TREATMENT OF MINE WATER FOR THE PROTECTION OF PUMPS

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SUMMARY

Results of settling hydraulics make possible the underground removal of the solid content of drained mine water. Sediment-free water can then be pumped by sediment-sensitive, large-capacity and efficient pumps. The separated sediment is conveyed to the surface by efficient hydraulic transport. Also, spoil can be conveyed by hydraulic transport. A large-capacity water treatment plant is described which can be highly automated and installed for a pumping station of 170 m^3/min.

INTRODUCTION

In Hungary, mining in the karstic region has been reaching greater depths under the karstic water. Thus water hazard in mines has been also increasing. The base rock is covered by weathered dolomite, increasing the yield but also the solid content of mine water inrushes.

As a result of greater depths, the economics of pumping has received more emphasis. Pumps less sensitive to sediment are less efficient for greater pumping height. On the other hand, submersible pump are efficient for greater pumping height but very sensitive to the sediment carried by water.

This situation prompted the idea to design an equipment for decreasing the sediment content of mine water to the extent satisfying submersible pump specifications.

Research leading to underground settling basins was reported earlier [1].

Those theoretical results were strenghtened by the help of pilot experiments and this more extensive experience permitted the design of a settling system for a 170 m^3/min pumping station of an underground mine under water hazard.

A great concern related to such settling stations is the subsequent disposal of settled sediment. In our design, manual sediment removal is envisaged first, which can be later automated. A hydraulic transport equipment is used for that purpose which has been successfully applied in several Hungarian and foreign cases [2].

MAIN EXPERIMENTAL RESULTS OF MINE WATER TREATMENT

Full-scale experiments were performed in order to check theoretical results. In Hungarian mining, it has been recognized that the safe control of mine water for a large-capacity mine cannot be solely based on a theoretically sound and well designed engineering solution. This new approach has contributed to attaining the considerable financial means for these full-scale experiments. The underground settling basin was constructed as an experimental basin on the surface.

Positive results were that settling efficiency was greater than the design theoretical value. On the other hand, the loading capacity and hydraulic efficiency were smaller than expected.

The experimental basin was flexible in view of sediment loading changes. However, much difficulty occurred in removing the settled sediment.

Hydraulic efficiency of the experimental basin

Hydraulic efficiency was determined for both clean water and sedimented water of various discharge.

Dye tracer was used.

For clean water the hydraulic efficiency ranged between 50 and 70 % depending on discharge.

For sedimented water the corresponding values ranged between 46 and 60 %.

The higher was the discharge the less was hydraulic efficiency. This efficiency decrease was less accentuated for sedimented water, but even the highest efficiency value was less than those referring to clean water. The explanation is that back flow occurs in the upper zone of the basin for sedimented water, leading to eddy formation. Most of these eddies were located at the end of the sediment collecting shaft near the weir.

Settling efficiency of the experimental basin

Settling efficiency was measured for various discharges, sediment qualities and loadings. Our objective to achieve 100 % of settling efficiency for 0,1 mm particles was attained in every but two cases.

For each case the settling efficiency related to total sediment loading was greater than 80 %. An example: 98.5 % settling efficiency was reached for a discharge of 17,5 m^3/min loaded with 4,5 % sediment consisting of 30 % coal and 70 % lime in particle size ranges of 0-5 mm. Some 40 % of this mixture contained particle sizes smaller than 0,1 mm. Under these conditions, the basin settled even particles of 0,05 mm with almost 100 % efficiency.

It is clear, however, that mining inrushes cannot be expected to have such well distributed sediment particles and uniform loading. All the same, the above results are significant for the proper design of in-mine settlers.

A detailed description of these experiments can be found in [3].

The above information permitted to prepare a technological design for an underground treatment plant of minewater and sediment. This plant will protect the water control system of a planned underground mine with a predicted water flow of 170 m^3/min.

Next, this plan is described by showing first water treatment, then sediment removal.

TECHNOLOGY OF MINE WATER TREATMENT

Two figures are used for describing the technology. In references, the first number indicates the number of the figure, the second number gives the serial number within the figure.

