Selection of control valves on water optimisation projects

By W Booysen, JF van Rensburg, EH Mathews, North-West University (CRCED Pretoria) and consultants to HVAC International and TEMM International

Controlling water flow to underground mining sections reduces the amount of water required to be pumped back to surface. This results in significant energy savings. Water flow and pressure can be controlled by installing control valves at strategic positions throughout the water reticulation system. Valve selection and specification requires several constraints to be satisfied in order to ensure an effective solution. This article addresses the process of analysing system parameters to determine characteristics; it also evaluates possible solutions to select a suitable valve solution based on the determined constraints. The case study used is a water system optimisation project on a mine close to Westonaria (Johannesburg, South Africa).

Mining water is used to cool equipment such as drilling machines. The water is also used to cool several other components such as ventilation air and the rock face. This used water is then pumped from underground levels back to the surface via a cascade pumping system; typically consisting of several dams and pump stations. The process of pumping water from underground back to the surface is energy intensive.

If the amount of water sent down a mine can be reduced, the energy used to pump the water back to surface will also be reduced. This reduction is achieved by matching water pressure and flow supply to actual (area specific) downstream requirements. The pressure and flow can be controlled by installing control valves on various underground sections. Selecting the ideal control valve for this operation requires a delicate balance of compromise between various sets of constraints. The installation of a valve in hazardous mining areas introduces additional constraints. This article will discuss the process of selecting valves, using information from a previously implemented project as a case study.

Control valve parameters

There are several constraints that need to be evaluated when selecting a control valve. The primary constraints would be the medium (such as air, water or steam), pressure and flow parameters. It is also important to understand to what extent the valve will control these parameters so that the type and rating of the valve can be determined.

There are however several other constraints that must be taken into account such as flow characteristics, control range, cavitation, flashing, water hammer, valve body size, actuator type, safety rating, control speed, maintenance and availability of after sales service.

Project background

The case study is of a water system optimisation project that was implemented on a mine close to Westonaria – *Figure 1* illustrates the basic layout of the mine water reticulation network.

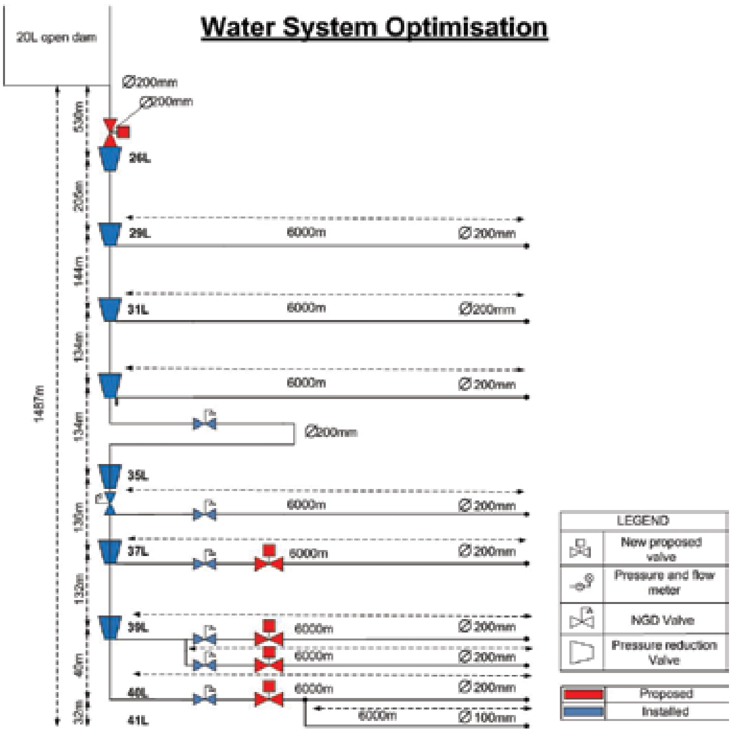

Figure 1: Water reticulation layout.

