Advanced Control Valve, Regulator, and Relief Valve Solutions Improve Mining Operations

Efficient and reliable mine operations rely on carefully specified automated valves and control equipment.

1. Introduction

Mining processes have always been brutal on control equipment. Abrasive and corrosive slurries are present throughout the facility, and many of the ore extraction steps involve corrosive chemicals that further escalate the challenge. Recent attempts to recover and reuse water from the tailings have only compounded the problem since reduced water content creates even more aggressive slurries, eroding pipes, pumps, and valves.

This paper focuses on the more difficult operations found in most mines. It identifies the challenges associated with each processing step and offers suggestions to help specify the best automated valves, regulators, and relief valves for the more demanding applications.

2. Main Mining Processes and Operations

The key operations in each mine vary significantly depending on the target material and other minerals contained in the ore. While the process steps of any given mine are different, a number of unit operations can be found in almost every mining application (Figure 1). Each of these steps will be described in the sections below, followed by a description of the critical control equipment that is necessary to ensure efficient and reliable operations.

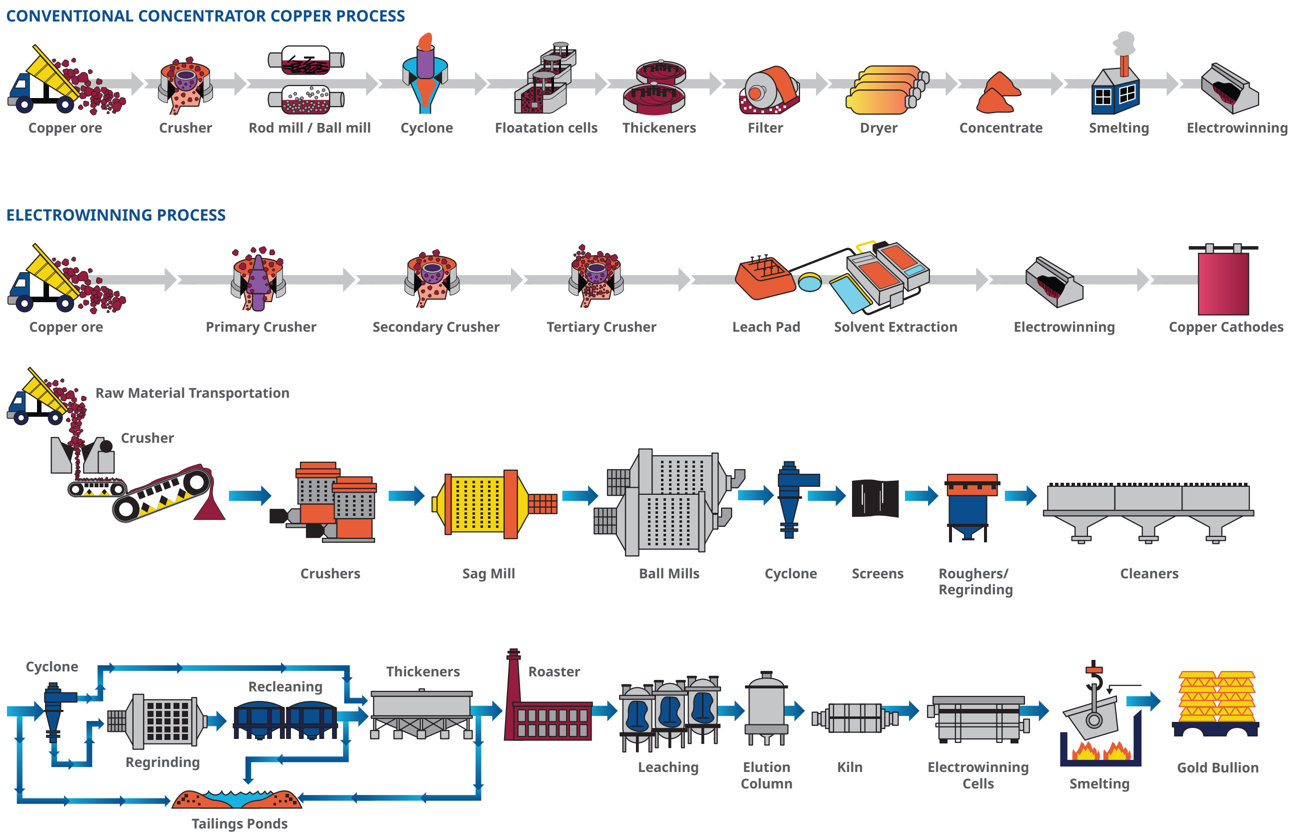

Figure 1: Mining processes vary by target mineral and ore byproducts. These process diagrams show major unit operation steps for conventional copper recovery (top line), copper electrowinning (2nd line), and gold (3rd and 4th lines).

