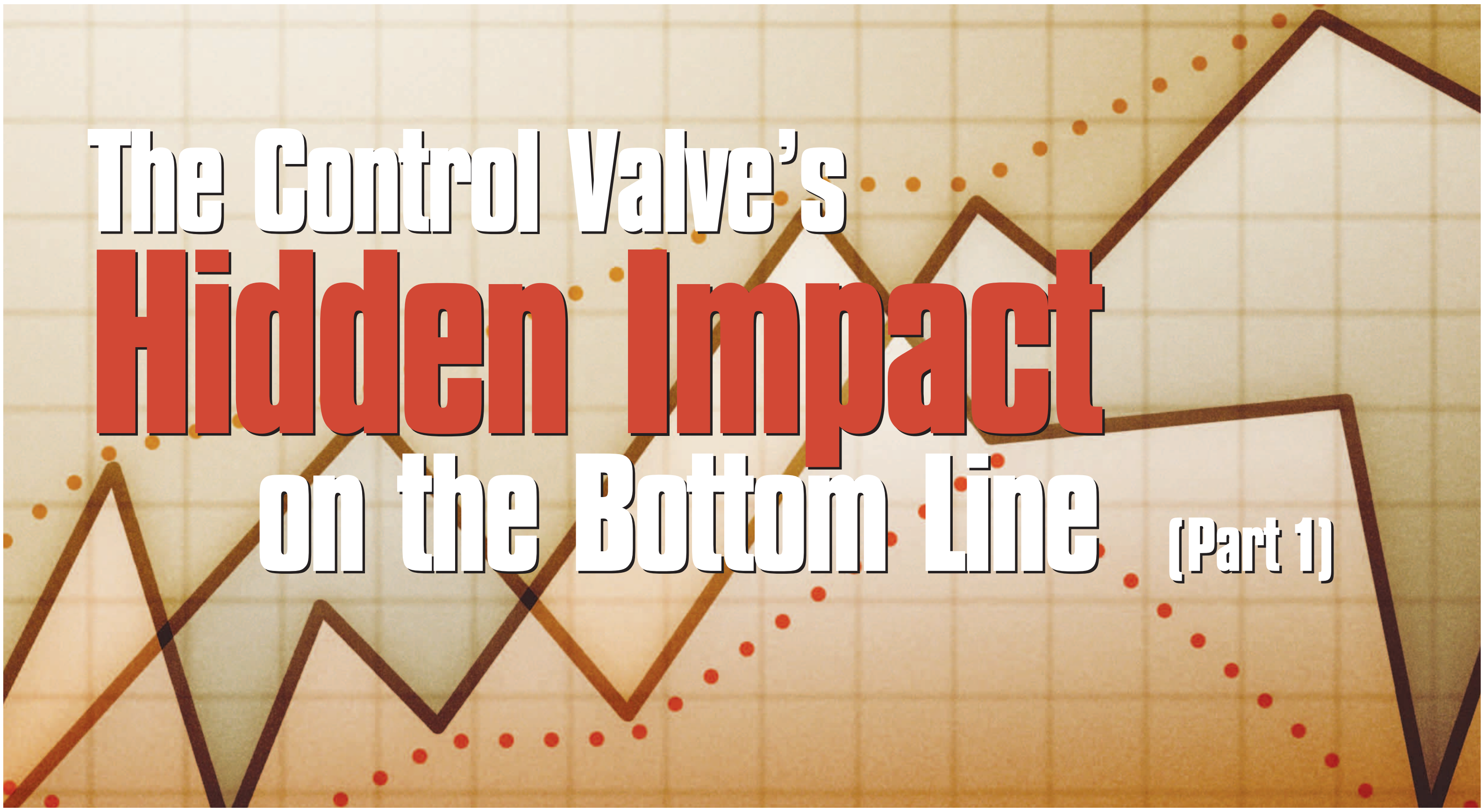


The Control Valve's Hidden Impact on the Bottom Line (Part 1)

