INDIAN INSTITUTE OF TECHNOLOGY
KHARAGPUR

NPTEL
ONLINE CERTIFICATION COURSE

On Industrial Automation and Control

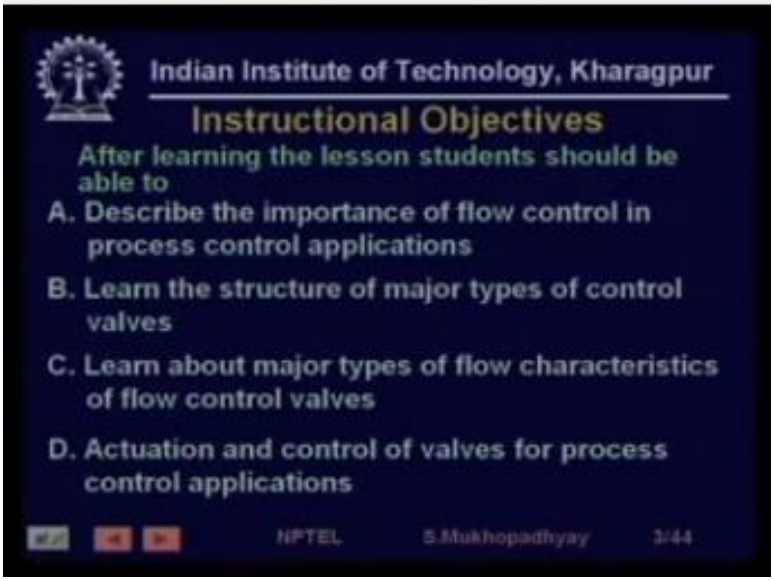
By Prof. S. Mukhopadhyay
Department of Electrical Engineering
IIT Kharagpur

Topic Lecture – 32
Flow Control Valves

Welcome to lesson 25 on flow control valves of the course on industrial automation.

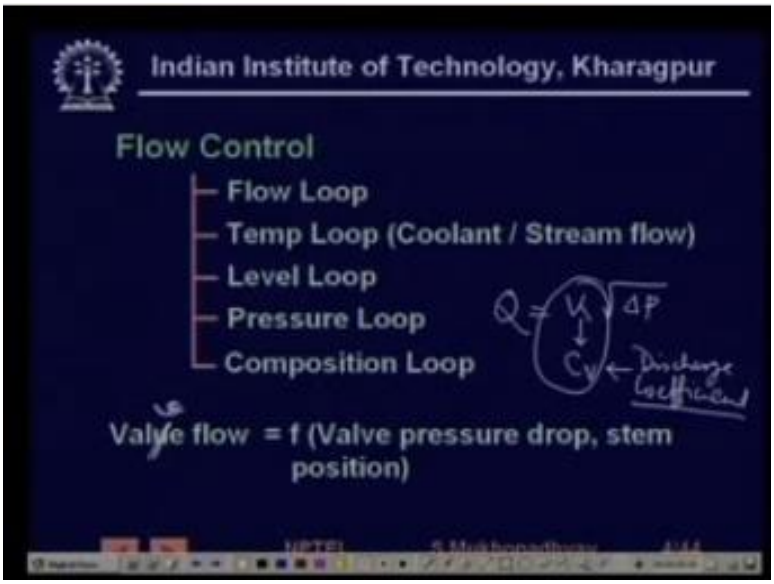
(Refer Slide Time: 00:30)

(Refer Slide Time: 00:33)



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 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: 01:28)



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 the 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 team. 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 loops because compositions of products are typically dependent on the compositions of the components in a, let us say reactor.

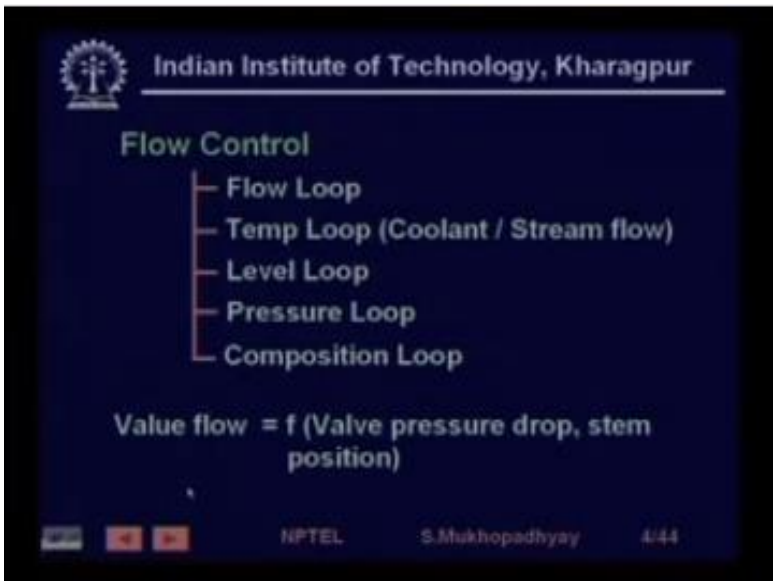
So if you want to control the composition of a particular product flow control is often a very important part of that control application. So we see that for most types of control applications flow control is a part and the element that finally achieves the control is the flow control valve, so its importance cannot be overstated and as we shall, as we need to mention again slight

spelling mistake, so this valve flow is actually a function of valve as the pressure drop across the valve and the stem position.

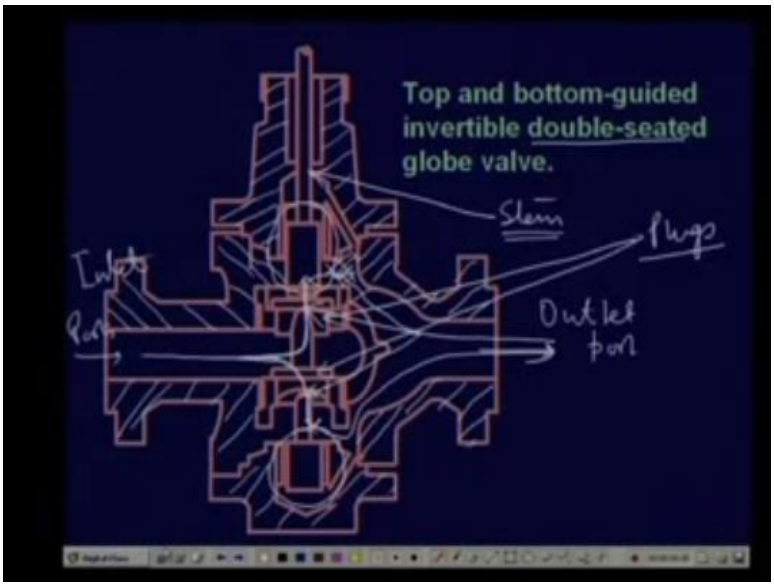
As we shall, as we perhaps know that by Bernoulli's equation the flow of a, flow through an orifice of a flow control valve is essential an orifice and it is the dimensions of the orifice which are varied is proportional to a root over of ΔP, ΔP is the pressure difference across the valve and K is a proportionality constant which contains among other things what we call a discharge coefficient or CV.

So the flow control valves it is this gay or this discharge coefficient of the valve which is changed by changing the orifice dimensions. So that is the way we achieve flow control.

