

New Frontier in Aeration Energy Efficiency: Basin Control Valves

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Introduction

A throttling valve restricts flow to regulate flow, pressure or temperature. A control valve is a throttling valve equipped with an actuator that acts within a control loop. In the case of a system providing process air to aeration tanks, the control valve opens and closes to adjust the flow into part of an aeration tank to control the dissolved oxygen concentration or the level of mixing energy.

The inherent characteristic of a valve is the characteristic published by the manufacturer, based on tests performed in a system where the pressure drop across the test valve is held constant at all valve openings and flow rates. The inherent characteristic, therefore, represents the relationship between valve flow capacity and valve opening when there are no system effects involved. Most control valves have either an equal percentage or linear inherent characteristic (Figure 1).

The inherent characteristic does not take into account the effect of the piping system on the pressure drop across the valve. If an equal percentage valve opens, the flow will increase in proportion to the flow before the valve opened. If linear valve opens, the flow will increase in direct proportion to the valve opening. If the pressure drop across the valve is small compared to the downstream losses, an equal percentage valve becomes more linear and a linear valve less linear.

The rangeability of a control valve is the ratio of the maximum to minimum flow that can be acted on by a control valve when it receives a signal from a controller. The sensitivity is the specific change in flow opening by a given change in the regulating element compared to the valve's previous position. A sensitive valve with a large rangeability will be able to fine-tune the

flow through the valve more effectively than a valve assembly that is less sensitive or has a lower rangeability.

The butterfly valve is the most commonly used aeration system control valve in North America. A butterfly valve controls the flow by rotating a disc through 90 degrees. Fully open the disc looks like a dinner plate aligned parallel to the pipe wall in the center of the pipe.

High-performance butterfly valves are designed so that the plate does not contact the seat until it closes. The disc and the rotating rod are moved to one side of the seat (i.e., single or double offset or eccentric designs). Butterfly valves are economical compared to other control valves and weigh less. The typical rangeability of a butterfly valve is 20:1.

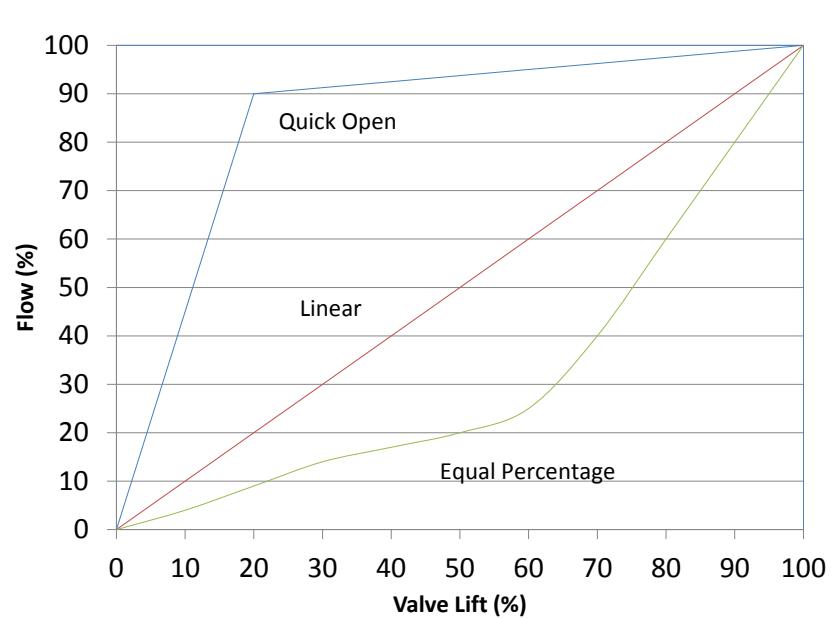
Aeration systems are the largest energy consumer at large wastewater

plants in Ontario, with heating and ventilation running a close second. The industry's focus on the production of more energy efficient blowers and diffusers has shifted to looking also at energy efficient control systems (e.g., most open valve loops, ammonia based control) and air distribution network design (e.g., reduced energy losses through control valves).

