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The Purpose, Use and Care of Process Control Valves.

Training For Operators, Maintainers, Technicians and Engineers.

Training Objective

This training teaches users and maintainers of process control valves why they are used, how they work, what causes them to go wrong and what is necessary to keep them operating properly.

Training Contents

- Purpose of the equipment.
- The principles of how the equipment works.
- Important parts and assemblies.
- In-service design and operation.
- How the equipment achieves its purpose and the necessary operating conditions.
- Most likely failure modes, their causes and what to do about them.
- On-Site, workshop or test bench observations of an equipment installation.
- Conduct site tests and trails on the equipment operation.
    - Compare the installation to the minimum design required.
    - Predict effect of changes.
    - Observe actual changes.
    - Identify impact of changes to the equipment operation.
- Learning Assessment
    - Explain purpose and use of equipment.
    - Identify how the equipment achieves its purpose.
    - Specify the required operating conditions for proper performance.
    - List what failures are possible at the workplace and how to fix them.
    - Training Supervisor review.

Outcomes of the Training

This training makes trainees clear and knowledgeable in the proper use, care and maintenance of process control valves. It gives them in-depth knowledge of the equipment and factors that affect operation. They will use the new know-how to better operate, tend and maintain such equipment.

Time Required

The training takes one hour to complete for able people with some industry experience.

Training in the Purpose, Use and Care of Process Control Valves

Purpose of the Equipment

A control valve is used to regulate and adjust the conveying of a liquid, gas or vapour to a desired flow rate. Whenever it is necessary to meter a liquid or gas into a process, a control valve can be used. The control valve adjusts the flow to maintain a required condition in another part of the process. The required process condition is pre-set and the control valve changes the flow through itself to hold the process condition at that setting.

Figure 1 is an example of a control valve being used to maintain a level in a reservoir. The position of the float is set during installation. The water flow into the reservoir is regulated by the control valve. The control valve is adjusted by a signal coming from the float in the stilling well. The float in the water of the stilling well 'tells' the control valve to either open, close or hold its current rate of filling. By adjusting the flow into the reservoir the level is kept at the set point.

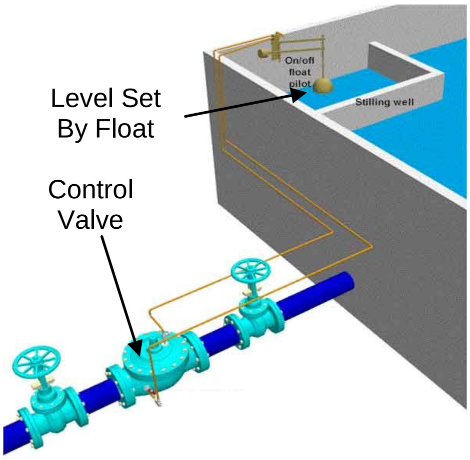


Figure 1 – Level Control Valve

In this way a control valve can adjust a process flow to suit the variable, or changing, requirements in a different part of the process. It makes an adjustment so that when the flow reaches that particular point in the process it is what is needed, that is the process is in control.

Principles of How the Equipment Works

The control valve is part of a control loop. A control loop is a chain, or series, of equipment that act together to control a process variable or process requirement. Most processes are automatic and self-adjust. They use closed-loop control. In closed-loop control information is measured about the process variable, or process condition, to be controlled, and that information is fed back to a controller to adjust the control valve.

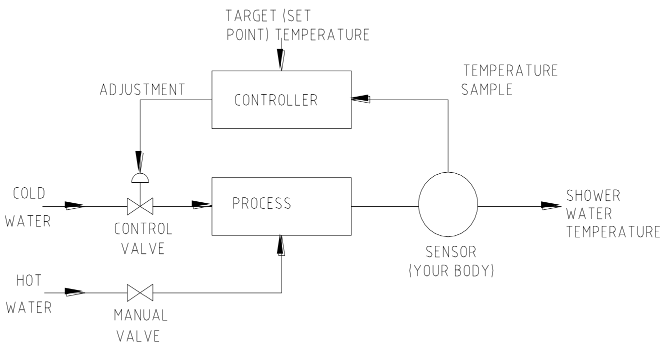


Figure 2 – Auto-Control in the Shower

As an example of how automatic process control works imagine that you are in a shower and you need to change the temperature. A diagram of the control equipment and process that we will use is

