SUMP CLEANING BY HYDRAULIC METHOD

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A brief review is given about various mine drainage plants and sump systems and the position of the settled deposit in the sump is discussed. Hydraulic sump cleaning methods are considered for mine drainage plants with settling sump systems and for those where settling takes place in the operational water sump.

Methods and theoretical solutions are discussed for removing deposits from various settling systems in small and great depths. Transport may occur in two stages /first to an underground mud handling plant and then to the surface/ or directly from the settling system to the surface.

1. INTRODUCTION

Cleaning the sumps and settling drifts, i.e. removing the settled deposits and mud, is essential from the safety point of view in the field of water control in mines. The lack of efficient water-treatment systems to protect pumps may often endanger, according to experience, the existence of the mines and in certain cases can even force miners to abandon it.

According to the conventional method, sump cleaning is performed by mine cars moving on a track in the water sump; and hand or mechanical loading is applied. Another method uses scrapers to transport the solids in the water sump and the sump incline to the main heading.

In the hydraulic technology of sump cleaning slurry pumps are applied. This is the best method for cleaning sump systems with dams. Suitable slurry pumps or hydraulic transport equipment can raise the mixture of settled solid and water directly to the surface. The application of jet pumps for this purpose is beneficial because they are of simple construction, do not contain moving parts and are always ready for service. A great advantage of hydraulic sump cleaning equipment is that they can be put into operation while the sump of the draining plant is being used and miners not have necessarily to enter the sump.

Hydraulic sump cleaning technologies will be considered in the paper for draining plants with settling drifts and for those where settling takes place in the operational water sumps. The paper analyses from the safety and economy point of view the methods of sediment removal from settling systems with horizontal and vertical flow to a central mud handling plant and from there to the surface, or from the settling system directly to the surface. Cases for small and great mine depths are equally considered.

2. MINE DRAINING PLANTS AND SUMP SYSTEMS

Mine draining plants in underground mining consist of sump system, pump chamber containing pumps, motors and other mechanical and electric equipment and the pipeline with fittings [1].

Requirements sumps have to meet are [1,2]:

/a/ containing and storing the inflowing mine water for time of breakdowns viz. electric breakdown, pump failure etc.;

/b/ settling the mine water before pumping to ensure safe operation and to increase pump life;

/c/ storing the inflowing mine water to ensure optimum operational conditions.

Mine draining plants can be equipped with horizontal - shaft pumps or submersible pumps. According to the vertical distance between pump chamber and sump, as well as the type of the pump, conventional, positive suction head and submersible pump type draining plants are distinguished. The main direction of flow in the sump systems can be horizontal or vertical and combined horizontal-vertical. The collected water can be pumped to the surface from each type of sump through a hoisting or air shaft, water shaft or borehole lined with a casing. Apart from the principal solutions, numerous other versions are known of which the most suitable one has to be selected by technical and economical analysis based on the actual situation, taking into account first of all mining safety.

2.1. Conventional Mine Draining Plants

The pump chamber of conventional mine draining plants is constructed higher than the highest level of the sump. This layout is characteristic of mine draining plants equipped with horizontal-shaft pumps, but vertical pumps also can be used and combined systems using both types arranged for series operation are also known /Figs. 1 to 3/.

In conventional draining plants the tasks of the safety sump, the settling sump and the so-called operational sump ensuring good pump performance can be solved by a single water sump /Fig. 4/. To ensure a safe cleaning of the sump without disturbing the operation of the draining plant, a full reserve to the sump is required. Water can be led to both sumps from all drifts, thus the settled solid and mud can be collected and removed if the sump just out of operation is separated from other parts of the draining plant. The water sumps of this type of dual system are constructed with an inclination towards the pump chamber that ensures for the solid to settle uniformly along the sump. The deposits therefore, are spread over a large area, along the whole length of the sump, consequently, removing the settled solids i.e. cleaning the sump is difficult, uneconomical and disadvantageous from the safety point of view because of its long time.

Sump systems with pre-settling facilities are more advanced. Solid is settled in these systems in parallel settling sumps designed and constructed for this purpose /Fig. 5/. Pre-settling may be performed in two stages in coarse and fine pre-settling sumps ensuring safe and plug-free operation even during water inrushes. From the settling sumps, water flows over dams to the operational sump. Also this has to be constructed in a twin-layout. In Figs. 6 and 7 two schemes are illustrated; the first is beneficial from the deposit-removal point of view while the second is simple and cheap. In the pre-settling sumps the deposit settles within a small area and only a small amount of fine mud enters the large water sump. Pump life is hardly affected by this contamination. The deposit settled in the pre-settling sump is easy to remove either continuously or periodically. Removing the deposit continuously, mining safety also increases.

2.2. Mine Drainage Plants with Positive Suction Head

Pump chamber is below the deepest level of the sump in this type of draining plant. The water collected in the drifts is led first to a dual settling sump-system with horizontal flow [3,4]. Thereafter, it flows with positive head to the pumps installed in the pump chamber through the suction pipe that can be closed by a gate valve. The pump chamber is protected by a safety sump from being flooded in case a pipe would break /Figs. 8 and 9/. Sump systems with pre-settling sumps are beneficial because they are feasible in mines exposed to water hazard with both low and high water outputs. The pumps can be operated under favourable conditions and they are easy to automate. Pumping plants with positive suction head and sump systems with pre-settling sumps in new mines are feasible and their use ensures all the advantages of up-to-date drainage plants. Reconstruction work, however, never has been able to achieve that because of existing features of the mine.

2.3. Mine Drainage Plants with Submersible Pumps

Draining plants with submersible pumps are first of all useful in deep underground mining. The clean water with contaminating particles less than 1 mm enters the operational sump through water-transport conducts and the settling sump-system. Suction takes place in the suction well where submersible pumps are operating. No horizontal pump chamber of great extension with complicated pipes and sparate safety sump are now needed. The submersible pumps are ready for service at any time, they are easy to automate, operate reliably and with a high efficiency, but their price is high. The settling system of this type of draining plant can be of horizontal or vertical flow [3,4].

In settling systems with horizontal flow /Fig. 10/ the contaminated water undergoes first a coarse pre-settling in a few settling sumps arranged for parallel operation. The pre-settling sumps can be omitted -as in the previous draining plants- if the solid is expected to contain only a small amount of coarse particles. The overflowing water of the fine settling system which is in series operation with the coarse one, contains only particles less than 1 mm if the settling system is properly designed. It is essential to construct a dual system of sumps also in this case.

In settling systems with vertical flow /Fig. 11/ the contaminated water enters first also a horizontal pre--settling sump being identical with that of the previous system. Coarse particles settle down here. The overflowing muddy water flows in a mud-pipe arranged centrally in the suction shaft. The lower part of the suction shaft operates as a settling tank with vertical flow. The submersible pumps suspended above the settling space, pump clean water to the surface while the solid settles to the bottom of the shaft sump. Thus solid concentrates to a small area in this system too, ensuring good conditions for sump cleaning.

3. SUMP CLEANING BY HYDRAULIC TECHNOLOGY

Depending on sump design, the solid settled from the mine water is uniformly deposited in the water sumps or concentrates in the settling sump. In conventional draining plants, a mud layer of considerable thickness spread over the whole length of the sump, has to be very often removed when cleaning it.

