL NALGANAS-DEKKET
NÅL NÅLFJELLGR.
KOM KOMSAGR.
DIV DIVIDALGR.
LAK LAKSEFJORDGR.
STB STABBURSDALFM.
FRI FRIARFJORDFM.
LAN LANDERSFJORDFM.
IFJ IFJORDFM.
VST VESTERTANAGR.
LØK LØKVIKFJELLGR.
BÅT BÅTSFJORDFM.
BÅS BÅSNÆRING FM
BER BERLOGASISSAFM.
KIS KISTEDALFM.
DUO DUOLBAGAISSAFM.
BRE BREIVIKFM.
STA STAPPOGJEDDEFM.
MOR MORTENSNESFM.
NYB NYBORGFM.
SMA SMALFJORDFM.
GRA GRASDALFM.
HAN HANGLECÆRROFM.
VAG VAGGEFM.
GAM GAMASFJELLFM.
DAK DAKKOVARREFM.
STG STANGENESFM.
GRØ GRØNNESFM.
EKK EKKERØYFM.
GLN GULNESELVFM.
PAD PADDEBYFM.
FUG FUGLEBERGFM.
VEI VEIDNESBOTNFM.
SKI SKIDNEFJELLFM.
SKG SKJÆRGÅRDSNESFM.
STY STYRETFM.
SAN SANDFJORDFM.
TYV TYVJOFJELLFM.
KON KONGSFJORDFM.
HLF HELLEFJORDGR.
FAL FALKENESGR.
STV STORELVGR.
KLU KLUBBENGR.
TAN TANAFJORDGR.
POR PORSANGER DOLOMITT
SEI SEILAND MAGMATISKKOMPL.
HON HONNINGSVÅG MAGM.KOMPL.
KPG PREKAMB. GNEIS I KALEDON
KRP PREKAM. AMFIB. I KALEDON
STØ STØRENDEKKET
GUL GULADEKKEKOMPL.ET
LED LEVANGERDEKKET
SKJ SKJØTINGENDEKKET
LEK LEKSDALSVATNDEKKET
HÆR HÆRVOLADEKKET
MER MERÅKERDEKKET
ØYF ØYFJELLDEKKET
ESS ESSANDSJØDEKKET
REM REMSKLEPPDEKKET
GJE GJERSVIKDEKKET
LEI LEIKVIKVATNDEKKET
BJØ BJØRKVATNDEKKET
SEV SEVEDEKKET
HEL HELGELANDSDEKKET
TØM TØMERÅSBERGARTER
OLD OLDENBERGARTER
GRO GRONG-KULMINASJONEN
OFF OFFERDALDEKKET
KAL KALEDONSKE B.A.
JO SJONA GRUNNFJELLSVINDU
HOT HØGTUVA GRUNNFJELLSVINDU

APPENDIX 6 - MAGNETIC FIELD CHARACTERISTICS NORWAY

MAP=map-sheet; F=Total Field; Z=Z-component of field
LD=local deviation (-West, +East);
True Direction = Magnetic direction + LD

MAP	F	LD	Z
1016	50100	-6.5	47820
1017	50200	-6.5	48000
1019	50400	-6.5	48400
1031	52020	-1.5	50650
1113	49700	-5.8	47300
1114	49800	-5.8	47500
1115	49900	-5.9	47690
1116	50100	-6.0	47870
1117	50200	-6.1	48020
1118	50300	-6.1	48200
1119	50400	-5.7	48400
1120	50500	-5.8	48600
1131	52070	-0.8	50700
1132	52190	-0.7	50880
1211	49500	-5.1	46900
1212	49600	-5.3	47100
1213	49550	-5.5	47300
1214	49850	-5.5	47500
1215	49950	-5.5	47700
1216	50100	-5.5	47890
1217	50200	-5.6	48050
1218	50300	-5.6	48210
1219	50450	-5.2	48420
1220	50600	-5.2	48600
1231	52120	-0.2	50750
1232	52220	-0.2	50900
1233	52300	-0.2	51050
1311	49550	-4.7	46950
1312	49650	-5.0	47110
1313	49750	-5.2	47300
1314	49850	-5.2	47520
1315	49950	-5.0	47700
1316	50100	-5.0	47900
1317	50200	-5.0	48060
1318	50300	-5.1	48230
1319	50470	-4.7	48430
1320	50600	-4.7	48610
1321	50700	-4.7	48810
1322	50870	-4.7	49000
1331	52160	0.6	50790
1332	52270	0.6	50950

