Control Valves
Match Size with Application

When control valves are mis-sized and/or misapplied, cost impact can extend far beyond the purchase price.

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KEY WORDS

- **Process control & instrumentation**
- **Process control valves**
- **Specifications**
- **Valves**

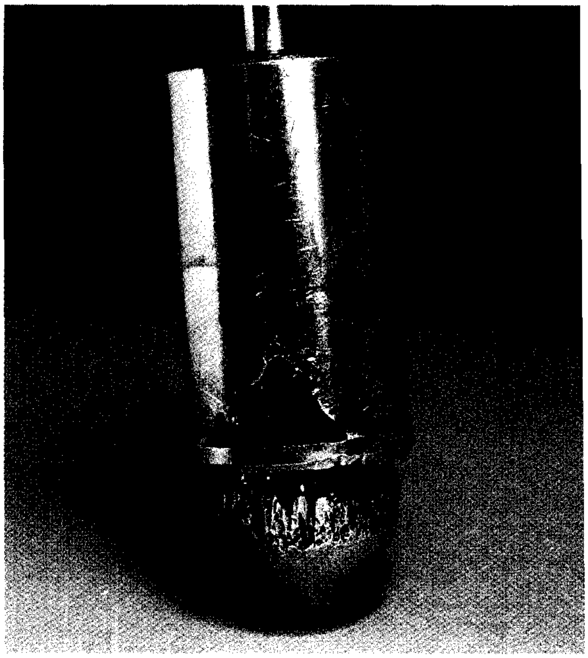
Big dividends in reduced maintenance cost can be obtained when control valves are engineered to match requirements of the application, and this is especially true for severe service applications. Though less than 10% of all control valves are installed in severe service applications, applying the information in this article will ensure every control valve is correctly engineered to meet the demands of the application.

Control valves are expected to precisely maintain pressures, flows, temperatures, and levels in thousands of installations, but too often are sized and selected without considering all requirements. For example, control valves installed in some hydrocarbon processing streams are required to perform with high pressure drops (1,500 psi ±300 psi) (105 bar ±20 bar), high operating temperatures (900 °F ±100 °F) (482 °C ±38 °C), and when solids, such as sand, clay, and coke particles, are present in the flow stream. Selecting and sizing a control valve suitable for a particular application requires:

- Process information;
- Selection and sizing criteria;
- Materials of construction; and
- Trim design.

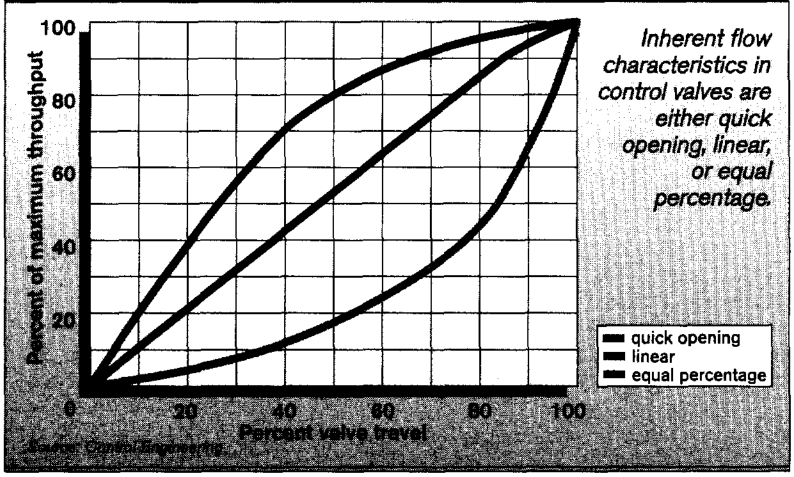
Process information

Complete process information includes normal operating conditions as well as startup and upset conditions. For example, startup conditions may require slowly warming a valve that contains coatings or special alloy inserts to prevent uneven thermal expansion and mechanical failure.



