

# Flow Control

The Magazine of Fluid Handling Systems



THE NEW  
BREED

Next-Generation  
Butterfly Valve Design



# Redesigning the High Performance Butterfly Valve

## Engineers Address User Need for Expanded Control Range

While many modern-day plants have invested in advanced automation systems for their process environments, control loops are often operated in MANUAL regardless of whether or not automation capability exists. And when operators are asked why they've taken their automated loop out of AUTO, they typically respond, "for better control."

It may seem strange that companies spend millions of dollars on automation in order to reduce their dependence on human factors only to have employees override those highly engineered systems in favor of hands-on control or detuned settings — both of which require constant operator attention. So why do they do it?

High performance butterfly valves are widely used for throttling control and do a good job for applications that have a constant pressure drop or for slow process loops. However, most process loops have varying pressure drop conditions or are a part of fast processes. In these loops, traditional HPBVs perform poorly outside a

very narrow control range because of a process gain that is very high at low travels and very low at higher travels. So, despite their name, HPBVs don't perform very well outside a control range from about 30 percent to 50 percent open. They tend to be unstable and may even require detuning a loop at low travels (below 30 percent). They're also sluggish above 50 percent. However, surveys of many valve users indicate that these valves are often forced to operate beyond their prime travel range to meet process flow demands. That's why so many control loops with HPBVs are in MANUAL or detuned — at the expense of process efficiency.

### Why HPBVs Are Controlled in MANUAL

Standard butterfly valves have traditionally been low-priced control valves for automated on/off applications — a role for which they are well suited. HPBVs were developed to extend butterfly valve usage to throttling applications for accurate flow control. Specifiers sometimes

use these valves for economy or to fit a given line size without considering their limitations. As a result, thousands of HPBVs are at work today in the process industries where lack of understanding of their limited control range can influence process variability and increase production costs.

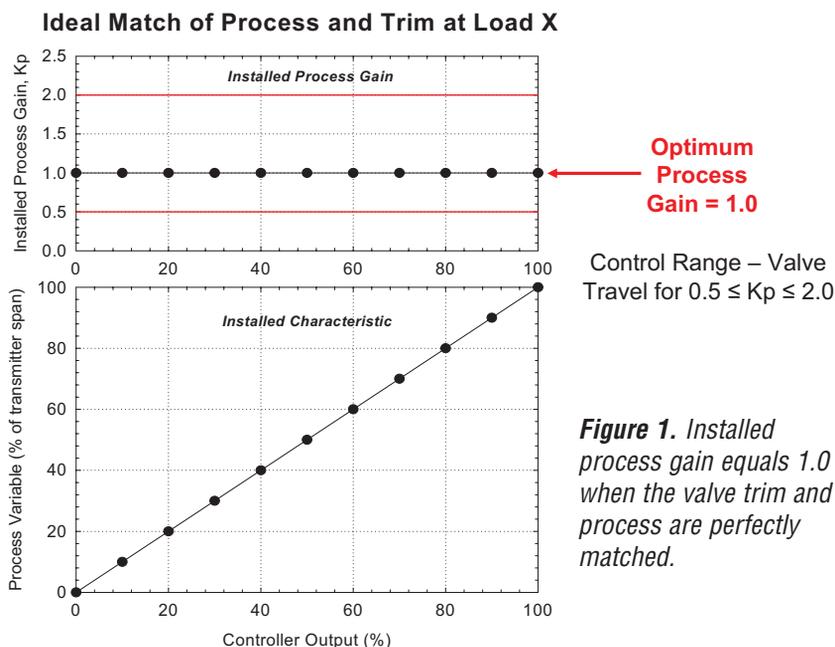
When end-users are unable to replace HPBVs with segmented ball valves or globe valves because of cost or space restraints, they resort to work-arounds, typically by switching to manual control. Operators get used to spending an excessive amount of time on a few such situations, even though productivity and product quality may be negatively affected.

