Mineral Processing Plant Design

- General Procedure for plant design
    - Process Design
    - Flow sheet Design
    - Process Plant Simulation
    - General Arrangement Drawings
- Detailed Design
- Metallurgical involvement in the construction phase
- Commissioning (Cold commissioning, Hot commissioning)
- Practical commissioning tips
- Acceptance runs
- Conclusions

Importance of Good Plant Design and in Time Commissioning

- A good plant design can minimize capital expenditure and maximize on long term profits.
- A good plant design together with careful planning and execution of the startup can greatly contribute towards:
    - easing commissioning problems, and
    - can ensure the plant brought into production in time.
- To Design capacity and efficiency, And Within budget.
- Delays in commissioning can prove to become an extremely costly exercise in terms of profit loss due to loss of production

General Procedure for plant design

- Ore testing,
- Process definition,
- Production of basic flowsheet,
- Production of piping and instrument drawings,
- Production of general arrangement drawings and conceptual models,
- Equipment selection and specification
- Costing and preparation of definitive budget,
- Production of final flowsheet,
- Construction,
- Commissioning

Process Design

Process design criteria

- A statement of what the plant will be required to do and the framework in which it will have to accomplish it. It includes:
  - The capacity of the plant,
  - Material to be treated,
  - The sources of feed,
  - The product,
  - Time schedule for the commissioning of the various stages,
- General information regarding the externally imposed parameters of the design.
- Normally prepared by the mining and financial consultants,
- Deals essentially with:
  - What the plant is to achieve,
  - Basic directive to the plant designer,
  - Setting limits within which they should operate,
  - And targets they must attain.

Flow sheet Design

- The flowsheet deals with the means by which the objectives are to be attained.
- Diagrammatic definition of how the requirements specified in the design criteria are to be achieved.
- Flowsheet design is a major and vital part of process design,
- The correct choice of flowsheet is crucial to the technical and financial success.

The design process

- Arranging in diagrammatic form the necessary equipment, installations and interconnections to achieve the goals specified in the design criteria,
- Compiling with the treatment method indicated by the laboratory analysis,
- And any other source of information or requirements
- Various possible alternative technical treatment routes are roughly plotted and considered

Quantified flow sheet

- ❖ For flowsheet to be used in subsequent costing, evaluation, and design stages it must be quantified. Ie. It must include the following information:
    - Flow streams throughput of the plant,
    - Equipment to be installed,
    - A table showing flow and equipment data,
    - All primary data (data on which the flowsheet is based as per design criteria and test results)
    - Flow rates must be based on the full length of time as specified on the design criteria,
- ❖ Initial flow rates must be correct when actual running times are available
- ❖ Secondary data calculations based on mass balance around the equipment must then be shown.

Estimation of actual running time

- Initially flow data is based on 100% running time,
- Consideration must be given to the number of hours it will be manned and is planned to run,
- The proportion of lost time due to random unplanned breakdowns and stoppages must also be considered.
- The legal constraints of operation must also be considered,

The following data must also be tabulated obtained from the lab results in order to complete the flow sheet:

- Size distribution,
- pH,
- temperatures and
- Reagent concentrations

❖ Equipment sizing and selection

- The design procedures so far described have provided some of the essential data on which equipment sizing and selection can be based,
- namely the flow data pertaining to each stream in the plant.

❖ The next step is to determine with the help of this data, what capacity volume or energy input is required to bring about whatever change is required in each stream, whether of position, size distribution, chemical state, moisture content, etc.

- There will be several combinations of available sizes and numbers of machine that will fulfil each requirement
- The decision as to which is the correct combination is essentially an economic one, that is, determination of the relative profitabilities of the various alternatives.

Crushing Plant Design and Layout Considerations

Introduction

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.

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

• Capital cost

• Ore characteristics

• Safety and environment

• Project location

• Life of mine/expansion plans

• Operational considerations

• Maintenance requirements

• Climatic conditions

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

The ***flowsheet*** specifies the <u>nominal design</u>, <u>peak production flow rate</u>, and <u>equipment sizing to handle those capacities</u>.

