CYANIDING CRIPPLE CREEK ORES

Cost of Treatment in Mills—Rates of Freight—Analyses of Ores—Description of the Isabella, and the Wild Horse Mills

Written for "Mines and Minerals," by F. L. Barker

The character of Cripple Creek ores is such that the extraction of their values economically has long been a serious metallurgical problem. The values are almost exclusively gold with a small and varying amount of silver. They carry no base metals such as copper or lead and hence they cannot be smelted unless mixed with ores from other places carrying such metals. About one-sixth of the tonnage sent out from the district goes to the lead and copper smelters. This is the richest ore only, while thus far the balance has for the most part been treated at the chlorination and cyanide mills located in the valley towns adjacent to the district. The principal mills receiving this ore for such treatment are the Standard and Portland mills of Colorado City and the Union mill of Florence. The Economic mill, also a chlorination mill, located between the cities of Cripple Creek and Victor in the heart of the mining industry, was recently burned and will apparently never be rebuilt. The Dorcas mill, a cyanide mill at Florence, was burned in the spring of 1906 and has never been replaced. This mill operated as a custom mill and was the only one to make a success of the cyanide process for many years; it was due largely to the success of this mill that cyanide treatment for Cripple Creek ores was kept before the eyes of the mine and mill operators of the district.

The treatment charges on ores at the chlorination mills have been gradually lowered during the year 1907, as shown by the following tables. This is due to the fact that the Golden Cycle Mining Co. has built at Colorado City a cyanide custom mill independent of the so-called "Mill Trust" and has begun the treatment of Cripple Creek ores on a large scale with a most modern plant thoroughly equipped.

The open rate for ore treatment at the plants of the U. S. Reduction and Refining Co. is contained in Table 1. Column 1 is the rate charged during the early part of the year 1907, column 2 the rate made on October 15, and column 3 the rate adopted December 26.

Table I

	Per Ton	Per Ton	Per Ton
Up to ½ ounce gold	$ 6.25	$ 5.25	$ 4.50
½ to ¾ ounce gold	7.50	5.75	5.00
¾ to 1 ounce gold	8.00	6.50	5.50
1 to 1¼ ounce gold	9.00	7.25	6.00
1¼ to 1½ ounce gold	9.25	7.50	6.00
1½ to 2 ounce gold	10.25	8.50	7.00
2 to 3 ounce gold	11.00	9.50	8.00
3 to 5 ounce gold	11.50	9.50	8.50
5 to 7½ ounce gold	8.50*	12.00	10.00
7½ to 10 ounce gold	9.50*	14.00	12.00
10 to 12.5 ounce gold			14.00

* Plus freight of $4.50 on 7½-ounce ore, and $5.50 on 10-ounce ore.

These charges include the freight to the mill from the place of loading in the district.

On February 28, 1908, the Golden Cycle Co. announced the completion of its mill rebuilt after the fire of last summer and offered the rates shown in column A of Table 2. These rates are given only for time contracts guaranteed from 3 to 6 years and include freight and treatment charges. To meet these rates the United States Reduction and Refining Co. announced the rates shown in column B, which also include freight and treatment charges. These are open rates and it is understood at this writing (March 1) that no contracts will be made at these figures.

Table 2

Column A Golden Cycle Rates	Per Ton	Column B U. S. R. & R. Co. Rates	Per Ton
Up to $8.00, inclusive	$ 4.00	Up to $8.00	$ 3.50
$8.00 to $10.00	4.50	$8.00 to $10.00	4.50
$10.00 to $15.00	5.25	$10.00 to $15.00	5.00
$15.00 to $20.00	6.00	$15.00 to $20.00	5.50
$20.00 to $25.00	6.50	$20.00 to $25.00	6.00
$25.00 to $30.00	7.00	$25.00 to $30.00	6.00
$30.00 to $40.00	7.50	$30.00 to $40.00	7.00
$40.00 to $60.00	9.00	$40.00 to $60.00	8.00
$60.00 to $100 00	9.50	$60.00 to $100.00	8.50
$100.00 to $150.00	12.00		
$150.00 to $200.00	13.00		
$200.00 to $300.00	13.50		
Over $300.00	13.50*		

* Plus 1 per cent. of assay value.

The keen competition of these two great plants has thus resulted in a lowering of rates highly beneficial to the shippers of the Cripple Creek District. The railroads of the district have recently made a change of rates also, best shown by Table 3.

Table 3. Freight Rates

Rate up to Dec. 23, 1907	Per Ton	Rate Effective Since Dec. 23, 1907	Per Ton
Up to $8.00, inclusive	$ .75	$20.00 and under	$1.00
$8.00 to $20.00	1.00	$20.00 to $25.00	1.25
$20.00 to $30.00	1.25	$25.00 to $30.00	1.50
$30.00 to $40.00	2.00	$30.00 to $40.00	2.00
$40.00 to $100.00	3.50	$40.00 and over	2.50
$100.00 to $150.00	4.50		
$150.00 to $200.00	5.50		
$200.00 to $300.00	6.50		

The effect of the changed rate is to increase the cost of milling to the valley mills by $.25 on ore under $8. As the bulk of the ore now shipped runs from $20 to $25, the cost of treating those ores is unaffected and only the comparatively small amount of high-grade ore running over $40 is effected by lowering the former rates to a maximum of $2.50 per ton.

The costs of mining, including stoping, developing and sorting, are given in the Professional Paper No. 54 of the United States Geological Survey as being nowhere in the district less than $8 per ton and in many cases much higher than that.

It is thus seen that these treatment charges combined with the costs of mining have been such that ore running less than $20 per ton was seldom mined, or if necessary to mine it to get it out of the way of the regular mining operations it was thrown on a separate dump to await the time when some process should be developed to render its treatment profitable. There are, therefore, millions of tons of low-grade ore lying on the dumps, or untouched but known in the mine stopes. For several years past many experiments have been made anticipating the treatment of these low-grade ores and as a result it has come to be generally believed that a proper manipulation of the ores in cyanide will solve the problem for almost any ore known in Cripple Creek.

