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Agglomeration and Heap Leaching of Finely Ground Precious-Metal-Bearing Tailings

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UNIT OF MEASURE ABBREVIATIONS USED IN THIS REPORT

°C	degree Celsius	in	inch
ft	foot	kW•h	kilowatt hour
ft ³	cubic foot	lb	pound
ft/s	foot per second	lb/h	pound per hour
gal	gallon	min	minute
gal/min	gallon per minute	mm	millimeter
gal/(h•ft ²)	gallon per hour per square foot	oz	troy ounce
gal/(min•ft ²)	gallon per minute per square foot	oz/ton	troy ounce of precious metal per short ton of ore
g	gram	pct	weight percent
h	hour	rpm	revolution per minute
hp	horsepower	s	second

AGGLOMERATION AND HEAP LEACHING OF FINELY GROUND PRECIOUS-METAL-BEARING TAILINGS

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ABSTRACT

During the 1970's, the Bureau of Mines investigated a particle agglomeration technique for improving the flow of leaching solution through heaps of clayey or crushed, low-grade gold-silver ores. This technology has been adopted on a broad scale by the precious-metal-processing industry. This report presents information on the application of agglomeration technology to finely ground precious-metal-bearing tailings. Two commercial operations that have benefited from agglomeration technology are discussed. The technology is cost effective because of decreased leach times and improved precious metal recoveries.

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INTRODUCTION

The Western United States has many tailings materials from former mining operations that contain significant precious metal values. Most of these tailings resources are too low grade or too small to warrant the capital expenditure to construct a conventional agitated cyanide leaching circuit. Heap-leach cyanidation is a low-capital, low-operating-cost method to recover precious metals from low-grade ores and wastes (1-2).⁵ Heap leaching has been successfully applied to many low-grade, oxidized, disseminated gold ores since the early 1970's. The Bureau of Mines developed agglomeration technology to improve heap leaching of clayey ores, and it has been rapidly adopted by the precious metal industry (3-9).

In contrast to ores that contain a small percentage of fines, most tailings materials are more than 50 pct minus 200 mesh, with no coarse material. The fine particles and clays, if present, prevent uniform flow of leaching solution through the bedded material. In extreme cases, the migration of fines and the swelling of the clay constituents blind the heap and prohibit any solution flow through the heap. It was necessary to determine

the best procedure for agglomerating finely ground tailings materials because they do not respond to agglomerating techniques in the same manner as ores.

Several types of agglomerating equipment are used by precious metal producers for agglomerating crushed ores and wastes. Some types of equipment are commercially available and others are custom designed and constructed. The commercially available types are agglomerating drums, pelletizing disks, and pug mills. Equipment that was custom designed and constructed include drop-belt conveyors, reverse-belt conveyors, and vibrating "staircase" chutes. Drums, disks, and pug mills impart a rolling action to effect agglomeration; the conveyors and vibrating chutes impart a tumbling or bouncing action to effect agglomeration. Both types of equipment produce suitable agglomerates from crushed material, but they might not be suitable for agglomerating finely ground tailings materials. A bouncing action may be detrimental for fine particle agglomeration because there is no coarse material present to act as nuclei for agglomerate growth, and the bouncing action may cause the green pellet to break soon after it is formed.

BENCH-SCALE INVESTIGATION OF PROCESS VARIABLES

EQUIPMENT, PROCEDURES, AND MATERIALS

Investigations to determine the best agglomeration parameters for fine tailings were conducted using 50-lb charges of material. The agglomerated material was leached in Plexiglas⁶ thermoplastic polymer columns 5 ft high and 5.5 in ID. Four inches of washed gravel in a perforated container were placed in the bottom of the column to prevent the tailing material from plugging the solution outlet. The 50-lb charge of material placed on

top of the gravel container gave a bed height of 4 to 5 ft. The pregnant cyanide solution from the column was pumped through three glass columns, each of which contained 30 g of minus 6- plus 16-mesh, coconut-shell activated carbon to adsorb the dissolved gold and silver. The barren solution from the carbon columns was recycled to the top of the leaching column. Pregnant and barren solutions were analyzed periodically throughout the leaching cycle.

Two mechanical variables were important for tailings agglomeration: the method of solution application and the method of mechanical tumbling during the agglomeration step. Both parameters are difficult to evaluate quantitatively, and the information given is based on observation.

⁵Underlined numbers in parentheses refer to items in the list of references at the end of this report.

⁶Reference to specific products does not imply endorsement by the Bureau of Mines.

Methods of mechanical tumbling are discussed in the equipment evaluation section of this report.

