The use of cylindro-conical settlers for the clarification of underground water

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SYNOPSIS

This paper analyses the performance of conical settlers on Harmony Gold Mine from 1959 to the present time, and describes the investigation that was undertaken to substantiate and improve the use of conical settlers for a new pump chamber in another part of the mine.

SAMEVATTING

Hierdie verhandeling ontleed die verrigtinge van die kegelvormige setlaars op Harmony Goudmyn vanaf 1959 tot datum en beskryf verdere ondersoek wat onderneem is om te bevestig en te verbeter op die gebruik van die kegelvormige setlaars vir 'n nuwe pompkamer in 'n ander deel van die myn.

Introduction

The removal of water from mines is a problem as old as mining itself, and, if full use is to be made of the high-lift centrifugal pumps now installed, efficient settling of mud and grit from the water is essential. When Harmony Gold Mine was planned, it was decided to use conical settlers from the outset[1].

Fig. 1 shows No. 3 Shaft at Harmony with the settlers, clear-water sumps, and pump chamber relative to the shaft pillar, and Fig. 2 shows an isometric view of the layout.

Initially, the settler adjacent to the shaft operated as a grit settler, and all the water was routed to this settler until recently, when it was decided that the coarse-solids fraction arriving at the pump chamber was not large enough to justify presettling. This has not resulted in abnormal problems with the mud pumps and saves the nuisance of transferring the product from the grit settler to the shaft loading boxes.

The remaining ten settlers operate as previously described[1], the only change being in the materials used for the feed launder, stilling box, and peripheral V-notches. These are now manufactured from fibre glass instead of sheet metal and have an estimated indefinite working life, but cost twice as much to install.

Operation of the Settler

Raw water at a pH of 6,8 is treated with milk of lime, which is pumped underground from a slaker situated in the Reduction Plant. The pH value is increased to approximately 8,5 to reduce corrosion caused by the chlorides in the water and to increase flocculation.

Since the flocculent used forms a gelatinous substance in water that is difficult to dissolve, batches of 0,9 kg of flocculent powder are mixed by air agitation with 182 litres of water in a tank. Small notched launders then distribute the mixed flocculent evenly across the raw-water stream at an average rate of 0,57 kg per megalitre of water.

The lime and flocculent are fed into the water upstream at 20 m and 10 m respectively from the first settler. The rate of water inflow to each conical settler is controlled by manual adjustment of a gate that slides over an inverted vertical 10° V-notch. This V-notch ensures that, as the flow in the drain feeding the settlers increases and the level rises, the first settlers in the line are not overloaded. A fibre-glass launder then delivers into a stilling box as seen in Fig. 3. The clear water flows over the lip launder into storage dams, and settled mud is drawn off the bottom of each settler into a mud dam every twenty minutes.

Flow Pattern in a Conical Settler

Although the stilling box terminates 1830 mm below the new flow level, the water velocity continues downwards, eventually fanning upwards towards the peripheral overflow lip. Particles settle out against a rising current induced by the overflowing water; hence, the action within the settler is that of countercurrent settling.

This was verified by samples taken from various points in a working settler using a long pipe with a stoppered end. When the pipe was in the desired position for a sample to be taken, the stopper was pushed out with a stiff piece of wire attached to the stopper through the bore of the pipe, thus allowing water to enter the pipe. The depth and position of the sample were recorded, the stopper was pulled back, and the sample was removed for analysis.

From these samples, the flow and settling patterns in the settler were plotted (Fig. 4).

Settling Tests at Harmony

The use of flocculent became essential when the quantity of water handled by each settler increased owing to an expansion of mining operations and the closure of a pump station at an adjacent shaft. The experiment detailed below indicates the advantage to be gained from the use of flocculents.

