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THE APPLICATIONS OF FLOWCUT GROUTING CURTAIN IN MINE WATER PREVENTING AND CONTROLLING

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PREFACE

The method of cutting waterflow with grouting curtain is used for changing engineering geological and hydro-geological conditions by artificial means. The method was first used for the prevention of water penetration in the construction of dam-shoulder and dam-base and other constructions concerning water conservation. Later, it was gradually getting its way into the reinforcement of building foundations, bridge foundations and road foundations. It has been used for the mine water preventing and controlling in high flow rate mines, not until the early 60s of this century, did the method prove successful in China. The first over 500 m flowcut curtain for preventing and controlling mine water in pits was built up in pit 3 of the Qingshanquan Coal-mine in Xuzhou from Feb. 1964 to Oct. 1966. And then the mines of the Chinese Metallurgy Department immediately adopted the method. In the recent years the method has been extended in the construction of water preventing and controlling in China's coal, metalline and chemical mines.

The particularity of the method is as follows: Pour setting gel of water resistance material or large-sized aggregate and menting gel of water resistance material into comparatively bigger water conductive channels in the underground aquifer to partly change the aquifer into aquiclude and cut off the water conductive channels, thus building an artificial water confining wall in the aquifer, cutting off the water supply from it, reforming the hydrogeological conditions unfavorable to the mining of mineral deposit, and assuring the effectiveness of the drainage of the mineral deposit, in which way, we can achieve the purpose of mining the mineral deposit safely, economically and rationally. So the method has, in theory, its exclusive advantages and a special significance in mine water preventing and controlling.

Since the applications of flowcut grouting curtain in the mine water preventing and controlling in China in 1964, the coal industry system, by 1984, had had 8 curtains in all get under way, of which 6 had either been built up or almost built up, and 3 had proved effective and would be lengthened. The metallurgical industry system had built 3 curtains, of which 2 had been completed and the other one would be completed soon. The mines of building material and chemical had already begun to build one. Altogether, 13 such large water control curtains had got under way, of which 9 had been completed, throughout the country. These curtains were, in various degrees, effective for controlling disaster, improving drainage, reducing mine inflow rate and lowering the production cost, besides which, there are especially function to the protection of environment of the mining area, the protection underground water resources, etc.

I. CONDITIONS SUITED TO THE CONTROLLING OF MINE WATER WITH FLOWCUT GROUTING CURTAIN AND THE ARRANGEMENT OF CURTAINS

1/The flowcut at the directive water supply aquifer of mines

The aquifer at the direct top and bottom of the coal or mineral layer, though with some aquiclude both above the top and under the bottom, which is often damaged in mining and must be drained, usually increases the mine inflow rate and worsens the productive condition. To reduce the mine inflow rate completely and drain the aquifer, further lower the production cost and better the productive condition, we can cut off the water supply by cutting flow with grouting curtain after the section of intake and water supply in these aquifers is found out (See Fig.1 - 1a).

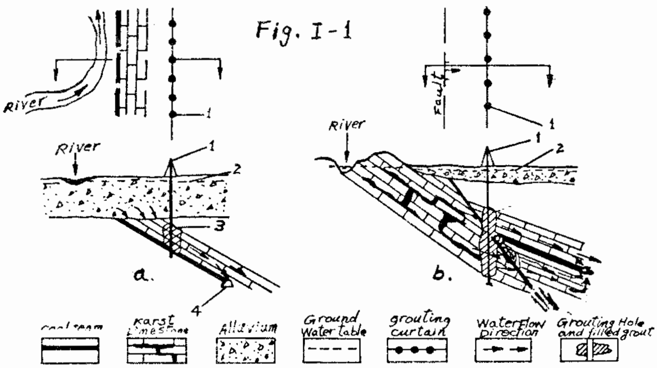


Fig. I-1

For the construction of flowcut grouting curtain into the shallow part as shown in Fig 1- 1a, see Items 2 and 6 in Table VI-1.

