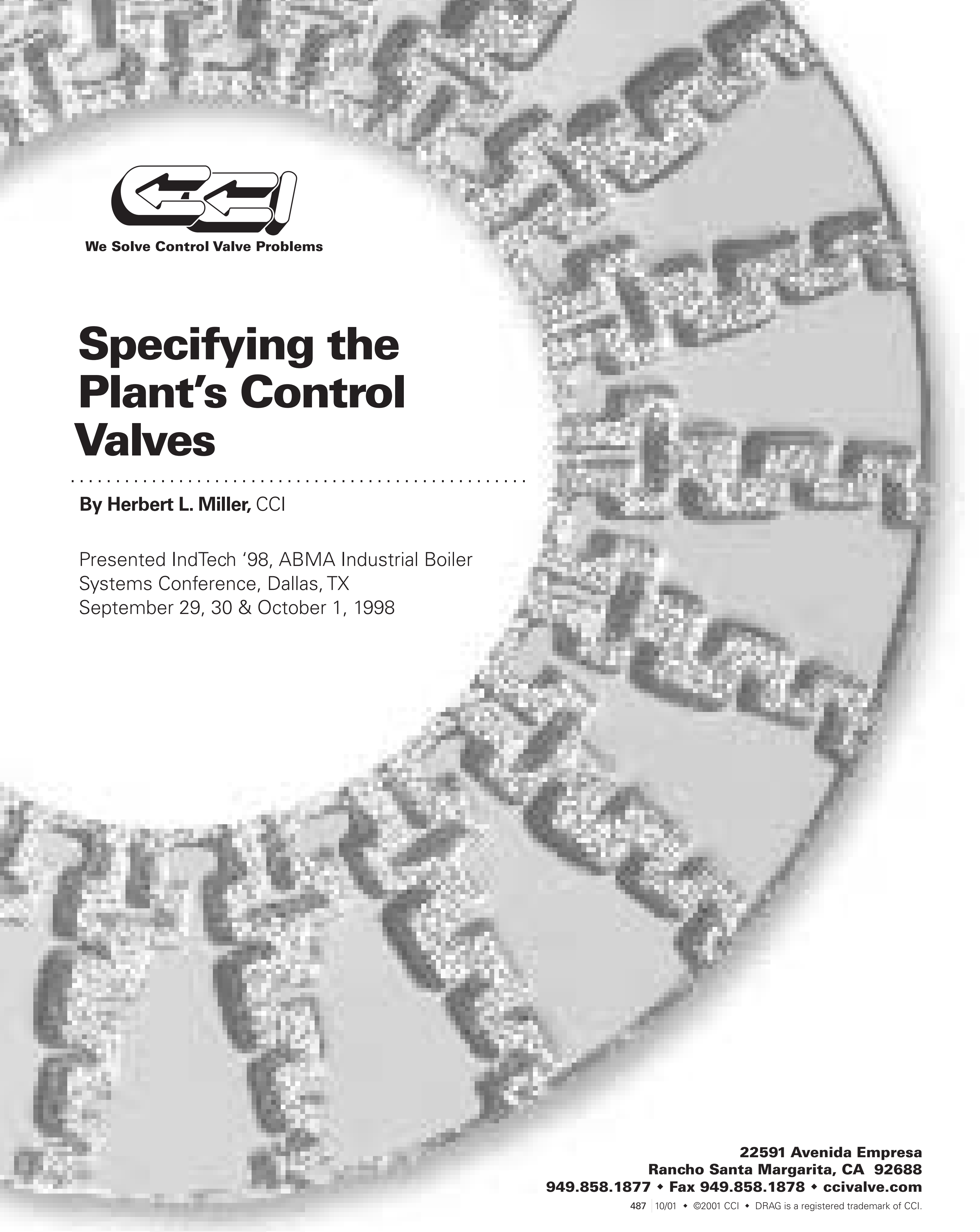

We Solve Control Valve Problems

Specifying the Plant's Control Valves

By Herbert L. Miller, CCI

Presented IndTech '98, ABMA Industrial Boiler Systems Conference, Dallas, TX
September 29, 30 & October 1, 1998

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Specifying the Plant's Control Valves

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Abstract

The many valve applications are divided into four categories and the attributes discussed that are key to a successful valve operation that meets the control requirements of the boiler system. The categories are: process control/feed regulation, continuous letdown, intermittent letdown and recirculation. These categories cover all of the valve applications in a power plant whether a utility boiler or an industrial boiler system. They cover the continuously operating valves as well as the startup and relief/safety functions.

