DANMARKS OG GRØNLANDS GEOLOGISKE UNDERSØGELSE RAPPORT 2002/79

EFP-2000: Displacement and deformation processes in fractured reservoir chalk

Determination of a moving water front in core samples using resistance logging: Hardware and software user manual ENS J. nr. 1313/00-0008

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GEOLOGICAL SURVEY OF DENMARK AND GREENLAND
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G E U S

Contents

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1. Introduction

The EFP-2000 project “Fortrængnings- og deformationsprocesser i sprækket reservoirkalk”, has been carried out by a group of danish research institutes headed by the Danish Geotechnical Institute (GEO). In this project the Geological Survey of Denmark and Greenland (GEUS) has developed a multi-electrode resistance technique to monitor a waterfront moving in a core sample. A semi-quantitative technique to determine water saturation has also been devised. The technique is a spin-off from the fundamental work done by Niels Olsen in his Ph.D. thesis “Tofasestrømning i opsprækkede porøse strukturer”. The technique was earlier adapted and modified by GEUS in two former projects (EFP-96 and EU “Joule 3”), and finally developed to it’s present stage in the EFP-2000 project.

This report documents the software and hardware developed, and should further be regarded as a user manual to the equipment installed at GEO.

2. Software

A new software called **ScanCore** was developed. It measures the resistance between electrode pairs placed along a sample. **Volfit -** the software that calculates the calibration curve from the resistance profile was adapted to fit the data provided from **ScanCore**

2.1 ScanCore

ScanCore controls the multiplexer (see section 3.1). It logs the data measured between 8 electrode pairs and presents the data as a graph on a PC screen. As the graph is updated with a dot for each measurement, there is a limit of 10.000 measurements before the graph exceeds the screen capacity and the program close down.

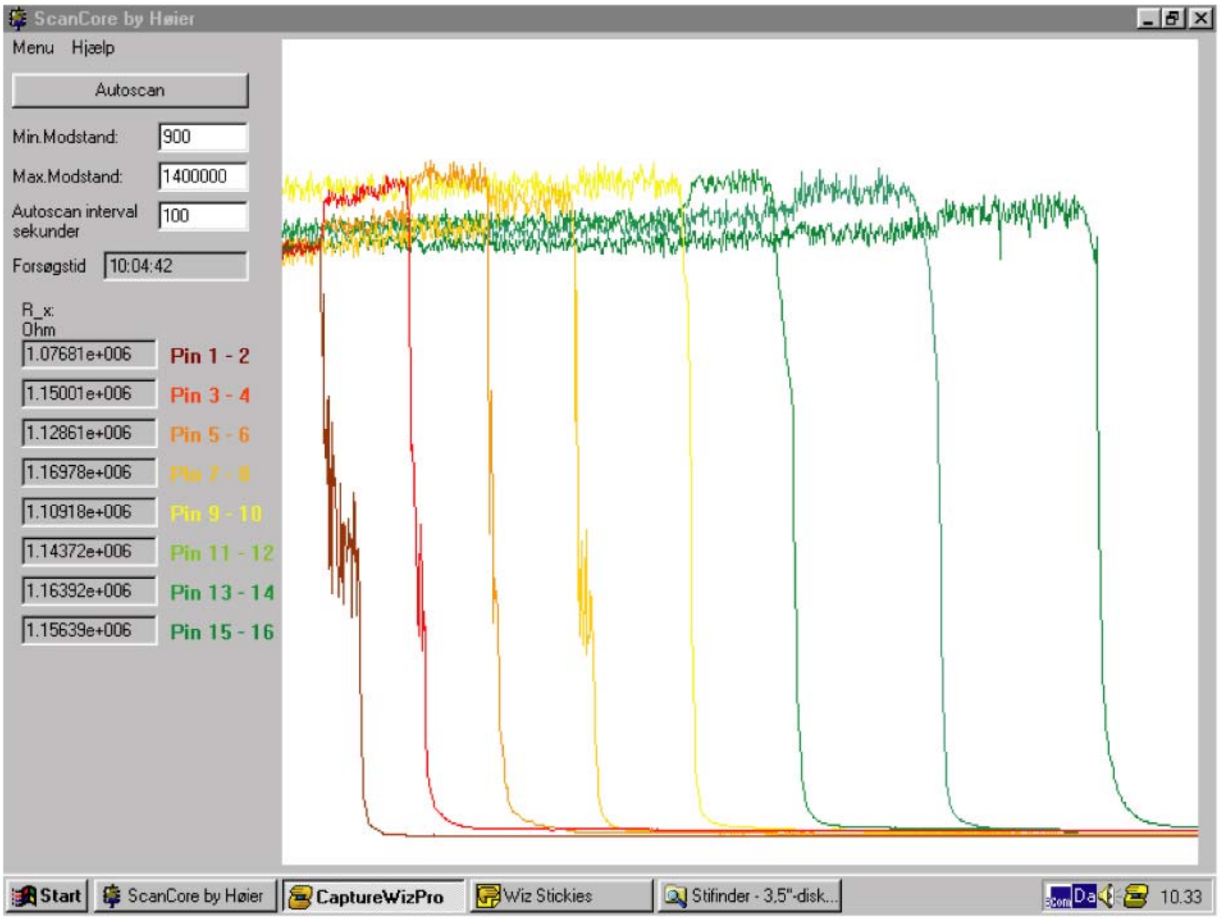


Figure 2.1: Screen picture of ScanCore program

The user can set **ScanCore** to auto scan the sample at fixed time intervals measured in seconds, or manually scan the sample whenever the "autoscan" button is pressed. At the first scan **ScanCore** will start a counter that logs the time in seconds. The time is saved with the resistance data measured from the multiplexer and placed in the folder

C:\EFP2000\Output

Data are given in the 2 formats as shown below:

File: output.txt (first number is the time and the next is the resistance (in ohm) from electrode pair 1- 8)

0	1090063.95	1139344.95	1109694.95	1213233.33	1101597.10	1147924.31	1138186.79	1179830.57
180	1090632.59	1147796.86	1108765.83	1217621.47	1106156.53	1158487.07	1127965.76	1179042.57
360	1082865.42	1145737.28	1110734.66	1212104.46	1101190.66	1159159.58	1134851.09	1183498.63

File output1.txt (first line is the time and the next 8 lines is the resistance (in ohm) from electrode pair 1- 8)

```
0
  1090063.95
  1139344.95
  1109694.95
  1213233.33
  1101597.10
  1147924.31
  1138186.79
  1179830.57
180
  1090632.59
  1147796.86
  1108765.83
  1217621.47
  1106156.53
  1158487.07
  1127965.76
  1179042.57
360
  1082865.42
  1145737.28
  1110734.66
  1212104.46
  1101190.66
  1159159.58
  1134851.09
  1183498.63
```

The format output.txt is used for plotting data in Excel or another program. **Volfit** uses the format output1.txt when calibrating the data.

ScanCore will overwrite any exiting output.txt or output1.txt in the output folder. The data is saved by renaming the files eg. to sample.txt and sample1.txt before **ScanCore** is started up again.

Scancore.exe is placed in:

C:\efp2000\scancore\debug

ScanCore needs CellNeighb.dat to run. CellNeighb.dat tells **ScanCore** witch electrode pair to scan between. CellNeighb.dat can be edited with e.g. Notepad if a different electrode configuration is wanted. CellNeighb.dat is placed in:

C:\efp2000\input

And the present format for CellNeighb.dat is:

1	1	2	0	0	0
3	1	4	0	0	0
5	1	6	0	0	0
7	1	8	0	0	0
9	1	10	0	0	0
11	1	12	0	0	0
13	1	14	0	0	0
15	1	16	0	0	0

The first column is the electrode name, the second column tells how many electrodes to connect to (max 4), column 3-6 list the names of the electrodes to connect to.

E.g. Row 1 is read like: electrode 1 is connected to one electrode, named electrode 2
Row 2 is read like: electrode 3 is connected to one electrode, named electrode 4
Etc.

2.2 Volfit

Volfit is a DOS-program that convert the resistance profile into a water saturation profile. The measured resistance is regarded as a function of the volume of water between electrodes and can therefore be translated to a water saturation.

2.2.1 Mathematical solution

To determine a correlation between water saturation and resistance an implicit method was developed by Olsen (1990). This method assumes that each electrode is measuring the true water saturation.

