

Design of Booster Stations for Paste Backfill and the Implementation at Hindustan Zinc's Rampura Agucha Mine

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ABSTRACT

Hindustan Zinc's Rampura Agucha Mine is a world class orebody that has successfully transitioned from an open pit operation to an underground sublevel open stoping with paste backfill operation. The mine currently has two identical paste plants that each can produce between 160-185 m³/hr of cemented paste backfill. Plant #1 was commissioned in 2014 and plant #2 was commissioned in 2019.

The two plants are equipped with Putzmeister piston pumps that pump from the plant to the edge of the pit, down a borehole to the North and South main ramps and then down the ramps to the top of the underground orebody approximately 500 m below surface. Each plant was designed with an operating and standby paste pump. Most of the orebody can be reached from these main lines, however, at the extreme north end of the pit, there is portion of the underground orebody that is above the uppermost underground delivery level and at a significant horizontal distance from the main paste trunk lines.

Because of the location of these northern stopes, an overland pipeline to the north of the pit is required before entering a borehole down to the stoping levels. This lateral distance on surface and underground would have resulted in very high pressure on the paste pumps, and a decision was made to temporarily install the standby pump from plant 2 at a booster station that would allow the northern stopes to be reached with a 2 stage pumping system instead of a single stage pumping system.

The booster station was installed and commissioned in 2019 and this paper discusses the design principles regarding booster stations in general as well as the specific design, commissioning, and operational experiences with the booster station at Rampura Agucha Mine.

INTRODUCTION

Hindustan Zinc Ltd. (HZL) is a producer of Zinc with several mines in India and around the world. HZL's Rampura Agucha (RA) mine is a world class orebody that is currently planning to reach 5 mtpa in production from its underground operations. The ground conditions are challenging at RA mine, and that fact combined with the desire to achieve high levels of production have led HZL to use an underhand sublevel open stoping (SLOS) with pastefill mining method. The stopes are relatively small (15 m wide, 20 m long and 25 m high) and to achieve the desired production rate, the backfill cycle time is quite short (maximum of 28 days for curing).

In order to meet the mining cycle time requirements, the operations team uses pastefill produced from twin plants that are each rated for 160 m³/hr. The two paste plants are usually run well into their design factors, and typically run at flowrates from 180 to 185 m³/hr - which is the peak flowrate obtainable from the paste pumps.

Each paste plant consists of a nearly identical process flowsheet with a deep cone thickener, 4 x 3.8 m diameter x 14 disc vacuum filters, a 14 m³ capacity mixer, and the capability to add both cement and fly ash to the mix. The paste is pumped to the underground operations by a piston style paste pump feeding an overland pipeline that extends from the paste plant (El 391 m) to the edge of the open pit, and then via boreholes from surface to either the north or south declines (bottom of decline at El -72 m). From the bottom of the declines, paste is distributed via a system of boreholes and level piping at 25 m level spacing to a planned depth of more than El -722 m.

The open pit extends from a surface elevation of 391 m down to approximately 0 m elevation. A crown pillar separates the bottom of the pit from the first mining level at El -72 m.

Paste plant #1 was commissioned in 2016 when the mine was running at 2.5 mtpa and Paste plant #2 was commissioned in 2019 as the mine started ramping up towards 5.0 mtpa. Figure 1 presents the overall paste delivery system on the mine.

