INDIAN INSTITUTE OF TECHNOLOGY
KHARAGPUR

NPTEL
ONLINE CERTIFICATION COURSE

On Industrial Automation and Control

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Topic Lecture – 33
Flow Control Valves
(Contd.)

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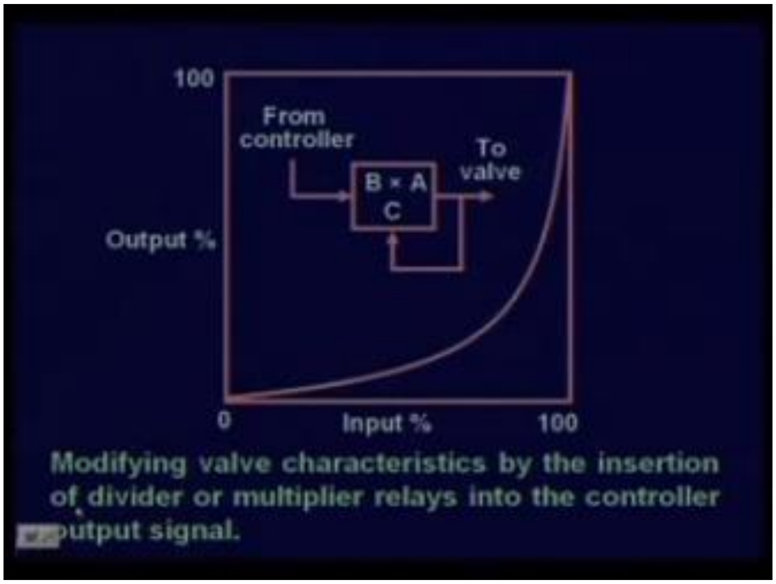

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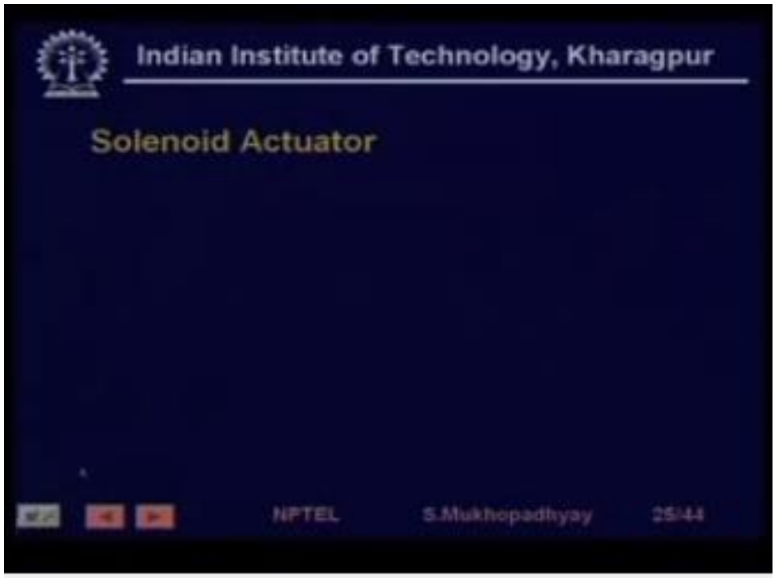

So now next we come to the various kinds of actuators how to actuate the valve. So we typically we have various kinds of actuators, we have electromagnetic actuator or solenoid actuators, we have pneumatic actuators, we have sometimes for large pulse you have hydraulic actuators right. So we can also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

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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 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 yet to come and fill the chamber and then create the pressure on the diaphragm. So pneumatic actuators are always generally slower than solenoid actuators.

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So we have higher speed lower size because pneumatic actuators 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 for even higher ratings we can use hydraulics. So solenoid actuators are generally of lower size.

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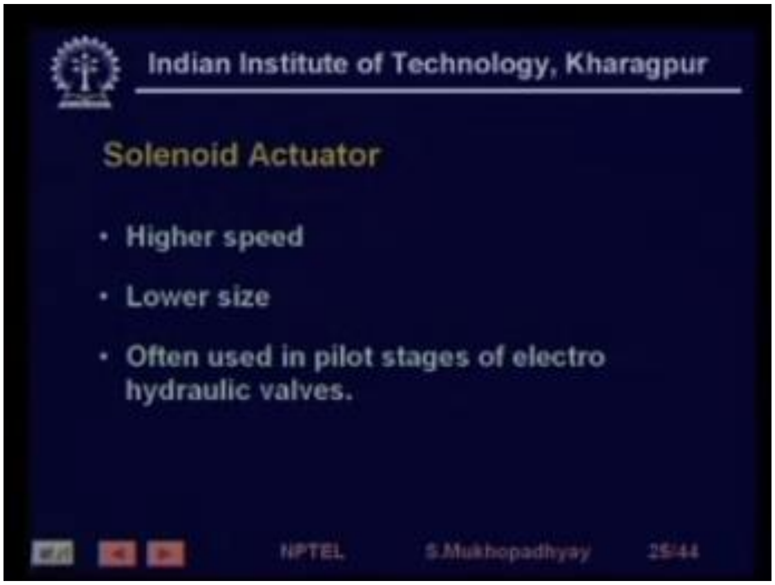

And often they are used as we will see they are often used in pilot stages of electro-hydraulic valve. So you have a big controlled valve and you want to move the valve. So see that big electro-hydraulic valve actually may be controls the flow. Now to move the valve also you need to create you need to move the valve.

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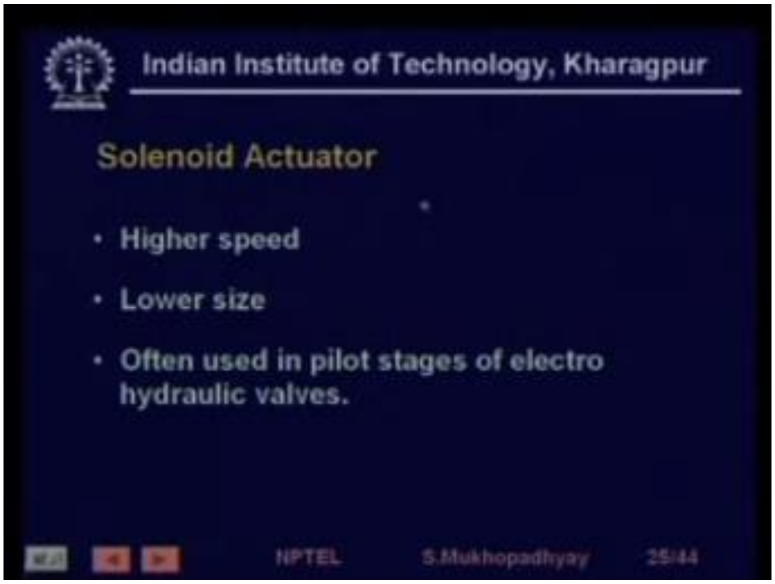

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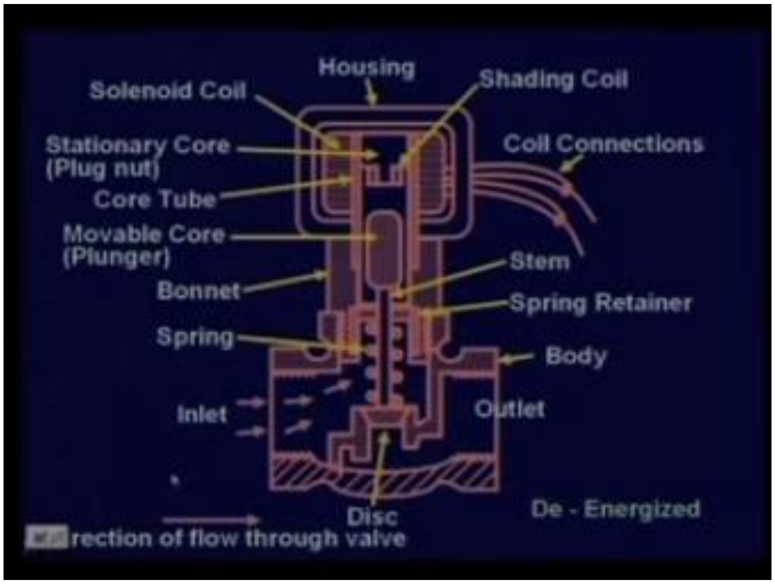

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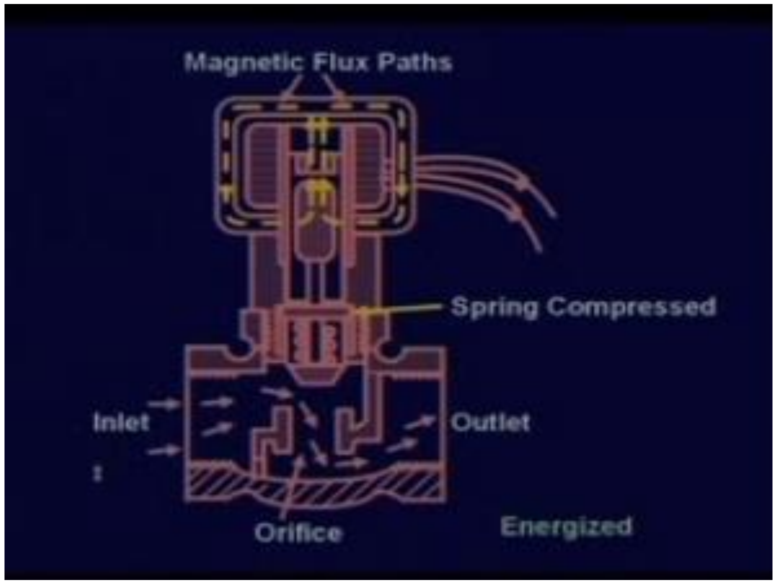