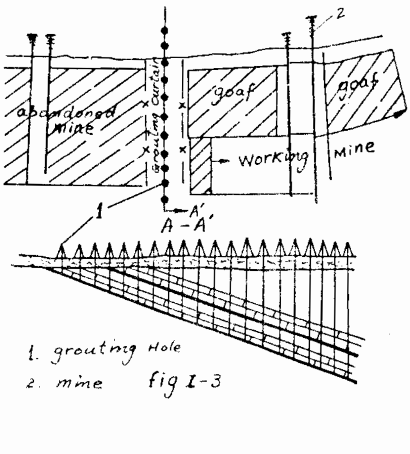
The grouting flowcut curtain shown in Fig 1 - 1b is built for the cutting-off of the water conductive fault, and the forming of an intake for the directive water supply aquifer of mine. The length of the section of flowcut curtain should be decided by that of the section of water conductive fault measured in exploration (See Items 5,9,12.13, in Table VI - 1).

2.The flow-cutting of the main sections of subsurface flow of the mine water supply aquifer of mine.

Generally, the main water supply aquifer, being thick, had a great area of water supply and with a great motion and static resource, often results in a great mine inflow, when close to the coal layer or mineral deposit. The aquifer, though sometimes far away from the mineral deposit, may become the main source of water supply of the mineral deposit, once it is connected with the directive water supply aquifer nearby by the structure of water conductive fault. It is uneconomic to merely drain the aquifer. So to reduce the amount of water to be drained, the flow can be cut off by artificial flowcut grouting curtain after confluence-forming section of under-ground subsurface flow is found out through the exrloration of regional hydrogeology, so as to reduce the ground water of tractive ground water supply, while draining the aquifer. The curtain holes are arranged at the main section of subsurface flow, which is at the entrance by which underground water flows into the coal field (mineral deposit area). Constructions 4 and 10 in Table VI-1 are just typical of it. The construction, though remains incomplete, has some function in the water resistance. Success is sure to be achieved if the construction is continued.

3.The flowcutting for the separation of abandoned mine with abundant water(goaf area.)

Some long-mined abandoned mines and mines submerged by the inrush of mine water often threatens the neighbour mines or greatly increases the mine inflow rate and pollutes the ground water with the water conduction of aquifer. To prevent and control the water hazard and pollution of ground water, a water separating curtain can be built in the aquifer with flowcut grouting curtain at the section of separating coal pillars between the two mines, in which way to cut off the water channels in the water conducting aquifer so as to prevent the water that may submerge the mine from finding its way into the mines in production or pollution of ground water. Fig. 1 - 3 Construction 1 in Table VI - 1 is just typical of it.

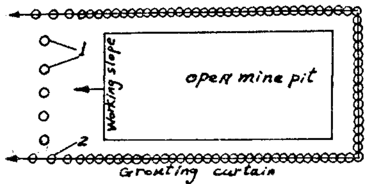


1. grouting Hole
2. mine fig I-3

4.The inflowcutting for open mine pits

The flowcut grouting curtain can also be applied to the cutting of flows around the opencut mine pits to reduce the amount of water to be drained and strengthen the slope stability.

Usually, eternal grouting curtain is built at the section of nonworking area, and provisional drain wells are used for cutting flow at the section of working area, for it is constantly extending forward. See Fig 1 - 4



1. dewatering wells 2. borehole for filling slurry

Fig I - 4

The shallow flowcut grouting curtain for the deep basement rock aquifer is often seen as one-row or two-row dense grouting pillar curtain. The shallow flowcut grouting curtain for the loosely covered aquifer can also be built by cutting a ditch with a ditch-cutting machine and filling the ditch with water resisting material (such as clay, etc.).

The cutting-off of flows from the aquifer of some depth or of thick firm rocks (fissured aquifer and karst fissured aquifer) should be done by boring grouting curtain as is shown in construction 7 Table VI - 1.

5. The flowcut at the drift and shaft construction passing the aquifer

For the aquifers, through which the drift and shaft may pass, which may not have been connected without mining (usually far away from the mineral deposit being mined with thick aquiclude in between) the flowcut grouting curtain can also be used to partly seal the aquifer section through which the drift will pass to avoid protracted inflow after the digging of drift and shaft, thus avoiding the protracted increase of inflow not having needed draining from the aquifer.