A 39-in, rotating-disk pelletizer was used to agglomerate 50-lb batches of feed for the leaching columns. The air-dried tailings charge was placed on the pelletizer, and binder was mixed in while the pelletizer was rotating. A controlled amount of liquid was slowly added from a graduated cylinder while the disk was running. The agglomerated feed was removed from the disk, placed in the leaching column and cured for a specified time at ambient conditions before percolation leaching. The column was capped to minimize drying of the green pellets. Previous work with ores had shown that if the pellets dried too rapidly, partial breakdown of the agglomerates occurred on wetting. Stronger agglomerates were produced if they remained moist during curing. Leaching was started by pumping solution on top of the charge. A layer of coco matting covered the bedded material to prevent erosion and to distribute solution uniformly.

Baseline percolation leaching experiments were conducted on each sample to simulate conventional heap leaching. The dry tailings were placed into the leaching column and an alkaline solution (pH 10.5) containing 2 lb NaCN per ton of solution was pumped onto the charge.

Calculated head analyses and precious metal recoveries were determined by the amount of precious metal adsorbed on the carbon, the amount remaining in the final pregnant solution, and the values remaining in the leached residue. All solid samples were analyzed by fire assay. Solution samples were analyzed by atomic absorption spectrophotometry. Maximum percolation rate measurements were made after leaching was completed. The material in the column was flooded with barren leaching solution, and the rate at which the solution drained from the column was measured. The high flow rates obtained under flooded conditions would be impractical in actual heap leaching operations but demonstrate that very stable, porous agglomerates are produced and do not break down under exaggerated leaching condition.

Two samples of precious-metal-bearing tailings were used in the investigation to determine the best process parameters. One sample was from a tailings pile in the Comstock District of Nevada. The tailings were 65 pct minus 200 mesh and contained an average of 0.04 oz Au and 2.0 oz/ton Ag. The second sample of tailing was from an old flotation mill in southeastern California. The tailings were 90 pct minus 200 mesh and contained an average of 1.4 oz/ton Ag. Both samples were siliceous and amenable to cyanidation. Detailed bench-scale data are presented only for the Nevada tailings sample because agglomerating parameters for both samples were the same except for curing time, which was longer for the California sample. After determining the best process parameters, several other tailings samples, which represented a cross section of types of materials likely to be candidates for heap leaching, were agglomerated.

RESULTS AND DISCUSSION

Effect of Binder Addition on Flow Rate

Preliminary investigations showed that Portland cement alone was not an adequate binder for agglomerating finely ground tailings unless about 50 lb binder per ton of dry feed was used. A combination of lime and Portland cement, in equal proportions, provided adequate agglomerate strength and permeability with less total binder additions.

Fifty-pound charges of the Nevada tailings were mixed with the lime and cement in ratios ranging from 0:0 to 25:25 lb of each binder per ton of dry feed. The material was tumbled on the pelletizer while 22 pct water was added and tumbling continued until it was agglomerated. The agglomerated feed was placed into the leaching column, cured for 72 h, and leached. Figure 1 shows that increasing the amount of lime and cement up to 15 lb of each per ton of feed markedly improved percolation rates. The binder supplied sufficient protective alkalinity during leaching to maintain the leaching solution pH at 11. This amount of binder was added during subsequent experiments.

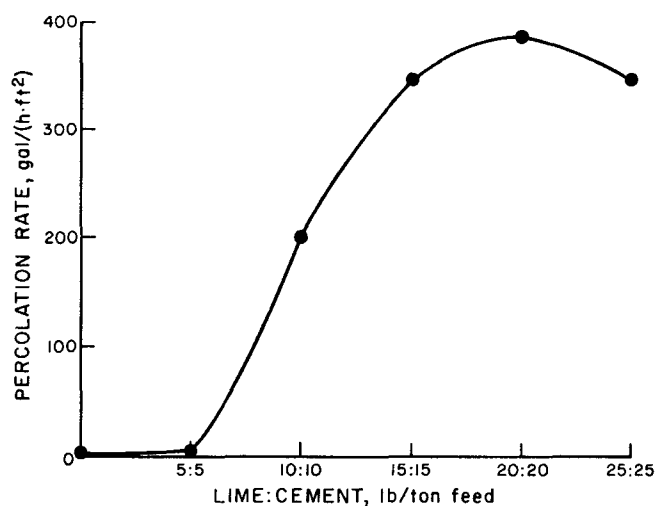


FIGURE 1. - Effect of binder addition on percolation rate.

Effect of Water Addition on Flow Rate

Experiments were performed on charges mixed with 15 lb lime and 15 lb cement per ton of feed and cured for 72 h. The amount of water added to the dry mixture ranged from 15 to 27.5 pct. The results are shown in figure 2. Solution flow rate through the agglomerated tailings increased with increasing moisture, attained a maximum of about 360 gal/(h·ft²) at 22.5 pct and then rapidly decreased to about 50 gal/(h·ft²) at 27.5 pct moisture. Figure 2 shows that the best moisture for agglomerating the tailings was 22.5 pct; however, moistures from 20 to 25 pct produced acceptable agglomerates.

