

GRAVITY SEPARATION DEVELOPMENT AT BODDINGTON GOLD MINE

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Introduction:

Boddington Gold Mine is situated 130km South-east of Perth, WA. The operation is managed by Worsley Alumina Pty Ltd. The Direct Leach plant was commissioned in mid 1986 at a rate of 3 million tonnes per annum. The plant was upgraded to 4.5 mtpa in 1988 and almost immediately to 6mtpa in 1989. Subsequent debottlenecking resulted in further increases in throughput up to 7mtpa by 1991.

The Supergene/Basement Plant was constructed in 1990 and commissioned in early 1991. It was designed to process both copper-gold-silver anomalies within the laterite gold orebody and future hard rock ores.

The Supergene plant incorporated control potential sulphidisation (CPS) and flotation ahead of CIL to remove a host of copper minerals. It operated in that configuration for 2 years at rates up to 350,000 tpa and average grades of 6.0 g/t gold and 1.2% copper. Gold recovery averaged 90.7% and copper recovery averaged 80.0% before the flotation circuit was decommissioned in March 1993.

Quartz hosted high grade, free milling oxide and basement ores were discovered at the northern end of the orebody in 1990 and now comprise the major feed source to the basement plant. Oxide ores are currently milled at a rate of 550,000 tpa, while basement ores are milled at a 350,000 tpa rate.

Metallurgical testwork during the feasibility stages indicated that up to 30% of gold in plant feed could be recovered by gravity separation methods. It was also highlighted that significant improvements in overall plant recovery and reduced operating costs would be achieved by maximising gravity gold recovery ahead of cyanidation. To achieve this, redesign and upgrade of the gravity circuit was necessary.

Based on the findings of an inhouse Quality Improvement Programme set up in October 1992, a fully automated centre discharge Knelson concentrator was retrofitted into the existing gravity separation circuit. It's selection, operation and performance thereafter is now discussed.

Process Overview:

Oxide and basement ores are processed in separate campaigns as dictated by current mining schedules. Oxide quartz veins are mined from the open pit and are milled semi-Autogenously, following primary crushing to 90mm. Basement ores are mined from an underground decline at a rate of 100,000tpa. The ore is secondary crushed to minus 10mm (80% passing size) prior to ball milling (figure 1).

Both high grade ore types are blended with lower grade material (1.5 - 2.5g/t) to maintain target feed grades averaging about 12 g/t, depending on ore presentation rates. Oxide ore is stockpiled and processed separately to basement ore, due to its high clay content, which would otherwise hinder secondary crushing and screening performance.

Production statistics for the oxide and basement ores milled since March 1993 are:

<i>Ore Type</i>	Grade (g/t)	<i>Gravity</i> Recovery	<i>CIL</i> Recovery	<i>Overall</i> Recovery
Oxide	8.5	31.9	65.4	97.3
Basement	11.8	68.9	29.3	98.2

A gradual improvement in gravity circuit recovery since March 1993 has allowed a reduction in blending requirements and a subsequent decrease in plant feed grade sensitivity. Higher grades can be processed without a detrimental effect on overall plant recovery or increased carbon stripping requirements (as the majority of the gold is recovered to gravity concentrate).

Circuit Development and Equipment Selection:

In October 1992 a Quality Improvement Programme (QIP Project) was initiated to review current gravity separation techniques, then recommend and implement modifications to the existing circuit to successfully treat the high grade, coarse gold ores. The project was driven by a recognition that:

- The existing spirals circuit would not maximise and efficiently recover coarse liberated gold.
- Materials handling difficulties restricted circuit performance at times.
- Milling circuit water imbalances arose due to slurry transport difficulties.

In order to meet our objectives the following criteria were set:

- A high upgrade ratio had to be achieved to allow direct smelting of gravity gold concentrates.
- Existing equipment was to be utilised (where possible) to minimise capital expenditure.
- New equipment had to fit within the existing design constraints (ie. space).
- The water imbalance had to be addressed.
- A requirement for high security and minimal operator input had to be met.

