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## Mine Slurry Transport

Climate change and the need for environmentally responsible, cost effective and efficient methods of ore and tailings transport place great demands on the industry. A growing number of operations are meeting the challenge by using more hydrotransport handling of solid/liquid mixtures in both short- and long-distance pipelines.

This most basic of techniques combines a number of handling advantages with minimum maintenance and low environmental impact. But there is still potential for cost savings, innovative application and transfer of technology and knowledge - optimising handling techniques and developing and deploying new engineering solutions.

Numerous long distance slurry pipelines world-wide rely on [Weir Minerals](#) division heavy duty pumps, including Warman centrifugal slurry pumps and Geho piston diaphragm slurry pumps. The company says the high availability and cost effectiveness of these pumps "is demonstrated by the handling of the most diverse slurries over distances of more than 300 km."

Its crankshaft driven piston pumps include the ZPR pump - one or two cylinder doubleacting piston pumps - and the TZP pump - three-cylinder single-acting piston pumps. Low and moderately abrasive slurries are economically handled by these crankshaft driven piston pumps. Also crankshaft driven are the highpressure piston diaphragm pumps - the three cylinder single-acting TZPM pump and the one or two-cylinder double-acting ZPM pumps.

The [Linatex Hard Wall Mining Hose \(808\) range](#) of custom hoses, also from [Weir Minerals](#), is designed for the most arduous of mining and industrial duties.

[Weir Minerals](#) is also a premium supplier of valves. The ISOGATE® series PV OB pinch valve is specifically designed for harsh, highly abrasive flow control applications in liquid solids slurry. The ISOGATE PV CB series pinch valve is a hand wheel operated enclosed body mechanical pinch valve for positive control of abrasive and corrosive flowing media. The ISOGATE PPV 1PS pinch valve is ideal for remote operation using typical plant air, and it does not require an auxiliary cylinder operator. The Pneumatic Pinch Valve - series PPV 2PL is specifically designed for harsh, highly abrasive on/off control applications in liquid-solids slurry services.

Oil sand mining is a sector where there is really no alternative to slurry pipeline transport. A key to this mining becoming more cost effective has been the development of equipment that is more efficient and more resistant to the extremely harsh conditions imposed by the process. GIW industries has been involved in oil sands mining and processing for nearly 25 years, and its technical and engineering expertise has allowed it to become a leader in the industry.

In the mid-1980s, most oil-sands plants used rubber-lined pumps to transport their tailings - the mix of water, sand and clay left over once the bitumen has been extracted. However, in transporting this extremely abrasive material, rubber-lined pumps could provide only about 2,000 hours of operation before they needed to be replaced.

The operations began considering all-metal pumps instead of rubber-lined pumps and asked several pump manufacturers to bid on the project. GIW designed and laboratorytested a new pump that proved highly successful, delivering 4,000 hours of operation.

The successful tailings application led the industry to consider using all-metal pumps for hydrotransport, a new technology that aimed to reduce the costs of mining oil-sands deposits. As mines grew larger and ended up farther away from the processing plants, hydrotransport became a more cost-effective option than conveyor systems. Implementing the use of hydrotransport proved to be highly successful.





Hydrotransport by long-wearing pumps allows the processing plant to collect oil sands from as far away as 40 km. GIW says it “is now the market-dominant supplier of hydrotransport and tailings pumps for this market. The company’s expertise has played a major role in today’s boom in the Canadian oil sands.”

In September 2010, a new mine, Jackpine, added 100,000 barrels/d to output. GIW played a critical part in the development of the Jackpine mining facility through the design, construction and installation of pump trains to move oil sand and its products from the mine site and through the production facility.

Planning for the Jackpine mine began in 2004, and GIW was involved from the start, providing input into design requirements. GIW was awarded the contract for the facility’s pump trains in 2006, and began shipping parts in 2008. A total of 34 pump trains were developed. The Jackpine facility processes 2 Mt/d of oil sands.

All of the pump trains, each consisting of a pump, gear reducer, motor, couplings, oil cooler and foundation pad, were developed specifically for the operation. The largest pump provided by GIW has a 1.83 m diameter impeller, weighs over 27,200 kg and has a 3,730 kW motor.

Because the pump trains could not be assembled and tested at GIW labs before shipment, GIW had to update its quality assurance (QA) procedures and create extensive, detailed documentation to ensure that all parts were developed to specification and went together perfectly. GIW assembled the pump trains in 2009 and 2010, and the facility was opened for production in September.

