

# Harnessing hydraulic transport

Pipeline transport of mineral slurries is a common practice at mine sites. Jay Norwood of Golder Associates explains how some sites have optimised the process to suit their needs

**H**ydraulic transport of solids has been occurring since the beginning of time – a trip to your local river delta clearly illustrates the long-distance transport of fine solids particles.

Engineering advances have converted this natural phenomenon into a commercially successful transport system for industrial minerals and other solids via slurry pipelines. Operational systems include hard-rock minerals (such as iron and copper concentrates), soft-rock ores (such as bauxite and nickel laterite), coal and virtually every type of mineral tailings.

Hydraulic transport of solids in slurry pipelines has been a common mining industry practice for over 100 years, with long-distance pipelines having more than 50 years of proven performance. However, this technology is far more flexible than a simple A-B transport system. Integrating upstream and downstream processes often provides significant economic benefits, and provides a more efficient overall system.

## PIPELINE BASICS

For transport in slurry pipelines, a carrier fluid is needed (usually water) as well as input power (slurry pumps, elevation change or gravity). It is theoretically possible to transport any size particle hydraulically – it is just a question of providing adequate power (ie the size of pumps and spacing of pump stations along the pipeline) and dealing with system-component wear.

In general, the size of the particles is the prime economic driver for transportation efficiency and, as such, the size of particles is usually managed within a suitable range if long-distance transport is considered.

## MINERAL SLURRY SYSTEMS

Long-distance transportation of mineral slurry is well suited to a significant portion of the mineral-processing sector. Water is often used during the grinding process and slurry is formed. The optimum particle size distribution for mineral extraction using flotation is close to the optimum particle size distribution for long-distance transport by pipeline.

The typical final step in mineral processing is filtration for shipment to another processing facility; a long-distance pipeline simply relocates the filter plant to the end of the transport system. There is no fundamental change in the mineral extraction/concentration process when a transport pipeline is used in these facilities.



Iron (if concentrated by silica removal), copper, zinc and lead-mining operations are well suited for the use of slurry pipelines for long-distance product transport.

Phosphate is also appropriate for pipeline transport, but for a different reason. Many phosphate facilities use haul trucks or conveyors to deliver ore to the process facilities. The ore is then ground for feed to the chemical or fertiliser plants.

An alternate configuration used in facilities such as Simplot in Idaho is to grind at the mine site and transport (in a slurry pipeline) the material for direct feed to the plant. The overall configuration of the system can provide dramatic cost savings (more than US\$2/t) over alternative transport configurations.

Another key factor in selecting a slurry pipeline as the most economical alternative

is the capacity of the existing transport infrastructure. For a greenfield project, slurry pipelines will have the lowest net present cost for those minerals suitable for pipeline transportation. However, if a significant transport infrastructure such as a rail system already exists, it could have an impact on the economics of the options.

For example, a slurry pipeline is much more likely to be the economic alternative in remote locations or developing nations than it might be in North America.

However, that is not a blanket statement. There are numerous slurry pipeline projects under way in India, specifically because the rail infrastructure has become so overloaded that it is unreliable. Rail companies in India are looking at slurry pipelines as a means to increase transportation volumes in the same corridor (install pipelines along the railways). ▶

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**Table 1: properties of solids for traditional mineral hydro-transport systems**

| Mineral type          | Specific gravity of solids | % – 65 mesh (210µ) | % – 325 mesh (44µ) |
|-----------------------|----------------------------|--------------------|--------------------|
| Iron concentrate      | 4.5-5.0                    | 100                | 60-80              |
| Copper concentrate    | 4.2-4.8                    | 97-100             | 55-85              |
| Zinc concentrate      | 4.0-4.3                    | 100                | 60-80              |
| Nickel laterite ore   | 3.3-4.0                    | >95                | 60-90              |
| Phosphate concentrate | 2.8-2.9                    | 65-85              | 35-50              |
| Bauxite ore           | 2.5-3.0                    | 95                 | 40                 |
| Coal                  | 1.4-1.5                    | 50-60              | 20-30              |
| Gold tailings         | 2.7-2.9                    | 100                | 60-80              |
| Copper tailings (ore) | 2.5-3.0                    | 70-90              | 30-50              |

► OCP (Morocco) is expanding its phosphate operation from 18-40Mt/y, and switching to slurry pipeline from rail, due to the negative economic and environmental impact of expanding the rail system.