The aim is to find a function $S_w = S_w(R)$, which minimises the volume balance error δ_j . The volume balance error δ_j is defined as the difference between the actual water volume in the sample and the water volume measured by the electrodes.

$$\delta_j = V_{wj} - \int S_w \, \phi \, dV \quad \approx V_{wj} - \sum_{l=1}^{E} S_{wjl} \, \phi_l \, V_l \qquad (2)$$

Where:

V_{wj}	=	the actual water volume in the sample
E	=	the number of electrodes
S_{wjl}	=	the measured water saturation at the l'th electrode in the j'th calibration point.
ϕ_l	=	the porosity of the l'th part of the volume
V_l	=	the bulk volume of the l'th part of the volume

The function $S_w = S_w(R)$ has the following form:

$$S_w = \frac{C_1}{R^4} + \frac{C_2}{R^3} + \frac{C_3}{R^2} + \frac{C_4}{R} + C_5 \qquad (3)$$

A function G is introduced with the aim of finding the curve with the best fit through the measured resistances.

$$G(c_1, c_2, c_3, \dots c_m) = \sum_{j=1}^{n} \delta_j^2 \qquad (4)$$

where n is number of calibration points.

To minimise $G(c_1, c_2, c_3, \dots c_m)$:

$$\frac{\partial}{\partial c_i} G(c_1, c_2, c_3 \dots c_m) = \frac{\partial G}{\partial c_i} = 2 \sum_{j=1}^{n} \frac{\partial \delta_j}{\partial c_i} \delta_j = 0 \qquad (5)$$

The value of constants $(c_1, c_2, c_3, \dots c_m)$ which minimise the volume balance error δ_j can now be found by inserting δ_j and $\partial \delta_j / \partial c_i$ into equation (5).

2.2.2 Using Volfit

Volfit is programmed to solve the above equations. **Volfit** is run using a DOS-prompt, and it is placed on the following location together with the electrode input file CellNeighb.dat:

C:\efp2000\Volfit\debug\Volfit.exe
C:\efp2000\Volfit\debug\CellNeighb.dat

Volfit.exe can be placed in any folder or harddisk as long as it is together with the “CellNeighb.dat” file. **Volfit** can handle data from **ScanCore** into different formats.

- The first format is the standard format from **ScanCore** (output1.txt file).
- In the second format the seconds listed in the output1.file are replaced with a corresponding water saturation, this must be done be the user.

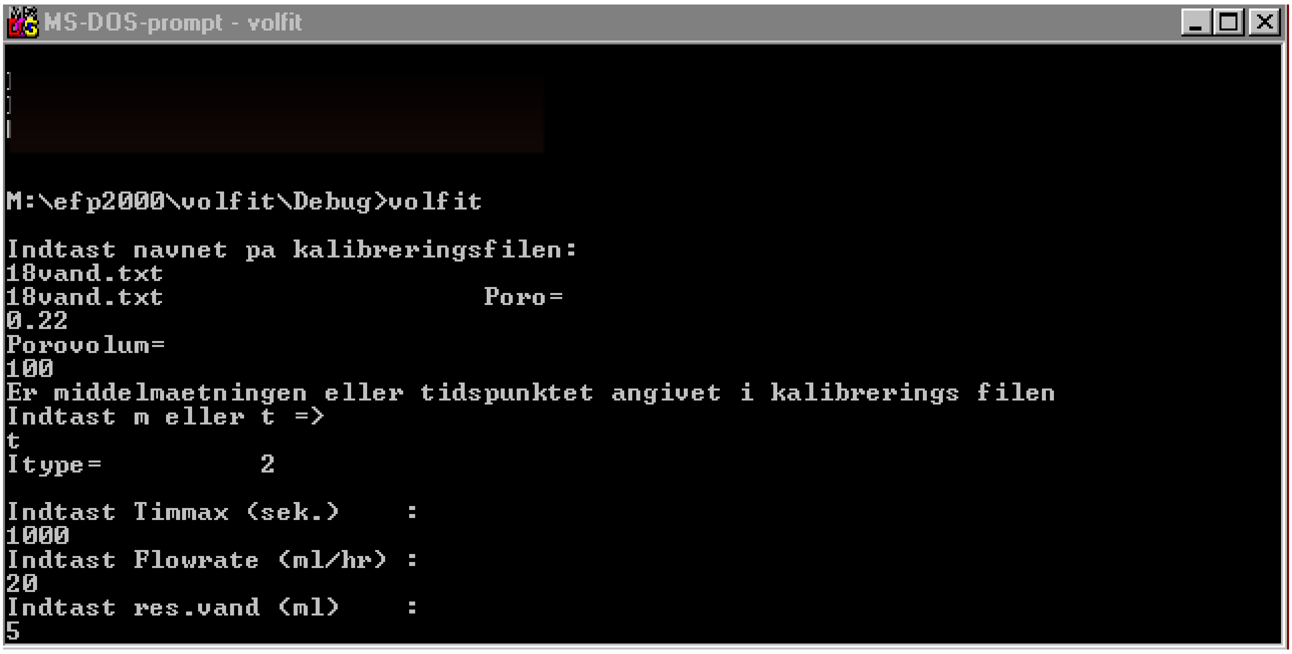
Normal output1.txt file:

```
0              (Seconds)
  1066709.29
  1087478.56
  1083575.62
  1148635.77
  1046739.66
  1063921.78
  1058431.83
  1050095.86
60             (Seconds)
  1062022.61
  1075723.83
  1084900.12
  1172674.02
  1054161.89
  1058657.46
  1042589.61
  1062189.53
```

Output1.txt file where seconds manually are replaced with a corresponding water saturation:

```
0              (Water saturation)
  1066709.29
  1087478.56
  1083575.62
  1148635.77
  1046739.66
  1063921.78
  1058431.83
  1050095.86
0.005865       (Water saturation)
  1062022.61
  1075723.83
  1084900.12
  1172674.02
  1054161.89
  1058657.46
  1042589.61
  1062189.53
```

If the sample is flooded at a CONSTANT rate, then **Volfit** calculates the corresponding water saturation using the standard “output1.txt” file and relevant input from the user. Running **Volfit** will look like this:



Volfit will guide the user thought the following steps:

1. **Volfit** asks for the calibration file (output1.txt).
   If the file is not placed together with volfit.exe then it is necessary to write the path to the file e.g. **C:\efp2000\output\output1.txt**
   Type the file name e.g. 18vand.txt

2. **Volfit** asks for the sample porosity
   Type the porosity as a decimal e.g. 0.22

3. **Volfit** ask for the sample pore volume in ml.
   Type the pore volume e.g. 100

4. **Volfit** ask whether the file contains seconds or water saturations. Type t for seconds or m for water saturations.
   Type t in this case (constant rate experiment)

5. **Volfit** ask for the max time in seconds. Max time is the time of water breakthrough.
   Volfit can not account for water saturation after breakthrough.
   Type the max time e.g. 1000

6. **Volfit** asks for the flow rate in ml/h
   Type the flow rate e.g. 20

7. **Volfit** asks for the sample initial water saturation in ml’s.
   Type the initial water saturation e.g. 5

Volfit will now start calculating the water saturation at each time step (until time max) given in the output1.txt file using the input data above. After a while more input will be asked for, ref. the screen dump below.

