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Slime Agitation and Solution Replacement Methods at the West End Mill, Tonopah, Nev.

BY JAY A. CARPENTER,* E.M., TONOPAH, NEV.

THIS paper deals with only one step in the treatment of ore at the West End mill; not because the other steps are repetitions of practice in other mills, but because in this particular step there is in use the Trent agitator. This device, although it has apparently failed in many mills, is here giving excellent service and has proved to be well adapted for making a thorough replacement of pregnant solution with a minimum amount of barren solution. The strong and weak points of this agitator, its present simple construction, and its use as a thickener for agitator or battery pulp are features of interest; but perhaps the point of greatest interest to the metallurgist in this day of continuous decantation is its use in a series of tanks for slime treatment by the replacement method.

The agitating department of the West End mill consists of six redwood tanks, 24 ft. in diameter, 18 ft. high, each equipped with a Trent agitator, a centrifugal pump, and a motor. The pulp is transferred by a pump from the top of a flat-bottomed tank to a set of arms and nozzles in the bottom of the tank, at just sufficient pressure to cause the arms to revolve. The streams from the many nozzles keep the bottom of the tank clean, and these streams, coupled with the effect of the revolving mechanism and the ascending current, keep the pulp in constant motion and of constant gravity.

These agitating tanks hold 90 tons of dry slime and 202 tons of solution with a 1.24 pulp, our ore having a specific gravity of 2.7. This capacity is about 10 per cent. in excess of the standard 15 by 45 ft. Pachuca tank. The tanks are connected in one series for continuous agitation, the pulp for each agitator being drawn by its pump through a branch suction from near the top of the preceding tank and delivered to the bottom of the tank by the agitator arms along with the regular pulp of that agitator. This method works automatically, since the flow through the branch suction varies directly with the difference in head of the two tanks. The chance for new pulp to pass out quickly is, therefore, much less than in many other systems of continuous agitation, since the new

* Mill Superintendent, West End Consolidated Mining Co.

pulp is delivered at the bottom of the tank, the discharge from the tank is near the top, and the ascending current is uniform and slow.

The pulp is delivered to the first agitator of the series at a gravity of 1.26 by a set of diaphragm pumps, which raise the pulp to a height of 10 ft. above the top of the battery-pulp thickeners, whence it flows first in an open launder and then in a pipe to the suction of the first agitator pump. At intervals in the open launder are placed pieces of battery screen at an angle, which, with those placed at the lip of the diaphragm pumps, catch and remove nearly all the lime scale, wood pulp, and like material from the slow-traveling thickened pulp.

The pulp from the last agitator is raised by an air lift to a Dorr thickener, 28 ft. in diameter and 22 ft. deep, where the pulp is thickened before filtering.

The slaked lime and half the lead acetate are added direct to the scoop box of the tube mills, while the greater portion of the cyanide and the rest of the lead acetate are added at the lip launder of the diaphragm pumps, and the remainder of the cyanide is added in the third agitator. For heating the pulp, live steam is introduced into three of the agitators, Nos. 1, 3, and 5, the purpose being to keep the temperature during agitation around 110° to 120° F., in order to hasten extraction and obtain good extraction with the use of lower-strength cyanide solutions. These high temperatures are readily maintained in a Trent agitator and are not uncomfortable to the operators, since the heavy coat of foam on the agitators acts as an insulating blanket, keeping the pulp from radiating its heat or moisture, as it does in many other types of agitators. The condensed steam adds to the tonnage of mill solution, but it freshens the solution by dilution of impurities and it is needed to replace the solution that is mechanically lost from the filter.

Once a day, at 4 a.m., pulp samples are taken from agitators Nos. 1, 3, 5, and 6, which are thoroughly washed and dried and made ready for the assayer at 7 a.m. Normally, these assays show respectively 50, 25.5, 19, and 15 per cent. of the valuable content of the agitator heads.

Air for the proper aeration of the pulp is compressed to 16 lb. in a compressor of 100 cu. ft. piston displacement, and is fed into the discharge pipe of the agitator pumps. By the time the air is discharged from the nozzles it is thoroughly dispersed in the pulp as minute air bubbles. These air bubbles slowly make their way to the surface and escape into the foam. This well-distributed aeration, in contrast to the short contact of pulp with air in any air-lift type of agitator, is much in favor of the Trent. The pumps of the agitators can be made to suck their own air by throttling the main pulp suction, but in a large installation it is probably more economical to use an air compressor.

