LABORATORY MODELING SYSTEM FOR UNDERGROUND GAS STORAGE

József SUBERT[1], Károly JÓNAP[1], Csaba VÖRÖS[1], Péter KALOCSAI[2]
1 – University of Miskolc Research Institute of Applied Earth Sciences,
2 – MOL Hungarian Oil and Gas Company Plc.

Applied Technology and Best Practices in CEE
Conference
Budapest, 17 November 2011

Society of Petroleum Engineers

Gas Reservoir Rock Core Test
Tasks

R&D activities

- **We prepared the analysis method specifically designed for injection and withdrawal cycles.**
- **We planned and prepared the equipment applicable for modeling of injection and withdrawal cycles.**
- **We performed sand production tests using rock samples from wells SzGT-4 and SzGT-19, 120-180 bar pressure rate, 250 bar rock load, 93 °C temperature.**
- **We analysed the measurement results gained from this modeling.**

Model Apparatus
Specification

Main parameter:

Pressure max.:	**250 bar**
Operational pressure:	**120-180 bar**
Temperature max.:	**120 ℃**
Operational temperature:	**93℃ ÷100 ℃**
Rock load:	**250 bar**
Flow rate:	**63 bar/30 min – about 10 ln/min**
Flow rate (higher):	**30 ln/min**
Core:	**1”x50…60 mm**
Pipe:	**∅6/4 mm**

Test Method
Flow rate calculation

The measurements of flow conditions before the test equipment are arranged so that the pressure change in terms of resale value was 63 bar/30 min.

Well yeald (source: MOL Nyrt.)

8 m average thickness and 450 em^3/day flow rate;
6 m effective thickness , 400 em^3/day flow rate.

