Process Control Elements in the Loop

A simple process control loop consists of three elements, the measurement, the controller and the final control element.

Measurement

Measurements have got to be one of the most important equipment in any processing plant. Any decision made on what the plant should do is based on what the measurements tell us. In the context of process control, all controller decisions are similarly based on measurements.

With the advent of computers, it is now possible to do inferential measurements, meaning telling the value of a parameter without actually measuring it physically. It should however, be remembered that inferential measurement algorithms are also based on physical measurements. Therefore, rather than rendering measurements redundant, they have made measurements all the more important.

Final Control Elements

Final control elements can refer to three things, control valves, variable speed drives and dampers. In any chemical process plant, more than 90% of the time, a final control element is a control valve. The issues relating to final control elements will be most relevant to control valves although they are applicable to a large extend to dampers and in some cases variable speed drives.

For more detail please see the files at "Fieldbus Class Room"

Basic Instrumentation Tutorial	850 kB
Instrumentation and Control Tutorial 1	31kB
Instrumentation and Control Tutorial 2	395kB
Instrumentation and Control Tutorial 3	124kB
Instrumentation and Control Tutorial 4	66kB

Measurement - Transmitter Tutorial

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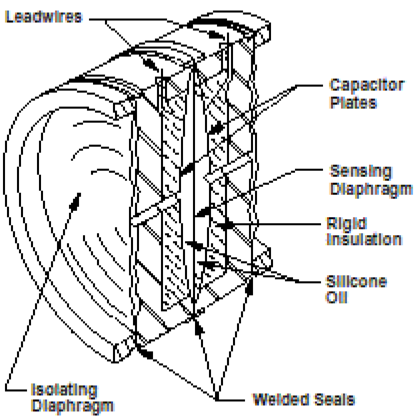
Pressure Measurement

The measurement of pressure is considered the basic process variable in that it is utilized for measurement of flow (difference of two pressures), level (head or back pressure), and even temperature (fluid pressure in a filled thermal system).

All pressure measurement systems consist of two basic parts: a primary element, which is in contact, directly or indirectly, with the pressure medium and interacts with pressure changes; and a secondary element, which translates this interaction into appropriate values for use in indicating, recording and/or controlling.



An electronic-type transmitter is shown in the figure above. This particular type utilizes a two-wire capacitance technique.

Process pressure is transmitted through isolating diaphragms and silicone oil fill fluid to a sensing diaphragm in the center of the cell. The sensing diaphragm is a stretched spring element that deflects in response to differential pressure across it. The displacement of the sensing diaphragm is proportional to the differential pressure. The position of the sensing diaphragm is detected by capacitor plates on both sides of the sensing diaphragm. The differential capacitance between the sensing diaphragm and the capacitor plates is converted electronically to a 4-20 mA dc signal.

Flow Measurement

Numerous types of flowmeters are available for closed-piping systems. In general, the equipment can be classified as differential pressure, positive displacement, velocity and mass meters.

Differential pressure devices include orifices, venturi tubes, flow tubes, flow nozzles, pitot tubes, elbow-tap meters, target meters, and variable-area meters.

Positive displacement meters include piston, oval-gear, nutating-disk, and rotary-vane types. Velocity meters consist of turbine, vortex shedding, electromagnetic, and sonic designs.

Mass meters include Coriolis and thermal types. The measurement of liquid flows in open channels generally involves weirs and flumes.

Temperature Measurement

How can I measure temperature?

Temperature can be measured via a diverse array of sensors. All of them infer temperature by sensing some change in a physical characteristic. Six types with which the engineer is likely to come into contact are: thermocouples, resistive temperature devices (RTDs and thermistors), infrared radiators, bimetallic devices, liquid expansion devices, and change-of-state devices.

Final Control Elements - Control Valves

Process control engineers treat final control elements in the same way they treat measurement devices - with absolute indifference. To most of them, a valve is a valve is a valve. It's job is to open and close according to what the controller tells them and they do just that. The problem is, in a shocking number of cases, they don't.

Control valves and dampers, being mechanical devices are subjected to a lot of mechanical issues like wear and tear, deterioration with time. Measurement devices these days are very robust and most would not deteriorate drastically with time. When they fail, they just go. The controller running inside the modern distributed control system (DCS) is even more reliable with a hot standby ready to take over in case of failure. The same cannot be said about final control elements. Therefore the weakest link in the process control loop is frequently the final control element.

The problems of control valves usually manifest themselves as stiction, deadband and hysteresis.

For more details please see the files at the "Fieldbus Class Room " Control Valves Handbook 29MB

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Deadband

Deadband is a general phenomenon where a range or band of controller output values fails to produce a change in the measured process variable. This is bad for process control. Process control systems these days execute at a rate of about 3 times per second. On top of that, each time it executes, the output changes in the magnitude of usually less than 1%. But most relevant in the case of deadband, the changes can occur is either direction.