The general character of the ores can be seen from the following table of analyses taken from Professional Paper No. 54 of the United States Geological Survey, page 172.

	1 Per Cent.	2 Per Cent.	3 Per Cent.	4 Per Cent.	5 Per Cent.	6 Per Cent.
Silica	57.81	54.91	54.68	55.98	59.12	59.58
Alumina	20.13	17.80	17.87	17.09	18.77	16.00
Iron		4.80	5.30	3.44	3.38	.67
Magnesia	.86	.36	.20	.47	.32	.03
Lime	1.32	2.04	2.65	.71	.38	2.03
Alkalies	10.53	12.00	12.00			12.91
Manganese dioxide	.31	.66	.94			
Sulphur		2.49	2.25	1.77	1.23	
Carbon dioxide		2.00				.26
Fluorite	.68					1.42
Pyrite	2.50					4.84
				oz. Per Ton	oz. Per Ton	
Gold	....	....	....	.98	1.52	
Silver	....	....	....	.62	1.04	

Column 1 represents mixed ores, partially oxidized, sampled from the ore beds of the Standard mill.

Columns 2 and 3 represent the normal ore from the Portland mine and contained one-fourth ounce silver to the ton. They were taken from the ore beds of the Portland mill.

Columns 4 and 5 represent ore from the Golden Cycle Mine.

Column 6 represents a granite ore from the Ajax Mine.

The principal primary minerals as given by the same authority are calaverite, tetrahedrite, sylvanite, barite, quartz, pyrite, fluorite, calcite, dolomite.

The principal secondary minerals are gold, gypsum, psilomelane, limonite, alunite, and epsomite.

These secondary minerals are found in the oxidized zone and their treatment by cyanide offers no great difficulty. The ores containing the tellurides of gold and silver, however, have to undergo some preliminary treatment to render the values soluble since the compounds of tellurium are not affected by cyanide solutions.

It has been found that it is not necessary to entirely eliminate the tellurium from the ore but to give it such treatment as to break up the compound of gold and tellurium, allowing the tellurium to remain as an oxide which does not appear to be an objectionable compound in treatment by cyanide. The destruction of the gold-tellurium compounds is now universally accomplished by means of roasting. Experiments have been made with various chemical processes for oxidation such as the bromo-cyanide process, but at the present time (January 1, 1908) there is no mill in the Cripple Creek District using any process for oxidation other than roasting.

There are now a number of mills in the district operating at the mines and treating oxidized ores, mostly by a simple coarse crushing and simple leaching. Prominent among these are the following:

	Capacity Tons Daily
Isabella	125
Phoenix	100
Ironclad	300
Wild Horse	100
Home Run	50
Santa Rita	50
Anaconda	100
W. P. H.	100
Joe Dandy	150
Blue Flag	100
Wishbone	75
Little Giant	150
Total	1,400

These have all had a somewhat troubled existence at times but some of them have emerged successful and are today working at a profit due to careful work and intelligent superintendence.

Of these mills those described below have been taken as typical examples where information was obtainable. The Joe Dandy owners have been for some time experimenting on their ores but do not care to given out their results further than to say that they will roast and fine grind all ores. The management is satisfied that they can treat their ores at the mine by the cyanide process and contemplate a complete modern plant for the near future.

The Venture Corporation operating the Stratton's Independence Mine have a mill of 800 tons capacity nearly completed and will shortly be operating on the large dumps surrounding their shafts and the low-grade reserves in the mine. This plant will be described at a later date.

Several other mills are planned for early construction and it seems that in a short time much lower grade ores will be mined and treated at the mines, and that the greater portion of ores from Cripple Creek will find their way to some cyanide mill and that less and less will be treated by chlorination.

THE ISABELLA MILL

This is one of the successful mills working adjacent to the mine and treating the material on the dumps and the low-grade ore from the mine. There are two dumps, one averaging \$4.50 per ton and the other \$3.60 per ton. This dump material is treated exclusively by the mill except at such times as it is not expedient for some reason to hoist shipping ore from the mine. Then the mine force is put to work on some of the low-grade reserves in the mine and the ore is delivered direct to the mill bins. The ore treated at such times runs from \$8 to \$10 per ton.

At the time of the writer's visit the mill was working on the lower grade dump and the day's assays shown him at that time gave a value of \$3.60 for the heads and \$.80 per ton for the tails. This was done with a leach of 4 days. When two tanks now in the course of construction are in commission however the leaching time will be increased to 6 days, as it has been proved that with this lengthened time of leaching the extraction will be much nearer complete. The ore is taken from the dump in ordinary mine cars and trammed to a bin at the head of the mill. Below this bin is a 9″×15″ Blake crusher fed by gravity and requiring little attention. With the ore, at the crusher, lime is added about 5 pounds to the ton of ore. From the crusher it goes to a 16″×36″ Davis roll and thence to two 14″×27″ Davis rolls. It is then passed over a ¼-inch mesh bumper screen the oversize from which is returned to the last set of rolls and the undersize goes by a belt conveyer to a storage bin of 200 tons capacity. The leaching tanks, six in number, are in a single row and this storage bin is directly over the two tanks at the center. A belt conveyer runs over the tanks. The two center tanks are filled directly from the bin by simply opening a gate at the bottom and allowing the sands to run into the tanks while the others are filled by the conveyer. The tanks are 5 feet deep, 30 feet in diameter, hold 125 tons, and are filled in 4 hours. The strong solution is then added, containing 4 pounds of cyanide to the ton of water, followed by a 3-pound, then by a 2-pound, solution, and finally by a wash of water. As these solutions are drawn off they pass through a battery of nine zinc boxes to a sump below. The leached sands are shoveled out through manholes in the tank bottom on to a belt conveyer and thrown on to the tailings dump. Two men can empty one tank in 8 hours. This method of emptying the tanks is used instead of sluicing because of the scarcity of water on the hills in the Cripple Creek District. Since the water used at the mill costs \$100 per month, less use is made of it than in more favored localities. It is cheaper to shovel out the tanks than to sluice them out.