(Refer Slide Time: 04:35)



(Refer Slide Time: 04:38)



Now so first of all we see the various kinds of valves and the first kind of valve that we see our 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 I am sorry not this one this part this is the body right so the fluid in fact there are this is a this is a top and bottom guided top and bottom guided means the basic valve assembly movement is guided and in the top and at the bottom and it is a double seated globe valve.

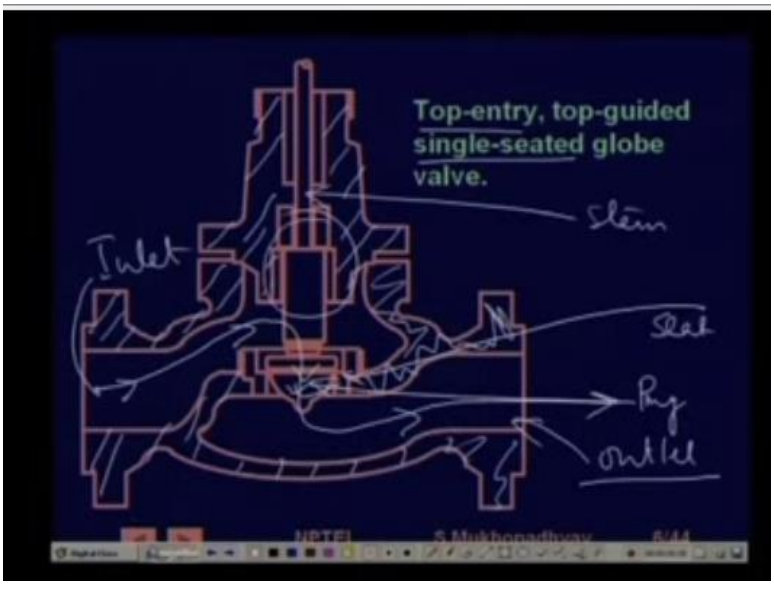
So there are two seats one seat is here another seat is here, so actually the fluid enters through this and we will go through this when this valve will rise it will go through this and will flow out similarly it will go through this it will go through this path and go out so since there are two seats 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 steam 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 the plug sometimes is to work against this force so to reduce for double seated valves although they are not so popular nowadays 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 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 one and number two is that because of you know slight mechanical problems it is very difficult to ensure that both the plugs actually seal thus orifice at the same time and therefore often you have problems of leaking through the valve like the shut-off of the valve is not so tight.

(Refer Slide Time: 09:00)

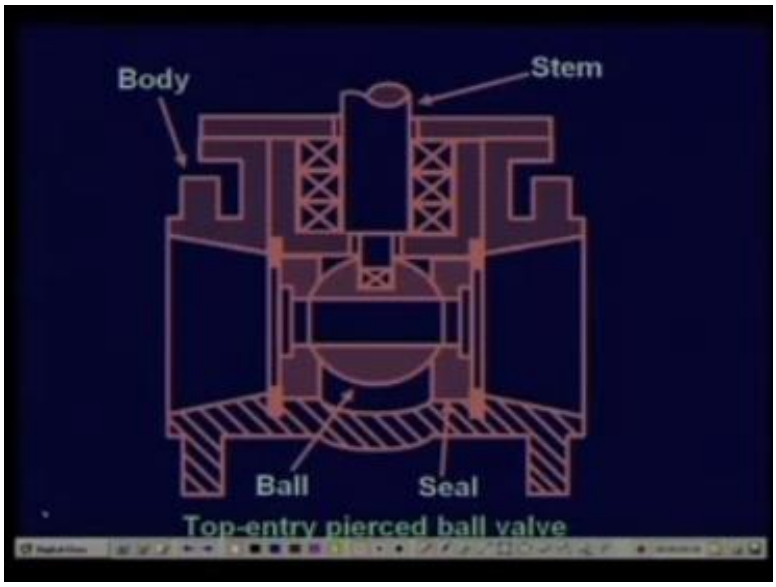


So it is for this reason that people nowadays prefer single seated valves so this is a single seated valve you know you this is the plug this is the plug you can see that this is the seat on which the

plug sits this is the seat this is the stem this is 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.

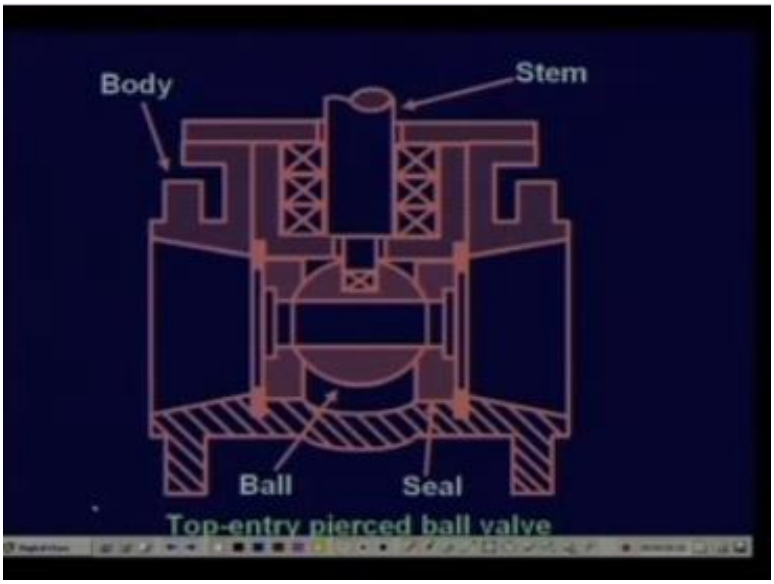
So this is a top entry top entry because the valve stem enters from the top, top guided here there is only one guidance one guiding piece that is top guiding not top and bottom guided, single seated because there is only one seat globe valve. So these valves are one of the most common types of valves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

(Refer Slide Time: 10:36)



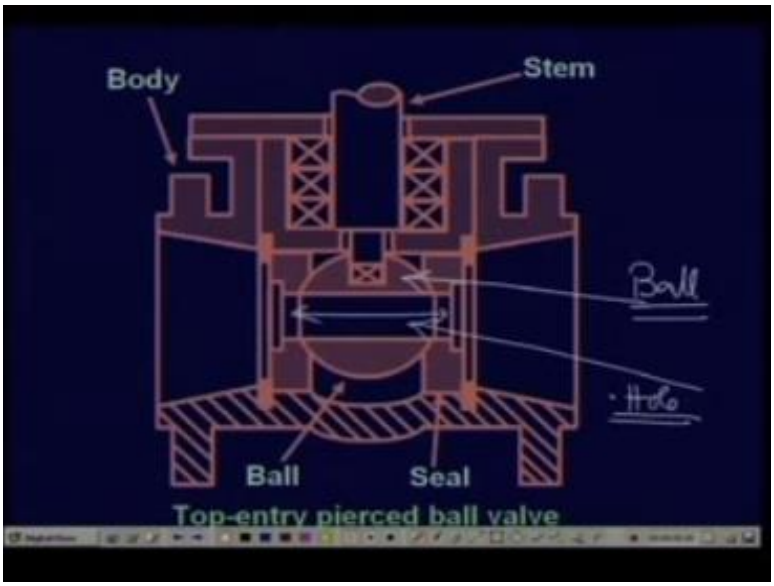
Next our ball valves, these valves have in the previous case the stem actually moves in a linear fashion up and down is for these valves.

