SPECIAL CONTROL METHODS OF UNDERGROUND WATER AND SEDIMENT IN THE VESZPRÉM COAL MINING COMPANY

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SUMMARY

The control of water inrushes from sandy aquifers is one of the most important tasks in the Veszprém Coal Mining Company, /VCMC/ due to the generally significant sediment yield. Methods of dewatering and drying of such sandy layers are described. The special technology of compressed air dewatering is detailed. A practical example demonstrates that the latter method is not constrained by closed hydrogeological formation. From time to time, several thousands m^3 of sediment may be carried by water inrushes from sandy aquifers into mine openings. Solid content of the water is generally greater in the initial period, but it may be cyclic. Sediment treatment, in traditional dewatering station, consists of the following process: settling, gathering and removing. By the use of slurry pump and hydrocyclon, settling and gathering can be eliminated. Several methods for mechanized sediment gathering are shown.

INTRODUCTION

The control of water hazard and all activities related to mine water have a great economic significance for VCMC. Among the various activities will be reviewed special technological problems and solutions for the removal of sediment stemming from sandy aquifers and entering mine openings.

Mine water control

A great part of our mines is under water hazard. Sandy aquifers are generally underlying but often also overlying the coal seams. The method of mine water control is always preventive drainage. Drainage equipment has been developed from several years of experience. The most generally used equipment is the filter located in the layer. Preconditions for the selected drainage method and equipment are that seepage velocity around the well should be smaller than the critical value causing hydraulic failure and the yield of well should stay as high as possible throughout a long period.

Between outer and inner sides of the filter, an energy drop is formed, whose magnitude can be controlled by the filter structure with due allowance to aquifer properties and piezometric head. The following filters are used: Simple-wall filter with various specific filtering surfaces, double-wall filter filled with gravel and glued gravel filter with outer and without inner walls. These filters correspond to greater and greater energy drop. Sieve cloth is not applied because of the formation of loam deposit. Experience has shown that this loam deposit leads to yield reduction.

A very important phase of drainage technology is well opening aiming at the gradual adjustment of energy drop and stable filter frame in the layer.

In case of an underlying aquifer it is generally sufficient to reduce piezometric head. This reduction has been achieved by regular drainage in the Várpalota and Balinka areas. For the Várpalota area, experts of the Central Institute for the Development of Mining have shown that the number and yield of possible inrushes are governed by the energy interrelationship between the underlying aquifer and the protective layer [1]. The total yield of inrushes depends on the average drawdown.

$$S = S_o - I_o m \qquad /1/$$

where m is the average effective thickness of the protective layer, I_o is the average threshold gradient of the protective layer and S_o is the original piezometric head. Data on the large number of inrushes from the underlying aquifer had been used to deduct threshold gradients which have been fully verified by practice. In order to prevent such inrushes, a necessary drainage network density was determined. However, even after the development of this prescribed network density, inrushes from the underlying aquifer occured over some areas. Experience has shown that such a network density prescription does not simplify the task, since the planning of the necessary further network development requires high expertise. Experts of our company demonstrated that, given threshold gradients for the protective layer, the satisfaction of prescribed piezometric levels for different areas should be sought. Now the task is really simplified since the density of drainage wells must be increased until the prescribed piezometric levels are recorded in observation wells. In overlying sandy aquifers, especially in those adjacent to the coal seam to be mined, it may happen that the required rate of dewatering cannot be attained. In such cases, piezometric head reduction is not sufficient because drying of the layer is to be sought. However, this drying process is much slower than pressure reduction due to smaller porewater energy. Drying of the two-phase, practically cohesionless sand into three-phase state results in an apparent cohesion known from soil mechanics. This is advantageous as far as the support of mine openings is concerned.

In case of direct overlying aquifers, dewatering intensity can, but not sufficiently, be increased by a greater number of wells. It is more efficient to increase the natural energy level of porewater. Before a special method for this purpose is described, hydraulics of the problem is reviewed.