MAP	F	LD	Z
1333	52370	0.6	51100
1334	52470	0.6	51250
1410	49500	-4.3	46800
1411	49600	-4.4	47000
1412	49700	-4.5	47140
1413	49770	-4.8	47370
1414	49870	-4.8	47570
1415	49960	-4.7	47710
1416	50100	-4.7	47900
1417	50200	-4.8	48080
1418	50340	-4.8	48260
1419	50460	-4.2	48430
1420	50600	-4.2	48620
1421	50680	-4.2	48820
1422	50900	-4.2	49010
1423	51000	-4.2	49220
1431	52200	1.2	50840
1432	52300	1.3	51000
1433	52400	1.3	51190
1434	52490	1.3	51300
1435	52600	1.3	51440
1511	49600	-3.9	47000
1512	49700	-4.0	47200
1513	49800	-4.1	47450
1514	49900	-4.2	47600
1515	49980	-4.3	47760
1516	50100	-4.3	47910
1517	50200	-4.4	48090
1518	50350	-4.4	48280
1519	50480	-3.5	48430
1520	50620	-3.5	48650
1521	50750	-3.5	48850
1522	50900	-3.5	49020
1523	51000	-3.6	49250
1531	52250	1.9	50900
1532	52330	2.0	51090
1533	52450	2.0	51240
1534	52570	2.0	51370
1535	52670	2.0	51500
1611	49600	-3.6	47000
1612	49730	-3.6	47260
1613	49830	-3.7	47450
1614	49910	-3.7	47510
1615	50000	-3.8	47790
1616	50130	-3.9	47920
1617	50250	-4.0	48000
1618	50360	-4.1	48280
1619	50500	-2.8	48490
1620	50670	-2.8	48680
1621	50800	-2.9	48870
1622	50920	-3.0	49020
1623	51050	-3.0	49260
1624	51180	-3.0	49430
1625	51250	-3.0	49700

MAP	F	LD	Z
1631	52300	2.7	50940
1632	52390	2.6	51120
1633	52460	2.6	51280
1634	52590	2.6	51400
1635	52710	2.7	51550
1712	49750	-3.2	47300
1713	49850	-3.2	47440
1714	49950	-3.3	47600
1715	50050	-3.5	47800
1716	50180	-3.6	47960
1717	50280	-3.6	48110
1718	50390	-3.6	48280
1719	50600	-2.1	48540
1720	50750	-2.1	48730
1721	50880	-2.2	48890
1722	51000	-2.3	49090
1723	51100	-2.4	49300
1724	51200	-2.4	49480
1725	51300	-2.4	49630
1726	51400	-2.5	49800
1727	51520	-2.5	49980
1728	51600	-2.5	50130
1729	51750	-2.5	50300
1732	52460	3.3	51180
1733	52540	3.3	51320
1734	52650	3.4	51490
1735	52790	3.4	51630
1736	52890	3.4	51750
1812	49790	-2.8	47300
1813	49890	-2.8	47440
1814	50000	-2.9	47620
1815	50100	-3.2	47820
1816	50200	-3.3	48020
1817	50300	-3.1	48130
1818	50400	-3.0	48290
1819	50700	-1.7	48560
1822	51050	-1.8	49180
1823	51150	-1.9	49400
1824	51250	-1.9	49550
1825	51350	-1.9	49690
1826	51460	-1.9	49830
1827	51550	-1.9	50000
1828	51660	-1.9	50160
1830	51890	-2.0	50460
1832	52540	4.0	51220
1833	52650	4.0	51420
1834	52720	4.0	51580
1835	52820	4.1	51700
1836	52930	4.1	51820
1912	49800	-2.5	47300
1913	49900	-2.5	47470
1914	50020	-2.6	47690