The selection of the air control valve is central to building a controllable, responsive and low-pressure loss air distribution system. The water industry has taken three steps to improve control valve performance:

- Improved piping design and selection of butterfly control valves
- Use of eccentric plug valves instead of butterfly valves
- Commercialization of new types of control valves.

Figure 1 – Inherent Valve Characteristics



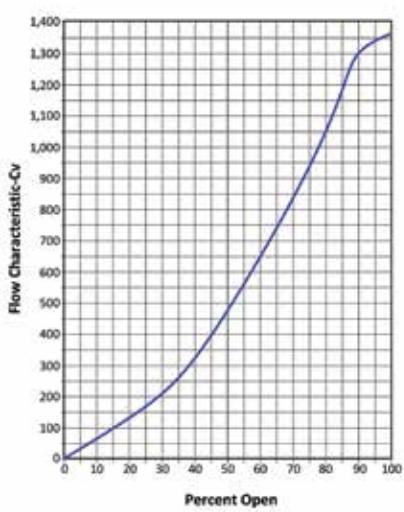
Improved Design Of Butterfly Valves

Industrial butterfly valves were originally and are still used as ‘shut off’ valves. While butterfly valves are not good control valves, they are used almost exclusively for this purpose in air lines at aeration basins throughout North America. Why? Aeration air lines are typically not small. Even though control valves should be smaller

Figure 2 – DeZURIK Single Offset Disk
(Courtesy of DeZURIK)



Figure 3 – DeZURIK BHP High-Performance Butterfly Inherent Characteristics
(Courtesy of DeZURIK)



than line size, they are still large. Large butterfly valves are reliable, have a low capital cost, and are light weight. The pressure drop across these valves is acceptable in low-pressure air systems. When they reach the end of their useful life, they are typically replaced rather than repaired.

The most linear portion of a butterfly valve’s operating range is typically from 40 to 70% open. If the valve is properly sized, pressure drops may be acceptable in only 20 or even 10% of this range. Properly sized butterfly valves used for control are most frequently one size smaller than line size if the piping is sized in accordance with industry standards. At plants where line size butterfly valves have been used, the valves attempt to control at the very low end of their range where the characteristic curve is far from linear. The result is that a very small change in valve position results in a large change in pressure drop so valve hunting frequently results.

Both DeZURIK and other manufacturers developed high-performance control butterfly valves. For example, the BHP Butterfly Valve is not a new technology; however, with incremental design improvements over the last 40 years, the BHP valves exhibit a much more linear inherent characteristic than conventional butterfly valves.

The valve uses a single offset disc (Figure 2) and provides a more linear characteristic curve from 40 to 90% open (Figure 3). The offset disc minimizes interference between seat and disc, lowering torque and increasing cycle life. It is available in sizes from 50 mm (2 in) to 1,500 mm (60 in) diameter with either a carbon steel or stainless steel body. Pricing is at least of the same order of magnitude as butterfly valves traditionally used for aeration control service.

Use of Eccentric Plug Valves

In the early 1990s, the UK Water Industry began to move away from butterfly to eccentric plug valves (Figure 4). Eccentric plug valves have been the preferred control valve in the UK Water industry for almost 13 years. An eccentric plug valve is similar to a ball valve. The control element rotates 90 degrees from being totally out of the flow (off to one side) to blocking the flow. Large eccentric plug valves are heavier and more expensive than butterfly valves. However, their typical rangeability is 100:1.

New Types of Valves

Iris and jet valves are two new valve types now being considered as an alternative to high performance butterfly valves.

Figure 4 – Island Road Wastewater Treatment Plant (UK) - Eccentric Plug Valves



Iris Valve

An iris valve resembles the human eye in that the central aperture becomes smaller and smaller as the valve closes (Figure 5).