Existing control valves, situated on underground levels, are used to reduce incoming pressure in order to protect underground equipment. The controllability of these valves is limited and the valves have to be serviced or replaced regularly. This is due to a high wear rate caused by severe cavitation. The scope of this project was to install and operate new control valves to regulate water pressure on underground mining levels. This required that the existing valves be replaced by new valves with increased durability, wider range control and more stable control. The levels where the valves were to be installed were selected based on the amount of water consumed. The specific number and type of users situated on a level also contributed to what type of control would be required.

System analysis

The initial step was to analyse and process all available data. This provided a clear indication of the functioning of the system. In this case study pressure and flow transmitters were already installed, allowing for sufficient data to be recorded. Portable instrumentation was also used where there was incomplete or no available instrumentation. *Figure 2* shows the layout of a typical underground level.

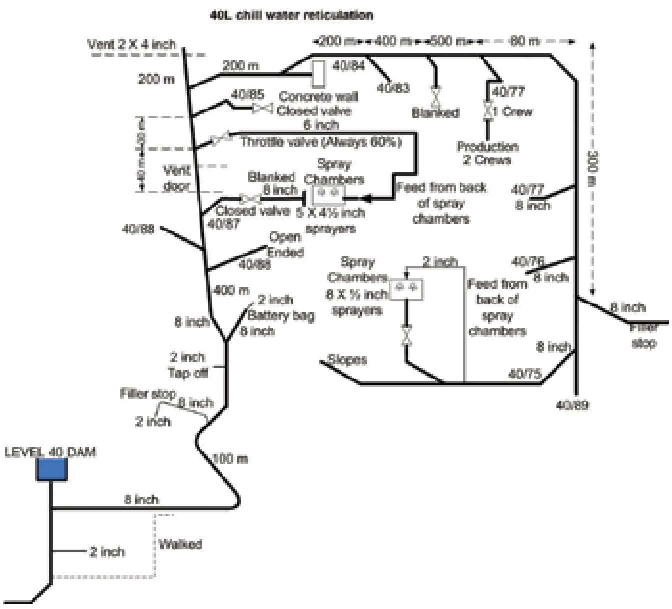

Figure 2: Example of underground level layout.

The data analysis revealed severe pressure fluctuations during system operation. These fluctuations occurred over relatively short periods. The source of the fluctuations can be traced to a control valve situated on 40L. The tempo at which the valve opening changes was too high, resulting in water hammer. This water hammer resulted in upstream pressure fluctuations propagating throughout the system.

Figures 3a and 3b show recorded system data. The graphs clearly illustrate how flow fluctuations on one level result in pressure fluctuation throughout the entire system. *Figure 3c* illustrates a pressure vs flow plot for a specific level. The graph gives a good indication of the new required flow/pressure operational range of the valve. The extent to which the data is scattered suggests that a valve with a wide range of control will be required.

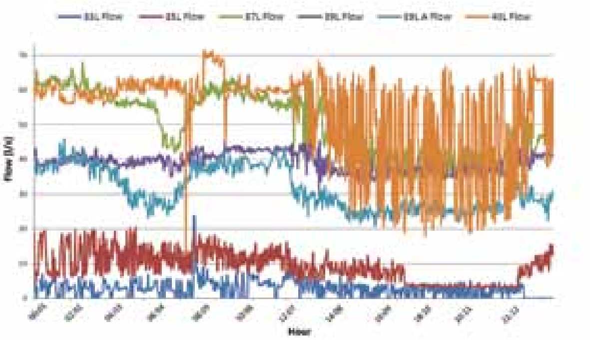

Figure 3a: Per level logged flow data.