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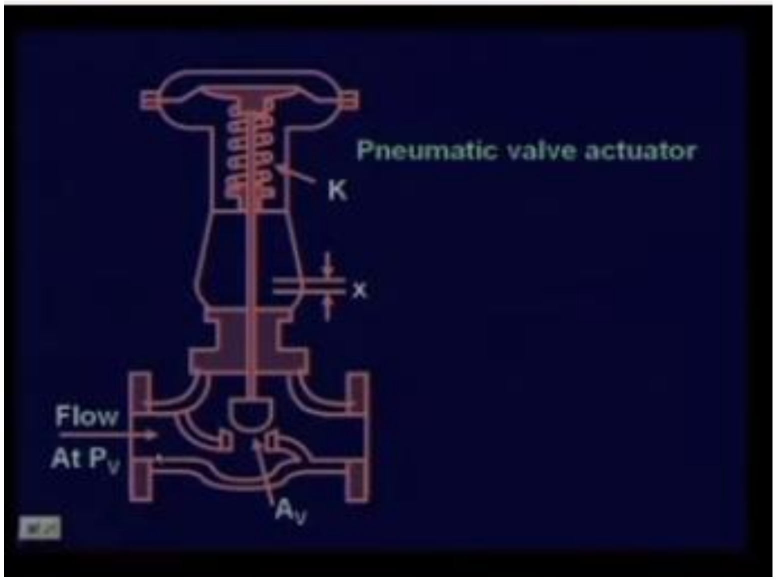

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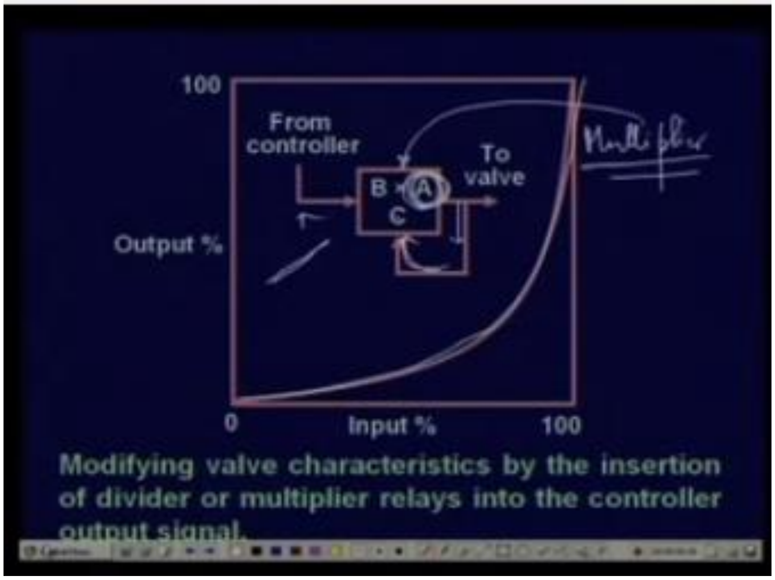

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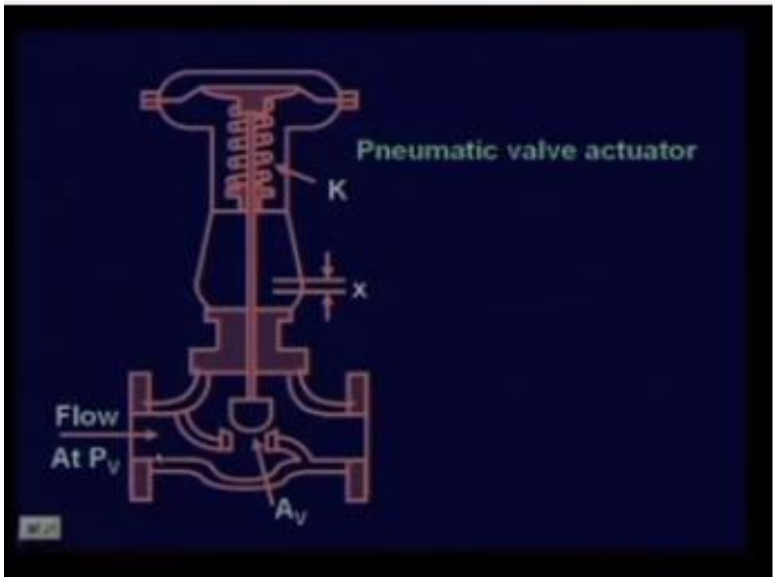

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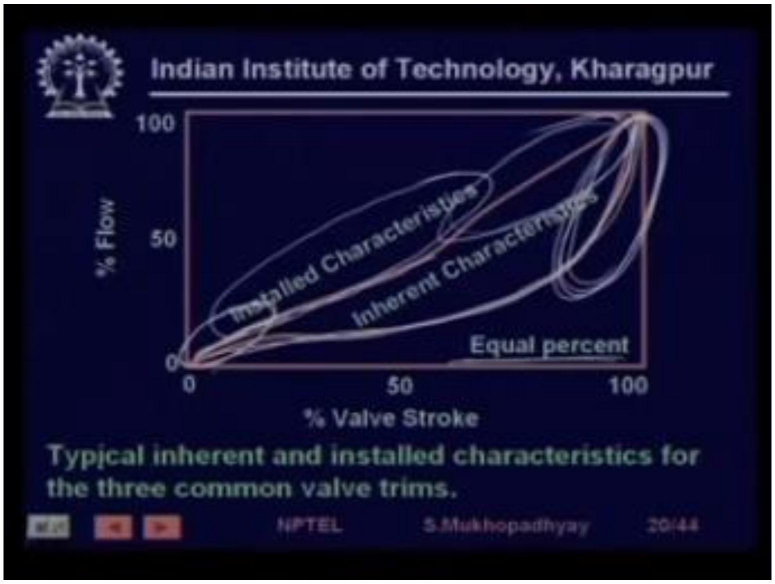

Okay this is a installed characteristic.

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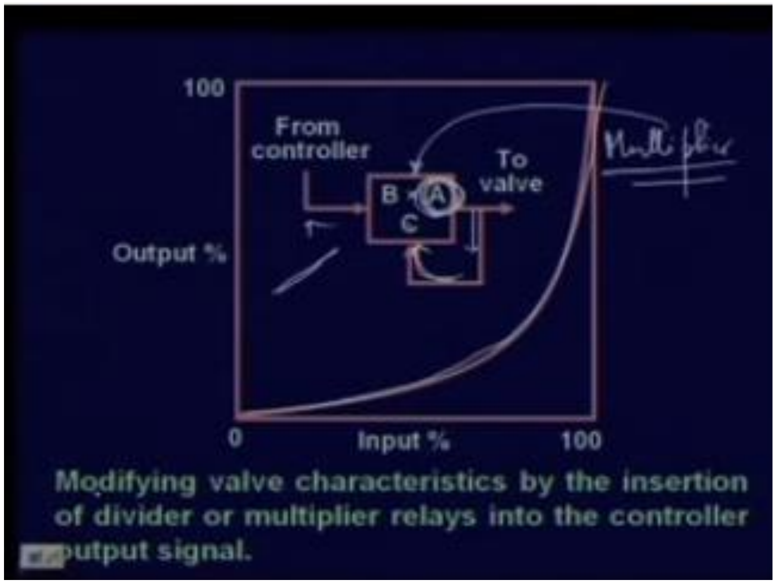

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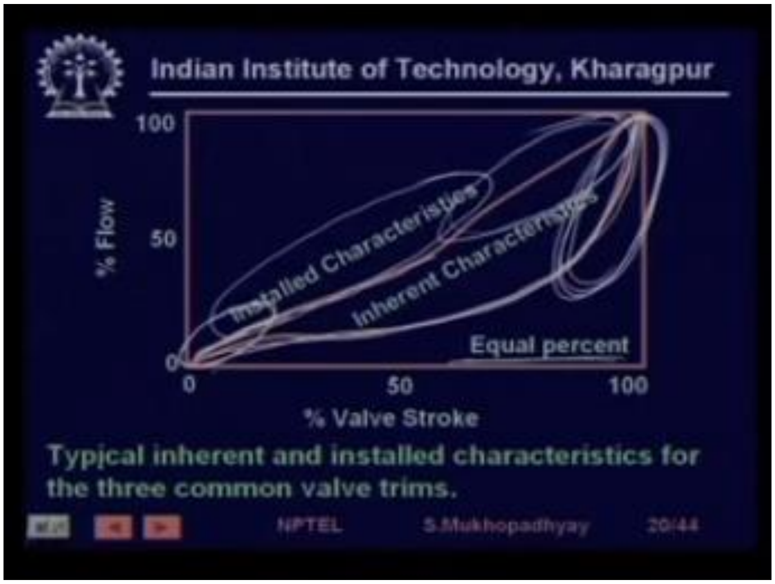