If a control valve is suffering from a deadband problem, when the controller output reverses direction, the control valve does not respond. Therefore the process variable also does not respond to the command of the controller. The controller does not know it, it thinks that its previous command is not good enough and so issues another (sometimes more drastic) command. When the control valve finally comes out of its deadband, the controller command has caused it to overshoot.

The controller then tries to go back the other direction only to be faced with the same situation. And the process will be driven to overshoot in either directions and cycles continuously forming what is called a limit cycle.

Stiction

This is somewhat similar to deadband except that it does not only happen when the controller changes direction. Again stiction (also known as 'sticky valve') can be due to a variety of reasons, a common one which is packing friction.

As far as process control is concerned, the effect of stiction is also like deadband whereby the valve fails to respond when required and when it does respond, overshoots the setpoint. The controller then tries to bring it back the other way.

Hysteresis

Hysteresis occurs when the same change in the controller output in both directions results in a different change in the process value. For example, when the controller output is 20%, the process variable is 30°C. when the controller output increases to 25%, the temperature increases to 35°C. However, when the controller goes back down to 20%, the temperature only goes down to 33°C.

This results in different process gains in both directions and will confuse the controller, which has been tuned for only one process gain. We have to remember that industrial controllers are linear. The following figure illustrates a case of valve hysteresis.

What are Butterfly Valves?

Butterfly valves have a lever that allows the operator to open or close the valve to control the flow. These valves are part of a family known as rotary valves, which are defined by the quarter turn that is used to move from the open to closed position and vice versa. This results in a lower surface friction, which means that these valves can be smaller than others and still operate efficiently.

Butterfly valves are available in numerous closure types and body configurations, depending on the type of flow control needed. These types of valves are commonly composed of metals, like aluminum and stainless steel, but also can be made from various plastics. One kind, flange butterfly valves, can be mounted between flanges. Another, lug butterfly valves, uses metal inserts that are attached to the valve's bolt holes. Using an independent set of bolts for each flange, this valve assembly is fixed between two flanges. Finally, wafer style butterfly valves are the cheapest and most popular type of butterfly valves because of their simplicity and ease of use.

Butterfly valves are used in many food transporting and chemical plants where controllable product flow is required. Other specific industries include HVAC, tertiary petroleum recovery and industries that use high pressure water. When properly used, butterfly valves offer many benefits. First of all, they are lower priced than many other types of valves, and generally have a longer life cycle. Butterfly valves are easy to maintain, are lightweight and compact and are able to handle a wide range of temperatures. These valves are also very reliable because of their tight shut-off, reducing the amount of leakage. One of the problems with butterfly valves, however, is that their design makes it difficult to efficiently and thoroughly clean all residual contaminants. Also, these valves are not good for use with highly abrasive or corrosive materials, because the disc can be easily eroded. Overall, butterfly valves are one of the fastest growing types of valves in the industry.

What are Ball Valves?

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A ball valve (like the butterfly valve, one of a family of valves called quarter turn valves) is a valve that opens by turning a handle attached to a ball inside the valve. The ball has a hole, or port, through the middle so that when the port is in line with both ends of the valve, flow will occur. When the valve is closed, the hole is perpendicular to the ends of the valve, and flow is blocked. The handle position lets you "see" the valve's position.

Ball valves are durable and usually work to achieve perfect shutoff even after years of disuse. They are therefore an excellent choice for shutoff applications (and are often preferred to globe valves and gate valves for this purpose). They do not offer the fine control that may be necessary in throttling applications but are sometimes used for this purpose.

The body of ball valves may be made of metal, ceramic, or plastic. The ball may be chrome plated to make it more durable.

There are three general body styles of ball valves: split body, top entry, and welded.

There are three general types of ball valves: full port, standard port, and reduced port.
- A full port ball valve has an oversized ball so that the hole in the ball is the same size as the pipeline resulting in lower friction loss. Flow is unrestricted, but the valve is larger.
- A standard port ball valve is usually less expensive, but has a smaller ball and a correspondingly smaller port. Flow through this valve is one pipe size smaller than the valve's pipe size resulting in slightly restricted flow.
- In reduced port ball valves, flow through the valve is two pipe sizes smaller than the valve's pipe size resulting in restricted flow.
- A trunnion ball valve has a mechanical means of anchoring the ball at the top and the bottom.

Manually operated ball valves can be closed quickly and thus there is a danger of water hammer. Some ball valves are equipped with an actuator that may be pneumatically or motor (electric) operated. These valves can be used either for on/off or flow control. A pneumatic flow control valve is also equipped with a positioner which transforms the control signal into actuator position and valve opening accordingly.

What are Globe Valves?

