

Crushing Plant Design and Layout Considerations

Ken Boyd, Manager, Material Handling, AMEC Mining & Metals , Vancouver, BC

ABSTRACT

In mining operations, the layout of crushing plants and ancillary equipment and structures is a crucial factor in meeting production requirements while keeping capital and operational costs to a minimum. This paper addresses the critical design parameters as well as the consideration of ore characteristics, geographical location, climatic conditions, expected operational life, expansion potential, safety, environment, and operability and maintainability.

INTRODUCTION

The fundamental goal for the design of a crushing plant is an installation that meets the required production requirements, operates at competitive cost, complies with today's tough environmental regulations, and can be built at a reasonable price despite the rising costs of equipment, energy and construction labor. The following industry trends must be taken into account:

- Equipment suppliers are offering ever-larger primary crushers, with 1,800 mm (72 in) gyratories expected soon, as well as secondary and tertiary machines of up to 3,000 mm (120 in).
- Rising energy costs are causing owners to increase the integration of mine and mill design, so that they can identify ways of reducing overall electrical power consumption.
- Electronic control of crusher discharge opening and feed rate. With adjustment of a crusher's discharge opening, as the production continues through an on-line coarse size analysis of the crushed product (digital image analyses). Dance, A. 2001)
- More attention is being paid to the impact on crushing circuit design caused by variations in ore characteristics, size distribution, moisture content, ore grade and climatic conditions.
- Operators have always dreamed of reducing the need for crushing equipment; when SAG mills were first introduced, it was hoped that they would eliminate secondary and tertiary circuits. As it turned out, designers are now adding secondary or pebble crushers to SAG circuits, on both greenfield and retrofit projects, to increase feed rate to the SAG mill. In other words, crushing plants, from primary to quaternary circuits, are here to stay.

There are three main steps in designing a good crushing plant: process design, equipment selection, and layout. The first two are dictated by production requirements and design parameters, but the layout can reflect the input, preferences and operational experience of a number of parties. These can include the owner's engineering staff, safety personnel, operations and maintenance personnel, equipment manufacturers, and the engineering consultant. Ideally, the consultant combines his knowledge and experience with an understanding of all parties' needs, to provide a balanced, workable, safe and economic plant design.

DESIGN PARAMETERS

The principal design parameters that drive crushing plant selection and configuration include:

- Production requirements
- Ore characteristics
- Project location
- Operational considerations
- Climatic conditions
- Capital cost
- Safety and environment
- Life of mine/expansion plans
- Maintenance requirements

Each of these is addressed in the sections that follow.

Production Requirements

The process design criteria define the project's production requirements, and typically include those shown in Table 1.

Table 1 Production requirements

Process Description	General Ore Characteristics	Operating Schedule
General	Maximum rock size in the feed	Days per year
Primary crushing	Ore types, compressive strengths	Hours per day
Fines crushing	and abrasion indices	Nominal annual throughput
Storage & reclaim	Ore specific gravity	Mining shifts per day
	Ore bulk density	Crushing plant shifts per day
	Ore moisture, wet season	System availability and utilization
	Ore moisture, dry season	
	Angle of repose	
	Angle of withdrawal	
	Angle of surcharge	

The flowsheet specifies the nominal design, peak production flow rate, and equipment sizing to handle those capacities. Manufacturers provide ratings for their equipment, preferably based on testwork and/or experience, so a project flowsheet specifies tonnage requirements and the equipment is selected to meet or exceed the capacities. Design criteria can be calculated from a simple spreadsheet as shown in Table 2.

Mine haul-truck capacity is an important factor at primary crusher installations, because it is cost-effective to integrate truck cycle time at the crusher station with mine/shovel operations. If a primary crusher dump pocket is undersized and unable to handle the mine's trucks, then operators must slowly meter the ore into the receiving hopper.

Table 2 Production Requirements - Typical

Example:	60" x 89" primary crusher & mill feed conveyor system	
	Operating schedule calculation - for 3 x 8 hours per shift	
	Days per year	365
	Tonnes per year	32,850,000
	Metric tonnes per day	90,000
TOTAL TIME AVAILABLE	8,760	Hours per year
UNPLANNED DOWNTIME	(Subtract planned or known downtimes)	
	Industrial	0
	Electrical - grid	24
	Weather	48
	Holidays	0
	Major scheduled maintenance	416 1x 8 hr maintenance shift /wk
	Crusher maintenance	78 1 concave change box 1, 2 months changes 24 x 2
	Minor scheduled maintenance	0
	Shift changes	183 10 minutes/shift
	Total lost time	749
PRODUCTION TIME	8,011	Hours per year
	(Time system is available)	
	System availability percentage	91 Production time/total time
UNPLANNED DOWNTIME	(Subtract unplanned downtimes)	
	No ore	401 5% of production time (8 hrs/wk no trucks delivering ore or other reasons)
	Crusher plug	160 2% of production time
	Chute plug	200 2.5% of production time
	Stockpile full	80 1% of production time
	Safety switch	200 2.5% of production time
	Metal on belt	52 Approx. 1 hr/wk
	Belt repair	240 3% of production time
	Electrical	200 2.5% of production time
	Mechanical Repair	200 2.5% of production time
	Others	0
Subtotal Unplanned Downtime Hours	1,734	
RUN TIME (Operating Time)	6,277	Prod. time minus unplanned downtime
	Total yearly downtime	2,483 Planned and unplanned hours
	System utilization %	78 Run time/prod. time
	Average hours per shift	6.24 Hours per day/3
	3 shifts, hours	18.72 Utilization % x 24 hrs
	System availability %	72 Runtime hours/total time available
NOMINAL OPERATING RATE	4,808	90,000/hours in 3 shifts
	(Average tonnes per hour)	
	Conveyor design rate - tph	5,769 (1.20 * operating rate) 20% factor added for conv. selection

Capital Cost

Direct Costs. The largest primary gyratory crushers cost US \$2 million or more, while overall crushing plant costs can be as high as \$18 million. It's necessary therefore to estimate crusher installation costs based on equipment costs plus the following direct costs, including construction contractor indirects:

- Earthworks
- Concrete
- Structural steel
- Architectural
- Mechanical
- Electrical
- Instrumentation.

Indirect Costs. Indirect costs can fall within a range of 40 to 60% of the direct costs, and include:

- Construction indirects
- Construction equipment
- Spare parts/first fill
- Engineering, procurement and construction management (EPCM)
- Startup and commissioning
- Freight
- Taxes/duties
- Owner's costs (relocation, hiring and training personnel, permits, licensing fees, etc).

In addition to the above, a contingency to cover unforeseen costs will be in the range of 10 to 20% of the sum of the direct and indirect costs.

The designer must be aware of the project-specific costs of all such elements, so that he can monitor costs and promote methods of reducing total installation costs. In some locations, for example, labor and material costs could make a gabion wall more expensive than a poured concrete wall, which has minimal structural backfill.

Ore Characteristics

Ore characteristics are a critical element in both crusher selection and plant design. Dry ores require greater provisions for dust suppression and collection, including dust enclosures around screens, sealing on conveyor skirts, and vacuum and wash-down systems. Wet, sticky ores can plug chutes, reduce surge capacity, and decrease the live storage capacity of bins and silos. To address this problem, chutes must be easily accessible for clean-up, and large feeder openings must be provided for bins, silos and tunnels. If it is practical to obtain representative ore samples, it is prudent to have testwork conducted to establish ore flow properties, which will influence design parameters.

At virtually all mines, ore characteristics change over time, and it can be costly to "design in" the optimal flexibility required to handle such changes. Some owners stipulate that initial capital investment be kept to a minimum, with design modifications paid for out of the operating budget. This is not always easy to achieve.

Safety and Environment

Safety must be designed into all mining facilities. North American mines must comply with local and national regulations such as OSHA, MSHA, the Mines Act and the WCB. The modern plant includes safety guards around all moving equipment, and emergency pull-cords on both sides of any conveyors with personnel access. The maintenance department and safety officer must keep these safeguards in working order. Ongoing safety training of plant personnel is imperative, and is considered to be one of the most vital and monitored feature of most mining operations.

Dust emissions must comply with the latest regulations for the jurisdiction. Designers must make provisions for the installation of dust abatement, suppression or collection equipment.

Spillages from feeders, chutes and conveyors must be minimized. Spill collection can be “designed in” on feeder installations; chute designs can minimize spillage at receiving and discharge points; and conveyor belts can be widened to be more forgiving (e.g., skirting internal back-to-back width can be reduced to allow the belt more side travel.) Skirting should be extended a minimum of three belt widths past the load point. Rules for conveyor and load point design should be used for guidance only, with transfers custom-designed to suit a particular project. It goes without saying that clean plants have lower operating costs.

Crushers, screens and dust-collection fans all contribute to high noise levels. Air-cooled lubrication systems are not only noisy, but often leak oil. Well-balanced, choke-fed crushers, dust-enclosed screens and dust collector fans with silencers can keep noise levels under control. Recirculating water can be used to cool crusher lubrication systems.

Project Location

A project’s geographical location, topography, geotechnical conditions, remoteness and climate can all affect crusher plant design.

Construction costs are generally much greater at high altitudes, in cold climates and at remote sites. To improve the economics of such locations, modular and pre-assembled structures and plant facilities are used prior to transportation to site. Local labor costs often dictate what material can be best used economically in a particular region; for example, cement structures are much cheaper to erect in Mexico than in Alaska.

Remote projects can suffer from difficulties in obtaining spare parts on short notice. Crushing plant design should accordingly provide for laydown and workspace for onsite equipment refurbishment and repair. Where possible, equipment manufacturers should be encouraged to stock and provide spare parts close to the mining operation.

Good geotechnical information is essential to crushing plant siting and design. Installing a primary crushing plant on solid rock reduces the cost of concrete and structural steel.

Life of Mine/Expansion Plans

The life of the mine is a key element in the design of any crushing plant. Short-term mine lives (three to eight years) require a very careful approach to design, layout and construction. Since the crushing plant’s structure and enclosure can represent the largest single cost element in a primary crushing plant, it is imperative to optimize these structural and construction costs to suit the life of the operation. Perhaps a steel-supported, modular design will be best for short-term operations, since the equipment can be relocated and re-used; while for long-life mines, large concrete structures with fully insulated enclosures might be more economical. In conducting trade-off studies, short-term operations should aim for lower capital cost, while long-life installations should be designed to minimize operating costs and emphasize maintainability. “Operating availability is a function of the design of the processing lines and the ease and type of their maintenance” (Shoemaker and Gould, *Modern Mill Design*, 1980).