GIW currently maintains the pump trains by providing spare parts that are delivered and replaced at Jackpine on a regular maintenance schedule. GIW keeps about eight weeks of spare parts on hand in Fort McMurray, Alberta so they will be ready for any scheduled or unscheduled downtime that may occur.

Goulds Model 5500 is the result of many years of experience designing and building severe duty slurry pumps. It’s not only built to stand up to the toughest abrasive slurry services, but also is designed for easy maintenance and safety. This is helped by a heavy duty bearing frame and shaft, extra thick wall sections and easily replaceable wear parts. It offers capacities to 3,180 m<sup>3</sup>/h heads to 139m pressures to 3,448 kPa and solids to 127 mm.

The extra thick wet end components offer extended wear life and the replaceable wear liner lowers maintenance cost. The heavy duty power end should provide increased mean time between failures.

To date Larox Flowsys has provided solutions for highwear and aggressive applications in more than 30, 000 mining and minerals installations around the world. Larox valves and pumps have proven their reliability among others in flotation, thickening, filtration, tailings, and additional systems such as sampling, dosing and water treatment applications.

Larox high performance pinch valves have a completely sealed stem assembly which prevents slurry or particulate from penetrating into the screw mechanism from both inside the valve and from the external environment. This ensures that when the valve is opened or closed it is as easy as the very first time it was operated. Larox’s patented valve designs use a unique rubber technology for their sleeves that is extremely abrasion resistant and therefore lasts longer than competitive designs, the company claims.

New progressive cavity pumps are designed for the most demanding abrasive, corrosive and other industrial pumping applications. Due to the pumps’ unique features and patented design, high efficiency and high pressure are achieved in a shorter construction. They require less energy and maintenance and are easy to install. There are longer service intervals and better pumping reliability at an expanded temperature range, resulting in very low Total Cost of Ownership, Larox reports.



## The pipes

"We call ourselves a pipe systems provider, instead of pipe manufacturer," says Stefan Gros, Executive VP of Product and Production Development for KWH Pipe. "The interaction with industrial customers is very rewarding. They ask us to come up with new ways to fix their problems. Other times, we approach customers with a new product. At first they might claim that their current product works just fine, but when we start asking questions about downtime, maintenance and installation, and explain how our solution works, it makes them think. At that time when they start analysing the costs, they realise just how much money KWH Pipe can save them."

KWH Pipe has worked on developing its range of Functional Piping Solutions (FPS). These products all have some things in common: a multilayer structure, a narrow focus on solving a particular problem and the possibility to customise a solution especially for the conditions of a specific project. Gros explains: "We have researched which polymers are especially resistant to, for example, abrasion or certain chemicals. Sometimes it's possible to produce a pipe entirely from those materials, but as these are specialty polymers it would be very costly. Therefore, in our FPS products, most of the pipe wall is made up of polyethylene, and the functional polymer layer is just as thick as it needs to be. It's costefficient and the polyethylene gives the pipe structural strength, flexibility, light weight and corrosion resistance."

Metal pipes might be abrasion-resistant, but metal is also brittle, and even though the pipe would withstand wear from the inside, it might be too brittle to handle stress from pressure surges or ground movements and would consequently break. The WehoSlurry pipe is designed to absorb this type of stress and offer optimal durability by combining the flexibility and corrosion resistance of polyethylene with an extremely wear-resistant inner layer. Also, instead of being hard, the inner polymer layer is soft since abrasion tests in laboratory as well as full-scale tests clearly indicate less wear for softer materials in most cases. This is how KWH Pipe can prolong the life span of a piping system using functional polymer layers.

On the border with Finland the Karelsky Okatysh iron ore mining and concentration complex, a subsidiary of the Russian steel giant Severstal, can produce 10 Mt/y of iron ore pellets. In the crushing and preparation plant, crushed ore is mixed with water into slurry and then transported in pipelines to hydrocyclones where valuable minerals are separated from waste gangue.

The slurry, with its average density of 1,300 kg/m<sup>3</sup> and particle sizes up to 0.8 mm, is not just any high-viscosity mass. The pipe used for slurry transport has to be highly resistant to wear, especially at the points of fastest flow speed - such as bends, branches and fittings for pumps. The company was using steel alloy pipes, but they were not able to withstand the aggressive wear and required frequent maintenance.