MAP	F	LD	Z
1915	50140	-2.7	47840
1916	50250	-2.8	48030
1917	50350	-2.7	48160
1918	50440	-2.6	48300
1923	51200	-1.4	49420
1924	51310	-1.3	49580
1925	51400	-1.3	49750
1926	51500	-1.3	49900
1927	51600	-1.2	50150
1928	51700	-1.3	50200
1929	51800	-1.3	50330
1932	52620	4.7	51320
1933	52720	4.7	51490
1934	52800	4.8	51630
1935	52900	4.8	51760
1936	53000	4.9	51900
1937	53090	4.9	52020
2012	49830	-2.1	47350
2013	49940	-2.2	47500
2014	50050	-2.2	47700
2015	50180	-2.2	47880
2016	50290	-2.3	48040
2017	50380	-2.3	48190
2018	50480	-2.1	48360
2025	51450	-0.9	49810
2026	51560	-0.7	49980
2027	51650	-0.7	50110
2028	51750	-0.6	50230
2029	51850	-0.6	50390
2030	51970	-0.7	50530
2032	52700	5.4	51380
2033	52890	5.4	51520
2034	52870	5.4	51670
2035	52960	5.5	51800
2036	53060	5.5	51980
2037	53140	5.6	52100
2114	50100	-1.7	47750
2115	50200	-1.8	47890
2116	50290	-1.8	48080
2117	50380	-1.8	48240
2118	50500	-1.8	48410
2127	51700	-0.2	50150
2128	51790	-0.2	50300
2129	51890	-0.1	50460
2130	52000	-0.2	50600
2134	52920	6.1	51720
2135	53000	6.2	51870
2136	53100	6.2	52030
2137	53200	6.3	52170
2229	51930	-0.6	50500
2230	52050	-0.6	50650
2234	52980	6.9	51790
2235	53080	6.9	51920
2236	53170	6.9	52090

MAP	F	LD	Z
2237	53250	7.0	52230
2333	52950	7.4	51720
2334	53050	7.5	51860
2335	53140	7.6	52000
2336	53220	7.6	52090
2433	53000	8.1	51800
2434	53100	8.1	51920
2435	53200	8.1	52070
2436	53300	8.2	52200
2534	53180	8.7	52000
2535	53280	8.8	52110

FILE NAME ON HP3000:

- PETFDZ.PETFYS.GEOF

APPENDIX 7 - FIELD SAMPLING-CONVENTION AND PREPARATION

3 principal sampling techniques are employed for sampling for petrophysical and palaeomagnetic purposes (see below). Orientation of cores and handsamples **should** and **must** be done with 360 degrees MAGNETIC or SUN compass - 400 degrees compasses are recommended to end up in the bin.

1 NON-ORIENTATED HANDSAMPLES OR ROCK-POWDER

SAMPLING

-No special sampling technique required, but samles should preferentially be in the order of 0.5 to 1 kilogram and rounded in shape

-Remove weathered surface

-Mark sample and paper-bag with an identification number

-Grid reference and rock-description must be noted

LAB-PREPARATION

-During unpacking check that identification number on sample and paper-bag is consistent

-Clean samples, i.e. remove loose particles

-Cut samples to fit susceptibility coil (max 103 mm) as well as removing weathering surface

-Put samples in a container with fresh water for 1-2 days before measurements. Porous samples should be kept in water for a longer period

-The sample surface must be dry before weight-measurements

Errors introduced by not water-saturating the samples or not drying them before measurements are both in the order of 20 kg/m^3 (Henkel & Mannby, 1976).