Again to quote Shoemaker and Gould, “Increased production of the final product is often more easily and economically attained through expansion than by increased recovery.” Planning for expansion is therefore a consideration in all but the shortest-lived operations. Even at mines with expected lives of only five or six years, it may be necessary to select equipment that can handle anticipated throughput increases. Expansion plans for most crushing plants can be incorporated in the early planning stages at much lower cost than waiting until the mine is up and running before deciding to expand.

More and more, operators want to increase primary crusher throughput, especially when they incorporate larger trucks into their mine planning or operations. One manufacturer has modified its 1,067 mm (42 in) and 1,371 mm (54 in) primary crushers to allow for larger rocks and increased

tonnage to pass through (larger openings at the top of each crusher), with minimal changes to the receiving hopper structure.

Operational Considerations

Designers of new plants must be aware of ways of making a plant simple and economical to run; many plant modifications and additions can be justified by reductions in operating costs.

Operation rooms should provide a comfortable, well-ventilated workspace with potable water and toilet facilities nearby. The operator should also be able to see all the main parts of the crushing facility under his control, through good direct visibility and by means of TV cameras and monitors.

Although spills cannot be avoided, plant layout must facilitate quick and easy cleanup. Provisions should be made for suitable plant cleaning equipment. Wash-down hoses should be located within easy reach throughout the plant. Water pressure should be sufficient to wash down hard-to-access areas. Some operators regularly wash their crushing plants from top to bottom to eliminate dust build-up on the structural steel and equipment. Build-up on structure steel members tends to filter down throughout the plant during operation.

Conveyors should have adequate clearance above the floor to permit access to spillage by shovels or plows.

Crushers, chutes and belts are all subject to extensive wear, and wear parts and plates can be heavy. The designer should keep the weight of replacement parts, which must be manhandled to within 27 kg (60 lb) for ease of installation. Monorails and hoists should be provided for ease of maintenance.

Maintenance Requirements

Plants must be designed for ease of access and maintainability if they are to meet their production goals. Keeping maintenance requirements to a minimum helps achieve higher overall operating availability.

Scheduled preventive maintenance at crushing plants involves a number of elements, including:

- Crusher wear parts
- Feeder wear parts
- Oil and lubrication
- Visual inspections
- Screen decks
- Conveyor skirting and adjustment
- Conveyor belt repair
- Electrical and instrumentation adjustments.

Provisions must be made for overhead cranes to remove and replace crusher wear parts. Supports must be provided for gyratory and conveyor main shafts and laydown space for the cone crusher bowls is essential. Some operators carry a complete spare screen and change out for major screen maintenance. Trolleys, jib cranes and pull points should be designed to facilitate equipment maintenance. Oil and lubrication systems should be centralized and designed for easy automatic changes, with provisions for well-ventilated centralized lubrication rooms where possible. (e.g., a line of fine cone crushers should have a central oil receiving area, with piping to and from each crusher lube package for quick and easy oil changes.)

Conveyor head chutes should be designed for easy access (not just through an inspection door, but through a man door in the chute). Conveyor belt change areas should be provided. Maintenance personnel should have easy visual and rapid access to screen decks for panel replacement.

Designers should work with the screen manufacturers to ensure that covers provide good access for working on screens. Screening facilities must meet rigid dust emission requirements, but many off-the-shelf screen dust covers have not kept pace with these requirements. It may be necessary to custom-design covers that minimize emissions and provide easy access to the screen.

Climatic Conditions

Building for cold-weather operations is very challenging, as is designing a plant in a desert environment. This is particularly true when year-round operation is required. Seasonal variations can change ore moisture content, so the crushing plant must be adaptable to changes in the material flow characteristics. Higher moisture requires greater angles of withdrawal, and stone-boxes must be designed to avoid plugging. The crushing plant equipment itself must be adjustable to climatic changes; for example, screen decks must be designed to maintain production, possibly by using wire mesh during the wet season and plastic during the dry. (Vary screen deck types dependent on seasons and material characteristics to achieve maximum passing through deck openings.

Climate also dictates the type of plant enclosures required as shown in Figures 1 and 2. Many crushers in milder weather climates or desert areas are installed with an open face and have no enclosures at all.



Figure 1 Teck Cominco, Red Dog Operations, Alaska

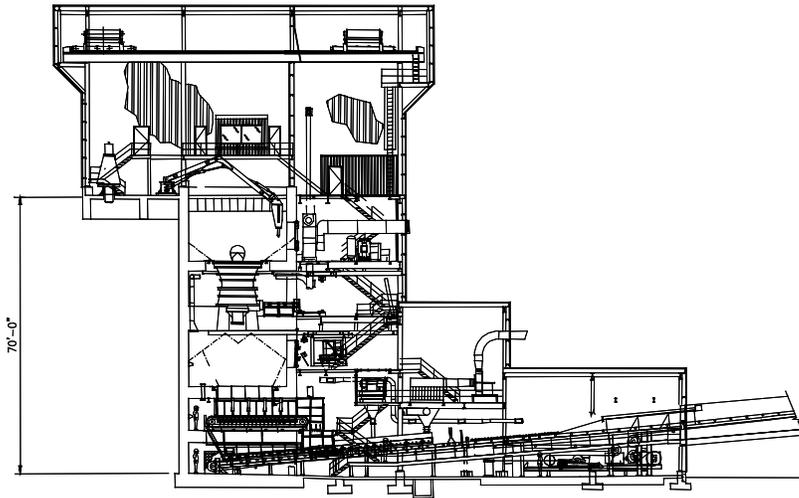


Figure 2 Teck Cominco, Red Dog Operations, Alaska - 42" x 65" gyratory

PROCESS DESIGN CRITERIA

Design Criteria Information

Typically, the information required to develop crusher process design criteria includes:

- Geographic data
- Civil design criteria
- Structural design criteria
- Mechanical design criteria
- Climatic data
- Process design data (process description, ore characteristics)
- Electrical/instrumentation design criteria.

Flowsheet

Some sample flowsheets are provided in Figures 3, 4, and 5 showing crusher circuits. Figure 6 shows a typical three stage closed crushing circuit with its ancillary equipment.

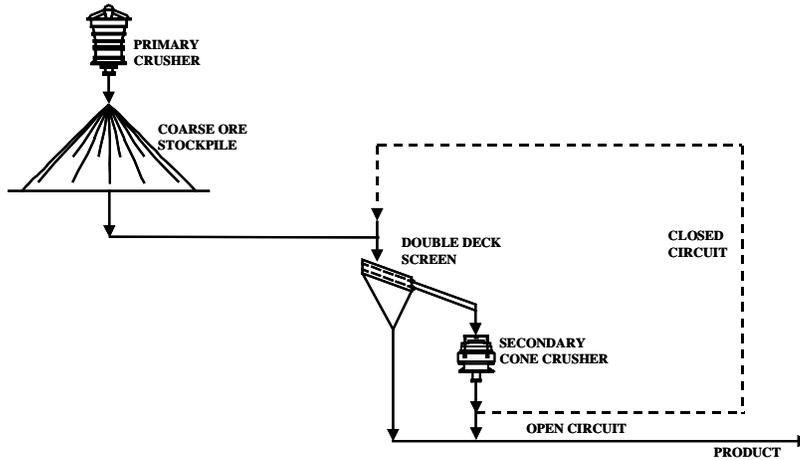


Figure 3 Two stage open/closed circuit

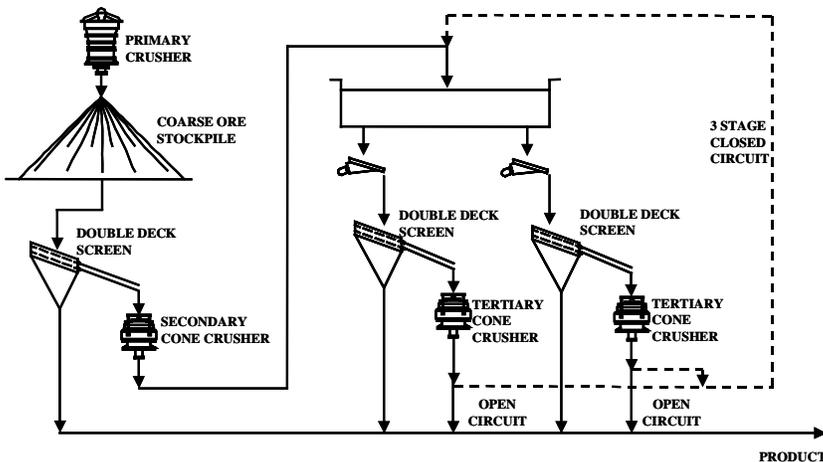


Figure 4 Three stage open/closed circuit

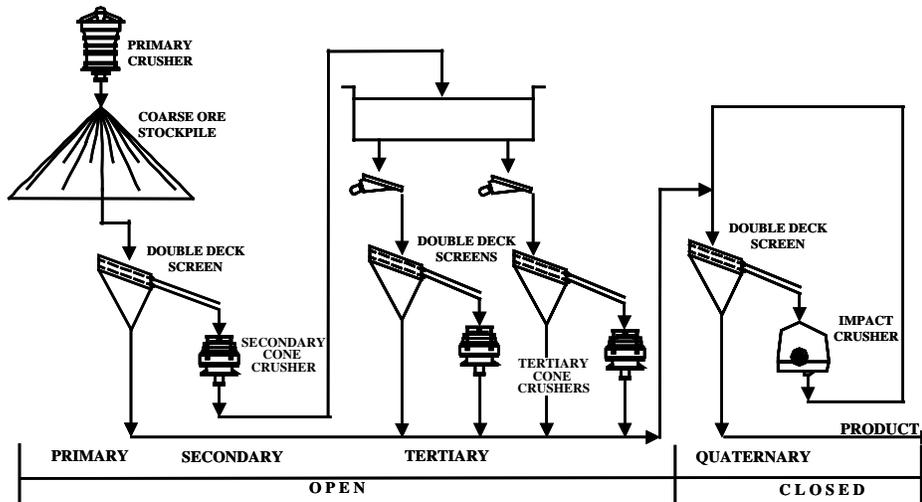


Figure 5 Four stage crushing circuit

EQUIPMENT SELECTION

Crusher Types

The choice of crusher depends on the type and amount of material to be crushed. Gyratory and jaw crushers represent the bulk of primary crushers used at mining operations today, although some operations use roll impact crushers, low-speed roll sizers and feeder breakers. Cone crushers remain the most popular for fine crushing applications, although some mines use vertical impact crushers for tertiary and quaternary crushing.