### PROCESS OPTIMISATION

Many minerals are not naturally suited to transport by slurry pipeline, but adjustments to the overall process can be made to implement the transport technology. In addition, there are many applications where the use of a slurry pipeline can optimise the overall process configuration of a facility.

#### ● Facility integration

Some minerals are not well suited to long-distance slurry transport in their natural form. Traditional power-plant coal is too coarse for transport by pipeline; the fine particles are typically washed off the coal prior to shipment by rail car or ocean tanker.

During the 1950s, Consolidation Coal, like all coal firms, was predominantly reliant on rail transport to deliver coal from mines to power-plant customers. Feeling the pressure of increasing railroad tariffs, it embarked on a development that resulted in the first significant coal slurry transport pipeline. The system included grinding facilities at the mine and dewatering facilities at the power plants.

Although a fully optimised, integrated facility was not built, the transport system ran successfully from 1957-63. At that time, Consolidation Coal was successful in getting a significant reduction in rail tariffs – conditional on shutting down the pipeline.

Next in the evolution of coal slurry transport was the Black Mesa pipeline, which was implemented in 1970. Again, coal was ‘over-ground’ to make it suitable for pipeline transportation. However, the coal was fed to a power plant designed and built for burning pipeline coal.

Coal dewatering at the power plant included centrifuges and bowl mills for drying and pulverising the coal dust, which was fed pneumatically to the power plant. The pipeline/power plant ran until December 2005, when it was shut down due to a battle over aquifer water rights for the slurry preparation and expiration of the power-plant permit.

In the 1970s, many envisioned a network of long-distance, coal slurry pipelines from coal-mining areas such as Wyoming and Montana to power-generation facilities in Ohio, Texas, and other locations. However, many railroads, fearing the competition from slurry pipelines, refused to grant easements across their right-of-ways, effectively cancelling all of the prospective coal slurry pipeline projects.



#### ● Mining method

The mining of mineral-rich sands provides an opportunity to use hydro-transport technology. New Zealand Steel’s Taharoa operation comprises sand-dredging and processing with simple, magnetic separation of iron-rich particles. The resulting iron concentrate is transported by slurry pipeline to a central stockpile, and the sand is directly discharged as it is coarse enough to free-drain.

Concentrate from Taharoa is taken by bulk ore carrier from New Zealand to customers in China. The ship-loading method is unique, again taking advantage of slurry pipeline technology. The ore carrier is loaded using a submerged buoy mooring (SBM). Iron concentrate is re-slurried and pumped through twin, 2.5km submarine pipelines to the SBM and on to the ship. Water (with some fines) is decanted off the ship – the water source is a local river, which discharges into the sea.

The overall configuration is simple, efficient and low-cost. While the sand transport is a relatively high-input energy system, the short transport distances make slurry pipelines a cost-effective solution.

#### ● Environmental

Bauxite, like coal, is typically fed to alumina refineries with a coarser particle size distribution than is economical for long-distance pipeline transport. Brazilian miner Vale owned some bauxite reserves in the Paragominas region of Brazil that could not be developed by alternate means – river transport was impractical given the location of the reserve, and shipping traffic on the Amazon River was already at high levels. Rail construction was impractical given the terrain and remoteness of the operation.

A pipeline was the only way. However, long-distance slurry-pipeline transport had never been done before and was considered by many in the industry to be technically unfeasible. There was significant concern about the ‘friability’ of the bauxite, which would cause particle breakage during transport. However, after significant research, the bauxite pipeline was proven viable and built. It has now been running reliably for more than four years.

