INTERPRETATION OF SEALING PRESSURE AS A METHOD OF DETERMINATION THE PARAMETERS OF SEALING COVER

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The paper deals with the integrated method of determination sealing cover parameters based on interpretation of sealing pressure. It is the development of Production Association SPETSTAMPONAZHGEOLOGIA works (1). The method includes: density during grout injection with the help of electronic device (ARS-1); mathematical treatment of this information and putting it into data base, which contains also technological, physical and geomechanical data including fracture voidage, hydrostatic pressure and stresses in the sealing area; interpretation of all information from data base with the help of the computer program (TAU), which executes the following actions: diagnoses grout propagation regime, determines dimensions of grouting cover and estimates quality of sealing.

Fig. 1 shows typical experimental curves obtained with the help of device ARS-1. Grout injection proceeds with stops. The pressure Po, which is registered at these stops is called residual pressure . The pressure Pi which is registered during the process of injection is called injection pressure. At each stage of injection between stops table of parameters is formed (Table 1).

It contains number of stages, average density of sealing grout, Pi at the beginning and at the end of each stage, residual pressure, average injection rate and volume of injection grout.

Table 2 contains additive information necessary for the program TAU - the Sealing Cover Formation Control System. TAU is based on the following hydrogeomechanical considerations.

Table 1

N	Average density g/cm3	Pressure MPa	Residual pressure MPa	Average rate l/s	Injected volume m3
1		0.38			0.0
	1.35	15.37	0.10	10.6	4.0
2		15.40			4.0
	1.35	14.59	0.60	16.6	23.0
3		16.61			23.0
	1.35	17.24	7.21	14.0	98.0
4		15.70			98.0
	1.35	15.60	5.64	12.0	102.0
5		16.93			102.0
	1.35	16.81	5.54	13.9	144.0
6		17.98			144.0
	1.35	17.64	7.52	14.0	177.0

Table 2

Borehole 70', horizon 338-356 m
Packer 0 m
Cement 200 kg/cu m; reagent 20 kg/cu m
Conditional viscosity 35 s
Voidage 0.0097
Hydrostatic pressure 1.9 MPa
1st principal horizontal stress 8.1 MPa
2nd principal horizontal stress 4.9 MPa
Full strata pressure 9.2 MPa
Young's modulus 20 GPa
Poisson's ratio 0.25
Adhesive capacity 1.5
Friction angle 30°
Rupture strength of rock 1.5 MPa

Results of numerical modelling of grout propagation in fractured rock taking account of stress-strain state of rocks, showed, that residual pressure Po differs from injection pressure Pi in the value of viscosity terms, which depend on injection rate. Due to this fact effective properties of fractured rock can be determined. Such an opportunity can be realized only at elastic regime of filtration, when all the fracture voidage is considered to be sealed. At each injection stage the following effective properties are determined in program TAU (Table 3): shear strength limit, which depends on rock permeability and dynamic shear stress;fracture permeability; capacity.

So it is not necessary to use as initial information such inaccurate definable parameters as fracture width,number of fractures per meter and capacity. They are replaced with a single parameter-voidage.

The Sealing Cover Formation Control System TAU has a "friendly" interface, very short calculation time, represents all the obtained results in convenient form with tables and graphics.

Table 3.

N	Well-foot pressur	Resid. pressur	Dynam. shear stress	Visc. *1e-3	Shear streng. limit	Fract. permeab	Volum. capacit	Grout propag. distan.	Useful grout volume
	MPa	MPa	Pa	Pa*s	MPa	D	1/GPa	M	cu m
1	0.1								0
	14.8	3.2	67.0	54.0	–	–	–	–	4.0
2	13.8								0
	13.0	3.7	67.0	54.0	–	–	–	–	19.0
3	15.4								0
	16.1	10.3	67.0	54.0	0.7	7.8	3.4	11.7	75.0
4	14.9								75.0
	14.8	8.7	67.0	54.0	0.6	6.5	0.2	12.0	79.0
5	15.8								79.0
	15.6	8.6	67.0	54.0	0.5	6.6	1.5	14.9	121.0
6	16.8								121.0
	16.5	10.6	67.0	54.0	0.5	8.1	0.7	16.8	154.0

The results of inculcation of introduced technological scheme in the Kuznetsk coal field are shown in the table. Cemented rocks are fissured sandstone, mudstone and siltstone. The capacity of cement pumps did not exceed 20m. The number of injected holes located along the perimeter of the vertical shaft was 6. The dia of shaft was 6-8m.

