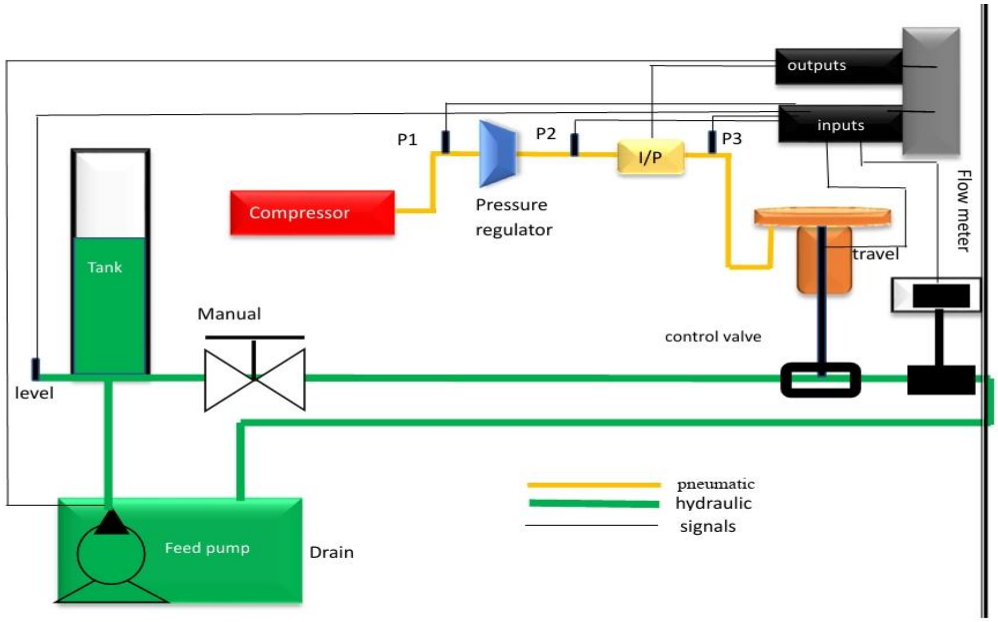
1. EXPLANATION OF THE KIT –



Control Valve Stroke Test Procedure

1. Assume the valve is a 4-20mA operated pneumatic valve. It also has a 4-20mA valve position feedback output.

2. Connect the universal calibrator (or source) to the input of the valve.

3. Connect the multimeter at the valve position feedback output as shown in above the setup figure.

4. Select the Source function in universal calibrator and the knob will help to vary the mA (4 to 20mA).

5. Select 4mA in the calibrator (also called as source meter).
The control valve will show a 0% valve position. We can verify the valve position on the scale provided on the control valve.

Also, the valve has 4 – 20mA output which indicates valve position feedback. We connected a multimeter to measure this valve position feedback. The valve position feedback range is 0 to 100 percent which is equivalent to 4 to 20mA. In this case, the multimeter will show 4mA.

6. Now increase the current (mA) in the calibrator from 4mA to 8mA. Now the valve will travel from 0% to 25%. The multimeter will show 8mA valve travel position feedback (25%).

7. Now increase the current (mA) in the calibrator from 8mA to 12mA. Now the valve will travel from 25% to 50%. The multimeter will show 12mA valve travel position feedback (50%).

8. Now increase the current (mA) in the calibrator from 12mA to 16mA. Now the valve will travel from 50% to 75%. The multimeter will show 16mA valve travel position feedback (75%).

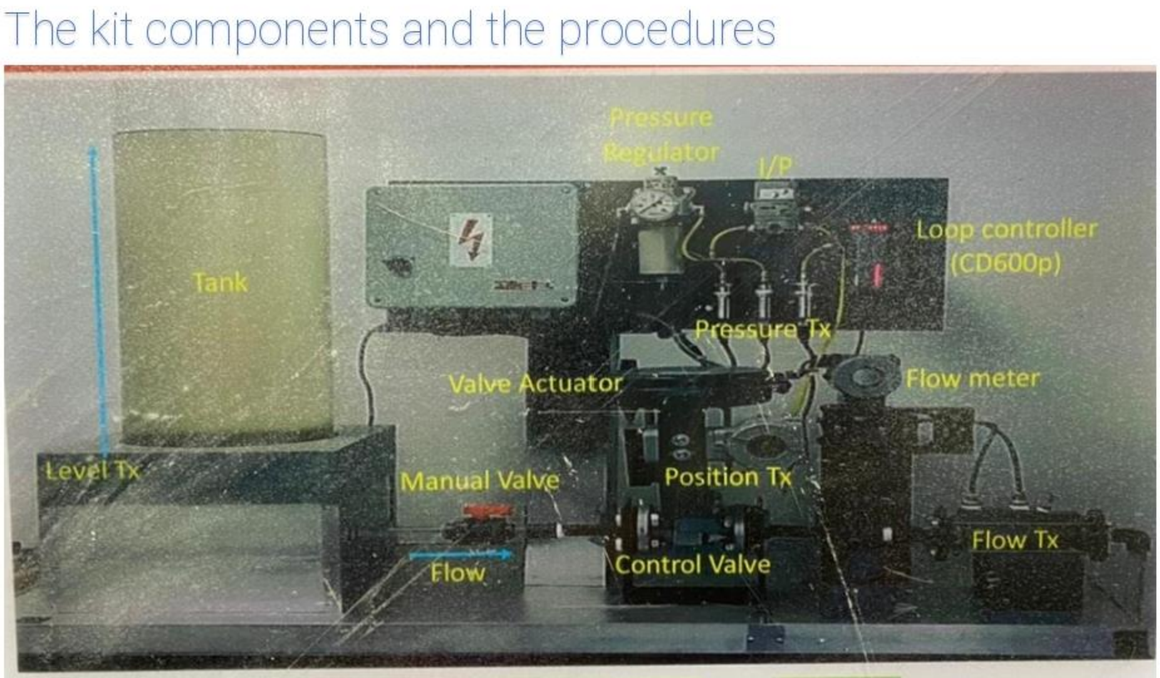
9. Now increase the current (mA) in the calibrator from 16mA to 20mA. Now the valve will travel from 75% to 100%. The multimeter will show 20mA valve travel position feedback (100%).

