Abstract

The use of water hydraulics world-wide over the last 120 years is reviewed including mining specific developments such as hydropower. Emerging from this are a many new opportunities such as digital hydraulics and low-pressure water hydraulics and new types of valves. The opportunities that the technology offers to both large and small operators is presented, and the new products and challenges of the future are explored.

The scope is not confined to traditional centralized hydropowered systems or distributed power-pack based systems, but is applicable to all mines that use water. The economic benefits of the system are included and the reduction in costs and improvements in equipment performance are emphasized. Further opportunities to reduce mining costs through new valves that were developed for conventional mines based on hydropower technology are considered. These include energy recovery systems, pressure control valves and water conservation valves.

Background

Water was there at the beginning of modern power hydraulics. In the 1880s a 7 MPa reticulation system in cast pipes delivered power for lifts etc under the streets of London. However, steam pumps and corrodirable materials and the dawning of the oil industry and electric power gave impetus to the electro-hydraulic oil industry which has become the dominant means of providing high linear forces and mobile power in most mining applications.

In South Africa in the mid 1970s the need for cooling in deep mines and the availability of pressure head in the incoming water was recognized and the concept of ‘hydropower’ as it is used here was born. Hydropower may be defined as:

The use of high-pressure water, typically 14 to 18 MPa, to power equipment and to improve the environment.

Initially envisaged as a centralized power source distributed from the shaft column to the rest of the mine the environmental improvement was seen to be primarily cooling at the point of use, but this has been extended beyond the local working environment to also include the global environment as the energy efficiency benefits reduce global warming.
The intention was to deliver more power to the rock face directly in a hose or pipe than was possible with compressed air (due to the higher pressure) and thereby improve the ability to mine. At the same time, cooling would be delivered to where it was needed—at the face where the people were.

The initial focus was to develop hand-held drills, but this was soon followed by water jetting to move rock.

The big boost to hydropower came with the decision to power Northam Platinum mine by hydropower due to the high virgin rock temperature of 65 degrees Celsius at 2000m depth. This was soon followed by Tau Lekoa, Kloof 4 Shaft and Beatrix 3 Shaft.

What has emerged from this is a ‘hydropower industry’ that provides a full suite of stopeing and development equipment, high-pressure reticulation systems, a range of affordable and durable high-pressure valves and new water-powered range of inexpensive mechanization equipment.

Hydropower technology has not become the mainstream technology in narrow reef mining for which is dominated by traditional compressed air hand-held drilling. Some of the contributing reasons are the aversion to water in the traditionally shallow Platinum mines, the initial cost of purchasing high-pressure water equipment and the ‘learning curve’ difficulties associated with changing from compressed air to hydropower in an existing operation.

The advantages of hydropower are well known and include higher power delivered to the face, flexible usage of the energy to power ancillary equipment, ease of reticulate, only one hose needed to a drill, safe, no electrocution risk, cannot contaminate the ore or reduce extraction efficiencies, oil free, no fogging, no grease or oil mist particles in the air to be breathed, excellent dust suppression, quiet compared with compressed air, cool and environmentally friendly.

This paper examines hydropower in South Africa, international water-hydraulics, challenges common to both and the opportunities looking forward.

Products Emerging from Hydropower

Full Range of Equipment

Two South African manufacturers of hand-held produce water rock-drills and several companies manufacture jetting equipment and power packs. A full range of standardized reticulation equipment conforming to international standards is also available. This includes clamps, combined excess flow and isolation valves, manifolds, compensators, hoses and fittings.

The need to safely control and reticulate high-pressure-water has spawned a whole new valve industry. The Safety Isolation Valve (SIV) has played a particularly important role in making
the industry safe. This valve automatically closes in the advent of a pipe failure downstream in a manner that eliminates excessive pressure surges. Other valves include the Manual Isolation Valve (MIV), Pressure Regulating and Ratio Valves (PRVs), the Surge Relief Valve (SRV), Pump Control Valve (PCV). These have all found their way into non-hydropower mines as the ability to control at high-pressure means added durability at medium pressures i.e. 2.5 to 13 MPa. These valves have found uses in pump chamber automation and some have been exported.

Figure 1 A typical twin-leg pressure regulating station with remote closing or manual isolation valves, safety isolation valves to limit excess flow and pressure regulating valves

In addition to the large bore valves, small control valves have also been developed. These include solenoid valves, pilot controlled valves, sequence and counter balance valves, 4/3 and 3/2 valves and other specialty valves.

A wide range of ancillary equipment and tools are also available. These include blast-hole cleaners, watering down guns and sprays, fans, hoists, grout pumps, sample cutters, motors, cylinders, accumulators, explosive loaders, dirty water jet pumps and loading systems for box hole chutes.

Appropriate mechanisation drill rigs and suites of equipment have emerged that offer faster drilling and rock loading rates than is possible with compressed air. These include stope drilling jigs, oil-hydraulic flat-end development rigs with water drills and 100% water powered drill rigs for face and support drilling, rock loaders, monorail mounted raise climbers, raise rigs and long-hole rigs for drilling rock pass blast-holes. These pieces of equipment when combined in suites offer superior safety and faster advance rates at cost comparative to traditional compressed air hand-held drilling. This is only possible due the power available in hydropower.
In addition to the supply of equipment, the adoption of a new technology by a user can be facilitated by the supply of training, implementation and maintenance support services. The latter are essential for successful technology transfer.

**International Water-Hydraulics**

The single biggest difference between the South African approach and the approach of the rest of the world has been the water quality. In South Africa, mine water is the hydraulic fluid.
and this is generally in an open circuit dumping to the footwall, compared with closed water systems with high levels of filtration elsewhere. Generally, international water-hydraulics has followed the oil hydraulic trend, but with finer tolerances and special materials. This excludes most off-the-shelf international equipment being used directly in mine water systems which necessitate dirt tolerant designs.

