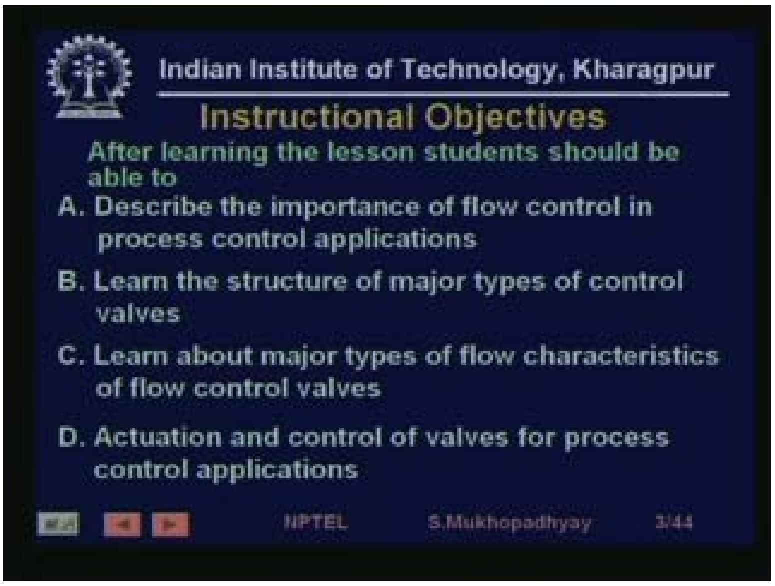
Industrial Automation & Control
Prof. S. Mukhopadhyay
Department of Electrical Engineering
Indian Institute of Technology, Kharagpur

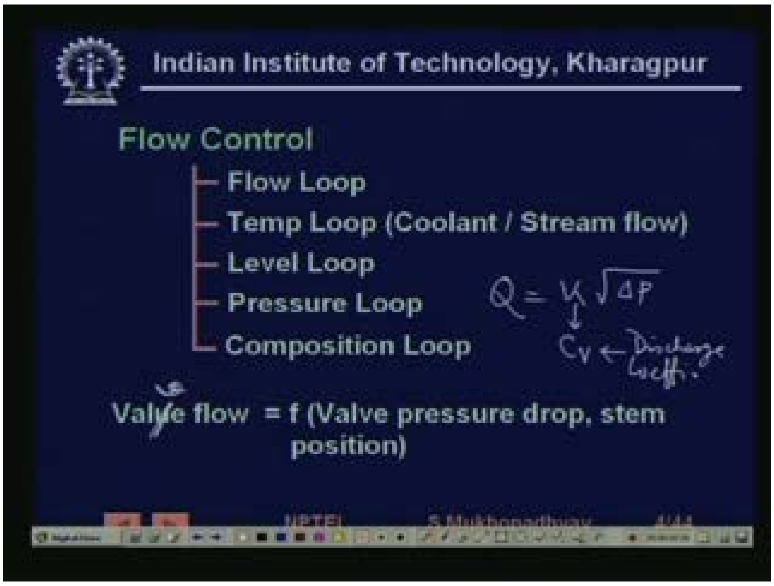
Lecture - 25
Flow Control Valves

(Refer Slide Time: 00:59)



Welcome to lesson 25 on Flow Control Valves of the course on Industrial Automation. Flow control valves are very important, so after learning the lesson, the student should be able to describe the importance of flow control valves, they are found everywhere in process industries. Learn the structure of major types of flow control valves, learn about the their flow characteristics, because that is very important in designing the applications. And finally, the how to actuate these valves and how to affect their characteristics to achieve a certain characteristic of the process control loop, so these are the topics, that the student is expected to learn from this lesson.

(Refer Slide Time: 01:52)



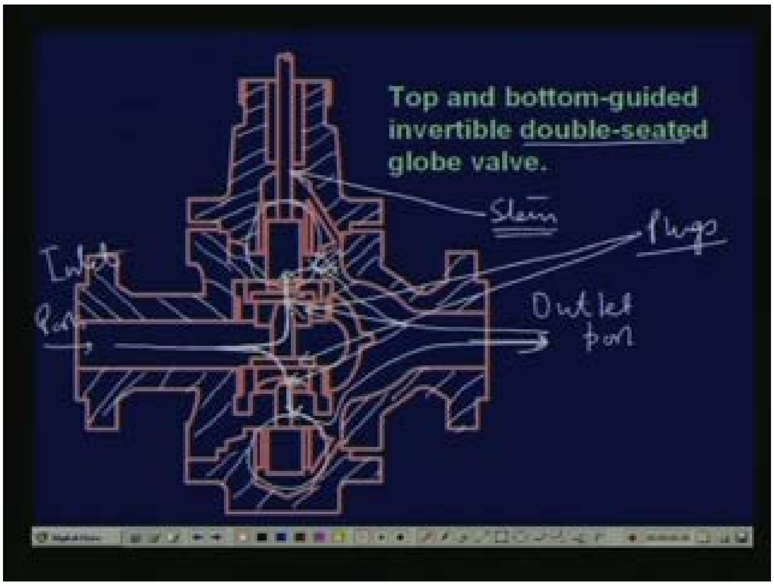
So, the first of all, let us have a look at, the importance of flow control, flow control is probably the most important control in a process control application, and as we shall see, during our process control module, that flow control loops, form a part of most type of control loops. For example, they are parts of flow loops, where directly flow has to be controlled, flow is a final objective of control, they are parts of temperature loops, because temperature is generally controlled by controlling, flow of either a coolant or and let us say steam, for heating, this is not stream, this is steam.

Of course, for level loops, because by integrating flow only you have level, so all level control is essentially flow control. Similarly, pressure loops, because again pressure control is achieved by using flow control, and composition loop, because compositions of products, are typically dependent on the compositions of the components in a let say a reactor. So, if you want to control the composition of a particular product, flow control is often a very important part of that, control applications.

So, we see that, for most types of control applications, flow control is a part, and the element that finally, achieves the control is the flow control part. So, it is importance, cannot be overstated and as we shall, as we need to mention again slight spelling mistake. So, this is a valve flow is actually a function of valve, the pressure drop across the valve and this, and the stem position, as we shall as we perhaps know that by Bernoulli's equation.

The flow of a, flow through a, through an orifice, of flow control valve is essential in orifice and it is the dimensions of the orifice, which are varied is proportional to, proportional to a root over of delta P. Delta P is the pressure difference across the valve, and K is proportionality constant, which contains among other things, a what we, what we call as discharge coefficient or C v, so the flow the inflow control valves, it is this K or this discharge coefficient of the valve which is changed, by changing the orifice dimensions, so that is the way, we achieves flow control.

(Refer Slide Time: 05:00)



Now, so first of all we see, the various kinds of valves and the first kind of valve that we see are globe valves. Globe valves are so before we must understand the various parts, so I am going to hatch it, so this is the, these are the ports, this particular flow control valve, this is inlet port, this is outlet port, this is another component of the body, not this one, not I am sorry, not this one, not this one, this part, this part, this is the body, the fluid in fact, there are, this is a top and bottom guided.

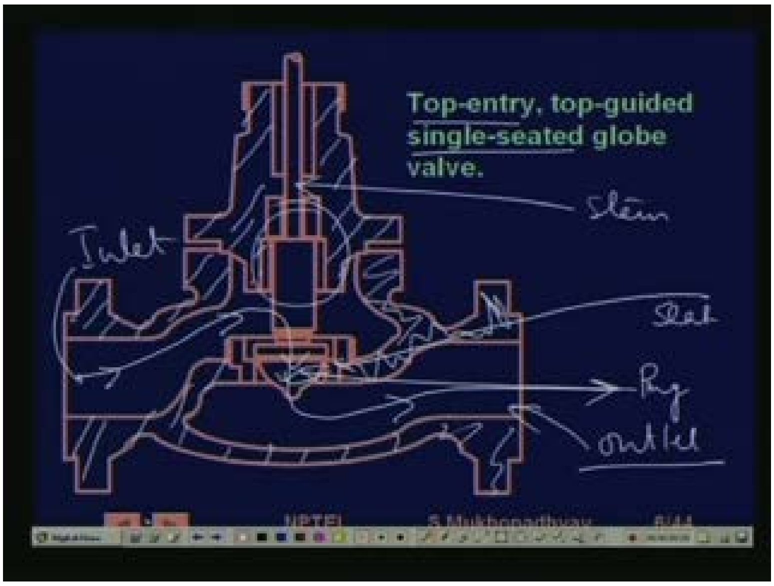
Top and bottom guided means the basic valve assembly movement is guided at in the top and at the bottom. And, it is a double seated globe valve, so there are two seats, one seat is here, another seat is here. So actually the fluid enters through this and will go through this, when this valve will rise, when this valve will rise, it will go through this and will flow out, similarly, it will go through this, it will go through this path and go out.

So, since there are two seats, it is a double seated globe valve, one of the advantages of double seating, is that the force as you can see, that the fluid when it flows through the valve, it actually exerts a pressure on, this valve mechanism, this is called the stem and these are called the plugs, these are the plugs. So, the plugs actually come and this is the seat, and the plug actually comes and sits over the seat, and seals the, seals the orifice and when the valve opens, this plug goes up, so the fluid flows through the orifice.

And, this plug movement is actually realized, by moving the stem, to which the plug is connected, so obviously, there is the fluid, exerts force on the plug and plug sometimes has to work against this force. So, to reduce for double seated valves, although they are not so popular now a days, but double seated valves, one of the biggest advantages of double seated valves is that, since the force, when the liquid is flowing in this direction and the force that the liquid exerts in this direction are opposing each other, so the net force on the stem is actually small.

So, therefore, it requires a smaller capacity of the actuator, to make a movement, but still nevertheless these valves are not so popular, because of mainly two reasons. Firstly, that single seated valves are can be realized with a much smaller size number 1, Number 2 is that, because of you know slight mechanical problems, it is very difficult to ensure that, both the plugs actually seal the, seal the orifice at the same time, and therefore, often you have problems of leaking through the valve, that the shut off of the valve is not so tight.