Atomizing solution spray did not achieve agglomeration. With the addition of moisture and tumbling, the tailings continued to wet but did not form nuclei to start agglomerating, and a wet slurry was produced. Coarser sprays of droplets provided nuclei for agglomerate growth. When a water droplet contacted the dry tailings, it was immediately coated with fine material and formed the nucleus necessary for growth. The nuclei grew into pellets by a layering process (10). This two-stage pellet-formation process was observed on the disk pelletizer.

Effect of Curing Time on Flow Rate

Fifty-pound charges were mixed with 15 lb lime and 15 lb cement per ton of feed,

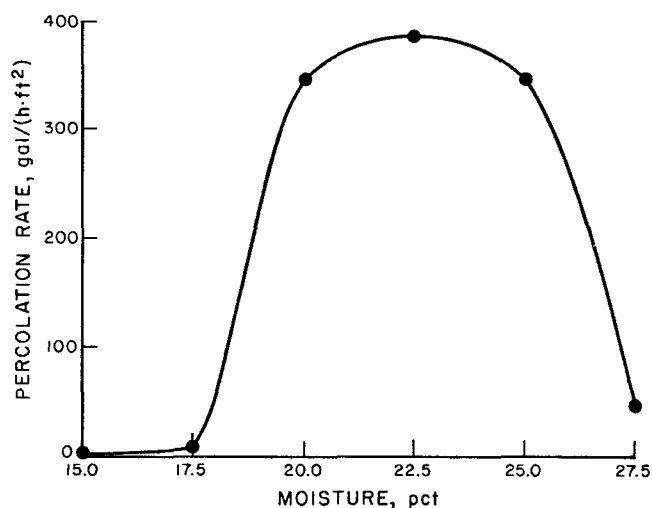


FIGURE 2. - Effect of moisture content on percolation rate.

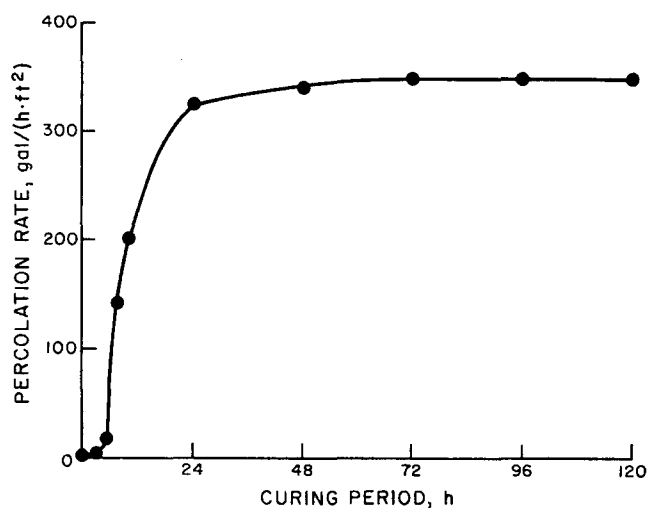


FIGURE 3. - Effect of curing period on percolation rate.

wetted with 22 pct water, and agglomerated. The agglomerated charges were cured for 0, 2.5, 5, 7.5, 10, 24, 48, 72, 96, and 120 h in capped leaching columns. Flow rates are presented in figure 3. For the Nevada sample, the data show that the duration of curing was important up to 24 h, after that time, no significant improvement in flow rate occurred.

A summary of the best conditions determined experimentally for the Nevada tailings and the California silver tailings is shown in table 1. Agglomeration pretreatment increased the percolation rate from zero to more than 300 gal/(h·ft²) for each sample. The precious metal

extractions by simulated heap leaching were within 5 pct of those obtained by agitated-bottle leaching tests of the two samples.

TABLE 1. - Summary of experimental results from two tailings samples

	Sample	
	Nevada	California
Best pretreatment conditions:		
Lime:cement		
lb/ton feed..	15:15	15:15
Moisture.....pct..	22.5	18.0
Curing time.....h..	24	72
Percolation rate, ¹		
gal/(h·ft ²):		
Baseline, no pre-		
treatment.....	0	0
With best pre-		
treatment.....	360	431
Gold extraction...pct..	85.7	NAP
Silver extraction		
pct..	61.4	74.2

NAP Not applicable.

¹Percolation rate measurements were taken under flooded column conditions.

Application to Other Tailings Materials

Agglomeration process parameters were tested on the following other tailings samples:

• A gold-bearing tailings material from a former cyanide mill in Montana.