If conventional cleaning methods are used, a track is constructed on the floor of the sump and the mud is loaded by hand or mechanically into mine cars. The hydraulic method of sump cleaning applies high-velocity jets to loosen the settled mud and the produced mixture is transported to its destination by pumps. Jet pumps are highly suitable for this purpose because, apart from other beneficial features, they do not need electric equipment in wet places [5, 6, 7, 8, 9].

The high-velocity /50-60 m/s/ jets are capable of effective winning loose and sandy deposits within a radius of 1-1,5 m in underwater operation. Thus jet pumps with movable winning heads can be applied for sump cleaning.

The hydraulic sump cleaning system is illustrated in Fig. 12. To operate the jet pump and provide water for the winning heads and to remove slurry, pipes are installed on the walls of the water sump. The jet pump equipped with a winning head receives its supply from the pipes through flexible hoses. The jet pump can be moved either on the floor or suspended from the roof, the winning head can be submerged into the mud and after loosening the settled solid, the produced mixture can be pumped to the discharge pipe.

To achieve an effective winning, a pressure of 1 MPa is needed at least. The jet pump is supplied with water of the same pressure, its head being 20-30 m in this case. This enables us to transport the slurry from the sump to the mud handling equipment near the water sump. Particles smaller than 50 μm can be separated by a hydrocyclon. The slurry containing finer particles can be settled only in settling equipment of great dimensions. Centrifuges or filters would increase the costs of the method to an unacceptable level.

If a pre-settler is applied, the settled solid from the mine water is collected in the relatively small thickener and is removed by a jet pump installed for continuous operation. Nozzles mounted in the pre-settler provide high-velocity jets to force the solid towards the suction pipe of the jet pump. Typical pre-settlers with jet-pump sump cleaning are illustrated in Figs. 6 and 13.

The discharge pipes of the pumps in the mine draining plant are tapped and the high-pressure water is used to loosen the settled solid as illustrated by the scheme in Fig. 13. The motive water for the jet pump is supplied by a separate clean-water pump . The pressure of this pump can be selected so as to ensure for the slurry to be transported from the settler directly into a pipe leading to the surface. To achieve this goal the head of the motive water has to exceed three times the geodetic head. This kind of technical solution is suitable for depths not exceeding 200 m.

If the pre-settler is of conic shape /s. Fig. 6/, the slurry can be easily collected since it has to be forwarded on an inclined surface. The slurry can be pumped to the surface in the same way as in the previous case, but substantially lesser fluidizing nozzles are needed.

The methods also apply for transporting slurry to mud handling equipment in very deep mines. Mud handling equipment ensure the separation of the solid from water and the treatment needed before hydraulic transport to the surface. It is of the highest advantage if the solid can be transported from the mud handling equipment to a worked-out area to be stowed hydraulically.

The transport of the solid settled in the sump can be combined with the separation of the particles coarser than 50 µm. If the head produced by the jet pump is not high enough, the slurry pipe has to be connected to the cyclon through a centrifugal booster pump. Ensuring sufficient pressure i.e. 0.3-0.4 MPa, the particles greater than 50 µm can be separated. This method is successfully applied in Balinka Mine affected by water inrushes that carry sand [10].

4. TRANSPORTING THE SLURRY TO THE SURFACE

The removal of the slurry collected in the water sump or in the settler can be combined directly with the transport to the surface if the depth of the mine is small. The jet pump used for sump cleaning i.e. slurry removal has now to be designed so as to produce a head equalling the sum of the elevation and the frictional head loss in the pipe. Fig. 6 shows an example for this solution. Previous investigations suggest that this method can be applied in mines not deeper than 200 m.

In knowledge of the geology of the mine, the composition of the solids carried by water inrushes can be predicted. If the solids concentration is expected to be low, the direct removal and transport of solid is to be preferred even in greater depths than 200 m because capital costs of this method are low. The higher energy consumption of this type of transport does not necessarily increase significantly the costs because operational time is short.

An air lift system arranged in series operation with a jet pump can transport slurry from depths as great as 400-500 m. The scheme of this type of transport for removing mud from the shaft bottom is illustrated in Fig. 14. The high-pressure clean-water pump arranged near the shaft provides the motive water for the jet pump that is equipped with winning nozzles. The air lift device is inserted directly behing the jet pump into the discharge pipe. The jet pump replaces submergence needed for the air lift system. Compressed air is supplied by a separate compressor. Minimum resistance has to be ensured at the air - - outlet device in the discharge pipe to keep flow at maximum. The slurry transported to the surface is first led to a settling tank and after that the clean water to a stream. Slurry is transported periodically depending on the amount of deposit collected. Between operational periods the settling tank on the surface can be cleaned by scraper or other equipment. If great quantities of solid are carried by the water to the mine, such equipment has to be chosen for the slurry transport to the surface which operates with low specific energy consumption. Possibilities for displacing the solid in the mine also have to be considered. In both cases underground mud handling equipment are needed.

The underground dewatering of the mud removed from the settling sumps and the transport of the solid in a dry state are not economical methods. The solids content of the mine water can only be dewatered namely by centrifuges or filters because of a relatively high percentage of fine particles. Both procedures are expensive and require sofisticated equipment. Underground dewatering is not competitive compared to the hydraulic slurry transport combined with settling on the surface from the economy and safety point of view.

Hydraulic stowage can only offer a temporary solution for displacing the solid. To ensure the required level of safety for mine drainage, the slurry collected in the settlers has to be continuously transported to the surface. Pipe chamber feeders can be suitably applied for this purpose. The scheme of the hydraulic transport system using a feeder is illustrated in Fig. 15. The slurry collected in the settlers will be transported by jet pumps to a central slurry collecting tank. This tank is suitable to be constructed in a staple or a steep inclined drift. The slurry can also be thickened in the slurry collecting tank in which case the overflow has to be led to the settler.

The main units of the pipe chamber feeder are a slurry pump filling the pipe chambers and high-pressure clean-water pumps emptying the chambers i.e. transporting the slurry to the surface. Because of the operational principle of the pipe chamber feeder the amount of water flowing out is equal to that of the slurry filled into the chamber. This water has to be led through a return pipe to the settler or water drift. If the pipe chamber feeder operates properly, the return water does not contain solid particles, thus this measure provides an increased safety.

It is characteristic of the operation of the pipe chamber feeder that the flow rate of the slurry transported to the surface equals the capacity of the high-pressure pump. On the other hand, the capacity of the slurry pump equals the flow rate in the return pipe. This means at the same time that the capacity of the high-pressure pump used for hydraulic transport, increases the built-in capacity of the draining plant.

The operation of the pipe chamber feeder is fully automatic. Filling and emptying the chambers are controlled by hydraulically operated gate valves. Operational experience of pipe chamber feeders proves the high reliability of these equipment. Breakdown of the hydraulically operated gate valves shows a rare occurrance. Therefore full reserve equipment are not justified from the safety point of view. A third chamber has to be installed as a reserve unit which can replace any of the two operating chambers if one of them breaks down. Disconnecting the faulty chamber and putting the reserve unit into operation can be performed electrically.

It is advantageous for the pipe chamber feeder to be connected to a 200 mm pipe. In this arrangement the maximum solids transport amounts to 220 t/h at 4 m/s flow velocity, 20 % by volume solids concentration and 2.5×10^3 kg/m^3 density. This value can be somewhat lower, depending on the praticle size distribution of the solid. The equipment can transport 180 t/h with great safety.