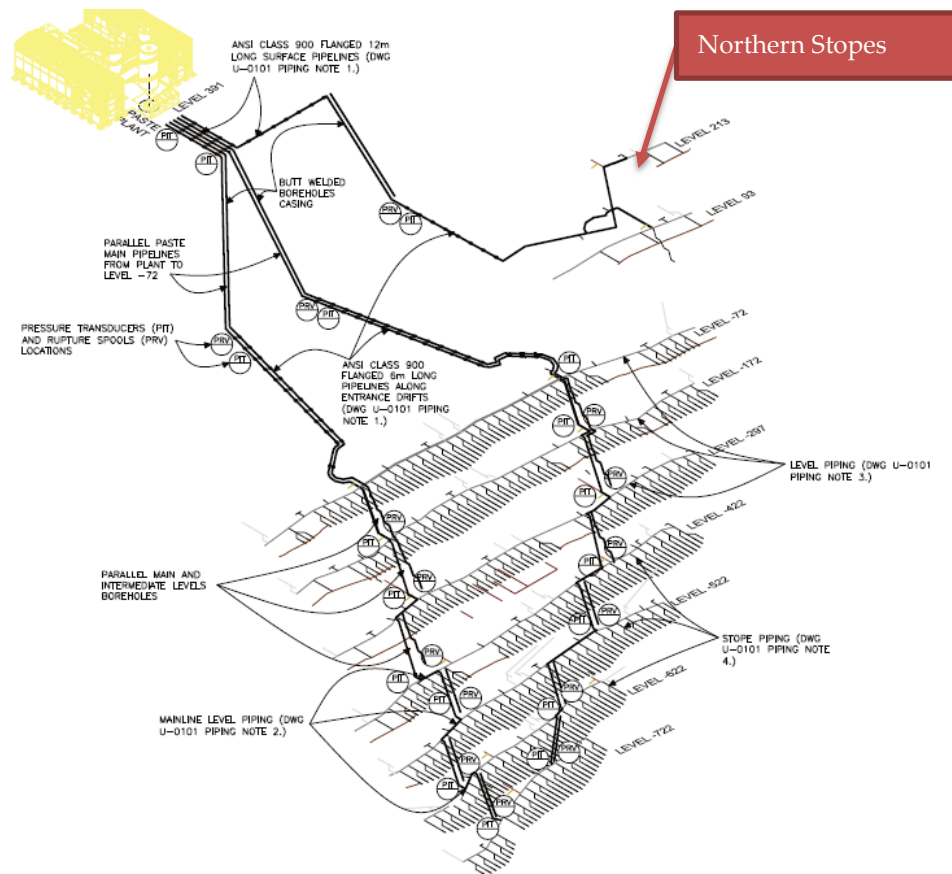


Figure 1 Original paste delivery schematic

Because of the extent of the pit envelope, some ore on the north end of the pit was left above the crown pillar and not easily accessible from the -72 m level or the bottom of the declines. During the construction of Paste Plant #2 in 2018, it was identified that some of the upper blocks of the orebody on the extreme north end would need to be filled from a pipeline that was run along surface to a point near the north end of the pit.

Originally this area of the orebody was planned to be filled using paste at a high slump and pumped directly from the paste plant, however, after several years of operation, RA personnel were uncomfortable with the operation of the pumps at high pressures approaching their design maximum. Because of this, alternate solutions were discussed such as:

- Increasing the slump even further to lower the friction losses to acceptable levels.
- Adding chemical additives to the paste to lower the friction losses to acceptable levels.
- Using ready mix trucks to deliver the paste from the paste plant to a remote borehole (which would have required a ready mix loadout station and dump station, since this capability was not included in the existing plant).

- Adding a booster station at a location approximately halfway between the paste plant and the borehole collar.

After some discussions with HZL operations and management teams, a decision was made to use the booster station option. The main reasons for the decision revolved around the uncertainty regarding the strength of high slump paste or paste with chemical additives, and a general desire to avoid the additional complexity of trucking paste via ready mix trucks.

DESIGN, CONSTRUCTION AND COMMISSIONING

Paste Pump Selection

One of the first decisions that was needed to be made regarding the booster station was whether or not it would have a dedicated pump or whether it would use the standby paste pump from Paste Plant #2 which was under construction at that time.

