5^{th} Semester

INSTRUMENTATION AND CONTROL ENGINEERING

SUBJECT : PROCESS CONTROL

SUBJECT CODE : 181553

DISCLAIMER

Chapter-1
(Basic Control Loops and Characteristics)

Introduction to Control System:

System: A system is a basic unit consisting of an element or no. of elements working in cohesion & desirably a single cohesion unit to perform desired controlled functions.

Depending on nature or requirements a system is electrical, mechanical, pneumatic, hydraulics, digital, analog etc.

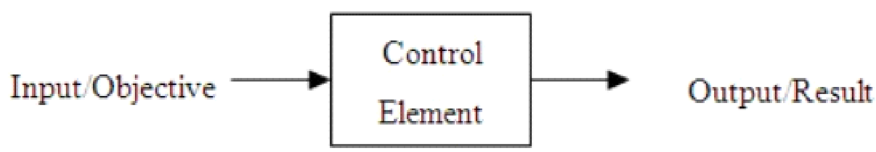
Control System: Control system is a science which deal system mechanism device or collection of objects joined to have some of interaction with a purpose.

Or

Control is defined for as system that provides required ordered output response with some implementation. It provides all..... Of design development & operation which assumes a cause effect relationship for the component of system.

There are basically three significant elements:

- Input of Objective.
- Process orsystem.
- Output or result.



Basic Components of Control System

Actuator: Actuator is a device whichcorrects the output quantity till the O/P quantity reaches at the desired value.

Process: Any operation which is done in any instrument to get \desired value. This action is known as "process" or The mean of I/P & O/P is known as "process"

Controller: A device which applies to determine a control output from the error signal in a closed loop.

Controlled device / O/P : It is a device that responds to the signal from the controller changes the condition of controlled medium. These are fans, pumps, value operation, electrical relay etc.

Automatic control system : Automatic control system is the maintains of a desired value of a quantity Or condition by measuring the output and comparing it with the desired value, if these is difference between desired value & the output and then taking the action for reducing this difference so that desired value can be maintained as soon as possible.

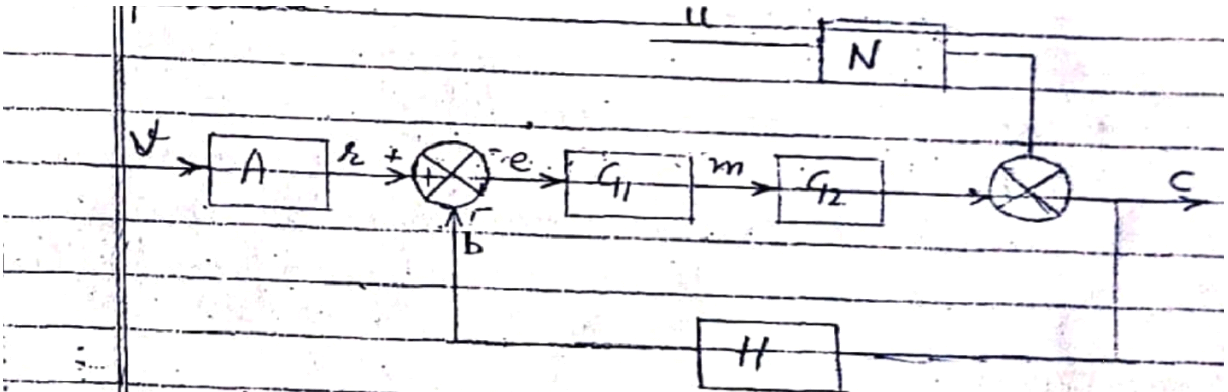


fig:- Block Diagram of a Control System.

Variables :

v = Set point
r = Reference input
e = Actuating singnal = r-b
m = Manipulated variable
c = Controlled variable
µ = Load varibale
b = feed back variable.

Elements :

A = Input element
G1 = Control element
G2 = System element
H = Feedback element
N = Load element

1. v (Set point) : It is the fixed point set by the user in the starting of the process to get desried output.

2. r (Reference input) : It is a input signal which is given to the system to get desried value.

3. e (Actuating singnal) : It is a difference between input and primary feed back. i.e. e = r-b

4. m (Manipulated variable) : It is a quantity of condtion which is varied by automatic control so as to effect the value of controlled variable.

5. c (Controlled variable) : It is the desired value which is set at the set point and required by the user as output.

6. µ (Load varibale) : It is the factor which is responsible for change/disturbance in output or controlled variable.

7. b (feed back variable) : It is the output value which return back to error detector for comparison with set point to check that whether the output value is desired or not.

The automatic control requires a closes loop of action & reaction operating without human aid.
To illustrate the closed loop action. Consider the control of a HOME HEATING SYSTEM.

Suppose that is desired to maintain the temperature of the room at 36º C. This desired temperature is known as the set point. A thermometer /thermistor/thermostat is install on the wall inside the room. It measures the increase in temperature & this is known as controlled variable. It measures the temperature continuously by mean of automatic & manually.

In manual control s/m when the thermometer notes the temperature 33º C. This difference less then the desired tem./set point then the actuating signal is of 3º C. This difference of temperature can be reduced by turning a switch that control the flow of ffuel gas to burn in furnace.

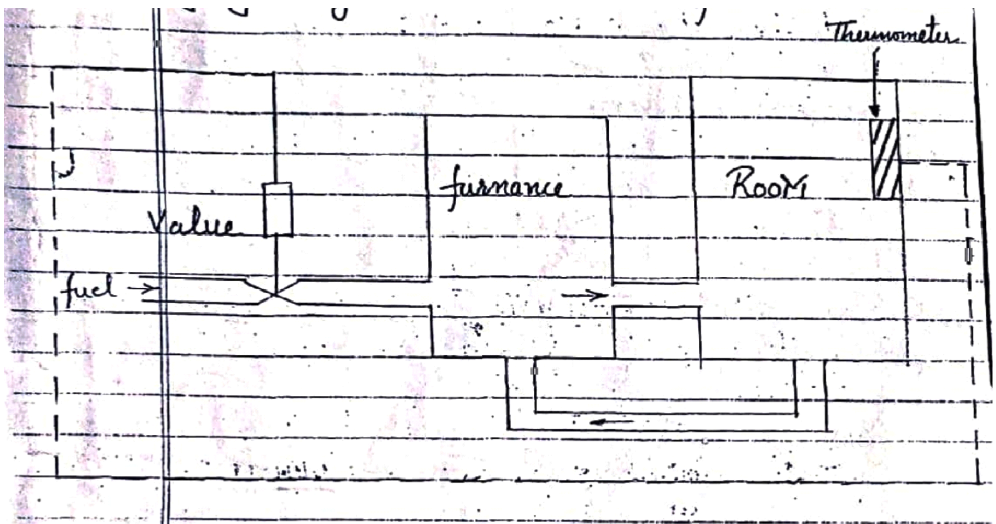


fig :- Home Heating Control.

The flow of gas (fuel gas) manipulated variable. As we increase the flow of fuel gas then the time is come so soon at which the temperature of room becomes equal to the desired temperature and the state at which the temperature increases above from the desired temperature is also come at this stage we close the switch that controls the flow of fuel gas, as a result of which the fuel gas is stop & temp. is remains constant at 36º C.

Open loop control systems & closed loop control systems:

- **Open Loop control systems:** Open loop control systems are those systems in which output has no effect upon control action. The input controls the output through the control action as shown in fig (a) in other words, output is neither measure non is a feedback for comparison with input. Hence O.I.C.S is also referred to as.

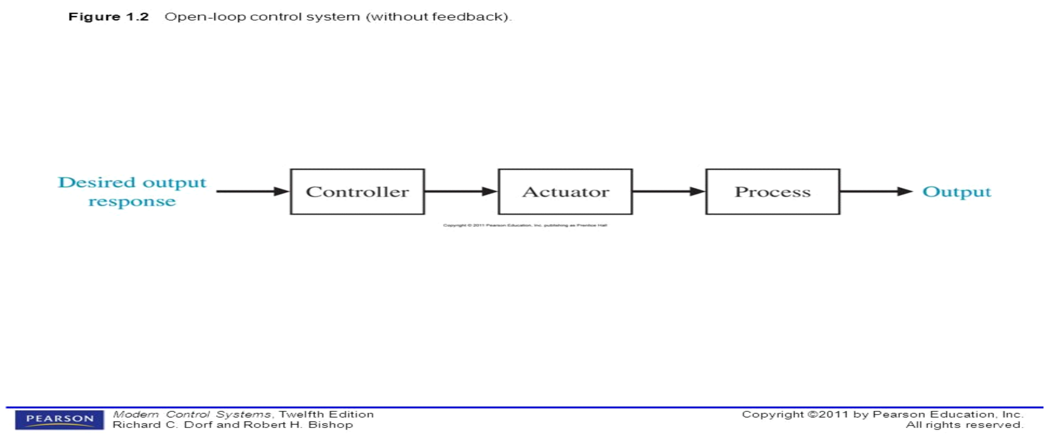
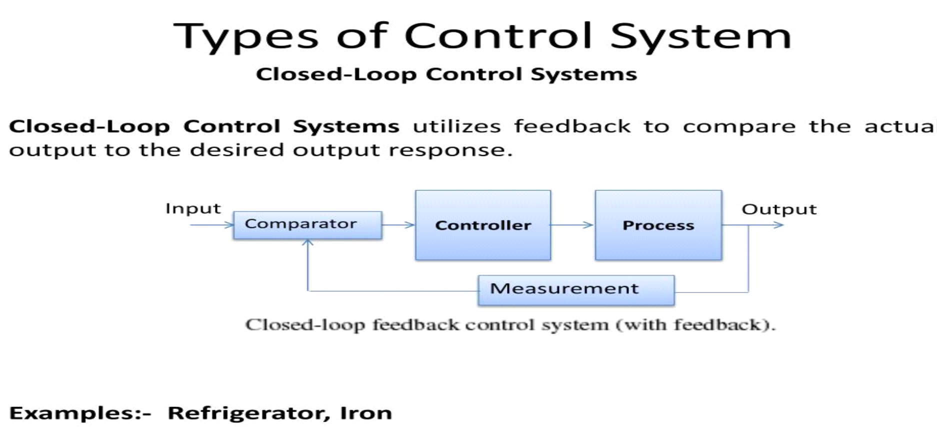
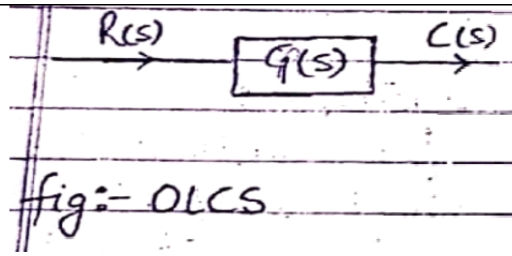
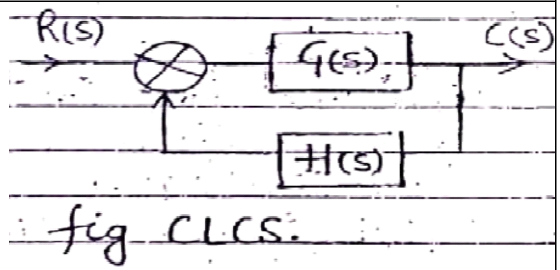


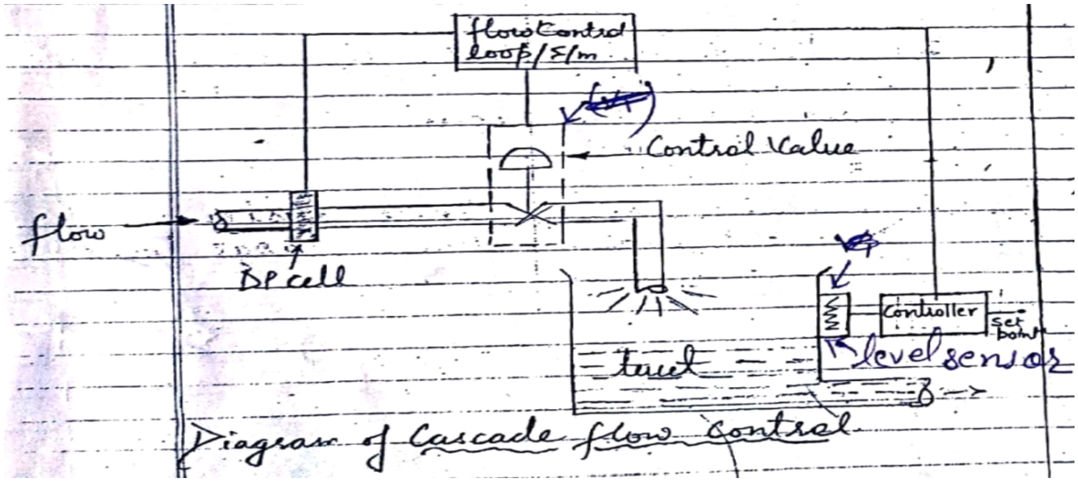
Fig. O.L.C.S (without feed-back)

- **Closed loop control :** Closed loop control systems are those control systems in which ouput has a direct effect upon contorl action through feedback. Therefore they are also known as feedback control system. In this r/m the actuatiing error signal which is difference between input singal and feedback signal (which may be output signal or singal with some operations on output) is feed to the controler so as to reduce the error & get the output of system to a desired value.



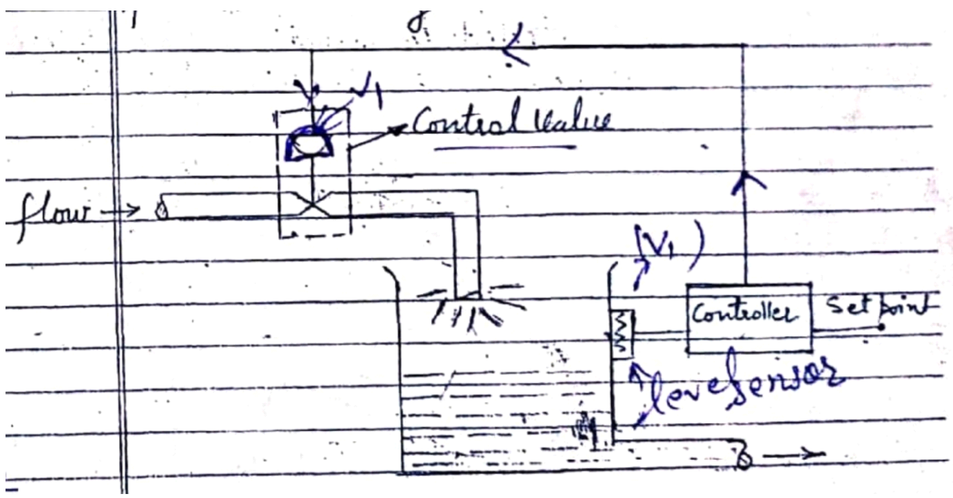
Sr. No.	Open loop control system	Closed loop control systems
1.		
2.	Accuracy depends upon the calibration of input.	Accuracy depends upon the feedback so the operate more accurately.
3.	There is no feed back in open loop systems.	Thereis a feedback present is the closed loop systems.
4.	Disturbances & change in calibration causes the error.	Disturbances have very maximum effect on the stability of a system.
5.	These is no change in the gain of a r/m.	The feed back improves the gain of the systems.
6.	These systems are cheap.	There systems are very complicated to construct.
7.	Simple construction & easy maintenance is required in the open loop system.	There systems are very complicated to construct.
8.	These spam's have low bandwidth.	There systems have large bandwidth.

III.Example of flow Loop : Consider a cascade flow control " In this system a flow loop is a single variable systems but a set point is determined by measurement of level. When the up stream load them the change in the level of liquid is never seen in the tank because a flow control loop/systems regulate such changes by DP-cell& Control value before they appears as a solid change in the level.



IV.Examples of "Flow loop control system" : Consider a "Direct flow control s/m" In this control system the level measurement is used to adjust a control value as a final element. A set point to the controller is a desired level.

In this system, as the up steam load changes then it cause a change in flow rate that results in a level change there the level change is a second stage effect. Therefore the system cannot response until the level has been change by flow rate change.



V.Example of " Single Loop Temerature Control System": To explain "Thermal process system" "The heat exchanges" is an example of thermal process.

Consider a Heat exchanges systems in this system the temperatures flow of inlet steam is measured & accordingly the steam pressure can be increased or decreased.

It means the disturbance directly & then calculate the effect of it on the process output & control action starts immediately after the change in disturbance has been detected to eliminate the effect of disturbance on the output of this system.

