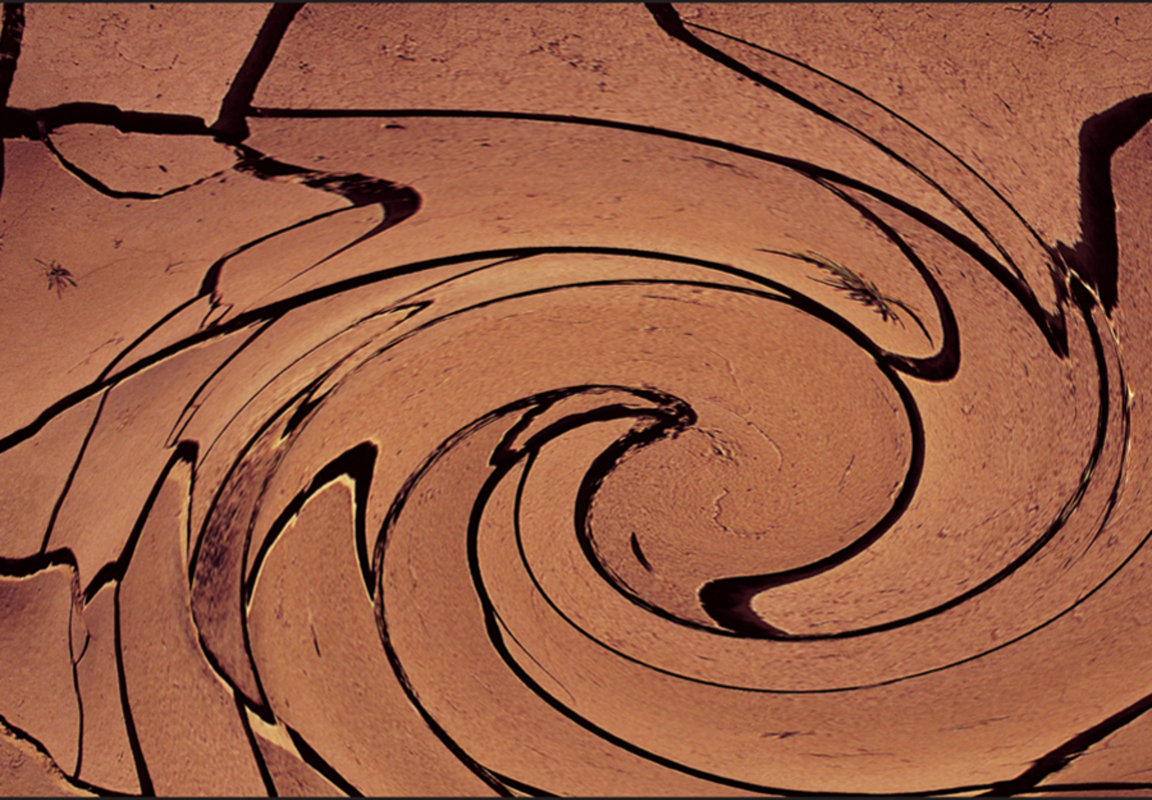
# The Circulating Load

## Practical Mineral Processing Plant Design by an Old-Time Ore Dresser

Robert S. Shoemaker



SME

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# PREFACE

In 1964 when I became chief metallurgist of Bechtel's Mining and Metals Division in San Francisco, I was fortunate to be able to see not only the minerals processing plants that Bechtel was designing and building but many others designed and built by other engineering firms. When I was in an area that had such plants other than the one I was visiting, I found that the managers and mill superintendents of these plants were most hospitable in showing me their operations and freely answered any questions I asked. During those visits I observed many clever ideas in plant design developed by the plant operators and other engineering firms and also many mistakes that resulted in higher capital and operating costs. The mistakes, by the way, were not limited to other engineering firms as we were not by any means omniscient and bloodied our noses as often as did others.

As a result of these observations and in order to improve our engineering capabilities, I started writing down what I (and some of my metallurgists) had seen and distributing the ideas not only to my people but also to the chief engineers in our other disciplines. These publications were called *The Circulating Load* and, very often, clients who had seen them would ask for back copies and to be put on the mailing list. These people would often copy them and send to their friends in the industry.

On the cover sheet of each issue were the words "Published frequently in the interest of fewer spills in the mill."

In this rewrite I have recaptured the best incidents from the past and added some observations and recollections from the last twenty years as a consultant. It is hoped that these practical methods will be of help to all the mill men who have made the mineral processing industry what it is today.

# 1

# PRIMARY CRUSHERS

We got one of our best ideas concerning primary crushers from a 54- × 74-inch gyratory crusher installed at the Ray Mines division of Kennecott Copper. This crusher had a rubber belt feeder under its surge pocket—one that we believe to be the first ever installed. It was 6 feet wide and about 80 feet long and was also used as a picking belt to remove timbers that came from the old underground mine. The total height of the installation from the belt feeder floor to the top of the dump pocket was 63 feet. The belt, which also handled old drill steel and miscellaneous scrap iron, had a life of about 14 months and handled 10 million tons in that time.

When we were designing the Similkameen copper plant in British Columbia for Newmont, Frank McQuiston and I spent many hours discussing the possibility of using an 8-foot-wide belt under the 54- × 74-inch gyratory crusher we planned to install there. There were several advantages that finally tipped the scales to the belt feeder rather than an apron feeder. The belt feeder was 40 feet long so that it permitted the downward-sloping takeaway conveyor to be straight instead of having a reverse vertical curve. The belt feeder required less height than an apron feeder, did not require the height for a takeaway conveyor under an apron feeder, and lastly, because of its width, permitted more live storage and less height in the surge pocket under the crusher. The capital cost savings was very substantial, and the total height from the feeder floor to the edge of the dump pocket was only 59 feet. When we last heard, the belt feeder had handled 120 million tons of the hard, jagged Similkameen ore without an hour of unscheduled downtime. The few gouges it had sustained were repaired with liquid rubber during regularly scheduled downtime. Newmont had purchased a spare belt, and Rolly Nice, the plant manager, told us that if the belt should ever need replacing they could probably never unroll the spare belt as it was so old. A few months after this crusher was completed, Gibraltar also installed an 8-foot belt feeder under their new crusher, and we used a belt feeder under the third gyratory at Palabora. Many other belt feeders have been used by others since then. Unfortunately, a few apron feeders are still being installed under primary crushers.

This (the Similkameen) was the first gyratory crusher we ever installed without using an overhead crane. Newmont had purchased an 80-ton mobile crane to lift the bodies on their 100-ton trucks, and this crane was capable of handling the 45-ton crusher mantle. After a year's operation we talked to Similkameen's manager and mill superintendent and asked their opinions on the crusher installation. They told us that when they arrived on the site before operations had begun they had been very apprehensive about maintaining the crusher, and visitors from other British

Columbia copper plants had predicted doom and destruction when they had seen this “cheap” installation.

Actual operation had, however, proved all their prognostications wrong. The first relining job using the mobile crane had taken 48 hours—no record of course, but very creditable, considering it was the first crusher relining job for the maintenance crew. They were certain the second relining could be done much faster. (A similar first relining job we know of using an overhead traveling crane at another plant required 87 hours.) To say the least, the manager and superintendent were very pleased.

## 2

## HOW TO CLEAN UP A DIRTY DUMP POCKET

Dust collection or suppression at primary crusher dump pockets has always been such a problem that many people have simply ignored it with the idea that dump pockets have always been dusty and always will be. (At the time of this re-editing, in 2002, the rules have been radically changed and such dusty conditions are rarely tolerated. However, the ideas presented here are the best we have ever seen and could be of use at a number of mines I have seen recently.) The problem here is the enormous, but momentary, need for dust collection volume during and shortly after a truck dumps its load into the crusher. Then, until the next truck arrives, there is no further demand on the system. The magnitude of the problem can be appreciated by taking a look at the 60- × 89-inch gyratory installation at Anaconda's operation at Butte, Montana, where a 62,500 cubic foot per minute baghouse is used to collect dust from the two dump pockets. Another baghouse of the same size is used inside the crusher building. Dust suppression could not be used because of Butte's low temperatures.

The people at Palabora in South Africa have approached the problem in another way that is highly successful. After trying various water sprays, including an enormous shower head that sprayed water directly over the truck body as it was being dumped, they finally settled on an adaptation of a commercially available dust suppression system but without the wetting agent usually employed. (The wetting agent had a deleterious effect on flotation.) The dump pockets (there are three 54- × 74-inch gyratories with two dumping positions at each crusher) have thirty-three 150-pound-per-square-inch (psi) nozzles on each end directly under the rear of the truck body in its raised position, and four 60-psi nozzles on each side. As each truck dumps, the eight side nozzles spray 10 gallons per minute (gpm) and the 33 end nozzles spray 50 gpm for a dosage of about 1 gallon per ton of ore. Dust suppression around the pockets is excellent, although overspray causes some wetness in the area. During freezing weather, which doesn't occur at Palabora, overspray could cause some problems, although it would seem that these could be overcome by judicious use of infrared heaters. Extensive subzero weather could probably preclude the use of any water at all, and dust might have to be collected instead of suppressed.

## 3

## SAMPLING A BALL MILL

Measuring the pulp density of the ground ore produced by a ball mill has been pretty much impossible. The operator can't very well dip the sample out of the mill nor can he hold the sample can beneath the mill trommel. It is also impossible to dip a sample out of the cyclone feed sump since water is always being added at this point.

At Cortez Gold Mines, the mill superintendent found an inexpensive and easy method that permits the mill operator to take pulp samples at will. We cannot guarantee complete accuracy of the sample, but certainly it is sufficiently accurate for mill control and, undoubtedly, if there is an error in sampling, it is always a consistent error.

As can be seen in the sketch in Figure 1, a piece of 3-inch angle iron was installed with the open side up and at a slope under the mill discharge trommel. The angle iron acts as a launder, catches a portion of the pulp that comes through the trommel, and delivers it into a funnel located just outside the splash guard around the trommel where the sample is taken. The funnel then directs the sample reject into the cyclone feed sump. The falling stream of pulp is always visible to the operator so that he can observe changes in its consistency.