By Bill Fitzgerald and Charles Linden

MANY OF THE PROFITABILITY ISSUES FACING THE PROCESS INDUSTRIES TODAY CAN BE LINKED DIRECTLY TO CONTROL VALVE PERFORMANCE. ARE THERE VALVE-RELATED ISSUES IN YOUR PLANT THAT YOU SHOULD BE CONCERNED ABOUT? PART 1 OF THIS ARTICLE WILL ADDRESS DYNAMIC PERFORMANCE OF THE CONTROL VALVE AND HOW IT IMPACTS YOUR BOTTOM LINE. PART 2 WILL SPEAK TO OTHER VALVE CHARACTERISTICS THAT ARE TYPICALLY IGNORED WHEN SELECTING CONTROL VALVES, SUCH AS LEAKAGE PAST THE SEAT, LONG-TERM RELIABILITY, AND MAINTAINABILITY. IT WILL CONCLUDE WITH SOME CASE STUDIES THAT ILLUSTRATE THE DRAMATIC IMPACT THAT CONTROL VALVES CAN HAVE ON THE BOTTOM LINE.

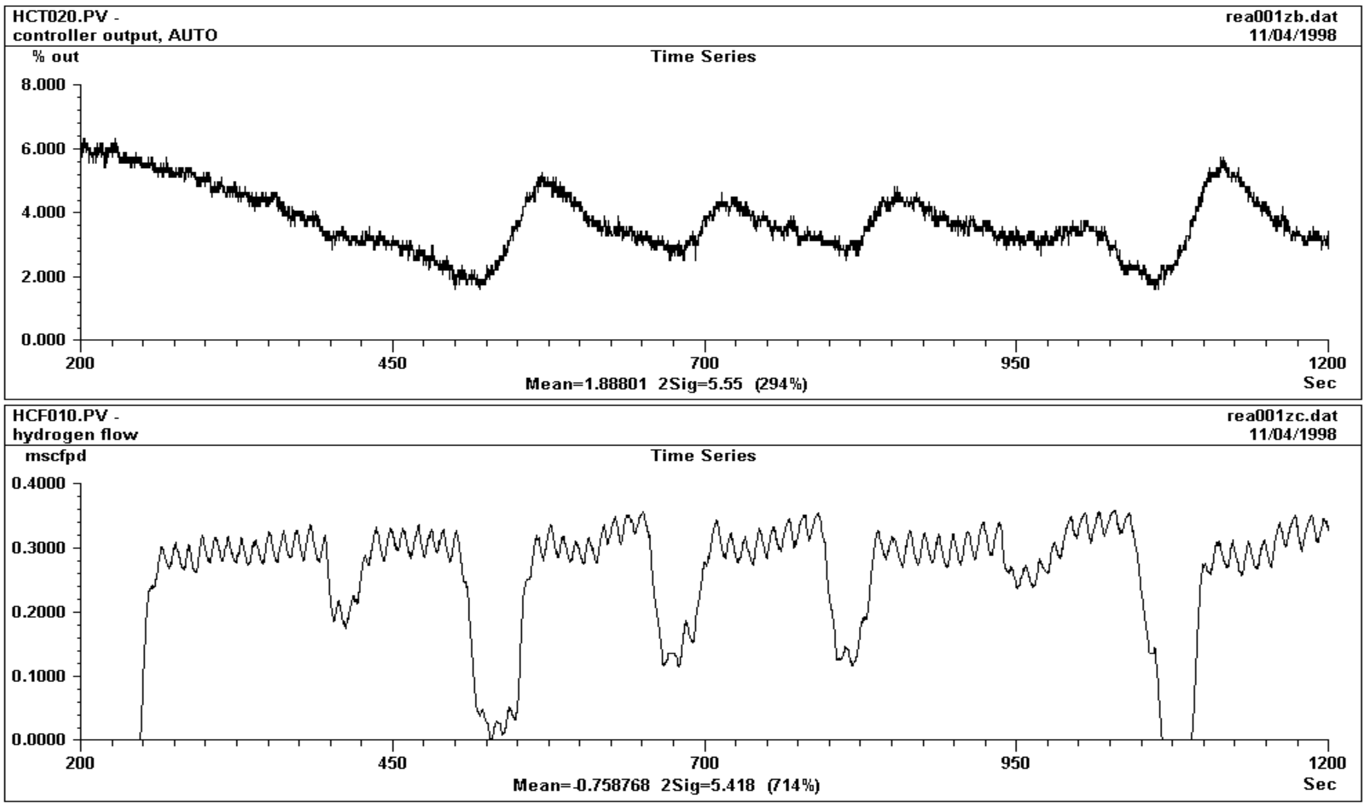
Let's face it. Control valves never make anyone's top 10 list of favorite topics. Yet while they may be considered boring, control valves can impact your bottom line in ways you may not have considered. A brief example illustrates why.