Some of the major process / unit operation mining steps include:

- Crushing / Grinding / Ball mills
- Digestion / Autoclaves
- Flotation / Thickening
- Leaching / Solvent Extraction
- Tailings Disposal
- Water Management / Chemical Makeup

Each of these operations are covered in the sections below.

2.1. Crushing / Grinding / Ball Mills

This operation is used in virtually all mines, regardless of the ore being processed. To isolate and extract the desired mineral from the rest of the ore, the material must first be crushed and eventually grinded and even pulverized (Figure 2). Each step of these operations grinds the material into ever finer particles that are more efficiently processed in the later steps.

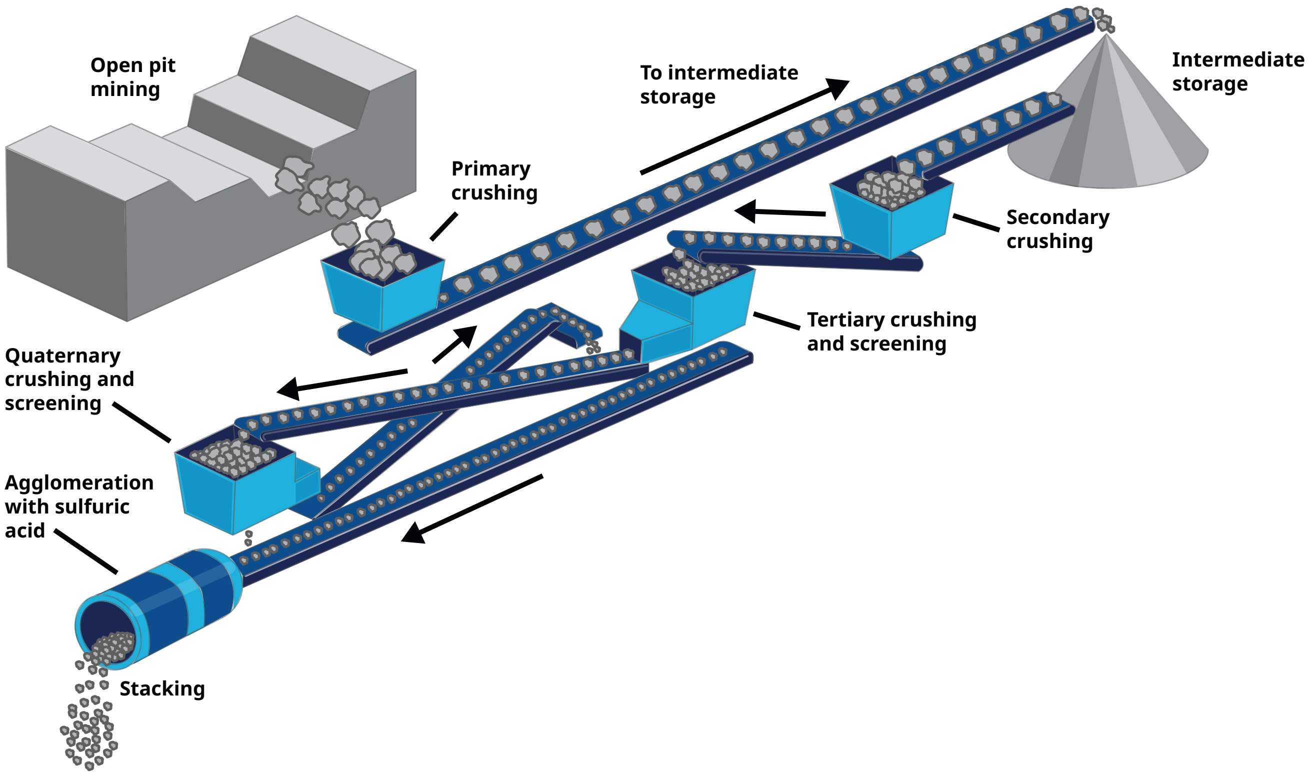

Figure 2: The raw ore is typically transferred via conveyors through a series of crushing/grinding steps to break up the ore into fine particles. Later steps in this process often use enormous SAG and/or ball mills to reduce the ore to a very fine, granular consistency.