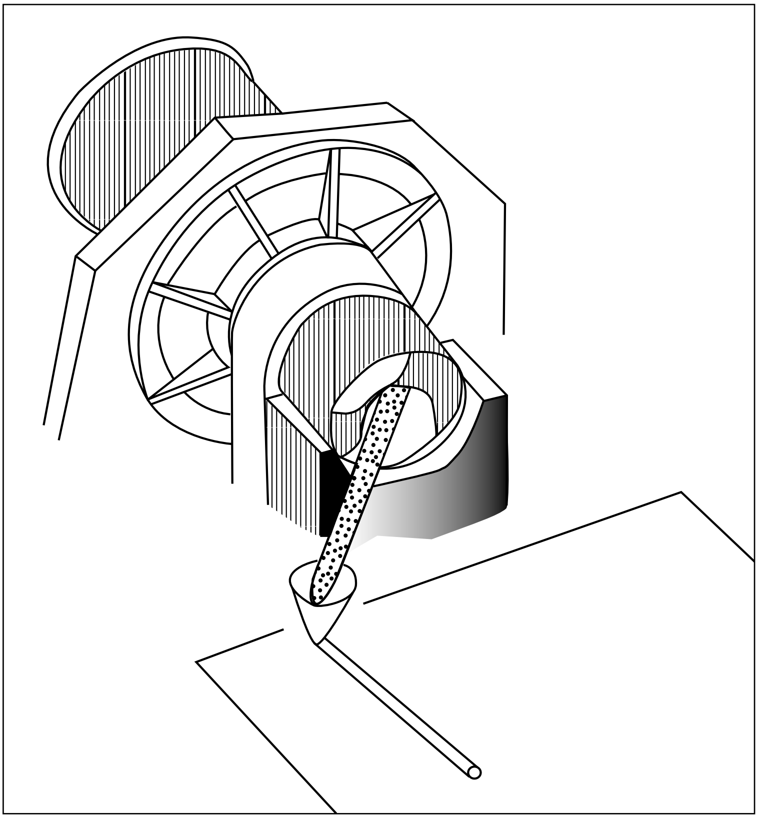


**Figure 1 Installed Angle Iron**

# 4 VIBRATING FEEDERS

The vibrating feeder, either electric or mechanical, is not a feeder in the true sense of the word but is actually—sometimes—a vibrating, self-destroying transport device. It is also inexpensive to install. Unfortunately, it is quite often employed in the vain hope of feeding material at a constant rate. This is where the trouble starts. Before any vibrating feeder is designed into an installation, it must be remembered that its feed rate will be radically affected by

- the moisture of the ore
- the size consistency of the ore
- the line voltage (in the case of an electric feeder)
- the height of the ore in the bin above the feeder
- the amount of clay in the ore
- the bulk density of the ore
- the desired feed rate (an electric feeder works best at about 70 percent of its rheostat setting).

At one gold plant the client insisted on installing a 5- × 22-foot mechanically vibrated feeder to draw run-of-mine ore from a bin and feed it to a 44- × 48-inch overhead eccentric jaw crusher. The feeder was equipped with grizzly bars set at 4 inches on its discharge end. The client stated that the ore would be relatively dry, but the ore as mined turned out to be extremely sticky most of the time. In operation, fines compacted and built up on the feeder pan and muck ran over the sides and back of the feeder, which created an enormous cleanup problem. The buildup on the pan radically reduced the feeder capacity and resulted in downtime to jackhammer out the compacted ore fines.

After several months of trouble, a fairly successful operation was finally obtained by tilting the feeder 9 degrees toward its discharge end and installing gas heaters under it. These two changes, plus that of installing a stainless-steel feeder deck, are about the only ones that can remedy a vibrating feeder malfunction caused by sticky ores. In this case fines still compacted and built up on the feeder pan and the constant attention of one operator was necessary to prevent overfeeding or underfeeding of the crusher.

At an iron ore plant, 4- × 6-foot mechanically vibrated feeders were specified by the client to minimize capital cost, and they were installed under bins holding 4- to 5-inch ore containing 15 percent moisture and $-{}^{5}/_{16}$-inch ore containing 15 to 20 percent moisture. The ore minerals were hematite and goethite. Here again, ore fines compacted on the feeder pans, but, in this case, vibration from the feeders was transferred to the column of compacted ore, then to the bin itself, and finally to the building. Vibration of the roof was severe. Extensive stiffening of the structure was required as well as rebuilding the feeder suspension systems. It was also necessary to apply heat under the feeder pans.

There are certain advantages to vibrating feeders and certain applications where they can be employed successfully. Vibrating feeders are low in initial cost and sometimes in maintenance costs. They require little headroom and don’t require dribble belts. However, extreme caution should be used in designing them into an installation, and manufacturers’ claims should be thoroughly investigated. No reputable manufacturer will guarantee the feed rate accuracy of a vibrating feeder.

# 5

# NOTES ON CONVEYORS

Vertical takeups on conveyors carrying sticky ores (and even dry ores when the conveyor gets overloaded) can only lead to trouble. The same can also be said for solid-faced tail pulleys. Vane-type tail pulleys and tail pulley takeups should be employed, or even screw takeups can be considered, if room for tail pulley takeups is lacking. Vertical takeups cause major cleanup problems under them (even with ores that are not sticky), and in combination with solid-faced tail pulleys, they will damage belts because chunks of ore get wedged between the pulleys and the belts. Vee-scrapers on top of the return side of the belt can be of help but are not 100 percent reliable. Incidentally, upside-down vee-shaped aprons between the carrying and return sides of a belt are preferred to flat aprons for preventing stalled idlers caused by piled-up muck. Don't ask us how that much material gets there, but it always does.

At an aluminum plant that I saw under construction the engineer (who shall go unnamed) designed what I call a fire-throwing slingshot. A 1,200-foot-long belt conveyor was intended to transport alumina ($Al_2O_3$) from the end of a ship unloading pier to a transfer tower between two large storage bins. A conveyor extended to each of the bins from the transfer tower. Because of the length of the first conveyor a vertical takeup pulley was located just outside the tower so that maintenance on the pulley could be performed from a working platform on the tower. Unfortunately, the counterweight was installed just below the pulley to accommodate the stretch in the long conveyor.

Just before the installation was completed, a worker who was using a hot wrench somewhat indiscriminately set fire to the creosote-treated timbers of the pier. Disaster, in the form of a Rube Goldberg chain reaction, followed immediately. The fire quickly spread to the belt, which burned in two. With the belt broken, the takeup pulley and the counterweight went through the safety stops and fell 75 feet to the ground. This, in turn, whipped a hundred or so feet of belt (with its burning end) into the transfer tower. Then the burning tangle of belt set fire to the two other belts. Only quick action by the construction crew in cutting these belts saved the day. One of the side effects of all this excitement, of course, was the fact that the construction superintendent blew his top like a Fourth-of-July skyrocket. The “fix” in this case was to install the counterweight much material closer to the ground so it wouldn’t fall so far.

Now, we will admit that this fiasco was a one-in-a-million accident; however, the moral of the story is that you must always try your best to make your plant design “people-proof.” You won’t succeed, of course, but you can try, can’t you?

During a visit to the Otanmaki Oy magnetite and ilmenite plant in Finland I saw one of the most ingenious conveyor belt transfer points I had ever seen. Magnetite filter cake had to be conveyed and elevated to a bin in the pellet plant. The plant didn’t use a vertically curved conveyor belt but instead dropped the filter cake onto a horizontal conveyor. Just behind its head pulley and above it they installed the magnetic tail pulley of an inclined conveyor. The concentrate traveled along the horizontal belt, and when it came to the magnetic tail pulley, it hopped up on the second conveyor with absolutely no spillage or dribble. No transfer chute was needed, and 8 feet of elevation was gained! Now why didn’t I think of that?

Speaking of conveyor transfer points, did you know that in many cases skirt boards are not needed if the transfer chute is designed right? After all, skirt boards only attempt to correct a misloading of the next belt that shouldn't have happened in the first place, at the expense of wearing two grooves on the belt. We have to admit that most mill men will not believe this but we have proof that it is true. At the Electric Furnace Products Company, a very large ferroalloy producer in Norway, skirt boards were removed from 27 conveyors handling chromite, fluxes, and very sticky manganese ores. The solution? Transfer chutes with "bootjack" shapes on their bottoms. They are simple to build and shape the ore on the next belt so that no skirt boards are needed. The design for this gadget is shown in Figure 2.

Most conveyor belts have a return idler close to the head pulley to increase the wrap on the pulley. At a transfer point to a second conveyor, many designers will locate the head pulley of the first conveyor too close to the tail pulley of the second conveyor, which means that the first return idler is behind the tail pulley of the second conveyor. Unfortunately, idlers will also act as belt cleaners, and material stuck to the first conveyor will end up in a pile under the transfer point and have to be cleaned up by an operator who should be operating instead of being a janitor. If a little more money had been spent on a slightly longer conveyor, there would have been nothing to clean up, because material removed by the idler on the first belt would have fallen onto the second belt.