An extensive review of gravity separation devices resulted in the selection of a number of centrifugal type separators for laboratory and pilot scale testwork. A 7½ inch Knelson concentrator was installed at Boddington for a 2 month trial period. The pilot rig was installed in parallel with the rougher spirals, fed at approximately 0.65 tph and 40% solids (equivalent to the rougher spirals at that time). A high grade parcel of oxide ore was treated during the trial period and an extensive test programme was undertaken.

Some of the results are summarised below:

Process Stream	Existing Circuit	Knelson Concentrator
Rougher Spiral Feed (g/t)	27.2	
Rougher Spiral Concentrate (g/t)	75.0	
Cleaner Spiral Concentrate (g/t)	745.0	
Knelson Feed (g/t)		30.1
Knelson Concentrate (g/t)		2290
Knelson Tail (g/t)		19.3
Upgrade Ratio	27:1	76:1
Overall Recovery (%)	5.4	36.1

The Q.I.P. project concluded that the centre discharge Knelson Concentrator provided:

- Excellent metallurgical performance
- A high level of security
- Robust equipment design
- A fully automated control system

It was therefore decided to install a fully automated 20 inch unit into the circuit. The rougher spirals were retained to upgrade minus 1.5mm material in order to maximise the split taken from the recirculating load and therefore maximise gold throughput to the 20 inch Knelson (which was the only fully automated Knelson available at the time). Recovery of the rougher spirals was maximised by increasing the cutter width of the middlings stream (figure 2 illustrates the current circuit).

The cleaner spirals were retained to dewater Knelson concentrator tailings, returning solids to the mill for regrinding and 'water' to the mill discharge sump to maintain the water balance. In this duty they would also serve as a back-up for the Knelson during maintenance downtime.

Operation of the Gravity Circuit:

Approximately 25% or 30tph of cyclone underflow is split from the recirculating load as feed to the gravity circuit. A two section DSM screen removes oversize from the cyclone underflow. Minus 1.5mm material feeds the rougher spirals (6 x double start MG4 spirals) at approximately 1.2 dry tph and 53% solids each start. Plus 1.5mm minus 3mm material (which contains the majority of coarse liberated gold) feeds the Knelson concentrator directly. Concentrate and middlings from the rougher spirals comprise the remaining feed to the Knelson concentrator.

The Knelson concentrator currently operates on a 40 minute batch cycle (which is variable), discharging concentrate over a vibrating screen to remove coarse material ahead of tabling. Both products are tabled daily in two stages. Wilfley table concentrate is upgraded on a Gemeni table to produce a 75 - 80% gold concentrate which is direct smelted.

The majority of liberated gold is recovered below 300 µm and is reasonably consistent with the gold size distribution of cyclone underflow (of which 70% passes 300 µm). Recovery of 'coarse' gold (predominantly minus 1mm plus 300 microns) is poor, for which detailed circuit surveys recently conducted have not clearly defined the reason. Tabling inefficiencies caused by large amounts of mill steel in gravity concentrate may be the single most significant contributor. The steel entrains flakey gold particles in the bed as it passes over the Wilfley table and the majority of steel (and gold with it) is rejected to gravity tails (returned to the mill for regrinding).

Table 1: Cyclone Underflow Solid and Gold Size Distribution

<i>Size (urn)</i>	<i>Solids wt %</i>	<i>Sol. Cum. Wt % Ret</i>	<i>Gold Assay (ppm)</i>	<i>Cum. Gold Assay (ppm)</i>	<i>Gold Dist. (%)</i>	<i>Cum. Gold Dist. (%)</i>
+600	16.8	16.8	28.4	28.4	9.3	9.3
+300	18.8	35.6	57.7	43.8	21.0	30.3
+150	29.8	65.5	24.0	34.8	13.8	44.1
+106	11.0	76.4	48.9	36.8	10.3	54.4
+75	5.7	82.1	81.0	39.9	8.9	63.3
-75	17.9	100.0	106.5	51.8	36.7	
Total	100.0		346.5		100.0	