A test apparatus holding three samples of water was set up in 700 mm high beakers to observe the settling characteristics. The first sample was raw water contain-

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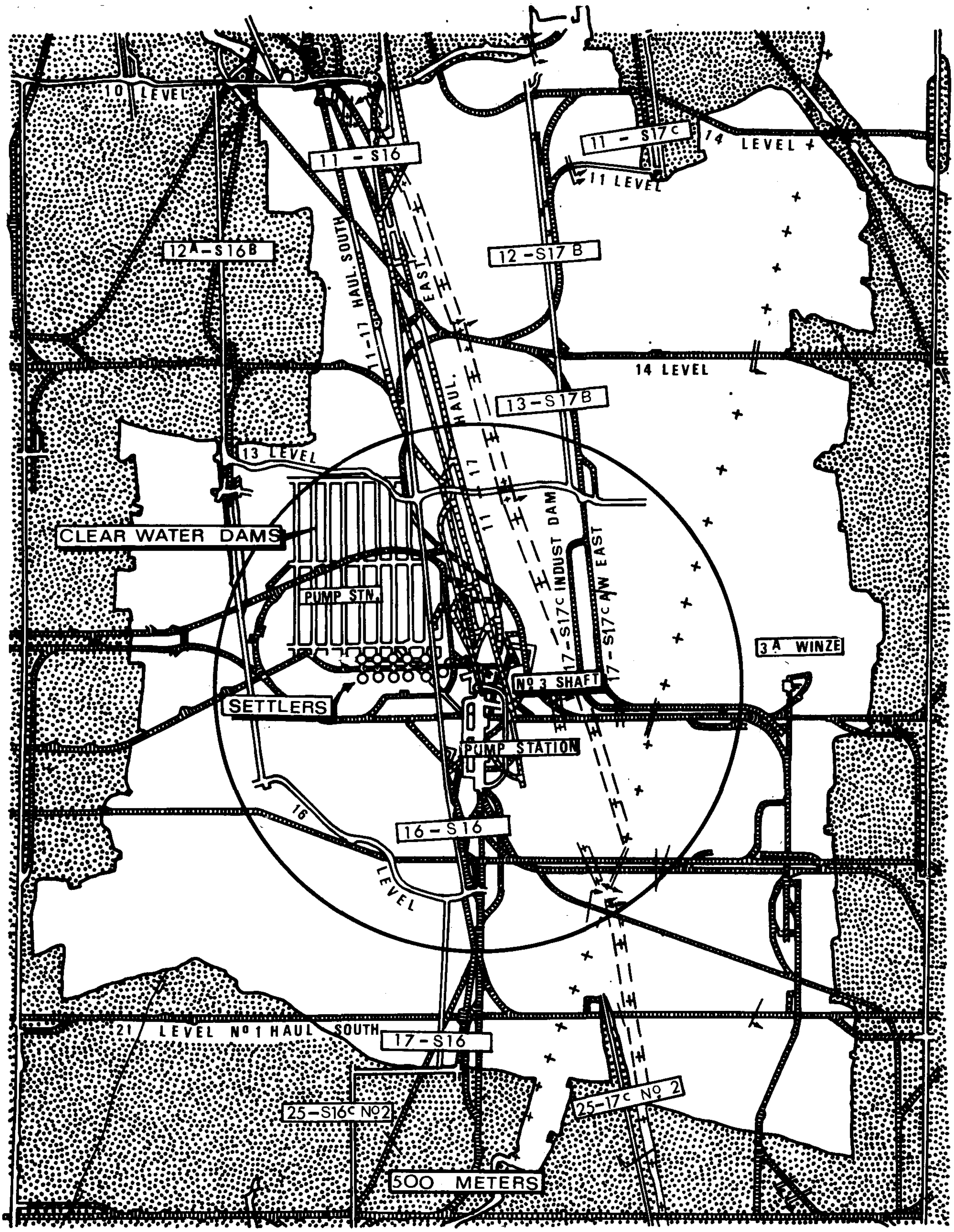