Figure 1 documents control loop performance testing within a power plant and reveals how control valves can affect a process. The loop in this case consists of a controller, a flow sensor, and a control valve that changes flow in the loop.

The bottom graph shows the process variable, that is, the process characteristic that we are attempting to control. It also shows a typical process constraint that the process variable cannot exceed in this case without problems cropping up. The solid line in the middle is the set point, which is the desired level for the process variable. Clearly, there is a lot of error between the set point and the process variable, indicating that the performance of the process control system is substandard. There is high steady-state cycling around the set point and then every 125 seconds or so there is a major correction that overshoots the set point followed by a reversing action.

The top curve is the controller output signal to the control valve. There is a lot of variability on this curve as well, but it is difficult to determine whether this variation is causing the cycling in the process variable or simply trying to correct for it. It is clear that the controller is sensing the error between the set point and the process variable and slowly

FIGURE 1



changing its signal to the control valve. Unfortunately, there is no change in the flow, so the controller keeps changing its output. Eventually, it appears that the valve breaks loose and jumps well past where it should. The set point finally does change but goes past the set point, and the controller has to reverse its signal, causing the valve to jump back in the other direction.

Because of the type of performance, the process variable is not controlled very well, which means that feedstock or energy may be wasted. It also means that the set point needs to be moved away from the process constraint to insure that we don't go past this level of flow during the fluctuations. This can also hurt the bottom line for many customers since efficiencies are normally directly related to maximizing things like flow, pressures, and temperatures. This derating of individual loops to account for variability can have a subtle but very marked impact on profitability by reducing throughputs and yields. Valve-caused process fluctuations also degrade overall process reliability by wearing out mechanical equipment well ahead of its predicted time for maintenance.

This is a very important point. Control loops that fluctuate result in an unstable plant. All major components in the plant—like pumps, compressors, vessels, and safety relief valves—are subjected to these fluctuations. These service excursions have been shown to age the equipment prematurely, which means higher maintenance costs and loss of system performance. Like an automobile, a plant that is brought up smoothly, and that is able to operate for long periods at steady state, will have much lower repair bills, so smooth process control is also critical in optimizing maintenance costs.

Surprisingly enough, even though this type of process control performance is costing a lot of money, it is typical of 30-50% of the loops that we check year in and year out. Why is this happening? Why are we not getting our return on investment out of our process control systems? We believe that many of the problems can be traced back to the lowly control valve and how it is

FIGURE 2

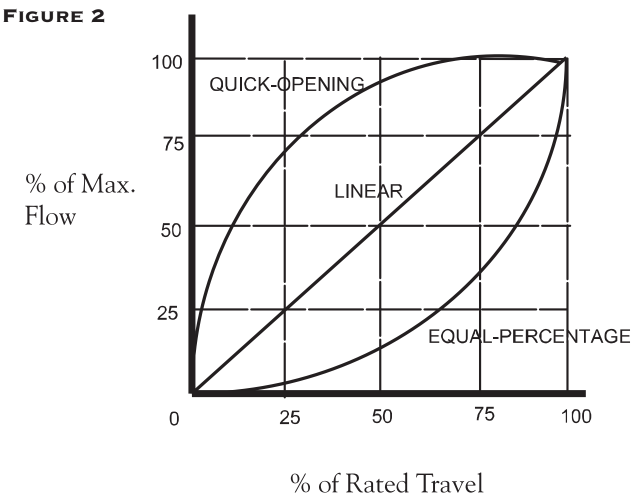
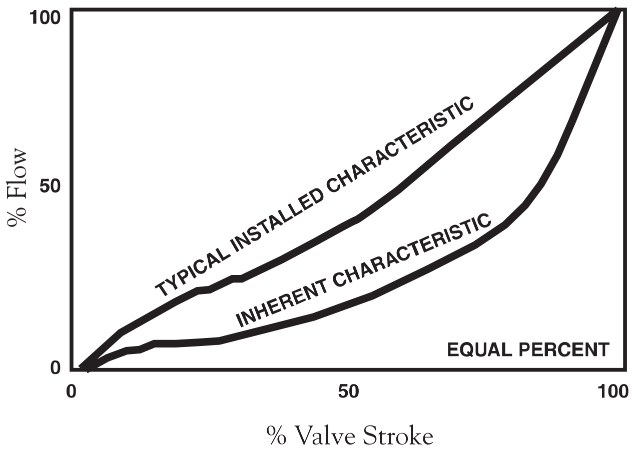
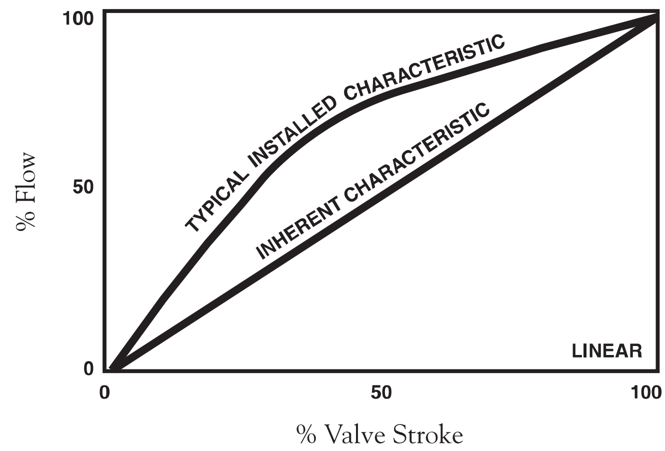