(Refer Slide Time: 10:50)



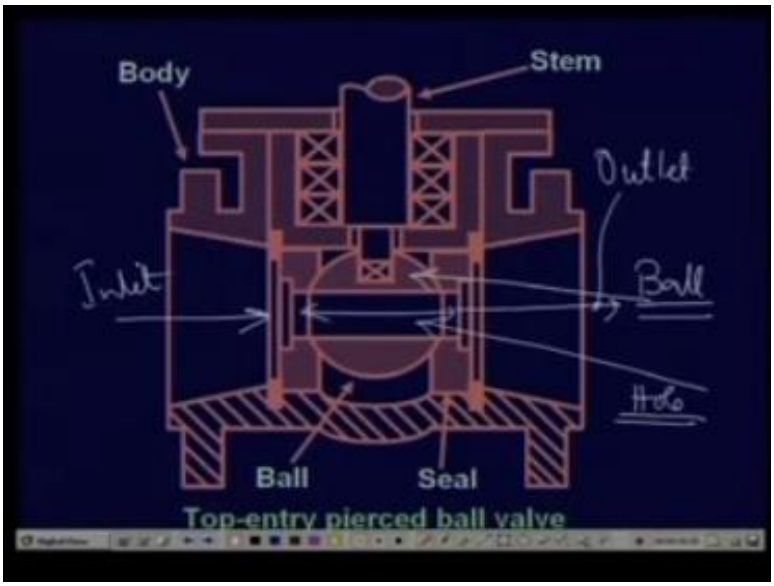
The stem actually rotates so it is a so it requires a rotary actuator can be directly coupled to a motor so you see that actually you have a ball a ball like structure through which there is a hole.

(Refer Slide Time: 11:08)



So you can see the hole this is the ball these ball valves and this is the hole through them this is the hole through the ball. So now suppose so this is the whole suppose so when the ball is in this position then you can understand that this is the inlet port.

(Refer Slide Time: 11:36)



And this is the outlet port so when the well 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, right.

(Refer Slide Time: 12:16)

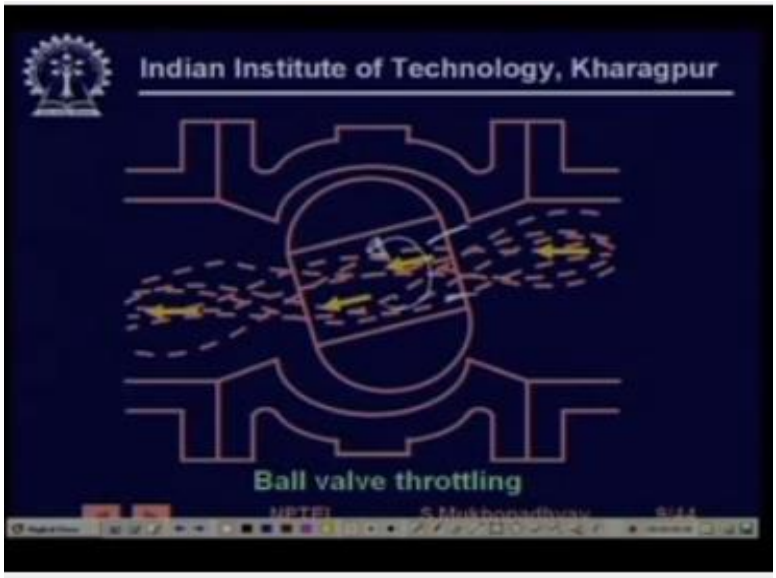
So this is the basic principle of a ball valve for example this is a multi-port ball valve so you can see the ball this is that this is a cross section.

(Refer Slide Time: 12:24)

So the ball is you know like this semi-cylindrical ellipsoidal and these are the holes so 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, right.

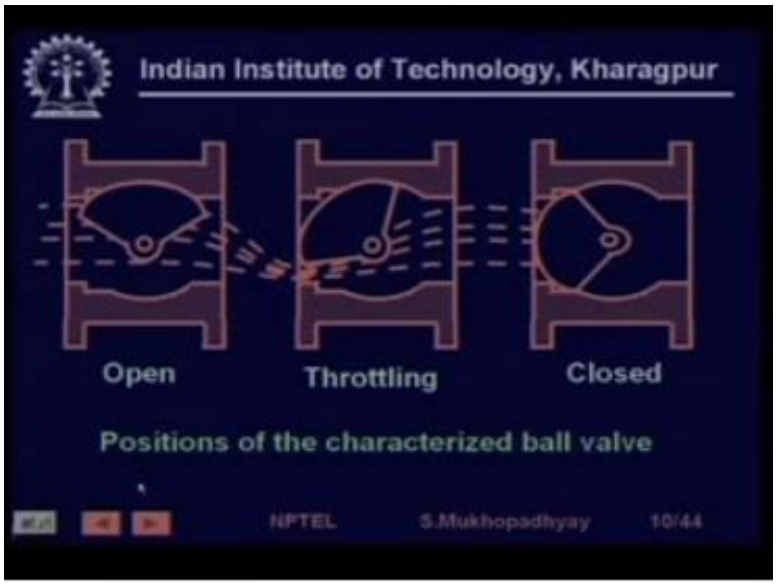
This is a tea ported ball valve you can have an angle ported ball valve and things like that, so this is the basic principle of ball valves.

(Refer Slide Time: 13:08)



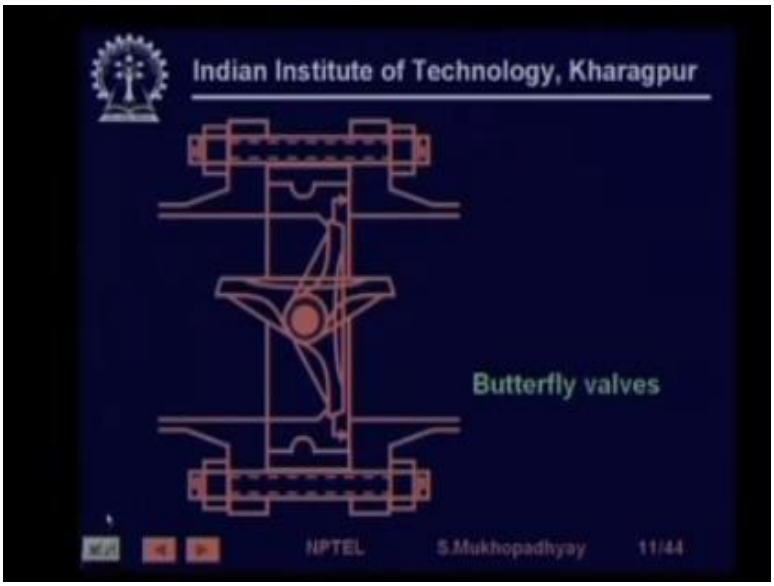
This is this picture shows how whenever now when a ball valve rotates then how the flow throttling takes place, so you see that as it is as it is rotating as it is rotating so this the effective area of flow gets reduced. So as it rotates slowly the effective area of flow will get reduced and therefore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

(Refer Slide Time: 13:38)