II. METHOD AND PRECISION OF HYDROGEOLOGICAL EXPLORATION IN GROUTING CURTAIN CUTFLOW WATER - CONTROL ENGINEERING

Because of tremendous amount of work and great expense in grouting curtain cutflow water-control engineering, mining areas or coal field require more detailed data of hydrogeo - logical exploration to ascertain the feasibility of grouting curtain cutflow method. In these data, the main water supply direction and general route of the aquifer, the target of cutflow, should be shown clearly (additional exploration work should be made if these data are not available).

In addition to the above-mentioned data, special explorations should be made as following:

1. Exploration for the plan of curtain line selection

1.1 Purpose, task of exploration

It is highly necessary to carry out the particular hydrogeological exploration to clearly find out the length of the intake section at the aquifer, the structure, depth, etc. of the water conductive section at the intake edge. Only when the various data are at hand can the plan of line selection and investment budget for grouting curtain cutflow engineering be made.

Then water quantity is reduced by 50% as far as possible and economic analysis on investment and effect is given against the plan of line selection for the min. amount of work.

1.2. Borehole arrangement

In upper reaches and lower reaches of intake edge of aquifer special hydrogeological boreholes for test & observation are arranged respectively. Borehole number is determined by calculating on the basis of intake edge length, hydrogeological structure, water conductivity of aquifer and flow velocity of ground water in aquifer, etc. Generally, for medium aquifer in water conductivity ($T=100m^2$/day), the boreholes arrangement is shown in Fig. II - 1

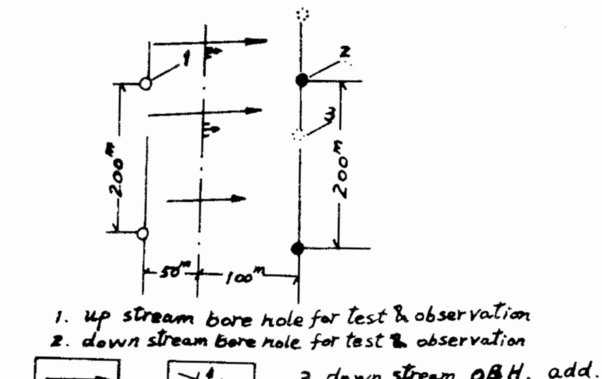


Fig II-1

After the water penetrable section is found out through the exploration test, the additional observation boreholes are fixed on the needs.

1.3 Content of test

a. Pumping and injecting test

After the hydrogeological boreholes for test and observation on both sides of intake edge are completed, special hydrogeological test should be done first. The method of test is to inject water into upper reaches borehole(s), or to pump water from aquifer in lower reaches pit (single borehole or a group of boreholes). If the conditions of pumping test in mine don't exist, pumping test can be made in lower reaches observation borehole(s). Through test, the flow field of under ground water in whole intake section is changed, and various hydrogeological parameters which conform to the regime of under ground water in the course of the test are debugged by means of finite element dimensional model. With the parameter, the edge intake yield of the cutflowed aquifer at various drainage stages can be calculated.

b. Ground water connect test with chemical tracer

In the course of above-mentioned hydrogeological test, various tracers with high sensibility (including organic and inorganic reagent, isolope, tritium, etc.) are put into the upper reaches boreholes respectively. Sampling is made or instrument is put in the lower reaches boreholes to measure underground water flow velocity in the main water-passing section and each section of the curtain.

c. Long-term observation of underground water regime

The changes of underground water flow field under natural condition, conditions of injecting, pumping tests and during the operation of curtain in the future are observed, so as to direct the curtain operation and to analyse and calculate the effect of grouting curtain cutflow.

2. Exploration for control of curtain engineering

2.1. Purpose and task of exploration

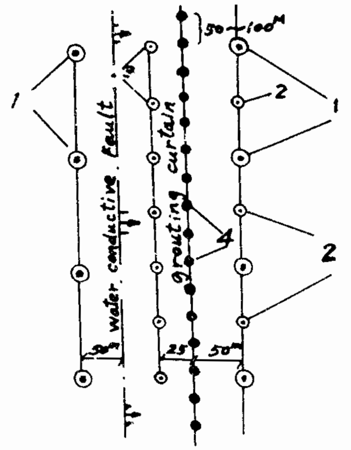
After the plan of curtain line selection is determined, detailed exploration for curtain control must be carried out along the curtain line to work out the working design of the engineering and decide material and technological system used when grouting and required quality index.