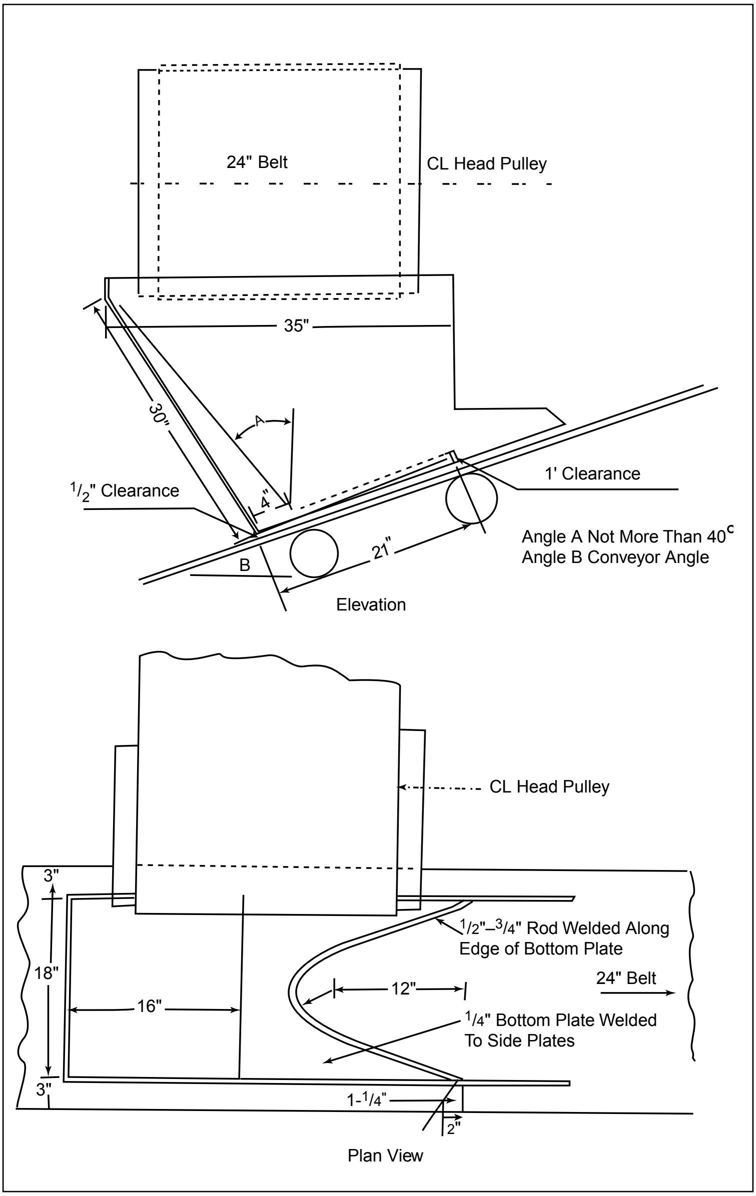


**Figure 2 Plan View**

As the demand for minerals increases, the ore bodies that are being found seem to get lower in grade, and the lower metal content seems to go hand-in-hand with an increase in material-handling difficulties. Some examples of this are the nickel-bearing laterites and some of the western coals, both of which stick to conveyor belts like glue. This brings to mind a method we used in Oregon to wash the return side of an extremely dirty conveyor belt that transported a low-grade nickel ore from a reclaim pocket to a dryer.

As shown in the sketch in Figure 3, water sprays were directed at the return side of the inclined belt over a 15-foot area just downhill from the head pulley. A collecting pan was installed under the belt and a couple of rubber wipers or squeegees were used to wipe the excess water from the belt. At the downhill end of the pan, the washings entered a pipe that followed the conveyor to ground level where they entered a 16-inch diameter spiral classifier set at right angles to the belt and positioned so that the settled solids dropped onto the load on the conveyor. Only slimes overflowed the classifier, and they were flocculated and thickened in a settling cone and pumped to the dryer.

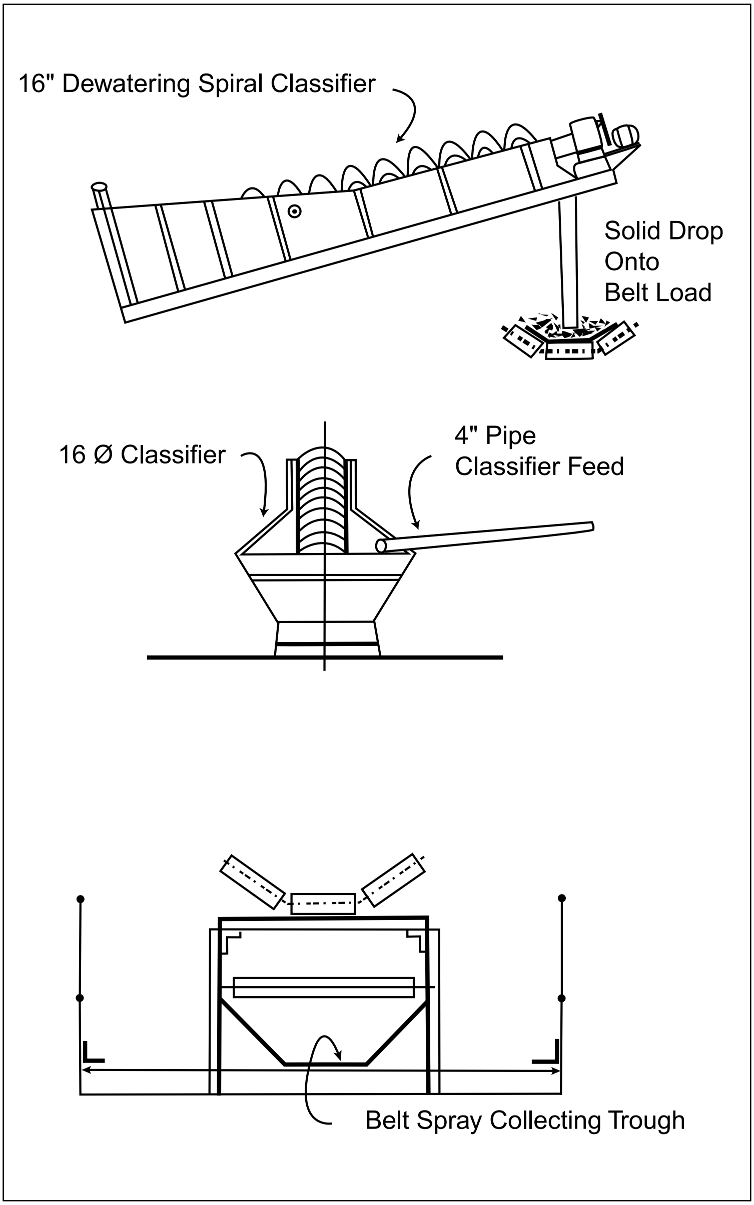


Figure 3 Cleaning a Conveyor Belt

Admittedly, this system won't work on long conveyors during severe cold weather, but under warmer conditions it will save the owner a bundle in cleanup and maintenance costs.

# 6

# STORAGE BINS

Ore storage bins and silos are often the bane of mill operators as the following example will demonstrate. It didn't appear in *The Circulating Load*, for obvious reasons, but since over 30 years have gone by, I believe it is now OK to recount a story that should be of interest to those people who have to handle sticky materials.

A joint venture of two power companies (A and B) hired Bechtel to build a coal-fired power plant and another engineering firm to build the coal-washing plant that fed the power plant 16,000 tons of washed coal per day. Power Company A operated the power plant and Power Company B operated the mine and the washing plant. The coal beds contained veins of kaolinite as much as 3-feet thick that had to be removed by the washing plant. The washing plant didn't work, and the construction superintendent (an old friend of mine) who was running the washing plant (it hadn't yet been turned over to Power Company B) was at his wits' end trying to fix it. Finally, Power Company A insisted (over the objections of Company B) that Bechtel send someone to look at the washing plant and give it (Company A) a report. I was chosen to make the trip even though I had no coal-washing experience, and when I arrived, Company B's vice president in charge of the mine and washing plant let me know in no uncertain terms that my presence was not appreciated. I was able to find the trouble with the washing plant in one day, but that's another story.

The 100-ton coal trucks dumped their loads into a toothed roll crusher and the resulting 6-inch raw coal (containing substantial moisture) was conveyed to a 40-foot-diameter × 90-foot-high circular concrete silo, which was supposed to feed the coal to the washing plant. The kaolin and moisture made the raw coal so sticky that it wouldn't come out of the bin, and the engineers had installed extremely high pressure air lines at various points up and down the silo. The air was released in bursts by a timing device, and it sounded like a 6-inch howitzer being fired. I noticed 6-foot-diameter black "spider webs" on the silo centered over the air inlet pipes through the concrete wall of the silo. Obviously, fine coal particles were oozing through cracks in the concrete. Before I left the washing plant I went to see the vice president of Power Company B and told him I thought the bin was in danger because the air was cracking the silo instead of loosening up the coal. In fact, the air was compacting the coal. He roundly cursed me, saying the spider webs were only surface imperfections, I had no business saying anything about the silo, and to get the hell off the property.

When I returned to San Francisco, I told the manager of engineering about the situation and he immediately called a meeting, attended by a couple of civil-structural engineers and a couple of lawyers. They concluded that because I had seen what I believed to be a dangerous situation, we must formally inform Power Company B or we would be liable even though we had no part in building the silo. I wrote a letter to the vice president (edited by the lawyers) and sent it off air-mail special delivery. At nine o'clock the next morning I received a phone call from the same vice president who had chewed me out royally. This fellow said that he would see to it that Bechtel would never get another job from his company. At ten o'clock, the silo collapsed. There wasn't a piece of it that was larger than a man's head. No one was injured, which was fortunate, but the result was both hilarious and fitting.

The mine office was close to the silo and elevated about 4 feet above the ground, and a concrete ramp with 2-inch pipe handrails gave access to the building. The vice president had parked his brand new Buick in front of the ramp, and when the silo collapsed, its contents had fluidized. It pushed the Buick into the handrail and bent the car in a right angle. The handrail wasn't damaged at all!

Since that time I have seen many devices that inject air into chutes and bins to dislodge compacted fines, but very few of them have worked well. Sometimes a sheet of stretchy rubber can be hung in a very steep chute, and when the fines build up on the rubber, it will stretch, which breaks the fines from it. Sometimes an air cannon between the chute wall and the rubber will solve the problem. The real solution is to design the chute or bin properly in the first place, but that is not always possible because the designer doesn't always know what the ore characteristics will be when the mine starts up. Lime bins are commonly designed in a conical shape with small bottom openings, which is a sure way to get a plugged bin. The most common solution is to give the operator the biggest sledge hammer you can find and let him beat the hell out of the bin. The only solution that will work is to install a vibrating bin bottom. The manufacturer of these devices will guarantee they will work or they will refund your money.

Another problem area is the back of the chute under a vibrating screen. Damp fines from the first panels on a screen will often build up here and cause much downtime from cleaning off the compacted material. A piece of Linatex can be hung in a shallow catenary curve from the side plates of the screen to catch these fines and move them forward so they drop over the opening in the bottom of the chute. The weight of the rubber and the fines that are bouncing on it is not sufficient to unbalance the screen, and the wear on the rubber is not at all serious.