Other equipment but pipe chamber feeder suitable for the transport of solid with coarse particles are not available at the present time.

CONCLUSIONS

Investigations performed prove that hydraulic transport is the most suitable method to transport slurry containing solid from the settling sumps. Methods and equipment to solve this tasks are available.

Greatest safety can be achieved if the solid removed from the settling sumps is continuously transported to the surface, thus ensuring safe conditions for the operation of the clean-water pumps in the draining plant.

Underground dewatering of the solid removed from the settling sumps and their transport to the surface in a dry state or underground deposition are not economical methods.

The study first concerns the cleaning method for sumps ensuring also settling the solids. The solids settled in the water sump or pre-settler is removed and transported by a movable jet pump equipped with a winning head. The removed slurry is led to mud handling equipment. Whether the slurry will be deposited, dewatered or transported to the surface, should be decided in view of local circumstances. This solution can be materialized when reconstructing existing mine draining plants.

The other main method applies slurry transport from the settling sump by jet pumps to a mud handling drift at a higher level. Slurry producing equipment provide high concentration here for the direct hydraulic transport to the surface. This method is suitable for application in new mines of high capacity with intensive water inflow where a central draining plant serves for the dewatering of the whole mine.

The slurry removed from the sump can be transported to the surface by a slurry pump /jet pump/, combined air lift-jet pump system or pipe chamber feeder, depending on the actual depth of the mine. The suitable fields of applications are also discussed.

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LIST OF CAPTIONS

Fig. 1. Conventinal mine draining plant with horizontal shaft pumps.

Fig.2. Conventional mine draining plant with vertical pumps.

Fig. 3. Conventional mine draining plant with horizontal shaft and vertical pumps arranged for series operation.

Fig. 4. Conventional sump system.

Fig. 5. Sump system with pre-settler.

Fig. 6. Conical settling sump.

Fig. 7. Pre-settling reservoir

Fig. 8. Draining plant with positive suction head

Fig. 9. Draining plant with positive suction head

Fig.10. Draining plant with submergible pumps and horizontal flow settling sumps

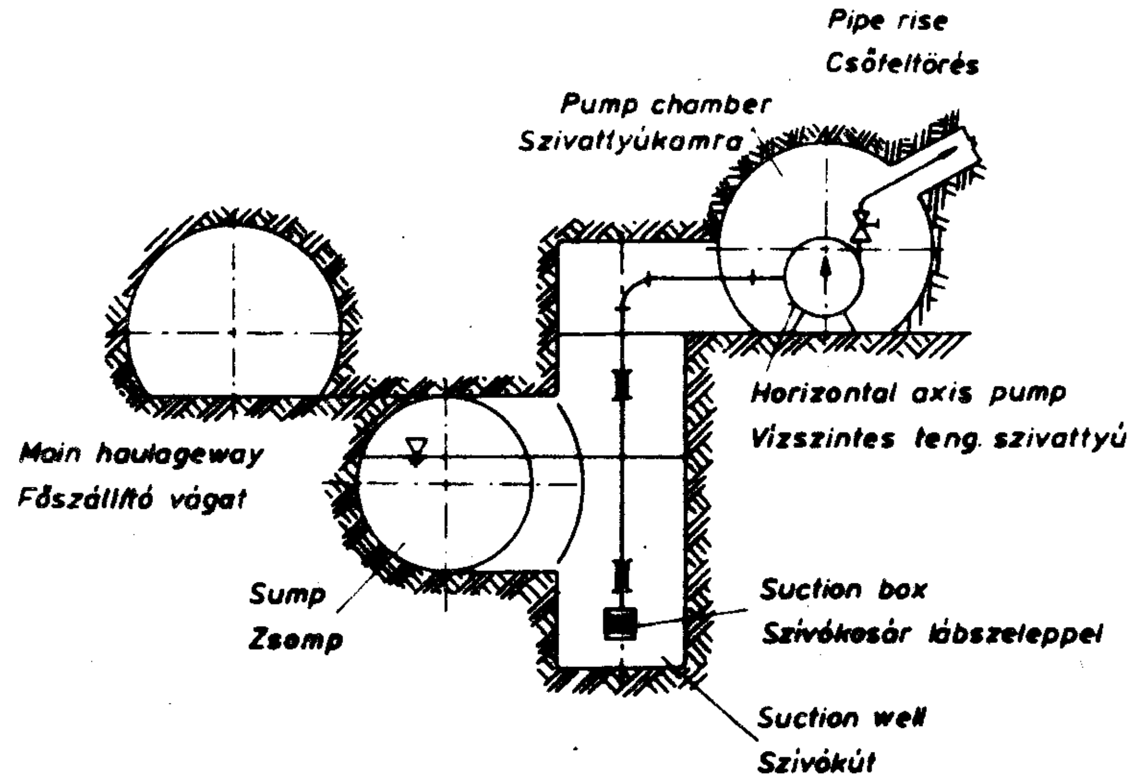
Fig.11. Draining plant with submersible pumps and vertical flow settler

Fig.12. Sump cleaning in convetional draining plants applying jet pump

Fig.13. Cleaning pre-settling sump by jet pump

Fig.14. Sump celaning by combined air lift-jet pump system

Fig.15. Mud transport to the surface by pipe chamber feeder



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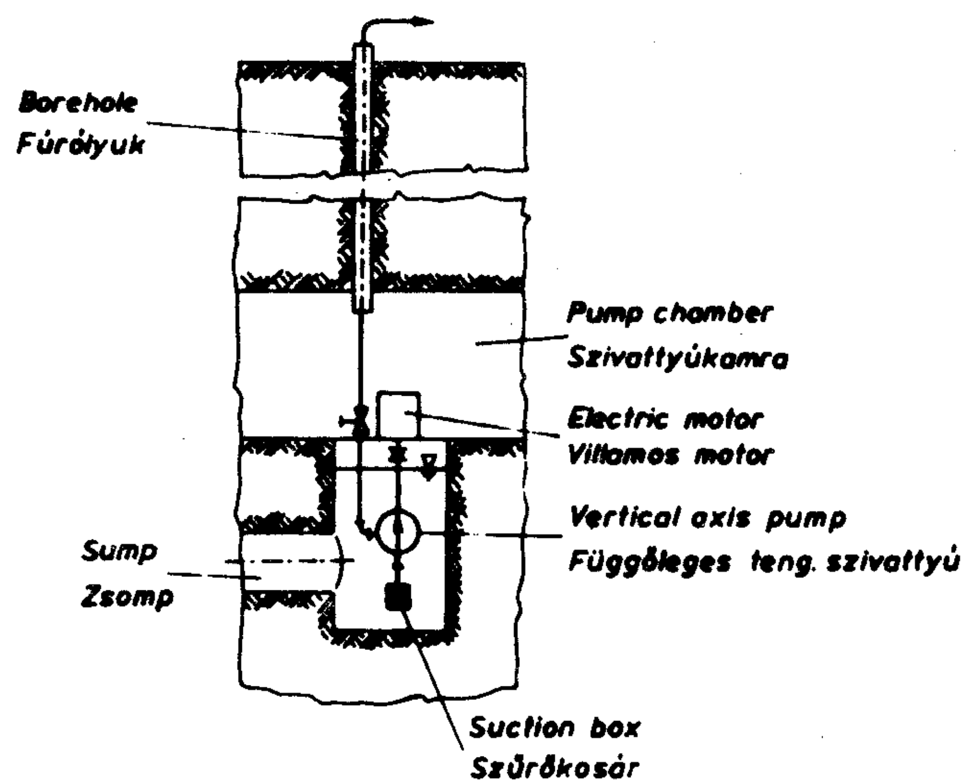

