Bulkheads Operating Successfully under 25-30 bar Water Pressure in Weak Rocks

By Zsolt KESSERŰ[1], István BAGDY[1], László SZENTIRMAI[1], Gábor KOVACS[1], Ferenc BENYŐCS[2], Miklós SZIKRAI[2]

[1] KBFI - Central Institute for the Development of Mining Budapest, Hungary
[2] Tatabanya Mining Co., Tatabanya, Hungary

ABSTRACT

New research results have been utilized for designing and constructing water sealing bulkheads in Hungarian mines under weak rock conditions. The new concept is based on a new theory of protective layers. Practical questions of designing and constructing such a new type of bulkheads are discussed. Experiences gained during testing and checking the operations are described.

INTRODUCTION

The operation of Many Colliery has been suspended due to economic and environmental reasons. There are valuable underground service establishments belonging to the mine. These can be maintained during the interruption by pumping 35 m^3/min water continuously. Our task was to separate parts of the mine with groundwater inflow from those to be maintained, in order to save energy costs and to save the karstic aquifer as well.

The task has been solved by three bulkheads of 2.5 MPa pressure resistance (see Fig.1). There are soft rocks with little compressive strength at the potential locations of the bulkheads. Hungarian standards do not allow to build bulkheads in these kinds of rocks. Therefore the task was very difficult, which was solved by utilizing two important new research results.

One of these was a new method for sizing and treating protective layers, which has the ability to form protective layers in extremely weak rocks. This ability is proved by theory and practice as well. The other was a patented procedure for building bulkheads[(1)], which supports the utilization of necessary and planned rock treatment methods. This procedure controls the efficiency of the rock treatment methods during constructing and operating bulkheads and gives the possibility of repeating of the treatment if necessary.

SIZING OF BULKHEADS

It is well known that in soft rocks the weakest link is not the bulkhead itself, but the surrounding rock bed. Therefore the main question of sizing is the protective ability of the rock. The sizing method has two new features: the sizing criterion which can be measured directly, and the method for making the rocks to be able to serve as a protective layer. The latter can be designed previously and can be controlled by measurements.

The new sizing concept is represented by Fig. 2, which shows that at first the open fissures in the rock surrounding the bulkhead must be grouted, then the state of stress of the rock must be changed to improve its resistance against hydraulic pressure. The new theory of protective layers is represented by another paper submitted to this congress(2). From now on we are going to discuss only practical questions.

Before sizing, those zones ought to be determined by measurements, the state of stress of which is unsatisfactory. According to the theory mentioned above these zones can be determined by measuring the shut-in pressure during a hydraulic fracturing process. Fig. 3 represents the location of a borehole system and some recorded data. (It is extremely hard to measure hydrofracturing shut-in pressures in soft rocks; a new measurement method has been developed which eliminates the errors due to permanent deformations of the rock.)

Knowing the results of these measurements, the rock zones were determined (by the method shown in Fig. 2) in which the state of stress ought to be changed.

In our practice the rock mass with satisfactory stress state ought to be at least 5 to 6 metres thick to avoid water break-through paths due to uneven treatment. Further length or total length of the bulkhead is determined by the need of supporting the rock zone of satisfactory stress state and the zones attaching to the latter (see Fig. 2). Hence the necessary length of bulkheads is 15 to 30 metres depending on the rock quality and rock damage. The sizing method was controlled by hydraulic fracturing tests. Due to the concept of sizing the test of the structure of the bulkhead is not primary, because gaps or leakage can occur in the very worst, which can be avoided by careful preparation. Therefore there is no need to test the bulkhead itself. As our method is novel and this was the very first utilization of it, another bulkhead (called "twin bulkhead", see Fig.4/a) was prepared. There were two bulkheads closing the section of the roadway which was needed for the tests (bulkhead No. 1 on Fig. 1). The satisfactory results of tests verified our theory. This gave the possibility of testing the only rock mass at the following bulkheads of the structure shown in Fig. 4/b. The test space of toroidal shape was prepared in the rock mass surrounding the bulkhead. During testing the movement of groundwater was monitored by geophysical measurements (by a monitoring system installed by the University of Miskolc); furthermore the water discharge, the deformation of the bulkhead and the variation of the hydraulic pressure were measured.