The gold having been precipitated from the solution by the zinc now lies with the zinc slimes in the boxes. These slimes are washed with water and the wash water passed through a filter made as follows: A wooden tank 7 feet in diameter has a perforated bottom, over which is placed first burlap, then a cheap cotton blanket, and last a muslin bag. When the gold-zinc slimes are washed they are dipped out of the boxes and thrown into a lead-lined tank, and, as they are being put in, full-strength sulphuric acid is added a little at a time. When the slimes are all in the lead tank, the portion caught in the filter is added and the whole is diluted by adding one-fourth its bulk of water. Live steam is then turned in and the contents of the tank boiled until the zinc is dissolved and the solution is clear. This is usually accomplished in 8 to 10 hours, when the tank is entirely filled with water, allowed to settle, and the solution decanted on to the same filter previously used. The dried muslin bag is then placed on top of the gold precipitates and burned. The gold is then drawn off from the bottom of the lead tank and dried. The dried precipitates are now ready for the smelting pot. A flux is prepared as follows:

	Parts By Weight
Borax	10
Bicarbonate of soda	10
Potassium nitrate	½
Silica	3

Equal parts by weight of gold precipitates and flux are mixed in a No. 80 crucible and melted in a gasoline furnace large enough to hold two of these crucibles. From this melt there is obtained a matte together with a gold button which are broken from the slag and put in a crucible with a charge of potassium nitrate and a soft iron rod and given a second melt. From this melt there is obtained a very pure gold bar that has run as high as 950 fine when shipped to the mint. There is a considerable amount of silver in all of the Isabella product and some of the bars have contained 33 per cent. silver. This silver accounts for the purity of the bars to a great extent as it has been found that when silver is present in considerable quantities the zinc boxes are less liable to become foul, and the addition of lead acetate is not necessary.

The mill power is electric, supplied by one 100-horsepower and one 20-horsepower induction motor. The actual average consumption of power is 57 horsepower from the larger and 12 horsepower from the smaller motor. The power costs \$350 per month. Ordinary labor costs \$3 per day. There are nineteen men besides the superintendent employed for the three shifts. The crushing room is run only two shifts. The costs are therefore higher than those of a mill located in the valley towns.

The average costs of treatment per ton are given as follows:

Tramming ore to mill	\$.22
Disposal of tailings	.09
Repairs	.02
Milling	.14
Cyaniding	.38
Acid treatment, fluxing, and melting	.02
Total	\$.87

No office expense is charged to the mill, and the assaying is done at the mine and no mill charge made.

Since the tailings run from 67 cents to 80 cents, the low-grade ore running over \$1.67 per ton can be profitably treated. There is therefore a nice margin of profit on even the poorest dump which as before stated runs \$3.60.

THE WILD HORSE MILL

Another of the successful small plants of the district is the Wild Horse mill, Thomas Kavanaugh, superintendent, which is treating about 50 tons per day. The ore milled at present is of two classes, dump and mine ore from the Ramona and Silver Tip Mines. Both ores are free from heavy sulphides and tellurides so that no roasting is necessary. The proportion of dump ore to mine ore milled is about 3 to 1. Most of the former has been on the dump for 5 years, is well oxidized, and the sulphates leached out. The dump ore runs about \$3 per ton and the mine ore \$7.

As the mill is located on the side of a steep hill the material is carried along by gravity without the necessity of much elevating. The ore bin at the top has a capacity of 200 tons. From this the ore passes over a grizzly having 1½″×½″ iron bars set 1¼ inches apart, the oversize going to a No. 2 Austin gyratory crusher whose product joined with the undersize from the grizzly passes directly to a 12′×2′ shaking screen. This screen is woven of No. 12 wire and has a ¼-inch mesh. The oversize falls to the roughing rolls set ⅜ inch, whose product goes to a 12-foot trommel also of ¼-inch mesh. This trommel will eventually be replaced by a shaking screen. The oversize from the trommel goes directly to the finishing rolls, which are set close, the product of which is mixed with the undersize from both the shaking screen and trommel. This combined product is elevated to a ¼-inch-mesh inclined screen placed over the crushed ore bin, the product from which falls into the bin while the oversize is chuted back to the finishing rolls.

It is seen that all the mill screens are of ¼-inch mesh but the maximum size of the screened ore particles leached is about ⅛ inch due to the space occupied by the heavy No. 12 wire. About 60 per cent., however, will pass 30-mesh. The rolls are both of McFarlane make 14 in.×26 in.

From the bin the finished product is drawn into a car running on a track over the row of four steel cyanide tanks. Each tank is 25 feet in diameter by 5½ feet deep, and has a capacity of 100 tons. Each is provided with a filter bottom and two tailings discharge openings. The strong solution contains 2.5 pounds *KCN* to the ton and the weak .5 pound. The consumption of *KCN* is about .65 pound per ton of ore. The time of leaching varies with the fineness of the gold in the ore from 4 days for very fine gold to 10 days for coarse gold, making an extraction of about 90 per cent. Leaching is usually continued as long as the head solution runs 50 cents per ton. To maintain the proper alkalinity, from 6 to 10 pounds of unslaked lime is mixed with the dry ore in each tank. The leached gold solution is drawn off clear into the gold tank, in which lead acetate is added. This is followed by the weak solution, then by wash water. The gold is precipitated in the usual zinc boxes.

At present the tailings are sluiced from the tanks to the dump. The mill water is supplied by the Altman Water Co. at a charge of $.60 per thousand gallons, and the monthly cost for water alone is about $250. It is therefore the intention of the management to cut down the water costs by substituting a system of shoveling out the tanks onto a conveyer belt, similar to that used by the Isabella Co. previously described.

(To be Continued)

An Assay Scheme for Cyanide Solution*

By Willett H. Barton

So much has been written regarding the assay of cyanide solution that the subject may seem old, but, to my knowledge, we have not had published, to date, a reliable method which will check itself, excepting schemes involving a crucible fusion.