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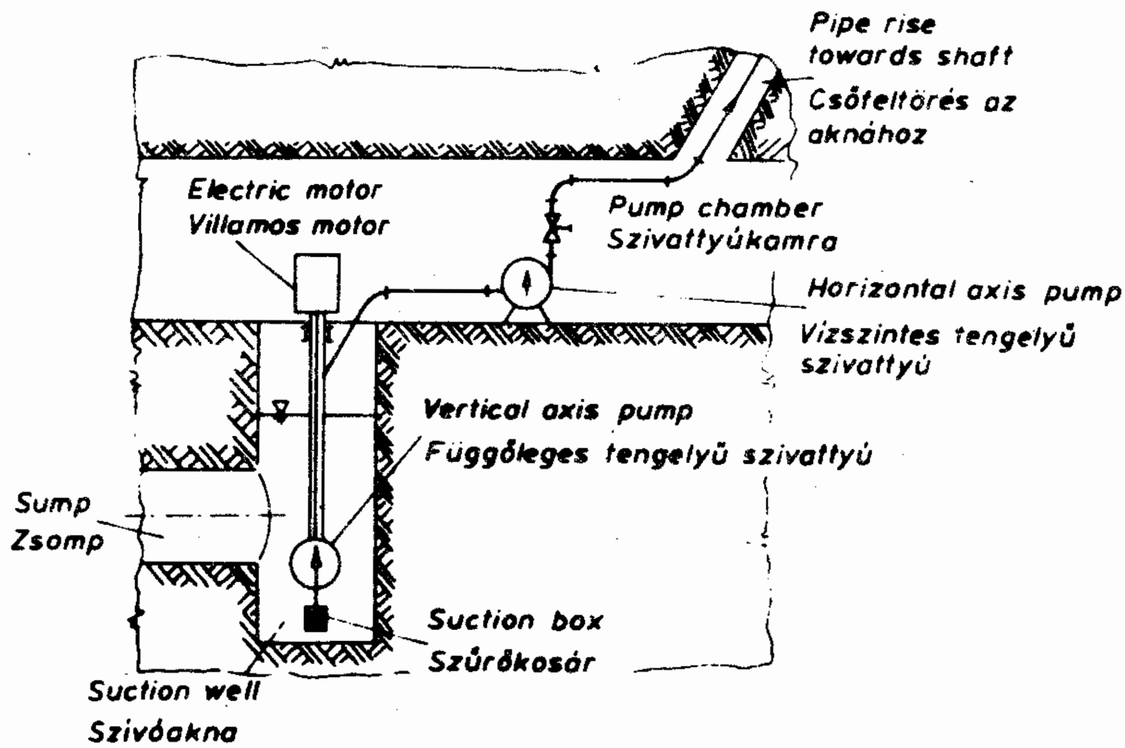

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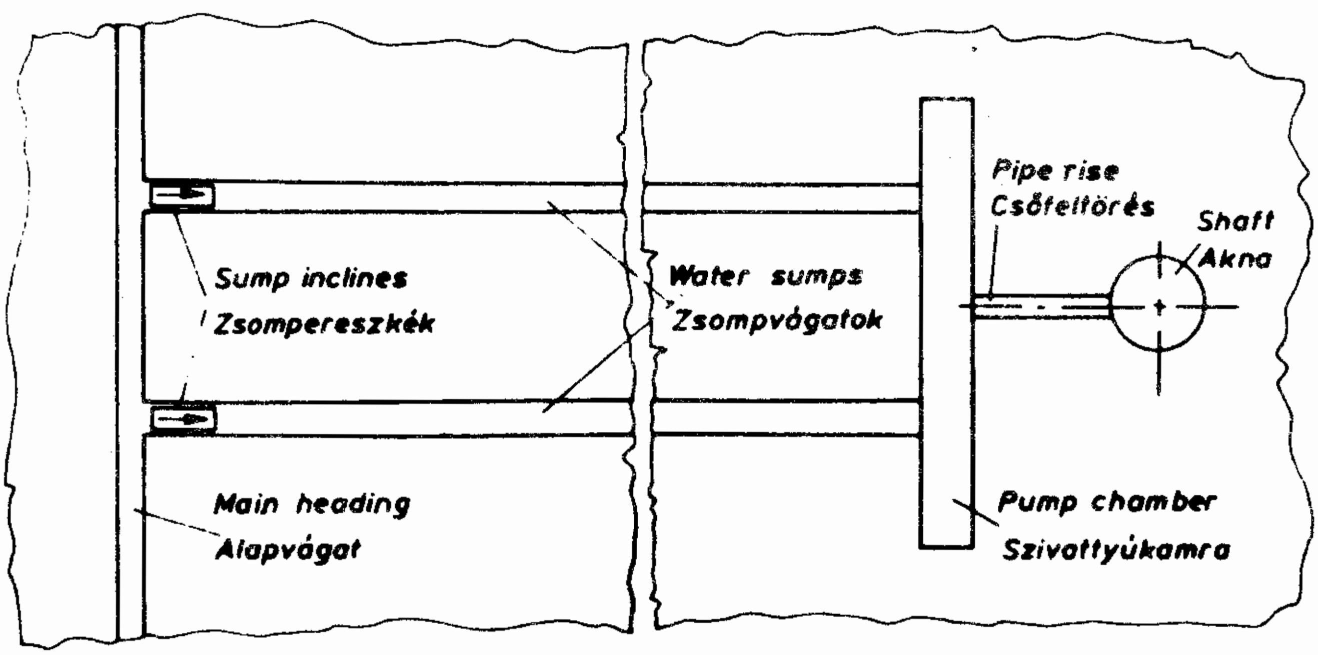