10. Now we tested the control valve from 4mA to 20mA upward direction. Now repeat the same in downward direction i.e. from 20mA to 4mA in steps.

11. Note: While sourcing you can view the Feedback on multimeter these will be nearby reading to source mA.

12. Now we completed the upward test from 4mA to 20mA. Repeat the same steps in a downward direction also i.e. from 20mA to 4mA in steps.

2. SCHEMATIC DIAGRAM OF THE KIT



Control Valve Consists of the following elements:

1. Actuator

2. Positioner

3. Valve Body

Actuator:

The Actuator is the Upper Portion of the Cylinder, which allows the diaphragm to move the valve steam upward and downward.

Positioner:

The Positioner is nothing but an advanced I to P converter, which converts the 4-20mA signal to Pneumatic 3-15Psi, and allows the stem of the actuator for the movement to and fro.

Valve Body:

Valve body manufacturing depends on the temperature and pressure in the line. The material of the valve body may be Forged carbon, SS316, SS314, Casting, etc.

3. INPUT AND OUTPUT DEFINITIONS AND HOW THEY ARE RELATED -

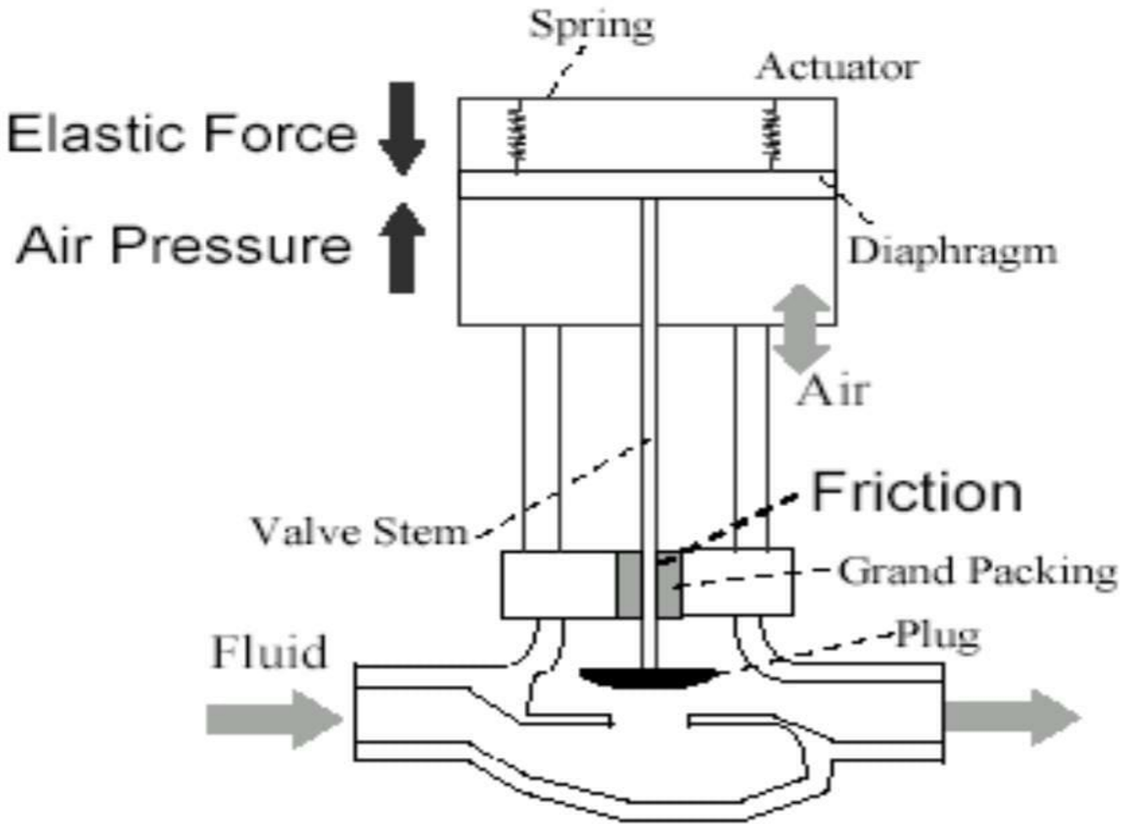
A control valve is a power-operated device used to regulate or manipulate the flow of fluids, such as gas, oil, water, and steam.

In the given circuit we have to use control valve used to maintain the level of liquid in the tank .

Control valve has two separate components: the Valve and the Actuator.

Control valve is a valve used to control fluid flow by varying the size of the flow passage as directed by a signal from a controller. This enables the direct control of flow rate and the consequential control of process quantities such as pressure, temperature, and liquid level.