The tailings were siliceous and contained granular sandy material. The feed was 50 pct minus 200 mesh and the coarser particles were minus 20 mesh. The sample contained 0.05 oz/ton Au and trace amounts of silver. The natural pH of the material in a 50-pct slurry was 4.6.

• A gold-bearing tailings material from southern Nevada that contained 0.13 oz/ton Au and 0.14 oz/ton Ag (southern Nevada 1). The tailings were 80 pct minus 200 mesh and had been previously cyanided. The natural pH of the material in a 50-pct slurry was 7.9.

• A tailings resource from southern Nevada that contained 0.03 oz/ton Au and 1.0 oz/ton Ag (southern Nevada 2). The tailings were 90 pct minus 200 mesh and contained significant amounts of clayey material. The natural pH of the material in a 50-pct slurry was 6.3.

Results from the column percolation leaching experiments are shown in table 2. Precious metal extractions from agglomeration-heap leaching were within 5 pct of those obtained by agitated cyanidation of the same size feed material. Agglomeration pretreatment markedly improved percolation rate and gold recovery, and decreased the leaching time compared to conventional heap leaching. The bench-scale results for the tailings samples demonstrate that agglomeration pretreatment provides a means of processing precious-metal-bearing tailings that otherwise might not be exploited.

TABLE 2. - Column percolation leaching tests

	Montana		Nevada 1		Nevada 2	
	Base-line	Agglom-erated	Base-line	Agglom-erated	Base-line	Agglom-erated
Calculated head, oz/ton:						
Gold.....	0.05	0.05	0.12	0.13	0.03	0.03
Silver.....	NAP	NAP	NAP	NAP	1.0	1.1
Binder, lime:cement.....lb/ton feed..	0	20:20	0	10:10	0	15:15
Moisture.....pct..	0	22.0	0	15.7	0	18.0
Percolation.....gal/(h·ft ²)..	0.08	119	0.009	510	0	533
Leaching period.....days..	4	2	27	3	NAP	6
Recovery, pct:						
Gold.....	40.0	80.0	16.0	80.0	NAP	76.7
Silver.....	NAP	NAP	NAP	NAP	NAP	69.0

NAP Not applicable.

NOTE.--Curing period for all samples was 72 h. The solution contained 2 lb NaCN per ton of solution. Flow rate measurements taken under flooded conditions.

EVALUATION OF PILOT-SCALE AGGLOMERATING EQUIPMENT

EQUIPMENT, PROCEDURES, AND MATERIALS

Several types of equipment were evaluated to determine the best type for tailings agglomeration. They were (1) reverse belt agglomerator (RBA), (2) drum agglomerator, and (3) disk pelletizer. Each piece of equipment was designed to agglomerate a minimum of 500 lb/h of dry tailings. The drum and the RBA were fabricated locally; the disk was purchased from an agglomeration equipment manufacturer.

A 3-ton sample of the tailings from the Comstock District of Nevada on which the initial tailings agglomeration research was done was used in the equipment evaluation. The sample was air dried, blended, and placed into sealed containers. Five-hundred-pound charges of tailings were premixed with 15 lb lime and 15 lb cement per ton of feed in a double cone dryer blender. Premixing of binder and tailings eliminated proper binder mixing as a variable in evaluating agglomerating equipment.

The RBA was constructed from a 12-ft by 10-in flat conveyor with variable belt speed and belt angle. To insure an adequate bed depth of material being agglomerated, the working width of the belt was decreased to 4 in by constructing sheet metal walls on the surface of the belt. Deflector plates attached to the sheet metal walls directed bouncing agglomerates back onto the belt surface. The binder and tailings charge was fed from a 5-ft³ hopper onto the belt by a vibrating feeder at a point 28 in from the top of the working length of the belt. The working length of the belt was 6 ft. Moisture was added along the belt through a drip irrigation system. At the uppermost moisture addition point, approximately 8 in above the dry feed addition point, 20 pct of the moisture was added to the feed on the belt. Two other moisture addition points were below the dry feed addition point. The RBA operated best at an angle of 50°, a belt speed of 4.1 ft/s, and a feed rate of 450 lb/h. The estimated retention time of feed on the belt was 10 s.

The disk pelletizer was 3 ft in diameter and 8 in deep; pan depth, angle, and rotational speed were variable. Figure 4 shows how the disk was operated for best pellet formation. Moisture was applied through nozzles that delivered droplets at a rate controlled by a metering pump. The disk operated best at a pan angle of 56°, at 45.5 rpm, and at a feed rate of 2,720 lb/h of dry feed. Agglomerate retention time was 2 min.