Major Equipment

The major equipment in a primary crushing circuit usually includes only a crusher, feeder and conveyor. Secondary and tertiary crushing circuits have the same basic equipment items, along with screens and surge storage bins.

Additional and Optional Equipment

Other equipment items in crushing circuits can include:

- Rock breaker
- Overhead crane
- Freight elevator
- Service air compressor
- Sump pumps
- Air vacuum clean up systems
- Rock grapple
- Conveyor belt magnets
- Conveyor belt metal detectors
- Belt monitoring systems
- Belt feeders
- Screw feeders
- Bin ventilators
- Apron feeder to the primary crusher
- Dust collection/suppression system
- Eccentric trolley removal cart
- Man-lift elevator
- Air cannons
- Water booster pumps
- Service trolleys
- Conveyor gravity take-up service winch
- Conveyor belt rip detector
- Conveyor belt weigh scales
- Vibratory feeders
- Lime/cement silos
- Sampling stations.

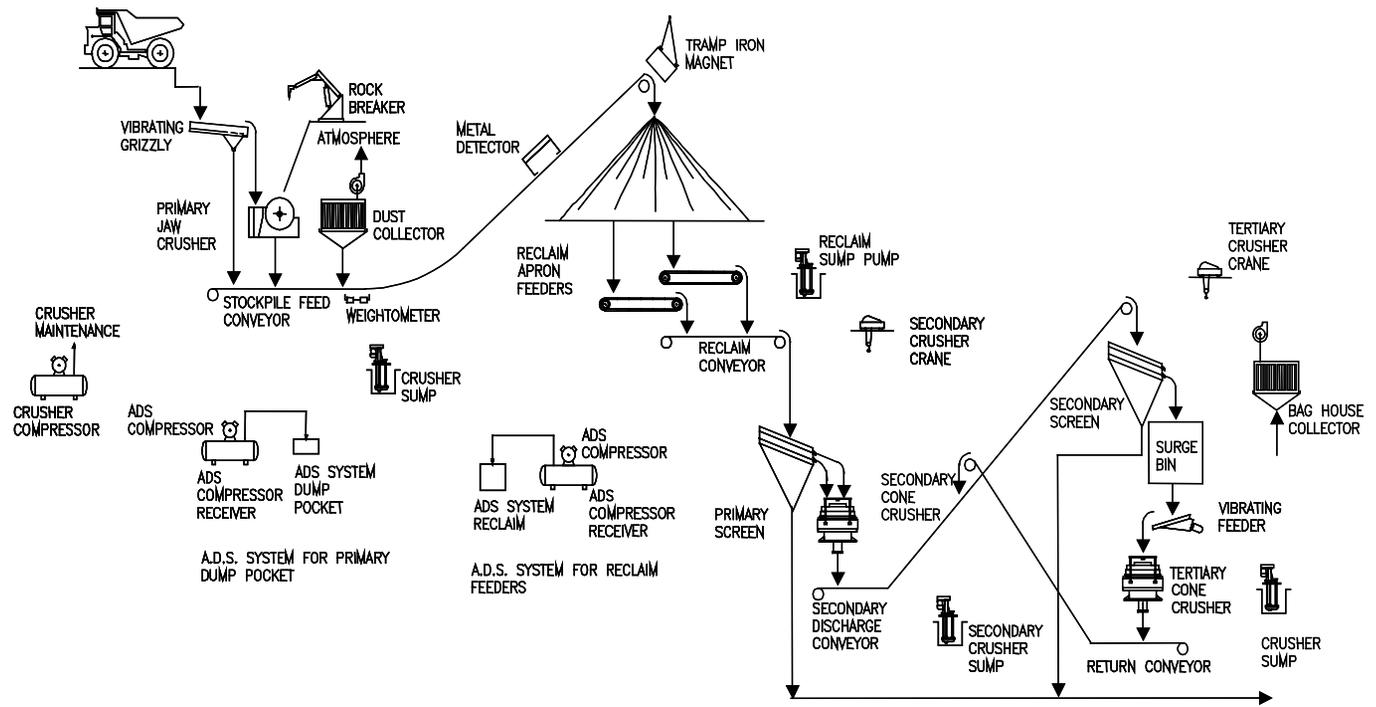


Figure 6 Three stage crushing closed circuit

PLANT LAYOUT AND DESIGN

A well-designed plant layout balances the capital versus operating cost over mine life. Buildings, infrastructure, and major equipment items, represent the major cost elements of a crushing plant. The designer must prepare a layout that suits the design criteria, flowsheet and selected equipment in the most economical possible configuration. It's important to keep structural costs down, to design for ease of maintenance and operation, and to combine best practices with advances in fabrication and erection. Input from an experienced mining plant structural engineer can be very helpful.

Crushing circuits and ancillaries have not changed a great deal over the years, so "Keep It Simple" is still the best way to design a plant. Owners may wonder why the design of head chutes hasn't changed in decades, but the explanation is simple: it's because the old, well-proven approaches still work best. On the other hand, it's dangerous to assume that a layout that works well at one mine will work just as well, or at all, at another.

Provisions must be made for the replacement of wear parts (e.g., install man-doors on head chutes with flood lighting inside the chute.) Faster part replacement means less downtime.

Layout tools can include cut-and-paste arrangements, 2D arrangements fitted onto site topography, or 3D CAD to superimpose the design on the selected site. The choice of tool depends on whether the work is being done at the prefeasibility, feasibility or detailed engineering level, as well as on the accuracy required of any associated cost estimate. The best designs are developed using basic approaches and tools: site visits, discussions with mine personnel, sketches, and cut-and-paste layouts. This writer believes that only after the initial concepts have been developed and optimized does 3D CAD have a role to play.

Different industries have different approaches to crushing plant design. The standard approach in the oil sands industry is to use MicroStation 3D CAD from the start; in some cases, the finalization of a system design (hopper, feeder, sizer crusher, and takeaway conveyor) has taken as much as two years, because of the uniqueness of the application. A similar design in the hard-rock mining industry takes from four to six months.

THE PRIMARY CRUSHER

Primary crushers, no matter what type, must all meet the design parameters described earlier. Design details that are fundamental to the layout of gyratory crusher plants are listed in the sections that follow. Some of these details are applicable to other types of crushers as well.

A typical in-ground gyratory crusher layout is shown in Figures 7 and 8. Figure 9 breaks this plant down into major areas that are identified as "project specific" or "necessary".

