Design Concepts
Related to
Concentrator Operations

James F. Wickham, Bechtel
Corporations, San Francisco, Ca.

In the twenty-five years that have passed since I graduated with a mining degree from the University of Arizona, I have been involved in Operations, Project Sales and Engineering Management, employed by various mining companies and by engineering/construction firms.

In retrospect most of my working experience can be compared, in my mind at least, to the combat soldier's life in the trenches. This condition of being "on the spot", from my first job as a shift boss in a small Mexican Concentrator up to and including an assignment completed last year, as a Project Engineer for Bachtel Corporation on a 40,000 tons per day copper concentrator complex in the Southwestern U.S., has resulted in my having a considerable empathy for the fellow who has to get a job done. This paper is an outgrowth of this concern for the well being of the operators of ore beneficiation plants.

I have recently visited a number of Concentrators, talking at length with plant personnel and with the aid of slides I will pass along to you the major "design deficiency" concerns noted during these visits.

Items to be noted are not personal preference items, neither mine nor others. Rather in all cases they are problems which came up again and again, to the point of being almost endemic. There is no intention to imply in this paper that these problems are solely restricted to my employer's competitors, on the contrary — I would say that to a large degree they are problems of the extractive metallurgical engineering/construction industry.

The remarks on each item are kept brief, not because more should not be said, but rather because of time limitations for this paper. It will be obvious that each area of concern could easily be expanded into a week seminar session. The intent of this paper is merely to highlight the existence of the problem, with the thought that those interested will take the time to pursue the matter in more depth.
Conveyors and Related Systems

Conveying systems have the dubious distinction of being among the worst offenders in disturbing the peace of mind of the operators, while at the same costing the owners heavily in “fix up” charges.

The difficulties with conveying systems are largely a matter of:

1. **Component Failures:**

   Failures of pulley end disks in both engineered and standard off-the-shelf conveying systems were common events at the plants visited. End disk failures in both flexible and rigid end disk design occurred in all pulley locations — drive house pulleys, head pulleys, tail pulleys and bend pulleys. The failures generally consisted of cracking of the end disks adjacent to the pulley hubs. The magnitude of failures is indicated by the fact that one operator had experienced failure in all of the pulleys in his crushing plant. Another operator had experienced over 50% failures. Surprisingly, incidence of failures seems to be greater in the newer systems (built during the last five years more or less). Pulleys which had been designed with contoured end disks, tube reinforcement of shafts and Ringfeder hubs seemed to be performing better than standard design pulleys. Admittedly, these premium pulleys had a higher first cost than the standard product.

2. **Spills:**

   Slide 1 Spills Jam Up Alongside Conveyor
   Slide 2 Spills Coarse Ore Feed Conveyor
   Slide 3 Spills Falling Onto Motor Control Building Roof

   The spills shown on the preceding group of slides result mainly from poor chute design and overloading of conveyor belts. More conservative design is called for in these areas because constant spillage creates high cleanup labor costs and damages components with resultant excessive maintenance costs.

   Slide 4 Cleanup Door — Tail Pulley

   This slide shows a good method for allowing tail pulley area cleanup to be placed on belt.

   Slide 5 Cleanup Door — Floor

   This slide demonstrates a floor door and chute method for easing the job of cleanup in tail pulley areas.

3. **Clearance:**

   Slide 6 Lack of Clearance
   Slide 7 Lack of Clearance
   Slide 8 Adequate Clearance

   Lack of adequate clearance, minimums 18” to 24” under return belts on conveyors causes serious operating and maintenance problems. When it is considered that this fact is supposedly well known it is amazing the number of installations where clearance minimums have been ignored by the designer.

4. **Trippers:**

   Slide 9 Tripper Discharge Chute
   Slide 10 Tripper Power Reel
   Slide 11 Tripper Seal Belt

   Faulty tripper design has resulted in tripper frames that distort under use, difficulty with tripper power leads and difficulty with seal belts tracking well and laying.
down well into slot. When considering the three available types of power leads, cable reel, sliding contact and sliding hoops it is apparent that the sliding contact tends to give the least problems. The seal belt problems seem to have been largely eliminated through the use of 3/4" transverse reinforced belting.

