Treatment Plant Operation at Giant Yellowknife

*By K. C. GROGAN**

(Annual General Meeting, Edmonton, April, 1953)

(Transactions, Volume LVI, 1953, *pp.* 88-99)

GENERAL

GIANT ORE is complex, with the gold values for the most part occurring in extremely close association with arsenopyrite, stibnite, jamesonite, and a wide group of antimonial minerals locally termed 'the grey minerals'. Pyrite is the most abundant of the sulphide minerals and minor quantities of chalcopyrite, galena, and sphalerite also occur. Pyrrhotite has been found in some sections of the mine, but to date none of it has been nickeliferous. Native gold occurs in varying amounts throughout the orebodies.

In 1944, ore dressing investigations were commenced on diamond-drill core rejects and samples of surface outcrop ore. Results soon indicated that treatment to produce satisfactory recovery of the gold values would involve fine grinding to 80-85 per cent minus 200 mesh, recovery of free gold by jigs, followed by flotation, roasting of the flotation concentrate, and subsequent cyanidation of the calcine. Proceeding from this information, the flow-sheet was prepared, plant design worked out, equipment purchased, and construction of the treatment plant commenced in May, 1947.

The crushing, grinding, and flotation units of the plant were rushed to completion and commenced operation on May 12th, 1948, at 225 tons of ore per day. This rate was maintained until January 27th, 1949, when the Allis-Chalmers roaster and cyanide plants were completed and commenced operation. During the period May 12th, 1948, to January 27th, 1949, gold recovered by amalgamation was the sole source of revenue. Flotation concentrate was stockpiled pending the completion of the Allis-Chalmers roaster and cyanide plants. As of January 27th, 1949, the stockpile contained 5,670 tons of flotation concentrate with a total gold content of 35,885 ounces of gold. In order to reclaim the concentrate from the stockpile as quickly as possible, the Allis-Chalmers roaster and cyanide plants were operated at rated capacity and the primary mill tonnage was maintained at 225 tons of ore per day. Clean-up of the concentrate stockpile was completed on September 15th, 1949, and mill tonnage was thereafter gradually increased to 425 tons of ore per day. While the operation continued at this rate, the primary 8 ft. by 10 ft. ball mill and 72-inch Akins classifier operated to a finished product and the secondary grinding circuit remained out of operation. By June 23rd, 1952, the Dorrco FluoSolids reactor was in satisfactory operation and, with the completion of the mill addition, the tonnage rate was gradually increased from 425 tons of ore per day to 700 tons of ore per day. The 700-ton rate was achieved on October 1st, 1952.

During the period May, 1948, to September, 1949, the plant was operated on Diesel-electric power supplemented by hydro-electric power supplied by the Bluefish plant of the Consolidated Mining & Smelting Company of Canada, Limited. The Diesel-electric units consisted of two 400 h.p. Dominion Engineering Company Diesel engines direct-connected to two 382 kva generators and one 540 h.p. General Motors Diesel engine connected through a chain drive to a 350 kva generator. Hydro-electric power from the Snare River plant of the Northwest Territories Power Commission was delivered to the operation on September 30th, 1949. The Diesel electric units provide stand-by power for essential services during outages of Snare River power.

Treatment plant water supply is provided by a B. & W. two-stage pump, 400 U.S. g.p.m. at 258 ft. total head. This pump is located at the water front of the main camp and is connected to an 8-inch iron pipe-line, 4,000 feet long, enclosed in a wooden pipe-box together with

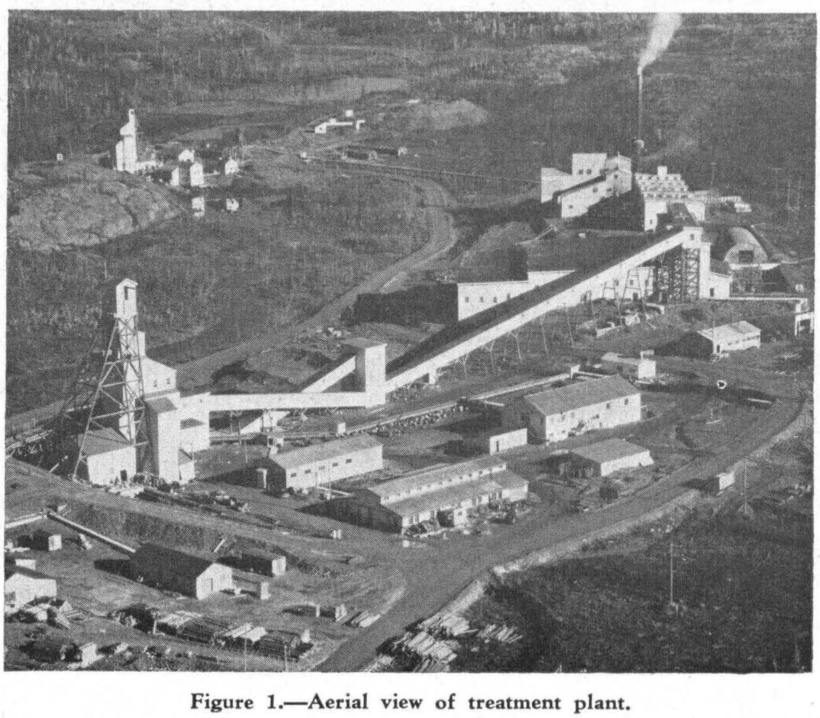

Figure 1.—Aerial view of treatment plant.

*Mill Superintendent, Giant Yellowknife Gold Mines, Limited.

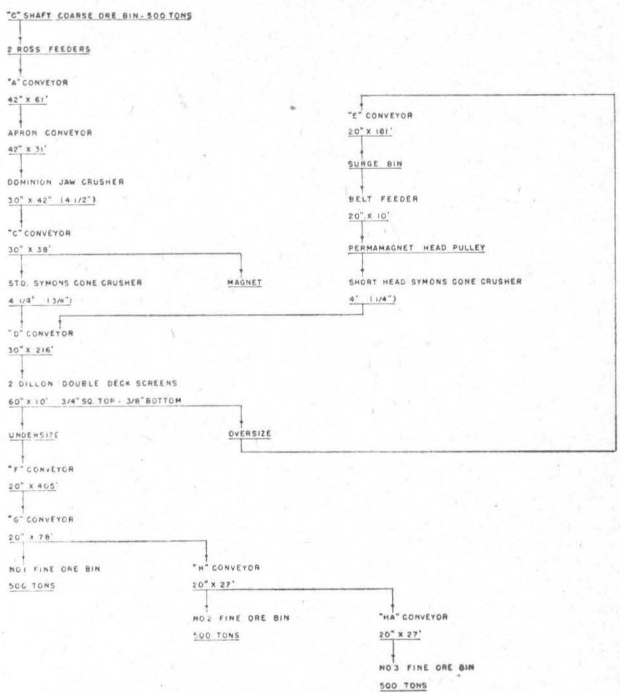

Figure 2.—Flow-sheet, crushing plant, 750 tons/day.

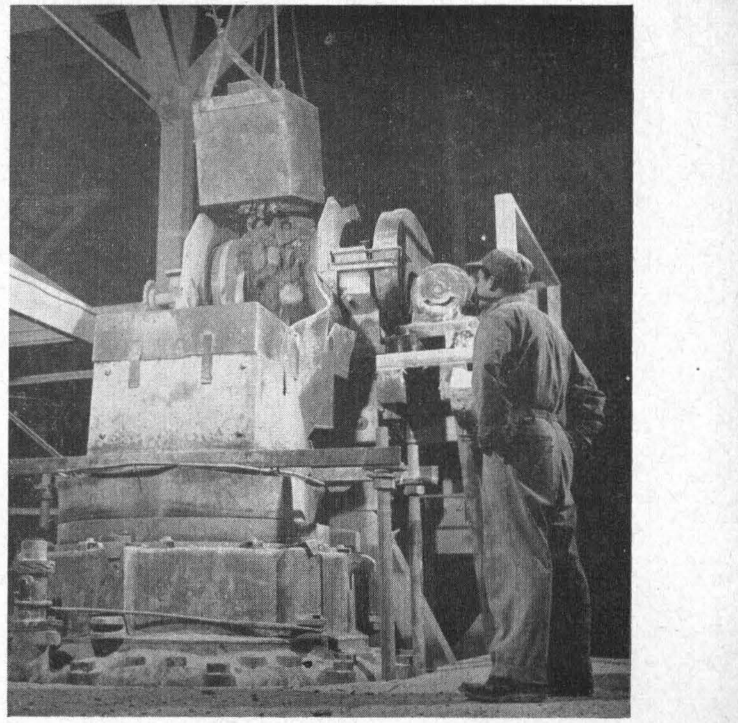

Figure 3.—4¼-foot Stasdard Symons cone crusher.

the steam line from the main boiler plant

With the exception of the Cottrell precipitator, Dorrco reactor, and refinery buildings, which are of fireproof construction, all other treatment plant buildings are of frame construction. Trusses are framed of B.C. fir and columns and siding are of local spruce from the south shore of Great Slave lake.

Fire protection, in all frame buildings, is provided by a Grinnell sprinkler system.