Material conveyors typically transfer the material from one griding step to the next. In some ore extraction processes, the ore is ground so fine that the powder can be blown through pneumatic systems.

Two very critical components of any grinding/milling operation are water addition and the mill lube oil system. Water is fed into some mills to keep the finer particles in suspension, and to help keep the downstream screens clean. Lubrication is crucial for any large piece of equipment, particularly the rotating mills and grinders common in this area of the process.

Water fed to the mills and screens is often recycled, so it tends to carry suspended solids and can create scale. There can also be significant pressure drops, which can create cavitation conditions. Large bore, v-ball type valves, such as the Fisher™ V150 and V300 valves, are a good option for this service (Figure 4). 316 stainless steel bodies with chrome carbide-coated balls and Alloy 6 seals and retainers provide long service life despite the conditions.

Figure 3: Recycled water feeds to the mills and screens usually require large port valves, like this Fisher V300 with stainless bodies and hardened trim, to handle the entrained particles.

Sometimes cavitation can be an issue due to high pressure drop. In that case, anti-cavitation accessories, like the Fisher Cavitrol™ Hex, can be added. It has larger ports than most anti-cavitation trims and has been specially designed to work with the Fisher Vee-ball™ valve series.

Grinding/milling equipment tends to be enormous, subjecting the bearings and motors to very high stress and vibration levels. The lube oil systems make operation possible, and failure of this system will cause catastrophic damage, requiring months to repair. Because the lube oil system is so critical, it must be carefully designed using redundant pumps and reliable pressure regulators (Figure 4). Most plants further protect the equipment with a strong layer of interlocks.