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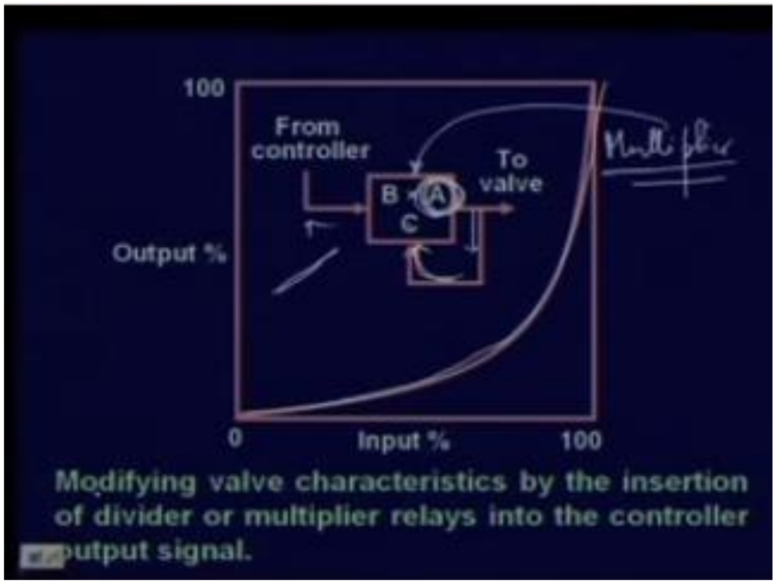

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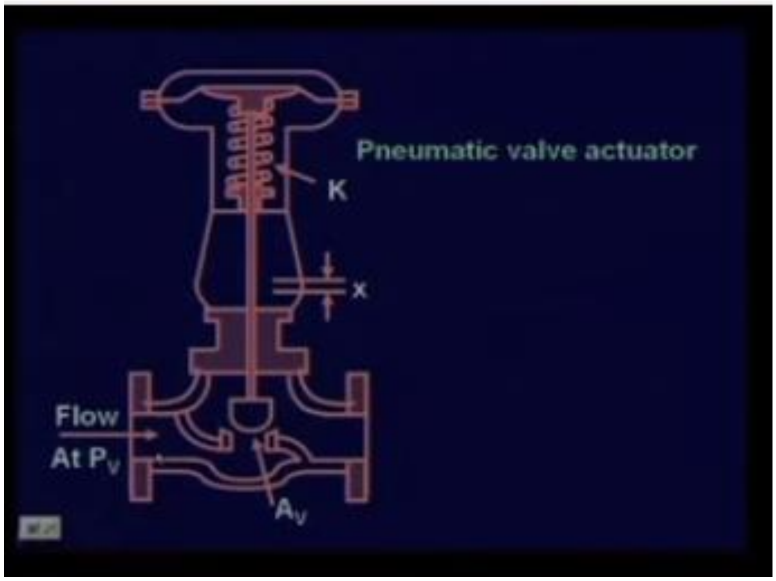

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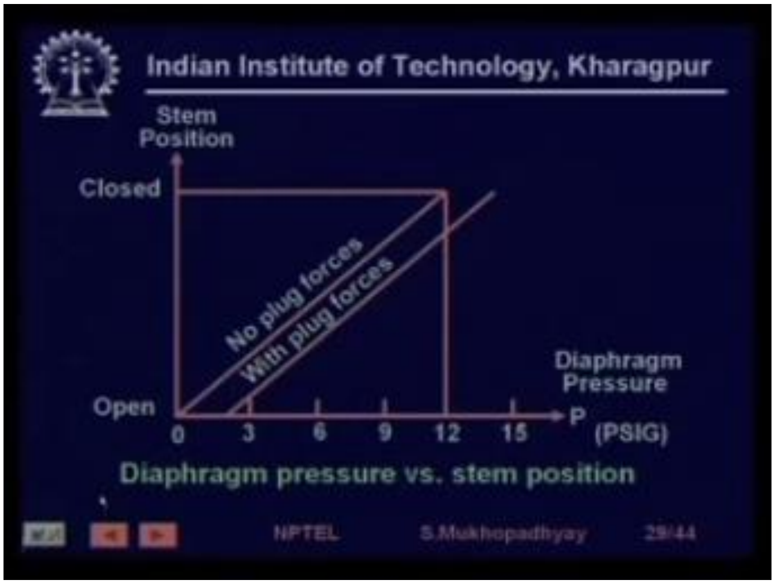

Just a moment.

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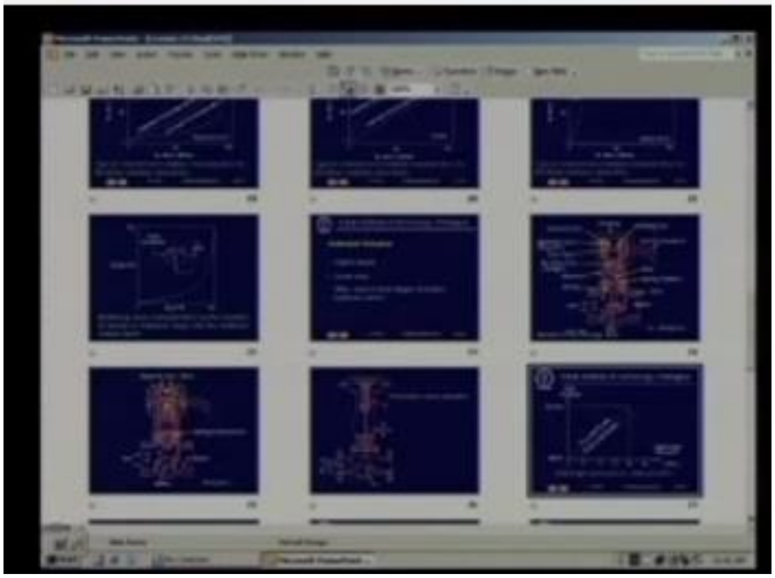

Yeah.

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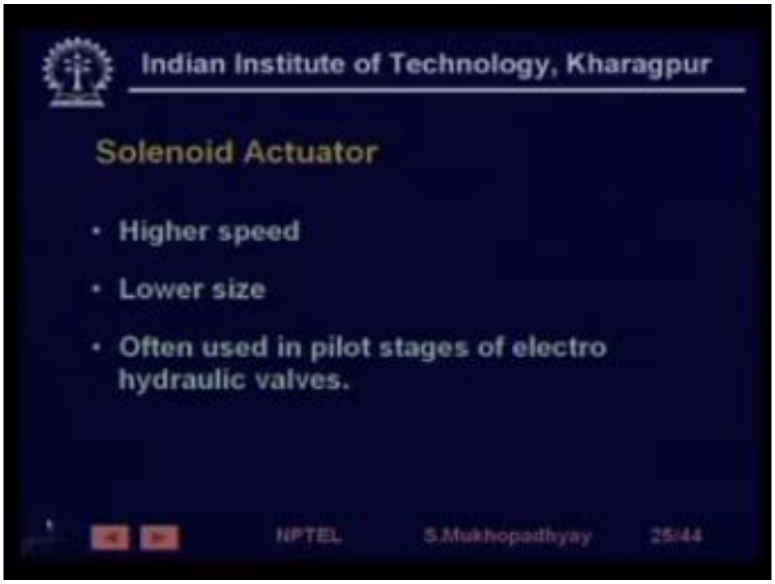

So we are talking about solenoid actuators that they can be used in pilot stages.

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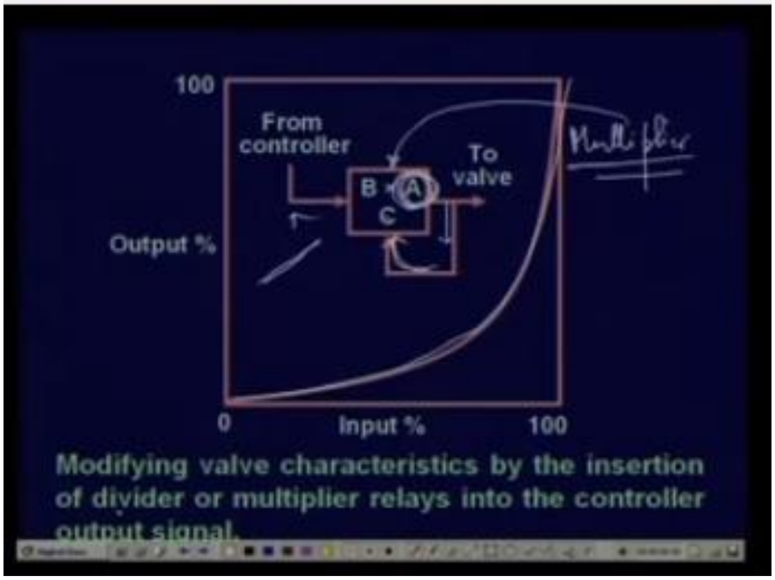

And why this is creating a problem.