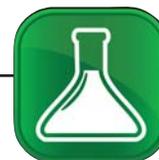
As the builder of various types and sizes of butterfly valves, Emerson Process Management — Fisher Valve ([www.fisher.com](http://www.fisher.com)) also has long recognized the economic value of HPBVs when used in the proper control range. Fisher Valve also knows that end-users frequently push HPBVs beyond their limitations, which is why the company has engaged in a lengthy program to widen the control range of such workhorse valves.

### Expanding the Control Range of HPBVs

The Fisher Valve Performance Laboratory in Marshalltown, Iowa, has been working to evaluate various valve trims in its quest to broaden the control rangeability of HPBVs. The limitations of existing HPBVs, including those made by Emerson and its competitors, have been well established in the lab through testing of valves in an actual process loop under load conditions.

In general, when the installed characteristic of the loop behaves in a linear manner, and the installed process gain equals one, the loop is easiest to control. Therefore, a process gain of 1.0 becomes the objective for good loop control with an acceptable range of 0.5 to 2.0 (a range





of 4-to-1, Fig. 1).

There are just three ways to influence process gain with a control valve. One is the valve style, the two extremes being the globe valve and the rotary butterfly valve. As shown in Figure 2, a good deal of the installed process gain of a typical globe valve falls within the desirable 0.5 to 2.0 range, but that comes at a higher price. The more restrictive control range of the HPBV is acceptable as long as the process demand doesn't change greatly from what the process engineers envisioned. Process gain can also be influenced by valve size in relation to the line in which it is installed. The third factor is the inherent, or installed, gain characteristic of the valve, which is directly related to its design.

Using the valve lab to test new butterfly valve disk designs under real-world conditions, Emerson's engineers succeeded in altering the inherent linear characteristic and created a disk with an inherent equal percentage flow characteristic. A butterfly valve equipped with this newly designed patented disk delivers an installed characteristic that, in the majority of applications, results in an installed process gain within the desired 0.5 to 2.0 range over a much wider travel. This results in significantly improved throttling control, especially in the lower travel ranges.

Figure 3 shows the process gain delivered by a butterfly valve equipped with the equal percentage disk versus that of a standard HPBV. The new design provides good control with the acceptable gain of 0.5 to 2.0 from about 11 percent open to 70 percent, a control range improvement of nearly threefold when compared to a typical HPBV of the same size. The equal percentage disk delivers overall lower process variability — a benefit that can be demonstrated in the lab.

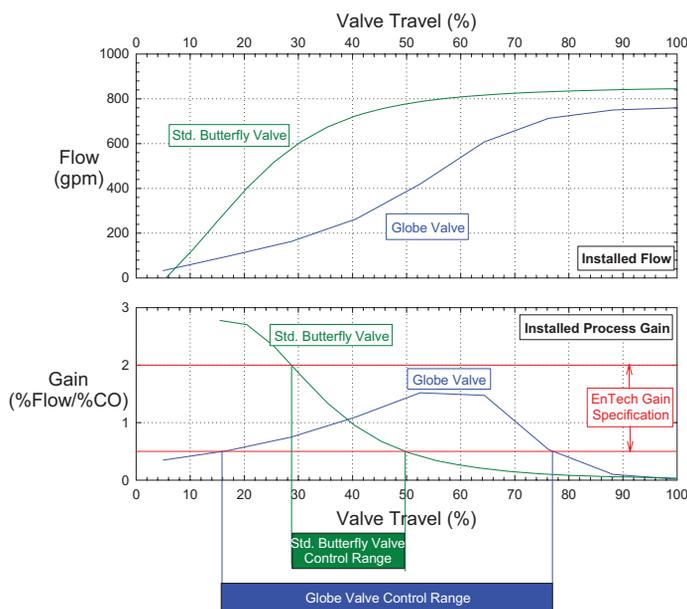
Figure 4 is a schematic of a typical test loop. While some people believe that testing in the lab cannot replicate real-world applications, lab testing of the past is not the same as that conducted in today's most modern flow labs. The closed-test loops in today's modern labs are designed to simulate real-world process applications, including a signal into the load valve based on actual field data. Emerson, for example, runs inlet pressures, typical drops, pipe runs, elbows, etc. typical of a real plant setup, and it is creating load disturbances based on real-world cases. Further, the validity of the data produced in these tests has been proved in more than a dozen field-trials all over the world.