#### ● Terrain

Mine sites are often situated in remote areas with difficult terrain. Surface area is at a premium and sometimes there is inadequate space for all of the necessary facilities. Slurry pipelines can enhance the immediate available space by carrying a significant process stream (tailings) away from the mining zone. This type of tailings-transport system can be found at Minera Los Pelambres in Chile, Batu Hijau in Indonesia and Cayeli Bakir Isletmeler in Turkey.

Minera Los Bronces in Chile went one step further – space was so limited at the mine that the process plant was split in two. Only ore grinding occurs at the mine site. An ore-slurry pipeline delivers the material to a flotation (copper recovery) plant located about 55km from the mine. Using the natural terrain to its advantage, Minera Los Bronces designed the pipeline to flow by gravity. Tailings are stored near the flotation plant, and neither this plant nor the tailings-storage area is competing for precious space at the site.

#### ● Tailings management

Slurry pipelines are commonly used to transport mine tailings to a planned storage area, whether that be a surface impound, backfill of a pit or underground

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mining area. These delivery systems can be designed to provide a seal for the containment dam (deposition along the upstream face of the embankment) and pond management (deposition sequence to manage pond location). Basic slurry transport systems can be effective tailings management tools.

However, the opportunity to do a lot more exists. The construction of containment dams using sand recovered from the tailings stream is becoming more common. For these facilities, whole tailings slurry is commonly classified using hydrocyclones, with the sand fraction (+75 micron) separated for construction sand. Both the resulting sand slurry and cyclone overflow (fines) can be carried using slurry pipelines.

Starting at the dilution water tank in a system at Cerro Verde, Peru, whole tailings slurry is delivered by gravity to a dilution sump and two-stage cyclone-classification circuit. Cyclone underflow (sand) is delivered through the pipeline on the right for placement on the embankment, and cyclone overflow (fines) is delivered through the pipeline on the left for deposition at the impound along the upstream side of the dam. The entire system operates using gravity.

Significant sand dams are being built using cyclone sand. Kennecott's Bingham Canyon mine in the US has constructed a ring dam covering about 65km<sup>2</sup>, which is completely filled with sand recovered from the tailings stream.

#### • Mine backfill

Hydraulic transport of tailings slurry has also been applied effectively in the backfill of underground mines. Hydraulic fill includes classified tailings and paste made from tailings, as well as paste tailings augmented with aggregate material.

Tailings from mineral-processing facilities are made into backfill material – paste tailings often have cement and/or other binder material to provide the required fill strength.

Hydraulic backfill of mines has proven a cost-effective option in many facilities as it eliminates the need for haul trucks to bring fill material underground. The use of cemented paste fill has been shown to reduce mining costs significantly. The rapid fill rate and quick cure times permit additional mining in adjacent stopes with a very short turnaround time permitting more efficient ore recovery.

#### WATER MANAGEMENT

No discussion of hydraulic mineral transport would be complete without considering water, the usual carrier fluid.

Water's availability at the start of the pipeline and the ability to dispose of it at the end are potentially significant issues. Water entering a traditional, long-distance pipeline is lost from the mine site, and must be treated and released, or otherwise used at the pipeline terminus.

It is rare, but occasionally the water does not require treatment at the end of the pipeline.

Consider the Taharoa ship-loading system – the process water is river water that is flowing into the ocean and the mineral is sand from the beach. Decanting of water from the ore carrier has no environmental impact.

In some systems, water is recirculated easily – most mine-tailings systems include water reclaim from the tailings impound, which is returned to the mine.

Worldwide, water is a precious resource. With any hydraulic transport system, the water balance must be a key part of the economic and process optimisation calculation. ▼

**“At Cerro Verde, Peru, whole tailings slurry is delivered by gravity to a dilution sump and two-stage cyclone-classification circuit”**

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