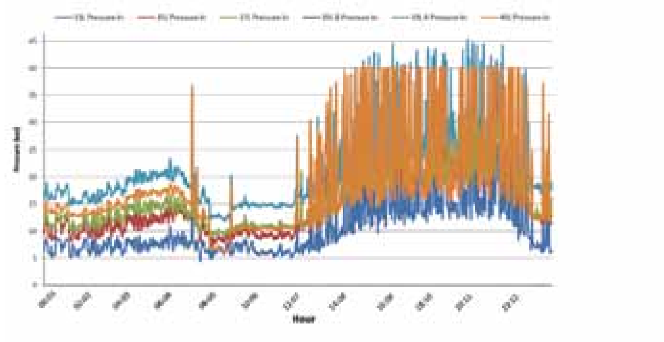

Figure 3b: Per level logged pressure data.

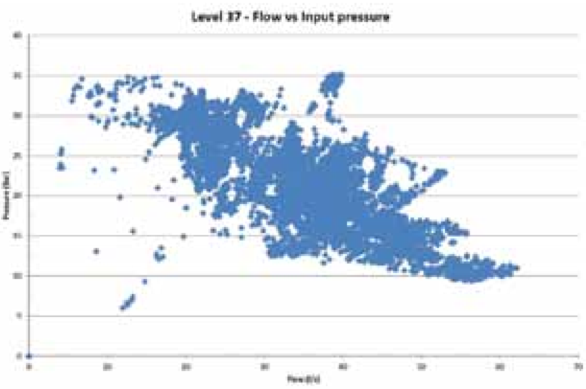

Figure 3c: A specific level pressure vs flow.

The system analysis revealed that the system is presently unstable due to flow and pressure fluctuations, further complicating the selection process. Selecting the correct valve solution may alleviate or even completely eliminate the unstable nature of the system. To better understand the complexities and interactions of the system a simulation model was developed. *Figure 4* shows the basic layout or the simulation model. Previously measured system data was used to verify the accuracy of the model. Several scenarios and control approaches were tested using the model.

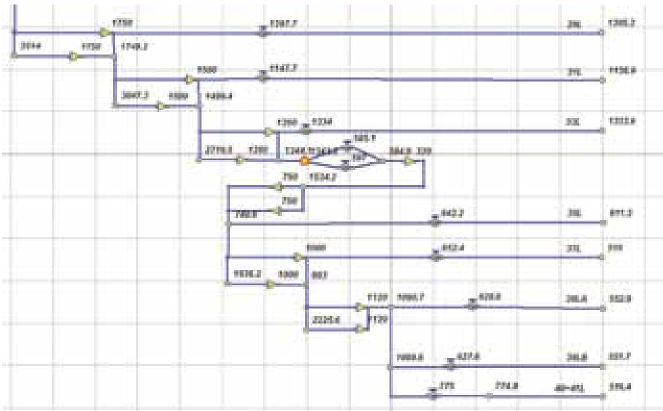

Figure 4: Simulation model layout.

The results of the simulation and data analysis provided a set of pressure and flow constraints. This set of constraints was used as the primary criteria for the new valves. The set consisted of three sections namely minimum limit, normal operation and maximum limit. The constraints are listed in *Table 1*.

	Input Pressure Range (Bar)	**Typical Input Pressure (Bar)**	**Output Pressure (Bar)**	**Flow Range (l/s)**	**Typical Flow (l/s)**
			Level 37		
Normal	10 – 30	20	5 – 1	20 – 40	24
Max limit	N/A	40	15	N/A	20
Min limit	N/A	10	5	N/A	50
			Level 39 A+B		
Normal	10 – 30	16	5 - 1	25 - 40	0
Max limit	N/A	40	15	N/A	25
Min limit	N/A	8	5	N/A	42
			Level 40		
Normal	10 - 20	12	5 - 1	40 - 60	44
Max limit	N/A	30	15	N/A	40
Min limit	N/A	8	5	N/A	65

Table 1: Valve specific parameters.