Flashing damage on this valve plug appears as a smooth, polished surface and occurs when the pressure at the valve outlet remains below the vapor pressure of the liquid and vapor bubbles remain in the flowing stream. Photo courtesy of Fisher Controls

Inherent Flow Characteristics



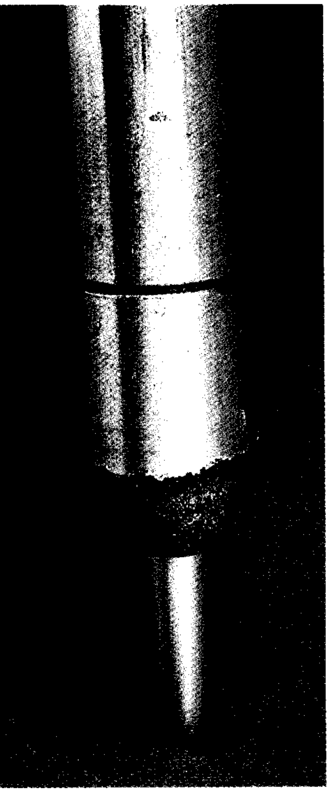
Inherent flow characteristics in control valves are either quick opening, linear, or equal percentage.

Source: Control Engineering

Identification of the physical property and fluid characteristics of the material that will pass through the valve includes:

1. Type of fluid and its physical properties;
2. Fluid phase (gas, liquid, slurry, multiphase, etc.);
3. Density (specific gravity, molecular weight, specific weight, etc.);
4. Vapor pressure;
5. Viscosity;
6. Critical temperature and pressure;
7. Degrees of superheat or existence of flashing (vaporization curve across the valve);
8. Corrosive properties due to contaminants (H_2S, chlorides, etc.);
9. Quantity and type of solids (sand, silica, catalyst, etc.);

Control valves require engineering to perform well



Valve plug cavitation damage leaves a rough, cinderlike surface and occurs if downstream pressure recovery is sufficient to raise the outlet pressure above the vapor pressure of the liquid causing vapor bubbles to collapse or implode. Photo courtesy of Fisher Controls

10. Other known properties;
11. Minimum, normal, and maximum inlet and outlet pressure at the valve;
12. Minimum, normal, and maximum operating temperature at the valve;
13. Minimum, normal, and maximum flow rates for each operational state including startup and upset situations;
14. Minimum, normal, and maximum operating pressure drop at the valve;
15. Pressure drop at shutoff;
16. Shutoff leakage requirements;
17. Startup conditions/procedures;
18. Upset condition inlet pressure and temperature;
19. Inlet and outlet pipe size and schedule;
20. Maximum permissible noise level and reference point;
21. Installation environmental conditions; and
22. Type of erosion occurring or expected (abrasive particle, cavitation, erosive-corrosive, or high liquid velocity impingement).

Selection and sizing criteria

Control valve manufacturers are constantly developing new technologies to provide improved control, reduce noise, minimize flashing and cavitation, extend product life, and reduce overall cost of ownership. To obtain these benefits requires permitting control valve manufacturers to engineer a solution based on process conditions rather than specifying what was used on the last project. Information considered when control valves are selected and sized by manufacturers includes:

- Valve body construction (angle, double-port, butterfly, etc.);
- Body material (316 stainless steel, Inconel, ceramic, etc.);
- End connections and rating;
- Valve plug or disk style (quick opening, linear, etc.);
- Valve plug or disk action (air to open or close);
- Port size (full or restricted);
- Valve trim materials;
- Action desired on failure of input signal (open, closed, or fail-in-place);
- Flow action (flow tends to open or close);
- Input signal type (pneumatic, electric, etc.);
- Actuator type and size;
- Environmental requirements;
- Packing material (Teflon, graphite, etc.);
- Area classification; and
- Accessories required (controller, limit switch, handwheel, etc.).

When all the options are examined, it becomes apparent why control valves need to be engineered for each application. For example, using a globe valve in a severe erosive service application is generally not practical because of multiple changes in the flow path. Likewise, ball valves may not be a good choice because the flow path may produce ball destroying eddies. Even ball valves "designed" for abrasive service can experience limited trim life as a result of the small differential pressure across the valve.