The drum agglomerator was 12.6 in ID, 37.5 in long, and rotated by a 1/3-hp belt drive motor. The angle and speed of the drum were variable to control retention time. The drum was lined with loosely fitted conveyor belt material to minimize moist feed buildup on the drum walls. When the drum reached the top of its rotation, the lining sagged and dislodged the adhering feed. A spray bar situated lengthwise in the drum delivered amounts of water controlled by a metering pump through three nozzles. The nozzles delivered moisture droplets in a fan pattern which covered almost two-thirds the length of the drum. The drum operated best at an angle of 1.5°, at 37.5 rpm, and at a feed rate of 2,800 lb/h of dry

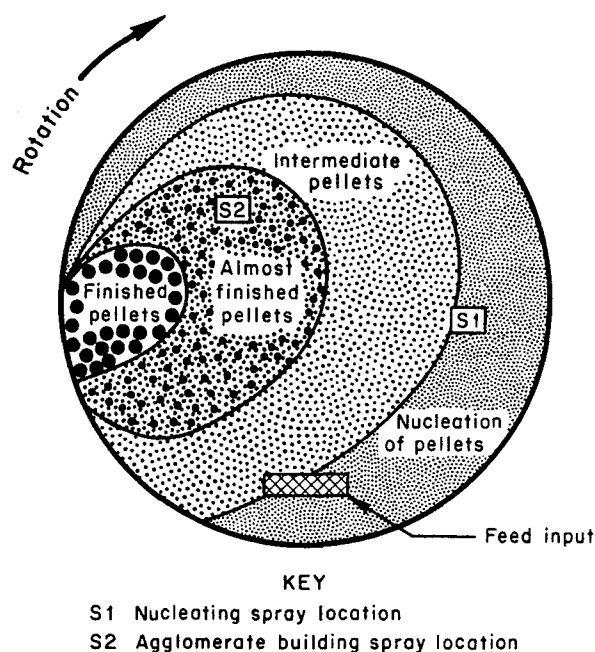


FIGURE 4. - Operation of disk pelletizer for agglomerating tailings.

feed. Agglomerate retention time was 42 s.

RESULTS AND DISCUSSION

Fifty-pound charges of agglomerates produced under the best conditions for each type of equipment were placed in capped bench-scale leaching columns, cured for 72 h, and leached. The leaching tests determined agglomerate strength and stability under leaching conditions and precious metal recovery. A solution containing 2 lb NaCN per ton was pumped through the agglomerates at a rate of 5 gal/(h·ft²). Results from leaching are shown in table 3.

TABLE 3. -Leaching results from agglomerates produced on three types of agglomerating equipment

	Type of equipment		
	RBA	Disk	Drum
Calculated head, oz/ton:			
Gold.....	0.035	0.037	0.039
Silver.....	1.26	1.26	1.27
Bed slump.....in..	5.5	None	None
Fines migration (observed).....	Yes	No	No
Percolation rate gal/(h·ft ²)..	7.0	604	435
Leaching period days..	7	3	3
Recovery, pct:			
Gold.....	73.7	85.3	86.0
Silver.....	53.2	61.1	51.1

NOTE:--Flow rate measurements were taken under flooded conditions.

The agglomerates produced on the RBA were of various sizes and contained some unagglomerated fines. Observations during column percolation leaching of the agglomerates showed severe slumping and fines migration and indicated that the agglomerates did not have sufficient green strength to withstand percolation leaching. The lack of competency was attributed to insufficient retention time of agglomerates on the belt. If the feed was allowed to remain on the belt for sufficient time to form proper pellets,

the green pellets broke apart as they bounced down the belt. If the retention time of feed on the belt was decreased to overcome agglomerate bouncing, there was insufficient time for proper pellet formation. The RBA could not tolerate fluctuation in feed and moisture addition rates and the bed depth was difficult to control. The RBA did not produce acceptable agglomerates.

The green pellets formed on the disk pelletizer under the best operating conditions were uniform in size at approximately 1/2 in diam. No slumping or fines migration was observed during leaching. The agglomerates were competent, permeable, and had sufficient strength to withstand percolation leaching. The best agglomerating conditions for the disk were easy to maintain constant. However, a change in one parameter affected the other parameters. For example, if the pan angle was changed, agglomerate retention time changed and affected agglomerate size, feed rate, and moisture addition rate. Changes in disk operation can be observed immediately by the operator.