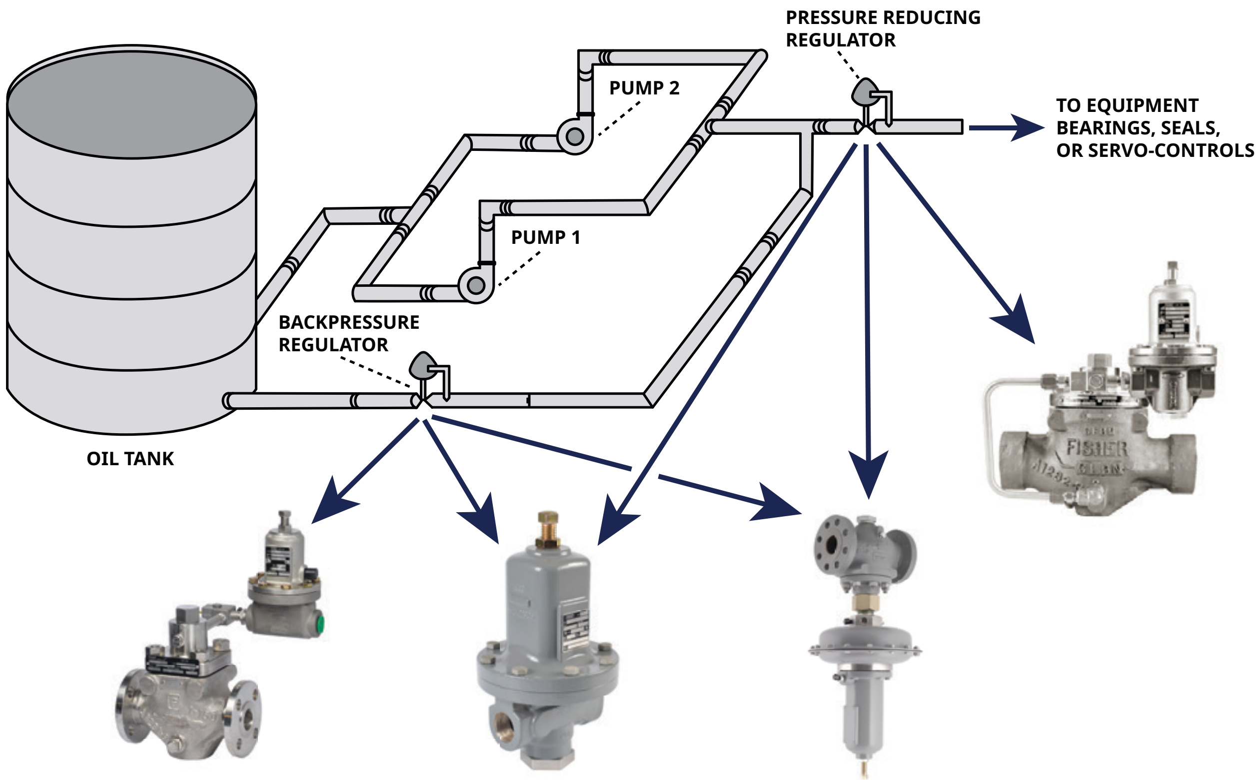

Figure 4: The lube oil system is critical for crushing/grinding/milling operations and must utilize high-tier regulators and controls to ensure very reliable performance. (Fisher™ models LR128, MR95/98, MR108 and LR125 shown left to right.)

Many lube oil circuits will utilize backpressure regulators—like the Fisher MR98, MR108, LR128, and 63EG—to maintain a constant pressure on the lube oil header. Lower pressure lubrication needs may require a pressure reducing regulator, like the MR95, MR105, LR125, or 1098. The proper regulator will depend on the pressure settings and flow requirements.protect the equipment with a strong layer of interlocks.

2.2. Digestion / Autoclaves

Some minerals require further processing at high temperatures and/or pressures to drive specific reactions that make extraction possible. For example, one of the first steps in the alumina process is reacting the crushed and washed ore with caustic in a digester at high temperature and pressure. This step dissolves the aluminum into a sodium aluminate solution so that the remaining ore residue can be filtered and discarded.

Alumina digester and flash tank pressure relief are particularly challenging applications. Materials tend to scale and stick to the internals of the vessel, either plugging lines or rendering them inoperable. Rupture discs can be used instead, but if these blow, the entire vessel must be fully depressurized before the disc can be replaced. During this whole time, the process is being vented, resulting in significant material loss.

A better option for this application is an Anderson Greenwood™ 500 series pilot operated relief valve with a high-pressure steam purge (Figure 5). The high-pressure steam purge is introduced below the relief valve to keep scale and mineral from coating and plugging the relief valve inlet.

Figure 5: This redundant pilot Anderson Greenwood 500 series relief valve is installed on an alumina digester. The steam purged installation reduced downtime and saved significant costs over the previous rupture disk arrangement.

When called into service, this fully-ported relief valve can quickly vent the vessel to relieve pressure and then close securely to contain the process and minimize product loss. It can also modulate, opening just enough to relieve the pressure and minimize emissions.

2.3. Floatation and Thickening

Most ore extraction processes involve floatation and thickening. In the floatation process, the pulverized ore is mixed with various chemicals and aerated in a large vessel. The rising bubbles from the bottom separate the material into a lighter froth that floats on top and a heavier material that sinks to the bottom. Sometimes the mineral of choice floats to the top and is skimmed off for further recovery. In other ore processes, the target material sinks to the bottom and is removed.

The floatation process requires the addition of specific chemicals, air, and sometimes oxygen and/or brine. Brine and oxygen valves require special materials of construction and must be specified carefully. A good option to regulate oxygen feeds is the GX/Easy E series valve with Monel body and internals (Figure 6). The material of construction for the brine depends on its specific properties.

Figure 6: Flow valves for oxygen and brine feeds to the floatation tanks often require careful selection of materials of construction. Exotic material requirements, such as Monel, Duplex, Ferralium, Avesta and others, are common.

For this service, a Baumann™ valve with Duplex, Ferralium, Super Duplex, or Avesta may be required to avoid corrosion and provide reliable, long-term service.