Crushing, Screening, and Conveying

The crushing plant, as designed, has a capacity of 1,000 tons of ore per day. Space has been provided for a second 4-ft. Symons short-head cone crusher which will give the plant an ultimate capacity of 1,500 tons of ore per day. Mine-run ore is delivered from the *C* shaft coarse-ore bin to the primary jaw crusher by means of Ross feeders, a 42-inch belt conveyor, and a 42-inch apron-type conveyor, respectively. The primary jaw crusher is a 30 in. by 42 in. Dominion Engineering Company crusher driven by a 125 h.p. 2,200-volt motor. Crusher setting is 4½ inches.

Secondary crushing is conducted by a 4¼-ft. Symons standard cone crusher set at ¾-inch, and a 4-ft. Symons short-head cone crusher set at ¼-inch. The discharge of these two crushers passes over two double-deck Dillon vibrating screens, 60 in. wide by 10 ft. long. Screen covers are ¾-inch square opening covers in the top deck service and ⅜-inch by 4½-inch opening covers in the under deck service. Screen oversize is returned to the 4-ft. Symons short-head cone crusher, and the screen undersize (minus ⅜-inch) is conveyed to the three fine-ore bins. The 4¼-ft. Symons standard cone crusher is protected against tramp steel by means of a Dings electro-magnet suspended over the conveyor feeding the crusher. The feed belt of the Symons short-head cone crusher is equipped with a Dings perma-magnet head pulley. The Symons cone crushers are each driven by a 150 h.p. 2,200-volt motor. At present, a Sly dust collecting system is in process of installation.

Crushing Plant Steel Consumption

30-in. by 42-inch Jaw Crusher

Lower swing jaw plates	0.0104 lb./ton ore
Swing wedge plates	0.0008 " "
Upper swing jaw plates	0.0029 " "
Lower stationary jaw plates	0.0080 " "

Stationary wedge plates (original installation in service—655,573 tons ore at December 31st., 1952).

Upper stationary jaw plates (original installation in service — 655,573 tons ore at December 31st., 1952).

Cheek plates (original installation in service — 655,573 tons ore at December 31st., 1952).

4¼-ft. Symons Standard Cone Crusher

Bowl liners	0.0230 lb./ton ore
Mantles	0.0193 " "

4-ft. Symons Short-Head Cone Crusher

Bowl liners	0.0309 lb./ton ore
Mantles	0.0277 " "

Screen Covers (425-ton rate)

¾-inch square opening top deck upper section	3 months
¾-inch square opening top deck lower section	4 months
⅜ inch by 4½ inch under deck upper section	4 months
⅜ inch by 4½ inch under deck lower section	5 months

Construction of the conveyor galleries and screen house are somewhat unique and warrant special mention. The rock outcrops which accommodate the crushing plant and the main mill building are approximately 800 feet apart. The intervening space consists of a steep pitching valley overlain to a maximum depth of about 100 feet with permanently frozen clay and gravel (permafrost). To extend the footings to bed-rock in this area was impossible in many cases and therefore it was decided to support the structures on wooden piles driven into the permafrost.

A portable steam boiler was employed as the source of steam and the permafrost was thawed to a maximum depth of 25 feet for the piles. Due to the rapid freezing of the permafrost, after thawing, a maximum of 4 or 5 holes were thawed at one time. Wooden poles of selected straightness and with a minimum top size of 10 inches in diameter were chosen. Piles were greased and bandage-wrapped with tar paper for the full submerged length of the pile to about one foot above ground level.

The winch attachment of an *RD*8 caterpillar tractor was employed to drive the piles to their required depth of 20 to 22 feet. As soon as the piles were driven they were checked for alignment and were supported in order that they would freeze in their proper positions. Piles were permanently frozen in place after four to five hours.

In the case of the conveyor gallery construction, the pile tops were cut off at the required height above ground level and the conveyor bents were placed upon them. For the screen house construction, the pile tops were cut off at the proper height above the ground level and the screen house was erected on top of the piles, leaving a space of about two feet between the ground and the screen-house floor for uninterrupted circulation of air. To date there has been no movement of either the screen house or the conveyor gallery structures, and pile construction is considered entirely satisfactory.

Grinding and Classifying

Fine-ore storage is provided by three circular wood-stave ore bins, 24 ft. o.d. by 26 ft. o.h. Two draw-off gates are located in the bottom of each bin and ore is drawn off by means of an individual 30-inch belt conveyor driven through a Link-Belt *P.I.V.* motor-reduction unit. A revolution counter is attached to the tail pulley of each feeder belt and hourly belt-weights are taken for mill feed tonnage calculations. A portion of each belt-weight is saved and forms a part of the 24-hour composite mill-feed head sample. No. 1 fine-ore bin feeder-belt feeds directly into the primary ball mill. The feeder belts of No. 2 and No. 3 fine-ore bins discharge onto a cross conveyor system which in turn feeds into the primary ball mill.

The primary ball mill is an 8 ft. dia. by 10 ft. Dominion Engineering Company mill, direct connected to a 300 h.p. 2,200-volt motor through a No. 5 Gearflex coupling. This mill operates at 22 r.p.m. in closed circuit with a 72-inch Akins Simplex high-weir classifier. Operating ball load is approximately 57,000 lb. consisting of 80 per cent 3-inch balls and 20 per cent 2-inch balls. Ball consumption is 1.2 lb. per ton of ore. The primary ball mill discharge density is maintained at 75 per cent solids and the primary classifier overflow density at 65 per cent solids. The primary classifier overflow passes over a 12-in. by 18-in. Denver Duplex mineral jig before being pumped to the secondary classifier. Pumps employed in this service are 5 in. by 5 in. *S.R.L.* and a 5 in. Wilkinson Linatex, one in operation, the other held as a spare.

The secondary grinding circuit consists of a 6 ft. dia. by 12 ft. Dominion Engineering Company ball mill direct connected to a 175 h.p. 2,200-volt motor through a No. 5 Gearflex coupling. This mill operates at 25.9 r.p.m. in closed circuit with a 54-inch Akins Duplex submerged classifier. The secondary classifier overflow is maintained at a density of 30 to 32 per cent solids and is pumped to flotation by means of a 5 in. by 5 in. *S.R.L.* pump (there are two of these pumps, one held as a spare). The secondary classifier sands pass directly by gravity into the secondary ball mill. Mill discharge, maintained at 65 per cent solids, passes over a 12-in. by 18-in. Denver Duplex mineral jig before joining the primary classifier overflow and thence returning to the secondary Akins classifier. The operating charge of the secondary ball mill consists of approximately 41,000 lb. of 1½ inch steel balls. Ball consumption of this mill is 0.8 lb. per ton of ore.

Manganese-steel liners were supplied with the primary ball mill and were employed as replacements until recently, when Ni Hard liners were adopted. A substantial increase in liner life is indicated by the use of Ni Hard liners in this service. The secondary ball mill is also equipped with Ni Hard liners. Due to the primary and secondary grinding circuits having been in service only since June, 1952, no reliable information is as yet available on liner consumption in either the primary or the secondary mill at the increased tonnage rate.

The re-lining of the primary ball mill has been conducted both with and without the removal of the ball charge. The accepted procedure is to leave the ball charge in the mill as this method eliminates the final laborious task of recharging the mill when the crew is weary following the heavy relining job. Wearing shoes of the 72-inch Akins classifier are renewed as complete sets and have a life of 8 to 9 months per set.

Screen analyses are given in Table I.

Jigs and Amalgamation

The jig installations include a 12-in. by 18-in. Denver Duplex on the primary classifier overflow (density 65 per cent solids) and a similar unit on the discharge of the 6 ft. dia. by 12 ft. secondary ball mill. Primary and secondary jigs are equipped with Dowsett valves which automatically discharge the hutch product of each jig into a 1-inch Denver vertical sand pump. These pumps discharge, *via* a one-inch line, into a covered jig concentrate collection tank located directly above the amalgam barrel. The combination of Dowsett valves and the Denver vertical sand pumps has operated most satisfactorily and eliminates the manual handling of the high-grade jig product.