Further tests were carried out to determine the measure of stressing of the rock. Fig. 5 shows the results of measurements of this kind. This test was carried out before the bulkhead test, before pressurizing and when the hydraulic pressure was needed to increase. Tests of the same kind were performed after the setup of the bulkheads in order to control the variation of prestresses due to lateral creeping or relaxation of the soft rock. Comparative test results showed that relaxation could be neglected (see Fig.-6).

THE STRUCTURE OF BULKHEADS

The structure of the bulkheads had to be constructed in a new way, that it would enable to treat rock masses of great extent during preparation and after the setup at every time and the control tests as well. Further demand was to enable to test the rock mass surrounding the bulkheads using only one bulkhead.

The construction and the preparation method that meet the new requirements are patented in Hungary, other elements of these are know-hows of KBFI, therefore we would avoid the representation of further details. The draft of the bulkheads are shown in Fig. 4/a and 4/b.

EXPERIENCES ON CONSTRUCTION AND OPERATION

The first and very important observation was that the rock behaved proving the truth of our expectations based upon theoretical assumptions and preliminary experiments. That is, if the stressing of the rock was insufficient, it leaked; and if it was stressed posteriorly, the test was successful. These results are shown in Fig. 5/a.

Another (rather disadvantageous) observation was that the grouting procedure, which provided the stressing of the rock, took a very long time, especially when the grouted material was shrinking. The longest part of the duration of the construction was taken by the grouting procedure. The 920 injection holes of the three bulkheads were grouted in 4 to 5 subsequent stages, which took two thirds (2/3) of the total construction time. it was well-known from experience on constructing bulkheads and other structures, that the concreting of the great size body of a bulkhead requires special technology and proper type of cement, which slows the setting, reduces the warming up of the structure and has the strength and impermeability meeting the designed requirements. For this purpose slow-setting cement was used, which type is utilized for water constructional works of great size. the early tests showed that careful concreting is necessary, otherwise leakage would occur by the tubes or at the gaps, which was not dangerous, but would make the working conditions uncomfortable in those working areas where farther test measurements were planned.

Two important experiences on the rock behaviour ought to be mentioned. The first is that the wetting of the rock could be monitored by geophysical measurements as well. The other is that in case of careful grouting 5 to 6 metres of protective layer thickness is sufficient if the measure of prestressing is satisfactory. It results from theory, but there were laboratory experiments as well. Direct proofs were provided by opened test holes located at the upstream side of the bulkheads, 6 to 8 metres from the flooded drift.

These opened boreholes remained dry up to now. Another unambiguous observation was that the reduction of stresses, what we were afraid of, did not occur. It can be explained on theoretical basis: The deviatoric stresses are to decrease in time, therefore in the vicinity of a bulkhead (regardless the ends of it) the least principal stress, which governs the shut in pressure, does not decrease but rather increase. The conclusion of these observations is that the structure based on the new sizing and building method enables to build bulkheads even under disadvantageous circumstances. Due to the high costs, building this kind of bulkheads is feasible only to satisfy special requirements.

FURTHER APPLICATIONS AND DEVELOPMENTS

Stressing the rock by grouting utilized in this case is expensive and takes a long time. This forced some of the authors of this paper to develop a new structure of bulkhead which provides a shorter duration of stressing. A bulkhead of this type has been built for a Hungarian ore mine, but it has not been pressurized yet. Another special kind of utilization of the bulkhead described above is closing up water inrushes under those circumstances, where very careful stressing of rock is necessary. An example of this kind is the case of Lencsehegy Colliery in Hungary, where a water inrush of 12 m^3/min occurred in a place surrounded by several drifts. Here very careful stressing of rock is necessary to provide sufficient conditions for localization of water inrush.

As this Congress is held in Slovenia, it is worth to mention, that the localization of a water inrush of this kind, where several drifts were at the vicinity of the inrush, has been carried out by one of the authors of this paper together with Slovenian colleagues at Kanižarica Colliery. There, due to the stressing grouting, between two drifts, close to the bulkhead a protective layer of 15 metres thickness was sufficient against 28 bar of hydraulic pressure for the duration of closing up the water. In the case of hydraulic pressure ought to be provided within a 8 to 10 metres distance in a weaker rock mass.

The results presented prove that a new, efficient and feasible method of protection of mines against water can be utilized to improve the safety of mining.

REFERENCES

1. Bagdy I., Szentirmai L. and Kovacs G. Methods and structure for realizing and repairing bulkheads. Hungarian Patent. (1989).
2. Kesserü Zs. Spontaneous hydrofracturing a frequent way of failure in natural and artificial rock/soil barriers and new ways for process control. Proc. of 4th IMWA Congress (in print). IMWA-GZL, Ljubljana. (1991).