Figure 3



(a)

Figure 4



(a)

selected and maintained. Many control valves are purchased with what we call "static specifications," like required flow capacity, pressure ratings, and fluid type. In reality, if we are to avoid the kind of process-control-related problems just illustrated, there needs to be a lot more attention paid the dynamic characteristics of the valve. These include:

- Installed gain
- Friction, hysterisis, and deadband
- Dynamic flow conditions
- Process-side error
- Stroking speed and overshoot
- Positioning resolution
- Force vs. travel profile
- Load sensitivity

We'll go over these in more detail in the following paragraphs.

Introducing Control Valve Gain

The gain of a control valve is the derivative or slope of the valve's flow characteristic, or more simply, the change in flow for a given change in travel. If gain is relatively constant over most of the valve travel, we can easily tune the loop for optimum control without worrying about changes in gain vs. travel affecting settings. Changes in gain that occur as the valve strokes can cause the loop to become either non-responsive or unstable.

To determine gain, we first have to understand what the inherent flow characteristic looks like for each valve. ***Figure 2*** shows typical curves by plotting flow coefficient (C_V) values vs. travel. We have to be careful how we use this data, however. C_V values are determined with a constant pressure drop across the valve. In real life, most valves are coupled to pumps and see a decreasing pressure drop with increasing travel. This means that the *installed* dynamic flow characteristic is different from the *inherent* characteristic curves shown in ***Figure 2***.

Figures 3, 4, and 5 illustrate what we mean. An *equal percentage* trim becomes more linear if there is a decreasing pressure drop upon valve opening. (Incidentally, this is why many throttling valves are sold with equal percentage trim.) *Linear* trim looks like quick opening if used with a pump and *quick opening* trim gets even worse if installed with a pump. The steep slope of the quick opening characteristic when the valve is in its first 25% of travel makes it a very high gain device. But the gain or slope changes to almost zero as the valve opens beyond 25%. This type of change in gain for different points in travel makes the loop very hard to tune. To simplify tuning, the preferred characteristic is one where the derivative or slope of the flow curve changes very little over the normal working range of the valve. In this case, if we assume that we are seeing a reduction in pressure drop as the valve opens, then a valve with an inherent equal percentage characteristic will look most linear when installed. The linear-installed characteristic gives us a relatively constant slope over the travel, which is easier to tune.