Concentrate produced by the two jigs amounts to 1,200 to 1,800 lb. per day. It is charged to the amalgam barrel and is ground for eight hours with 10 lb. lime and 3 to 5

Table I.— Screen Analyses

Mesh	Primary Ball Mill Feed		Primary 72-in. Akins Classifier O'Flow		Secondary 54-in. Akins Classifier O'Flow	
	Per Cent	Cumulative %	Per Cent	Cumulative %	Per Cent	Cumulative %
+½ inch......	1.2	1.2	—	—	—	—
+ 3 mesh.....	38.4	39.6	—	—	—	—
+ 4 "	16.5	56.1	—	—	—	—
+ 6 "	8.9	65.0	—	—	—	—
+ 8 "	5.6	70.6	—	—	—	—
+10 "	4.9	75.5	0.4	0.4	—	—
+14 "	4.3	79.8	1.5	1.9	—	—
+20 "	3.1	82.9	3.1	5.0	—	—
+28 "	3.4	86.3	4.7	9.7	—	—
+35 "	2.0	88.3	6.9	16.6	—	—
+48 "	1.5	89.8	7.6	24.2	—	—
+65 "	1.5	91.3	7.6	31.8	0.1	0.1
+100 "	1.1	92.4	7.0	38.8	1.4	1.5
+150 "	1.0	93.4	7.5	46.3	8.0	9.5
+200 "	0.7	94.1	5.3	51.6	9.9	19.4
−200 "	5.9	100.0	48.4	100.0	80.6	100.0
Total........	100.0		100.0		100.0	

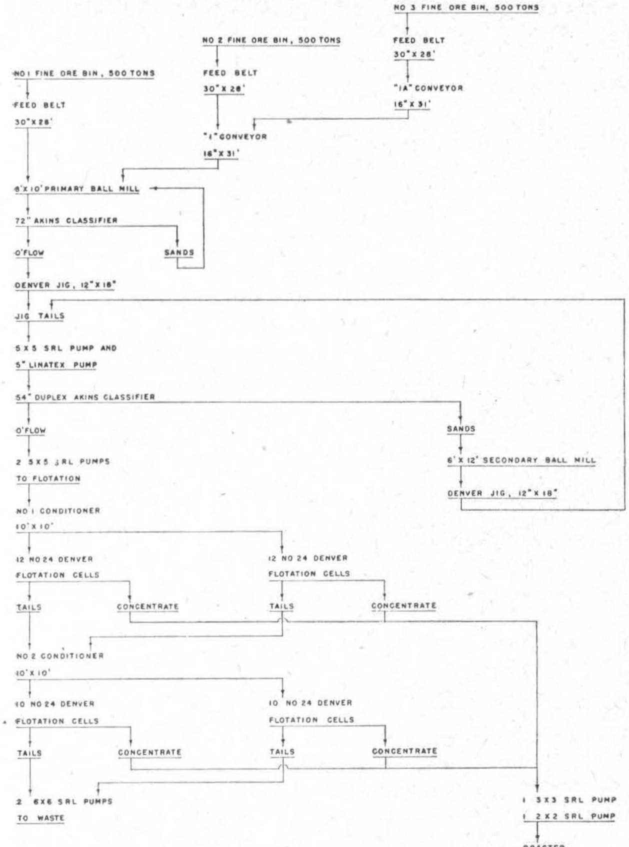

Figure 4.—Flow-sheet, grinding, classifying. and flotation; 750 tons/day.

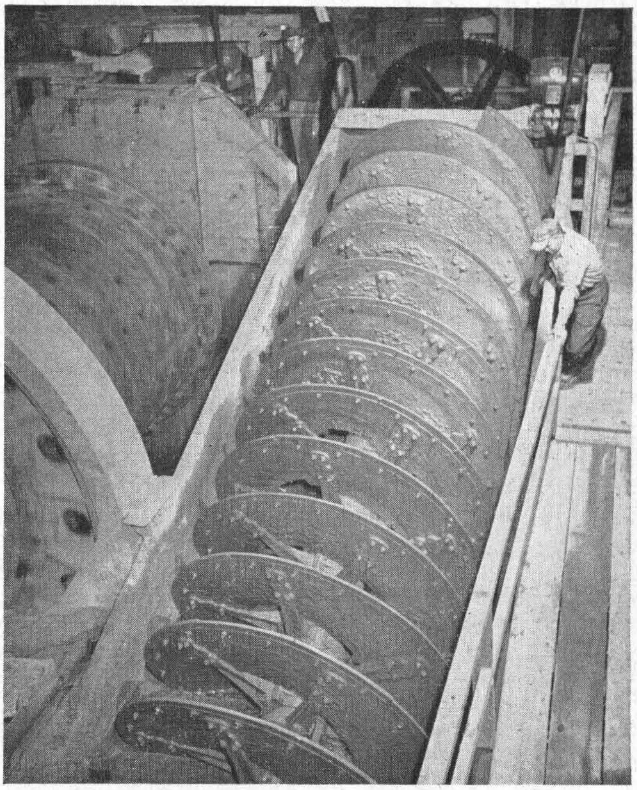

Figure 6.—Primary 8 ft. by 10 ft. ball mill and 72 in. Akins classifier.

Figure 5.—Cutting mill-feed tonnage sample.

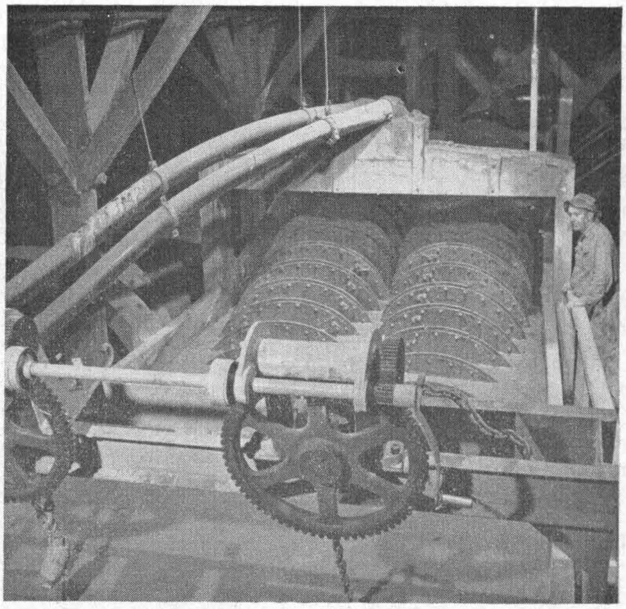

Figure 7.—Secondary 54 in. Akins Duplex classifier.

lb. lead nitrate. The following day the barrel is stopped, the solids are permitted to settle, and the solution is decanted from the barrel. The charge is then washed with fresh water. When the washing is completed, fresh water is added to the barrel with 5 lb. soda ash and 25 to 50 lb. mercury and the charge is ground for one hour. The barrel is opened at the completion of the amalgamation operation and the contents are discharged through a Denver amalgam separator. The amalgam is collected in a glass container and the amalgan barrel tailing passes through a hydraulic trap, then over an amalgamation plate, through another hydraulic trap to a 1-inch Denver vertical sand pump which discharges into the launder feeding the primary jig.

Amalgam is cleaned by means of hot water, and tramp steel is removed by means of an electromagnet. Excess mercury is squeezed by hand from the amalgam and batches of 50 lb. amalgam are retorted for recovery of the mercury prior to melting the sponge gold into bullion bars. From the commencement of operations, amalgamation recovery has varied between 10 and 25 per cent and for the fiscal year ending June 30th, 1952, it averaged 16.17 per cent.

Flotation

The secondary classifier overflow, at a density of 30 to 32 per cent solids, is pumped to the No. 1 10 ft. by 10 ft. Denver conditioner. Soda ash and copper sulphate are added to the pulp *en route* to the conditioner and sodium silicate, Dowfroth, aerofloat, and a portion of the xanthate are added to the conditioner. Discharge of the latter is divided between the two twelve-cell banks of No. 24 Denver flotation cells. These cells are 'super-charged' with 12-ounce air supplied by a Spencer turbo-blower, 1,000 c.f.m. capacity. A rougher concentrate is removed from these cells. Froth consistency is maintained and clean-up is assisted by additions of Dowfroth-aerofloat No. 25 mixture and xanthate to the No. 7 cells of each bank.

The tailing from each bank of cells enters the No. 2 10 ft. by 10 ft. Denver conditioner, to which additional xanthate and Dowfroth-aerofloat No. 25 mixture are added. Discharge of this conditioner passes to the west bank of ten No. 24 Denver flotation cells from which a final clean-up concentrate is removed. The final flotation tailing from this bank of cells passes through an automatic sampler *en route* to disposal. Two 6 in. by 6 in. *S.R.L.* pumps connected to individual 6-inch wood-stave pipe lines discharge the flotation tailing to storage in Bow lake, 1,800 feet from the plant. Each pipe line is equipped with drainage facilities in case of pump failure. One pump only is in operation at a time, the other being held as a spare.

Concentrates from the two stages of flotation combine and are pumped to the roasting plants by means of a 3 in. by 3 in. *S.R.L.* pump and a 2 in. by 2 in. *S.R.L.* pump connected to individual 800-foot 'Carlon' pipe lines; a spare line is also provided in this service. One pump normally handles the present volume of concentrate, 80 to 90 tons per day plus water to give a density of 20 to 25 per cent solids. 'Carboxel' C-12 is added to the concentrate pumps to aid in roaster thickener settling.

On several occasions, a middling product has been made. However, no benefit has ever been indicated by this procedure and a straight roughing operation has been adopted. The middling thickener, which was included in the initial mill unit, is therefore inactive in its designed capacity, and is employed as a collection unit for spills, drainings, etc., in the flotation circuit. The east bank of ten No. 24 Denver flotation cells is also inactive and is available for tonnage increase or as the operation demands.

For the fiscal year ending June 30th, 1952, from mill feed averaging 0.755 oz. gold per ton, a flotation concentrate assaying Au 4.81 oz./ton was produced and the flotation tailing assayed Au 0.046 oz./ton. Recovery was 93.57 per cent and the ratio of concentration was 8.12 to 1.