If the hot water is first put on, the control valve becomes the cold water tap. Your body senses the temperature of the water. If the water is too hot you open the cold water tap. You wait a while (the time lag) to sense the effect of increasing the cold water flow. You adjust the cold water until the temperature from the combined flows is just right. Once the temperature is right the valves are left alone and the temperature is stable. If a change occurs, such as someone doing the laundry with cold water, there is a drop in cold water flow to the shower. The shower water gets hotter. You sense the changing temperature and make adjustments to the taps. In response you open the cold water tap further or close the hot water tap.

The whole process involved sensing the temperature and moving the valve positions until the parameter under control (shower temperature) stabilised. A control valve works the same way.

Important Parts and Assemblies

The Control Valve

Within a control valve body is a hole or gap that can be opened and shut. The opening consists of a seat and a sealing plug, disc or ball. The seat and plug, disc or ball are known as the 'valve trim'. The trim can be selected to create a variety of passage shapes that control the flow in deliberate ways. A control valve opens the gap by moving the plug, disc or valve away from the seat. The length of the stroke determines the opening size and how much liquid, gas or vapour passes the seat.

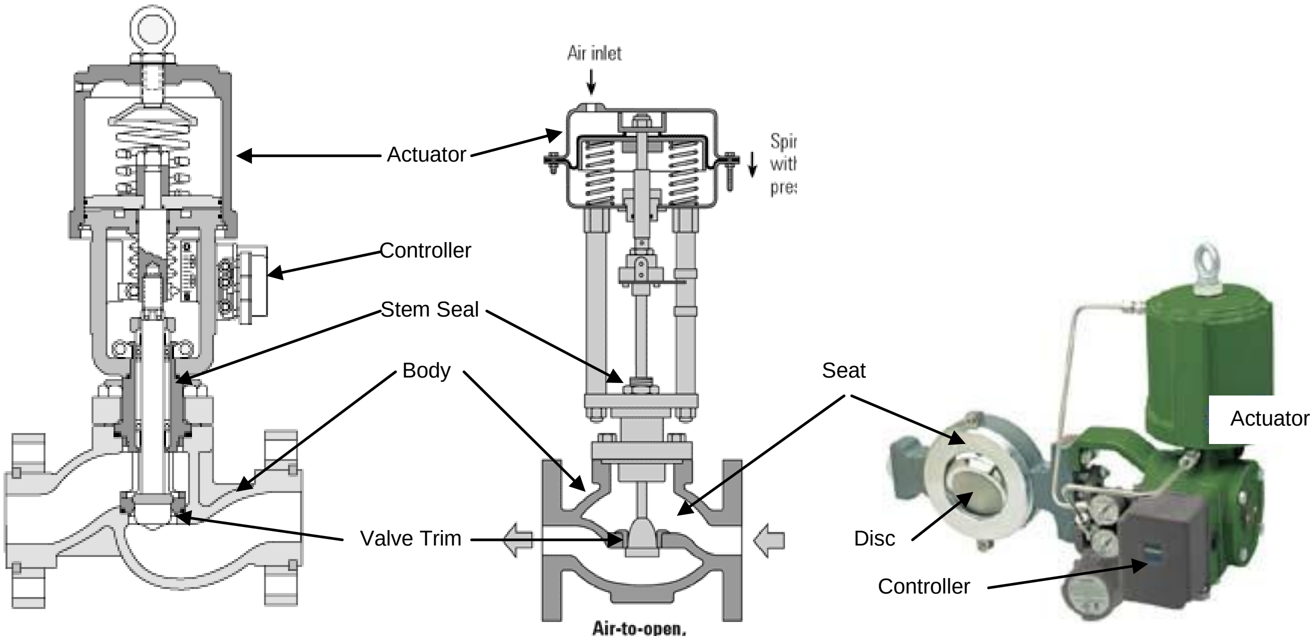


Figure 3 Control Valve Trim Types and Components

By altering the size of the internal gap the control valve increases, decreases or holds steady the flow through itself. The control valve alters the opening whenever the process parameter, or variable, being controlled does not equal the value it is meant to be (the set point).