Either controlled or uncontrolled inrush water is collected by a main water tunnel or cut beneath workings, and carried to the treatment plant gravitationally. Prior to the main water cut, rough sediment collectors are built into block water cut, preventing the arrival to the main water cut of sediment particles greater than 25 mm.

The main water cut reaches the treatment plant /1-1/. Inflow water comes to the distribution channel distributing water and sediment among operating settling elements /1-4/. Distribution channels are located in the inflow cut /2-1/. Each of these channels can be closed in order to permit maintenance.

Each distribution channel is connected with a settling basin /1-5 and 2-2/ through an inflow head / 2-7 /. Several types of such head were investigated such as the Stuttgart-head, Stengel-system, type Geiger, "T" heads. The "T" head proved to be the best solution, so it will be designed for the mines. Settling basins are planned to be constructed by using the section of roadway 2 - I .

Specifications of the settling basin

Longitudinal flow, sediment collector shaft, counter-inclined bottom, sectional cleaning.
Volume: 525 m^3, surface area: 210 m^2.
Average surface loading: 4,2 $m^3/m^2/h$, average flow velocity: 58.8 m/h.
Average residence time of water: 0,595 h.
Design loading: 882 m^3/h.
The maximum discharge per one basin is 1,133 m^3/h if one settling basin is out of operation and the peak minewater discharge arrives. In this case the average flow velocity is 75,5 m/h and surface loading is 5,4 $m^3/m^2/h$.

The Reynolds number of the basin is 16700 for the design loading and about 21000 for peak loading. The corresponding Froude-numbers are $1,9 \cdot 10^{-5}$ and $2,9 \cdot 10^{-5}$. Settling efficiency for the design load is 95 % and for the peak load: 82 - 87 %.

The particle sizes greater than 0,1 mm of in-mine sediment is 60-75 %. Thus settling efficiency of 82-87 % will safely remove particles harmful to submersible pumps.

Specifications of the sediment collector shaft

Transversaly divided by plates, circular cross-section due to mining technological and construction reasons, conic bottom /2-8/ . Collected sediment corresponding to 60-75 % of income sediment slips down to the outlet during cleaning. Total volume is 100 m^3. 75-80 % of this volume can be efficiently used, otherwise collected sediment decreases net cross sections of the settling basin, leading to smaller settling parameters.

Water flows out of the basin through a sharp-crested weir of controllable height /2-4/. Its loading is 137 $m^3/m/h$ for the design flow and 189 $m^3/m/h$ for the peak flow. These observed numbers are in accordance with literature values [4] showing that except disturbed zones accounted for in the design, weir loading does not influence settling and hydraulic properties of the basin. Next, water enters the collector cuts at both sides of the plant /1-7 and 2-5/. These cuts have the cross-section: 2 - IV. Energy dissipators are built into these cuts /2-6/. These patented dissipators prevent the increase of water velocity higher than 3,5 m/s and erosion of the concrete channel bed.

A sluice built in the right-hand outflow cut /1-9 and 1-8/ assures water-supply for sediment removal. Excess flow is united with water of the other outflow cut /1-15/ and is directed toward the sump of the pumping station /1-2/.

TECHNOLOGY OF SEDIMENT REMOVAL /Fig. 3./

Collected sediment is emptied through a valve /1/ in the basin outlet. These valves can be telecontrolled. Emptying is going on subsequently. Sediment flows through collector pipe /2/ to the suction pipe of slurry pump /3/, then through the slurry pipe /4/ to the open chamber of the removal equipment. Diameter of all slurry pipes is 200 mm.

The water-supply pipe has a diameter of 350 mm. From the two high-pressure pumps /5/, hydraulic transport requires one pump. The 10 m head on the suction side is advantageous since the ten-step pumps cannot be operated under suction.

Water from pumps /5/ is conveyed to the removal equipment through clean water pipe /6/.

A flow meter and controller /7/ is installed into pipe /6/. Its sensor is a Venturi meter together with a mercury pressure gauge and a recording unit. The controller is a valve operated by an electric motor.