Fig. 1—Plan of No. 3 Shaft pillar, showing the location of the settlers

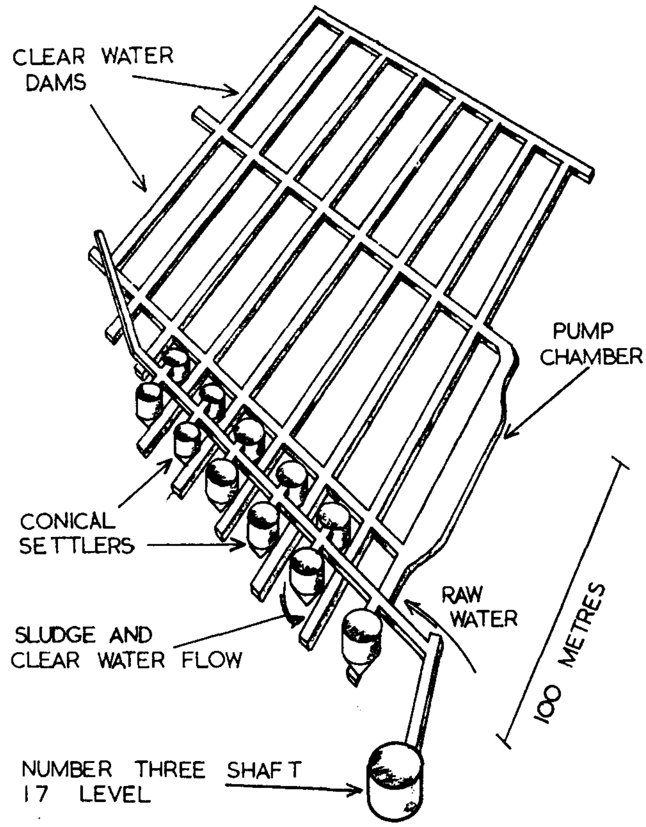

Fig. 2—Isometric view of the pump chamber, clear water dams, and conical settlers

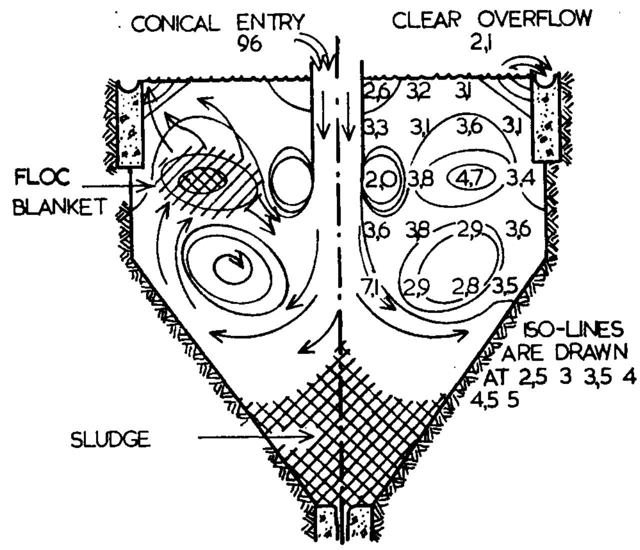

Fig. 4—Flow pattern in a conical settler (the solids analyses are given in p.p.m.)