Since HZL had already had years of experience with the exact same paste plant system and the same paste pump, the availability and utilisation data was readily available. The life of the northern stoping area is only 4 years and therefore the evaluation included an assessment of whether or not the Paste Plant #2 could operate at the desired availability and utilisation rate with only a single operating pump. The design utilisation of the paste system at peak production of 5 mtpa is 52% and it was determined that the plant could meet a 52% utilisation factor without having a standby paste pump. It should be noted that this decision was more complex than it may appear as, although the system only runs at a 52% utilisation, the demanding stope cycle time means that when backfill is required, it is needed right away, or it will affect production. Therefore, although the utilisation target was quite low, the required availability target was very high.

In addition, due to the timing of the decision to use a booster station and the scheduled first pour of paste in the northern stopes, it was clear that there was insufficient time available to procure an additional pump. This made it a clear decision that the standby pump from Paste Plant #2 would have to be used for the booster station to satisfy the mining schedule.

Flow Modelling

The flow modelling for the booster system was not overly challenging since the system is essentially two systems, a pumped line that is nearly horizontal from Paste Plant #2 to the booster station, and then a short distribution system from the booster station to a shallow borehole, and a short lateral pipeline to the stope.

The major consideration when reviewing the flow modelling was where to locate the booster station along the total system length. The following was taken into consideration:

- A desire to balance the pressures between the two pumps evenly. Although it is not strictly required, it is known that wear rates for piston pumps tend to be higher at higher pressures and presumably keeping both pressures in balance will not result in one pump experiencing higher than normal wear rates. In addition, balancing the pressures between the two pumps lessened the chances of over-pressurisation of one of the pumps if upset conditions occur

where very high pressures are present in the line (such as trying to pump out a line that had sat idle for some time during a power outage etc.).

- The options for the booster station location were limited. The pipeline from Paste Plant #2 runs along a relatively narrow corridor between the tailings dam and the open pit. A haul road is present in the same corridor as the pipeline and there were only a few areas along the length where sufficient width in the corridor permitted the installation of a booster station.

Figure 2 presents the overland piping configuration of Paste Plant #2 and the booster station.

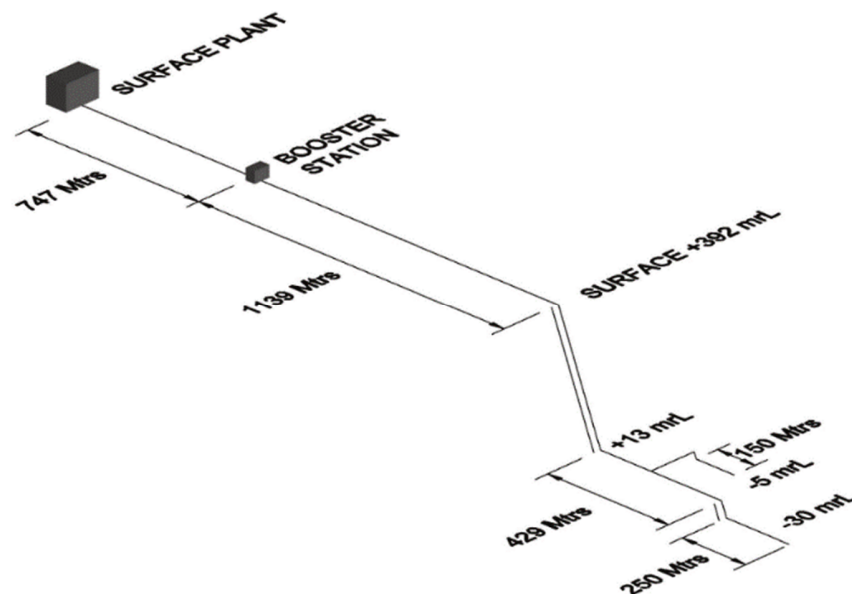


Figure 2 Schematic layout of distribution system to the stoping area

The pipeline to the underground stopes from the booster station included a 1139 m horizontal run of piping to the borehole collar at +392 m elevation, followed by an inclined borehole to the +13 level. Subsequent boreholes and level piping reach the ultimate extent of the northern area at -30 level and approximately 750 m from the bottom of the surface borehole to the discharge into the furthest stope.