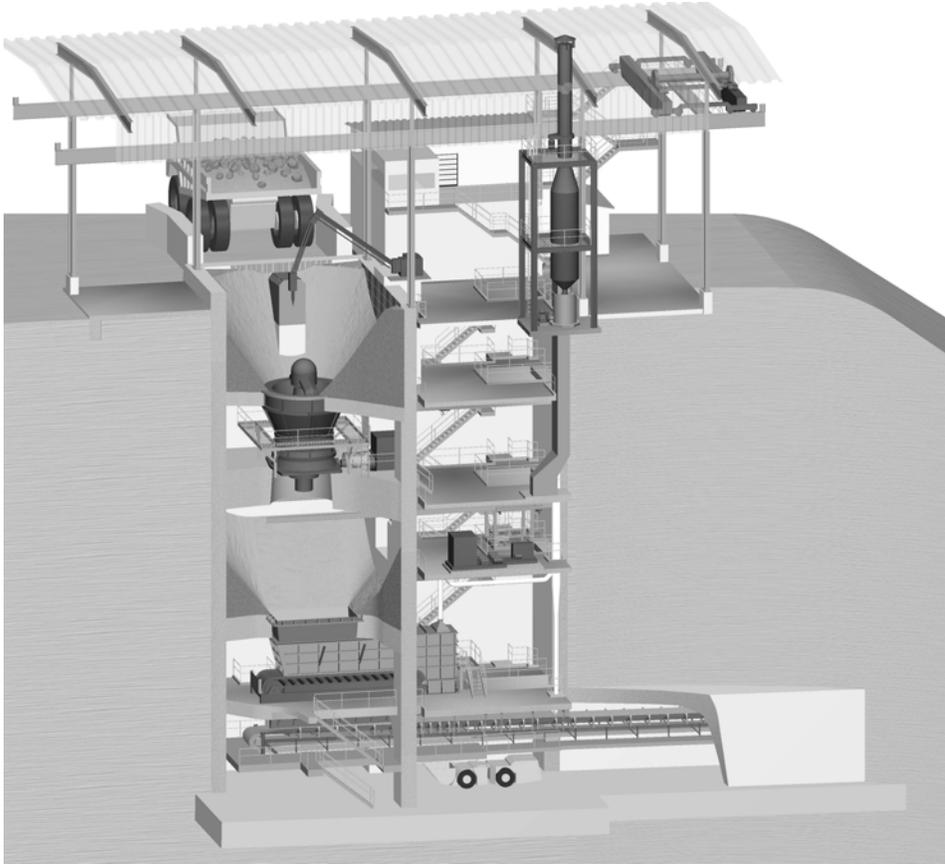


Figure 7 60' x 89' gyrotory installation, Freeport, Indonesia

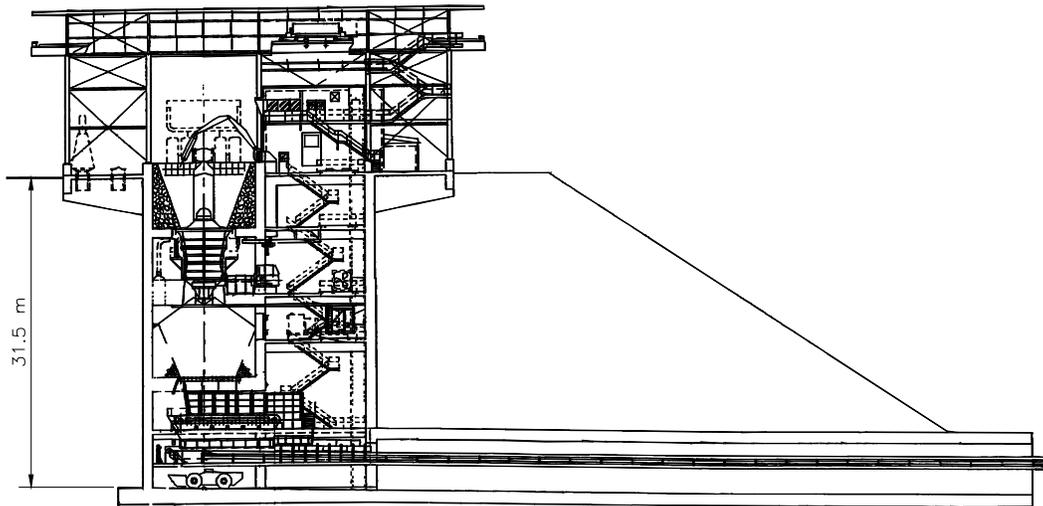


Figure 8 60' x 89' gyrotory installation, Freeport, Indonesia

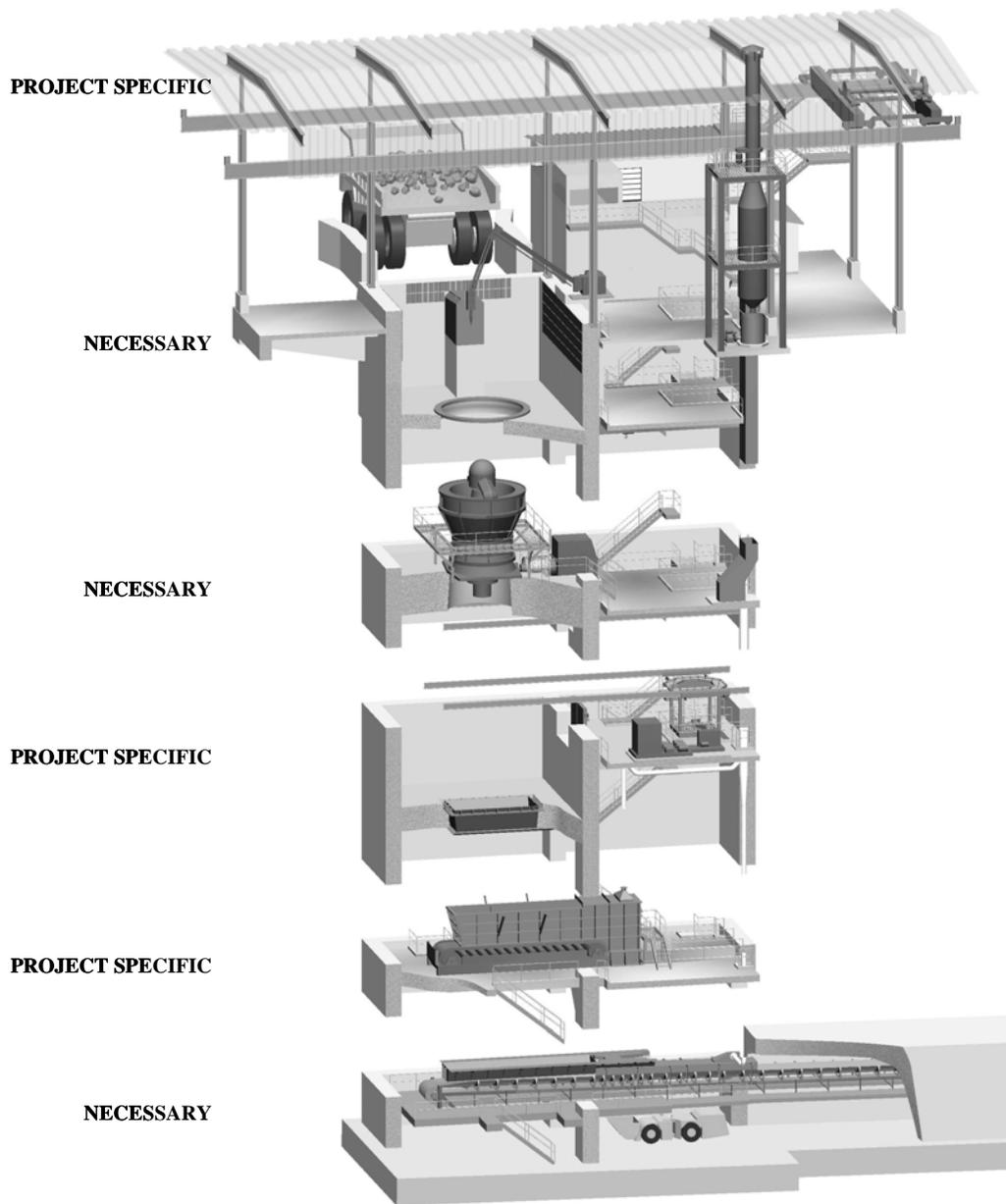


Figure 9 Gyratory broken into necessary process portions and project specific portions

A typical jaw crusher plant is shown in Figure 10 and Figure 11 shows a typical underground jaw crusher layout. A typical low speed roll sizer plant is shown in Figure 12.