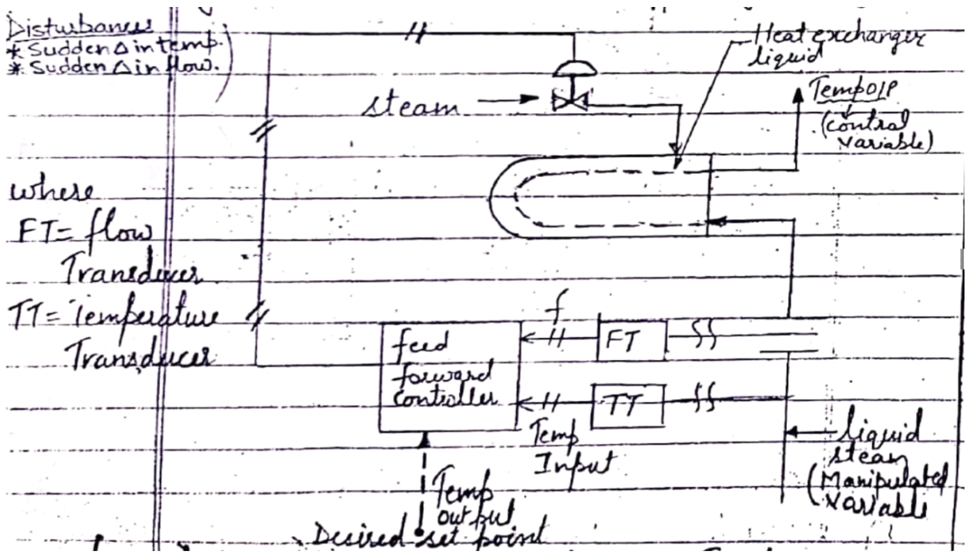


Diagram of Heat Exchange systems

Lags :

"Lag" is the retardation on delay of one physical condition with respect to some other condition to which it is closely related.

The lag is of following types: -

- Process lag.
- Measurement lag.
- Transmission lag.

a. Process Lag:

During process control operations if at any point of time this occurs a loud change which causes the change in control variable. The process control loop responds to this change at a finite time & the control variable returns to the set point. A part of this time is consumed by the process itself and is called as the "Process lag".

Consider a "Liquid temperature control process" In which temperature is controlled by opening & closing of steam inlet value if there is a large process load change which interns reduce the temperature of liquid. Therefore for reaching the set point the steam inlet value should be opened so that more heat given to the system and thereby achieving the desired set point.

Now the physical opening of control value is the slowest part of the system and thereby these must be time lag for achieving a desired temperature (set point). This lag is known as the "process lag".

b. Measurement Lag:

When a control variable experiences a sudden change, the process control loop reacts by giving a command to the final control element have a new value to compensate for the detective change, The measurement lag refers to the time for the process control loop to make necessary adjustment to the final control element.

How much value should be given to the final control element (steam inlet value) and time required to give this signal to the steam inlet value is known as the "measurement lag."

The effect of large measurement lag is always cause large amplitude oscillations ....return or stabilization.

c. Transmission lag:

The time which is taken to transmits the corrective action or the action taken by the controller to remove the error from the opening value.

Or

The time taken to transmits the corrective action from the opening value of the water tank.

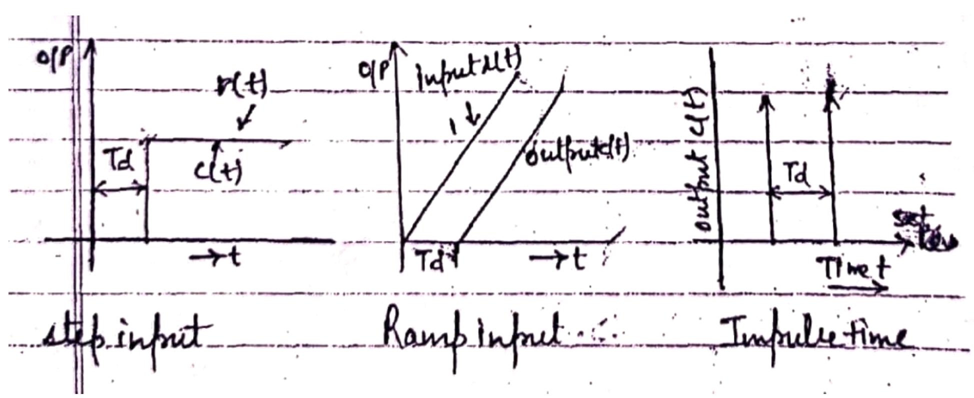
In any process the time taken by the fluid to transmit from the value opening to stasis tank, this time is known as "Transmission lag"

VI. Dead Time:

It is a internal of time b/w the changes of an input to an element and the beginning of response to the input.

Or

This the claps time between the movement a deviation occur & the corrective action first occurs. This movement of time is called "Dead Time"



When a deviation is detected a control s/m quickly changes value setting to adjust the steam flow rate, But if the pipe is quite long there is a period of time during which no effect is fent in change in temperature of the process. This is the time required for the new steam inlet flow rate, to move down the length of pipe & this time is known as "dead time."

Sensor :

The sensor which measures the controlled medium or other control input in an accurate and repeatable manner.
There are extremely important part of the control system.

Chapter-2
Basic Controller Modes and Characteristics

On/off Control

There are different types of control: On/Off, Proportional, PI, PD, PID and fuzzy logic. On/Off control is the simplest control method and hence the cheapest to implement. The following provides a description of how On/Off control works.

ON/off

On/Off control is the simplest form of control. The output from the device is either 100% ON or OFF, with no middle state. An On/Off controller will switch the output only when the reading crosses the set point.

For pH acid control, the output is ON when the pH is above the set point, and OFF below the set point.Since the pH crosses the set point to change the output state, the acid pump will be continually cycling, going from above the set point to below, and back above.

Figure 1 represents the operation of an On/Off system for pH control using an acid pump. The acid pump turns ON when pH is above the set point and turns OFF when the pH is below the set point.

The disadvantage of On/Off control is that dosing pump doses the same amount at both points A and B on

Figure 1.

As can be seen from the diagram less acid would be required to be dosed when the pH is at point B as it is heading towards the set point. WeWhen pH is at point A, potentially the maximum amount of acid injection is required to prevent extra deviation from the set point, whilst at point B minimal to no injection may be required to reach the set point. More sophisticated control systems include the rate of change in the system to adjust the dosing rate providing better control. However due to the simplicity of On/Off control it is unable to do this and always doses at 100%.

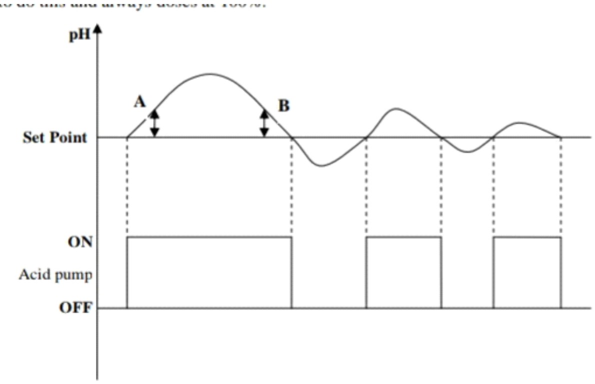


Figure 1. The operation of an On/Off system in controlling the pH below or equal to the set point

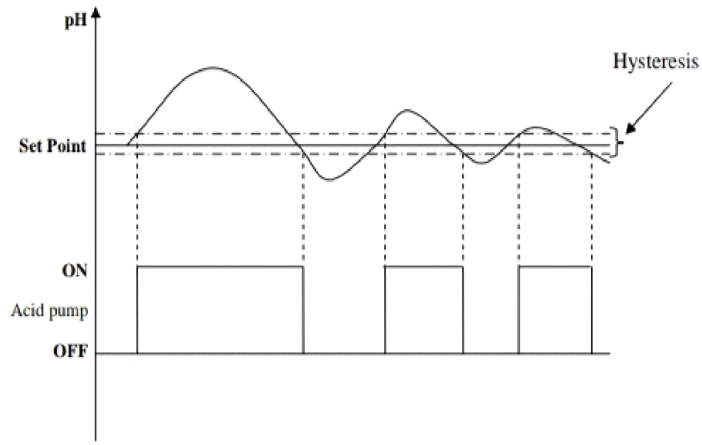


Figure 2. Operation of an On/Off system in controlling the pH using hysteresis

In cases where cycling around the set point occurs rapidly, and to prevent damage to contactors and valves, an On-Off differential, or “Hysteresis”, is added to the control parameters. Figure 2 shows how hysteresis works. The pH must exceed the set point by a predefined amount (hysteresis) before the output will turnON or OFF. Hysteresis prevents the output from “chattering” or making fast, continual switches if the cycling above and below the set point occurs rapidly.

Advantages:

- On/Off control is very easy to design, understand and implement.
- On/Off controllers are very cheap.
- On/Off control systems are usually used when precise control is not necessary.
- They are useful in slow changing systems

Disadvantages:

- They are either 100% ON or OFF regardless of where the reading is with respect to the set point. This can cause considerable over shoots and undershoots.
- They perform poorly when controlling rapid system fluctuations. Hence they provide poor control and are not recommended for chemical processes.
- If no Hysteresis is implemented, they can damage actuators and pumps due to rapidly switching them ON and OFF around the set point.
- When Hysteresis is used, there is a constant error around the set point.
- Performance varies significantly based on the system size and is dependent on the dosing pump
- size, i.e. oversized dosing pumps will cause overshooting.

Proportional Controllers

All controllers have a specific use case to which they are best suited. We cannot just insert any type of controller at any system and expect a good result – there are certain conditions that must be fulfilled. For a proportional controller**,** there are two conditions and these are written below:

- The deviation should not be large; i.e. there should not be a large deviation between the input and output.
- The deviation should not be sudden.

Now we are in a condition to discuss proportional controllers, as the name suggests in a proportional controller the output (also called the actuating signal) is directly proportional to the error signal. Now let us analyze the proportional controller mathematically. As we know in proportional controller output is directly proportional to the error signal, writing this mathematically we have,

$$A(t) \propto e(t)$$

Removing the sign of proportionality we have,

$$A(t) = K_p \times e(t)$$

Where K_p is proportional constant also known as controller gain.

It is recommended that K_p should be kept greater than unity. If the value of K_p is greater than unity (>1), then it will amplify the error signal and thus the amplified error signal can be detected easily.

Advantages of Proportional Controller

Now let us discuss some advantages of the proportional controller.

- The proportional controller helps in reducing the steady-state error, thus makes the system more stable.
- The slow response of the overdamped system can be made faster with the help of these controllers.

Disadvantages of Proportional Controller

Now there are some serious disadvantages of these controllers and these are written as follows:

- Due to the presence of these controllers, we get some offsets in the system.
- Proportional controllers also increase the maximum overshoot of the system.

Integral Controllers

As the name suggests in **integral controllers** the output (also called the actuating signal) is directly proportional to the integral of the error signal. Now let us analyze integral controller mathematically. As we know in an integral controller output is directly proportional to the integration of the error signal, writing this mathematically we have,

$$A(t) \propto \int_0^t e(t)dt$$

Removing the sign of proportionality we have,

$$A(t) = K_i \times \int_0^t e(t)dt$$

Where Ki is an integral constant also known as controller gain. The integral controller is also known as reset controller.

Derivative Controllers

We never use derivative controllers alone. It should be used in combinations with other modes of controllers because of its few disadvantages which are written below:

- It never improves the steady-state error.
- It produces saturation effects and also amplifies the noise signals produced in the system.

Now, as the name suggests in a derivative controller the output (also called the actuating signal) is directly proportional to the derivative of the error signal. Now let us analyze the derivative controller mathematically. As we know in a derivative controller output is directly proportional to the derivative of the error signal, writing this mathematically we have,

$$A(t) \propto \frac{de(t)}{dt}$$

Removing the sign of proportionality we have,

$$A(t) = K_d \times \frac{de(t)}{dt}$$

Where, K_d is proportional constant also known as controller gain. The derivative controller is also known as the rate controller.

Advantages of Derivative Controller

The major advantage of a derivative controller is that it improves the transient response of the system.

Proportional and Integral Controller

As the name suggests it is a combination of proportional and an integral controller the output (also called the actuating signal) is equal to the summation of proportional and integral of the error signal. Now let us analyse proportional and integral controller mathematically. As we know in a proportional and integral controller output is directly proportional to the summation of proportional of error and integration of the error signal, writing this mathematically we have,

$$A(t) \propto \int_0^t e(t)dt + A(t) \propto e(t)$$

Removing the sign of proportionality we have,

$$A(t) = K_i \int_0^t e(t)dt + K_p e(t)$$

Where, K_i and k_p proportional constant and integral constant respectively.

Advantages and disadvantages are combinations of the advantages and disadvantages of proportional and integral controllers.

Through the PI controller, we are adding one pole at origin and one zero somewhere away from the origin (in the left-hand side of complex plane). As the pole is at the origin, its effect will be more, hence PI controller may reduce the stability; but its main advantage is that it reduces steady-state error drastically, due for this reason it is one of the most widely used controllers.

The schematic diagram of the PI controller is shown in Fig-6. Against step input, for the values of K=5.8, K_i=0.2, Its time response, is shown in Fig-7. At K=5.8 (As a P- controller, it was on the verge of instability, so just by adding the small value of an Integral part, it became unstable. Please note the Integral part reduces the stability, which does not mean that system will be always unstable. In the present case, we have added an integral part and the system became unstable).

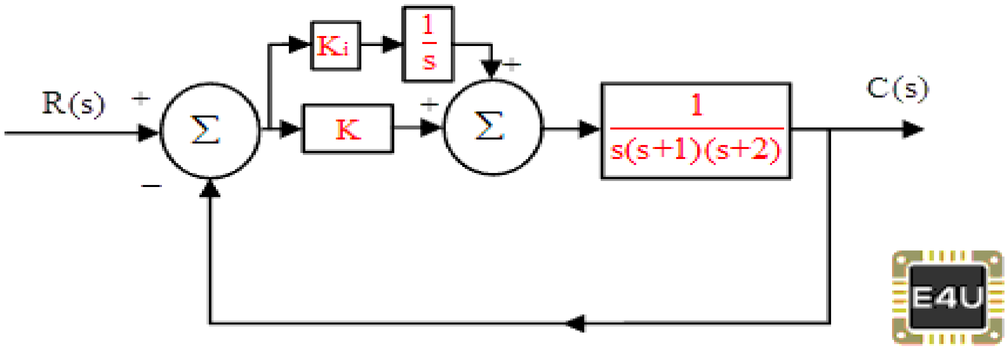


Figure-6: The closed loop control system with PI Controller

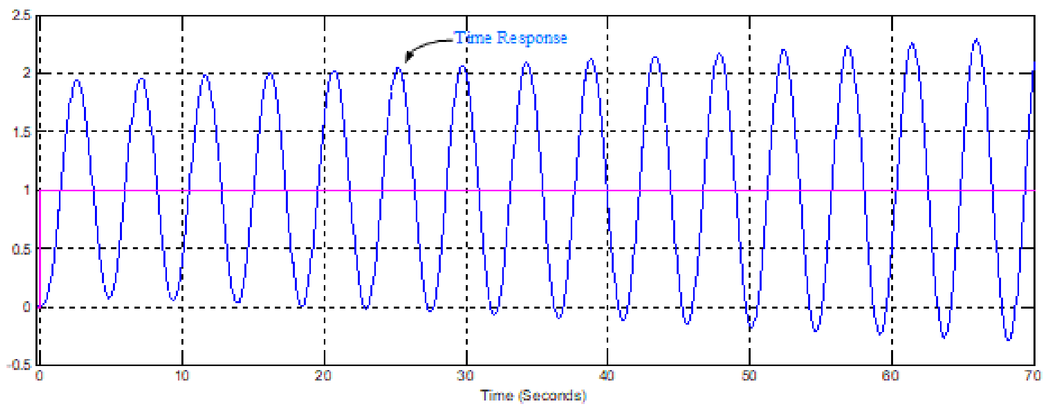


Figure-7: The response of the system shown in Figure-6, with K=5.8, Ki=0.2

Proportional and Derivative Controller

As the name suggests it is a combination of proportional and a derivative controller the output (also called the actuating signal) is equals to the summation of proportional and derivative of the error signal. Now let us analyze proportional and derivative controller mathematically. As we know in a proportional and derivative controller output is directly proportional to the summation of proportional of error and differentiation of the error signal, writing this mathematically we have,

$$A(t) \propto \frac{de(t)}{dt} + A(t) \propto e(t)$$

Removing the sign of proportionality we have,

$$A(t) = K_d \frac{de(t)}{dt} + K_p e(t)$$

Where, K_d and K_p proportional constant and derivative constant respectively.
Advantages and disadvantages are combinations of advantages and disadvantages of proportional and derivative controllers.

Readers should note that adding 'zero' at the proper location in the open-loop transfer function improves stability, while the addition of pole in the open-loop transfer function may reduce the stability. The words "at proper location" in the above sentence are very important & it is called designing of the control system (i.e. both zero & pole should be added at proper points in the complex plane to get the desired result).

Inserting the PD controller is like the addition of zero in open-loop transfer function [G(s)H(s)]. Diagram of PD Controller is shown in Fig-8

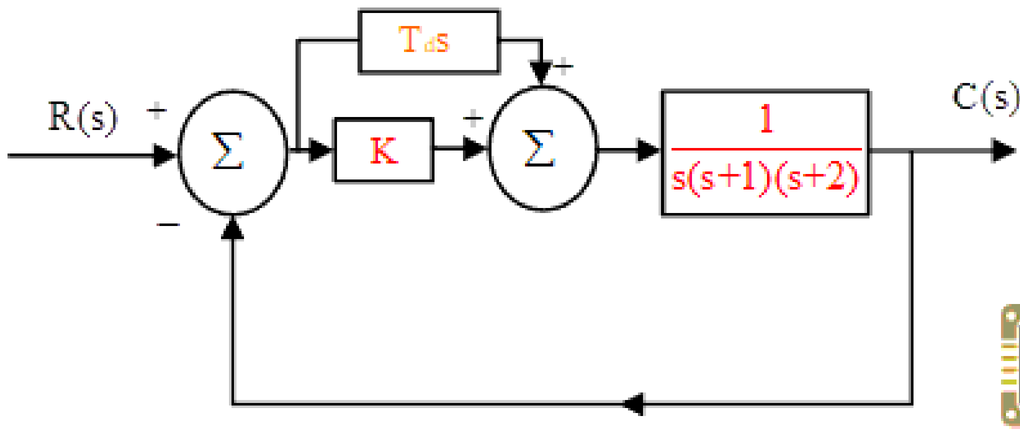


Figure-8: Closed-loop Control system with PD Controller

In the present case, we have taken the values of K=5.8, Td=0.5. Its time response, against step input, is shown in Fig-9. You can compare Fig-9, with Fig-5 and can understand the effect of inserting the derivative part in the P-controller.

