Control Valve

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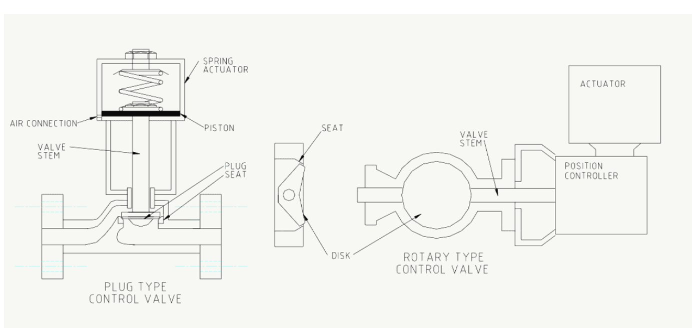
<u>Objective</u> : To study the following characteristics of the above-mentioned valves

1) Inherent Characteristics
2) Installed Characteristics
3) Control Valve Coefficients
4) Rangeability

<u>Theory</u>:

The rate of fluid flow is regulated by a control valve when the position of the valve plug or disc is altered by an actuator. Control valves are used to keep a process variable as close to the target setpoint as possible. Flow rate, pressure, and temperature are commonly used as controller setpoints. A control valve is also referred to as a "final control element".Control valves are used in just about every process system used at wellsites, oil batteries, gas plants, refineries, and petrochemical plants. Electrical, hydraulic, or pneumatic actuators are commonly used to open or close automatic control valves. Valve positioners are typically used with modulating valves, which can be set to any position between fully open and totally closed, to ensure the valve achieves the required degree of opening.A valve body, actuator, positioner, and accessories make up a control valve installation. A bonnet assembly and trim pieces are included in the body. Its design can endure fluid static pressure and differential pressure while also allowing fluid flow, providing pipe-connecting ends, and supporting seating surfaces and a valve closure part. Actuators are devices that provide the force to open and close valves. They can be pneumatic, hydraulic, or electrically operated. To maintain a desired set-point, positioners monitor and control real actuator movement. Electro-pneumatic transducers, pressure regulators, hand wheels, position indicators, and limit switches are examples of accessories.

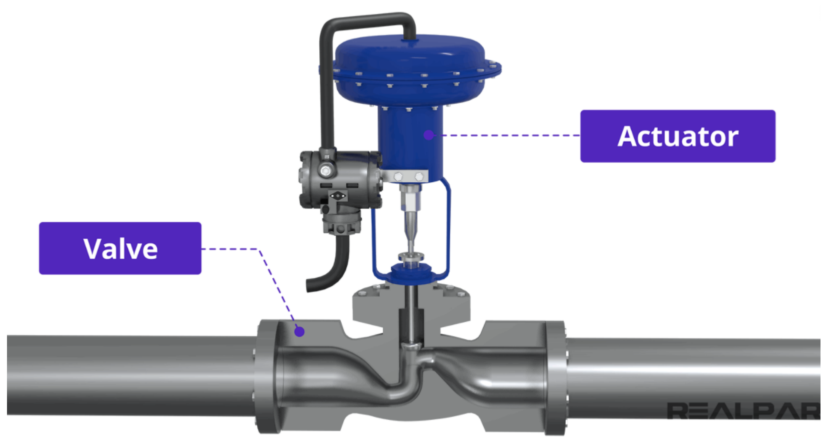
A pneumatic actuator is primarily made up of a piston or diaphragm that generates motive force. It allows air pressure to drive the diaphragm or piston to move the valve stem or rotate the valve control element by keeping air in the top portion of the cylinder.Pneumatic Actuators use an air or gas signal from an external source to produce a modulating control action.