The rate of flow through the valve depends on the pressure difference between the upstream inlet pressure and the downstream outlet pressure. To slow the flow the valve is closed, which causes a greater difference between the inlet and outlet pressures. The backpressure forces the fluid to slow. To increase the flow the valve is opened, which reduces the pressure difference across the valve. The higher backpressure can now flow more freely through the valve.

Figure 4 shows a control valve and air operated actuator. The actuator has a diaphragm pushed up by strong springs. The diaphragm is connected to the valve stem, at the bottom of which is the valve plug. With the stem forced upward by the springs, the plug is firmly held against the seat and the valve is shut tight.

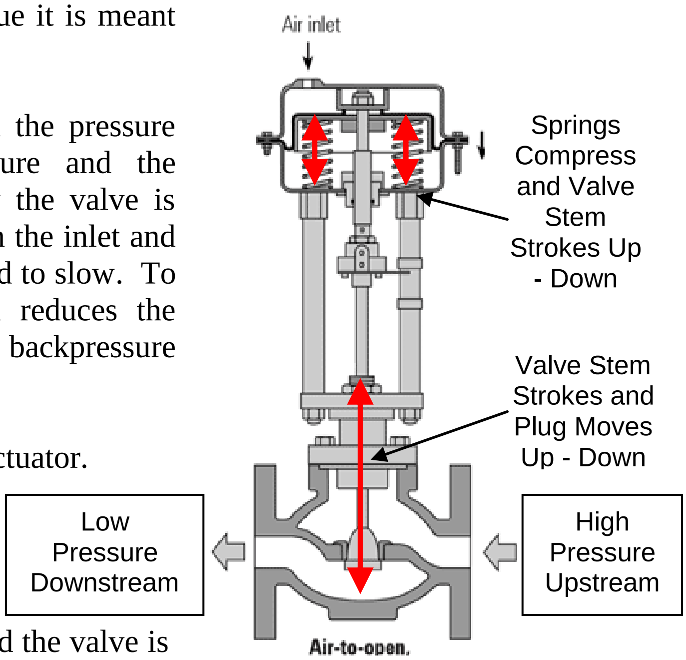


Figure 4 - Control Valve Stroking

To move the plug and open the valve air is introduced into the space above the diaphragm. The air pressure forces the diaphragm down and compresses the springs. When the diaphragm moves down the valve stem strokes and the plug moves off the seat. The process fluid then flows from the high pressure upstream through the gap now created between seat and plug to low pressure downstream.

The Sensing Element

The equipment that measures the process condition being controlled is known as the sensing element.

Temperature Pressure Flow Level Conductivity

Figure 5 Various Process Condition Sensing Elements

The process conditions measured by the sensing element include temperature, pressure, flow, level, weight, chemical strength, colour, and even noise. Figure 5 shows a range of sensing elements used to detect and measure a particular condition that is important to control so that the right product is manufactures to its quality specifications.

The sensing element is located at a key position in the process where it can detect the true process values. If the sensing element provides wrong information then the process cannot be done right.

The Valve Controller

In order for the valve plug, disc or ball to move it must be 'told' where to move to. The position of the stem is managed by the controller. The controller can be a remotely located computer programmed with software to adjust the stem position. It can also be locally mounted on the valve body or nearby on the wall. Figure 6 shows a control valve with a locally mounted controller that can be programmed by computer.

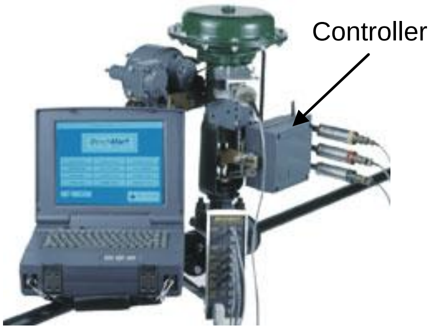


Figure 6 – Local Controller

The job of the controller is to adjust the control valve opening to a point that keeps the controlled process condition, or variable, where it should be - its set point. The controller uses the detected condition in the process being controlled and compares it to what it needs to be. If they are not the same the controller makes adjustments to the size of the opening in the control valve.