The original agitators as installed in 1911 were of the Trent underfeed type, with the large grit-proof bearing in the bottom of the tank and with the arms fitted with 15 ¾-in. nozzles. While these agitators gave excellent service, there was a gradual wear, which necessitated repairs on the grit-proof bearing, due to absorption of the air in the air chamber and consequent rise of slime pulp to the ball race. An occasional cleaning of the nozzles was also necessary, due to their choking with bits of wood pulp,

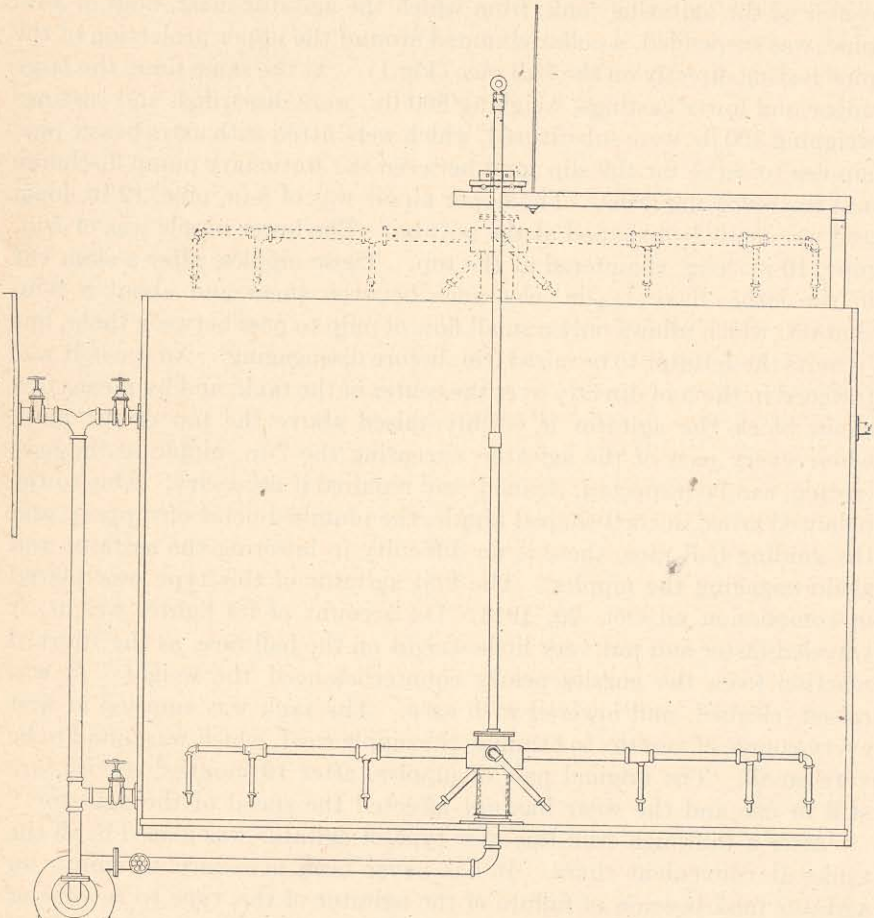

FIG. 1.—TRENT AGITATOR, CARPENTER TYPE.

waste, and chips, as a nucleus, surrounded and packed tight by sand from the pulp. On a charge system these repairs could be taken care of easily when the tank was emptied, but when the continuous system was adopted it was necessary once in two or three months to empty each agitator into the following unit by the aid of the transfer pump, and make these repairs, to avoid the danger of an agitator stopping at a time when there was not room in the mill circuit to empty it. The author, after seeing a Trent agitator suspended from a ball race at the Tonopah Extension mill, because the lower submerged ball race was worn out, conceived the idea and built a new type of this agitator which could be raised, cleaned, and dropped back into position without disturbing the pulp level in the tank. It consisted of a ball race, on timbers over the center of the agitating tank, from which the agitator mast, built of 3-in. pipe, was suspended, a collar clamped around the upper projection of the pipe resting directly on the ball race (Fig.1). At the same time, the large upper and lower castings, weighing 800 lb., were discarded, and castings weighing 300 lb. were substituted, which were fitted with extra heavy pipe nipples to serve for the slip joint between the stationary pump discharge and the revolving arms. The upper nipple was of 8-in. pipe, 12 in. long, and was made bell-shaped at the bottom. The lower nipple was of 7-in. pipe, 10 in. long, chamfered at the top. These nipples, after a skim cut in the lathe, have $\frac{1}{64}$-in. clearance between them and about a 9-in. contact, which allows only a small flow of pulp to pass between them, but permits the agitator to be raised 9 in. before disengaging. An eye bolt was fastened in the roof directly over the center of the tank, and by means of a chain block the agitator is readily raised above the top of the pulp, where every part of the agitator, excepting the 7-in. nipple in the base casting, can be inspected, cleaned, and repaired if necessary. Due to the balanced arms, the bell-shaped nipple, the plumbed point of support, and the guiding ball race, there is no difficulty in lowering the agitator and again engaging the nipples. The first agitator of this type was placed in commission on Oct. 20, 1913. On account of its lighter weight, it traveled faster and put very little weight on the ball race, as the upward reaction from the nozzles nearly counterbalanced the weight. It was raised, cleaned, and lowered with ease. The tank was emptied at first every couple of months to examine the nipple wear, which was found to be very small. The original pair of nipples, after 19 months' service, are still in use and the wear has not affected the speed of the agitator.

