How DRAG valve technology contribute to reducing O&M costs

By Bob Katz

The repair and maintenance of control valves which operate in critical environments such as nuclear power plants is a major contributor to high O&M costs. To minimize the main cause of poor valve performance - excessive fluid velocity - Control Components Inc (CCI) produces valves based on the velocity-control technique of its DRAG disk-stack trim construction.

There are three principal reasons for operation difficulties with valves used in severe-service applications. The majority of problems involve valves that have been misapplied and simply cannot perform as originally specified. In other cases, the valves meet the design specifications, but fail when systems are operated at pressure and flows beyond the specified design parameters.

When convention valves have been used in severe-service applications, such as the high pressure and temperature conditions experienced during start up and shut down procedures of nuclear plants, the result can be thermal inefficiency, with lost-power production cost-than the maintenance.

While a design review of the poor performing valves need not be difficult, care must be taken to find and cure the root cause of the problem, and not just merely treat the symptoms. Taking into consideration the economic factors of both maintenance and power production, valve improvements can have a payback period of only one to two fuel cycles.

Furthermore, with a better understanding of the key factors that affect valve performance under severe service conditions, valve failures can be prevented. This will reduce a plant's O&M costs significantly.

DESIGN SHORTCOMINGS

Conventional valve designs can be characterized by the way each manufacturer approaches trim design. In most cases, process fluids flow through some version of a single (Fig. 1) or a multiple-area orifice. Though these designs may perform well under normal conditions, common problems are encountered in severe-service applications such as control, mechanical vibration, noise, cavitation and erosion, resulting in

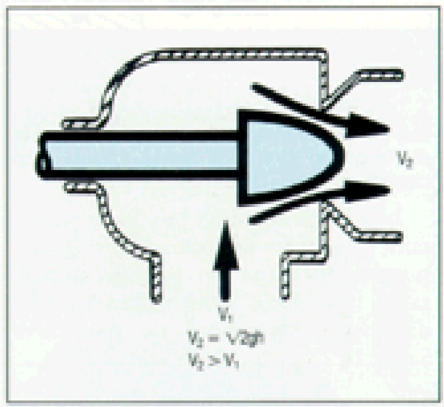

Fig. 1. Process fluids are often controlled by single-orifice valves.

shortened life for the valve and increased expense for the plant operator.

When problems do occur, two fluid flow parameters are usually involved. Often, the pressure ratio across the valve is found to be greater than three - that is, the absolute pressure of the fluid exceeds three times the downstream pressure. Also, the pressure level is frequently greater than 7 MPa (1000psi) although the valves have been known to be damaged internally at lower pressures as well.

The second is the temperature of the flowing fluid. When the fluid, if a liquid, is sufficiently hot, it will vaporize as the pressure within the valve drops below the flash point. This leads inevitably to internal valve damage from cavitation and erosion.

VELOCITY IS THE KEY

In general, poor valve performance in severe-service applications is due primarily to excessive fluid velocity. Even the use of harder materials in the valves to offset erosion from cavitation, or the use of pipe-lagging or downstream chokes, can only marginally offset valve failure from this cause. Velocity must be controlled at all valve settings. That is the reality for maintaining performance.

In looking for a way to reduce pressure and velocity, it was thought that a better method would be to control velocity by dividing the fluid stream into multiple, but discrete, flow passages and to dissipate the fluid energy (and velocity) in a continuous manner by inducing controlled turbulence in the flow.

CCI perfected such a process in a patented disk-stack trim designated DRAG technology. This approach to severe-service applications prevents the negative effects of excessive fluid velocity and controls virtually all negative flow and control characteristics in a custom-tunable manner. These valves have been used in many nuclear applications (see table below).

The disk-stack approach uses a series of flat metal discs to form a trim assembly. Each disk has a flow-pattern of successive, right-angle grooves cut into one side of the flat surface. With up to 40 right-angle turns per disk, the flow is controlled in the trim in a manner that maintains positive operating characteristics throughout the valve's opening-range (Fig. 2). The flow path for each disk is opened as the plug moves within the center opening of the disk stack. By forcing the fluid to take the tortuous turns required to pass through the stack to the outlet, the desired pressure drop is achieved by a reduction of the velocity head, $V^2/2$, for each right turn. Test results indicate a higher multiple than one velocity is achieved for each turn encountered.

Examples of CCI valves in nuclear applications

Application	Nominal size range (mm)
Pump recirculation	150 to 250
Feedwater regulator	.300 to 500
Turbine bypass	200 to 400
Steam generator blowdown	60 to 150
Service water	50 to 400
HP coolant injection	150 to 250
Reactor water clean-up	50 to 200
Heater drains	50 to 200

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Overall fluid velocity is controlled by the number of pathways assembled into the individual disk stack. Additional velocity control can be achieved by varying the flow area within each pathway. This is illustrated in Fig 3, where the outlet area, A_2, is greater than the inlet area, A_1, with a continuously increasing flow area between inlet and outlet.