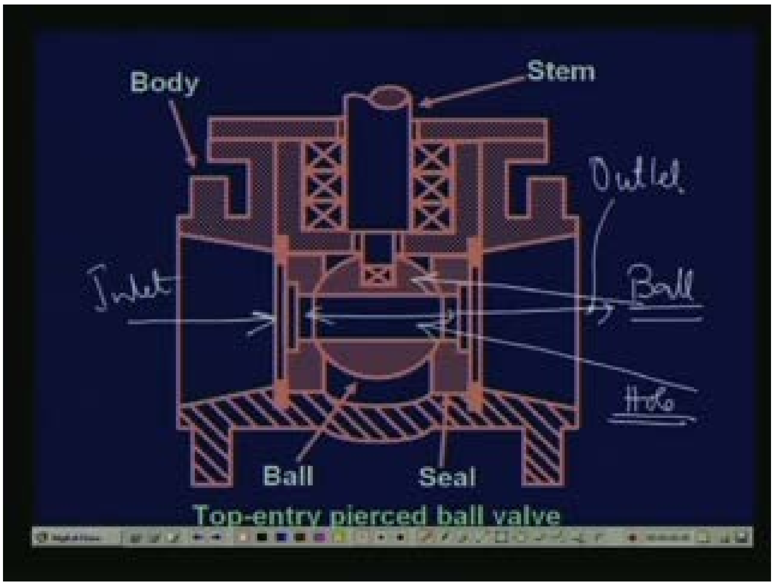
(Refer Slide Time: 09:29)



So it is for this reason that people, nowadays prefer single seated valves, so this is a single seated valve, you know you this is the plug, this is the plug you can see that. This is the seat on which the plug sits, this is the seat, this is the stem, this is the, these are the bodies, this is the body. So, the fluid actually flows like this, like this, like this, so this is the fluid path, when the valve opens, this is the inlet port, inlet and this is the outlet port.

So, this is a top entry, top entry because the valve stem enters from the top, top guided here there is only one guidance, one guiding piece, that is top guided not, not top and bottom guided, single seated, because there is only one seat globe valve. So, these valves are one of the most common types of valves used in the process industry.

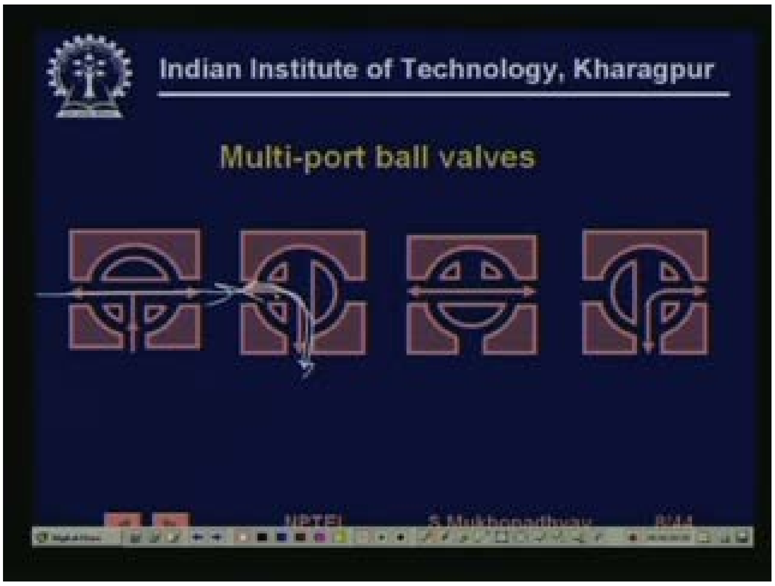
(Refer Slide Time: 10:59)



Next are ball valves, these valves have, the in the previous case, the stem actually moves in a linear fashion up and down, and for these valves the stem actually rotates, so it is a so it requires a rotary actuator, it can be directly coupled to a motor. So, you see that, actually you have a ball, a ball like structure, through which there is a hole, so you can see, the hole, this is the ball, these are ball valves and this is the hole through the, this is the hole through the ball.

So, now suppose, so this is the hole suppose, so when the ball is in this position, then you can understand, that this is the inlet port and this is the outlet port. So, when the suppose the fluid is coming like, this is the inlet port and this is the outlet port, so when the hole is aligned with the inlet port and outlet port holes, then the fluid can flow from inlet to outlet. On the other hand if the ball rotates, then the flow is blocked, so it is by rotating the ball, that various amounts of flows can be realized, so this is the basic principle of a ball valve.

(Refer Slide Time: 12:39)

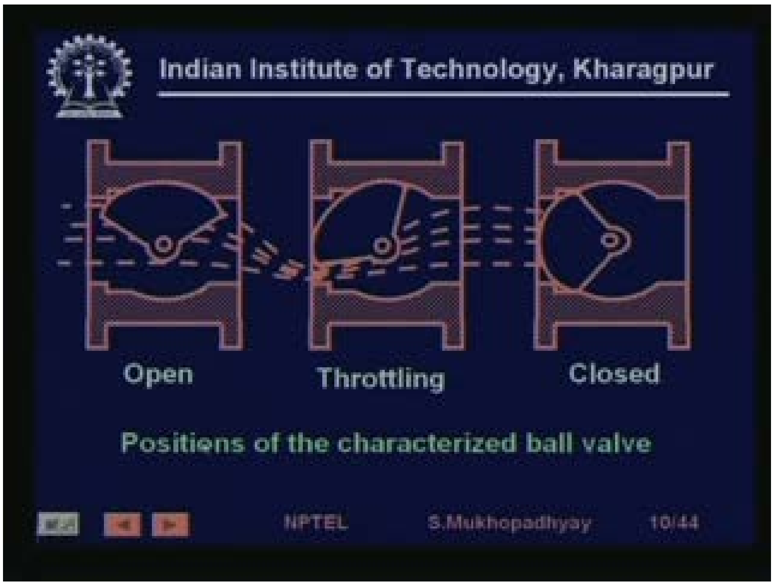


For example this is a multi-port ball valves, so you can see the ball, this is a cross section, so the ball is you know like this, semi cylindrical ellipsoidal, and these are the holes. So, the in this case, this has this can take care of three ports, so you can see that, in various positions of the ball, if the ball is aligned like this, then liquid can flow from here to here, if it is aligned this way, it can flow from this to this or this to this. So, under the various positions of the ball valve, you can have various kinds of, various ports can be connected to various others. This is a T ported ball valve we can have an angle ported valve, ball valve and things like that, so this is the basic principle of balls valve.

(Refer Slide Time: 13:30)

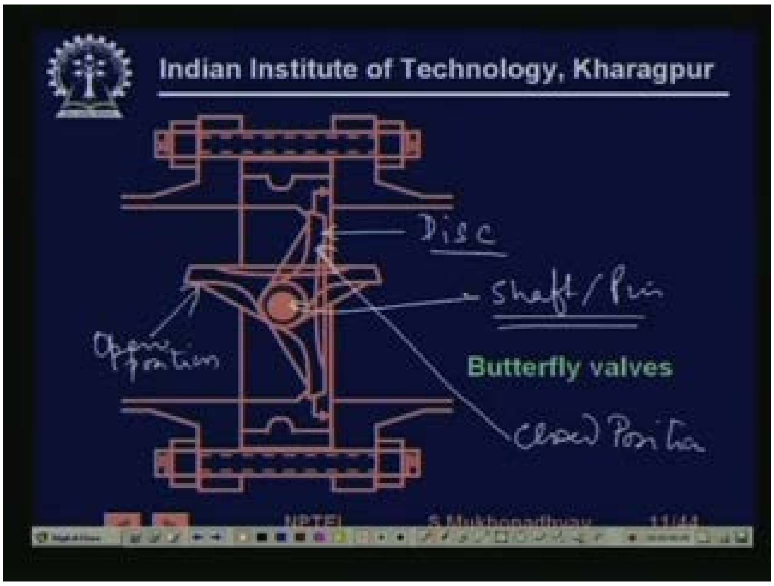
This is this picture shows how when a ball valve rotates, then how the flow throttling takes place, so you see, that as it is rotating. So this, the effective area of flow, they gets reduced, so as it rotates slowly the effective area of flow, will get reduced and therefore, the flow will get reduced, so the flow gets throttled.

(Refer Slide Time: 14:02)



This is another, kinds of ball valve, where the ball is of a certain shape, so it is called a characterized ball valve. So, here you can see that, as again as it rotates this surface, slowly comes and closes the flow, and therefore the flow the flow can be throttled or it can be completely shut off, so these are this is another kind of ball valve called the characterized ball vale.

(Refer Slide Time: 14:31)

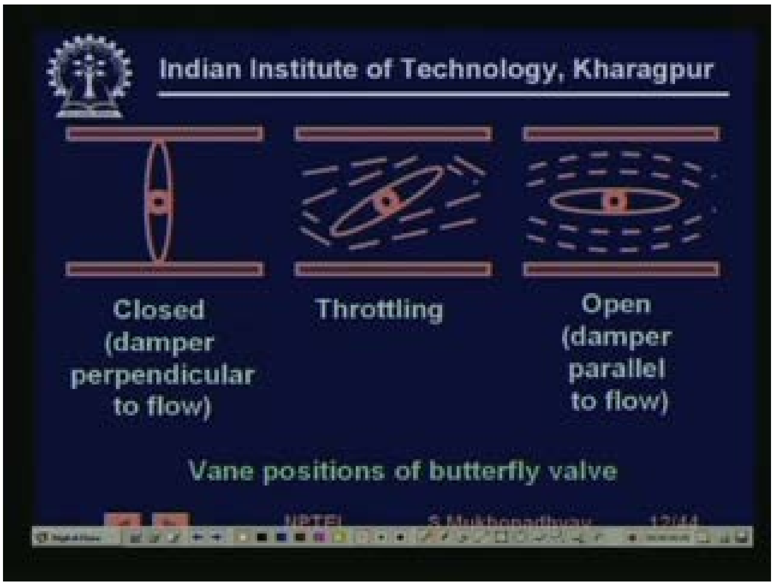


The third kind of valve, actually there are various kinds of valves, we are going to only talk about some major ones, but there are at least ten, fifteen different types of valve, which are, which are used in various kinds of applications in the industry diaphragm valve, pinch valve a sliding gate valve, etcetera, etcetera. So, this is another kind of valve, which is called a butterfly valve, so basic idea is that, this is butterfly valves are used in large pipes, they are also used for the apart from you know, applications in let us say, a liquid applications like water, water flow control etcetera.

They are also used in gas applications, like they are used in a, heating ventilation, air conditioning applications of large buildings, where the airflow needs to be controlled. so in such applications butterfly valves are also used. So, basic idea is that, in all valves there has to be an variable obstruction right, so it is this disc, which is the, which creates the obstruction, and there is a shaft or a pin about which, so you can understand, that you can understand that this is a butterfly valve and there is basically a shaft runs across it and this shaft is driven.