Table 2: Gravity Concentrate Gold Size Distribution

<i>Size (um)</i>	<i>Weight (gms)</i>	<i>Wt % Retained</i>	<i>Cum Wt % Retained</i>	<i>Cum Wt % Passing</i>
+600	145.4	6.8	6.8	93.2
+425	60.9	2.8	9.6	90.4
+300	89.0	4.1	13.7	86.3
+212	197.4	9.2	22.9	77.1
+150	276.4	12.9	35.8	64.2
+106	385.3	17.9	53.7	46.3
+75	510.1	23.7	77.5	22.5
-75	484.2	22.5	100.0	
Total	2148.7	100.0		

Knelson Concentrator - Operating Experience:

The fully automated centre discharge Knelson concentrator at Boddington operates on a 40 minute concentrating cycle. This was determined by maximising the number of discharges per day (to maximise recovery) while maintaining tabling time at an acceptable level. Determination of the optimum fluidising water flowrate required was attempted during commissioning. However, sampling and assaying inconsistencies resulted in inconclusive findings. Fluidising water volumetric flowrate has since been maximised to reduce the frequency of blinding of the fluidising water holes. Feed to the Knelson concentrator averages 12 tph at about 55% solids. Lower slurry densities are accepted on oxide ores due to less favourable slurry rheology. Key operating parameters are:

Feed rate	12tph
Feed Density	55% solids
Feed Size	minus 3mm
Fluidising Water	27m ³ /h
Bowl Pressure	40 - 90 Kpa
Cycle Time	40 minutes
Concentrate Weight	16kg per discharge

- Fluidising water is supplied via a dedicated pumping and filtration system. No problems attributable to poor water quality have been experienced to date.
- Inner bowl changeouts are conducted every 3 - 4 weeks due to gradual blockages of fluidising water holes by solids (indicated by an increase in operating or bowl pressure). A rotating spare was purchased for this duty. Increasing the fluidising water flowrate from 16 to 27 m³/h during the first six months of operation (to try and overcome this problem) reduced the frequency of changeouts. This phenomenon has not been satisfactorily resolved.
- Cementing of gravity concentrate within the ribs arose during the first basement ore campaign. This was believed to have been caused by increased SG of the concentrate (due to an increase in sulphide and steel content) resulting in insufficient water pressure to discharge concentrate from the ribs during a flushing cycle. Increasing the volumetric flowrate and reducing the flush time satisfactorily resolved the problem.
- Wear on the underside of the ribs of both inner bowls at BGM has been identified. This has resulted from uneven drill pattern of the fluidising water holes during fabrication. It is understood, however, that Knelson have successfully overcome this design flaw.
- Availability of the Knelson concentrator has been high, averaging 99% since production started in March 1993. A successful preventative maintenance programme and robust design features of the Knelson concentrator have contributed to this excellent performance.

Future Development:

The gravity circuit operates well above initial design expectations, however a number of bottlenecks and operating deficiencies exist which need to be addressed.

