# AMBEDKAR INSTITUTE OF TECHNOLOGY

## PRACTICAL MANUAL

## Sub:- PROCESS CONTROL & INSTRUMENTATION PRACTICALS

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# EXPERIMENT NO 1

**AIM: Study of flow, temperature, pressure and level feedback control system with standard signals in the loop**

## APPARATUS:

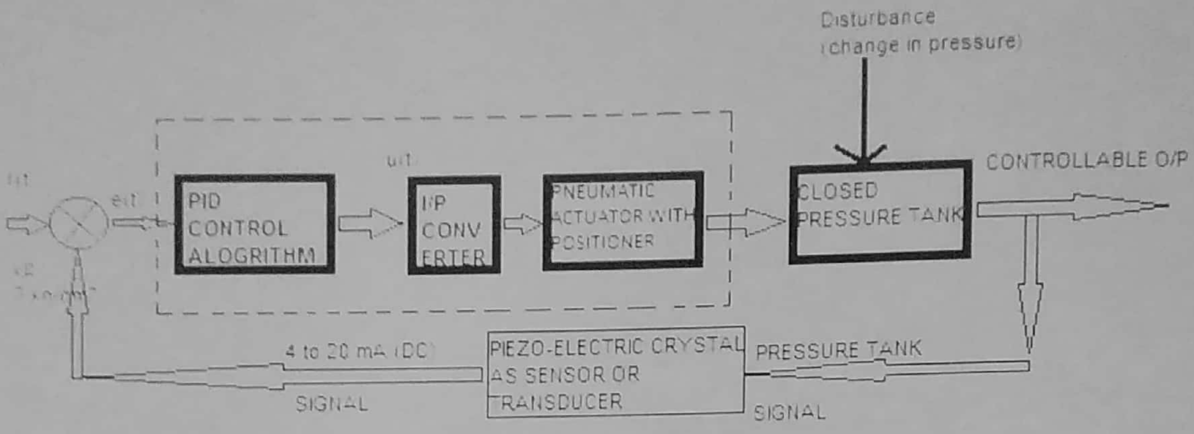
1. Experimaental setup (trainner)
2. Compressor
3. Power Supply
4. Personal computer (interface)

## PRESSURE CONTROL LOOP:

1. **Process:** In the given setup pressure in the closed tank is the process variable pressure of air is maintained by pumping air from the compressor to the closed tank and excess pressure if of air is released by the pneumatic control valve.
2. **Sensor:** Piezo-electric crystal.
3. **Transmitter:** The signal coming from the piezo-electric crystal is transmitted by the transmitter (i.e voltage signal is converted into 4 to 20 mA) and is transmitted to the PID controller.
4. **Controller:** since pressure is not easy to control, a simple ON-OFF control action will notgive fine control. A"PID" control is hence used. Input signal (4 to 20 mA) d.c is proportional to the pressure.

   Depending on the proportional band, the integral time and derivative time, the controller output varies from 4 to 20 mA DC.
5. **Converter:** since the output of PID controller is electronic and 'FCE' (pneumatic control valve) needs 20 psi pneumatic supply. The 4 to 20 mA (DC) signal is converted into a 2 to 15 psi signal.
6. **Final Control Element:** The pneumatic control valve with positioned is the 'FCE' with reference to the input 3 to 15 psi from I to P converter there is a change in stem position of the control valve.

7. **Output Display:** The DAC (Data Acquisation System) software accepts the present data from the closed tank and is displayed on 'PC'. Whose O/P display can be taken out or print.



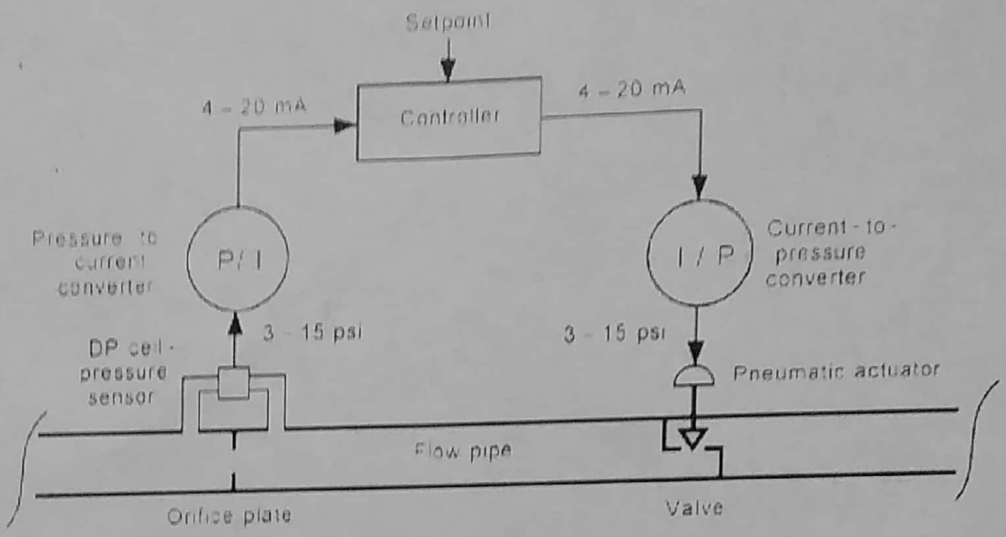
CLOSED-LOOP PRESSURE CONTROL SYSTEM

FLOW CONTROL LOOP:

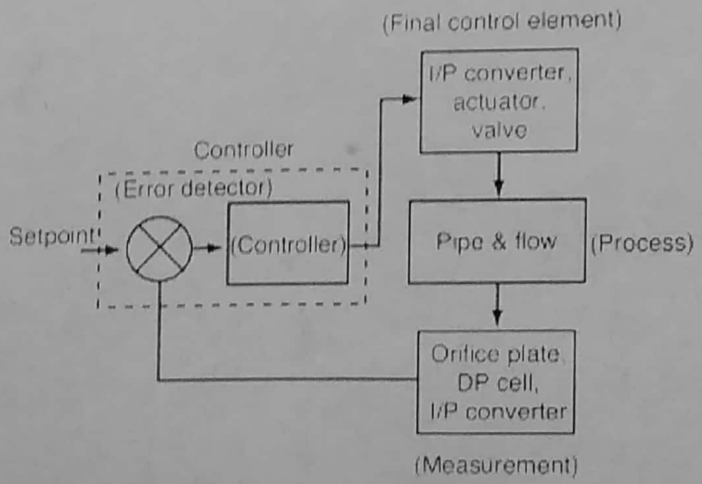
1. **Process:** In the given setup flow is the process variable. Water flow is maintained by pumping water from the tank and bringing it back to the tank.
2. **Sensor:** Orifice is the sensor used.
3. **Differential Pressure Transmitter (DPT) or Delta Cell:** The differential pressure signal (0 to 760 mm of Hg) is converted into 4 to 20 mA d.c signal and transmitted to transmitter(2:wire transmitter).
4. **Controller:** Is same as previous in pressure control loop.
5. **Current to pressure (I to P) converter:** since the output of PID controller is electronic and final control element needs 3 to 15 psi pneumatic signal. Hence I to P converter is used which works on the principle of flapper: Nozzle transducer.
6. **Final control element:** The Pneumatic control valve is the final control element. The type is single seated and pneumatically operated.

