THE KNELSON CONCENTRATOR: APPLICATION AND OPERATION AT ROSEBERY

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ABSTRACT

Rosebery has a long history as a base metals sulphide mine. Copper, lead and zinc concentrates are produced for sale, both within and externally to the Pasminco group. Silver values have always been high in the lead concentrate, while gold has historically been seen as a bonus in both the copper and lead concentrates.

During the late-1980s. a concerted effort was made to improve the recovery of gold liberated in the grinding circuit by the installation of a conventional gravity circuit. Spirals and tables were employed in this circuit which treated a bleed stream from the tertiary cyclone underflow. The concentrate produced was added to the copper concentrate. The conventional gravity circuit required the attendance of one operator around the clock.

In 1992, a doré plant was constructed to treat the gravity concentrate on site and produce a gold doré bar. This plant provided the incentive to improve the gravity recovery of gold and channel this through the doré plant.

Plant surveys demonstrated that the gold was liberated in the primary grinding circuit and concentrated in the primary cyclone underflow streams. From this point on. the capacity to recover this gold is hindered by over-grinding, flattening, and tarnishing of the surfaces of liberated gold particles.

Knelson concentrators have proven to be extremely successful in gold plants within Australia, where free gold exists in the grinding circuits. In January 1993. a full-scale plant trial using a 30-inch manual discharge Knelson concentrator was commissioned. In February 1993, the gravity plant was decommissioned and all new feed to the dore plant now comes from the Knelson concentrator.

The installation was not without problems however. Providing a good quality feed split from two parallel cyclone underflows in a confined area posed a number of problems. These were overcome by the development of a screen/cutter device within the cyclone underflow box,

The successful operation of the Knelson concentrator has not only lifted the gold recovery but also reduced the operating requirements of this section of plant. The manual discharging Knelson is attended to for one-hour three times per day, consequently freeing up labour for other duties.

Installation of the self-draining ***central*** discharge Knelson concentrator in February 1994 will see the gravity operating requirements reduced from 24 hours to one-hour per day, while the recovery of gold to doré is increased from 15 per cent to 30 per cent.

Rosebery must now be considered a zinc/gold mine, with 65 per cent income generated from zinc and 14 per cent generated from gold.

INTRODUCTION

Rosebery has been a base metals sulphide mine for 100 years. The mine is located on the West Coast of Tasmania. Gold is a significant component of the complex copper-lead-zinc sulphide ore treated in the Rosebery concentrator. The focus on gold at Rosebery has steadily increased since the late-1980s when a conventional gravity circuit was commissioned. In 1992 dort Production commenced at Rosebery, and in 1994 the central discharging Knelson concentrator was commissioned. Gold is currently second only behind zinc in the contribution of revenue to the Rosebery operation.

The application of the Knelson concentrator to recover liberated gold from the grinding circuit has not only provided improved metallurgical performance, but also improved operational performance.

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OPERATIONS

The composition of run of mine Rosebery ore is shown in Table 1. The contained gold is both free, and in solid solution or finely locked within the pyrite.

TABLE 1

Rosebery concentrator head grades.

3.1%	Pb	(Galena)
10.8%	Zn	(Sphalerite)
14.3%	Fe	(Pyrite)
0.5%	Cu	(Chalcopypyrite)
2.4 g/t	Au	(Free, Pyrite Associated)
105 g/t	Ag	(Tetrahedrite, other)

Mining operations at Rosebery are currently producing 550 000 tonnes per year of ore. Size reduction begins underground with the use of an MMD Sizer, which crushes to minus 300 mm. On the surface the ore passes through a jaw and a cone crusher, both of which are in open circuit, after which the minus 40 mm ore enters two fine ore bins, providing 8000 tonnes of storage.

The Rosebery concentrator operates on a 12-hour, seven day, continuous shift roster. Throughput varies from 75 to 85 tonnes per hour.

The milling circuit is preceded by two parallel roll crushers in closed circuit with five millimeter single deck vibrating screens. The ore then passes into a two-stage grinding circuit, consisting of two parallel primary ball mills and two parallel secondary ball mills, as shown in Figure 1. The target grind size for this circuit is 75 µm. The slurry subsequently enters a single thickener in order to achieve the optimum flotation feed density of 46 per cent solids.

The sequential flotation circuit, as shown in Figures 2,3 and 4, consists of a two-stage copper flotation circuit, followed by a four-stage lead flotation circuit, and finally a two-stage zinc flotation circuit. Products from the flotation circuits are dewatered and filtered using pressure and vacuum filters.

DORE PLANT

During the late-1980s a conventional gravity plant was commissioned. A flowsheet of this plant is shown in Figure 5. A bleed stream was taken from the then tertiary cyclone underflow stream to feed the gravity circuit. The circuit consisted of primary and secondary spirals followed by middlings and concentrate tables.