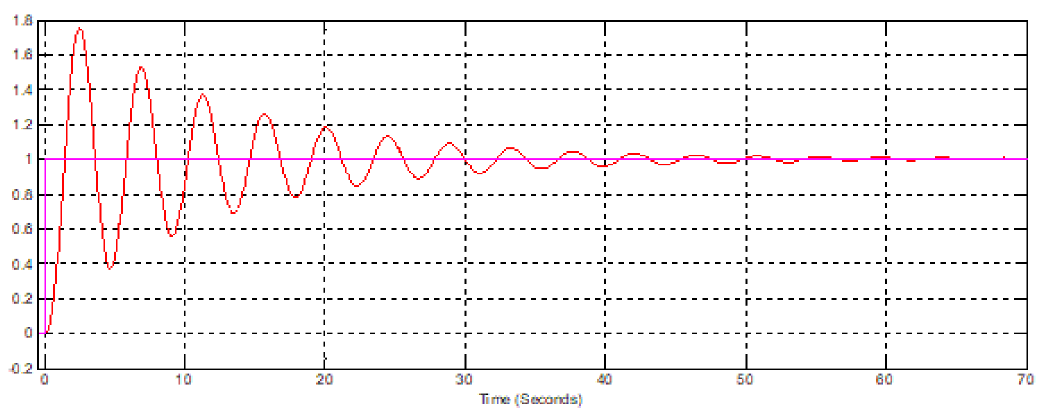


Figure-9: Response of system shown in Figure-8, with K=5.8, Td=0.5

The transfer function of the PD controller is K+Tds or Td(s+K/Td); so we have added one zero at -K/Td. By controlling the value of 'K' or 'Td', the position of the 'zero' can be decided.

If ‘zero’ is very far away from the imaginary axis, its influence will decrease, if ‘zero’ is on the imaginary axis (or very close to the imaginary axis) it will also be not accepted (root locus generally starts from ‘poles’ & terminates at ‘zero’, Designer’s aim is generally such that root locus should not go towards the imaginary axis, due to this reason ‘zero’ very near to imaginary axis is also not acceptable, hence a moderate position of ‘zero’ should be kept)

Generally, it is said, PD controller improves transient performance and the PI controller improves the steady-state performance of a control system.

Proportional plus Integral plus Derivative Controller (PID Controller)

A PID controller is generally used in industrial control applications to regulate temperature, flow, pressure, speed, and other process variables.

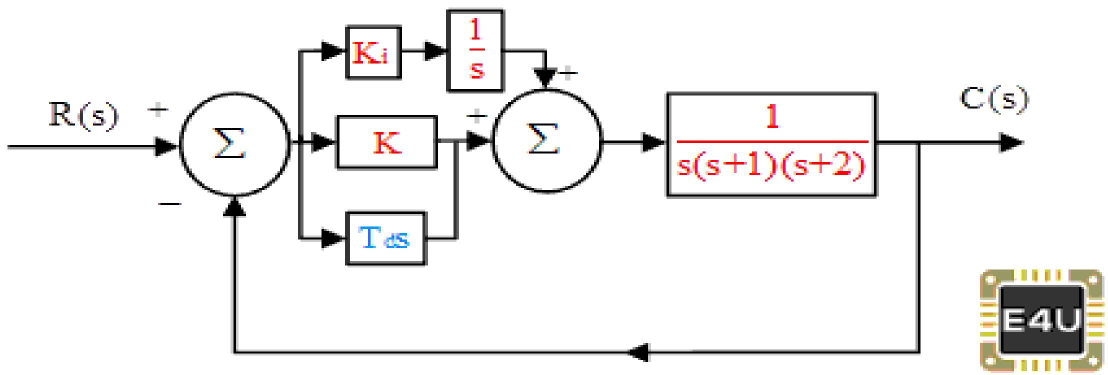


Figure-10: Closed loop control system with PID Controller

The transfer function of the PID Controller can be found as:

$$Tds + K + \frac{Ki}{s} \text{ or } \frac{Tds^2+Ks+Ki}{s}$$

It can be observed that one pole at origin is fixed, remaining parameters T_d, K, and Ki decide the position of two zeros. In this case, we can keep two complex zeros or two real zeros as per the requirement, hence PID controller can provide better tuning. In the olden days, the PI controller was one of the best choice of control engineers, because designing (tuning of parameters) of the PID controller was a little difficult, but nowadays, due to the development of software designing of PID controllers have become an easy task.

Against step input, For the values of K=5.8, K_i=0.2, and T_d=0.5, Its time response, is shown in Fig-11. Compare Fig-11 with Fig-9 (We have taken values such that all the time response can be compared).

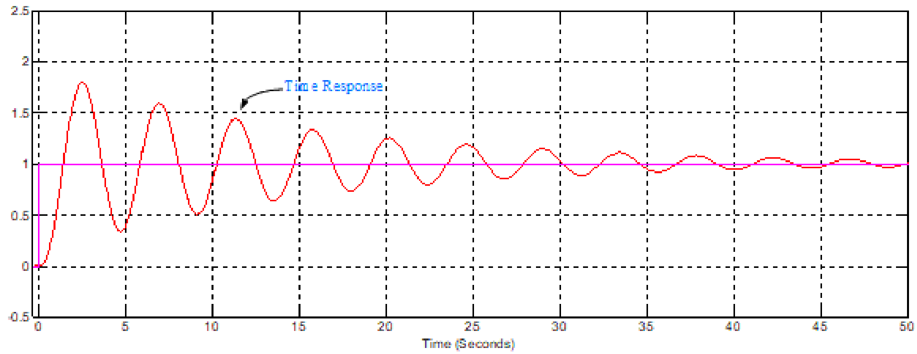


Figure-11: Response of system shown in Figure-10, with K=5.8, Td=0.5, Ki=0.2

General Guidelines for Designing a PID Controller

When you are designing a PID controller for a given system, general guidelines to obtain the desired response are as follows:

- Obtain the transient response of closed-loop transfer function and determine what needs to be improved.
- Insert the proportional controller, Design the value of 'K' through Routh-Hurwitz or suitable software.
- Add an integral part to reduce steady-state error.
- Add the derivative part to increase damping (damping should be between 0.6-0.9). The derivative part will reduce overshoots & transient time.
- Sisotool, available in MATLAB can also be used for proper tuning and to obtain a desired overall response.
- Please note, above steps of tuning of parameters (designing of a control system) are general guidelines. There are no fixed steps for designing controllers.

Fuzzy Logic controllers

Fuzzy Logic controllers (FLC) are used where systems are highly non-linear. Generally most of the physical systems/Electrical systems are highly non-linear. Due to this reason, Fuzzy Logic controllers are a good choice among researchers.

An accurate mathematical model is not needed in FLC. It works inputs based on past experiences, can handle non-linearities and can present disturbance insensitivity greater than the most other non-linear controllers.

FLC is based on fuzzy sets, i.e. classes of objects in which the transition from membership to non-membership is smooth rather than abrupt.

In recent developments, FLC have outperformed other controllers in complex, nonlinear or undefined systems for which a good practical knowledge exists. Therefore, boundaries of fuzzy sets can be vague and ambiguous, making them useful for approximation models. The important step in the fuzzy controller synthesis procedure is to define the input and output variables based on previous experiences or practical knowledge.

This is done accordingly with the expected function of the controller. There are no general rules to select those variables, although typically the variables chosen are the states of the controlled system, their errors, error variation, and error accumulation.

Chapter-3
Control Elements

What are Limit Switches?

Limit switches are used to automatically detect or sense the presence of an object or to monitor and indicate whether the movement limits of that object have been exceeded. The original use for limit switches, as implied by their name, was to define the limit or endpoint over which an object could travel before being stopped. It was at this point that the switch was engaged to control the limit of travel.

How does a limit switch work?

A standard limit switch used in industrial applications is an electromechanical device that consists of a mechanical actuator linked to a series of electrical contacts. When an object (sometimes called the target) comes in physical contact with the actuator, the actuator plunger's movement results in the electrical contacts within the switch to either close (for a normally open circuit) or open (for a normally closed circuit) their electrical connection. Limit switches use the mechanical movement of the actuator plunger to control or change the electrical switch's state. Similar devices, such as inductive or capacitive proximity sensors, or photoelectric sensors, can accomplish the same result without requiring contact with the object. Hence, limit switches are contact sensors in contrast to these other types of proximity sensing devices. Most limit switches are mechanical in their operation and contain heavy-duty contacts capable of switching higher currents than those of alternative proximity sensors.

Components of a limit switch

Limit switches consist of an actuator with operating head, the switch body mechanism, and a series of electrical terminals that are used to connect the switch to the electrical circuit that it is controlling. The operating head is the part of the limit switch that comes in contact with the target. The actuator contains is connected to the operating head, whose linear, perpendicular, or rotary motion is then translated by the actuator to close or open the switch. The switch body contains the switch contact mechanism whose state is controlled by the actuator. The electrical terminals are connected to the switch contacts and enable wires to be joined to the switch through terminal screws.

Industrial machinery that undergoes automatic operations usually requires control switches that activate according to the movements involved in a machine's performance. For repeat usage, the accuracy of the electrical switches needs to be reliable and their response rate should be prompt. Due to the mechanical specifications and performance parameters of different machines, factors such as size, operational force, mounting method, and stroke rate are important characteristics in the installation and maintenance of limit switches. In addition, a limit switch's electrical rating should be matched to the mechanical system loads that it will be controlling in order to avoid instrument failure.

Limit Switch Uses and Operation

In most cases, a limit switch begins operating when a moving machine or a moving component of a machine makes contact with an actuator or operating lever that activates the switch. The limit switch then regulates the electrical circuit that controls the machine and its moving parts. These switches can be used as pilot devices for magnetic starter control circuits, allowing them to start, stop, slow down, or accelerate the functions of an electric motor. Limit switches can be installed into machinery as control instruments for standard operations or as emergency devices to prevent machinery malfunction. Most switches are either maintained contact or momentary contact models.

Limit Switch Contacts

Control schematics for limit switches usually display a limit switch symbol to indicate the state of the switch contacts. The most common contact symbols show whether the device has normally open or normally closed limit switch contacts. The symbol for a "normally open held closed" state indicates that the contact has been wired as a normally open contact, but when the circuit is put into its normal off state, part of the machine keeps the contact closed. Likewise, a limit switch that is designated as "normally closed held open" will have a closed wiring design but be held open. Other types of contacts, such as those used in pressure and flow switches, can be configured in a similar way.

Micro Limit Switches

The micro limit switch, or micro switch, is another type of limit switch commonly found on control circuits. These switches are much smaller than their standard counterparts, allowing them to be installed in narrow or cramped spaces that would normally be inaccessible to other switches. Micro switches usually have an actuating plunger that only has to travel a small distance in order to trigger the contact sequence. The actuating plunger is often found at the top of the micro switch and must be depressed a predetermined amount before it activates. A small degree of movement is able to change the contact positions due to a spring-loading mechanism that causes movable contacts to snap between alternating positions. Micro switches can be designed with a range of different activating arms, and have contacts with electrical ratings that are usually around 250 volts of alternating current and between 10 to 15 amperes (amps).

Much like micro limit switches, subminiature micro switches are intended for use in applications requiring compact designs and limited space availability. They have contact arrangements with spring-loading mechanisms similar to those of micro switches but tend to be from one-half to one-quarter the size of regular micro switches. Depending on the particular model, subminiature switches have contacts with electrical ratings ranging from about 1 to 7 amperes due to the reduced size of the switches themselves.

Advantages and Limitations of Limit Switches

Limit switches offer several advantages intrinsic to their design:

- The designs are generally simple and straightforward
- They work well in almost any industrial setting
- They exhibit high accuracy and repeatability
- They are low power consumption devices
- They can switch high-inductance loads
- They can be used to switch multiple loads
- They are simple to install
- They are rugged and reliable
- They typically have heavy-duty electrical contacts meaning they can be used to switch higher levels of current directly without the need to utilize secondary relay control

Limit switches also have several limitations, which means they may not be suited for every application:

- Because they rely on mechanical action, they generally are used in equipment that operates at relatively low speeds
- They are contact sensors, meaning they must make physical contact with the target for them to operate
- The nature of their mechanical design means that the devices are subject to mechanical wear or fatigue over time and will need eventual replacement

Key limit switch terminology

There are several key terms that are associated with the design of limit switches. Here is a brief summary of those terms for reference:

- Pretravel — represents the distance or angle through which the actuator on the limit switch must travel before it trips the switch contacts
- Operating Point — represents the actuator's position when the switch contacts move into the operating position
- Release Point — represents the actuator's position when the contacts return to their original state
- Differential — represents the distance or angular displacement (degrees) between the operating and release points (i.e. between when the contacts trip and when they reset)
- Overtravel — represents any motion of the actuator component past the trip point of the switch
- Initial Position — represents the position of the switch's actuator when it not subjected to any external forces

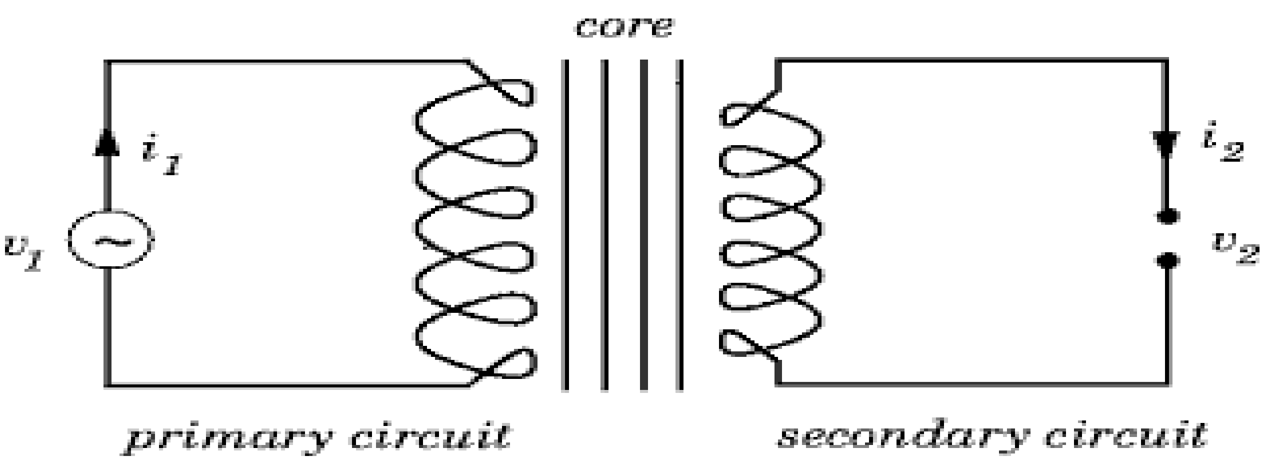
- Operating force (torque) — represents the magnitude of the force (or the torque for angular movement) that is needed to produce actuator movement.
- Minimum return force (torque) — represents the magnitude of the force (or the torque for angular movement) that is required to return the switch actuator to its initial position
- Total Travel — the maximum distance the actuating element is capable of traveling during its operational cycle
- Repeat Accuracy — represents a measure of the degree to which the limit switch is able to repeat its characteristics during repeated (successive) operations.

What is Autotransformer: Working Principle, Construction & Applications

Autotransformer is a single winding transformer that works on the principle of Faraday's Law of electromagnetic induction. Mostly used in low voltage range, for industrial, commercial and laboratory purposes. Also known as variac, dimmer stat, etc. autotransformer can be single and three-phase. Due to single winding, autotransformers have fewer losses, more efficient and robust. By taking tapping on the secondary side, a wide range of voltage can be obtained. In some applications, they are also connected to converters for rectifying the output AC voltage.

What is Autotransformer?

