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Valve trim retrofits

Solving chronic control problems

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Valves designed to control flow, pressure, temperature, or fluid levels are a continuing problem in many industries. The power, oil and gas, and related process areas are subject to high maintenance costs and performance problems caused by these valves. These problems range from poor flow control, noise, and vibration to severe physical damage.

Fixes that attempt to solve these problems such as lagging to reduce excessive noise and using harder materials to resist erosion seldom succeed. Usually, these band-aid efforts are aimed only at the problems symptoms. Rather, you must identify the root causes of the problem.

You must know:

- What causes the noise, vibration, and damage?
- What causes the poor flow-control and instability?

Only through a thorough investigation will the root cause be identified; then you can take intelligent problem solving action.

In many cases, the best solution lies in trim retrofitting, (see Figure 1). This involves replacing the trim and frequently the bonnet and actuator as well. The original valve body remains in place. This is especially desirable when the body is welded into a heavy wall piping system or is in an inaccessible location.

Every effort should be made to retrofit a valve without machining the valve body. This simplifies the installation process and saves time and money. The body should, however, be repaired to correct any damage and be brought back to its original condition. This is critical if the body-sealing surfaces have been damaged or if the minimum wall thickness has become less than required.

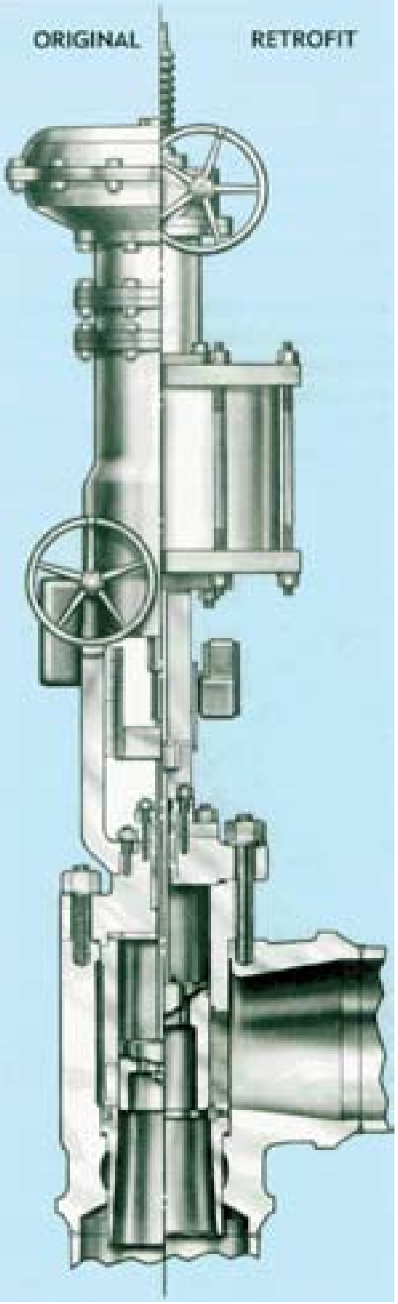

Figure 1: An original valve design compared to the same valve as retrofitted.

Sufficient body flow area must be available. Usually, this is the case in which the original trim design was of a cage guided type or, as is frequently the case, the valve was oversized in the first place.

If a valve has been oversized, a reduction of the flow capacity factor generally permits a smaller trim size to be used. This may provide the necessary flow area in top-guided valve designs.

Another solution to inadequate flow area is increased stroke that can be provided by a new bonnet and actuator. This increased stroke frequently has the benefit of improved flow control since the same actuator signal range operates in a longer flow area.

The first step in solving these control valve problems is, of course, to establish the root causes for the unsatisfactory performance.

Root causes

While many possible root causes exist, the vast majority fall into one of two classifications: excessive original design margins or inappropriate original design and selection for the intended service.