### Testing HPBV Designs

Most four-inch HPBVs control a process well and track the setpoint very closely at a flowrate of 350 GPM. But if the flow must be reduced to 200 GPM, the standard valve will need to close to a point well below 20 percent, causing the process gain to rise above 2.0. (Figure 3). In this position, the valve becomes very sensitive and begins to cycle, consistently overshooting the setpoint. Variability rises well beyond an acceptable range. On the other hand, the equal percentage disk handles low flowrates very well, maintaining an optimum process gain at flows well below 200 GPM.

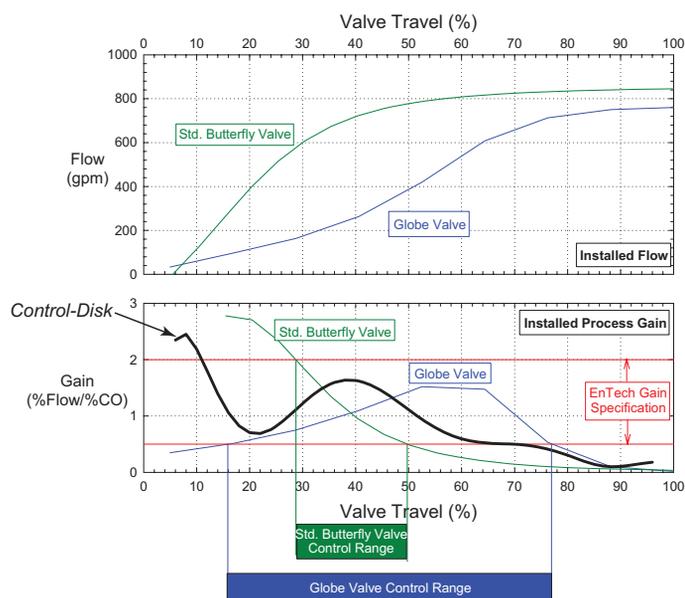
In Emerson's Valve Performance Lab, two duplicate

**Installed Flow Characteristic & Control Range**  
4" Control Valves in a 4" Test Loop

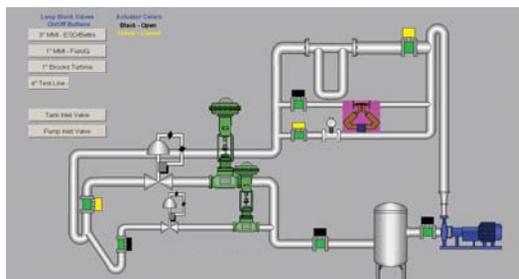


**Figure 2.** The actual control range of a standard high performance butterfly valve within a desirable process gain of 0.5 to 2.0 is from about 30 percent to 50 percent of total valve travel. A typical globe valve has a much greater control range within this gain, but that comes at a higher price.

**Installed Flow Characteristic & Control Range**  
4" Control Valves in a 4" Test Loop



**Figure 3.** The process gain delivered by a butterfly valve equipped with the equal percentage disk extends from about 11 percent of travel to about 70 percent.