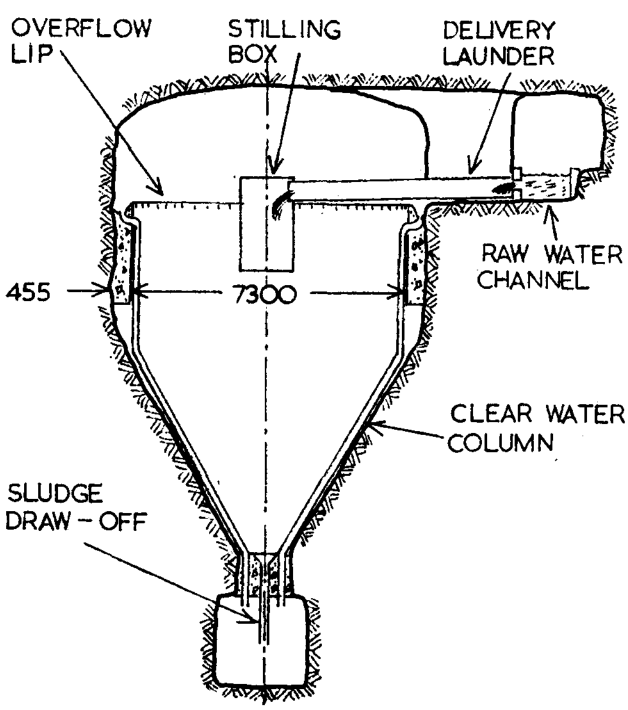

Fig. 3—Cross-section of a conical settler

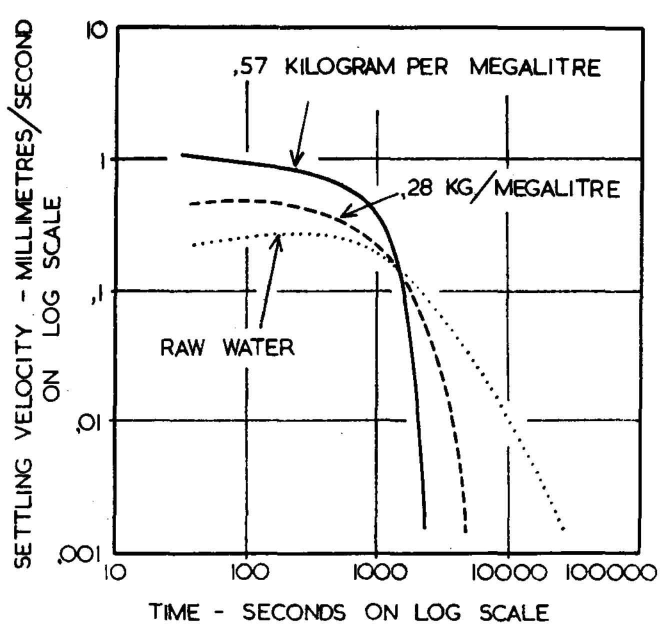

Fig. 5—Settling velocity versus time

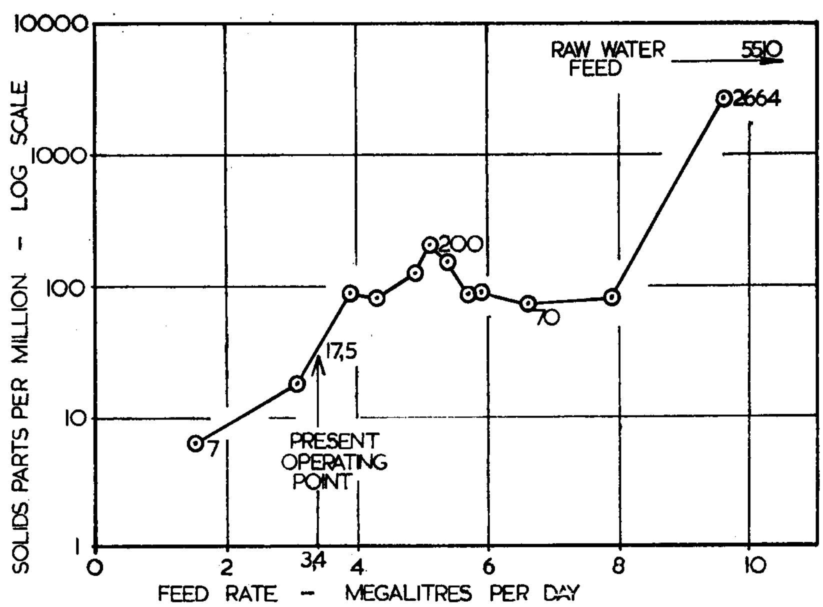

Fig. 6—Feed rate to conical settler versus clarity of overflow water

ing 50 464 p.p.m. of solids, with lime added but no flocculent. The second sample had lime and half the regular dosage of flocculent, and the last sample had lime and the regular flocculent dosage of 0,57 kg/Ml.