7. **Real time display:** the tuning of PID controller is done by changing the value of proportional band, reset time and integral time in the software by trial and error method.

In response to the change value of proportional band, TI & TD the flow in the pipeline is controlled to the desired set point. The data is acquired by DAS.



(a) Physical diagram of a process-control loop



(b) Block diagram of the process-control loop

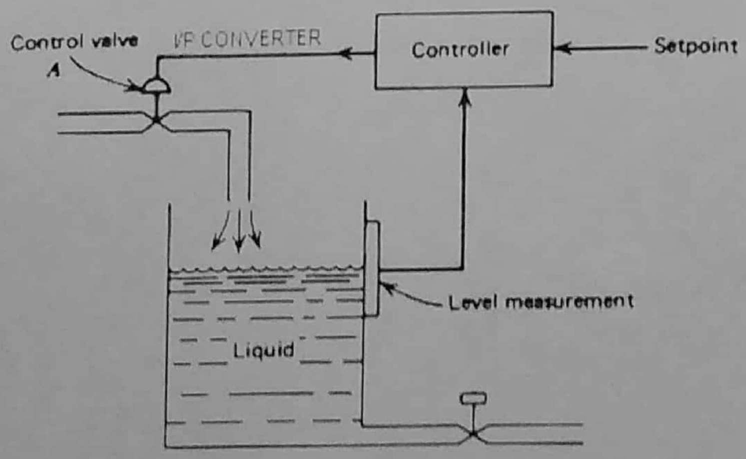
CLOSE LOOP FOR FLOW CONTROL

## LEVEL CONTROL LOOP

1. **PROCESS**: In the given setup level is the process variable. Level is maintained by using closed loop to increase or decrease the value of capacitance.
2. **SENSOR**: Float, concentric cylindrical capacitor.
3. **TRANSMITTER**: The signal coming from the cylindrical capacitor by changing the developing potential due to level is transmitted by the transmitter.
   i.e. (voltage 'V' = q/c signal is converted into 4 to 20 mA) and is transmitted to 'PID' controller.
4. **CONTROLLER**: Is same as previous in pressure control loop.
5. **ELECTRO PNEUMATIC TRANSDUCERS (I to P)**: Is same as previous in flow control loop

   I/P = 4 to 20 mA

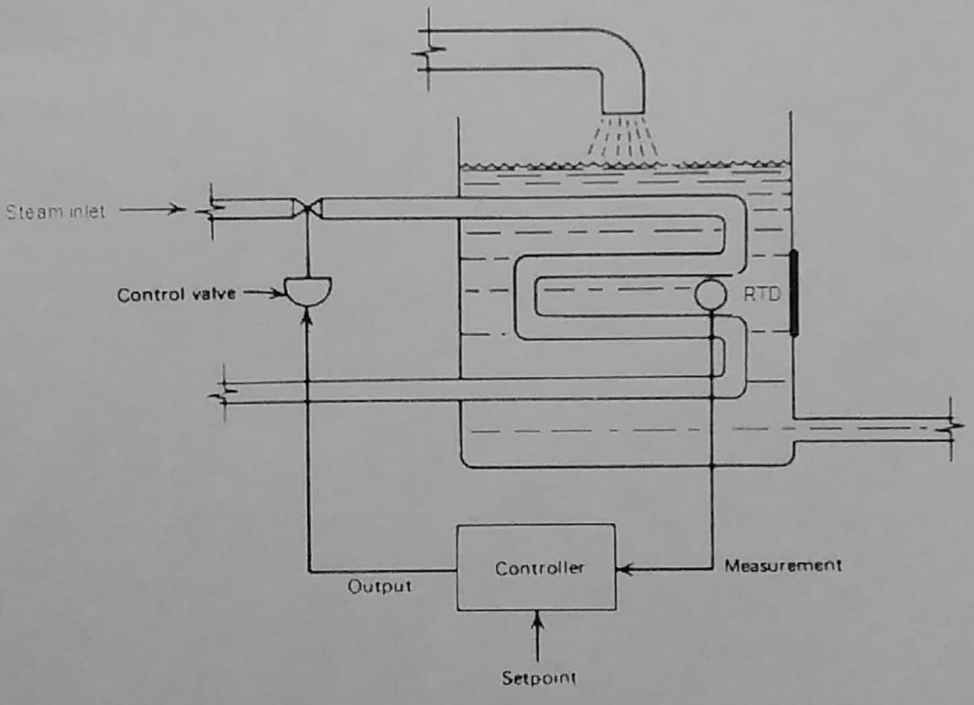
   O/P = 3 to 15 psi
6. **FINAL CONTROL ELEMENT:** pneumatic control valve.
7. **DISPLAY**: Data is acquired by DAS.



Level-control system (CLOSED LOOP)

## TEMPERATURE CONTROL LOOP:

1. **PROCESS:** In the given setup temperature is the process variable. Temperature is maintained by heating water in the tank by heating element.
2. **SENSOR:** RTD is sensor used
3. **TRANSMITTER:** Here the RTD output (change in resistance) is converted into 4 to 20 mA d.c. signal.
4. **CONTROLLER**: Is the same as previous in pressure control loop.
5. **FINAL CONTROL ELEMENT**: Here the relay switch is the 'FCE'. Which is operated when PID controller gives the error (e) signal after comparing the actual temperatures of tank with its set points and as per the error signal heater element is ON-OFF.
6. **TEMPERATURE RECORDER OR DAS**: The data is accepted by the PC in the form of voltage and display the real time on the window.



Control of temperature by process control.