# 7

# THE DESIGN AND OPERATION OF FLOORS (FROM THE MILL OPERATOR'S STANDPOINT)

Floors are a good deal like the weather: everyone walks on them, but no one seems to do much about them. A floor is just as much a piece of operating equipment as a ball mill, but it is one with which the operator has contact 100 percent of the time. If he continually stumbles or slips on a badly designed floor, he will pay more attention to where he walks than to how much ore he puts through the mill. Badly designed floors are also common causes of accidents that result in sore rear-ends for the operators and sore heads for management. We have been taken to task about floors we have designed and have seen a number of others that were badly designed by our honorable competitors. Herewith are a few examples.

At one time we built a concrete floor in the reagent mixing section of a flotation mill. Now it is a little-known fact to other than mill operators that all flotation reagents have complicated names, like ammonium lignin sulfonate, oleic acid, sodium cyanide, and pine oil, and that they are often corrosive, poisonous, smell like a garbage dump, and are slippery underfoot. The floor in this area was a beauty—smoothly troweled and with an artistic curb around it. Unfortunately, there was no slope to the floor and no drain was installed. Because of leaking pumps and reagent spills, this floor soon became a messy, slippery, stinking wading pool for the mill operators. Get the point? An excellent reagent-room floor is sloped to a drain, has a curb around it and, best of all, a level grated surface elevated several inches above the sloping concrete floor.

For some odd reason, construction people cannot seem to read drawings about concrete floors. If the drawing calls for a $^1/_4$-inch-to-the-foot slope in one direction, the floor will very often have a $^1/_8$-inch slope in the opposite direction. If it doesn't, it will be approximately level or have low spots where large puddles of water collect. After a long battle, I finally got Bechtel to make $^3/_8$-inch slopes the minimum, with much larger slopes in areas around grinding mills where spills of slurry often happen. There is nothing worse for an operator than having to constantly wade through water and slurry when he is making his rounds, or to a maintenance man who has to lie down in the same stuff when he is repairing a piece of machinery.

In gold plants, where the ore almost always contains mercury, concrete floors where mercury is handled should always be perfectly smooth and hardened and the walls should sit on curbs that are cast integrally with the floor so as to leave no cracks where mercury can collect. Ventilation should be done by pressurizing the room with an elevated fan, and the air should be exhausted near the floor through openings in the walls so as to sweep out the heavy mercury vapors and keep them from being inhaled by the operators. Lying down on this job can be fatal.

Speaking of mercury, a very famous and extremely competent metallurgist (whose name every gold metallurgist would know if I mentioned it) once told me that during World War II he worked in a mercury recovery plant in southern California that treated cinnabar flotation concentrates from Mexico. Part of his job was to tend the hoeing table where the mercury was separated from the dust from the condensers and to fill the mercury flasks for shipment. Normally, hoeing tables are located outdoors, but the one in this plant was in a room with no ventilation except from an open door. To make things worse, the people who built the plant had installed gas jets under the table so the heat would help coalesce the mercury droplets. He said that if anyone should have contracted mercury poisoning, he should have. On the other hand, he said that he never had syphilis. Then he added that there must be some connection because there had never been a recorded case of a tuna fish getting syphilis either!

Now back to floors. For some unknown reason, designers like to install grating floors in crushing plants next to conveyors handling the crushed ore. Dust and fines will indeed fall through gratings but, on the other hand, rocks of any size will not. Rocks will jam halfway through the grating, making it impossible to shovel up spills and also providing a surface that can cause dangerous falls for the operators. These floors should always be made of checkerplate, and even though they cost a little bit more, they will make the plant a much safer place to work.

At one plant I visited, grating was used for a floor in a conveyor and tripper gallery over the fine-ore bins. The bins had conical tops, and dust in the gallery settled through the grated floor to fall on the conical bin covers. Vibration caused the dust on the bin tops to slide down the covers and fall in a continuous shower on the mill floor and personnel working there. The owner was installing, at his extra cost, sheet steel over the grating.

We saw another extremely poor design of a floor in the filtering, drying, roasting, packing, and shipping area of a molybdenum concentrator. Now, molybdenum disulfide occurs in flat, platy crystals that have very low coefficients of friction, which is why it is used in many greases. The concrete floor in this area was troweled smooth, and spilled molybdenite made it slippery to the point of being very hazardous. In addition, the gratings used on elevated floors and stairs were of the flat-top variety and were also extremely slippery. In this case, the concrete floors should have been only wood-float finished, and the gratings and stairs should have had a surface similar to expanded metal, which would have given sharp edges to walk on. Smooth nosings on stair treads are hazardous in any installation.

Everyone seems to have a different idea about how to make sloping concrete floors (such as are installed in feeder and conveyor tunnels under stockpiles) safe to walk on. These ideas generally take the form of boards nailed crosswise to the floor, ridges in the concrete, or small trenches cast in the concrete. All of these items result in two problems: a hazardous walking surface and a surface that is impossible to sweep clean. Sloping concrete walkways should be rough-wood floated until the slope becomes too steep, then long steps should be used. The sloping portion and the steps should also slope crosswise to a drain for easy housekeeping.

Occasionally, we still see grating-covered floor trenches installed in new plants. There is never enough water in floor trenches to move the solids that fall into them, and the grating covers always have the longest dimension of the slot running at right angles to the trench. Now there are probably many sound engineering rules that say the slots should run this way, but any mill operator will tell you that these theories are all wrong. The quickest way to clean out a trench is to walk along it with a fire hose, but when the grating slots run crosswise to the trench, the stream from the hose cannot be directed at the proper angle to be used effectively, and the cleanup man either has to remove the gratings or get soaking wet while doing a poor job. Since only a percent or so of the readers of this epistle have ever washed down a floor trench, it is difficult to get our and the mill operator's point across.

However, we are sure that all of you male readers have splashed your trousers from the slots in that generally poorly designed wall-mounted object in the men's room. The principle here is the same. In most cases, floor trenches are far more of a nuisance than they are worth. With adequately sloped floors and sufficient drains, and with provision for removing coarse rocks and trash, the expense of installing floor trenches can generally be dispensed with.

If floor sumps are to be provided with level controls, be sure to locate them in an active area of the sump. If they are located on the side or in a corner, more times than not they will sand up and become ineffective.

All these examples point out that a floor is not just a floor to be designed with no thought behind it. Every floor should be specially designed for the particular area in which it is to be used. A "pre-floor conference" between the civil, mechanical layout, and metallurgical engineers on the job will save the mill operator many headaches and spills, and make his job much easier. After all, isn't that the object of your job?

# 8

# DETERMINING VELOCITIES IN PIPELINES THE EASY WAY

With the invention of the magnetic flowmeter, it is easy to determine velocities in pipelines, but sometimes you may want to determine velocities where there is no flowmeter. The equipment used to accomplish this measurement is quite simple—a length of 1-inch pipe, some electrician's plastic tape, a battery, two stopwatches, a pint-sized plastic bottle, an electric blasting cap, some potassium permanganate, and a helper. The plastic bottle is half-filled with the permanganate, filled to the top with water, and sealed with a screw cap. The bottle is then taped to the end of the pipe, and the blasting cap is taped to the bottle next to the pipe. The stopwatches are started at the same time, and your helper takes one of the watches to the discharge end of the pipeline. When you are sure that he has reached the end of the pipeline, you place the bottle in the sump at the intake of the pump. The blasting cap is then exploded and, at the same time, you stop your stopwatch. The bottle will break and the permanganate solution will immediately enter the pipeline and travel as a slug through the line and exit at the end as a brilliant purple color that is visible in all but the blackest of slurries. Your helper stops his watch when he sees this color emerge from the pipeline and a simple calculation then gives you the velocity through the line. This method is extremely accurate and is far better than putting the permanganate in a paper bag and shoving it down into the sump, as we have seen some people do. The bag often breaks before you can locate it, right at the pump suction, and the color is too diluted to observe accurately at the end of the line. We were attempting to measure a pipeline velocity using the paper bag method and encountering entirely irreproducible results when a friend of ours by the name of Bob Coleman, who was General Patton's chief safecracker during his march across Europe, observed our frustration and came up with the blasting cap idea. It works every time!

## 9

## NOTES ON FINES

If we didn't have to cope with fine ore particles, it is most probable that we all would lead much less interesting lives. Fines are the source of dust, mud, blinded screens, plugged chutes, choked bins, ruined bearings, designers' headaches, and operators' short tempers. Most probably there is only one thing that is worse than an ore full of fines, and that is an ore that has been dried and then ground so that it is all fines. We have encountered this condition at several plants and can only hope that we will never encounter it again. In order that we avoid the egg-on-the-face syndrome on future projects, it might be good at this time to review some of our past flopolas and perhaps a basic principle or two.

First, fines don't ever behave like they're supposed to. Just because fines are said to have a bulk density of 90 pounds per cubic foot doesn't mean that they actually weigh that much. With a little aeration such as they can receive in an elevator boot or a transfer chute, they can weigh as little as 50 pounds per cubic foot, and with a little vibration such as they receive from a few conveyor belt idlers, they can easily weigh as much as 100 pounds per cubic foot. Then, too, their quantity can go up and down like a yo-yo as the ore varies in softness or hardness or comes from a different location in the mine. In short, fines are pretty troublesome things to have around, but since they will always be with us, we might as well learn to live with them.

## BELT CONVEYING OF FINES

Dried and ground ore can be carried on a conveyor belt if care is taken in the conveyor design. For instance, a ground ore must be loaded onto a horizontal section of a conveyor, and a good rule of thumb is to leave a bare minimum of 8, and preferably 12, feet of horizontal belt before a vertical curve is even started. Additionally, the belt should be skirted and have a minimal trough or no trough at the loading point. Troughing should be increased to 35 degrees as the belt enters the curve. By taking these steps, the fines will deaerate themselves before they start up the hill and will stay on the belt where they are supposed to be.

Loading fines on an inclined belt can lead to disaster. Instead of going uphill with the belt, they often go downhill in waves like water, because the air that sucked in under the fines by the moving belt completely fluidizes them so they cannot possibly cling to the moving surface. An installation like that caused us a lot of trouble a couple of years ago. Fortunately, we were able to lessen the conveyor angle sufficiently so that it would carry the ore. To do so, however, we ended up with a 4-foot clearance for a walkway that was under the conveyor which will result in a lot of bumps on heads during the life of the plant.