After a thorough trial this new type of agitator was placed in all the tanks at convenient times. It has never been necessary to empty an agitator tank because of failure of the agitator of this type to revolve or keep the pulp agitated. The oldest agitator of this type had operated 10 months (on May 15, 1915) and three others nine months without lowering the pulp in the tank; and, judging from the speed of rotation and the feel of the bottom of the tank, they are good for months to come. When the agitator has been in operation for from four to eight weeks a rod drawn along the tank bottom will strike ridges, which are indications of choked nozzles. After raising the agitator and cleaning out an average of a half-dozen choked nipples, the agitator is lowered to within 6 in. of its usual depth until the cleaned nozzles have cut away the ridges.

These agitators have been shut down for hours at a time and have started off after a few minutes' aid in making the first revolution.

This new type of agitator has now been adopted by the Trent Co. as its standard design, adding to the previous good points of this agitator those of simplicity, durability, and reliability.

The pump used on the agitator is a 4-in. centrifugal, driven by a 10-hp. motor. This pump, made by a local foundry, is lined, and has a white-iron open runner. The liners have given an average life of eight months and the runners and shafts of six months; the cost of upkeep of the pump is about $5 a month. At first, the pumps were driven at 525 rev. per minute and required 6.5 hp. At present, the speed is 460 rev. per minute, taking 5.8 hp., and keeping the pulp all of the same specific gravity with the aid of the 1.2 hp. used for compressed air. The speed can be dropped to 360 rev. per minute with good agitation, but not with the constant specific gravity desired for continuous agitation. There is often a false economy in cutting power costs of grinding or agitation a cent a ton, with a probable consequence of twice that loss in extraction. The actual power used, figured as motor input, is 7 hp. per agitator, or about 1 hp. for each 12 tons of ore or 42 tons of pulp. At the Goldfield Consolidated mill 200 tons of ore in a 1.5 to 1 pulp has been agitated for 7½ hp., or 1 hp. for 26⅔ tons of ore or 66⅔ tons of pulp.

Several of the earlier failures of the Trent agitator were due to too small an area of nozzle discharge and to improper sizes and speeds of the pumps used. The following tests will illustrate some of the points governing the Trent agitator. With the agitator equipped with 15 ¾-in. nozzles, with the pump running at 450 rev. per minute, and with 3 ft. of pulp in the tank, the pressure on the pump discharge was 7¾ lb. With the pump stopped, the pressure from the static head on the discharge was 1½ lb. The actual increase of pressure, due to the pump, was 6¼ lb. With the pump running and the discharge valve slowly closed, the pressure increased to 15 lb. and the power decreased one-half. With the agitator run under similar conditions, but equipped with 1½-in. nozzles, giving four times the discharge area, the pressure on the discharge pipe was 2½ lb., or only 1 lb. increase of pressure above the static head; yet the agitator turned at the same speed of 2 rev. per minute and the motor input of 5.6 hp. remained the same. The reason for the power remaining the same is that a centrifugal pump, running at a given speed, takes approximately the same horsepower for a wide range of heads, but the efficiency, it is to be remembered, varies greatly within this same range. The reason for the agitator running at the same speed is that the greater volume pumped in the second case, acting under less pressure, exerted as much turning force as the lesser volume under greater head.

Figuring from nozzle formula, the quantity discharged in the second case was twice that in the first case, giving, therefore, twice the upward velocity in the tank. The stronger the upward velocity, the more uniform the specific gravity of the pulp. It is evident, therefore, that a large nozzle area, with a pump designed for handling a large volume at a low head and slow speed, is the best combination, and such a pump, made along the lines of the modern Traylor sand pump, should not need repairs for a period of a year. In both the above cases, as the agitator was filled from 3 ft. in depth to 17 ft., the pressure on the pump discharge increased, but nearly in the same amount as the static head, giving the same difference or actual working head, the same power, and the same agitator speed. Consideration of these points takes the successful installation of this agitator and its pump out of the realm of guesswork.