Unlike the butterfly valve, there is no obstruction in the central portion of the flow path, which, in many cases, results in a reduced pressure drop. There are approximately 400 iris valves installed in North America to date with the oldest installation dating back to 2010. Iris valves are typically sized one to two sizes smaller than their butterfly valve counterparts. The characteristic curve is typically linear from about 25 to 80% open. Control is stable over a range of 17 to 94% open, and the gain equation is met throughout the range. The gain equation (c.f. sensitivity) stipulates that, for a position change of 10%, flow cannot change more than 20% or less than 5% (Figure 6).

The term "h" in Figure 6 is the position of the valve-regulating element in percent fully open from 0 to 100. Therefore, "h100" is the position when the valve is fully open. The term "Q"

is flow. The flow is to be controlled between a minimum (Q_{min}) and maximum value (Q_{max}). The controller can move the valve through its full range from fully closed to fully open. However, control is normally over a minimum to maximum flow range, which means the valve does not fully close or open when controlling the flow. The reader can compare the characteristics of the two valves against an ideal linear characteristic shown as a dotted line, ($BKLLin$). The butterfly valve is slightly more than 40% open at Q_{min} and 65% open at Q_{max} . The iris valve is 24% open at Q_{min} and 90% open at Q_{max} . The actuator will move the valve a fixed value with each control action. The actuator will move the butterfly valve over 25% of its range while the actuator will move the iris valve over 66% of its range. Another issue with the butterfly valve is that its full range is only 90 degrees as it is a quarter turn valve. This means the butterfly valve control is only over 23 degrees. These are the reasons that a control loop with an iris valve will have a higher degree of controllability than a loop with a butterfly valve.

These valves are not bubble tight when closed. Leakage is approximately 1%. Egger recommends a butterfly isolation valve is included to allow for better sealing, installed so the shaft is horizontal. They also indicate the isolation valve is beneficial for flow straightening. While this would seem to be detrimental to the goal of decreased pressure drop, Egger indicates that DO set point repeatability is improved. Refer to Figure 7, which is reproduced from an actual plant SCADA screen illustrating how closely the DO reading tracks the set point when an iris valve is used. Egger targets a 7 to 9-year payback with a power cost of \$0.09 to \$0.10/kWh. Flow repeatability of +/- 1 percent with 7-degree reducers upstream and downstream is guaranteed. If standard reducers are used, the guaranteed flow repeatability is +/- 3 percent.

Egger will also pipe the valve together with a thermal dispersion flow meter 10 diameter upstream, with a one-diameter straight run downstream also required. The controllability of the loop will improve if the flow meter and the iris valve are matched by the vendor because

Figure 5 – Iris Valve (Courtesy of Egger)



Figure 6 – Iris and Butterfly Valve Characteristics (Courtesy of Egger)