MS-DOS-prompt - volfit

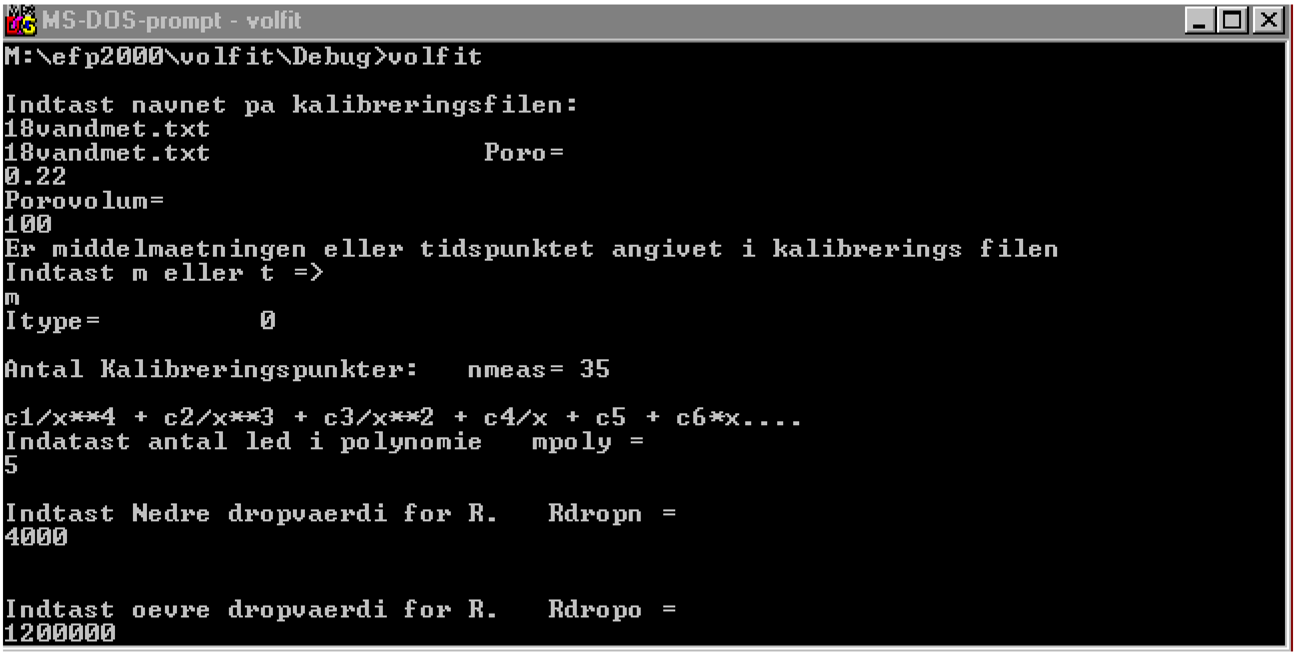
```
     58.3000000000000000        5.323888888888889   5.323888888888889E-002
     60.4000000000000000        5.335555555555556   5.335555555555556E-002
     63.7000000000000000        5.353888888888889   5.353888888888889E-002
     67.5000000000000000        5.375000000000000   5.375000000000000E-002
     70.5999999999999990        5.392222222222222   5.392222222222223E-002
     72.9000000000000010        5.405000000000000   5.405000000000000E-002
     76.4000000000000010        5.424444444444444   5.424444444444444E-002
     79.7000000000000000        5.442777777777778   5.442777777777778E-002
     82.4000000000000010        5.457777777777778   5.457777777777778E-002
     85.0000000000000000        5.472222222222222   5.472222222222222E-002
     89.0000000000000000        5.494444444444445   5.494444444444444E-002
     92.4000000000000010        5.513333333333334   5.513333333333334E-002

Antal Kalibreringspunkter:   nmeas= 35

c1/x**4 + c2/x**3 + c3/x**2 + c4/x + c5 + c6*x....
Indatast antal led i polynomie   mpoly =
5

Indtast Nedre dropvaerdi for R.   Rdropn  =
4000


Indtast oevre dropvaerdi for R.   Rdropo  =
1200000
```

8. **Volfit** asks for the number of constants to be used in the polynomial fit.
   The Polynomial is fitted to the output1.txt data, and the best solution gives the calibration curve.
   Five constants are in most cases sufficient.
   Type numbers of constants e.g. 5

9. **Volfit** asks for the lowest resistance value in ohm you want to include in the calibration calculations.
   This is a fitting number for a stable solution and a means to filter out noise.
   Type the lowest accepted resistance value e.g. 4000

10. **Volfit** asks for the highest resistance value in ohm you want to include in the calibration calculations.
    This is a fitting number for a stable solution and a means to filter out noise.
    Type the highest accepted resistance value e.g. 1200000

If the experiment is NOT run at constant rate, then the user will have to edit the output1.txt file and replace the seconds with the corresponding water saturations. Running **Volfit** will look like this:



Volfit will guide the user thought the following steps:

1. **Volfit** asks for the calibration file (output1.txt).
   If the file is not placed together with the volfit.exe then it is necessary to write the path to the file e.g. **C:\efp2000\output\output1.txt**
   Type the file name e.g. 18vand.txt

2. **Volfit** asks for the sample porosity.
   Type the porosity as a decimal e.g. 0.22

3. **Volfit** asks for the sample pore volume in ml.
   Type the pore volume e.g. 100

4. **Volfit** asks whether the file you want to calibrate contains seconds or water saturations. Type t for seconds or m for water saturations.
   Type m in this case (manually calculated water saturations)

5. **Volfit** asks for the number of constants in the polynomial fit.
   The Polynomial is fitted to the output1.txt data, and the best solution gives the calibration curve.
   Five is in most cases a good number.
   Type numbers of constants e.g. 5

6. **Volfit** asks for the lowest resistance value in ohm you want to include in the calibration calculations.
   This is a fitting number for a stable solution and a means to filter out noise.
   Type the lowest accepted resistance value e.g. 4000

7. **Volfit** asks for the highest resistance value in ohm you want to include in the calibration calculations.
   This is a fitting number for a stable solution and a means to filter out noise. Type the highest accepted resistance value e.g. 1200000

The output from **Volfit** is placed in the following folder:

C:\efp2000\volfit\debug

And contains the following 4 files:

Cvar.txt	The calculated constants that is inserted into equation 3 to calculate the water saturation
Grafsr.txt	2 columns of values. The first column is the water saturation and the second column is the corresponding resistance.
Grafvv.txt	2 columns of values. The first column is the injected volume of water into the sample and the second column is the calculated volume of water.
Dump.txt	List all output.

2.3 Obtaining good calibration data

To obtain a reliable conversion of resistance to water saturation, the experiment saturation history must be known. In most cases there is a good control of water injected into the sample, and if the water in the outlet is recorded as well then the hole experiment can be used to calculate the conversion. If the outlet water production is not recorded then only data until water breakthrough can be used in the conversion. This however will normally lead to missing calibration data at higher water saturations.

The example below shows how data is obtained and evaluated:

ScanCore measured the resistances profile in successive time steps, as water was injected into a synthetic sample. Calibration data was obtained at water saturations from 6 % to 57 %, and additional data points at 100 % water saturation were added to improve the calibration. **Volfit** used the measured data from **ScanCore** and the output: Grafsr.txt and Grafvv.txt were plotted to inspect the quality of the data, figure 2.2.

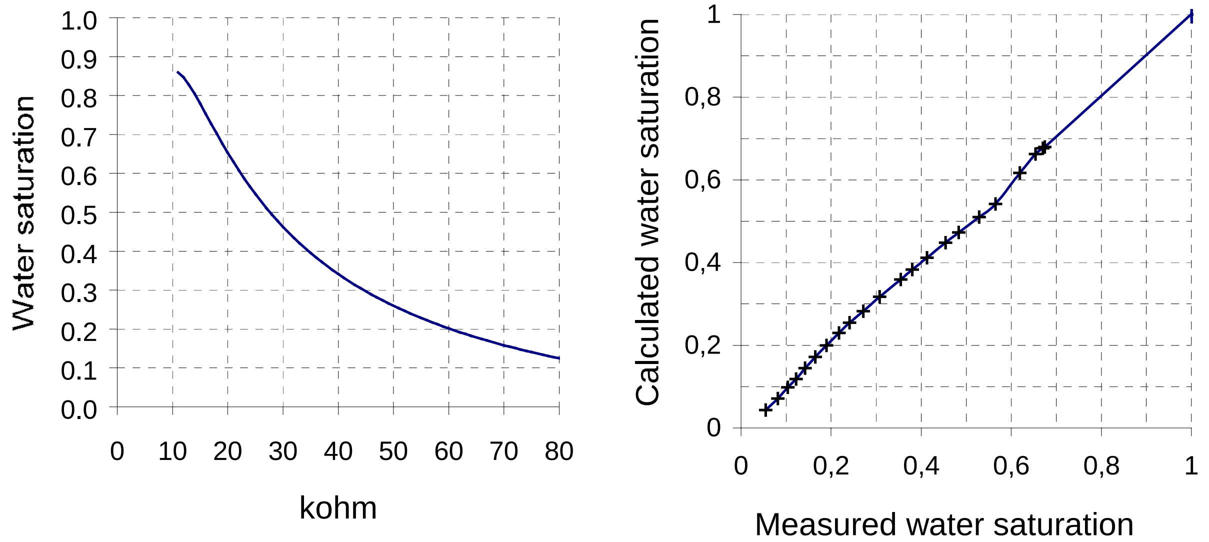


Figure 2.2: Left: Water saturation as a function of resistance. Right: Water saturation measured by the electrodes and plotted against the actual water volume injected into the synthetic sample.