Booster Station Design Considerations

The booster station design is simple in concept, however, there are a few decisions that need to be taken to ensure that the system works properly. One of the key decisions required to ensure proper operation is to determine the method of flushing.

Normally, when paste is flushed to the stopes at RA mine, the paste hopper is filled with water and the paste pump is used to pump flush water through the line until pressures achieved are low enough that compressed air can be introduced and flush the paste and water out of the line. Once the initial flush is completed, a small amount of water (3 m³) is pumped into the pipeline followed by

compressed air which blows rapidly through the line at high velocity. This high velocity flush is required (especially in long horizontal lines) as a water flush alone will frequently not scour the pipe clean of paste unless it is pumped at very high velocities or flows by gravity at high velocities.

The pipeline from Paste Plant #2 to the booster station discharges into a small hopper above the paste pump. Using compressed air blow to flush water from the overland pipeline would result in large spillages in the booster station and potential hazards to personnel.

To eliminate this hazard, two potential solutions were considered as follows:

1. Use 2 diversion valves to allow the flush to bypass the booster station and flush from Paste Plant #2 all the way to the stope.
2. Use a single diversion valve to allow the flush to be diverted just upstream of the booster station paste hopper and discharge the flush to a pit. The discharge of the booster station paste pump to the stope is then flushed using dedicated water, compressed air and flush isolation systems.

The hopper and pump suction is cleaned by manual hosing of the hopper and then pumping the water through the pump into the pipeline. Although this does not clean the short section of the pump discharge line up until the branch inlet for the flush, the section of line between the pump and the flush inlet is quite short and as build-up occurs it can be cleaned periodically by opening up the pump discharge piping and cleaning the short section of pipe that does not get flushed with the high velocity air flush.

Water from the process water pumps is supplied to the paste hopper via a 100 mm pipe and manual valve that allows the operator to fill the paste hopper with water.

Figures 3 and 4 presents process flow diagrams of the options that were considered.