Both the top and bottom exit streams of the floatation tank are usually passed through a thickener to recover water for other ore recovery processes. The thickener receives the slurry and typically adds some type of flocculant, which makes the solids aggregate and settle to the bottom. The relatively clean water rises to the top and overflows into a channel that carries the water away for further processing. As the thick sludge builds on the bottom, it is removed for further processing. If the bottom sludge is a waste material, it is usually transferred to the tailings header for disposal.

The key valve applications around the floatation and thickening feeds vary by process and feed, but they typically utilize a number of low-pressure valves to divert feeds, underflow, and overflow slurry streams. In these applications, zero leakage, high-performing knife gate valves are required, such as the Clarkson™ KGA and KGD (Figure 7). The valves are full-ported and have replaceable sleeves to extend service life.

Figure 7: Knife gate valves are common around the floatation and thickener areas. The best valves are tight shutoff, full ported and reversible valves such as the Clarkson™ KGA (left) and the higher pressure rated KGD (right). Both offer zero leakage, replaceable sleeves and handle a range of process pressures.

Either valve can be actuated with pneumatic or electric actuators as required by the plant and offers reliable, leak-free operation in low-pressure slurry applications.

2.4. Leaching and Solvent Extraction

A common unit operation in many mine processing areas involves leaching and solvent extraction. The refined and pulverized ore is stacked in piles and a solvent is poured over it to dissolve the target mineral into solution. The resulting leachate is processed in various ways to remove and condense the mineral of choice and recover the solvent for re-use.

The solvent is typically caustic or acidic and may include cyanide solutions in some ore recovery applications. These solvents are often very corrosive and difficult to handle.

The best valves for these applications are lined butterfly valves to suit the particular process needs (Figure 8). For larger line sizes up to 36 in., the NeoSeal butterfly offers a PTFE-lined seat and disc that offers a similar extended service life.

Figure 8: Leaching and solvent extraction involve a range of very corrosive chemicals. Lined valves, like the NeoSeal butterfly valve, are impervious to chemical attack and offer reliable long-term service.

2.5. Tailings Disposal

One of the more punishing applications in a mine can be found in the tailings disposal network. The movement of large amounts of dense, abrasive material through a very long piping network is never easy, but the problem has been made much worse as mines have removed increasing amounts of water from the tailings slurry as part of their conservation efforts. This makes the resulting slurry even thicker and more difficult to transport.

The natural result of dewatering is significantly elevated pressures at the front end of the disposal piping system, where very large pumps must push the material over long distances (often miles) to reach the disposal area. All the valves in the system face very abrasive and erosive conditions, but the valves at the head of the network also face very high pressures requiring 300# flange ratings.

The best valves for this service are a range of full-ported severe service knife gate valves depending on the location in the tailings network. Clarkson™ KS3 valves are very well suited for the head of the network since they carry full 300# flange pressure ratings. As pressures fall, the Clarkson KS1 works well as they are less expensive with their 150# flange rating (Figure 9). Both valve designs utilize full port entries, are reversible, and employ wear rings to extend valve life.

Figure 9: The Clarkson KS1 (left) carries a full 150# flange rating, while the severe service Clarkson KS3 (right) carries a 300# flange rating. Both valves are reversible, have rotatable wear rings, and have advanced seals for excellent shutoff and zero environmental leakage.

In addition, both the KS1 and KS3 have a large, precision-molded seat mounted below the flow stream to provide reliable shutoff, and each has a field adjustable transverse seal to limit leakage outside the valve body. KS1 and KS3 can be actuated with pneumatic, hydraulic, or electric actuators.

2.6. Water Management and Chemical Makeup

In addition to all the mine unit operations discussed above, there are many necessary processes involving utilities, water recovery and management, and chemical makeup. Each of these will need automated isolation valves that provide long service life with minimum maintenance.

Simple water management can be handled with butterfly valves with stainless disks and EPDM seats, such as the Keystone™ GR series valve (Figure 10). Chemical makeup valves usually involve more corrosive chemicals, such as caustic or sulfuric acid. In these cases, a resilient seated butterfly valve with PTFE lined body and disc, such as the Keystone F990, is a better choice.

Figure 10: The Keystone GR butterfly valve (left) works well for basic water processes. The Keystone F990 (middle) is well suited for chemical makeup and corrosive applications, and the Keystone GRF (right) comes in line sizes up to 72 in. for tailings water recovery applications.