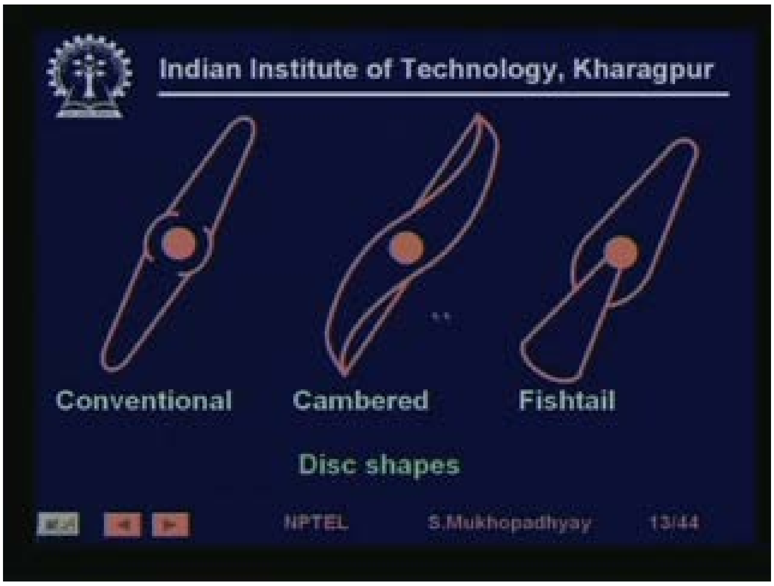
So, this is valve is actually, stuck to this and if you rotate this actuator, then this valve can be either in this position or in this position. So, if you have pipe here, if you have a pipe here, then if you connect in this position then it is open, if you connect at this, if you put it in this positive then it is closed. So, exactly that is the position, so the these two positions are shown, so this is the open position of the disc, open position and this is the closed position of the disc, both positions are shown closed position. And this is the shaft or pin, which is driven to move the disc, various shapes of discs are used to you know again, to reduce the torque requirement on the shaft or to reduce noise, of these such big discs, when you have a fast flowing fluid can sometimes vibrate and create noise.

(Refer Slide Time: 17:12)



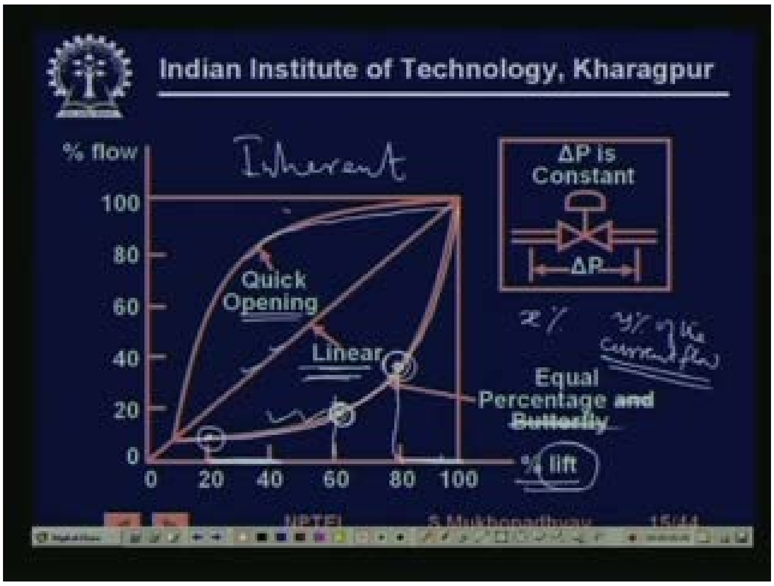
So, this is the picture which shows that, so look from a side, when the disc is, in this position then the damper or then the damper is perpendicular to flow and the valve is closed. When it is moving in and throttling or controlling the flow and when it is in this position, then when damper is parallel flow, then is completely open.

(Refer Slide Time: 17:41)



So, there are various kinds of disc, which are used as I said to take care of various factors like torque and noise.

(Refer Slide Time: 17:50)



Now, we so we have seen three different types of valves, characterized in terms of construction. Now, we shall characterize valves in another way, depending on their flow characteristics, so depending on their flow characteristics, valve can be generally characterized, in into three different classes. One is butterfly valves are typically of equal percentage type, that is why and butterfly was written, so one is this equal percentage,. so another is linear and the third one is quick opening.

So, this equal percentage valve is you can see, equal percentage means, that if you have a this is percent lift, percent lift means, the stem if it is lifted by a certain percentage, this the stem is moving, so percent lift or percent stem position it, this it may not be, though it is called lift, it may not be always a lift you know, sometimes it may be a rotation also. Basically means, that percent of the total stem movement, so it says that, if you increase the stem movement by x percent, then y percent of the current flow will it, so the flow will increase by y percent of the current flow.

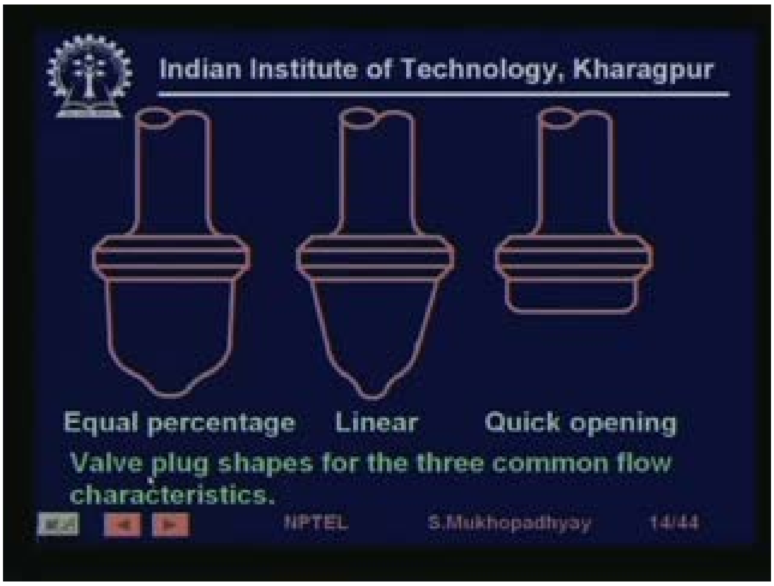
So, if you make x percent change, if you make a delta x, x percent of full scale, so if you make a 20 percent change here, then may be 5 percent of the current flow, which is here will take place. On the other hand, if you make a 20 percent change here, then 5 percent of the current flow, which is here will take place, if you make twenty percent change here, then 5 percent of the current flow which is here will take place. So, you see that for the same 20 percent change, at 20 percent, 40 percent, 60 percent, 80 percent the change in flow is going to gradually increase, giving rise to this characteristics.

So, an equal percentage of the current flow will take place, if you make a certain, a certain fixed percentage of lift change, that is the reason, why these valves are called equal percentage. So, you can easily analyze, you can easily understand, that this sort of characteristic exponential kind of characteristic arises, so on the other hand, we have linear, which is obvious, that is for a certain percent of lift change, a certain fixed percentage of the total full scale change, not current flow will take place, so it is a linear it is added by constant.

Actually, the linear and the equal percentage are mostly used in process applications, quick opening valves are you know like our bathroom taps are typically quick openings. So, you must have seen that, if you the almost full flow is realized by, a may be, even one turn or one and a half turns of the tap, while if you move it more and more, then not much flow increase takes place. So, these walls there is a quick, increase of flow and then for the rest of the movement there is very little flow.

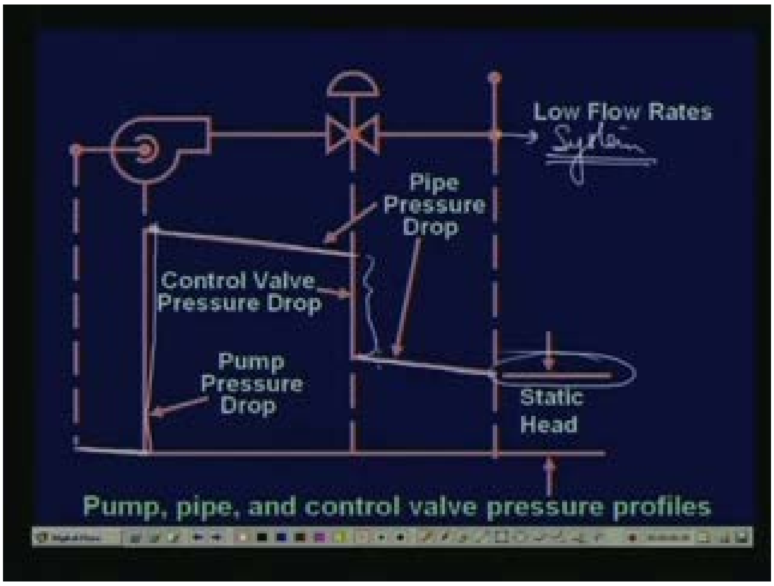
So, it is a kind of opposite of the equal percentage and they are typically used more in you know, on off kind of applications or some certain special kinds of process control applications, but most of the control applications, they use linear and equal percentage parts. Remember one thing, that these characteristics have assumed, that this characteristic are called inherent characteristic and are provided by the manufacturer, inherent characteristics of the valve and are provided by the manufacturer, under conditions that the pressure across the valve is constant. So, they actually maintain the pressure across the valve and then they characterize this curves, so this is important to understand.

(Refer Slide Time: 22:17)



And, now how are these characteristics realized, they are realized by various profiles of the plug, so in the case of the globe valve here, say we have there are three kinds of, these are three plugs, which realize equal percentage, linear or quick opening characteristics.

(Refer Slide Time: 22:38)

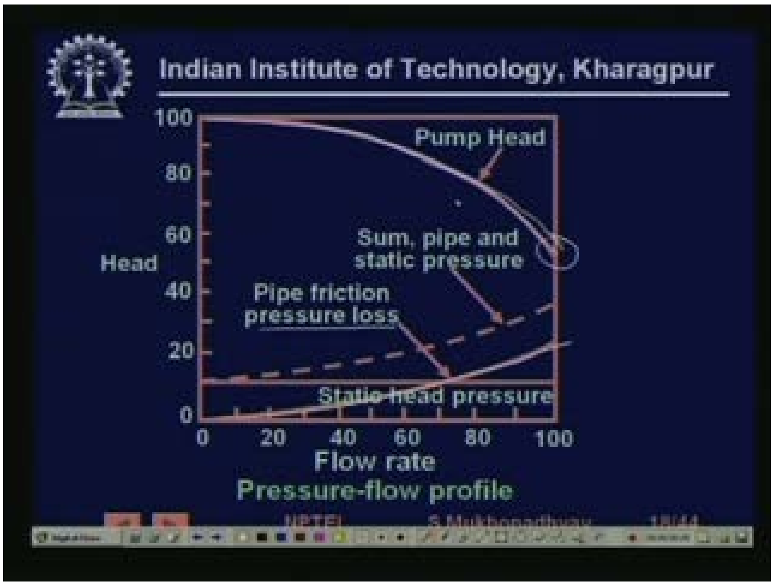


Now, it turns out one must realize, that if you actually put the valve, into an application and connected up, with you know other components pumps systems pipes etcetera, then the inherent characteristic will not be realized. So, the pressure flow characteristic of the actually the rather the stem lift versus flow characteristic of the valve, which is provided by the manufacturer, which is the inherent characteristic will not be realized, because of the fact, that delta P will not remain constant.