## FINES IN BUCKET ELEVATORS

Aeration and subsequent fluidity of fines can also cause equipment other than conveyors to cease to function or become grossly undersized. For instance, aerated fines being fed into an elevator that is too closely sized (most of them are) will overflow the buckets as their volume exceeds the carrying capacity of the elevator. Then, as the level of fines in the boot rises to the tail shaft, the down-coming buckets pump more air into the fines, which increase further in volume so that more air is entrained ... ad infinitum.

## BINS FOR FINES

On one of our trips beyond the shores of the United States we saw at one plant four cone-bottom, table-feeder-equipped bins that were supposed to hold 500 tons each of dried and finely ground copper ore. Filling these bins was a somewhat harrowing experience because until they contained about 120 tons of fines, the ore was sufficiently uncompacted that it squirted like water out of every crack and opening around the table feeders. This in turn meant that the table feeders could not be operated with the bins lightly loaded. The weight of more than 120 tons would compact the fines sufficiently so that the table feeders could operate effectively. The operators weren't very happy because they had 480 tons of storage capacity that couldn't be used, and the owners weren't happy because they had paid for that 480 tons of useless capacity. A vibrating bin bottom and a vibrating tube feeder for shutoff would have prevented all the hard feelings that were generated.

Oftentimes when a dryer is designed into a flowsheet, the designer says "that's that" and forgets all about it. But an ore will often emerge from a dryer containing one to several percent of moisture and having a temperature of 150 degrees or more. Now, suppose you convey this ore to a bin with a pneumatic transport system, and in order to collect the dust from the air as it emerges from the bin you install a baghouse on the vent. Besides containing dust, the stream of air will be high in moisture, which is evolved from the still-warm ore. As this air stream contacts the cooler bags, the moisture condenses in the cloth, and the bags blind instantly.

Unfortunately, we don't have a ready solution to this problem other than to install a scrubber in place of the baghouse, but then you must add a thickener and a filter and put the dust back into the dryer.

## PNEUMATIC CONVEYING OF FINES

At one time we encountered a very poorly operating pneumatic transport system for fine ore that contained a 50-foot section of pipe that was angled at 57 degrees from the horizontal. We learned long ago, by extremely bitter experience, that sloping pipes won't work on pneumatic fines-handling systems. At that time, after trying everything in the manufacturer's operating manual to cure a sick system, an old-timer told us to take out the inclined section of pipe and replace it with horizontal and vertical sections of longer total length. We did so and the problems were solved. It seems that the coarsest particles drag along the lower side of an inclined pipe at a much slower velocity than that of the fines that stay entrained in the air stream. Very quickly, a mass of larger particles accumulates on the bottom of the pipe, which then start to fall back or reflux. At this time a plugged pipe is only seconds away. Incidentally, for the same reason, inclined pipes should not be used to handle slurries.

# 10

# OVERENGINEERING

Recently we were talking with the manager of one of the larger copper concentrators in Arizona when he took off on the subject of overengineering and standardization and engineers who practiced the former but had no acquaintance with the latter. The particular reason for his wrath at that moment was $70,000 worth of conveyor head, tail, and other pulleys of every size, shape, and description that were cluttering up his warehouse and drawing much dust but earning no interest on the money he had spent for them. He said he was forced to carry this enormous inventory because the engineer-constructor had designed everything to the last gnat's eyebrow and he didn't think there were more than two pulleys of the same size in the place.

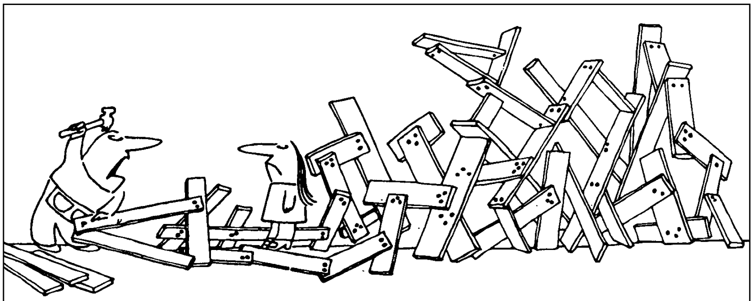
If we assume an average cost of $1,000 per pulley (the price in the late 1960s) in that warehouse, he would have seventy pulleys on hand and waiting to be used. Now, that seems to be a lot of pulleys, since equipment such as that isn't supposed to fail with any degree of frequency, so we questioned his need to have them all on hand. Here he had us. He said that even the pulleys were overengineered to the point that there weren't two dollars' worth of spring in each of them and they seemed to collapse with regularity. When considering that an hour's downtime on a large grinding mill can cost many thousands of dollars, we can see why he had to keep his own spares instead of relying on the manufacturer's supply in some other, perhaps distant, city.

We wonder what it would really cost the owner to have only one common diameter for head, tail, and bend pulleys for each conveyor width in his plant. Would it pay to standardize only 24-inch-wide, 36-inch-wide, etc., belts instead of buying these sizes plus in-between sizes also? Wouldn't it pay to buy the next larger size bearing for a few bucks more instead of paying time and a half plus call-out pay (to say nothing of lost production) to get a mechanic out of bed at two o'clock in the morning to replace a bearing that wouldn't take an overload?

We had the additional thought of standardizing about half the existing motor sizes we usually use, but our double-E chief down the hall rather pointedly asked if we wanted our conveyors to be yanked out by the roots when they overloaded and the oversize motors wouldn't overload and kick out. He went off mumbling something about high-voltage ore dressers.

Looking back on this now, we wonder if the problem wasn't the owner's fault by demanding that the capital cost be kept to a minimum. It could also have been the owner's fault by not having the mill and maintenance superintendents oversee the engineer during the design phase of the plant. This thought reminds me of a statement made many years ago by John Ruskin:

> "There is hardly anything in the world that some man cannot make a little worse and sell a little cheaper, and the people who consider price only are this man's lawful prey."



***"I'm a carpenter, ma'am; if you want anything particular built, you call an architect."***

# 11

# CAGE MILLS, IMPACTORS, AND HAMMER MILLS

Cage mills, impactors, and hammer mills are three of the least understood and most misapplied beasts in the stock-in-trade of the comminution engineer. When they are misapplied, and often when they are used correctly, they can cause more grief than any mill operator deserves. Other crushers, such as jaws, gyratories, cones, and double rolls that comminute by squeezing, do only that. But the three devices discussed here are almost dual-effect machines because they not only crush but in many cases they also pump annoying, and sometimes disastrous, amounts of air. Their rotors act as displacement blowers.

A case in point was a 1,500-horsepower double-rotor cage mill on a coal-crushing operation for a power plant with which we were concerned. This mill crushed a 2-inch feed to a nominal 3⁄8-inch size and at the same time pumped over 19,000 cfm of air down through its rotors and out with the crushed product. Collection of this large amount of air with its entrained coal dust would have been costly, especially since two more cage mills were scheduled to be installed on two adjacent crushing lines. The solution to the problem was sealing (as well as possible) the opening where the feed conveyor entered the feed chute above the mill and installing a recirculation duct from the hooded product conveyor skirts back up to the feed chute. Because there was negative pressure in the feed chute, positive pressure under the crusher, and a fairly well-sealed feed opening, the air being pumped simply circulated around and through the mill. A dust collector having a capacity of only a fraction of the quantity of the air being pumped by the mill took care of the in-leakage and solved the dust problem that had previously appeared almost insurmountable.

A hammer mill installation that we were asked to re-engineer had the same dust problem. It crushed limestone of 7 to 12 inches in closed circuit with two screens and produced 12 inches of dust a day on the floor. This hammer mill had the additional ability to throw rock back up the feed chute in such quantities that the new feed piled up around the head pulley of the feed conveyor, spilled onto the return side of the belt, and fell into the vertical takeup, causing serious belt damage. Unfortunately, there had been no plow installed on the return side of the belt to remove any rocks before they got to the takeup.

The rocks came back up the feed chute because it was designed so the crusher feed entered the hammer circle at an angle other than vertical. The hammer mill was reversible, as all of these particular types of crushers are, and when it was turning in one direction it worked fine, but when it was turning in the opposite direction, the hammers threw much of the material back up the feed chute. The fix, of course, was to redesign the feed chute to permit the limestone to fall vertically into the hammer mill. A recirculating air duct was also installed to solve the dust problem.

The distance the feed particles fall into an impact type of machine is extremely important. If the space is too small, the entering velocity causes extreme tip wear on the hammers or breaker bars. Additionally, the feed should be spread across the hammers or bars to prevent uneven wear on them as well as on the crusher liners. Designing the feed conveyor to direct its load onto a spreader plate will prevent this problem from happening. Wear on an impactor can be extreme, even with softer ores, and as its impact surfaces wear, the efficiency of the machine can drop off radically. In cases where this occurs, the use of a variable speed drive is indicated. An increase in speed, within limits, will often restore efficiency and increase hammer or breaker bar life.

Because an impactor ejects its crushed product at a high velocity, the question of whether or not to install a wear belt or an apron feeder under the impactor always arises. If a conventional take-away conveyor is used, the belt is generally traveling so fast that a clean belt surface is continually being exposed to the impact of particles being thrown from the crusher rotor, and high wear on the belt results. However, if the product belt is made wider than normal and travels slower, much of the impact of the ore particles will be absorbed on the bed of crushed ore that has already been deposited on the belt.

Don't get me wrong; I am not condemning all impact-crushing machines. They have their place in mineral processing. However, I have seen too many of them installed to crush materials that should never have been brought near an impactor. When I was only a year out of college and working for Union Carbide, I was asked to take a look at an impactor that was supposed to crush high-carbon ferrochrome and slag from 6-inch to 1½-inch size in a jig plant. Why the manufacturer ever agreed to sell the machine for that duty is beyond me. Its nine 90-pound hammers were completely wearing out in two hours. I worked with the manufacturer on the metallurgy of the hammers and finally came up with hammers that lasted 18 hours. We had to replace the machine with a super heavy duty cone crusher at considerable expense.