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 <u>*important factor*</u> 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			
(Subract 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
- Mechanical
- Concrete
- Electrical
- Structural steel
- Instrumentation.
- Architectural

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

- Construction indirects
- Startup and commissioning
- Construction equipment
- Freight
- Spare parts/first fill
- Taxes/duties
- Engineering, procurement and
- Owner's costs (relocation, hiring and training construction management (EPCM) 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. Mines works must comply with local and national regulations such as OSHA (*Occupational Safety and Health Administration*), MSHA (*Mine Safety and Health Administration*) and Mines Act.
- 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.
- 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.
- Planning for expansion is 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.

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

• 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.

☒ 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.

☒ Conveyor head chutes should be designed for easy access. Conveyor belt change areas should be provided.

☒ Maintenance personnel should have easy visual and rapid access to screen decks for panel replacement.

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 stoneboxes 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.

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

Process Design Criteria

Design Criteria Information

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

• Geographic data

• Climatic data

• Civil design criteria

• Process design data (process description, ore

• Structural design criteria characteristics)

• Mechanical design criteria

• Electrical/instrumentation design criteria.

Flowsheet

Some sample flowsheets are provided in Figures 1, 2, and 3 showing crusher circuits. Figure 4 shows a typical three stage closed crushing circuit with its ancillary equipment.

