Improving Efficiency in Underground Mine Process Water Reticulation Systems

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Abstract

Process water is an integral part of mining operations. Underground machinery requires water to operate, with most sites usage reaching several hundred gallons per minute. Establishing a reliable supply of process water in underground mines is one of the main challenges affecting mining operations globally. Underground water shortages are far too common, in most cases occurring daily, costing millions annually in lost production. When revenue generating equipment doesn't have a reliable supply of water, operations shut down. Most mines have struggled to implement a dependable underground process water management strategy. Historically when water surges or starvation occurs, the solution is to "live with it" and fix the damage caused or apply a makeshift approach without looking at the root of the problem – the overall system design.

A traditional installation is gravity fed and allows water to flow through several PRV stations on its way down the mine ramp or shaft, known as a cascade system. Most pressure reducing valves (PRVs) in use today are pressure regulating valves, which allow for the outlet pressure to be set and adjusted. The issue is that regulating PRVs often struggle with system pressure changes, sudden flow changes, and increasing water demand. This, combined with valve droop, is the root of almost all underground process water delivery issues.

To avoid costly shutdowns due to poor process water delivery, mine owners have begun to deploy a new approach to system design. This new strategy, that in part involves valves with specialized capabilities, has proven to eliminate fluctuations in water pressure and availability, eliminating costly water shortages or surge situations.

The first step is to separate the main water supply from the underground levels to create a cascading standpipe. This should incorporate ratio PRV's in place of regulating PRV's throughout the cascade system. Unlike regulating valves that have a calculated output pressure, ratio valves operate on a fixed ratio pressure, so there is no set pressure on the outlet side of the valve. This, in turn, mitigates the issues previously associated with valve hunting within the standpipe system. The next step is to separate the water supply to each level by employing specialized regulating valves designed to eliminate droop. By creating one system for the shaft piping and another system to supply each level, mines can effectively manage process water.

This presentation will review the challenges associated with the current design of most underground process water management systems and review a new approach to system design to alleviate the long-term challenges associated with inconsistent water supply. We will discuss system design changes, the real effect of valve droop in gravity fed systems, and the value of a high-performance underground process water system. Using actual case studies, we will review productivity gains realized within global mining operations that have employed this new approach to process water management.

Introduction

Globally, mines face challenges associated with inadequate water supply on a recurring basis. From water surges to insufficient water delivery, these events result in lost production time and costly repair or clean up. Instead of looking at the underlying issues with underground gravity fed reticulation systems, most mines apply a superficial strategy that does not address the root problem. Underground water storage tanks, booster pumps, orifice plates, and control valves are commonly used but often don't work, or only marginally improve performance.

To truly alleviate the time loss and cost associate with inconsistent process water supply, mine owners can't look to the impacted system, but instead need to look at the root cause, system design. When a system is properly designed to manage process water flow at all levels, 100% process water uptime is an achievable goal. Yet to meet this goal we must first understand the challenges mines are facing daily. Process water management issues are rooted in several recurring problems impacting operations. We will walk through these challenges and a design change that has been proven to alleviate these issues and deliver consistent water flow to every level within a mine.

Instability

Instability within underground mining operations is generally seen when the valves installed in a system are designed to regulate on a constant downstream pressure. These valves, traditional known as pressure regulators, will open more if the supply pressure drops and close when supply pressure rises to maintain downstream pressure. Larger systems with long pipe runs store a significant amount of compression energy, an increase in valve opening after a pressure reduction has been sensed can cause the valve to "make up" for the decompressed volume and react to pressure drops from the increased flow. Though this reaction time is quick in small systems, in larger applications the time between pressure change and valve reaction is delayed, and this slow reaction time results in large pressure surges within the piping system. The closing and opening of a single regulator valve can become out of phase with the system and will cause the subsequent valves to operate erratically. This phenomena is known as valve hunting and is the main cause of instability in underground process water cascade systems.

System Design

The root of many process water management challenges can be traced back to the cascade system design. Traditionally the shaft piping system utilizes the same valves to bring process water down the shaft and feed the levels of the mine. Yet water, which by its nature looks for the flow path of "least resistance", flows easily down the shaft, bypassing the horizontal levels required to feed a mine. These systems, in turn, typically see water shortages within upper levels and water surges at the base levels of the mine.