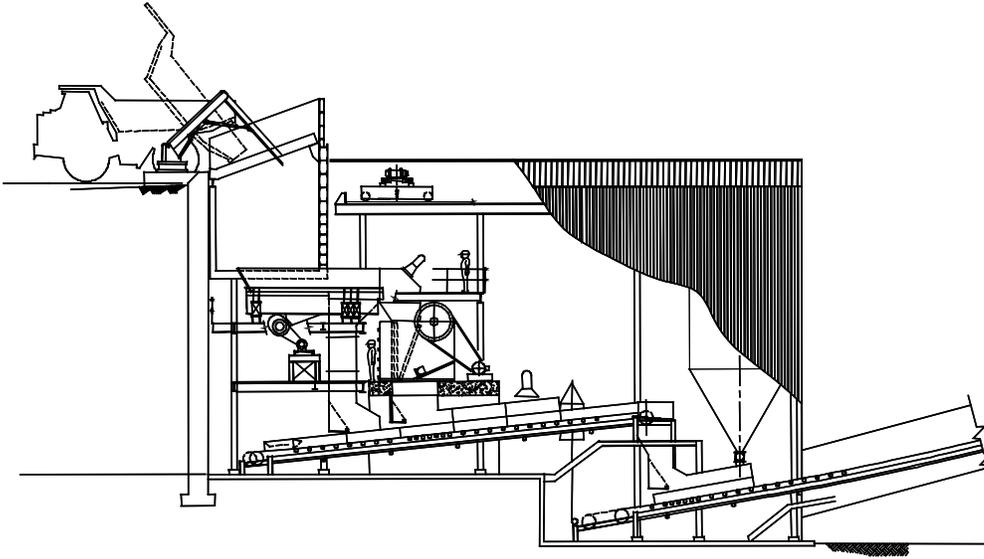


Figure 10 Typical jaw crusher plant enclosed

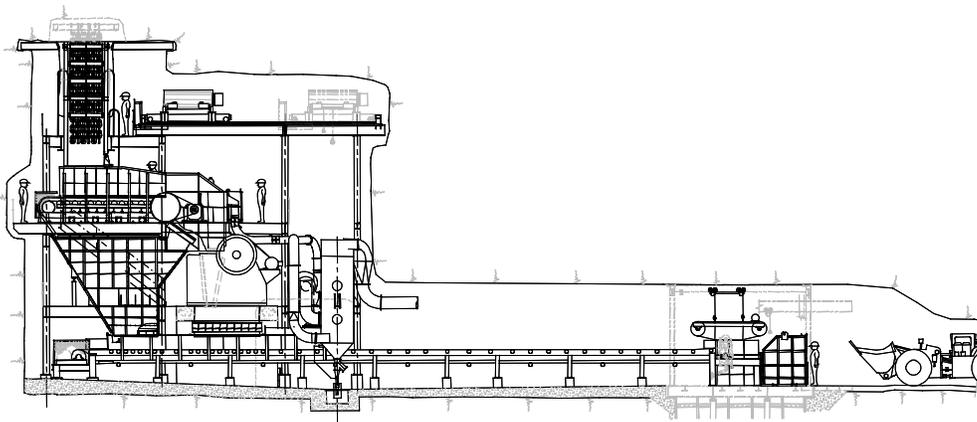


Figure 11 Typical underground jaw crusher installation

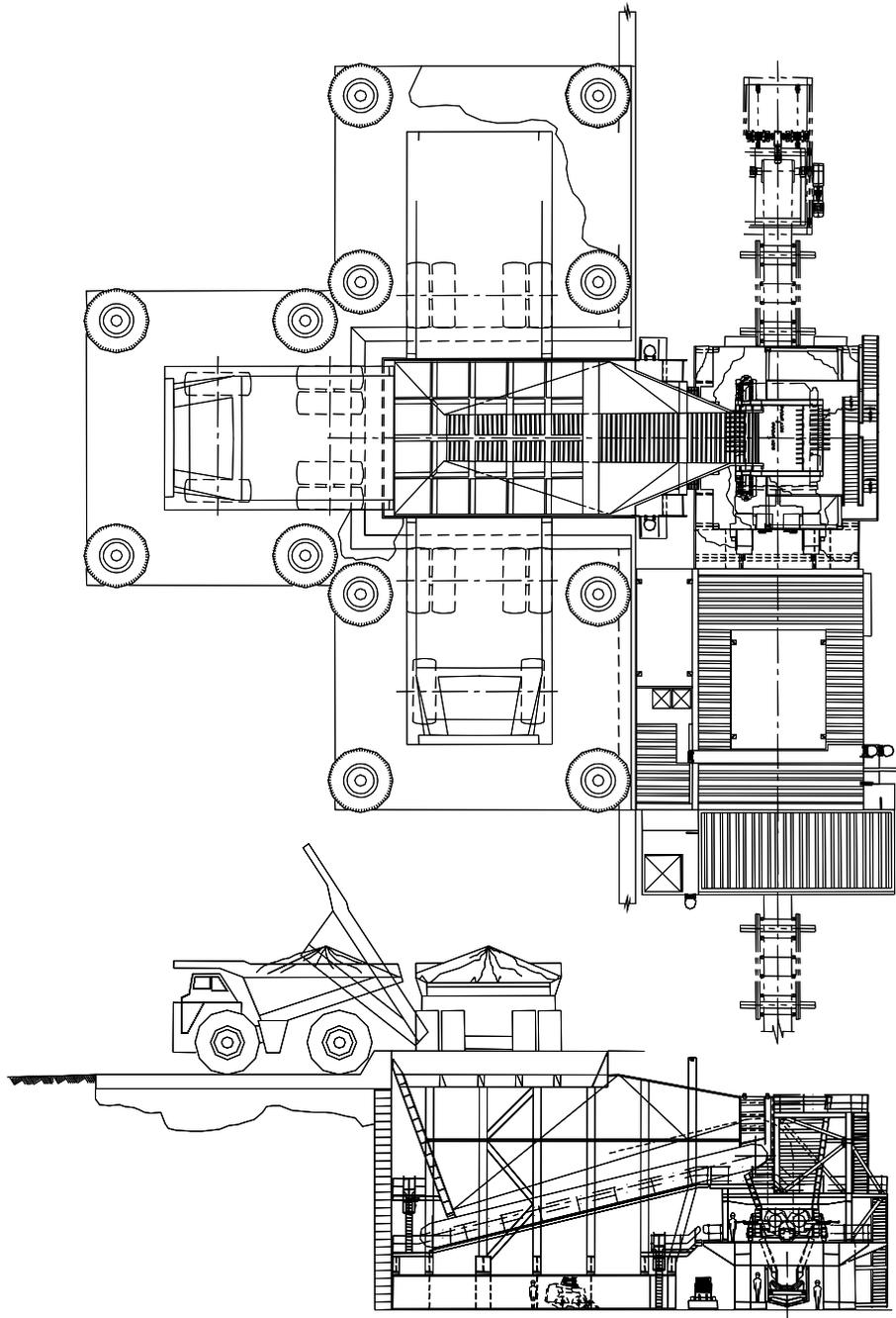


Figure 12 Typical low speed roll sizer installation

Upper Superstructure

- It is always a challenge to size the crane. Should it be used to install the crusher, or to just service the components of the crusher? The main service hook doesn't need to travel any further than the top of the crusher; beyond this point, slings can be added to lift anything at lower levels.
- Crane main hook speed should be slow, for inserting the main shaft.
- Always prepare a hook coverage plan to check all areas of crane service.
- Crane maintenance access should include stairs and a platform to service an overhead bridge crane.
- Choose the type of crane, overhead bridge, jib, gantry or mobile crane required to meet project requirements.
- A well-ventilated crusher control room is required.
- There must be a washroom, with or without potable water.
- The electrical room can be located at the upper or lower level; keep high-voltage runs short.
- The location of the dust collector should consider operating lengths of ductwork..
- Two main shaft supports are required, for the shaft in use and a spare. Storage must be provided for both. The spare shaft may be stored near the crusher or in the truck or maintenance shop.
- Provision may be required for a furnace and zincing, although most of today's crushers use epoxy instead.
- Provide a maintenance laydown area.
- Locate the plant air compressor in a room away from dusty areas.

Receiving Hopper Area

- Determine whether a grizzly is required in the receiving hopper area. This is very expensive in gyratory installations, but is frequently used in jaw crusher installations.
- A splitter may be required in the receiving hopper area, to reduce impact on the spider, particularly in the expectation of large run-of-mine material. Some crusher manufacturers request that protection be provided from direct rock impacts on the spider. The design of a splitter remains a very controversial design subject and has to be reviewed for each project, remembering that any splitter installation can be very expensive. Investigate the design of the receiving hopper relative to where the material impacts as it leaves the truck.
- Well-hatch covers should be fixed-hinge on one side so they won't accidentally drop to a lower level.
- To minimize dust emission, a vertical dump hopper spray system is best, with up to ten sprays per header. This provides greater distance for dust to pass through.
- A receiving hopper dust-hood plenum is required for plants using dust collection.
- Care should be exercised in determining whether receiver hopper liners are required, and if so, how many and what type. These items are costly. Often it is preferable to install only the steel inserts in the concrete for attaching liners. When the hopper deadbeds are formed, liners need to be applied only on exposed areas.
- Design a simple, easily removed, drop-in circular steel seal for the crusher and dump hopper. A rubber lining will prevent or minimize water leakage.
- Installing a receiving hopper access door at the crusher seal level allows for quick access when concaves are being changed.

- The ability to easily dig out the upper crusher pocket is critical. A long length of stud link chain can be placed on the pocket floor with one end exposed for lifting out and breaking up the stone boxed material in the pocket.
- Rock breaker location is critical to provide reach in all areas of the hopper, and also for concave removal. Ensure that the breaker impact head can be parked in the vertical position out of the way of truck dumping.
- Determine whether the rock breaker should be remotely and/or locally controlled.
- The control room operator should be able to see down into the dump box, preferably through a window installed to the floor. He should be able to see approaching trucks.
- The operator should have access to washroom facilities.
- Truck bollards can be of concrete, old tires or tree trunks. The bollards should be located so they will always deflect the truck body away from any structural columns.

Crusher Floor Level

- A walkway platform should be installed around the crusher for easy spider removal.
- A built-in circular monorail under the concrete floor level at the top of the crusher will provide support for a trolley support air hammer, which can be used to remove or install the spider nuts
- Choose countershaft, in-line drive versus V-belt drive and clutch.
- The spider lube system should normally be located at the crusher floor level.
- The air-seal compressor can be located on the crusher floor.
- The balance cylinder should be located close to the crusher, with maximum pipe bend radii for ease of quick response. Provisions must be made for oil relief collection.

Surge Bin Area

- The surge bin access door should be split horizontally on one side, to allow easy man-access to one side without opening the whole door.
- For the crusher discharge opening, tapered concrete with a welded AR plate is preferred.
- Air cannon discharge points must be pre-designed. Locate the air receivers and valves out side the surge bin.
- Level detectors should be installed at high and low points in the surge pocket.
- For the eccentric trolley, a hung design is best, complete with a man-access platform at the top of trolley to permit servicing the crusher hydraulic cylinder and eccentric.
- Surge pocket withdrawal opening liners should be made in a minimum number of large pieces for ease of removal. Drop-in design is best, without bolts. Liners can be lifted with a sling from the service crane hook through the crusher .
- The surge pocket opening slot should be made as long as practical to maximize live capacity.
- At a minimum, one truckload's worth of live capacity should be provided, but a capacity of 1.5 or 2 truckloads is better. Some plants are designed with no surge bin under the crusher, with a wide, high-speed take-away conveyor to take the surge (flush rate) to a nearby stockpile or to a external surge bin.
- Install floodlights in the surge pocket to facilitate inspection and maintenance.
- Provide two pick-up openings through the crusher floor level for dust collection at the back of the crusher.
- Provide low-level protection for the surge feeder, possibly gamma detectors. This maintains a bed depth of material to protect the feeder from material falling directly on it.

Crusher Lubrication

- The crusher lubrication package must have maintenance access at all points.
- Crusher oil piping must consider protection and ease of maintenance. Lube piping routing is critical; correct slopes must be maintained as per the manufacturer's recommendations. Pickling of the lube lines can be a problem in some jurisdictions; stainless steel may be the best solution.
- Automatic drain and re-supply piping must be provided.
- The crusher lube package must be in a well-ventilated area, and in a closed room if possible.
- Choose an automatic or manual system for crusher oil changes.
- Choose water- or air-cooling for the crusher lube system.

Feeder Area from Surge Bin

- Choosing a suitable feeder to draw material from the surge bin is always interesting. Some common types are apron feeders, hydra-strokes, belt feeders, magnetic or mechanical vibratory feeders.
- Dust collection facilities should be installed at the feeder discharge point.
- Dribble chutes should pass spillage onto the receiving belt, with the feeder discharge being designed to minimize the distance the rock will fall. This loading point should also ensure that under all material handling conditions, material will not stone box or build backup into the feeder.
- The design of feeder skirting should always provide relief in the direction of flow.
- Design a clean-up chute, which will allow spilled material from the floors above to pass down onto the take-away belt.
- To assist in maintenance of the feeder, provide for equipment pull points in the structures near the feeder.

Maintenance Items

- Gyratory crusher pre-fitted concave liner platforms can provide rapid concave replacement if pre hung on installation platforms. Chipping off existing concaves and letting them fall to the surge bin below facilitates the installation of new concaves. Remove old concaves from the surge bin at the same time as new concaves are being installed.
- Provide air hammer support (spider bolt removal) from a circular monorail.
- Pull points should be located in a manner that provides maximum assistance for equipment maintenance.
- Provide a hoist and trolley for lifting the crusher and feeder motors.
- A man-elevator is always useful in a gyratory crusher plant, but is often eliminated to reduce capital costs. Provisions should be made for installing one at a later date.
- Service air and water stations should be located throughout the plant. Include hoses and nozzles at predetermined washdown stations.

Take-Away Conveyor

- The take-away conveyor should have easy access under it for cleanup. Try to support the conveyor stringers from the floor above.
- There should be easy man-access into the feeder discharge chute.

- If possible, allow for access by a “Bobcat” for cleanup on both sides of the conveyor and at the lower floor level.
- Provide dust collection measures at the conveyor (hood, plenums or sprays).
- Try to have the floor slope down and self-drain to an outside sump, to eliminate sump pumps within the plant structure.
- Keep good clearance under the conveyor tail pulley (a minimum of 400 mm).
- Provide walkway access to service the conveyor skirting.

Electrical

- The electrical MCC/transformer electrical rooms can be located at the top or bottom of a crusher plant.
- Electrical cable tray routing and orientation should be checked by the mechanical process engineer. Vertical trays should be used to eliminate collection of spilled material in the trays.
- If the substation/electrical room is at the surface level, ensure there is no possibility of damage from impact from haul trucks.