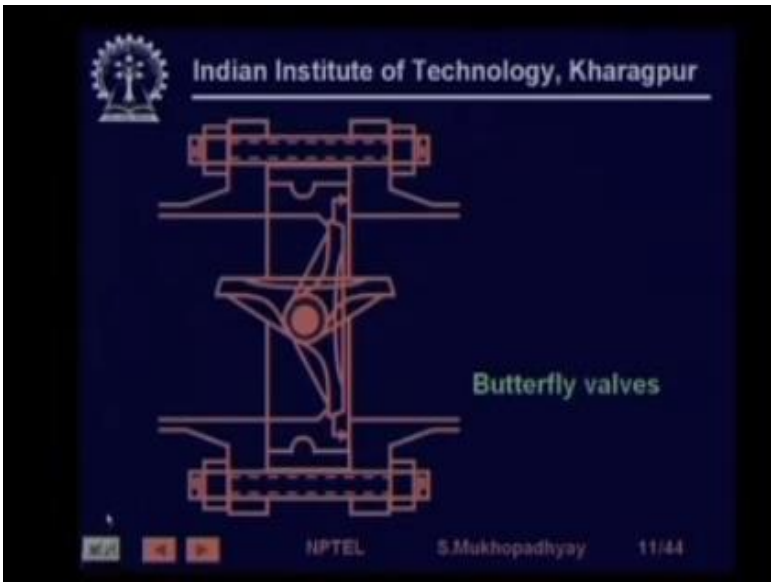
This is another kind of ball valve where the where the ball is of a certain shape so it is called a characterized ball valve, so here you can see that as again as it rotates this surface slowly comes and closes the flow and therefore the flow if flow can be throttled or it can be completely shut off.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

(Refer Slide Time: 14:07)



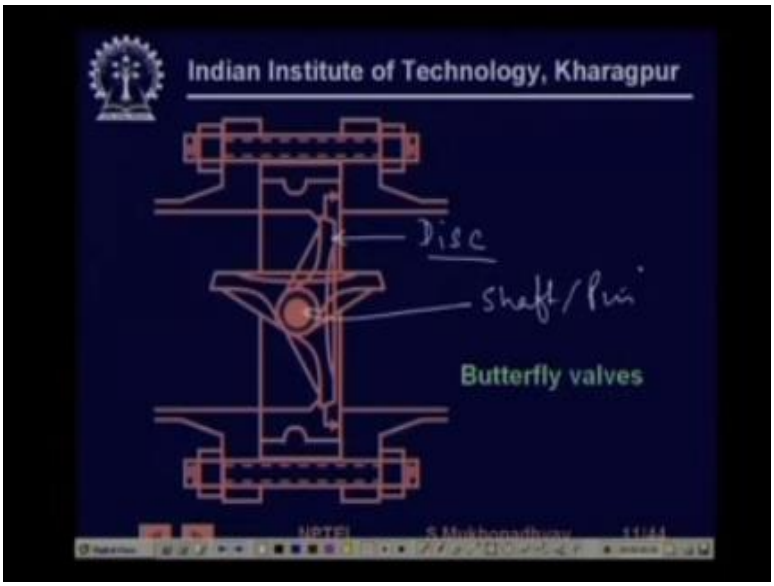
The third kind of actually there are various kinds of valves we are going to only talk about some major ones but there are at least 10 15 different types of valves which care which are used in various kinds of applications in the industry de from valve peach valve sliding gate valve etc. So this is another kind of valve which is called.

(Refer Slide Time: 14:34)



A butterfly valve so basic idea is that this is butterfly valves are used in large pipes there they are also used for the apart from you know applications in let us say liquid applications like water r flow control etc there they are also used in gas applications like they are used In heating ventilation air conditioning applications of large buildings where the air flow needs to be controlled so in such applications butterfly bulbs are also used.

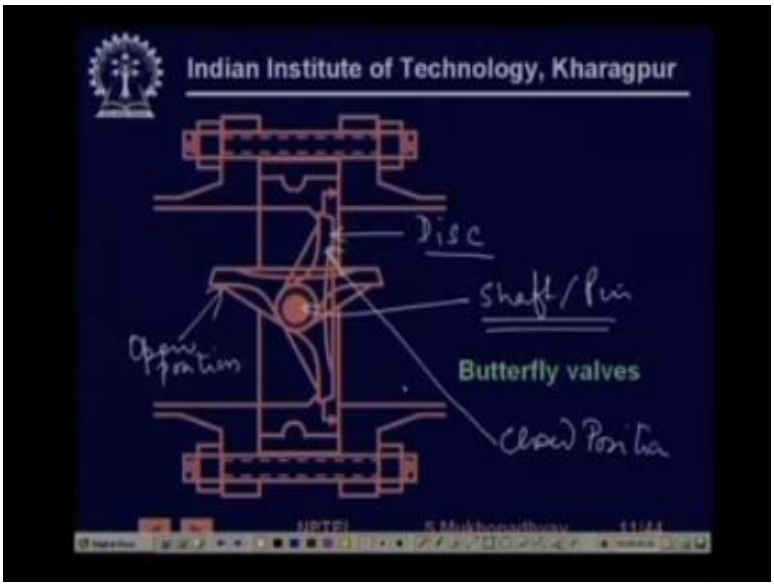
(Refer Slide Time: 15:03)



So basic idea is that in all valves there has to be an there is a variable obstruction right so it is this disk which is the which creates the obstruction and there is a there is a shaft or a pin about which so you can understand that you can understand that this is this is the butterfly valve and there is basically a shaft runs across it and this shaft is driven so this valve is actually this valve is actually stuck to this and if you rotate this actuator that this valve can be either in this position or in this position.

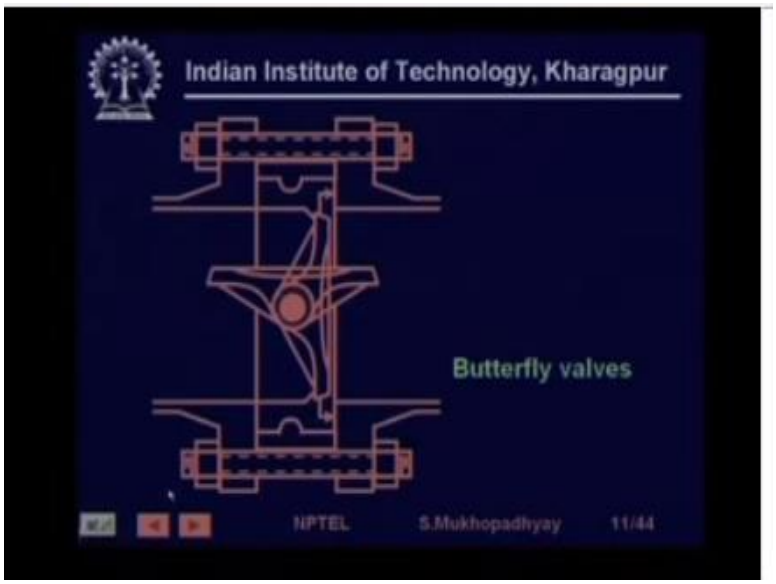
So if you have a pipe here if you have a pipe here then if you connect in this position then it is open if you connected this position if you put it in this position that is closed right.