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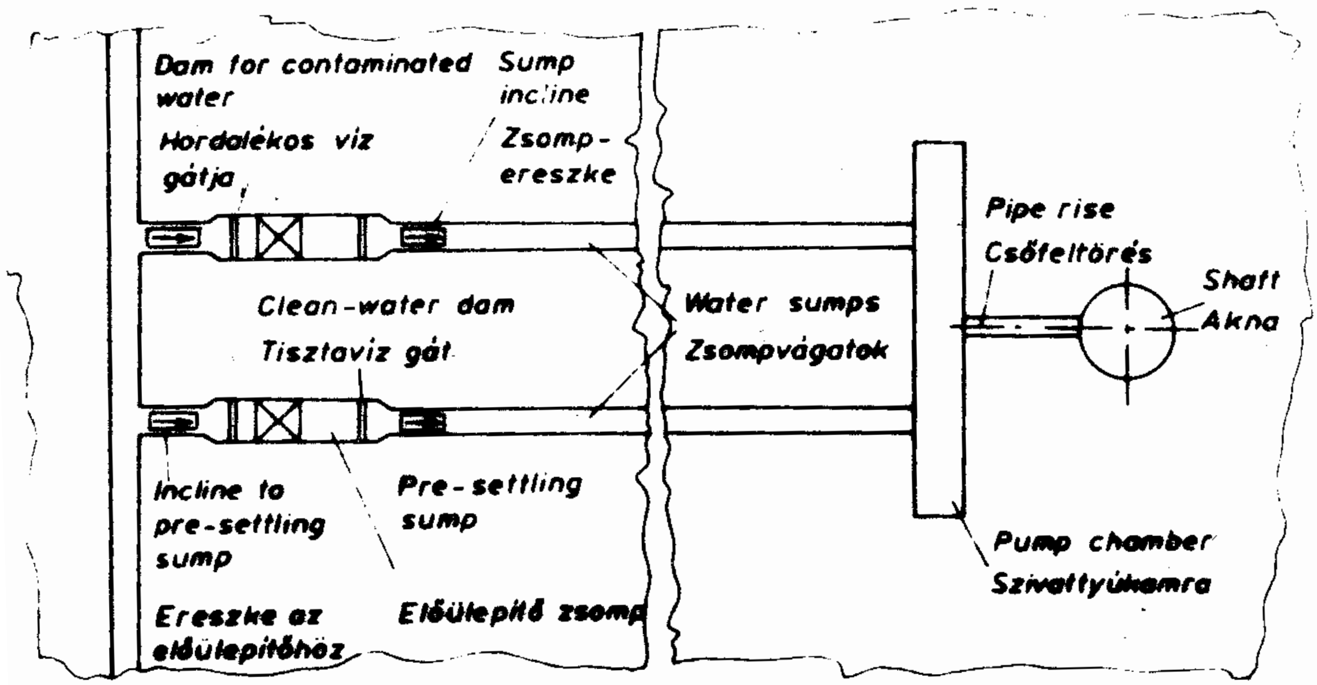

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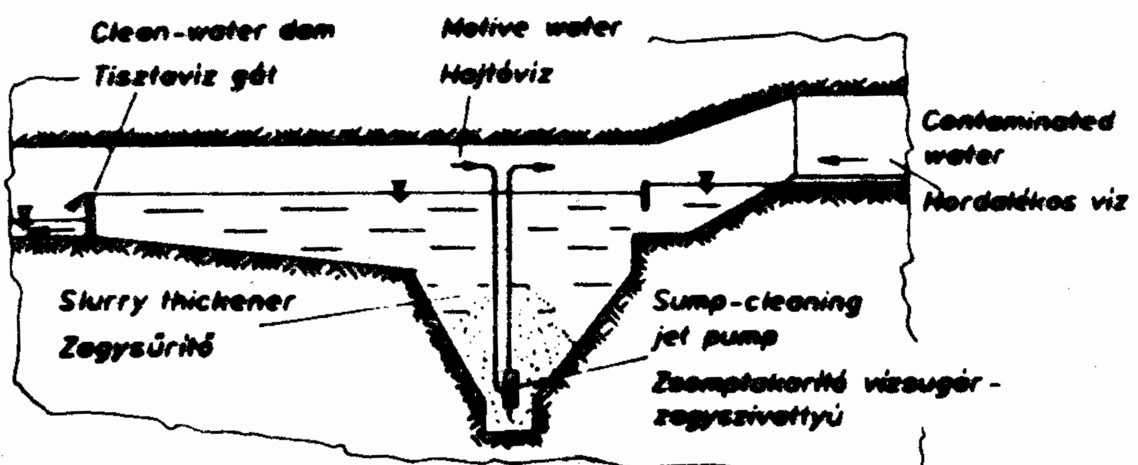

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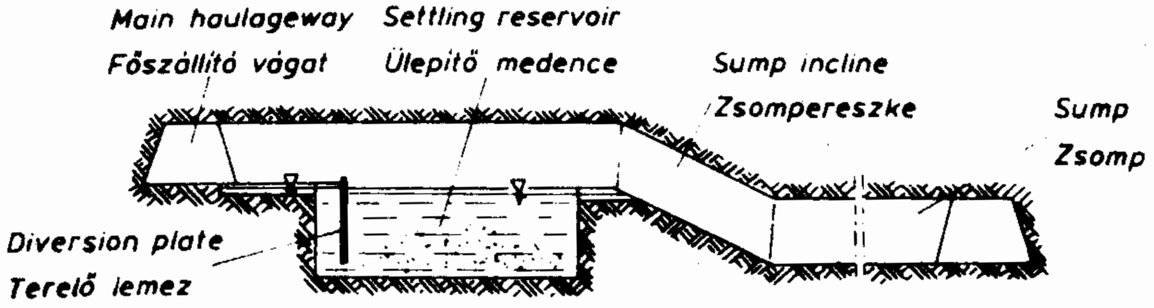

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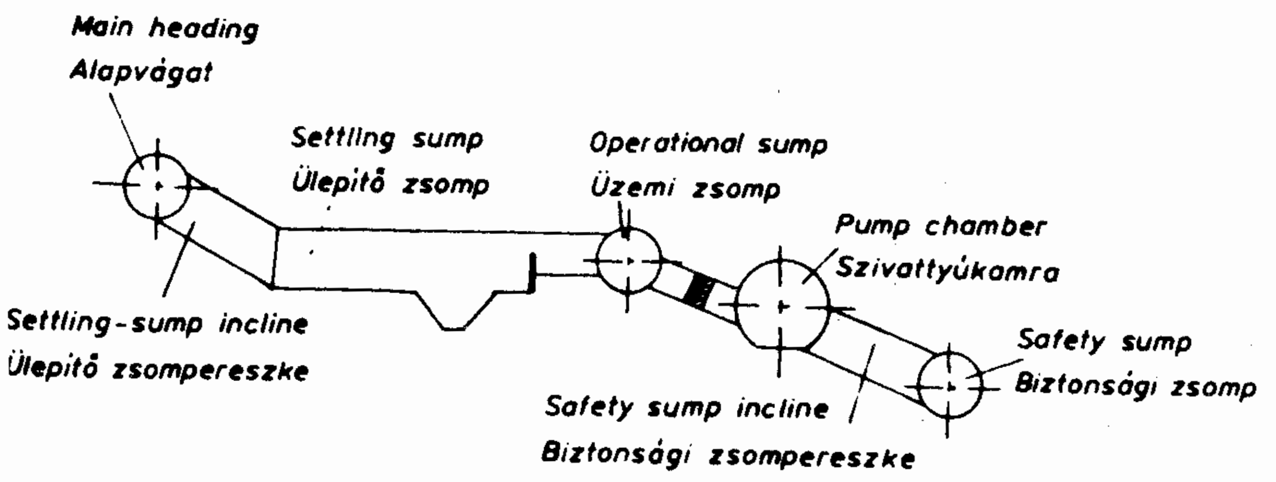