The Valve Positioner

A valve positioner is used to accurately locate the valve stem in spite of the unbalanced forces generated in the valve body from the pressure differences across the opening and from stem seal rubbing.

The positioner detects the location of the valve shaft and measures its travel distance. At the same time, for pneumatic actuation, it also measures the pressure in the pneumatic actuator. It alters the pressure in the actuator and so forces the valve stem to move. When it changes the actuator pressure the combined force created by the process pressure in the valve body and the actuator springs makes the stem move. This causes a change in the flow through the valve which then affects the process variable being controlled.

The positioner acts against the forces generated from the process pressure and the actuator so the opening in the valve trim allows the requirements of the process to be met.

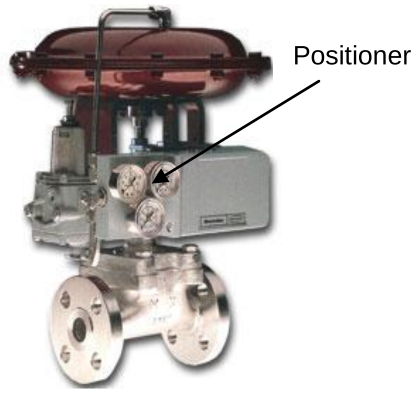


Figure 7 - Valve Positioner

<u>The Valve Actuator</u>

The actuator is used to move the valve stem into the position required to maintain the process variable set point.

Valve actuators are typically pneumatic, i.e. air or gas operated, or they can be electric motor operated. An electric motor operated actuator is shown in the top left picture of Figure 8. Pneumatic actuators can be the bonnet style with a diaphragm inside the bonnet, as in the lower picture of Figure 8. Or they can be the rotary style with a cylinder and ram within the actuator body, as in the top right picture of Figure 8.

Figure 8 - Valve Actuators

Rotary actuators are used on quarter turn valves such as ball, plug and butterfly valves. There are usually the lower cost control valves. Bonnet actuators are used on globe, gate and sliding valves. Rams can also be fitted to axially closing valves as shown in the actuator of Figure 9.

Springs can be fitted within the actuator to both provide assistance in moving the stem and to insure the valve fails in a safe position if there is a loss of signal to the valve. It is a very important requirement for the actuator is to ensure the valve returns to a fail-safe position if the valve cannot control.

At times the control signals can be lost due to a power failure, lightning strike, vehicle impact, accidental damage, damaged control cables, aging equipment, equipment failure, etc. If the valve was to remain open in such cases, without a way of adjusting itself to control the process, the process may 'run-away' and lead to dangerous or unsafe situations.

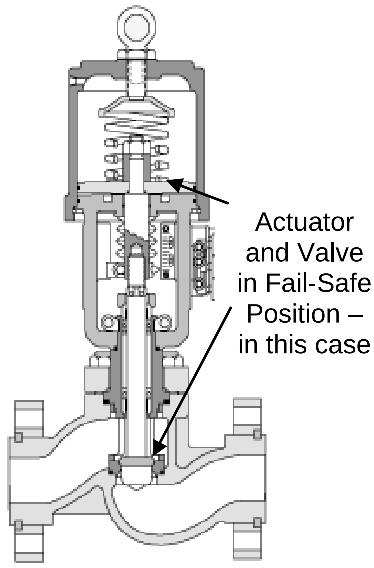


Figure 9 - Valve in Fail-Safe Closed Position

<u>The Valve Trim</u>

The control valve trim are the items inside the valve that work together to restrict the flow. The trim sits within the valve body and comprises the seat or cage in the body and the movable plug, disc or ball. Figure 10 shows a wide variety of trim types.

In situations where the control valve has to drop a lot of pressure between the upstream and downstream sided the trim incorporates means to cause large pressure loss across the valve. Such trim can be cages with holes within other cages with holes or slots. The flow paths have pressure staging shapes which achieve the required pressure drop while avoiding conditions that would cause trim damage.