# 12

# ENVIRONMENTAL CONTROLS FOR GRINDING MILLS

With all the effort being put into cleaning up the environment these days, maybe the time is past due when we should start making the environment in a concentrator somewhat more palatable. Some of the worst-looking things in every plant are the mill and mill drive foundations. It seems that nine out of ten mill trunnion and bull gear seals leak, and the lubricant not only turns each foundation into a greasy mess but it runs down onto the floor and creates a serious slipping hazard for passers-by. Bad leaks will dump a substantial amount of oil that can get into the float cells via the floor sump pump and the grinding circuit. When this happens, one can occasionally hear voices raised in the vernacular as the mill superintendent wades through the froth on his way to a conference with the maintenance foreman.

Greasy mill piers, slippery floors, lost time from accidents, froth up to the hip pockets, and mill superintendents' tantrums could all be avoided if a sloping channel iron were attached to the edge of the top of each mill and mill drive foundation (much like a rain gutter on a house) to catch any oil leaks and direct them down a pipe to a barrel on the floor.

***"Sir, I'd like to report that the drive on No. 3 mill is throwing oil again."***

# 13

# THAT ODIOUS PUMP

The Oliver Diaphragm Slurry pump, usually called an ODS, is sometimes referred to as “that odious pump” when it is incorrectly installed and operated, which happens quite often for some unknown reason. With an understanding of how the ODS pump works and a few operating tips, the user can enjoy a dependable, trouble-free installation.

It would be difficult to design a simpler pump or one with fewer moving parts than the ODS—made up of a pump bowl with diaphragm, base tee, two check valves, a solenoid valve, and a timer (Figure 4). The sequence of operations is as follows:

1. Slurry flows by gravity into the pump, lifting the diaphragm as it fills the pump body.
2. Compressed air is admitted above the diaphragm through a timer-controlled solenoid valve, pushing the diaphragm to its lowest position. The slurry is then forced through the discharge check valve as the inlet check valve closes against the pressure.
3. When the diaphragm is in full contact with the lower part of the body, the flow from the pump ceases. At the same time the ball in the discharge valve drops back onto its seat, held by the discharge back pressure.

4. The solenoid valve de-energizes, exhausting the compressed air above the diaphragm, and the head of slurry on the inlet side again opens the inlet valve and fills the pump for the next cycle.

Such a simple principle of operation, but how easy it is to cause an engineering foul-up. The ODS fills by gravity, it pumps only half the time, and its capacity depends on the slurry handled and the way in which the pump is installed.

The rated pump capacities are based on handling water with a 3-foot positive suction head and a 30-foot discharge head. Capacities

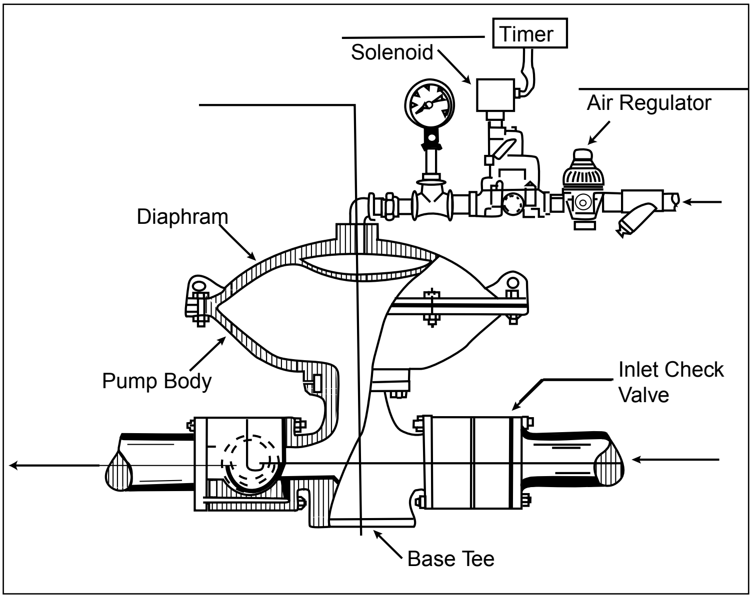


**Figure 4**

on a slurry will be reduced, depending on its viscosity, length of suction pipe, and required discharge head. Usually a 75 percent factor on rated capacities is safe. Remembering that the ODS unit pumps only half the time, the discharge piping should be sized for twice the actual flow. A good general rule is to use piping the same size as the discharge valve.

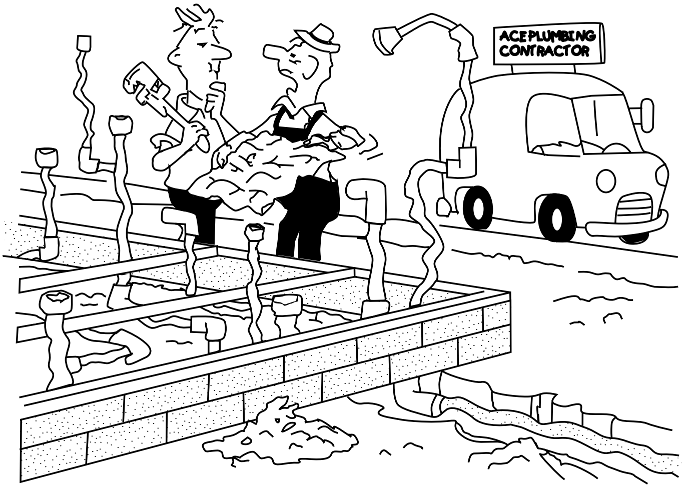
When using the ODS for a metering pump, as on a thickener underflow, be sure to have more head on the discharge side than the suction side, otherwise the underflow can run through the pump at a speed limited only by pipe friction. The usual arrangement is to install a gooseneck extending to the height of the thickener tank, being careful not to design in a siphon.

Operating instructions for the ODS should caution against the use of excess air pressure. The pump needs about 5 psi more than the theoretical discharge head requirement (neglecting suction head, of course). Higher-than-required air pressures drastically reduce the diaphragm and check valve life. High inlet or discharge heads may require air chambers to cushion vibrations. A diaphragm incorrectly installed with the “bulge” down will not work with normal suction heads. An oiler in the air line is good insurance against sticky solenoid valves.

# 14

# NEVER HIRE A PLUMBER WHO CLAIMS TO BE A PIPEFITTER

This reminds me of the time when we were just finishing up odds and ends at the Pinto Valley copper concentrator while the operators were starting it up. Copper concentrates were thickened at the plant and then pumped about four miles to a smelter where they were dewatered in two large disc filters. In order that holes in the filter cloth and leaks around it would not waste any of the concentrates, the filtrate was directed to a small thickener equipped with an ODS underflow pump that returned the concentrates to the filters. I got a call from the construction superintendent, who was highly irate; he said the ODS pump was too small and he had just ordered another one twice the size. I checked the drawings and the calculations and couldn't find anything wrong with them so I got on an airplane to Phoenix and drove to the plant, which was near Miami. The superintendent took me out to see the filters and, sure enough, the ODS was putting out a stream smaller than the size of a lead pencil and the thickener was almost full of concentrate. We then went down to see the 3/4-inch pump. There was only about 40 feet of 3/4-inch pipe between the pump and the thickeners, but the pipe contained fourteen 90-degree elbows and two 45-degree ells. Alan Taylor used to say that three 90-degree ells in a slurry line were equivalent in friction loss to a blind flange, and in this case, it was more than true. Engineer-constructors don't usually put 2-inch-diameter or smaller piping on the construction drawings, and the "pipefitter" who had done the job was really a locally hired plumber who had no appreciation of the science of pumping slurries. We replaced all those ells with two long sweep ells, the pump worked fine, and the superintendent had to cancel his order for a large pump.



***"Didn't it occur to you that the plans w ere WRINKLED, Reinhart?"***

# 15 PILOT PLANTS

Personnel from engineering firms frequently use data from pilot-plant operations for designing a full-scale plant. Data from pilot-plant testing may be supplied by the client, by independent research laboratories, or, in other cases, by the engineering people involved in the pilot-plant operation to develop their own engineering, metallurgical, and chemical data.

It is obvious that the information obtained from a small-scale operation can be no more accurate than the test work that is performed. As large expenditures may hinge on the results from a pilot plant, personnel assignments and monetary expenditures should be made to ensure that all required data is collected in a timely and accurate manner. Failure of a major installation that is based on inaccurate test data reflects no credit on the client or on the engineering firm involved.

When a small replica of a commercial plant is properly installed and operated, a wide range of essential information can be obtained, and the use of such pilot plants is common in many industries. This example will deal particularly with pilot plants used to develop techniques for the mineral dressing industry where such information can be obtained from a separate pilot plant, or, as in the case of many concentrators, a portion of the full-scale plant can be operated independently of the remainder of the plant and permit testing new processes, new techniques, or different reagents.

Many of the requirements for a reliable test installation are widely recognized as follows:

- Ore for the pilot plant must be representative of that to be treated in such characteristics as size, grade, mineralogy, hardness, and moisture content.
- Equipment must be properly proportioned in both size and number of units for the required treatment.
- Water-supply systems, such as those for water reclamation and recirculation, must be similar to those proposed for the full-scale treatment.
- All pilot-plant inputs, outputs, and process streams require weighing and sampling followed by accurate assaying of samples.

Deficiencies, of which the following are representative, can generally be found even in the most carefully planned pilot plants.

- In an effort to avoid the use of too-small equipment units, attritioning is commonly performed in one cell, conditioning in one tank, and flotation cleaning in one or possibly two flotation cells. Because of pulp short-circuiting, such equipment errors will indicate the need for more than the correct amount of time for attritioning, conditioning, flotation, etc., and will result in erroneous recoveries.