Numerous installations have shown severe erosion service applications with high temperature and pressure drops less than 500 psi (34 bar) can be controlled using an eccentric disk valve. Where temperatures are high and pressure drops are greater than 500 psi, sweep angle valves work well.

Some applications require use of exotic alloys and metals to withstand severe service. These materials are more expensive but end up costing less over the life of the valve.

Materials of construction

Usually materials used in the body, bonnet, and

Control-valve sizing improves

Sizing control valves is like many other areas of process control; there is no substitute for experience. Those who have successfully overcome the trials and tribulations of an improperly specified, sized, and/or installed control valve develop an appreciation for the importance of approaching control valve applications with tools and common sense.

To assist with the tools portion, numerous control valve sizing calculation methods have been developed including ISA's (Durham, N.C.) S75.01 and IEC's (International Electrotechnical Committee, Geneva, Switzerland) new 60534-1 control valve sizing standards.

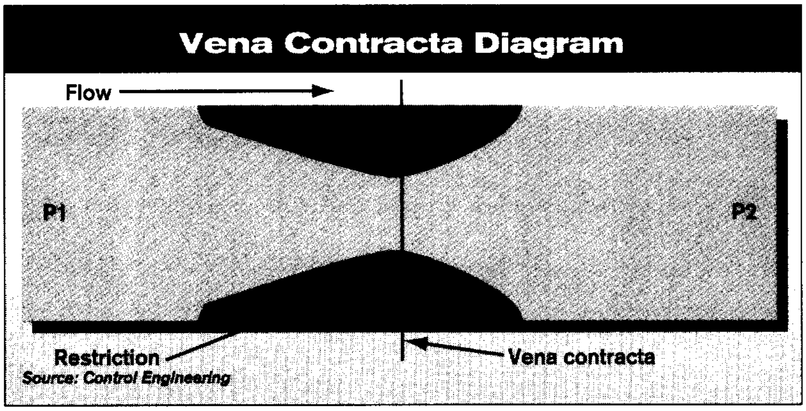
IEC 60534-1 is more complex than ISA's S75.01 standard, and provides more accurate results when used to size control valves for very viscous liquids with laminar flow. Over the years experienced practitioners had observed that S75.01 consistently resulted in valve undersizing and flow-definition problems for liquids and gases in valves other than globe type. IEC 60534-1 appears to have corrected this problem.

Most major control valve manufacturers have sizing and selection software for their products. To make these programs "user friendly," many manufacturers require minimum of information. Obviously risk is associated with such an approach; users should exercise caution.

Another "watch out" occurs when sizing software adapts the basic liquid sizing equation to gas applications. When the ratio of pressure drop to inlet pressure exceeds 0.02, this approach can produce misleading results.

Experienced control valve practitioners are able to apply common sense to valve sizing calculation results and make educated adjustments and recommendations. Less experienced users would be wise to seek competent counsel.

Some control valve sizing programs can mislead



Vena Contracta Diagram

Source: Control Engineering

Just past a restriction is where a liquid is most necked down. This is called the vena contracta. When the pressure at the vena contracta drops below the vapor pressure of the fluid, bubbles form that can choke the flow and cause flashing or cavitation damage.

end connections of a control valve are different than the material used for the plug and seat ring trim parts. The plug and seat ring are usually more susceptible to erosion damage thus trim part material selection depends on fluid temperature, velocity, corrosiveness, hardness of flowing particles, angle of impingement, and the machinability of the material selected.

Materials offered by control valve manufacturers range from the common low alloy steels and Type 304 and 316 Stainless steel to exotic materials with names like K Monel, Inconel, and Nitronic 50.

Advances in overlay technology have resolved adherence problems making Tungsten Carbide and ceramic overlays practical solutions.

To keep cost down, especially for valve bodies, manufacturers often overlay a softer material with harder materials such as Chrome or Tungsten Carbides, or Alloy 6. For example, when Tungsten Carbide is applied in thickness of 0.007 to 0.010-in. (0.018 to 0.025 cm) a highly erosion-resistant surface is produced.

