Water Inrush Danger Reduction by Cavern Detection and Stowing

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ABSTRACT

The paper discusses the preventative measures undertaken in a brown coal mine in a karstic limestone reservoir the town of Dorog in Hungary. Before the mine was opened the water conductivity of the limestone was reduced and the danger of water inrush during mining. This was achieved by stowing based on hydrodynamic volume determination of the caverns and by special strengthening of the stowing material.

INTRODUCTION

The important raw material of the Dorog area is the Eocenic brown coal. For more than 200 years practised there has been coal mining in the area and during the second half of it, there has been a continuous struggle against water danger from the bedrock side.

A geological feature of the area is a fissured, in some places becoming considerably karstic, very thick Trias limestone situated under the mined Eocenic coal layers, with wedged in bedrocks of 10 to 60 m thickness.(1)

The tectonic influence has caused a deep fissure within the limestone, resulting along it in a karstic process during different geological history periods. It has been justified that along ruptured structures water headings of large diameters and water reservoir caves can appear. The large caves are connected by a fissure net, ensuring a hydraulic connection between caverns, thus the limestone mass can form a uniform water holding formation in the basin and even over the whole Transdanubian Mountain territory.

Having been constrained to work on deeper and deeper levels, the mining activity had to face step by step the karstic water danger from bedrock side. Since during the exploitation under karstic water standstill level the water ingress from the limestone became more and more frequent, with a very changing rate; there were water inrushes of 0,1 to 100 m^3.

The importance of experiences acquired during the struggle against water danger thereatening the Dorog mining is exceeding the basin, because the entire coal resources and a considerable part of the bauxite ones on the Transdanubian Mountain territory can be found under similar geological circumstances.

There were developing different methods of defence in the struggle against karstic water danger. However they were succeeding in certain extent but the danger could not be eliminated.

In the recent decades, the mining has reached the depth of 200 to 400 m under karstic water. In the defence against the bedrock side water pressure of 20 to 40 bar, the mining profession had often to succumb by closing the mines in succession because of water inrushes.

The increasing pumping was limited, because of economical influence, by environmental protection points of view as the Budapest thermal and medicinal waters and most of the drink water supply of this area are also supplied by this system. The limits of the water reservoir systrem are delimiting the mining pumping.

The task for us should be to elaborate a water protection system to restrict the occuring probability and quality of water inrushes.

One of the possible ways of water inrush prevention can be the cavern stowing. The outlined in our study multiple stowing method has been adopted at the Lencsehegy mining plant. The essence of it is to detect the large volume caverns and water headings by geophysical measurements, open them up by deepened from the surface drilling, determine their volume and close them before the mine exploitation, with the packing material intruduced through bore holes.

THE HYDRODYNAMICAL METHOD OF CAVERN VOLUME DETERMINATION

We have to determine the cavern sizes to be able to design cavern packing. By knowing the volume, we can select the stowing technology and economically plan the operation.

The outlined in the introduction hungarian mining conditions required developing the method of cavern volume determination.

According the examination technology[2], the volume of the filling the cavern fluid will be rapidly increased, usually by take out of liquid from the cavern. The liquid mass-acceleration and deceleration because of the fast blowing off will take place in some seconds.

Considering further pressure changes as noise, the cavern size can be calculated from the pressure decreasing with the help of material balance and the thermodynamic equations. The action of volume increasing (pressure decreasing) will be replaced by filtering from the surrounding the cavern permeable rock parts and the temperature and pressure balance can be restored again.

Table 1 is demonstrating the ideal pressure change developed in the cavern during the operation, in the pressure-time coordinate system, where (1) represents the static pressure at (2) point of time when we take out ΔV_{KAV} volume from the cavern, under the influence of which a ΔP_{KAV} (3) pressure decrease will occure, then the (4) curve will show the pressure restoring, determined by the reservoir rock permeability.

The basic formula of cavern size determination:

$$V_{KAV}=\frac{\Delta V_{KAV}}{c \cdot \Delta P_{KAV}}$$

where c is the compressiolity of the filling the cavern liquid.

There's only one practicable restricted control of hydrodynamically determined cavern sizes, thus we have calibrated the measuring-evaluating method on well known volume spaces.

Calbration examinations have been made with a 1000 m^3 closed steel tank, on a 2505 m^3 2380 m long stressed concrete water conduit, in a 870 m^3, resp. 110 m^3 open oil, and water storage and on a dissolved in a 149000 m^3 volume salt dome cavern.

The calibration results have justified the applicability of the measurement evaluation method.

Table 1 indicates the determined for packing process cavern volume, adopted at the Lencsehegy mining plant of Dorog mine, including the volume of the pressed into caverns stowing material.