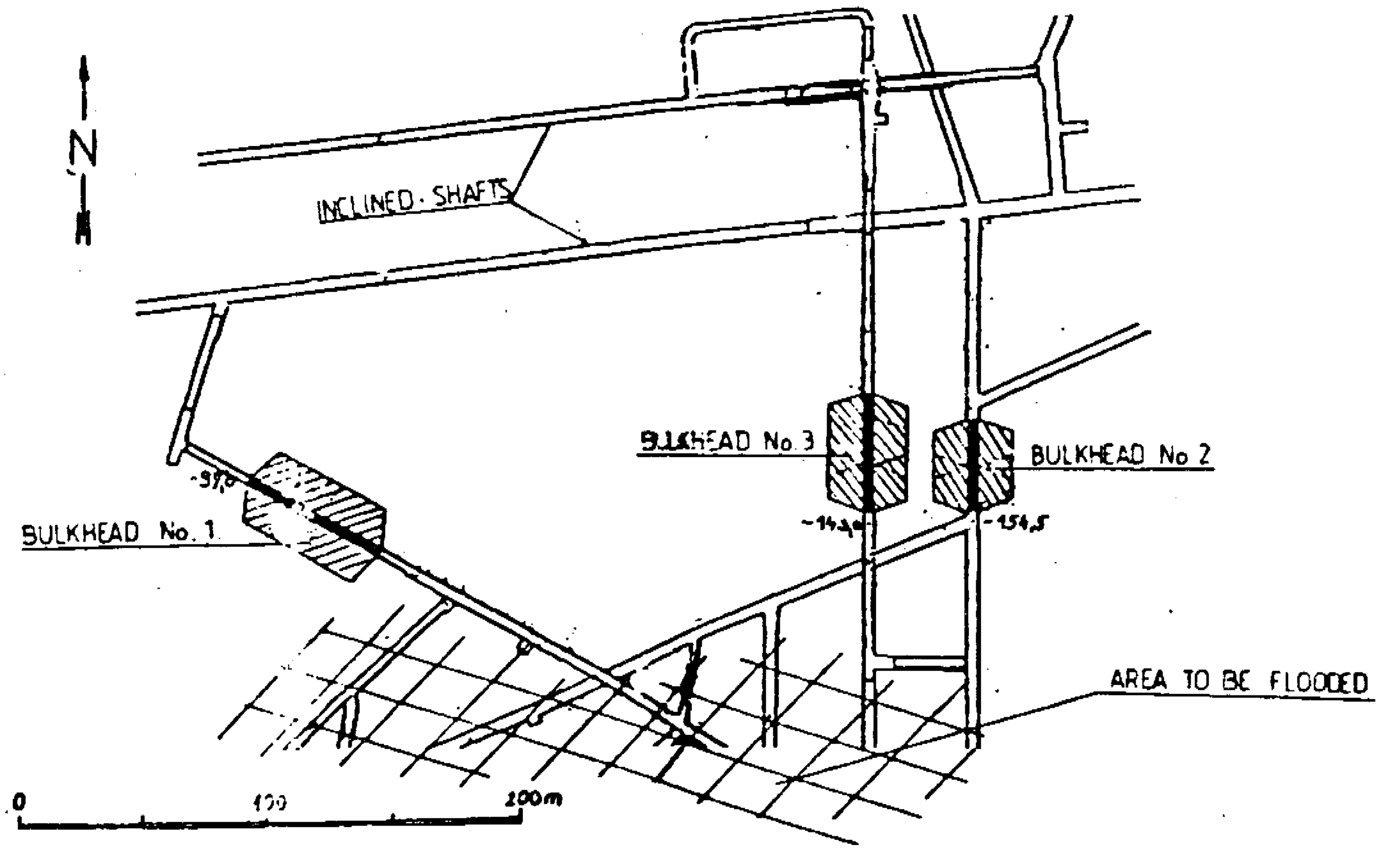


Fig. 1.