A control valve is a valve used to control fluid flow by varying the size of the flow passage as directed by a signal from a controller.



llustrates the input-output behavior for control valve with stiction. The dashed line represents the ideal control valve without any friction.

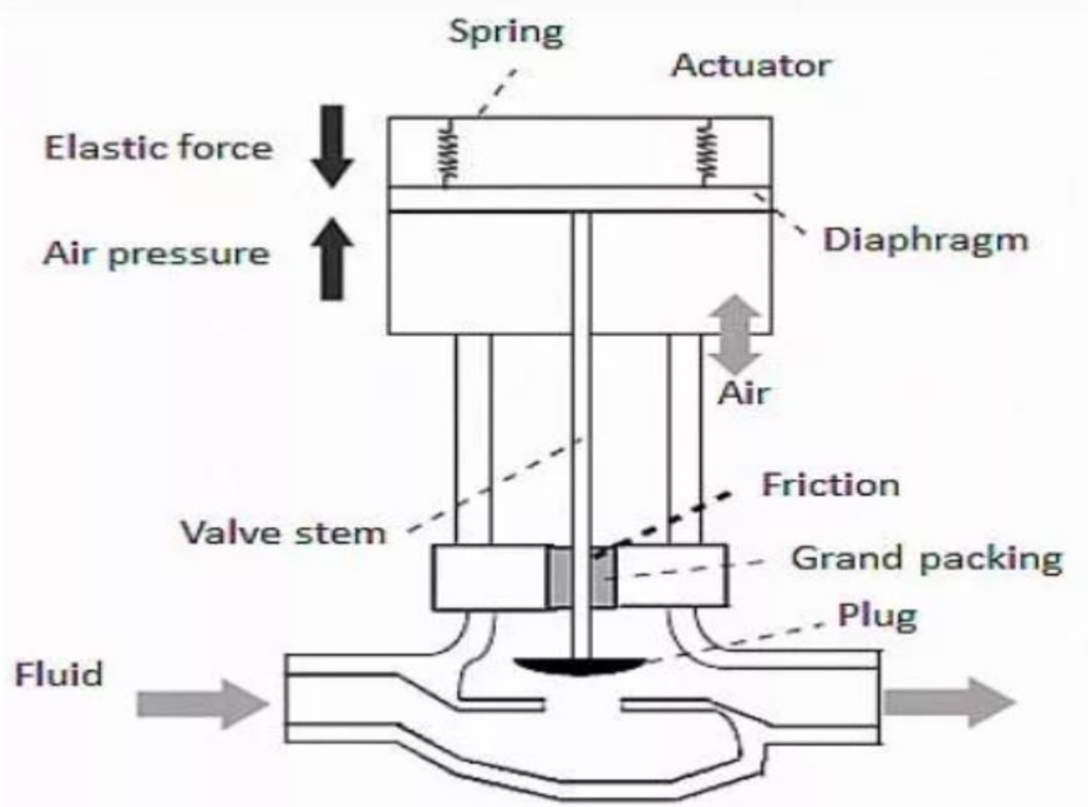
4. EXPLANATION OF CONTROL VALUE OPERATION WITH FREE BODY DIAGRAM AND FLOW METER OPERATION -

The process control industry includes control valves as the final control element. Control valves manipulate fluids, such as water, gas, steam, or chemical compounds, to compensate for load disturbances, keeping the regulated process variable as close to the desired set point as possible.

Typically, automatic control valves are opened or closed by electrical, hydraulic, or pneumatic actuators. When a modulating valve can be set anywhere between fully closed and fully open, valve positioners are normally used to ensure that the valve achieves the desired degree of opening.

The simplicity of air-actuated valves makes them popular, as they are only powered by compressed air, as opposed to electrically-operated valves, which require additional cabling and switch gear, and hydraulically-actuated valves, which require high-pressure fluid supply and return lines.

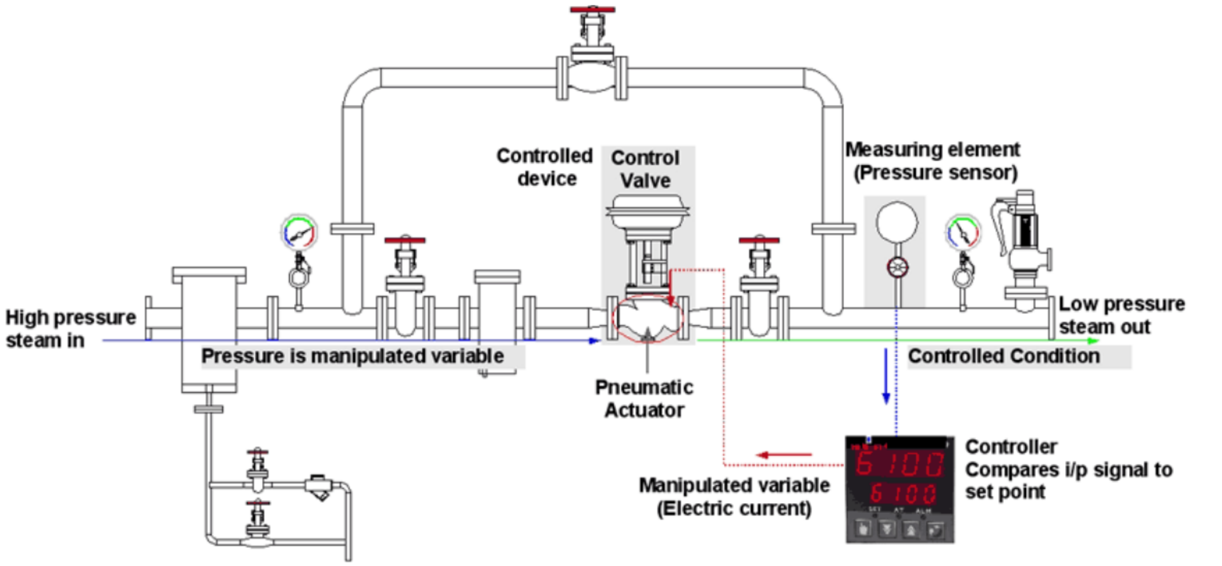
Control signals for pneumatic systems are typically based on a pressure range of 3 to 15 psi (0.2 to 1.0 bar) or, typically, on a 4-20mA electrical signal for industry or a 0-10V signal for HVAC systems. Today, electrical control often includes a smart communication signal that can be superimposed over the 4-20mA control signal, allowing the controller to monitor and signal valve health and position back to the controller.