Trim design of the valve affects how the flow through the control valve changes as the valve moves through its complete travel. Because of the variation in trim design, many valves are not linear in nature. That means that a percentage of valve movement does not produce an equal percentage of changed flow.

Valve trims are instead designed, or characterized, to meet the large variety of control applications. Many control loops have inbuilt non linear behaviour, which may be possible to compensate by selecting a certain control valve trim style.

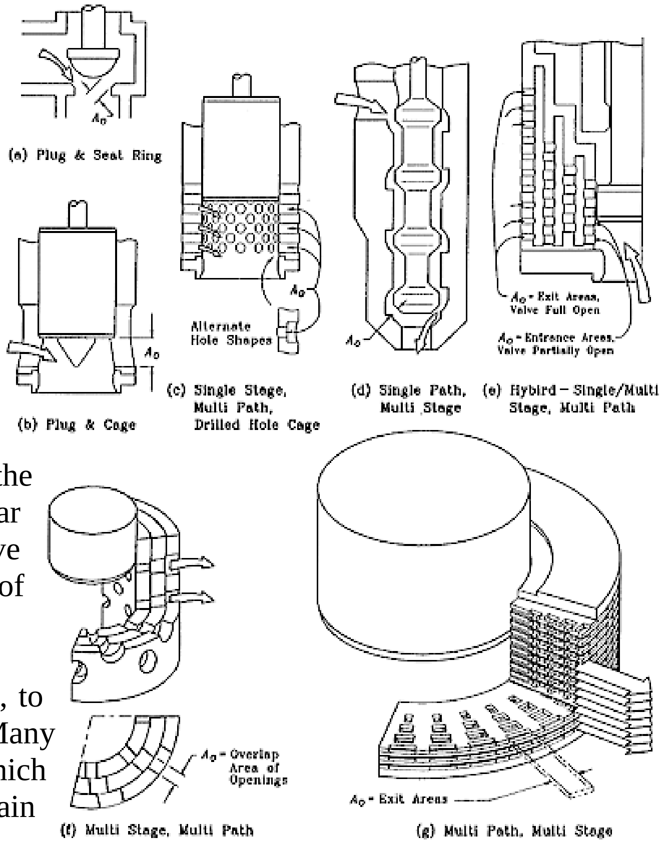
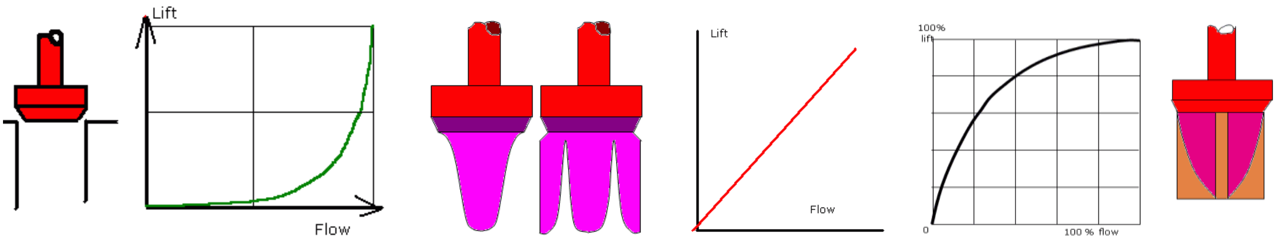


Figure 10 – Variety of Control Valve Trim

The relationship between control valve throughput and valve stem travel is known as the Flow Characteristic of the Control Valve.



Quick Opening Linear Equal Percentage
Figure 11 How Valve Trim Affects Flow Characteristics Through A Control Valve

The most common characteristics and plug shapes that produce them are shown in the figure above. The percent of flow through the valve is plotted against valve stem position. The curves shown are typical of those available from valve manufacturers. These curves are based on constant pressure drop across the valve and are called inherent flow characteristics.

Linear - flow through the valve increases linearly with valve travel.
Equal percentage - flow capacity increases exponentially with valve trim travel. Equal increments of valve travel produce equal percentage changes in the flow through the valve.
Quick opening provides large changes in flow for very small changes in lift. It usually is limited to on-off service because the change in flow is so huge for a small change in position that the control valve would be fluctuating open-closed continuously trying to keep a steady flow.