- Particularly when one section of an operating plant is used for test purposes, it is often inconvenient to arrange that it be equipped with its own return-water circuit, and water may be supplied from the general mill reclaimed-water system. Although such an arrangement is acceptable under some circumstances, in others it can give erroneous test results through failure to develop a proper build-up of detrimental impurities in the test-plant water circuit.
- Unless special care is taken it often develops that insufficient provision has been made for accurate sampling of one or more of the test products. This may lead to the omission of some automatic samplers and the requirement that some products be hand-sampled by the pilot-plant operator at carefully specified and frequent intervals. This situation is loaded with dynamite. At those times when the plant is not operating at maximum efficiency, the operator is torn between the desire to make the necessary adjustments to correct the situation, while at the same time the clock says it is sampling time; and it is rare that the sampling wins the argument with the operator's conscience, so poor results are not properly represented by the samples.
- Spills must not be accepted as a normal factor in pilot-plant operation, and any accidental spillage should be regarded

seriously enough to result in discarding the figures from that portion of a test program. In many cases, a pilot plant is in use to prove or disprove someone's pet theory, and too often that someone is supervising the test operation. The pilot-plant operators are under constant pressure with someone breathing down their necks to maintain the best possible results. Under these circumstances, most plants can be operated to give an unduly high grade of concentrate and an attractively low grade of tailing at the expense of a constantly increasing circulating load of middlings that may eventually exceed the pump or launder capacity and spill on the floor. At night the operator can attain still greater distinction by temporarily stopping the pump that recirculates the middlings, thus dumping this difficult material so he can report milling results that will soon lead to his promotion.

- The need to weigh all products from a pilot plant cannot be too strongly emphasized. In too many cases, it is considered adequate to weigh at one point (generally the plant feed) and to believe that tonnages of products can be accurately calculated using either assays, screen sizings, or pulp densities. Such a system removes any possibility of double-checking for deficiencies in sampling or in operation of the test plant, and this lack can set the stage for a major disaster. Usually, a good

> deal of money is affected by the outcome of the pilot-plant testing, and it is good insurance to measure all products to allow cross-checking of metallurgical results so that they can be accepted with complete confidence in their reliability.

In summary, a pilot plant must be designed and operated to satisfy two objectives. First, it must treat representative ore in a manner consistent with anticipated commercial operation, yielding all data required for feasibility and profitability studies, and final plant design. Second, the data from a pilot plant must be in sufficient detail to allow assessment of reliability and reproducibility.

[The previous section was written by Leo Abell, one of the finest metallurgists and mill operators that I have ever known.]

# 16

# PRECIOUS METALS COLUMN AND HEAP LEACHING PILOT PLANTS

Pilot plants for the leach testing of gold and silver ores can be designed in several ways: column, and large or small heaps. Each type has its advocates, but it is the writer's belief that column leach testing of 100 pounds to 15 tons of ore is far superior to the leaching of 1,000- to 10,000-ton heaps. Testing of these small ore heaps suffers from many drawbacks.

Tonnage quantities for heap testing must be obtained from near-surface ore, or a decline must be driven into the ore body. The use of only near-surface material for testing is obviously bad practice, and a decline not only takes much time to drive but also must be very long and therefore expensive. (A decline has a distinct advantage over an adit in that ore from different depths in the ore body may be tested.) Material for the heaps is very awkward to weigh accurately, but just as important is the inability of flowmeters to give accurate readings of the small flows that are required. Proper sampling of on-and-off solutions is very difficult, if not impossible, and grab samples are often used. Even a 10,000-ton heap has a large sloping-side-area to top-area ratio, and sprinklers must be used to apply leach solution. Sprinkling causes much evaporation of solution and also much cyanide loss. From a perusal of these drawbacks, it is easy to understand why relatively small test heaps should not be used for heap leach testing.

The use of a 6-inch core drill will furnish tonnage samples of an ore from the top to the bottom of an ore deposit. The cores should be logged both by a metallurgist and a geologist. The metallurgist can determine the amount of clays and fines at various depths that will slow or stop the leach rate on a heap and he can easily see the mineralogy of the deposit. Test leaching should be done first on samples of the cores crushed to a nominal 1½-inch size because that is what can be produced by two-stage crushing. This can be accomplished in

12-inch-diameter columns 10- to 12-feet high in a laboratory. To save time, $^3/_4$-inch ore can be test leached in 6- or 8-inch columns about 8-feet high. These columns will permit accurate measurement of solution volumes. I have found that if an ore will leach satisfactorily at one size, the chances are good that it will leach as well—or almost as well—at double that size. The results obtained from 6-inch rock leached in 4- or 5-foot-diameter columns will closely approximate those obtained from leaching run-of-mine ores. Again, solution flows can be measured accurately and wire samplers will give representative solution samples for assay.

# 17

# SUMPS, PUMPS, ETC.

We all know that for cyclones to operate efficiently they must be fed constant volumes and pulp densities. When difficulties arise in the grinding circuit, one of the first things to look at is the cyclone feed sump. If the sump bottom is not steep enough or there is insufficient turbulence in the sump, it is common for the coarser particles to build up on the sump bottoms and then slough off, thus slugging the pump and cyclone and upsetting the entire system by giving the pulp density meter (if there is one) a bump. This happened to us at one copper plant where the operators had to concrete in steeper sump bottoms as a remedy.

When operating a pilot-plant grinding circuit, it is often difficult to exactly adjust the flow to the cyclone(s) without diluting the cyclone feed with too much water. A simple solution to this problem is to install a tee in the cyclone overflow line and extend a vertical pipe down into the sump. At the end of the pipe, use a leaky valve that is made of a rubber cone extending up into the pipe and attached to the arm of a float. The valve leaks a little all the time, but when the level in the sump drops, the float does too, and opens the valve to permit cyclone overflow to enter the sump and maintain its level. We have used this arrangement several times and it always works like a charm. A sketch of the leaky valve system is shown in Figure 5.

Power failures are another common problem in pumping slurries, and those operators who have had to dig out a sump will agree completely. One of the handiest things you can design into a circuit is a dump valve located between the sump and pump. The simplest and most effective dump valve we know of is a tee having the middle leg so short that it is virtually flush with the outside of the pipe on which it is installed. A rubber-faced flapper hinged at the top is held against the tee leg by a long lever arm equipped with sufficient weight on its end to keep the flapper closed tight (Figure 6). To open the valve the operator merely gives the lever a flip. The short tee leg keeps the valve from sanding up, and it works every time.

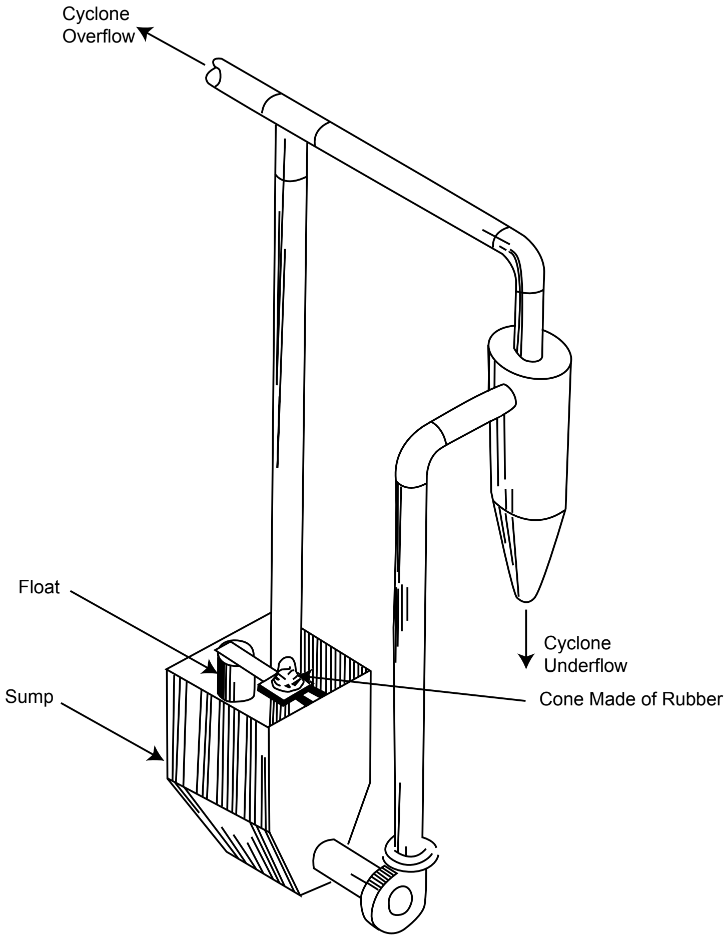


**Figure 5 Leaky Valve System**

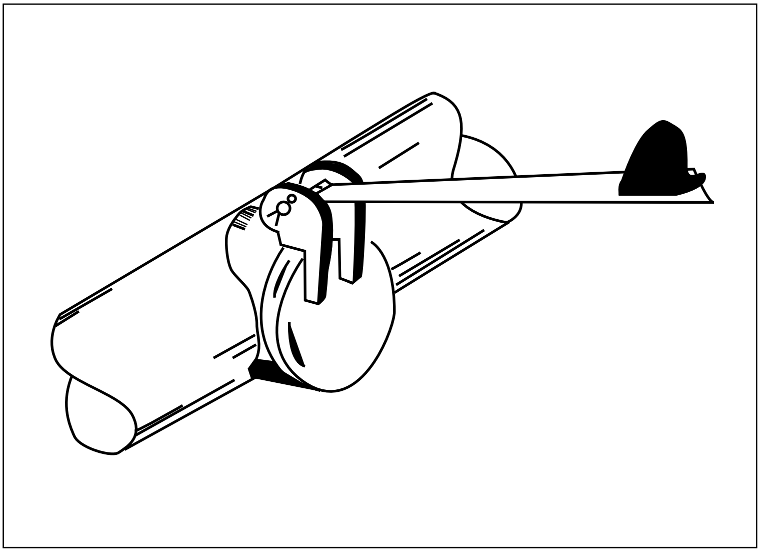


**Figure 6 Dump Valve Flapper Closed Tight**

We once ran into an embarrassing problem when we designed a very long pipeline handling a slurry. In fact, the pipe was so long that its volume exceeded the volume of the sump above its level control. When the pump was shut down, the line drained back into the sump, which promptly overflowed and created a cleanup problem. The larger the pipeline, the more likely this will happen. It is a problem that can be avoided, however, if the engineer goes to the trouble of making that one extra calculation.

A related problem occurred at another of our plants where a heavy magnetite slurry was pumped through a straight but slightly sloping line approximately 300 feet long. At that point there was a Victaulic elbow. Every time the pump was started, the slurry would hit that elbow with sufficient force to knock it off the pipe. After that happened three or four times, the elbow was welded to the pipe. Then when the slurry hit the elbow the resulting shock and consequent vibration felt like a truck hitting the side of the mill building. The problem was solved by installing a long-sweep elbow, which should have been done in the first place.