The actuator receives the force of the pneumatic signal through a top port. Then, it distributes the signal across the actuator's diaphragm. As a result, the diaphragm exerts pressure on the diaphragm plate. This moves the valve stem downward in a way that strokes the control valve.Diaphragm valves (also known as membrane valves) are made up of a valve body with two or more ports, an elastomeric diaphragm, and a "weir or saddle" or seat that the diaphragm shuts. Depending on the intended function, the valve body might be made of plastic, metal, wood, or other materials.

Three main components of a control valve are:

- Valve actuator: It is further classified into 3 types namely electrical, hydraulic and pneumatic actuators. Basically, actuators utilize the energy from electricity, air or water to perform some mechanical movements.
- Valve positioner: A positioner monitors and receives feedback from the valve stem and helps in maintaining the desired setpoint value by increasing or decreasing the air load pressure on the valve actuator.



- Valve body: This is the framework that holds everything together. It remains in direct contact with the liquid and contains the modulating element, plugs, globe, ball etc.

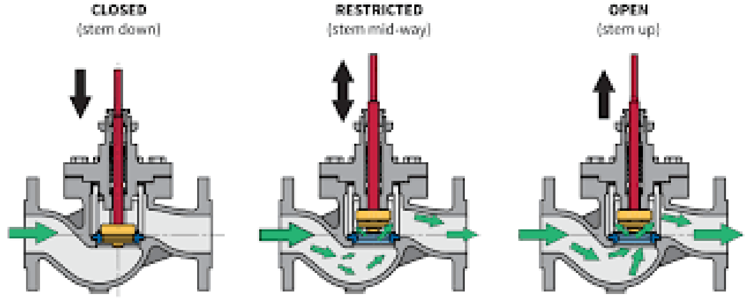
- Other important parts include bonnet, trim, position indicators, limit switches, handwheels, pressure regulators, and electro-pneumatic transducers.

Working of a Control Valve

The control valve is the most frequent final control device in the process control industry. To compensate for the load disturbance and keep the regulated process variable as close to the desired set point as possible, the control valve manipulates a flowing fluid, such as gas, steam, water, or chemical compounds.

Control valves are the most critical aspect of a control loop, yet they're also the most overlooked. The instrument engineer's lack of acquaintance with the numerous elements, terminology, and areas of engineering disciplines such as fluid mechanics, metallurgy, noise control, piping and vessel design that can be involved depending on the severity of service conditions is frequently the reason.

- Compressed air pressure is supplied to a flexible diaphragm to generate the operating force. The actuator is built so that the force exerted (in the opposite direction) by the spring is exceeded by the force generated by air pressure multiplied by the area of the diaphragm (s).
- An airtight Diaphragm separates the top chamber of the housing into two parts, with pressure delivered from the controller to the top region and pressure supplied to the bottom region by/to the spring-loaded stem, which is connected to the plug beneath. As a result, the Diaphragm's motion is driven by the net action of pressure from both sides.
- When the fluid flow exceeds the desired amount, the sensor sends a signal to the controller, instructing it to boost the air pressure for the top channel, which is 15 psi. As a result, the diaphragm is pushed down, and the plug is pushed into the orifice cross section, decreasing fluid flow.
- When the fluid flow is less than the desired amount, the sensor sends a signal to the controller to lower the air pressure for the top channel, which is now set at 3 psi. The diaphragm is forced upward together with the stem by the compressed spring's pressure action, which opens the aperture and increases fluid flow.



Stem Raises and Lowers to Control Flow from Inlet to Outlet

<u>Flow capacity characteristics of Control Valve</u>

- The Flow Link is the relationship between control valve capacity and valve stem travel. The control valve's trim design affects how the control valve capacity varies as the valve travels through its full range of motion. Many valves are not linear in nature due to variations in trim design.
- Valve trims are created, or characterized, to fulfill a wide range of control application requirements. Many control loops have intrinsic nonlinearities that can be compensated by adjusting the control valve trim.
- The shape of the plug primarily decides the flow characteristics. The flow characteristic of a valve is normally defined in terms of:
    - Inherent or ideal characteristics: Decided by the shape and size of the plug.
    - Effective or installed characteristics: When valves are installed with pumps, piping and fittings, and other process equipment, the pressure drop across the valve will vary as the plug moves through its travel.
- By maintain a constant pressure drop condition across the valve, we can plot the percent of maximum flow through the valve against stem position (its displacement) for different types.