Many times plant operations repeatedly maintain the same valves over and over. In many cases this is perceived to be normal and annually the budget is created with cost to cover continued overhaul of the valves. By having a better knowledge of the requirements of the application the root cause of the valves' deterioration can be established and the valve corrected or replaced with one that meets the needs. Doing so eliminates the costly and repeated maintenance. Significant cost savings are realized with payback periods of less than a year in many cases.

Introduction

As a supplier of severe and tough service control valves we see many common problems in the field associated with the valves. These problems are characterized by:

- Frequent maintenance needs; for example, a user will say that 'we have to rebuild this valve every shutdown.' The maintenance cycle has been done so many times it has become the norm.
- Valves that work perfectly after rebuild maintenance but in a relatively short period become a headache again, performing poorly and unreliably.
- Cause concerns during startup and shutdown as to whether they will get through the transient. However once the system is at full load the problems go away.
- Valves for which the control system has to be put in manual operation because trips occur when the system is in automatic.
- Valve bypass loops are put into service during startup and shutdown transients to allow stable operation of the main valve.
- Extensive perturbations to the system when transferring from a parallel startup valve. The upset can cause trips or lifting of relief and safety valves. The corrective procedures become the standard to work around the problem.

These problem valves exist because of:

- Misapplication of the valve design selected.
- Over or under sizing the valve for the process need.
- Poorly specified requirements to the supplier.

The subject of this paper is the proper specification of the control valve to avoid many of the problems noted above. To provide information so that the valves' attributes that are important for the application are noted and that over specified needs are minimized. Over specifying needs result in compromise and trade off decisions in the design and result in higher initial costs.

In this discussion all applications of control valves are classified into four categories. In describing the applications, the attributes that will be emphasized are important to each of the four categories independent of the many different application names used from industry to industry. There can be exceptions within every category because of needs unique to a specific process within an industry, however this paper will discuss those needs associated with industrial and power boilers.

It is assumed in the following discussion that the right valve designs have been selected and the valves have been sized correctly. A couple of good references for correctly selecting and applying control valves are presented by Driskell 1993, and Hutchison 1976. A correctly sized valve is a major key to a successful application. The use of the ISA data sheet, ISA-S20 (1988), assures that all the pertinent information is available for the selection and sizing decisions.

The application categories are:

- Process control/Feed regulation
- Continuous letdown
- Intermittent letdown
- Recirculation

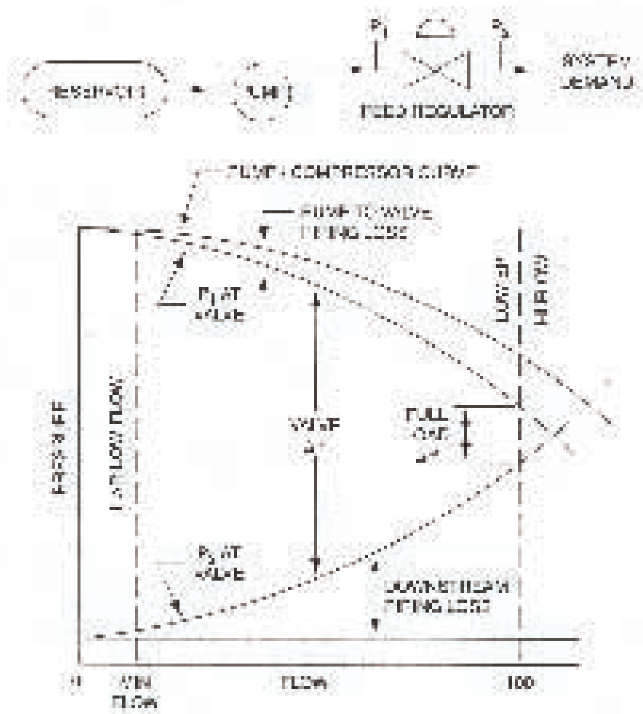

Figure 1

Process Control/Feed Regulation

In this category, a control loop or system has been pressurized and has a valve that is controlling the feed to a process in response to a control signal. The control signal could be based on a need for flow, to maintain a pressure or temperature to the process, or to maintain a fluid level. Characteristically, this requires continuous valve operation. Frequently there are parallel control valves to aid in startup or shutdown when wide rangeability is required.