(Refer Slide Time: 16:03)



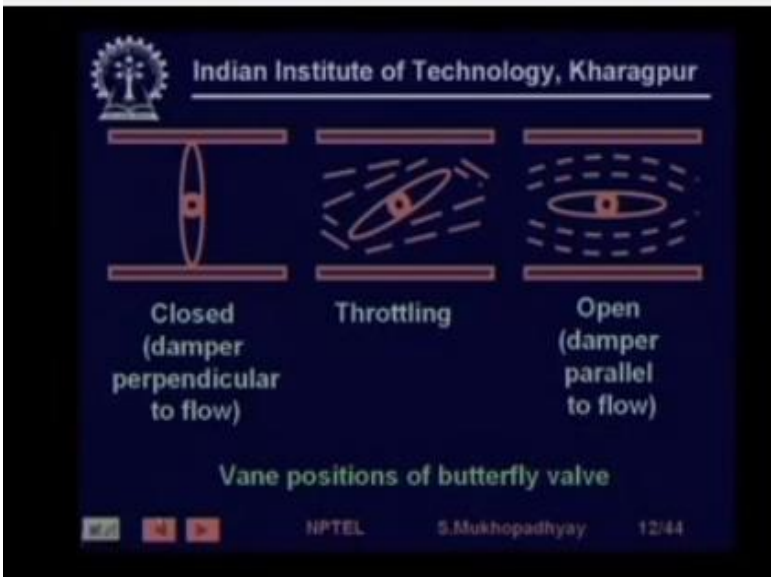
So exactly that is the position so the they are this these two positions are shown so this is the open position of the disc open position and this is the closed position of the disc both positions are shown closed position and this is the shaft or pin which is driven to move the disc various shapes of discs are used to do you know again to reduce the torque requirement on the shaft or to reduce noise so these such big discs when you have a fast flowing fluid can sometimes vibrate and create noise.

(Refer Slide Time: 16:44)



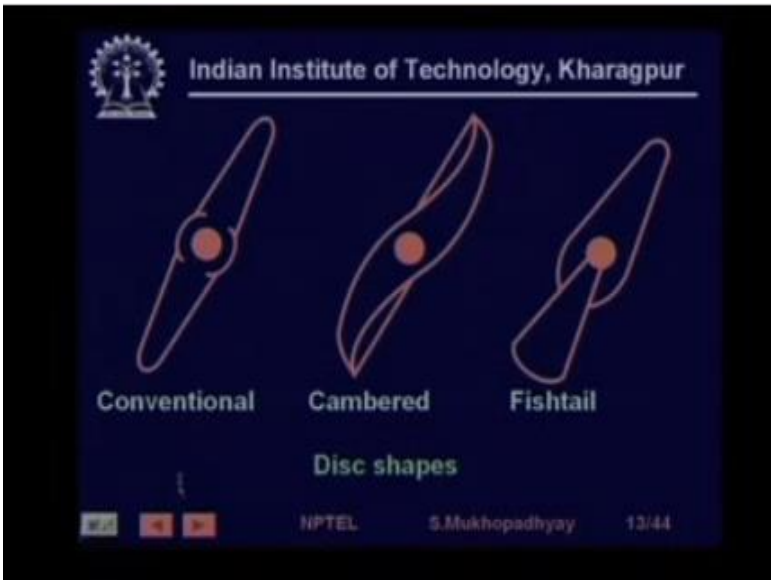
So.

(Refer Slide Time: 16:47)



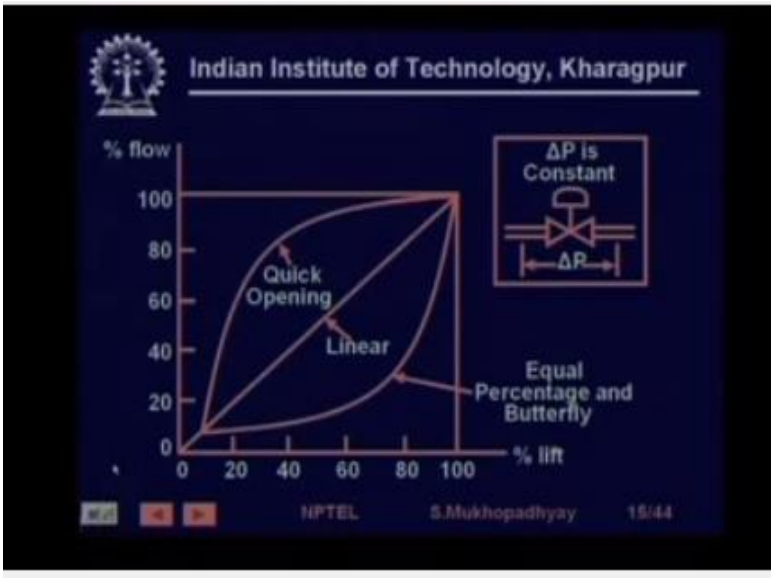
This is a picture which shows that so look from aside when the disc is in this position then the damper or then the damper is perpendicular to flow and the valve is closed when it is moving against throttling or controlling the flow and when it is in this position then when Apple's parallel flow hands completely open.

(Refer Slide Time: 17:17)



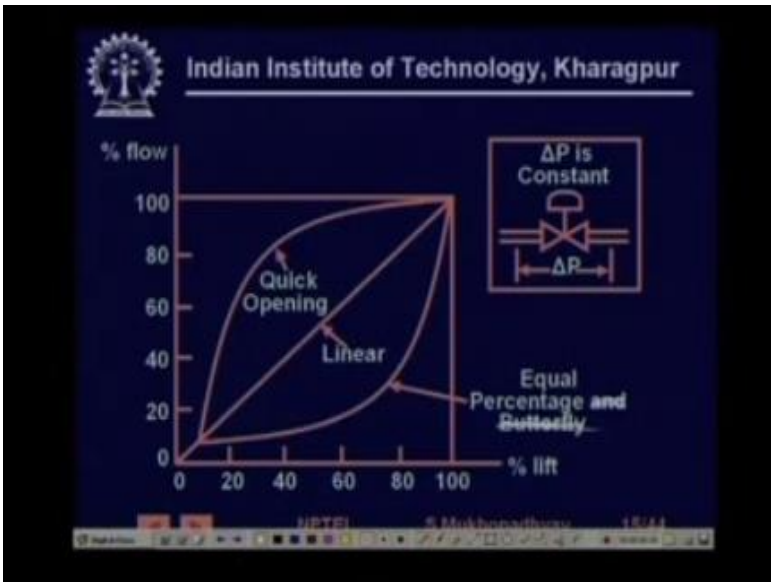
So there are various kinds of discs which are used as I said to take care of various factors like torque and noise.