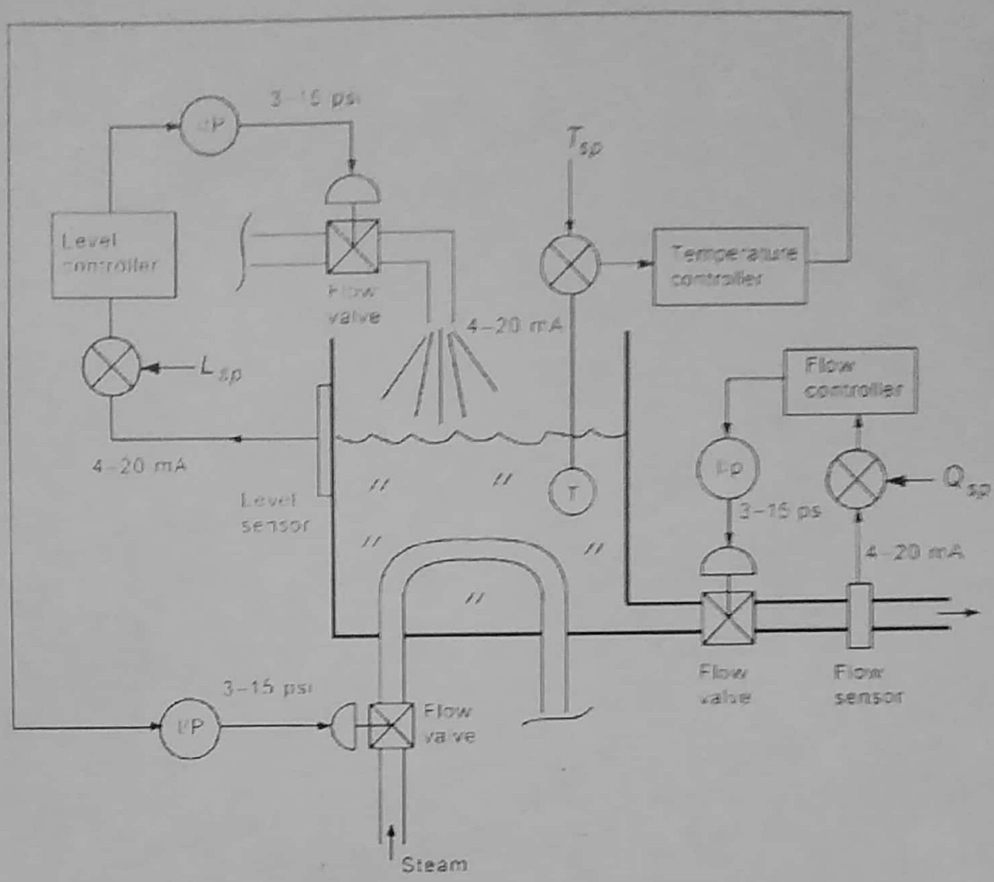


FIG. SHOWING THE TEMPERATURE, FLOW, LEVEL CONTROL WITH STANDARD SIGNALS

# Experiment no.2(a)

**AIM:** Study of Open Loop response Level Control (manual mode) ,313 software

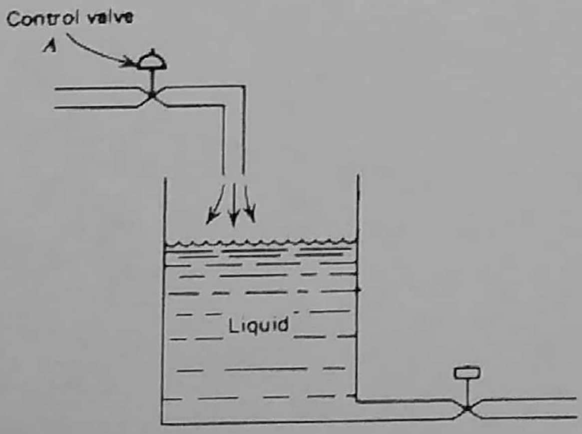
**Apparatus** : 1.Water tank

2. Pump
3. Storage tank
4. Personal computer (interface)

**Theory:** Open Loop Control System

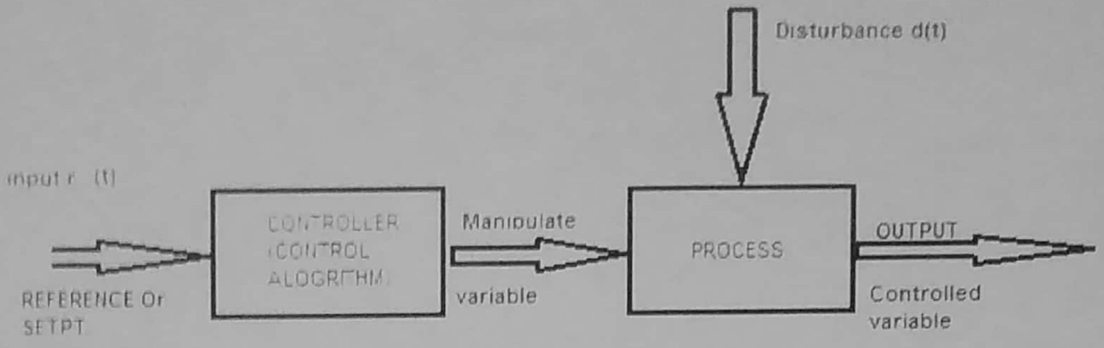
The input has no control over the output (controlled variable). In the system the valve is adjusted to make output $c_a$ equal to input $c_d$ but not readjusted continuously to keep the two equal . The limitation of an open loop control is that the difference between desired and actual level.

(Error 'e' $=c_d-c_a$) gets developed due to disturbance acting on system and parameter variation of the system .it is simple to design.



Level-control system (OPEN LOOP)

Fig: Open loop response for level control(Manual control)



BLOCK DIAGRAM OF OPEN-LOOP FOR LEVEL CONTROL

## Procedure :

1. Startup the set and adjust the drain valve.

2. Select LIC level control for the process .

3. Select open loop option from '313' software

4. Close the control valve. By increasing the controller output into 100%

5. Apply the step change by the 10% to controller output in manual mode , wait for the level to reach the steady state valve.

6. Repeat above step until the controller output reaches to minimum i,e 0%

## RESULT

From the above data , note the OUTPUT required for maintaining the level at desired set point by manual control.

# Experiment no.-2(b)

AIM - STUDY OF ON/OFF CONTROLLER FOR LEVEL CONTROL FLOW CONTROL BY USING '313' SOFTWARE & PC.

**Apparatus Requirement**- 1. Experiment set up(trainer)

2.Power supply

3.Personal computer

Theory-

**ON/OFF CONTROLLER –Two position mode**- The most elementary controller mode is ON/OFF, Or two position mode. This is an example of a discontinuous mode 'Analytic equation'.

$$p= \{0\% \ e_p<0 \quad 100\% \ e_p>0\}$$

'p' is the controller o/p. '$e_p$' is error signal. This relation show that when the measured value is less than set point ,full controller output result .when it is more than the set point ,the controller output is zero.

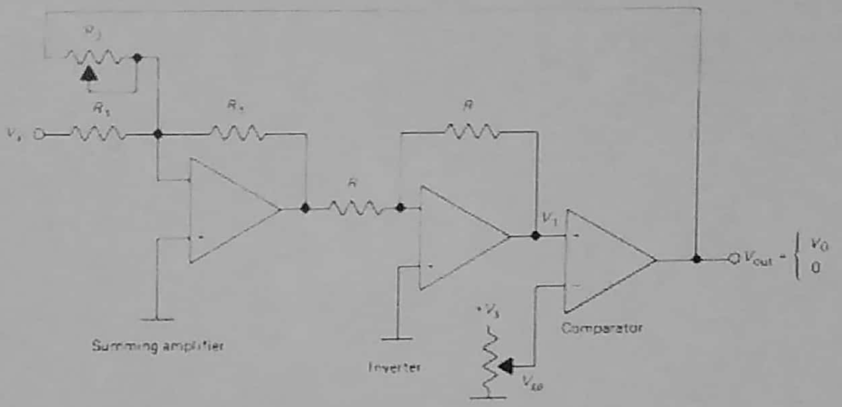
It is the simplest and cheapest.