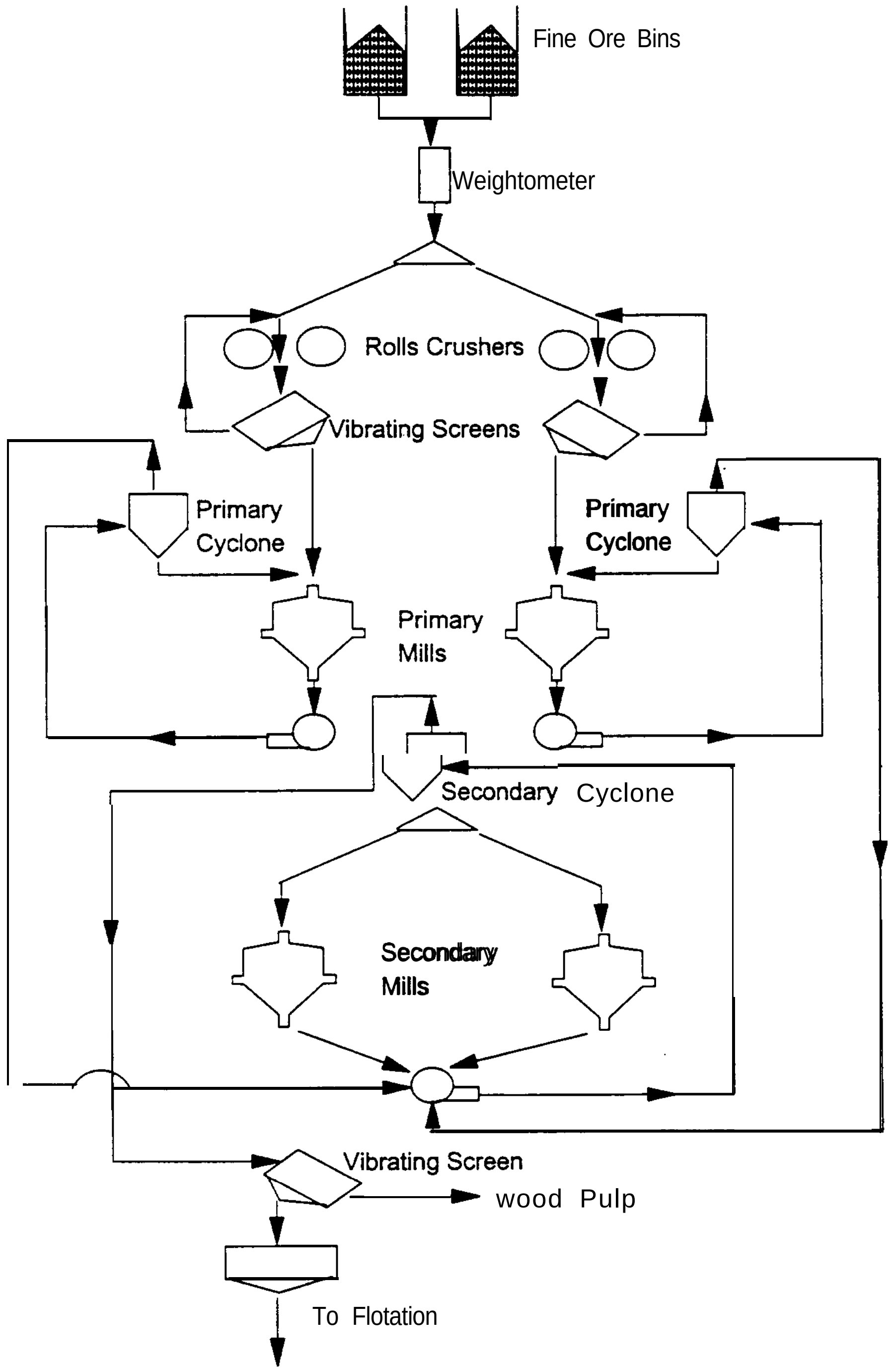

FIG 1 - Grinding circuit flowsheet.