High-pressure water enters sediment removal equipment /10/ through pipe /6/, valves /8/ and auxiliary valves /9/. The principle of sediment removal is to fill chambers alternatively by slurry and to empty them by hydraulic means. Water left in the chamber is pushed out during the next filling.

Both slurry flow and water flow are continuous as an effect of the three chambers of 300 m long each. Each chamber is equipped by four main and two auxiliary gates, valves. Thus the total number of valves /8/ is 12 and that of auxiliary valves /9/ is 6.

Outflow pipe /11/ is connected to the chambers through the main valves and it contains the measuring and controlling device /12/ of filling flow. Outflow water is directed to the sump tunnel.

The fourth pipeline connected to the equipment is the transport line conveying slurry to the surface.

Alternative operation of valves /8/ and /9/ of the equipment is controlled automatically by hydraulic unit /13/ with electric and telecontrol devices /14/.

Sediment loosening is necessary for sediment release from the settlers. For this purpose water flow of 14-15 bar comes from pumps /15/ to pipe line directing to settler outlets. Loosening nozzles /17/ are branched from this pipeline.

Vertical boreholes directly reach the upper edge of the slurry dump /18/; so the horizontal transport line can be short and directly connected to the distribution pipe of the slurry dump.

Specifications of hydraulic transport

For the hydraulic transport of the given sediment /specific density: 2,7 t/m³, max. particle size: 40 mm/ pipe diameter 300 mm is necessary at least with slurry velocity of 3,8 - 4,4 m/sec.

Under these conditions the sediment removal equipment assures a slurry concentration of 30 % /weight/.

Pipeline diameter:	200 mm
Slurry velocity:	3,8 - 4,4 m/sec
Slurry loading:	430 - 500 m³/h
Slurry concentration:	30 %
Max. bulk density:	1,22 t/m³
Yield of solid transport:	130 - 150 t/h

Filling pumps

Type: Warman 8/6 F-AH /Tatabánya/

Slurry flow approx.:	8,3 m³/min
Pumping height approx.:	45 m
Revolution number:	1000/min
Capacity:	132 kW
Max. particle size:	70 mm

Transport pumps

Type: OW 250 A 10 /Polish/

Discharge:	492 m³/min
Pumping height with 10 steps:	700 m
Revolution number:	1450/min
Efficiency:	75 %
Capacity:	1250 kW
Weight:	4820 kg

Loosening jet pumps

Type: DEB 200 II. /Dorog/

Discharge:	1600 l/min
Pumping height:	160 m
Revolution number:	2900/min
Capacity:	110 kW

Energy requirement of the equipment

1 water pump; OW 250 A 10	1250 kW
1 slurry pump; Warman 8/6 F-AH	132 kW
1 oil-hydraulic unit; Danuvia 320 TE 80-160	30 kW
2 loosening jet pumps	220 kW
2 sump pumps; Bibo B-2250	108 kW
Total requirement:	1740 kW

The specific energy requirement is about 12 kW/t sediment transported.

The above equipment extended with a mixing tank can be used for the hydraulic transport of spoil. Mixing tank can be the conic outlet of a non-operating settler. Spoil crushed to 40 mm particle sizes is fed in dry state and slurry is formed by water inflow. A joint dump of sediment and spoil can be formed on the surface.

SETTLING PLANT OPERATION

It is required that the plant should be operated by skilled workers.

Settlers do not need any special maintenance except the daily cleaning of inflow heads and weir edges and the removal of floating garbage.

Sediment collector shafts should be emptied in case of 50 % fullness without the interruption of settling operation. A 10 m³/min increase of dicharge requires the introduction of a new settler. Settlers out of operation should be kept empty. As a result, in case of a great inrush the filling of new settlers gives enough time for the preparation of excessive pumping and sediment treatment.

If silt thickness reaches 30 cm over the counter inclined bed of the settler, it should be emptied through the collector shaft. Silt from the bottom should be washed into the shaft by jet effect.