At times, when the mill heads were high, it became necessary to replace pregnant with barren solution. The battery-tank solution fed to the glands of the pumps acted as an increasing diluent in the continuous circuit, but did not remove pregnant solution. The top suction of the agitator is about 4 ft. below the top of the tank, and by cutting off the air to the agitator this top 4 ft. becomes a static thickener, ending abruptly in the moving pulp at the agitator suction line. The pulp in the tank from this line down will have a constant gravity without the aid of the air. A decanting pipe placed in this top 4 ft. of the agitator removed the pregnant solution direct to the silver tank. The decanting of a full 3-in. pipe stream can begin 30 min. after the air is turned off.

With a crowding of tonnage for several months to over 200 tons a day, which was beyond the capacity of the thickeners ahead of the agitators, the overflow of the four 8-ft. Callow cones in the concentrating department was diverted from the thickeners direct to a well, 2 ft. in diameter and 3 ft. deep, in the center of the above agitator, which was No. 2 in the series. This pulp was very thin and contained the lightest particles of the ore; yet, with all this pulp flowing into the top, this agitator delivered the mill flow of ore in a thicker pulp and of a lower value of solution to No. 3 agitator than it received from No. 1, and, while keeping its pulp in constant agitation for 14 ft. of its depth, it delivered a clear stream of pregnant solution to the silver tank. At another time for several months, with less tonnage but a higher grade of ore, No. 4 agitator was fitted with an overflow launder, and a well, 2 ft. in diameter and 4 ft. deep, to take the feed from No. 3 agitator. The agitator was run without air, with top suction closed, bottom suction open, and a bottom discharge to No. 5 agitator. The pulp entered the agitator at 2½ to 1, and was discharged at 1 to 1 to agitator No. 5, where barren solution was added. The extraction in the tank remained the same as before, when it had air, which, in my opinion, was due to the fact that the greatest extraction had taken place by the time it reached this agitator, and the air included in the pulp was sufficient for extraction. I have known a Dorr thickener, placed in the middle of a series of agitators, to make a greater extraction than the preceding agitator. However, when the air has been cut off No. 1 Trent agitator in our series, only half the usual extraction has been made. The No. 4 agitator pump on this work was cut to 340 rev. per minute, taking 3.5 hp.; yet the agitator started up in its 1.45 pulp after a shutdown as rapidly as the other agitators with only 1.25 pulp. The reason for this is that as the gravity increases the viscosity also increases, hindering the settlement of the heavier sandy particles, which are further handicapped by a diminished difference in gravity between themselves and the surrounding pulp. On this basis, with a proper thickening of the pulp, pyrite concentrate can be readily agitated in a Trent agitator, as is being done at present at the Original Amador Consolidated Mines Co. mill at Amador, Cal.

The next and final step in replacing of solutions was proposed to us by L. C. Trent, the inventor of the agitator. The idea was to feed to the agitator pump a ton of barren solution for each ton of ore fed to the tank, to overflow from the tank the whole tonnage of solution fed to it, and to discharge a 1 to 1 pulp from the bottom of the tank, the solution in which should be the barren solution fed to the pump. This was to be secured by feeding the new pulp to a distributing umbrella on the surface of the pulp in order to feed it in a thin sheet, traveling nearly horizontally, and by having the bottom suction draw pulp from all over the tank by means of a perforated bustle pipe inside the tank, these two doing away with all strong currents. A bypass between the discharge and the suction of the pump would regulate the speed of the agitator, and a series of manifold valves would regulate the flow of barren solution to the pump. A 1 to 1 pulp would be established in the bottom 6 ft. of the tank, and above this a sharp change to thin pulp, and then to clear solution at the top of the tank. The new pulp entering the tank would enter on the surface, only causing a ripple. The solid content would settle through the clear zone into the thick pulp below, but the solution would overflow into the launder, since there would be no downward current, due to the fact that as much solution was introduced at the bottom of the tank as was removed. For a similar reason, the solution fed in at the bottom would find no rising current, and, being mixed with the pulp, would be discharged as an integral part of the discharge pulp. By this method, the inventor reasoned that it would easily be possible to make a 90 per cent. replacement of the dissolved silver entering the tank.

At the time of this visit, every agitator was needed for agitation purposes, the canvas-leaf filter was doing good work, and, lastly, we had little faith in making a high replacement of pregnant solution by this method, for all the many efforts along this line had been failures; and it was generally conceded that the diffusion of solutions of equal gravity took place so quickly and so completely that such a scheme was not practical. However, these replacers were installed at the Gold Cross and

Imperial Reduction Co. plants near Ogilby, Cal., and news of their successful operation came to us not only from the company headquarters, but from the traveling fraternity of millmen looking for a job.