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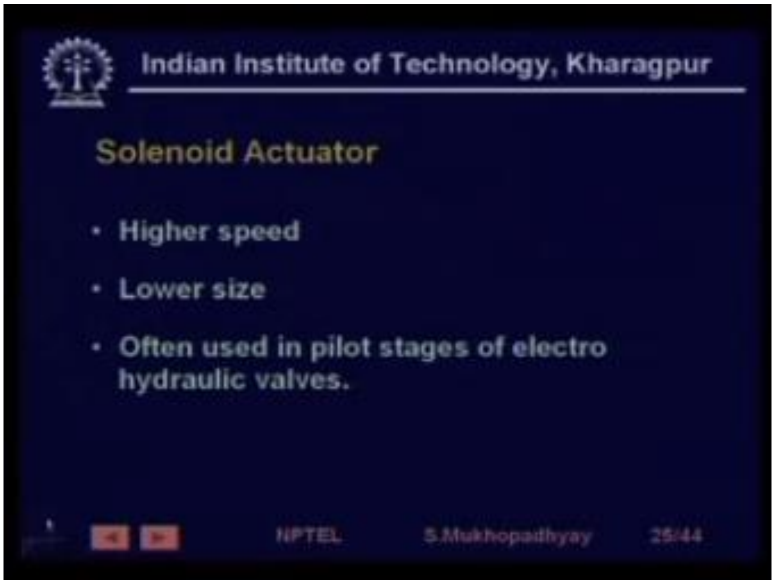

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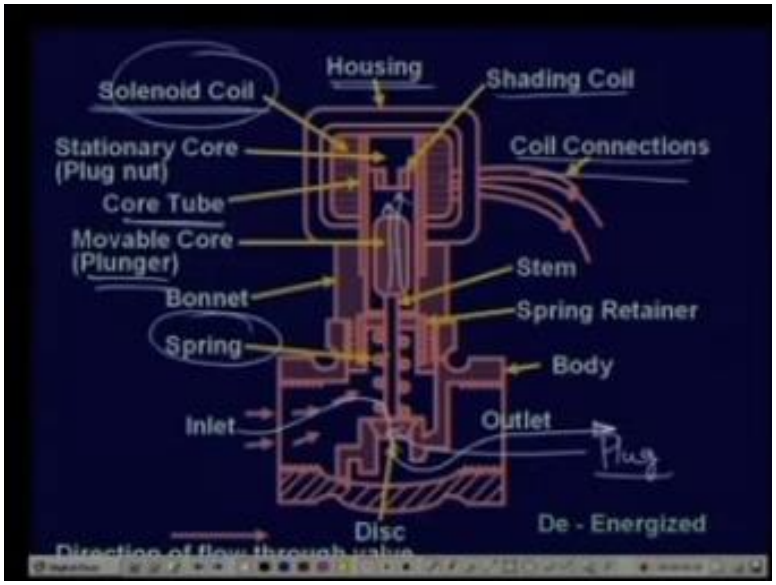

Okay, so right. So what I was saying is that the electro-hydraulic valve pilot stages the solenoid valves are used and this is a particular construction of the solenoid valve. So you see that this is the valve, this is the plug and this is the closed position shown. So this is inlet and is flowing through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

And here you have a high current carrying, high force creating coil so this is the coil assembly solenoid coil housing okay, shedding coil, shedding coil is used to, you know guide the flux through the course so that the proper force is created and actually the force created by the flux so one has to guide the flux, so that an upward force is created. And this is the movable code 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 this spring will push and keep the valve closed right.

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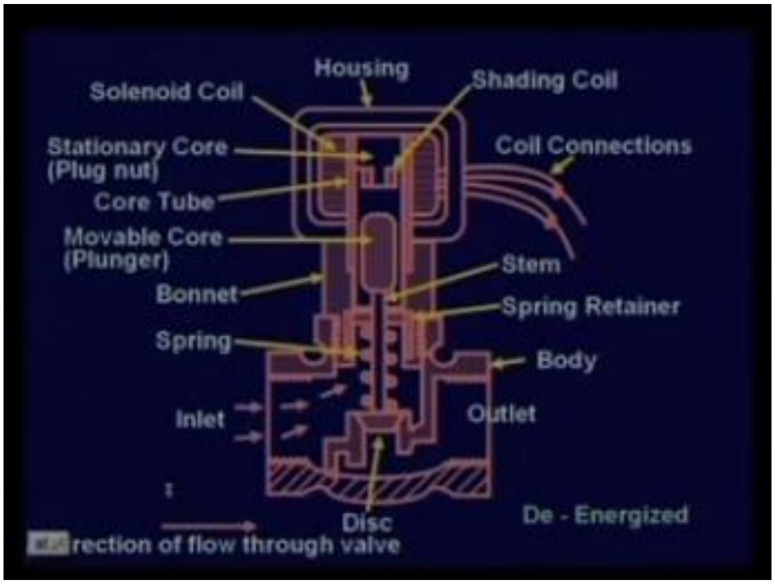

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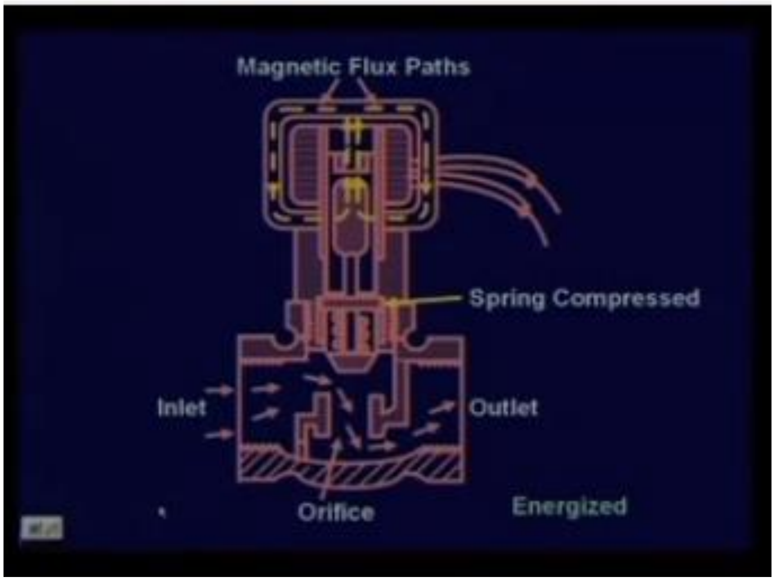

On the other hand when this will, you see that if this is energized then the flux is flowing like this as shown and it is pulling the plunger up. So when the pulling the plunger up then this spring is compressed and this opening is open and the fluid flows. So this is the way our solenoid actuator will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

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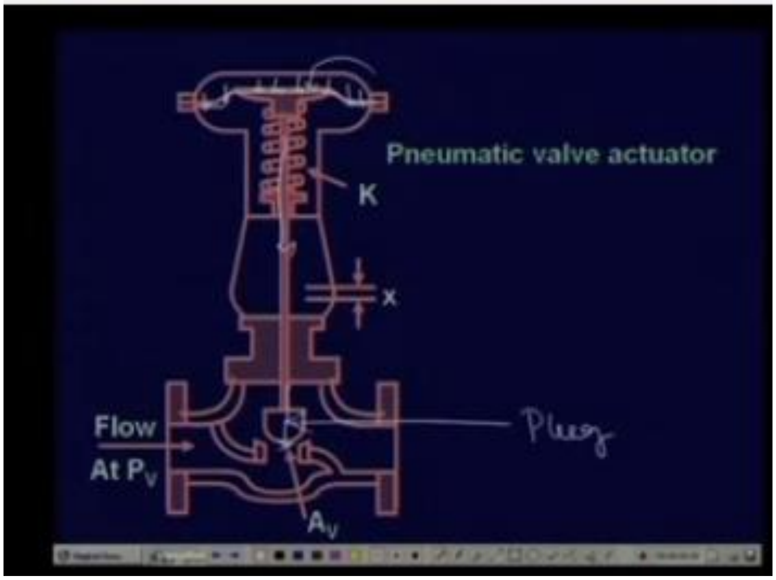

This is on the other hand this is a particular pneumatic actuator so again same thing, again you have a plug and you have these ports. So what happens is that here by spring force this is a particular valve where you can close the valve by applying here in the normal position it will stay open. So there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

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 is going to push it down and close it right. So this is the operation basic operation of a pneumatic valve.

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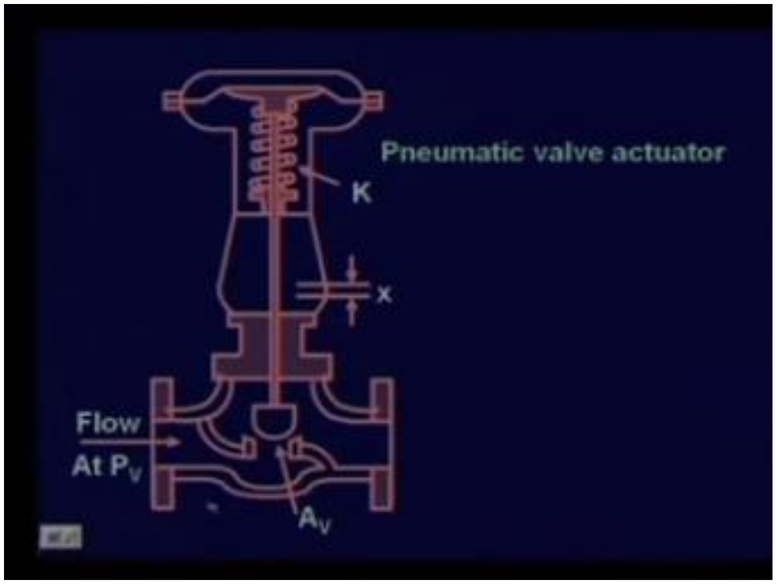

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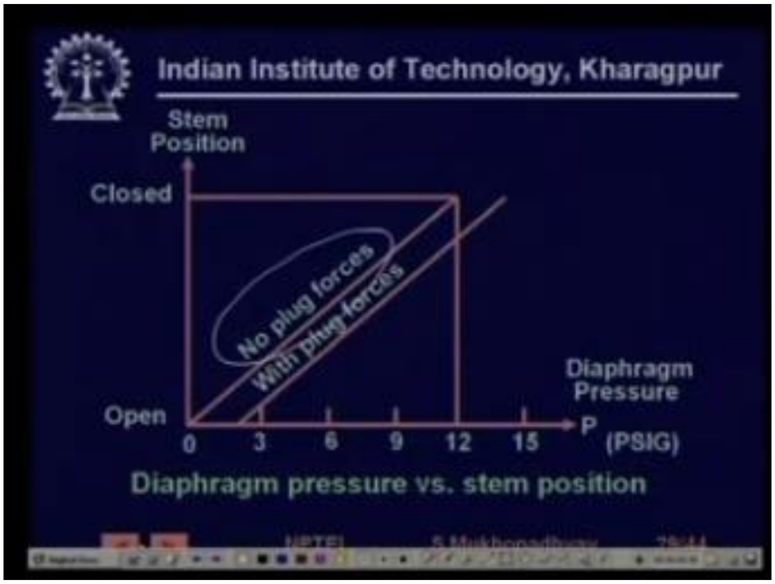

So as we shall see that if you see the characteristics of this valve then obviously there are as we said that there are forces acting on the plug because from the fluid is flowing out through the orifice it is actually pushing the plug up or down depending on the flow profile. So there is a, so there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

So how much diaphragm pressure is required to create what is 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 ΔP. 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 right.