Maintenance works can be accomplished in the empty basin. It is of great importance to check the horizontality of weir crest. If the deviation from horizontality is greater than 1 mm, our measurement shows that an asymmetrical flow pattern arises, leading to decreased hydraulic efficiency.

Depending on the type of pumps used in the sediment removal equipment various operational and maintenance regulations should be prepared.

The removal equipment receives clean water from the clean water tank and used water flows into the safety sump /1-12/ from where water arrives in the settlers again through the pumping station and sump shaft /1-13/.

The safety sump is sized in such a way that enough time of escape should be available for workers through the escape shaft /1-13/ and for deelectrifying in the case of a simultaneous failure of two settlers of 50 % fullness. Workers of the treatment plant can reach staff transporting equipment and exits located at higher points over against water flow.

Automation possibilities

Almost a full automation is possible for the treatment plant.

By level sensing of the settlers the introduction of new settlers can be automated. Also, by sensing silt level the whole process can be automated: collector shaft emptying, watering of released sediment, starting of chamber feeding pumps, alternative chamber operation.

Silt level sensing on the bottom of the settlers may indicate the necessity of settler cleaning. This, however, can not be automated, similarly to the hydraulic formation of the dump.

CONCLUSION AND RECOMMENDATION

The described design of a large-capacity minewater treatment plant will be realised soon. Some further remarks are as follows:

- Silt collected in the shaft can be removed by a submersible slurry pump instead of the method shown earlier. The same submersible pump may fill the chambers too.

- It is believed that the removal capacity is sufficient for the transport of mining spoil too. In this case proper crushing equipment and spoil storage would be necessary, but the process would not change.

- A basic figure of treatment plant design is sediment loading; a rather uncertain quantity. In order to avoid both over and underdesign, research, possibly experiments would be necessary how to estimate this loading. So far, mostly financial means have delayed such a research.

References

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4 Graber, S.D.: Outlet weir for settling tanks. Journal WCPF; 46.10. 1974. X.

LIST OF FIGURES

Fig. 1. Scheme of the settling plant

1. Inflow of untreated minewater
2. Outflow of treated water to submersible pumps
3. Transport of settled sediment to dump
4. Inflow tunnel, distribution channel
5. Settlers /10/
6. Sediment collector shafts of settlers
7. Treated water collector tunnels /right side and left side/
8. Clean water storage for the sediment removal equipment
9. Blocking clean water storage
10. Material input cut of sediment treatment level
11. Transformator and machine place for the sediment removal equipment
12. Safety sump to protect sediment treatment level
13. Escape shaft and pump sump
14. Sediment capturing cuts and machine place of pumps
15. Outflow cut for treated water

Fig. 2. Section B-B for Fig. 1. and cross-sections for the settling plant

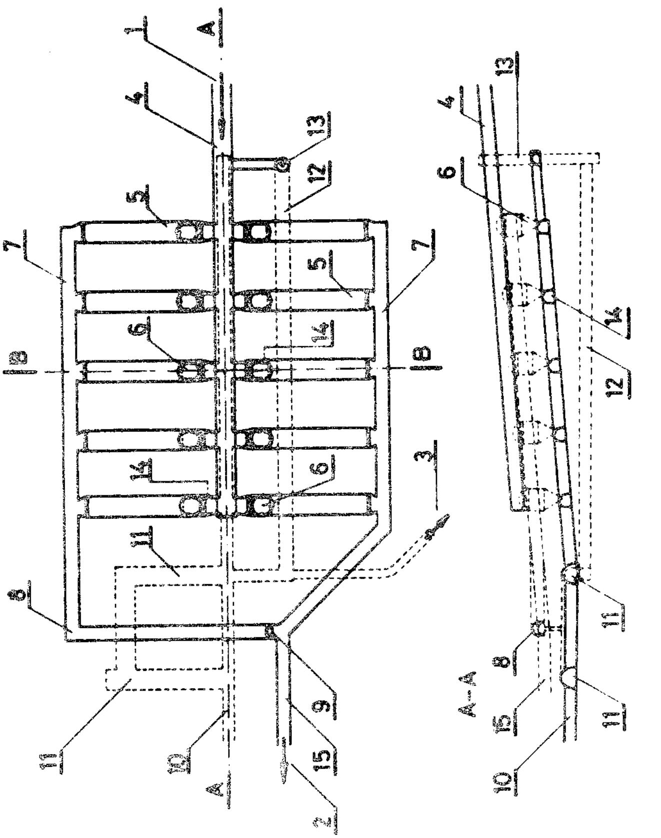
1. Inflow cut
2. Settling basin
3. Operational water level
4. Weir made of concrete and steel edge
5. Treated water collector cut
6. Energy dissipators
7. Feeding heads, type Geiger
8. Sediment collector shaft
9. Sediment capturing cut and machine place of the pump
10. Machine place of the removal equipment and connecting cut