5. Liners and Rock Boxes:

Slide 12 Ceramic Liners in Tripper Discharge Leg
Slide 13 Secondary Cone Crusher Feed Chute
Slide 14 Secondary Cone Crusher Feed Chute
Slide 15 Rock Box In Action
Slide 16 Rock Box In Action

During the last few years, design engineers have been barraged by vendors of exotic wear resistance material. The claims made for these materials lead the designer into the trap of believing that a wear resistant liner is the ideal solution for a wear point where there is no escape from use of liners, i.e., on a ball mill trommel, then wear resistant materials such as rubber, are indicated. However, in far too many cases, the designer ignores the fact that by using a little more space and good judgement a rock box can be placed at the wear point. With the result of rock falling on rock, the effect is to virtually eliminate the wear problems at such impact points.

To summarize conveyor systems. The overall impression given by the newer conveying systems was that the various conveyor vendors had competed with each other until arriving finally at the point where their lowest priced competitive product was in fact unsatisfactory in service. It would also appear that the CEMA Conveyor Standards are not adequate for the heavy duty service required in the mineral industry.

It seems that the decision made by both owners and engineering designers to economize on conveyor systems has too often been a classical case of "penny wise and pound foolish", when the increased cost of operating and maintaining the deficient systems are taken into account.

Crushing Plants

1. Unhoused Installations:

Slide 17 Open Air Crushing Plant
Slide 18 Open Air Screening Plant

In areas where rainfall is minimal (less than 15"/year occurring in a short season) unhoused crushing and screening plants are operating well to economical advantage.

2. Oversize Rock Removal:

Slide 19 Oversize Rock

Despite the fact that rock grapples, air operated impact tools and pile drivers have been tried to either pick up or break oversize rock delivered to the primary crusher by the mining department, to date the most effective method for handling this material continues to be a cable hook from overhead crane. Using the cable hook method the rock is turned until it is nipped or in the worst case the rock is removed from the crusher with a cable sling for breakup outside.

3. Dust Suppression Primary Crusher Pocket:

Slide 20 Concentric Dust Sprays

Dust control around primary crusher pockets is being effectively handled by high pressure atomizing water sprays interlocked to truck dumping cycles.
4. **Liners Primary Crusher Pocket:**

Slide 21 Primary Crusher Pocket

Liners have been installed in various primary crusher pockets, but in those numerous cases where no liners were used, few signs of wear were seen. It would appear that liners are not necessary at this location with properly designed dump pockets.

5. **Water Seal Primary Crusher Pocket:**

Slide 22 Primary Crusher Water Pickup Trough

In many cases where spray water was being added to the primary crusher pocket or the ore was quite wet, leakage around the crusher pocket seal caused a drip through mess onto the floor below the pocket. No effective seal was seen to eliminate this problem; however, a circular trough installed below the crusher pocket carried the spill away satisfactorily.

6. **Dust Collection System:**

Slide 23 Dust Collection Pipes

Complaints were rather general regarding lack of adequate provision for wear points on dust collection ducts. Where rubber lining has been used at wear points there have been several very costly fires and therefore wear resistant plate should be considered in preference to rubber at wear points.

**Structures**

1. **CMP Tunnels:**

Slide 24 Coarse Ore Conveyor Tunnel

The use of corrugated metal pipe in place of cast in place concrete resulted in an effective economical tunnel at many operations.

2. **Structural Failure Ore Pulldown:**

Slide 25 Cantilevered Conveyor

Failures of supporting steel structures have occurred at various locations due to burying steel structures in ore pulldown zones.

3. **Precast Concrete Tunnels:**

Slide 26 Precast Concret Thickener Underflow Tunnel

Where some concern for possible corrosion of corrugated metal pipe is a factor, precast concrete road conduit has proven to be an effective and economical tunnel material.