The aim of the exploration for curtain control is to find out flow velocity and direction of underground water in various sections of the cutflowed aquifer, opening degree of water-conduction fissure(diam. of water conduction pass of karst aquifer), location of the main water conduction zone and the accurate length of the curtain to be built up.

2.2 Borehole arrangement and test content

1). Curtain controlling hole

As above mentioned, borehole arrangement is calculated and determined in accordance with flow velocity of underground water and water conductivity in the cutflowed aquifer, thickness and depth of the aquifer. For medium water-conductive aquifer, as indicated in Fig II - 2



1. test observation bore hole
2. observation borehole
3. out of curtain observation bore hole
4. 1st process Bore hole for grout

Fig II-2

boreholes are arranged at intervals of about 50 - 100m along the line of grouting curtain. (they can be used as 1st process boreholes for grout). In addition to have all kinds of test again in every borehole, single-hole special tests must be given as below: a. specific injecting yield of the aquifer section in hole; b. velocity and direction of flow; c. opening degree of water conduction fissure or diam. of water conduction pass in the section of aquifer, etc. Apart from that, for karst aquifer, down hole radioexamination meter should be used for among-hole examination, so as to make certain of development situation and section of water conduction pass between boreholes.

2). Long-term observation hole on both sides of the curtain:

As shown in Fig. II - 2, three lines of observation borehole are arranged during exploration of curtain engineering. a. observation boreholes of water supply aquifer on intake edge (the observation boreholes drilled during exploration for line selection plan are employed), b. generally, observation boreholes inside intake edge and outside curtain should be arranged. c. the inside curtain observation boreholes: It would be planed to be roughly opposite to the out-of-curtain observation boreholes.

III. THE RESEARCH AND EXPERIMENT ON HYDROGEOLOGY IN THE CONSTRUCTION OF GROUTING FLOWCUT CURTAIN

Although detailed hydrogeological exploration and the exploration of the control of the flowcut construction is made before the appearance of its construction design, it is highly important to study the hydrogeological information abtained during the construction of every grouting hole, the information of the regime of underground water shown by the observation holes, and the hydrogeological information from special experiment, for the judgement of curtain information and guidance for the construction, for the construction of flowcut grouting curtain in itself is a largescaled experiment of hydrogeology. So the analysis and judgement of hydrogeology and the experiment on it is thought to be the decisive factor and key part for the success of the construction of flowcut grouting curtain, according to which the whole construction assignment, technological measure and the construction technique preceed. The work details as follows:

1.The building of the long-term observation holes net-work of the underground water regime of the flow-cutec aquifer.

2.The determination of the hydrogeological parameters of the grouted aquifer in the flowcut grouting curtain holes.

1).The specific injecting yield value (q) is determined.

2).Determine the porosity, porous diameter, opening degree of fissures and diameters of karst pipes etc. of the grouted layers or sections in the grouting holes.

3).Determine such data as the velocity and direction of underground water.

3.Radio perspective of the holes

1).Make a radio perspective exploration of the holes and determine the position of the water conductive channels between each two neighboured holes and the relatively grown section of the water conductive gaps with a computer before the construction of the grouting of every holes.

2).Make another test and perspective and judge the formation of the flowcut grouting curtain between the two holes by the attenuation of the electro-magnetic waves.

4.Comprehensive analysis and research of hydrogeology

1).Make by hand or a computer a diagram of the flow field of underground water and hydrogeological situation of the curtained area both before and during different periods of the construction.

3).Analyse and calculate the change in water resistance and the rate of surplus passing water at different sections of aquifer after grouting, so as to regulate the arrangement of curtain holes and decide the key point of the construction.

IV. SELECTION OF GROUTING MATERIAL AND TECHNOLOGY FOR GROUTING CURTAIN CUTFLOW

1.Selection of grouting material and technology

Selection of grouting material and technology for grouting curtain cutflow primarily depends on the object and task of curtain cutflow. For prevention and control of mine water hazard, only if water inrush of over $5m^3/min$. can be avoided, it wouldn't be harmful to safe production in mine. For this reason, cheap materials, such as cement, clay, bentonite, sand and stone, are used as curtain grouting materials as far as possible. Small amount of waterglass, triethanolamine and other accelerated cementing agent can be used. In order to prevent underground water pollution and reduce grout cost, try to use chemical grout as little as possible.