So by applying and 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 there is some gain calculated.

So people will think that now okay, so this is the floor so now I know the flow characteristics. So therefore, this much of stream 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 where the valve is going to be controlled. But it so happens that this stem position to diaphragm which are 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.

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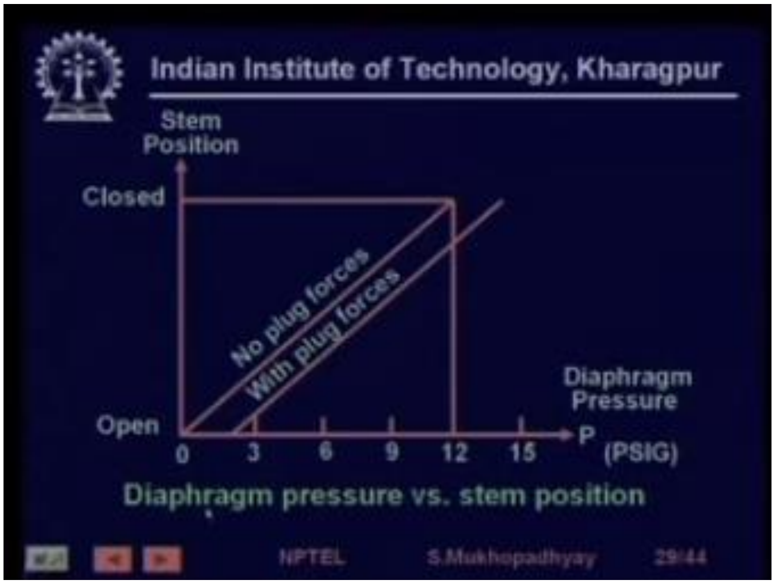

So we need to make it is necessary to make valve invariant to such variations of force.

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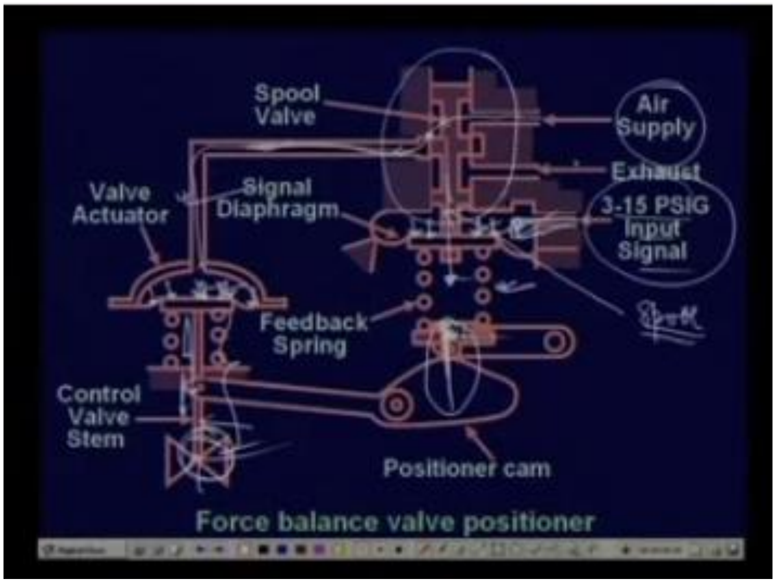

So for it is for such purposes that we use often use what is known as a valve positioner. So valve positioner is actually itself a control system. So what it does is the following, so you see that in this case this is the valve right, this is the valve stem, again there is a spring and this is the diaphragm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

So how it is being controlled, so we are applying a 3 to 15 PSIG input signal which is a low power input signal that is being applied here in this chamber. So that creates 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 their 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 down word 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 balanced by this, that will be balanced by the spring force as well as this force.

So therefore, since this is an applied pressure and the spring force depends on the displacement, so therefore, the, 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 trying to come down and therefore, this is going to go up increasing the spring pressure.

So the spring pressure will actually balance this force when a particular displacement of the spring takes place and by the mechanism this particular displacement of this spring implies a particular displacement of this stem. So therefore, 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 at obviously this should have enough power to, you know overcome this force.

So but if you have created enough power then just enough force will be created here, so that the final displacement will actually balance this pressure. So the final displacement is all over 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 right, because by closed loop control.

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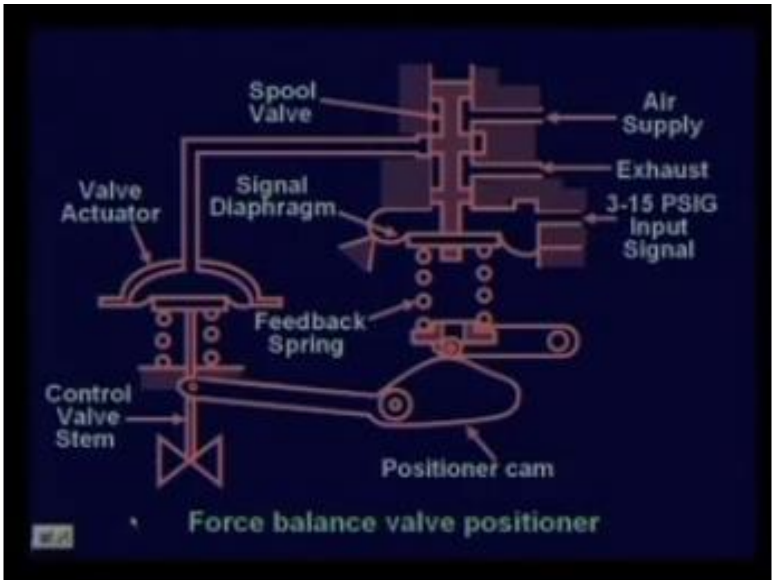

So such a thing is called a valve position and there are various other mechanisms is just one mechanism which we have shown there are various or the flapper nozzle with based mechanisms etc.

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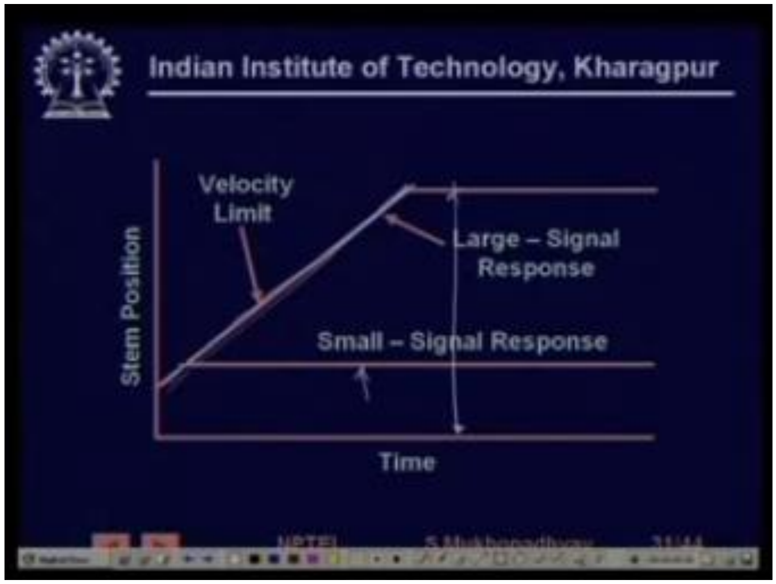

So now we come to take a look at some valve characteristics for example, you know this there are certain characteristics of the stem position movement especially dynamic characteristics right. So if you give a small core value of command this, the stem position will be this much, if you give a large command with this much, but you see there is a certain restriction on the rate at which these stem can travel right.

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.