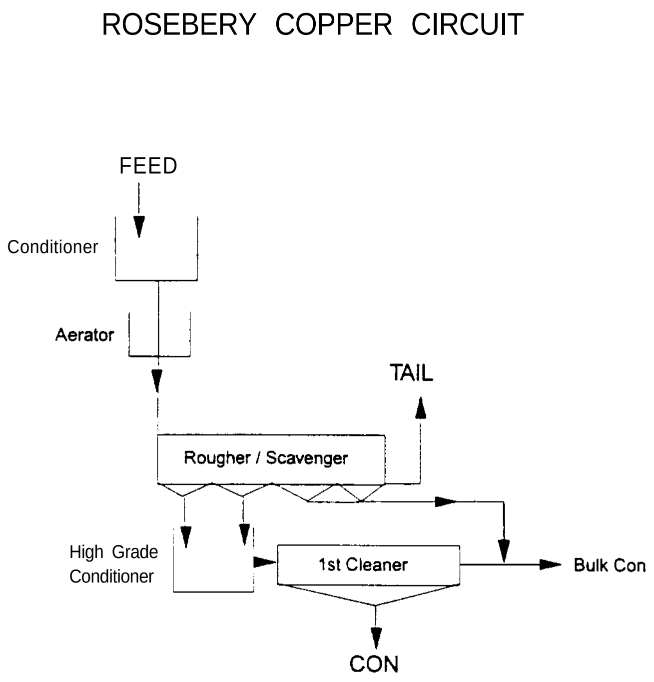

FIG 2 - Copper flotation circuit

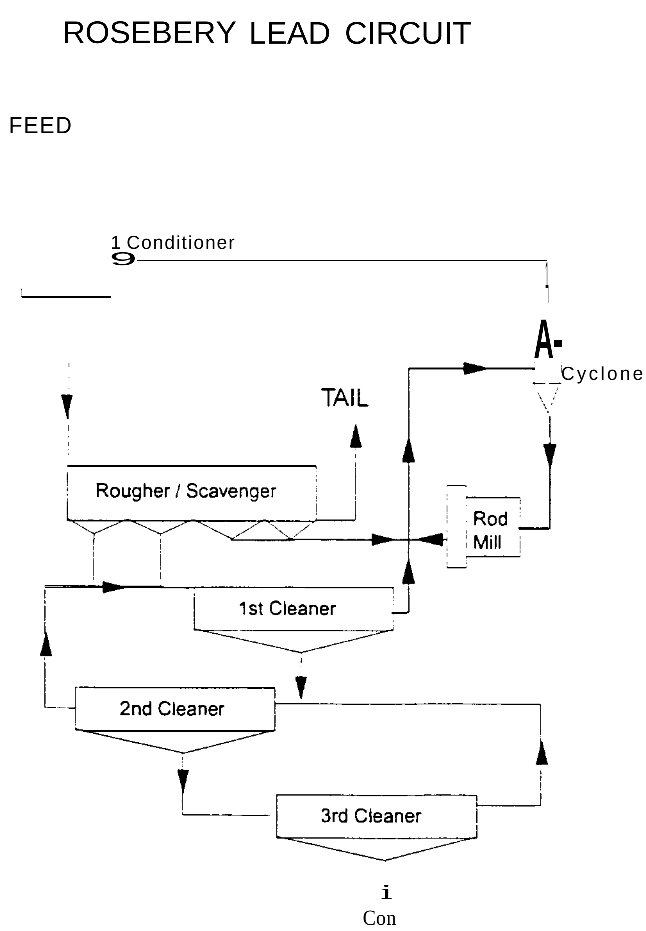

FIG 3 - Lead flotation circuit.

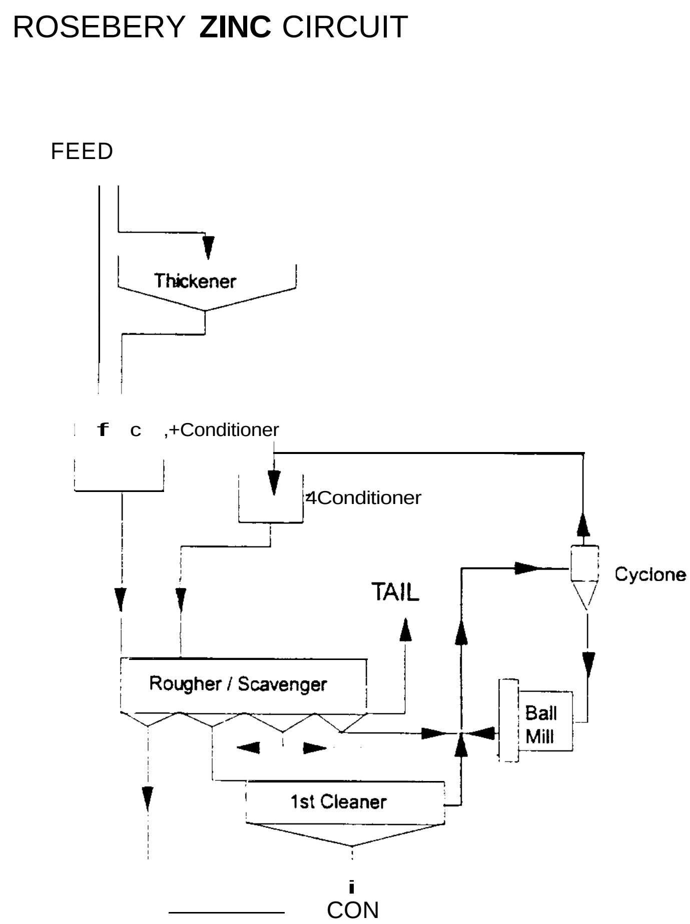

FIG 4 - Zinc flotation circuit.