## 18

## FOOLPROOF PLUG VALVES

Many years ago we visited Anaconda's uranium mill at Bluewater, New Mexico, and our attention was called to a plug valve that we had never seen before. For acid leaching of the ore, agitated leach tanks arranged in a staggered configuration were used. Flow between tanks was achieved by launders and bypasses so that any tank could be taken out of service for repairs. Flow into a tank or its bypass was controlled by plugging either one of two holes in the bottom of the launder. Heretofore, we have always seen this done with a tapered plug (like a bathtub drain stopper) with a tee-handle mounted on it. This type of plug is generally rammed in so tight to prevent leakage that it has to be removed with a come-along.

The Anaconda people invented a better mousetrap, or in their case, a better plug valve. Two steel discs were welded to a 4-foot length of 1/2-inch pipe, as shown in Figure 7. A tire valve was mounted on the upper end of the pipe, and a rubber expandable doughnut was fabricated over and around the steel discs and glued to them. The doughnut was slipped into the hole in the bottom of the launder, and air pressure was supplied to the doughnut through the tire valve. The doughnut expanded into the hole in the launder, thus completely plugging off the flow. To remove the plug, the air pressure was released. Pretty slick, huh? It occurs to us at this time that this type of valve could be used effectively on the carbon columns of a gold and silver heap leaching or carbon-in-pulp plant. Would someone like to try it?

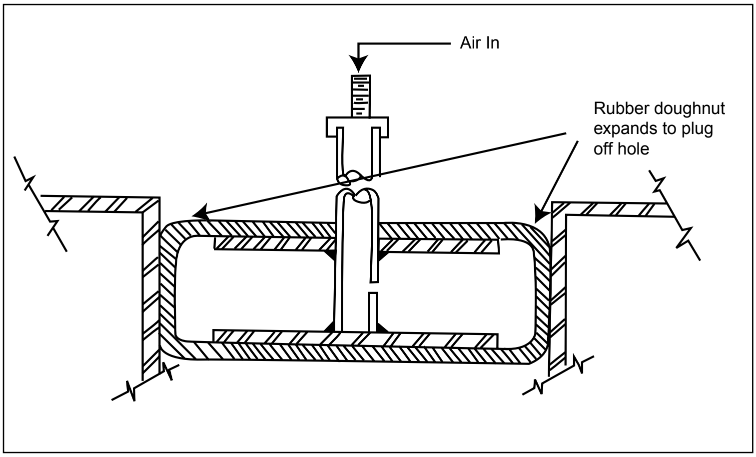


**Figure 7 Plug Valve**

# 19

# DESIGN FOR MAINTENANCE

We sometimes wonder about metallurgical plants that look as if they were designed for the operators instead of the maintenance people. When the right number and sizes of crushers, grinding mills, flotation cells, thickeners, and filters are provided, there isn't much the operator can do to improve production after he has established the proper operating parameters such as ore and water flow, reagent combination and quantity, and proper personnel training. At that point, the real key to production and the success of the plant is rapid and proper maintenance. But if the plant is not designed for easy maintenance, the owner will forevermore have the albatross of higher-than-necessary costs hanging around his neck.

In order to make this point clear, let us first indulge in some mathematics of maintenance and then present a few examples of how poor maintenance design can be an unnecessary evil. For a 30,000-ton-per-day (tpd) mill, treating a 0.5 percent copper ore with a 90 percent recovery, each hour of downtime for maintenance costs the owner about 12,000 pounds of copper not produced. During this hour of downtime, the owner must continue to pay his employees and pay interest to the bank from which he borrowed the money to build the plant. In addition to the owner's dislike of downtime, the plant metallurgist knows that each hour of downtime is equivalent to a

4 percent decrease in recovery that day. A metallurgist can get pretty disgusted when he has worked his tail off to increase recovery by 1 percent and then see all his efforts go down the drain because of poor maintenance design or poor maintenance practices. And yet today, although we see some mills with operating availabilities as high as 97 percent, we see others with availabilities in the low nineties and a few with availabilities as low as 85 percent.

Now for some good and bad examples. In one semiautogenous copper plant that we built, it takes 30 minutes from the time a mill is stopped until the relining machine is in place and ready to go to work. In a plant we didn't design, 2 1/2 hours are required. In that hypothetical 30,000-tpd plant mentioned previously, if the grinding units are relined or partially relined four times a year, those extra eight hours of downtime represent 0.092 percent of the hours available in a year. Now the difference between 95 percent and 95.092 percent doesn't look like much on the operating logbook for the year, but it represents 96,000 pounds of copper not recovered. At today's copper prices that's a lot of money, and at tomorrow's prices it may be a lot more.

Here is another example. We recently studied a client's tailings pumping and pipeline system in an effort to remedy its low availability, a situation that had become a serious problem as his production rate increased. His tailings pond was substantially higher than his concentrator, and at one of his booster stations he had nine 20-inch pumps, three on each of three pipelines. Unfortunately, the crane installed to service these pumps was hand-operated and was equipped with a hand-operated chain hoist for lifting. To remove a pump for maintenance and replace it with a new one required only four hours, but because it was deemed an unsafe practice for a man to operate the chain hoist while standing next to the pump being lifted, all of the pumps were serviced in place. This procedure required 12 hours. The problem was easily solved by equipping the crane with remote-controlled electric travel and hoist mechanisms.

At each pump station there was an air-operated Flo Ball valve on each pipeline that was supposed to close on power failure. Often the valves would stick and resist closing. When enough air pressure built up, the valve would slam shut, but by this time it was like trying to stop a freight train and the resulting water hammer split pipe sections from end-to-end, pulled pipe sections apart at the couplings, and caused pumps to explode. We recommended a positive-acting hydraulic-valve operating system, which solved the problem.

Another problem was uncontrolled expansion and contraction of the pipelines as the ambient temperature varied from way-below to way-above zero. The pipelines had originally been buried but had been relaid on the surface to facilitate their rotation as they wore. Unfortunately, no attention had been paid to controlling expansion and contraction through anchoring at pertinent points, use of long barrel couplings, and welding of several pipe sections on curves. When these problems were taken care of, the entire system operated satisfactorily. Design for maintenance means a number of things:

- Ready access by crane, fork truck, cherry picker, and most importantly, workers, to equipment needing repair.
- The ability to remove and replace equipment without having to first clear away piping, electrical wiring, or any other equipment.
- The prevention of equipment shutdown caused by pumps that cannot be easily replaced, pipelines that plug, cable trays that are damaged by a vehicle or crane hook, spills that cannot be controlled so they damage equipment, and a thousand other causes.
- The proper selection of wear-resistant materials. As a general rule, cast manganese steel is used for heavy impact, but very thick rubber is also being widely used. Ceramics are best for sliding abrasion.

To sum this all up, we firmly believe in and advocate the use of our very best efforts in plant design for good and rapid maintenance. Good maintenance is at least equal in importance in plant operation as operation itself, and a mill that is down for repairs longer than it should be is no better, and is sometimes worse, than no mill at all.

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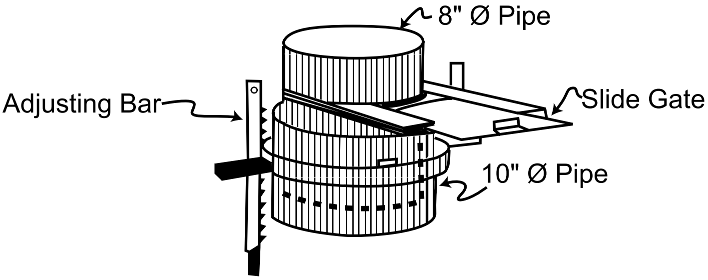
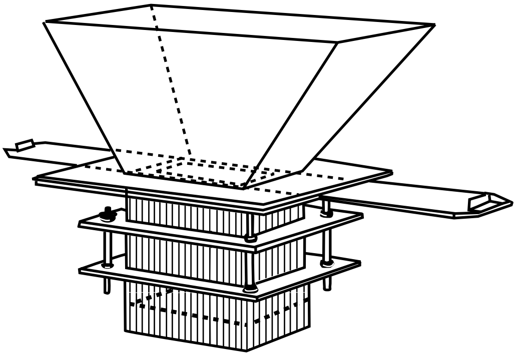
# MEXICAN FEEDERS

Mexican feeders are the most functional, inexpensive, and workable of all feeders when the ore being handled is free-flowing and will stay free-flowing. Unfortunately, until recently we had never seen a really excellent design for this type of unit. The design shown in Figure 8 was developed by Cortez Gold Mines. It can be freed of large rocks or tramp material that accidentally get into the system by merely raising up on the adjustment lever. The pivot action on the outer pipe permits the feeder to move slightly at all times to help pass rocks that may be only slightly oversized.

The Mexican feeder we installed at Bougainville is also shown (see Figure 8). These feeders are working excellently and have received praise from the client. They are somewhat more difficult to adjust and are not capable of freeing large rocks as easily as the Cortez units.



Feeder at Cortez Gold Mine



Feeder at Bougainville

**Figure 8  Mexican Feeders**

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# SUPERVISING THE ENGINEER–CONSTRUCTOR

The biggest mistake an owner can make when he is having a new plant designed and constructed is not adequately supervising the engineer–constructor in all phases of the plant design and construction. After 20 years of consulting on more than 120 projects, we still see owners stationing only one or two engineers (sometimes only part time) in the engineer's office during the design phase of a new plant. Invariably, the resulting plant will then require months to attain its design capacity and mineral recovery. In several cases we have seen the plant fail entirely. It is amusing, and also tragic, to read in a company's annual report that their new mill is suffering from "teething problems" as if every new plant had them. "Teething problems" could be translated (in most cases) as "incompetence by the owner." However, the blame is generally laid on the shoulders of the engineer–constructor.

Proper supervision of an engineer should be done by placing the following people in residence at the engineer's location: the plant general manager, the mill superintendent, the plant metallurgist, the mine superintendent (if the design includes the truck shop), the maintenance superintendent, the owner's construction manager, and the metallurgical, mining, and electrical engineering consultants (part time). Similar supervision should be done at the construction site.

She's deep enough.

***"Actually, we're looking for a metallurgist with less experience and more Phd."***