Steel pipes are popular in Russia, as they can be joined by normal welding, but in this case they were simply not sufficiently wear resistant. WehoSlurry was the solution. To test this, a 50 m steel pipe section was replaced with KWH Pipe's WehoSlurry system. Use of this section began on April 7, 2009 and was monitored on a regular basis. Ten months later, February 7, 2010, an inspection was made after 6,908 hours of continuous operation. No visible signs of erosion of the inner layer were detected. Additionally, no changes in the condition of the pipe had occurred even at the most exposed section immediately after the slurry pump. After more than 8,000 hours there was still nothing to detect indicating abrasion of the surface. Over the same period, two sets of steel pipes have been completely replaced in other sections of the slurry line.



According to the inspection record, the estimated operational life for the trial pipeline is going to be five to ten years compared to the six months replacement intervals for steel pipe.

Wear-resistance was not the only benefit of WehoSlurry here. The light weight and flexibility considerably facilitated the installation process as the DN/OD 355 mm pipes had to be brought through various obstacles, such as grates and wall sleeves. The system offers several different pipe jointing methods, each with their own advantages but all

developed to ensure optimal performance even in harsh abrasive conditions. At Karelsky Okatysh, flange joints were found most suitable. Other methods available include butt fusion welding, electrofusion and mechanical couplings.

Robor Pipe Systems is a leading supplier of conveyance systems for mining applications. Various linings and coatings are available, from high-density polyethylene (HDPE) to epoxy coating, meeting any requirements mines may have in the conveyance of slurry, water, gas or corrosive fluids.

Supported by an installation and maintenance services business unit, the company offers the southern African mining industry value-added steel pipe and complete pipe systems, delivering comprehensive solutions by utilising the latest technology in addressing wide-ranging conveyance needs.

The company's HDPE-lined steel polypipe system combines the inherent strength of steel with the visco-elastic properties of HDPE to deliver high pressure capability, structural integrity, resistance to mechanical damage and chemical and abrasion-resistant properties. This high-performance pipe system, ranging in size from 50NB to 1,500NB, is ideal for the reliable and efficient conveyance of corrosive fluids and abrasive slurries, especially where service conditions cannot be adequately satisfied by traditional piping materials alone. With low resistance to flow, reduced friction loss and lower operating costs, HDPE lining helps to reduce down-time and replacement expenses, presenting an opportunity for the cost-effective refurbishment of existing pipelines.

Transvaal Rubber Co (Truco) supplies a lot of mines in South Africa, including hoses and reusable split flange couplings to a platinum mine, in the Western Bushveld Complex in the Northwest Province. According to Mike Stuart, Hose Director, the reusable Truco split flange coupling is a unique item that is especially helpful and cost-effective in applications where the required length of the pipes is not known.

"The couplings allow operators to cut the hose to length, on-site, and install it quickly and easily. The use of these couplings also assists in reducing plant downtime. If a hose fails, a new one can simply be cut to length and installed. From a cost saving point of view, if the hose needs to be replaced, the couplings can be taken off and reused on the new section of hose. This also leads to reduced spares holding for customers because the need to stock various hose lengths is negated," says Stuart.

The versatile reusable Truco aluminium split flange couplings have been designed to handle pressure up to 1,000 kPa and are ideal for slurry hoses. They can connect hose to hose, hose to steel pipe, or rubber hose to HDPE pipe, and are corrosion resistant.

### **Complete systems**

Ausenco PSI, part of Ausenco's Process Infrastructure business is a world leader in the engineering, design and implementation of long-distance slurry transport systems. Among its many achievements in slurry pipeline system design is the Anglo Ferrous Minas-Rio project in Brazil, which is now under construction. The project includes a 522 km, 610 and 660 mm diameter iron ore pipeline, which when complete will be the longest and largest (tonnage) iron concentrate pipeline in the world.

Two pump stations have been provided for the pipeline with the provision to add additional pumps later should iron ore transport capacity increase as the mine develops.

Ausenco PSI's scope includes conceptual design, feasibility study, basic advanced and detailed engineering, supervision for earthmoving detailed design, procurement support and construction supervision.

Ausenco PSI's Control Systems group is providing a supervisory control and data acquisition (SCADA) system and telecommunications system. The system also includes its Pipeline Simulator for simulating steady-state operation, batch operation, pipeline start-up and shutdown; operator training and operations planning; and Pipeline Advisor for process optimisation and leak detection. The project is planned for completion in 2012.



The Da Hong Shan pipeline is another innovative iron ore installation. It is one of the longest in China and has the highest operation pressure of any pipeline there. It is one of the few slurry pipelines in the world that pumps steeply uphill over most of its length and it has the largest total lift of any pipeline. Commissioned in 2007 for Kunming Iron & Steel Corp, the 171 km, 229-mm diameter pipeline system is designed to transport a maximum of 2.3 Mt/y of iron concentrate from Da Hong Shan mine in Yunnan Province to the steel mill at the Anning Terminal.