PURPOSE

- Susceptibility
- Density
- NRM intensity

2 ORIENTATED HANDSAMPLES

SAMPLING

-Strike is measured with a magnetic compass or a sun-compass
-Right hand convention, i.e. dip mark should be to the right of the strike mark (Fig. 29).
-See previous section for other sampling details

LAB-PREPARATION

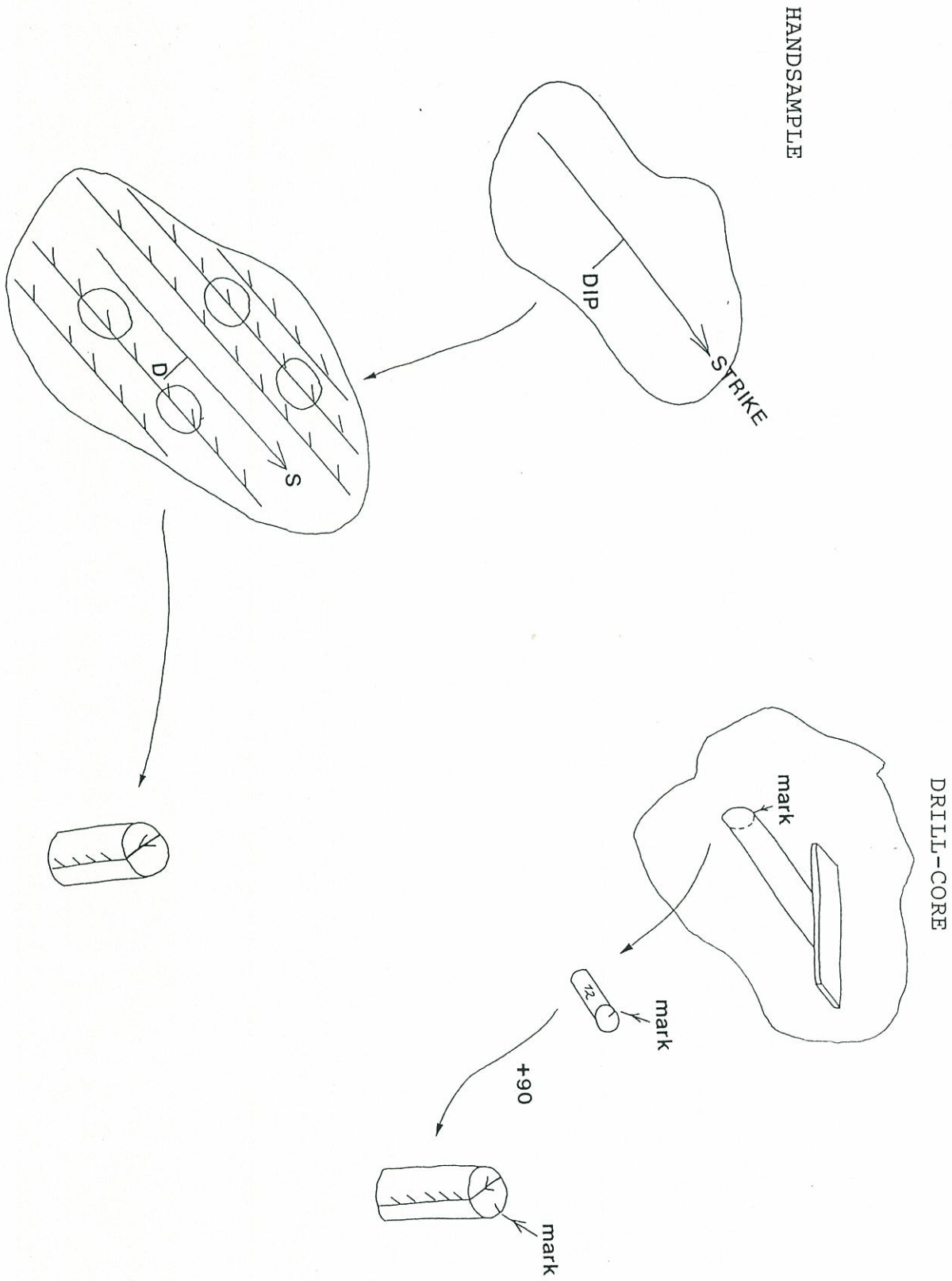
-See previous section

Orientated handsamples can also be drilled in the laboratory, thus providing cores which can measured on the spinner magnetometer (see next Appendix).