Structural Considerations

- Provide easy stair access to each level.
- Provide access to both sides of the take-away conveyor.
- Braces and structures must be located away from equipment service and maintenance areas.
- Primary crushing plant enclosure costs can represent up to two-thirds the capital cost of a crusher station. It is therefore very important to select the most economical structure for the support of the crusher and ancillary equipment. There are many approaches: total concrete structures, round concrete structures, a mixture of concrete and steel, and reinforced earth structures with steel levels. The designer should spend considerable effort on selecting a structure that best suits the design parameters outlined above.

Dust Collection/Suppression

- There are many choices for dust collection/suppression systems, including bag filters, scrubbers, cartridge collectors, surfactants, water sprays and sonic fog. Whether one system or a combination is selected, care must be taken to provide service and maintenance access.
- Control, lube, compressor and electrical rooms should all be well-ventilated.
- Surge bins must include collection hoods.
- The take-away conveyor should have provisions for dust collection/suppression.
- Determine whether dust-collector air must be preheated in cold climates.
- A collector fan silencer should be considered, as fan noise can be excessive in closed areas.
- If an aircooling system is selected for crusher-oil, it will require venting for hot-air evacuation.

Crusher Installations

A summary of previous gyratory crusher installations is shown in Table 3.

Table 3 Primary crusher plant installations

	Mine	Location	Crusher Mfg	Qty	Year Installed	Product Size	Normal Capacity	Service Crane	Approx. Overall Height	Approx. Crusher Flr	Approx. Concrete
							stph	stons	ft.	sq. ft.@	cu. yds
42" (1)	Bethlehem Copper	Highland Valley, BC	42 x 54 AC	1	1962	6"	700	40/5	51	600	3280
	Endako	Endako, BC	42 x 54 AC	1	1964	7"	1500	50/5	74	1400	1811
	Granisle	Topley, BC	42 x 54 AC	1	1966	7"	1000	40/5	52	1150	n/a
	B.C.Moly	Alice Arm, BC	42 x 54 AC	1	1967	5"	750	40/5	56	1300	n/a
	Marcopper	Phillipines	42 x 54 AC/Kobi	1	1969	7"	1500	35/5	74	2500	n/a
	Bell Copper	Babine Lake, BC	42 x 54 AC	1	1972	6.5"	1500	45/11	70	2300	2561
	Afton	Kamloops, BC	42 x 54 AC	1	1977	8"	2000	35/5	70	1680	2120
	Equity Silver	Houston, BC	42 x 54 AC	1	1980	n/a	n/a	35/5	70	1600	2054
	Gibraltar	McLeese Lake, BC	54 x 74 AC	1	1972	7"	3000	75/10	82	2600	3260
	Ruttan	Lynn Lake, MB	54 x 74 AC	1	1972	6"	1800	50/10	81	2100	2388
54" (1)	Aznalcollar	Aznalcollar, Spain	54 x 74 AC/Kobi	1	1977	8"	1760	11-Jun	81	1950	3270
	Gibraltar/Pit	McLeese Lake, BC	54 x 74 AC	1	1979	7"	3000	pit crane	63	1662	1500
	Similkameen No.2	Princeton, BC	54 x 74 AC	1	1979	9"	2880	mobile	79	1200	n/a
	Ranger Uranium	Jabiru, Australia	54 x 74 AC	1	1981	6.5"	1400	60/10	86	2100	n/a
	Cadomin Quarry	Hinton, AB	54 x 74 AC	1	1982	6"	2000	44/5	u/g	n/a	n/a
	Highmont	Highland Valley, BC	54 x 74 AC	1	1990	8"	3000	75/10	81	2000	1500
	Similkameen No.1	Princeton, BC	54 x 74 AC	1	1972	8.5"	1500	82 mobile	59	1200	n/a
	Palabora Mining Twin	Phalaborwa, South Africa	54 x 74 AC	2	1966	8"	1265 ea.	75/15	75	6000	8566
	Kennecott/Ray	Ray, AZ	54 x 74 AC	1	1966	8"	1200	60/10	61	2500	n/a
	Anaconda/Twin Butes	Sahuarita, AZ	54 x 74 AC	2	1968	8.5"	2250 ea.	35/mobile	n/a	n/a	n/a
54" (2)	Bouganville	Papua, New Guinea	54 x 74 AC	2	1972	6"	1750 ea.	60/10	102	5300	9500
	Inspiration Cons.	Inspiration, AZ	54 x 74 AC	1	1972	7"	1500	75 mobile	76	1100	1550
	Climax Moly	Henderson, CO	54 x 74 Traylor	1	1976	8"/9"	3000	75/15	111	6100	9475
	Palabora Mining	Phalaborwa, South Africa	54 x 74 AC	1	1977	8"	1265	80/20	101	circular	7680
	Kennecott/Bonneville	Salt Lake City, UT	54 x 74 AC	1	n/a	6"	2000	75/15	139	5800	n/a
60" (1)	Brenda Mines	Peachland, BC	60 x 89 AC	1	1969	7"	3500	100/10	87	4200	4300
	Cerro Verde	Arequipa, Peru	60 x 89 AC	1	1976	7"	3200	90/19	98	1800	n/a
	Rio Tinto Minera	Rio Tinto, Spain	60 x 89 AC	1	1980	n/a	n/a	88/11	100	2200	n/a
60" (2)	Cyprus Mining Corp.	Thompson Creek, ID	60 x 89 Traylor	1	1982	n/a	4500	100/30	96	2400	4238
	Iron Ore Co.	Lab-City, NF	60 x 89 AC	2	1962/72	7"	4000 ea	75/10	97	10000	n/a
	Reserve Mining	Babbitt, MI	60 x 109 AC	1	1955	8.5"	3000	130	1665	circular	11000
	Anaconda/Butte	Butte, MT	60 x 89 AC grizzly feed	1	1971	5.5"	5000 combined	75/20	122	4200	1280
	Cities Service	Miami, AZ	60 x 89 Traylor	1	1971	8"	3500	80/20	86	2100	4874
	Lornex	Logan Lake, BC	60 x 89 AC	1	1972	10"	4000	75	85	2800	6255
	Duval Sierrita	Tucson, AZ	60 x 89 AC	2	1976	6"	2500 ea.	70/20	89	4400	8000
	Southern Peru	Cuajone, Peru	60 x 89 AC (grizzly feed)	1	1976	8"	4000 combined	80/20	125	5500	8400
70"	Cdn. Johns-Manville	Asbestos, QE	72 x 93 Traylor	1	1972	7.5"		100/20	106	2100	n/a

- (1) Wright Engineers Ltd. Internal study of Primary Crusher Design, 1982
- (2) McQuiston F.W. & Shoemaker R.S. "Primary Crusher Design" "American Institute of Mining, Metallurgical and Petroleum Engineers" Jan.1978

Underground Crushers

Gyratory, jaw and roll sizers have all been installed underground to act as primary crushers prior to the transportation of the ore to the surface. There are a few gyratory crusher installations in hard rock mines (the latest, 1998, being Phelps Dodge Henderson mine 1,371 mm x 1,880 mm [54 ft x 74 in] in Colorado) but the greatest percentage of crushers working underground are jaw crushers. Until a few years ago, double toggle crushers were the underground crushing choice, however, these are now being replaced with more efficient and less expensive single toggle crushers. A typical underground jaw crusher installation is shown in Figure 11.

FINE CRUSHING (Secondary, Tertiary and Quaternary)

Fine crushing circuits can be more challenging to design than primary crusher installations. There are more equipment options, and each has different installation and maintenance requirements. The process flowsheet dictates the expected performance of the items in the flow stream. The designer must configure the equipment and structures into a balanced, economical plant design. Screens, feeders, stockpiles, bins, conveyors and crushers must all be interfaced with the most economical supporting structures and buildings.

An open-circuit crusher is easier to design and lay out than a closed-circuit design, since it has fewer equipment items and structures. Figures 13, 14, and 15 show some typical secondary crusher open circuit layouts. Figure 16 shows some typical open circuit secondary and tertiary crushers. Provisions should be made for possible future conversion of an open-circuit plant to a closed-circuit version.

Cone crushers remain the choice for most secondary and tertiary operations, with some gyradisc and vertical-impact crushers also utilized on certain ore types. Water-flush cone crushers have been introduced in secondary and tertiary installation, which requires careful design of the water systems to and from the crusher.

Most open-circuit secondary and tertiary crushers include scalping screens to remove fine material prior to the secondary crushers. Closed-circuit crushers use tertiary screens to control the final product size. (See Figure 17 and 18 for typical closed circuit secondary and tertiary crushers.) In some larger installations, the secondary and tertiary crushers are located in one plant area and the screens in another. (See Figure 18f.) Crushers and screens in these plants have common bins feeding to the multiple crushers or screens. Most plants now have the screen feeding the fine crusher, providing for easier access to service the screens.

As with primary crushers, fine crushers must meet the design parameters listed above. Design details that are helpful to fine crusher plant layout area listed in the sections that follow.