In this example there is a very good agreement between the measured water volume and the actual injected water volume, which indicate the calibration curve is accurate. In general the determination of water saturation by the resistance technique was observed to be precise within 3 % water saturation.

If the calibration curve had proven unstable or ambiguous, then the highest or lowest resistance accepted by **Volfit** can be changed until a better solution is obtained.

Errors in the calculations can be caused by:

- Poor input data - poor knowledge of the injected water volume
- Poor calibration interval e.g. only data from 0 - 25 % water saturation
- High resistance (Mohm and above) whereby the precision of the multiplexer is reduced. This will lead to a greater uncertainty in estimating the water saturation. The high resistance measurements are obtained at low or no water saturation
- An inhomogeneous sample will also lead to errors in the calculation as **Volfit** distribute the pore volume equal among the 8 electrode compartments into which the sample is divided.

2.4 Development of software

Søren Mondrup and Christian Høier programmed **ScanCore** in C++. **Volfit** was programmed in Fortran by Niels Olsen and modified by Christian Høier. Both programs were developed in Microsoft develop studio 4.0, which is installed on the computer. The source code and software is free and may be modified in anyway. It is backed-up on the CD-ROM.

3. Hardware

A computer with data acquisition card and multiplexer is needed for the data collection

3.1 Multiplexer

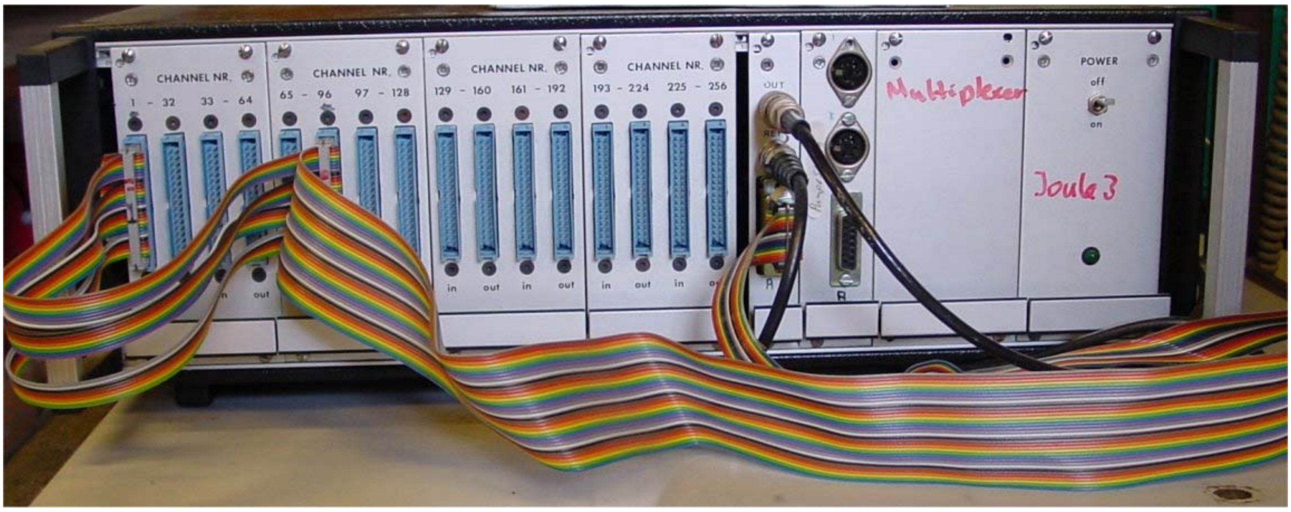


Fig. 3.1: Multiplexer front panel.

The multiplexer is a box with a large number of electronic switches that can be controlled by a computer. It is connected to the electrodes on the chalk sample. A generator in the multiplexer creates the voltage U_g . When an electrode pair is switched on, the multiplexer generates an electric field and the computer will measure the voltage drop U_{ref} between the electrodes over a reference resistance R_{ref}. The computer-aided multiplexer system is depicted in Fig.3.2.

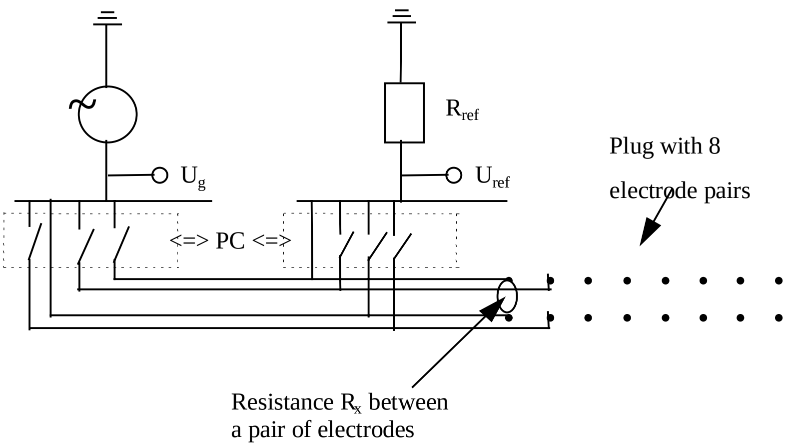


Fig3.2: Sketch of the experimental set-up showing the principle of the resistance measurements.

The resistance between two neighbouring electrodes was calculated by the computer using the following equation.

$$R_x = R_{ref} (U_g/U_{ref} - 1) \quad (1)$$

The multiplexer system successively switches the connections between the electrodes on and off. It takes 8 measurements to get a snapshot of the resistance distribution in the chalk sample containing 16 electrodes. This was carried out by the multiplexer within 1 second.

The multiplexer was build by students at DTU and later given to GEUS. The supplied documentation has been added in appendix 1.

3.2 PC and data acquisition cards

A 120 MHz Pentium PC running Win95 with 2 data acquisition cards are used to control the multiplexer. The data acquisition cards are:

CIO-DAS08-AO	from Computer bords, Inc. supplied by ENGBERG a/s
AT-MIO-16XE50	from National Instruments

Drivers to the CIO-DAS08-AO card are placed in the following folder:

C:\cb

No drivers were installed for the AT-MIO-16XE50 card.

3.3 Setup

The multiplexer is connected to the 2 data acquisition cards installed on the computer, as shown on the figure below. From the multiplexer is a flat cable connected to the sample. The connection of the flat cable is shown in fig. 3.1.