The drum agglomerates fine particles in the same manner as the disk, but the agglomerates vary in size. The agglomerates with a range of sizes could be stacked with a steeper angle of repose than could the uniform-sized agglomerates produced by the disk. The green pellets produced by the drum agglomerator operating under the best conditions varied in size from 3/4 in diam to approximately 10 mesh. No slump or fines migration was observed during leaching. The agglomerates were competent, permeable, and strong enough to withstand percolation leaching. It was difficult to maintain steady-state conditions in the drum because of feed surging, which caused non-uniform moistening of the agglomerates. The situation could be improved by a better designed feeder system; however, the drum agglomerator will tend to have a pulsed output. Changes in operating conditions were more difficult to monitor than with the disk. Since the operator can only observe the agglomerates as they discharge from the drum, a waiting period

equal to the feed retention time occurs before the effect of a change can be determined.

The disk pelletizer and drum agglomerator are the types of equipment most suitable for tailings agglomeration. The disk is favored because of its ease of operation. The disk is also slightly favored in capital cost to tonnage

throughput ratio based on capital cost estimates from three agglomeration equipment manufacturers. The drum is favored because the agglomerates produced are varied in size, which improves their stacking characteristics on a heap. Selection of agglomerating equipment should be based on the specific needs of each agglomeration operation.

COMMERCIAL APPLICATION OF TAILINGS AGGLOMERATION TECHNOLOGY

Tailings agglomeration-heap leaching is being used at least a minimum of two commercial operations. The operators performed bench-scale conventional heap leaching tests on their materials. Results showed that without agglomeration, they could not be heap leached because of the extremely poor percolation characteristics of the materials.

GOLD AGGLOMERATION-HEAP LEACHING IN CENTRAL NEVADA

A tailings material from the central Nevada Goldfield District was processed by agglomeration pretreatment and heap leaching cyanidation (fig. 5). The tailings resulted from a cyanide milling operation that was active just after the turn of the century. The original ore was high in sulfides and gold recoveries were low. The tailings oxidized for approximately 70 yr by natural weathering and the residual sulfides oxidized to soluble sulfate. The natural pH of a 50 pct solids slurry was 1.7 because of the soluble sulfates. The tailings were 65 pct minus 200 mesh and contained 0.08 oz/ton Au. The maximum gold recovery by agitated cyanidation was 83 pct.

The tailings were moved to the agglomerating plant by a front-end loader and dumped into a hopper. The tailings were conveyed to a 8-1/2- by 22-ft drum agglomerator, which was a modified asphalt kiln. The drum rotated at 10.5 rpm, had a slope to the discharge end of 4°, and was lined with loosely fitting conveyor belt material. A spray bar was situated lengthwise in the drum and delivered a fan droplet spray that covered three-fourths of the length of the drum. A

lime-cement slurry was applied through the spray system to add binder and bring the final moisture content of the agglomerates to between 12 and 14 pct. The total binder addition was 50 lb lime and 10 lb cement per ton of dry feed. The large lime addition was required to adjust the pH of the tailings from 1.7 to 10.5. A 12-in weir on the inside of the

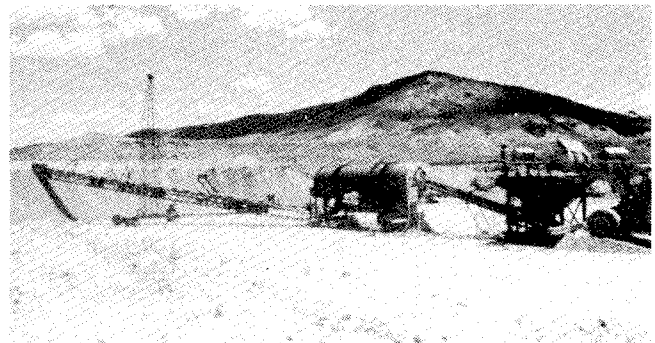


FIGURE 5. - View of Goldfield agglomerating plant.

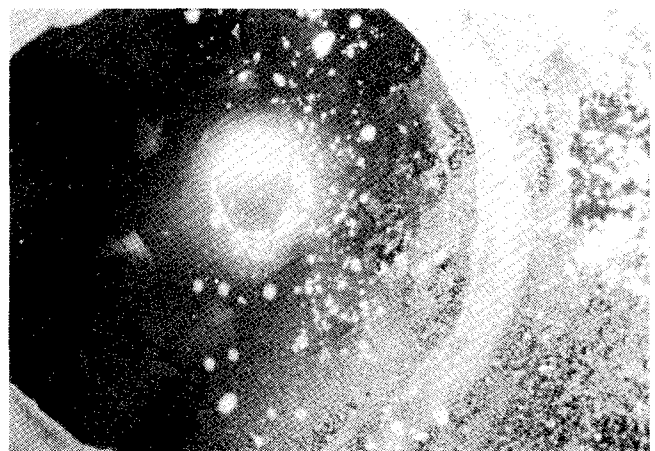


FIGURE 6. - Inside view of drum agglomerator at Goldfield operating at 50 tons/h of dry feed.

drum was 4 ft from the discharge end to increase feed retention time and to prevent discharge surging (fig. 6). The agglomerates discharged from the drum to a transfer point feeding a radial arm stacker. The green agglomerates were gently placed on the heap by the stacker and cured during heap building.

