Optimum plant design

Simon Courtenay* says the purchase of individual minerals processing equipment should be a task that is reviewed with the complete plant design in mind

Although the performance of equipment as individual process units can be assessed by a review of process data, limitations can occur through upstream and downstream conditions. Considering these conditions early in the design phase can have a significant impact on the plant economics. Issues such as options for tank arrangements, supporting structures, piping and personnel access will affect both capital and operational costs. From an engineering perspective, the goal in working with the client is to find an optimum design to minimise initial structural costs as well as ongoing operational costs. This article briefly looks at the important steps in developing such an optimum design.

The recommended approach to good plant design is to follow a sequence of:

- ◆ Confirmation of process data and equipment sizing
- ◆ Define personnel and equipment access requirements
- ◆ Design supporting structures to suit

Understanding the fundamental process system is the first step. Typically, this is described in the form of a Process Flow Diagram (PFD) and contains a simplified snapshot of the total plant flow regimes. Minimum, maximum and normal slurry flows at specific densities are a crucial part of the design puzzle as they are required to assess volumetric capacity of the equipment, along with particle size, which is important when considering the likelihood of sanding in pipe lines. Slurry temperature and pH can be important if they are likely to cause premature corrosion of structures. Major items of equipment are selected at this stage, including mills, flotation cells, and thickeners. The PFD does not consider what the overall plant will look like, but rather what it will do.

In developing the physical plant description, the Process and Instrumentation Diagram (P&ID) typically will describe the system in more detail than the PFD, by including proposed pipe connections, sizes and instrumentation. Flow rates will determine pipe sizes and hence velocities and head losses, which in turn govern the relative elevation between equipment. Elevation of inlets and outlets become critical interface points for minerals processing equipment items, including such things as a thickener feedpipe flange or a flotation cell outlet nozzle.

In sizing the piping for optimum slurry transport velocities, the target is for the slurry velocity to be above the solids settling velocity but low enough so not to create abrasive wear of piping and fittings. As the driving head through the piping system is proportional to V2, there is a need to keep velocities generally in the 1 – 2 m/s range.

Upstream feed conditions to both thickeners and flotation cells are important for different reasons. With a thickener, for example, the ideal feed should arrive as a fully de-aerated slurry flowing at a steady speed, allowing sufficient time for good mixing of flocculant and feed solids.

Excessive velocities and air entrainment of slurry entering a thickener can adversely affect the opportunity for effective settling of solids within the tank. While air entrainment is less of a concern for feed to flotation cells, it still

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needs to be minimised. Minimising slurry velocity to reduce abrasive wear of feedbox areas is also critical. When there are multiple cell banks being fed from cyclone clusters. It is important to ensure that flow is consistent to each bank, and there is not the propensity for one bank to preferentially receive coarser material. Building planning and piping layout need to be considered concurrently when initially developing such a flowsheet. Obviously, other factors, including grind size of the ore, affect the flotation cell performance and are determined by upstream process functions.

In selecting pumps for transport, disposal or recycle, the key elements are obviously flowrate and head required, along with density and solids particle size for mineral slurries. When designing a slurry process system, the designer should consider which flow stream will need to be pumped and which can be allowed to flow by gravity. As a general rule, the large volume flows, which are also the dominant plant flow, are intended to flow by gravity, whereas the high density, low volume flows are usually pumped.

With obvious operational savings to be made from gravitational as opposed to pumped flows, this is a major driver in the layout behind flotation banks. With steps between cells needing to be typically around 800 mm to force the slurry through the dart valves or pinch valves, total elevation of flotation cell banks can have a significant influence on plant layout.

In the case of Counter Current Decantation (CCD) thickening circuits, the layout will depend on whether the interstage flows are by gravity, in which case subsequent tanks will be at stepped elevations, or pumped. Once again a question of economics – both approaches are correct but one involves significantly higher capital costs, while the other leads to higher operational costs.

Site ground conditions and the horizontal seismic acceleration coefficient are particularly relevant for the design of thickeners, as the slurry loads contained are significant and determine the economics of the structure. Whether the client chooses to construct the thickener on ground or as an elevated structure will depend upon a review of civil costs versus steel fabrication costs, and the effect of concentrated column loads versus uniform pressure on supporting foundations.

In designing structures for horizontal loads, including wind and seismicity, the foundation reaction loads increase proportionally with the height of structure. As an example, for a high sidewall paste thickener with slurry around SG 1.80, and in a high seismic region, the resulting foundation column loads are significant (in the order of 1,000 skN). Depending upon allowable ground bearing pressure, it is likely that thickener installation onto foundation piers or an increase in the number of columns is required.

Practical considerations on plant layout should also be considered - for instance, pedestrian access underneath thickener tanks or adjacent to flotation cells, will also influence the final levels of the plant. One example of an often overlooked detail in plant layout is the inclusion of such things as monorails under thickener tanks for maintenance of pumps; pedestrian clearance under the beam should be considered at the plant layout stage, or this may result in reduced headroom if added at a later date. While not affecting the process of the thickener, this may have a large impact upon safety and efficiency of maintenance tasks.

Designing adequate personnel access for operations and maintenance is a key step in good plant design, as it becomes the human interface with the plant system.