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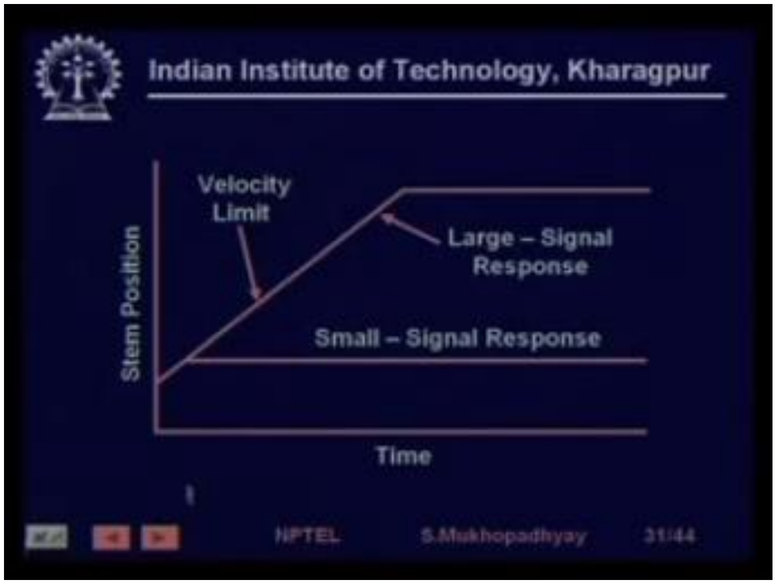

And you will get responses like this.

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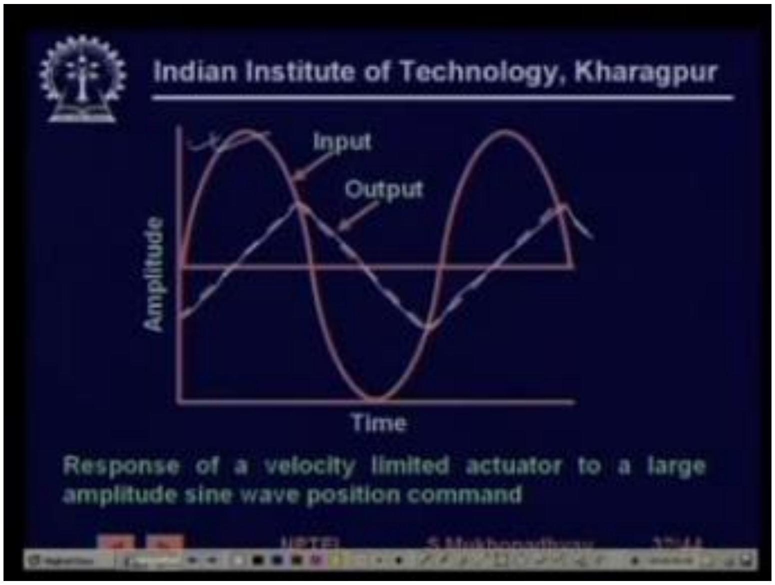

So for example, if you give a large and then high frequency sinusoid then the stem position will not be able to follow it, but rather it will go up like this. So there will be a distortion, you know. So these things are to be kept in mind when one is designing a process control loop with a valve right,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

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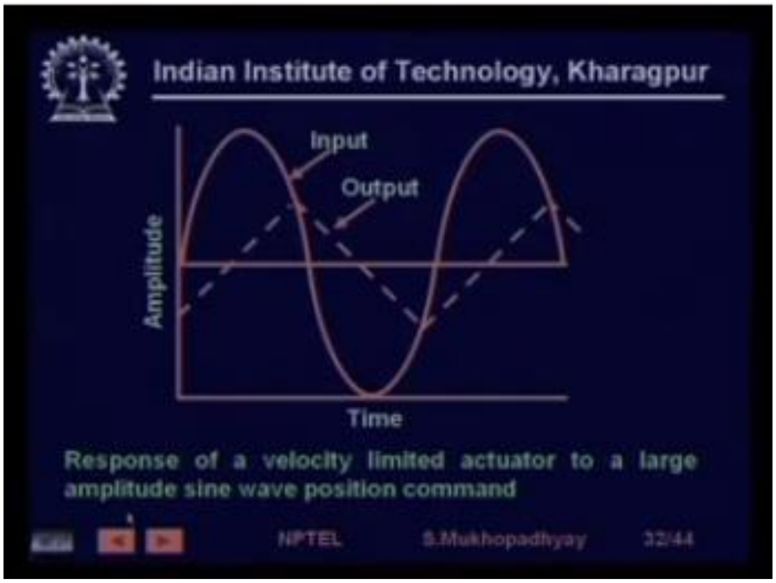

Any actuator most of the electromechanical actuators actually have a rate limit.

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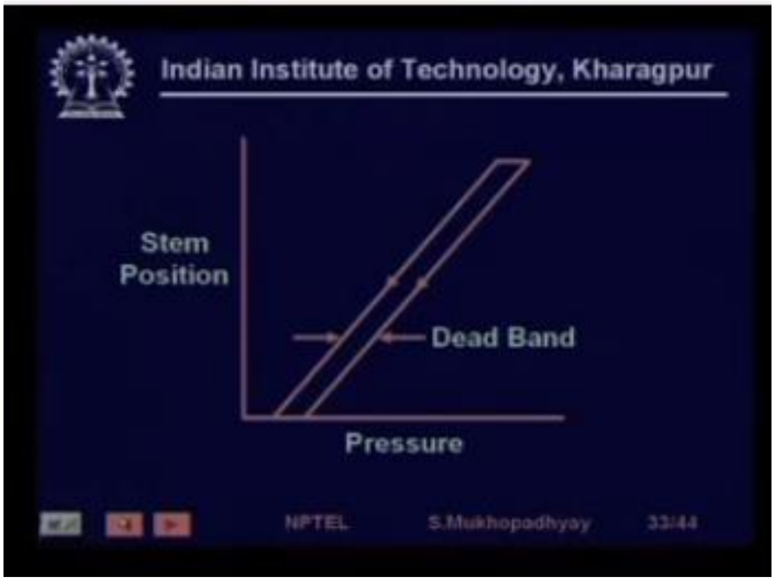

Similarly there may be a hysteresis in the stem position due to various factors you know. So when you are increasing the pressure the stem position may actually follow this curve and when you are decreasing the pressure it may not follow exactly the same curve. Now such dead bands as we know from, you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

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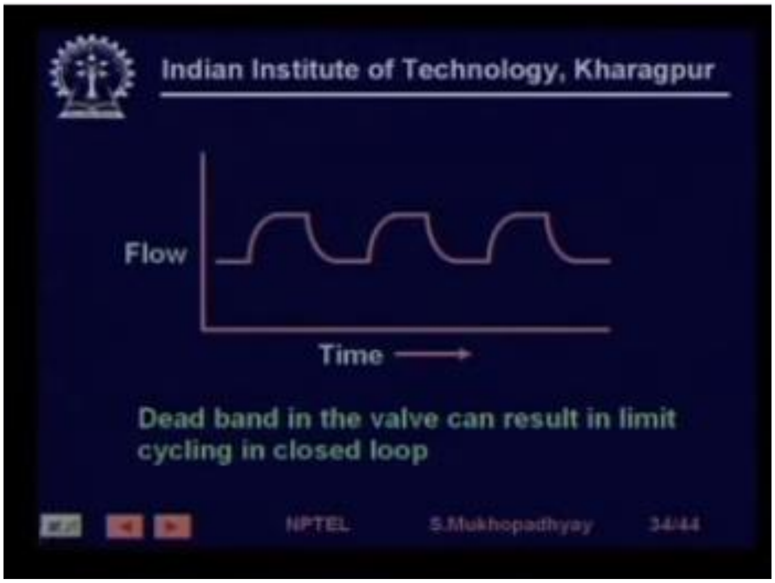

So this, you know this process control loops flow loops the if you if you given an alternating command then the process control loop may actually oscillate. So these are called limit cycles in the closed loop.

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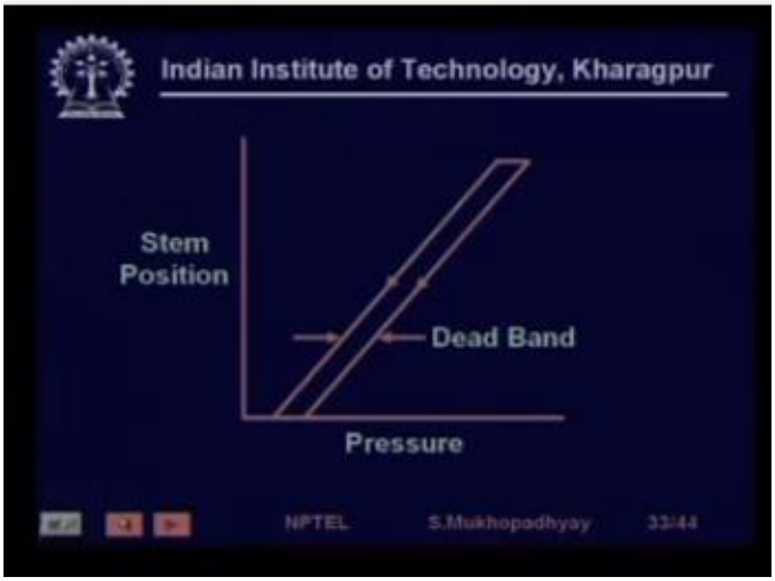