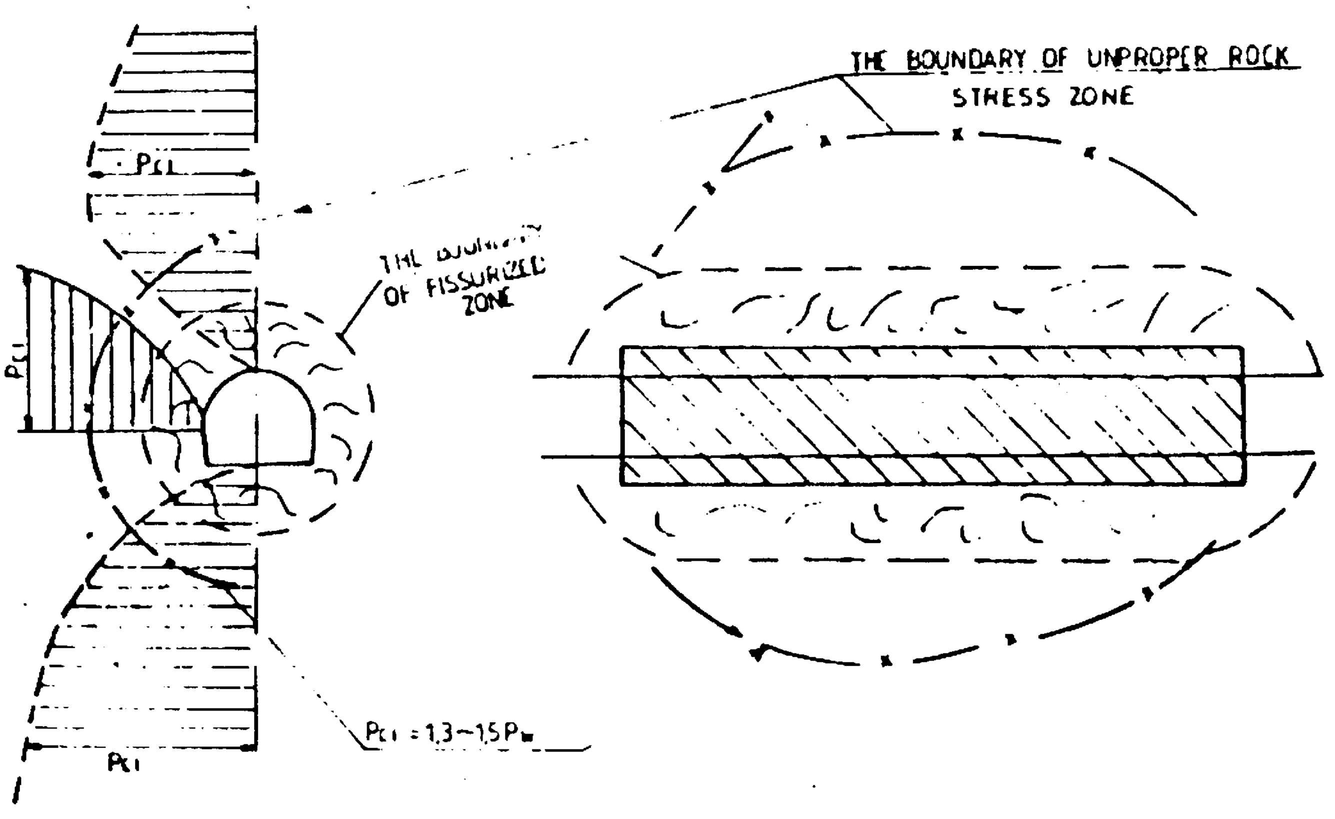
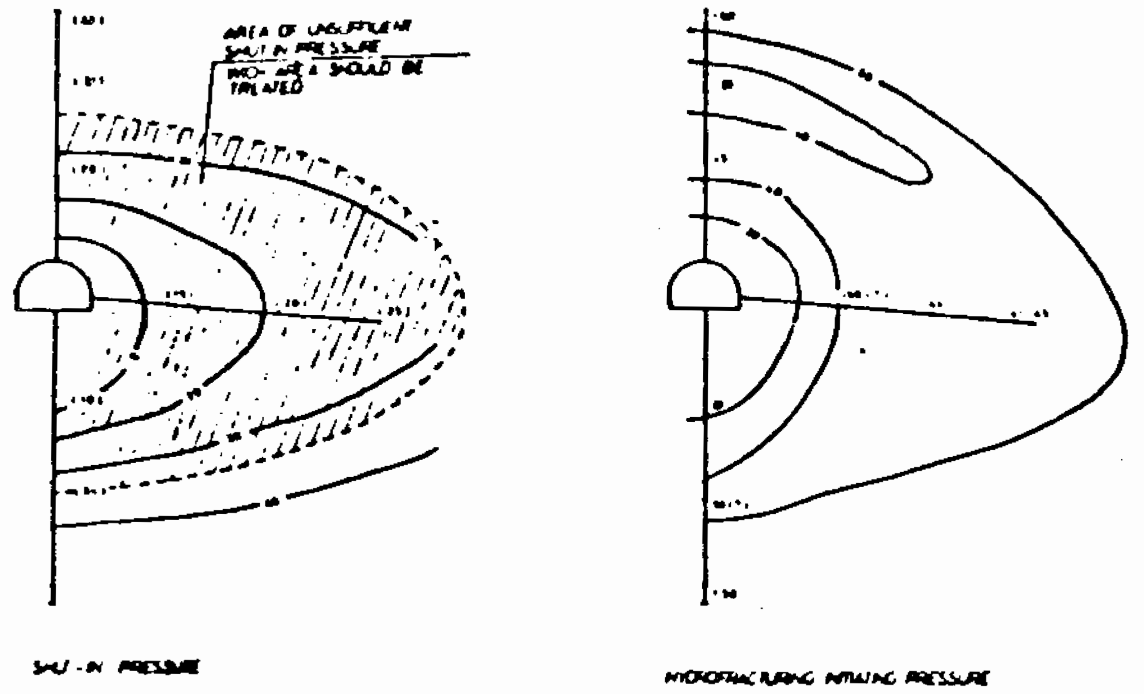