Globe valves are named for their spherical body shape. The two halves of the valve body are separated by an internal baffle which has an opening forming a seat onto which a movable disc can be screwed in to close (or shut) the valve. In globe valves, the disc is connected to a stem which is operated by screw action. When a globe valve is manually operated, the stem is turned by a handwheel. Although globe valves in the past had the spherical bodies which gave them their name, many modern globe valves do not have much of a spherical shape, but the term globe valve is still often used for valves that have such an internal mechanism. In plumbing, valves with such a mechanism are also often called stop valves since they don't have the global appearance, but the term stop valve may refer to valves which are used to stop flow even when they have other mechanisms or designs.

Globe valves are used for applications requiring throttling and frequent operation. For example, globe valves or valves with a similar mechanism may be used as sampling valves, which are normally shut except when liquid samples are being taken. Since the baffle restricts flow, they're not recommended where full, unobstructed flow is required.

Globe valves are typically two-port valves. Ports are openings in the body for fluid flowing in or out. The two ports may be oriented straight' across from each other on the body, or oriented at an angle such as a 90° angle. Globe valves with ports at such an angle are called angle globe valves.

A bonnet provides leakproof closure for the valve body. The threaded section of stem goes through a hole with matching threads in the bonnet. Globe valves may have a screw-in, union, or bolted bonnet. Screw-in bonnet is the simplest bonnet, offering a durable, pressure-tight seal. Union bonnet is suitable for applications requiring frequent inspection or cleaning. It also gives the body added strength. A bonnet attached with bolts is used for larger or higher pressure applications.

Economical globe valves or stop valves with a similar mechanism used in plumbing often have a rubber washer at the bottom of the disc for the seating surface, so that rubber can be compressed against the seat to form a leak-tight seal when shut.

Many globe valves have a class rating that corresponds to the pressure specifications of ANSI 16.34. Bibcocks and sillcocks are variations of globe or stop valves used in plumbing. Needle valves are variations of globe valves where instead of a separate attached disc piece, the internal end of the stem is conically tapered to act as the disc to fit into a matching seat for fine flow adjustment. Other different types of valve usually are called globe style valves because of the shape of the body or the way of closure of the disk. As an example typical swing check valves could be called globe type.

What are Gate Valves?

A Gate Valve, or Sluice Valve, as it is sometimes known, is a valve that opens by lifting a round or rectangular gate/wedge out of the path of the fluid. The distinct feature of a gate valve is the sealing surfaces between the gate and seats are planar. The gate faces can form a wedge shape or they can be parallel. Gate valves are sometimes used for regulating flow, but many are not suited for that purpose, having been designed to be fully opened or closed. When fully open, the typical gate valve has no obstruction in the flow path, resulting in very low friction loss.

Gate valves are characterised as having either a rising or a nonrising stem. Rising stems provide a visual indication of valve position. Nonrising stems are used where vertical space is limited or underground.

Bonnets provide leakproof closure for the valve body. Gate valves may have a screw-in, union, or bolted bonnet. Screw-in bonnet is the simplest, offering a durable, pressure-tight seal. Union bonnet is suitable for applications requiring frequent inspection and cleaning. It also gives the body added strength. Bolted bonnet is used for larger valves and higher pressure applications.

Another type of bonnet construction in a gate valve is pressure seal bonnet. This construction is adopted for valves for high pressure service, typically in excess of 15 MPa (2250 psi). The unique feature about the pressure seal bonnet is that the body - bonnet joints seals improves as the internal pressure in the valve increases, compared to other constructions where the increase in internal pressure tends to create leaks in the body-bonnet joint.

Gate valves normally have flanged ends which are drilled according to pipeline compatible flange dimensional standards. Cast Iron, Cast Carbon Steel, Gun Metal, Stainless Steel, Alloy Steels & Forged Steels are different materials in which Gate Valves are made available.

What are Solenoid Valves?

Solenoid valves are electrically operated devices that control the flow of liquids. Solenoid valves are electro-mechanical devices that use a wire coil and a movable plunger, called a solenoid, to control a particular valve. The solenoid controls the valve during either the open or closed positions. Thus, these kinds of valves do not regulate flow. They are used for the remote control of valves for directional control of liquids. Solenoid valves have two main parts: the solenoid and the valve. After the coil receives a current, the actuating magnetic field is created. The magnetic field acts upon the plunger, resulting in the actuation of the valve, either opening or closing it.

There are two general types of solenoid valves: direct-acting and pilot-operated. Direct-acting solenoid valves have a plunger that is in direct contact with the primary opening in the body. This plunger is used to open and close the orifice. The pilot-operated solenoid valve works with a diaphragm rather than a plunger. This valve uses differential pressure to control the flow of fluids. The air-venting valve is opened to allow the pressure to equalize and permit the fluids to flow through.