The principle of the autotransformer is the same as two winding transformers. It works on the principle of Faraday's Law of electromagnetic Induction, according to which whenever there is a relative change in magnetic field and conductors, an emf is induced in the conductors. Consider a two winding transformer shown below



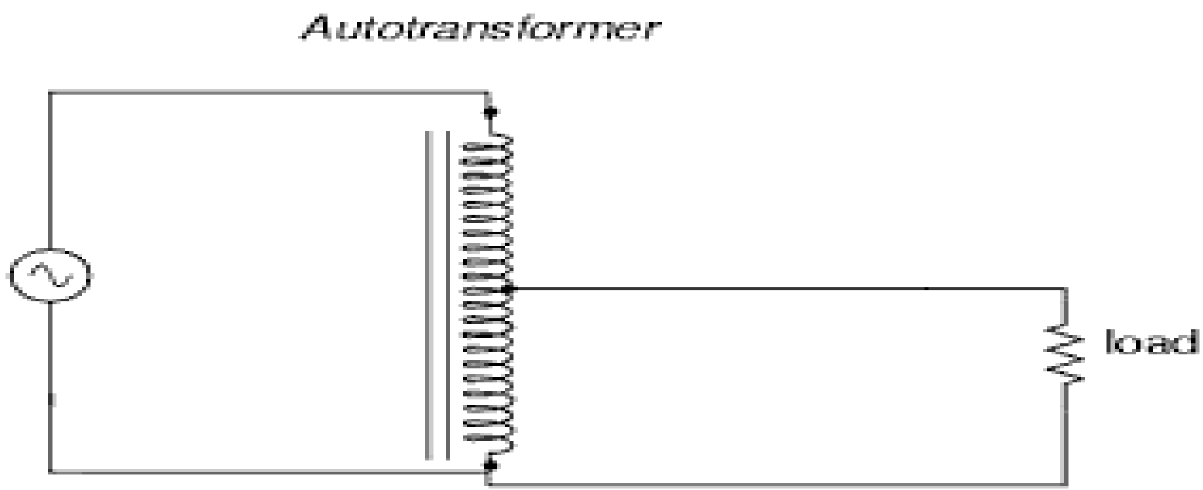
Transformer

When an alternating voltage is applied to the primary winding, it induces an emf in the primary winding due to the alternating nature of the magnetic field created due to AC supply and static conductors. According to Faraday's Law of electromagnetic induction, there must be relative displacement between field and conductors, and in this case, the field is alternating and conductors are constant. Because of which an emf is induced in the primary winding of the transformer.

Induced emf in the primary winding creates an alternating flux in the primary winding. Flux links the secondary winding of the transformer by passing through the core of the transformer. This is called mutual induction. An emf is induced in the secondary winding. And based on the number of turns on secondary winding, the magnitude secondary induced EMF is calculated.

Autotransformer Working Principle

Now consider the autotransformer circuit diagram shown below. As compared to two winding transformers as shown in Figure 1, Autotransformer has single winding. When an alternating supply is given to the primary circuit, because of Faraday's Law of electromagnetic Induction, an emf is induced in the primary part. Since the magnetic field is alternating in nature, and conductors are stationary.



Autotransformer

The induced emf in primary produces a flux, which is called as primary winding flux. This flux links the secondary winding and induces an emf on secondary winding due to mutual induction. Hence emf is transferred in the secondary winding. Based on a number of turns on the secondary side, the magnitude of induced emf is determined.

Autotransformer Working

The emf equation of induced emf is given as

$$E=4.44\phi Nf$$

This can be generalized for both primary winding emf and secondary winding emf. If we take ratio we get as

$$E_1/E_2 = N_1/N_2 = k$$

It could be seen that the magnitude of induced emf is directly proportional to a number of turns. If a number of turns are greater on the secondary side, it is called a step-up autotransformer. If several turns are less, it is called a step-down autotransformer. It is also observed that, in two winding transformers, flux links the secondary winding through the core of the transformer. There is no electrical link between primary and secondary. For that reason, the transformer is called as electrically isolated but magnetically coupled device. But for an autotransformer, there is electrical isolation. There is only one winding. For this reason, autotransformer is called as electrically and magnetically coupled device.

The nature emf induced as shown in above is statically induced emf. If the source is alternating and conductors are constant, in that case, nature induced emf is statically induced emf. If conductors are rotating and the magnetic field is constant in that case emf induced is dynamically induced emf. In the transformer and autotransformer, induced emf is statically induced emf. In the case of DC generators, induced emf is dynamically induced emf. For statically induced emf, the direction of currents is given by Lenz's Law. In the case of dynamically emf, it is given by Fleming's Right Hand Rule. Hence in autotransformer, the direction of induced emf is given by Lenz's Law.

Also in two winding transformers, energy from primary to secondary is induced through induction, but whereas in autotransformer, energy is transferred through both induction and conduction. It is to be noted that, for induction of emf on the primary side, as per Faraday's Law of Electromagnetic induction, there must be relative change between the magnetic field and set of conductors. For this reason, we get AC voltage on the primary side, which is alternating in nature. If we give, DC, then autotransformer or two winding transformers will not operate, because of the constant nature of supply. Hence we say that the transformer does not operate in DC. In fact due to low resistance of primary winding, when DC supply is given, due to large currents, the winding will burn.

Properties of Autotransformer

The properties are

- Auto Transformer is electrically and magnetically coupled device
- In Autotransformer, power is constant
- In autotransformer, overall flux is constant
- In autotransformer, frequency is constant
- Voltage and current vary based on a number of turns.
- Autotransformer is also called a phase-shifting device
- The losses are less in autotransformer as compared to two winding transformer due to single winding
- The efficiency of the autotransformer is more as compared to two winding transformers

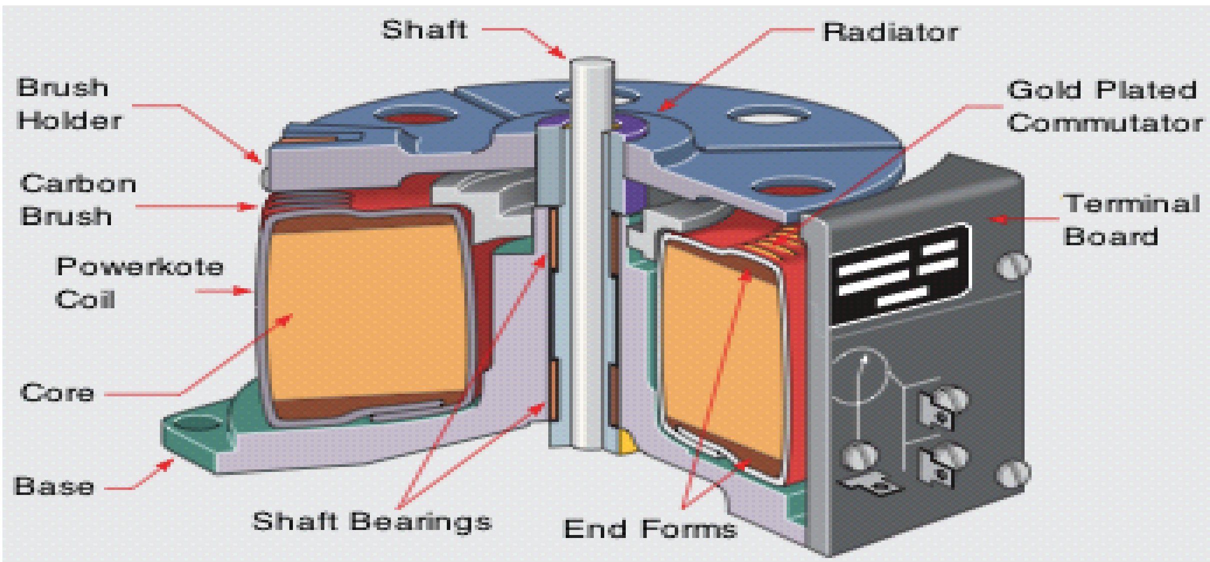
- Both iron and copper losses are less an autotransformer.

Auto Transformer Construction

A transformer basically consists of two parts

- Conductors
- Core

The conductors in the autotransformer are made up of copper. They are of low resistance. The copper conductors are insulated with each other. The material used for insulation is impregnated paper, mica, etc. The insulation also helps in reducing eddy current losses. The winding is wound around the core. For a single winding transformer, the requirement of copper is less as compared to two winding transformers.



Auto-transformer-construction

To transfer flux from primary to the secondary, core is used. The core is made up of magnetic material like silicon steel, CRGO steel, etc. CRGO steel is the most efficient material for core, as it has the least hysteresis losses. The role core is to transfer flux from one part of winding to other parts.
Other important parts as shown in figure 3 are bearings, brushes, terminal boards, etc. The parts shown are used for dimmer stat basically used for laboratory purposes.

Advantages and Disadvantages of Autotransformer

The advantages are

- Losses in Autotransformer are less
- The efficiency of the autotransformer is more
- Copper Requirement is less
- The core requirement is less

The disadvantages are

- Autotransformers cannot be used for high voltages. Since any discontinuity in the primary winding would result in complete primary voltage on the secondary side, therefore it cannot be used for high voltages
- The insulation requirement is more. Since autotransformer is both electrically and magnetically coupled, the requirement of insulation is more.
- Because of common winding, a neutral connection is difficult.

Applications of Autotransformers

The following are the applications of autotransformers.

- Autotransformers are used for starting induction motors
- Auto Transformers are used for voltage regulation
- Autotransformers are used for laboratory purposes.
- Autotransformers are used in many industrial applications like paper mills, factories, etc.

Magnetic Amplifier

Sometimes abbreviated "Mag Amp," a saturating inductor which is placed in series with a power supply output for regulation purposes.

A magnetic amplifier is an electromagnetic device that amplifies electrical signals utilizing a transformer's core saturation principle, and the core non linear property. It consists of an iron core with two or more coils wound around it. Current control is achieved by varying the magnetic flux in the cores using the appropriate DC current through the control winding.

The static device has no moving parts, no wear mechanism and has good mechanical and vibration tolerance. In addition it requires no warm up time and can withstand momentary overloads better than the solid state devices. They are used in power supplies, in measurement systems, in nuclear power applications amongst other uses.

Construction and operation of a magnetic amplifier

A typical amplifier is made of two cores with an AC winding and a control winding. A small DC current supplied to the control winding alters the saturation levels of the core and is able to control large ACcurrentintheAC windings.

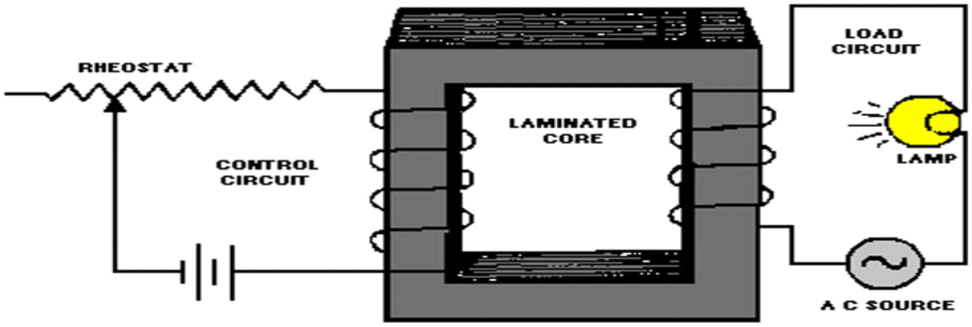


Figure 1 Basic construction of a magnetic amplifier – Image Credit

The amplifier uses the inductive element as a controlled switch. The coil is wound on a core having square B-H characteristics which gives the core two modes of operation. When the core is unsaturated, it causes the coil acts as high impedance that supports a large voltage with little or no current. When saturated, the coil impedance drops to almost zero and allows current to flow with very little voltage drop. The two modes thus enable the magnetic amplifier to act as an ideal switch with several benefits as compared to the switching regulators.

Factors that affect amplification in a magnetic amplifier

- Core cross section area
- Core magnetic path length
- Flux density gauss
- Magnetizing force
- magnet amp coil turns

Magnetic Amplifier Controllers

Circuits to control the magnetic amp may either be discrete components or specifically designed integrated circuits designed as magnetic amp controllers.

Types of Magnetic Amplifier circuits

There are two commonly used configurations namely the:

- Half wave magnetic amplifier: utilizes one half cycle of the AC supply
- Full wave Magnetic amplifier: utilizes both half waves of the ac supply

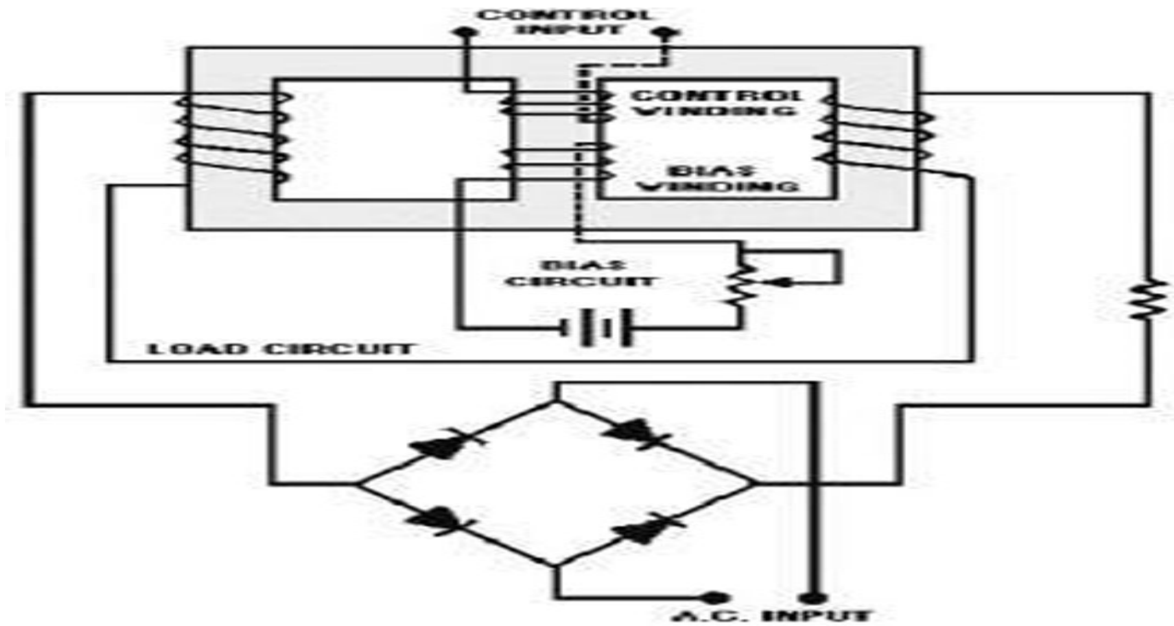


Figure 2: Full wave magnetic amplifier

Advantages of magnetic amplifiers

- No wear since there are no moving parts
- Good mechanical shock and vibration tolerance
- Doesn't require warm up time
- Can withstand momentary overloads better than solid-state devices
- The cores can withstand neutron radiation

Limitations of magnetic amplifiers

- Low and limited single stage gain as compared to electronics amplifiers
- Frequency response limited to about one-tenth of excitation frequency
- Bulky
- Complicated when designing multistage amplifiers due to

Applications of Magnetic Amplifier

- As switching components in switched mode power supplies
- In radio communications high frequency alternators
- Arc welders
- Measuring high dc voltages
- stage lighting
- nuclear plants applications
- Speed regulators in paper, steel and other assembly lines

How Does an Electric Actuator Work

An electric actuator is a mechanical device used to convert electricity into kinetic energy in either a single linear or rotary motion. It automates damper or valve in order to increase process efficiency and complexity. Designs for electric actuators are based on the specific tasks they accomplish within the processes for which they're intended, and they can vary in both dimension and size.

There are now more applications for electric actuators due to the movement toward massively increased decentralization taking place in automation technology. New process controllers can now be equipped on last-generation electric actuators, which makes it simpler to meet recently updated automation standards. Thanks to failsafe capabilities that preserve user control over the process even in the event of power loss, using electric actuators is now safer than ever before.

Main Components of an Electric Actuator

The motor of an electric actuator can operate on any voltage and is used across many different industries. The most common voltages used in single-phase motors are

· 115 VAC

· 24 VAC

· 12 VDC

· 24 VDC

· 208 VAC

· 230 VAC

In addition to these options, three-phase motors also use voltages of 230 VAC and 460 VAC.

An actuator's brake is mounted on top of the motor. It's responsible for stopping the media from forcing the valve open when it should be closed by locking the motor rotor in position when not in use.

The motor start capacitor is the third main component of an electric actuator with AC motor. It gives the motor enough power to start. Electric actuators with DC motors do not require a capacitor.

The final critical component of an electric actuator is the two single-pole, double-throw (SPDT) end of travel limit switches. One is for the closed position, and the other is for the open position. These switches provide the adequate number of electrical contacts in the immediate, closed, and open positions.

Applications: Where are Electric Actuators Used?

Electric actuators appear in a number of industries. Typically, they're used in industrial applications associated with manufacturing valves, pumps, and motors. They most commonly automate industrial valves, and many types of technical process plants use them, including:

· Upstream, midstream, and downstream oil and gas plants

· Wastewater treatment plants

· Power plants

· Food and beverage plants

· Farming and agricultural plants

.

Pulp and paper plants

Pneumatic system

Pneumatic technology deals with the study of behaviour and applications of compressed air in our daily life in general and manufacturing automation in particular.

Pneumatic systems use air as the medium which is abundantly available and can be exhausted into the atmosphere after completion of the assigned task.