Concentrates from the gravity circuit were initially combined and sold with a lead-copper concentrate. In 1991 production of this concentrate ceased in favour of a higher grade, low lead, lower volume, copper concentrate. From this point, gravity concentrates were stockpiled awaiting the construction of a facility to produce gold dare on site. The dare plant was commissioned in May 1992. The dare plant initially utilised the Merrill-Crowe process to produce a product suitable to fire. A flowsheet for this process is shown in Figure 6.

Gravity plant concentrate was slurried with a one per cent sodium cyanide solution and allowed to leach for 24 hours. The pregnant solution was then decanted to separate tanks where zinc dust was added to precipitate the gold from the solution. The precipitate was acided, washed and fired to produce a dor& bar assaying 70 per cent Au and 25 per cent Ag.

With the introduction of the Knelson concentrator replacing the conventional gravity plant, significant changes were required in the dare plant to treat the new feed material. Cyanide leaching of the Knelson concentrate was tried but was unsuccessful due to the coarse nature of the concentrate and inefficient mixing vessels. Further gravity concentration methods were then employed, along with acid leaching to treat the Knelson concentrate. This is shown schematically in Figure 7.

Jigs were installed to further concentrate the Knelson product. The jig concentrate is acided to remove sulphides, using nitric acid and heat. The product of this process is further cleaned using another jig, a half-size table and second aciding step still using nitric acid and heat, The product is then dried and fired to produce a doré bar assaying 65 per cent Au and 30 per cent Ag.

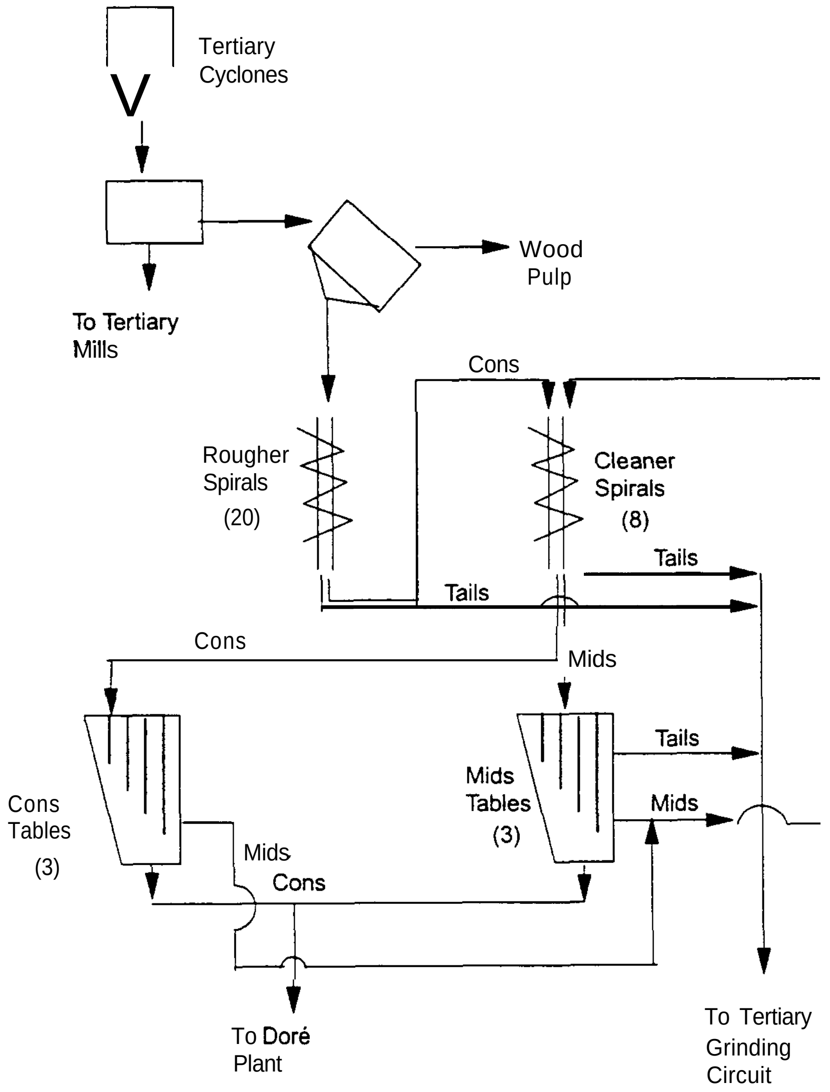

FIG 5 - Gravity plant flowsheet.