So, how does that happen, so you see that, when you are connecting, so this goes to the system wherever, you want to send this flow and we are just you know, arbitrarily assuming that the head of the, that the system takes a particular kind of static head. So, what happens is that during flow there are actually pressure drops, so there is some pressure drop at the inlet of the pump, then the pump rises, the pressure, that is the job of the pump, it creates a pressure head.

Then this flows through the pipe, so again there is some friction loss and there is some pressure head. Then there is a drop across the valves, because all, because all valves will have a, you know if it has flow through an orifice, there has to be a delta P, then again there is a drop at along the pipe and then the available pressure at the system is there, so this is the way the pressure drops and actually as we shall see now.

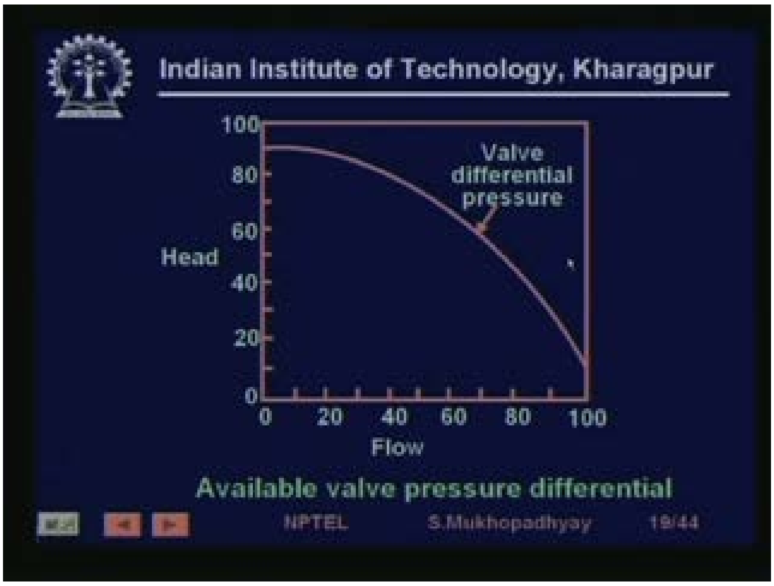
(Refer Slide Time: 24:14)



That now, as now as we know, that these pressure various pressure drops, vary with flow itself, so for example, the pipe friction pressure loss, will also rise with flow. Similarly, if the pump head, because there are pressure losses inside the pumps, so the pump head available, the pump head that will be generated, will also be lower. Similarly, here we have assumed a static head pressure, it may be constant or in some cases, even this for example, if the fluid is a you know, kind of heat exchanger, then again the heat exchanger is actually nothing but, a intertwined length of pipe.

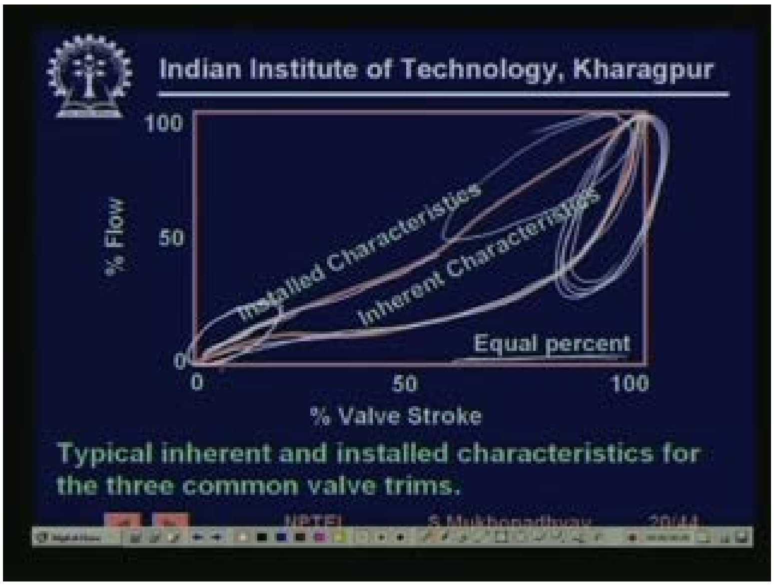
So, basically the pressure head across the system will also increase with flow, so eventually what happens, is that see the pump is the prime mover right. So, the total pump head available is this one, and that must be equal to the sum of the drop in pipes, drop in the valves, plus drop in the system. So, as the drop in the pipe and the drop in the system rises, there is less and less delta P available, across the valve and, so the flow actually reduces.

(Refer Slide Time: 25:48)



So, the operating point that are established, will always have delta P falling, so the valve differential pressure available, actually falls quite sharply with the flow, so it is not constant.

(Refer Slide Time: 26:01)



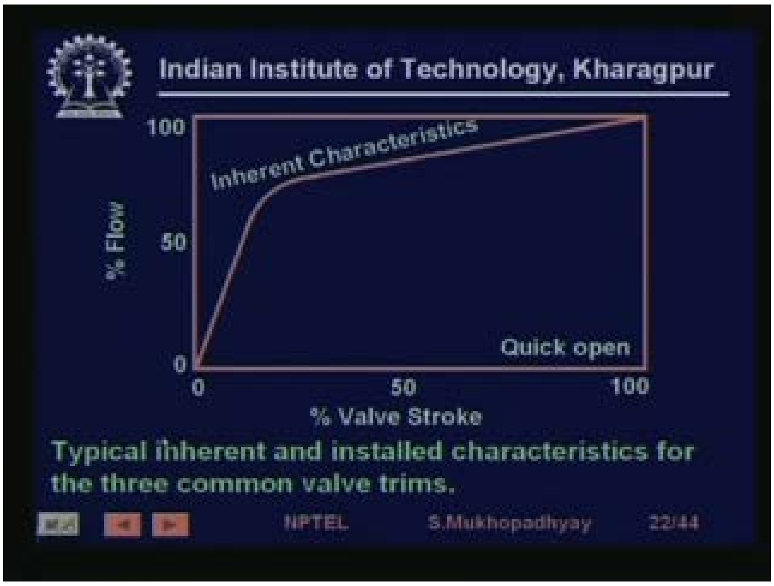
In effect what happens is that, for example, this is the case of an equal percentage valve, at some delta P, so you see that the inherent characteristic is almost like an equal percentage nearly. On the other hand, if you put the valve, that valve into along with a pipe and a pump and a system, then initially, there is a lot of fresh delta P available, because there is hardly any drop, in the flow is low, so there is hardly any drop in the system.

So, the pump, so the valve flow with change in lift, because delta P available across the valve is now quite high at this stage, so there is a, for a sudden change in lift, there is a good change in the flow, so the rate remains high. On the other hand here, you see that in this part, for the inherent characteristic the rate of flow change is high, but that much rate of flow change is not achieved in the installed characteristics, because of the fact, that now the delta P has come down.

So, if the delta P has come down, then for a then for a given change in the lift, now so much change, which was available see previously when delta P was held constant, a lot of change could be possible, by changing a certain part of the lift. But now, since a delta P is going to fall, so therefore, so much change is not possible, and we get a different characteristic, that characteristic is called the installed characteristics, and this must be remembered, because it is the installed characteristic finally, which is going to decide the characteristic in the process control.

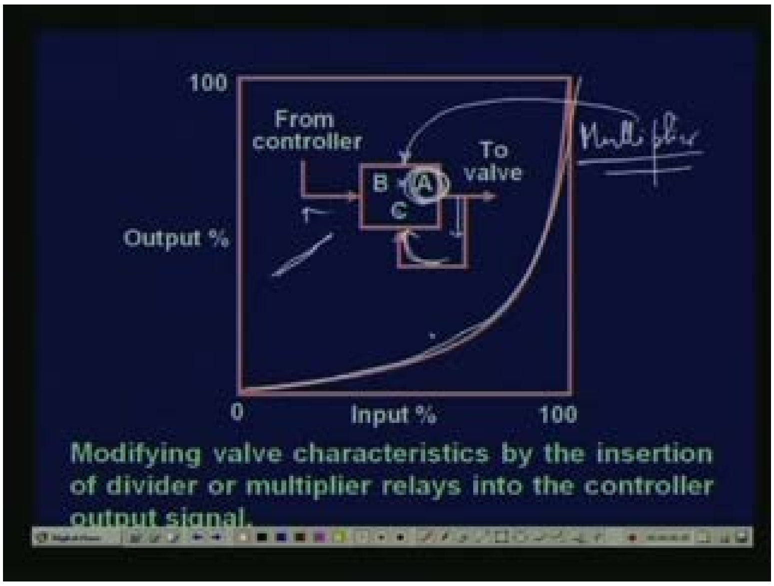
So, therefore, we must understand that the inherent characteristic gets changed, because of pressure drops and the resulting characteristic is called the installed characteristic. So, the same thing happens for, linear valves again there is a high higher than, inherent you can we are assuming that the inherent characteristic delta P will be will be maintained, you know somewhere in the middle of the delta P range. So, initially you have higher, you have a higher delta P, so therefore, the rate of rise is high, later on the, rate of rise is lower, than the inherent characteristic, this is what happens?

(Refer Slide Time: 28:24)



This is the characteristic for an inherent characteristic for a seeing, and they are not so much use, so the installed characteristic is actually not drawn.