To provide proper valve control there is usually a need for trim characterization. This valve trim is required for process startup and shutdown which, of course, cannot be avoided even though it may not be frequent. When the system is operating at low loads both the flow rate and system pressure drop are low, but valve inlet pressure can be high due to pump runback. This results in high pressure drop across the control valve at low flow. At full flow (full load) conditions, the system pressure loss has increased to result in lower pressure drop across the control valve as shown in Figure 1. These conditions point to the need for good valve rangeability that usually results in reciprocating stem type valves with equal percentage trim characteristic. With parallel startup valves and/or low pressure applications, this regulation may be possible with rotary type valves with a modified ball design.

Figure 1 shows a schematic of the situation covered by this application. Also shown is a frequently encountered pressure versus load curve for the application. As seen at the low load condition, the pressure drop across the valve is very high. This is the difference between the pressure developed by a pump, or compressor upstream and the pressure drop through the system.

The names assigned to the valves in this application are numerous. Some of them are:

- Flow control
- Level control
- Pressure control
- Pressure reduction
- Regulator (flow)
- Throttle

Key attributes for this application category are:

- Accuracy of control - the output of this valve affects most all of the downstream functions in the process. If a steady feed rate cannot be maintained, then all of the pressures, temperatures, and flows will be continuously changing, sometimes with an increased gain or error signal multiplication. In some processes the variation of an inaccurate valve output may not be noticed at the process output because of a damping due to long residence times. In these cases though, the continuous variation may lead to long period oscillations and fatigue in process equipment near the valve. Small signal response is often important to optimize efficiency or process output.

- Rangeability - this is the second most important attribute for this valve because the process must be controlled during start up and shutdown. Also, during operation, abnormal conditions may frequently exist that create the need to operate at reduced loads.

  To handle the startup and shutdown conditions, it has been traditional to use two valves in parallel to achieve the needed rangeability. There are, however, valve designs today that can handle this function in one valve body as illustrated in Figure 2.

- To achieve good rangeability and linearity of the valve flow to stem position (installed linearity), the valve trim must be characterized. Thus, at the low load conditions, a valve capacity versus position curve (characterization) will look like that shown in Figure 3. This characterization not only provides better rangeability and control, but also assures that the valve closure member does not operate near the seat and thus minimizes damage to the critical seating surfaces due to excessive fluid velocities. Depending upon the low load pressure drop, other measures may be necessary to limit high fluid velocity erosion such as the use of multi-stage trim designs. These designs become a consideration when pressure ratios, p_1/p_2 across the valve exceed three or pressure drop across the valve could result in cavitation or excessive noise. Cavitation and excessive noise can occur at pressure drops as low as 30 psi (0.2 MPa) for some fluid conditions. The characterization and trim erosion considerations are very important because they contribute significantly to the most vital function of this valve and that is accuracy of feed control.

In this application, other attributes are usually secondary. These are:

- Failure Mode - fail-safe is the preferred failure mode, which is usually in place or last position. This means that all actuator types can be used; pneumatic, electric, or hydraulic.
- Stroke Speed - generally not a consideration because the boiler cannot change load conditions quickly due to stored energy or product in the system. Thus, normal valve speeds are quick enough to respond to the demands imposed.
- Shutoff - this is usually not a consideration because these valves are seldom shut. So, an ANSI/FCI 70-2 leakage class III or even less is sufficient in most cases.

The most obvious example of valves in this application would be a boiler feedwater regulator valve where a constant speed feed pump is used. The pressure condition for the valve inlet (pump output) and valve outlet (system pressure) are shown on Figure 1. A representative set of conditions for this application would be a flow rate of 55000 lb/h (Metric 25 t/h) at a pressure differential of 735 psi (5.07 MPa) at start up. At a full load flow rate of 990,000 lb/hr (450 t/hr) the pressure differential is 30 psi (0.20 MPa). Thus the pressure drop across the valve changes by 25 times as flow is varied by 20 times over the load range. The resultant valve rangeability is nearly 100 in that the minimum Cv is 4 and the maximum is 370. However, to provide control at the maximum condition a valve Cv of over 400 is required.