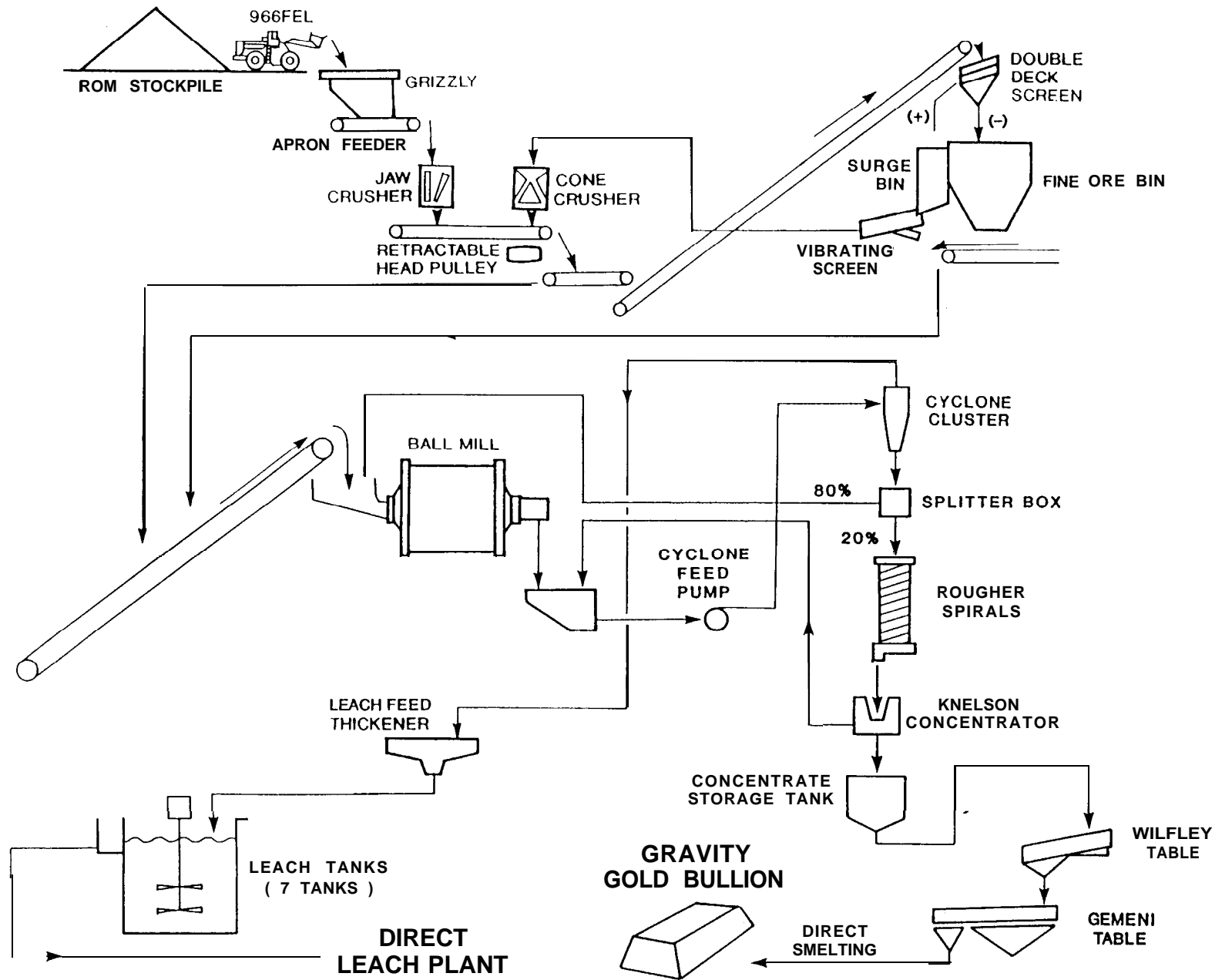
- As the fluidising water flowrate was increased (to reduce the extent of blinding of the fluidising water holes) the volume of water exceeded the capacity of the cleaner spirals.
- The circuit attracts high maintenance and operating costs due to the number of transfer stages and pumping requirements.
- Steel arising from the breakdown of grinding media causes tabling inefficiencies, which reduces gravity gold recovery below that which is recovered from the Knelson. It has been determined that a significant amount of this gold could be recovered by removing the magnetics ahead of or during tabling.

Proposed future development of the circuit should address these problem areas leading to reduced operating and maintenance costs while maintaining gravity gold recovery at the current level (figure 3).

Key features of the proposed circuit are:

- Significant reduction in transfer stages.
- Gravity flow is maintained throughout (no pumping).
- Removal of mill steel from gravity concentrates.
- Second Knelson provides emergency capacity should one be off-line (spirals are inadequate security).