Cut sections

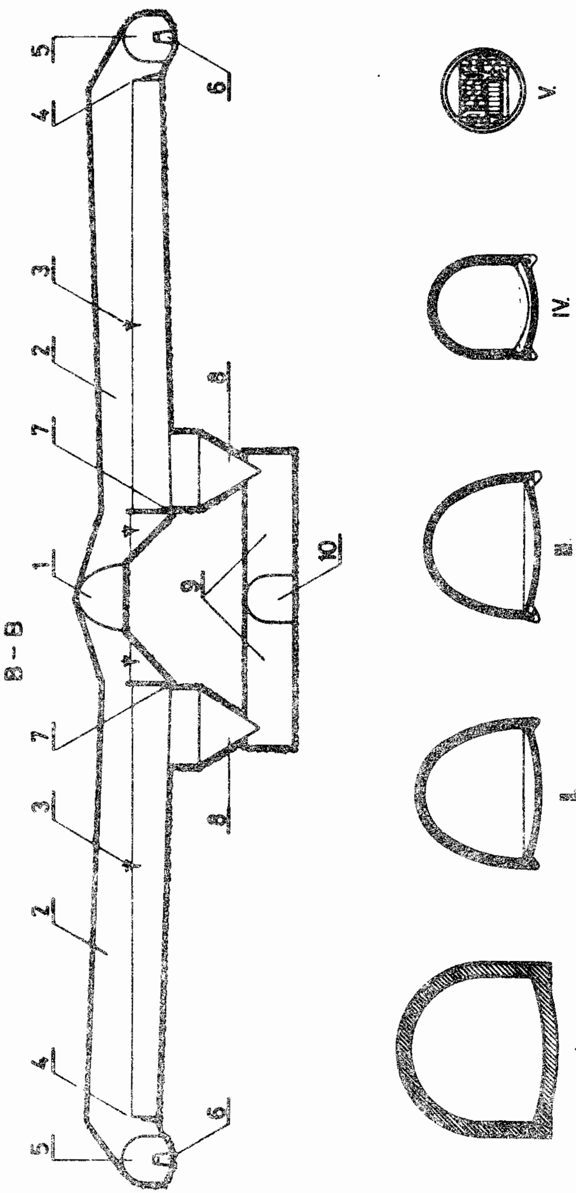
I. Settling basins, with 2-row concrete bricks, 27,25 m^2
II. Inflow cut, bell section of 25 kg and shot-concrete support, 18,2 m^2
III. Machine place of the removal equipment, bell section of 25 kg, shot-concrete support, 16,5 m^2
IV. Collector cut of treated water, outflow cut, machine place, sediment capturing cuts: bell section of 25 kg, shot-concrete support, 12,0 m^2
V. Escape cut, pumping shaft of the safety sump, concrete brick support, 7,0 m^2

Fig. 3. Scheme of sediment transport

1. Release valve
2. Slurry collecting line
3. Slurry pump
4. Slurry pipeline
5. Transport water pump
6. High-pressure water manifold
7. Flow meter and controller
8. Main valves of the sediment removal equipment
9. Auxiliary valves
10. Chambers
11. Release pipe
12. Feeding flow meter and controller
13. Hydraulic servo unit of the removal equipment
14. Control device of the removal equipment
15. Loosening water pumps
16. Loosening water pipe
17. Nozzles
18. Hydraulic dump



1. ábra Fig 1.



