GRAVITY CONCENTRATION AT MONTANA TUNNELS

MARY ANNE ANTONIOLI, BYRON DARNTON & STEVE LLOYD

Montana Tunnels Mining, Inc
PO Box 176
Jefferson City, MT 59638 USA
Phone: (406) 933-8314
Fax: (406) 933-8373

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BACKGROUND

Pegasus Gold Corporations' Montana Tunnels mine began operation in March 1987. The process plant at startup consisted of a bulk flotation circuit followed by leaching of the reground bulk concentrate. The leach residue then advanced to selective Pb/Zn flotation. This original circuit had its share of problems, and the leach circuit was abandoned after six months. The bulk flotation circuit was modified to selective Pb/Zn flotation at this same time.

Gravity concentration was researched early on, prior to selecting bulk flotation with leach as the flowsheet of choice. Flotation was deemed to be more practical than gravity due to the lower capital and operating costs. No further work was done concerning gravity concentration until 1990 when it was decided to investigate ways to diminish the occurrence of free gold reporting to the flotation tailings.

GRAVITY CIRCUIT MILESTONES

Date	Description
Early 1990	Batch testing on various mill streams with rented Knelson Concentrators.
Oct. 1990	Gravity pilot plant installed.
July 1991	Permanent Gravity circuit start up.
July 1993	Installation of 30" Automatic CD Knelson Concentrator.
March 1994	Decision to move and expand the gravity circuit.
Sept. 1994	Startup of expanded gravity circuit.
Oct. 1994	Steady state operation of the expanded gravity circuit.

EARLY RESEARCH

Montana Tunnels has an average gold head assay of 0.02 oz/ton, with the majority of the gold occurring as native electrum assaying approximately 70% Au and 30% Ag. Gold spike occurrences in tailings, prior to gravity circuit installation, occurred an average of 19 times per month and accounted for 7.7% of the total gold lost to tails. In an effort to reduce these gold spikes in tailings, a 7 1/2" Knelson Concentrator and a 30" manual discharge Knelson Concentrator were obtained and batch tested. Early mineralogical work had shown that between 25% and 35% of the gold in MIMI ore was free and amenable to gravity concentration. Through batch testing it was decided that the most logical place to install a gravity circuit would be on cyclone underflow. Cyclone underflow typically runs ten times the mill feed grade in gold, and more than 40% of this gold is +48 mesh.

A pilot plant consisting of a pinched sluice, a 4' x 8' vibrating screen, and one 30" Knelson was installed at the feed end of the ball mill. The feed for this pilot plant was supplied by diverting the underflow from one of eight primary cyclones away from the ball mill feed and into the pinched sluice. This pilot plant was later modified to include another 30" Knelson, and feed was alternated between the two machines. Results from this gravity circuit were impressive with 15.3% of overall gold recovery reporting to gravity con. An automatic CD Knelson was purchased and installed as the primary concentrator, with one manual unit remaining as a backup.

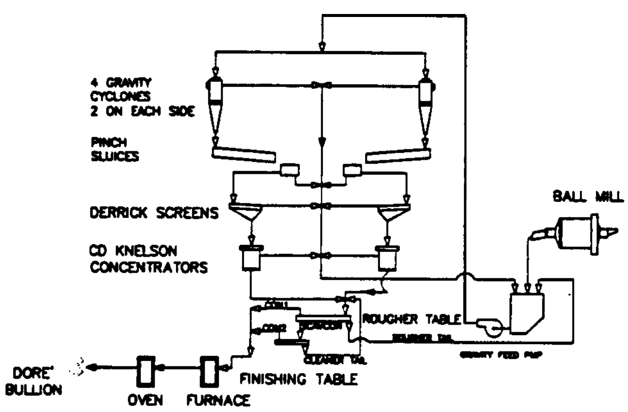
GRAVITY RELOCATION & EXPANSION

The gravity plant as it then stood was restricted in way of any future expansion. This restriction was due to the lack of extra room in the area and the fact that this initial location required pumping the Knelson tailing & screen oversize to the ball mill discharge. Pumping these combined streams was very difficult due to the lack of fines, the extreme abrasiveness of the material, and the amount of tramp metal contained in them.

In March 1994, the final decision was made to move and expand the gravity circuit. The circuit was moved from the feed end of the ball mill to the discharge end of the ball mill. A gravity feed pump and four new cyclones were installed. Two parallel gravity concentration lines were built. Each line consisted of a pinched sluice, a vibrating screen, a 30" CD Knelson Concentrator, and a rougher concentrate storage tank. The screen oversizes were combined on a conveyor equipped with a magnetic head pulley for tramp metal removal. The combined tailings from these two circuits (sluice overflows, screen oversizes, Knelson tailings, & cyclone overflows) were gravity flowed back to the ball mill discharge sump. The Knelson rougher concentrates were processed over a 28" Sweco with a l/4" screen. The +1/4" is hand sorted to remove any coarse flakes, and the -l/4" is fed to a magnetic drum separator which removes tramp metal. The mag separator tailings are pumped to the rougher table feed tank. The material is then processed over full size and half size Wilfley shaking tables, with the rougher table tailings returning to the ball mill. A high grade (approx. 5000 opt Au) table concentrate is produced and advanced to the refinery for further processing. Figure A illustrates the expanded gravity circuit flowsheet.

Tables l& 2 show gravity production statistics for the past eight years.