PURPOSE

- Susceptibility
- Density
- NRM intensity, declination and inclination

FIG 29
Sampling and marking convention of handsamples and cores



3 ORIENTATED DRILL-CORES

SAMPLING

-Cores are drilled with a petrol-driven or battery powered drill (Fig. 30). Typicaly 5-8 cores from each locality (SITE). Drillbits must have a diamond head and a special bronze steel pipe. Water-cooling during cooling (Fig. 30).

-Cores are orientated with a special orientation device using either a magnetic compass or a sun compass

-Insert orientation device in core-hole carefully

-Position compass on top of orientation device

-Write SAMPLE NO., STRIKE and DIP in log-book

-Write rock-description and grid-reference in log-book

-Mark wall-rock in front of orientation device (Fig.29)

-Remove orientating device

-Transfer mark on wall-rock to core

-Remove core from hole with special removal device

-Mark sample properly and write identification number on sample

LAB-PREPARATION

-With a special 90 degrees device (Fig. 31) the original mark should be turned 90 degrees - this because field-mark is not true strike, but bearing of core (see Fig. 29).

-Add 90 degrees to strike in **note-book** +/- magnetic deviation
East deviation = + West Deviation = -

-Broken samples can be glued with **non-magnetic** Carlson glue

-Cut sample with special bronze saw blade (either 19 or 25 mm length; cf.next appendix

-Mark sample properly according to Fig. 29
Arrows should now point in strike-direction (+X) and right-way-up of core

-Put samples in water 1-2 days if density calculations are to be done. Surface must be dry before measurement.

PURPOSE

- Susceptibility
- Anisotropy of magnetic susceptibility - Magnetic Fabric
- Density
- NRM intensity, declination and inclination (spinner MAG)
- Thermal and AF cleaning to test the stability of NRM