(Refer Slide Time: 28:32)



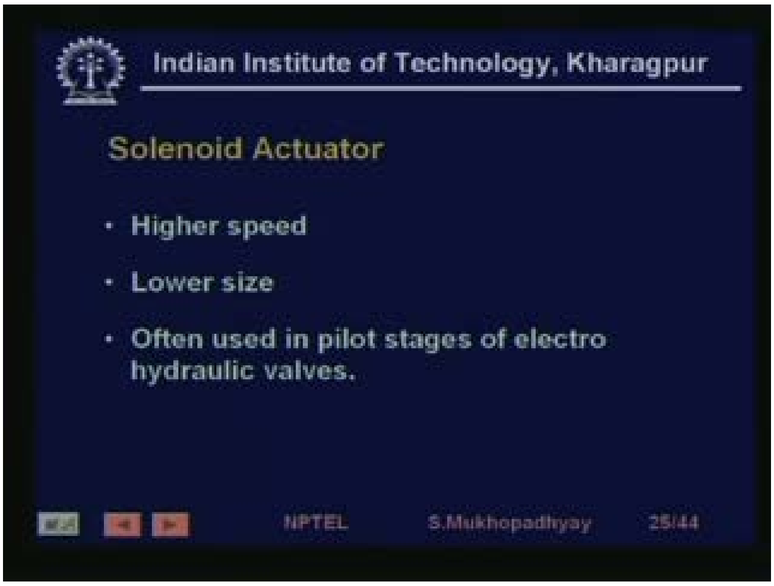
Now, these characteristic sometimes you know, especially when you are trying to design process control application, the valve gain, the valve gain also comes along with the process gain. So, if so when we want to decide the controller gain, then sometimes it is it is desirable, that we change the, that we change the valve characteristic to actually suit the, requirements of the process, for example as we shall see that we can we may like, to have, that the valve process combination gain, remains more or less flat over the operating region, this may be requirement for designing a good, good controller.

So, what I am trying to say is that, from the, you know there is an electronic controller, from which output is actually going to the valve actuator, the valve stem is being moved by some mechanism called actuator as we shall see, so this is going to the actuator. Now, between this control and the actuator, sometimes we can put some signal processing blocks, which are for example, in this case, this is a, this is called a multiplier relay.

So, what we are achieving here, is that, the see the signal available at the A port, is a multiplication of B to C port, so suppose this is increased. So, immediately this will increase, then this will, also increase and therefore, this will increase sharper, so what happens, is that, if you change this linearly, that is if the input is changed, in a linear fashion over time, then the output will change, in this fashion, so what happens, is that effectively actually, so if you put this really now, then what will happen, is that a linear valve, will start behaving like an equal percentage part.

So, what we, what is the massage is that, by putting such signal processing blocks, we can change the valve characteristic, I mean depending on the availability sometimes, it may not be, it may not be easy to locate a valve of that appropriate characteristic in the market. But, by signal processing after the controller, we can always change the valve characteristics.

(Refer Slide Time: 31:11)



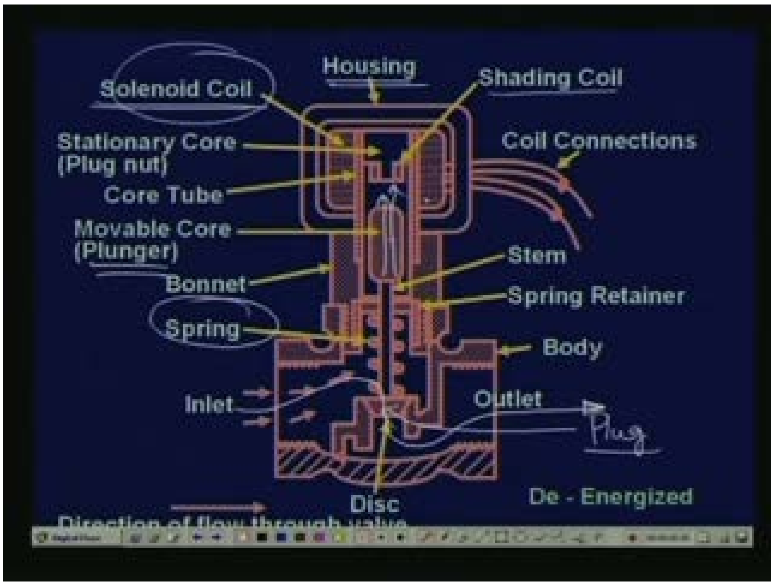
So, now next we come to, the various kinds of actuators, you know how to actuate the valve, so we typically, we have various kinds of actuators, we have electro electromagnetic actuator or solenoid actuators, we have pneumatic actuators, we have sometimes for large valve, we have hydraulic actuators. So, we can also, typically we can also have mechanical actuators also, manual actuators, so in this case, we will type typically look at two actuators, one is a solenoid actuator and the other is an pneumatic actuator.

So, solenoid actuators have you know higher speeds, they are lower ratings, but higher speeds, because higher speeds because, as we will see, that the force on the actuator can be quickly controlled, because it is and it is controlled by current, so current can be driven pretty fast. So, therefore, forces can be created very fast, varying forces can be created and therefore, the valve actuation becomes fast, on the other hand for pneumatic actuators, the force is created by, you know by bringing pressurized air on to work on a surface or a diaphragm.

So, since there is some volume involved, so there is certain amount of time required for that air to come and fill the chamber and then create the pressure on the diaphragm. So, pneumatic actuators are always generally slower than solenoid actuators, so we have higher speed, lower size, because pneumatic actuator can be, of quite high, I mean of larger size, because by just by increasing, the diaphragm sometimes, we can create a lot of pressure or even higher ratings we can use hydraulics.

So, solenoid actuators are generally of lower size and often they are used as we will see, they are often used in pilot stages of electro hydraulic valves. So, you have a big control valve and you want to move the valve, so you see that, that big electro hydraulic valve, actually may be controls the flow. Now, to move the valve also, you need to create you need to move the valve, so you know, you have a valve, this is the installed characteristic page up just a movement. So, we were talking about solenoid actuators, that they can be used in, pilot stages I know why this is creating a problem.

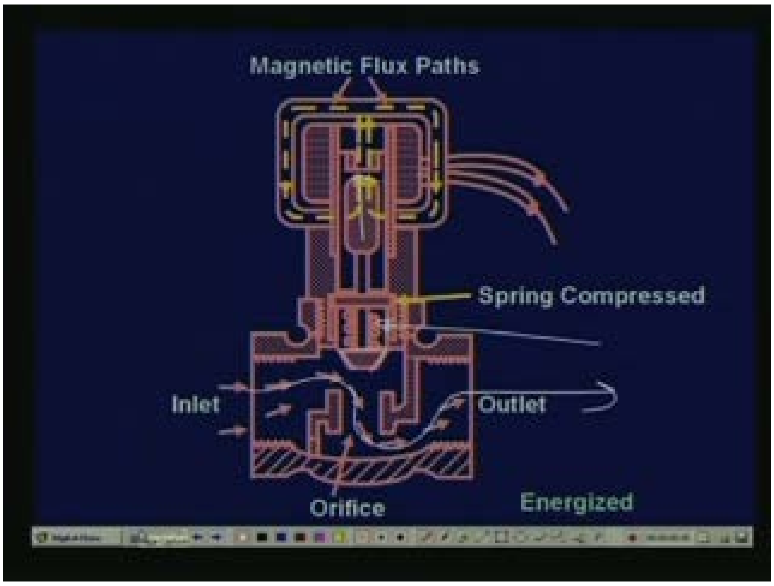
(Refer Slide Time: 34:52)



So, what I was saying is that the electro hydraulic valve pilot stages solenoid valves are used and this is a particular construction of the solenoid valves. So, you see that this is the valve, this is the plug, this is the plug, and this is the closed position shown, so this is inlet and it is flowing through this, and going to this is the flow of fluid, there is a spring loading, this is here the stem is actually connected to a magnetic core, which is called the plunger.

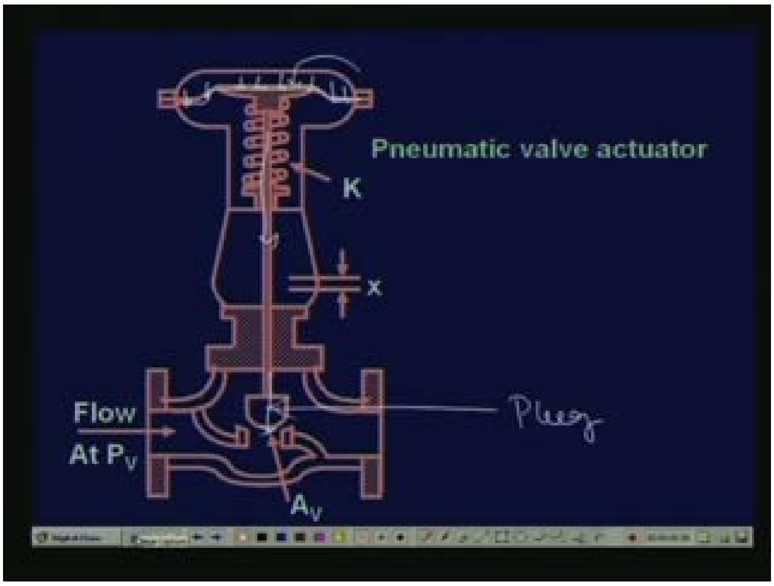
And, here you have a high current carrying, high force creating coil, so this is the coil assembly, solenoid coil, housing, shading coil is used to, you know guide the flux through the core, so that that proper force is created and flux, actually the force is created by the flux, so one has to guide the flux, so that an upward force is created. So, and this is the movable core, this is the tube, through which the core moves, these are the connections, so what happens is that, in when the coil is de-energized, then the spring will push and keep the valve closed.

(Refer Slide Time: 36:27)



On the other hand, when this will, you see that, if this is energized, then the flux is flowing like this as shown and it is pulling the plunger up. So, when the pulling the plunger up, then this spring is compressed and this opening is, opened and the fluid flows, so this is the way a solenoid actuator will work.

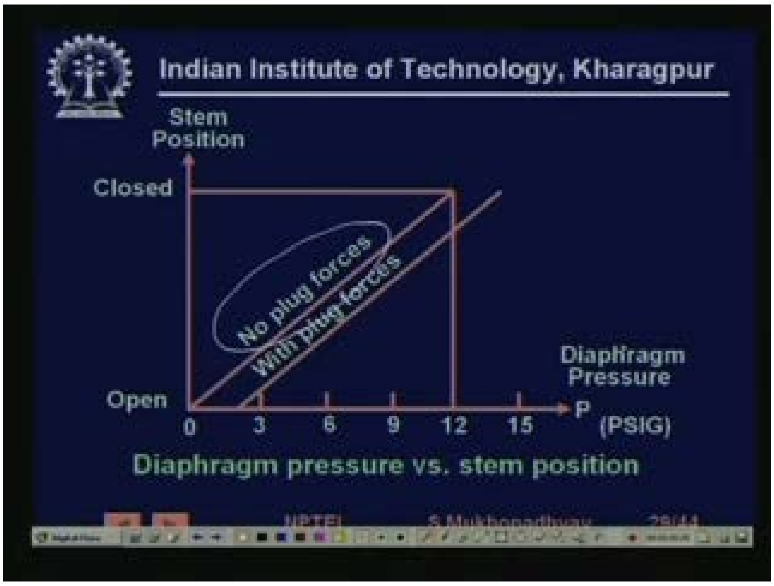
(Refer Slide Time: 36:55)



This is on the other hand, this is the particular pneumatic actuator, so again same thing, again you have a plug and you have these ports. So, what happens, is that here, by spring force, this is a particular valve, where you can close the valve by applying air in the normal position, it will stay open. There are various kinds of valves as we shall see, that if you apply energy or force, they will close or if you apply energy or force they will be opened, they will open.