The lead-boat method does not permit of the use of a large amount of solution. The next best is the Chiddey method, using lead acetate and zinc dust or shavings. In the numerous modifications of the latter which have been published, unless each assay is given special attention, there are these objections: First, a slightly low and uneven result; second, the attention required at the exact point when the zinc is dissolved, as, if carried beyond this point, the lead will dissolve and break into small flakes, which are hard to collect without filtering; third, when taken up before the solution of zinc is complete, a loss occurs in cupeling by the oxidizing of the retained zinc in the operation.

The remedy for these unsatisfactory results is simply a small piece of aluminum foil dropped into the solution just after the bulk of the lead sponge is formed. Our method of operating is as follows:

Five or 10 A. T. of solution in a beaker or Erlenmeyer flask is brought nearly to boiling point. With a 10 c. c. pipette (from which the lower tube has been broken off near the cylinder, to permit a quicker filling when immersed in a beaker of solution) add a saturated solution of lead acetate, which is quite acid with acetic acid, to prevent the lead precipitating as a hydrate; add about .5 g. zinc dust, let stand for about two minutes and acidulate with about 10 c c. *HCl*.

When sponge is fairly well formed, add the small square of aluminum foil, which will precipitate any remaining lead and prevent the sponge already formed from disintegrating. Another 10 c. c., or less, of *HCl* may be dripped onto the sponge from a pipette, after the excess of zinc is apparently dissolved. The assay may remain on the hot plate throughout the operation, until there seems to be no action except on the aluminum foil. Remove and pour the liquor off; squeeze the sponge together with a rubber policeman, place on a piece of lead foil about 2 inches square, roll with a large glass tubing to eliminate excess of moisture, fold, roll into a ball, puncture with a small point for steam escape, and place in a hot cupel.

Our assays of solution are made up in batches of 35 to 40 in number. The time required for one assay, taking it straight through, is 45 minutes, collecting and cupeling; they check in both gold and silver, need no extra precaution, and will work alike on solution clean or foul, weak or strong.

* Paper read at third annual meeting of Western Association of Technical Chemists and Metallurgists, Deadwood, South Dakota, January 2-4, 1905.

Canadian Mining Institute

The Tenth Annual Meeting of the Canadian Mining Institute was held at Ottawa, Ontario, March 4 to 7. Headquarters were at the Russell House, where the meetings were also held. At the opening session, Wednesday, March 4, a brief opening address was made by the President of the Institute, Mr. Keffer, who introduced the Minister of Mines, Hon. Wm. Templeman, who, in the name of the Premier Laurier, welcomed the Institute to Ottawa. Letters of regret at their inability to attend were read from a number, including Doctors Kemp, Irving, Emmons, and Lane. A message of sympathy, on account of his illness, was sent to Mr. Low, Deputy Minister of Mines.

The first paper, "The Classification of Coal," by Mr. D. W. Dowling, of the Canadian Geological Survey, brought up a very interesting discussion upon the subject of coal analysis. Other papers read during the morning and afternoon of Wednesday were "The Carbon Minerals of New Brunswick," by Dr. R. W. Ells; "Secondary Mining Education," by H. H. Stoek; "Occurrence of Tungsten Ores in Canada," by Dr. T. L. Walker; "Topographical Methods," by W. H. Boyd; "Gold in the Eastern Townships of Quebec," by J. Obalski, and the "Occurrence of Canadian Graphite," by H. P. H. Brumell. The latter paper especially brought out an extended and very interesting discussion. A paper by Mr. Hodges upon "Handling Three Thousand Tons of Ore Per Day at the Granby Mines," was read by Mr. Hedley.

At the evening session three papers illustrated with a lantern were given: "Metallography Applied to Engineering," by Dr. Campbell, Columbia University; "Prospecting for Coal," by D. B. Dowling; and "Conventional Signs for Showing Mineral Occurrences on Maps," by E. D. Ingall.

The meeting of Thursday morning was a business session, including the President's address, the report of the Council, and the report of the Treasurer. These reports showed the Institute to be in a very flourishing condition, with a good balance in the treasury and with a substantial increase in membership during the past year. The committee appointed at the last annual meeting of the Institute to confer with the Ontario Government about the tax of mines reported suggesting the appointment of a Royal Commission to investigate the subject. Messrs. Hobart, Wilson, and Brock were appointed scrutineers to examine the ballots.

Dr. Porter presented the report of the committee appointed to revise the Constitution of the Institute.

The afternoon session was devoted to the subject of iron. The first paper by Prof. C. K. Leith, of the University of Wisconsin, upon "The Iron Ores of Canada," gave a very clear classification of iron ores, based upon the method of formation. Other papers were "Iron Ores of Ontario," by A. B. Wilmot; "Electric Smelting in Ontario," by R. Turnbull; "Possibilities of Electric Smelting," by Dr. A. Stansfield, McGill University; "New Iron Ore Field in Eastern Canada," by John E. Hardman; "Moose Mountain Iron Ore Deposits," by N. E. Leech.

Thursday evening was given up to a smoker-concert held in the dining room of the Russell House, which was very much enjoyed.

On Friday at 10 A. M., memorials were presented from the lead producers of British Columbia in regard to the removal of the bounty upon lead ores in the near future. Statements showed that the removal of the bounty would work great hardship to the mines of British Columbia and would probably result in closing down a number of them. A committee was authorized to be appointed by the President to present this matter to the Government with the indorsement of the Institute. A condensed statement of the mineral statistics of the Dominion of Canada for the year 1907 by Mr. Jno. McLeish brought about an interesting discussion upon the different methods of reporting as used by the Canadian Geological Survey and the several Provincial Departments. As a result of this discussion a resolution was passed calling the attention of the Minister of Mines to the advisability of attempting to arrange for a uniform system of reporting statistics by the general government and by the several Provinces. Upon the motion of Mr. Tyrell, it was voted to memorialize the railroads to grant reduced fare tickets to prospectors similar to the tickets now issued to home seekers. Mr. P. McN. Bennie read a paper upon "The Grondell Process."