Figure 5

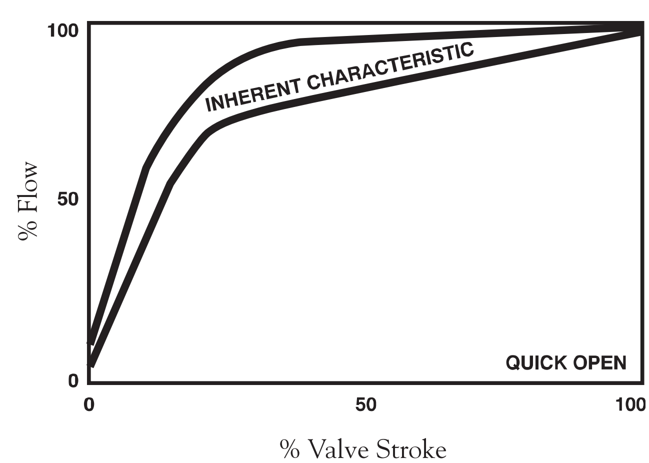


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Figure 6

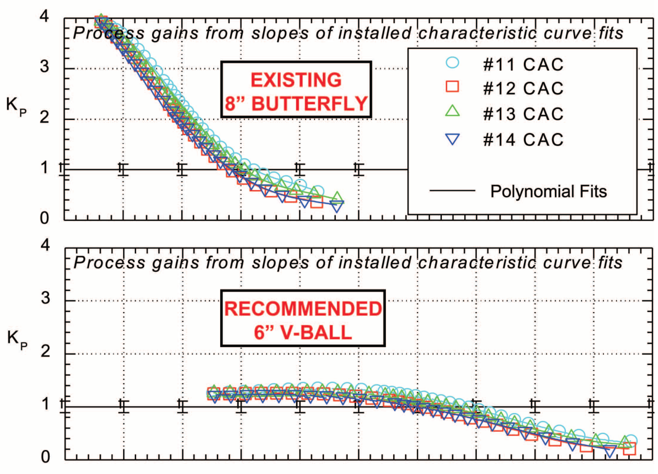
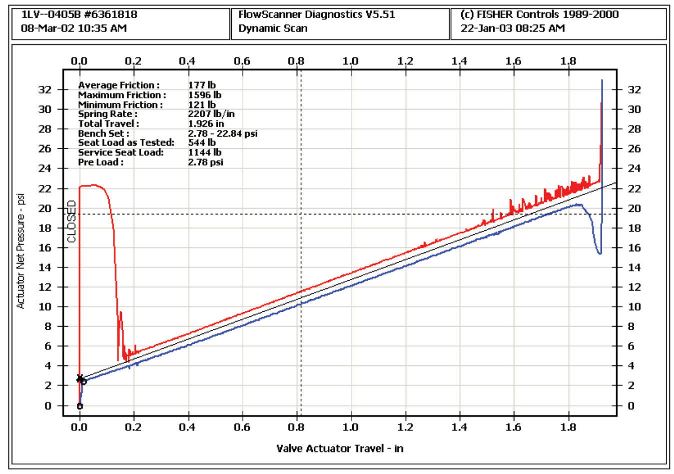


Figure 7



Understanding Gain vs. Characteristic

For a better understanding of what this discussion of gain and flow characteristic really means, let's look at the two different types of control valves.

Figure 6 illustrates the LoopVue diagnostic program, which lets us model the installed gain for a valve as it operates over its normal control range. The top curve shows installed gains for 8-in. butterfly valves used in a Containment Air Cooler (CAC) application. The travel span for operation between 1650 and 1950 gpm is only 5% or 6% for each CAC valve. The process gain, labeled as KP, varies from 1.3 to 2.7 over the same flow range.

The high process gain, together with the deadband usually encountered in the drive train of butterfly valves, would typically cause measurable limit cycling with this type of valve. Note also that each valve must stroke approximately 80% of full travel to move from wide open to the throttling position.

Another problem evident here, which is typical of oversized valves, is the essentially zero process gain at wide open. If gain scheduling cannot be used in the controller, then the control loop will respond slowly near the wide-open condition, even if the control valve responds instantly to the controller output. High controller gain might be used to compensate, but it could lead to valve overshoot and large cycles at the throttling position, as can be seen in the examples in ***Figures 7 and 8***.

The lower half of ***Figure 7*** shows the LoopVue diagnostic results for a modern Vee-port valve design with full 90° travel. The travel range for 1650-1950 gpm varies from approximately 8% for the #11 CAC valve to 11% for the #14 CAC valve. Process gains vary from 0.8 to 1.3 in the same flow range, which is a much smaller variation in gain. This means easier tuning of the loop.

The Vee-port valves would need to stroke only about 40% from wide open to reach the throttling flow of 1800 gpm. Their maximum flow is trending to at least 2300 gpm, allowing more design margin than with the butterfly valve. The bottom line is that this type of design will give much better control and will provide a much better return on investment.