The leaching pad was constructed by compacting barren tailings in 6-in layers and covering them with a 20-mil PVC liner. The heaps were built by adjusting the radial-arm stacker to its lowest angle, sweeping across the width of the pad, raising the stacker discharge end 1 ft, and sweeping the opposite direction across the width of the pad. This procedure continued until the heap was 16 ft high. The stacker remained at 16 ft, and new agglomerates were added to the heap by sweeping the stacker across the width of the pad and allowing the agglomerates to cascade down the heap (fig. 7). Heaps built in this manner avoided compacting the agglomerates. The agglomerating equipment and the stacker were moved as a unit by a dozer before a new row of agglomerates was added to the leaching pad. A width of PVC liner was rolled out the width of the pad and welded as necessary to continue heap building. The agglomerated tailings are shown in figure 8. The agglomerates cured for several days while the 6,400-ton heap was built. The heap

was leached by spraying a cyanide solution containing 2.0 lb NaCN per ton of solution on it at a rate of 0.003 gal/(min·ft²). The pregnant solution that drained from the sloped leaching pad collected in lined ditches and flowed by gravity to a pregnant solution pond. Gold was recovered from the pregnant solution by carbon adsorption-desorption-electrowinning.

Gold recovery by agglomeration-heap leaching was 76 pct. Cyanide consumption was 0.7 lb NaCN per ton of tailings. The leaching-washing cycle was about 24 days.

SILVER AGGLOMERATION-HEAP LEACHING IN SOUTHEASTERN CALIFORNIA

A tailings pile from a former flotation operation in southeastern California was processed by agglomeration-heap leaching to recover the contained silver values (11). The tailings were 90 pct minus 200 mesh and contained an average of 1.4 oz/ton Ag. The operators of the property conducted both bench- and pilot-scale experiments to evaluate agglomeration-heap leaching for recovering silver from the tailings. Bench-scale results showed that 63 pct of the silver was recovered by agitated cyanidation and 72 pct of the silver was recovered by agglomeration-heap leaching.



FIGURE 7. - Agglomerated feed being placed on heap by radial-arm stacker at Goldfield.



FIGURE 8. - Agglomerated feed on heap at Goldfield.

The plant was designed to agglomerate and heap leach 100 tons per day of dry tailings. The tailings were mined and crushed to break up the large chunks of clayey material. The crusher discharge was conveyed to two mixers where 35 lb Portland cement per ton of dry feed was added as a binder. The binder and feed mixture was conveyed to a 10- by 30-ft drum agglomerator. A scraper, which rotated in the opposite direction to the drum, was situated along the length of the drum to prevent agglomerate buildup. Water was applied as a coarse spray through a spray bar lengthwise in the drum. The water was added at the bottom of the drum and mixed with the tailings to bring the final moisture content to 12 to 15 pct. The agglomerates discharged the drum to a transfer point feeding a radial-arm stacker. The green agglomerates were placed on a stockpile by the stacker and cured 4 days before being transported to the leaching pad. A view of the operation is shown in figure 9. The agglomerated tailings are shown in the stockpile in figure 10.

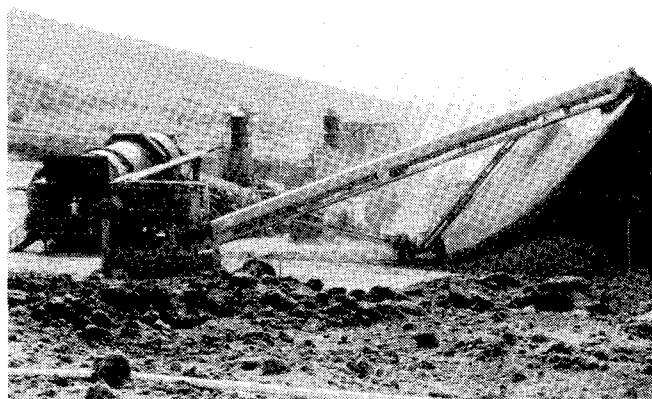


FIGURE 9. - View of agglomerating plant in southeastern California.

The leaching pad was constructed from moistened clayey silt material compacted in three layers. The middle layer was mixed with bentonite to insure impermeability of the leaching pad. A cushioning layer of sand was placed on the prepared pad to minimize pad degradation by equipment during heap construction. The heaps were built to a height of 13 ft by a front-end loader to avoid driving on the agglomerates.