So, in the previous case, for opening the valve we needed to apply current, in this case, for closing the valve, we need to apply air force, so the air will enter here, this is the diaphragm, on which it will create a pressure. So, the pressure multiplied by the area of the diaphragm, will give the force and this force will be going to push it down and close it, so this is the operation basic operation of a pneumatic valve.

(Refer Slide Time: 38:04)



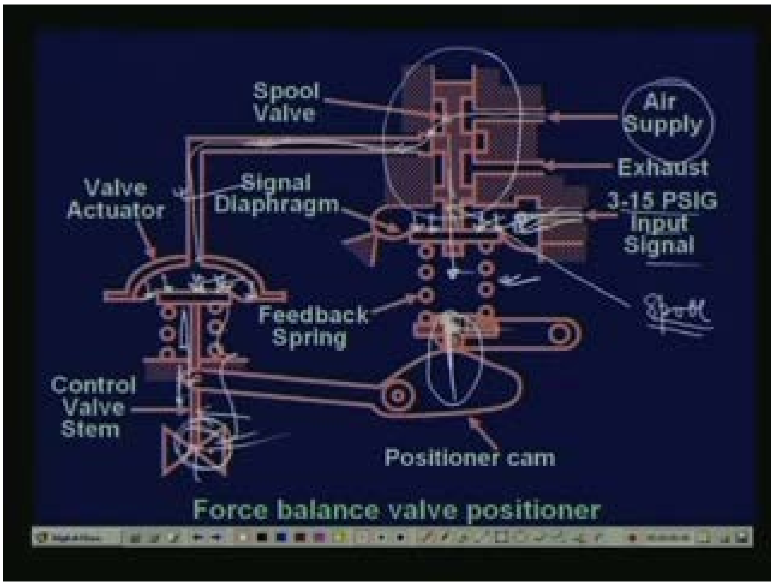
So, as we shall see, that if you see the characteristics of this valve, then obviously, there are as we said, that there are forces, acting on the plug, because when the fluid is flowing out through the orifice it is actually, pushing the plug up or down, depending on the flow profile. So, there is a, so there are forces acting on the plug, so what happens is that, because of this the plug, the valve stem position percent, and the I mean diaphragm pressure, see there are two things.

Firstly, diaphragm pressure to stem position, so how much diaphragm pressure is required to create, what stem position and then stem position to flow stem position to flow characteristic is essentially guided by the construction of the valve, and the applied delta P. On the other hand, the diaphragm pressure applied to stem position, is guided is essentially affected by how much force is actually acting, on the on the stem, so when you have, high plug forces then this stem position to diaphragm pressure characteristic gets shifted.

So, by applying and what is, what is controlled, what is controlled from the controller, is actually the diaphragm pressure, you know actually there is a controlled air supply pneumatic source. So, what amount of pressure will be applied on the flow control valve diaphragm that is what is control so if the stem position diaphragm pressure, so in open loop control, we will you know there is some gain calculated. So, people will think that, now so this is the flow, so now, I know the flow characteristics so therefore this much of stem position must be realized.

So, for realizing this much of stem position, I have to apply this much of diaphragm pressure, so that much of output will come from the controller, this is the way, the valve is going to be controlled. But it so happens, that this stem position to diaphragm pressure characteristic will change, depending on whether there is plug force or not, so we depending on the plug force, we may or may not be able to and the plug force depends on so many things, the plug force depends on the current value of pressure, in the pipe, so we need to make it is necessary, to make this make valves invariant to such variations of force.

(Refer Slide Time: 40:23)



So, for it is for such purposes, that we use often use, what is known as a valve positioned, so valve positioner is actually a itself a control system, so what it does, is the following. So, you see, that in this case, this is the valve, this is the valve stem, again there is a spring, and this is the, this is the diaphragm on which the, is the pressure is being applied. So, the diaphragm is coming from the air is coming from here, and it is through this valve, that the pressure the position of this spool, position of this spool that the pressure here is being controlled.

So, how it is being controlled, so we are applying a 3 to 15 PSIG input signal, which is the low power of a input signal, that is being that is being applied here in this chamber. So, that crates a force on this. once it creates a force on this, this spool will move downward, so when it moves downward the air supply which is a high pressure air, will flow through this and through this and will come here, so depending on the opening there will be a kind of pressure drop and the final pressure will be realized here.

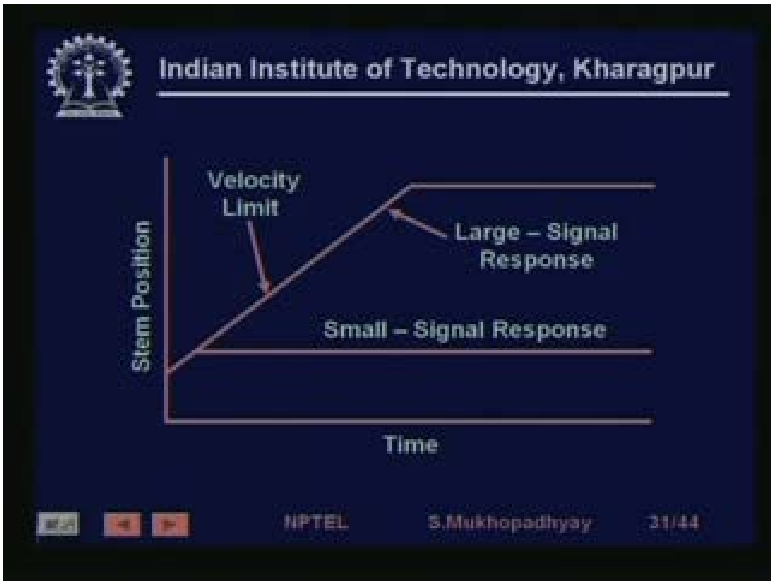
Now, as this pressure increases, this thing now starts moving downward and the valve opens, on the other hand, because of this mechanism when this comes downward, there is a force applied upward. So, you see it is a force balance principle, so finally, whatever pressure is being applied here, that must be balanced that will be, that will balanced by this that will be balanced by this spring force, as well as this force, so therefore, since this is an applied pressure, and this spring force depends on the displacement.

So, therefore, the this for a for a given pressure here, the valve will as long as this force is not balanced, say when this force is higher, then it will start opening and this pressure will keep increasing. As it is keeping increasing, this is come trying to come down and therefore, this is going to go up increasing the spring pressure, so this spring pressure will actually balance this force, when a particular displacement of this spring takes place, and by the mechanism, this a particular displacement of this spring, implies a particular displacement of this stem.

So, therefore, you when you apply a particular pressure here, a particular displacement of the stem is achieved, irrespective of what are the forces here. So, till this displacement is achieved, this will start moving and obviously, this should have enough power to you know, you know overcome this force. So, but if you have created enough power, then just enough force will be create here, so that the final displacement, will actually balance this pressure.

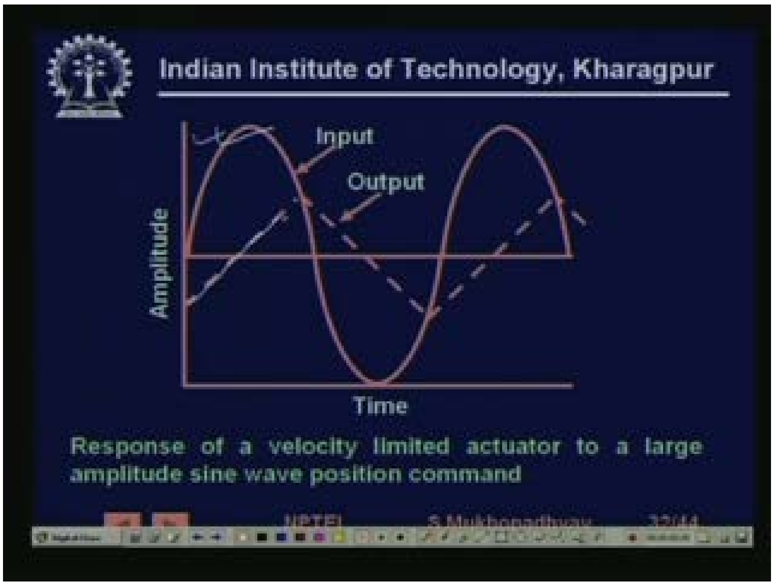
So, the final displacement is always invariant, irrespective of whatever is the force on this stem, so in this way, you achieve a particular stem position to control input signal, it does not depend on the plug force, because by close loop control. So, such a thing is called a valve positioner, there are various other mechanism, there is just one mechanism, which we have shown, there are various other ((Refer Time: 44:03)) based mechanisms etcetera.

(Refer Slide Time: 44:08)



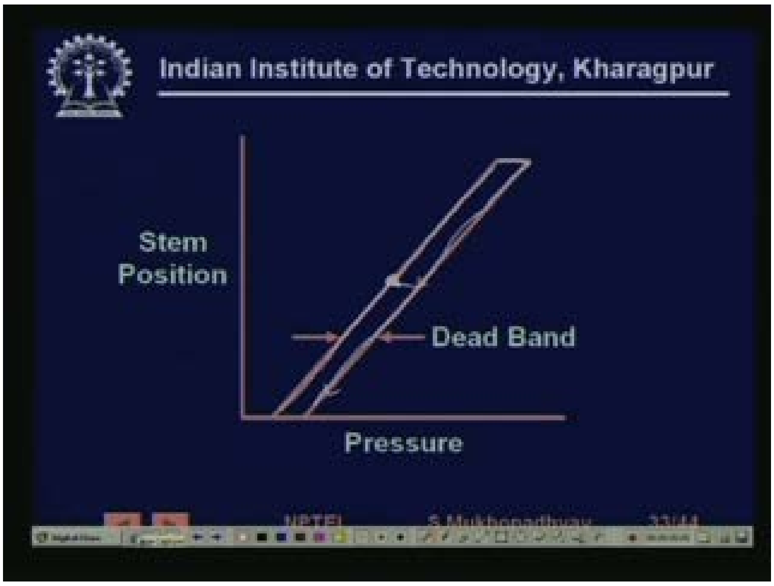
So, now we come to, take a look at some valve characteristics for example, you know this, there are certain characteristics of the stem position movement, especially a dynamic characteristics. So, if you give a small value of command this, the stem position will be this much, if you give a large command will be this much, but you see there is a certain restriction on the rate at which, the stem can travel, so therefore, you cannot give very large and at the same time very high frequency commands. If you give them, then that input command will not be realized, in terms of stem position and you will get responses like this.