In February, 1915, with a decrease in tonnage, No. 4 agitator was fitted up for a trial as a replacer. With the agitator filled with 1.20 specific gravity pulp, containing 203 tons of solution assaying 7 oz. silver, the feed of pulp and the air were cut off, and the bottom suction opened. Three hours later, when the pulp in the bottom of the tank reached 1.36 specific gravity, a flow of barren solution, assaying 0.13 oz. silver per ton, was admitted to the pump at the rate of about 3 tons an hour. At the end of 12 hr. the gravity at 4 ft. from the bottom was 1.36, at 8 ft., 1.11, and at 12 ft., clear; and the solution assays were 3.94, 4.57, and 6.97 oz., respectively. In 36 hr. there had been added a little over 100 tons of solution, and the specific gravity at 4 ft. from the bottom was 1.34; at 8 ft., cloudy; at 12 ft., cloudy, and the overflow clear; and the solution assays were 1.79, 2.52, 6.21, and 6.6 oz., respectively. Since there was no discharge from the tank, the addition of barren solution had to be slow to keep from thinning the pulp in the bottom of the tank. The replacing action is distinctly shown by the assays. At the end of this time pulp feed and pulp discharge were started into and from the replacer. The results of the next two days' work are shown in Table I.

The sharp reduction in the value of the ore, due to the extraction made in the replacer, makes it difficult to calculate the efficiency of the replacement, but, since most of the ore is in the bottom 6 ft. of the tank in the barren-solution zone, it is probably true that most of the dissolved silver goes out with the discharged solution.

During the second day there was more solution discharged from the tank than barren solution fed into the pump, and the effect is shown by the assays.

On the third day the agitator slowed down, and shutting the bypass did not increase the speed; yet the turning pressure of a man's hands on the ball race would turn the agitator faster. It pointed clearly to a choked suction pipe, which, with an inventor's optimism, was submerged under 12 ft. of pulp. Not being able to continue the experiment, the top suction was opened and the agitator started off at 3 rev. per minute. The result of the experiment demonstrated that a barren zone could be maintained in the bottom of the tank and a high percentage of replacement made, but it also showed that the capacity of the 24-ft. tank was limited to 60 tons of ore per day at a 2½ to 1 dilution, in order to keep a clear overflow, and proved that the mechanical arrangement was defective.

To improve the mechanical defects, the author designed both a new arrangement for the incoming pulp and a new suction for the replacer pump. Instead of the umbrella, a well, 2 ft. in diameter and 4 ft. deep, was placed at the center of the tank around the mast. The bottom was made solid and the sides perforated with ¾-in. holes. An arm was put on the mast, which kept the bottom of the well clear.

The suction of the pump was carried around the outside of the tank as a bustle pipe, with the diameter proportioned to the flow. Twelve 1½-in. branches entered the tank at the floor level and ended at varying lengths in upturned ells. Each branch suction was connected to the main pipe by a plug cock, and each had a ¾-in. connection for testing the flow and for connecting high-pressure water if it was choked.

On Mar. 5, 1915, the replacer was started again with these changes. The new well still introduced the incoming pulp horizontally, but below the surface, giving a greater distance down to the slime line at the overflow launder. The new suction made it possible to test and keep open the 12 suction ports at all times, and left nothing inside the tank to give trouble. The agitator, being the new style, was capable of being raised out of the tank for cleaning the nozzles, and for repairs if necessary, and dropped back without affecting the solution zones in the tank. In starting the experiment, the introduction of the barren solution, as before, gradually established a barren zone, or, rather, in this case, a zone of low grade at the bottom, increasing in value upward in the tank. This suggests a method for very small plants, such as used on old dumps, of using the replacer as a thickener first, an agitator second, and lastly as a replacer, discharging after making a second replacement with water. After establishing the barren zone, the feed into and discharge from the replacer were started, and the results obtained are shown in Table I.

A detailed study of the table brings out many interesting features of the replacer. A feed of replacing solution considerably in excess of discharge solution for the period of a shift results in a marked lowering of the solution value in the thick pulp and a decrease in that of the thin pulp, while the opposite condition of feed will increase the value likewise. The sharp change in the silver content of the solution is between the thick 1 to 1 pulp and the thin pulp above it, for the reason that the diffusion in the thin pulp is rapid. Hence, there is no advantage, in installing a replacer, in having any more depth above the 6 ft. of thick pulp than is necessary for the settling of the ore. It is possible to discharge the pulp thicker than 1 to 1, but it takes more power applied to the pump to turn the agitator. With a positive drive overhead, taking very little power, the pulp could be discharged as an 0.8 to 1 pulp or thicker with better replacing results.