In a porous-media aquifer, the amount of drained water is proportional to the rate of water level lowering, and depends on the drained area, seepage coefficient, and hydraulic gradient. The seepage coefficient cannot be changed. Greater flow can be attained by increasing the drained area and/or the hydraulic gradient. The increase of drained area is expensive and its effect is relatively limited. The only possibility is, thus to increase the hydraulic gradient.

The following simple model has been constructed for the study and illustration of the process. There is an open basin filled with saturated sand. Pore water can be removed through an outlet of the basin. Three cases are analysed as shown in Fig. 1.

In the first case, the saturated sand is drained by borings and underground openings. There is atmospheric pressure P_o at both the water level and drainage.

The hydraulic gradient is: $I = \frac{h}{l}$ /2/

In the second case, vacuum is formed at the outlet: $P_v < P_o$.

The hydraulic gradient is: $I = \frac{h + /P_o - P_v}{l}$ /3/

In the third case an excess pressure P_k is induced at the inflow place, that is, $P_k > P_o$, and

$$I = \frac{h + /P_k - P_o/}{l} \qquad /4/$$

A fourth case can be a combination of the second and third ones.

In the third case, hydraulic gradient can be much higher than in the vacuum case, since theoretically:

$$/P_o - P_k/_{max} = 10 \text{ m}$$

but is not more than 5-6 m practically.

Our applied method uses compressed air to reach the third case: $P_k > P_o$. Boreholes or any mine opening may serve for feeding in and drainage.

In practice, the dewatering system is always open. There is no air storage in the system. As a result, there is a fear that compressed air will escape due to the great viscosity difference between water and air, that is, one cannot increase the energy content of an open system.

The resultant of passive forces per seepage path length depends on rock properties, seepage path length and seepage velocity. The amount and pressure of continueous compressed air input control the pressure level in the inflow zone. These phenomena may transform a closed system into an equivalent open system.

The mining application of this technology was preceded by a successful pilot experiment. The first full-scale mining experiment was performed in 1974. First, we had prepared to observe drainage flow then compressed air has been fed into a cased borehole. Fig. 3. shows fitted observed pressures and flows. In the first part of the experiment, flow has strongly been increasing except two attenuation sections. Attenuations have happened around 40 l/min as a result of a provisional closure of the gate valve and around 160 l/min. This latter one was terminated as air has blown out. At the drainage place, highest flow increase occured during air blow-out noticed by eye and ear as well. Water has become turbid, and flow has increased 27.5 times to 220 l/min.

After closing the gate valve, flow has sharply decreased.

This experiment was repeated several times before full-scale use of the technology. Main conclusions drawn from these experiments are as follows:

- the method can efficiently be used for the acceleration of the drainage process and for dewatering;
- an excess increase of input air pressure may exert adverse dynamic effects on the system, and drainage flow becomes fluctuating;

-flow can be increased even if drainage area is not increased;
-there is an upper limit of seepage velocity;
-critical flow should be approached by gradual pressure increase;
-there is a relationship between air pressure and flow, which can be used for process control within certain pressure limits /Fig. 4./.

Sediment treatment

In spite of the planned control activities, water inrushes could not always be prevented.

Ensuing engineering problems and correction measures are reviewed through the example of a Balinka karstic water inrush. This inrush occured on level -30 m in facing No. 312/III of the Western area, on 19, Sept. 1974. As typical to every inrush, the greatest problem was caused by sediment carried by inrush water.

The sandy aquifer directly overlying a great part of preliminary roadways suffered hydraulic failure due to seepage flow and filled the suction pipe of pumps. From the inrush place to the double roadway in the division level W.IV. water was heavily pumped by a series of pumps BIBO-200, BIBO-5 and centrifugal pumps in a 200 m long incline in order to maintain a step-by-step backward escape. Sediment carried by water wore out the pumps shortly /sometimes within 1-2 days/, and unexpected mud inflows captured some of the pumps. Water could be controlled only at the horizontal section of the double roadway by using torcrete lining along a 200 m length of the double roadway to stop interface between water and sand. Water conveyed by booster pumps flowed into the sump system of the pumping station underneath the shaft. Sediment carried by water filled up this sump system and the suction line had to be shortened. Suction head of pumps was 5,5-6 m, and cavitation occured during even clean water pumping. Stronger cavitation emerged during the pumping of sandy water of higher density.