(Refer Slide Time: 44:47)



So, for example, if you give a large and then high frequency sinusoid, then the stem position will not be able to follow it, but rather it will, go up like this, so there will be a distortion you know. So, these things are to be kept in mind, when one is designing, a process control loop with a valve, that they have, this rate limits any actuator, most of the electromechanical actuators, actually have a rate limit.

(Refer Slide Time: 45:20)

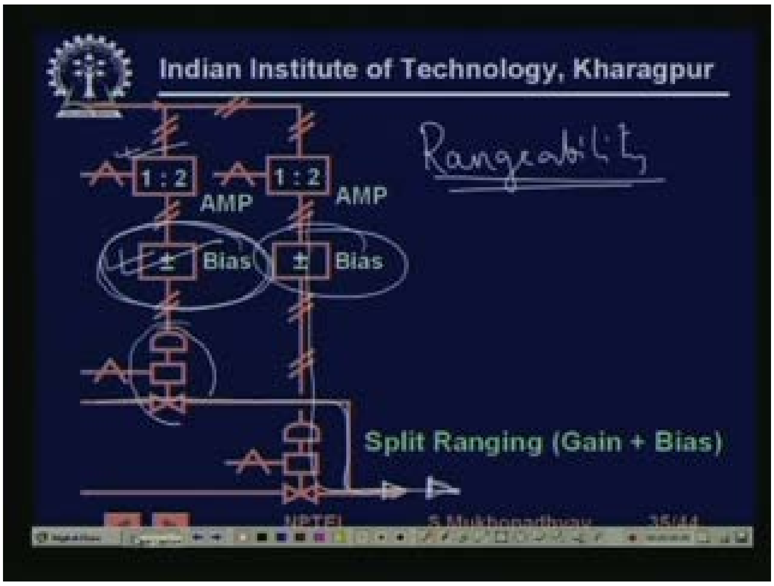


Similarly, there may be a, there may be hysteresis in the stem position, due to various factors you know. So, when you are increasing the pressure, the stem position may actually, follow this curve, and when you a decreasing the pressure, it may not follow exactly the same curve. Now, such dead bands, as we know from, you know standard non-linear control systems, often give rise to oscillations.

(Refer Slide Time: 45:55)

So, these you know, this process control loops, flow loops the if you give an, if you give an alternating command, then the process control loop may actually oscillate, so these are called limit cycles in the closed loop.

(Refer Slide Time: 46:14)



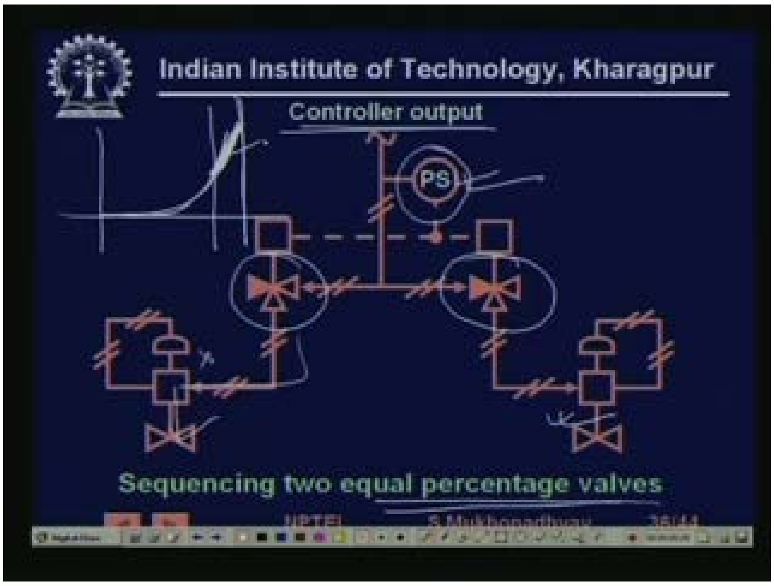
Similarly, these are sometimes you know, there is, there is a very important quantity for a valve called range ability. So, range ability means, that what is the maximum to minimum flow ratio, so the maximum flow to the minimum controllable flow is it to say, so valves can have, you know some sometimes valve manufactures claims, that they have you know, 10 is to 1, 15 is to 1, 13 is to 1, 30 is to 1, kind of you know range abilities.

So, sometimes in some applications it may happen, that you need a very high range ability that is you can sometimes need, very, very small flows, sometimes you need very, very high flows. So, in such applications, you sometimes have to you know, have valve sequencing, that is you actually have more than one valve, and in one part of the operating region, you operate one valve, and in another part of the operating region, you operate another valve.

But, you have to ensure, you know certain things like you know transitions, such that suddenly the when you move from one valve to another valve the process control loop characteristic do not change. So, one of these is by, you know split range control, which we have also seen, in the case of our process control modules, so you have two valves, and they are fed through an amplifier and a bias, so these biases are made different and in certain parts of the region, the actually, the control signal comes to this valve.

So, this valve will operate, then after sometime, when this valve input will actually saturate, then this valve will operate no longer and, then this valve will start operating. So, this the overall range of operation is split, using this gain and bias mechanisms and in different parts of the operating region, different valves are employed, Similarly sometimes, you can have there may be another scheme.

(Refer Slide Time: 48:28)



This is another valve sequencing scheme, where you have a pressure sensor, you know so this pressure, this is actually the controller output, which is going to the valve actuator. So, when the controller output, so the here, this the switching, which is by this three way valves is actually done, based on how much controller output is being exerted to this valves, and depending on them, one of the valves will be operating, either this will be operating or this will be shut off or this will be vented and this will be operating.

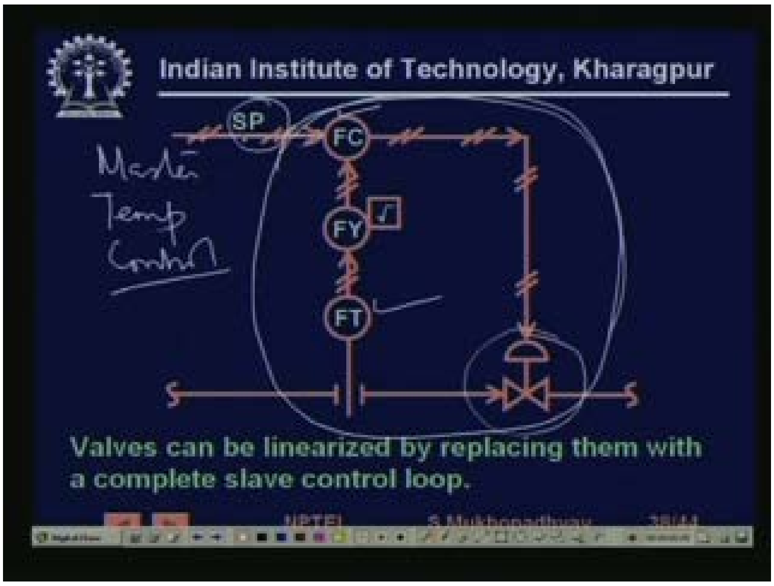
So, and it turns out, that for such sequencing you know, when you will for example typically, the gain of large valves, will be actually larger, than the gain of small valves. So, one has to ensure, that the when you are switching from the small valve to the large valve, the gain is not, the gains are the gains do not suddenly change, because that is going to change the overall gain of the process control loop, and may bring in you know things like instability problems, instability or saturation problems.

So, for doing that, that is why, it is for such kind of sequencings, equal percentage valves are actually better suited, because as we know from the equal percentage characteristics, the equal percentage characteristics is like this, stem position to flow. So, you see that, for the small valves, when you are just before closing the small valves, the actually small valve, actually has a very high gain, so when you are switching on, from this gain to the gain of the large valve, so the large valve actually has a high value of gain, but it is operating in it is low gain region.

.

So, we are transforming from the high gain region of the small valve characteristic, to the low gain region of the large valve characteristic. So, therefore, the gain switching, the suddenly when you switch from the small valve to the large valve, the overall process loop gain, does not suddenly change. So, this is one reason, why you know equal percentage valves are better suited for valve sequencing, rather than linear valves.

(Refer Slide Time: 50:46)



Often, as we have seen that, as we know I mean this is, this shows that often you know valves are actually put in the closed loop. So, it is actually a part of the flow control loop, generally and if you have a, that is rather than, suppose you have a temperature loop, so in the temperature loop output, controller output rather than giving directly to the valve, which has nonlinearities, which has dead bands, which has hysteresis as we have seen it, is better to set up a flow control loop, which is a slave loop, in the sense that the temperature control loop is actually the master control loop.

So, the temperature controller output will give a flow set point, as we have seen, in the case of cascade, so what will happen is that, so ((Refer Time: 51:38)). So, this is the this is the one coming from the master say temperature control loop, then if you set up this is the flow controller, this is the flow transmitter. So, if you set up then even if the valve is non-linear, the characteristic of this loop, that is between this point and this point, are much more linear, let us say, it may not be absolutely linear in the mathematical sense.

But, there will be much more linear and that makes it, much easier to accurate design, the designer ensure that the characteristic of the temperature control loop, remains uniformly good over the, over the whole region of operation, so sometimes, many times, we set up this kind of loops.