After the first 100 seconds, the sample of water fully loaded with flocculent had approximately 4,5 times the clarity of the unflocculated sample (i.e., 2000 p.p.m. as against 9000 p.p.m.). However, the final products over a prolonged period of 2,7 hours were very similar.

Flocculent greatly increased the speed of settling of clear water to the mud interface — from 0,25 mm/s for raw water with no flocculent to 1 mm/s, as shown in Fig. 5.

Performance Tests

As previously indicated[1], the original layout was designed to treat a daily maximum of 4,59 Ml of raw water per conical settler, with a normal daily rate of 1,636 Ml/d. However, the inlet-flow control plate has since been enlarged and the average throughput increased to 3,4 Ml/d for a total of 27 Ml/d (eight units). About 45 per cent of the treated water is pumped to surface, while the balance is recirculated for drilling and mining purposes.

A series of tests was conducted to indicate the maximum quantity of water that could be treated in an emergency, the maximum quantity being governed by the quality of water acceptable for re-use as machine water.

For these tests, a variable-inlet (flow-control) gate was manufactured so that the flows could be in excess of the 3,4 Ml/d being treated at present. Downstream from this gate a rectangular weir was installed to measure flow.

It was found that, owing to 'channelling' of the overflow, i.e., overflow concentrated in certain sections of the overflow lip, the maximum quantity that could be treated efficiently occurred when the water level in the conical settler rose to a point just below the top of the V-notches round the periphery of the settler.

Eleven different flow rates were forced onto a settler, and samples of the overflow were taken at various points round the periphery of the settler for each flow rate.

Flow rates of up to 9,5 Ml/d were achieved during this test, but the settling at this flow rate was unsatisfactory. The test indicated that flows in the region of 8 Ml/d per conical settler could be achieved with moderate results, provided that the settled mud was drawn off regularly.

To ensure that there would be no build-up of mud in the settlers, a study was made of the drawing off of mud with the intention of making this a continuous process. Various sizes of orifice were fixed to the bottom of the settler in an attempt to find the right balance between a small orifice that would become choked and a large orifice that would discharge so much that water instead of mud would be transferred to the mud dam. No satisfactory condition was attained, and it was concluded that 150 mm valves opened at regular intervals are still the best solution (Fig. 6).

Daily Operating Costs

Labour (including benefits):	
Part-time supervision	R52,50
Operators, 4 per shift	12,50
Lime R24,00/t at 10 t/month=0,33 t/d	8,00
Flocculent, 14 kg/d at R2,45/kg	34,30
Maintenance and repairs	5,00
Total daily operating cost	R112,30

The cost based on 27 Ml settled per day is therefore R4,15/Ml.

New Settlers and Pump Chamber

Excavation work is in progress for a new pump chamber, conical settlers, and clear water sumps that