Fig. 2 Zones to be treated around roadways when bulkheads are applied.



Isolines of the initiating and the shut in pressures pointing to one of roadways in which a bulkhead was to be built in.

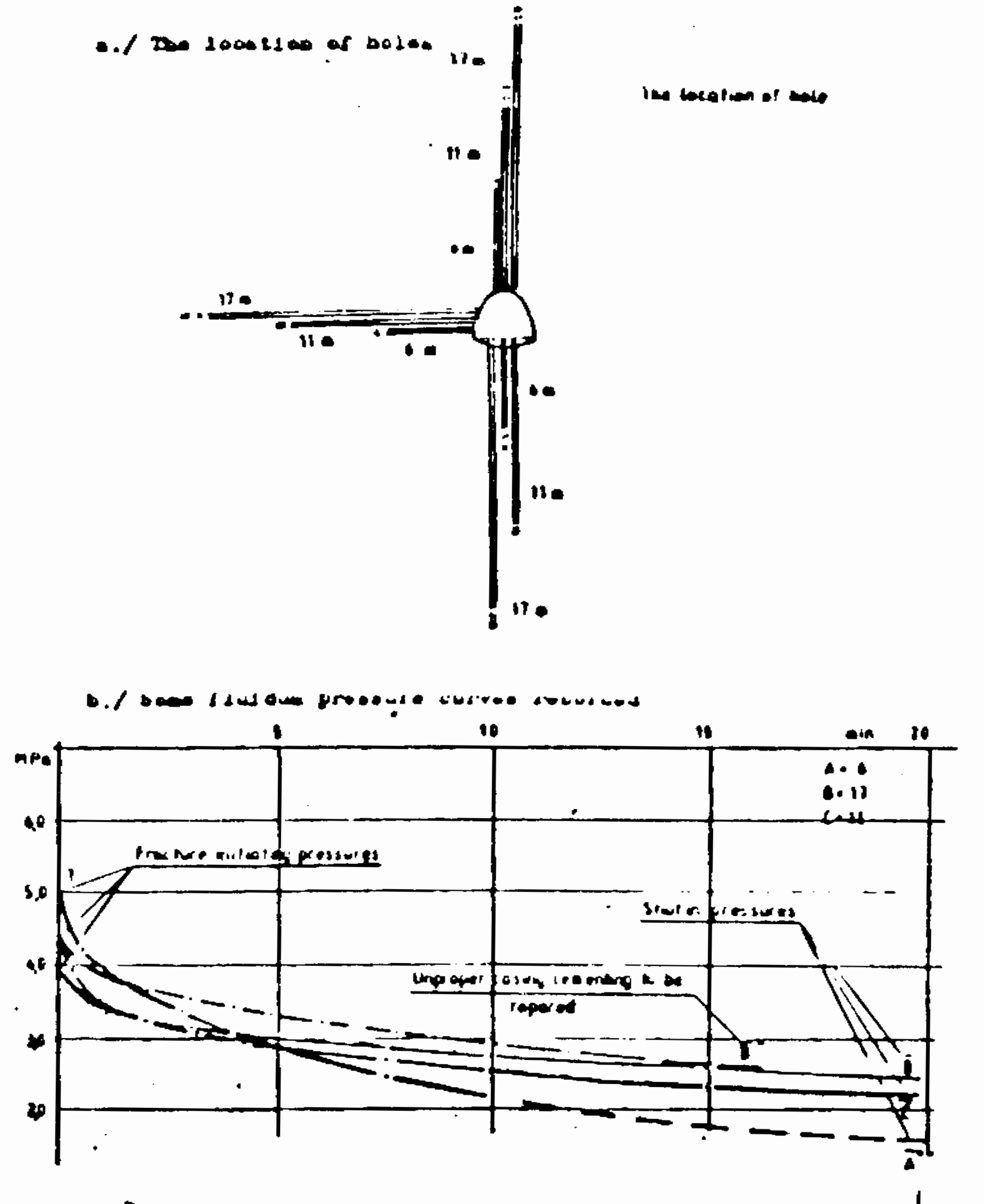


Fig. 3. Testing the zone of decreased hydrofracturing pressures around roadways.