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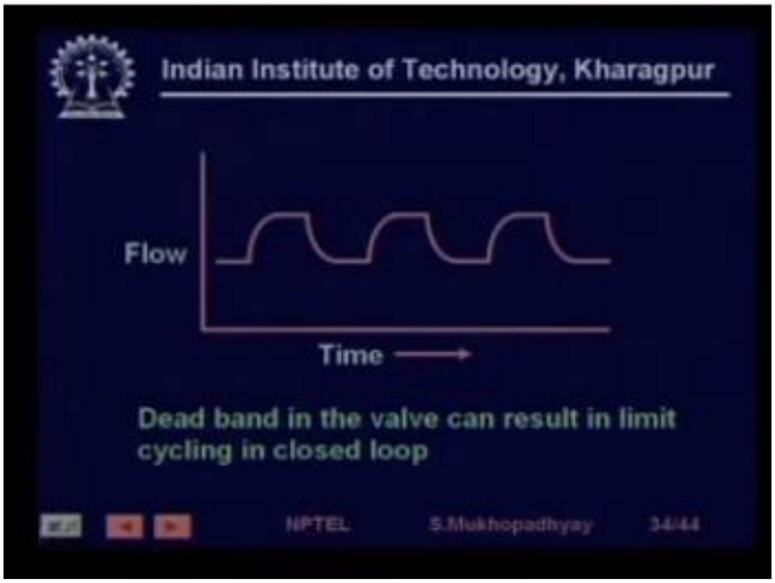

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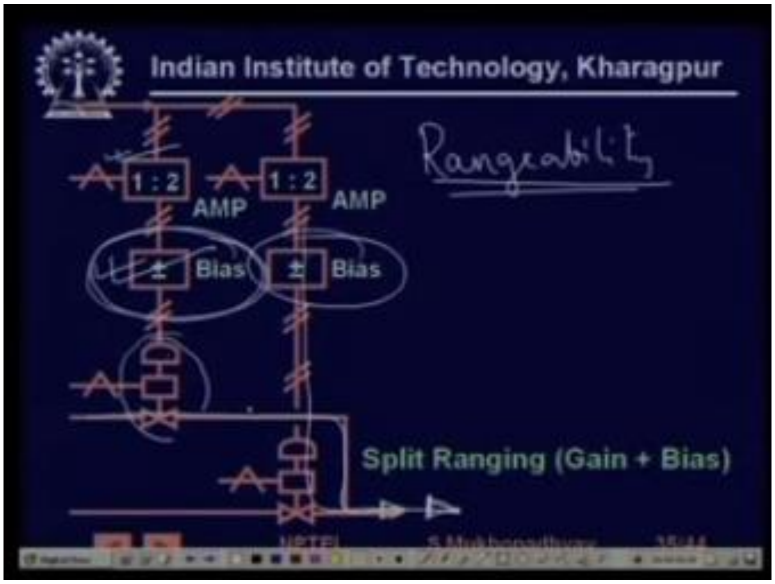

Similarly these are sometimes, you know there is a very important quantity for a valve called a range ability. So range ability means that what is the maximum to minimum flow ratio, so the maximum flow to the minimum controllable flow is it is said. So valves can have you know sometime valve manufacturers claim that they have, you know 10 : 1, 15:1, 13:1, 30:1 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 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 operation region you operate another valve.

But you have to ensure, you know certain things like, you know transitions such that suddenly when you move from one valve to another valve the process control loop characteristics 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 module. So you have two valves and they are fed through an amplifier and a bias right.

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 some time when this valve input will actually saturate then this valve will operate no longer and then this valve will start operating. So 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.

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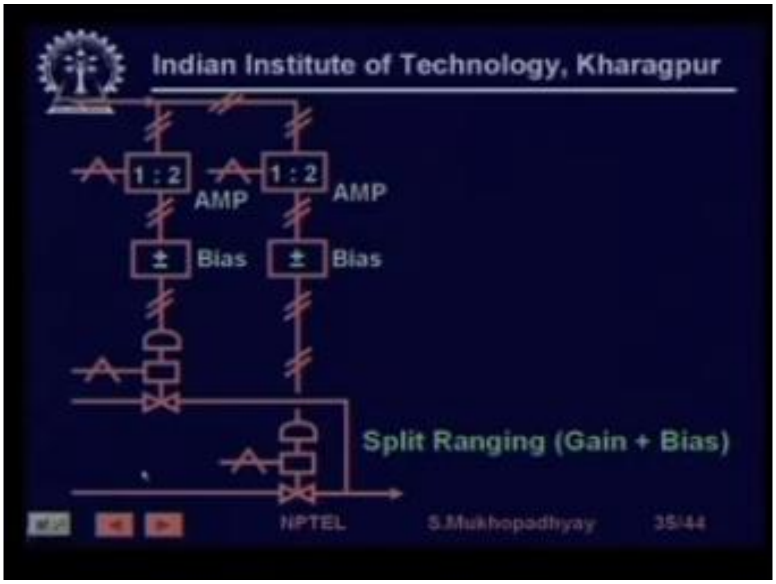

Similarly sometimes you can have.

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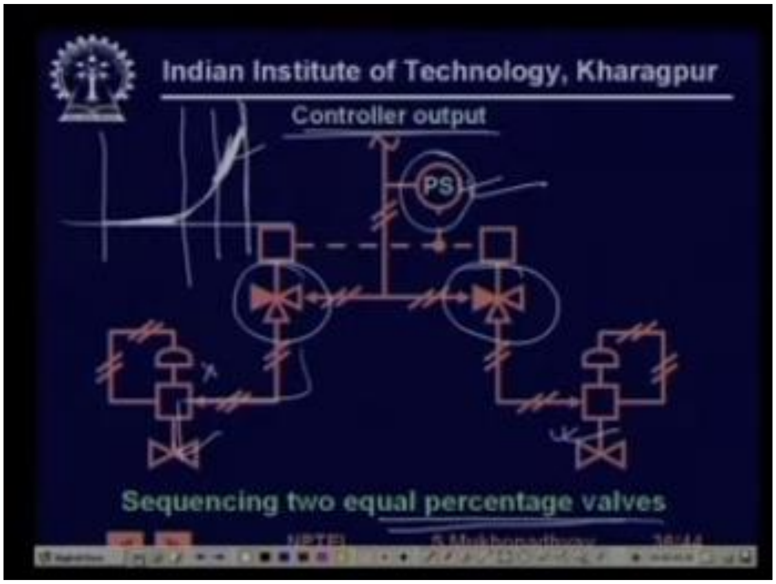

There may be another scheme this is another valve sequencing scheme where you have a pressure sensor. So this pressure, this is actually the controller output which is going to the valve actuator. So when the controller output, so here the switching which is by this three-way valves is actually done based on how much controller output is being exerted to these 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 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 problem.

So for doing that, that is why it is for such kind of sequencing equal percentage valves are actually better suited, because as we know from the equal percentage characteristics the equal percentage characteristic is like this right, same position to flow. So you see that for the small valve 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 its 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 vavle sequencing rather than linear valves.

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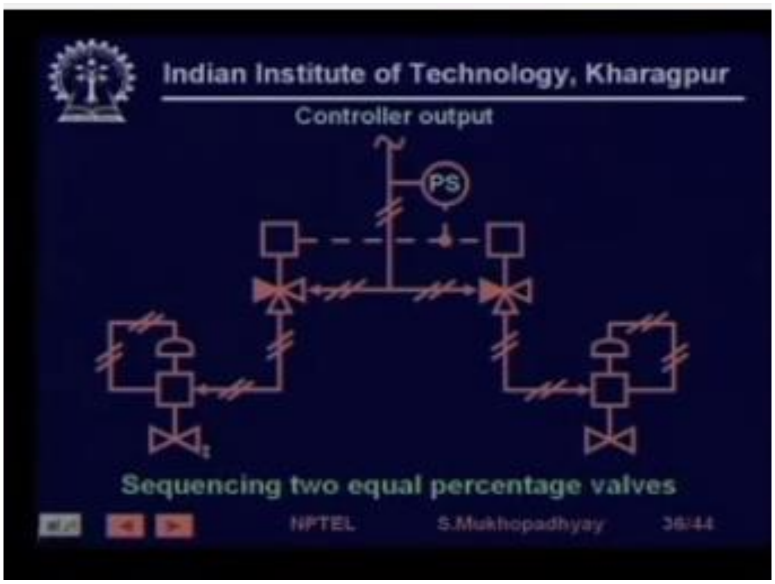

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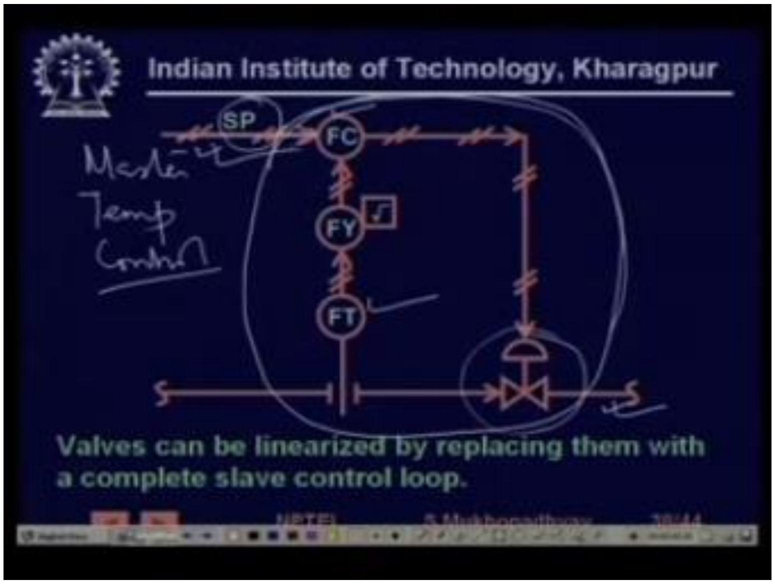

Often as we have seen that as we know this shows that often you know valves are also actually put in the closed loop. So it is actually a part of the flow control loop generally and if you have a, that is rather than suppose you have a temperature loop, so in the temperature loop output controller output 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 if you set up, so this is the one coming from the master say temperature control loop, then if we set up this is a flow controller, this is the this is the flow transmitter. So if you set up then even if the valve is nonlinear 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 a mathematical sense but there will be much more linear and that makes it much easier to actually design the, design and ensure that the characteristic of the temperature control loop remains uniformly good over the for the whole region of operation. So sometimes many times we set up this kind of loops.