As an effect of the joint wear caused by cavitation and sand, performance of the pumps deteriorated within two months in such a degree that the 6 dewatering pumping units could lift 4-6 m^3/min with great difficulties. A number of repairs had to be continuously effected.

The performance of pumps has been measured 3 months after the inrush event. The original pump performance curve and the pipeline performance curve correspond to a discharge of 6,1 m^3/min. However, the actual suction head of

$$H_{sz} = 3,2 + 1,31 = 4,51 \text{ m}$$

resulted in a discharge of 4,7 m^3/min only, which further decreased to 1,8 m^3/min when water level dropped by 0,4 m.

In order to improve suction performance, the company ordered the design of jet pumps to be connected to the pumps from the Miskolc University of Heavy Industry /MUHI/. As a result, pumps were later equipped with adapter jet pumps.

By December, 1974 both sumps of the pumping station beneath the shaft were filled up with sand, and pumps failed. As a consequence, water arriving gravitationally from the Western inrush was conveyed through a pipe-line to the sump system of the Southern pumping station. In this sump, sand settled as a result of slow velocity and long pathway, and the pumps lifted relatively clean water.

In the meantime, both flow and sediment load decreased in the horizontal double roadway W. IV. However, on December 17, 1974 the inrush flow of 2,5-3,5 m^3/min appeared again through a new pathway, abandoned mine openings in the vicinity of the sump cleaning roadway of the Southern pumping station. From time to time, its solid content was 10-15 %. This slurry entered the sump through the sump cleaning incline. Under it, flow velocity suddenly decreased, and a sediment block was formed close to it within a short time, preventing flowing further to the part of the sump not yet filled-up. Sediment removal could be effected, in the first period, by scoop shovel from the sumps in an alternating way, but in February, 1975 a block was formed in the operating sump when sediment removal was not finished in the other one. In order to slacken this block development, water had been kept at the lowest possible level in the sump. As a consequence, pumps conveyed sandy water without settling. Though pumps in the Southern pumping station were already equipped with jet pumps and operated efficiently, sandy water caused serious troubles within some days.

This time, 30-35 skilled workers per day repaired the equipment of the two pumping stations. In mid. April, 1975 slurry, at its entering to the sump, was directed into an open settling canal separating a part of the solid materials of high settling velocity into a bogies. This operation was of low capacity and low efficiency. The task emerged to prevent sand inflow into the sump since it would have been partly deposited there, the loading of bogies was expensive and sand would have caused pump failure.

After the inrush, by May-July 1975, the sandy water flow of 2,5-3,5 m^3/min wore-out, in spite of continuous repair, equipment of the pumping station of 104 m^3/min capacity in such a degree that mine flooding endangered occasionally.

This predicament was solved by the application of slurry pumps and cyclone station. Slurry was directed into a slurry pump 4'/3 D-AH, and conveyed through a 400 m long pipeline of 150 mm diameter to a cyclone-station located under the shaft. This cyclon separated the majority of particles greater than 60 µm into bogies, which were hauled directly to the surface/Fig. 6./.

As a further development, upper water of the cyclone of 350 mm diameter was directed into a slurry pump 3/2 C-AR, and cleaned further by a cyclone of 250 mm diameter. Overflowing water from the cyclones was conducted into the cleaned sump system of the pumping station underneath the shaft. In this sump one part of the slurry settled, the other part was conveyed together with water to the surface. Sand deposited in the sumps was put into bogies, by the help of slurry pump CS-100 and compressed air transporter Putzmeister P 484 FMR.

According to the design of the Institute for Mineral Preparation of MUHI, a fluidizing equipment was constructed along a 50 m long section of the sump. In such a way, deposited sand of 1-1,2 m thickness was fluidized and transported to the surface by a centrifugal pump. This equipment operates even now when needed. So far no significant deposition has occured along this section.