Valve characteristics and constraints

An important valve characteristic is its flow coefficient. The valve flow coefficient (Cv) gives an indication of the pressure drop over the valve for a specific flow and temperature. *Figure 4* shows a valve Cv as a function of its opening. Ideally a valve should not be operated at low percentage opening as this will increase the risk of cavitation and result in excessive wear. *Figure 5* illustrates a standard globe valve Cv range as a function of % opening.

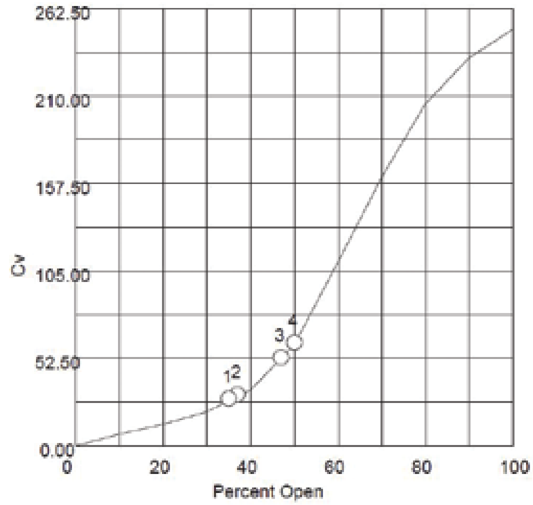

Figure 5: Standard valve control curve.

Cavitation occurs when the absolute pressure inside the valve falls below the vapour pressure of the water [1]. This causes the formation of vapour bubbles which will suddenly collapse as the water flows into a region of higher pressure. This event is extremely destructive to the valve. *Figure 6* illustrates the pressure drop through a valve with P1 upstream pressure, P2 downstream pressure and Pv the vapour pressure of water.

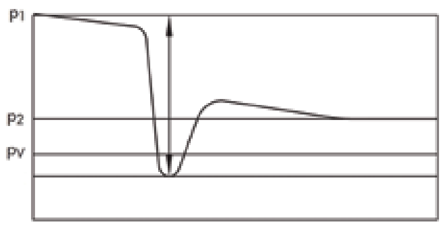

Figure 6: Pressure drop resulting in cavitation [1].

The effects of cavitation can be limited or prevented by adding additional trims to the valve configuration. The trims will either reduce the occurrence of cavitation or direct the cavitation in such a way that minimal damage occurs. *Figure 7* shows an example of cavitation (left) and two trims diverting the cavitation away from the valve body (centre, right)

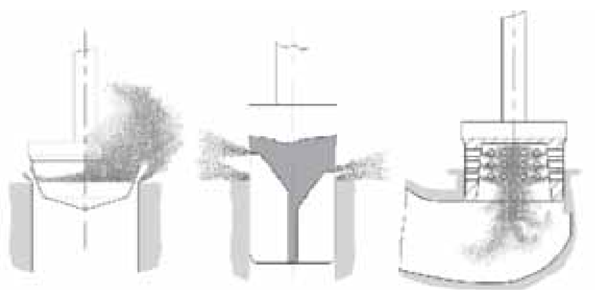

Figure 7: Cavitation limiting trims [1].

The addition of trims will however influence valve control range. *Figure 8* shows the control curve for the same valve as in *Figure 5*, but with a six stage linear trim included. Using multiple stages minimises the impact on the valve control curve at small valve openings.

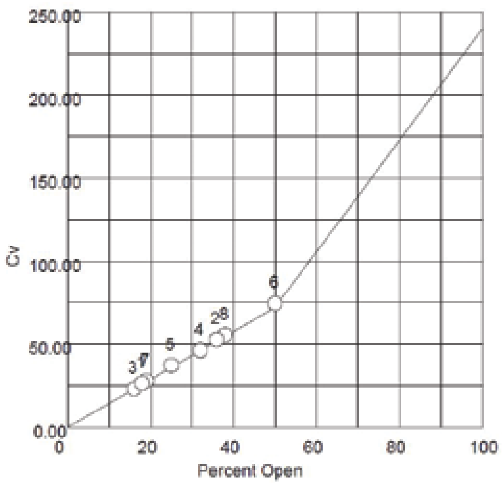

Figure 8: Multi trim valve control curve.