Chrome Carbide overlays are frequently used because that material can be welded, doing so results in a softer surface than using a cast alloy that will be several Rockwell hardness points harder than an overlay.

Trim design

The replaceable internal parts of a control valve, including the valve plug or disk, stem, disk holder, and seat ring, make up the trim parts and are primary in determining flow characteristics.

A control valve's flow characteristic is the relationship between the flow rate through the valve and valve travel between 0 and 100% valve opening. Flow characteristics are typically either quick opening, linear, or equal percentage (see Inherent flow characteristics diagram, and *CE*, Feb. '99, p. 77).

Quick opening characteristics permit about 70% of a control valve's capacity to be obtained in the first 40% of travel. Quick opening characteristics are frequently found in relief valve applications.

Linear characteristics provide a flow rate directly proportional to travel. This proportional relationship produces a constant slope that yields a constant valve gain with a constant pressure drop. Linear characteristics are commonly specified for liquid-level and flow-control applications.

Equal percentage characteristics produce an equal percentage change in flow for each equal increment of travel. Change in flow rate is proportional to the flow rate just before a change in valve plug, disc, or ball position. Equal percentage characteristic is common where the system itself absorbs a large percentage of the pressure drop, such as pressure control applications.

Selecting the appropriate flow characteristic requires understanding the application and the results the inherent characteristics will produce in the actual installation.

During control valve selection inherent and installed flow characteristics may creep into the conversation. Inherent flow characteristics are those shown in control valve literature and only observed when the pressure drop across the valve remains constant. Installed characteristics are obtained after the valve is in use and may be different than inherent characteristics since the pressure drop across the valve may change as the

Selecting pneumatic actuators

Determining which actuator (pneumatic, electric, or hydraulic) to use isn't always obvious. Pneumatic actuators are the most common for control valves, but when in doubt, evaluate the following points:

Pneumatic actuators are generally simpler, less costly, and easier to install and maintain.

With no electricity, and thus no spark potential, deployment of pneumatic actuators in hazardous classified areas is a popular choice; but don't ignore that many control valves are accessorized with solenoid valves, limit switches, or electronic controllers.

The simplicity of pneumatic actuators makes them easy to adapt to fail-open or fail-closed configurations. However, depending on the pneumatic actuator type, fail-in-place configurations can be complex.

Most plants have air supply lines running throughout the plant making it relatively easy to connect a new actuator.

Pneumatic actuators come in a variety of styles including diaphragm, rack and pinion, scotch yoke, lever and link, vane, and multiturn.

Diaphragm actuators are common on globe-style control valves requiring infinite positioning. They usually include an opposing spring to provide fail-safe action.

Rack and pinion actuators use two pistons acting on opposite sides of a rack and are best suited to quarter-turn applications.

Vane actuators allow pressure to be applied to one side of a vane while the other side is vented to provide action similar to rack-and-pinion actuators but with fewer moving parts.

Scotch yoke actuators use a cylinder and piston. They are frequently used to move large ball or butterfly valves requiring significant torque to move the ball or butterfly away from the seat.

Lever and link actuators are similar to the scotch yoke actuator but produce less torque.

Multiturn actuators are pneumatic motors used to drive a worm and wheel or rack-and-pinion mechanism. Multiturn actuators can generate a lot of torque but are generally slow to travel from full open to full close.

Flashing or cavitation can shorten a control valve's life

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Go to www.controleng.com to read:

"Control valve characteristic guidelines"

"Seat leakage classifications"

opening in the valve changes.

Control valve flow characterization is necessary to provide relatively uniform control-loop stability over the expected operating range. Establishing flow characteristics necessary to match a given system requires dynamic analysis of the control loop; however common processes have been analyzed and guidelines for the selection of the most appropriate flow characteristics are available (visit www.controleng.com for Control valve guidelines).

Flashing and cavitation are two physical phenomena in liquid streams that can cause structural damage within control valves. Either can limit the flow through the valve and must be considered to accurately size a control valve.