- **Basic Components of Pneumatic System :**

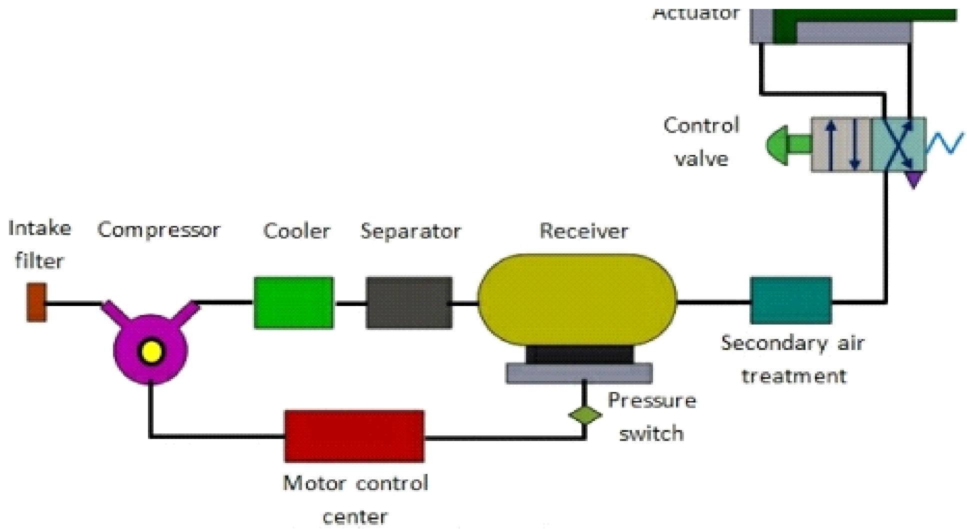


Fig. 6.1.1 Components of a pneumatic system

Important components of a pneumatic system are shown in fig.6.1.1.

a) Air filters: These are used to filter out the contaminants from the air.

b) Compressor: Compressed air is generated by using air compressors. Air compressors are either diesel or electrically operated. Based on the requirement of compressed air, suitable capacity compressors may be used.

c) Air cooler: During compression operation, air temperature increases. Therefore coolers are used to reduce the temperature of the compressed air.

d) Dryer: The water vapor or moisture in the air is separated from the air by using a dryer.

e) Control Valves: Control valves are used to regulate, control and monitor for control of direction flow, pressure etc.

f) Air Actuator: Air cylinders and motors are used to obtain the required movements of mechanical elements of pneumatic system.

g) Electric Motor: Transforms electrical energy into mechanical energy. It is used to drive the compressor.

h) Receiver tank: The compressed air coming from the compressor is stored in the air receiver.

Advantages and Limitations of Pneumatics

Advantages

- Simple
- A Easy to control
- A Can apply a lot of force from a small, light package
- A Force is limited by air pressure and cylinder diameter
- The speeds and forces are infinitely variable
- A Pneumatic tools when over loaded will stop and so safe, as compared to electrical system.
- No fire hazard as in Electrical Systems. So can be easily used in dangerous areas like mines.
- Simple in construction, the pneumatic system components are easy to maintain & repair.
- The used air is exhausted. So no return lines as in hydraulic system.

Disadvantages

- Smooth and uniform speeds against loads are not achievable as in Hydraulic systems.
- Beyond certain load usage of pneumatic system is expensive.

APPLICATIONS

Pneumatic equipment's can be used for applications, whereoperation cycles need certain routine functions like

1. Pushing
2. Pulling
3. Lifting
4. Feeding
5. Clamping
6. Pressing
7. Forming, etc.

All about pneumatic Pressure

You may not realize this, but pneumatics is all around us and we encounter it through our everyday life all the time.

Whenever you are on a bus, truck, or airplane, pneumatic pressure is being used around you and it's a core element that makes these vehicles function.

Pneumatic pressure isn't just found in mechanical objects either, it can also be found in things which can be inflated, such as your car's tires, pressure sensors and regulators, and anything where there is pressurized air.

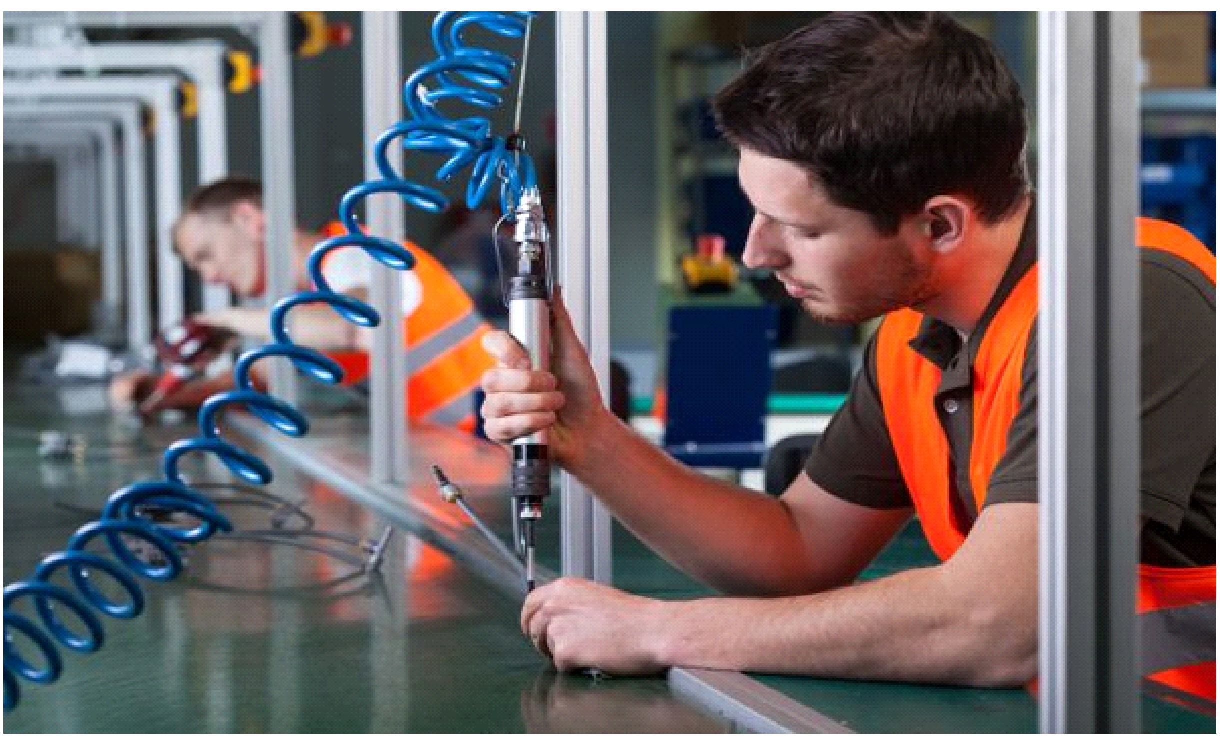
Pneumatics are a popular method of making things work and function because they can be incredibly energy efficient and also very long-lasting with minimal maintenance required.

This is why they are such commonplace when it comes to machinery and most industrial equipment and many of the things we take for granted in our everyday lives wouldn't work without it.

What Is Pneumatic Pressure & How is It Used?

In short, this is the pressure that is exerted by a pressurized gas. There are many various types of gasses which can be used to create pneumatic pressure and one of the most commonly used ones is compressed air.

This can be used to create the shape of a plastic bottle that we use to drink from, provide the cabin pressure on an airplane, and operate the doors you see on a bus.



Alternatively, pneumatic pressure can also be created by inert gasses, which are gasses that do not have chemical reactions under certain circumstances.

The most common types of inert gasses are known as 'noble gasses' and they are all colorless, odorless, and have a very low chemical reactivity. In total, there are six noble gasses which are naturally occurring and they are argon (Ar), helium (He), krypton (Kr), neon (Ne), radon (Rn), and xenon (Xe).

Air can be pumped into a receiver with the use of a compressor and the receiver will then hold onto this air.

The pneumatic system will then draw from the receiver when it needs to in order to perform its function(s).

What Is a Pneumatic Actuation System?

Pneumatic actuators are highly reliable, efficient and safe sources of motion control that use pressurized air or gas to convert energy into rotary or linear motion. They're especially appropriate for the repeated opening and closing of valves and other industrial applications where the use of electricity may cause a fire or ignition hazard. Actuators are commonly used to control the valves that direct the movement of fluids in the chemical and process industries.

Pneumatic actuators have several different names, including pneumatic cylinders, air cylinders and air actuators. Each of these terms is synonymous with the other, as they all identify the device as air pressure based. Another name for an air cylinder is pneumatic ram, in which the ram is referring to the linear piston.

How Does a Pneumatic Actuator Work?

Pneumatic actuators rely on some form of pressurized gas — most often compressed air — entering a chamber, where the gas builds up pressure. When it has built up enough pressure in contrast to the outside atmospheric pressure, it results in the controlled kinetic movement of a device such as a piston or gear. This resulting movement can be directed in either a straight line or circular motion.

Since the conversion of compressed gas into energy can be highly controlled and is reliable and repeatable, pneumatic actuators are one of the most popular mechanical devices used in a wide array of modern industries.

Types of Pneumatic Cylinders

There are two primary varieties of pneumatic linear actuators — single-acting and double-acting. They both work to push forward a piston, but the main differences are the return method and number of ports.

Single-acting cylinders have one port that allows air to flow into the cylinder. The pressure increases and pushes the piston forward or backward, depending on whether it is a push or pull type. A large spring returns the piston to its original position, preparing it for another burst of pressure. The spring is either positioned inside the cylinder or on the outside.

Double-acting cylinders operate without a spring and instead have two ports, one on either end of the piston. The first application of pressure pushes the piston forward, a step in the process that the two models share. Then, the second burst of pressure on the other side of the cylinder pushes the piston back into place. The device applies pressure back and forth to create a smooth linear motion.

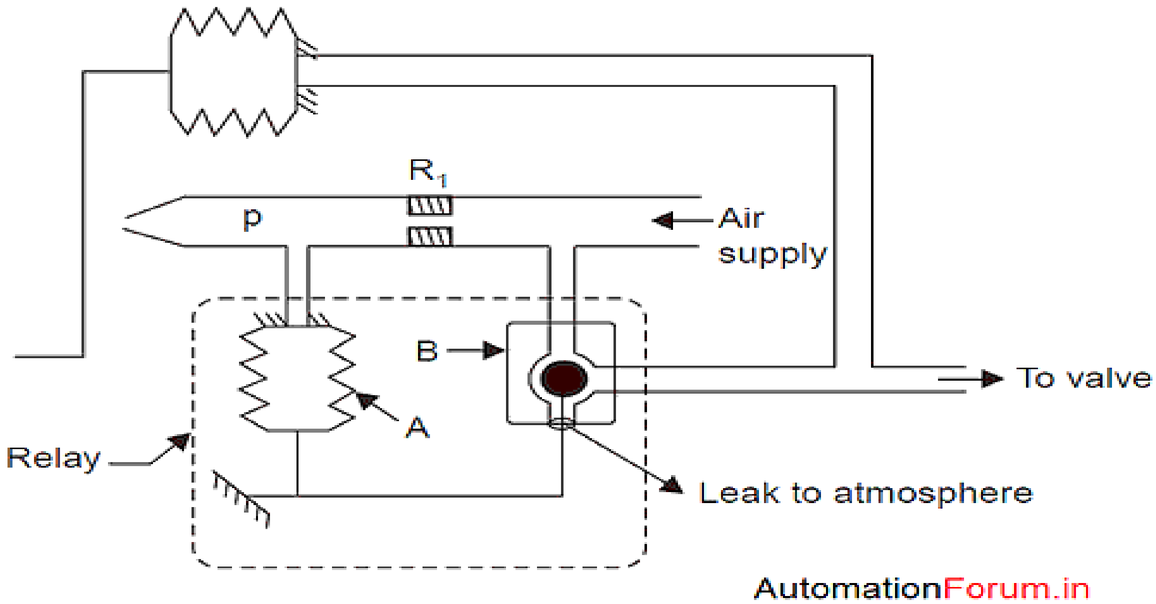
Typically, double-action cylinders are better for industrial uses that require speed and strength, as they provide more force at a faster rate. They may also offer a longer lifespan before needing replacement. However, they are a more expensive option in comparison. Single action cylinders also have other advantages besides cost. They have a more straightforward design, are more compact and require half the amount of compressed air to function.

What is a relay?

The relay is automatic switching device which can set ON/OFF large signal lines using comparatively small signals.

A pneumatic relay works in 3-15psi pneumatic signal which can control much higher signal that can control large devices large than 15 psi pressure.

Pneumatic Relay working:

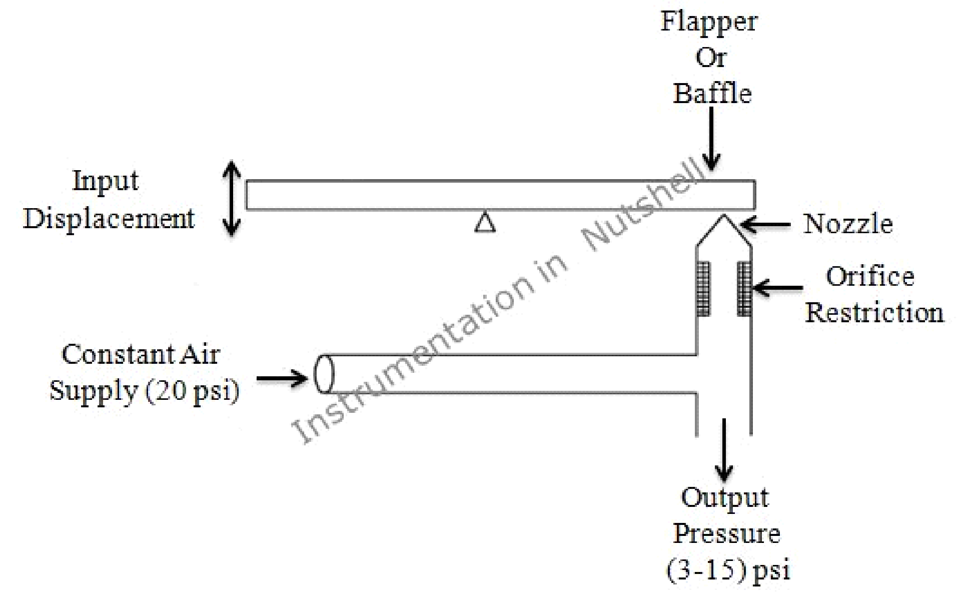


A power amplifier is needed to act on a large control valve. A pneumatic relay is a power amplifier. The relay is composed of small volume A bellows and a specially designed valve. In the nozzle pressure is transmitted to bellows A and, as the pressure increases, the bellows expand the ball down the valve B cavity, decreasing the leakage to the atmosphere and increasing the pressure Pv.

The relay is made in such a way that the output pressure Pv is proportional to the signal pressure p. The airflow of the relay will be much greater than the flow rate through the nozzle, since the resistance to the air supply may be too small compared to the resistance Rr in the nozzle. A relay valve can be designed as direct acting, in which case the outlet pressure is directly proportional to the inlet pressure, or it can be reverse acting, in which case the outlet pressure is inversely proportional to the inlet pressure.

Flapper Nozzle System

Pneumatic systems are still used in process control industries even after the entry and domination of electrical signals, electronic and digital systems. The flapper-nozzle is a basic component of pneumaticmeasurement, control, and transmission system. It works as a pneumatic secondary transducer, by translating a very small displacement into a pressure signal.



The Flapper Nozzle System

Construction

The flapper or baffle is a movable flat metal and it is attached to a member whose displacement is to be detected. The flapper is positioned in front of the nozzle in such a way to cover or uncover the nozzle and vary the gap between them when moved.

The nozzle comprises of a variable nozzle restriction in series with a fixed orifice restriction. A constant supply of pressurized air (usually 20 psi or 1.4 kg/cm^2) is applied to the nozzle through the orifice restriction. The pressurized air comes out of the nozzle through the gap between the nozzle and flapper.

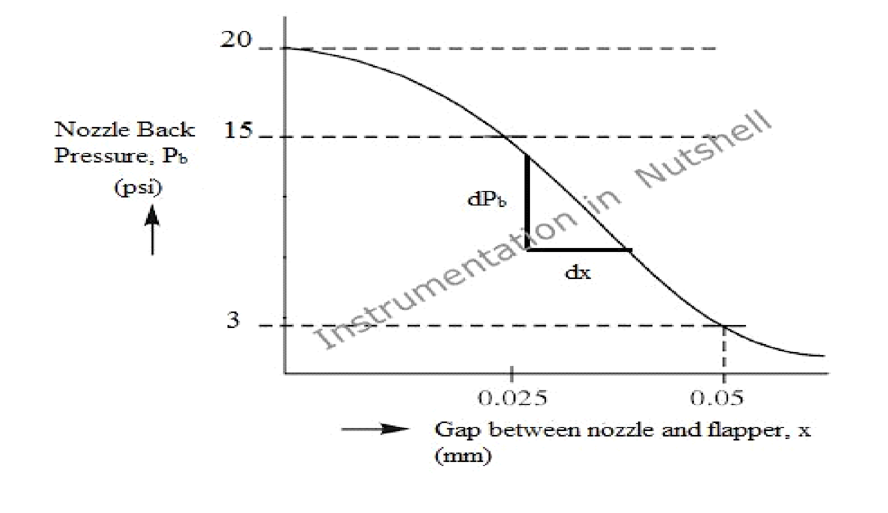
For the generation of sufficient back pressure and proper functioning of the system, the diameter of the nozzle has to be 1.5 to 2.5 times greater than the diameter of the orifice. In general, the orifice diameter is of the order of 0.25 mm and the diameter of the nozzle is of the order of 0.625 mm.

Working Principle

When the flapper is moved towards the nozzle, the gap between the nozzle and flapper gets reduced. This increases the restriction to the outflow of air through the nozzle and also increases the nozzle back pressure. Once the flapper completely covers the nozzle, there is no outflow of air through the nozzle. The nozzle back pressure is at its maximum and equals to the supply air pressure.