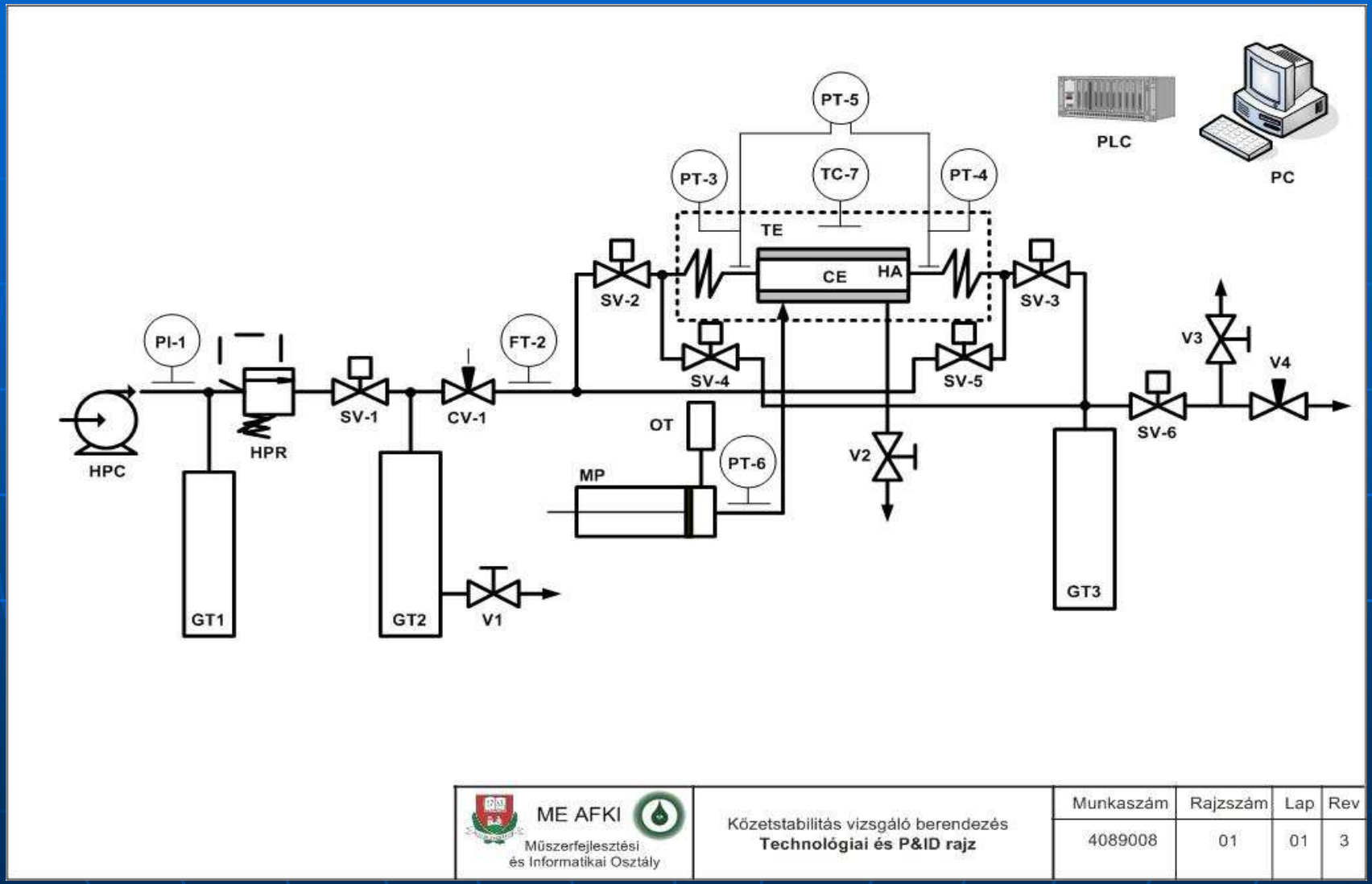
Inflow on surface

1st version: 7,02 m^2;
2nd version: 5,26 m^2.

Flow rate

at 5 cm^2 core surface: 22,26 ln/min or 26,41 ln/min.