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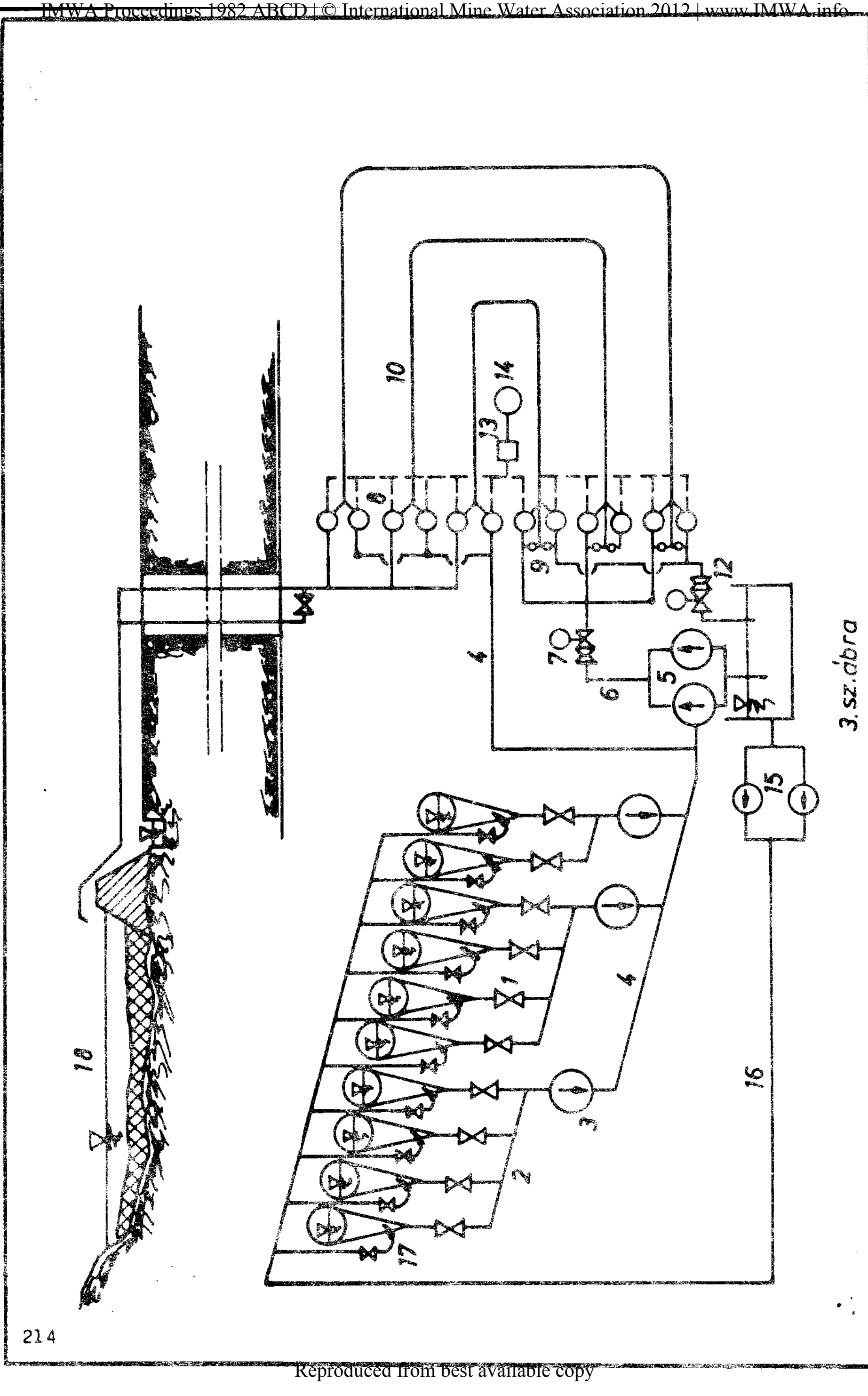

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