**Single mode**-In the following system ,op-amp CKT illustrate methods of implementing the purse modes of controller action.

**Two-position with OP-AMP(ON/OFF)**- Op-amp implementation of ON/OFF control with adjustable. Neutral zone is given in the figure. We assume that, if the controller input voltage in reaches a values VH,then the comparatus output should go to the ON state ,which is defined as OV .the voltage on its input ,$V_1$ is equal to the set point $V_{sp}$.

Analysis of this CKT show that the high (ON) switch voltages

$$V_H = V_{sp}$$



Two-position controller with neutral zone made from op amps and a comparator

**Procedure-**

1. Run in cascade mode.
2. Start up the set up.
3. Select experiment to study level control/flow control.
4. Select close lop option for control .change the set point to the desired value.
5. Set the controller to ON/OFF mode.
6. Press tune & set the upper and lower hysteresis of the controller.
7. Change the value of the set point and observe the control operation.

**Application**- Generally, two-position control modes best adapted to large scale system with relatively slow process rates. i.e

1. Melting of iron , room heating or air-condition system.
2. Liquid both-temperature control.
3. Level control in large volume tank.

**RESULT:**- Process value decrease than the set point control value opens i.e the controller operates like ON/OFF switch.

# Experiment No:3

AIM:- Study of proportional as throttling controller for very low proportional Band valve and response to the system at load change.

Apparatus required –

1.experiment setup trainer.

2.power supply.

3. Personal computer

Theory :

Proportional Control Mode: In the Proportional mode where a smooth, linear, relationship exist between the controller output and the errors the range to error to cover the 0% to 100% controller output is called proportional Band because the one to one corresponding exist only for errors in this range the mode can be expressed by.

$$P=k_p.e_p + p(0)$$

where's, $K_p$= proportional gain between errors and controller output.

P(0)= controll output with no errors.

Implementation to Proportional Mode.

$$P= k_p. e_p + p(0)$$

p= ccontroller output 0%-100%

$k_p$= proportional gain .

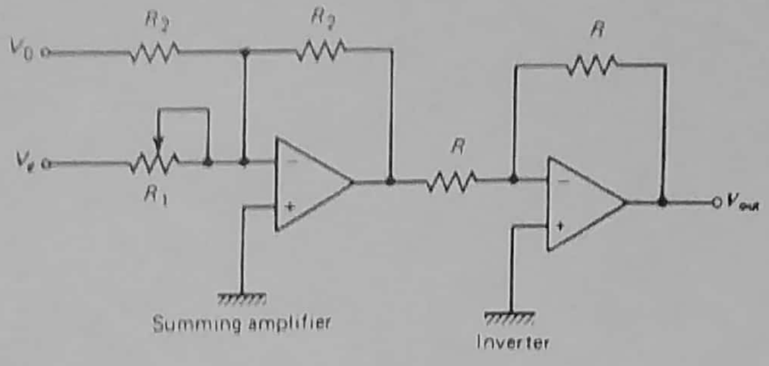
$e_p$=error in percent to variables usage .

p(0)= ccontroller output with no errors. *

if we consider both the controller output and error to be expressed in terms of voltage we simply say summing amplifier. The op-amp circuit shows such as electronic proportional controller analog electronic equation for the output voltage is

$$V_{out}= G_p. V_e+ Vo.$$

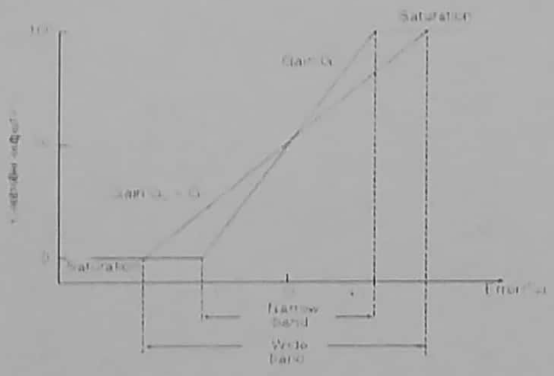
$V_{out}$ = out voltage
$G_p$ = R2/R1 = gain
$V_e$ = error voltage
$V_0$ = output with zero error



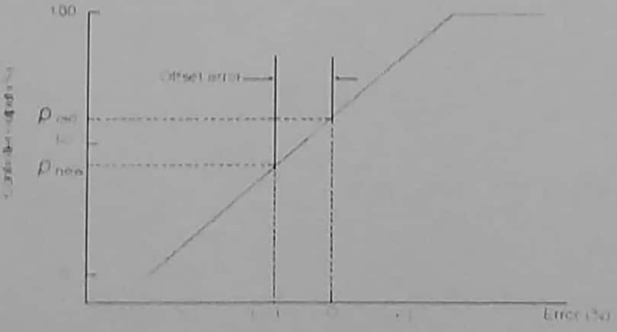
An op amp proportional-mode controller

Proportional Band: It is a range of errors form which controller output changes form 0%-100%

**P. B= 100/kp** ; kp is the gain



The proportional band of a proportional controller depends on the inverse of the gain



An offset error must occur if a proportional-only controller requires a new zero-error output following a load change

**Proportional Control Mode**

Offset residual error: An important characteristics of the proportional control mode is that it produces a permanent residual error in the operating point to the controller variables when a change in load occur this errors is referred as offset

**Procedure:**

1) Start up the setup

2) Select close loop option for control from software

3) Set the controller to proportional control (p) mode

4) Adjust the process valve by switching the controller to mannul mode to a particular level/ flow (say 50% ) on the screw and apply output to the controller as bias valve changes the proportional Band to 100%

5) Switch the controller to automate start data logging

6) Apply step changes to 100% to set point switch the controller to mannul mode decrease proportional Band to half of the previous valve with each decrease obtain a New response of the step changes

7) Ensure that the set point changes are around the same operating point

**Operation** : Observe the effect to very low proportional Band valves observation table and graphs for level control by using software to desired set point.

**Results** : Observed the response to the system at load changes load changes can be given by slightly manipulating the drain valve of the tank.

# Experiment No:4

AIM:- Study of PI Controller for temp/level/flow control and observed the effect of reducing integeral time on the response of process.

APPARATUS:-

1: Experimental setup (Trainer)

2:Power supply

3:Personal computer(Interface)

THEORY:-

Proportional Intergral Control (PI) mode

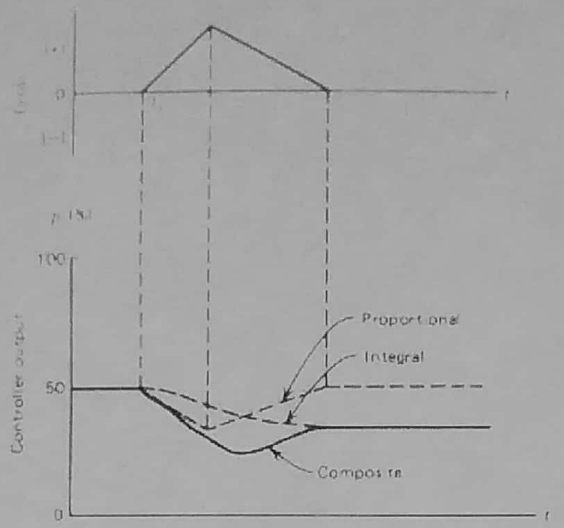
This is a control mode that results from a combination of the proportional and Integral mode.