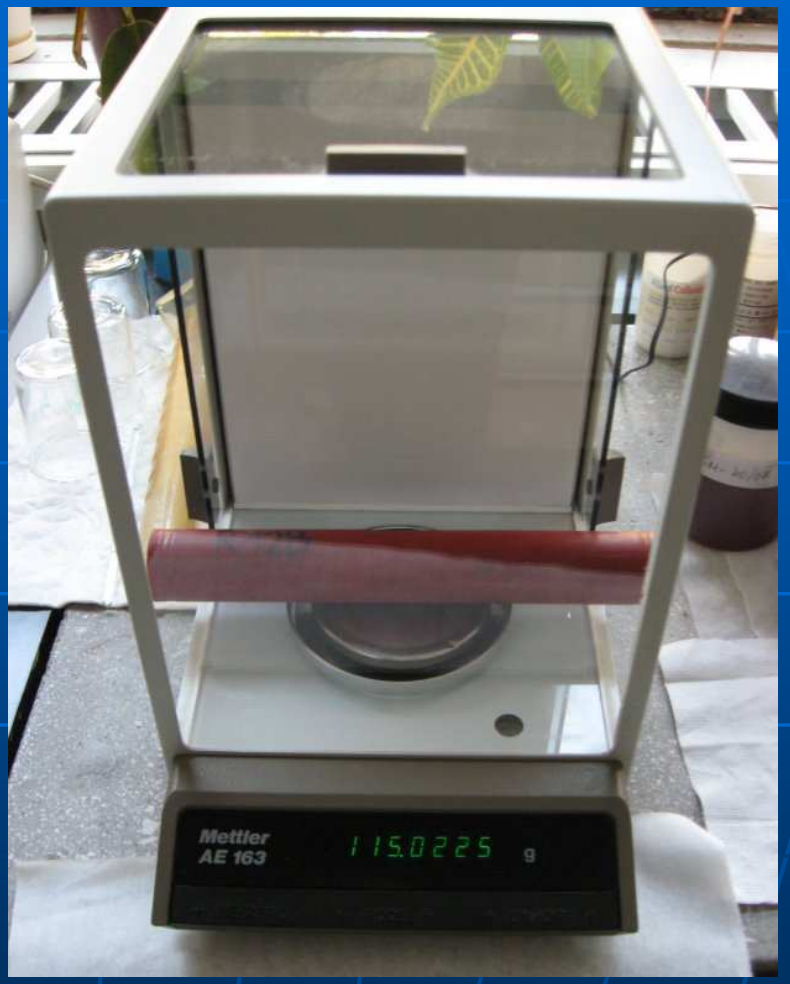
Model Apparatus
P&ID



Investigate Schedule
Tested methode

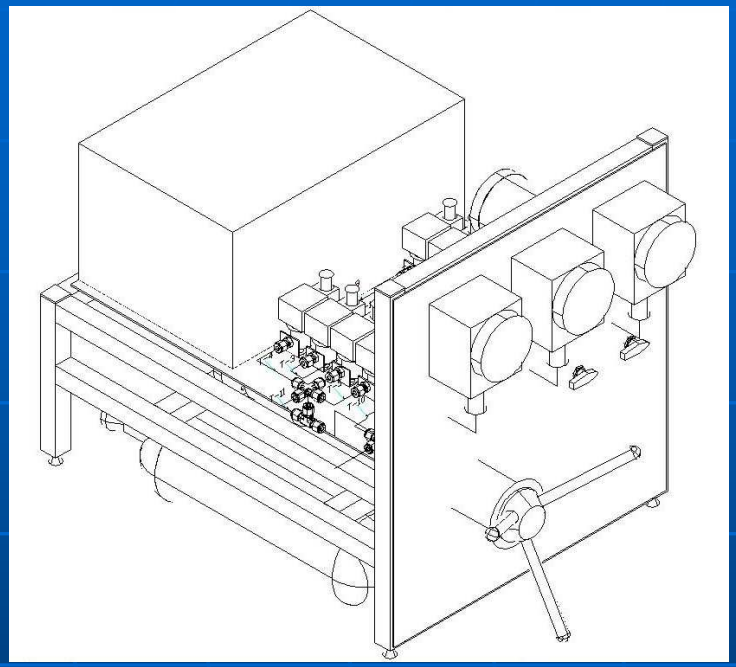
1. Drying of rock sample on 60 ℃, over 48 hours
2. Photographing the rock samples
3. Measurement of the mass of the samples
4. Heating and temperature set (4 hours).
5. Pressure position to 120 bar (rock pressure 250 bar).
6. Permeability measuring.
7. Compressor pressure set to 180 bar
8. Flow rate set to 30 ln/min
9. Stop measuring at 180 bar
10. Pressure holding for 5 min
11. Recirculation from 180 bar to 120 bar with constant rate flow
12. The cycle repeats 40 times
13. Drying of rock sample
14. Measurement of the mass of the samples

Measurement of the Mass of the Sample

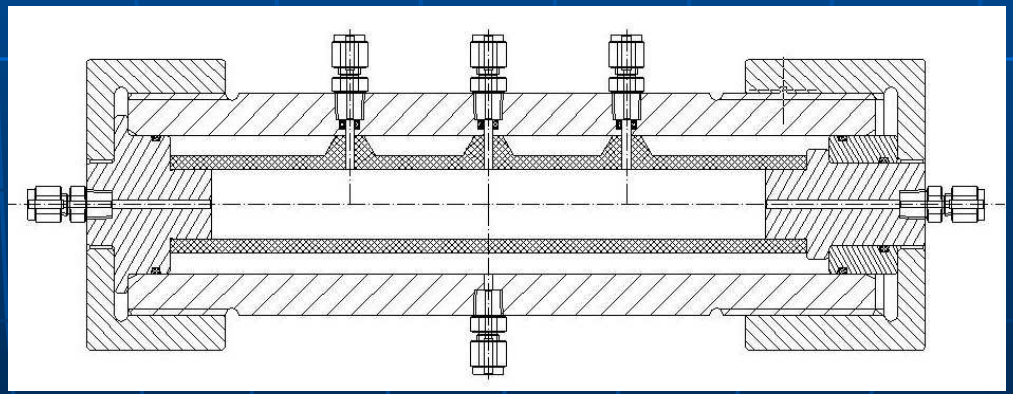


Moduls of Apparatus

CAD design and up to date control system



- Hassler holder in cell
- Controlled valve
- Monitoring by PLC
- Data base on computer
- Remote desk by WEB server
- HMI on website