FIG 30
Drilling and orientating equipment

A Battery powered drill

B Water-container for cooling during drilling

C Orientating device

D Marking device

APPENDIX 8 - CUTTING OF CORES AND DRILLING OF HANDSAMPLES

Cutting of drill-cores

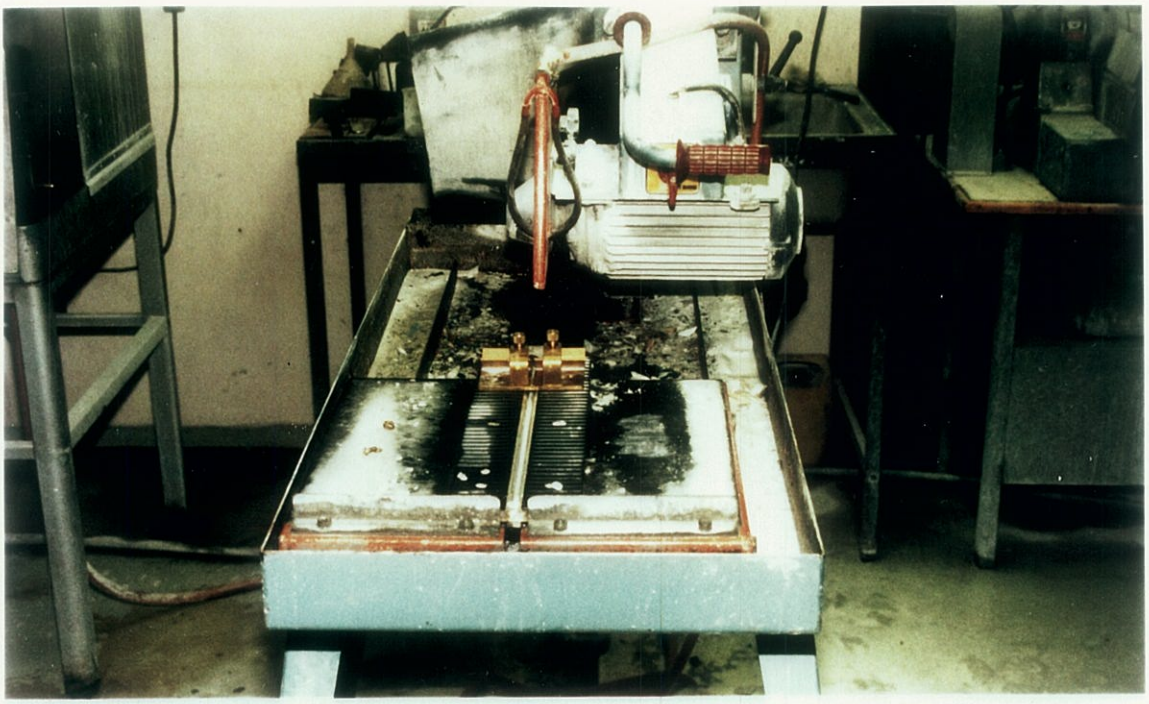
- Before cutting samples using a bronze saw-blade, the samples should be marked according to Fig. 29 (see also previous section).
- Sample is inserted in special holder (Fig. 31b)
- Cut sample (19/25 mm length)
- Top core is marked A, next B etc.

Drilling of handsamples

- Draw a number of marks parallel to strike arrow (Fig. 29)
- Balance strike-dip surface horizontally in drilling device (Fig. 31c).
- Penetrate handsamples with holes (Fig. 29 and 31c)
- Mark them as cores (Fig. 29)

NOTE THAT STRIKE IS ALWAYS CORRECT ON HANDSAMPLES

FIG 31



A

B

C

APPENDIX 9 - EQUIPMENT AND MANUFACTORS

Important equipment and tools

OLIVETTI M240 PC, 2 RS232, 20 Mb HARDDISK, 2 DISKS, MATH.PROC.
-Olivetti Norge A/S

OLIVETTI DM40 PRINTER
-Olivetti Norge A/S

MOLPIN MAGNETOMETER
-Molspin Limited, UK

SCHONSTEDT DIGITAL MAGNETOMETER DM-2220
-Schonstedt Instrument Company, USA

ANALOG FLUX-GATE MAGNETOMETER
-Førster Instruments, Germany

PRECISA 3000C WEIGHT / RS232 INTERFACE
-Nerlien Kjemisk Tekniske

PHILLIPS PM6669 FREQUENCY COUNTER / IEEE INTERFACE
-Philips Norsk Aktieselskap

MINICOR 41 TEMPERATURE-CONTROL (FURNACE)
-Tormatic A/S

TEMPERATURE POWER-SUPPLY (VARIAC, 220V-7.5A)
-Arthur Ulrichsen

AMPLICON MOD88 DIGITAL VOLTMETER
-Tormatic A/S

AMPLICON PC-26 16 BIT A/D CONVERTER
-Tormatic A/S

Ni-Cr NIKKEL THERMOPROBES
-Thermoelektro A/S

THERMOPROBE HOLDERS
-Export Technische Keramik

QUARTZ HOLDERS ETC.
-Thermal Syndicate, UK

NON-INDUCTIVE FURNACE ELEMENTS
-Lindberg, USA

u-METAL SHIELDS
-Magnetic Shields Limited, UK

IEEE-488 INTERFACE CARD
-Olivetti Norge

DIAMOND HEADED DRILL-BITS WITH SPECIAL BRONZE STEEL PIPE
-Ondix, HOLLAND

BRONZE SAW-BLADES 200*1.6
-Hellum & Sønn A/S

NON-MAGNETIC PAINT FOR SAMPLES : PELIKAN TUSCHEA **18** WEISS
-ordinary book-shop