The majority of control applications are valves with linear, equal-percentage or some modification of these flow characteristics.

In-Service Design and Operation

Figure 12 shows a basic installation for a control valve. The strainer upstream is to protect the small passage ways in the valve trim from becoming blocked due to particles and sediment.

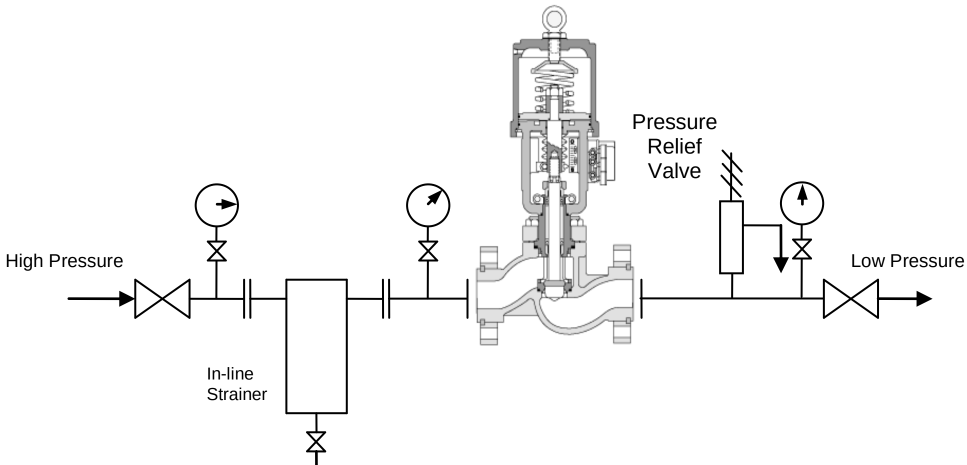


Figure 12 - Basic Control Valve Station

If the control valve were in a steam line or gas line where moisture is present then it would be necessary to install condensate removal liquid traps before and after the valve. If the condensate is not removed there is a great likelihood that a slug of condensate will smash into the valve internals at high flow rates, and during start-up when the valve is first opened and product is rushing through.

How The Equipment Achieves Its Purpose And The Necessary Operating Conditions.

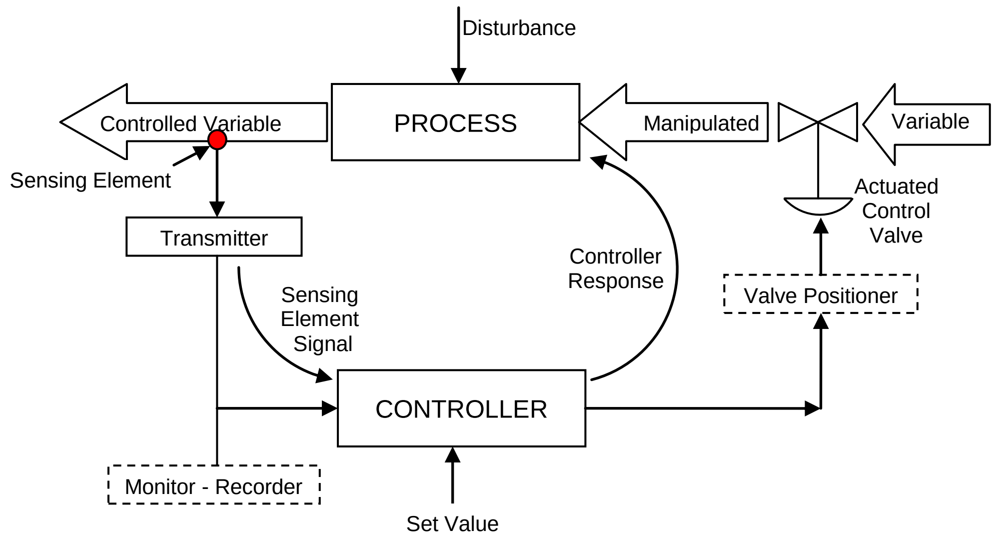


Figure 13 – Closed-Loop Process Control

Figure 13 shows a typical closed-loop control system. A signal is taken of the process variable under control and input into the controller. The controller generates an output signal to correct any difference between the process variable and the set point that it should be. The signal drives the final control element, the control valve, in a direction that tens to return the controlled variable to the desired condition.