Table

Mine	Heading	The length of cemented area, m	Expected water inflow cu.m/h	Residual water inflow cu.m/h
"Raspadskaya"	5th block shaft, ventilation shaft of the 4th block	101 118	90 208	4 5
"Beryozovskaya"	Ventilation shaft air supply shaft skip shaft	70 294 124	175 175 175	5 5 3
Mine named after Lenin	Cage shaft	246	127	10

The residual water inflow more than normal 5 cu.m/h in the cage shaft at the mine named after Lenin is explained by the fact that the shaft crossed the pebble-sand parting which was not cemented.

As a whole the results of carried out researches show that registration of physical peculiarities of cementation allow to provide its quality using unstable cement solutions.

If anisotropy in stresses exists, hydraulic expansion occurs mostly along those fractures, the walls of which are acted by smaller confining stresses. Radius of hydraulic expansion zone RH is less than radius of elastic sealing zone Rh. Inside the zone with radius Rh the quality of sealing cover is guaranteed to be high, in the zone $Rh < R < Rh$ quality is good. Injection of grout with high values of dynamic shear stress and viscosity in low-permeability zone near borehole or to the formerly sealed zone may be accompanied with vertical hydraulic fracturing along the direction of maximum confining stress. In our method the failure condition at the beginning and at the end of each injection stage is checked. Usually the process of hydraulic expansion in sealing zone is accompanied with vertical hydraulic fracturing near the boreholes.

Development of horizontal disk-shaped fracture or horizontal grout propagation in layered formation may take place in impermeable rock without vertical fractures. It is a non-desirable process and it should be avoided.
Another regime of sealing is free flow of grout. At free flow regime the propagation of grout is not elastic, because grout internal pressure is less than normal confining stress acting on fracture walls. So the mechanical effect of grout influence upon the rock is not essential. Fracture voidage is partly sealed of big tectonical fractures and joints or zones of anomalous high permeability takes place. Investigation of injection pressure and residual pressure behaviour helps in diagnosing this regime. The volume of grout injected at free flow regime is not included in the "useful" volume, which determines the dimensions of grouting cover, but it is necessary for the preparation of sealed horizon before the elastic regime.

Finally, when grout is propagating through the medium with low resistance, it may come out to the overlaying horizons, so the quality of sealing will be low.

All these regimes of grout propagation are diagnosed in the program TAU, which gives the description of events taking place during grout injection. Thus the process of sealing is fully program-controlled.Fig.2 shows in example of how the desktop looks like while TAU is working.

Geophysical experiments with the application of acoustic emission technique during the process of sealing cover formation (2) and numerical modelling of clay grout propagation in fractured rock taking account of stress-strain state of rocks showed: creation of sealing cover with high efficiency proceeds with elastic deformation of sealed fractures walls up to shear failure in the fractures of in the surrounding microfractures. This process is accompanied with the process of hydraulic expansion of rock, which forms high residual pressure and provides its conservation during some time. Thus the reaction of fractured rock necessary for the creation of qualitative sealing cover is achieved. High quality of sealing in the hydraulic expansion zone is explained as follows. When grout injection is finished, the inverse deformations of rock cause the additive compression of grout in fractures, its condensation and good adhesion with rocks.

When internal pressure of grout is greater than confining stresses in rock, the "elastic sealing regime" takes place. Deformation of fracture walls occur, while the anisotropy in stresses leads to the appearance of so-called "induced" anisotrophy in permeability.

We consider regime of hydraulic expansion to be the optimum
regimes of hydraulic expansion to be the optimum regime for qualitative sealing cover formation. It is the basic approach of proposed method to distinguish it from formerly used methods.

Dimensions of hydraulic expansion zone are determined by comparison of internal grout pressure in the area of sealing with theoretical value of hydraulic expansion pressure in fractured-porous rock.