Ausenco PSI's scope included conceptual design, basic and detailed engineering, construction supervision, start-up and commissioning and operator training. This state-of-the-art pipeline system uses three high-pressure pump stations with a maximum discharge pressure of 25 MPa. The company also provided a supervisory control and data acquisition (SCADA) system, including system integration, programming and field installation; a fibre optic telecommunications system; and Pipeline Advisor for process optimisation and leak detection.

In early 2008, the company was selected to perform a feasibility study for expanding the existing pipeline from 2.3 Mt/y to 3.5 Mt/y. This expansion involved modifying three existing pump stations and the terminal as well as adding two new pump stations. Since that time, the company has performed basic and detailed engineering for the project as well as construction supervision. The expansion project and tailings system were completed at the end of last year. The company is currently working on the basic engineering for the Da Hong Shan third expansion project, which will transport 5.0 Mt/y of iron concentrate to two different locations.

Andean operations lend themselves to these systems - making the most of the gravity advantage. Achievements there include, in Argentina, Minera Alumbrera's 312 km system designed to transport some 875,000 t/y of copper concentrate through a special 152-mm diameter steel pipeline. In 2001, the company commissioned the 302 km, 210-250 mm diameter multi-product Minera Antamina pipeline in Northern Peru.

The thickness of each pipe is 10 mm and the thickness of the polypropylene cover: 7mm. It is made from reinforced steel - inside and outside. It is normally subject to a pressure of 70 bar, but is designed to withstand up to 200 bar. The different sections are joined by electric welding. The average trench depth is 1.3- 1.5 m.



Antamina says the advantages of an ore pipeline over hauling the ore overland are:

- Fewer negative impacts on the environment and greater safety
- Less social impact
- Easier access for construction, operation and maintenance
- Lower operating cost

Ausenco PSI's Control System's group provided a complete turnkey package for the pipeline SCADA system and telecommunications system at Antamina. The system also includes the proprietary software solutions - Pipeline Simulator and Pipeline Advisor.

Also, the pipeline includes parallel-laid fibre optic cable that sends data about the ore flow through the pipe and which is digitally interfaced with the main offices. Antamina's fibre optic cable installations, thanks to an agreement made with Telefonica Peru, have been extended to Huaraz and bring benefits to other towns in the Callejon de Huaylas and Callejon de Conchucos.



A variety of minerals have been successfully transported for many years via pipeline, over distances ranging from a few kilometres to 400-plus km. However, until the Mineracao Bauxita Paragominas project, bauxite had not been one. The design of the world's first longdistance bauxite pipeline in the State of Para, Brazil - and its successful commissioning in 2007 - put the hard-to-transport bauxite myth to rest once and for all.

Ausenco PSI's scope of work included conceptual engineering design, laboratory testing, basic and detailed engineering, pipeline construction management, operator training, start-up and commissioning, and operation and maintenance assistance.

Originally designed to transport 8.0 Mt/y of bauxite, the 244 km, 610 mm diameter pipeline can now transport up to 13.5 Mt/y. This project proved beyond doubt that not only was a hydrotransport bauxite ore system feasible - it was reliable and economically viable.

In 2010, Hatch completed a condition assessment of the Paragominas pipeline for Norsk Hydro, on a fast-track schedule. Hatch stated "the slurry pipeline is the only means of transporting bauxite from the Paragominas mine to Alunorte," the world's largest alumina refinery.

"Norsk Hydro requested the assessment to confirm the integrity of the bauxite-slurry pipeline and its potential performance over the next 25 years, before agreeing to a \$4.9-billion purchase of the pipeline, bauxite supplies and Alunorte from Vale."

### **Monitoring and control**

Pipeline system design and engineering is a major component of Paterson & Cooke's work. The company has designed numerous pipeline systems around the world, including in-plant slurry pipelines, tailings pipelines and long distance overland pipelines. It has completed numerous bankable feasibility studies for long distance pipelines. These include phosphate pipelines, iron ore and magnetite pipelines, and copper and gold concentrate pipelines.

The company notes that "long distance pipelines require special hydraulic analysis and design tools not normally associated with short distance pipelines, and we have these facilities in-house."

Paterson & Cooke has developed some specific technologies, like the patented Energy Dissipator (ED). Its function is to control the flow rate and hydraulic profile in piping systems with significant changes in elevation.