In order to accelerate and simplify sump cleaning an experiment was effected in one of the sump branches of the Western pumping station. Slurry pump 3/2 C-AR was equipped to a bogie frame, a gathering plate was installed before it, equipped with nozzles, using pressurized water of 2,5 MPa. By the help of the nozzles, and if it was necessary, by manual jet tubes the deposited sand was fluidized and removed by a slurry pump. The cyclone station separated sand from the slurry. This way, 70-80 % of deposited sand could be removed. This sump cleaning method is much quicker and needs less labour than the use of transporter.

Also, according to the design of the above Institute, further experiment was effected to remove deposited sediment by the help of a special slurry pump using the principle of jet pump. At present, the Institute is charged by us to design the whole system of sediment removal.

The occurrence probability, control and elimination of water inrushes as a natural hazard, depend on natural and technical conditions.

Recent experience has shown that in addition to the knowledge of natural conditions, technical conditions have become more and more decisive.

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List of Figures

Fig. 1. Illustration of the drainage of a sandy aquifer

P_o: atmospheric pressure
l : length of seepage path
h : piezometric head
P_v: vacuum used
P_k: excess pressure

Fig. 2. Experiment on drainage by compressed air

B 415: borehole to feed compressed air
V : drainage, roadway
sand
clay
coal seam
marl

Fig. 3. Discharge as plotted against head and time

Q : discharge
t : time, days
P : compressed air pressure at well B 415
A : air blow-out

Fig. 4. Discharge as plotted against head

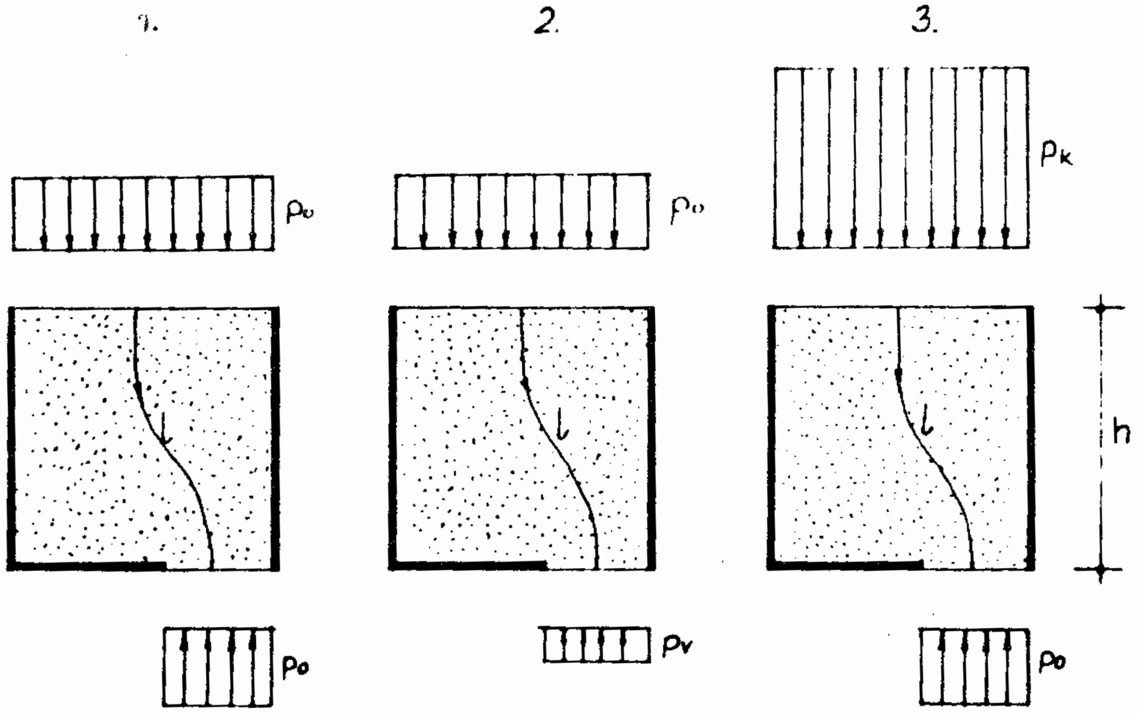
Q : discharge
P : compressed air pressure at well B 415