Over design: Popular design conservatism usually involved performance margins in operating parameters, flow rate, operating pressures, differential pressures, and temperatures. Generally, margin is applied at the initial design phase to account for unknown system operational performance. While some conservatism may be appropriate when applied once, if consecutively applied at each of sequential system design stages – to the pump, to the flow rates, to the system pressure losses, and with multiple, worst case scenarios – it easily leads to destructive overdesign compared to actual system operational needs.

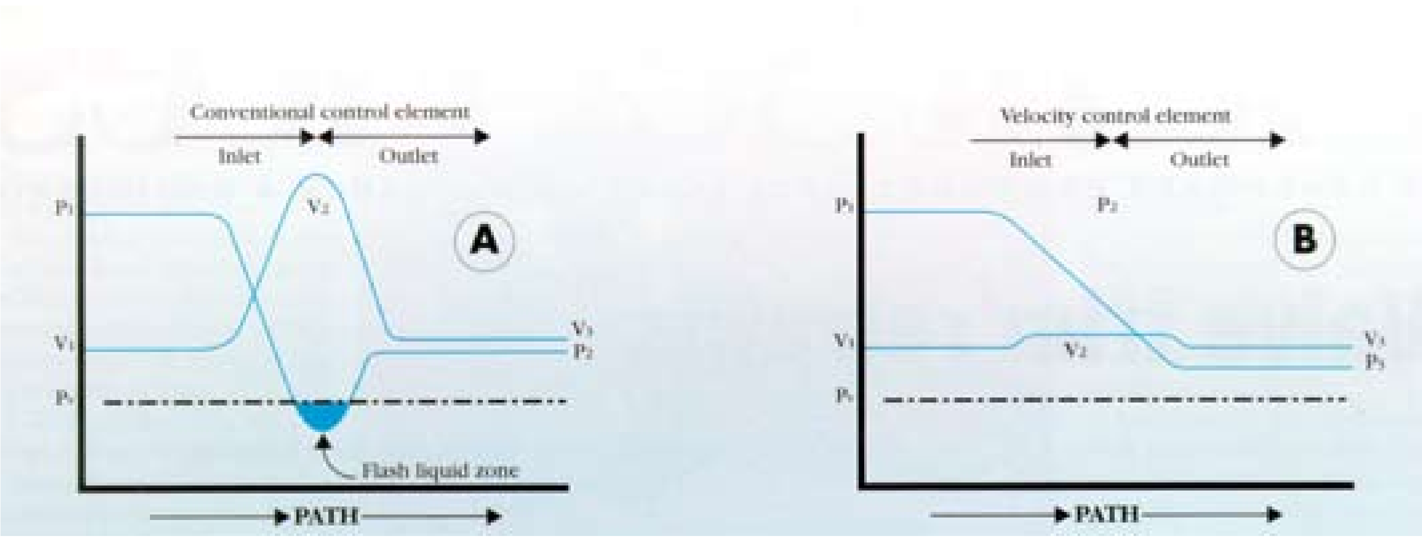

Figure 2: Pressure and velocity on flow path showing cavitating and non-cavitating characteristics.

Design considerations

A control valve, for example, designed for a high capacity, equivalent to a valve coefficient (Cv) of 14,000, actually operated in a capacity range having a Cv of less than 2000. This means the valve plug was too big and hovered very close to its seat in normal operation. This created damaging high fluid velocities in this area. The result: rapid plug and seat erosion and ultimately, shutoff leakage regardless of plug-to-seat loading force applied.

Similarly, the pressure drop across a condenser sparger is often much less than the value calculated. Result: much lower valve downstream pressure, leading to flashing and consequently severe trim and body damage and pip vibration.

Also, a pump recirculation valve was designed for an operating temperature of 400°F and a back pressure below the corresponding vapor pressure. For this flashing service a stellited – a hardened, wear-reisistant surface – trim was selected, but it did not incorporate anti-cavitation pressure breakdown provision. Thus, the valve exhibited cavitation damage and started to leak shortly after startup. The problem proved to be that upon startup the water was only 60°F (15.5°C), far cooler than the design temperature of 400° F (204°C), and cavitation occurred across a wide operating range as the fluid got hotter.