The analytic expression for this control process is found from a series combination of equation.

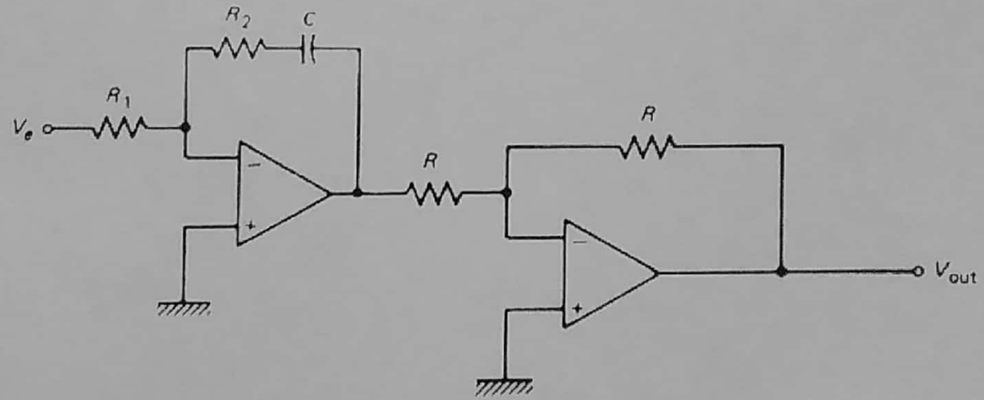
$$p = K_P e_p + K_P K_I \int_0^t e_p \, dt + p_I(0)$$

Where P t(0) integral term valve, if t=0(initial value)

The main advantage of this composite control mode is that the one-to-one correspondence of proportional mode is available and Integral mode eliminates the inherent offset. The integral feature effectively provides a reset of the zero error output after a load change occurs.



[illegible] integral contribution. The [illegible] reverse action.



An op amp proportional-integral (PI) mode controller.

$$V_{out} = \left(\frac{R_2}{R_1}\right) V_e + \left(\frac{R_2}{R_1}\right) \frac{1}{R_2 C} \int_0^t V_e \, dt + V_{out}(0)$$

## PROCEDURE:-

1. Start up the setup.

2: Select close loop option for control.

3: Select experiment to study LIC(level control) or FIC(Flow control)

4. Select PID controller set the proportional band estimated in proportion control.

5: Set derivative time to 0 sec and Integral time 6000 sec, which will cutoff the derivative action and widen the effect of integral action.

6: Set the set point to desired level/ flow valve.

7: Allow the process to reach at steady state.

8: Record the steady state error.

9: Switch the controller to manual mode, reduce the integral time to half of the previous valve.

10: Switch to auto mode and apply step change (+/-10%) to the set point note the response of the system.

11: Repeat above step to observe the effect of changes in integral setting.

## OBSERVATION:-

Observe the effect of reducing integral time on the response of the process.

## APPLICATION:-

This mode can be used in system with frequent or large load changes because of the integration time, however the process must have relatively slow changes load to prevent oscillations induced by the integral overshot.

**RESULT:-** PI Mode:

1: When the error is zero, the controller output is fixed at the valve that the integral term had when the error went to zero.

2: When error is not zero the proportional term contributes a correction and the integral term begin to increased or decreased the accumulated valve [initially PI(0)].

# Experiment no.- 5

AIM:- Study of PD controller for temperature/level/flow control by increasing the derivative time gradually finally compare the steady state Response of PD with PI controller.

Apparatus:-

1) Experiment set up
2) Personal computer
3) Power supply

Theory-

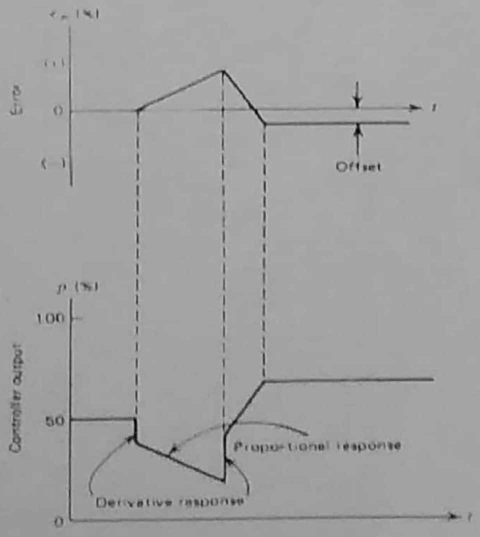
Proportional-Derivative Control Mode(PD) :-

A second combination of control modes has many industrial applicatons .It involves the serial(cascaded) use of the proportional and derivative nodes.

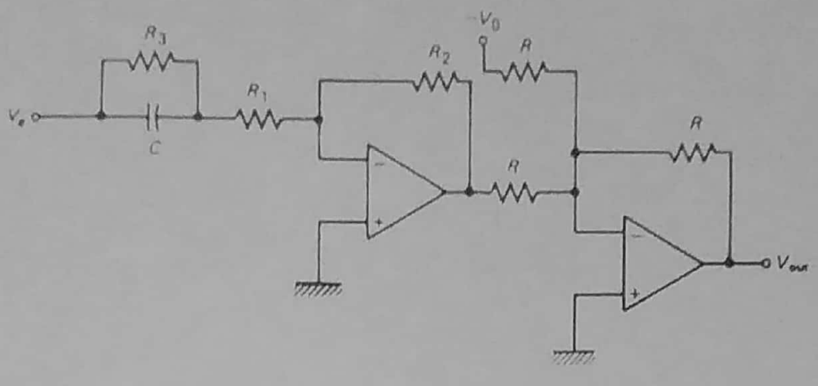
The analytic Expression for this mode is found from a combination.

$$P=K_p e_p + K_p K_D \frac{dep}{dt} + P_0$$

It is clear that this system cannot eliminate the offset of proportional controllers.



Proportional-derivative action showing the offset error from the proportional mode. This example is for reverse action.



An op amp proportional-derivative (PD) mode controller

## Procedure-

1) Start up the set up
2) Select experiment to study i.e LIC or FIC
3) Select close loop option for control
4) Select PD controller set the proportional band estimated term proportional control(P only) set derivate time to O and integral time=6000sec
5) Set the set point to desired value. Allow the process to reach at steady state .Note the response of system.
6) Switch controller top manual mode increase the derivative time by 1sec. switch to auto mode and apply step change to set point by 5 to 10% .Note the response of the system,
7) Increase the derivative time gradually and observe the process response for step change.