Physically, the external appearance of a disk-stack valve is essentially the same as a conventional globe or angle-type control valves, with the disk stack forming cylindrical valve trim, and the flow rate controlled by the up-and-down movement of the plug (Fig 4).

TAILORING FLOW-CHARACTERISTICS

DRAG disk-stack trims provide linear or equal percentage flow characteristics. Where more precise system control is desired, the disk stack can be characterized to match pump curves or boiler performance specifications. This diversity of choice in flow characteristics saves the plant engineer from having to compromise with an off-the-shelf valve that might not meet the specific application requirement.

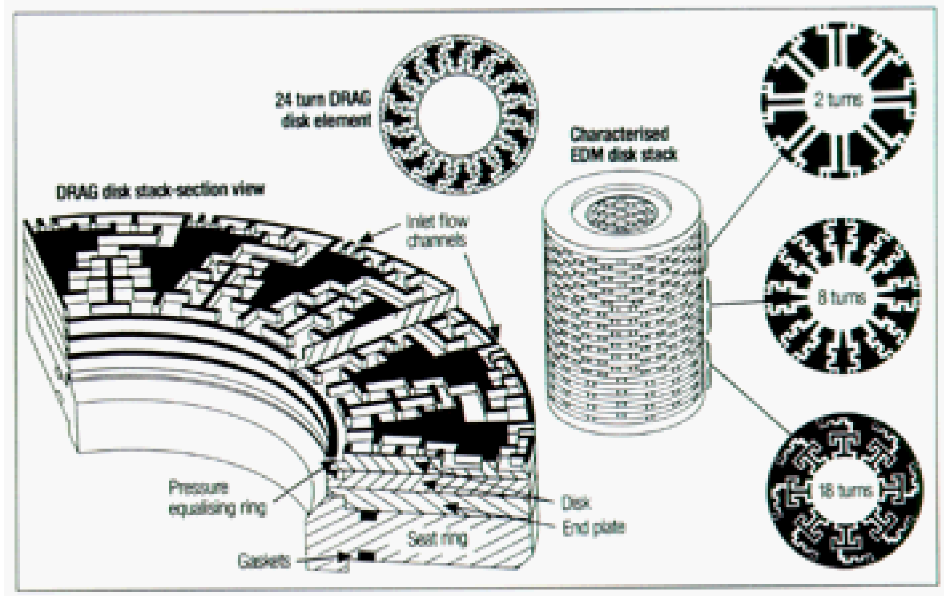
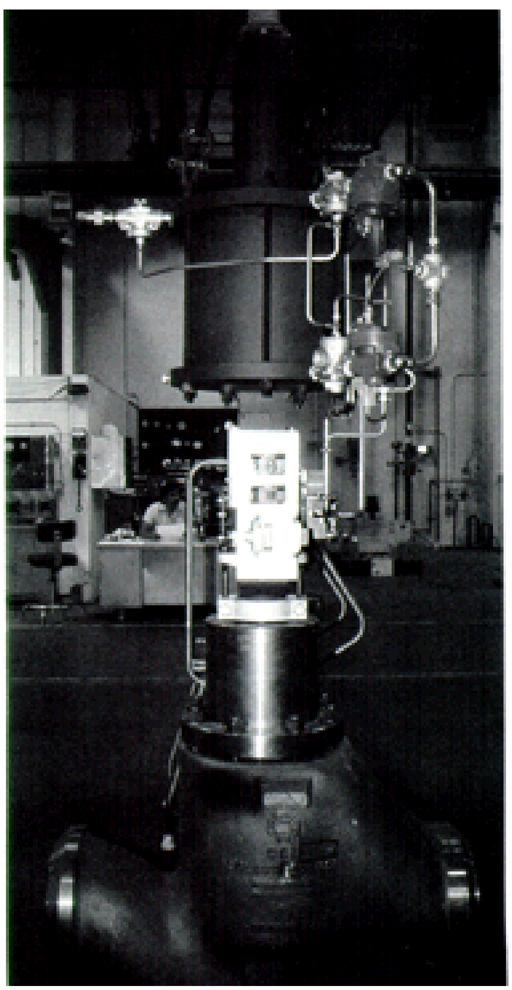
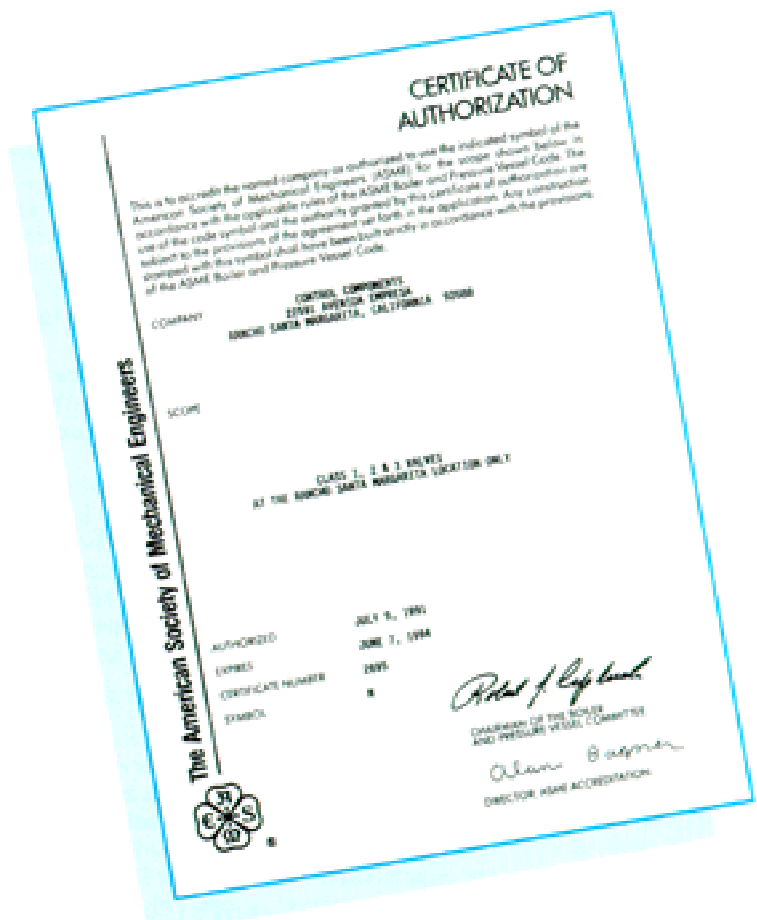