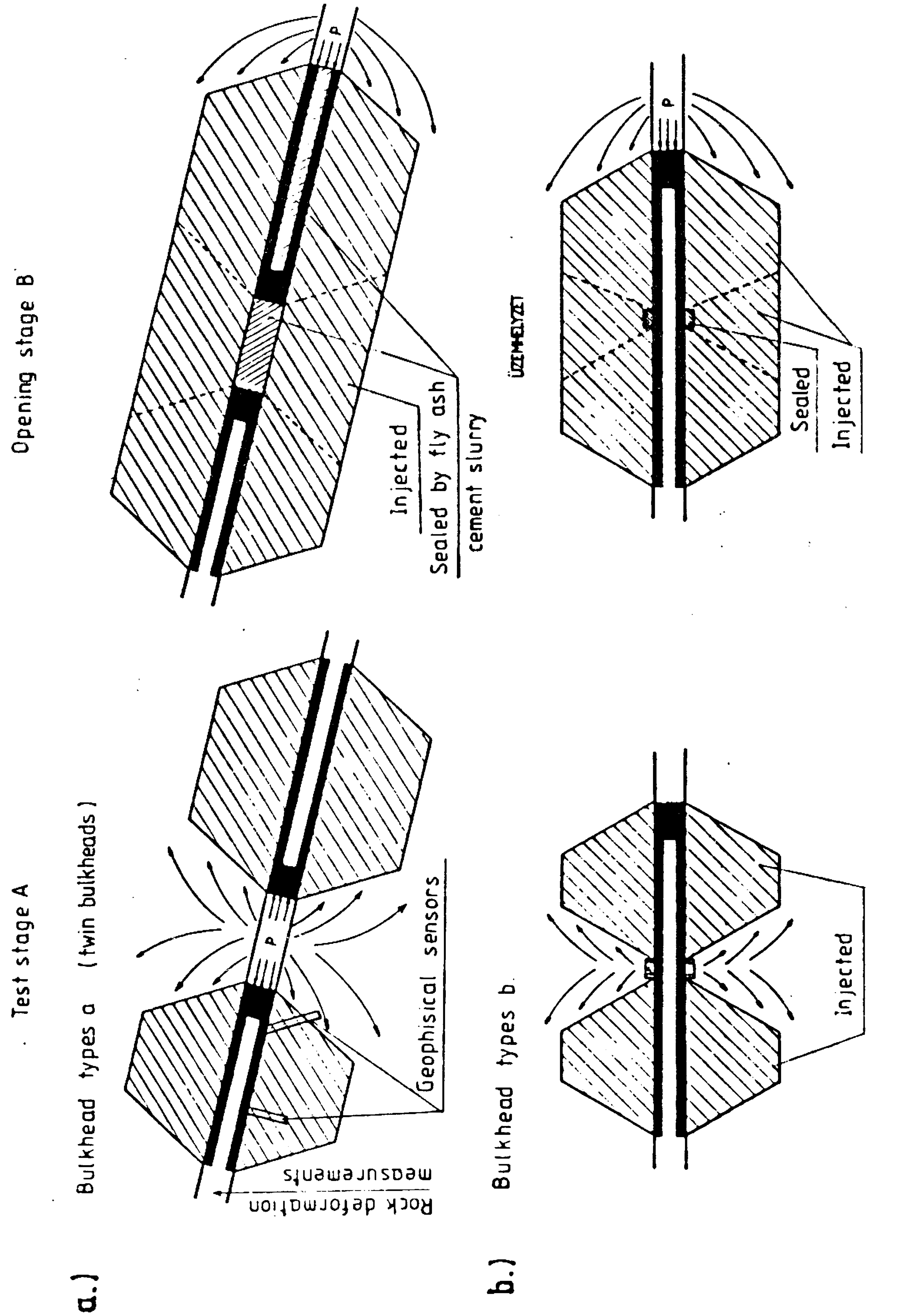
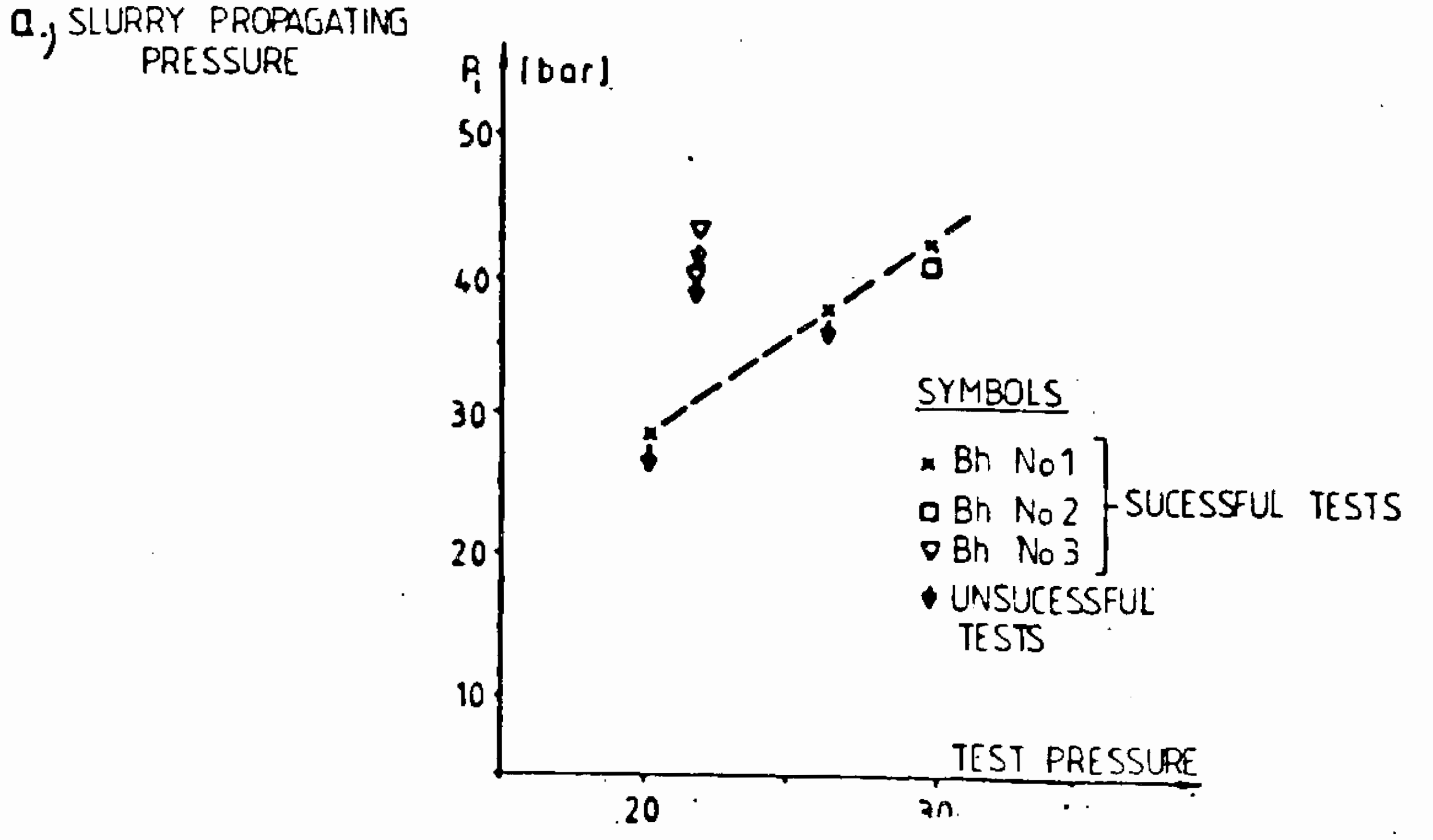


Fig. 4. Types of bulkheads tailored for applying the hydro-fracturing theory of sizing and for rock treatment.