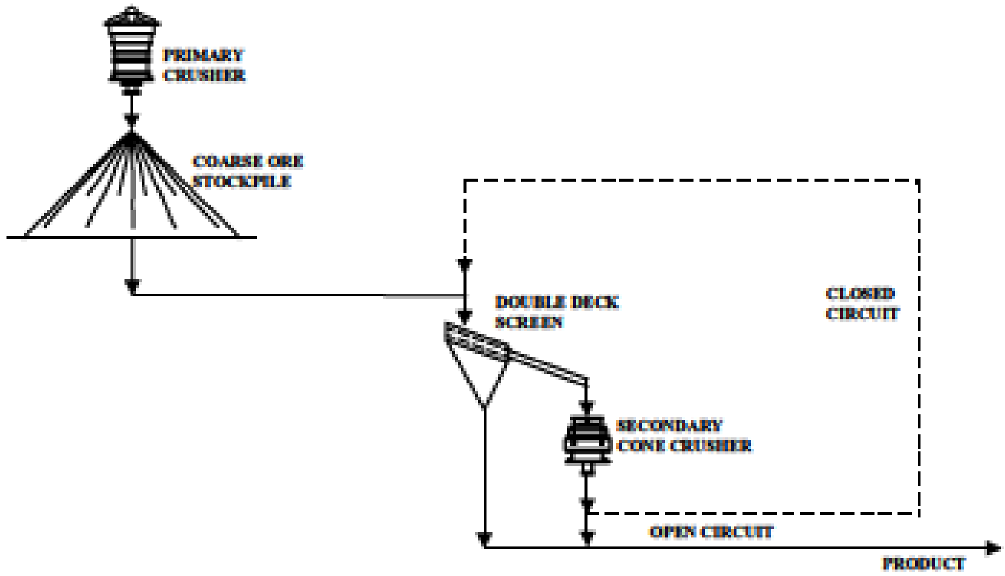

Figure 1 Two stage open/closed circuit

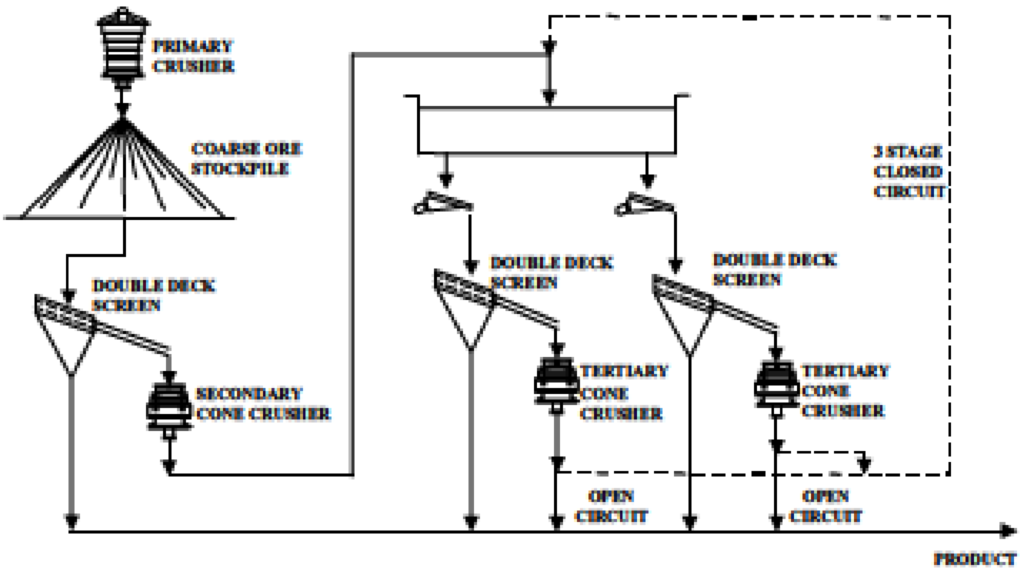

Figure 2 Three stage open/closed circuit

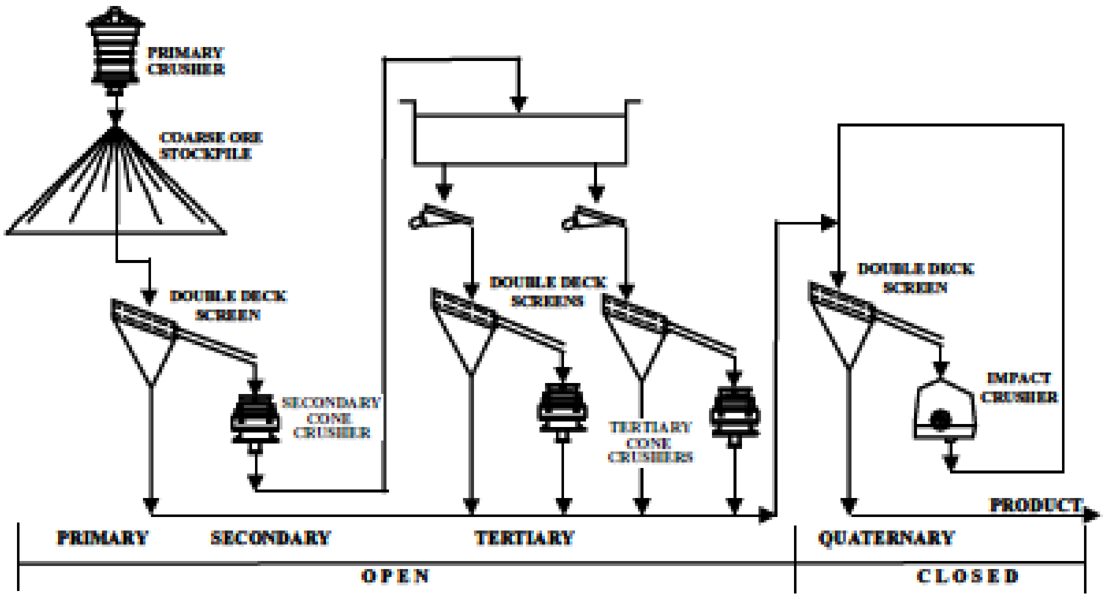

Figure 3 Four stage crushing circuit

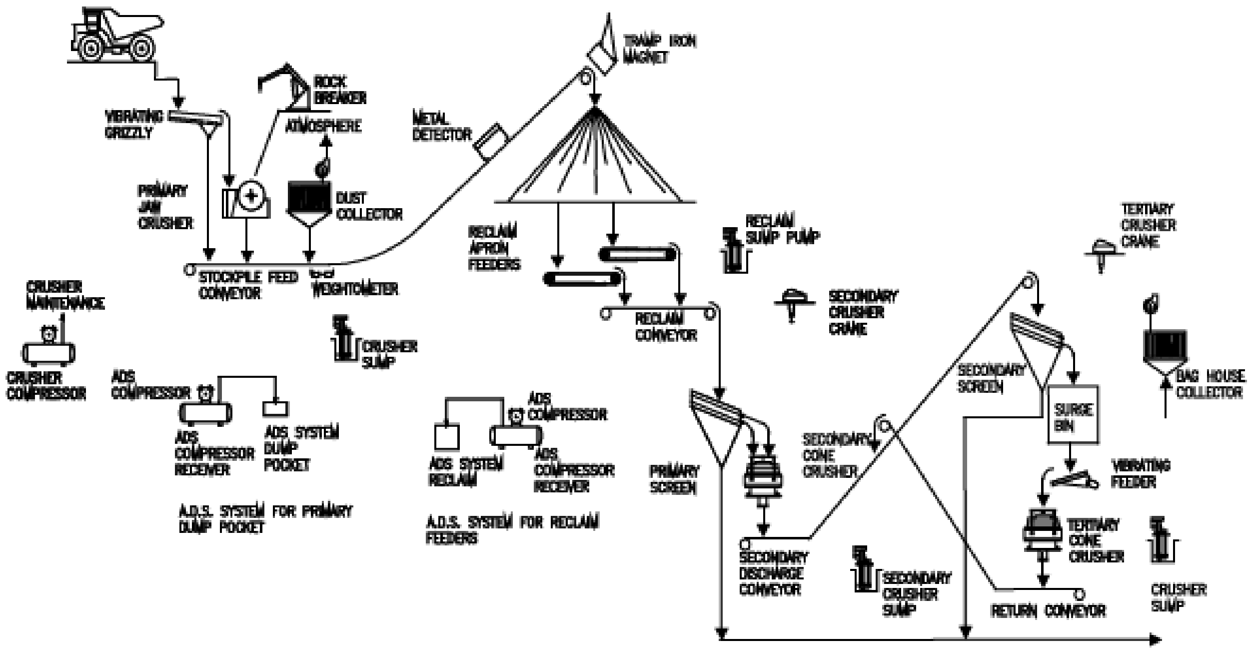

Figure 4 Three stage crushing closed circuit

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.

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.
- 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 cutand-paste layouts.
- 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.