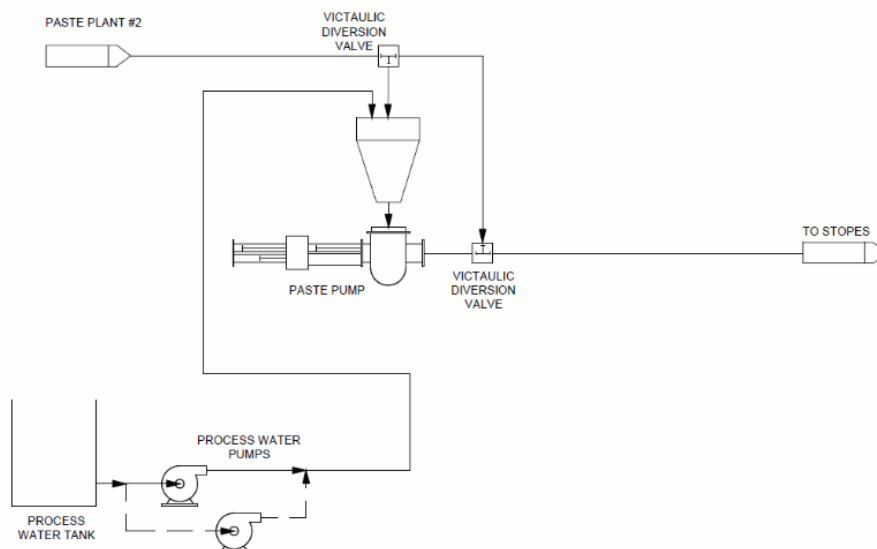


Figure 3 Booster system flush Option 1

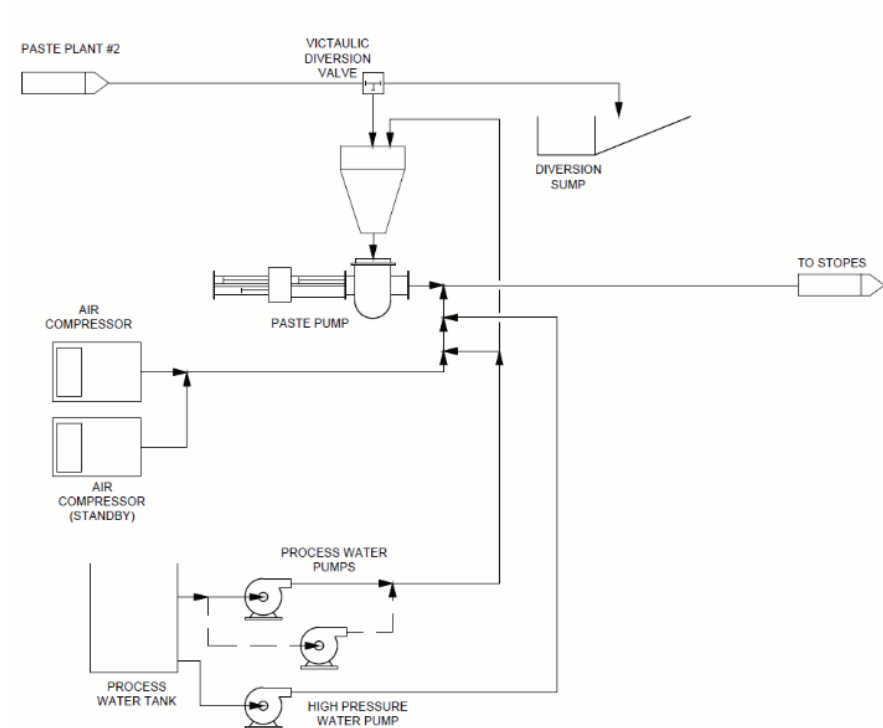


Figure 4 Booster system flush Option 2

After consultation with HZL, it was decided that option 2 presented a more reliable solution as it did not rely on the correct operation of the diversion valves to ensure the ability to flush the paste all the way from the paste plant to the stope. It also duplicated the flush arrangement present in the Paste Plant #2 and presented the operator with an identical flushing system and procedure.

Figure 5 presents photos of the flush water diversion valve and diversion sump.



Figure 5 Booster station diverter valve (left) and diversion sump (right)

Commissioning Experience

Commissioning of the booster station was completed within 2 days which is largely due to the system essentially being a replica of the paste pumping, flushing, and utilities in Paste Plant #2. The programming and procedures for the booster station were also all very similar to those present in Paste Plant #2 and there was very little debugging or modification of the program required.

Paste pump speed control is accomplished by increasing the speed with increasing level in the hopper. Although there is some PID loop control in the logic, it is largely driven by the direct relationship between hopper level and pump speed. Therefore, paste flow rates are increased as the level in the hopper rises and decreased as the hopper level lowers in order to maintain an operating level band within the hopper. To use this paste pump control methodology, it was necessary to make the relationship between 0 and 100% pump speed proportional to the operating band of 30 to 60% level in the hopper. This was done to allow time for the pump to react during an upset condition and prevent the hopper level reaching 0% (in which an undesirable case of air being introduced into the pump will occur) or reaching the 100% level in the hopper and overflowing.

When flushing the booster line, it is normal mine operation to use the process water pumps to fill the line with 3 m³ of water before flushing with air. High pressure water pumps are also installed at both Paste Plant #2 and at the booster station in order to have a backup capability in the upset condition

of a paste pump failure. These high pressure water pumps are used as backups to flush the discharge paste lines prior to flushing with the low pressure water pump and the compressed air. The high pressure water pump in Paste Plant #1 is occasionally required to clear the dead leg in the line between the flush valve and the paste line. In the case of the booster station, the flush valve was mounted close to the main paste line using a flush mounted, threaded flange to limit the length of the dead leg. This eliminated the need for the high pressure pump to push out the hardened dead leg material at the booster station.