In accordance with practical experiences drawn from grouting curtain objects in China and scientific research tests, selection of grouting material is shown in Table IV - 1

SELECTION OF MATERIAL AND TECHNOLOGY USED IN GROUTING CURTAIN CUTFLOW UNDER DIFFERENT CONDITION

TABLE IV - 1

Features of water conductive medium layer		Pore and fissure aquifer (dia. of pore and opening degree of fissure < 0.01m	Fissure and pipe line aquifer (opening degree of fissure and dia. of pipe line: 0.01 - 0.5m)	Karst fissure (dia. of karst, pipeline and buried river > 0.5m)
P (Bar)	q / Vm/sec	0.05 - 5 (L/min. m^2)	1 - 300 (L/min. m)	20 - 1000 (L/min. m)
< 5	< 0.005	Clay & bentonite slurry grouted by high pressure	Maninly clay & bentonite slurry, sand added when q > 20, gravel added when q > 100	Sand and gravel filled first, then clay & bentonite slurry
	0.005 ~ 0.05	Clay and bentonite slurry grouted by high pressure, slurry C can be grouted locally.	Mainly clay and bentonite slurry, sand filled when q > 20, gravel and slurry C added when q > 100	Mainly filled with sand and gravel first. clay and bentonite slurry grouted until pressure rise, then slurry C added for reinforcement.
	0.05 ~ 0.5	Clay and bentonite slurry grouted with high pressure, then slurry C used for reinforcement	Slurry C + S grouted mainly, sand filled when q > 20, sand with gravel used when q > 100	Filled and compacted with sand and gravel, then seeled with slurry C or C+S for reinforcement
5 - 10	0.01 ~ 0.1	Slurry C or mixture of slurry C + betonite	Primarily slurry C, sand filled when q > 20, gravel added when q > 100 till pressure rise, then slurry C grouted for reinforcement	Filled with sand and gravel, then slurry C used for reinforcement
	0.1 ~ 0.5	Slurry C or slurry C + S	**Mainly** Slurry C + S or slurry C.S, sand filled when q > 20, gravel added when q > 100; after pressure rise, stop filling sand and gravel	Mainly filled with sand and gravel then slurry C or slurry C + S grouted intermittently for reinforcement.
	0.5 ~ 1.0	Slurry C.S or slurry C + S	Primarily slurry C+S and slurry C.S sand filled when q > 20, gravel added when q > 100, after pressure rise, stop filling sand and gravel.	Sand and gravel filled first, slurry C or slurry C+S used for reinforcement.
10 - 20	0.01 ~ 0.1	Mainly slurry C	Chiefly slurry C, sand filled when q > 20. sand and gravel filled when q > 100. after pressure rise, stop filling sand and gravel.	Mixture of sand, gravel and slurry C grouted intermittently until pressure rise, slurry C used for reinforcement.
	0.1 ~ 0.5	Slurry C or slurry C+S, slurry C.S can be used if necessary.	Mainly slurry C or slurry C+S, sand filled when q > 20, gravel added when q > 100, stop filling sand and gravel after pressure rise	Mainly filled with sand and gravel, then slurry C or slurry C+S grouted with pressure for reinforcement.
	0.5 ~ 1.0	Slurry C+S or slurry C.S	Mainly fo slurry C+S or slurry C.S, sand filled when q > 20 , gravel added when q > 100, stop filling sand and gravel after pressure rise.	Mainly filled with sand and gravel, then slurry C.S or slurry C+S grouted by pressure for reinforcement.

q- specific injecting yield, P- water pressure borne by curtain, V- flow velocity of underground water in the area of curtain.

Notes:

1).Grout C- accelerated cementing slurry made of cement and triethanolamine

2).Grout C+S - cement, waterglass and thicking accelerated cementing slurry.

3). Grout C.S - quick-setting grout made of cement and water-glass.

4).Attention should be paid to the diam. of pass when filling gravel. Generally, diam. of gravel is allowed to be 1/4 to 1/5 that of pass. For sake of safety, when filling, the size of gravel is increased gradually up to 50mm.

5).To avoid hole blockage when filling aggregate, filling operation should be stopped and value q should be measured in every 1 or 2 hours, so as to find out changes of grouting capacity in time. Once great changes occured, aggregate filling should be stopped immediately.