NON-MAGNETIC GLUE FOR SAMPLES : CARLSON GLUE
-ordinary shop

Addresses, how to order and line-drawings

Christian Falchenberg A/S (Thermoprobe holders)
Postboks 1974
Granåsveien 1
7048 Trondheim
Tel. 07-912040

Example of order:

We hereby order:
20 stk. Isoslasjonsrør, pythagoras med 2/bor
3 x 0.8 x 200 mm

or

Export Technische Keramik (Thermoprobe holders)
Staudinger & Co. KG
Postfach 1265
D-8011 Kirchheim/Heimstetten
F.R. Germany

Example of order:

We hereby order:
20 Pytagoras 2-Lochrohre, 3 x 0.8 x 200 mm

Hellum & Sønn A/S (Bronze sawing blade)
Boks 45, 2011 STRØMMEN, Norway
Tel. 06-812271

Contact person NGU : Jacobsen

Lindberg (furnace elements)
2450 West Hubbard
Chicago Illonois 60612
USA

MAGNETIC SHIELDS LTD (u-metal shield)
Headcorn Road, Staplehurst
Kent, TN12 ODS
ENGLAND
Telefax: 0580-893345

Example of order:

We will hereby order a 2 mu-metal layered cylinder (1mm thick) for magnetic shielding purposes. Spesifications:

2 layered mu-metal cylinder (open in both ends):

Diameter inner shield (1): 20 cm. - Length 80 cm.
Diameter outer shield (2): 24 cm. - Length 80 cm.

DR. MOLYNEUX (spinner magnetometer)
Molspin Limited
School of Physics
The University
Newcastle Upon Tyne NE1 7RU
ENGLAND

or

MOLSPIN LIMITED
2 Leazes Cresent
Newcastle Upon Tyne
NE1 4LN
ENGLAND

Nerliens Kemisk-Tekniske A/S (Weight)
Granåsvegen 1
7048 Trondheim, Norway
Tel. 07-912040

Main Office:
Tel. 02-194310

OLIVETTI NORGE A/S (computers)
Trondheim
Tel. 07-913840

B.V. ONDIX (drill-bits)
3945 ZG COTHEN
Postbus 1
Bredeweg 5
HOLLAND

Example of order:

We hereby order 5 drill-bits (see enclosed figure):

diameter 22/19 mm
diamond head 10 x 1.5 mm
conc. C 74, grain 40/50 mesh
special bronze bond nr. 22
stainless steel pipe
nr. 83154-83158

Drawing of drill-bits has to be enclosed (see FIG. **31**)

Norsk Aktieselskap Philips (Frequency Counter)
Sandstuveien 70
Postboks 1, Manglerud
0612 Oslo 6
Tel. 02-680200

SCHONSTEDT INSTRUMENT COMPANY (Digital magnetometer)
1775 Wiehle Avenue
Reston, Virginia 22090-5199
USA
Tel : (703) 471-1050
Telex: 710-833-9880

Thermal Syndicate Limited (quartz sample-holders)
P.O. Box 6, Neptune Road
Wallsend, Northumberland
NE28 6DG
ENGLAND
DRAWING MUST BE ENCLOSED