Flashing and cavitation represent an actual change of the flowing media from liquid to vapor and result from an increase in fluid velocity at or just downstream of the greatest flow restriction, normally the valve port. As liquid passes through a restriction it must neck down. It reaches its narrowest point just downstream of the actual restriction. This point is the *vena contracta* (see Vena contracta diagram). As the liquid passes through the restriction the velocity increase is accompanied by a substantial decrease in pressure at the vena contracta. As the fluid stream expands further downstream velocity decreases and pressure increases, but not to the original pressure. The pressure differential that exists between P1 (inlet) and P2 (outlet) is the amount of energy dissipated in the valve. High recovery valves, such as ball valves, use streamlined flow paths to minimize pressure loss. When the pressure at the vena contracta drops below the vapor pressure of the fluid, bubbles form.

At this stage there is no difference between flashing and cavitation, but the potential for structural damage to the valve exists. If the pressure at the valve outlet (P2) remains below the vapor pressure of the liquid, the bubbles remain in the downstream system and the process is said to have "flashed." Serious damage to trim parts can be caused by flashing. When trim parts are examined, the erosion damage caused by flashing appears as a smooth, polished surface. Flashing damage is usually most severe at the point of highest velocity; frequently at or near the seat line of the valve plug and seat ring.

If downstream pressure recovery is sufficient to raise the outlet (P2) pressure above the vapor pressure of the liquid, the bubbles collapse or implode to produce cavitation. When vapor bubbles collapse energy is released and a noise, similar to gravel flowing through the valve, can be heard. When bubbles collapse close to the solid surfaces in the valve, the released energy tears away material leaving a rough, cinderlike surface. Cavitation erosion damage may also extend well in to downstream piping.

Aside from physical damage due to flashing or cavitation, formation of vapor bubbles in the liquid causes a "crowding" condition at the vena contracta that limits or chokes the flow through the valve. A basic liquid sizing equation will indicate that as long as the differential pressure across the valve increases there is no limit to the amount of flow through the valve. But such a simple equation ignores the choked flow phenomena flashing and cavitation will produce. The choked flow effects caused by flashing and cavitation should be included in valve-sizing calculations.

To the inexperienced, control valve selection appears to be relatively straightforward and may even be considered a commodity purchase, but experienced control valve practitioners know better. The best measurement device and most sophisticated control system can't make up for a mis-sized and/or misapplied control valve. □

Electric actuators

A growing popularity in motor operated valves (MOVs) stems from the simplifications they provide for plant flow control challenges.

Virtually any conventional valve converts to an MOV by application of an electric motor actuator; and MOVs integrate well with plant automation systems.

Quarter-turn and multiturn actuator configurations, including bevel, spur, and worm gear attachments, serve fractional through 100-in. (2.5-m) valves. Thus, smaller MOVs are taking on control valve duties while larger MOVs are increasingly being applied to interlocking, sequencing, and mid-range positioning control schemes.

Smaller MOVs serve chemical/refinery, water, food/pharmaceutical, and similar applications. Larger MOVs are typically applied to a growing number of applications with large flows and/or high process pressures where high actuator torque is needed, but fast stroke times are not. Large MOVs are found in pipeline/terminal facilities, tank farms, power plants, water/sewage treatment, and aqueduct/water distribution networks.

Plant operators often favor MOVs for their low downtime and maintenance and most MOVs support handwheels; a nice benefit during power outages.

Instrumentation engineers enjoy the MOVs optional network communications and control-action configurability. Valve automation is easily implemented, although fast-response/high duty-cycle modulation, typical of control valves, is generally appropriate only for valves smaller than 4-in. (10 cm).

Safety engineers appreciate electric actuators' certified explosion-proof designs, which meet or beat most other plant electrical equipment for hazardous area duty. They also like that MOVs can be submerged in valve pits and still perform flawlessly.

Process engineers increasingly favor MOVs where flow hammering and freezing temperatures exist.

Like most devices, integrating microprocessors into MOVs delivers advanced self-diagnostics, jammed valve protection, easier setup, intuitive human interfaces, and multi-language capability, increased usability, and reduced ownership cost.

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