It is primarily used on backfill systems, but can be used on any system where there are significant changes in elevation. EDs are installed at the bottom of steep vertical piping sections to maintain full flow conditions in the piping and to prevent problems associated with slack flow. Many backfill systems suffer from such problems, like accelerated pipeline wear and pressure transients.

The ED can also be used at valve stations to provide bypass pipeline resistance to achieve controlled pipeline shutdown with minimised valve wear.

Installing the ED at the bottom of a shaft controlled pipeline operation without pressure transients. In systems operating with a batch water and slurry mode the ED can be used to control the hydraulic gradeline of pipelines to maintain a positive pressure in the line under varying operating conditions.

The dewatering bin separates the solids and liquids from a dilute slurry stream. The size of the separated solid particles can range from fine sand to coarse gravel. The size fraction that reports to the overflow can be specified by the client and final adjustment made during commissioning.

Many mineral and mining processes transport dilute slurry initially, but then have to deal with the burden of the superfluous liquid by over sizing downstream process equipment unnecessarily. The company says "the dewatering bin provides a compact solution to remove excess process liquid without the loss of valuable product."

The decoupling of two stages of a mineral process is often achieved by a buffer storage facility. The dewatering bin design offers a wet bin storage facility where the solids can be stored in a saturated form over the short or the long term without agitation and extracted when required at a controlled rate and concentration.



CiDRA's SONARtrac flow technology is an industrial flow meter, using measurement principles that are distinct from all other flow meter technologies operating in mining. SONARtrac non-intrusive flow monitoring systems make no contact with the slurry and can be removed and reinstalled without process interruption.

Last year, for example, CiDRA Minerals Processing successfully installed and commissioned SONARtrac process monitoring systems at Minera Hierro Atacama, located in Copiapó Province, Third Region, Chile. This project was developed to recover iron from the tailings of a copper mine.

The SONARtrac flow meters are on the long-distance slurry pipeline that transports the iron concentrate from the magnetite plant to the seaport where the concentrate is filtered and stored for later dispatch. At both ends of the transport pipeline, a SONARtrac flow meter together with a nuclear density meter are installed for operational use, which includes measuring the volume of the concentrate transported and leak detection.

In the Hierro Atacama application, the ore has magnetic characteristics that are detrimental to the performance of some conventional flow meter technologies; however, the SONARtrac is immune to these effects. Its passive, sonar-based technology enables measurements of single phase and multiphase fluids, as well as slurries, with the same level of accuracy and performance. The company says "SONARtrac technology is a proven standard on pipelines with magnetic slurries and is repeatable and reliable in the harshest environments and slurry conditions."

### Looking to the future

Dr Jie Wu, from CSIRO's Minerals Down Under Flagship, leads the AMIRA International P599B project. In an effort to reduce both water and energy consumption and improve the slurry transport's reliability, researchers have built a fundamental understanding of slurry flow design - particularly for highly concentration slurries - via two previous AMIRA International projects, P599 and P599A.

Although a goal is to use less water in the transportation process, doing so creates thicker, more paste-like slurries, which in turn creates other issues, says Wu. On one hand more product can be moved at a time at lower velocities, but on the other, pipes and associated infrastructure have to be designed to handle the thicker flows.

To address these issues, researchers will use and fine tune methods embodied in PipeTools, a software program developed in the previous P599 projects that provides a more accurate prediction of the behaviour of concentrated suspensions compared to existing tools.

Wu says there are huge errors - up to 600% - associated with conventional designs of these high concentration flows, which result in pipeline transport failures or the inability to pump the desired amount of solids. "Being able to make more accurate predictions will help the industry to optimise design and achieve a much better outcome."

As well as extending PipeTools, the project aims to help industry sponsors apply this technology and in turn reduce energy use, water use and capital design costs, while operating pipelines with better reliability. Wu says further research will be undertaken into high concentration, wide-size distribution suspensions through horizontal and inclined pipes at energy consumptions comparable to conventional conveying techniques.

Vertical hoisting, where material is lifted straight up and out of mines, will also be researched. "The anticipated benefits of vertical slurry pipelines as a future technology for deep mine transport include less in-ground manpower, less maintenance, potentially lower capital and running costs, and it will be inherently safe," Wu says.

Research will focus on developing optimum designs to convey ore solids via vertical pipes at reduced energy cost and with high reliability. Blending of crushed ore with carrier fluids will be used to achieve stable, low speed and safe conveying. **IM**