Anaysis of flotation concentrate for the fiscal year ending June 30th, 1952, is as follows:

Au.. 4.81 oz./ton	Sb.. 0.60 per cent
Fe.. 21.46 per cent	Pb.. 0.32 "
S.... 19.17 "	Zn.. 0.33 "
As.. 8.22 "	

Reagent consumption and point of addition at 700 tons/day, December, 1952, are shown in Table II

Flotation reagent mixing tanks and pumps for delivering reagents to the reagent feeding floor are located adjacent to the flotation machines. The reagent feeding floor is at sufficient elevation above the flotation cells to provide gravity flow of reagents to all required points of addition. Soda ash, xanthate, Dowfroth, and the Dowfroth and aerofloat No. 25 mixture, are fed by Clarkson reagent feeders. Copper sulphate and sodium silicate are fed by means of syphon feeders, and aerofloat No. 25 by means of a Denver Equipment Company aerofloat feeder.

Roasting

General

The treatment of 700 tons of ore per day produces 85 to 90 tons of flotation concentrate. Roasting of this concentrate is conducted in the Dorrco FluoSolids reactor which roasts 60 to 70 tons per day, and one hearth of the Allis-Chalmers Duplex flat hearth roaster, which roasts the remaining 15 to 25 tons. Calcine produced by each unit is pumped to the cyanide plant by means of a 3 in. by 3 in. *S.R.L.* pump from the Dorrco plant and by two 2 in. by 2 in. *S.R.L.* pumps in tandem from the Allis-Chalmers plant.

A 'Carlon' pipe line is employed from the Dorrco plant and a guttapercha conducting hose in the Allis-Chalmers service. The original calcine line from the Allis-Chalmers plant was a standard iron line but, due to the highly corrosive nature of the pulp (*pH* 4.8 to 5.2), line failures were frequent and replacements were costly. The guttapercha line with rubber-lined Saunders valves and fittings was installed in October, 1949, and has required no maintenance to date. The Dorrco calcine is slightly corrosive (*pH* 6.4 to 6.8), however, for facility of installation, and, to safeguard against line failure, the acid-resisting 'Carlon' line was installed in this service.

Gases from the Dorrco reactor and the Allis-Chalmers roaster combine and pass through an insulated duct to the Cottrell precipitator for removal of the arsenic as crude white arsenic. The recovered white arsenic is stored underground and the cleaned gases exit to the atmosphere.

Allis-Chalmers Duplex Flat-Hearth Roaster

In the original 500-ton plant design, an Allis-Chalmers Duplex flat-hearth roaster was chosen for the roasting of 50 to 60 tons per day

TABLE II.— REAGENT CONSUMPTION AND POINT OF ADDITION

Reagent	Method of Feeding	Point of Addition	Lb./Ton Ore
Soda ash	15% solution	54-in. Akins K. o'flow launder	0.599
Copper sulphate	10% solution	54-in. Akins K. o'flow launder	0.291
Isopropyl xanthate	10% solution	No. 1 conditioner No. 7 cells (primary) No. 2 conditioner	0.290
Dowfroth	10% solution	No. 1 conditioner	0.112
Aerofloat No. 25	Straight	No. 1 conditioner	0.036
Dowfroth-Aerofloat No. 25 mixture	5 parts Dowfroth+, 1 part Aerofloat No. 25	No. 7 cells (primary) No. 2 conditioner	Included in above amounts
Sodium silicate	10% solution	No. 1 conditioner	0.100

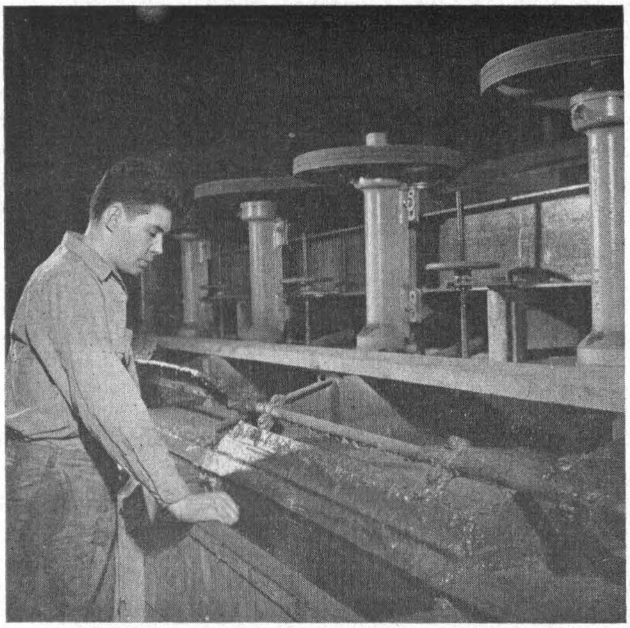

Figure 8.—No. 24 Denver flotation machine.

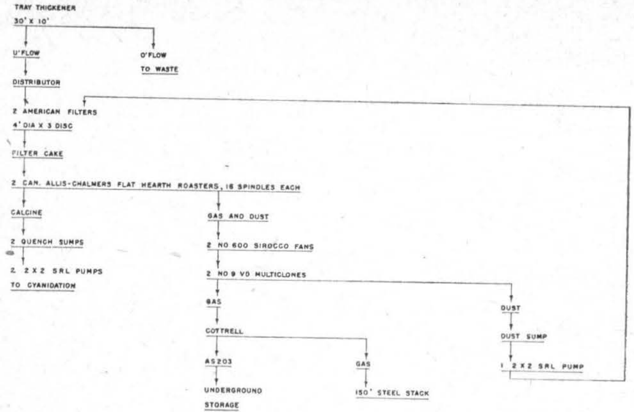

Figure 9.—Flow-sheet, Allis-Chalmers flat hearth roaster.

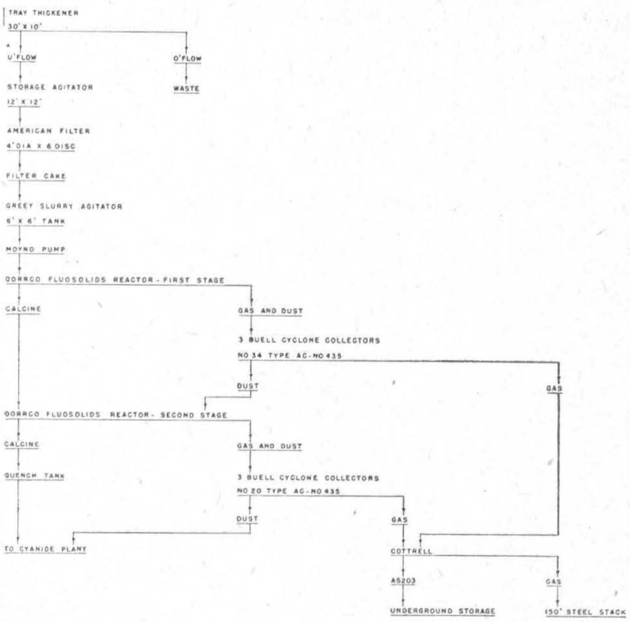

Figure 10.—Flow-sheet, Dorrco FluoSolids reactor.

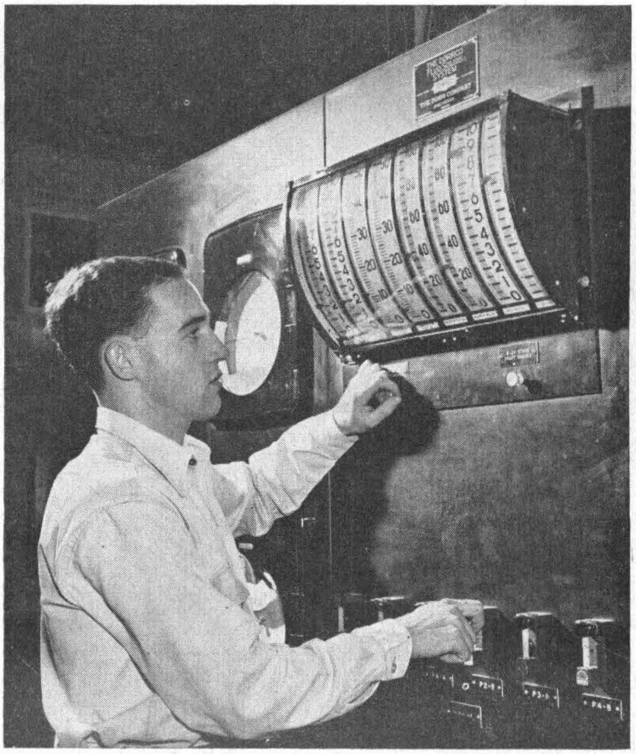

Figure 11.—Control panel, Dorrco FluoSolids reactor.

of flotation concentrate. Each hearth is equipped with 16 spindles and hearth dimensions are 127 ft. 6 in. inside length by 14 ft. 8 in. inside width. Hearth slope is ¼-inch per foot.