In order to calculate the replacement of solutions in these tests, two methods are used as checks: First, dividing the ounces overflowed by the ounces fed; second, dividing the ounces discharged by ounces fed. However, before doing this, the ounces extracted from the ore and the ounces fed in with the replacing solution should be divided between the ounces overflowed and ounces discharged. These two items amount

TABLE I

Time Date	Shift	Pulp Feed								Overflow Solution			13 Ft. Valve	
		Spec. Grav.	Ratio Solution to Ore	Ore			Solution							
				Tons	Oz. per Ton	Total Oz.	Tons	Oz. per Ton	Total Oz.	Tons	Oz. per Ton	Total Oz.	Spec. Grav.	Oz. per Ton
First Test:														
1/28	3–11	1.24	2.25	22.7	4.90	122	51.2	7.91	405	70.0	6.66	466	1.05	5.66
	11–7	1.23	2.37	21.9	4.56	100	51.8	7.41	384	61.0	6.60	402	1.05	5.63
	7–3	1.21	2.63	24.2	4.14	100	63.8	7.02	448	50.0	6.47	323	1.05	5.82
24 hr.		.....	.....	68.8	4.68	322	166.8	7.42	1,237	181.0	6.58	1,191	.....	......
1/29	3–11	1.19	2.95	18.1	4.02	72	53.1	6.82	362	74.0	6.36	471	1.06	6.29
	11–7	1.21	2.63	18.6	4.49	83	49.1	6.88	338	34.0	6.35	216	1.06	6.50
	7–3	1.20	2.78	21.5	4.41	95	59.9	6.82	408	50.0	6.83	341	1.06	6.59
24 hr.		.....	.....	58.2	4.31	250	162.1	6.83	1,108	158.0	6.50	1,028	.....	......
Second Test:														
3/7	24 hr.	1.25	2.15	63.6	2.23	142	108.0	5.62	607	120.0	4.40	530	1.07	4.59
3/8	7–3	1.25	2.15	22.7	.....	.....	49.0	6.84	.....	50.0	.....	.....	1.09	......
	3–11	1.22	2.50	21.5	.....	.....	54.0	6.84	.....	51.0	.....	.....	1.09	......
	11–7	1.23	2.37	18.6	.....	.....	44.0	6.84	.....	45.0	.....	.....	1.11	......
	24 hr.	1.23	2.34	62.8	2.32	146	147.0	6.84	1,005	146.0	5.20	760	.....	5.24
3/9	7–3	1.23	2.37	19.0	.....	.....	45.0	.....	.....	.....	.....	.....	1.09	......
	3–11	1.21	2.63	17.9	.....	.....	42.0	.....	.....	.....	.....	.....	1.10	......
	11–7	1.23	2.37	16.5	.....	.....	43.0	.....	.....	.....	.....	.....	1.10	......
	24 hr.	.....	.....	53.4	2.32	124	130.0	6.80	882	155.0	5.60	866	.....	5.72
3/10	7–3	1.20	2.78	16.8	.....	.....	45.0	.....	.....	.....	.....	.....	.....	......
	3–11	1.20	2.78	19.1	.....	.....	53.0	.....	.....	.....	.....	.....	.....	......
	11–7	1.19	2.95	20.6	.....	.....	61.0	.....	.....	.....	.....	.....	1.09	......
	24 hr.	.....	.....	56.5	2.24	126	159.0	5.66	900	184.0	5.30	970	.....	5.28
3/11	7–3	1.18	3.13	18.0	2.24	40	56.0	5.62	314	55.0	5.39	296	.....	5.30
Totals:														
First Test......		.....	.....	127.0	4.50	572	328.9	7.13	2,345	339.0	6.54	2,219	.....	......
Second Test....		.....	.....	254.3	2.30	585	600.0	6.18	3,708	660.0	5.17	3,416	.....	......

to considerable in our tests, because we were not equipped to add barren solution, and, secondly, the ore still lacked sufficient agitation to be ready for filtering. Since the replacing solution is fed to the bottom of the tank, and assays show that it remains there as a partly barren zone, and since over 90 per cent. of the ore is in the bottom half of the tank and a large part of it in contact with the barren replacing solution, it is fair to presume that over 80 per cent. of the replacing solution and ore extraction go out in the discharge and 20 per cent. reaches the overflow.