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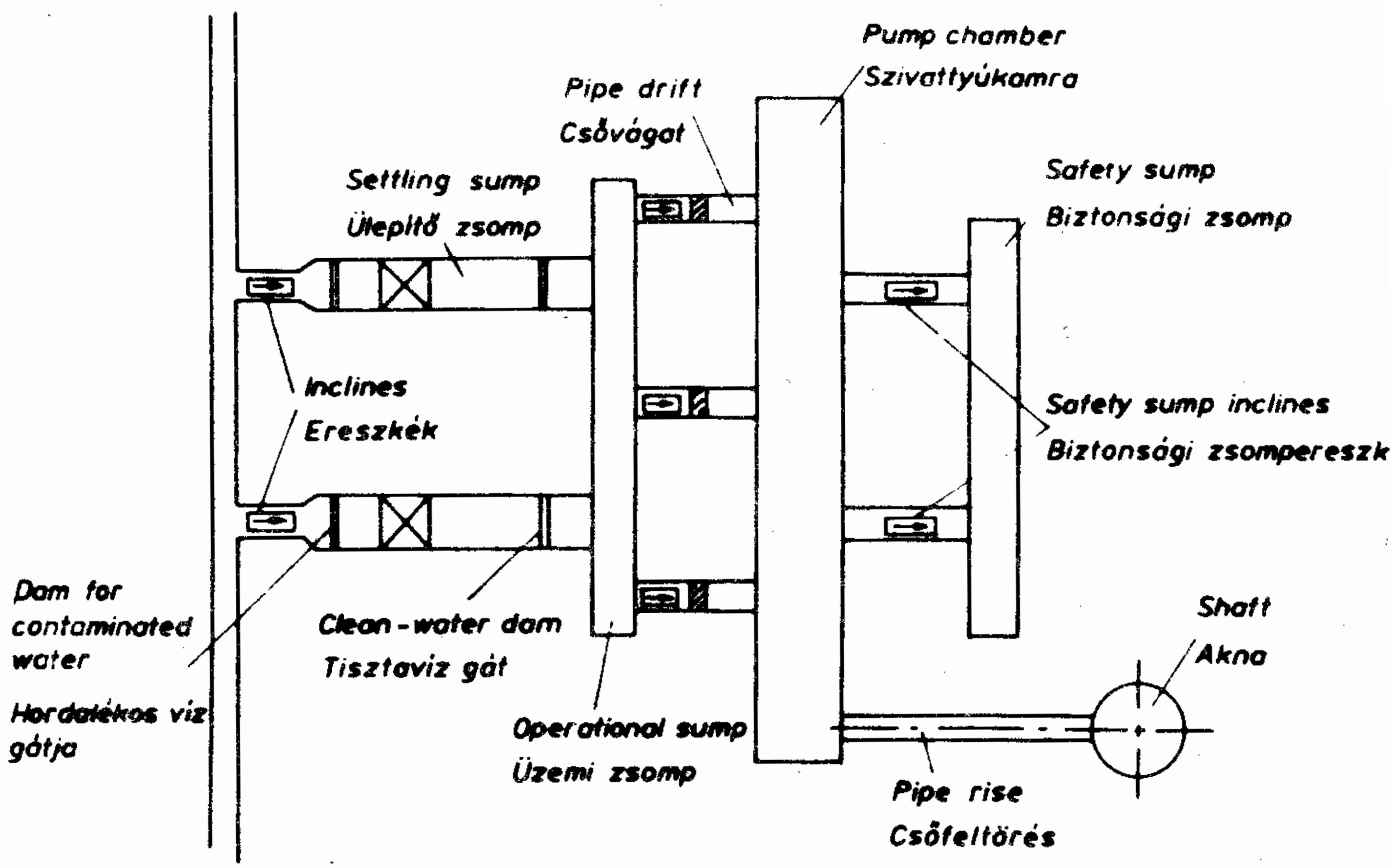

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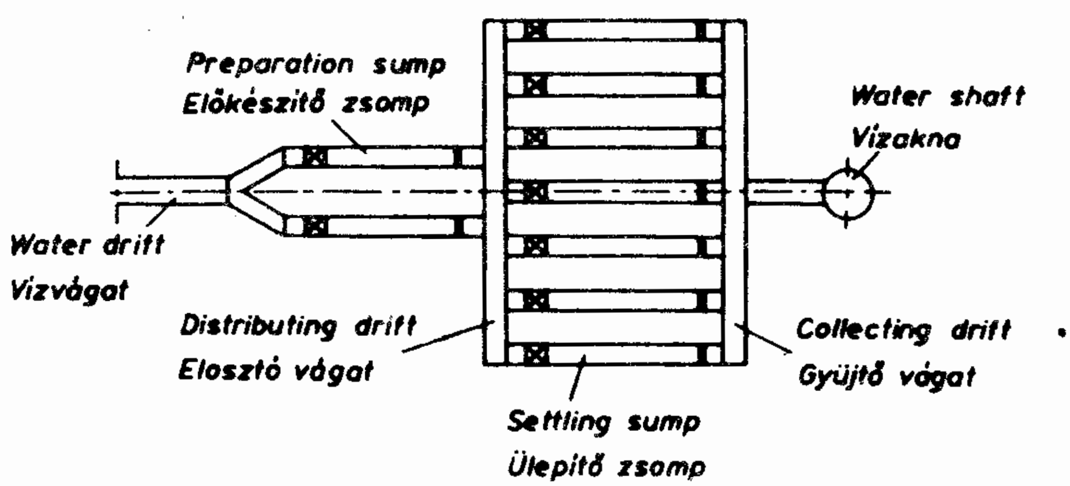

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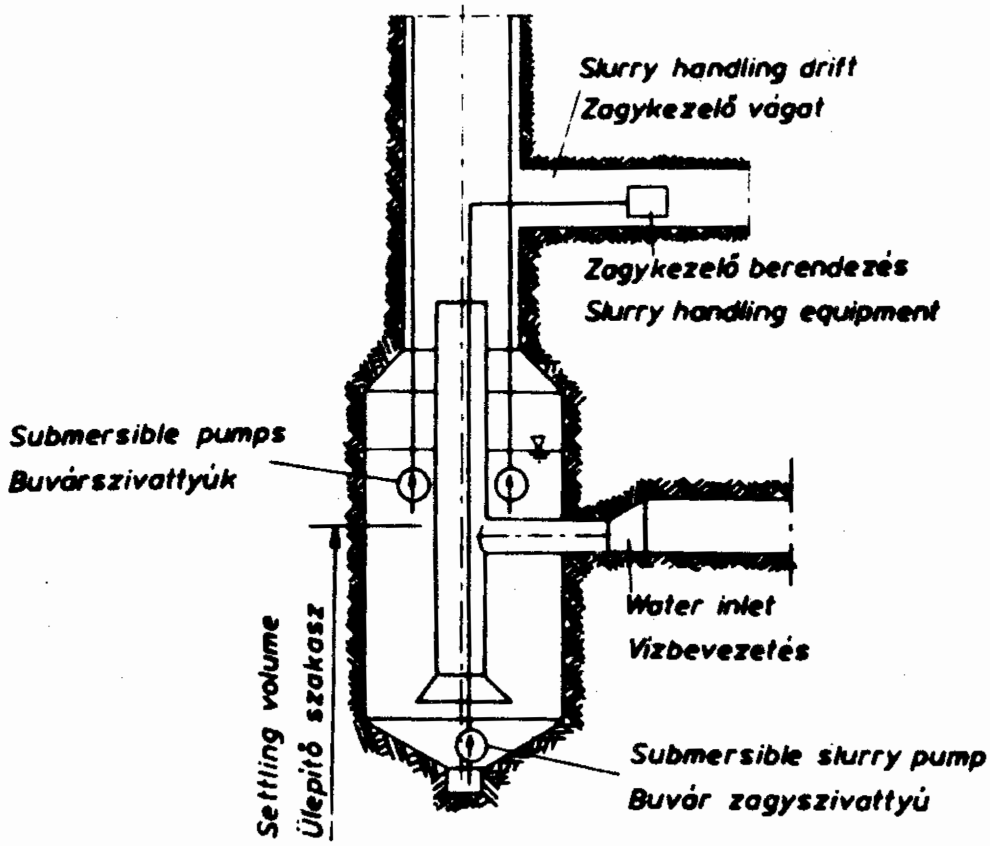