Free body diagram

Arrangement of Control Valves

The following image illustrates how the flow rate in a line can be controlled using a control valve. A “controller” receives pressure signals and compares them with the desired flow. If the actual flow varies from the desired flow, the control valve adjusts to overcome the difference. It is possible to control any one of a number of process variables in a similar manner. The most commonly controlled variables are temperature, pressure, level, and flow rate.



Flow meter operation

5. RESPONSE OF THE SYSTEM AND TO DETERMINE THE STEADY STATE ERROR, RISE TIME,SETTLING TIME AND TIME CONSTANT.

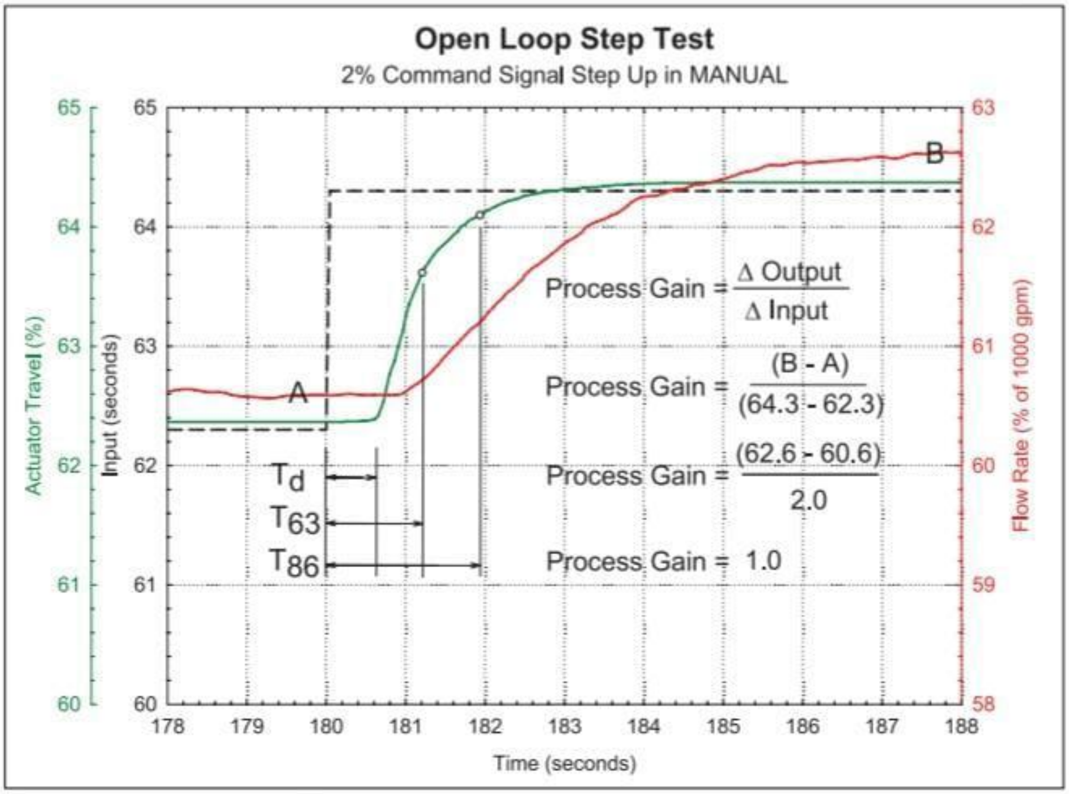
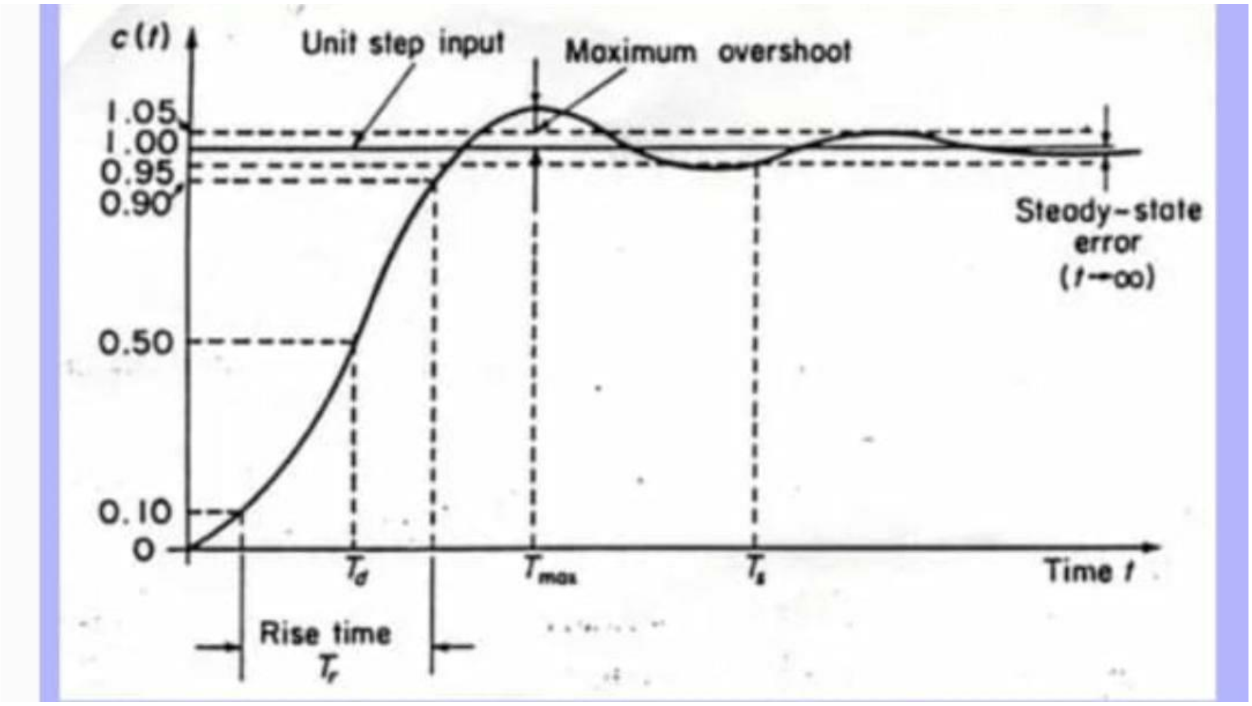
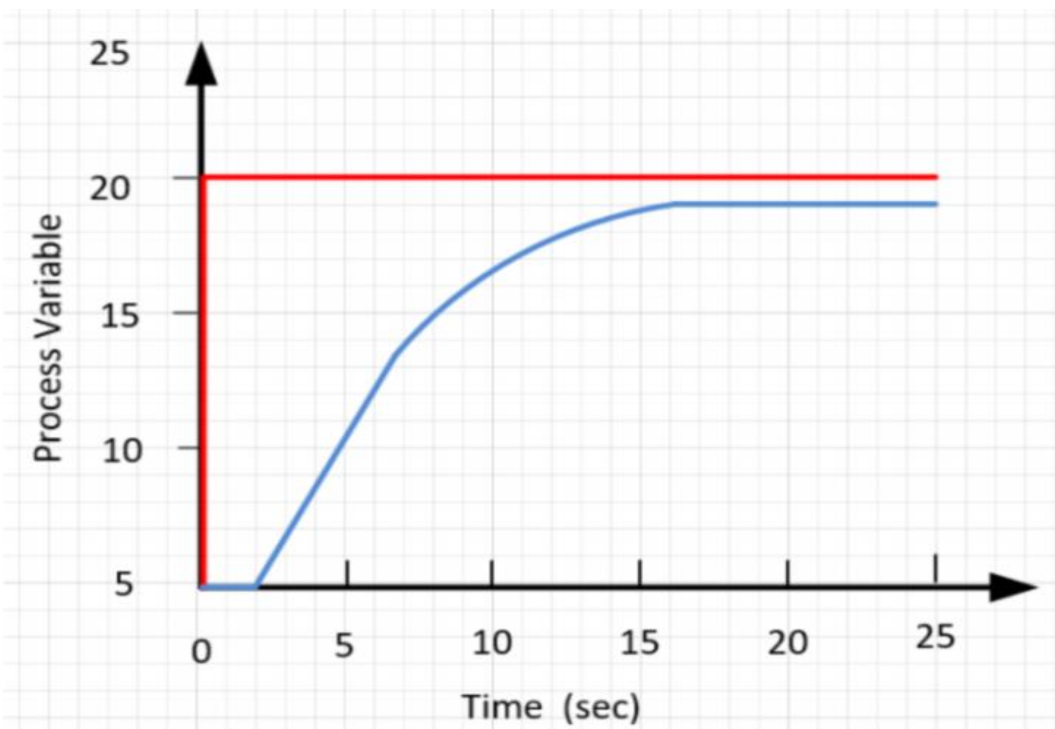
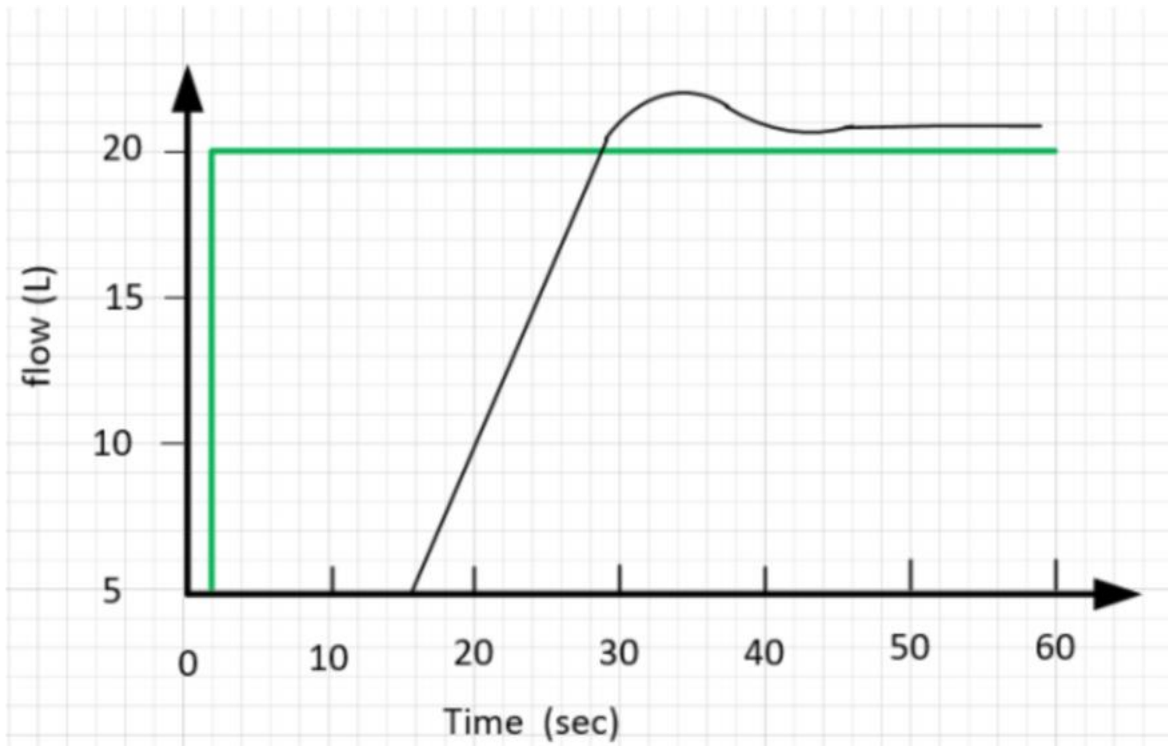