The controller tuning dictates the way the control valve responds to the changing process variable. The tuning of a control valve sets the speed and intensity of the valve response when the need for a correction is detected. The controller contains internal logic that produces an output to the actuator to move the stem a predetermined amount. To determine how fast and how far to move the stem the logic looks at:

a) the size of the discrepancy between the set point and the current value of the controlled parameter (Proportional),
b) the length of time the discrepancy has been present (Integral),
c) the speed at which the discrepancy has been changing (Derivative).

Once the position of the trim is altered the controller waits for the next sample signal from the sensing element to check the difference remaining to` the set point. The valve stem is moved and the flow altered until the difference between the set point and the actual value of the controlled parameter is within tolerance. An illustration of tuning a control valve can be likened to the earlier example of adjusting the shower taps to get the water temperature right. The sketch below shows the logic involved in controlling the water temperature.

<u>Possible Failure Modes Causes, Prevention and Corrective Actions</u>

There are several key factors that must be confirmed to insure successful equipment operation so that the process is controlled and quality product is produced.

- The control loop needs to be kept in tune so that the control valve regulates the way the process requires it to. The calibrations can be regularly to a predetermined schedule or they can be done whenever it is noticed that the control valve is not adjusting the process correctly. In quality critical or safety sensitive situations the control valve calibrations must be done to a schedule as proof that you are managing the situation. Complete records of before and after performance values must be recorded for historical proof of proper calibration.

- Control valves can be sized too large. An overly large control valve is insensitive when fine adjustments are needed, and it is an unnecessary expense. Usually control valves are one or two line sizes smaller than the pipe they are in.

- A control valve can have excessive lag (react too late) because the sensor is located too far away. Keep the sensor close to the control valve position, yet just far enough away to be sure it is sensing the true reading. Also keep the control valve close to any blending point so that there is little product left in the line that must first be run out before a control variation progresses through the pipe to the blend point.

- The pneumatic actuator air supply pressure can be low or it leaks away and so produces insufficient force to move the stem. This is a regular maintenance issue and at least one a year the valve and air connections need to be checked for leaks and damage.

- The control valve stem can become sticky if the packing is tight or product leakage causes binding of the stem. When a control valve is sticking it requires maintenance to replace the stem seal. Else you cannot be sure that the positioner will be able to move the stem to the right place in sufficient time.

- Complicated and intricate process control loops are difficult to keep in tune and if they go out of tune too often they are left that way and the valve is put into manual control. Because of the continual inconvenience and downtime retuning the loop people just give up and get into the habit of adjusting the valve manually. This introduces a major risk to product quality and equipment integrity. It is better to use more process control equipment which results in a simple, reliable plant than to have too few instruments and control valves set-up in complicated ways.

- High velocity through the valve trim will create noise, vibration and cavitation at low pressure points. This usually means the control valve is trying to drop a high pressure difference across the trim. Often a change in trim design is needed to release the pressure across more steps or stages. Another possibility is to install a means to reduce some of the high pressure elsewhere upstream, such as an orifice plate or needle valve, before it enters into the control valve.

- Control valves in gas or vapour service will need to have condensate removal traps before and after the valve. If condensate is not removed the slug of liquid will travel at high velocity down the pipeline and hit the next thing down-line.