The Wednesday afternoon session opened with a discussion of the proposition to change the headquarters from Montreal to

CYANIDING CRIPPLE CREEK ORES

Description of the Blue Flag Mill—Tube Mill Practice—Standard Plant at Colorado City—Portland Mill

Written for "Mines and Minerals," by F. L. Barker

(*Concluded from page 424*)

THE BLUE FLAG MILL

This mill treats ore direct from the Blue Flag Mine and is located at the mouth of the shaft on Raven Hill. The ore is of the oxidized variety and will average $8 per ton. A short tram delivers the ore from the mine cars to the mill bin, from which it is discharged into a 11″ × 15″ Dodge crusher. Cyanide solution is fed from a ¾-inch pipe into the crusher with the ore and the ore crushed to pass about a 1-inch ring.

Below the crusher are two Tatman high-speed mills. These mills were developed and perfected by Mr. J. C. Tatman, of Denver, and those installed in the Blue Flag Mill are the first tried on a working basis. The mill owners express their entire satisfaction with their operation and their intention to install others of the same kind as they need them in the future.

The mill is circular, 7 feet in diameter and 4½ feet high and weighs 18,000 pounds. It has a capacity of reducing 50 tons of quartz from ½ inch to 20 mesh in 24 hours and requires only 7 horsepower to operate. In outward appearance it does not differ greatly from the Chilian mill. Internally, as shown by Fig. 1, it is made with circular channeled piece, 6 feet in diameter, forged from chrome steel, forming the floor, called the ring die. Revolving in this ring die are seven mullers 22 inches in diameter each weighing 800 pounds. These mullers have a chrome-steel tire, conical in shape to fit the channel of the ring die. They are mounted on axles that tip slightly from the outside toward the center and hence the mullers themselves tip slightly from the vertical. The shape and position of the mullers, it is claimed, minimize the end thrust and friction, increase the grinding surface, distribute the ore particles under the whole of the grinding surface and allow the mullers to travel at high speed without leaving the ring die. The standard speed of the mullers is 100 revolutions per minute. This is great enough to lift the particles of ore and throw them at a tangent from the mullers against a screen surrounding the whole of the mill. The screen surface is 2 feet high by 18 feet and in these mills the screens are 16 mesh. The impact of the ore particles is sufficient to force any that are ground fine enough to pass through the screen.

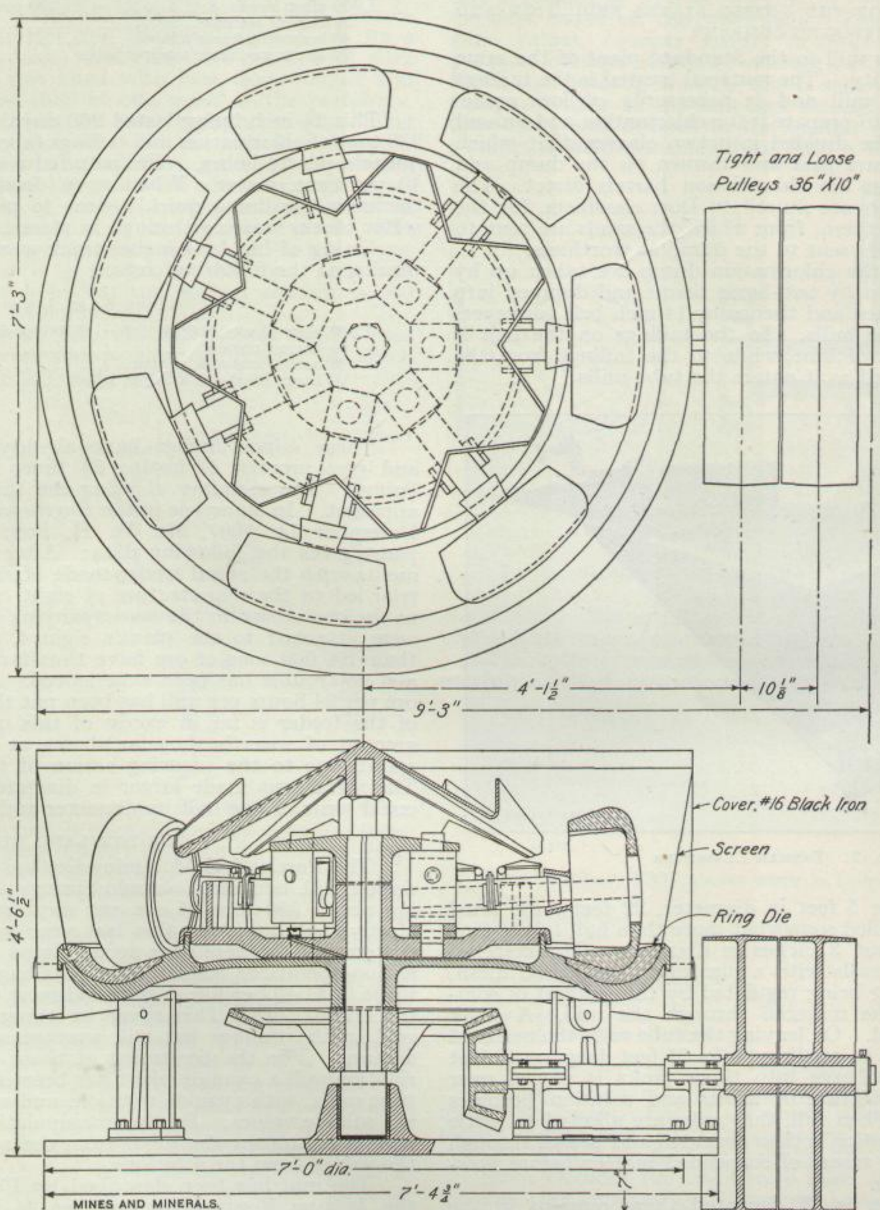

FIG. 1. TATMAN MILL

Instead of the usual central mill feed there is a cone under the feed channeled to direct the ore between the mullers and so attached that it revolves with the mullers.