Roaster walls consist of two courses of fire-brick and one outer course of insulating brick supported upon a concentrate foundation set on bed-rock. The dividing wall between the two hearths is made up of two courses of fire-brick with a course of ordinary brick between them. The arch is constructed of fire-brick 13½ inches thick supported by fire-brick skewbacks. Expansion joints are spaced at 16 ft. 4 in. centres throughout the entire length of the arch and are overlain with fire-brick splits and covered with thermoflake insulation. The entire arch is insulated to a depth of two inches with loose diatherm insulation. Each hearth is equipped with a brick dust-chamber through which the gases pass *en route* to the multiclones and Cottrell precipitator. The hearth beds between the concrete wall-supporting foundations are filled with gravel to a depth of about three inches below the rabble teeth.

The spindle drive of each hearth is through a bevel gear and pinion assembly by means of a 15 h.p. motor and reduction unit. Speeds of ½ r.p.m., ¾ r.p.m., or 1 r.p.m. may be obtained by changing of the drive pinion. All three speeds have been investigated and the 1 r.p.m. rate has been adopted as most satisfactory.

Oil-fired burners are located in each hearth between Nos. 7 and 8, 9 and 10, 11 and 12, and 13 and 14 spindles. These are employed for heating of the hearths following a prolonged shut-down, or during the roasting of flotation concentrate of low sulphur content. Normally, the sulphur content of the concentrate is sufficient to maintain an autogenous roast. Gas offtakes are located at No. 1 and No. 6 spindles and at No. 2 and No. 9 spindles of each hearth for the removal of excess hot gas directly to the dust chambers. Micromax temperature recorders are installed on each hearth and are connected to the thermocouples located as follows:

THERMO-COUPLE No.	SPINDLE No.	TEMPERATURE °F.
1.........	3	525°
2.........	4	675°
3.........	5	700°
4.........	6	835°
5.........	8	900°
6.........	10	950°
7.........	13	775°
8.........	Exit duct to Cottrell	410°

Each hearth is equipped with a No. 9 *VD* multiclone through which the roaster gases pass for removal of calcine dust before continuing to the Cottrell precipitator. The multiclone dust is removed from each of the hoppers by means of a screw conveyor which discharges into the multiclone dust sump. The dust is repulped with water and is pumped to join the original roaster feed and thereby receive a re-roast. Each hearth is also equipped with a No. 600 Sirocco fan located between the hearth and multiclone.

A splitter box in the Allis-Chalmers roaster building divides the flotation concentrate in the proportion required by the Dorrco and Allis-Chalmers roasting units. The Allis-Chalmers portion is thickened in a 30 ft. dia. by 10 ft. *Type ATO* Dorr tray thickener. Overflow goes to waste. The underflow (70 per cent solids) is removed by means of a 3-inch Simplex Dorr diaphragm pump and thence is delivered to the filter distributor by means of a 2 in. by 2 in. *S.R.L.* pump. Each hearth is provided with a 4-ft.-dia. 3-disc American-type filter mounted above the dust chamber. The filtrate is discharged to waste and the cake drops directly into the path of the No. 1 spindle rabble arms. The rabble arms turn in reverse rotation and mesh so that they overlap in their rabbling action. The concentrate is moved through the length of the hearth by means of the rabble action aided by the 1/4-inch slope of the hearth. Finally, at the sixteenth spindle, the rabble arms pass over an 8-inch drop hole in the floor of the hearth and the hot calcine is discharged into the quench sump. The calcine is quenched in water and is pumped to the cyanide plant by means of two 2 in. by 2 in. *S.R.L.* pumps in tandem.

Spindles and rabble arms are water-cooled and the cooling water is collected and pumped to the mill where this hot water is employed as make-up water in the primary grinding circuit and as water wash on the 5 ft. dia. by 4 ft. calcine regrind filter. Cast-iron rabble arms and rabble teeth have given satisfactory service.

One item worthy of mention is the corrosion of the seal water pans which encircle the roaster spindles. Within a year's operation, these pans had commenced to fail due to the corrosive condition prevailing with hot water and steam in a sulphur-bearing atmosphere. The replacement, with pans of similar design to the originals, threatened a major shut-down and removal of each spindle for installing the seal water pan. Therefore, liners of No. 316 stainless steel were obtained to fit inside the original seal water pans. They were fabricated in two halves for field-welding in place and were installed with a maximum of three hours shut-down per liner. All 16 spindles of each hearth are equipped with these liners and, to date, there are no indications of corrosive action.

Analysis of Allis-Chalmers calcine for the fiscal year ending June 30th, 1952, is as follows:

Au..	5.99 oz./ton	Sb..	0.35 per cent
Fe...	28.62 per cent	Pb..	0.53 "
S....	3.22 "	Zn..	0.46 "
As...	0.99 "		

The Allis-Chalmers roasting plant is equipped with a *B.W.G. & Mc.* compressor, capacity 240 c.f.m. at 25 lb., and a *B.W.G. & Mc.* vacuum pump of 300 c.f.m. displacement.

Dorrco Split Compartment FluoSolids Reactor

A two-stage Dorrco FluoSolids reactor, rated capacity 50 to 55 tons of flotation concentrate per day, was chosen as the roasting unit for the increased tonnage programme. This unit commenced operation in April, 1952, and at the present time is operating at the rate of 60 to 70 tons of concentrate per day. The reactor is housed in a separate steel-framed building covered with trafford asbestos siding and insulated with limpet abestos insulation. The building is connected to the Allis-Chalmers roaster building by means of a fireproof gallery equipped with steel fire-doors at the entrance to each building.

Flotation concentrate is pumped from the flotation section of the treatment plant to a 30 ft. by 10 ft. Dorr-type *ATO* tray thickener. Thickener overflow goes to waste and the underflow is removed by means of a 2-inch Denver Duplex diaphragm pump and thence flows by gravity to a 12 ft. by 12 ft. storage agitator. Pulp from the storage agitator is pumped to a 4 ft. dia. 6-disc American-type filter located directly above the slurry agitator. The filter cake drops directly into the slurry agitator tank and is repulped to a density of 80 per cent solids by means of a Greey turbo mixer. The density is automatically maintained at the required figure by means of a slurry density controller. A size *A*202 Moyno pump, driven through a Reeves vari-speed reduction unit, delivers the 80 per cent slurry to the reactor through an air-jacketted feed gun, which discharges into the first stage compartment above the upper level of the FluoSolids bed. Feed rate is controlled within very close limits.

The reactor consists of a cylindrical steel shell, 16 ft. 3 in. dia. by 22 ft. 6 in. high, completely lined with brick. Shell lining consists of 9 inches of insulating brick and 4 inches of high-temperature fire brick (diameter inside lining 14 ft.). The arch is constructed of 9 inches of high-temperature fire brick covered with a 4-inch layer of lightweight castable refractory. The constriction plate, located between the bottom of the reactor and the wind-box, is covered with a 4½-inch layer of insulating brick and 4½ inches of high-temperature fire brick. The wall dividing the reactor into two compartments is so located that the first stage compartment occupies approximately three-quarters of the total reactor volume and the second stage the remaining one-quarter. The dividing wall is constructed of tongued and grooved high-temperature fire brick and contains the transfer ports through which the active bed material passes from the first to the second stage compartment. The conical steel wind-box beneath the reactor compartment is divided into two sections in the same proportion as the reactor compartments, thus providing each compartment with an individual wind-box section. Air at a pressure of 64 oz. is supplied by a Spencer turbo blower connected to the individual wind-box compartments. Admission of air to the reactor is by means of 136 non-sifting-type orifices equipped with umbrella type plates on top to prevent the calcine from passing into the wind-boxes. The orifices are spaced at one-foot centres throughout the entire area of the constriction plate of each compartment. The air so introduced maintains the reactor beds in fluidized condition.

Feed enters the first stage compartment through the feed gun and, immediately upon coming in contact with the hot gases and actively roasting FluoSolids bed material, it dries and ignites. Incoming feed displaces an equivalent volume of partially roasted material which passes from the first-stage compartment to the second-stage compartment *via* the transfer ports. The ports adjacent to the circumference of the reactor are equipped with high-pressure air lances which maintain these ports in a fully open state and thus insure uninterrupted transfer of material. The hot dust-laden gases issuing from the fluidized bed of the first-stage compartment, pass through the freeboard section and thence through the primary cyclone system, consisting of three Buell No. 34 type *AC*-435 cyclones connected in series. The 8-inch tail pipes of these cyclones extend into the second-stage compartment and discharge the cyclone product into the fluidized bed for additional roasting. The gas exiting from the third primary cyclone enters the reactor duct leading to the Cottrell plant.

The second stage of the reactor completes the roasting operation and discharges through an overflow pipe into a quench tank in which the hot calcine is quenched with water. The hot dust-laden gases rising from the fluidized bed of the second-stage compartment pass upward through the freeboard section and thence through the secondary cyclone system, consisting of three Buell No. 20 type *AC*-435 cyclones connected in series. The 6-inch tail pipes of these cyclones discharge into individual quench tanks and the gas leaving the third cyclone enters the reactor duct leading to the Cottrell plant.

The calcine from the second-stage quench tank and the products from the second-stage cyclones join in a collecting tank and are pumped *via* a 3 in. by 3 in. *S.R.L.* pump and a 'Carlon' pipe line to the cyanide plant.