(Refer Slide Time: 17:26)



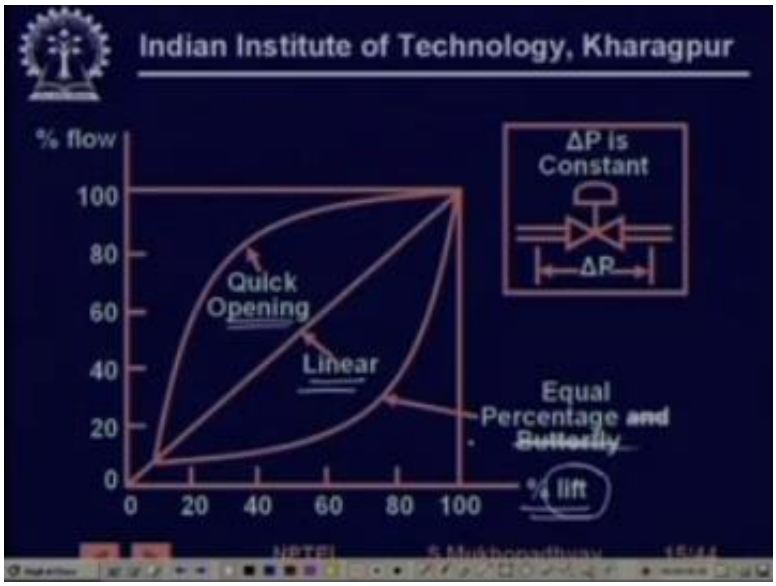
Now we so we have seen three different types of Valve's characterized in terms of construction right now we shall characterize vaults in another way depending on their flow characteristics.

(Refer Slide Time: 17:42)



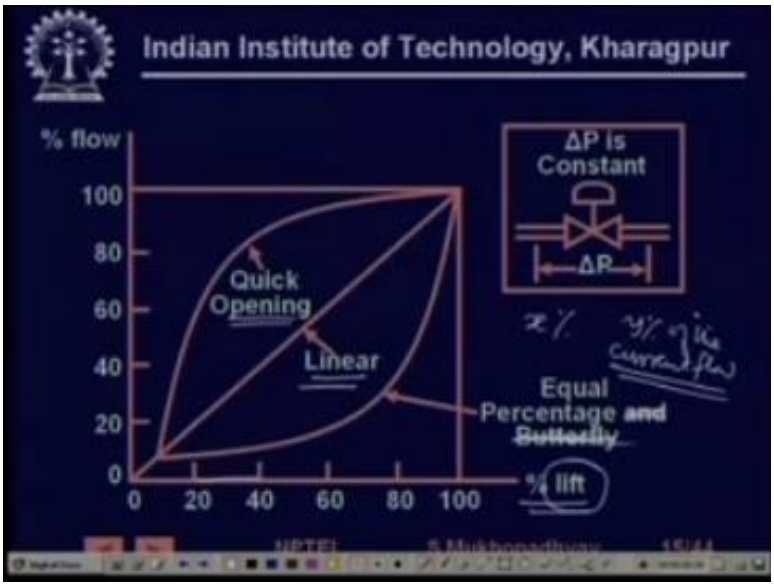
So depending on their flow characteristics valve can power can be generally characterized in into three different classes one is I mean butterfly valves are typically of equal percentage type so that is why and butterfly was written so one is this equal percentage type so that is why and butterfly was 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.

(Refer Slide Time: 18:14)



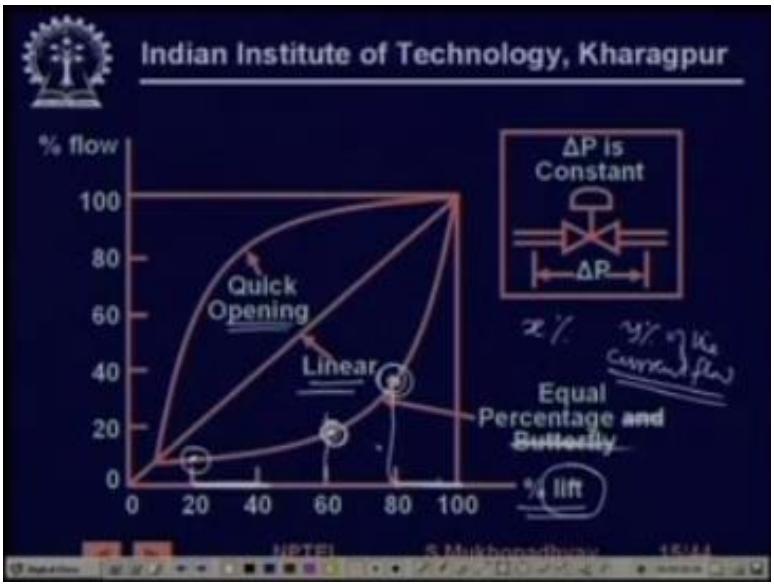
If you have a this is percent lift, percent lift means this stem, if it is lifted by a certain percentage the stem is moving so percent lift or percent stem positions with this it may not be though it is called leaf it may not be always a lift you know sometimes it may be a rotation also, basically means that the percent of the total stem movement.

(Refer Slide Time: 18:40)



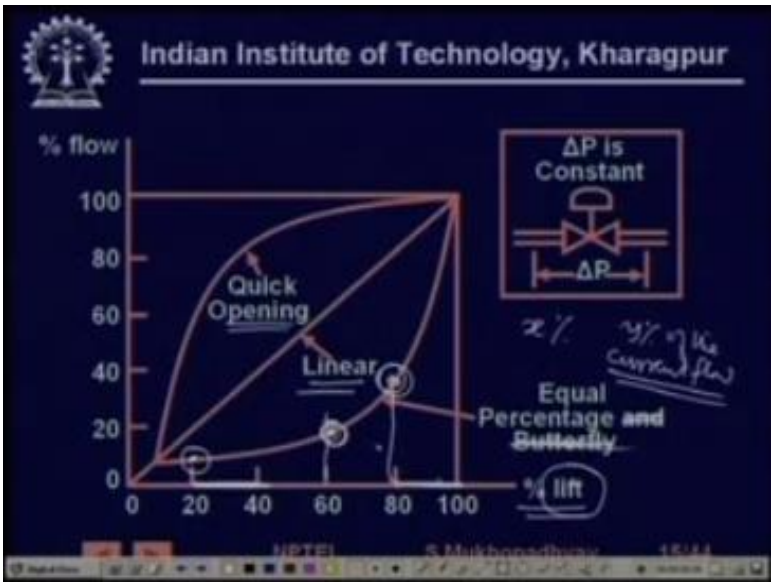
So says that if you increase the stem movement by x% then y% the, of the current flow, will so the flow will increase by y% of the current flow, right. So if you make x% change if you make a Δx.