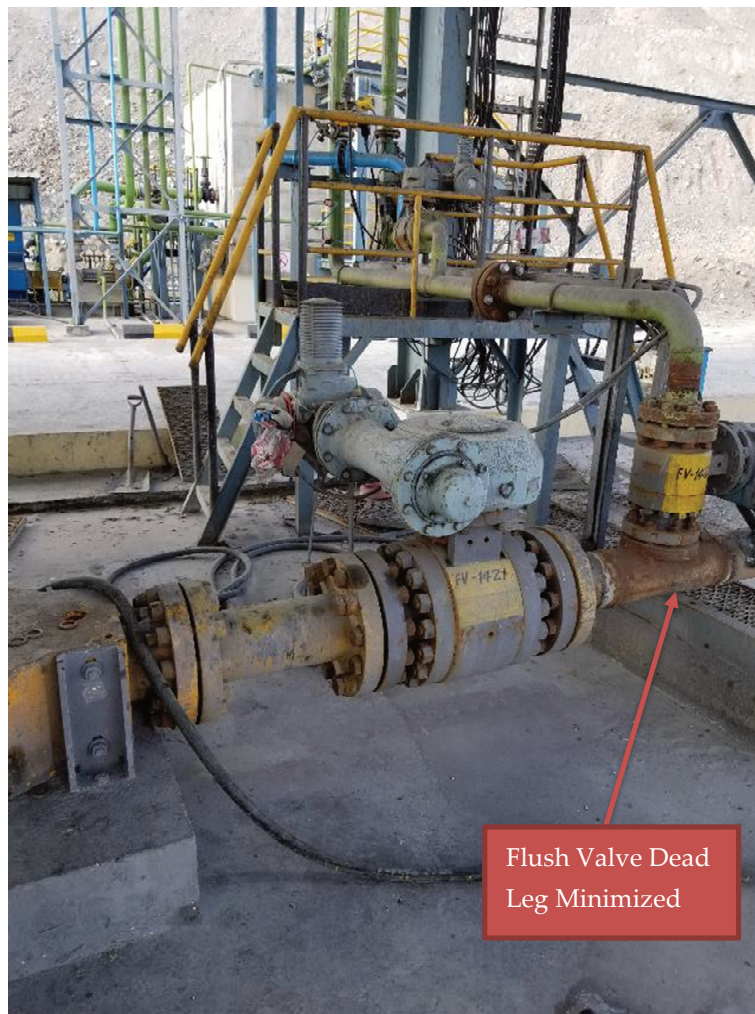


Figure 6 Flush flange on flushing valve at the booster station

CONCLUSION

Using a booster station to increase the range of a paste backfill system was relatively simple and effective. The design, construction, and commissioning of the system was simple, and the most pertinent design challenge was to ensure that flushing is incorporated appropriately.

The main impediment to the implementation of booster stations is the cost. While the booster station in this case study represents the most thorough and flexible style of booster station with its own supply of flushing utilities, the cost of the booster station can be substantially reduced if a source of compressed air, process water and even high pressure water is available. When the utilities are removed, the booster station essentially becomes as simple as a paste pump, and hopper with the appropriate valves and instrumentation for flushing and/or diversion. For this reason, the viability of a booster station solution depends significantly on the location of the facility and the proximity to these services. In the case that a booster station can be located underground, it eliminates the need for a building, and it has been found that booster stations can be installed in relatively small underground excavations (typically a 5 m slash on the side of a drift).

The one cost that cannot be avoided is the paste pump and the accompanying electricals. This, in conjunction with the cost of a new pump, is a major cost in a booster station and must be balanced against the economics of not extracting the ore that is beyond the capability of the paste plant pump to reach the required stopes (or the use of other methods of delivering paste to the stopes such as trucking).

In the case of HZL, the booster station has allowed the mine to exploit a part of the orebody that otherwise would have left significant pillars. The ore at RA is of high value and costs for the booster station were easily offset by the additional revenue obtained from mining these pillars.