Another Factor: Hysteresis/Deadband

Another factor that plays heavily in determining how well a valve can control is hysteresis/deadband. This is a quantitative indication of how much a valve's actual position deviates from the desired position. It is defined using a standardized ISA test procedure, and in general it measures the friction and "looseness" that exists in a control valve's drive train. The test does not give an exact indication of control capability because it is generally conducted without flowing load and ignores what we call process-side error. However, in general, the lower the hysteresis/deadband number, the better the control. A typical test is shown in ***Figure 9***.

Many valves in service can have hysteresis/deadband values greater than 10% due to either design or maintenance problems. With values that high, it proves very hard to control within better than +/-10% accuracy, especially if there is higher friction present under load.

Figure 8

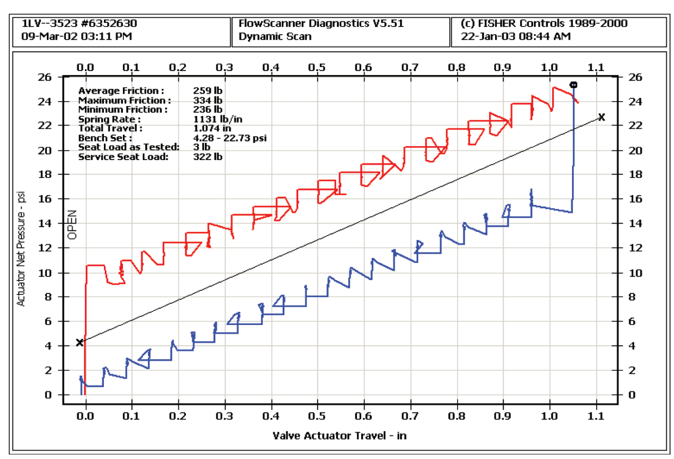


FIGURE 9

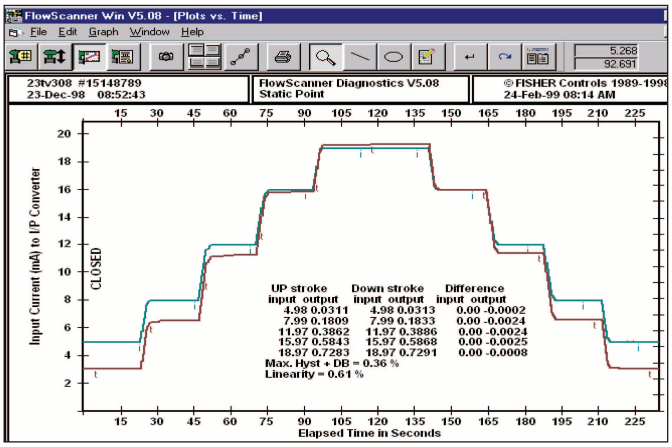
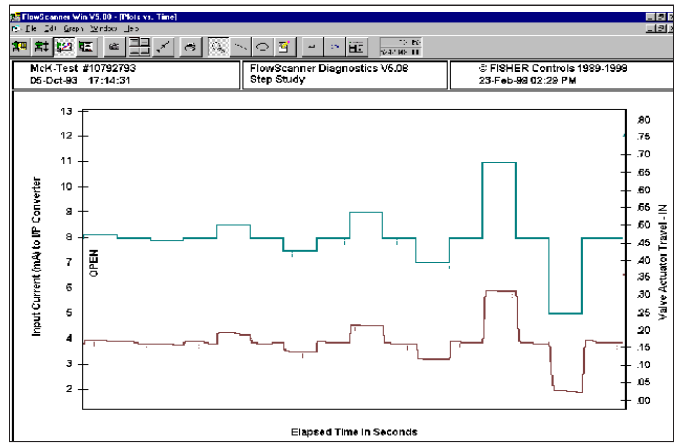


FIGURE 10



PROCESS-SIDE ERROR

Although not technically a valve characteristic, process-side error is included here because it is a good general indicator of process control performance, and it is impacted by valve performance. To determine the value for a given loop, we begin with small variations in the input signal to the valve and then watch how the process reacts. With many control valves, the input signal to the valve has to change by more than 5% before we see any change in process variable. In cases like this, the result is very poor process control with the process variable wandering all over the place—***Figure 10***.