Which areas of the process need to be regularly monitored or sampled? Which items need to be inspected or removed regularly for maintenance? Is forklift or crane access required into an area?

For example thickener underflow piping beneath tanks should be located with consideration not only to adequate lengths of straight line for flow meter operation, but also

for adequate access to underflow pumps. To install piping and cabletrays in the most direct route often does not lead to the best maintenance access down the track.

If the plant is to be inside a building, there are additional questions – such as whether an overhead crane for removal of major items will be installed or whether access needs to be provided for mobile cranes. In the case of flotation cells, it is important that the building's internal height is sufficient to accommodate vertical removal of a cell mechanism.

Design stage

The important thing to take into account at the plant design stage is the relationship between the inherent process system and the surrounding structure, and the way in which these two factors integrate via the plant layout. Supporting structures of major equipment such as flotation cells, mills and thickeners will form the core elements of the plant structure, while support of associated items such as walkways, hoppers, chutes, pumps, etc. are the final element.

So with the plant process defined, elevations confirmed and structure determined, the next step is how to best control the plant. The plant designer should consider the plant 'outputs' (i.e. all motors and actuated equipment) before evaluating necessary 'inputs'. How the driven equipment needs to operate will determine the type and accuracy of sensor required, particularly whether it is digital (operating as 'on' or 'off') or analog (operating through a range). Process sensors might include level sensors, pressure sensors, flow meters etc. There is little benefit in installing complex field instrumentation if the actuation of a drive is dependent upon only one input signal.

The critical aspects of layout in order to successfully design a processing plant include the following:

- Flowrates and densities of main streams
- Equipment sizing
- Site ground conditions
- Site environmental conditions (wind and seismic factors)
- Accessibility for removal of items requiring regular maintenance
- Personnel accessibility required to certain areas
- Supporting structure layout
- Elevation/location of walkways

When a plant's daily operation and maintenance tasks are included into the plant design from the outset, it is likely there will be greater operational consistency, increased safety and less maintenance downtime. Most reputable technology providers will encourage these aspects of the supply to ensure they maximise their contribution to a successful project. ***IM***

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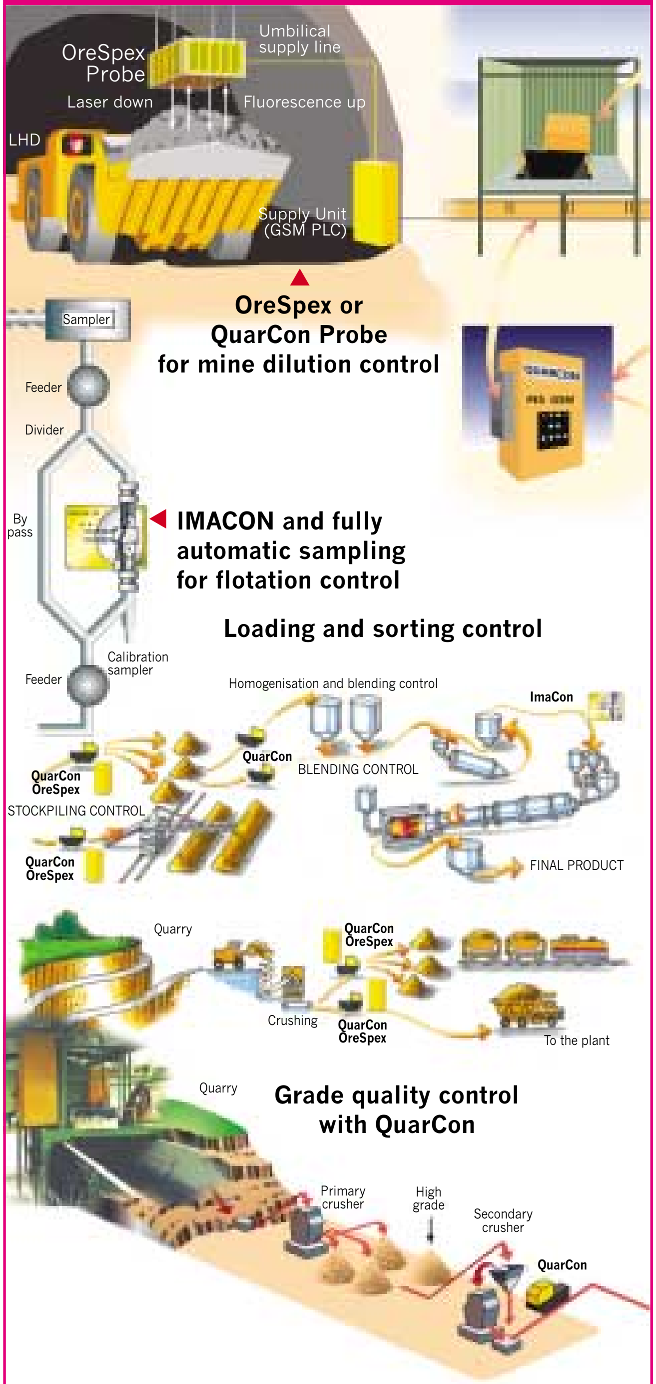

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