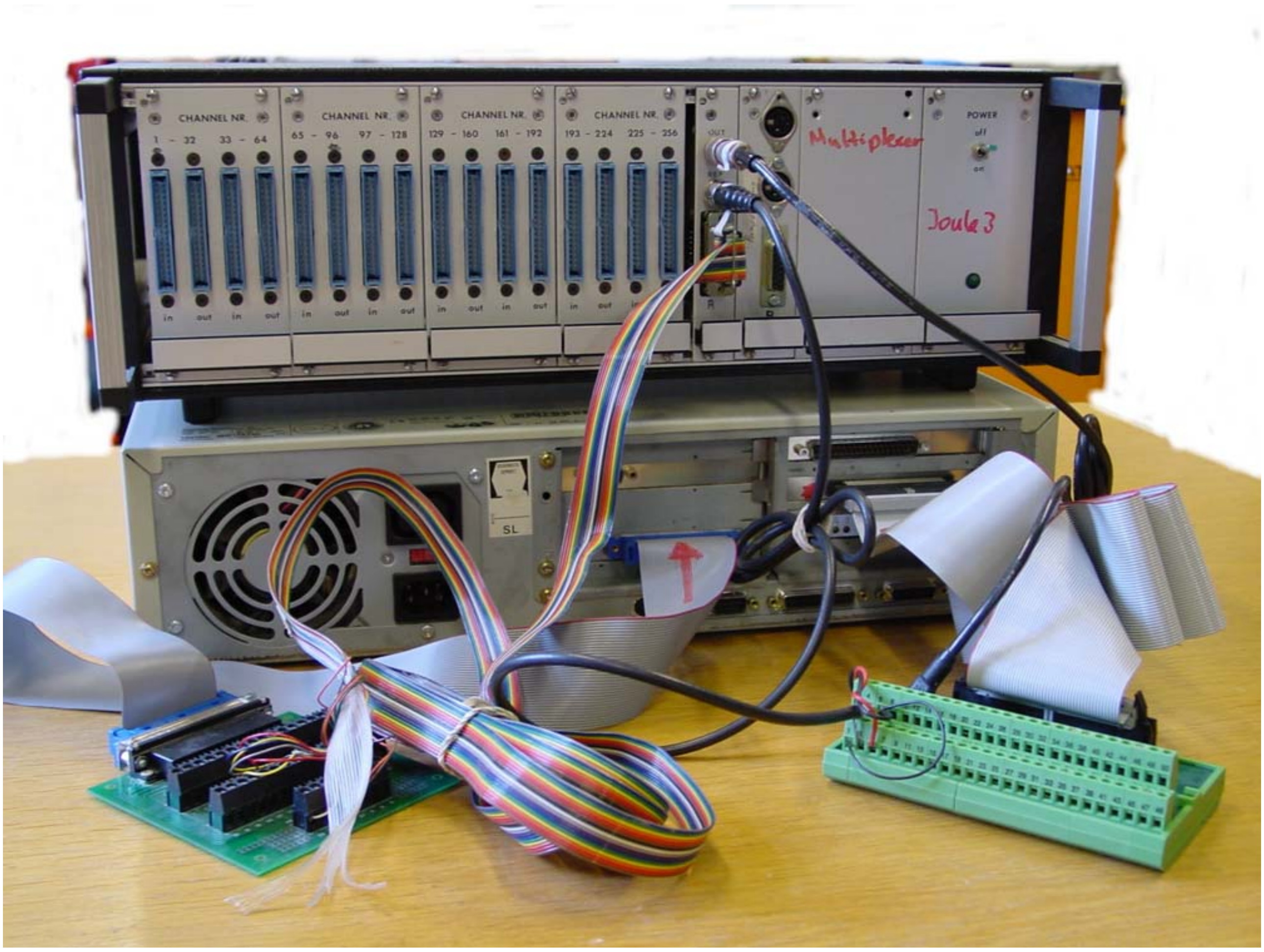


Fig. 3.3: Multiplexer connected to the computer.

4 Test of system

4.1 Test on various standard resistances

The range and precision of the multiplexer was tested on various standard resistances. A standard resistance was connected to an electrode pair and measured several times (each dot is one measurement) and then moved on to the next electrode pair and so on. The paired electrodes are named serie 1 – 8 in the figures.

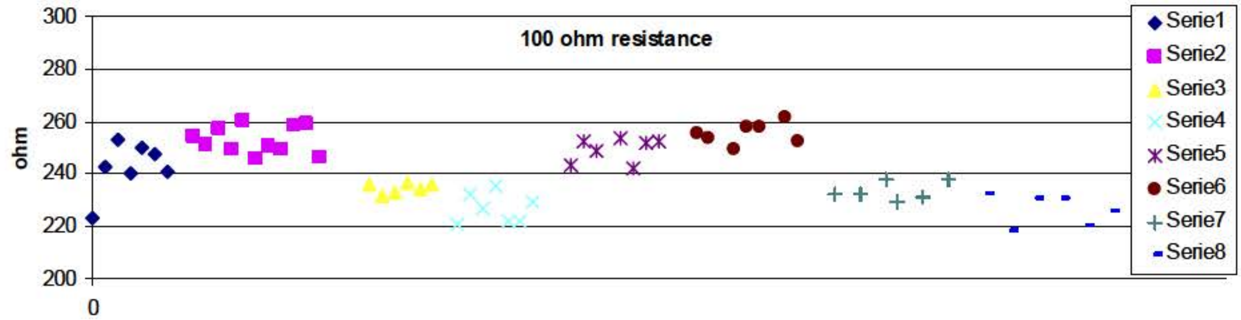


Figure 4.1: Measured system impedance for a standard 100 ohm resistance.

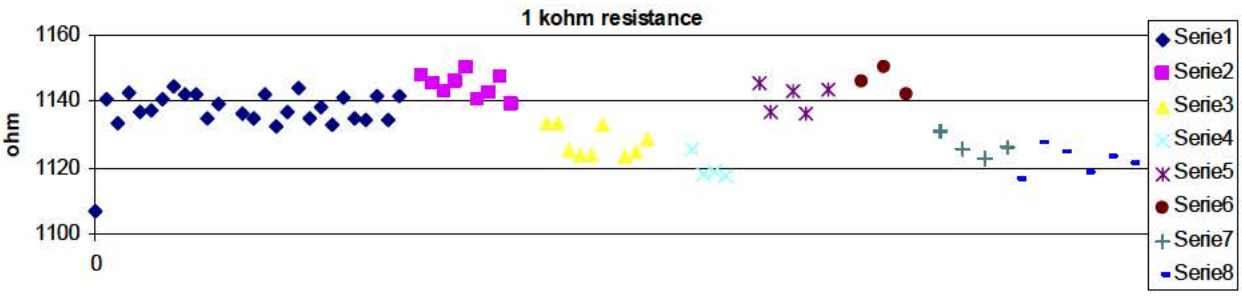


Figure 4.2: Measured system impedance for a standard 1 kohm resistance.

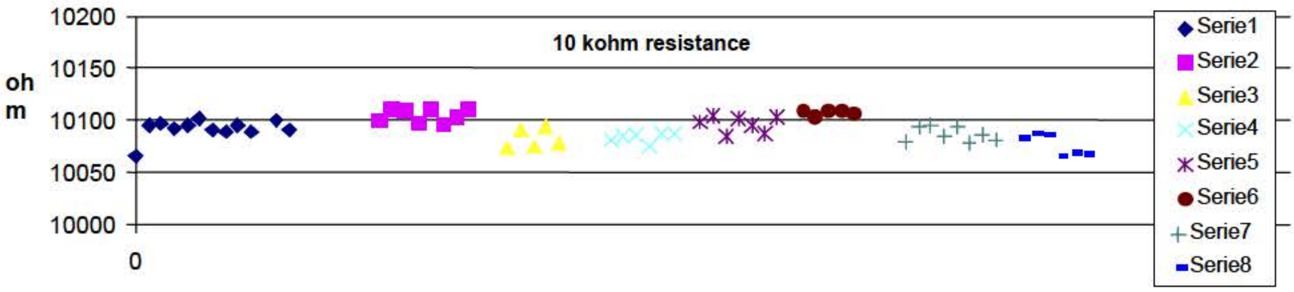


Figure 4.3: Measured system impedance for a standard 10 kohm resistance.

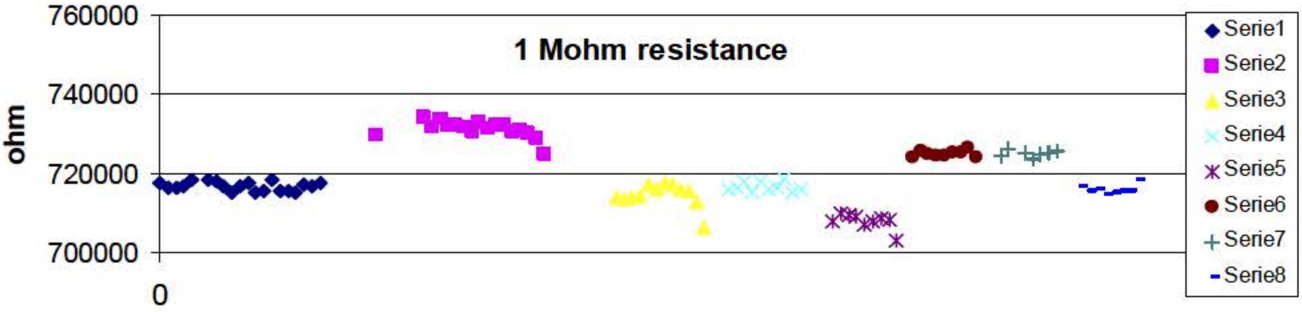


Figure 4.4: Measured system impedance for a standard 1 Mohm resistance.