TECHNICAL BACKGROUND

The conventional gravity circuit operated successfully for a number of years. The circuit required significant operator attention, adjusting cutters, unblocking and cleaning feed splitters, in order to produce a quality product. One operator was dedicated to this task, along with a number of other smaller tasks around the concentrator. Even with this operator attention, the conventional gravity plant was extremely sensitive to changes in ore type and feed tonnages.

Recovery of gold to doré via the gravity plant was on average less than ten per cent of the gold in feed. The unit recovery of the gravity plant was found to be very poor. Gold was being presented to the gravity plant and reporting to tails.

During 1992 a circuit survey of the Rosebery grinding circuit, and a number of other plant investigations revealed several significant facts:

Free gold presented to the gravity plant had been tarnished and flattened due to over-grinding in the then three closed circuit grinding stages.

Gold particles were observed to be one to two microns in one dimension and 50 to 500 microns in the other two dimensions. This characteristic caused the gold to float across the conventional gravity tables and report to the tail.

Gold was found to be concentrated in all cyclone underflow streams. The concentrations of the cyclone underflow streams are shown in Table 2.

TABLE 2

Gold concentration of cyclone underflow streams.

Streams	Au (g/t)
Primary cyclone u/f	70
Secondary cyclone u/f	17
Tertiary cyclone u/f	36

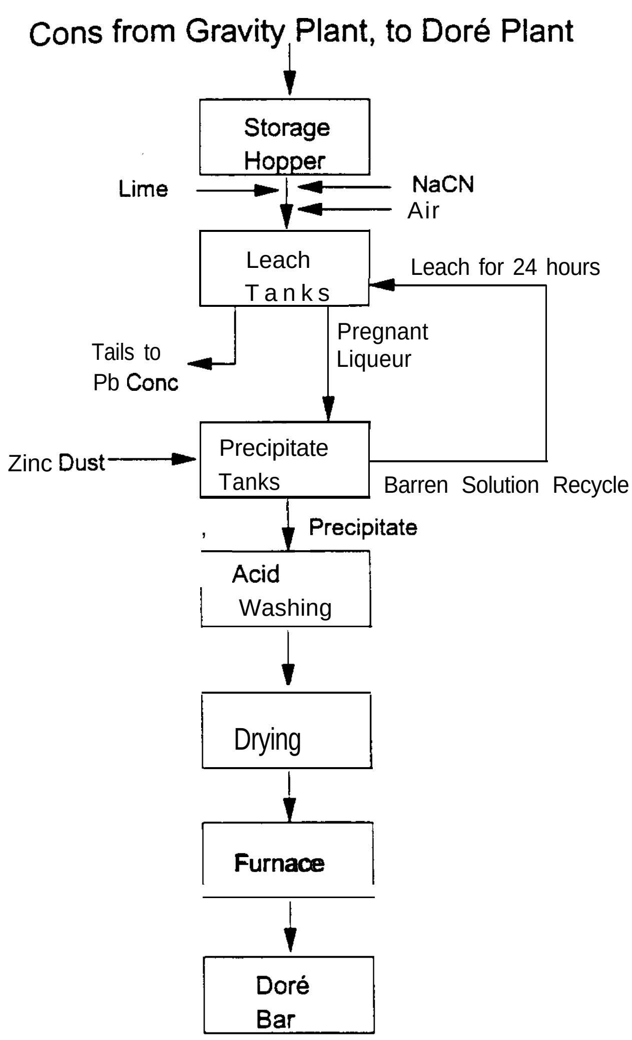

FIG 6 - Doré plant Merrill-Crowe flowsheet.