When the flapper is moved away from the nozzle, the gap between the nozzle and flapper is increased. The restriction to the outflow of air through the nozzle is reduced and the nozzle back pressure is also reduced. The minimum value of nozzle back pressure is 2-3 psi.

With an input supply of 20 psi (1.4 kg/cm^2), an output pressure of 3-15 psi (0.2 – 1.0 kg/cm^2) can be generated through the flapper nozzle system. The output pressure produced by the flapper nozzle system is proportional to the input displacement and it can be directed to operate an indicating instrument or any other system.



Flapper-Nozzle Gap vs Nozzle Back Pressure

The above diagram depicts the typical graph plotted between the nozzle back pressure (P_b) and the flapper-nozzle gap (x). The slope dP_b/dx at any point of the curve is called as nozzle sensitivity or gain of the system. The curve indicates that the system exhibits an approximately linear behaviour in the range between 3 and 15 psi.

Advantages

1. The flapper-nozzle system possesses the advantages of being simple to install, operate and

   maintain. They are explosion-proof and so they can be used in hazardous environments.

2. The flapper-nozzle system produces a linear output ranging from 3 to 15 psi, which falls under the limits of industrial control pressure making it acceptable to use for practical purposes.

Limitations

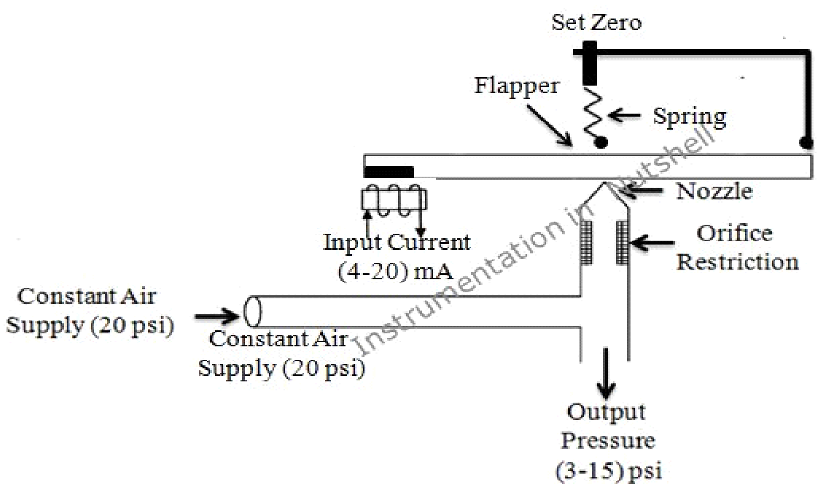
1. The flapper is positioned by the displacement producing element that is usually a low-force element. So, there are chances for the position of the flapper to be disturbed by the blast of air coming out of the nozzle. It can be nullified by implementing a feedback system to reposition the flapper.

2. The flapper moves a very small distance for its one full action from minimum to maximum nozzle back pressure. This makes the flapper nozzle system affected by vibrations.
3. The flapper-nozzle system provides amplification of the order of 10^5 but this output power is not sufficient to operate pneumatic actuating valves in industrial process control systems. So, the flapper nozzle system is used as a first stage amplifier and in conjunction with pneumatic relays. Pneumatic relays are known as power amplifiers and it amplifies the nozzle pressure.
4. The transmission of pneumatic signals is slow and it introduces a time lag in the system.

Application

Current to Pressure Converter

Current to Pressure converter or I/P converter, as it is shortly known, is an important application of the flapper nozzle system. As most of the control valves used in industries are pneumatic, the I/P converter is used for the conversion of 4 to 20 mA electrical signal into 3 to 15 psi pneumatic signal.

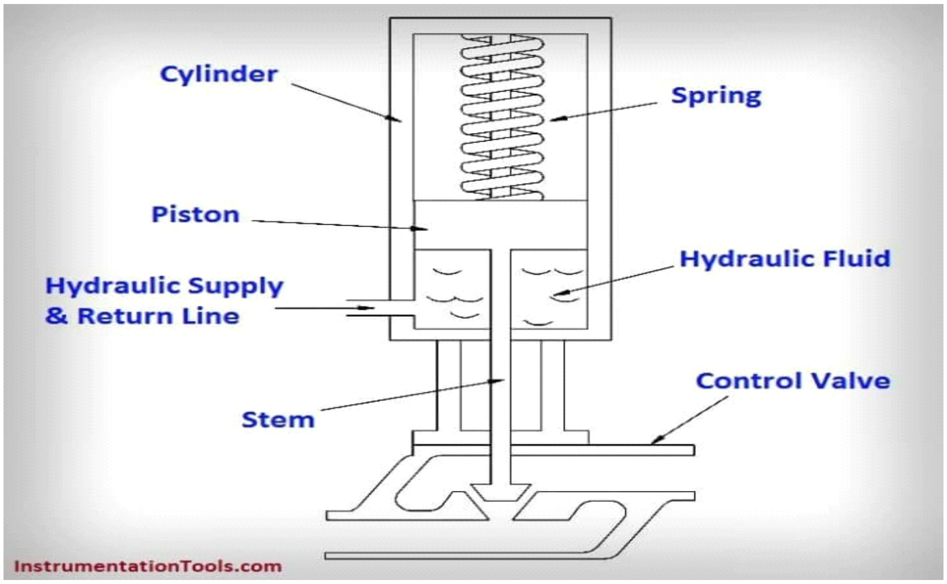


Current to Pressure Converter

The spring holds the flapper farther to the nozzle at its zero position in such a way that the resultant pressure at the output is at its lowest (3 psi). When the current is passed through the coil, it makes the flapper move towards it. This decreases the flapper-nozzle gap and thus increases the output pressure. When the current is 20 mA, the output pressure is maximum (15 psi). There is a linear relationship between current and pressure.

3.4| Hydraulic Actuator System

Hydraulic actuators use liquid pressure rather than instrument air pressure to apply force on the diaphragm to move the valve actuator and then to position valve



The hydraulic supply and return line is connected to the lower chamber and allows hydraulic fluid to flow to and from the lower chamber of the actuator. The stem transmits the motion of the piston to a valve.

Initially, with no hydraulic fluid pressure, the spring force holds the valve in the closed position. As fluid enters the lower chamber, pressure in the chamber increases.

This pressure results in a force on the bottom of the piston opposite to the force caused by the spring. When the hydraulic force is greater than the spring force, the piston begins to move upward, the spring compresses, and the valve begins to open.

As the hydraulic pressure increases, the valve continues to open. Conversely, as hydraulic oil is drained from the cylinder, the hydraulic force becomes less than the spring force, the piston moves downward, and the valve closes. By regulating amount of oil supplied or drained from the actuator, the valve can be positioned between fully open and fully closed

The principles of operation of a hydraulic actuator are like those of the pneumatic actuator. Each uses some motive force to overcome spring force to move the valve. Also, hydraulic actuators can be designed to fail-open or fail-closed to provide a fail-safe feature.

Advantages of Hydraulic Actuators

Hydraulic actuators are rugged and suited for high force applications. They can produce forces 25 times greater than pneumatic cylinders of equal size. They also operate in pressures of up to 4,000 psi.

A hydraulic actuator can hold force and torque constant without the pump supplying more fluid or pressure due to the incompressibility of fluids.

Hydraulic actuators can have their pumps and motors located a considerable distance away with minimal loss of power.

Disadvantages of Hydraulic Actuators

Hydraulics will leak fluid. Like pneumatic actuators, loss of fluid leads to less efficiency and cleanliness problems resulting in potential damage to surrounding components and areas.

Hydraulic actuators require many complementary parts, including a fluid reservoir, motor, pump, release valves, and heat exchangers, along with noise reduction equipment.

Haydraulic Valve

A hydraulic valve properly directs the flow of a liquid medium, usually oil, through your hydraulic system. The direction of the oil flow is determined by the position of a spool. A hydraulic system can only function - as per requirements - by using valves. Thus, you should always look for the correct type of hydraulic valve to serve your intended purpose. The required size is determined by the maximum flow of the hydraulic system through the valve and the maximum system pressure.

A HYDRAULIC VALVE PROPERLY DIRECTS THE FLOW OF A LIQUID MEDIUM, USUALLY OIL, THROUGH YOUR HYDRAULIC SYSTEM.

Hydraulic valves are available in a variety of sizes and according to multiple International Standards. Hydraulic valves are available with many different mounting styles: e.g. mounting in pipe lines, with threaded connection as cartridge valves, subplate mounting or flanged mounting. Hydraulic valves are subdivided into three main categories: directional control valves, pressure control valves and flow control valves. All valves operate a different function in the hydraulic system.

Examples of Hydraulic System

Hydraulic Lifts. Hydraulic lifts are used for moving goods or people vertically. ...

Hydraulic Brakes. Braking system of the vehicle is an important example of hydraulics. ...

Hydraulic Steering. ...

Hydraulic Jacks. ...

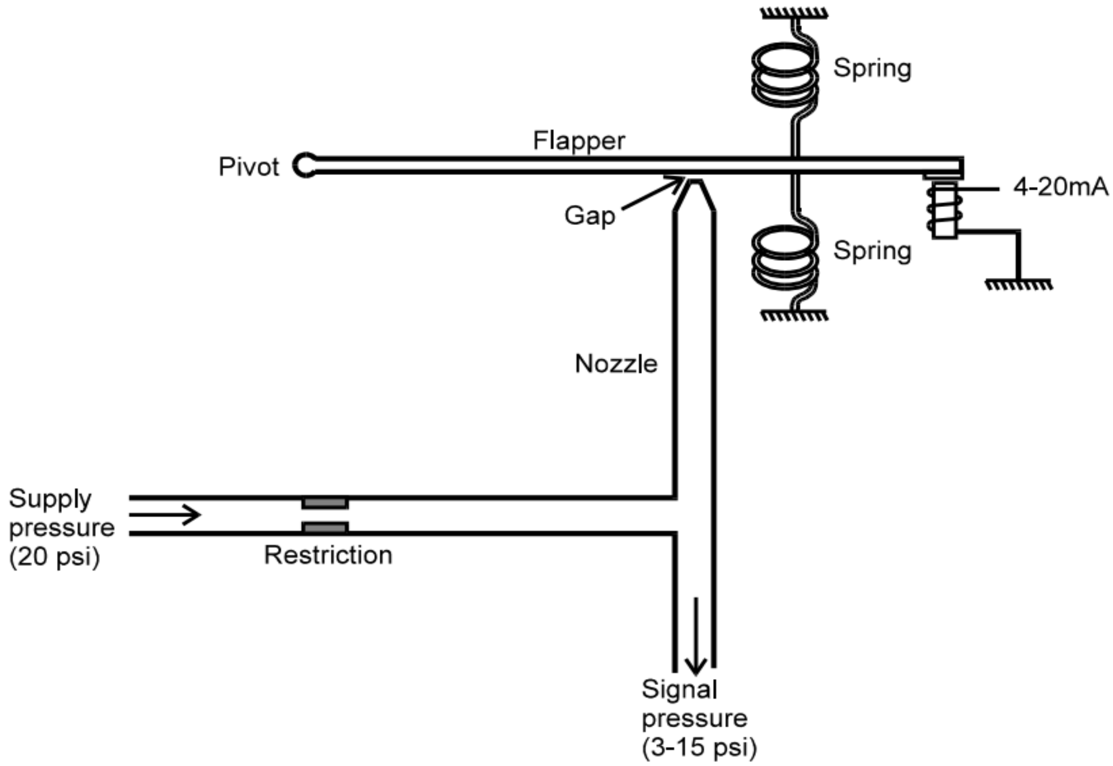
Heavy Equipment. ...

Airplanes. ...

Hydraulic Shock Absorbers Absorbers.

3.5 Current to Pressure (I/P) Converter Principle.

Current to Pressure Converter works on flapper nozzle method. The input is 4 to 20mA signal and the equivalent output is 3 to 15 PSI pressure.



Principles of a current-to-pressure converter

Current to Pressure Converter Principle

In the Current to Pressure converter, we usually give input current signal as 4 – 20 mA . We also give a continuous supply of 20 P.S.I to the Flapper Nozzle assembly. As we give input current signal, Electromagnet gets activated.

If the current is more, then the power of magnet will get increased. The Flapper of the Flapper-Nozzle instrument is connected to Pivot so that it can move up and down and a magnetic material was attached to other end of flapper and it is kept near the electromagnet.

As the magnet gets activated. the flapper moves towards the electromagnet and the nozzle gets closed to some extent. So the some part of 20 P.S.I supplied will escape through nozzle and remaining pressure will come as output.

If the current signal is high, then power of the magnet will increase, then flapper will move closer to the nozzle, so less pressure will escape through nozzle and output pressure increases.

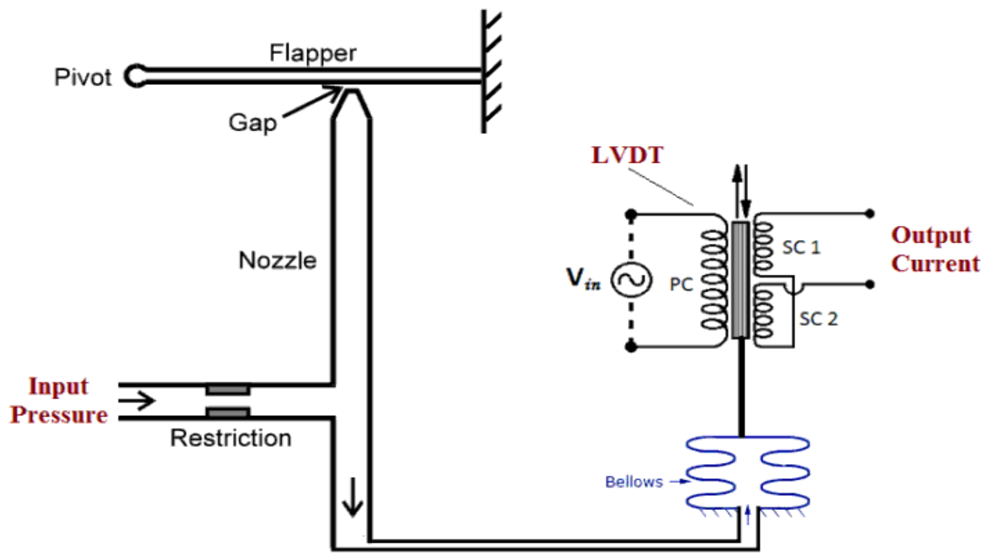
In this way the output pressure will be proportional to the input current.

For the input current of 4 – 20 mA we can get the output pressure of 3 – 15 P.S.I

Pressure to Current (P/I) Converter Principle

We can construct a pressure to current converter using a Flapper- Nozzle arrangement , Bellows and a Linear Variable Differential Transformer (LVDT) circuit.

Input pressure is given to Flapper-Nozzle arrangement and the output current will come through the LVDT.



First Input pressure is supplied to the Flapper- Nozzle arrangement. Then it will supplied through a pipe and that pressure is given as input to the bellows. These bellows are connected to the Core of LVDT.

When pressure is applied to bellows, they will expand thus core displaces and the voltage is induced on the secondary coils of LVDT.

As voltage is induced, current will flow through the coil. That current is proportional to the input pressure applied. Thus Pressure is converted into equivalent current.

HuWhen compared with standard values we can covert 3-15 P.S.I of pressure can be converted to 4-20 mA of current.

3.6 Difference between Pneumatic & Hydraulic control system:

The main difference between pneumatic and hydraulic control is one use air and the other liquid/oil as operating media respectively. Pneumatic control apply only small power, where hydraulic control can deliver to a large amount of power.

Pneumatic control is used for small factory instruments compare to hydraulic instrument used for small to heavy machine

Air can be compressed but liquid can't so its needed more space

Pneumatics

Pneumatics are typically used in factory set ups, construction, mills, building, and technology by using a central source of compressed-air for power. Medical applications of pneumatics are likewise common including the high-powered drill of a dentist. Practically everything could run on pneumatics including any form of transportation. That little tube in a bank's drive-teller operates through pneumatics via a high pressure source of compressed air.

Hydraulics

Hydraulics have varied uses in everyday life and most of them are applicable to machines. For instance, hydraulics are applied in a car's braking system. They only require a small force as the driver steps on the car brakes but a greater force is already produced to stop or slow down a car as it equally acts on all of the 4 brake pads.

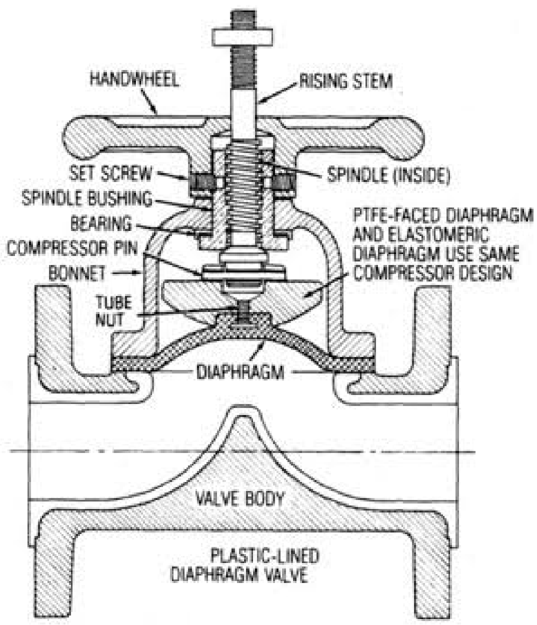
Hydraulic applications are also evident in lifting equipment such as wheelchair lifts, excavating arms on machineries like diggers, hydraulic presses for forging metal parts, and wing flaps on aircrafts. Obvious uses of hydraulics are with heavy equipment.