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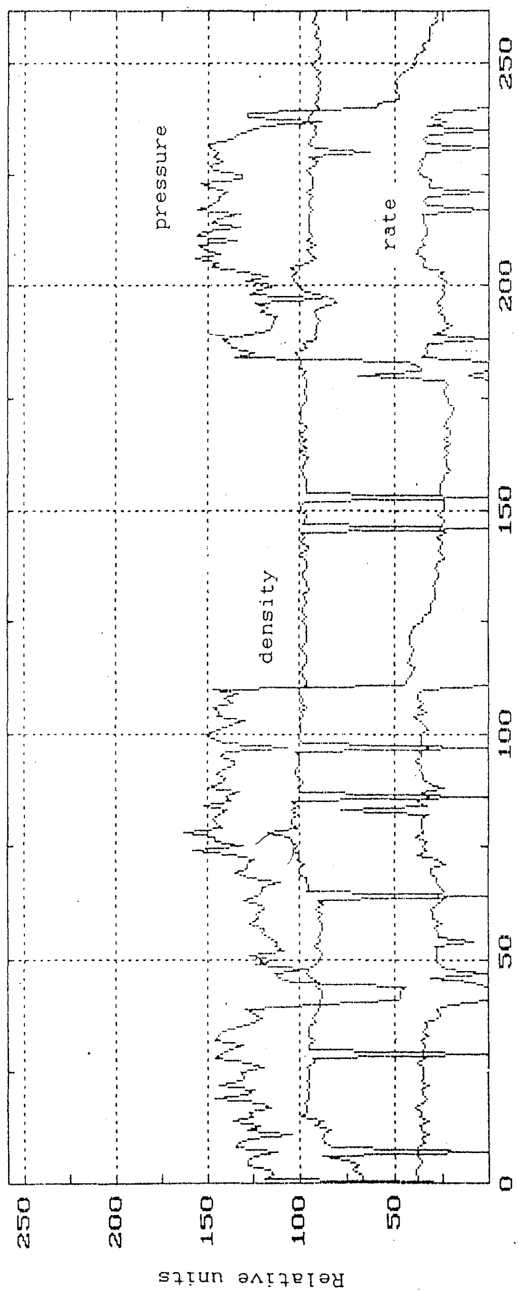
pressure
density
rate
Relative units
250
200
150
100
50
0
50
100
150
200
250

Fig.1

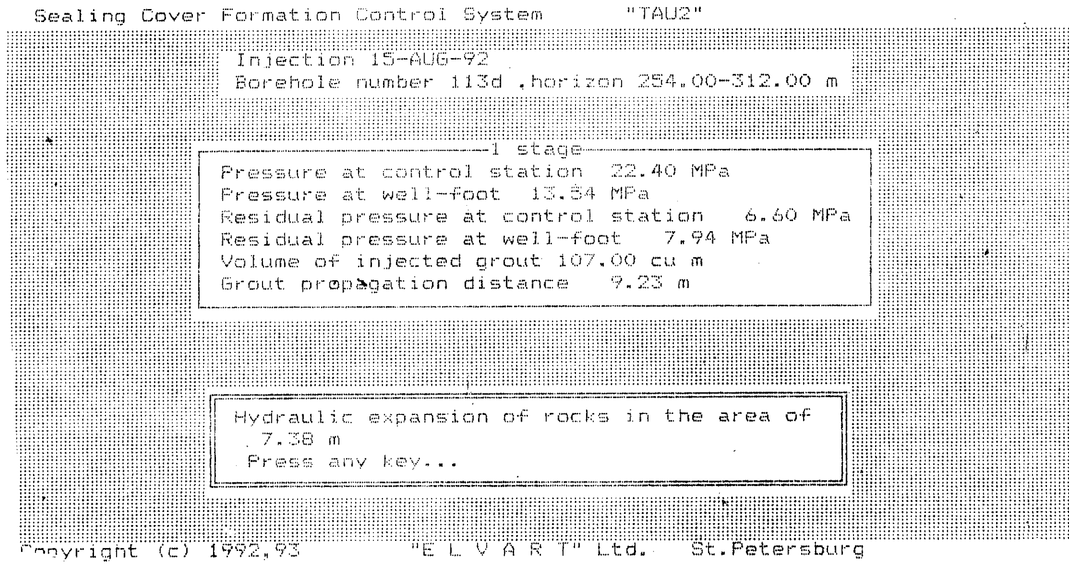
Sealing Cover Formation Control System "TAU2"
Injection 15-AUG-92
Borehole number 113d .horizon 254.00-312.00 m
1 stage
Pressure at control station 22.40 MPa
Pressure at well-foot 13.54 MPa
Residual pressure at control station 6.60 MPa
Residual pressure at well-foot 7.94 MPa
Volume of injected grout 107.00 cu m
Grout propagation distance 9.23 m
Hydraulic expansion of rocks in the area of
7.38 m
Press any key...
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Fig.2