The lesson here – carefully review current operating parameters as well as the original design specifications. The chances are good that there are wide differences between original specifications and actual operating parameters. These differences cause severe problems. Once defined, users must figure out how to deal with them.

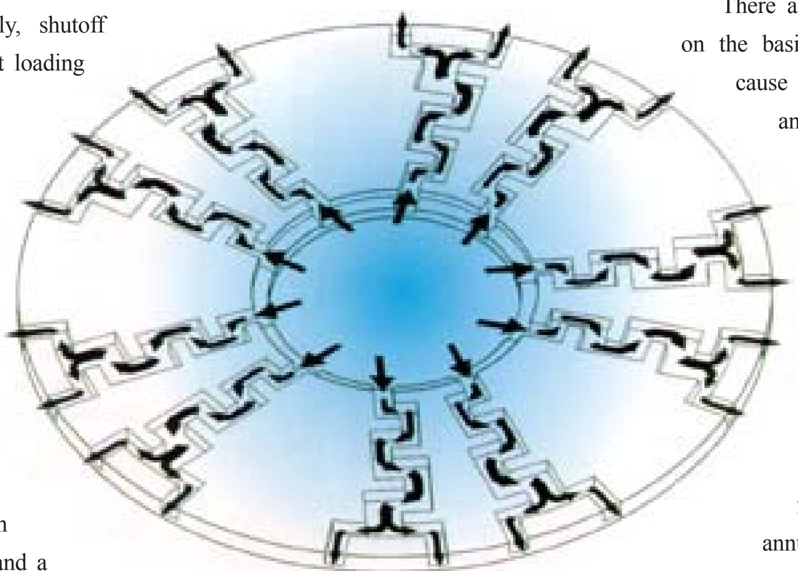

Figure 3: A typical flow-to-open, multi-stage disk.

Inadequate design: It is valuable to have a basic understanding of the primary selection criteria. Many factors are of importance here.

First is the valve coefficient, Cv. The required flow capacity is based on the fluid properties, flow rate, and pressure drop. The selected valve Cv must exceed the calculated required Cv. The maximum case is critical for this, but there are many valves for which the minimum flow case is not considered. While several users wish to have the maximum Cv occur at about 70 to 85 percent of valve stem travel, there is no absolute rule. Imposing such a rule on a valve that generally operates at low lifts – low Cv values – forces a valve to be oversized.

There are many problem valves quoted on the basis of only maximum flow that cause problems for plant operations and maintenance. The spray water attemperation – steam temperature regulating – valves in many fossil power plants are a case in point. There are many off –the-shelf valves sized for the maximum-flow, low pressure-drop case. These valves generally operate at low flow and, in many cases, requires annual maintenance.

A second set of parameters relate to liquid flow for cavitation and choked flow considerations. Incipient cavitation is the point at which enough vapor bubbles form in the flow stream to begin to affect the valve Cv calculation accuracy. At a later point, so much vapor has formed that the flow is choked – no additional flow can occur, no matter how much lower the back pressure is. While it is important to the correct Cv value provided, it must be noted that the damaging cavitation may exist at these flow conditions. Further,