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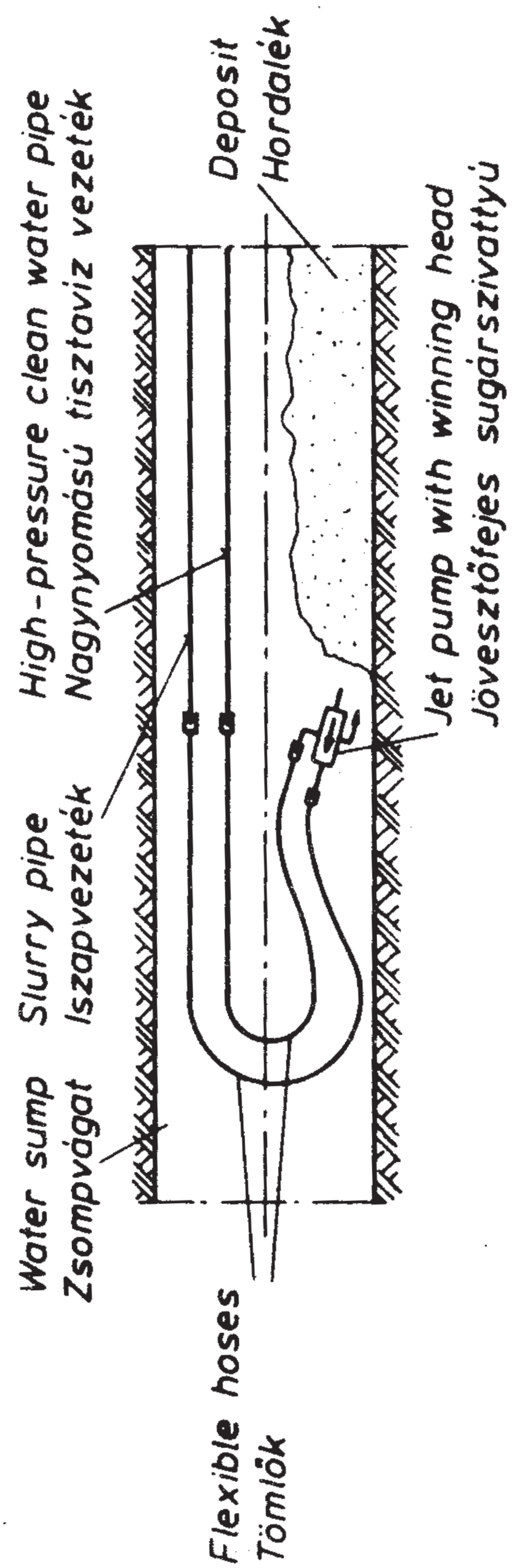

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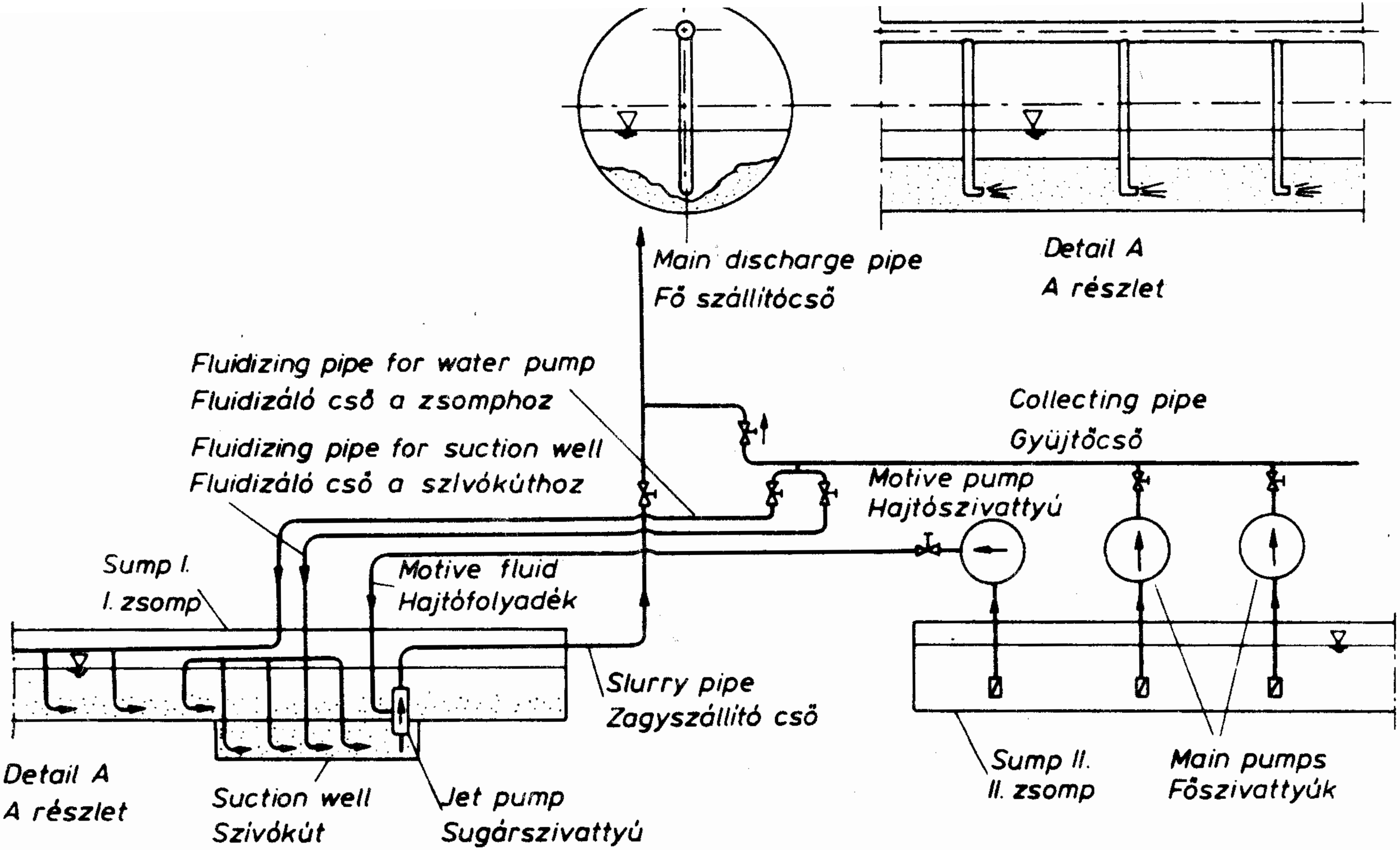