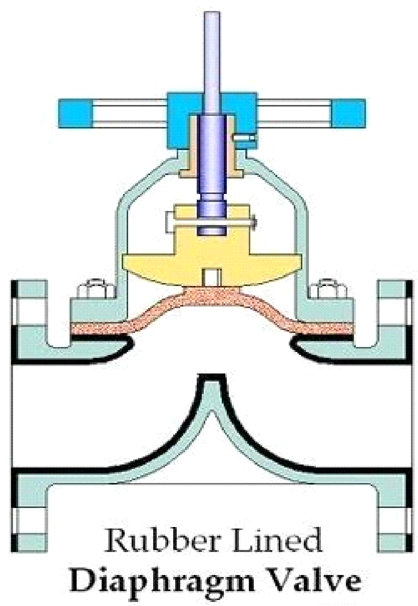
Here at Worlifts, we have experience in the supply and maintenance in many industries such as Oil & Gas, Engineering, Rail and Renewables.

Chapter -4
Control valves

Principle of operation, constructional details and applications of Diaphragm operated valve

Diaphragm Valve is to use the diaphragm as the opening and closing piece to close the flow channel, cut off the flow, and the valve body cavity and valve cover cavity separated by the cut-off Valve. Diaphragm commonly used rubber, plastic and other elastic, corrosion-resistant, non-permeable materials.





Construction & Working Principle of Diaphragm valve

Working Principle of Diaphragm valves are, in fact, simple "pinch clamp" valves. A resilient, flexible diaphragm is connected to a compressor by a stud molded into the diaphragm. In valve diaphragm ,the compressor is moved up and down by the valve stem. Hence, the diaphragm lifts when the compressor is raised. As the compressor is lowered, the diaphragm is pressed against the contoured bottom in the straight through valve or the body weir in the weir-type.A straight through type diaphragm valve is shown below.

Diaphragm valve

Straight through type Diaphragm Valve

The weir-type diaphragm control valve is the better throttling valve but has a limited range. It uses a two-piece compressor component. Instead of the entire diaphragm lifting off the weir when the valve is opened, the first increments of stem travel raise an inner compressor component that causes only the central part of the diaphragm to lift. This creates a relatively small opening through the center of the valve. After the inner compressor is completely open, the outer compressor component is raised along with the inner compressor and the remainder of the throttling is similar to the throttling that takes place in a conventional valve.A weir type diaphragm valve is shown below.Diaphragm type valve has stem that does not rotate.
Diaphragm valve

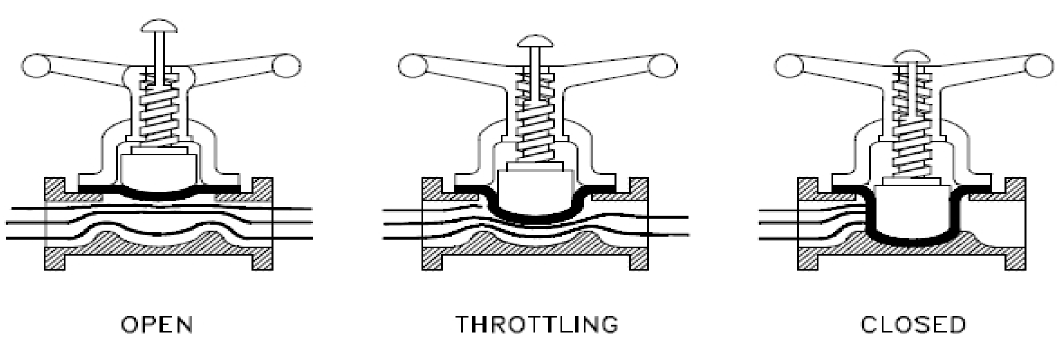
Weir type Diaphragm Valve.

Some diaphragm valves use a quick-opening bonnet and lever operator. A 90° turn of the lever moves the diaphragm from full open to full close position of valve. Diaphragm valves may also be equipped with chain wheel operators, extended stems, bevel gear operators, air operators, and hydraulic operators.

Applications:

Diaphragm Valves are ideally suited for:

- Corrosive applications, where the body and diaphragm materials can be chosen for chemical compatibility. (E.G. Acids, Bases etc.)
- Abrasive applications, where the body lining can be designed to withstand abrasion and the diaphragm can be easily replaced once worn out
- Solids entrained liquids, since the diaphragm can seal around any entrained solids and provide positive seal
- Slurries, since the diaphragm can seal around entrained solids and provide positive seal



Diaphragm valve function:

Diaphragm Valve Function

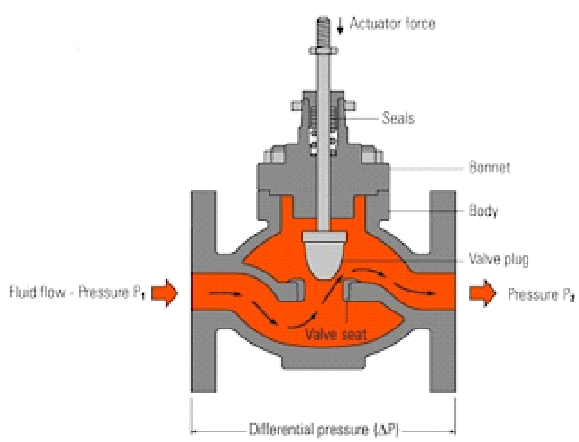
The diaphragm is connected to a compressor by a stud molded into the diaphragm. To start or increase flow the compressor is moved up by the valve stem. To stop or slow flow, the compressor is lowered and the diaphragm is pressed against the bottom of the valve.

Construction of diaphragm valve

Diaphragm valves (or membrane valves) consists of a valve body with two or more ports, an elastomeric diaphragm, and a "weir or saddle" or seat upon which the diaphragm closes the valve. The valve body may be constructed from plastic, metal, wood or other materials depending on the intended use.

4.2 Globe valve

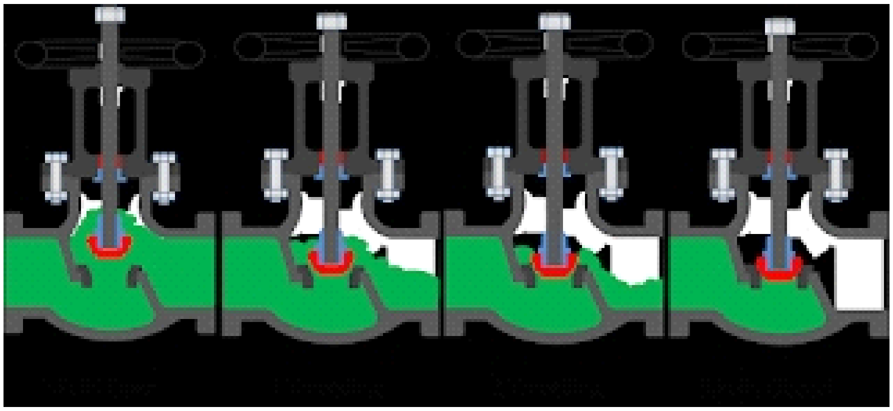
There will be one handle wheel, as shown in figure, with valve which is used to open and close the globe valve. When handle wheel will be rotated, it will move the valve plug in upward or downward direction across the line of fluid flow.



Globe Valve

We can see here the figure of a globe valve, where we will come to know that there will be two section of globe valve. Bottom section will be connected with the inlet line and outlet line with the help of flanges and upper section of globe valve will consist with the valve plug and steam. Handle wheel and valve plug will be attached with this stem with the help of pin assemble or screw assemble.

Working mechanism of a globe valve



Working principle of globe valve is as displayed here in following figure. When handle wheel will be rotated in clockwise direction, steam and valve plug will move in downward direction across the fluid flow line and valve plug will be tightly located between the two valve seats. Hence there will not be any leakage of fluid through the valve once valve is closed completely.

The following are some of the typical applications of Globe valves:

Cooling water systems where flow needs to be regulated

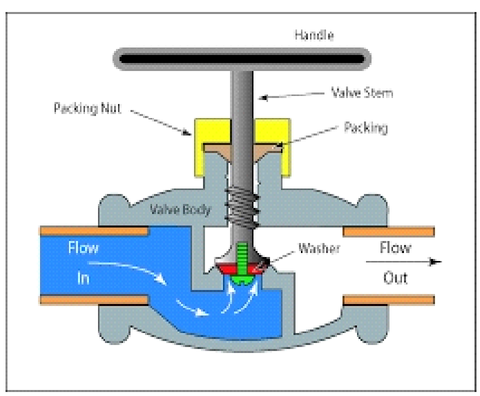
Fuel oil system where flow is regulated and leaktightness is of importance

High-point vents and low-point drains when leaktightness and safety are major considerations

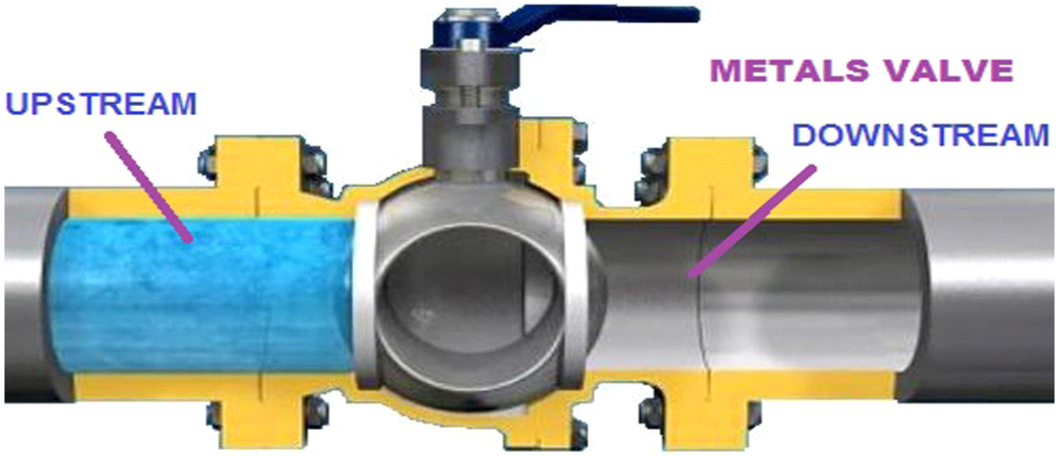
Feedwater, chemical feed, condenser air extraction, and extraction drain systems

Boiler vents and drains, main steam vents and drains, and heater drains

Turbine seals and drains



Turbine lube oil system and others.



4.3 Ball valve

The Ball valve uses a hollow, perforated and pivoting ball to control flow through it. The ball valve drives the valve handle to rotate by a transmission, which in turn drives the ball to rotate about an axis perpendicular to the flow.

It is open when the ball's hole is in line with the flow and closed when it is pivoted 90-degrees by the valve handle.

Working:

A ball valve is a device with a spherical closure unit that provides on-off control of flow.

Ball valves have a spherical closure unit that provides on/off control of flow. The sphere has a port (bore) through the center. When the valve is positioned such that the bore is aligned in the same direction as the pipeline, it is in the open position, and fluid can flow through it. When rotated 90°, the bore becomes perpendicular to the flow path, meaning the valve is closed, and fluid cannot pass through. Ball, butterfly, and plug valves make up the quarter-turn valve family.

Advantages

- They contain a compact and low-maintenance design that requires no lubrication
- They are cost-effective among all of the valves
- The biggest advantage of ball valves is that they have poor throttling characteristics that can cause the seat of a ball valve to easily erode.
- They provide leak-proof service.
- They open and close quickly.
- Ball valves have multi-way design flexibility.

Disadvantages

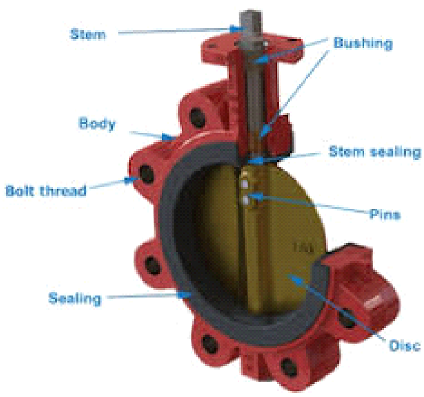
• Ball valves are not suitable for permanent throttling.

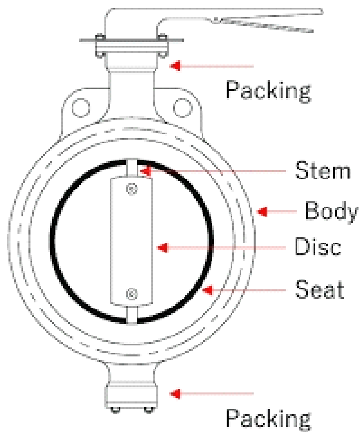
• In residual fluids, the particles in the fluid collide with the surfaces and stick to them. This may cause leakage, abrasion, and other problems.

Applications:

• Ball Valves are used for flow and pressure control and shut off for corrosive fluids, slurries, normal liquid and gases.

• They are used in the oil and natural gas industry, but also find a place in many manufacturing sectors, chemical storage, and even residential uses.





4.4 Butterfly Valves

A butterfly valve is from a family of valves called quarter-turn valves. In operation, the valve is fully open or closed when the disc is rotated a quarter turn. The "butterfly" is a metal disc mounted on a rod. When the valve is closed, the disc is turned so that it completely blocks off the passageway .Butterfly valves are configured to operate electronically, manually or pneumatically.

They can be used for a broad range of applications within water supply, wastewater treatment, fire protection and gas supply, in the chemical and oil industries, in fuel handling systems, power generation etc. These valves can be operated by handles, gears or actuators according to specific needs.

Advantages

• Butterfly valves are very accurate, which makes them advantageous in industrial applications.

• They are quite reliable and require very little maintenance.

• They have the capability to throttle flow.

• They can be installed or removed without pipe system dislocation

Disadvantages

• Butterfly valves have no tight shut offs

• Some portion of the disc is always presented to the flow, even when fully opened. This may result in a pressure switch across the valve, regardless of the setting.

Applications:

• Butterfly valves can be used in pharmaceutical, chemical, and food processing services.

• They are used for corrosive liquids at low temp and pressure.

4.5 Solenoid valve:

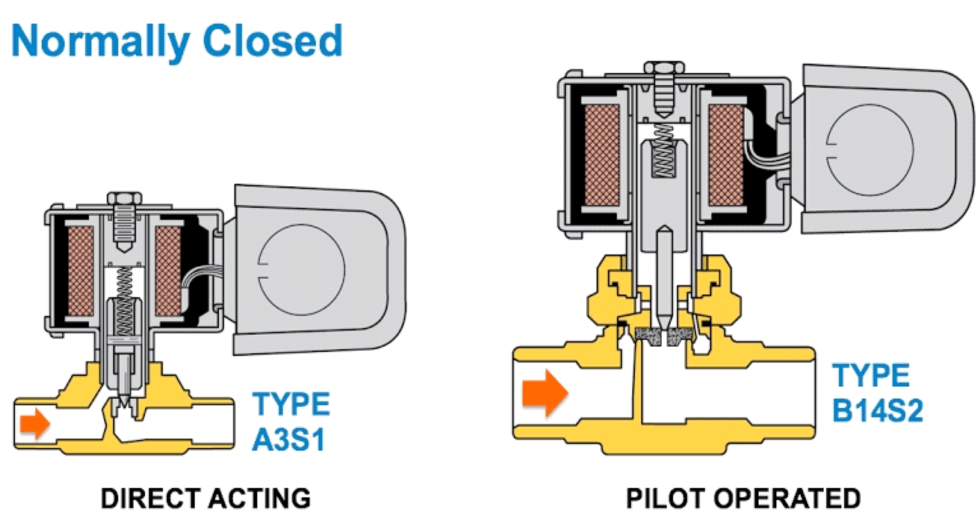
A solenoid valve is an electromechanically operated valve. Solenoid valves differ in the characteristics of the electric current they use, the strength of the magnetic field they generate, the mechanism they use to regulate the fluid, and the type and characteristics of fluid they control.

Working of solenoid valve:

A solenoid is a device comprised of a coil of wire, the housing and a moveable plunger (armature). When an electrical current is introduced, a magnetic field forms around the coil which draws the plunger in. More simply, a solenoid converts electrical energy into mechanical work.

- The coil is made of many turns of tightly wound copper wire. When an electrical current flows through this wire, a strong magnetic field/flux is created.
- The housing, usually made of iron or steel, surrounds the coil concentrating the magnetic field generated by the coil.
- The plunger is attracted to the stop through the concentration of the magnetic field providing the mechanical force to do work.

Type of solenoid valve:



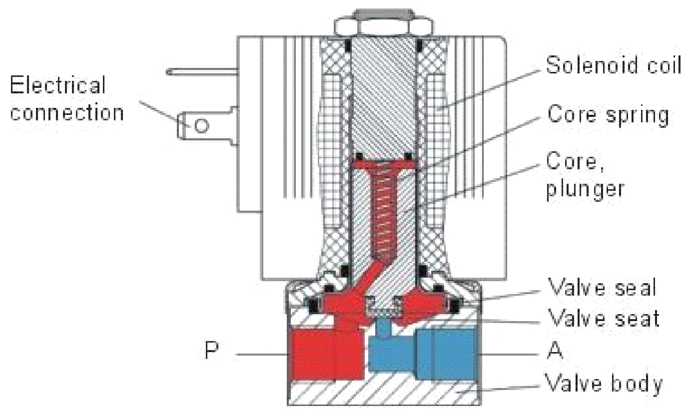
Direct Acting Valves

In a direct-acting solenoid valve, a coil magnetically opens the valve in direct action, lifting the shaft and the seat of the valve without depending on outside pressure.