The line sizes for tailings water recovery can be very large. In these applications a PTFE lined butterfly valve, such as the Keystone GRF, can be a good option as it spans line sizes from 2 to 72 in.

These areas typically include chemical storage tanks that may require nitrogen blanketing and overpressure protection. The focus here is to protect the tank while minimizing nitrogen usage and avoiding tank emissions to the atmosphere. Fisher™ offers a complete line of tank blanketing regulators suitable for a wide selection of setpoints and flow capacities. Tank vents should be carefully chosen as some models tend to leak significantly near setpoint, increasing emissions. The Enardo™ ES tank vent series can operate up to 90% of setpoint while keeping leakage less than 0.1 SCFH, making it well suited for this application.

3. Valve Actuators

Historically, most mines have employed a combination of pneumatic actuators around the processing areas, and some manually powered hydraulic actuators in the very remote tailings areas. Electric actuators were less common due to torque limitations and electric power availability. The advent of much more efficient, high torque motors, spring failure options, robust diagnostics, and wireless remote access has greatly changed the suitability and viability of electric actuators (Figure 11). Some mines are also faced with very limited water availability, making it difficult and increasingly expensive to operate an air supply system. As a result, many sites are increasingly utilizing electric actuators.

PNEUMATIC	ELECTRIC
• Initial cost lower but life cycle cost higher • Operating costs tied to compressor size and utilization • Tight positioning options significantly raise cost	• Initial cost higher, but life cycle cost lower • Efficient operation • Very fine positioning possible
• Higher failure rate due to solenoid, tubing, positioner, and dependence on air • Partial Stroke Testing possible with add on • Advanced diagnostics and connectivity available as options, but supply of electric power required • Winter freezing possible with poor air quality	• Significantly reduced failure rate • Integrated feedback and Partial Stroke Testing • Advanced diagnostics and connectivity easy to include • Operates reliably down to -50° F
• Stroke can be controlled, limited torque control • Configuration tied to hardware calibration, so fast changeover is not typically feasible • Reliable operation dependent on air supply pressure/quality	• Fully adjustable stroke and torque options • Altered configuration can be downloaded, providing fast changeover options • Can run on solar batteries in remote areas • Requires only electricity

Figure 11: Advances in electric actuator torque, efficiency, and remote monitoring have altered the economic landscape driving valve actuation selection in mining applications.

While pneumatic actuators are still commonly utilized in chemical processing areas where air is usually needed anyway, valves installed on remote tank applications or tailings networks tend to employ advanced electric actuators, such as the Bettis™ RTS and XTE3000 (Figure 12).

Figure 12: Next-generation electric actuators (Bettis XTE3000 - left) provide SIL 2/3 reliability, programmable stroke profiles, and advanced diagnostics. Other electric actuator designs (Bettis RTS actuator - right) can fail open or closed using a fail-safe spring. Both models provide continuous modulation or on/off service and remote monitoring options.

The embedded controls and communication options of these actuators enable remote control and monitoring of far-flung tailings distribution networks even when power is limited. These features also allow advanced control in remote tank applications as described in the use case below.

4. Use Case

A mine uses water trucks for dust control on roads throughout the pit. To reduce travel distance to refill the trucks, the mine decided to repurpose a tank located far away from the processing area. They then needed a way to fill this tank without any external controls because the location lacked wiring or radio telemetry. The main water supply lines were approximately one mile away, with a 300-foot difference in elevation, with the tank being higher than the water lines.

The tank was fitted with a local level transmitter, and a water supply line was run to the tank from the process area. However, the mine needed a means to keep the tank full without running control wires over that same distance. The solution was to mount a Bettis™ RTS actuator with built in PID functionality on a 10” Keystone™ K-lock isolation valve installed on the water feed line at the tank. The level transmitter was wired into the RTS actuator, and a stroke profile was programmed to open the valve when the level dropped too low and close it when the level approached full. This solution resolved the control and communication issues by providing a flow setpoint from the local actuator.

At the other end of the pipe in the process area was a VFD that sensed local pressure in the water line. When pressure fell, the VFD would start and ramp to speed. As the pressure rose above a certain value, the pump stopped.