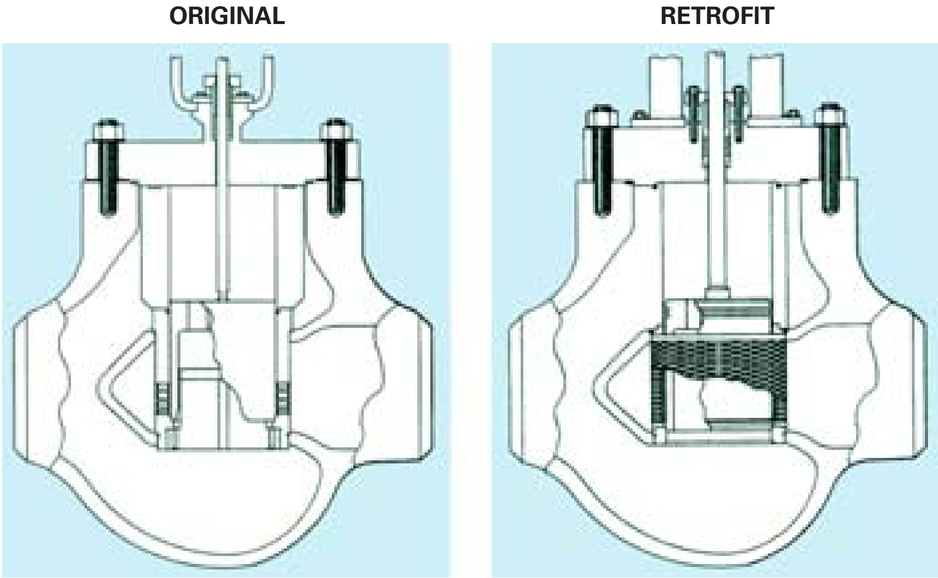

Figure 4: Original and retrofitted feedwater regulator.

economic and competitive pressures often cause the limits designated for the trim to be stretched by those involved in the initial selection. Also, higher pump pressure or lower system losses results in incorrect definition of the selection parameter.

The sizing parameter used for gas and steam flow is the ration of the differential pressure to the inlet pressure. Most manufacturers have trim designs that reduce noise and vibration up to some defined ration of this term. Of course, they reduce the noise to some extent but may still yield sonic trim outlet velocities and damage.

Also, single stage pressure reduction through control valve trim results in excessively high velocities with resultant rapid pressure drops, frequently below the fluid's vapor pressure, (see Figure 2a). Under these conditions the fluid boils and the flashed fluid can erode trim material. Any conventional control valve with a single-stage, mulitple-orifice trim encounters this problem due to the uncontrolled velocities in the area of each vena contracta – the smallest flow areas of the valve trim fluid jet. Then, as the flashed fluid moves out of this area the velocity falls and pressure recovers above the vapor pressure. At this point the tiny bubbles implode – cavitation. The energy released causes local surface stresses greater than 200,000 psi that rapidly erode even stellited surfaces.

Multi-stage velocity control

On the other hand, multi-stage trim incrementally reduces the differential pressure to limit velocity head a the trim outlet. Velocity head is calculated as $\rho V2/2$ (Fluid density ρ times the velocity squared divided by 2) and is a more useful design parameter. Experience indicates that holding trim outlet velocity head below 70 psi, the excessive noise and vibration that lead to damage and loss of operational control is eliminated. Thus, within the trim the pressure drops to the design exit pressure, it never falls below the fluid's vapor pressure, (see Figure 2b), flashing and resultant cavitation cannot occur.

This multi-stage pressure drop technology employs a stack of tortuous path disks, (see Figure 3), whose built-in, right angle turns create multi-stage pressure reduction. The disk stack surrounds the valve plug throughout its stroke. The flow capacity increases as additional disks are exposed.

In addition, each disk incorporates a pressure equalizing ring on its inside diameter to ensure equal pressure acting on the valve plug at all times. This eliminates plug vibration and resultant galling.

Recent material and design improvements allow this type of trim to be made of tungsten carbide materials. This is valuable in services with fluids carrying particles, particularly well-head chokes. In these services, the combination of tough materials with multi-stage pressure breakdown combine to provide service life of ten times that of the previous trim.

Retrofit examples

Hundreds of control valves have been retrofitted successfully to solve operating and high maintenance problems. These include sizes from 1-1/2 inch through 24 inches in ANSI ranges up to 2,500 pounds and API 10,000 pounds. A few specific examples illustrate the wide range of successful retrofits accomplished in many industries and applications.

On an off-shore oil rig, several anti-surge compressor recycle valves served a train of centrifugal compressors. They were of the single stage, drilled cage type and suffered from noise, vibration, and resulting damage from the very outset.

The valves saw gas flow rates as high as 750,000 pounds per hour, pressures as high as 8,500 psia, and differential pressures up to 3.300 psi. After the installation of multi-stage valve trim that limited the velocity head to 70 psi, noise levels dropped below 80 dBA and the previous high maintenance problems ceased.