Control

Thermocouples located in the wind-box, bed, and freeboard section of each stage and connected to a 6-point Foxboro temperature recorder give a complete record of temperature variations of the operation. A thermocouple located within the upper part of the first-stage bed is connected to the automatic-spray water control and this maintains the operating temperature within very close limits. Pressure taps are located in the wind-box, constriction plate, and across the cyclones of both compartments and are connected to a Hayes 8-point draught gauge. All instruments and gauges are located on the instrument panel of the operating control room and, in addition to the above mentioned items, also included are (1) a Foxboro air flow recorder for total air flow; (2) an air flow indicator (1,500 c.f.m. maximum) for the 1st stage; (3) an air flow indicator (700 c.f.m. maximum) for the 2nd stage; (4) a Foxboro temperature recorder, 1st stage; (5) a Foxboro temperature recorder, 2nd stage; (6) a quench water flow indicator; (7) a spray water flow indicator; (8) a slurry density controller; and (9) a purge air indicator for pressure taps.

The Dorrco reactor is normally maintained in continuous 24-hour operation but on occasions it has been out of service up to twelve hours and operation has been resumed without difficulty. The unit is in satisfactory operation but is considered to be still in the investigational stage and therefore details of its operation and results are not considered to be sufficiently reliable for publication at this time.

Cottrell Electrical Precipitator

The precipitator is type *K*, consisting of two units of two sections per unit. The rated capacity is 45,000 c.f.m. of gas originating from the roasting of 80 to 90 tons per day of arsenical gold-bearing flotation concentrate. The precipitator building is of steel-framed construction, sheathed with trafford asbestos tile and insulated with limpet asbestos insulation.

The collecting electrodes are of the rod curtain type and the discharge electrodes are ⅛-inch square twisted steel wire. The electrode rapping system includes shrouded automatic-type rappers on the discharge electrodes and inpulse air-type rappers on the collecting electrodes. Compressed air for the rapping system is supplied by a type *EH* 220 Broome and Wade compressor delivering 60 c.f.m. free air at 100 lb. pressure. The rapping system is also connected to the mine compressor air supply in order to insure the operation of the rapping system in case of failure of the Broome and Wade compressor. The electrical system includes two trans-

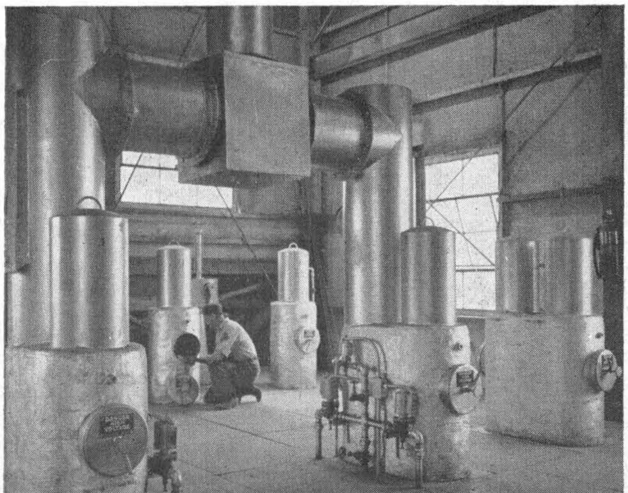

Figure 12.—Operating floor of Cottrell precipitator.

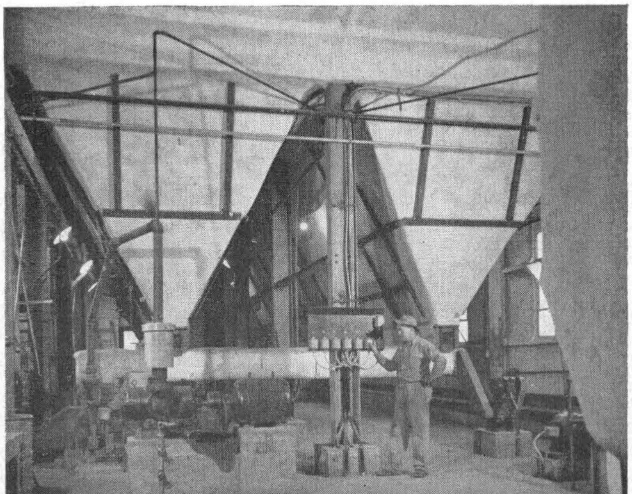

Figure 13.—Hoppers and conveying equipment of Cottrell precipitator.

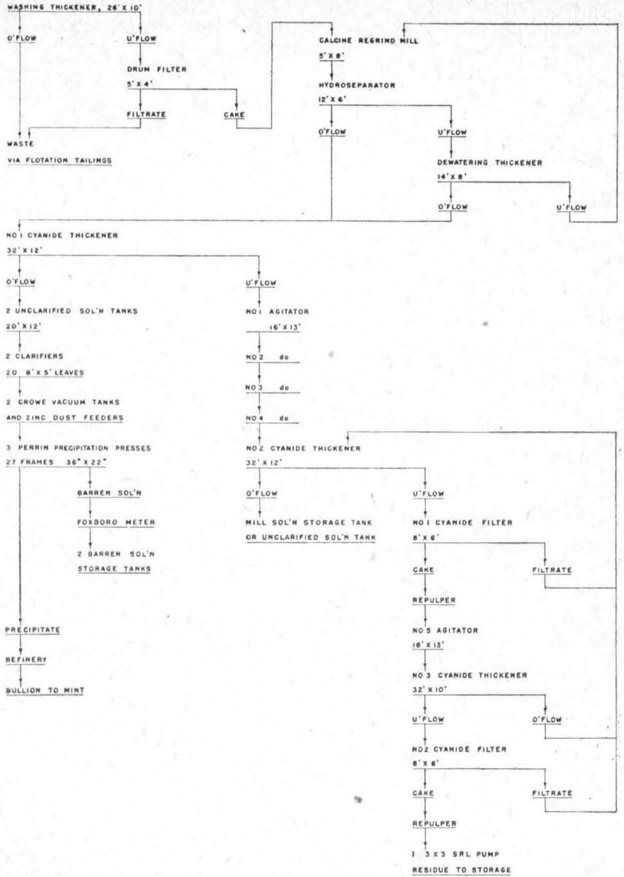

Figure 14.—Flow-sheet, cyanidation.

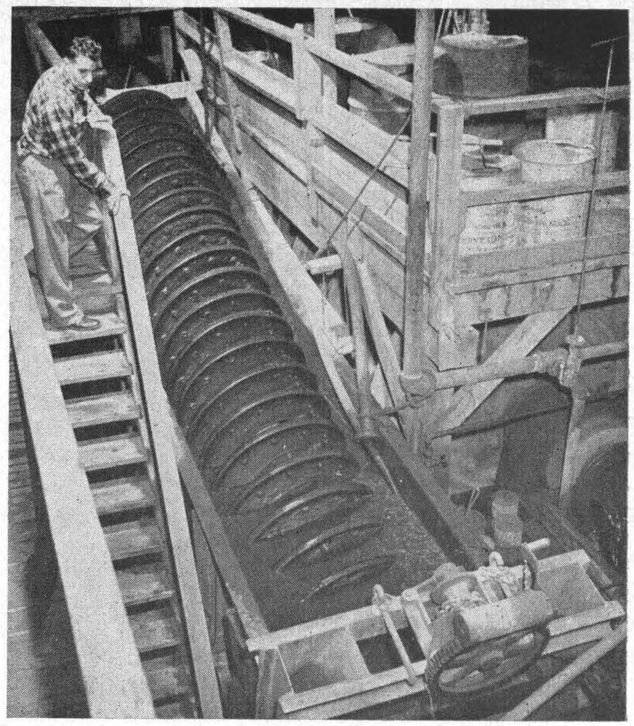

Figure 15.—36 in. Akins classifier of calcine regrind circuit.

formers, nominal rating primary 550 volts, secondary 75,000 volts, 75 kva, and three full wave manual polarity rectifiers. Gas distribution is by means of multivane dampers, motor driven on the inlet side and manually operated on the outlet.

Exit gases from the Allis-Chalmers roaster and the Dorrco reactor are cooled by the addition of outside air before passing through the mixing fan and entering the precipitator. The condensed arsenic in the form of crude white arsenic is removed and the cleaned gases discharge to atmosphere through the 5 ft. 6 in. dia. by 150 ft. steel stack.

Screw conveyors installed beneath the hoppers of the precipitator deliver the accumulated crude white arsenic to a 5-inch type *H* Fuller-Kinyon pump connected to a 6-inch 'Carlon' pipe line which discharges into the underground arsenic storage stope. Two to four hours' operation of the disposal equipment on day shift only are required to clear the 24-hours' collection of arsenic from the hoppers. The screw conveyor and Fuller-Kinyon pump installations have operated most satisfactorily in this service.

Calcine Regrind

Calcines from the Allis-Chalmers roaster and the Dorrco FluoSolids reactor are delivered to the 36-inch Akins classifier of the calcine regrind circuit of the cyanide plant *via* individual *S.R.L.* pumps and 650-foot pipe lines. Classifier overflow is pumped to the 26 ft. by 10 ft. washing thickener. The thickener overflow goes to waste *via* the flotation tailing line and the underflow is removed by a 3-inch Dorrco Simplex diaphragm pump and thence delivered by gravity to a 5 ft. dia. by 4 ft. drum-type filter.