- **Pilot-Operated Valves**

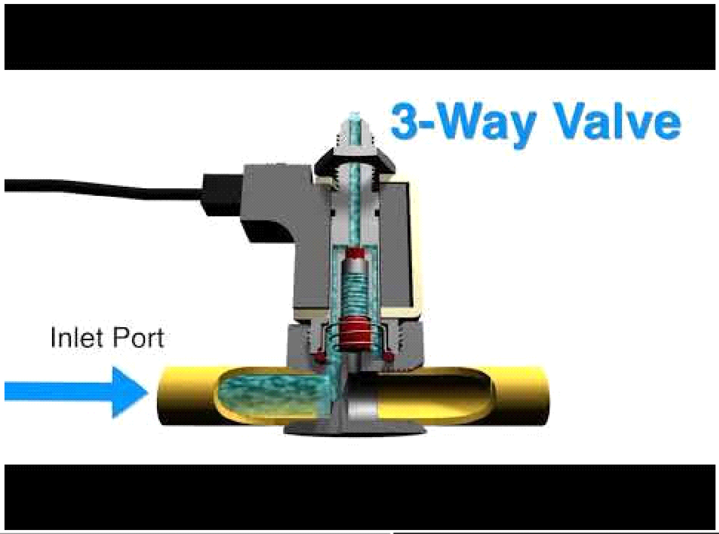
In pilot operated valves, the solenoid activates a much smaller “pilot” valve that in turn opens up a larger valve operating at much higher pressure, such as required in hydraulics, steam, etc., or at a greater volume flow, as for releasing large quantities of liquids, gases, steam, or air.

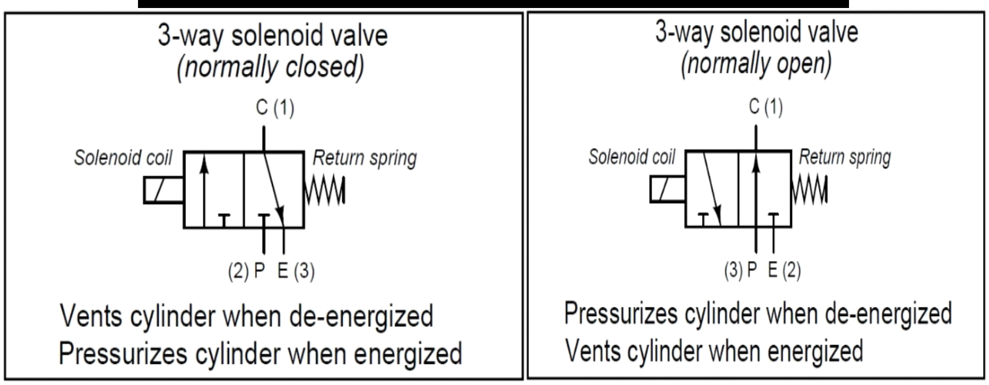
Although piloted valves require less electrical energy to operate, they usually need to maintain full power in order to remain in an open state, and they perform at a slower rate than direct-acting solenoids. Direct-acting solenoid valves only need full power when opening the valve, as they can hold their open position even when operating on low power.



- **Two-Way Valves**

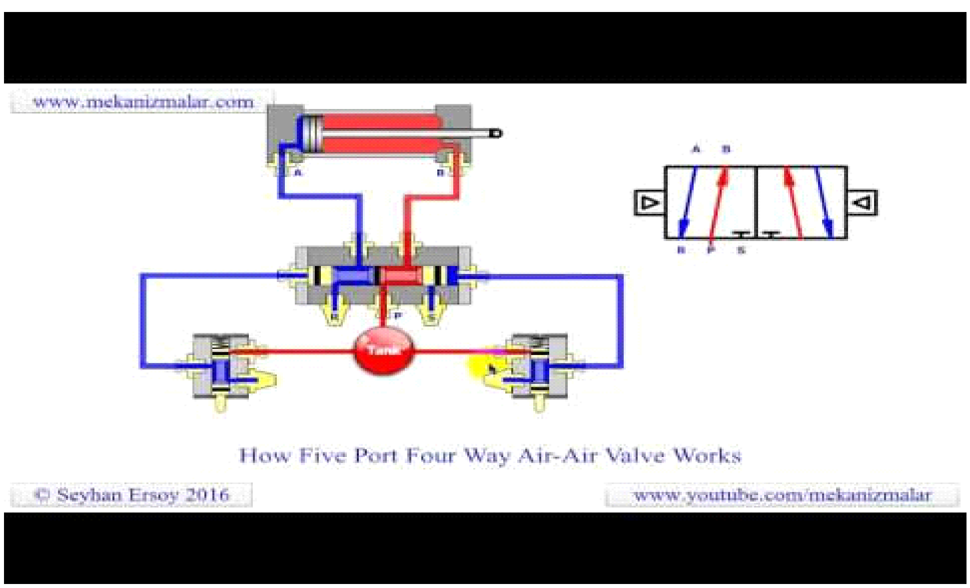
Each of the two ports on a two-way valve is alternately used to permit flow as well as close it off. A two-way valve can be specified to be either “normally open” or “normally closed” in its operation. With a normally open valve, the valve remains open until some type of current is applied to close the valve. Suspension of the electrical power causes the valve to automatically reopen to its normal state. A normally closed solenoid valve is the most common, working in the opposite fashion, remaining closed until a power source causes it to open.



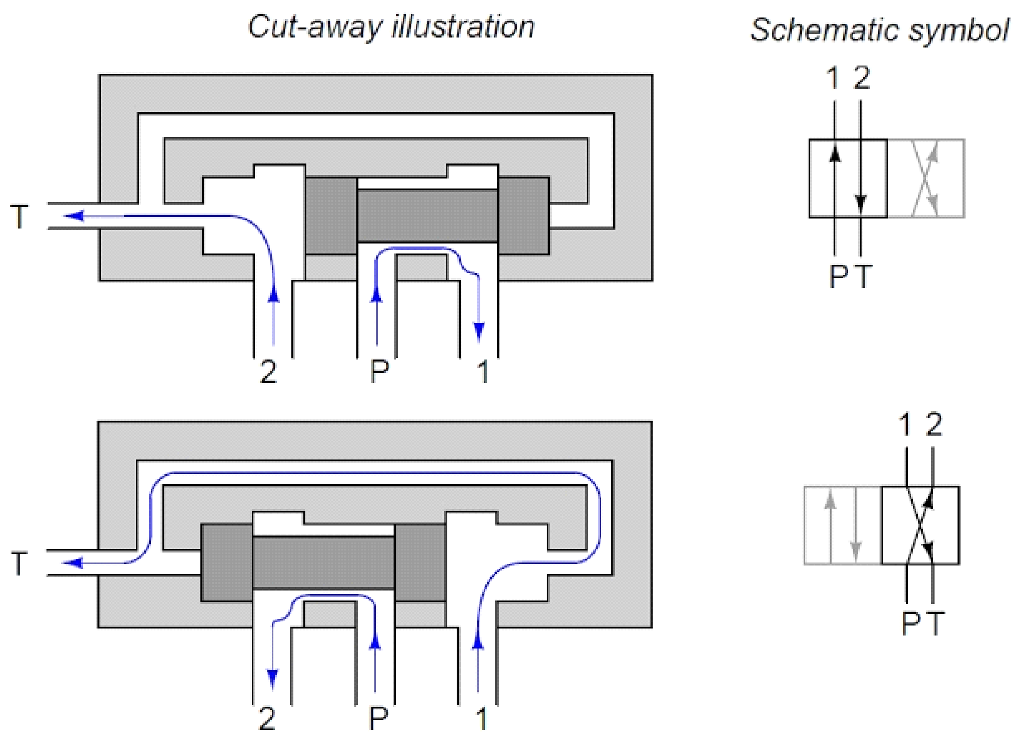


- **Three-Way Valves**

Three-way valves come with three ports. These are commonly used when alternate and exhaustive pressure are required for operation, as with a coffee machine or dishwasher.



- **Four-Way Valve**



These valves can have four or more port connections. Four-way valves are commonly used with a dual-acting cylinder or actuator. In this version, half of the port connections supply pressure, and the remaining connections provide exhaust pressure. You can specify these valves to be either normally closed, normally open or universal.

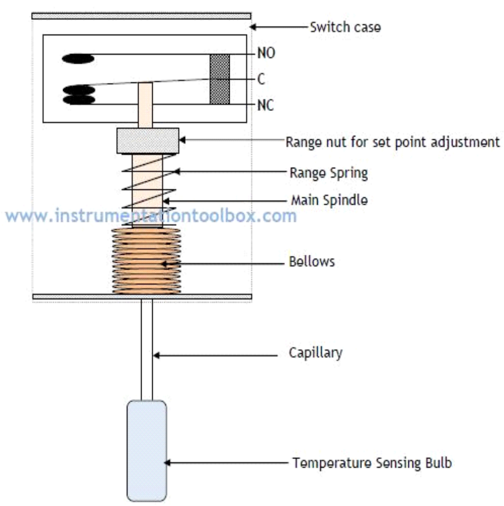
Chapter-5
Switches

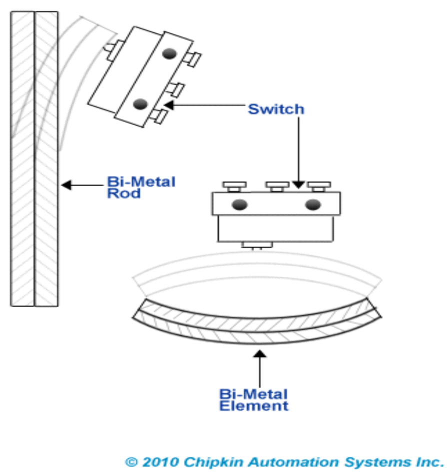
Temperature Switches:

A Temperature switch works just like a typical electrical switch for on /off application. In this case, the temperature switch operates to switch on or off at discrete process temperatures. ... (a) A sensing part immersed in the process whose temperature is required to be controlled.

Working

As the switch begins to increase in temperature, the bimetal heats up until it reaches the temperature where it deflects and thereby opens the electrical contacts. When the temperature decreases, the bimetal returns to its original shape and closes the electrical contacts.





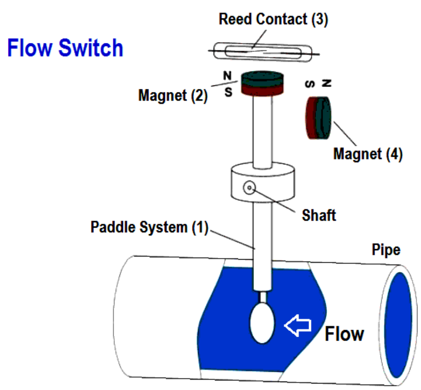
1 TEMPERATURE SWITCH CONSERVES ENERGY.

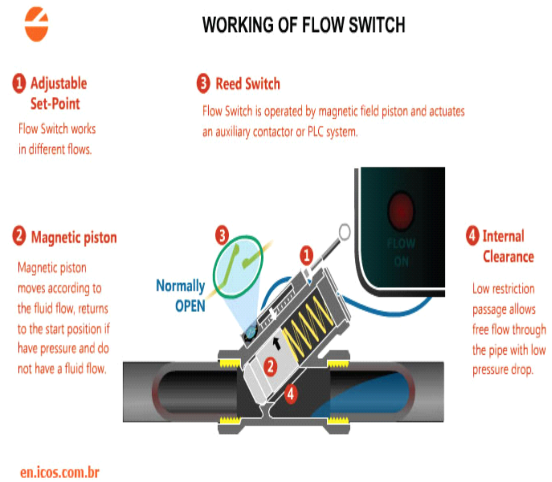
2 TEMPERATURE SWITCH USED FOR FREEZE PROTECTION.

3 TEMPERATURE SWITCH TRIGGERS BOOSTER FAN.

Temperature Switches are designed to control safety systems on automated processes. Temperature Switches utilize a bimetallic element to make or break a circuit. The materials which are used to produce bimetal react differently when heat is induced into the bimetal element either through exposure to heat generated by the application or caused by the self-heating effect created by passing current through the bimetallic element; or a combination of both. This permits the bimetallic element to "bend" creating the workforce required to make or break an electrical circuit. To learn more about temperature switches.

Flow Switches:





Understanding Flow Switch

The flow switch is designed to monitor the flow of air, liquid or steam. The device transmits a trip signal through to another device in the system, called a pump. Flow switches are typically built to indicate to the pump regarding shutting off or to turn on. A flow switch has several different uses. Some of the uses of flow switches include cooling-circuit protection, pump protection, and alarms for too high or very low flow rates.

Working

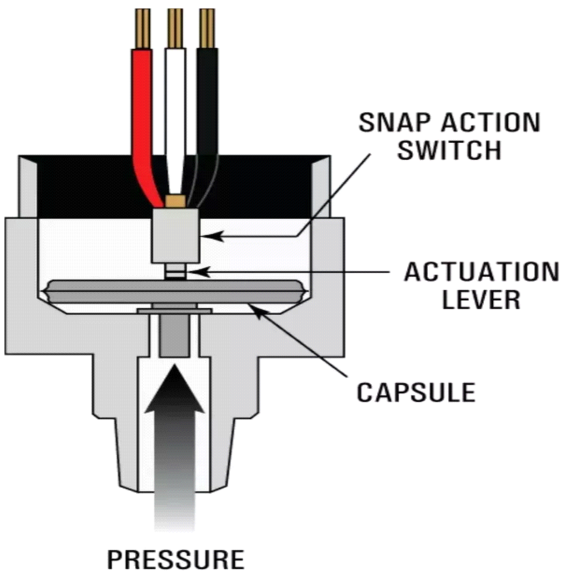
A flow switch operates by conveying a trip motion (relay, reed switch, paddle) to another machine within the system, usually a pump. The trip signal will indicate to the pump to turn on or turn off. It is necessary to provide damage protection and circuit cooling or adjust flow rates that are too high or too low.

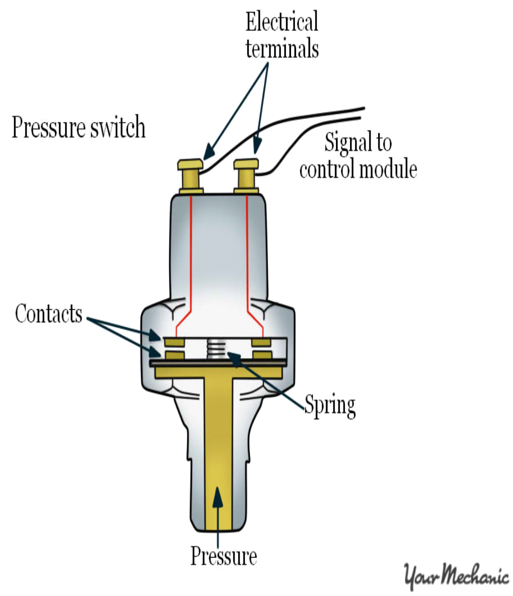
Applications

- These switches find application in the detection of fluid flow and measurement of fan speeds.
- A flow switch might be used to protect a central heating system electric heating element from being energized before the air flow from the blower is established.
- Flow switches might also be used to alarm if a ventilation fan in a hazardous location fails and air flow has stopped.
- Pump protection.
- Safety spray nozzle monitoring.

- Cooling water or heat exchangers.
- Oil well system testing.
- Drain line flow.
- Relief valve monitoring.

Pressure Switches:





A pressure switch is a form of switch that operates an electrical contact when a certain set fluid pressure has been reached on its input. The switch may be designed to make contact either on pressure rise or on pressure fall.

Working :

Pressure switches rely on water pressure to do all the work. The change in pressure that activates the switch is provided via the water from the well. The pressure moves up through the diaphragm which presses against a piston and spring, which in turn opens or closes the contacts. Open contacts located within the switch, closes when pressure drops. This completes an electrical circuit, which in turn activates the pump. When the set pressure is reached, this allows the contacts to open again which turns off the pump**.**

Application:

Pressure switches are widely used for a large range of applications throughout industry and manufacturing. Their function is to provide systems with electrical ...

They are used in a wide range of industrial and manufacturing applications, such as:

- Well water pumps.
- Electronic gas compressors.
- In-cell charge control inside a battery.
- Activating an alarm if aircraft cabin pressure drops.
- Pressure panels on sliding doors.
- Switching high currents, e.g., pumps and drives.

Interlocking And Sequencing Circuit:

Definition of sequence interlock

An interlock provided between a number of manually controlled electrical circuits, which are required to function in a prescribed order, and which prevents a circuit from being operated unless the preceding circuit has completed its part in the sequence.

An interlock is a feature that makes the state of two mechanisms or functions mutually dependent. It may be used to prevent undesired states in a finite-state machine, and may consist of any electrical, electronic, or mechanical devices or systems. In most applications, an interlock is used to help prevent a machine from harming its operator or damaging itself by preventing one element from changing state due to the state of another element, and vice versa