(Refer Slide Time: 19:09)



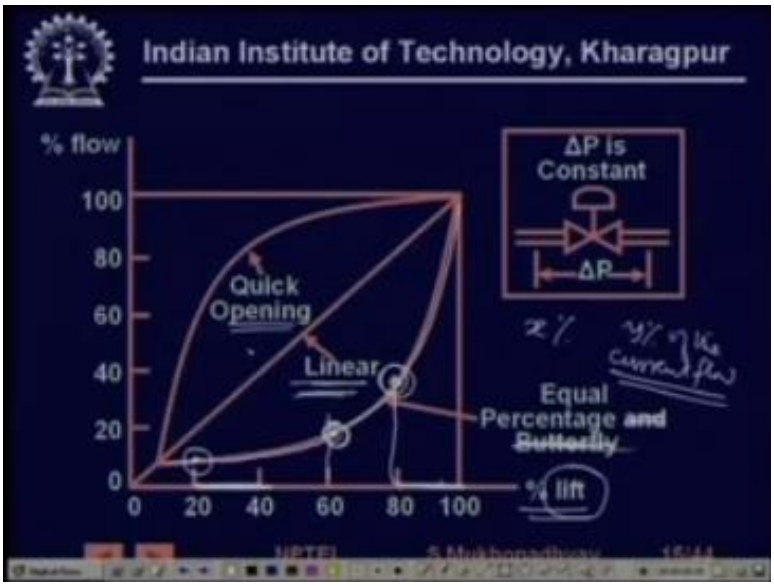
x% of full-scale so if you make a 20% change here then may be 5% of the current flow which is here will take place. On the other hand if you make a 20% change here then 5% of the current flow which is here will take place, if you make 20% change here then 5% of the current flow which is here will take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

(Refer Slide Time: 19:45)



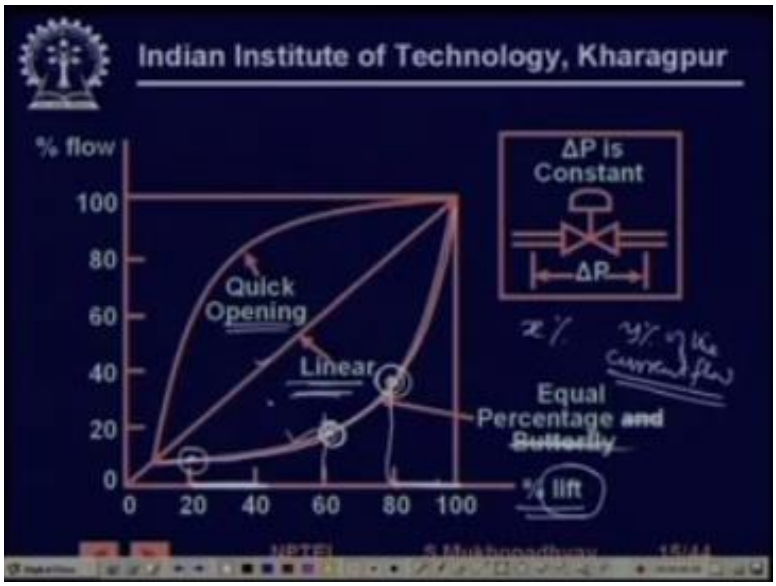
So an equal percentage of the current flow will take place if you make a certain fixed percentage of lift change that is the reason why these valves are called equal percentage.

(Refer Slide Time: 20:02)



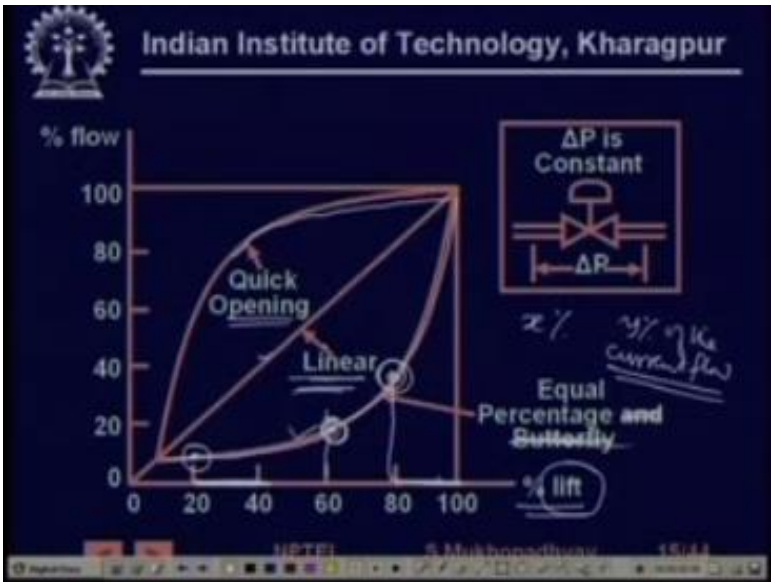
So you can easily analyze as you can easily understand that this sort of characteristic exponential kind of characteristic arises. So on the other hand we have linear which is obvious that is for a certain percent of lift change a certain fixed percentage of the total full-scale change not current flow will take place so it is a linear it is guided by constant.

(Refer Slide Time: 20:32)



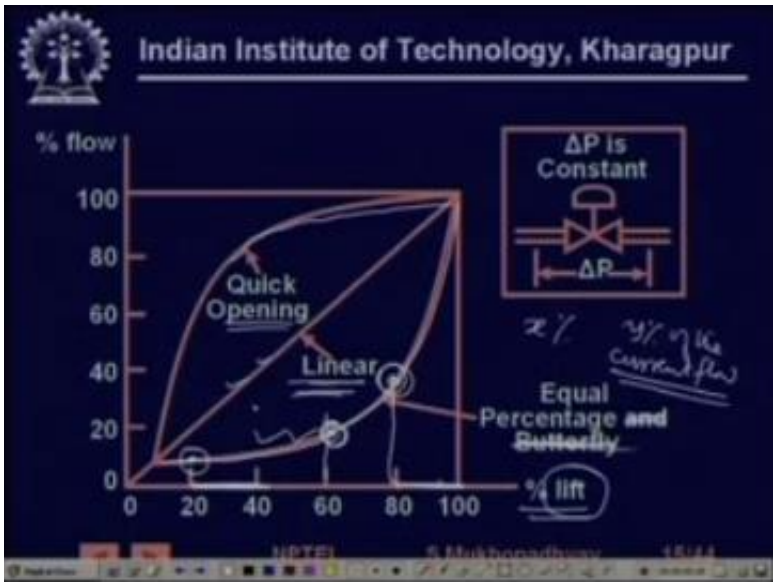
Actually the linear and the equal percentage are mostly used in process applications, quick opening valves are you know like our like or bathroom taps are typically quick opening, so you must have seen that if you the almost full flow is realized by a maybe even one turn or one and a half turns of the tap while if you move it more and more then not much flow increase takes place.

(Refer Slide Time: 21:03)



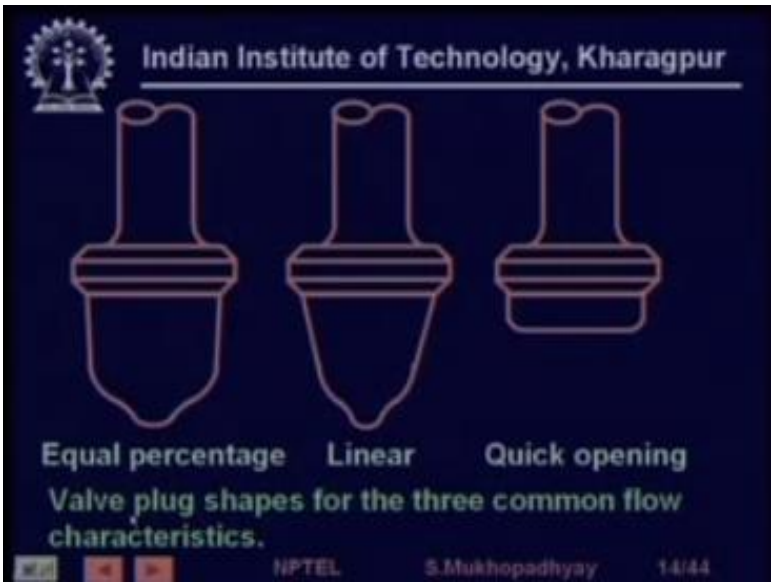
So this valves there is a quick increase of flow and then for the rest of the movement that is very little flow, so it is all kind of opposite of the equal percentage and they are typically used more in you know on off kind of applications or some certain special kinds of process control applications but most of the control applications.