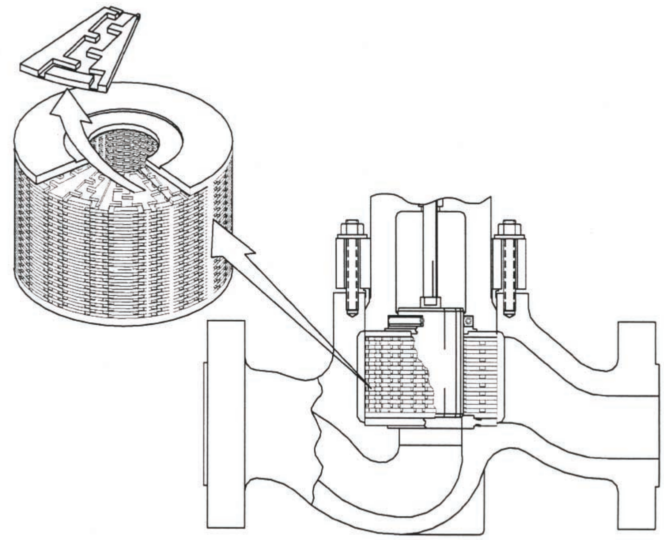

Figure 2

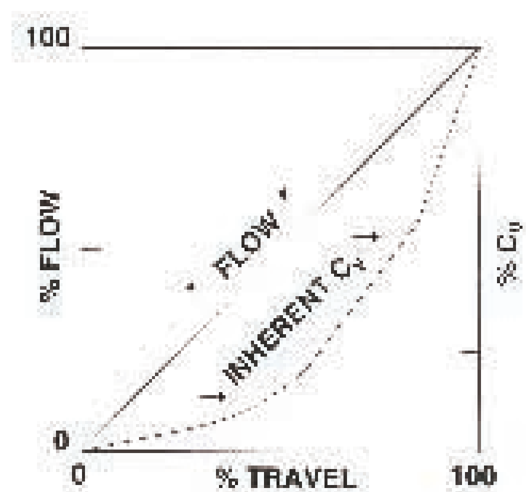

Figure 3

Continuous Letdown

In this application category, the valve is located between two large reservoirs of different pressures where the downstream reservoir could be the atmosphere. In this case, the valve sees a constant pressure drop so flow control is established by the valve position. There is no need to provide anything other than a linear trim characterization for this purpose unless extended duty at low feed rates are also required by the process. An equal percent closure member will allow travel farther off the seat for extended operation at low flows.

Reliability and ruggedness are the keys to this continuous duty application, so selecting the proper valve design for the pressure drop condition is important. Table 1 provides a guideline for the type of valve to select for specific pressure ratios.

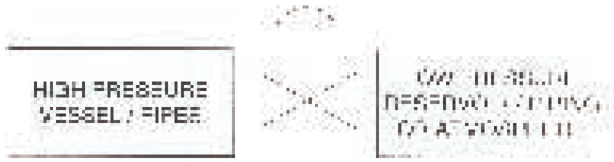

Figure 4

Figure 4 shows a schematic of the situation covered by this application. The most frequent control condition is that of either upstream or downstream pressure or level control. Feed rate is varied as necessary to maintain pressure or level. An example of downstream pressure control would be for steam to an auxiliary turbine and gas flow into a distribution system such as for multiple burners. The control variable can also be flow instead of pressure. This would be the case for burner control valves and spray or mixing valves used for pressure or temperature control.

In specifying conditions for these valve applications, the most common error is one of omitting the off-load operating conditions. Usually, only one set of operating conditions is provided, that of steady state full load. The off-load conditions are important because of the complexity of most plant startup procedures, which require holding at partial loads for extended periods. Thus, need for good rangeability is usually missed in these applications resulting in poor valve selection with a corresponding result of poor control of the process startup or part load performance.

Typical names assigned to these valves are:

- Attemperation
- Blowdown
- Flow control
- Letdown
- Level control
- Pressure control
- Pressure regulator
- Reducing
- Spray

Key attributes for the continuous letdown applications are:

- Accuracy of control - as with the process control valve, this is the most important function for this valve. Maintaining a near constant pressure, flow, or temperature condition is essential to the process and reliability of the equipment affected by the control. A continuously varying output would have many short and long term damaging influences.