In general, the equation for flow rate in a valve is given by:

$$q = C \times \sqrt{\frac{\Delta P}{G}} \quad \text{where } C = Cv \times f(x)$$

x is the relative position of the valve plug to its closed position.
The value of f(x) varies from 0 to 1 and it depends on the flow characteristic of the valve. As mentioned above, by keeping the values of the square root term on the right-hand side constant, the flow rate varies exactly as f(x).

Depending on the function f(x), control valves are classified into:

Linear Valves:

- These valves are designed in such a way that flow rate varies linearly with valve lift, at a constant differential pressure. This relationship is achieved by maintaining a linear relationship between valve lift x and orifice pass area. Since the pass area is directly proportional to flow rate, by transitive property flow rate is also directly proportional to valve lift.
- f(x) can be expressed as (K * x), where K is any constant.

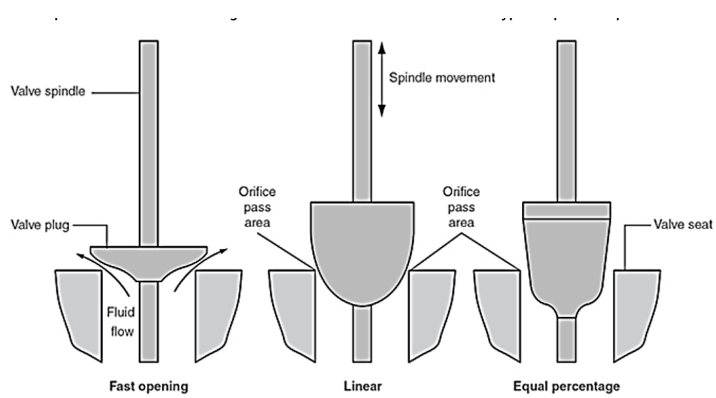
- Linear valves are used in most applications except temperature control, some of the common applications are :
    - These valves are often used for liquid level control and certain flow control operations requiring constant gain.
    - Used in systems where pressure drop across the valve is expected to remain constant.
    - Used when the pressure drop across the valve is a large proportion of the total pressure drop.

Equal Percentage Valves:

- These are the most commonly used valves. They are designed such that each increment in valve lift increases the flow rate by a certain percentage of the previous flow.
- The inherent valve characteristic, f(x) is generally given by manufacturers in the form f(x) = R ^ (x-1), where R is a constant.
- The relationship between flow rate and valve opening is logarithmic.
- These valves are used in systems where a large pressure drop is expected but it is desired that the pressure drop through the valve should be small compared to the total drop in pressure. They are also used in temperature and pressure control loops where linear valves cannot be used.

Quick Opening Valves:

- These valves provide a large change in the flow rate for a very small change in valve lift. The characteristic of the valve resembles a linear relation in the beginning but an additional increase in the valve lift increments the flow with a sharply decrease slope.
- Because of their high gain, they cannot be used in modulating control and are generally limited to on-off services such as sequential operation of batch or semi-batch operations. They are also widely used in coolant systems and other safety systems where instantly large flow is desired.
- The relationship between control valve capacity and valve stem travel is known as the Flow



Observations

Valve - 1

Lift (mm)	Flow rate (LPH)	Press drop (mm H2O)
30	400	68
22	250	68
14	100	68
10	70	68

Valve-2

Lift (mm)	Flow rate (LPH)	Press drop (mm H2O)
30	580	105
22	340	105
14	170	105
10	50	105