## Observation:-

Compare the steady state response of the PD Controller with PI Controller obtained in the previous experiment.

## Result:-

Effect of Derivative action in moving the controller output in relation to the error rate change.

# Experiment no.- 6

AIM :- Study of PID Controller for temp./level/flow/and compare steady state response with P, PI and PD controller.

Apparatus:-

1) Experiment set up
2) Personal computer(interface)
3) Power supply

Theory-

Proportional –Integral-Derivative control

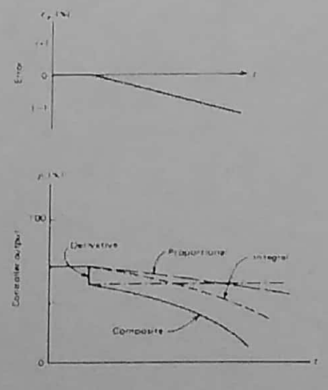
One of the most powerful but complex controller mode operation combines the proportional ,Integral, and Derivative modes.

The analytic expression is

$$P=K_P\, e_P+ K_p K_t \int_0^t ep\, d_t+K_p K_D \frac{dep}{dt}+ P_t(0)$$

This mode eliminates the OFF set of the Proportional mode and still provides fast response.

Implementation of PID with OP-AMP:- The zero error term of the proportional mode is not necessary because the integral automatically accommodates for off-set and nominal setting.This mode can provide by a straight application of OP-AMP circuit.



[illegible] and derivative action

Three-Mode:-

$$P=K_p\, e_p+ K_p K_I \int_0^t ep\, d_t + K_p K_D \frac{dep}{dt} + P_I(0)$$

P=controller o/p in percent of full scale

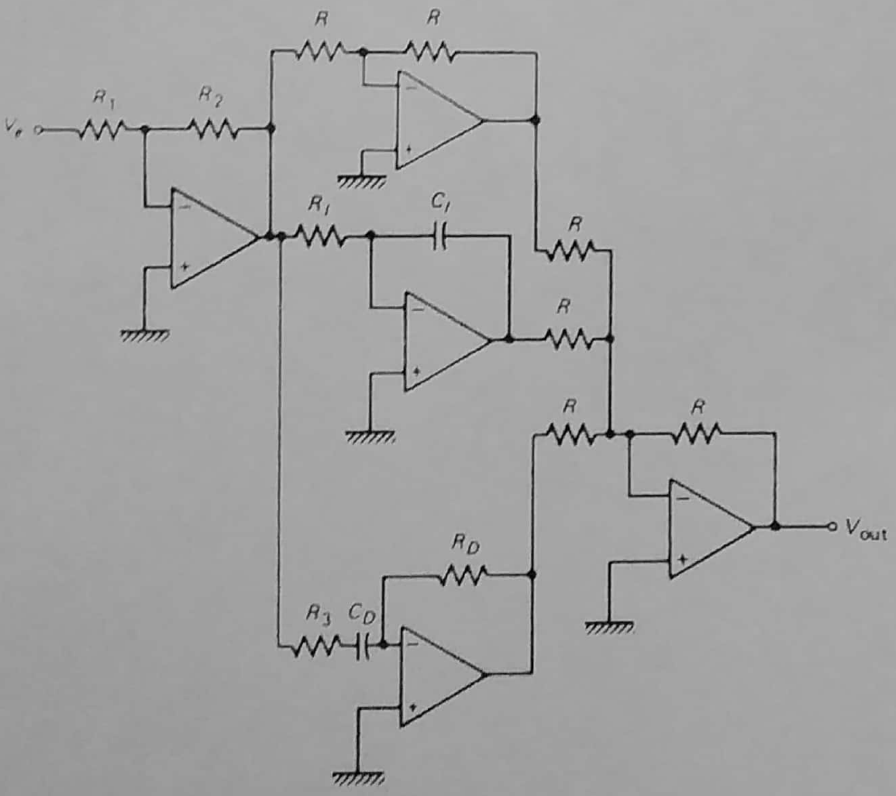
$e_p$=process erropr in percent of the max.

$K_p$=proportional gain

$K_I$=integral gain

$K_D$=derivate gain

$P_I(0)$=initial controller integral output



Direct implementation of a three-mode (PID) controller with op amps. Circuits with fewer op amps are often used

## PROCEDURE:-

1) Start up the set up
2) Select experiment to study i.e LIC or FICV
3) L select PID controller
4) Switch the controller to Mannual Mode. Change the proportional band to the value that estimate in proportional controller .Set integral time and derivative time based on the response in pervious experiment.
5) Adjust the set point to @50% switch the controller to auto mode.Apply set up change of 100% observe the process response.
6) Change the proportional band, Integral time, derivative time and observe the response of the process for se up change for each change in setting.

## OBSERVATION:-

Compare the steady state response of the PID controller with P, PI and PD controller

## RESULT:-

The output is

-Vout $=\frac{R2}{R1} V_e + \frac{R2}{R1}\frac{1}{R1C1}\int Ved + (R2/R1)R_D\, C_D\,\frac{dve}{dt} + V_{co}$

Gp$=\frac{R2}{R1}$

$G_{D=}R_D C_D\ ,\ G_{I=}\frac{1}{R1C1}$

# Experiment no.- 7

AIM:- Study of tuning of controller (open loop method) for level/flow control system. Plot the graph of process valve v/s time for process reaction curve ,calculate P,PI PID setting and above response of the system for different PID controller.

Apparatus:-

1) Experiment set up
2) Personal computer
3) PID Controller

Theory:-

Controller Tuning:-The three mode controller (PID) is the most common feedback controller used in Industrial control.The method of determination of the optimum mode gains depending on the nature and complexity of process is known as tuning.

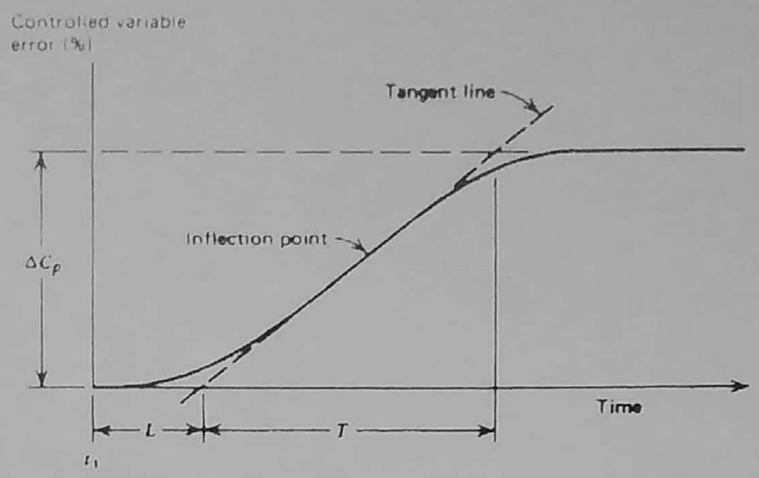
Choice of proportional band ,integral time and derivative time is a compromise between the set point trucking and disturbance .A widely used set of rules is proposed by Zigler-Nichol by open loop method.