2.Grout thickness:

Thickness of prepared grout should be roughly in line with grouting capacity of water conductive pass. Too thick or too thin grout can not achieve a good result economically and rationally (See Table IV-2)

SELECTION OF GROUT THICKNESS

TABLE IV-2

Specific injecting yield q (1/min.m)	< 0.01	0.01 - 0.1	0.1 - 1	1-10	10-20	20-100	100-500
Water-cement ratio of cement type grout 2 (W/C)		1	0.8	0.7	0.6	0.6	0.6
Aggregate added					fine-sand	sand	sand & gravel

3.Design of pressure and yield of finish grouting and total grouting amount for each hole

The value of this design is determined by calculating based on the factors of the rock layer and the max. water pressure which the grouting curtain must be beared after the curtain founded.

4.Analysis and examination of curtain quality

Curtain quality must be examined through inspection holes. From changes of specific injecting yield (obtained in injecting test) of every process grouting hole during operation, we can see whether water conductive capacity in curtain area decreases with the operation of every process borehole. Consequently in generally speaking, operation of the later process borehole can be regarded as examination of the former process borehole quality. When specific injecting yield of the last process inspection hole comes to below 0.01 l/min.m, it's supposed to be up to standard.

Besides these former inspections, the method of analysis of ground water regime and radioexamination etc. can be used.

V. EVALUATION OF GROUTING CURTAIN CUTFLOW EFFECT

1. Calculation and comparison method

1). On the basis of observation data on regime of underground water flow field and test material (data) of hydrogeological exploration in curtain area before grouting, the hydrogeological parameters, resistance (hydraulic gradient) and water penetrating yield of curtain area are calculated and determined with computer.

2). After grouting, above-metioned calculation is made again according to second-time test data and observation data of underground water regime.

3). Compare the calculated value of water conductive coefficient and yield before and after grouting with each other and evaluate the percentage of effect.

2. Comparison method of drainage test and pumping test in mine

Before grouting for curtain cutflow engineering, all kinds of data are obtained from pumping and injecting tests made in the cutflowed aquifer, as well as long-time observation data of underground water regime. After grouting, similar tests are carried out once again. The data obtained before and after grouting are processed by computer and turned into curve group $Q = f(s)$ for comparison. Moreover, it's of even greater practical significance to adopt water conduction yield at same drawdown or drawdown caused by identical water conduction yield for comparison. In this way, percentage of effect is worked out.

Generally speaking, the latter is more reliable. But sometimes, because of long operation of curtain, mining conditions before and after operation vary greatly and the latter method can not be used. In this case, the former method must be adopted for calculation and comparison.

VI. GENERAL SURVEY OF GROUTING CURTAIN CUTFLOW PROJECTS OF MINES IN CHINA

(See Table VI - 1)