There are no bolts or nuts on the moving parts of the machine which argues for correct construction on mechanical principles and an avoidance of many of the difficulties in the usual types of high-speed mills.

From the Tatman mills the pulp is sluiced to a classifier, see Fig. 2, also designed by Mr. Tatman. This consists of an inverted pyramid of three sides, two of which measure 6 feet along the base and the third 3 feet, while the height of the pyramid is 3 feet. A pipe runs along the inside of the longer dihedral angle discharging solution at the apex of the pyramid. This pipe is covered with a flat 3-inch strip to keep sands from settling around it. The intake for the pulp is at the open end of the long dihedral angle and 24 inches from this point is a perforated baffle board reaching to within 1 inch of the top and set parallel with the short side. The upper part of this baffle board is perforated with ½-inch holes with a half inch of metal between them and the lower part with ⅜-inch holes with ⅜-inch metal spaces between. This baffle with the flaring side of the classifier slows down the current and the sands settling to the bottom are washed free from slimes by the upward stream of solution from the pipe discharging at the apex. The sands are discharged from the holes seen near the bottom of the shortest side and the slimes escape through the slot seen at the top. The classifier is made entirely of No. 14 galvanized iron, with corners of angle irons and weighs 140 pounds. The products of the classifier are 60 per cent. sands very free from slimes, so that rapid leaching is possible, and 40 per cent. slimes.

The sands go to one of three leaching tanks to which they are delivered by Butters distributers. The slimes fall to a slime trough and are thence by centrifugal pumps delivered to Callow thickening tanks. From here they go to one of three slime tanks having conical bottoms, in which the slimes are agitated by means of centrifugals pumping the slimes up the outside of the tanks and discharging at some distance above the top in order to carry air down into the tank. The sands are allowed to leach for 48 hours and the slimes are agitated for about the same period. The solution from the slime tanks is decanted and passes through a gravity filter to remove any suspended matter, and the slimes are washed. Usually but one washing is required but this is determined by assay in each case, and if another wash is needed it is given. The solutions bearing gold are passed through five zinc boxes and the precipitated gold slimes receive the acid and smelting treatment for reduction to bullion. The total extraction is 88 per cent. most of the values lost being in the tails from the slimes.

The consumption of cyanide is 1¼ pounds per ton of ore. The amount of water used is about 3 tons to the ton of ore. The mill is at present working two 8-hour shifts and treating 30 tons of ore per day.

The costs of treatment are given in outside figures as follows: Crushing and grinding, 50 cents; cyaniding, 70 cents; precipitating, 60 cents; melting, 12½ cents; a total of $1.92½.

The mill is just nicely beyond the experimental stage and a material reduction of these costs may be looked for shortly. The mill is well arranged and presents little for criticism in its construction and operation.

THE COLORADO PLANT OF THE UNITED STATES REDUCTION AND REFINING COMPANY

This is an auxiliary mill to the Standard plant of the same company at Colorado City. The material treated is the tailings from the chlorination mill and is necessarily of low grade. It has all been roasted to prepare it for chlorination and ground to 12 mesh. It may be divided into two classes, that which has been treated in years past and thrown on the dump and that which comes from the chlorination barrels direct. The tailings from the barrels are sluiced to Dorr classifiers, for the purpose of unwatering them, from which the sands are sent to tube mills and the slimes sent to the dump as worthless.

The tailings from the chlorination dump are taken up by ordinary scrapers drawn by two-horse teams and dumped into hoppers through grizzlies, and thence by 14-inch belt conveyers are carried to the tube mills. To the tailings on the belt is added a small amount of lime, while to the tailings from the barrels the lime is added as it enters the tube mills.

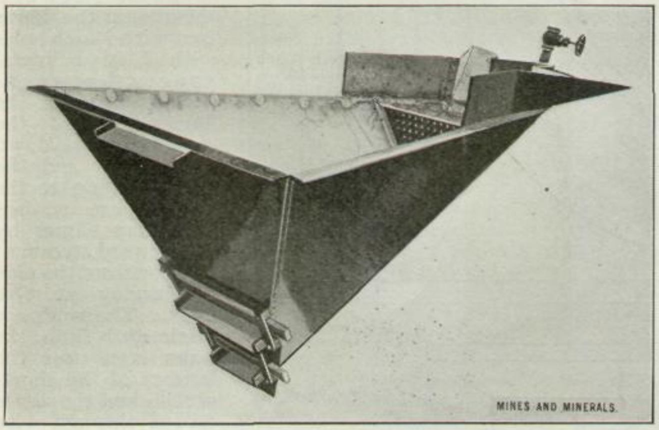

Fig. 2. Tatman Classifier

The tube mills are 5 feet in diameter, 22 feet long, lined with flint blocks and filled somewhat more than half full of flint pebbles averaging about 3 inches in diameter. The material issues from the tube mills with a maximum size of 80 mesh, the fineness of grinding being regulated by the amount of solution used to sluice the material through the mill. A weak cyanide solution is used. On leaving the tube mills the material is now slime and flows to settling tanks 25 feet deep by 45 feet in diameter. The discharge into these tanks is placed over the center and the mixture of slimes and solution becomes aerated as it falls. When full, the tanks are allowed to settle for 8 hours and the solution is then decanted and passed through a filter to remove any traces of suspended matter before flowing through zinc boxes.

When the solution is all decanted there remains in the bottom of the tank about 8 feet of slime. This slime is then washed out of the tank and pumped into another of the same size, this washing being done with the weak solution that has passed through the zinc boxes. This washing and sluicing thoroughly mixes the slime with solution and air. When it has again settled in the second tank the solution is again decanted, filtered, and precipitated, and the slime given a final wash with water.