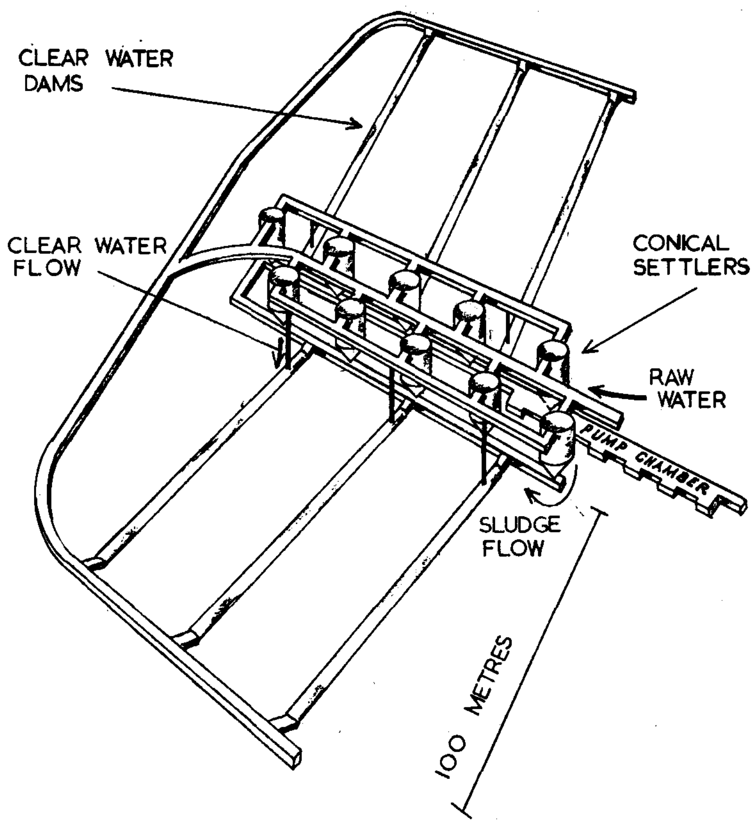

Fig. 7—Layout of new pump chamber, clear water dams, and conical settlers

are to be situated in overstoped ground. The layout is shown in Fig. 7.

The capital cost of this project, without any mechanical or electrical equipment, is estimated to be R219 000.

The following are the reasons for the establishment of this new pumping complex.

(1) Because of the extensive ground movement in No. 2 Shaft pillar, the settling and pumping arrangements at this shaft were abandoned in 1971. The present settling and pumping facilities are confined to No. 3 Shaft and will have to be abandoned when the mining of No. 3 Shaft pillar takes place at some future date.

(2) The existing layout of No. 3 Shaft is being subjected to high rock pressures, which are affecting the pump alignment and pipe connections in the pump chamber, together with caving of the tunnels connecting the settlers and the water dams. Expenditure on rock support became necessary in 1972 and has risen rapidly as conditions deteriorate.

As a result of (1) and (2), it was decided to excavate and install new pumping and settling arrangements in overstoped ground. The pumping capacity of this pump station will be increased from the present capacity of 34,5 Ml/d to cope with any emergency flooding condition.

Rock Mechanics Aspects

Theoretical Considerations

Vertical excavations with circular profiles are structurally stronger than the profiles typically used for horizontal settlers, both because they cut across planes in the geological succession and also because stress distribution round circular openings is more uniform. Further, with suitably designed and installed support, any rock failure and eventual slabbing can be effectively restrained. The conical settlers have a shape closely approaching that of a vertical cylinder.

The application of smooth-wall blasting techniques is very much more effective in circular excavations, particularly when they cut sharply across the geological strata and when the excavation has a vertical orientation.

Practical considerations

Analytical, as well as analogue- and digital-computer, techniques clearly demonstrate that induced compressive-stress concentrations and deformation magnitude increase rapidly towards the perimeter of a shaft pillar. Factors determining the stress field within the pillars include depth below surface, excavated stoping width, and extent of stoping radially away from the pillar.

Theoretical and practical analysis of complex horizontal layouts shows that circular excavations should not be sited closer together than three times the maximum dimension of the excavation, while rectangular or square excavations should never be sited closer than six times the maximum dimension.

Ideally, vital excavations such as dams, settlers, and pump chambers should be sited outside the shaft protection pillar and overstoped as expeditiously as possible. However, extra expense during the initial establishment of operations at shafts has generally been against the adoption of such a policy. Because of their superior strength, conical settlers can be placed closer together and therefore occupy less space. Space is at a premium because of the gold values contained in shaft pillars.

The theoretical strength of conical settlers has been borne out in practice. Actual observation shows less side-wall and general deterioration, and therefore less initial support cost and less subsequent support involvement.

Summary

From experience, conical settlers as installed at Harmony have proved to be very successful both from a rock mechanics point of view and from the point of view of efficient operation.

Acknowledgement

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Reference

1. THIEL, E. W. Use of cylindro conical settlers for underground water clarification on Harmony Gold Mining Company Limited. Association of Mine Managers of South Africa, 1959.

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