STROKING SPEED/OVERSHOOT

Figure 11 shows the valve response to a step change in instrument signal and gives a general idea of the speed of response for the valve. We see a lot of valves on fast processes that should be able to respond to a load or set-point change within a second or two, but actually take 30 seconds or more to get to their new position. Or, they go well past the actual required position, which can also cause problems. Once again, poor response means poor control.

POSITIONING RESOLUTION

This is another good benchmark for valve response. ***Figure 12*** tells how well a control valve assembly can follow small adjustments in input signals. If a valve's minimum stroke resolution is 1/16th of an inch, then we can control no closer than half of this amount in terms of flow. If the valve installed gain is high, this small movement can mean a big change in flow, which sets up a limit cycle as the valve jumps past the set-point and then has to move back in the opposite direction. Again, there's an impact on control and reliability.

FORCE VS. TRAVEL PROFILE

For a valve to control smoothly, the valve flow characteristic should also be free of any negative gradients, which tend to make the valve unstable and hard to control. Negative gradients result from flow forces on the controlling element within the valve body and can result in large changes in valve position that do not result from a change in input signal. This results in additional process error.

FIGURE 11

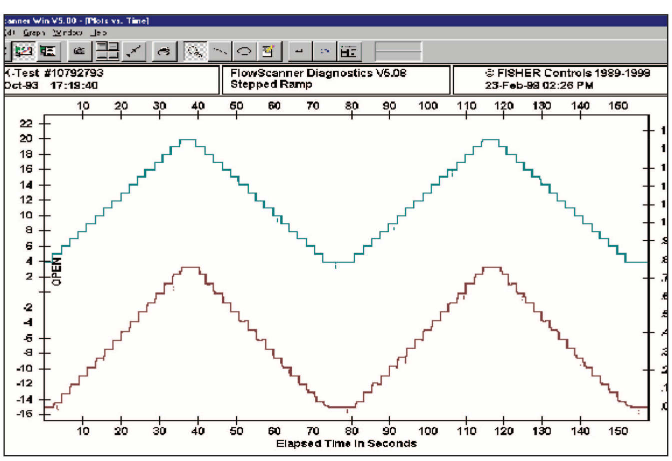
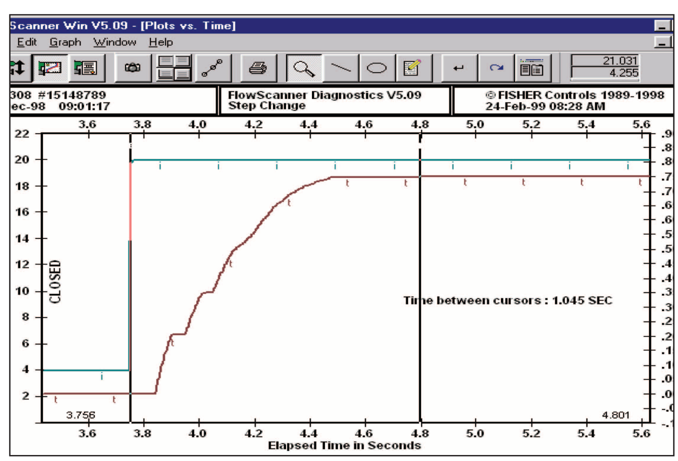


FIGURE 12



Load Sensitivity

The valve actuator needs to be stiff enough to resist movement when the flowing load changes. In most cases, this is not a problem as OEMs tend to design their actuators with a lot of stiffness. However, in unbalanced flow-down applications this can explain poor control stability and may need to be checked.

As you can see, there are a lot of characteristics that can contribute to poor control that are not normally considered when specifying a control valve. As a result, we believe that many customers are not sure right now if they are getting everything they can out of their process control investments. If they are not, it is impacting their bottom lines.

The potential causes for this lack of performance are many. The valve may not have been purchased to the right specification. Maybe the maintenance program needs to be more proactive and more focused on dynamic process control performance. Or it could be that the operating conditions for the loop have changed, since most plants are being asked to behave in ways that are different from their original charters.

In any case, it may be time for a process control assessment centered on the control valve. Start with the current application information and work from the basement up to make sure you've got the right valve and that your purchasing and maintenance programs identify and focus on what you really need from your process control system. There is some homework to be done here, but as you'll see in the second part of this article, the payback can be huge. VM

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