MINERAL PROCESSING PLANT DESIGN AND COST ESTIMATES

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Design of mineral processing plants is a function of -

(a) Process flowsheet - which has been firmed up after considerable laboratory investigations and pilot plant trials.

(b) Scale up - which has been done based on many imperical considerations tempered with down-to-earth experience of practising mineral engineers leading to selection of equipment with due operating bias.

(c) Plant layout - which has been conceived and developed within the constraints of available space, topography and the other possible linkages with which the proposed plant may have to be dovetailed.

The flexibility of various design parameters could have been thoroughly examined before giving a final blue print on design and the technical considerations could have been an overriding factor so far.

While the 'type' and 'make' of equipment do have their place in the total gamut of mineral processing plant design, operating experience does provide some distilled lessons. For example, in flotation plants work experience would indicate that the arrangement of machines and transport systems have more predominating influence than the choice of particular type of flotation machine in a balanced system.

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Futuristic outlook on Plant Design :

Larger unit operations with built-in design flexibility coupled with a higher degree of instrumentation, control and automation seem to be the evolutionary trend in mineral processing ventures wherever feasibility studies support such a pattern. In the various sub-systems and unit operations, the following scenario is likely to emerge with respect to plant design:-

(a) Primary Crushing Systems :

Where large scale mining operations are envisaged, primary crushing plants may have to be located as close to the pit head as possible and the big lumps would have to be preferably crushed by the gyratory crushers. Where such plants have to form adjuncts to open pit mines, the emphasis could be towards in-pit or even mobile crushing systems. Naturally, an optimal fit between blasting techniques, shovel-dumper combinations and the selection of primary crusher have to be found on case to case basis. In view of environmental control measures, dust suppression and dust extraction will receive increased attention. The future installations of crushing systems may have complete enclosures over the individual crushers provided with efficient dust removal systems and hoods over all the dust generating points for entrapment of dust. All dust so collected may join a centralised wet system linked to the process stream at an appropriate point.

(b) Handling systems :

In view of sizeable upstream and down stream operations in future mineral processing plants, heavy duty conveying equipment have to be considered. The handling systems and the associated structures need to be designed for the highest availability with low maintenance. Since conveyors are almost never duplicated a break-down in handling system may lead to a total shutdown of the process plant. Design of conveyor loading points and their associated tribology would deserve more attention.

(c) Fine crushing systems :

For preparing feed to conventional grinding circuits, secondary and tertiary stage crushers would continue to be cone crushers preferably with hydraulic set controls. The feed to secondary crushers may have to be scalped while tertiary crushers may have to be close circuited by locating screens either before or after the tertiary or quaternary crushers. The mechanical vibrating screens of either two bearings or four-bearings designs would continue to operate in such circuits. In the very fine screening areas high frequency (or some times referred as 'resonance screens') would also find an increasing application. Here again dust control measures would have to be introduced with proper monitoring through strategically located probes. Noise levels may also have to be suitably monitored and brought to acceptable decible levels.

(d) Grinding Systems :

Depending upon the trade-offs with respect to capital and operating costs of the plant there may be large autogenous grinding mills accepting directly run-of-mine ore or as an alternate option three or four stages of crushing followed by conventional grinding mills. The cost benefit analysis, however, has to be looked into in either case but definite trend towards larger mills is discernible. For the purpose of cost optimisation, crushing & grinding operations need to be seen in the integrated perspective of size reduction and selection of equipment should be made accordingly. Foundation and support design of heavy grinding mills will receive due attention owing to economic considerations.

(e) Flotation Cells :

There has been steady progress towards going in for larger flotation machines. This trend has been all over and in Indian context also 14 m^3 flotation cells would soon emerge for industrial and base mineral beneficiation.

(f) Gravity concentration :

Gravity concentration will receive better consideration as an alternative process route in future. The spiral concentrators and Reichert Cones of Australia may find more application either in association with tables or without them depending upon the mineralogy and the textural association of valuable minerals with gangues. Presently, chromite beneficiation plants and uranium recovery plants from copper ore tailings in India are cases in example.

(g) Dewatering circuits :

The conventional thickeners at places may be replaced to some extent by more compact high capacity thickeners like Lamella and the enviro-clear thickeners. The dewatering scene, however, would still be dominated by conventional thickeners & for some more time drum filters and continuous belt filters would be more common adjuncts to hydro-metallurgical plants where leach pulps are processed.

(h) Effluent disposal :

Tailings and effluent disposal system would be of over-riding considerations from the view point of environmental clearance. In many cases, it would even influence plant location and may constitute a worthwhile chunk of the total outlay.

COST ESTIMATES

The total capital cost in a mineral processing plant constitutes of two components :-

(a) Fixed capital

(b) Working capital

While the fixed capital component indicates the first cost or the amount of money required for procuring necessary plant, equipment, auxiliaries and related off-site facilities, the working capital component indicates the fund that should be available to commence the plant production.