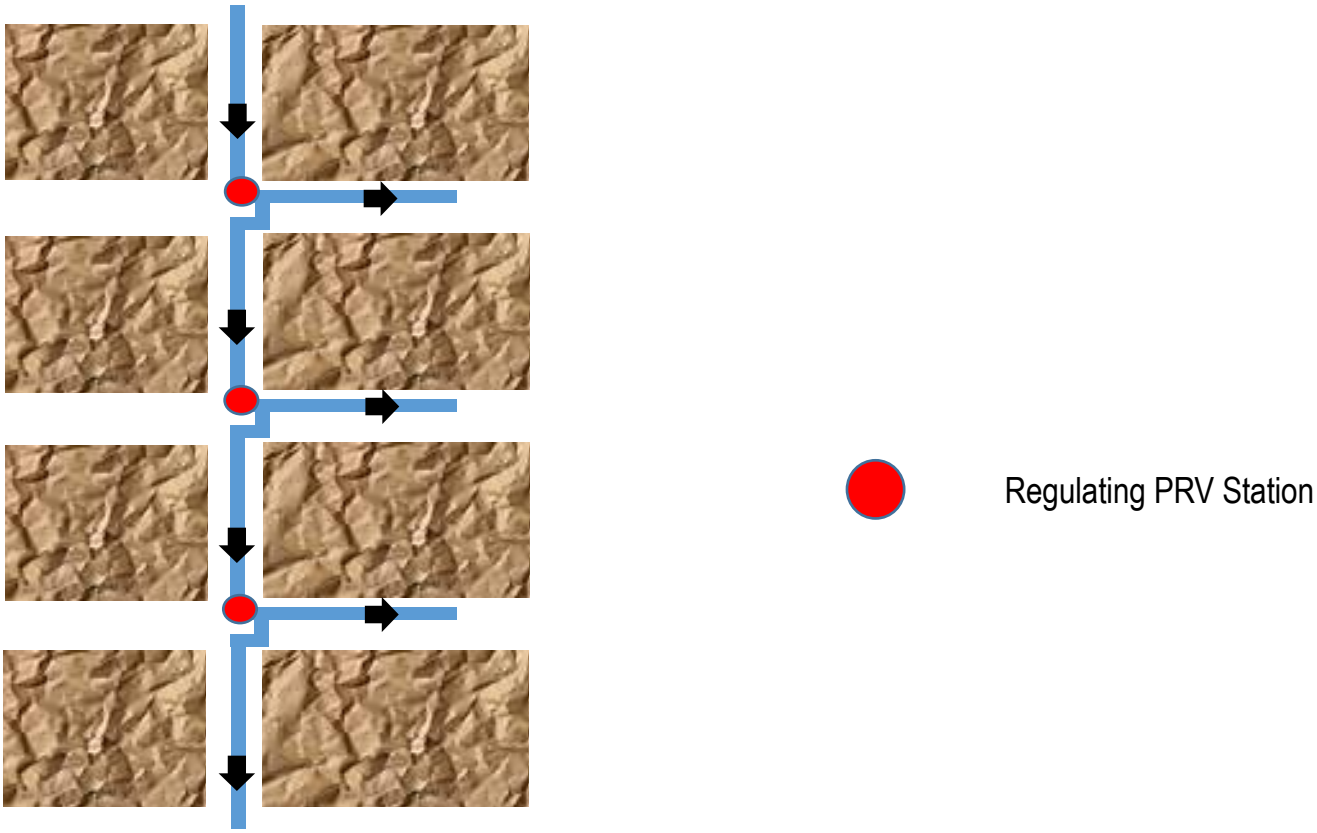

Figure 1: Traditional shaft design incorporating regulating PRV's in cascade system

This inconsistent flow can cause water starvation on production levels, leading to equipment failures, with surges occurring at the base levels of a mine.

Droop

The two styles of regulating PRVs commonly used in mining operations are pilot operated globe valves and Direct Acting Pressure Reducing Valves (DAPRV). All PRV's create a controllable flow restriction which breaks the energy of incoming water and sets the desired downstream pressure. Pilot operated globe valves use an external pilot that, according to downstream pressure, drains or fills the upper chamber of the valve which controls the flow restriction and thus the outlet pressure. DAPRVs operate differently to a pilot operated globe valve, employing a spring directly on the flow restriction. As downstream pressure rises or falls, the restriction opens and closes accordingly to allow more or less flow.

Ideally only the restrictor should perform the task of pressure reduction. Pressure reducing globe valves (pilot operated or direct acting) used in mining are mostly a "T" pattern, meaning as water flows through the valve it changes direction several times and is constricted through cavities, losing energy uncontrollably. Think of these valve bodies as orifice plates. At low flows the controllable restrictor is doing all the work to reduce pressure, however as flow increases the valve body effectively becomes an orifice plate, lowering outlet pressure beyond the set point and limiting flow rates. Traditional cascade systems use several regulating type "T" globe valves in series, so this orifice effect is exacerbated.

In underground mining operations these valves commonly experience droop – a decrease in outlet pressure from the set value resulting from an increase in flow rate – equipment that relies on a specific water volume and pressure cannot function properly and productivity suffers. Valve droop can have dramatic consequences for a mine, amounting to millions of dollars of lost production each year. In figure 1 above, the first valve in the cascade system sees all the flow in the mine, causing a significant droop. This droop, combined with frictional losses of long lengths of horizontal pipe, are another cause of water shortages around equipment.