Ziegler-Nichol Method:-

Open loop method(Process reaction curve):- In open loop method the process is assumed to be model of first order.The step response i.e. process reaction curve , allows to obtain the approximate values of P,I and D parameter with the feedback loop open a step response is applied to manipulated variable and the values of P,I and D are estimated.

**Slope R:-** Slop of line drawn tangent to the point of inflection.

$$R=\frac{\%\text{change in variable}}{time(\text{min}\quad)}$$



Process reaction graph for loop tuning

**Dead time L**:- Time between the step change and the point where tangent time crosses the initial value of controller variable

ΔP= step change applied in %

**For P,I and PID controller the parameters as follows.**

| MODE | P.B(In%) | Integral Time (in min) | Derivate Time (in min) |
|---|---|---|---|
| P | 100RL/ΔP | | |
| P+I | 110RL/ΔP | I/0.3 | |
| P+I+D | 83RL/ΔP | I/0.5 | 0.5L |

**RESULT**:- Observe the value of P,I,D and Plot graph . and inflection point.

# Experiment no.- 8

AIM :- **Study of flow characteristics of control valve and its calibration.**

Theory:-

Control valve:- Valve is essentially a variable orifice control valve is a value with a pneumatic , hydraulic, electric or other externally powered actuator that automatically , fully or partially opens and closes the valve to a position. Control valve are used primarily to throttle energy in a fluid system and not for shut off purpose.

Linear:- Flow is directly proportional to valve lift.

$$Q=KY$$

Where,

Q=Flow at constant pressure drop

Y= Valve opening

K= constant

Equal% - Flow changes by a constant percentage of its instantaneous valve for each unit of valve lift.

$$Q=bxe^{av}$$

Where,

Q=flow at constant pressure drop

Y=valve opening

e=base of natural logarithm

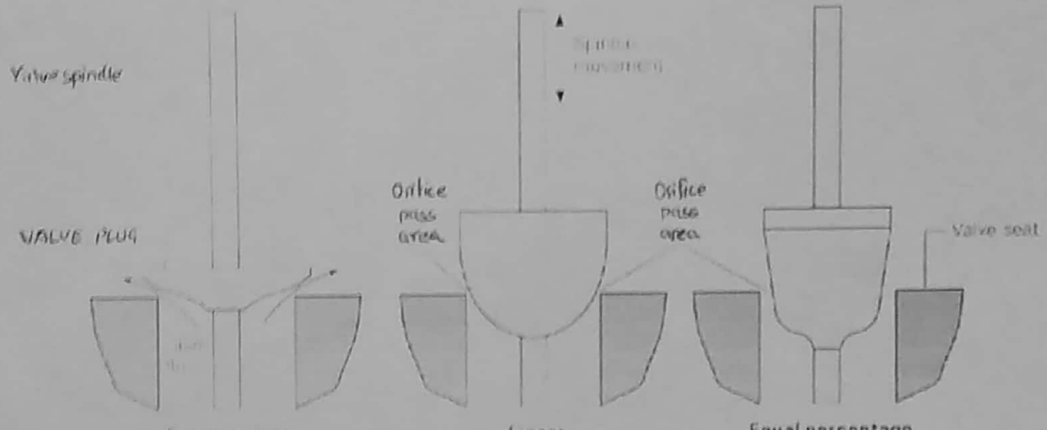
a and b = constant

constant a and b can be vaulted to give more convenient from.

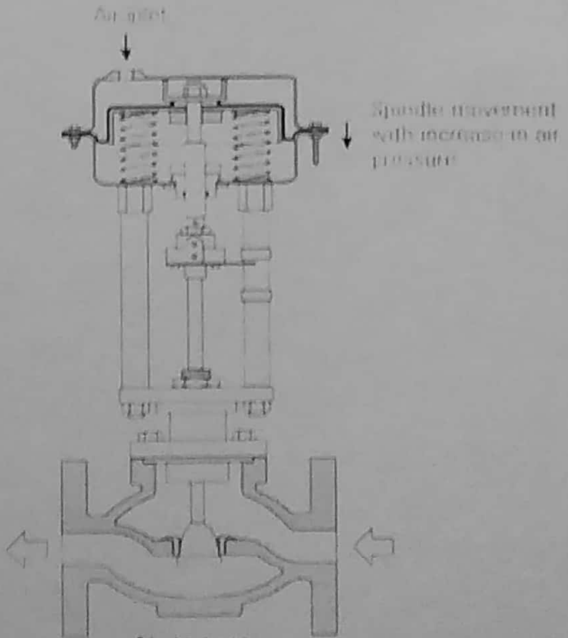
Valve characteristics:- The amount of fluid passing through a valve at any time depends upon the opening between the plug and seat. Hence there is relationship between stem position plug position and the route of flow which is described in terms of flow characteristics of a valve.

Inherent characteristics:- The inherent flow characteristics of control valve is the relation between the flow and the valve travel at constant pressure drop across the valve.

Installed characteristics: The valve described are subject to distortion due to variation in pressure drop with flow. Line resistance distorts linear characteristics towards that of quick opening valve and equal % to that of linear.



Fast opening Linear Equal percentage



Air-to-open,
normally closed

Scanned by CamScanner

**Control-Valve Principles** Flow rate in process control is usually expressed as Volume per unit time. If a mass flow rate is desired, it can be calculated from the particular fluid density. If a given fluid is delivered through a pipe, then the volume flow rate is

$$Q = Av$$

Where

$v$ = flow velocity (m/s)
$A$ = pipe area ($m^2$)
$Q$ = flow rate ($m^3/s$)

The purpose of the control valve is to regulate the flow rate of fluids through pipes in the system. This is accomplished by placing a variable-size restriction in the flow path, as shown in Figure **A**. You can see that as the stem and plug move up and down, the size of the opening between the plug and the seat changes, thus changing the flow rate. Note the direction of flow with respect to the seat and plug. If the flow were reversed, force from the flow would tend to close the valve further at small openings.

There will be a drop in pressure across such a restriction, and the flow rate varies with the square root of this pressure drop, with an appropriate constant of proportionality, shown by

$$Q = K\sqrt{\Delta p}$$

where $K$ = proportionality constant ($m^3/s/Pa^{1/2}$)
$\Delta p = p_2 - p_1$ = pressure difference (Pa)

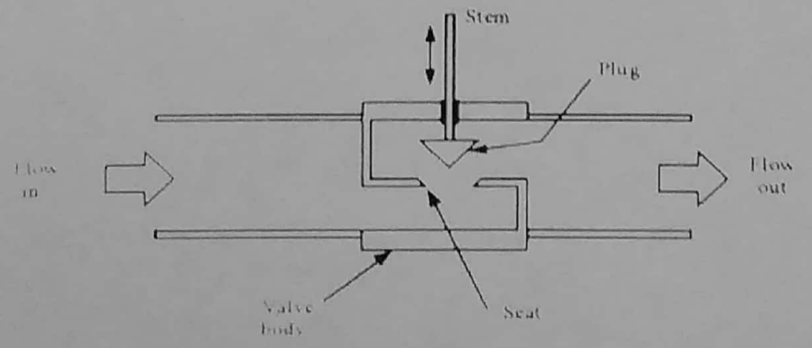


FIGURE A
A basic control-valve cross section. The direction of flow is important for proper valve action.