Model Apparatus

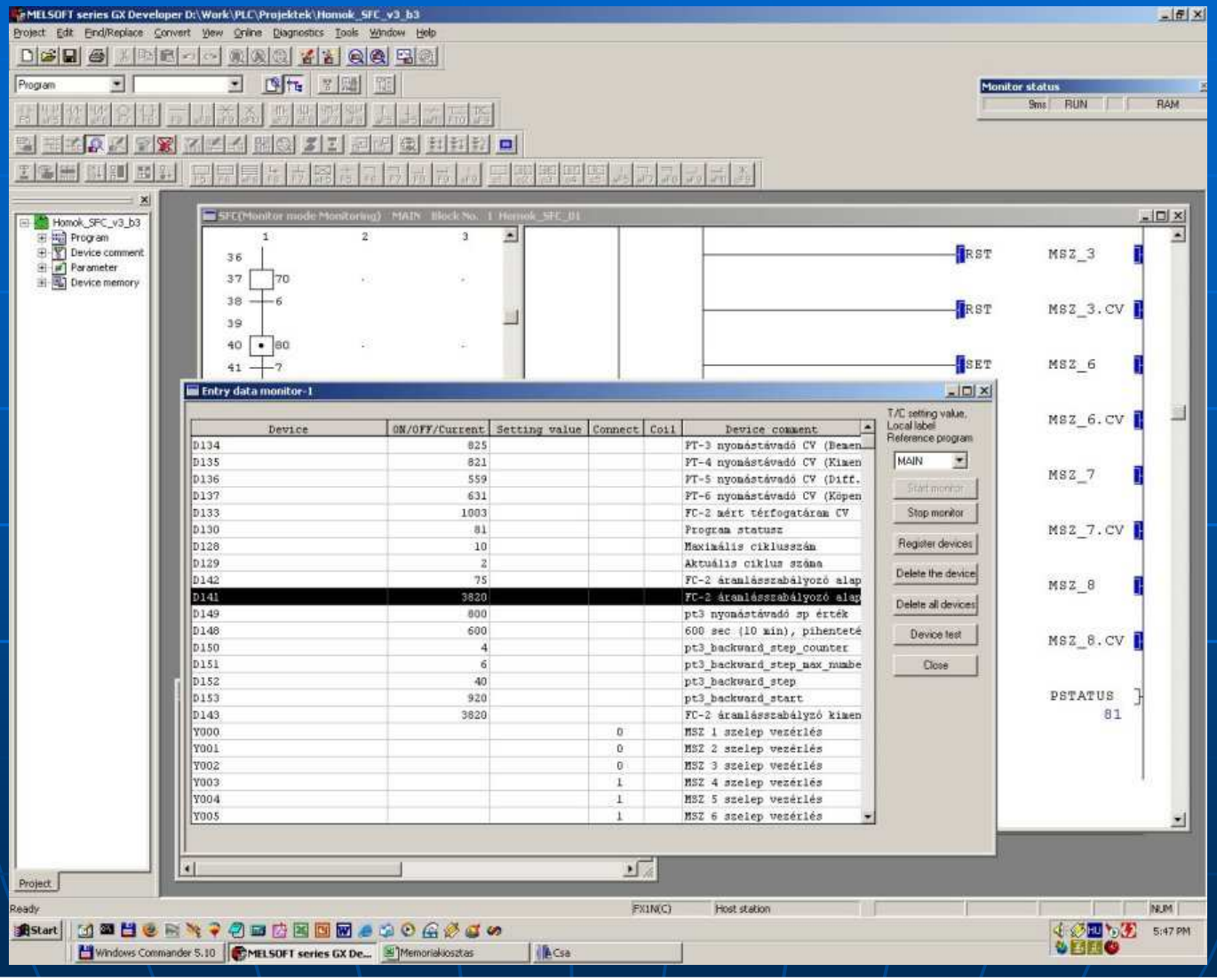
Apparatus in laboratory

Oven with Core Holder

Control System

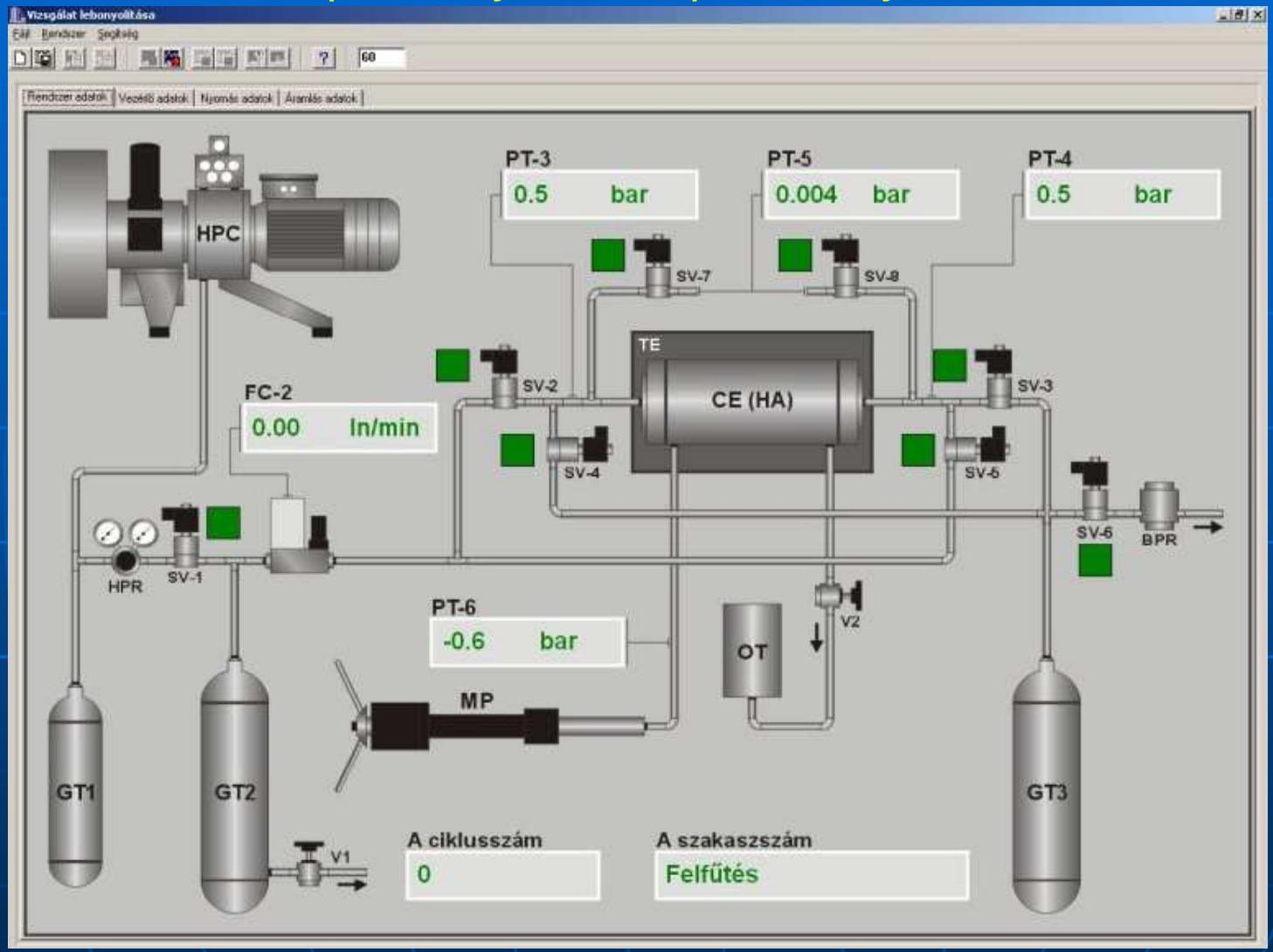
Mitsubishi FX1N PLC and magnetic valves

PLC Program Modules
Mitsubishi FX1N ladder diagram



Human Machine Interface

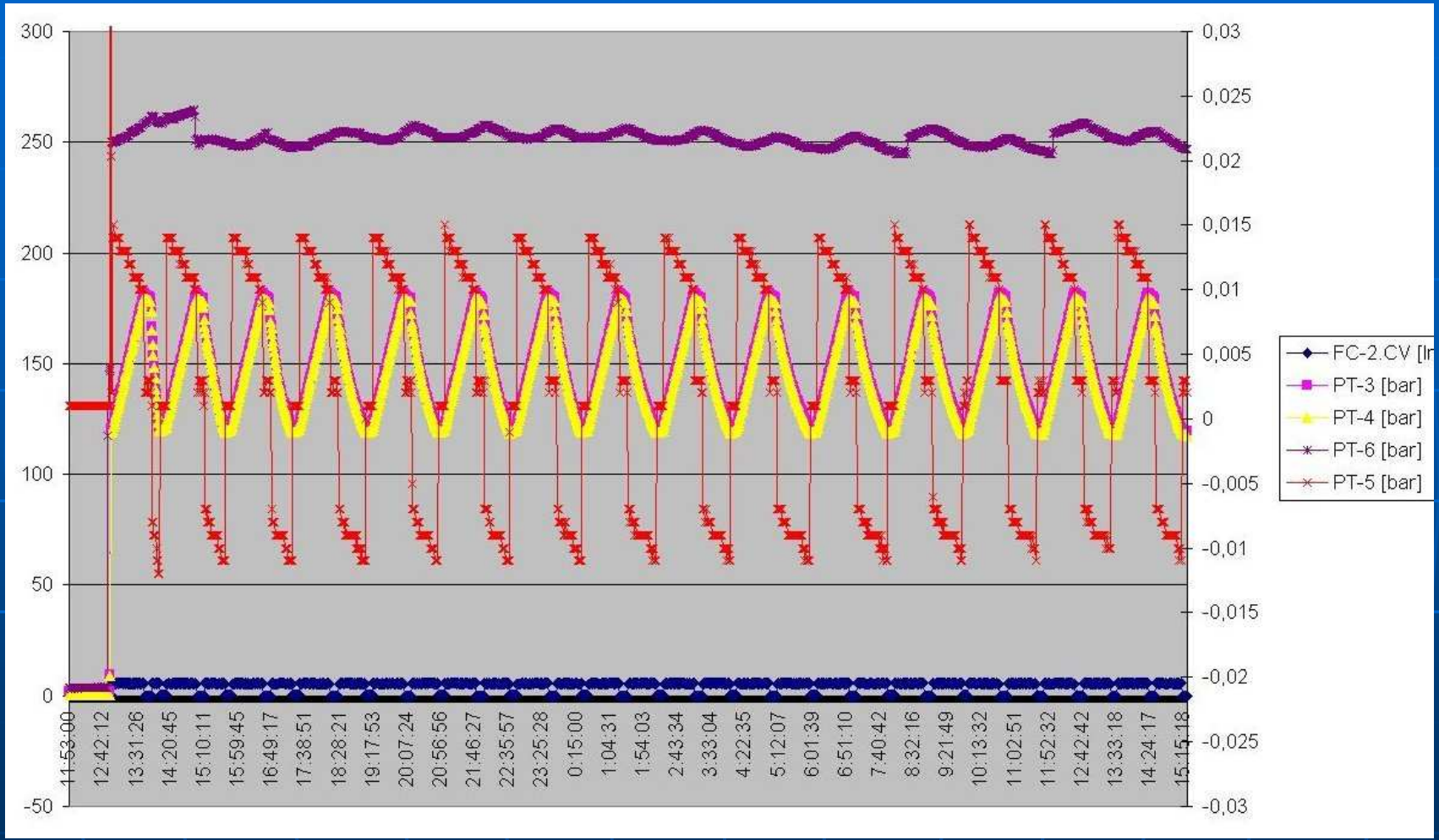