-350 gpm P1= 40 psig  
 -200 gpm P1= 48psig  
 -Parallel 4" test lines used for the side by side comparison  
 -The load valve has a random input signal with amplitude and frequencies typical of a field application

**Figure 4.** In a typical laboratory setup, tests were run with flows of 200 GPM and 350 GPM using parallel four-inch test lines for side-to-side comparison. The load valve has a random input signal with amplitude and frequencies typical of a real-world process application.

where the temperature of an end process must be kept within plus or minus .5 C. Anything outside this limit spoils the product. Previously installed control valves could not maintain control of the temperature regulating fluid at low travel ranges, and operators had great difficulty producing suitable product. Two replacement valves incorporating the new technology were operated successfully down to 11 percent travel, solving the problem and assuring product quality.

In another case, two four-inch valves with the equal percent trim replaced valves in a vacuum control loop used for removing water from pulp stock in a Minnesota paper mill. Control had been an issue for years at this critical point in the papermaking process, leading to inconsistent feedstock and sheet formation problems. The two standard HPBVs originally installed to control this loop were never able to achieve the required performance. As a result, the loop was always kept in MANUAL control, requiring constant operator attention. Even then, variability ranged from 3.5 percent to 8 percent. There were problems during startup as well. Space limitations prevented the mill from installing segmented ball valves designed for throttling at low travel.

After new valves with equal percentage disks were installed, the machine was brought online quickly without incident. The operation was quickly stabilized, the valves were immediately put in AUTOMATIC and have been working as intended with no additional tuning. Variability has been reduced significantly — from 8 percent to 3 percent on one valve and from 3.5 percent to 1.6 percent on the other. 

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[www.fisher.com](http://www.fisher.com)

process loops were set up to compare an equal percentage valve with a standard linear butterfly valve. A switching arrangement allowed a fluid flow to be controlled by either loop. The four-inch HPBV bodies, actuators and digital valve positioners used for this test were identical. The only difference was that one butterfly valve had a conventional disk, while the other butterfly valve was equipped with the equal percentage disk.

With the process running under automatic control at a setpoint of 350 GPM, both valves operated very well. Performance was stable with the standard trim valve open about 31 percent and a variability of about 2.6 percent. The valve with equal percentage trim controlled the same flow at a position of about 58 percent open with equivalent process variability.

When the load was changed to 200 GPM, the standard HPBV had difficulty maintaining control with valve travel fluctuating between 15 percent and 20 percent. The valve was cycling in an effort to maintain the setpoint, and variability was extremely high — over 40 percent. As such, viable control was essentially lost.

In an actual process, this is where an operator would have to step in and switch the loop to manual in order to provide a relatively stable flow so the process could continue to run. While variability would be better under manual control, it would not be ideal, and the efficiency of the entire process would suffer. An alternative would be to detune the loop to be less sensitive, which would slow its operation with greater valve travel. In either case, the result is high process variability. This happens too frequently in the real world. A valve may be sized to handle a specific

within its control range, but if process conditions change, that valve may be asked to perform beyond its control range, resulting in a loss of stability and growing inefficiency.

Back in the lab, the valve with the equal percentage trim was able to maintain a stable 200 GPM flow without difficulty. With valve travel at about 34 percent, variability was low — about 2.9 percent. The new valve design engineered by Emerson as a result of its lab tests on HPBVs handled the change in flow without sacrificing variability at all. In a real-world setting, low and stable variability translates into process efficiency, lower costs and higher end-product quality.

To calculate the relative cost of high variability at a flow of 200 GPM, the difference in variability at that setpoint achieved by the two valves (39 percent) is multiplied by the flow in gallons per day (288,000) and a hypothetical cost of the liquid (say \$.05 per gallon). The cost of variability for this application would be more than \$5,600 per day.

Obviously, running a valve beyond its optimum control range can be very expensive, which is why installing valves with the equal percentage flow technology will be an economically viable solution in the many situations where HPBVs are currently running in MANUAL.

### HPBV Field Evaluations

Following successful laboratory tests, a number of valves with the equal percentage trim were installed in different industries and applications around the world. In every case, the new valve has outperformed the HPBV it replaced.

One test site was a chemical plant that produces film in the United Kingdom,