THE EFFECT OF THE REPEATED PRESSURIZING OF ROCK BY CEMENTE SLURRY GROUTING



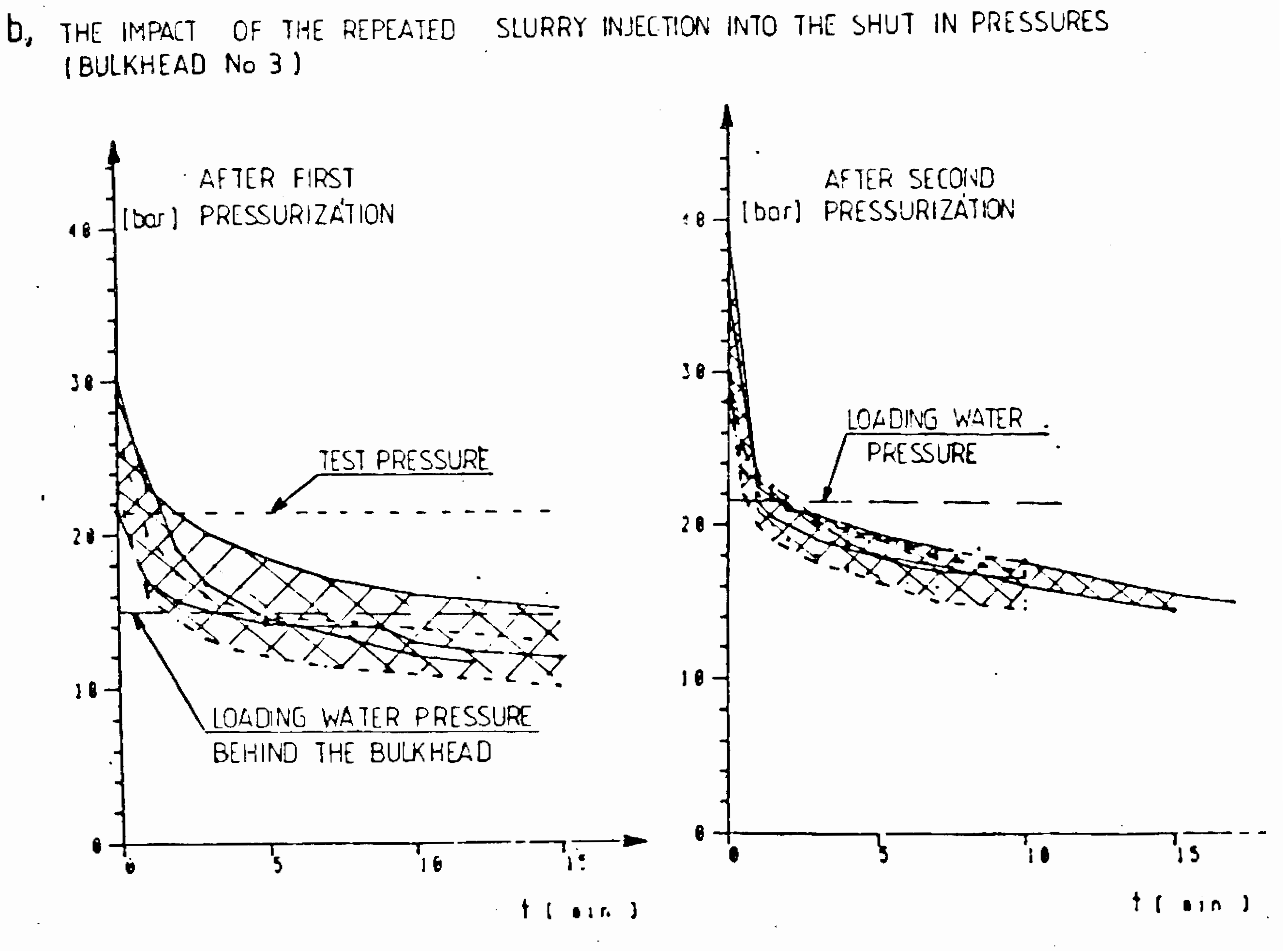


Fig. 5.

HYDROFRACTURING TESTS AT THE SAME PLACE OF BULKHEADS IN DIFFERENT PERIODS

Fig. 6.