  This application is fairly routine in terms of its demand on the control valve. Many different types of valve designs can handle the conditions imposed without detrimental effects. There, of course, can be exceptions where the following attributes may assume more importance.
- Rangeability - this is not generally an important issue because most valve designs provide sufficient rangeability to meet the process needs. A reasonable need is for a fifteen to one rangeability. Since the pressure drop across the valve is constant, the trim of the valve is linear.
- Failure Mode - this depends upon the specific application and all modes of failures on loss of power to the actuator are used. A generalization would be to have this valve fail-in-place so that the system is not disturbed by an abrupt change in pressure or flow conditions.
- Stroke Speed - this is usually not a consideration.
- Shutoff - not an important consideration because the valves are rarely closed.

Intermittent Letdown

As with Continuous Letdown applications, the valve reduces the pressure between two large reservoirs and frequently the downstream reservoir is the atmosphere. The pressure drop could be constant or variable depending upon the specific application. The variable case would occur on a blowdown situation, so the inlet pressure would decrease with time. The valve stroke would be increased if a near constant flow rate was desired to minimize blowdown time.

Figure 4 is the same for continuous and intermittent letdown applications. As implied by the name, the only difference in the two processes is the time of operation or duty cycle on the valve. Even though the valve is used less frequently, the conditions for the valve represent a tougher service. In this case, the control valve must perform the dual functions of providing control and tight shutoff. The latter usually means a Class V or VI leakage (ANSI/FCI 70-2), but in many cases this is not sufficient. A block valve leakage requirement must be used to provide a sufficient criterion for the permissible leakage. The reason a tight shutoff is needed is that any leakage through this valve means a loss of process fluid that is needed upstream for providing steam for the process or various turbines.

Valves in intermittent letdown service primarily perform a bypassing function. The valve is opened to bypass the entire process or parts of the process during a startup/shutdown function or a safety relieving function. In some cases, the valve can perform both functions of bypassing for control and safety relief. However, local codes must be checked to see if a dual role is permitted.

Typical names assigned to various intermittent letdown valves are shown below. Frequently, the name of the equipment being bypassed or blown down is used in combination with these labels.

- Dump
- Auxiliary
- Extraction
- Relief
- Blowdown
- Startup
- Bypass
- Injection
- Vent (ing)
- Depressurizing
- Letdown

The attributes for the intermittent letdown application are:

- Accuracy of control - for most valves in this application this is not an important function as most control valves provide sufficient resolution to meet the requirements. An exception frequently exists when the valves are in a startup bypass function where a fine, accurate control is needed to maintain flow or upstream pressure conditions over extended periods. The pressure drop across these valves is constant for most of the operating conditions. As a result of this and the accuracy needs, a linear characterization of the trim is normal.
- Rangeability - Normal design capability is sufficient.
- Failure Mode - Normally, this valve is in a fail-close configuration, its normal status, so that if power is lost to the valve, the process is not disturbed unnecessarily. Occasionally, process system needs will require the valve to fail in its last position. When the valve is in a safety role, the valve configuration must be in the fail-safe direction, which is usually fail-open.
- Stroke Speed - The dual functions of these applications dictate the speed of operation. When the valve is used in a safety function, the speed needs to be very fast, on the order of one-half to five seconds. The safety function could be to protect personnel, equipment, or the process output. This would only be necessary for the opening direction because, in this mode, it is usually relieving pressure from an over pressurized upstream system.

  When the valve is used in the process bypass mode, for startup and shutdown function, speed is generally not a priority consideration. Speeds can be achieved without special considerations as commercial positioners usually have sufficient capacity for pneumatic actuators. Electric drives, although tending to be relatively slow, are fast enough. Hydraulic actuators for speed purposes would be over design except when the valve is used for safety relief.
- Shutoff - This is a key and critical function of valves in this application, regardless of whether the valve is performing a bypass or a safety role. Any loss of fluid through this valve is a reduction in the process efficiency. Either pumps or compressors must work harder to overcome the leakage, or maximum loads achievable are reduced.

The minimum shutoff requirement would be a Class V leakage for a control valve. However, frequently a Class VI or even a MSS-SP61 block valve closure is prudent for long term reliable valve operation. For this reason, many control valve designs use the fluid pressure to assist the closure member in maintaining a tight seating force. Soft seats are frequently used but these may not be reliable in high pressure drop situations, over 1500 psi (10 MPa), that frequently occur in this application category.