The hydrodynamic cavern size determination itself doesn't give any answer for cavern morphology, but by using modern hydrodynamic measuring and evaluating methods, we made promising experiments to determine the maximal cavern extent.[(3)]

PACKING EXPERIENCES AT THE DOROG-LENCSEHEGY MINING PLANT

To determine the cavern volume is an essential factor of packing before water inrush. One has to know the cave volume for the economic decision in order to work out the packing technology.

The essence of the multiple packing method is to get a reliable cave shutting by one or two stepped technology, depending on the cave size.[(4)]

When the explored by drilling cave colume is more than 1000 m^3 and its absorbing capacity 1,0 m^3/min or bigger, the packing shall be made in two steps.

By the first step we have to introduce granular material in pulp shape - sand, sandy loess - into the cavern, with a determined by the surface elevation pressure difference.

Natural porous materials can be often found on the Dorog coal basin surface, to introduce the large volume material doesn't mean any problem according industrial practices. Otherwise, the cave filling in this manner has been employed over 70 years, with varying success in Dorog.

The material introduction should be continued until the bore hole absorbing capacity could be reduced to 400 to 500 l/min.

After that, we have to press with high pressure a pulp - consisting of a mixture hardening under water - into the unfilled water headings and in the pores of the limestone.

The overpressure employed for packing is 110 to 120 bar. The high pressure material introduction has several effects:

- the continous high pressure pulp flow hinders the distribution of the mixture components,

- the packed material is filling a considerable part of the fissure and pore volume,

- the high pressure can compress the filling material which could considerably reduce the flowing out possibility of the cavern,

- at the upper part of the cavern, i.e. at the belt near the mining operations, it can ensure a firm shutting against water flow in.

When preparing the hardening pulp, we try to reach the technical and economical optimum, thus the hardened material will have suitable solidity parameters.

The final strength of the binding material will be 7 to 10 MN/m^2 under laboratory conditions. The solidity of the bore samples will also reach the 4,5 to 6,5 MN/m^2 values, which - taking in consideration the destructing drilling activity as well - could be acceptable.

The cavern filling according the outlined above method has been adopted in Dorog since 1986.

Until publishing this study, we have opened up by 15 drillings caverns having a volume of 1500 to 88000 m^3 (Table 1).

It was the principle for settling of drillings to locate them into the zones limiting a part-territory.

We have expected by filling a fissure volume around a tectonic unit to considerably reduce the flowing in new water supply and by it, the yield of water inrush.

For entire excluding the water inrush on a very karstic territory, we would have to practise such a drilling frequency that could result in non-profitable coal mining.

Of 15 opened up caverns, the shutting of 8 has been finished to date.

The introduced packing material is 115.140 m^3, approximatively of which 10% is a strenghtening material.

It is not possible yet to determine in the present Lencsehegy mining action the packing effectiveness in an unambigous manner. By establishing the effect, the hydrogeological features of the territory, maybe their changes should be taken in account.

Factors referring to the effectiveness of packing are:

- 90% of the 32 to 34 m^3/min pumping of the Lenssehegy mining plant comes from the former territory without packing,

- where the headings were surrounded by stowing there was no inflow.

It could be reasonable to determine to what degree a given cavern packing process could reduce the liquid conductibility of the territory.

For further development of the packing technology:

- we try to secure the operation by packing before gallery drift work in such a way that we could execute it without water flow in and/or packing material,

- we make attempts even this year to eliminate water inrush from surface streams.

On the basis of all these circumstances, it can be evident that the outlined method could be successfully adopted for the considerable reduction of karstic reservoirs water conductibility where, because of economical considerations an entire water sealing is uneconomic.

CONCLUSION

1. Pureed to make deeper and deeper excavation, the Dorog coal mining had to face gradually the threatening from bedrock side karstic water danger. This danger has been caused by the fissured, karstic limestone under the coal.

One of the possible ways of water defence could be the cavern detecting measure definition and stowing before mining operations. The cavern stowing could regionally reduce, in extreme cases even eliminate the transmissivity of the limestone reservoir.

2. The hydrodynamic cavern volume determination has to take place on selected by opened up by drilling with previous geophysical research, caverns. The volume of caverns with approximatively infinite transmissivity, connected with the whole reservoir space by filtering, will be determinated in such a way that a quick (in 1 to 5 sec) take out of water of a known quantity enable us to calculate the volume after having measured the pressure decrease.

3. With full knowledge of the cavern volume designed stowing method, first the sand - that can be found on the surface - should be fed into the cavern, then a pulp strenghtening under water should be packed into the partly filled cavern, and which entering into the fissures on the cavern cover part and the pores of the material introduced to the cavern, can cause filling up the cavern and considerably reduce its hydroconductibility.