Valve - 3

Pressure (psig)	Lift (mm)	Press drop (mm H2O)	Flow rate (LPH)
3	2	25	120
5	4	25	560
7.5	14	25	570
10	22	25	580
12.5	25	25	590
15	30	25	600

S.No.	**Flow rate (LPH)**	**Press drop (mm H2O)**
1	88	500
2	108.5	540
3	73	460
4	57	420

Calculations

1) **Study of Control Valve Co-efficients**

a) **Linear Valve Characteristics**

Lift (mm)	**Flow rate (LPH)**	**Press drop (mm H2O)**	**Q**	**delta P (bar)**
30	400	68	0.4	0.006668344627
22	250	68	0.25	0.006668344627
14	100	68	0.1	0.006668344627
10	70	68	0.07	0.006668344627

b) **Quick Opening Valve**

S.No.	Flow rate (LPH)	Press drop (mm H2O)	Cv
1	88	500	6.243
2	108.5	540	6.073
3	73	460	6.307
4	57	420	6.516

c) For equal percentage control Valve

Pressure (psig)	Lift (mm)	Press drop of H2O (mm H2O)	Flow (LPH)	Q	delta P (bar)
3	2	25	120	0.025	0.0117677
5	4	25	560	0.025	0.05491578
7.5	14	25	570	0.025	0.05589642
10	22	25	580	0.025	0.0568771
12.5	25	25	590	0.025	0.057857
15	30	25	600	0.025	0.0588383

2) Study of Installed Characteristics:

Valve Type	Flow (LPH)	Lift (mm)
	400	30
	250	22
	100	14
Linear Valve	70	10
	580	30
	340	22
	170	14
Quick Opening Valve	50	6
	120	2
	560	4
	570	14
	580	22
	590	25
Equal percentage Valve	600	30

3) Study of inherent coefficients:

Lift (mm H2O)	Flow (LPH)	Q	delta P (bar)	Valve Coefficient (Cv)
88	500	0.5	0.008629622459	6.243557211
108.5	540	0.54	0.01063993224	6.072706868
73	460	0.46	0.007158664085	6.306665964
57	420	0.42	0.00558964182	6.516513358

4) Study of Rangeability

Lift (mm H2O)	Flow (LPH)	Q	delta P (bar)	Valve Coefficient (Cv)
88	500	0.5	0.008629622459	6.243557211
108.5	540	0.54	0.01063993224	6.072706868
73	460	0.46	0.007158664085	6.306665964
57	420	0.42	0.00558964182	6.516513358

Calculations

WKT, $C_v = 1.16 \, Q \sqrt{\frac{G}{\Delta P}}$

where $Q \rightarrow$ Flow Rate in m^3/hr

$G \rightarrow$ Specific Gravity of fluid ($G = 1$ for water)