Supervisory and Acquisition system



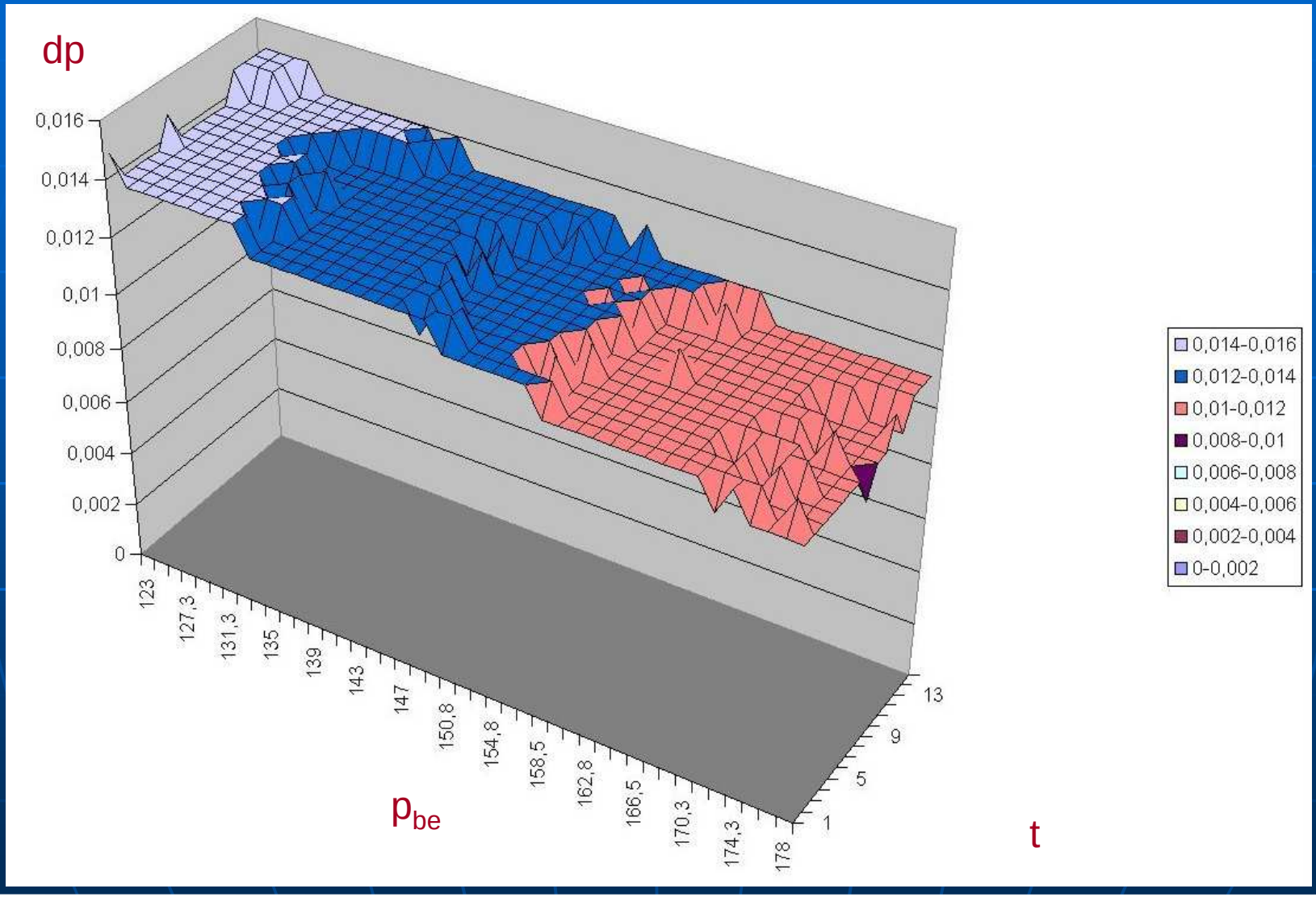
Core data
Rock sample parameters

Core No.	Well No.	Depth	Density	Porosity	kL equivalent	Diameter	Length
		[m]	[g/cm3]			[mm]	[mm]
3	SzGT-32	1821,27-1821,40	1,90	0,2879	708,08	24,80	51,00
5	SzGT-32	1824,18-1824,30	1,84	0,3188	1567,719	24,70	51,00
9	SzGT-32	1825,21-1825,35	1,87	0,3074	608,471	24,60	50,00
12	SzGT-32	1826,28-1826,40	1,83	0,3084	438,307	24,80	51,00
13	SzGT-32	1826,83-1826,94	1,81	0,3322	788,969	24,60	44,40
18	SzGT-32	1827,30-1827,40	1,74	0,3357	930,823	24,80	44,20
1.7.1.B	SzGT-2	1838,54-1898,74	1,76	0,3456	1408,111	24,90	50,70
1.7.2.B	SzGT-2	1899,00-1899,19	1,87	0,3231	601,889	24,90	50,00
1.7.3.B	SzGT-2	1900,46-1900,64	1,84	0,3057	1460,607	25,10	51,10
2.3.2.A	SzGT-2	1913,64-1913,75	1,76	0,3281	1424,698	24,80	45,00
2.3.3.B	SzGT-2	1916,73-1916,90	1,71	0,3488	3819,226	24,30	50,40
2.3.4.B	SzGT-2	1917,42-1917,59	1,67	0,3592	4490,258	24,10	50,30