The constant, *K*, depends on the size of the valve, the geometrical structure of the delivery system, and, to some extent, on the material flowing through the valve. Now the actual pressure of the entire fluid delivery (and sink) system in which the valve is used (and, hence, the flow rate) is not a predictable function of the valve opening only. But because the valve opening does change flow rate, it provides a mechanism of flow control.

**Control-Valve Types** The different types of control valves are classified by a relationship between the valve stem position and the flow rate through the valve. This *control-valve characteristic* is assigned with the assumptions that the stem position indicates the extent of the valve opening and that the pressure difference is determined by the valve alone. Correction factors allow one to account for pressure differences introduced by the whole system. Figure **B** shows a typical control valve using a pneumatic actuator attached to drive the stem and hence open and close the valve. There are three basic types of control valves, whose relationship between stem position (as a percentage of full range) and flow rate (as a percentage of maximum) is shown in Figure **C**.

The types are determined by the shape of the plug and seat, as shown in Figure **A.** As the stem and plug move with respect to the seat, the shape of the plug determines the amount of actual opening of the valve.

1. *Quick Opening* :This type of valve is used predominantly for full ON/full OFF control applications. The valve characteristic of Figure **C** shows that a relatively small motion of the valve stem results in maximum possible flow rate through the valve. Such a valve, for example, may allow 90% of maximum flow rate with only a 30% travel of the stem.

2. *Linear* :This type of valve, as shown in Figure **C**, has a flow rate that varies linearly with the stem position. It represents the ideal situation where the valve alone determines the pressure drop. The relationship is expressed as

$$\frac{Q}{Q_{max}} = \frac{S}{S_{max}}$$

where
$Q$ = flow rate ($m^3/s$)
$Q_{max}$ = maximum flow rate ($m^3/s$)
$S$ = stem position (m)
$S_{max}$ = maximum stem position (m)

FIGURE B

A pneumatic actuator connected to a control valve. The actuator is driven by a current [illegible]

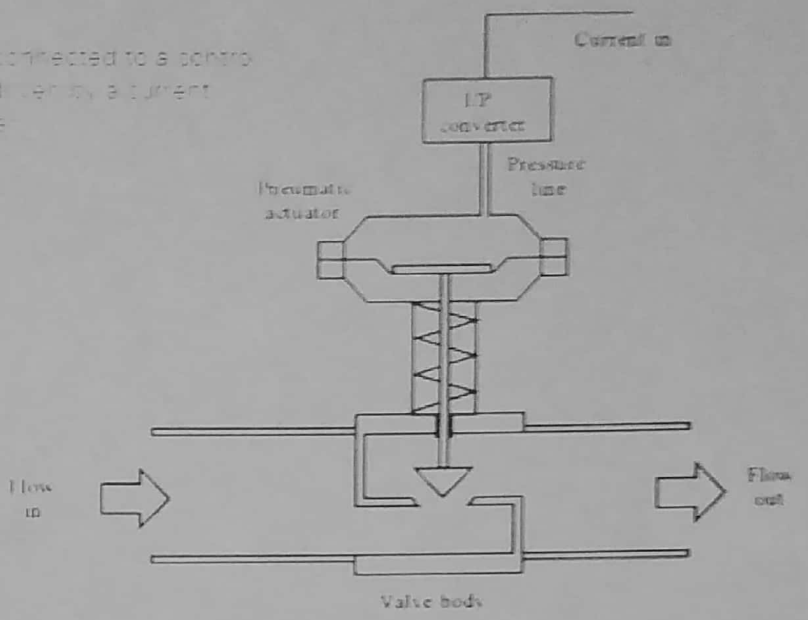
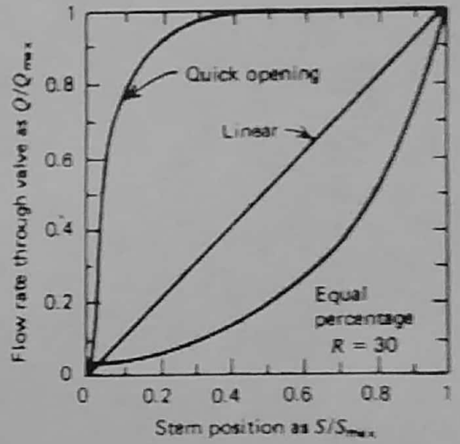


FIGURE C

Three types of control valves open differently as a function of valve stem position.



3. *Equal Percentage* :A very important type of valve employed in flow control has a characteristic such that a given percentage change in stem position produces an equivalent change in flow—that is, an equal percentage. Generally, this type of valve does not shut off the flow completely in its limit of stem travel. Thus, represents the minimum flow when the stem is at one limit of its travel. At the other extreme, the valve allows a flow as its maximum, open-valve flow rate. For this type, we define *rangeability, R,* as the ratio

$$R = \frac{Q_{\max}}{Q_{\min}}$$

The curve in Figure C shows a typical equal percentage curve that depends on the rangeability for its exact form. The curve shows that increase in flow rate for a given change in valve opening depends on the extent to which the valve is already open. This curve is typically exponential in form and is represented by

$$Q = Q_{\min} R^{x/x_{\max}}$$

where all terms have been defined previously.

**Control-Valve Sizing :-** Another important factor associated with all control valves involves corrections to Equation $Q = K\sqrt{\Delta p}$ because of the non-ideal characteristics of the materials that flow. A standard nomenclature is used to account for these corrections, depending on the liquid, gas, or steam nature of the fluid. These correction factors allow selection of the proper size of valve to accommodate the rate of flow that the system must support. The correction factor most commonly used at present is measured as the number of U.S. gallons of water per minute that flow through a fully open valve with a pressure differential of 1 lb per square inch. The correction factor is called the *valve flow coefficient* and is designated as . Using this factor, a liquid flow rate in U.S. gallons per minute is

[illegible] valve flow coefficients

| Valve size (inches) | $C_V$ |
|---|---|
| [illegible] | 0.3 |
| [illegible] | 3 |
| 1 | 14 |
| 1½ | 35 |
| 2 | 55 |
| 3 | 108 |
| 4 | 174 |
| 6 | 400 |
| 8 | 725 |

$$Q = C_V\sqrt{\frac{\Delta p}{S_G}}$$

where $\Delta p$ = pressure across the valve (psi)
$S_G$ = specific gravity of liquid

Typical values of $C_V$ for different-size valves are shown in Table 1. Similar equations are used for gases and vapors to determine the proper valve size in specific applications.