The feed to the tube mills deserves special mention as it was here developed and perfected. The pulp is delivered to a trough at the head of the mill. Attached to and revolving with the mill is a spiral similar to a spiral sand pump. This spiral has an opening 6 inches square and as it revolves scoops up the pulp and delivers it to the center of the mill. The supply of pebbles is fed through this as well as the pulp and renders unnecessary shutting down of the mill for the replenishment of the pebbles stock. There is but very little wear and as it occurs the trough is raised and the feed thus kept at the proper amount. These iron spiral castings weigh about 350 pounds each. The actual foundry cost was 3 cents per pound, making the metal cost alone $10.50, while the additional cost for pattern work, etc., brought the total first cost up to about $35 each.

In this connection the following cost data on tube-mill linings given by Superintendent Fox is of value. The tubes are 22 ft. × 5 ft., lined with silex blocks laid in cement. The first linings were made using blocks 2½ inches thick and the following are the costs:

2½-Inch Silex Lining

1,300 silex blocks, 8 × 4 × 2.5 = 11,320 pounds, cost...	$204.88
5¼ barrels cement	17.19
48 hours mechanic's labor	16.50
96 hours mechanic's helper labor	21.60
	$260.17

This 2½-inch lining lasted 260 days, grinding an average of 230 tons of chlorination mill tailings (about 30 mesh) to 60-mesh fineness per 24 hours. The pulp fed was 60 per cent. ore and 40 per cent. water. When worn down to about an inch in thickness the lining quickly went to pieces on account of the softer blocks wearing through in places.

Lining of blocks 4 inches thick was then tried with better results, at the following costs:

4-Inch Silex Lining

1,300 silex blocks, 8 × 4 × 4 = 17,381 pounds, cost....	$340.28
5½ barrels cement	17.79
48 hours mechanic's labor	16.50
96 hours mechanic's helper labor	21.00
	$395.57

These 4-inch linings have already lasted about 2 years and give promise of lasting 2½ times as long as the 2½-inch linings. The economy of using the thicker lining is therefore apparent. In an article in the *Engineering and Mining Journal*, December 14, 1907, Mr. W. H. Fox, superintendent of the plant gives the following data: After the preliminary experiments with the spiral feeder made of sheet steel, its successful trial led to the manufacture of eight cast-iron feeders, similar to the one shown in the accompanying drawing, Fig. 3. These were attached to the plant's eight 5′×22′ tube mills. More than 100,000 tons of ore have thus far been handled by them and no trouble has been experienced. As much as 160 tons of ore per 24 hours per mill has been put through and the capacity of the feeder is far in excess of this quantity. Only a small amount of wear is thus far shown at the intake edge of the spiral, due to the scouring action of the sand in the trough. The spiral was made larger in diameter than necessary, so it could wear to one-half its diameter and still feed.

THE PORTLAND MILL

The Portland Gold Mining Co. has long operated a chlorination mill, between Colorado Springs and Colorado City, treating about 350 tons of ore per day from the Portland Mine chiefly, but operating this last year to a limited extent as a custom mill. There have accumulated as a result of the chlorination operations 500,000 tons of tailings containing an average value of $1.49 per ton in gold and most of the silver that was in the original ore. This silver at times equals in weight the gold in the tailings but will average somewhat less than that amount. For the treatment of these tailings from the chlorination mill a cyanide plant has been installed, fine grinding in tube mills, with cyanide solution, and extracting practically all the soluble values. Further manipulation is solely for the purpose of separating the solids from the solutions, and extracting the values from the solutions.

The mill has been described by Prof. Regis Chauvenet in the *Mining Reporter* for October 24 and 31, 1907, and the clean-up by Mr. J. M. Tippett, metallurgist of the plant, in the January, 1908, number of the *Western Chemist and Metallurgist*. The material in these two papers will be freely used in this article, modified as may be necessary to suit the most recent development.

The dump material now considered as ore is loaded by means of a steam shovel into electrically operated cars and dumped on to and conveyed by a 14-inch belt conveyer to the top of the cyanide plant and discharged into a storage bin. From the bin Challenge ore feeders regulate the discharge into two launders each one leading to two tube mills.

As it falls into the launders, strong solution (1.2 pounds cyanide to 1 ton of water) meets the ore and sluices it to the tube mills. The strong stock solution tank, 32 feet in diameter by 16 feet deep holding 480 tons, stands on the same level as the foundations for the tube mills, and it is necessary to pump the solution high enough to feed into the launders. At first this was done directly but it was found that the centrifugal pumps threw an intermittent stream and much difficulty was experienced with the feed. To remedy this a small tank was installed at the top of the mill and the solution was pumped to this. From the small tank the solution runs by gravity at a low head and the amount fed can be regulated to a nicety. About 5 pounds of lime is added to the ore at the same point as the solution. The lime is first dry slaked in the lime house and then by belt conveyer thrown into a tank, made into an emulsion and fed by gravity We have, then, going into the tube mills, the ore previously ground to 14 mesh after having been given a sweet roast, strong solution, 1 ton of solution to 1 ton of ore and a lime emulsion containing 5 pounds of lime for each ton of ore. The two tube mills, of Allis-Chalmers make, are 5 feet in diameter and 22 feet long and fed by a spiral through the trunnions. Both are now lined with silex lining. Previously one was lined with cast iron wedged and keyed to a fixed piece of shell at one point of the periphery. The capacity of each mill was the same though the silex lining reduced the diameter by 8 inches and the cast iron by only 2 inches. It was found that the mill having the cast-iron lining required 84 horsepower and the mill with silex lining 62 horsepower. The consumption of pebbles, moreover, was twice the amount in the iron-lined as that in the silex-lined tube. The consumption of pebbles was formerly ½ pound to the ton of ore, the present consumption is ⅓ pound to the ton. One mill has treated 14 tons in an hour but the normal amount is 400 tons for the two mills in 24 hours.