Figure 3. Open-loop step tests results showing T_d, T_{63} and T_{86} response times for a 2% input step change. The process gain (Δ process/Δ input) for this particular loop is 1.0.

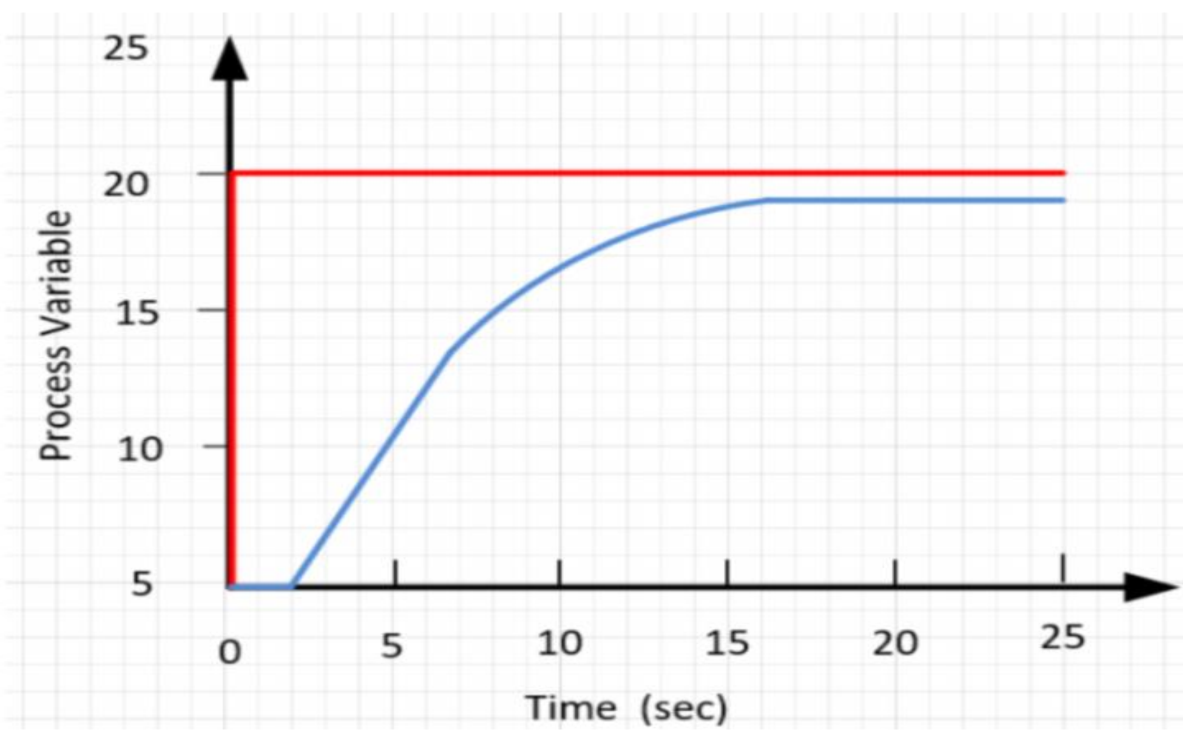


From the data of Test 5 , we made this graph and now we can find the various parameters





flow (L)
20
15
10
5
0
10
20
30
40
50
60
Time (sec)



Process Variable
25
20
15
10
5
0
5
10
15
20
25
Time (sec)

6. TRANSFER FUNCTION OF THE FUNCTION -

The baffle motion results in a proportional increase in pressure in nozzle and valve top which result an increase in cooling water flow.