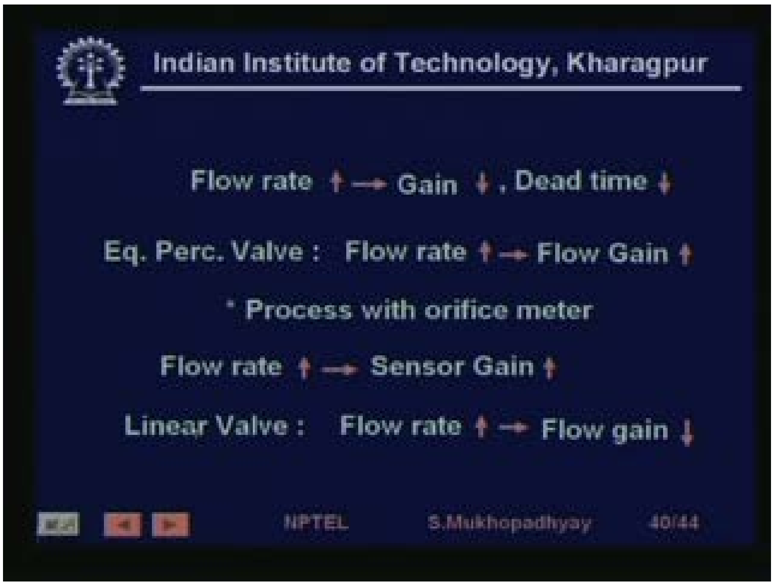
(Refer Slide Time: 52:24)

Sometimes, you know valve characteristics can be very cleverly used, to you know match the system characteristic, so for example, take the case of a liquid to liquid heat exchanger. So, what happens is that, now you know, this is the input, which is the cooling flow and what is the output, the output is, the outgoing temperature of the liquid, which is being heated let us say, so when there is a slow flow rate, that is when this flow rate is low, then obviously, this liquid stays within the tube for a longer time.

And therefore, for both the gain between this point to this point, that is the temperature for a given rate of flow of the heating liquid. The increase in temperature between inlet and the outlet will be higher, not only that, this will be also, then the delay between if you make a step here, then the then this will go up, but the delay between this step and this step will also be higher, because of the fact, that the that the liquid is traveling slowly.

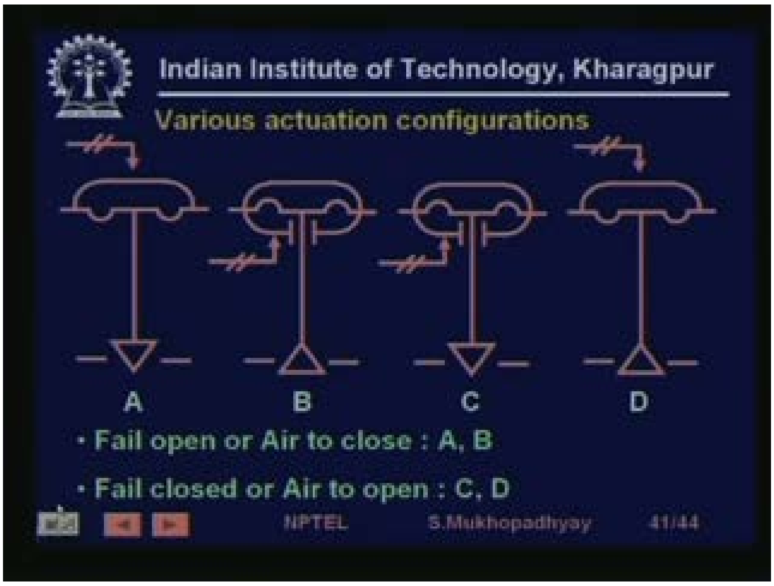
So, but on the other hand, when you are, so you see that this is a situation, when you have a high gain and you have a high delay. So, you need to keep, as we know, that the controller gain needs to be kept low, in this region. On the other hand, if this flow is increased, this flow rate is increased, then the gain will fall and the delay will also fall. So, now, is the case, when you can have a, you can for better improve transient performance, you can have a higher controller gain, but it is not you know, automatically easy to actually change controller.

(Refer Slide Time: 54:13)



So, for this application, if you use, if one uses a, an equal percentage valve, then as we know, that the valve gain goes up, as the flow rate goes up. So, automatically the loop gain increases, as the flow rate increases. So, the overall process, loop transient characteristic is maintained uniform, simply by the valve characteristic, simply by the choice of the valve right, so this is what I am saying. Similarly, at the, an opposite situation can occur, if you have an orifice meter, so you know, so in an orifice meter as the flow rate increases the, sensor gain also increases. So, again the loop gain increases, so in such a case the, one has to have, the overall gain reducing, so one can use a linear valve for this.

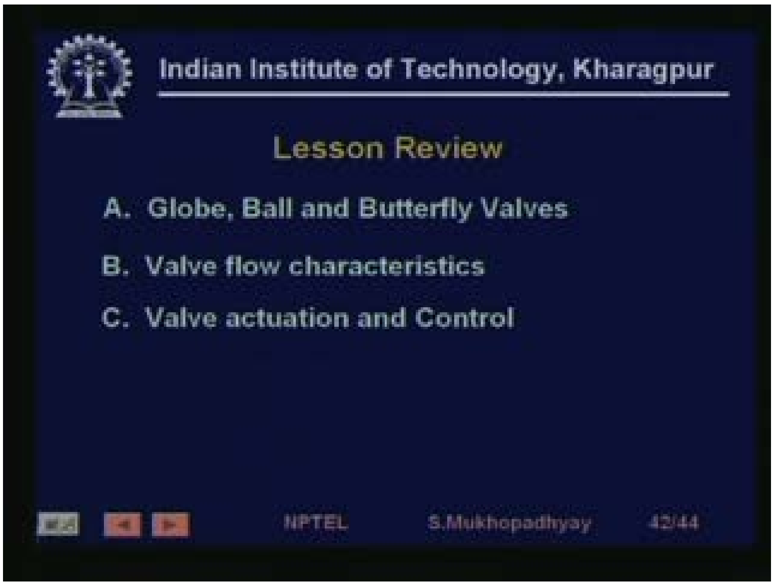
(Refer Slide Time: 55:03)



The lastly, you know valves are, one has to put and have a view towards, what will happen, if the actuation fails, because you know sometimes this flows, can actually cause explosions etcetera. So, valves are constructed in various configurations, which are shown here, for example, fail open or air to close, so if this air supply somehow fails, then this valve will fail and it will fail in an open situation, so the, if the air supply is not there then the valve will remain open.

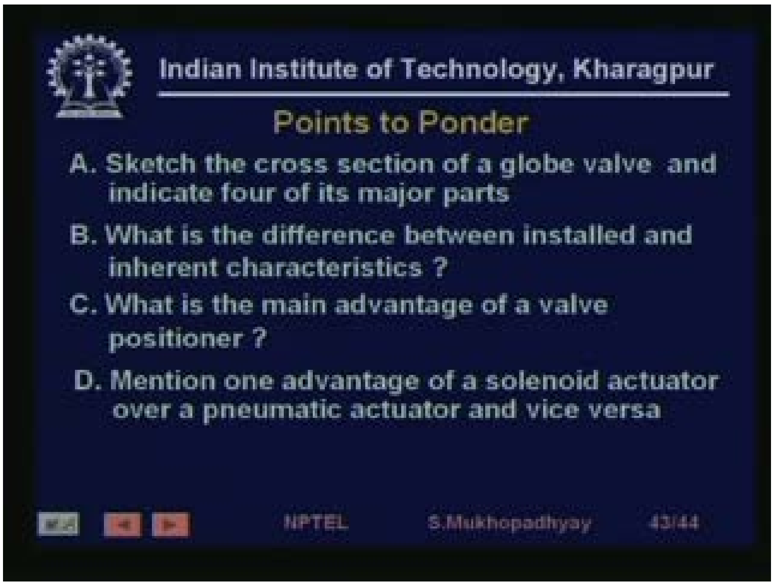
Similarly, there are air to open valves, where if the air supply closer fails, then the valve will close, so these, so one has to chose a particular actuation configuration, to you know avert industrial accidents, under various kinds of failures, so that brings us to the end of this lecture.

(Refer Slide Time: 56:04)



So, as a matter of review, we have typically seen globe valve, ball and butterfly valves, we have seen various kinds of valve flow characteristics, both static and dynamic, and we have seen how valves are actuated and controlled. There is one aspect, which is treated in books, which is called valve sizing, that is for a given application determining, that the size of the valve, we have, we are not talking about, that because this is essentially a process design exercise, and not, does not concern auto machine control.

(Refer Slide Time: 56:40)

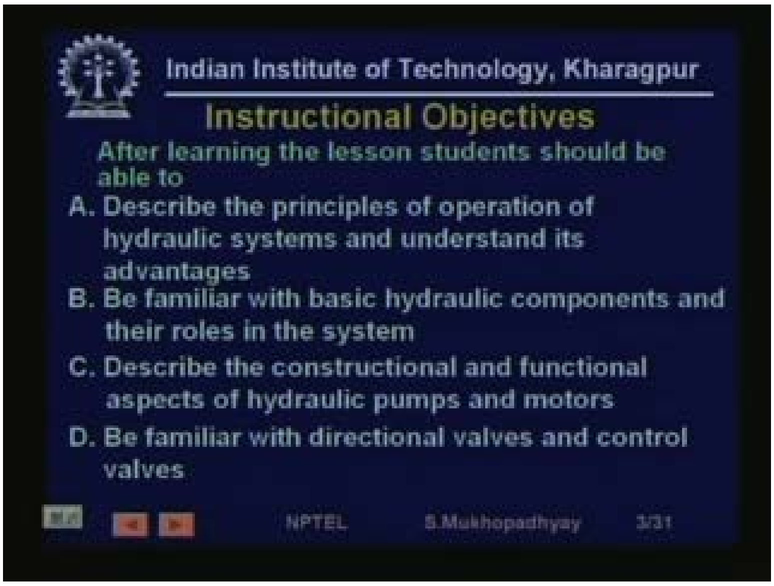


So, to end points to ponder, first is sketch the cross section of a globe valve, and indicate four of it is major parts, you should be able to do that. What is the difference between installed and inherent characteristics, this is extremely important and why this occurs, What is the main advantage of a valve positioner, why one puts it. And finally, mention one advantage of a solenoid actuator over a pneumatic actuator, and one advantage of a pneumatic actuator over a solenoid actuator, so that brings us to the end of the lecture, thank you very much.

(Refer Slide Time: 57:33)

Welcome to today's lecture, which is lesson number 26 of the course on industrial automation and control. Today, we are going to take our first look at hydraulic control systems and we will review some elementary basic concepts, and then we will first look at the components, which make a, hydraulic control systems. In the subsequent lectures, we shall see, some special components, and we shall see as to how these components, can be used to make a hydraulic control system, so we give, we begin here, before we begin we look at the instructional objectives.

(Refer Slide Time: 58:11)



So, the instructional objectives are basically to describe the principle of operation, of hydraulic systems and understand it is advantages, what is involved and why it is almost irreplaceably used, in certain applications there are certain advantages. Then of course, we have to be, the main purpose of the lesson is to be familiar with the basic hydraulic system components, and their roles in the system, what they do. And describe the constructional and functional aspects of hydraulic pumps and motors, how they function, and be familiar with directional valves and control valves, they are very important components.