**Slurry Pumps**

1. **Suction Lines and Valves:**

Slide 27 Regrind Cyclone Pumps Suction Lines
Slide 28 Final Concentrate Pumps Suction Lines
Slide 29 Moly Concentrate Pump Suction Line
Slide 06 Final Concentrate Pump Suction Lines
In far too many cases designers have made no attempt to keep suction lines as short as possible on slurry pumps. Excessively long suction lines have caused operators untold grief. Knife gate valves on pump suction are effectively replacing the previously used lubricated plug valves and space wasting pinch valves.

2. Sump Shape and Height:

Slide 31 Concentrate Sump

The cross-sectional sump shape did not seem to affect pumping capability as long as sump areas were kept restricted enough to avoid the dangers of slumping. On the other hand, operators generally stated that the higher the sump the more flexibility the slurry pump exhibited in handling varying volumes of feed.

3. Middling Circuits Sump Size:

Slide 32 Copper Cleaner Tailing Pumps
Slide 33 Copper Cleaner Tailing Sump

Many of the operators expressed a concern over the loss of process surge capacity in concentrators as a result of the trend towards omission of primary classifier pools, middling thickeners and conditioners.

The suggestion was made that middling thickeners continue to be given serious consideration and, where they are not installed, that some provision for handling middling surges be installed in partial compensation for the overall loss of surge capacity. The belief is that a large middling circuit upset sump ($\pm 10$ minutes) should replace the common one minute retention size sump at this location. This upset sump will allow the operators time to adjust the circuit to alleviate upset conditions before excessive sump spillover is experienced.

4. Vertical Versus Horizontal Pumps for Handling Frothy Slurries

Slide 34 Rougher Concentrate Vertical Pump
Slide 35 Regrind Mill Discharge Vertical Pump
Slide 36 Combined Rougher Concentrate and Cleaner Tailing Vertical Pump

The belief is quite general that vertical slurry pumps could be expected to handle difficult frothy pulps better than horizontal pumps. In many operations excellent results had been obtained where rubber-lined vertical pumps were installed to replace horizontal pumps which were operating poorly.

Slurry Piping

1. Direct Routing and Curve Radius:

Slide 37 Dust Slurry Overflow Line
Slide 38 Rougher Concentrate Pipeline

The bane of operators is slurry pumping systems that are installed like plumbing systems. Again and again operators brought to my attention, the importance of routing slurry lines using the shortest distance between two points concept. Operators feel that three elbows are equivalent to a blind flange. In fact, the best slurry piping design uses no elbows but rather long sweep curves instead.

It should also be mentioned that manifold valves on slurry pump lines were troublesome to the extent that most operators preferred that separate discharge lines be installed on spare pumps on all shorter runs.

2. Hose Curves:

Slide 39 Slurry Hose Curves
Slide 40 Slurry Hose Curves
Slide 41 Slurry Hose Curves
Hose curves are gaining rapidly in popularity on all slurry piping. The superiority of hose curves over fabricated pipe curves more than discounts the additional supports required for hoses. Several hose manufacturers are now selling equipment which allows repairs to be made to worn out sections of the hoses which saves the loss of much undamaged hose. Entire hose runs are being used with excellent results on small slurry systems (2” in diameter or thereabouts) such as sample systems and molybdenum systems.

3. Gravity Lines and Launder:

Most operators complained of a continuing tendency by designers to design gravity slurry pipes with too small a diameter and deficient slope.

There remains a decided affection throughout the industry for launders on troublesome gravity pulp flows, and especially on alternate gravity flow systems where it is felt that a launder system dart valve combination is superior to a pressure piped system.

4. Overland and Gravity Pulp Lines:

Gravity overland tailings lines are operating well at grinds of 15% to 25% + 65 mesh and percent solids of 45% to 55% with grades of 0.6% minimum. Gravity sand lines operated well at 60% solids with about a 4% grade.

Mills

1. Chute Feed Versus Scoop:

Feed chutes have satisfactorily replaced scoops at many operations. Entrance seal problems on these chutes have been solved by careful design and fabrication.