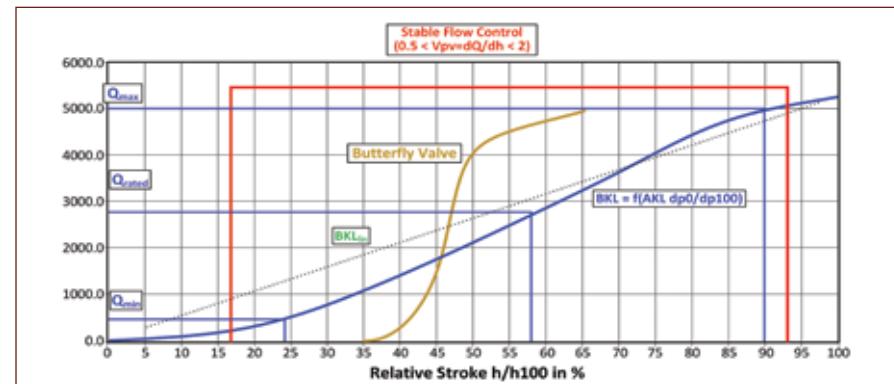
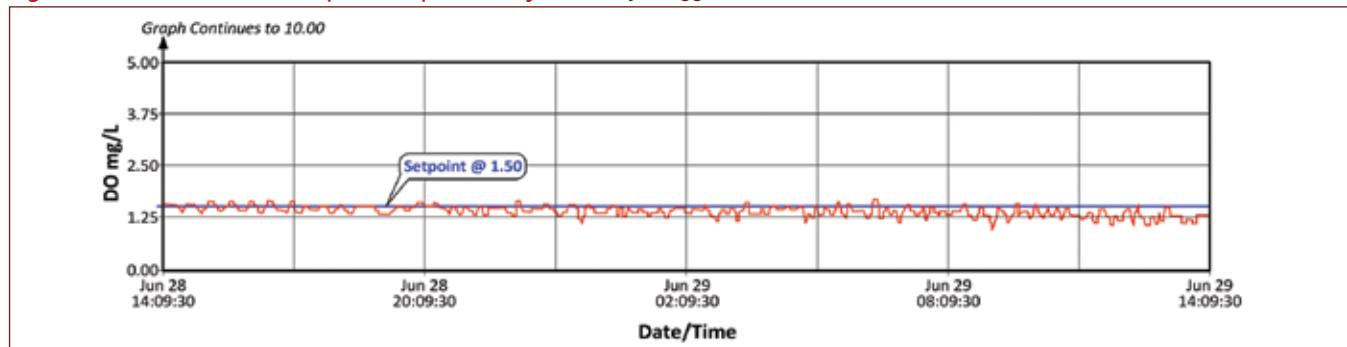


Figure 7 – Iris valve - DO Setpoint Repeatability (Courtesy of Egger)



the flow meter can be used to refine the instructions to the valve actuator. Iris valve weight is about three times that of a corresponding butterfly valve that is one size larger. When comparing stainless steel materials, pricing is about 1.8 to 2.3 times the price of the high-performance butterfly valve described above while being one to two sizes smaller. Stainless steel construction is standard in North America. Other materials options include a cast iron body with stainless steel segments or a cast iron body with bronze segments. The alternate materials result in a slight 10% cost savings. Special materials are available on request. Valves are available from 25 mm (1 in) to 400 mm (16 in) diameter. Yearly replacement of an automatic greaser is the required maintenance.

Jet Control Valves

Binder Vacomass Jet Control Valve is a low headloss control valve with a linear characteristic and large rangeability (Figure 8 and 9, Courtesy of Binder). The valve is unique and is significantly dimensionally longer than a butterfly or iris valve. It is a venturi style valve, and air flows through the annular space. The venturi design results in recovery of a portion of the pressure loss, which accounts for much of its energy efficiency.

These valves were recently installed at their first plant in the US, but the startup has been delayed due to cold weather. Vacomass guaranteed at this plant a positioning accuracy and repeatability of 0.2 percent. A recent economic analysis showed that replacing the existing valves with Vacomass Jet Control valves at a 680 MLD (180 mgd) wastewater treatment plant would pay back in seven years based on a power cost of \$0.09/kWh.

The valve can be equipped with a thermal dispersion flow meter in an integrated package with the flow meter mounted only one half pipe diameter upstream of the valve, saving appreciably on the piping straight run required between a flow meter and butterfly, eccentric plug, or iris valve. The size of a Vacomass Jet Control valve may either match a butterfly valve, be 1 to 2 sizes smaller, or in some cases, may be a size larger due to the limited range of sizes available. A bubble-tight shutoff is provided, and valves are linear from 5 to 95% open.