Fig 2. With DRAG technology, good fluid velocity control is maintained throughout the valve's opening-range as the flow follows the many right-angle turns through the disks of the trim. The flow path for each disk is opened as the plug moves within the centre opening of the disk stack.

In a linear stack, all the disks have the same number of passages, the same number of turns per passage and the same flow area. This makes the flow directly proportional to the valve's stroke at constant differential pressure.

In a characterized disk stack, all disks are not the same, but rather are chosen to provide a distinct, variable flow pattern over the full range of the valve opening.





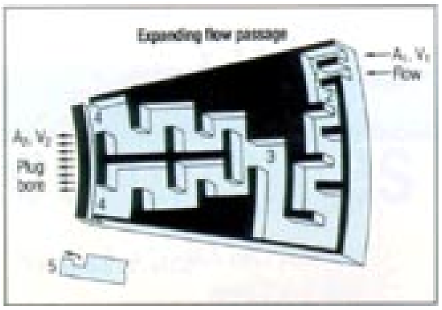


Fig 3. As the flow area within each pathway is gradually increased between inlet and outlet, additional velocity control Is achieved.

For example, in an application where fine control is needed at low flow rates and larger flow is needed at the full-open position, the lower disks in the stack are designed with fewer flow passages and more 90° turns, while the stack's upper disks have more flow passages with fewer 90° turns. This is known as a characterized design.

Different disk-stack configurations can be customized for other inlet and outlet pressure characteristics over a valve's flow range, to match specific plant requirements. This trim can also be installed into existing control valves without cutting the body out of the line.

AVOIDING VALVE FAILURES

The control of flow velocity offered by the disk-stack valve also avoids many of the causes of valve failures: Erosion by cavitation. When liquid pressure is reduced to or below its vapor pressure, flashing and bubble formation occurs. In conventional valves, (Fig 5, top graph), fluid enters at pressure P_1 at velocity V_1. As it moves through the reduced area of the valve trim, it accelerates to velocity V_2 and its static pressure drops to P_2 - a level at or below the fluid's vapor pressure P_V.

At this point, the fluid boils. Any conventional valve with a multiple-orifice trim will encounter this problem, due to the uncontrolled velocities in the area of each vena contracta (that is, the smallest flow area of the valve). As the fluid moves out of the throat of the valve, pressure recovery begins, converting kinetic energy back to potential energy. Full recovery to downstream pressure is indicated at P_3 and velocity V_3. When the recovery pressure exceeds the fluid's vapor pressure, P_V, the just-formed bubbles collapse, causing cavitation. The energy released in this event causes local surface stresses greater than 1400MPa (200,000psi), which can erode even stellited trim very rapidly.

In valves equipped with a DRAG-type disk stack, the controlled-velocity trim design prevents *vena-contracta* pressure from dropping to the liquid's vapor pressure (Fig. 5, lower graph), provided the outlet is greater than the vapor pressure, thus avoiding cavitation and erosion.