A typical example of this application is the steam turbine bypass valve. This valve is installed to bypass the steam around the turbine until pressure and temperature are at appropriate turbine startup conditions. These turbine bypass valves can also be used for pressure relief valves per some code regulations, particularly in Europe. The American Society of Mechanical Engineers' Boiler and Pressure Vessel Code does not permit use of this bypass control valve as the pressure relief valve for safety purposes. For the turbine bypass function, the most important valve attributes are usually shutoff, accuracy of control, and opening speed.

Recirculation

This application could be thought of as a subset of Intermittent Letdown in that the duty cycle is intermittent and the function performed is generally a pump bypass situation. The bypass need is usually driven by the startup, shutdown, or system upset conditions. However, because the applications listed under this category are usually the most severe within the system, they need special consideration to assure reliable and long term operability.

Thus, the recirculation application is reserved for the cases in which a pump is bypassed as shown in Figure 5. In this case, the fluid that has been pressurized is reduced in pressure and returned to the pump inlet reservoir. The valves experience a wide range of pressures and temperatures. Rangeability and flow control are seldom critical. The valve is usually closed and its performance is judged by how well it shuts off. If shutoff is not maintained, the fluid must be repressurized for use by the process at increased energy expense. There have been cases in which recirculation loss is so high that total output of the boiler turbine system is measurably reduced.

This valve will see the highest pressure drop in the entire plant when bypassing the main pump. Because most fluids are erosive, particularly boiler feedwater, a small leak through the valve will result in rapid deterioration of the seating surfaces. The cost of fluid leakage through this valve traditionally exceeds many times the purchase price of a new valve. This loss is seen in reduced plant efficiency, unavailable load and increased pumping power to pressurize or compress the fluid stream. It is not an application where the engineer should compromise on valve selection. The engineer must select a valve that will meet the long term seat integrity requirements to assure leak free operation. Frequently, this would utilize a design in which the fluid pressure assists in assuring good seating forces between the closure member and the seat ring.

Valves in this application go by many names. The most common names are:

- Mini-flow
- Dump
- Bypass
- Leakoff
- Recirculation
- Letdown

In addition to the comments about leakage and control attributes discussed under the intermittent application, there are two other significant considerations concerning the selection of these valves. For liquid recirculation applications, those considerations are cavitation and vibration. The detrimental affect is caused by the high pressure drop associated with these valves and the accompanying low back pressure. The back pressure is usually near atmospheric but could be a vacuum if the downstream reservoir is a condenser. These applications frequently demand severe service valves as shown in Figure 2 that are specifically designed to handle these conditions.

In summary then, the key attributes for valves in this application are:

- Tight Shutoff - usually pressure assisted via piloted designs or unbalanced plug designs with large actuators.
- Anti-cavitation/Low noise trim

Secondary considerations include the following:

- Failure Mode - normally open
- Stroke Speed - 2 to 5 seconds for compressible
  - up to 25 seconds for liquids

Summary

To assure that a proper control valve is installed it is important that the attributes associated with the application are understood. With this understanding emphasis can be placed on the attributes that will result in a properly specified control valve. Properly specifying the valve in combination with design selection (ball, butterfly, globe, severe service) and sizing correctly will result in trouble free and reliable operation with minimum maintenance.

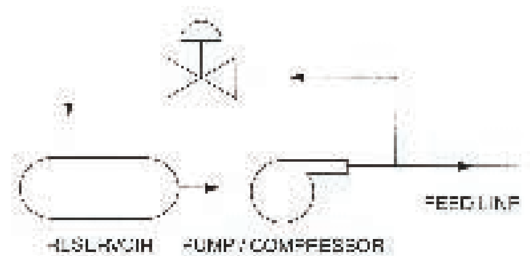

Figure 5

Table 1: Valve Type Selection Guide

Valve Type	Flow Direction	p_1/p_2 Limit*	$\Delta p/p_1$ Limit
Multi Stage, Multi Path	------	No limit	1.0
Multi Stage, Single Path	------	5.5	.82
Single Seat Globe	Open	3.3	.70
	Close	2.3	.57
Double Seat Globe	-------	3.3	.70
Angle Body Cage	Open	3.0	.67
	Close	2.3	.57
Pinch	------	2.9	.66
Butterfly, 60% Open	------	1.5	.33
Reduced Ball, 80%	------	1.2	.17

* $p_1/p_2 = 1/(1- \Delta p/p_1)$

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