SCHEDULE OF THE CONSTRUCTION OF FLOWCUT GROUTING CURTAIN IN CHINA

TABLE VI - 1

No.	Mine	The property of underground water of flowcut grouting curtain	Length (m)	Depth	Date	The construction cost	Grouting curtain effect
0	Xiaqiuo Coal Mine, Xuzhou Mining Bureau	Small-sized test of technique for shallow flowout grouting curtain	210	19.6 to 7.3	May.1963 to Oct.1963	34,010 $ Test completed as planned	Test of technique for flowcut grouting curtain completed
0	Liangzhuang Coal Mine, Xinwen Mining Bureau	shallow flowcut grouting curtain preventing the penetration of water in the alluvium into mine	About 200m		1966	Test completed as planned	Test of technique for shallow flowcut grouting curtain completed
1	Qingshanquan Coal Mine, Xuzhou Mining Bureau	Separate the water that has inrushed into No 3 shaft through limestone aquifer Nos.9&10 after No.2 shaft in Qingshanquan was flooded.	565	30--80	Feb.1964 to Oct.1966	271,794$ Completed	Industrial test of controlling water with flowcut curtain completed. Mine water inrush in rainy season has been prevented, saving [illegible]$/year needed for draining water of pits
2	Yanmazhuang Coal Mine, Zaozhuang Mining Bureau	Pressure-bearing water of Ord Limestone aquifer, separated by shallow flowcutting, flowing into mine by 8th. Limestone out-crop through alluvium.	930	20--50	Apr.1965 to June. 1966	298,500$ Completed	Mine inflow rate reduced by 18m³/min. saving a yearly fund for draining water by 500,000 $
3	Guodong Well, Tiantun Coal Mine, Zaozhuang Mining Bureau	Prevent river water in rainy season inflows in mine through aquifer in large quantities.	262	20--85	Feb.1967 to 1968	49,777.7$ Completed	Mine inflow rate reduced. Accident of mine flooding by water's break-in prevented. 22,444$ of a yearly draining fund saved.
4	Yiagongtang Mine, Lead & Zinc Mining Company of Shuikou Mountain	Reduce water supply of Limestone aquifer.	560	10--	Feb.1970 to 1982	2,275,626$ 80% of the total construction completed, the winding-up construction of closure remaining incomplete.	Accident of mine flooding by water's break-in from karst limestone in large quantities in rainy season prevented. Mine inflow rate reduced by over 30 %
5	[illegible] Well, Ganlin Mine, Zaozhuang Mining Bureau	Separate water of Ord.limestone aquifer through fault to recharge the carbonicain limestone aquifer, protect water-supply springcluster	4[illegible]	[illegible]0-30	1971--1972	[illegible]86,667 $ Completed	Water supply resource area returned. Fund needed for draining mine water reduced by 87,778 $.
6	Xiezhuang Coal Mine, Xinwen Mining Bureau	Reduce water of alluvium that flows into mines through limestone aquifer of the coal system by shallow flowcutting	3200	10--20	Mar.1972 to 1980	Completed	Original mine inflow rate of [illegible]m³/min. reduced by 15m³/min., to 2m³/min., saving 166,677$ of draining fund every year.
7	Heiwang Iron Mine, Zibo	Reduce inflow rate of aquifer in opencut iron mines and prevent river water from inflowing into mine pits.	1560	100 to 150	1975-- Mar. 1982	3,989,444 $ Completed	The inflowing of river water into mine pits in rainy seasons prevented. Mine inflow rate & points greatly reduced.
8	Jinan Iron Mine	Reduce water amount to be drained in mining. Protect spring-clusters and water-supply source in Jinan.	480	200-460	Dec.1975 to Sept.1979	4,138,889 $ Completed	Industrial water supply source in the eastern suburbs of Jinan and springclusters in Jinan protected. Fund for draining mine water reduced by 1,185,111$.
9	Mine No. 2, Pengfeng Mining Bureau	Separate water of Ord.limestone aquifer through fault to recharge the carbonicain limestone aquifer. Reduce water amount to be drained in Mine.			Mar.1978 to Dec. 1980	1,111,111 $ 70% completed with 30% remaining incomplete	Water amount to be drained in mining effectively controlled. Water amount reduced by 7m³/min. Effect:over 30%----40%.saving 194,444$ of draining fund.
10	Shankouchong Enkou Coal Mine, Lianshao Mining Bureau	Reduce the water supply of the area of tractive ground in draining mine water by flowcutting	About 1,0[illegible]	About 200		278,000$ 30% of the total construction completed	There has been difference between water level at the main water conductive channel section. Amount of passing-water in rainy season controlled to a certain extent.
11	Jinzhou Asbestos Mine, Puzhouwan	Cut flow to prevent sea water from inflowing into mine pits through fissured aquifer at the seaside caused by the draining of mine water.				Completed	The inflowing of sea water into mine pits prevented.
12	Yanmazhuang Coal Mine, Jiaozuo Mining Bureau	Separate water of Ord.LS.& 2nd LS. aquifer through the west 2nd fault to recharge the 8th. LS. aquifer to prevent it inflowed into mine.	400	200--300	Nov.19[illegible] to Dec.1982	777,778 $ Completed	Inflow rate in mine pits reduced by about [illegible]m³/min. A yearly draining fund of 5[illegible] saved
13	Nengaoyu Coal Mine Peicheng Mining Bureau	Separate water of Ord. LS. aquifer flowing into carbonicain LS. for reduce the inflow rate in mine	12[illegible]	50--130	1984	430m. Completed 855m. still under construction	There has been a 40m difference of water level at the section both inside and outside the curtain. Mine inflow rate reduced by 6m³/min. A yearly draining fund of [illegible] saved