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Table 1. Cavern volumes measured by hydrodynamic method and stowing data

Well No.	Cavern size m^3	Stowing m^3
E-11/a	6000	6090
E-33	1500	-
E-62	-	7770
E-72		-
E-129	2800	-
E-130	6000	15150
E-151	7500	4970
E-152	25000	58640 *
E-153	55000	14500 * *
E-154	88000	-
E-156	2600	480
E-159	23000	-
E-160	1600	1040
E-161	23000	6500
E-163	65000	-

Notes:

* After feeding in of 22000 m3 stowing material, the cavern filled up, then broke through.
* * After 14500 m3 the stowing has been stopped.

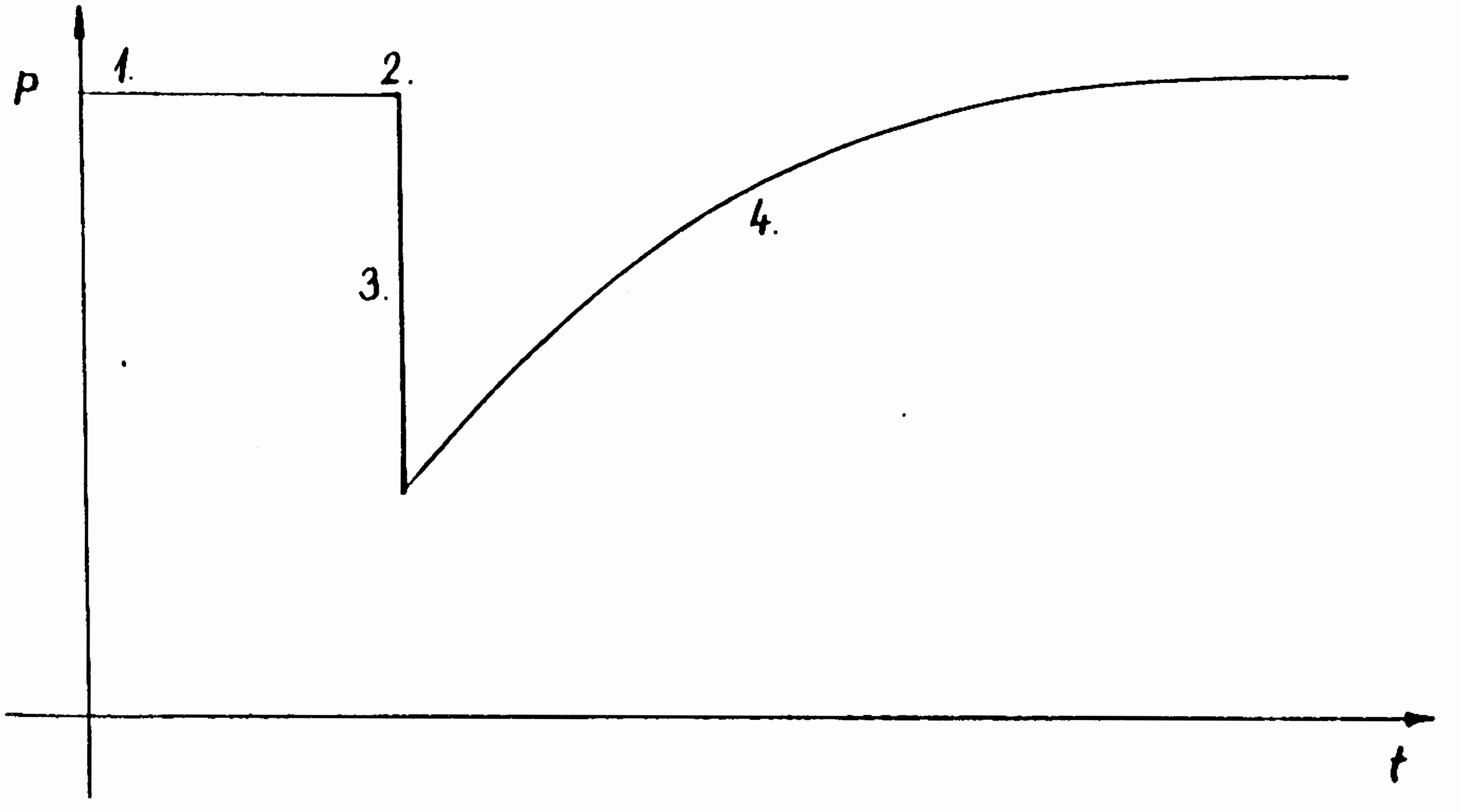

Figure 1. Hypothetical cavern pressure change during the dynamic cavern size determination