In the first test, 27 oz. of silver was introduced with the replacing solution, and 112 oz. of silver was yielded to the solutions by the ore, or a total of 139 oz., 20 per cent. of which is 28 oz. and 80 per cent. 111 oz. Silver to the amount of 2,345 oz. was fed with the pulp solution, and of this 2,219 oz. less 28 oz. was overflowed, giving 93.2 per cent. replacement. Figuring by the second method, of the 2,345 oz. of silver fed, only 310 oz. less 111 oz. of it was discharged, giving 91.5 per cent. replacement.

In the second test 43 oz. of silver was introduced with the replacing solutions and 158 oz. of silver derived from the ore. The silver fed with the pulp solution was 3,708 oz. and of this 3,416 oz. less 40 oz. was over-

TABLE I—*Continued.*

9 Ft. Valve		4 Ft. Valve		Pulp Discharge								Replacing Solution		
				Spec. Grav.	Ratio Solution to Ore	Ore			Solution					
Spec. Grav.	Oz. per Ton	Spec. Grav.	Oz. per Ton			Tons	Oz. per Ton	Total Oz.	Tons	Oz. per Ton	Total Oz.	Tons	Oz. per Ton	Total Oz.
1.29	4.99	1.41	2.41	1.38	1.29	5.1	4.13	21	6.6	2.10	14	14.0	0.20	3.0
1.23	4.04	1.43	2.34	1.45	1.03	10.2	4.17	42	10.4	2.22	23	18.7	0.20	3.7
1.07	4.88	1.42	2.40	1.42	1.13	26.5	4.01	106	30.0	2.17	65	20.2	0.23	4.6
......	......	......	......	......	......	41.8	4.07	169	47.0	2.19	102	52.9	0.21	11.3
1.06	6.04	1.45	3.00	1.43	1.10	21.4	4.02	87	23.6	2.60	61	16.3	0.27	4.4
1.07	6.25	1.49	3.20	1.46	1.00	22.9	3.93	90	22.9	2.73	62	15.3	0.29	4.4
1.09	6.25	1.45	3.10	1.42	1.13	29.5	3.91	114	32.9	2.60	85	25.0	0.29	7.5
......	......	......	......	......	......	73.8	3.95	291	79.4	2.62	208	56.6	......	16.3
1.17	4.44	1.47	1.83	1.46	1.00	43.4	1.70	74	43.4	1.52	66	50.4	0.16	8.0
1.12	......	1.45	......	1.43	1.08	22.8	......	......	24.4	1.30	32	25.5	......	......
1.10	......	1.46	......	1.46	1.00	24.0	......	......	24.0	1.52	36	21.3	......	......
1.11	......	1.48	......	1.48	0.94	20.4	......	......	19.2	1.58	30	20.2	......	......
......	4.60	......	1.91	......	......	67.2	1.92	129	67.2	1.46	98	67.0	0.16	10.7
1.10	......	1.45	......	1.46	1.00	19.5	......	......	19.5	1.63	32	23.9	......	......
1.12	......	1.48	......	1.48	0.94	13.5	......	......	12.5	1.72	21	24.0	......	......
1.10	......	1.48	......	1.49	0.92	13.3	......	......	12.2	1.70	21	22.6	......	......
......	5.63	......	2.36	......	......	46.3	1.92	89	44.2	1.68	74	70.5	0.15	10.5
......	......	......	......	1.48	0.94	13.0	......	......	12.2	1.53	19	19.0	......	......
......	......	......	......	1.47	0.95	20.2	......	......	19.0	1.45	27	24.6	......	......
1.10	......	1.52	......	1.51	0.87	17.3	......	......	15.0	1.67	25	22.0	......	......
......	5.02	......	1.80	......	......	50.5	1.90	96	46.2	......	71	65.6	0.16	10.5
......	5.00	......	1.90	1.50	0.89	20.9	1.90	39	18.7	1.37	26	22.0	0.17	3.7
......	......	......	......	......	......	115.6	3.98	460	126.4	2.46	310	109.5	0.25	27.4
......	......	......	......	......	......	228.3	1.87	427	219.7	1.52	335	275.5	0.16	43.4

flowed, giving 93.2 per cent. replacement. Figuring by the second method, of the 3,708 oz. fed, only 335 oz. less 160 oz. of it was discharged, giving 95.3 per cent. replacement.

In actual practice there is always a little silver in the replacing solution, and, as has been found in the continuous-decantation method, there is always an extraction from the ore, no matter how long it has been treated before decantation. These items were not considered in the foregoing calculations, as they were exceptionally high under our conditions. Again, in the tests, 11 per cent. more replacing solution was added than was discharged, which could be done with the final water replacing, due to the building up of solution tonnage.