Spiral sand product of the 36-inch Akins classifier, and the cake from the filter, are delivered by gravity to the 5 ft. dia. by 8 ft. Dominion Engineering Company ball mill. This mill is direct connected through a No. 4 Gearflex coupling to a 75 h.p. 2,200-volt motor. Mill speed is 29.0 r.p.m. Discarded detachable drill bits are employed as grinding media and a grind of 92 to 95 per cent minus 325 mesh is maintained.

Lime and cyanide are added to the calcine regrind mill, this being the initial introduction of reagents into the cyanide circuit. Dissolution of 60 to 75 per cent of the gold in the calcine takes place in this circuit. For the period October 1st to December 31st, 1952, total consumption of cyanide per ton of concentrate roasted was 5.88 lb., and of lime, 4.16 lb.

Calcine regrind mill discharge at a density of 65 per cent solids is pumped to a Dorr hydroseparator, 12 ft. dia. by 6 ft. Hydroseparator overflow at 10 to 15 per cent solids is pumped to No. 1 cyanide thickener, the underflow at 60 per cent solids is removed by a 3-inch Dorrco Duplex diaphragm pump and thence goes by gravity to the regrind mill.

As designed, the calcine regrind circuit also included a de-watering thickener, 14 ft. dia. by 8 ft. The feed to this unit was the underflow of the hydroseparator. De-watering thickener overflow joined the overflow of the hydroseparator to be pumped to the No. 1 cyanide thickener. The de-watering thickener underflow was removed by a 3-inch Dorrco Duplex diaphragm pump and was then delivered by gravity to the calcine regrind mill. No metallurgical advantage was indicated by the operation of this unit and, as it required considerable attention, operation was discontinued.

As was mentioned previously, corrosion was a serious problem during the early stages of operation and extended to the cyanide plant equipment, prior to the addition of lime. The most vulnerable item in this regard was the 36-inch Akins

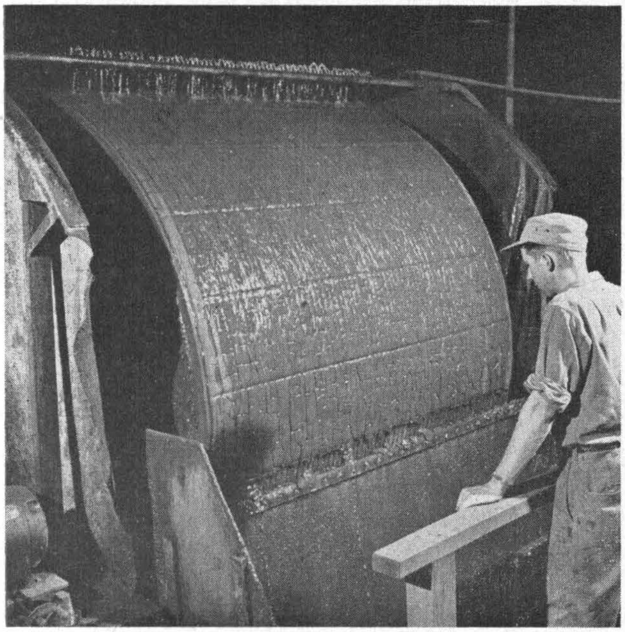

Figure 16.—No. 1 cyanide filter.

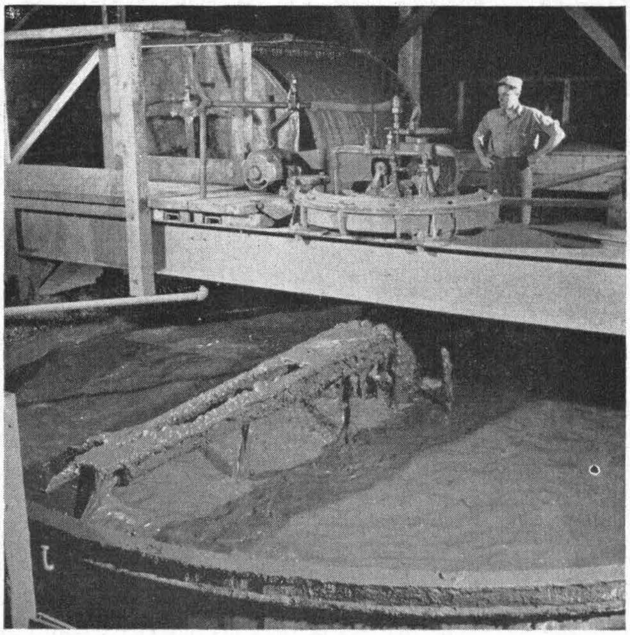

Figure 17.—No. 5 Dorr agitator.

classifier. Replacements of spirals and arms, and patching of the classifier tank, became a very serious problem. In October, 1950, a complete new classifier was installed with spirals, arms, shaft, and tank interior covered with 'Linatex'. This installation has been in continuous operation for over two years. No maintenance has been required and the Linatex is in excellent condition.

Average canvas life on the 5 ft. dia. by 4 ft. filter is 60 to 70 days.

The 5 ft. dia. by 8 ft. regrind mill is equipped with Ni Hard liners, the original set of which is still in service. Hence no information is available on liner wear in this mill.

Calcine Thickening, Agitation, Filtering, and Repulping

The hydroseparator overflow is delivered by a 2 in. by 2 in. *S.R.L.* pump to the No. 1 cyanide thickener, Dorr type *A*, 32 ft. dia. by 12 ft. Thickener overflow goes by gravity to clarification and precipitation and, *en route*, Alchem No. 918 is added at the rate of 1/300 lb. per ton of solution. Thickener underflow at 50 per cent solids is removed by means of a 3-inch Simplex Dorr diaphragm pump and flows by gravity into No. 1 cyanide agitator. The pulp is diluted to a density of 25 per cent solids for agitation and proceeds by gravity through Nos. 1, 2, 3, and 4 agitators. Cyanide strength is maintained at 1.0 to 1.2 lb. per ton of solution throughout agitation. Cyanide additions as required are made at any one of the four agitators. All agitators are 16 ft. dia. by 13 ft.

The discharge of No. 4 agitator flows by gravity to No. 2 cyanide thickener (Dorr type *A*, 32 ft. dia. by 12 ft.) where it is diluted with barren solution to a density of 10 to 15 per cent solids. Thickener overflow partially goes to clarification and precipitation and partially to the mill solution tank, by means of a 3 in. by 2 in. *Dor-K* pump, from whence it is drawn, as required, for cyanide plant services. Underflow is removed, at a density of 50 per cent solids, by means of a 3-inch Simplex Dorr diaphragm pump and thence flows by gravity to No. 1 cyanide filter for the first stage of filtration.

No. 1 cyanide filter is a drum-type filter, 8 ft. dia. by 6 ft. face. Filtrate is pumped to join the overflow of the No. 2 cyanide thickener and the cake is discharged into a repulper which repulps the cake with barren solution to a density of 25 per cent solids. This pulp is pumped, by means of a 2 in. by 2 in. *S.R.L.* pump, to No. 5 agitator which, in turn, discharges to a similar pump for delivery to No. 3 cyanide thickener, which is a Dorr tray-type *A.T.B.*, 32 ft. dia. by 10 ft. This thickener was the unit employed for flotation feed thickening during the 425 tons per day operation and therefore became available for other service with the tonnage increase. Pulp on entering the thickener is diluted with barren solution to a density of 10 to 15 per cent solids. Thickener overflow flows by gravity to clarification and precipitation or to mill solution services, as required. The thickener underflow, at 50 per cent solids, is removed by a 3-inch Dorr Simplex diaphragm pump and thence flows by gravity to No. 2 cyanide filter for the final stage of filtration. This filter is a drum type, 8 ft. dia. by 6 ft. face. The filtrate from No. 2 filter is pumped to join the overflow of No. 2 cyanide thickener and the cake is repulped with water to a density of 30 to 40 per cent solids and is pumped to the calcine residue storage by means of a 3 in. by 3 in. *S.R.L.* pump and an 1,800 ft. 'Carlon' pipe line.

Barren solution is employed as wash on No. 1 and No. 2 cyanide filters. For the fiscal year ending June 30th, 1952, the soluble loss averaged 0.0054 oz. gold per ton. Winding wire is No. 14 bright steel. Filter covers employed are *ST*10 twill and their average life is 100 days per cover. Filters are scrubbed twice per week using a 5 per cent muriatic acid wash followed by a 5 per cent sodium hyposulphite wash.

Compressed air supply is provided by a *B.W.G.* & *Mc.* compressor, 425 c.f.m. of free air at 25 lb. pressure. A connection to the mine compressed-air system serves in case of failure of the mill compressor. Filter blow-back air is reduced to 2 lb. pressure by means of a pressure reducing valve.

Vacuum for filter service is provided by a *B.W.G.* & *Mc.* vacuum pump, 600 c.f.m. displacement.