Erosion by abrasion Saturated and slightly super-heated steam can increase in moisture content while flowing through most control valves. This moisture is highly erosive, especially with uncontrolled trim velocities. Flashing water (liquid water and steam) causes extensive damage to control valves. This is often seen in steam generator blow-down valves and numerous tank and heater drains.

Seat leakage. Leaking valves rob plants of performance capability. The higher the fluid temperature, the more the loss. Cavitation erosion, abrasion and vibration caused deformation all contribute to leakage problems, and all originate with uncontrolled velocity.

Insufficient seat loading is also a problem. Many valves were not designed for long-term shut-off, and will be a problem until they are changed. As a minimum, seat loads should exceed 7.2kg/mm (net seating force divided by seat circumference) for reliable shut-off.

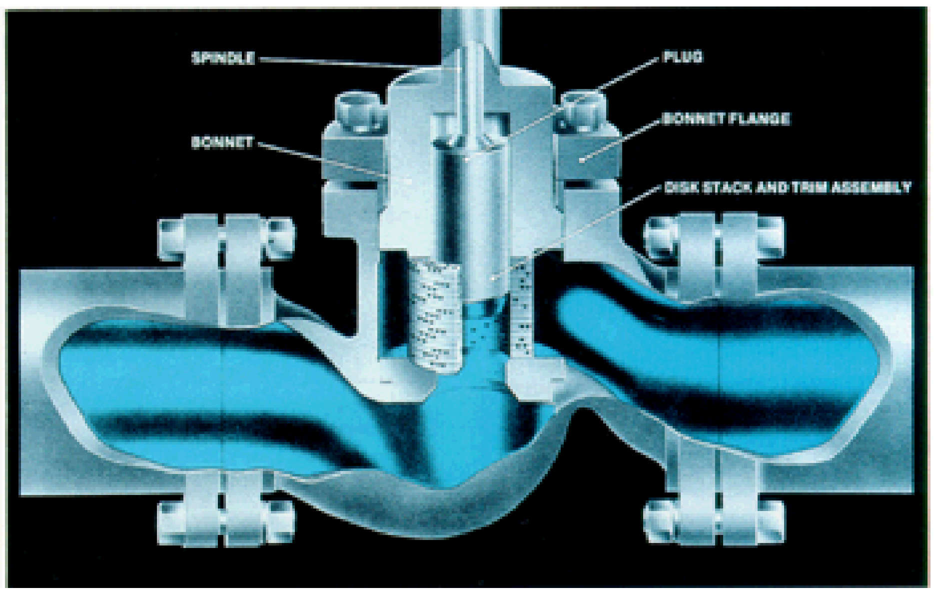


Fig 4. A disk-stack valve looks like any conventional globe or angle-type control valve with the disk stack forming a cylindrical valve trim and the flow rate controlled by the up-and-down movement of the plug.

Noise and vibration control. Any valve whose trim allows the development of high fluid velocities will create excess noise. This can be from the formation of turbulent eddies in the mass-flow stream or from sonic shock waves that develop as fluids hit critical velocity. Down-stream noise from valves is virtually unattenuated, In-line mufflers can be used downstream, but they are capable of reducing noise by only, 15 to 20dBA. Installing acoustic lagging achieves only about 5dBA attenuation. It is also very costly and susceptible to damage. When throttling or venting compressibles, near plant environmental noise levels can reach l20dBA; and even with modified-trim valves using diffusers, can still exceed 100dBA.

Because disk-stack technology presents gradual and continuous resistance-to-flow, fluid velocities are held to well below MACH I and can be custom-designed to fall within plant-specified noise limits.

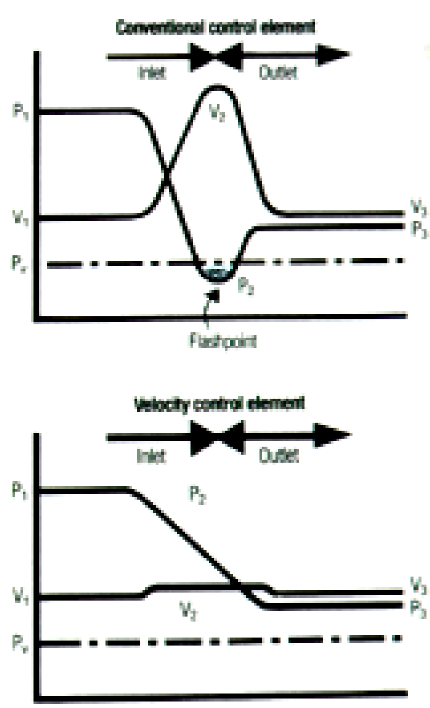


Fig 5. In conventional valves, flashing and bubble formation occurs when liquid pressure is reduced to or below its vapor pressure (top graph). The controlled-velocity trim design can prevent this, thus avoiding cavitation and erosion (bottom graph).

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