The biggest international usage of water-hydraulic is in hot metal industries where fire risk with oil hydraulics is a major concern. This includes steel making and furnace tapping. Typically High Water Based Fluids (HWBFs) are used. These consist of emulsions with between 2 and 5% oil or synthetic based products added to the water to improve lubricity and inhibit corrosion. HWBFs were used in the early days of hydropower in South Africa, and are widely used in coal mining longwalls, but were soon superseded in favour of open circuit systems using mine water.

![Figure 3: High Water Based Fluids are widely used in hot metal industries](image)

The off-shore and under water industries also employ water hydraulics. Here non-flammability and the advantage of being able to return the water to the sea without the risk of pollution favour the use of water. The non-contamination and environmentally friendly properties of water are also important in the paper industry.

High-pressure cleaning of buildings and concrete rehabilitation and demolition with ultra-high-pressure is a growing industry both internationally and in South Africa. Profile cutting with ultra-high pressure water involves Sapphire nozzles, abrasive grit injection into the jet and the use oil hydraulic-to-water hydraulic pressure intensifiers to generate the high pressures required.

Niche applications for power packs and valves exist in many industries and these are served by companies that have developed propriety solutions. Two examples would be the nuclear industry where high radiation levels denature standard hydraulic fluids making water the hydraulic fluid of choice.
In contrast, Danfos of Denmark has invested heavily in developing a range of water-hydraulic commodity products. This includes valves, pumps, motors and cylinders. They have seen a steady growth in their sales vindicating their investment decision. Unlike the South African mining operations most of this range of products is orientated around small flows with clean water as would be encountered in say, a food factory.

**Bara vanligt vatten**

![Danfoss Vattenhydraulik](https://www.danfoss.se)

**Figure 4 Typical commodity water-hydraulic components**

In the mining arena, the development of the Wassara In-the-Hole (ITH) hammer by LKAB in Sweden has the most significance for the South African mining industry where it is used for drilling long holes. In Europe, this is also seeing significant growth in the construction industry for rapid drilling of holes for pile foundations.

In all these industries the positive displacement plunger pumps is still mainstay when it comes to pressure generation at low volumes (i.e. less than 40 litre/sec), for higher volumes, centrifugal multi-stage pumps are popular.

**Challenges Facing Water-Hydraulics**

In the South African mining industry a significant challenge is to reduce drilling and component costs. This is not easy as, compared with air and oil technologies, hydropower makes much greater use of more costly stainless steel and manufacturing volumes are small.

Worldwide water hydraulics has been held back by the absence of a variable displacement pump and the difficulty of the achieving reliable proportional control valves due to the erosive power of water on line contact valve seats. A solution to these issues is in sight with the advent of digital hydraulics which is being pursued in Finland.

Digital hydraulics, unlike conventional or analogue hydraulics, does not variably throttle a flow in a single valve to achieve a reduce flow. Instead a number of smaller valves are connected in parallel flow and a reduced flow can be achieved by opening fewer valves. This lends itself to inexpensive automation and computer control. By having a number of different
sizes of valves a wide range of flow steps can be achieved without having to throttle the flow in a single seat or having to measure the precise position of the seat.

**Figure 5** Digital hydraulics: Left—A control system using inexpensive commodity valves, Right—‘Hiab’ truck crane controlled digitally

Cavitation is present in all hydraulic systems, and where it is cannot be eliminated, its effects can be reduced to a minimum by careful design. For example, non-return valves on drains drain lines increase the back pressure thereby preventing cavitation.

The erosive power of water jets is well known, but a new range of ceramic materials is overcoming the limitations of the past. Plasma sprayed coatings or 100% ceramic components have significantly better erosion resistances. Full area contact valve seats rather than line contact seats are widely used in valve designs although they present a varying pressure area to the valve design engineer.

Similarly, the issue of corrosion can be addressed by the correct selection of stainless steel and the use of polymers.

**Driving Forces in the Hydropower Industry**

The need for higher safety and productivity in the mining industry will continue to provide impetus of hydropower and mechanisation in areas where large diesel-powered equipment cannot fit.

As mines get deeper and hotter the original motivation of delivery of power and cooling to the people at the face is still an issue and will favour hydropower solutions.

Energy efficiency and cost will also favour hydropower and electric hand-held drilling over compressed as the power sources of choice. This is well illustrated in Table 1 below which estimates the percentage of energy reaching the face for various methods of drilling.
Table 2 Energy efficiency estimate for different types of drill powering systems

Lastly, the less tangible advantages of hydropower still apply although these are unlikely to justify a more costly approach. These include reduced noise, ore contamination and pollution.

Future of Hydropower

There is a whole industry allied to hydropower based on hydropower valve technology. This includes 3 Chamber Pump System energy recovery devices and valves designed to reduce water consumption of mine thereby reducing the cost of mining. Furthermore, extensive use of valves developed for high-pressures will be used in medium-pressure, non-hydropower operations.
Mechanisation through micro-hydropower systems will continue to grow. These will be boosted by the advent of drifter on the market for drilling holes up to 15m and the further use of the Wassara hammer for holes up to 100m.

Real costs will continue to decline as volumes increase and the equipment improves incrementally.

Electric drilling will become more popular and this will necessitate ancillary new low-pressure and so-called ‘dry’ hydropower equipment.

Digital water-hydraulics, combined with new materials and coatings and the greater availability of commodity products will see water-powered, computer-controlled automation become common.