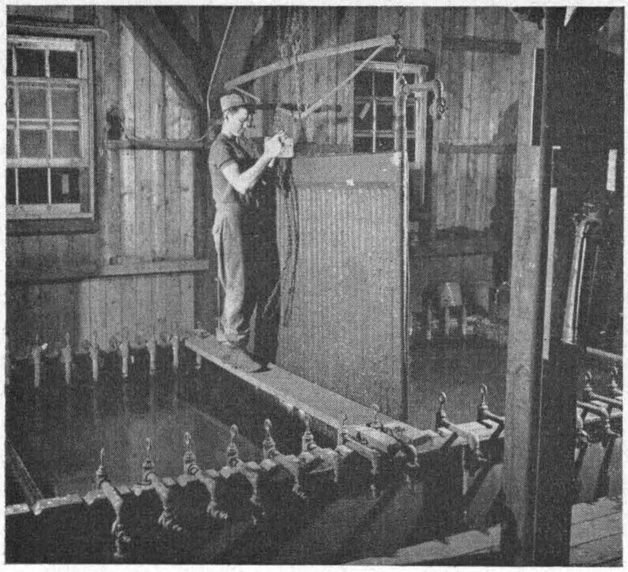

Figure 18.—Removing clarifier leaf from clarifier.

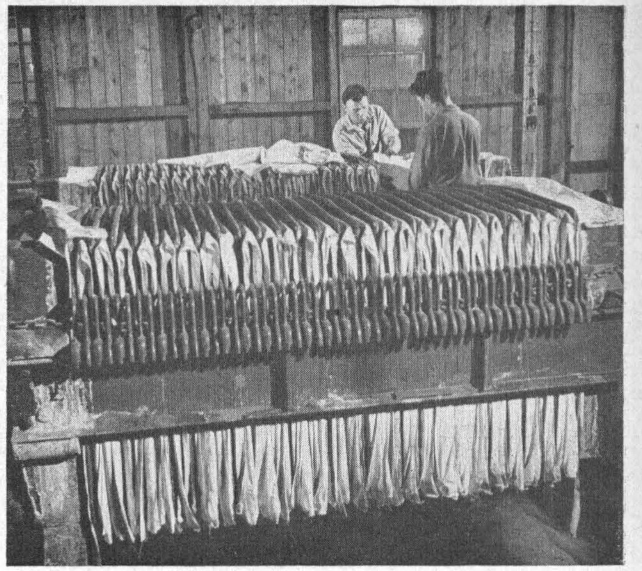

Figure 19.—Dressing Perrin precipitation press.

Clarification and Precipitation

Clarification and precipitation are conducted in the original mill unit at the rate of 1,800 to 1,900 tons of solution per day. Solution to these circuits consists of the entire overflow of No. 1 and No. 3 cyanide thickeners and a portion of the overflow of No. 2 cyanide thickener. Solution flows by gravity to a 20 ft. o.d. by 12 ft. o.h. unclarified solution tank and, *en route, Alchem* 918 is added at the rate of 1/300 lb. per ton of solution. A 4 in. by 3 in. Dor-K pump rated at 340 U.S. g.p.m. pumps the unclarified solution to a clarifier tank containing twenty 8 ft. by 5 ft. clarifier leaves (actual capacity 40 leaves). Two Perrin plate and frame precipitation presses, 36 in. by 22 in., each equipped with twenty-seven frames, a 5 ft. dia. by 12 ft. Crowe vacuum receiver with a Worthington 4¼ in. by 4 in. vacuum pump, a *B.W.G. & Mc.* two-stage precipitation pump, and a belt-type zinc dust feeder, complete the precipitation equipment. Barren solution passes through a Foxboro measuring tank *en route* to the 20 ft. o.d. by 12 ft. o.h. barren solution storage tank. A 4 in. by 3 in. Dor-K pump rated 340 U.S. g.p.m. delivers barren solution to the various mill services. Zinc dust is fed to the zinc cone at the rate of 48 to 54 lb. per day, and lead nitrate is fed to the clarifier tank at 3.75 lb. per day, by means of a syphon feeder.

No. 10 canvas duck and No. 20-40 cotton sheeting were originally employed for dressing the precipitation presses. For the past year the presses have been dressed with two layers of No. S 20-40 cotton, eliminating the No. 10 duck. When the presses are cleaned, the outer layer of cotton sheeting is removed and burned and the inner layer is transferred to the outer service, with a new inner layer of cotton, for the next press cycle. This procedure is most satisfactory and is more economical in view of the high price of canvas.

Clarifier bags are of No. 10 canvas duck with reinforced corners. Life of these bags is from 8 to 12 months. Dicalite speed plus filter aid is applied manually as a slurry before returning cleaned or newly dressed clarifier leaves to service.

Alchem No. 918 has been employed for approximately two years. Its benefits include improved clarification, longer life of clarifier bags, and elimination of incrustations on the plates of the precipitation presses.

Equipment installed in the new mill addition for the increased tonnage programme is a duplication of the equipment above described except that the unclarified and barren solution pumps are 5 in. by 4 in. Dor-K units of 400 U.S. g.p.m. capacity. Also one only Perrin 27 frame precipitation press is included in the new unit. With the new equipment in operation, approximately 3,000 tons of solution will be precipitated per day and grade of solution will be reduced from the present figure of 0.15 to 0.25 oz. gold per ton to 0.10 to 0.15 oz. per ton.

Analyses of unclarified solutions and of gold precipitate, both by courtesy of Mr. Van H. Smith, North American Cyanamid Company, are given in Tables III and IV.

Table III.— Quantitative Analysis of Unclarified Solution

	Solution Per cent	Sediment Per cent
NaCN (titration	0.073	—
NaCN total (distill'n)	0.204	—
CaO	0.C09	—
NaCNS	0.017	–
Fe	0.C013	–
Cu	0.0185	—
Ni	0.0017	—
Mo	0.00013	—
Zn	0.040	—
SO_4	0.247	—
Fe_2O_3	—	22.4
Al_2O_3	—	9.5
$CaCO_3$	—	14.5
$MgCO_3$	—	10.7
Insol.	—	40.9

Table IV.— Quantitative Analysis of Gold Precipitate

Au	44.80 per cent
Ag	16.56 "
Pb	8.91 "
Zn	0.95 "
Cu	3.86 "
As	6.28 "
Sb	Trace
Cd	0.20 per cent
Ni	3.24 "
Hg	Trace
CaO	0.72 per cent
S	0.26 "
Undetermined*	14.22 "

*Undetermined includes combined H_2O, O, CO_2, CN, etc.

Refining

Refining is conducted in a 'Butler' prefabricated sheet aluminum building located at a safe distance from other surrounding buildings. Equipment consists of a small oil-fired retorting furnace for the amalgam service and two oil-fired bullion furnaces, one a King, the other a Rockwell. One bullion furnace only is employed at a time, the other being held in process of refractory liner drying. Oil storage consists of a 1,500-gallon tank buried in the ground adjacent to the refinery and equipped with an electric pump for delivering the oil to the refinery services. Air from the mine compressor system, reduced to required pressure by means of a pressure reducing valve, is employed for the furnace burner.

Carbofrax lining was employed in the bullion furnaces during the first year of operation. However, its use was discontinued due to the formation of speiss on the bullion bars despite the increasing of fluxes and variations in furnace operation technique. Sillimanite lining has been employed for the past two years, resulting in complete elimination of speiss and a reduction in flux requirements. Furnace lining life is from 150 to 175 furnace hours per linings.

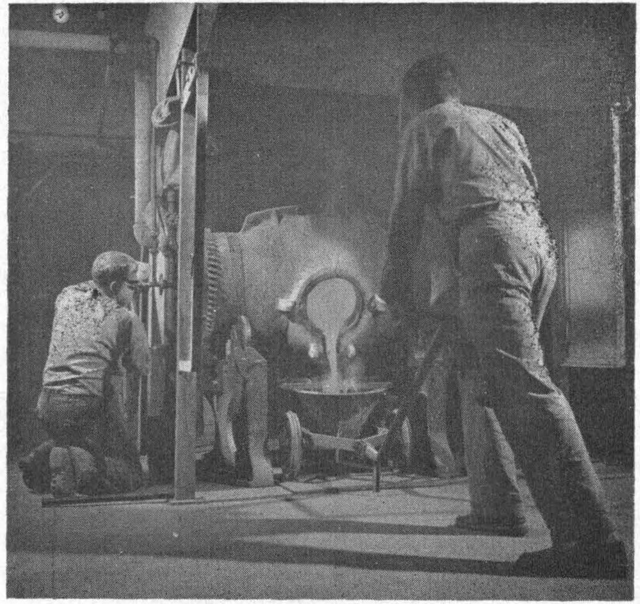

Figure 20.—Pouring bullions.

Furnace charge for the refining of precipitate is as follows:

Precipitate	100 lb.
Borax powder	55 lb.
Soda ash	20 lb.
Sodium nitrate	9 lb.
Silica powder	11 lb.
Fluorspar	5 lb.
Manganese dioxide	5 lb.

Gold sponge from the retorting of amalgam is melted and poured into bullion bars, employing the following flux for 40 to 60 lb. of gold sponge:

Borax powder	7.0 lb.
Soda ash	2.5 lb.
Sodium nitrate	2.5 lb.
Silica powder	1.5 lb.