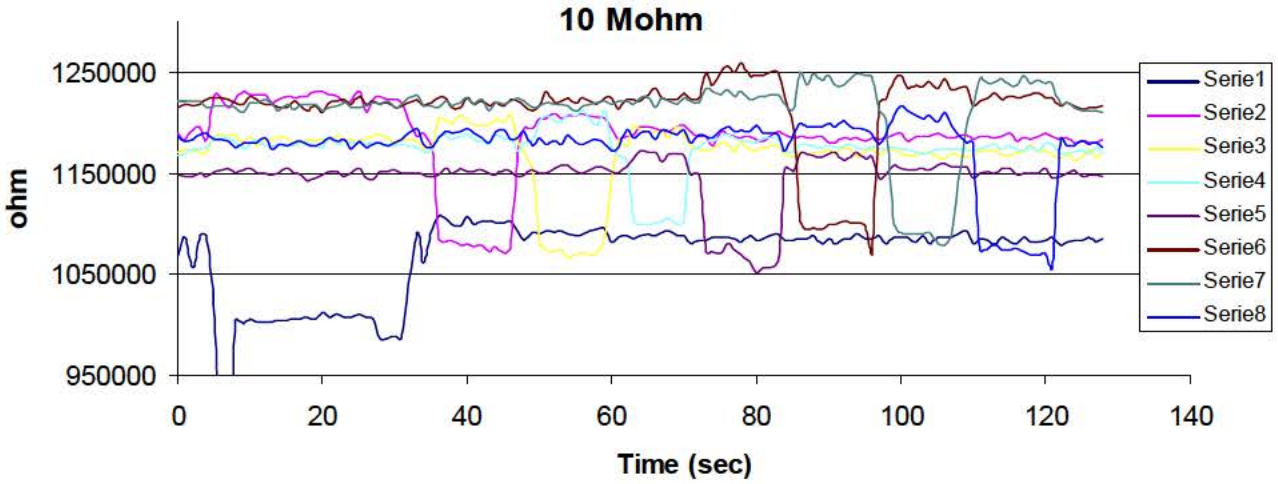


Figure 4.5: Measured system impedance for a standard 10 Mohm resistance.

As observed the system reads approx. 140 ohm higher than given from the standard resistance in the ohm and kohm range. In the Mohm range the precision of the system starts to fail. 1 Mohm is measured as approx. 720 kohm and 10 Mohm as 1.1 Mohm.

Figure 4.5 is a continuous recording of the electrode pairs. The connection of the 10 Mohm resistance can be seen as a resistance drop on the curves. "Serie 1" is connected first (the dark blue line) and the resistance drop, then "Serie 2" (the pink line) and the recording drops off as well and so fort. When the 10 Mohm resistance is disconnected, the system measures the resistance of air. The figure showes that the system can monitor a 10 Mohm resistance, but the value is given as ~1 Mohm. An infinitely high resistance is given a value around 1.2 Mohm.

A high precision is not essential for the multiplexer, because the waterfront is detected as a change in resistance and not from an actual value. It will however affect the accuracy of the water saturation determination.

4.2 Test on a 54 mm chalk plug

The technique was tested on a Ø~54 mm chalk plug from Hillerslev. 16 electrodes were drilled 2 mm into the plug. The spacing between electrodes was 1.2 cm and 1.0 cm between the end of the plug and the first electrode pair, figure 4.6. The chalk plug was fully saturated with oil to test if the oil would isolate the electrode from the plug. As shown later this turned out not to be the case.

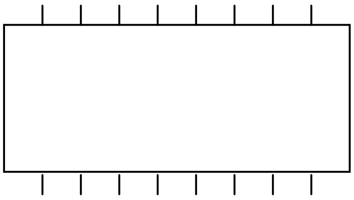


Figure 4.6: Ø~54 mm plug with 16 electrode attachment.

Brine was injected into the fully oil saturated plug at rate of 15 ml/h. The resistance across the 8 electrode pairs was logged every minute. Water breakthrough was registered after 6 hours and 14 minutes. Data can be seen in table 4.1 below.

Table 4.1: Experimental data

Length	10.77 cm
Diameter	5.38 cm
Bulk volume	245.13 ml
Porosity	45 %
Pore volume	110 ml
Rate	15.00 ml/h
breakthrough	6.23 hours
Injected water	93.50 ml
S_{or}	16.81 ml
S_{or}	15.24 %

	Electrode position cm	Volume injected ml	Time hours	CWf PV
Electrode pair 1	1.00	8.68	0.58	0.09
Electrode pair 2	2.20	19.10	1.27	0.20
Electrode pair 3	3.40	29.53	1.97	0.32
Electrode pair 4	4.60	39.95	2.66	0.43
Electrode pair 5	5.80	50.37	3.36	0.54
Electrode pair 6	7.00	60.79	4.05	0.65
Electrode pair 7	8.20	71.21	4.75	0.76
Electrode pair 8	9.40	81.63	5.44	0.87
Breakthrough	10.77	93.50	6.23	1.00

Table 4.2: Calculated position of the waterfront (CWf) using 93.5 ml as the mobile pore volume (PV)

Assuming an evenly distributed residual oil saturation and a piston like displacement, a waterfront can be calculated as show in table 4.2. The calculated results (the dotted line) are shown below with the measured resistance log.

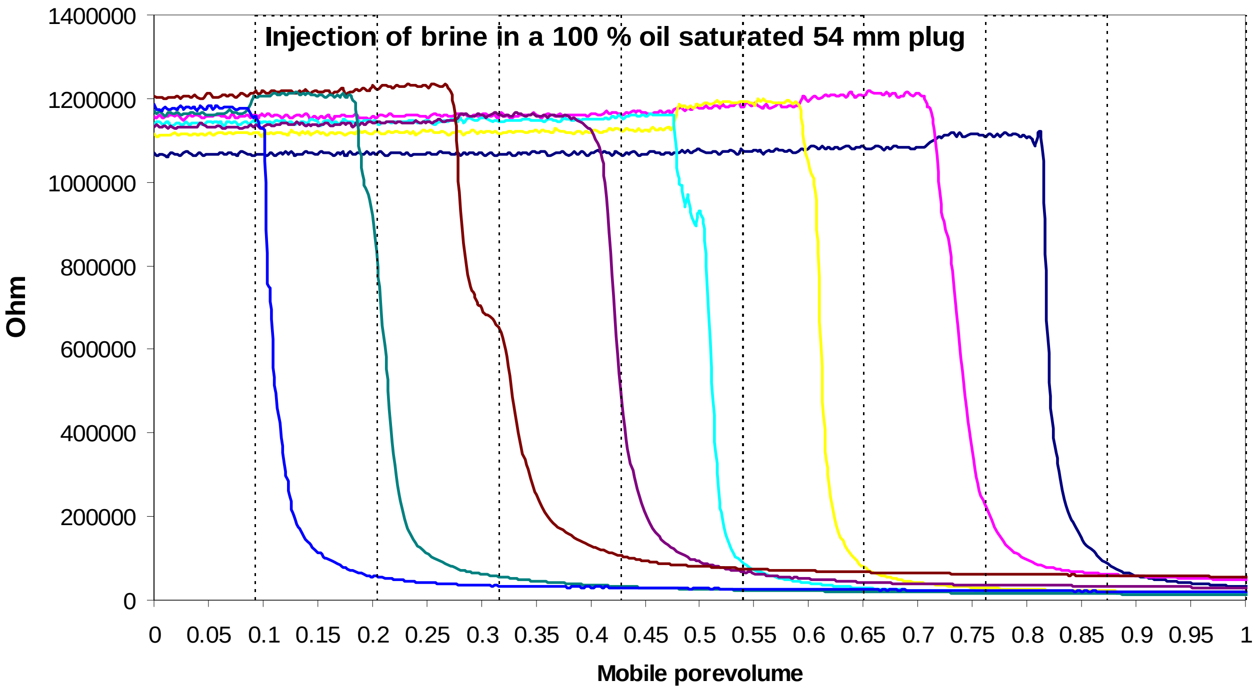


Figure 4.7: The measured resistance log plotted together with the calculated waterfront (the dotted line).

The figure demonstrates that the position of the waterfront is suitably monitored by the 8 electrode pairs. The resistance drops rapidly as the water is detected and the waterfront looks very sharp. The uncertainty due to diffusion and dispersion of the waterfront is about 0.05 mobile pore volume, which translates to a distance of 0.2 cm.