Figure 8 – Binder Vacomass Jet Valve Flow Profile (Courtesy of Binder)

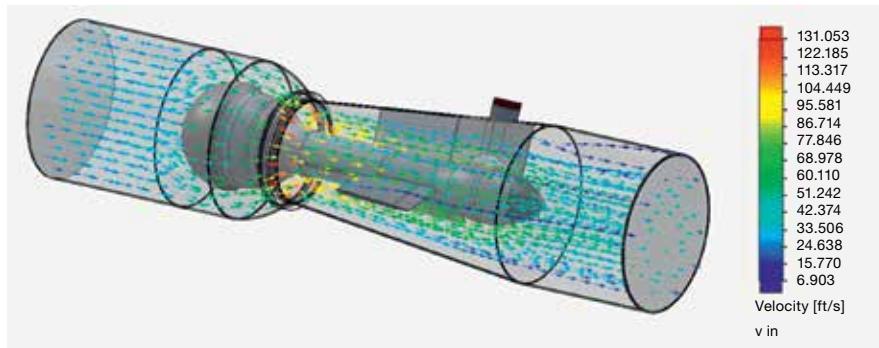


Figure 9 – Binder Vacomass Jet Valve (Courtesy of Binder)



The following table compares the Iris and Jet Control valves to a DeZURIK high performance butterfly valve.

	DEZURIK BHP HIGH-PERFORMANCE SINGLE OFFSET BUTTERFLY VALVE	EGGER IRIS CONTROL VALVE	BINDER VACOMASS JET CONTROL VALVE
Size range, mm inches	50-1,500 2-60	25-400 1-16	250-400 10-16
Controllable range, % open	40-90	17-94	5-95
Standard materials	Carbon steel or Stainless steel body	Stainless steel; cast iron with stainless segments; cast iron with bronze segments	Stainless steel
Bubbletight shutoff?	Yes	No	Yes
Weight comparison	--	Approx 3 x butterfly valve	3.5 to 5.5 x butterfly valve
Price comparison	--	1.8 to 2.3 x butterfly valve	1.12 to 1.56 x butterfly valve
Performance guarantees	--	+/-1% flow repeatability with 7 degree reducers	Positioning accuracy & repeatability of 0.2%
First North American installation	More than 40 years ago	2010	2017
Straight pipe diameters between flow meter and valve	10	10	0.5



The weight of a Vacomass Jet valve is 3.5 to 5.5 times that of its typically larger diameter butterfly valve equivalent, and the capital cost is 12 to 56% higher than a high-performance butterfly valve. These valves are available only in stainless steel, and the size range is limited from 250 mm (10 in) to 400 mm (16 in) currently. Like a butterfly valve, the equipment life is assumed to be 20 years. Unlike a butterfly valve, Vacomass offers an exchange and refurbishment program for about 1/3 the cost of a new valve.

Procurement

It is worth noting that the DeZURIK high-performance butterfly, Egger Iris, and the Vacomass Jet valves are proprietary products. One approach to specifying for competition would be to specify one versus the other. The piping layout would need to be adjusted for the valve type selected. The specification could include a requirement for the range over which the gain equation must be met as well as valve characteristic curve values.

Actuators

A discussion of control valves would not be complete without considering valve actuators, another area where there have been technological advances and some often overlooked creative options are available. Even in instances where industrial butterfly valves continue to be used, controllability improvements can be realized by utilizing a different type of valve actuator. Since the actuator type does not impact system pressure drop, energy savings would come from reaching the DO set point more quickly and within a tight band of control. Actuator options to be aware of include:

Rexa Electrohydraulic – Another proprietary product, these actuators have been used successfully for over 20 years primarily in the Pacific Northwest region of the US. They feature completely sealed oil systems, which are typically maintenance-free for 10 to even as much as 20 years.

These actuators require only a 120-volt power supply, which is an easier to quantify energy saving feature. They offer smooth controllability without overshoot or undershoot and also fail in the last position in the event of a power failure.

Some of the major electric actuator manufacturers now offer actuators with variable frequency drives (VFDs). The VFD allows smooth operation, also minimizing any overshoot or undershoot tendencies. The VFD compensates for voltage fluctuations and can be programmed to slow near the closed end of the stroke to provide tight shutoff without over-torque, again saving energy.

Conclusion

In conclusion, while ensuring that aeration blowers are at their most efficient available results in the largest impact on system energy, basin control valves and actuators should not be overlooked as a vital part of the total system power requirement and may go a long way toward reducing controllability headaches. ♦