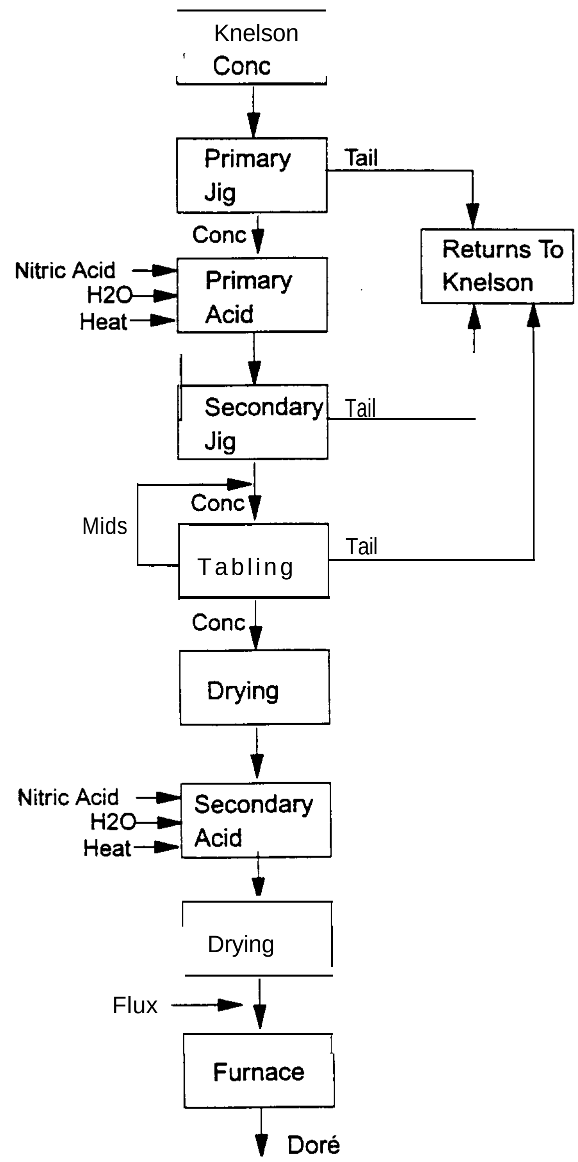

FIG 7 - Doré plant operating flowsheet.

The concentration effect was being used to advantage, with a bleed stream from the tertiary cyclone underflow providing a high feed grade to the gravity circuit. The concentration effect however, was also a major disadvantage. The high circulating load for gold was contributing to the flattening of the free gold particles.

As mentioned, gold was concentrated to 30 times mill feed in the primary cyclone underflow. Modelling of this data indicated that a significant portion of the gold in the primary cyclone underflow was in fact liberated. This gold was also observed to be far less tarnished or flattened than that present in the tertiary cyclone underflow stream.

Due to the recovery problems experienced in the conventional gravity circuit, a number of alternative concentrators were trialled in parallel to the gravity plant. These included a Falcon concentrator and a Knelson concentrator. No significant improvements were observed with these trials probably due to the nature of the unfriendly gold particles. Prior to these trials in the gravity plant, several trials were conducted in the flotation circuit using a Falcon concentrator a Knelson concentrator and a Kelsey jig. Again these trials displayed little improvement.

It had now become clear that to improve gold recovery prior to flotation we must target the primary cyclone underflow stream. This stream was known to contain particulate free gold. The Knelson concentrator was chosen to recover this gold for a number of reasons:

- The Knelson concentrator can accept feed and recover gold across the full size range from two millimeter to two microns.
- The Knelson concentrator is not reliant on operator attention to achieve results.
- The Knelson concentrator was small and compact, and could be installed easily and relatively cheaply into the primary grinding circuit.

KNELSON CONCENTRATORS

Operating principle

The Knelson concentrator is a centrifugal concentrator that uses a fluidised bed subject to centrifugal force to perform its concentrating duty.

The heart of the unit consists of an inner bowl bolted to a rotating outer bowl. The inner bowl is a tapered polyurethane ribbed inner cone. Each rib creates an independent ring within the bowl. At the base of each ring there are a series of fluidising water inlet holes.

Water is introduced into the cavity between the inner bowl and the outer bowl through the hollow drive shaft and passes through the fluidisation holes at the base of each concentrating ring.

The entire inner and outer bowl assembly is rotated at a fixed speed during the concentrating cycle to produce a centrifugal force of 60 times the force of gravity at the base of the cone increasing to 80 G's at the top of the cone due to the increased diameter.

Feed material with a maximum particle size of 6 mm is introduced into the concentrator through a central feed tube. The per cent solids of the feed slurry does not affect the performance or operating efficiency of the Knelson and can range from O-70 per cent. The upper limit of the feed solids to the Knelson is only limited by the ability of the slurry to flow to the unit.

At the start of the concentration cycle feed material is introduced at the base of the inner bowl where it is deflected radially outward by a replaceable deflector. The material initially fills the inner rings. The material collected within the rings is prevented from packing by the controlled flow of water through the bowls fluidisation holes from the water jacket.

This flow of water results in the formation of a fluidised bed within each ring. As further material is fed to the concentrator lighter particles due to their low Specific Gravities (SG) are unable to force their way into the fluidised bed in each ring and simply pass over the top of each ring in a thin film. This material then passes over the top of the inner bowl and reports to the tailings launder. As particles of high SG material enter the concentrator they force their way into the fluidised bed by displacing lower SG particles.

This exchange of material is further assisted by the constant agitation of the material in the rings caused by injecting water through the fluidisation holes in a tangential direction opposite to the direction of rotation of the bowl.

This exchange of low SG for high SG particles takes place over the entire concentrating cycle.