2. Cyclone Pack Configuration:

In some cases cyclone overflow lines have been dropped vertically below the vortex finder at the cone, with disastrous results to cyclone efficiencies. Many operators prefer to keep a slight positive head on the cyclone overflow.

3. Oversize Reject on Large Overflow Mills:

The large 18’ x 21’ overflow ball mills have shown a decided tendency to reject tramp oversize rock (+ 1”) and it would appear that these large overflow mills require a separate oversize rock handling system.

Floor Cleanup
Floors too flat in cleanup areas was the standard complaint of operators. Floors that cleaned up quickly were seen to have 3/4" to 1" per foot slopes.

Grating covered floor launders, designed to handle major spills over long distances to central cleanup sumps, did not perform well. The general conclusion seems to be that gratings of covered floor launders are satisfactory for keeping everyday cleanup off floors if they extend only short distances to local cleanup sumps. To handle the inevitable heavy spills that can occur, spill areas should have steeply sloped floors to local vertical pump sumps. The vertical pumps should be suspended overhead so that they can be raised or lowered easily in the sumps.

More thought should be given to provisions to pick up the coarse spill material occurring around primary grinding mill sumps during shut down.

Another common complaint of operators was that designers had not installed sump overflow pipes nor made arrangements for floor launders or depressions to handle sump overflow to adjacent pickup sumps. The result is, that large floor areas are covered at times with muck resulting from relatively small sump overflow quantities.

Basically operators said that engineering design appeared to ignore provisions required to handle spill properly — including requirements for high pressure floor wash systems to allow quick cleanup of spills.

Thickeners

1. Underflow, Density Control:

Slide 51 Copper Thickener Underflow Pumps

Many operators had experienced difficulty with variable speed centrifugal underflow pump which had been designed with the double duty of controlling thickener underflow density and at the same time pumping to a relatively high static head. Density control requirements, in actuality, caused these pumps to “fall off the curve”.

The preferred underflow system was to discharge the thickener by gravity exercising density control utilizing a throttle valve such as a Clarkson “C” valve. The thickener underflow line is then discharged into a sump for separate pumping.

Filler Plant

Slide 56 Filtrate Systems Pumps

Filter plants (or areas) were, rather consistently, more of a mess than other plant areas. In general, the filter areas had not been designed to handle the required concentrate cleanup easily. This spill cleanup problem was also rather notable around concentrate thickener areas and it appears that there should be more thought given during design to cleanup provisions (sloped concrete pads, cleanup sumps) around and under thickener areas. The designer is aware that a thickener has slurry inside but he does not often enough appreciate the liability for having spills around vessels and pipes containing slurry.

Many operators suggested that filtrate systems not be installed with closed circuit filtrate pumps, but rather with a barometric leg filtrate discharge system discharging into a seal tank or vertical pump sump with subsequent pump out be a slurry pump. Shaft seals on “water type” centrifugal filtrate pumps have provided operators with many a headache due to excessive maintenance.

Reagent Systems

Slide 57 Homemade Bucketwheel Type Reagent Feeder

Solenoid control systems on circulating reagent loops dispensing relatively large amounts of reagent, such as lime, were seen to be operating satisfactorily. For smaller reagent additions (promoter or frother) most operators have tried either metering pumps or rotameters. Neither method has proven entirely satisfactory. Quite generally, the operators preferred to use Clarkson reagent feeders as they felt this method allowed them to exercise positive control over reagent additions.
The result of these jobsite review trips has served to further convince me that engineering/construction organizations must increase their efforts to reflect actual operating conditions in the detail design of their projects.

It should also be appreciated by Owners, Operators, and Engineer/Constructors that when the Owners of a new process plant believe that their plant is not performing up to expectations the definition of expectation is crucial. Granting that the design basis for a plant will state capacity and recoveries/grades but rarely will operating/maintenance costs and operating "grief" be quantified in this criterion. Too often during the design stage realistic evaluations were not made regarding criterion for economy, i.e., least first cost, least operating cost, least down-time, best metallurgy or most capacity. An awareness of process problems that are a reflection of design must be accompanied by an understanding of economic reality.