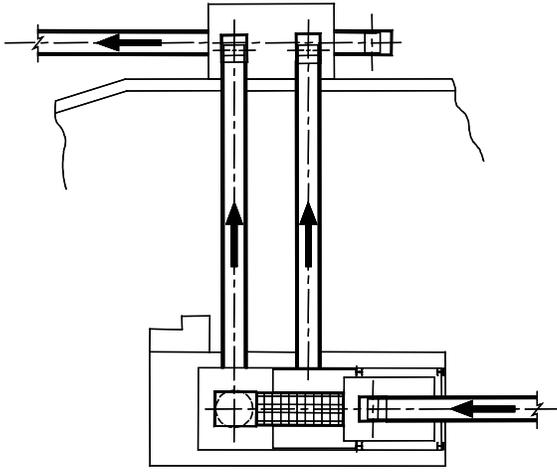


Figure 13 Open circuit (1) secondary crusher

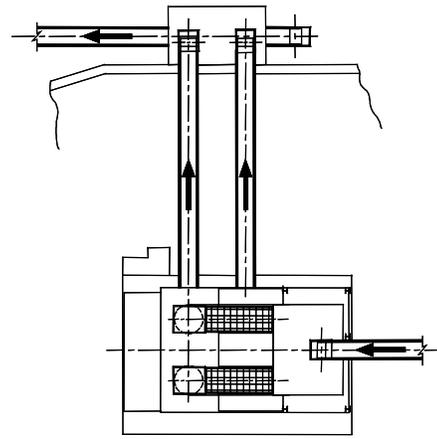


Figure 14 Open circuit (2) secondary crushers

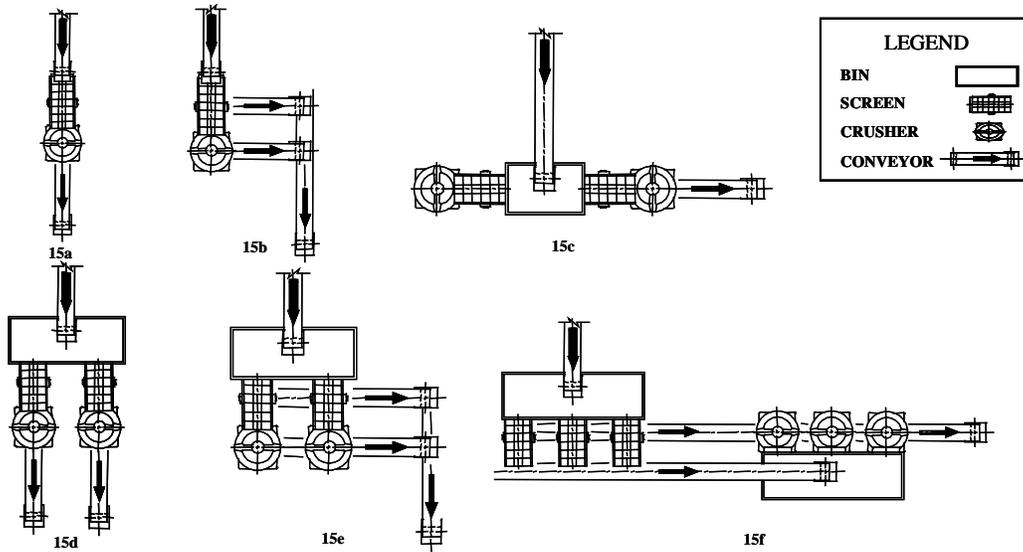
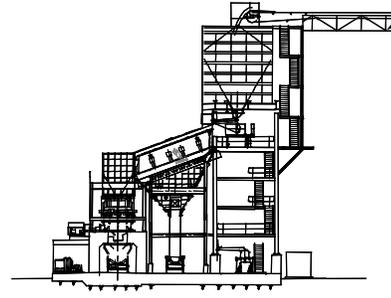
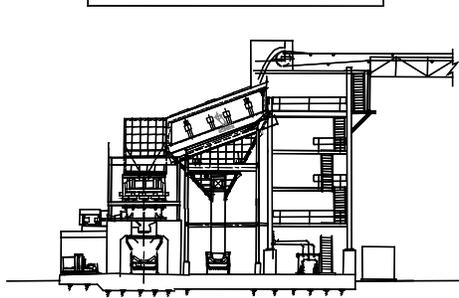


Figure 15 Typical open circuit secondary crusher options

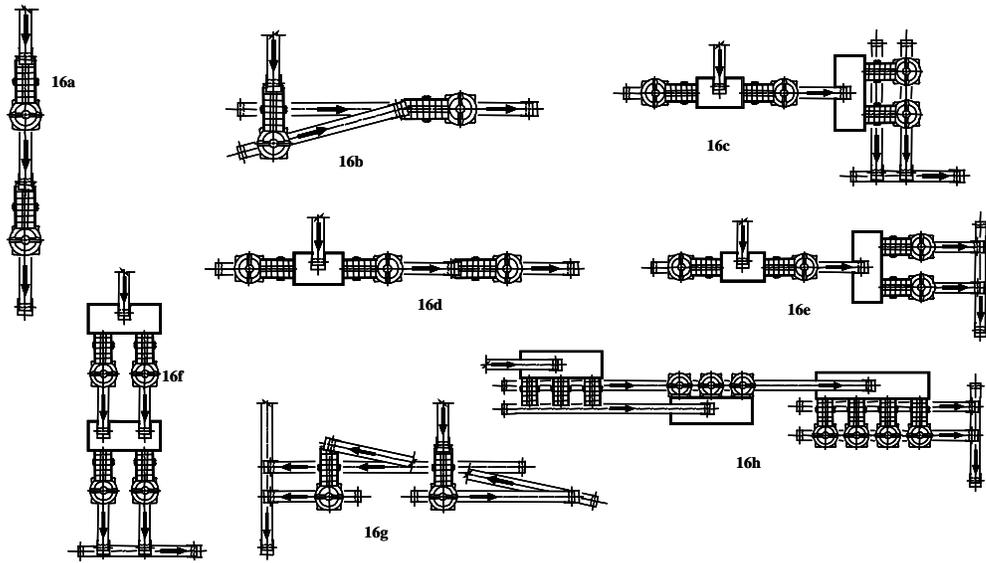


Figure 16 Typical open circuit secondary and tertiary crushers

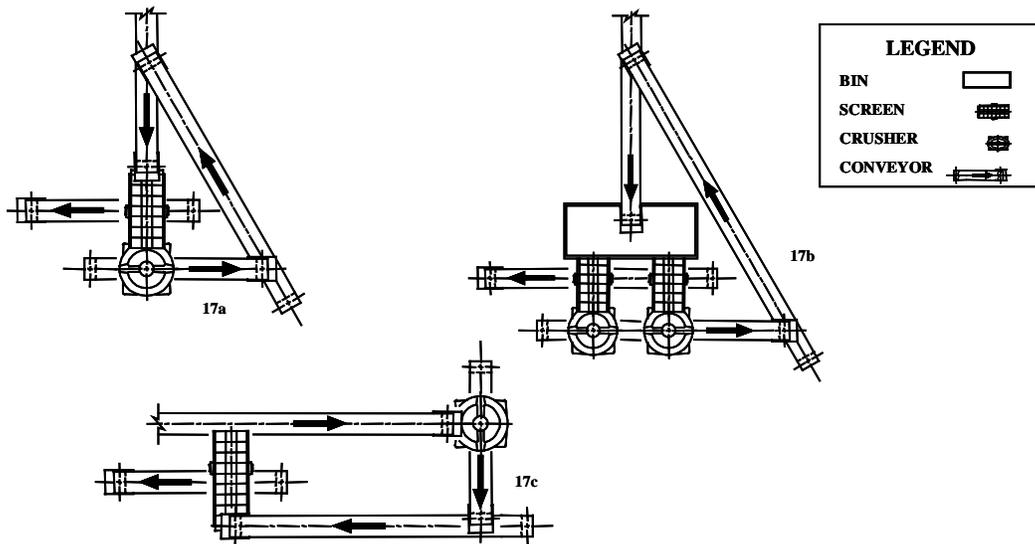


Figure 17 Typical closed circuit secondary crushing

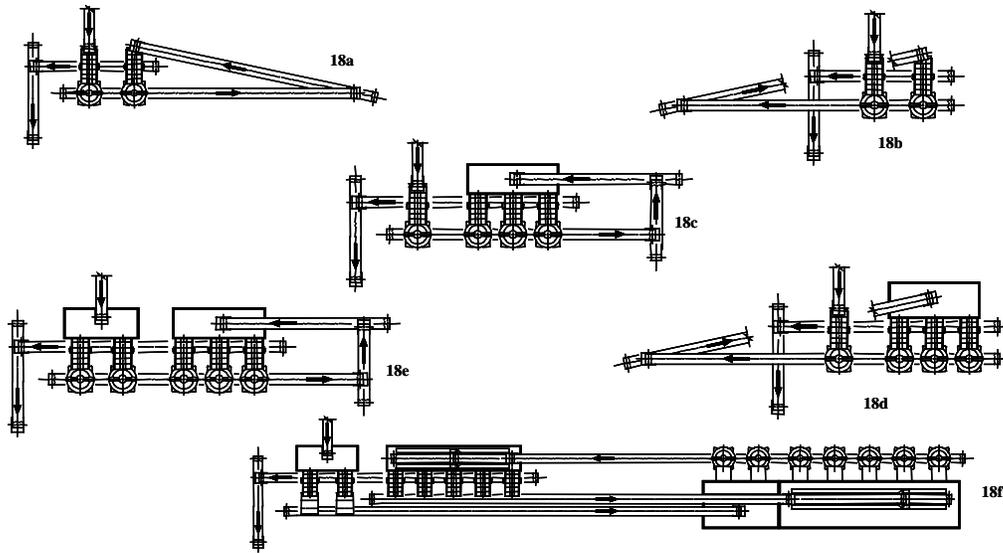


Figure 18 Typical closed circuit secondary and tertiary crushers

Coarse Ore Stockpile

- The primary crushing circuit is normally separated from the secondary crushing circuit by provision of a coarse ore stockpile, which retains the primary crushed ore. For mines with short lives and small tonnage rates, operators may eliminate the coarse ore stockpile to reduce costs.
- Stockpile live capacity is a source of controversy. Coarse ore stockpiles were originally designed for three days' capacity (a long weekend), but this is impractical for some of today's mines with high daily throughputs. Now, it is possible to size a stockpile by simulation, using pile specific criteria.
- There are many types of coarse ore stockpiles (e.g., conical, elongated, radial, covered or open, heated) with just as many types of withdrawal arrangements and feeders. (See chapter on bins, stockpiles, and feeders.)
- The stockpile provides improved overall system utilization by de-linking the primary and subsequent crushing operations.
- Coarse ore stockpiles also provide the capability to continue operation of the secondary crushing facilities should the primary crusher become inoperative, by bulldozing the stockpile into the reclaim openings.

Feed to Screens or Direct to Secondary Crusher

- The conveyor or feeder transporting ore directly to a secondary crusher should be retractable (or tilt at the head end) to permit crane access to the crusher. (See Figure 17c.)
- The conveyor feed chute to a secondary screen should have sufficient height to allow the material to feed to the total width of the screen as rapidly as possible. This is especially critical when feeding from a conveyor to the new wider banana screens.
- The installation of a bin feeding to a single secondary crusher or screen can allow for the future installation of an additional secondary crusher and screen. (See Figures 14, 15c, 15d and 15e.)