The Knelson concentrator is a semi-continuous batch unit operation so at the completion of the concentrating cycle the unit is required to be taken off-line and the concentrates are required to be removed. The period between concentrate discharges typically ranges from as low as one-hour up to 24 hours dependent on the duty.

With the conventional Knelson concentrator the unit has to be manually cleaned out. This takes a single operator ten to 15 minutes to accomplish and is achieved by removing the plug from the base of the inner bowl and by washing the concentrate through the concentrate launder into a secured collection vessel.

Knelson centre discharge concentrator

The reliance of the conventional Knelson concentrator on operator attention for clean out introduced a number of operating and security problems that concerned some potential users of the units particularly in the hard rock industry. As a result of this and as part of the continuing development of what is a relatively new product, the Knelson Centre Discharge Concentrator was introduced to the mining industry in early-1992. The development of the Knelson Centre Discharge Concentrator has now made available a centrifugal concentrator that can operate without the need for any operator attention. It can also be fully automated to reduce the off-line time for concentrate discharge to less than two minutes. Concentrate discharge is simply achieved by stopping the rotation of the inner bowl. This removal of the centrifugal force allows the concentrate bed to be flushed out, using an increased fluidisation water flow, through a central drain in the inner bowl.

To assist in the appreciation of the many design differences between the newly developed Knelson Centre Discharge Concentrator and the Conventional units, a brief history of the development process of the Knelson concentrator is required.

Originally the Knelson concentrator was developed for the alluvial mining industry. Due to the short life of most alluvial mines and the limited capital funds available, a low cost piece of equipment was required.

As the principle of the Knelson concentrator has been proven and accepted by the gold mining industry the unit has now become a valuable part of many hard rock mines. The change in duty from alluvial to hard rock applications has now placed a completely different emphasis on the requirements of the Knelson concentrator. In addition to the dramatic change in duty, the performance expectations of hard rock users of the units, including maintenance requirements, wear characteristics and equipment life, have also increased dramatically.

Although design improvements have been incorporated into the conventional units to meet the requirements of the industry it was not until a total design review was completed and the Knelson CD Concentrator was developed that a unit became available that was capable of meeting all the operational and maintenance needs of a hard rock installation.

The numerous mechanical design improvements included in the Knelson CD Concentrator are only the beginning of the advantages by this unit. The major advantages the CD unit makes available to the user are significantly improved security and operating advantages that will lift the overall recoveries achievable by gravity concentration.

The improved security of the CD unit is a result of removing the need for any operator attention. In operation of the conventional Knelson concentrator to discharge the concentrate, the operator is required to shut down the unit and manually wash out the concentrate from the inner bowl. The CD unit can be automated to discharge the concentrate without the need for any operator attention. Total time off-line for clean out is reduced to less than two minutes. Many mines are limited to removing the concentrates on day shift only or when security is present. This may result in the unit not being cleaned out at the optimum time thus resulting in lower overall recoveries.

As there is no need for operator attention during normal operation of the CD unit, and the fact that the operator does not come into contact with the concentrates produced, the feed, tails and concentrate lines cannot be accessed without a pipe being broken. Hence, the CD unit can be made completely secure by simply installing pad locks into the locking arrangements supplied on the lid of the unit. The concentrate produced by the CD unit can simply be piped by gravity to a locked vessel for further treatment at a convenient time.

The overall operation of the CD unit is ideally suited to maximising the operating efficiency of the concentrator by continually monitoring the fluidisation water flow and operating pressure. By closely monitoring these two variables the performance of the machine can also be determined and problems such as scaling or blockage of the flushing holes can be immediately detected and rectified with minimal interruption to production.

Further developments in centrifugal concentrators are at various stages of development, these include; 100 TPH Knelson CD concentrator, Knelson concentrate clean up unit for upgrading Knelson concentrate to a directly smeltable grade, and a continuous Discharge Knelson concentrator.

FULL-SCALE PLANT TEST

A full-scale plant trial was chosen over a pilot plant study for two main reasons:

1. The difficulty of presenting a representative stream to a pilot plant.
2. The dynamic nature of the circulating load of gold with respect to the size of the trial concentrator.

A 30-inch (760 mm) manual discharge Knelson concentrator was installed in January 1993.

Cutting a feed stream from the two independent primary cyclone underflow streams proved to be a difficult problem to overcome. The cyclone underflow streams contained particles up to five millimetre in diameter, and running at around 200 tonnes per hour. The Knelson concentrator required a feed stream of approximately 50 tonnes per hour at 100 per cent passing two millimeter. An in-stream screen-cutter, as shown in Figure 8, was developed. It utilises a double screen deck consisting of a worn five millimetre screen mat and a used section of one millimeter DSM screen. The screen-cutter is contained within the cyclone underflow box. The screen is rotated under the cyclone underflow stream, cutting the desired feed flow from the stream. The feed cut from both circuits is combined and presented to the Knelson concentrator.