Additional constraints

Due to the large potential pressure drop shown in Table 1 additional multi-stage trims will be required. Mine water quality is considered to be a major constraint. Any insoluble particles in the water would eventually block the multi stage trims. This will make any valve with internal trims unsuitable for use in the mine. No single valve could satisfy all the various project specific constraints. Alternative approaches such as bypass sections, custom valve design and multi valve installations were investigated.

Valve selection

The final solution was to install two identical valves in series. The first valve will reduce the system at a fixed ratio allowing the second valve to regulate the downstream pressure while avoiding cavitation. Without the risk of cavitation the valve design and specification will be less complex, allowing for a robust low maintenance valve to be selected. *Figure 9a* illustrates the proposed configuration; *Figure 9b* illustrates the valve assembly.

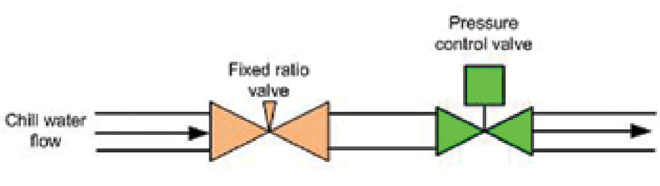

Figure 9a: Proposed valve configuration.

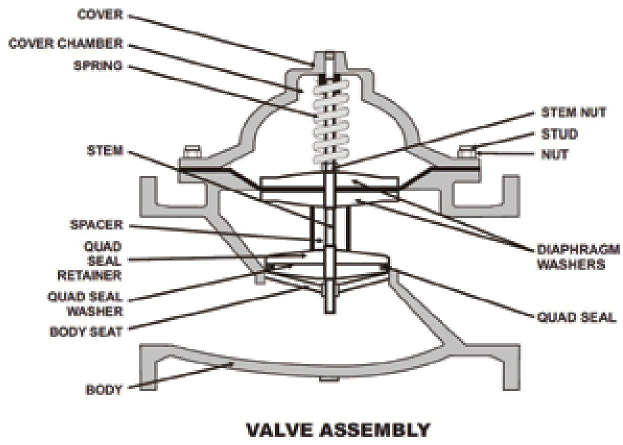

Figure 9b: Proposed valve assembly [2].

Conclusion

The selection of a control valve requires a delicate compromise between various constraints. System analysis and simulation provides a good indication of the major constraints. It is however extremely important to include system specific constraints to ensure the optimum valve selection.

References

[1] Samson, Technical Information - Cavitation in Control Valves, Mess- Und Regeltechnik Weismüllerstraße 3, 60314 Frankfurt am Main, 2003.

[2] Premier Valves, Baker Automatic Control Valves, 3 Potgieter Street, Alrode, Alberton, RSA, 2007.

Acknowledgement

This topic was presented by Walter Booysen at the 2011 Proceedings of the 8th Conference on the Industrial and Commercial Use of Energy.

Walter Booysen (principal author) holds a Masters degree in Electrical engineering from the North West University. He is currently a senior project manager at HVAC International and has enrolled for a PhD at the North West University. Enquiries: Tel. 012 809 0461 or email wbooysen@rems2.com.

Dr Johann van Rensburg (co-author) holds a PhD degree in Engineering from the North West University. He is currently an engineering lecturer at the North West University as well as a consultant to HVAC International and TEMM International. Enquiries: Tel. 012 809 0653 or email jvanrensburg@rems2.com.

Professor Edward Henry Mathews (co-author) holds a PhD in mechanical engineering. He is a contract lecturer at the CRCED Pretoria, a division of North-West University's Mechanical Engineering Faculty. He is a consultant to HVAC International and TEMM International. Enquiries: Tel. 012 809 0995 or email ehmathews@rems2.com.

About the authors