SUPERGENE / BASEMENT PLANT PROCESS FLOWSHEET



Figure

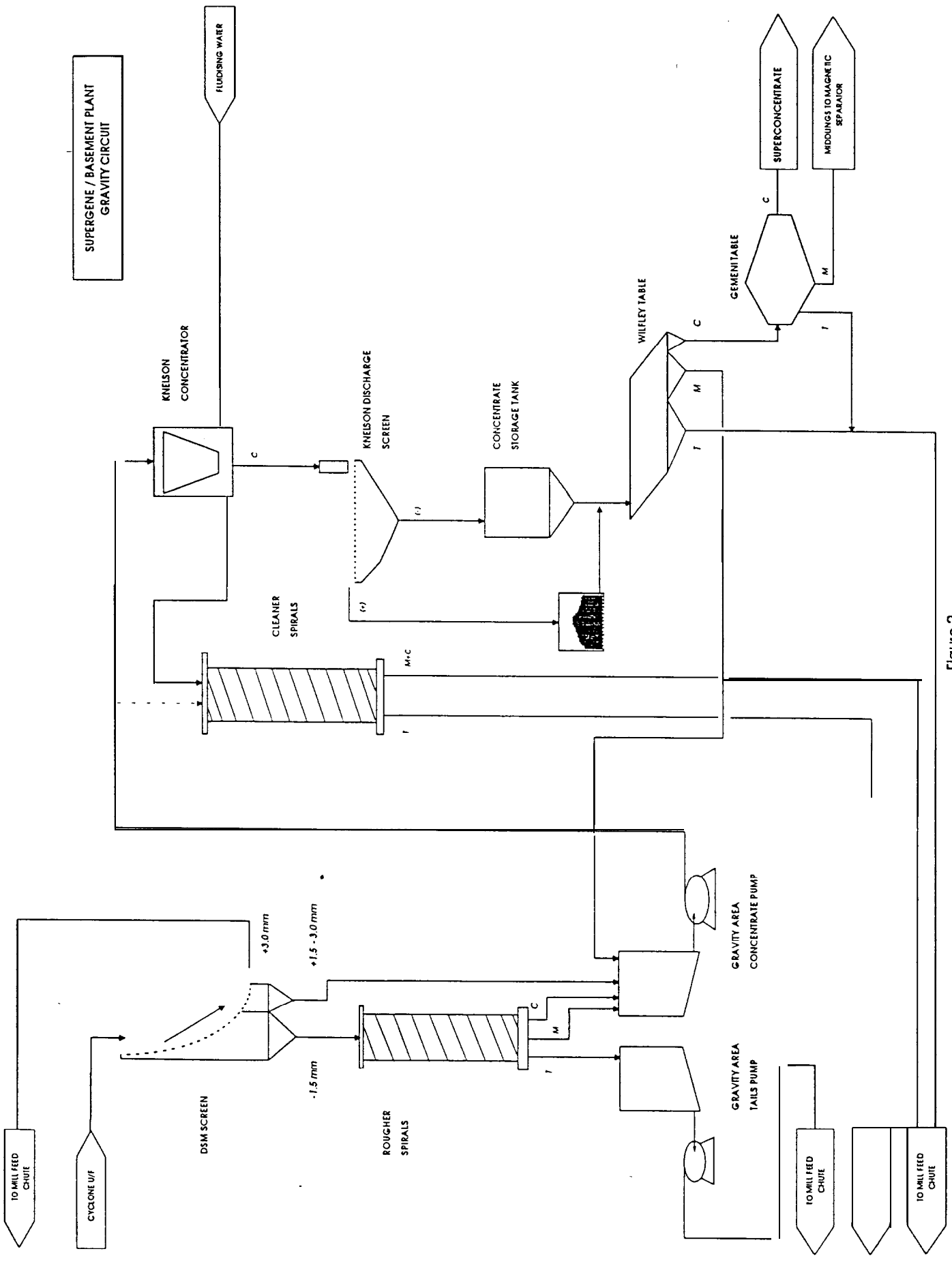