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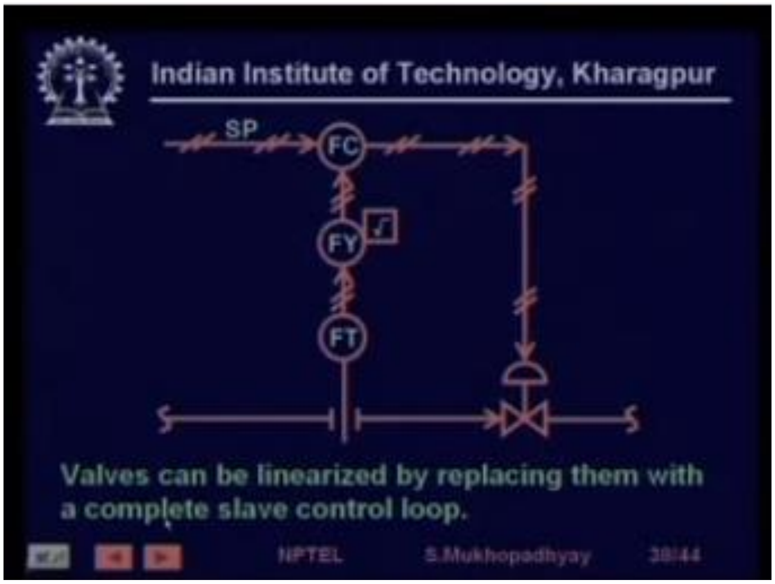

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Sometimes you now valve characteristics can be very cleverly used to, you know match the match the system characteristics. So for example, take the case of a liquid to liquid heat exchanger, so what happens is that now, you know this is the input which 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 longer time and therefore for both the gain between this point to this point, there is a temperature for a given rate of flow of the heating liquid the increase in temperature between the 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 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 situation where you have 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, if 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 improved transient performance you can have a higher controller gain, but it is not, you know automatically easy to actually change controller.

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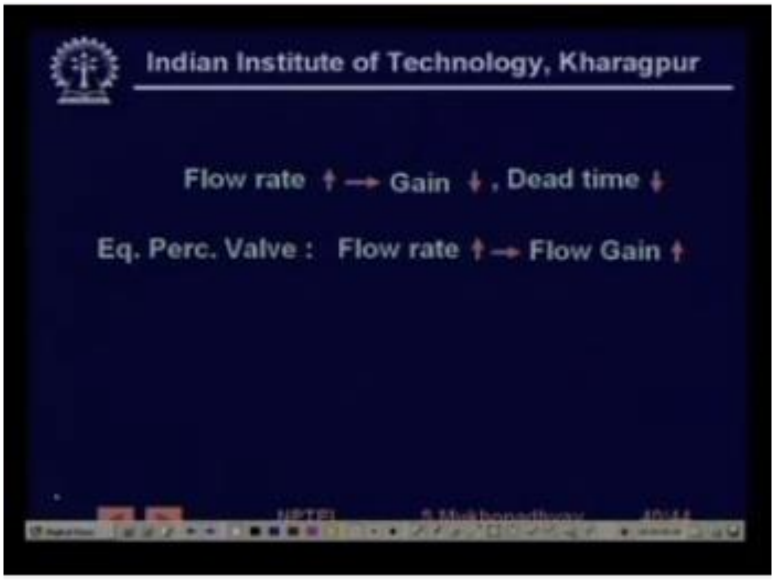

So for this application if you use, if one uses an equal percentage valve then as we know that the valve gain goes up as the flow rate goes up. So automatically the loop gain increases as the flow rate increases, so the overall process loop transient characteristic is maintained uniform simply by the valve characters and simply by the choice of the valve right. So this is what I am saying.

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Similarly at the end and an opposite situation can occur if you have an orifice meter, 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 right. So one can use a linear valve for this.

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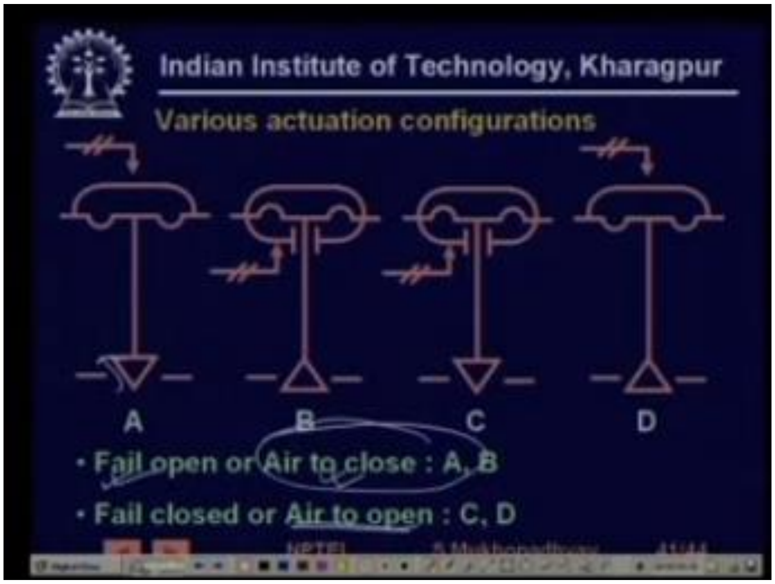

The, lastly you know valves are one has to put a, or have a view towards what will happen if the actuation fails, because you know sometimes this flows can actually cause explosions etc, so valves are constructed in various configurations which are shown here. For example, fail open or air too close. So if this air supply somehow fails then this valve will fail and it will fail in an open situation.

So that if the air supply is not there then the value will remain open. Similarly, there are air to open valves where if the air supply close and fails then the valve will close. So these, so you one has to choose a particular actuation configuration to, you know avert industrial accidents under various kinds of failures.

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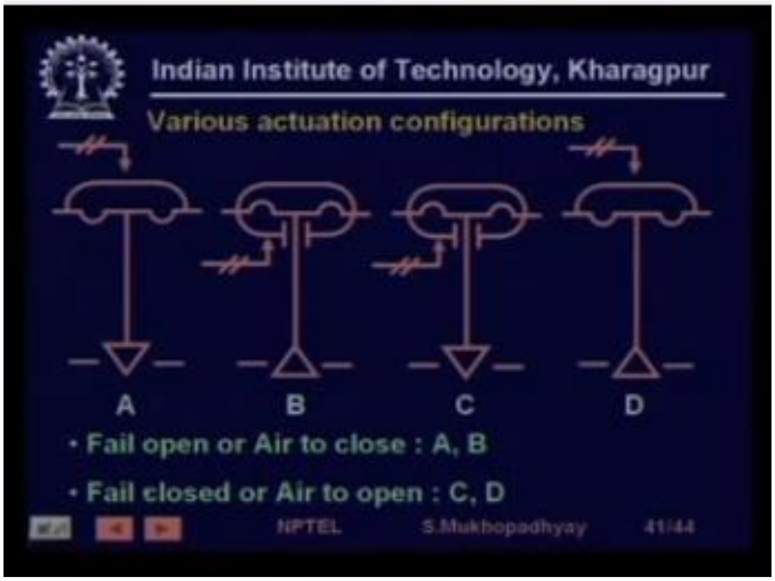

So that brings us to the end of this lecture.

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So as a matter of review we have typically seen globe 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 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 automation control.

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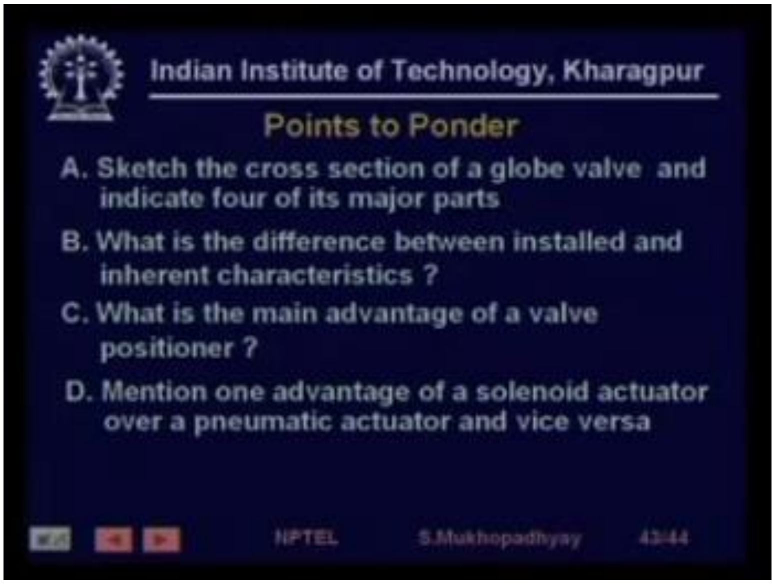

So two end points to ponder, first is sketch the cross section of a globe valve and indicate four of its major parts you should be able to do that, what is the difference between installed and inherent characteristics this is extremely important and why this occurs, what is the main advantage of a valve 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.