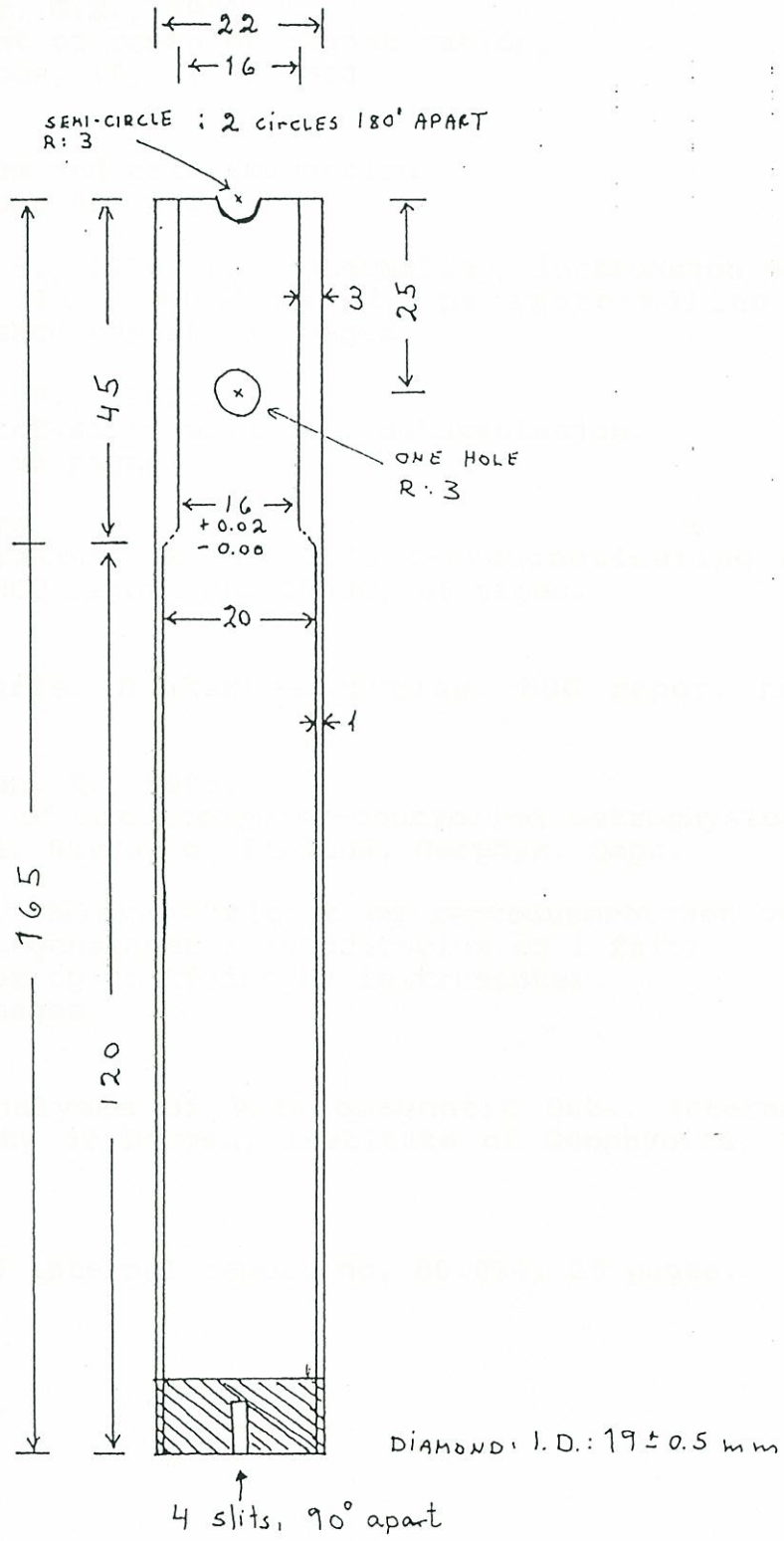
TORMATIC A/S (Thermo, AD, Voltmeters)
Skreppestad
N-3250 Larvik
Tel. 034-25011
Fax. 034-24085
Telex 21 941

Contact person: Tore Guldbrandsen

GENERAL CONTACT-PERSONS:

T.H. Torsvik	NGU :	07-921611 (Ext. 258)
	OXFORD UNIV:	095-44-865-272051 (Palmag lab.)
O. Olesen	NGU (Head of laboratory)	
K. Kirkeby	NGU (Instruments construction)	
O. Blokkum	NGU (Instruments/electronics)	

FIG 31
Diamond tipped drillbit (Stainless steel)



All measures in mm.
Scale 1:1