VII. THE COMPARISON OF LOWERING PRESSURE BY DRAINAGE AND CUTTING FLOW BY GROUTING CURTAIN FOLLOWED BY DRAINAGE FOR CONTROLLING MINE WATER IN THE MINING OF MINERAL DEPOSIT

Controlling mine water of aquifer by lowering pressure through drainage is a traditional method in the mining of mineral deposit, which is uneconomic for the aquifer with abundant motion resource. It is too uneconomic to make no use of or no store of water drained out in large quantities. What's more the exhaustion of the underground water resource, the damage to such natural environment as spring-clusters, marshland, lakes and climate, and the loss to the human beings caused by the large-scaled drainage will never be made up for. The advantage of the method is that people have quite an advanced technology in using it. The drainage process is expected to be more and more accurate and the cost of drainage is being constantly lowered with the wide application of computers and submerge pumps of great power and high lift.

Draining after cutting flow with grouting curtain plays an extremely important part in reducing the water amount to be drained, in perfecting draining effect, in controlling and reducing the extent to which the underground water needs draining or lowering, and in lowering the cost of draining water of the mineral deposit, especially in protecting and restoring the original spring-clusters in the mining area, as well as in keeping the underground water resource, the natural environment and ecology in the mining area.

But the construction of the flowcut grouting curtain is a rather complicated one, which requires high technology and an accurate judgement of the hydrogeological condition.

So special hydrogeological tests should be constantly carried out and the condition and information of hydrogeology be often comprehensively analysed apart from the directional drilling of holes, explosion in the holes, high-pressed grouting and a series of test technology in the holes that it must be carried out till the effect of construction comes true as expected.

Therefore the cost of building curtain will be greatly increased. The following table shows the practical cost of construction of flowcut grouting curtain in our country:

Depth of grouting curtain (m)	Thickness of hard rock aquifer that must be grouted (m)	Unite cost average of the grouting curtain $/m
50	40	320
50 - 100	40	500
100 - 500	100	8600

Judging from what has been said previously, preventing and controlling mine water hazard by merely draining doesn't require much technology, whereas cutting flow by grouting curtain followed by drainage requires a lot, the investment of the two being similar. It is feasible to build flowcut grouting curtain through delicate work from a long-term point-of-view. The method has extraordinary advantages to the preventing and controlling of mine water along with the development and improvement of the construction technology. But since the method involves large investment and complicated technology, we can never be too careful when using the method.

POSTSCRIPT

PROBLEMS IN AND PROSPECTS FOR CONTROLLING MINE WATER WITH FLOWCUT CURTAIN

For many years we have been trying to find a way both to ensure a safe production in the mining of mineral deposit and to reduce the water amount of aquifer to be drained to the lowest degree in order to overcome the troubles in the mining of mineral deposit mentioned previously, the attempt of which is to lower the production cost to such a degree as can no longer be lowered and to protect the underground water resources and the natural environment of the mining area. This is just what we call "draining after cutting flow with grouting curtain". We have made several tests of the method and have put it in practice also for several times in the past twenty years. To apply the method our attention should be paid to the following points:

1.Detailed work on hydrogeology should be done in advance so as to be clearly informed of the various particularities and parameters of the flow field of underground water and avoid the error in choosing the schemes.

2.There should be reliable, relative aquiclude or aquiclude edge at the two ends or bottom of the curtain. Otherwise the underground water will be flowing around the two ends and the bottom after the curtain is built up, resulting in a poor effect or the increase of work in the construction.

3.The technology involved in the construction should be delicate and the grouting of every hole should be of fine quality so as to avoid redoing the work just because of the gaps on the built-up curtain.

The construction is sure to be a success as long as our attention is paid to these points.

Being largely invested, the flowcut grouting curtain, when completed, will have a protracted effect once and for all for the controlling of mine water. Just as the work done by the human beings in other fields, the work of controlling water is a way to improve on nature with the wills and abilities of man is believed to be perfected in its development. It is hoped that our colleagues the world over engaged in the work of mine water control will work shoulder to shoulder, make still greater efforts and exchange our technology and experience for the development of the work. We are also willing to transfer the possession of all our technique involved in the construction the various hydrogeological calculating process.