The heaps were sprayed with a solution containing 2.0 lb NaCN per ton of solution and at a rate of 0.01 gal/(min·ft²). The pregnant solution collected in lined ditches and drained by gravity to a pregnant solution pond. The pregnant solution contained an average of 1.0 oz Ag per ton of solution and was pumped to the precipitation circuit at a rate of 150 gal/min. The solution was clarified, de-aerated, and contacted with zinc dust to recover the silver. Silver recovery was 73 pct after a 25-day leaching and 40-day washing cycle.

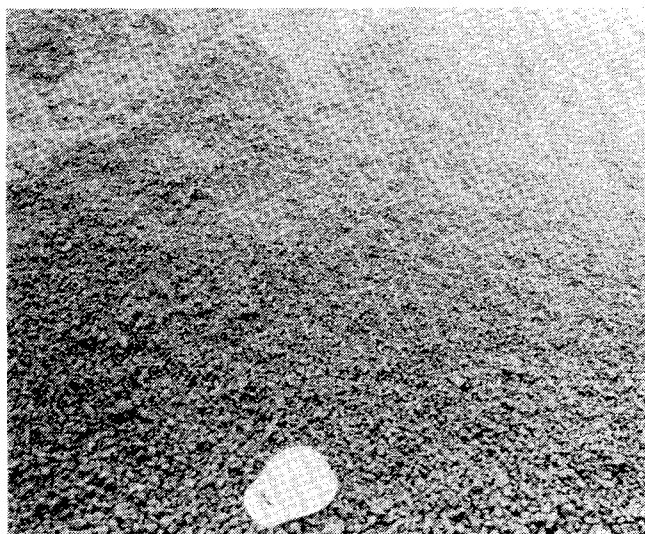


FIGURE 10. - Agglomerated tailings on stockpile in southeastern California.

CONCLUSIONS

Agglomeration pretreatment makes possible heap leaching of very fine material, such as tailings. A mixture of lime and cement was the most suitable binder. Moisture addition was critical. If too much or too little was added, the material did not agglomerate. A curing time of 24 h was required. The mechanical method of tumbling the moistened mixture was

important in agglomeration. Any equipment that imparted a bouncing action prevented good pellet formation. When these criteria were met, strong, durable, and porous pellets that could readily be heap leached were produced and the processing of low-grade and/or small resources that are in a finely divided state is possible.

REFERENCES

1. Heinen, H. J., D. G. Peterson, and R. E. Lindstrom. Processing Gold Ores Using Heap Leach-Carbon Adsorption Methods. BuMines IC 8770, 1978, 21 pp.
2. Potter, G. M. Recovering Gold From Stripping Waste and Ore by Percolation Cyanide Leaching. BuMines TPR 20, 1969, 5 pp.
3. Heinen, H. J., G. E. McClelland, and R. E. Lindstrom. Enhancing Percolation Rates in Heap Leaching of Gold-Silver Ores. BuMines RI 8388, 1979, 20 pp.
4. McClelland, G. E., and J. A. Eisele. Improvements in Heap Leaching To Recover Silver and Gold From Low-Grade Resources. BuMines RI 8612, 1982, 26 pp.
5. McClelland, G. E., D. L. Pool, and J. A. Eisele. Agglomeration-Heap Leaching Operations in the Precious Metals Industry. BuMines IC 8945, 1983, 16 pp.
6. Lewis, A. Producing Gold for \$160/TrOz in Victor, Colorado. Eng. and Min. J., v. 183, No. 10, Oct. 1982, pp. 102-105.
7. Steele, G. L. Candelaria: Famous Silver Producer. Min. Eng., v. 33, No. 6, June 1981, pp. 658-660.
8. Engineering and Mining Journal. This Month in Mining. Alligator Ridge Uses Heap Leaching To Produce Gold Bullion Bars. V. 182, No. 8, Aug. 1981, pp. 35-37.
9. _____. Pelletizing Aids Tombstone Leaching Operation. V. 182, No. 1, Jan. 1981, pp. 94-95.
10. Kapur, P. C. Role of Similarity Size Spectra in Balling and Granulation of Coarse, Liquid Deficient Powders. Ch. 10 in Agglomeration '77, ed. by K. V. S. Sastry (Proc. 2d Int. Symp. on Agglomeration, Atlanta, GA, Mar. 6-10, 1977). AIME, 1977, pp. 156-175.
11. Milligan, D. A., and P. R. Engelhardt. Agglomerated Heap Leaching Anacosta's Darwin Silver Recovery Project. Pres. at Soc. Min. Eng. AIME Fall Meeting and Exhibit, Salt Lake City, UT, Oct. 19-21, 1983. Soc. Min. Eng. AIME preprint 83-430, 9 pp.