As the pulp issues from the tube mills it will mostly pass through a 60-mesh screen and a large proportion is much finer, as is shown by the following screen analyses:

	No. 1 Per Cent.	No. 2 Per Cent.	No. 1 Assay Ounce Per Ton Au	No. 2 Assay Ounce Per Ton Au
On 60 mesh	9.4	6.6	.08	.04
On 80 mesh	15.6	14.4	.04	.06
On 100 mesh	17.0	18.6	.04	.12
On 120 mesh	7.4	3.2	.04	.06
On 150 mesh	8.4	8.2	.06	.06
On 200 mesh	4.4	5.4	.08	.08
Through 200 mesh	38.0	42.8	.08	.08

Another test made on the final tails gave the following:

	Per Cent.	Assay Ounce Gold Per Ton
On 60 mesh	4.6	.02
On 80 mesh	12.8	.04
On 100 mesh	15.6	.02
On 120 mesh	5.4	.02
On 150 mesh	6.8	.02
On 200 mesh	4.4	02
Through 200 mesh	49.0	.02

The solution issuing from the tube mill has a strength of about 1 pound to the ton and is then diluted by a stream from the weak-stock tank carrying 0.4 to 0.5 pound to the ton until the strength of the solution in the pulp is 0.6 pound to the ton. The pulp is pumped to one of two launders on top of the settling tanks. These launders are 30 inches wide and 70 feet long and have a bottom covered with a cheap grade of woolen blanket. About 100 pounds of material are caught on these blankets in 12 hours and its value varies from 50 cents to $1 per pound. While one tank is being filled, the blankets from the bottom of the launder leading to the other tank are taken up, washed clean of their values and replaced. The gold caught here is of a peculiar nature and is believed to be a product of roasting previous to chlorination. It was not recovered in the chlorination process, has escaped the concentration tables, over which all the tailings from the chlorination mill pass; it has refused to amalgamate on plates and defied the dissolving power of cyanide solutions, but it settles in the meshes of a woven blanket and is saved at the expense of a few blankets each month. It was first believed to be free gold slightly off color, but it has recently been examined and is now believed to be a mixture of gold, iron, tellurium, and calcium sulphate. It is planned in the near future to put more of these blankets in the path of the pulp and it is believed that still further savings will result.

The pulp flows to one of two settling tanks for 12 hours and is then turned into the other. As soon as any clear solution shows at the top, decantation is begun and continues until the solution is removed as clean as possible, then the remaining pulp is sluiced out by weak solution and pumped into another tank of the same size as the first. It is here that it is proposed to introduce another series of blankets. Again the pulp settles, the solution is decanted as closely as possible and the pulp is discarded as waste carrying about 40 cents per ton in value. There is of course some weak solution left with the pulp and lost, but the total value of 40 cents per ton in the final tails does not seem to warrant the introduction of filters for its removal, but some other plan of saving this is now contemplated.

The solutions saved by decantation pass to their respective strong or weak gold boxes. These are three in number, 57 feet long, 14 feet wide, and 8 feet deep and have a sand and gravel filter on the bottom for removing the suspended matter in the solutions. The filter is not entirely satisfactory and it is probable that some other method of filtration may be soon adopted. Leaving the filters the solution passes through a series of six zinc boxes. There are 18 of these boxes in a series each of which is a cube 4 feet each way with a pyramidal-shaped bottom. They each hold 200 pounds of zinc which has been dipped in a 2-per-cent. lead acetate solution. A white precipitate is formed as well as the gold in these boxes, especially in the first boxes on the weak side. This precipitate, carrying some values, consists mainly of calcium ferrocyanide, zinc hydrate, calcium sulphate, calcium carbonate, and fine slime. When the clean-up is made this is separated from the gold by means of riffles in the launders through which all is washed, then dried, and shipped to the smelter while the gold is given a sulphuric-acid treatment, run into a filter press and sent to

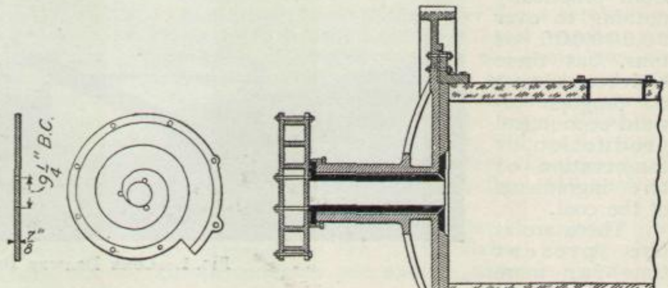

FIG. 3. SPIRAL FEED ATTACHED TO TRUNNION OF TUBE MILL

the melter. The sulphuric acid used is saved and at intervals cleaned up, this operation paying well for the effort.

The costs of treatment as given by Professor Chauvenet for July, 1907, are as follows:

	Cents
Tailings to mill	13.07
Tube milling	13.48
Treatment*	6.31
Solution†	11.54
Melting and precipitation	12.08
Bullion expense	.14
By-products	.43
Total	57.05

The October, 1907, costs were as follows:

	Cents
Tails to mill	16.90
Tube milling	11.22
Treatment	3.94
Solution	8.41
Melting and precipitating	9.98
Bullion expense	.16
By-products	.17
Concentration on blankets	.22
Total	51.00

During October, 11,540 tons of ore were treated and the total costs for a portion of the above were included in the following items: Zinc, $370.43; sulphuric acid, $30.82; potassium cyanide, $528; lime, $211.44; pebbles, $73.57; power, $723.72.

Since October the costs have been less than 50 cents per ton and it is believed that they will soon be down to 40 cents per ton. The consumption of cyanide is ½ pound to the ton treated and the consumption of zinc 0.14 pound to the ton.

In the winter the dump is frozen and operations are discontinued in the cyanide department. It is quite probable that some unwatering device will be installed before another winter unless indeed the whole method of treatment be changed and chlorination tailings are no longer produced. The mill is equipped with a complete experimental plant and experiments are being constantly conducted on a large scale so that it is not entirely beyond the bounds of reason to expect the chlorination process to be superseded by some other at the Portland mill.

*Treatment includes that portion of electric power given to the pumps, water, storehouse, lights, portion of pay roll including watchman, three machinists, one sluicer, one foreman.

†Solution takes its proportion of electric power, salary of superintendent, all the cyanide and about the same on pay roll as "Treatment."