EXPANDED
GRAVITY CIRCUIT



REFINING

Smelting

When the gravity pilot plant was first installed, the final table concentrate was refined using an oxidation smelt. This resulted in the production of a melt product composed of a slag layer, a matte layer, and a precious metal button. The slag contained a considerable amount of Au/Ag prills, and between 10% and 20% of the gold was tied up in the matte phase. The matte phase was recycled to the next melt, and the slag was crushed and screened to remove prills. The matte problem continued to build from melt to melt, and the slag crushing process was messy & time consuming, as the slag would hydrate very badly and was irritating to handle. Air sampling during the refining process indicated that the health risk was considerable, as the oxidation smelt resulted in the evolution of large amounts of lead and silver into the atmosphere. It was decided to change the refining process from an oxidation smelt to a reduction smelt. This process is essentially the same as doing a large scale fire assay. Galena rich table con is combined with a Soda/Borax/Silica flux and melted in a gas-fired furnace. A few pieces of scrap iron are used in the furnace to drive the reduction reaction. The slag is poured off and a lead bar is cast.

Cupelling

Cupels are made out of portland cement, bone ash, magnesite, water, & sodium silicate solution (binder). This mixture is placed into 12" x 8" x 3" molds and compressed with 30 tons of pressure exerted by a hydraulic press. The cupels are cured for several days, at which time they are brought up to temperature (@1900 F) in a laboratory assay oven. Lead bars are placed on the heated cupels. Once the lead opens, an air lance is introduced to help drive the process. After approximately two hours of cupelling time, the cupel has absorbed 99.5% of the lead and leaves behind a dore' flat which assays approximately 65% Au, 34% Ag, and < 1% of Pb. This is in sharp contrast to the dore' cast during the oxidation smelt process, which analyzed over 20% Pb. The used cupels are broken into several pieces, and any

Table 1 -- Mill Feed Rates and Overall Gold Recovery

	1988-89	1990	1991	1992	1993	1994	1995
Feed (TPH)	496	502	526	552	605	657	659
Au Rec. %	81.8	82.3	84.7	87	83.8	85.3	85.0

Table 2 -- Montana Tunnels historical trends for gold distribution

	1988-1989	1990	1991	1992	1993	1994	1995
Leach	0.7	1.5					
Gravity			5.8	15.3	15.2	14.9	25.2
Pb Con	78.5	84.0	79.0	73.0	72.4	71.8	61.4
Zn Con	20.8	14.8	15.2	11.7	12.4	13.3	13.4

noticeable prills are removed. Cupels are spread at the ROM stockpile and are recycled through the mill. Slag is broken up, barreled, and shipped to the smelter approximately three times per year.

Gold recovered into dore is payable at 3.9% more than if it were recovered into lead concentrate and almost 30% more than if it were recovered into zinc concentrate. This increase in payable metal yields significant increases in revenue as shown in Table 3.

SUMMARY OF RESULTS

Problems and Improvements

The implementation of gravity concentration at Montana Tunnels has been very successful. However, several Difficulties had to be overcome along the way, and several things would have been done differently if the chance presented itself. The major drawback in the original pilot plant and initial gravity plant setup was the location, which required that the circuit tailings be pumped. The difficulty in pumping this coarse, abrasive, and heavy material was that wear rates on the pump and lines were excessive and plug ups were common. All of the initial gravity circuit components exhibited a high degree of wear, which led to reduced operating time and higher operating costs. Wear problems were solved with the addition of more durable materials, including urethane screen decks instead of stainless steel, rubber lining of all piping, and a beefed up design incorporated in the new CD Knelson units.

The main problems which presented themselves in the relocated and expanded gravity circuit were the lack of available headroom, and having to install another pump on the ball mill discharge box to feed the gravity circuit. The lack of head room required many streams to run on a very shallow slope. Pulp densities, flush water, and tonnages were kept within parameters determined through trial and error to be the most effective at preventing plug ups while maximizing production. The lack of head room also made it difficult to set up a method for measuring tonnage to the gravity circuit. Nuclear density gauges, coupled with flowmeters are currently in use. However, the application is marginal due to the lack of space necessary to get a consistent flow across the units. The gravity feed pump had to tie into the ball mill discharge box at a difficult location, resulting in a high potential for sanding the line. A dump valve and a flush water valve were installed before the gravity feed pump to clear the line should the pump shut down for any reason.

The new CD Knelsons have several beneficial features in addition to their heavier design. One benefit is the automatic dump feature, which eliminates the need to access the machines, thereby increasing security. Another is the fact that the machine consistently cleans itself out, reducing the potential that a partial load of concentrate is left in the bowl at the end of a cycle.

Operating Costs

Total gravity and refinery operating costs for 1995 were $0.07 per ton of mill feed, or $16.73 per ounce of gravity gold produced. Table 4 shows the economic estimates for the gravity circuit as compared to actual results.

REFERENCES

Darnton, B.T., Lloyd S., Antonioli M.A., 1992, "Gravity concentration research, design, and circuit performance at Montana Tunnels," ***Proceedings,*** Randol Gold Conference, Vancouver, B.C. Canada, March.

Darnton,B.T., Lloyd S., Antonioli M.A., 1995, "Gravity circuit improvements at Montana Tunnels," ***Mining Engineering,*** October 1995.

Table 3 – Overall Net Gold Payment

1988 - 89	1990	1991	1992	1993	1994	1995
90.6	92.5	92.3	93.6	93.4	93.1	93.5

Table 4 – Gravity economic comparison, predicted vs. actual

	Estimated without expansion	Estimated with expansion	1995 Actual Results
Operating costs	$324,486	$373,143	$396,266
produced	14,327	21,270	23,682
Cost per ounce	$22.65	$17.54	$16.73