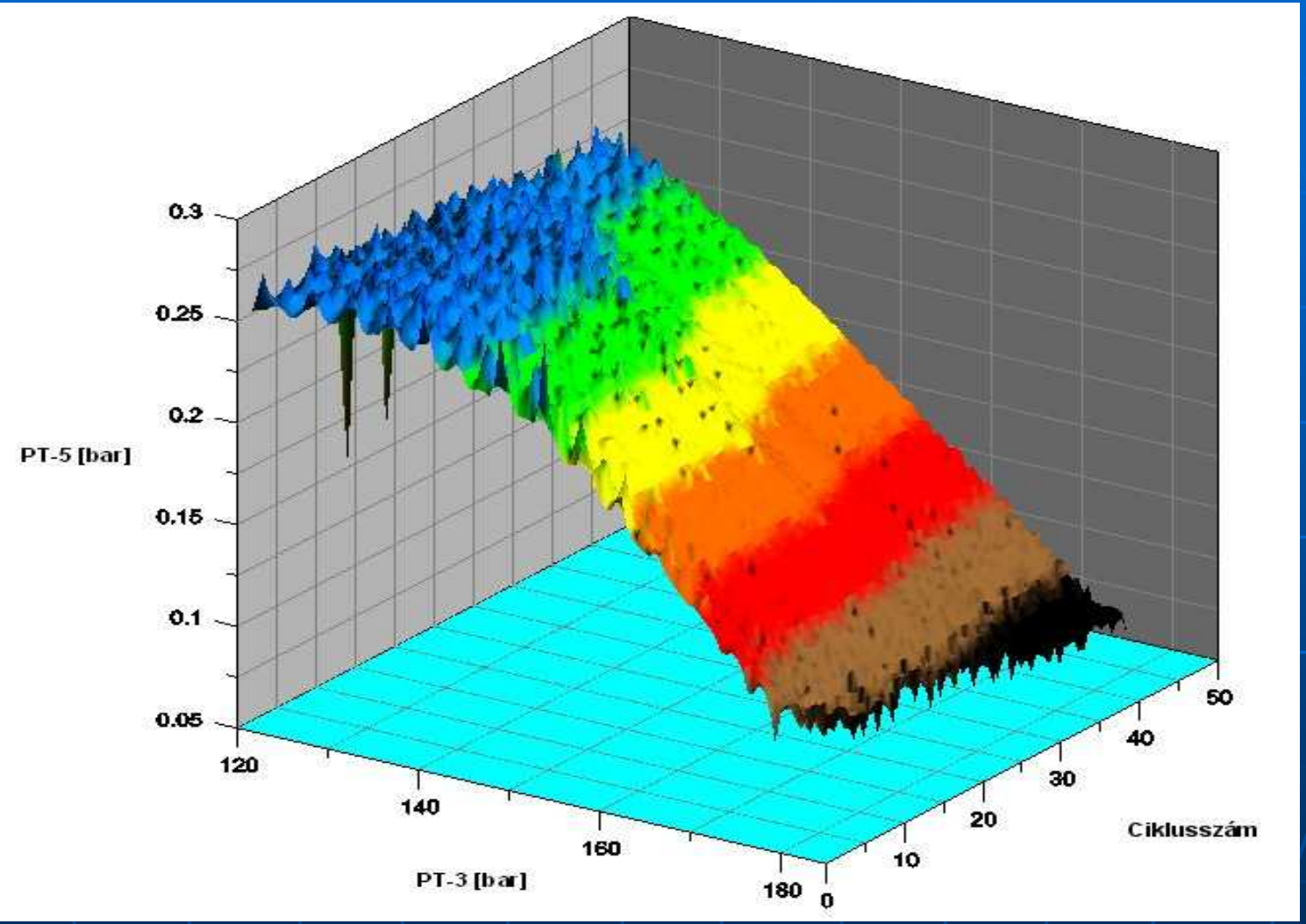
Cycle diagram
Measurement results



Results on 3D diagram



Results on 3D diagram



Results
Core mass results – 40 cycles

Core No.	Well No.	Core mass	Mass with rubber	Rubber mass	Core mass	Mass with rubber	Mass change	Mass change
		[g]	[g]	[g]	[g]	[g]	[g]	[%]
3	SzGT-32	46,7630	91,4258	44,6628	46,6352	91,2980	-0,1278	-0,2733
5	SzGT-32	45,0228	88,9076	43,8848	44,8004	88,6852	-0,2224	-0,4940
9	SzGT-32	44,5177	89,8943	45,3766	44,4114	89,7880	-0,1063	-0,2388
12	SzGT-32	45,1735	89,2551	44,0816	45,0060	89,0876	-0,1675	-0,3708
13	SzGT-32	38,1692	78,8808	40,7116	38,0640	78,7756	-0,1052	-0,2756
18	SzGT-32	37,1903	82,9185	45,7282	37,0825	82,8107	-0,1078	-0,2899
1.7.1.B	SzGT-2	43,3428	88,0058	44,6630	43,2119	87,8749	-0,1309	-0,3020
1.7.2.B	SzGT-2	45,5516	90,4542	44,9026	45,0494	89,9520	-0,5022	-1,1025
1.7.3.B	SzGT-2	46,3985	92,1220	45,7235	46,2749	91,9984	-0,1236	-0,2664
2.3.2.A	SzGT-2	38,2689	82,0046	43,7357	38,1222	81,8579	-0,1467	-0,3833
2.3.3.B	SzGT-2	40,0036	84,6959	44,6923	39,3632	84,0555	-0,6404	-1,6009
2.3.4.B	SzGT-2	38,3335	84,3246	45,9911	-	-	-	-

Results
Changes in pressure during the 40 cycles

No	PT-3 (1.c) [bar]	dp (1.c) [bar]	PT-4 (40.c) [bar]	dp (40.c) [bar]	dp [%]
3	171.3	0.27	171.3	0.263	97.41
9	172.3	0.22	172.8	0.213	96.82
12	171.6	0.27	171.3	0.271	100.37
1.7.1.B	169.6	0.215	169.6	0.208	96.74
2.3.2.A	170.3	0.171	170.3	0.207	121.05
2.3.4.B	-	-	-	-	-

Results
Real permeability (170 bar)

No	ln/min	PT-3 [bar]	d	dp	m	l [cm]	v [cm/s]	k [d]
3	35,51	170,8	2,48	0,268	0,0218	5,10	0,717693	0,297735
9	21,88	170,6	2,46	0,245	0,0218	5,00	0,449963	0,200188
12	26,25	169,3	2,48	0,153	0,0218	5,10	0,535239	0,388941
1.7.1.B	29,88	168,3	2,49	0,197	0,0218	5,07	0,607963	0,341095
2.3.2.A	32,5	170,1	2,48	0,194	0,0218	4,50	0,659561	0,33352
2.3.4.B	-	-	2,41	-	0,0218	5,03	-	-

$$k[D] = \frac{v[cm/s] \cdot m[cP] \cdot l[cm]}{dp[bar]} \qquad [1]$$

$$v[cm/s] = \frac{4000 \cdot q[\ln/\min]}{60 \cdot p[bar] \cdot d[cm]^2 \cdot \pi} \qquad [2]$$

93 °C-on: $m = 0{,}0218\ cP$ [3]

Summary

General

- The equipment and the measuring principle has been established, then the unit transformed the experience, as expected.
- The test method and the device works well in practice, be used.
- The rock cores, each lost in the mass region (below 1 wt%).
- The unstable structure of rock core was cause the measurement eliminate.

Measurements

- Rock stability measurement at 5,5 ln/min flow rate.
- Rock stability with 40 cycle at 30 ln/min average flow rate.

Thank you for attention