However, it was established to our satisfaction:

1. That replacing with the Trent apparatus is practicable.

2. That it is easy to control and regulate the replacer; the one important factor being to regulate the solution fed to the pump and that discharged from the replacer. In a plant designed for this system this would be a much easier matter than in our case.

3. That on a quick-settling pulp it would handle a remarkably large

tonnage as far as adding the necessary barren solution is concerned, but that on a pulp carrying a fair percentage of light, flocculent slime it is limited in tonnage to the rate at which the light, flocculent slime will settle in a neutral or no-current tank. In a Dorr thickener there is a downward current to aid settling. At the new mill at Aurora, Nev., the light slime hardly settled in a Dorr thickener, and practically remained in suspension in the Trent replacer.

4. That mechanically the replacer worked very satisfactorily, but that changes could be made to cut down the power consumed and yet make the rotating action more positive.

5. That with a mixture of Tonopah ores, 60 tons of ore in a 2½ to 1 pulp, with 60 tons of replacing solution, was all that a replacer 24 ft. in diameter and 18 ft. high could handle with a clear overflow and a 1 to 1 discharge.

The use of this agitator for replacer experiments necessitated bypassing all but 60 tons past this agitator, and caused a loss in extraction that made it necessary to stop the experiment without a working test extending over a few weeks' time; but the author believes the same results would have continued, as everything about the installation was capable of easy adjustment and repair.

Before changing back to an agitator, the replacer was run as an ordinary thickener with a 1 to 1 discharge, all replacing solution and gland water being cut off the pump, and the speed of the agitator cut to one revolution in 5 min. Hose lines were strung to add a large tonnage of solution to the 60 tons of ore in a 2½ to 1 pulp. To run as a thickener and make 90 per cent. replacement with a 1 to 1 discharge, the 60 tons of ore would have to be diluted to a 10 to 1 pulp by the addition of 450 tons of barren solution to the 150 tons of pregnant solution. About a 7 to 1 pulp was all that could be supplied without interfering with mill operations, but the slime line rose rapidly from 4 ft. below the surface up to the overflow launder. The 60 tons capacity of the replacer had appeared disappointing, but the test showed it to be a good tonnage on this particular ore compared with replacement by dilution; but it also confirmed the author's conviction that on an ore containing considerable flocculent slime the various replacing methods will have a strong rival in the older leaf and pressure filters that make an easily washed cake from the mixture of the flocculent and sandy components of the ore.

The great advantage of the replacer over the thickener-dilution method is in the smaller installation required, and the small amount of barren solution required compared with the large tonnage of barren and partly barren solution of the dilution method.

The main drawback to the replacer system has been, first, lack of faith in its principles, and second, lack of faith in its mechanical features.

To one that has operated the replacer it is easy to understand that in a

1 to 1 and thicker pulp, the pulp is so thick that the ore and solution are approaching a solid, and that the viscosity of the pulp is so great that the solution is not free to move above amid the ore particles, but, rather, is constrained to move with them; and that, once the barren solution is whipped into the pulp by the pump, it tends to remain locked up in it. The pump is of such a size that the difference in specific gravity between its suction and its discharge is only a couple of hundredths, so that the discharge pulp has no tendency to rise in the tank. This explains why the Trent method is a success and why other methods of adding the replacing solution directly into the bottom of a tank have failed.

The last year has brought about a marked improvement in mechanical simplicity and reliability in the mechanism of the replacer. One strong objection to it, compared with the dilution system, is the power required to operate it. However, this does not seem excessive when one considers the saving of the power that is consumed in handling and precipitating the large tonnages of solution required by the dilution methods. The author believes the power consumption of the replacer can be made nearly as low as that required by the equivalent number of thickeners, by the simple device of not depending entirely upon the pump to rotate the agitator, but to drive the agitator from overhead by a worm drive similar to that of the Dorr thickener and to use the pump more as a mixer and circulator of pulp, running it at a slower speed and with larger nozzles on the agitator. Our experience was that it required about 3 hp. on the motor to turn the agitator at only 1 rev. per minute in a 1 to 1 pulp, when a man with a 1-ft. leverage on the mast could turn it with ease. Why, then, should pump nozzle velocity be relied upon to turn the agitator when its proper function should be that of mixing the barren solution into the pulp and giving only the turning effect derived from that function? The pump, with a slower speed and lower working head, should need only annual repairs.

With these modifications, the author believes that the replacer will become an accepted machine in the treatment of slime that is not too colloidal in its nature.