In most of the cases, these estimates may be required much before the designs have been frozen or completed. The estimates may have to be used at pre-feasibility stage of project formulation or to even to incorporate in detailed project reports. In either case, the estimates are needed before it can be ascertained accurately.

Fixed Capital Estimates :

A few mode of estimation has been proposed by the American Association of Cost Engineers in respect of fixed capital costs. These could be as under :

(a) Order of magnitude estimate :

This is arrived at by using some historical cost data which are updated as under :-

$$\text{Cost now} = (\text{Cost then}) \frac{\text{Index now}}{\text{Index then}}$$

It is estimated that the probable accuracy of this mode of estimate would be ± 30%.

(b) Budget authorisation estimate :

These are also preliminary estimates based on sufficient data to permit budgeting. The probable accuracy of this mode is ± 20%.

(c) Project control estimate :

These estimates are more definitive as they are based on almost complete data available before the complete specifications have been drawn or design drawings have been completed. Here the probable accuracy is $\pm$ 10%.

(d) Detailed or Contractor's estimate :

These are based on complete engineering drawings, specification and site surveys. Here the probable accuracy is expected to be $\pm$ 5%.

Here (a), (b) & (c) refer to pre-design estimates of fixed capital cost for which less detailed information is required. These estimates are intended to serve the following purpose :-

(i) an immediate assessment of initial capital requirement

(ii) to arrive at 'go' or 'no-go' decision in respect of the project

(iii) to look for alternative or more economical process route

(iv) to explore sources of funding the venture in case the project has to be launched.

WORKING CAPITAL COST ESTIMATE

Working capital cost estimate, many a times, is obtained by taking a percentage of fixed capital investment. Ten percent appears a reasonable figure. However, working capital cost can be estimated with the help of the following data :-

(a) Raw material inventory (one month's supply at cost)

(b) Materials-in-process inventory (one month's supply at cost)

(c) Product inventory (one month at manufactured cost)

(d) Accounts receivable (one month at selling price)

(e) Available cash (to meet expenses of wages, raw materials, utilities, supplies for one month at manufactured cost)

Working capital = (a) + (b) + (c) + (d) + (e)

The following example applicable in American context has been reproduced from "Mineral Processing Equipment Costs & Preliminary Capital Cost Estimates (Special Volume 18)" published by the Canadian Institute of Mining & Metallurgy :-

TOTAL CAPITAL INVESTMENT FOR A 1200 TPD PLANT

1.	Purchased equipment costs	...	$ 1,629,000
	Crushing $ 303,000 Grinding $ 493,000 Copper Flotation $ 294,000 Zinc Flotation $ 539,000		
2.	Installed equipment costs (1.43 times item 1)	...	$ 2,330,000
3.	Process Piping (10 percent of item 2)	...	$ 233,000
4.	Instrumentation (3 percent of item 2)	...	$ 70,000
5.	Buildings and Site Development (35 percent of item 2)	...	$ 816,000
	Mill Building Crusher Building Assy, Machine Shop Administration Building		
6.	Auxiliaries (5 percent of item 2)	...	$ 117,000
	Water Supply Diesel Standby Power		
7.	Outside lines (8 percent of item 2)	...	$ 186,000
8.	Total physical Plant costs (Items 2+3+4+5+6+7)	...	$ 3,752,000
9.	Engineering and Construction (25 percent of Item 8)	...	$ 938,000
10.	Contingencies (10 percent of Item 8)	...	$ 375,000
11.	Size Factor (5 percent of Item 8)	...	$ 188,000
12.	Fixed Capital Costs (Items 8+9+10+11)	...	$ 5,253,000
13.	Working Capital Cost (10 percent of Item 12)	...	$ 525,000

This is only illustrative of the factors which do undergo some changes in Indian conditions owing to structural changes in cost pattern, relatively cheap installation costs in a labour intensive situation and contingencies. In a situation where jobs are tendered and competitive bids are evaluated on identical technical parameters after pre-qualification procedures the Contractors build in the following in price estimates by adding items shown as (1) to (5) :

1. Estimated costs based on the quotations received from prospective suppliers.
2. Overhead expenses as a percentage (1) based on the accounting data of the contracting organisation.
3. A profit margin (depending upon what the traffic can bear) usually taken as a percentage of total direct cost i.e. (1) + (2).
4. A contingency as a percentage of (1) to take care of any errors of ommissions and for firming up the prices, if required.
5. A negotiating margin 'up the sleeve' which may be partly or wholly given off across the negotiating table if the situation demands so for bagging the order.

At times, Contractors bid for the job and other time they may bid for the market. This is why many a times prices quoted by the various bidders do not conform to a known or anticipated trend. It is mainly dictated by market forces and bidders' seriousness to execute the job.