Screens

- Screens are being manufactured wider so the feed must have more height to allow the material to spread out across the width of the screen.
- The chute feeding the screen should have easy man-access for replacement of liners and easy removal of material build-up.
- Most screen installations should be totally enclosed. Screen manufacturers have yet to develop a cover that allows for ease of maintenance and access.
- Adequate platforms should be provided for access around the entire screen, to facilitate rapid inspection and changing of screen decks.
- The discharge chute from the screen should seal against the screen, and be designed as one piece for ease of removal. When the chute is removed, there should be sufficient opening in the floor to lift out the crusher bowl and head.
- The discharge chute should have a full man-door.
- Permanent floodlighting should be installed inside the chute for ease of inspection.

Crushers

- Some cone crushers require servicing and removal of components from the bottom. The design and layout should allow for such service requirements.
- There have been many changes recently in the manufacture of cone crushers. A careful assessment of each suppliers' requirements for lubrication, water and air services to the crusher is mandatory.
- Automatic bowl adjustment is now common on most cone crushers and is definitely going to be used for on-stream electronic control adjustment to maximize input and product size control.

Tertiary Feed Bins

- Most manufacturers ask for controlled ore feed rate to their tertiary crushers. The secondary crushed material (and in the case of a closed circuit, the recirculated material) is usually stored in a bin, and fed to the tertiary screen or directly to the crusher with a variable speed feeder. (See Figure 19.)
- When the feed comes from a bin via a feeder directly to a crusher, the feeder design should be retractable so that the tertiary crusher head and bowl may be removed by a service crane.
- Feed to the tertiary feed bins is dependent on the number of crushers being fed. A single point discharge will be adequate with three crushers, although feed distribution is not good. Five crushers can be fed with a two point feed discharge system, with the main feed conveyor feeding directly to the bin or using a flop gate to a fixed horizontal conveyor to feed to the other discharge point (or a tripper conveyor can be utilized) See Figures 18d, 18e and 18f.

Feeders from a Tertiary Bin

- A belt feeder will maximize live volume in the bin
- Vibratory feeder/magnetic/mechanical is less expensive but provides less live storage in the bin.

Lubrication

- Some lubrication systems are mounted on skids which can be as large as large as 4 x 2.4 m (12 x 8 ft), therefore sufficient access space must be provided.
- Other fine crusher lubrication considerations are the same as for primary crushers.

Maintenance Items

- Pull points should be located in a manner that provide maximum assistance for equipment maintenance.
- If an overhead crane is provided, it should be able to service all main equipment items. For crushers without building enclosures, a modified gantry crane or mobile crane can be used.
- A man-elevator is always useful in large crushing and screening plants, and is a necessity in very large capacity plants.
- Service air and water stations should be located throughout the plant. Include the hoses and nozzles at predetermined wash-down stations.
- Adequate water pressure should be provided for wash-down and cleaning of all areas of the plant.
- Allowance of adequate working width on each side of the lower-floor conveyors, and sufficient clearance under conveyors for easy cleaning
- Man-doors should be provided on all chutes for maintenance and replacement of wear parts. Inspection doors should not be used to provide access for wear plate replacement and unplugging of chutes.
- Clean-up chutes should be provided at various levels, to enable spilled material to be passed to a receiving conveyor at the lower levels.

Conveyors

- Conveyor design considerations for fine crushing circuits are the same as for primary crushers.

Electrical

- Locate the electrical/MCC room centrally to minimize long cable runs.
- Electrical cable tray routing and orientation is critical and should be reviewed by mechanical process personnel. Vertical trays are preferred to horizontal (vertical trays allow no collection of spilled material in tray)
- Allow for plenty of lighting in all areas of a plant, including inside chutes and bins.

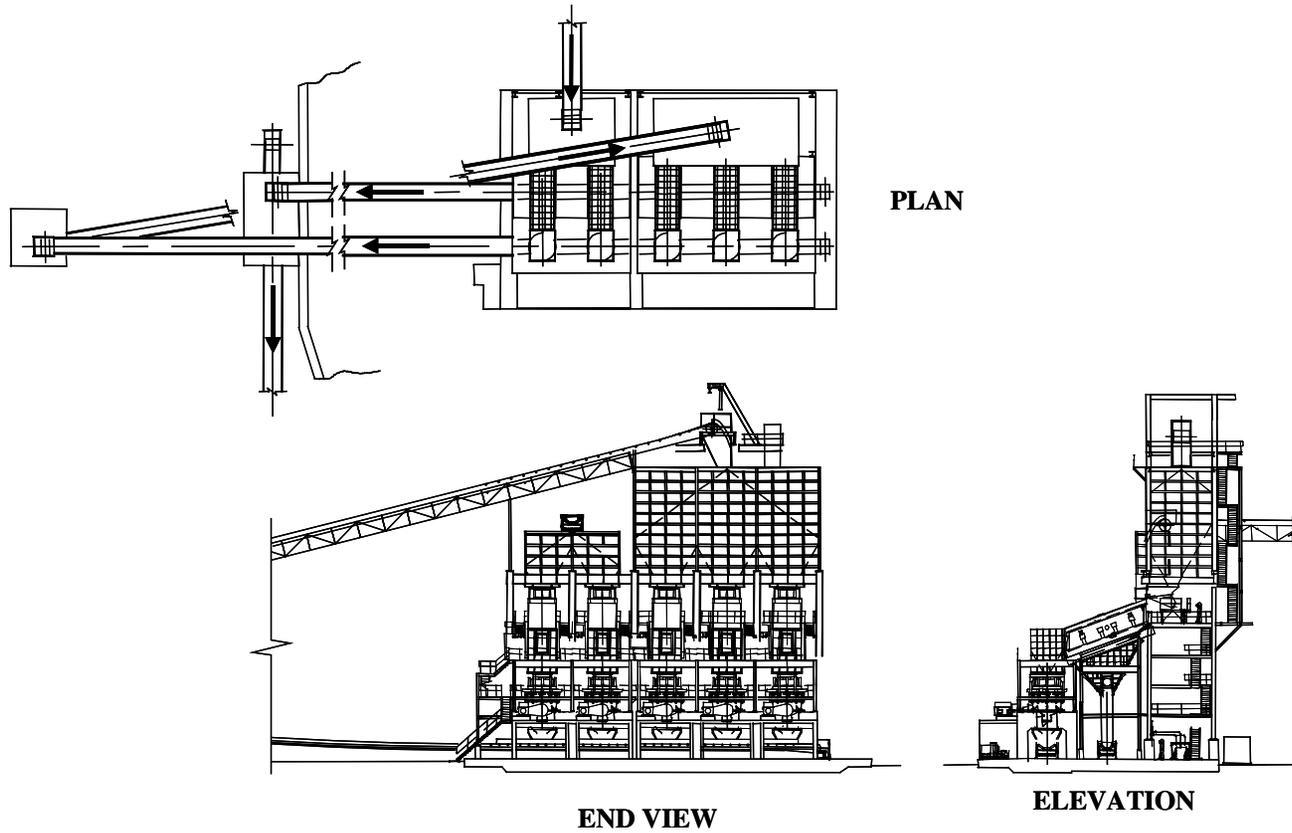


Figure 19 Typical secondary and tertiary closed circuit layout

Structural Considerations

- Provide easy stair access to each level.
- Provide access to both sides of the take-away conveyor.
- Braces and structures must be kept away from equipment service and maintenance areas.
- As with primary crushers, structural costs for fine crushing circuits are very high. It is therefore very important to select the most economical structure for the support of the crusher and ancillary equipment. The designer should spend most of his effort on selecting a structure that best suits the design parameters.
- The selection of the types of flooring in a crushing plant is always controversial. Some selections are grating, checker plate and concrete. Checker plate flooring allows for easier clean-up and does not allow for smaller rocks or spillage to any floors below. (The most suitable flooring for conveyor galleries in northern climates is wood.)

Dust collection/Suppression

- There are many choices for dust collection/suppression systems, including bag filters, scrubbers, cartridge collectors, surfactants, water sprays and sonic fog. Whether one system or a combination is selected, care must be taken to provide service access.
- Control, lube, compressor and electrical rooms should all be well-ventilated.
- Bin air/dust evacuators are required.
- In cold climates, determine whether dust-collector air must be preheated.
- A collector fan silencer should be considered, as fan noise can be deleterious in closed areas.
- If an air system is selected for crusher-oil cooling, it will require venting and hot-air evacuation.

CONCLUSION

Primary crushing will see the introduction of bigger, 1,800 mm (72 in) gyratory crushers, and low-speed, high-tonnage roll sizers will become more generally accepted. These larger crushers are required to handle the higher throughputs, and 400- to 500-tonne capacity trucks, expected on some future projects.

Fine crushing has already seen the introduction of 10 ft cone crushers. Much wider banana screens, with sizes up to 4 x 8 m, are also being introduced. Vertical impact crushers are still finding their place for certain crushing applications.

Safety and the working environment remain the two areas of plant design, which require more attention. Noise abatement and the reduction of dust emissions remain the goals of most operators and crushing plant designers.

As designers become better trained and familiar with 3D software, then 3D plant design may become the method of choice to optimize the most economical plant designs.

The biggest change, which is now being introduced into the design of crushing plants is the design of the mining process as one complete system, from mine quarry and pit to the final product. Digital image analysis is now allowing electronic monitoring of the size distribution of the material being handled at any point in the product stream. This monitoring and analysis of the size distribution from the pit face to the mill or heap, now allows for the adjustment of the crusher discharge openings as production continues. We can now plan for a more uniform product, increased production, less wear, and longer mine life.

ACKNOWLEDGEMENTS

The author would like to thank Bill Dowall for reviewing the paper, Andrew Solkin and Shirley Ernewin for editorial assistance, and David Ng for his assistance in preparing all the CAD figures.

REFERENCES

- McQuiston, F.W. & Shoemaker, R.S. 1978. "Primary Crusher Design" Book for "American Institute of Mining, Metallurgical and Petroleum Engineers".
- Boyd, K.L. & Dowall, W. Wright Engineers Ltd. 1982. Internal study of primary crusher design
- Gould, D.G. & Shoemaker, R.S. 1980. "Mineral Process Plant Design", Chapter 40, Society of Mining Engineers, "American Institute of Mining, Metallurgical and Petroleum Engineers".
- Dance, A. 2001. "The Importance of Primary Crushing in Mill Feed Size Optimisation", International Autogenous and Semiautogenous Grinding Technology 2001, pp I-201.