Comparing the measured and calculated waterfront shows that there is a good agreement between the first 4 waterfront positions but then they start to deviate. The deviation is to be expected, as the oil is in fact not distributed equally along the sample.

The plug test verified that the system is able to monitor a moving waterfront and that the results are trustworthy.

5. References

Olsen, N.K., 1990: Two-Phase Flow in Fractured Porous Media. Laboratory for Energetics, Technical University of Denmark.

Lindgaard, H. F., Høier, C., 1998: Experimental and numerical analysis of two-phase flow in fractured porous media. GEUS report 1998/33, Geological survey of Denmark and Greenland.

Høier, C., Rosendal, A., Lindgaard, H. F., 1999: Experimental and numerical analysis of water-oil displacement in fractured porous media. GEUS report 1999/66, Geological survey of Denmark and Greenland.

6. Appendix 1

The following appendix is a documentation of the data multiplexer (in danish).

DATA MULTIPLEKSER

Poulsen Elektronik Design 1988.

DATA MULTIPLEKSER

2 X 64 Kanaler X 4

DATAOPSAMLINGSMULTIPLEKSER

Indholdsfortegnelse:

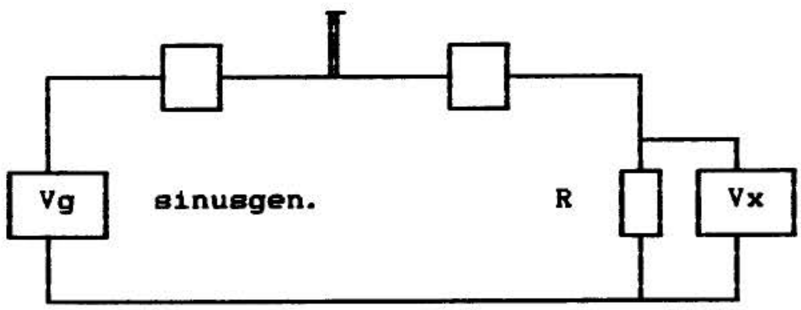
SYSTEMBESKRIVELSE.

Multipleksersystemet er opbygget omkring et standard 19" rack til enkelte europakort med DIN-konnektoren 41612 (64 pol).

Rack'et indeholder:
- 4 multipleksermoduler á 2 x 64 kanaler
- 1 oscillator og interfacemodul (til pc)
- 1 pumpestyringsmodul
- 1 powersupply +/- 9V

De 4 Multipleksermoduler er opbygget til at udnytte måleprincippet vist fig. 1.
Modstanden i den tilsluttede probe kan udregnes hvis udgangsspændingen af generatoren og spændingen over den kendte modstand R måles.

fig.1:

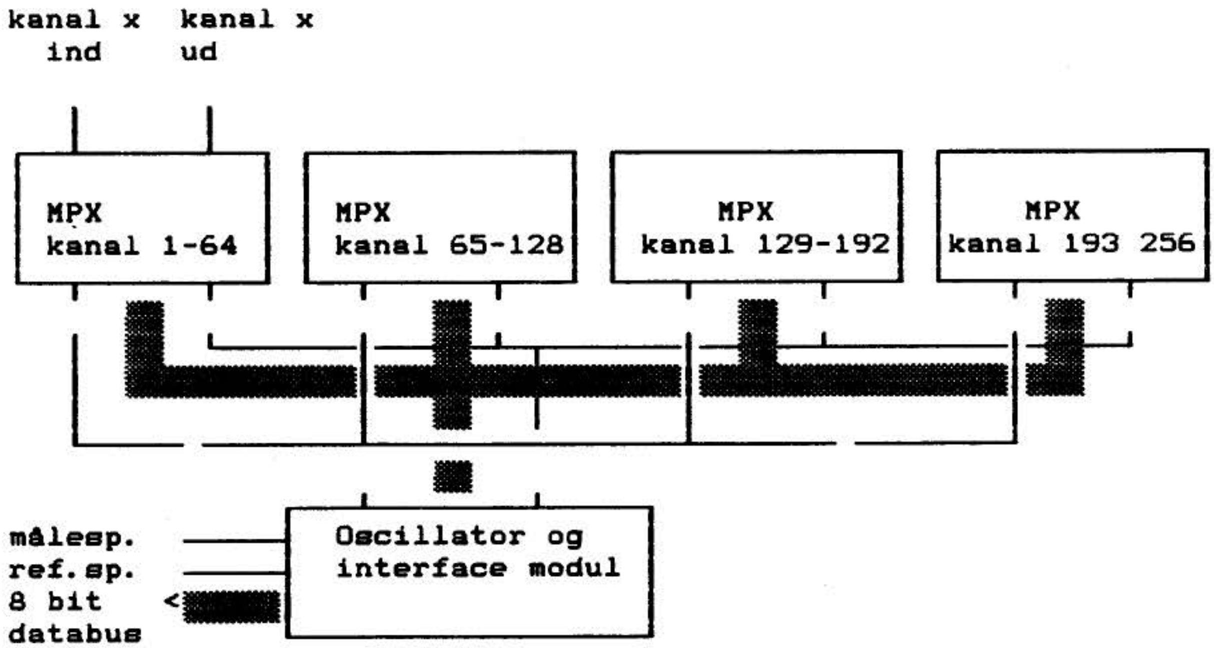


R probe = R * Vg/Vx-R

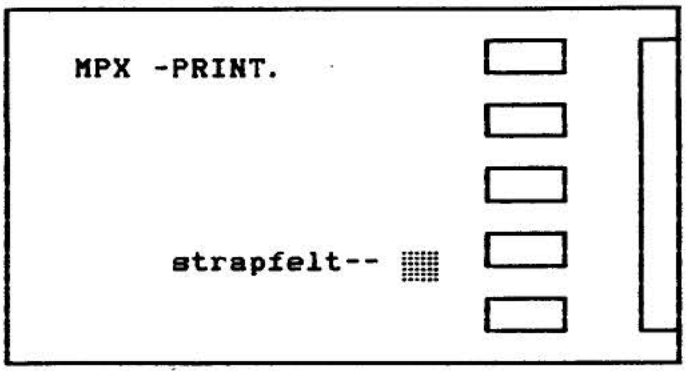
Ved at indskyde to multipleksere på hver side af proben kan flere prober måles med samme målegenerator og voltmeter. De enkelte kanaler selekteres ved hjælp af en 8 bits adresse, der påtrykkes dataindgangen på oscillator og interfacekortet.(se fig.2). Multipleksernes ind og udgange er ført ud på forpladen med 34 polede fladkabelstik hvor pin-numrerne refererer til de respektive kanalnumre. Multiplekseren vil altid selektere det kanalnummer der til enhver tid er udskrevet på databussen, hvilket bevirker at data på bussen skal stå stabilt i hele den periode man ønsker at måle på den pågældene kanal.

NB: BEMÆRK at f.eks kanal nr.1 til 64 = digitalværdi 0 til 63
Det enkelte modul kan skifte mellem 64 sæt kanaler.Til bestemmelse af hvilket område modulet skal arbejde i, er der anbragt et strapfelt ,hvor moduladressen bestemmes ifølge tabel 1

Fig. 2:


kanal x ind
kanal x ud
MPX kanal 1-64
MPX kanal 65-128
MPX kanal 129-192
MPX kanal 193 256
målesp.
ref.sp.
8 bit databus
Oscillator og interface modul

Tabel 1:



<table>
<tr><th colspan="2">Kanalnr.</th></tr>
<tr><td>1 -64</td><td>0 0
| |
0 0</td></tr>
<tr><td>65-128</td><td>0 0
|
0 0</td></tr>
<tr><td>129-192</td><td>0 0
|
0 0</td></tr>
<tr><td>193-256</td><td>0 0

0 0</td></tr>
</table>

| = kortslutning isat.

<u>Oscillator og interfacekortet</u> indeholder en 1kHz måle-oscillator, referencemodstand og to sæt indgangsbufferer med levelshifterer til den 8 bits databus(Data a) ,og den 6 bits ekstra databus (Data b).
Oscillatorfrekvensen kan justeres efter formlen :

$$F = 1/(2\pi * R2 * C2), \text{hvor } R2=R3 \text{ og } C2=C3.$$

På forpladen er 1kHz reference og målespændingen over modstanden udført til to BNC-stik. Til datainterface er der benyttet et 15 pol D-sub stik.