Fig. 6. Sump cleaning activity

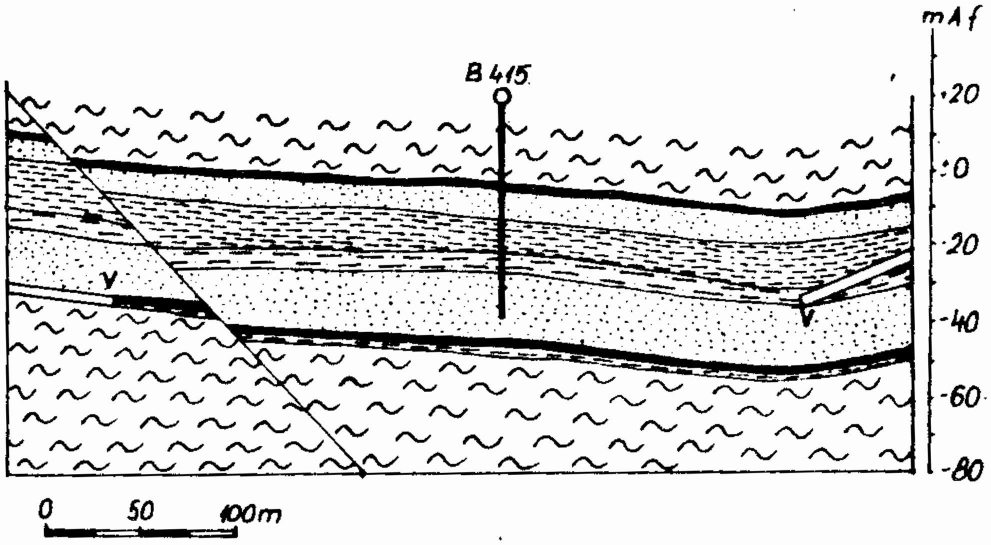
manual and mechanized loading
separated sediment
separation by hydrocyclone

Fig. 6. Principle of cycloning

A : water and sediment
B : slurry pumps
C : outlet tube
D : hydrocyclone
E : outflow of treated water into the sump



1. ábra Fig. 1



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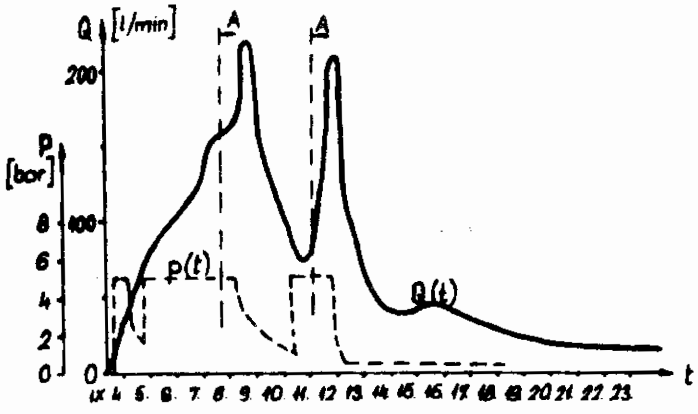

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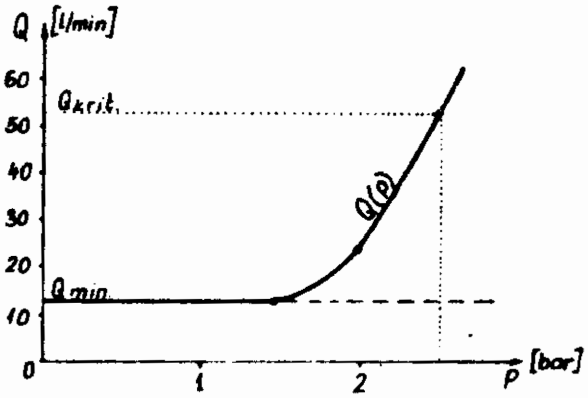