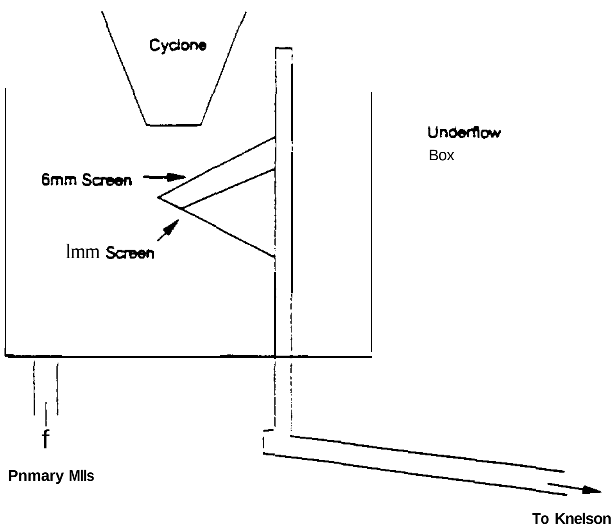

FIG 8 - Cyclone underflow screen / cutter.

Consistent performance from the Knelson enabled the conventional gravity plant to be decommissioned during February 1993. The trial consistently recovered 15 to 20 per cent of the gold in feed, an improvement of seven per cent.

During the period from 15 April 1993 to the 8 May 1993 the Knelson concentrator was manually drained three times per day recovering 31 per cent of the gold in feed. Draining (recovering the concentrate) the trial Knelson concentrator has been restricted to two times per day on a production basis, due to time and security restrictions.

Further testwork has shown that the optimum time for draining the Knelson to maximise recovery would be once every four to five hours. Figure 9 shows a graph of circulating gold values versus a 12 hour Knelson operating cycle.

The full-scale plant test was a success and as such the unit was maintained on a production basis until the installation of the new central discharge (CD) Knelson concentrator in March 1994.

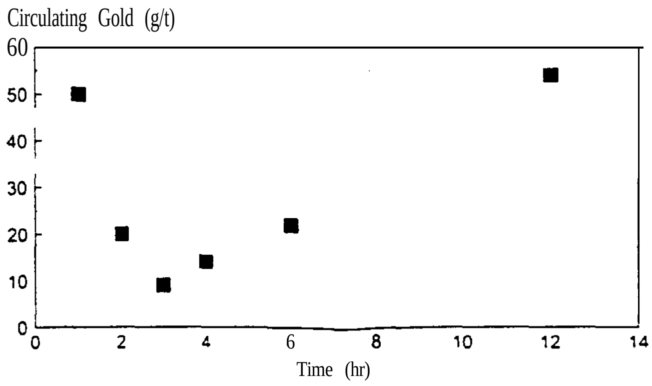

FIG 9 - Circulating gold values versus time.

CENTRAL DISCHARGE KNELSON AT ROSEBERY

Installation

It was important that the new Knelson concentrator installation be easy to operate, easy to control and secure. The same screen-cutter system was improved and automated. Automatic feed control was critical to the successful operation of the self discharging Knelson. Monitoring of critical parameters such as fluidising water flow and pressure was also automated. The Rosebery concentrator's distributive control system (DCS) was programed to control the entire process. Critical operating parameters are made available as menu items to assist with the optimisation of the new Knelson concentrator.

Operation

The CD Knelson requires approximately one hour per day of labour and this is purely to remove the valuable concentrate from a storage vessel.

The concentrator automatically executes the full discharge sequence draining the concentrate into a receiving vessel. The duration of the cycle and all other parameters are entered as menu items into the control package.

Results

It is expected that the new Knelson concentrator will exceed 30 per cent recovery of gold in feed to the doré product.

These results will obviously be dependent on the quality and type of gold available in mill feed.

Knelson optimisation is currently underway during April/May 1994. Further results will be available at the completion of this optimisationon period.

CONCLUSIONS

Installation of the Knelson concentrator at Pasminco Mining's Rosebery concentrator has provided a significant improvement in gold recovery to doré product. A critical factor in the selection of the Knelson concentrator was the characterisation and identification of the correct feed stream to be used. Significantly the CD Knelson concentrator has dramatically reduced the operational requirement for this function. Also, a far greater consistency in operation has been achieved by the automation of this function.

With these improvements in gold metallurgy brought about by the application of the Knelson concentrator, Rosebery must now be considered a zinc/gold mine. Sixty-five per cent of Rosebery's income is generated from zinc and 14 per cent is generated from gold. With its ease of operation the Knelson concentrator will continue to find new applications within the industry.

ACKNOWLEDGEMENTS

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REFERENCES

All references used were unpublished Pasminco Metallurgical Department reports.