<u>Pumpestyringsmodulet</u> er opbygget til styring af to peristaltiske pumper fra firmaet Pharmacia. Disse pumper kan styres med en frekvens fra 0 til 200Hz og en digital indgang til kontrol af omløbsretning.
Pumpestyringsmodulet kan styre to pumper ved hjælp af to indgangsspændinger og 5 databit. Databus og styringsspænding tilsluttes via et 15 polet D-sub stik på forpladen og de to udgangsstik til pumperne er et 5 polet DIN-stik.
Pumpernes omløbshastighed er afhængig af den påtrykte indgangsspænding. Ved 5v indgangsspænding fås 200Hz output, og ved 0v ind fås< 0,1 Hz. Tænd / sluk og omløbsretning styres af de 5 databit som vist i tabel 2.

Tabel 2:

Databit:					
D4	D3	D2	D1	D0	FUNKTION
X	X	X	X	0	ingen ændring
0	0	1	0	1	pumpe 1 off
0	0	1	1	1	pumpe 1 on
0	1	0	0	1	pumpe 2 off
0	1	0	1	1	pumpe 2 on
0	1	1	0	1	pumpe 1 forword
0	1	1	1	1	pumpe 1 reverse
1	0	0	0	1	pumpe 2 forword
1	0	0	1	1	pumpe 2 reverse

X Don't care

Som det ses af tabellen bruges D0 kun til at "klokke" de resterende bit ind i et register. D.v.s databussen godt kan bruges til andre formål blot D0 ikke ændrer værdi.

<u>Powersupply:</u>
Der er mulighed for at justere udgangsspændingerne på de to uafhængige udgange. Justeringsområde ca. 5-20 volt.

TEKNISKE SPECIFIKATIONER.

Maksimal inputspænding på multiplekserindgange :	+/- 8,0 V
Typisk modstand gennem èn multiplekserkanal:	80 Ohm
Second harmonic distortion RL=10kohm f=1kHz Vin=5Vpp :	0,07 %
Interface til PC :	TTL

Stikbelægning :

Euro - connector DIN 41612 64 Pol (J1):

pin no.	
1c	Data 0 a
2c	Data 1 a
3c	Data 2 a
4c	Data 3 a
5c	Data 4 a
6c	Data 5 a
7c	Data 6 a
8c	Data 7 a
10a	data input (1kHz osc.)
10c	GND
11a	data output (mux)
11c	GND
12c	GND
20a	Data 0 b
21a	Data 1 b
22a	Data 2 b
23a	Data 3 b
24a	Data 4 b
25a	Data 5 b
30a-c	GND
31a-c	VEE (-9V)
32a-c	VCC (+9V)

34 pol multipleksørstik :

1 til 32	Kanal nr.
33 og 34	GND.

15 pol D-sub stik til PC interface (J2) :

Pin 1	D0 a
Pin 2	D1 a
Pin 3	D2 a
Pin 4	D3 a
Pin 5	D4 a
Pin 6	D5 a
Pin 7	D6 a
Pin 8	D7 a
Pin 9	GND
Pin 10	D0 b
Pin 11	D1 b
Pin 12	D2 b
Pin 13	D3 b
Pin 14	D4 b
Pin 15	D5 b

15 pol D-sub stik til pumpestyring:

Pin 1	D0
Pin 2	D1
Pin 3	D2
Pin 4	D3
Pin 5	D4
Pin 9	GND
Pin 10	Inp A styrespænding
Pin 11	Inp B styrespænding

Styklíste multipleksermodul:

R1 100 K
R2 100 K

RN1 100K

C1 - C5 100nF

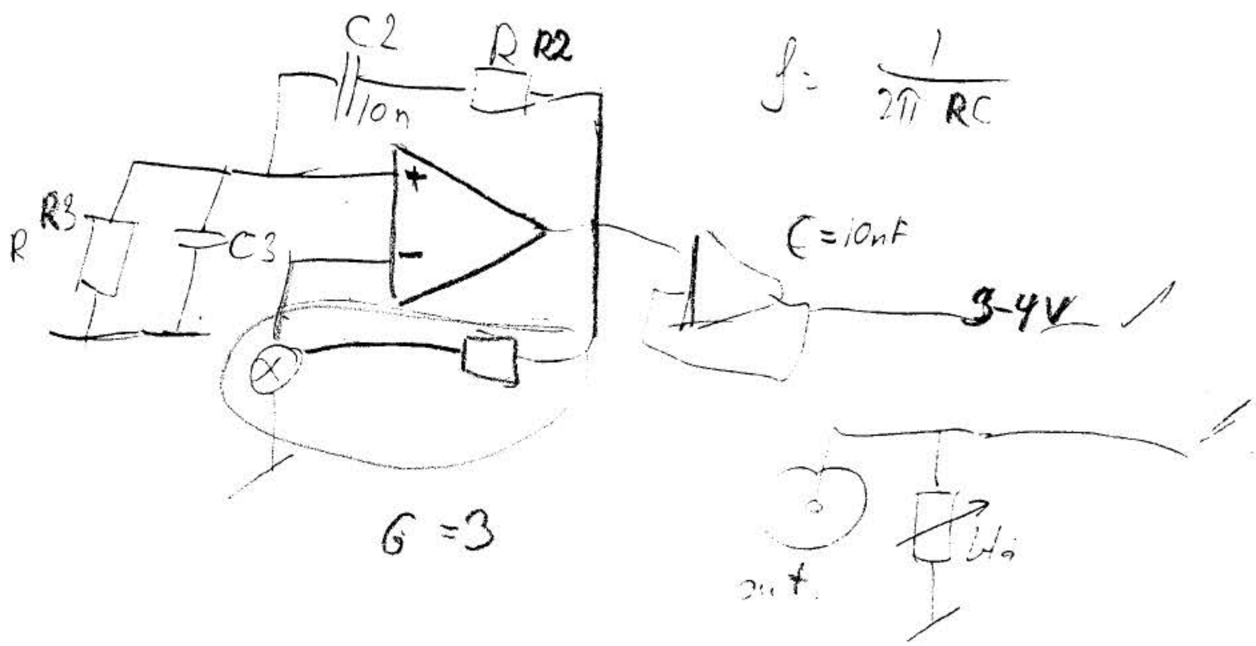
U1 4070
U2 4093
U3 4556
U4 - U19 4051

J1 41612 64 pol

JP1 - JP4 34 pol cannon G80

Stykliste PC-interface og oscillatormodul:

R1	150 ohm
R2	18 K ‖ 220 K
R3	18 K ‖ 220 K
R4	680 ohm
R5	4,7 K R 53 special modstand
R6	10 K
R7	6,8 K
R8	120 K
R9	10 K
R10	10 K 1 %
RN1	100K
RN2	100K
C1	100 nF
C2	10nF
C3	10nF
C4	ikke monteret
C5	ikke monteret
C6	22 myF/16V
C7 - C11	100nF
U1 - U3	MC 14504 B
U4 - U5	LM 741
J1	41612 64 pol
J2 - J3	BNC
J4	DB 15 pol soc. D-sub



Styklista Pumpestyringsmodul

R1	1,54K	
R2	10K	
R3	1,54K	
R4	10K	
R5	1M ohm	Trimmepotentiometer
R6	100K	
R7	1M ohm	Trimmepotentiometer
R8	10K	
R9	10K	

C1	120pF
C2	10myF
C3	120pF
C4	10myF
C5 - C7	10myF

U1 - U2	4051
U3 - U4	4046
U5 - U6	4013
U7	4011
U8 - U9	4040
U10	LM7805

J1	41612 64 pol
J2	DB 15 pol soc. D-sub

Styklište powersupply:

R1 - R2	220 ohm
C1 - C2	4700myF/35V
C3	100nF
C4	100nF
C5	10myF/25V
C6	100nF
D1 - D4	1N4004
P1 - P2	10K Multiturn
U1	LM 117
U2	LM 117
T1	Transformator 15/18 - 0 - 15/18 V 0,5A nr. 21111
F1	Sikring 100 mA
F2 - F3	Sikring 500 mA
J1	41612 64 pol

Appendix:

1: Diagrammer.

2: Komponentplacering og checkplot.