When the tank required water, the RTS actuator would open the valve, dropping the water header pressure. The VFD would then ramp up to speed, pumping water over a mile into the tank. As the tank filled, the RTS actuator closed off, raising the water header pressure, and eventually tripping the pump. The tank was kept full without running control wires, and the fail-safe electric actuator on the tank’s fill valve protected the tank from overfilling, even during loss of local power.

5. Key Takeaways

The best control equipment choices will vary from mine to mine and process to process. However, there are common applications across nearly every mine that can be effectively handled with the right choice of actuated valves, regulators, and relief valves. The major process challenges include:

- *Grinding/Crushing/Milling:* Water feeds to this equipment often contain particles, which can create scaling and erosion. Full-ported Fisher™ Vee-ball™ valves with stainless bodies and hardened trim can provide excellent service. If cavitation is an issue, the Cavitrol™ Hex can be added to these models. Grinders and mills are usually large, expensive, and involve high horsepower motors with massive seals and bearings. The lubrication system for this equipment is critical for reliable operation and should employ a range of high-performing regulators—such as Fisher LR125/128, MR95/98, and MR108—to ensure continuous operation.

- *Digester/Autoclaves:* These vessels operate under elevated pressure and temperature, and they are prone to material buildup and plugging in the overhead lines. Pressure relief devices such as the Anderson Greenwood™ 500 series with steam purges on the inlet lines will provide reliable, high-capacity relief and immediately seal once the pressure has been relieved.
- *Floatation/Thickening:* Brine and oxygen feeds to the floatation cells must be carefully specified to be compatible with their service. The user would be wise to consult their Emerson control valve rep to determine the best valve and material of construction for a particular flow application.

  Most of the erosive slurry flows around these areas are controlled with low pressure knife gate valves. Full-ported, reversible and serviceable knife gate valves such as the Clarkson™ KGA and KGD series provide reliable, long-term service and zero leakage seal-off despite the difficult application.
- *Leaching/Solvent Extraction:* The valves around these process areas are often subjected to very corrosive process streams with varying line sizes. For this application, the Neotecha™ lined ball valves and the NeoSeal lined butterfly valves work well. The lined body, discs, and seat are impervious to the corrosive process fluids and the body sizes range from 1/2 to 36 in.
- *Tailings Disposal:* Water conservation efforts have greatly reduced the water content of the tailings, resulting in very erosive slurries and elevated pressures at the head of the pumping network. This application now requires severe service knife gate valves with much higher-pressure ratings and better designed to handle the thick, abrasive tailings slurry. Clarkson KS3 knife gate valves have a full 300# flange pressure rating and work well in the high-pressure pumping areas at the head of the tailings distribution network. As pressures fall, the KS1 knife gate works well. Both valves are reversible, have wear rings, are fully maintainable, and offer advanced seal designs to provide zero environmental leakage and excellent shutoff.
- *Water Management / Chemical Makeup:* Water management may involve simple applications but can involve very large line sizes around the tailings water recovery areas. Chemical makeup usually involves concentrated and dilute acid and caustic solutions that can be quite corrosive. For less challenging water applications, valves like the Keystone™ GR provide reliable service. Larger line sizes may require lined butterfly valves such as the Keystone GRF. Corrosive applications often require a fully lined butterfly with tight shutoff such as the Keystone F990. Hazardous storage tanks may require blanketing regulators and tank vents. The Enardo™ ES series tank vents can significantly reduce emissions since they can operate at 90% of set pressure yet have minimal leakage. When paired with a properly designed tank blanketing system, the equipment can protect the tank while keeping nitrogen usage and tank emissions low.

Mining processes offer a diverse set of challenges for automated valves and controls. Proper equipment selection requires a full understanding of the difficulties associated with each unit operation, as well as a knowledge of the numerous equipment options available to satisfy those needs.

Emerson has extensive experience in a broad range of mining applications and a proven track record of successful installations in many mines worldwide. It also offers a broad selection of control solutions, and the expertise to help mine operations select the right equipment that meets all requirements.

Emerson

19200 Northwest Fwy
Houston, Texas 77065 USA
T: +1 800 558 5853
+1 972 548 3574
www.Emerson.com