The System Design Solution

To solve the above stated issues, mine owners must deploy a different approach to system design. The first step is to separate the cascade system from the system that feeds the mine levels (Figure 2). This change in design will remove the bias for water to flow down and bypass levels, allowing equal access to process water at each operational level. To do this, regulating PRV stations must be removed from the cascade system. In place of the regulating PRVs, a standpipe is created using ratio pressure reducing valves to control the column pressure, with regulating valves installed off to the side to feed operating levels. The key is to separate the two systems, one for cascade, and the other for operating levels. Installing regulating PRV stations as a means to feed the levels, rather than within the cascade system, eliminates surges and

swings in system pressure, increasing system stability, reliability and safety, as relief valve blowoff and other effects are no longer a concern.

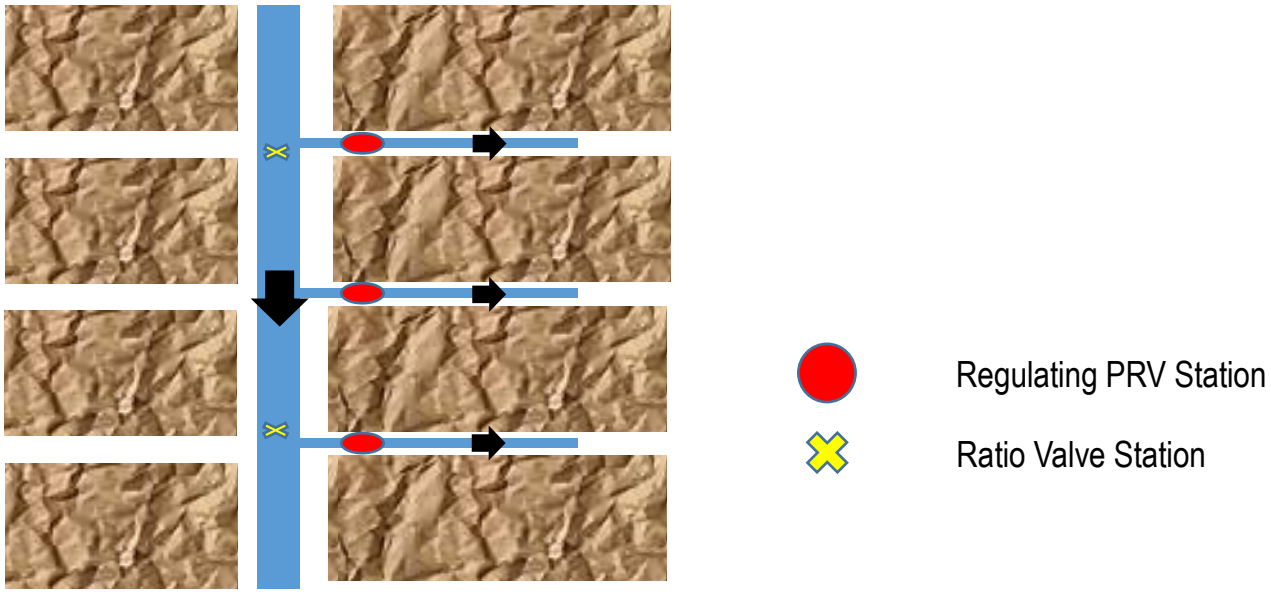

Figure 2: New shaft design with ratio PRV in cascade system and regulating PRVs feeding levels

To implement this new design, process water management systems must use ratio valves for cascading, which have been underused in underground mining operations. Unlike regulating valves, the stability of ratio valves is assured because any change in pressure, water supply, or demand, will immediately cause a pressure change in demand or supply proportionate with the set ratio of the valve. Ratio valves installed in series as in deep vertical mine shaft pipelines have proven to show no instability and maintain consistent predictable performance throughout the demanded flow range.

Once the feed piping is stabilized, the next step is ensuring that valve droop and frictional losses in horizontal piping do not cause water shortages around revenue generating consumers. The solution for this lies in the pressure reducing valve design. “T” pattern DAPRVs and pilot valves will droop and obstruct consistent water pressure to the levels. Valve droop combined with frictional losses in long runs of horizontal pipe are a key cause to water shortages at the consumers. To solve this, mines have begun to specify y-pattern valves that provide a nearly unobstructed flow path through the valve, meaning valve droop is removed from calculations. The use of these valves eliminates tampering, as the valve’s outlet pressure can be set based on consumer requirements and the calculated frictional loss on the pipe run with no variation, meaning consistent water supply and pressure.

Conclusion

The design of process water management systems in underground operations has a substantial impact on the operational productivity of a mine. Reliable water flow is a challenge that mines have grown to see as a day-to-day inconvenience, causing equipment failures and costly shutdowns. Water needs to be balanced to ensure that every area of the mine has equal access to an adequate supply and using a proper design method for the cascade piping and levels has become a trusted solution in mines around the world. With enhanced system designs available, there is no need to continue to live with production losses caused by recurring process water management issues.