$\Delta P \rightarrow$ Pressure Drop in bar

Consider, $\Delta P = 88$ mm of H_2O

$Q = 500$ L/hr

$\therefore \quad C_v = 1.16 \times 0.5 \sqrt{\frac{1}{0.00863}}$

$= 6.243$

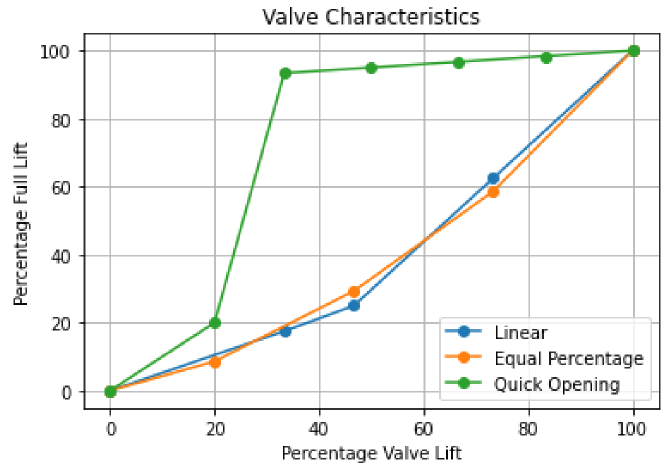
$\therefore \quad C_v = 6.243$

Cv max = Cv at lift = 57 mm = 6.516513358

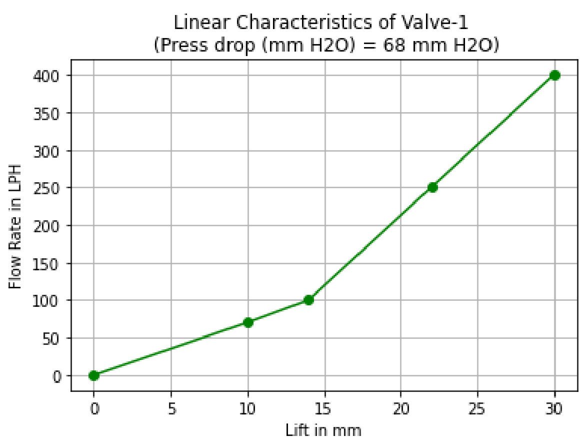
Cv min = Cv at lift = 108.5 mm = 6.072706868

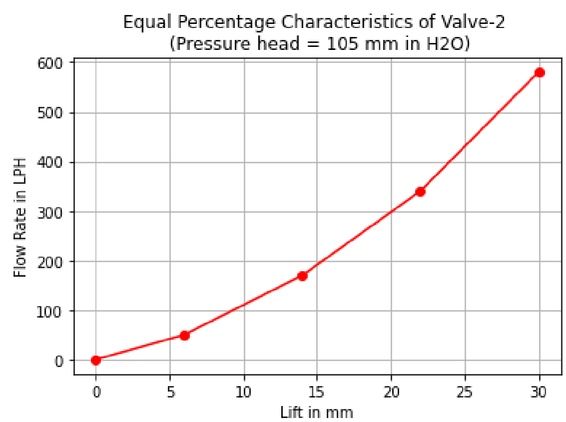
Rangeability = Cv max / Cv min = 1.073081167

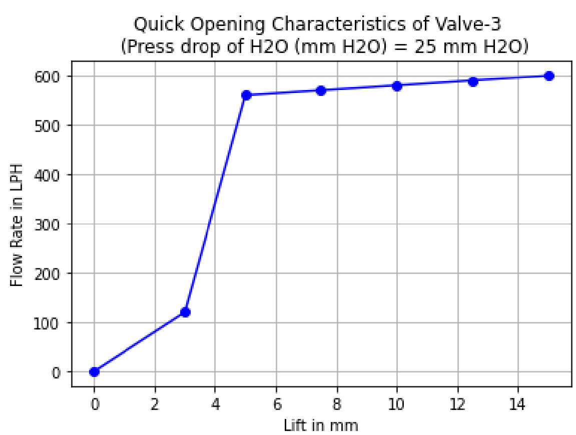
Graphs



Since, the flow rate increases as pressure increases, we can conclude that this is a reverse-acting control valve.







Conclusion:

- Inherit characteristics and installed charasteristics are thus analysed.
- Equal % Valve might be leaking. So, this valve may not lead to accurate readings.
- The basic properties of the Linear Control valve are linear, in that the flow capacity grows linearly with valve movement, but in practise, we find certain variances owing to human or instrument error.
- The pressure valve must be kept constant in order to see the intrinsic properties, as it will increase if left unmodified.
- Human error, instrumentation error, and random error are all potential sources of mistake.
- Linear control valve is the most expensive control valve among the three.
- Equal percentage control valve is widely used control valve such as piping purposes at ourhome.
- Whereas quick opening control valve is used for safety purposes. In this Experiment
- We can conclude that for linear control valve, the flow capacity increases linearly with the valve travel, with an error . For equal percentage control valve, the flow capacity increases exponentially with valve trim travel.