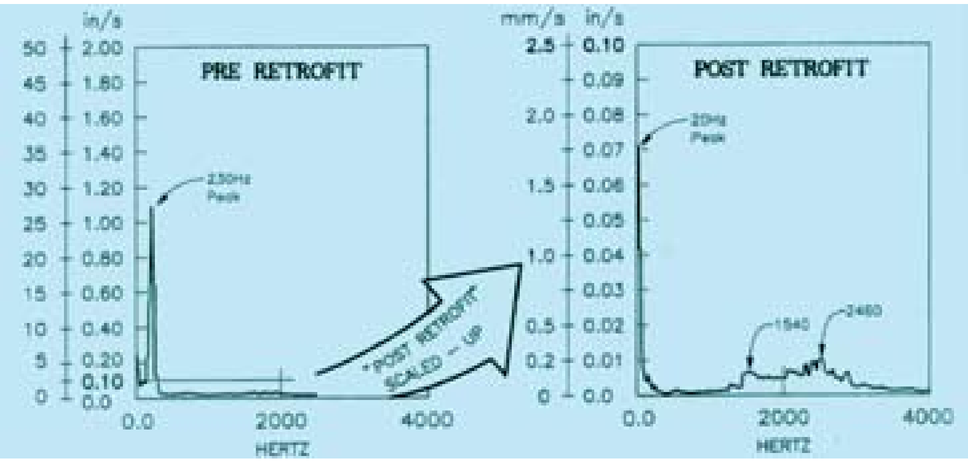

Figure 5: Before and after retrofit vibration profiles of a nuclear residual heat removal valves.

An ANSI 900 pound feedwater regulator with an original 12-inch single-stage, window cage, double seated control valve suffered wide control pressure swings resulting in vibration acceleration levels of up to 1.9-g. Sixteen-mil displacement peak-to-peak occurred at flows above 50 percent of full load. Valve stem breakage was not uncommon. To preclude tripping the unit because of instability, manual feedwater regulation was sometimes necessary. The retrofitted multi-stage trim was characterized to meet precise feedwater requirements and operated without the previously experienced damage. Figure 4 shows before and after trim configurations.

In a nuclear power plant, the residual heat removal valves suffered severe vibration and damage whenever the system was in required periodic test operation. The original 14-inch valves were conventional, single seat glob valves. Figure 5 shows valve vibration velocities perpendicular to the piping centerline before and after multi-stage trim retrofit. This shows a change from heavy flow induced vibration to negligible piping system vibration at identical flow conditions.

In a natural gas pressure letdown station, a 2-inch single-stage valve suffered severe noise and vibration problems and extensive trim damage, (see Figure 6). This erosion was due to the gas containing high oxide corrosion products flowing through the trim at 1020 feet per second – 695 miles per hour – the equivalent in this case of an actual velocity head of 360 psi. These corrosion products dictated that the designers plan the retrofit multi-stage trim for a very low velocity head, only 30 psi. this produced a trim exit velocity of 294 feet per second, a 70 percent reduction over the original single-stage, pressure reducing valve.

Figure 6: The damaged single-stage trim in a gas pressure letdown valve.

In addition to these specific retrofits, other similar projects have included such services as auxiliary steam, feedpump recirculation, spray water, turbine bypass, core spray test loop, high pressure flare control, wellhead choke, and many other control valve services.

Usually, troublesome valves have been opened up a number of times for repair. As a result the valve's internal condition is a known quantity before a retrofit project begins.

Additionally, plants benefit from trim retrofits by keeping the valve body in place and the trim replacement may be treated as a maintenance expense. This can preclude some expensive paperwork and processing that often delays and may kill plant-betterment projects. It also ensures that the project is controlled by those who are responsible, rather than possibly purchasing just another low – price and high – cost problem valve.

Thus, trim retrofit proves itself to be a viable, relatively inexpensive, and successful way to eliminate chronic noise, vibration, trim damage and operational instability problems in control valves throughout industry.

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