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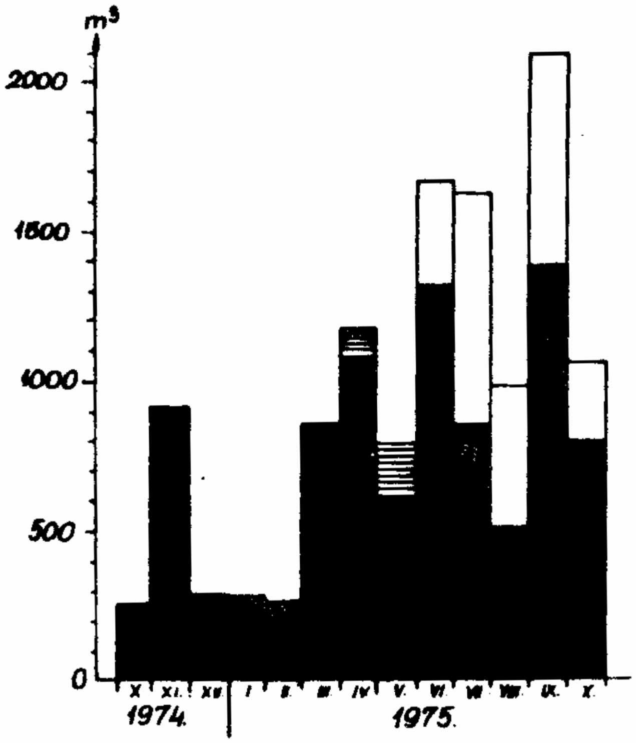

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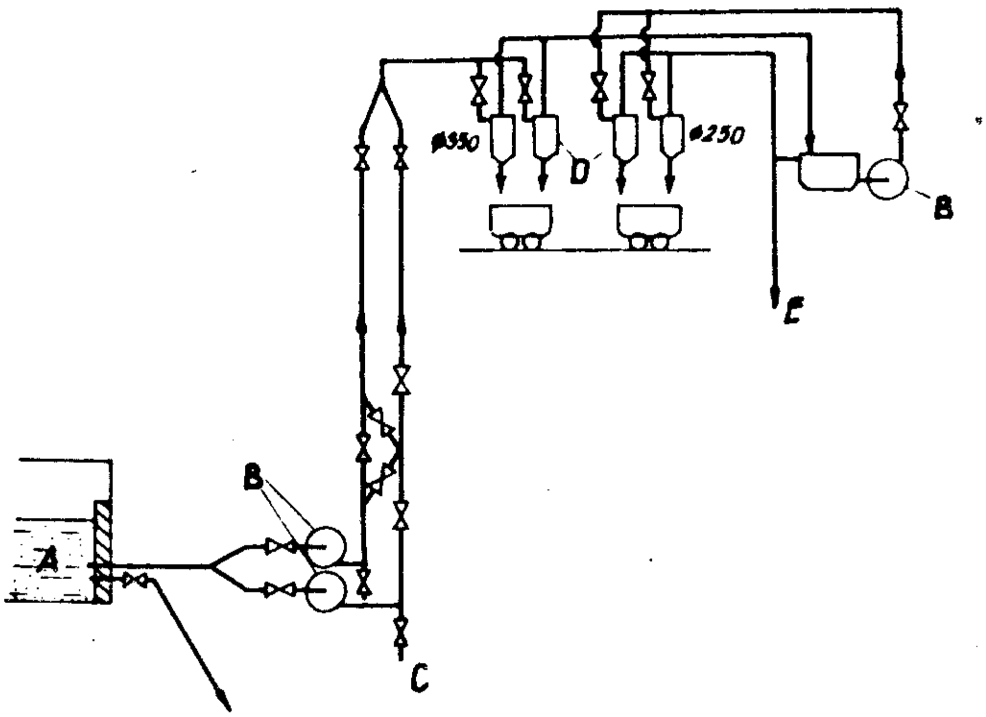

6. ábra Fig. 6