Factors affecting crusher performance

Figure 5 shows a number of factors that can affect the performance in ore crushing plant. However, these factors can be illustrated by three categories of influence: ore characteristics, equipment factor and operation factor.

Identifying problems and debottlenecking in a crushing plant is a challenging task because it requires information and experience of the plant.

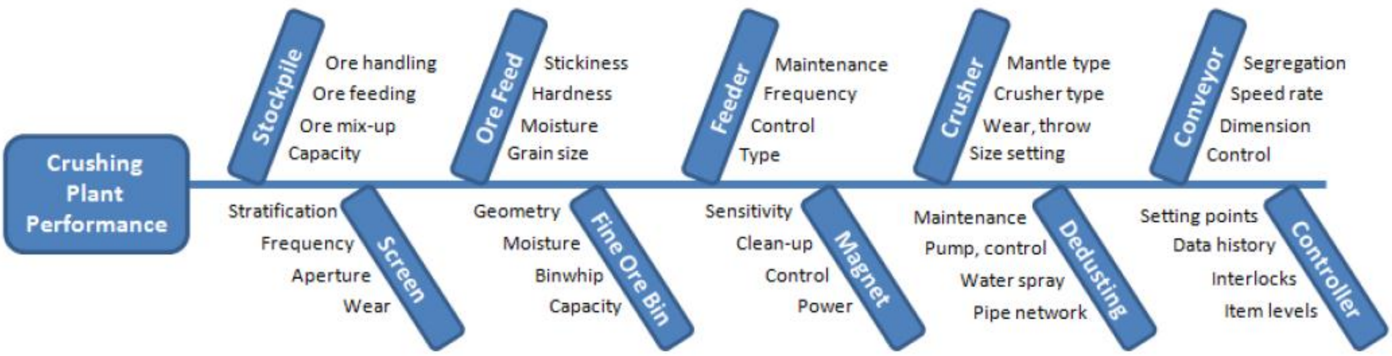

Fig. 5. Cause-and-effect diagram showing factors that can influence plant performance