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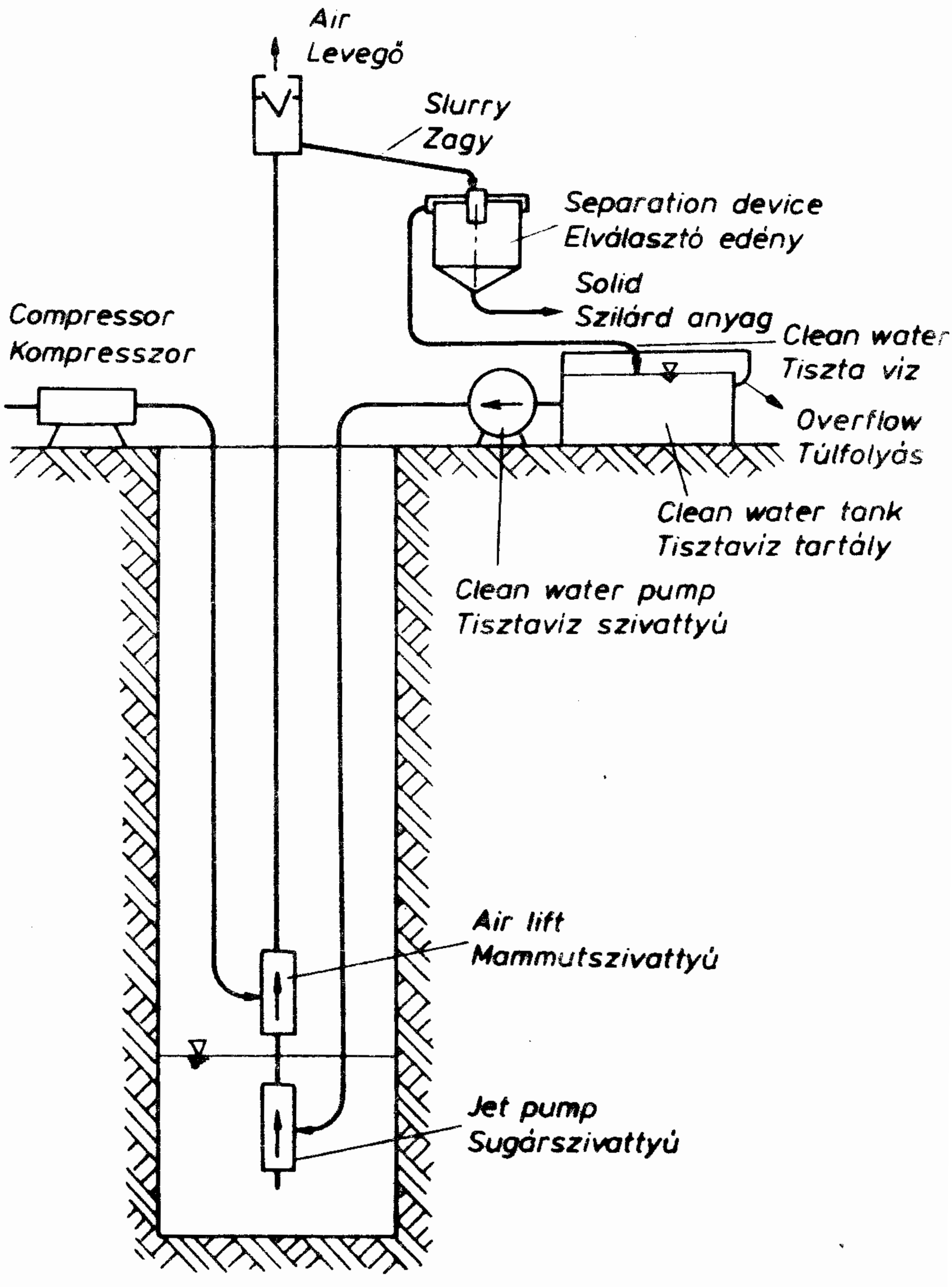

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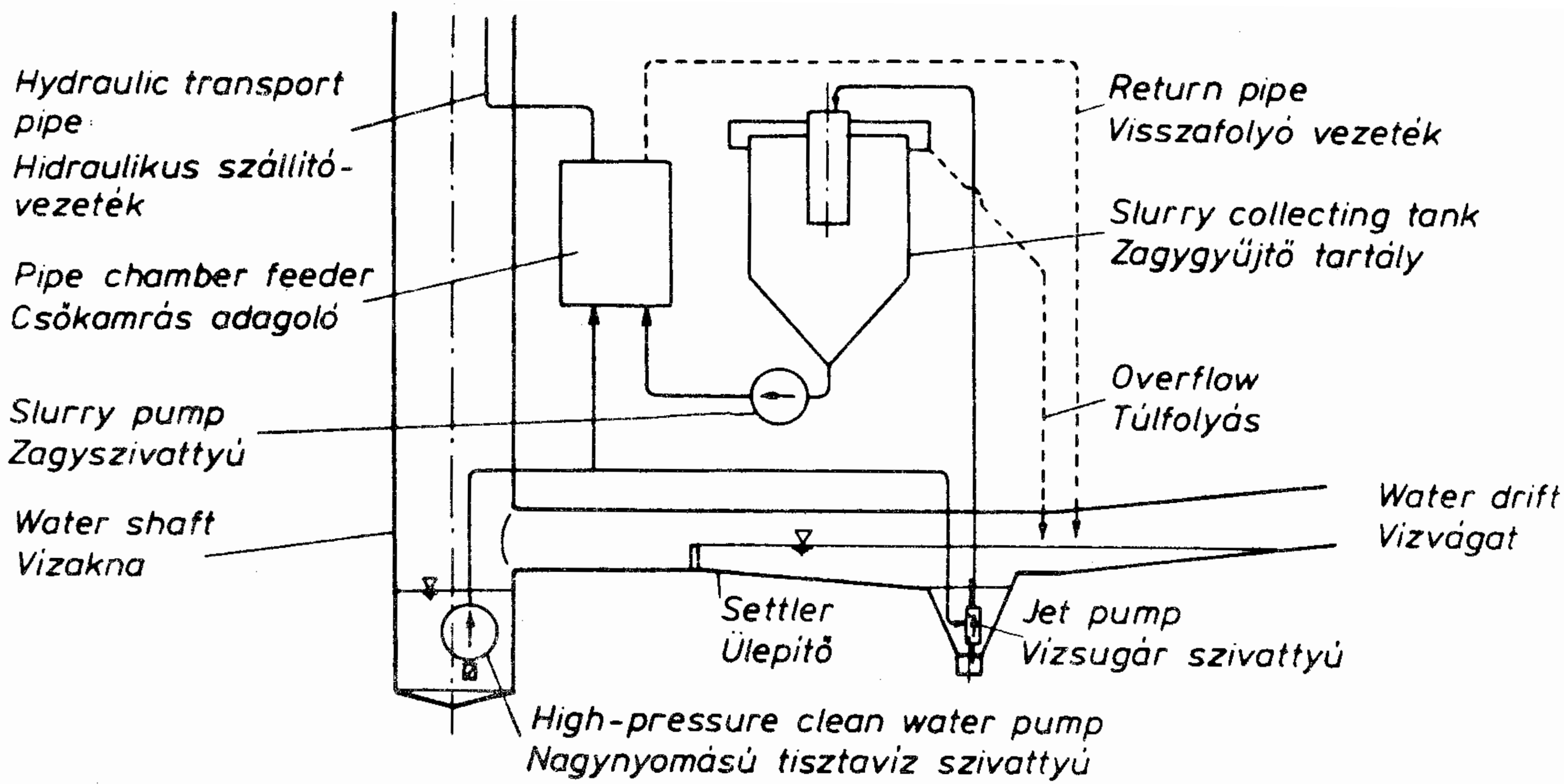

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