As the baffle is moved toward the nozzle, the pressure P in the nozzle increases because the area for air discharge is reduced. The nozzle pressure becomes equal to the supply pressure when the nozzle is closed by the baffle and the system is so designed that the nozzle pressure falls linearly as the baffle to nozzle distance is increased.

With the increase in pressure the plug moves downward and supplies the flow of cooling water through the valve.

In general, the flow rate of the fluid through the valve depends upon the upstream and downstream fluid pressures and the size of the opening through the valve.

In this system, we assume that at steady state, the flow is proportional to the valve top pneumatic pressure. A valve with this relation is called a linear valve.

$$\frac{Q(s)}{P(s)} = \frac{K_v}{\tau_v s + 1}$$

So,

$$\frac{Q(s)}{P(s)} = K_v$$

In order to obtain transfer functions deviation variables should be introduced.

$P = p - p_s$

ε is already a deviation variable (at t=0, $\varepsilon_s = 0$)

$$P(t) = K_c \varepsilon(t)$$
$$P(s) = K_c \varepsilon(s)$$
$$\frac{P(s)}{\varepsilon(s)} = K_c$$

This mode of control is described by the relationship,

$$p = K_c \varepsilon + \frac{K_c}{\tau_I} \int_0^t \varepsilon dt + p_s$$

where,

Kc: gain

τ_I: integral time

p_s: constant set-up

$$\frac{K_c}{\tau_I} \int_0^t \varepsilon \, dt$$

this term is proportional to the integral of the error. The K_c and τ_I values are adjustable.

$$p - p_s = K_c \varepsilon + \frac{K_c}{\tau_I} \int_0^t \varepsilon dt$$

$$P(s) = K_c \varepsilon(s) + \frac{K_c}{\tau_I} \frac{\varepsilon(s)}{s}$$

$$\frac{P(s)}{\varepsilon(s)} = K_c \left(1 + \frac{1}{\tau_I s} \right)$$

Time elapsed	y(t) as % of ultimate value
τ_p	63.2
$2\tau_p$	86.5
$3\tau_p$	95
$4\tau_p$	98

- Assume that the effluent flow rate F_o is related linearly to the hydrostatic pressure of the liquid level h, through the resistance R:

$$F_0 = \frac{h}{R} = \frac{\text{driving force for flow}}{\text{resistance to flow}}$$

- The total mass balance gives;

$$A\frac{dh}{dt} = F_i - F_0 = F_i - \frac{h}{R}$$

$$AR\frac{dh}{dt} + h = RF_i$$

at steady state $h_s = RF_{i,s}$

$$AR\frac{dh'}{dt} + h' = RF_s'$$

where

$$h' = h - h_s$$

$$F_i' = F_i - F_{i,s}$$

$\tau_p = AR$ = time constant of the process

$K_p = R$ = steady state gain of the process

$$G(s) = \frac{H'(s)}{\overline{F}_i'(s)} = \frac{K_p}{\tau_p s + 1}$$

This is the required transfer function of the system.

7. MODELLING OF CONTROL VALVE AND LIQUID LEVEL SYSTEM –

Fluid flow basics- it is necessary to divide flow regimes into laminar flow and turbulent flow according to the magnitude of Reynolds number.

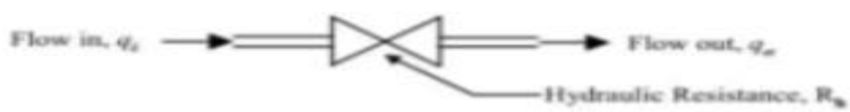
Industrial processes often involve flow of liquids through connecting pipes and tanks. The flow in such processes is often turbulent and not laminar.

Systems involving turbulent flow often have to be represented by nonlinear differential equations.

If the region of operation is limited, however, such nonlinear differential equations can be linearized.

Hydraulic Resistance:

- Figure shows liquid flow in a pipe, with a restricting device (a valve) providing a hydraulic resistance (R_h) to the flow.



- Note that the walls of the pipe will also provide a small amount of resistance to flow, depending on how rough they are.

- When turbulent flow occurs from a tank discharging under its own head or pressure, the flow is found by the following equation:

$$q_o = KA\sqrt{2gh} \qquad (5.1)$$

- Where q_o is the flow rate (ft^3/s), K is a flow coefficient, A is the area of the discharge orifice (ft^2), g is gravitation constant (ft/s^2), and h is pressure head of liquid (ft).
- We can define hydraulic resistance (R) to flow as follows:

$$R = \frac{Potential}{Flow} = \frac{h}{q_o} \qquad (5.2)$$

When turbulent flow occurs from a tank discharging under its own head or pressure, the flow is found by the following equation:

$$q_0 = KA\sqrt{2gh} \qquad (5.1)$$

Where q_0 is the flow rate (ft^3/s), K is a flow coefficient, A is the area of the discharge orifice (ft^2), g is gravitation constant (ft/s^2), and h is pressure head of liquid (ft).