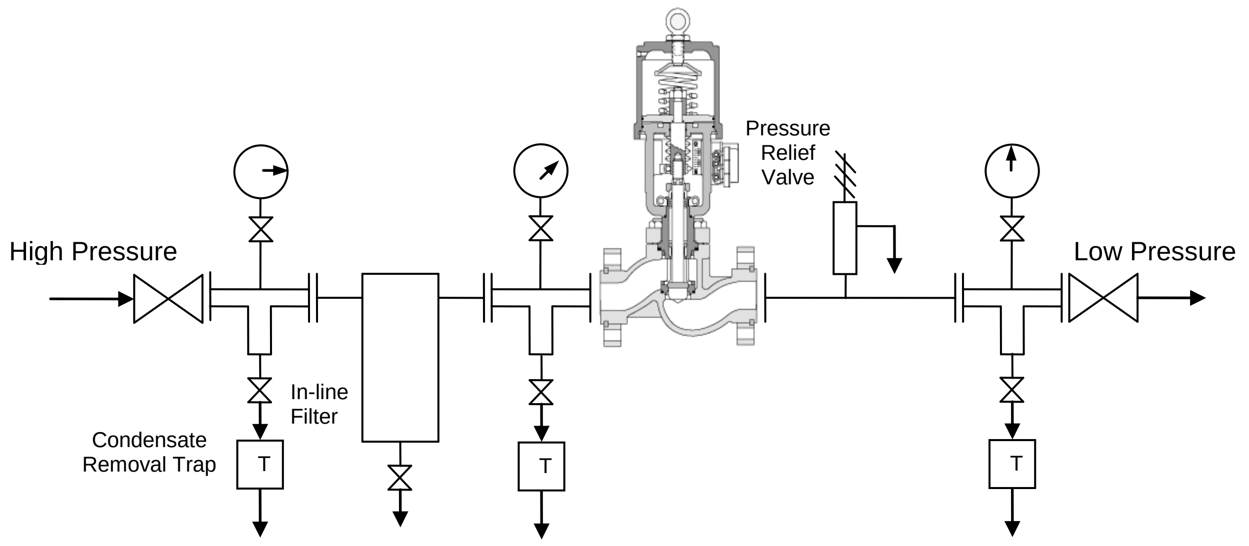


Figure 7 Pressure Reduction Station with Condensate Removal

On-Site Test, Workshop or Lab Test of an Installation and Learning Assessment

It is now time to do some 'hands-on' training in the field, or with a spare, or on the test-bench. To thoroughly understand this topic it is best to see what happens in a working situation and practice by making and controlling changes. You will better understand what the equipment does, and how to run it well, if you can operate it. Locate suitable equipment in your plant or spares that you will be allowed to adjust and inspect.

1. Locate the manufacture's operating manual if available or find it on-line over the Internet. Take the time to read it. Tag anything you don't understand and come back to it at the end of the training to see if you come to know what they mean.

2. Hand-sketch below the chosen control valve and sensor installation at your workplace and write the name of the individual equipment items on the sketch. If there is more equipment used in the station than the minimum basic design previously shown write down what each extra item of equipment is used for in the space under the drawing.

3. Close Inspection

3.1. Get a control valve, open it and look inside. If that is not possible get a manufacturer's manual for the valve you use. Using the manufacture's manual, name and describe each part.

3.2. Write a short description of how the valve is built and how it is designed to work.

3.3. Describe how the valve up is set for the required service in your facility. How is it calibrated?

4. If at all possible, and once you have supervisor permission, operate the equipment to see what effects happen as the operating conditions change. If you cannot operate a real item of equipment, then describe as best you can using information from your reading and discussion with others, what will happen to the process due to the change.

4.1. Start-Up Conditions.

Describe what see and hear, and how much the pressure changes, upstream and downstream of the control valve once it is in use.

4.2. Process Fluctuations.

Shut the downstream isolation valve as if there were a blockage and describe what happens to the pressures, flows and valve equipment. Repeat the same for the upstream isolation valve.

5. Possible Modes of Failure

5.1. List the ways that control valves have failed to perform properly at your workplace. Talk to the experienced operators and maintainers if necessary.

5.2. Getting the Equipment Back to Proper Operation.

For each failure mode listed above, describe in detail what needs to be done to correct them.

This is the end of this training. Please record the following details and hand your answers back to the supervisor in charge of this training.

Trainee ________________________________ **Signature** ______________________________
(Print Name) (Trainee)

Supervisor ______________________________ **Signature** _____________________________
(Print Name) (Supervisor)

Assessment Result: ☐ Pass

☐ Repeat

Completion Date ___________________ 'Pass' recorded in the Trainee's training records ☐