Figure 2

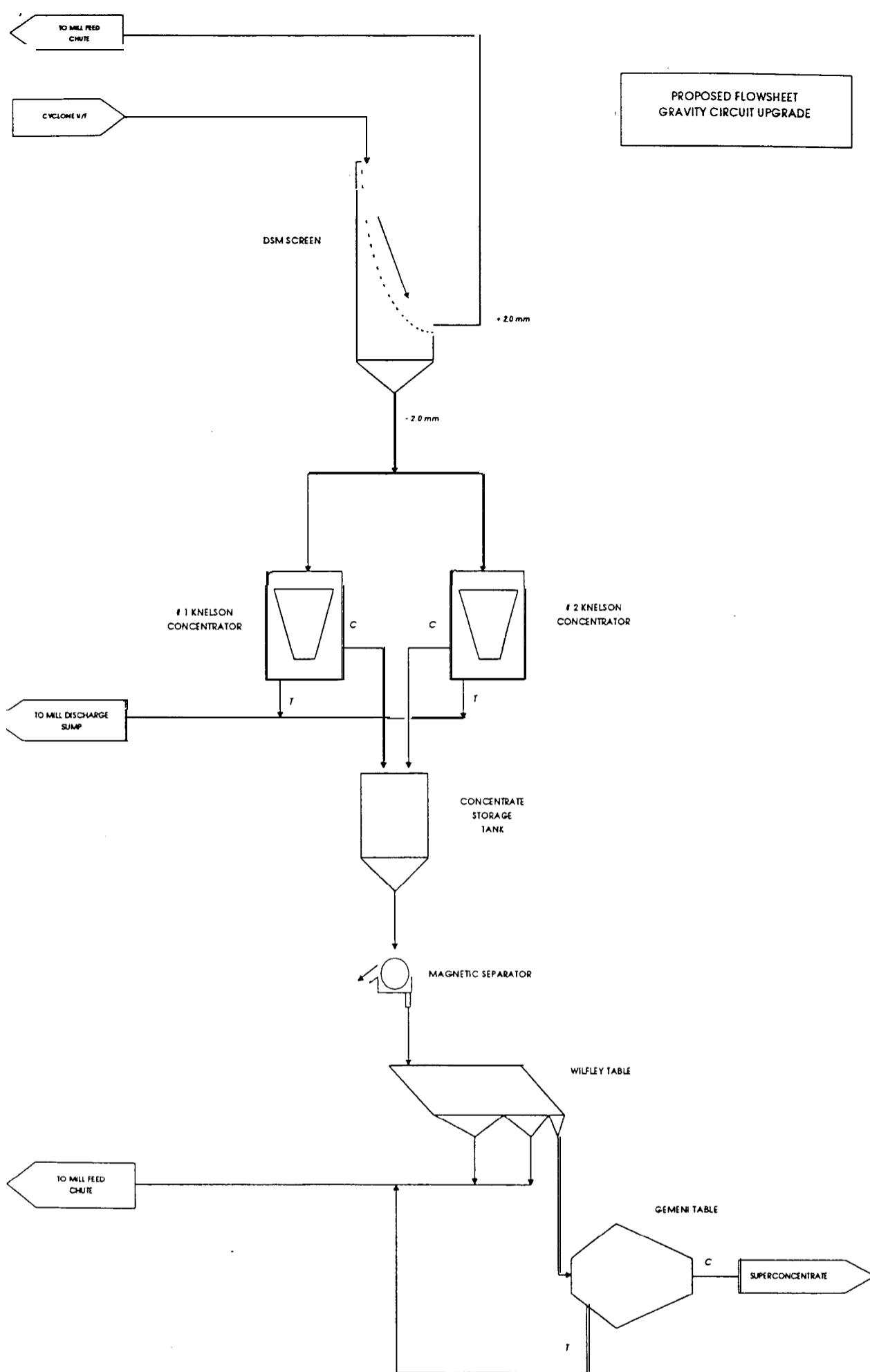


Figure 3