The design of solenoid valves allows them to have many applications. Their most common use is as water valves, oil valves, gas valves, steam valves, solvents valves, cryogenics valves, air and vapors valves, as well as many other applications as hydraulic valves and pneumatic valves.

Typical environments for solenoid valves are in medical and biomedical equipment, analytical instrumentation, semiconductors, HVAC and other industrial OEM environments. A unique feature that solenoid valves have is the automatic triggering from remote locations by different voltages, making them useful in rough or hazardous locations.

Important items to consider when looking at solenoid valves are proportionality, linearity, frequency response, repeatability, power consumption, leakage, life expectancy and cost. With so many types of solenoid valves and other related valves, the application requirements are very important. Because solenoid valves are designed to perform operations, ranging from water valves, air valves pneumatic valves or used in applications such as ones to restrict, meter and maintain the flow of liquid and gaseous materials, they are widely used in vastly different fields and industries.

What are Check Valves?

Check valves, also referred to as "non-return" or "one-way directional" valves, are very simple valves that allow fluid, air or gas to flow in only one direction. When the fluid moves in the pre-determined direction, the valve opens. Any backflow is prevented by the moveable portion of the valve. A swinging disc, ball, plunger or poppet moves out of the way of the original flow. Since these devices are slightly larger than the through hole, the pressure of backflow will cause them to tightly seal, preventing reversal of flow. Gravity or a spring assists in the closing of the valve.

Check valves are indispensable in every area of life. Domestically, they are found in devices such as faucets, toilets and dishwashers. Without them, fresh water would be impossible and common plastics would be unheard of. Industries use them to control flows of all types—from the thinnest gas to radio active materials, from molten metal to highly corrosive materials. Check valves can range in size from less than an inch in diameter to 30 feet across. The simplest check valves can be purchased at the local hardware store, but they may also be precision-designed for highly sophisticated systems.

As aforementioned, check valves use different means of preventing backflow. Swing disc valves are typically used with liquids, such as slurries, that can easily damage the valve seat. They may be installed either vertically or horizontally, but a lever and counter-balance is recommended when vertically installing swing disc valves. Ball check valves use a ball with a small hole in the middle, which can be either free-floating or spring-loaded. These valves have a wide variety of applications. They are more resistant to plugging than other valves, and thus can be used to handle even fluids that deposit gummy residue. A check valve may also utilize a plunger, which is spring-loaded and usually used to prevent backflow of pressurized gases, or backpressure. A poppet in a check valve is spring-loaded and typically installed in systems that require prevention of backpressure.

Because check valves have so many applications, they are made of a wide variety of materials. Some companies exclusively manufacture plastic check valves. Other companies produce check valves made of brass, electroless nickel plated brass and stainless steel. The components of valves may be made of different materials, such as cast iron or bronze, depending on the application. Specialized valves may also be constructed of Teflon. Elastomer products may also be used to construct valves.

What are Hydraulic Valves?

Hydraulic valves are used to contain and transfer the flow and pressure of hydraulic fluid in hydraulic power systems. The specific types of valves range from those that have simple shutoff valves to precise control valves used in motion control systems. The basic components of a hydraulic valve are its body, bonnet, disc and seat. Other types of valves have variations of these components, depending on their specific functions. Hydraulic valves are very similar to other valves in general purpose, regulating flow and design, but unlike many others, hydraulic valves are strictly used in hydraulic-related systems and components.

Hydraulic valves allow the flow of fluid when in their open position and prevent flow when closed. These valves work in tandem with hydraulic cylinders , pumpsand motors to maintain a proper flow of hydraulic fluid through a system. Some examples of hydraulic valves that are commonly used include solenoid valves, ball valves, directional control valves and relief valves.

These valves are used for sealing and releasing in different situations, and some allow flow in only one direction while others are capable of managing more. Many hydraulic valves are computer controlled and do not require the monitoring of an operator.

Most valves are used within a fluid control system as a simple way to prevent improper levels of pressure and fluid from flowing. Some valves simply shut off flow when flow rates get too high. Other valves are designed to send impulses to valves further down the hydraulic line in order to provide a systematic balance of flow. Still other valves will direct the stream of the fluid to specific areas where fluid is needed, as do directional control valves. Directional control valves often have more than the standard two connections. Hydraulic tools and vehicles that use hydraulics commonly use these types of valves.

The size and shape of hydraulic valves can vary greatly. Narrowing of the fluid passage is a common method for reducing the overall size and cost of a valve. Sometimes a larger end is connected to a valve in order to make the valve capable of connecting to a larger line. Some valves use electro-magnetic power to actuate the valve. Current is applied to a coil within the valve and a magnetic field is created. These types of valves are used as a manual switch or control within a hydraulic system.