We can define hydraulic resistance (R) to flow as follows:

$$R \equiv \frac{Potential}{Flow} = \frac{h}{q_0} \qquad (5.2)$$

- Therefore, the instantaneous rate of change of hydraulic resistance to flow is

$$R_{hi} = \frac{dh}{dq_0} \qquad (5.3)$$

- Rearranging Equation 5.1, we arrive at:

$$\sqrt{h} = \frac{q_0}{KA\sqrt{2g}} \qquad (5.4)$$

- Differentiating Equation 5.4 with respect to q_0 gives us,

$$\frac{dh}{dq_0} = \frac{2h}{KA\sqrt{2gh}} \qquad (5.5)$$

Therefore, the instantaneous rate of change of hydraulic resistance to flow is

$$R_{hi} = \frac{dh}{dq_0} \qquad (5.3)$$

Rearranging Equation 5.1, we arrive at:

$$\sqrt{h} = \frac{q_0}{KA\sqrt{2g}} \qquad (5.4)$$

Differentiating Equation 5.4 with respect to q_0 gives us,

$$\frac{dh}{dq_0} = \frac{2h}{KA\sqrt{2gh}} \qquad (5.5)$$

Hydraulic Capacitance:

- In a tank being filled with a liquid, the equation for the volume (V) of the liquid in the tank is given by the following equation:

$$V(t) = A \times h(t) \qquad (5.7)$$

where

$V(t)$ = the volume of liquid as a function of time

$h(t)$ = height of liquid

A = the surface area of the liquid in the tank

- Note that the volume V of the tank and the liquid height or head are a function of time. The flow of liquid into the tank, q_{in}, and the flow liquid out of the tank, q_{o}, vary with time.

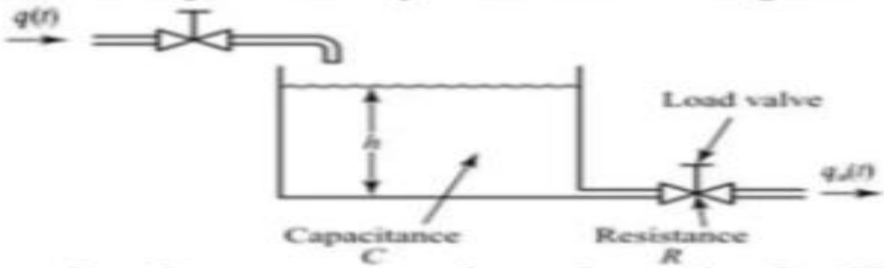
* Rearranging equation 5.7,

$$A = \frac{V(t)}{h(t)} = \frac{Quantity}{Potential} \quad (5.8)$$

* Comparing this equation to the equation for electrical capacitance (i.e., $C=q/V$) clearly shows that liquid capacitance C_l is simply the surface area of the liquid in the tank, or $C_l = A$. Furthermore, taking the derivative of Equation 5.8 with respect to time yields

$$\frac{dV(t)}{dt} = A\frac{h(t)}{dt} \quad (5.9)$$

* Consider the liquid-level system shown in Figure.



* Assume that the system consists of a tank of uniform cross-sectional area A, which is attached a flow resistance R such as valve, a pipe, or a weir.

---

* Substituting eqn. 5.10 into 5.11,

$$q_i(t) - \frac{h}{R} = A\frac{dh}{dt} \quad (5.12)$$

* Rearranging eqn. 5.12,

$$q_i(t) = A\frac{dh}{dt} + \frac{h}{R} \quad (5.13)$$

* Rearranging eqn. 5.13,

$$Rq_i(t) = RA\frac{dh}{dt} + h \quad (5.14)$$

* Taking Laplace Transform of eqn. 5.14 by assuming zero initial conditions,

$$(RAs+1)H(s) = RQ_i(s) \quad (5.15)$$

- where,
  $H(s) = \mathcal{L}[h(t)]$ and $Q_i(s) = \mathcal{L}[q_i(t)]$
- Rearranging eqn. 5.15,

$$\frac{H(s)}{Q_i(s)} = \frac{R}{(RAs+1)} \quad (5.16)$$

- If however, q_0 is taken as the output, the input being the same, then the transfer function is

$$\frac{Q_0(s)}{Q_i(s)} = \frac{1}{(RAs+1)} \qquad Q_0(s) = \frac{H(s)}{R} \quad (5.17)$$

- To obtain the differential equation in terms of variable q_o, dh/dt must be expressed in terms of dq_o/dt.
- We know from the equation 5.11 and 5.6 that

$$q_i(t) - q_0(t) = A\frac{dh(t)}{dt}$$

$$R_h = \frac{dh}{dq_0}$$

- or $dh(t) = R_h * dq_0(t)$. Taking the derivative of this equation with respect to time yields

$$\frac{dh(t)}{dt} = R_h \frac{dq_0}{dt}$$

Therefore, the system equation becomes

$$q_i(t) - q_0(t) = AR_h \frac{dq_0(t)}{dt}$$

Rearranging and Taking Laplace Transform both sides,

$$q_0(t) + AR_h \frac{dq_0(t)}{dt} = q_i(t)$$

$$Q_o(s)(1 + AR_h s) = Q_i(s) \Rightarrow \frac{Q_o(s)}{Q_i(s)} = \frac{1}{(1 + AR_h s)}$$

8. CONCLUSION AND ANALYSIS ABOUT HOW TO MINIMISE ERROR-

Control valves are a highly engineered product and should not be treated simply as a commodity. Addressing control valve performance has a dramatic effect on process plant efficiency, overall profitability and control valve life-cycle costs. While traditional valve specifications certainly play an important role in performance, it is also crucial that valve specifications address dynamic performance characteristics to achieve true process optimization.The performance of the control loop in the process should be the prime consideration when specifying equipment.Valve manufacturers that understand control performance can share those capabilities and show they can conform to a user’s performance specifications. Finally, implementing the best online,in-service diagnostics will optimize maintenance efforts if the information is used properly. Following these steps and adopting work practices to take full advantage of the digital tools available will have a positive impact on all parameters of plant efficiency and used effectively in industry to minimize error.