(Refer Slide Time: 21:20)



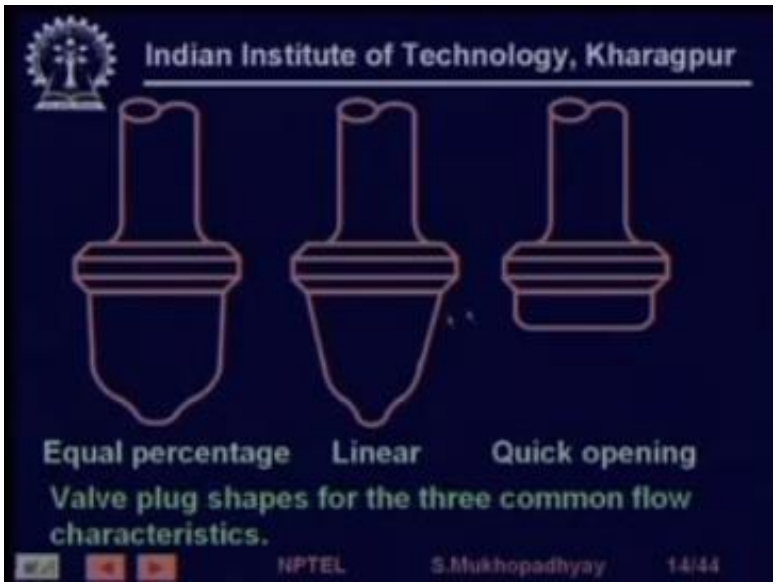
Which use linear and equal percentage valves? Remember one thing that these characteristics have assumed that these characteristics are called inherent characteristics and are provided by the manufacturer. Inherent characteristics of the valve and are provided by the manufacturer under conditions that the pressure across the valve is constant. So they actually maintain the pressure across the valve and then they characterize this curve, right.

(Refer Slide Time: 21:51)



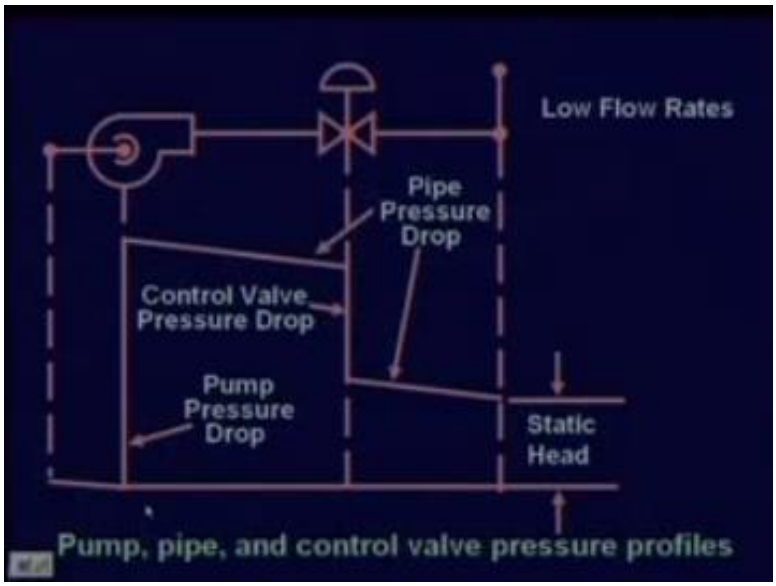
So this is important to understand and now how we are these characteristics realized they are realized by various profiles of the plug, right. So in the case of the globe valve here say we have.

(Refer Slide Time: 22:06)



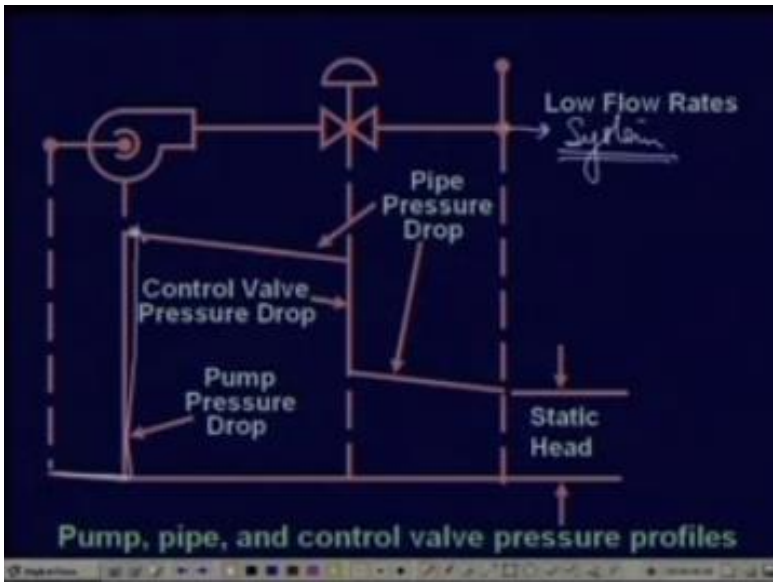
There are three kinds of these are three plugs which realize equal percentage linear or quick opening characteristics.

(Refer Slide Time: 22:14)



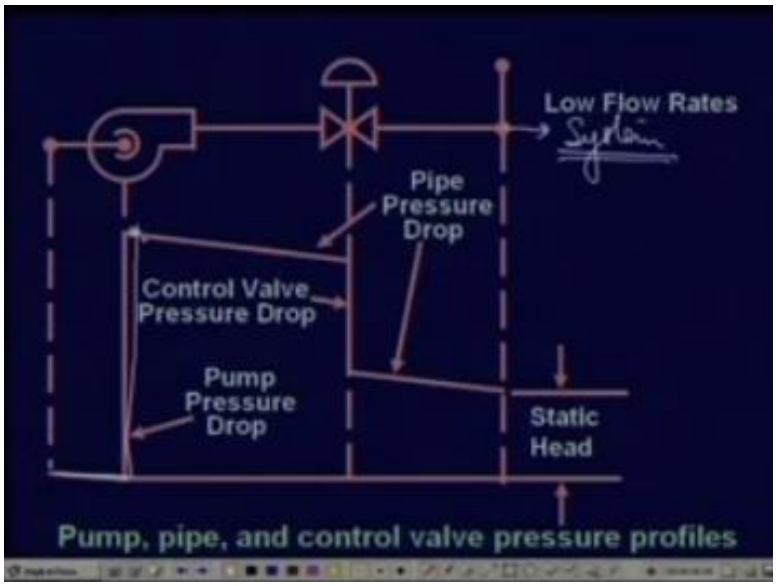
Now it turns out one must realize that if you actually put the valve into an application and connect it up with you know other components pumps systems pipes etc then the inherent characteristic will not be realized so the pressure flow characteristic of the of the actually these rather the stem lift versus flow characteristic of the valve which is provided by them an facture which is the inherent characteristic will not be realized because of the fact that ΔP will not remain constant so how does that happen.

(Refer Slide Time: 22:51)



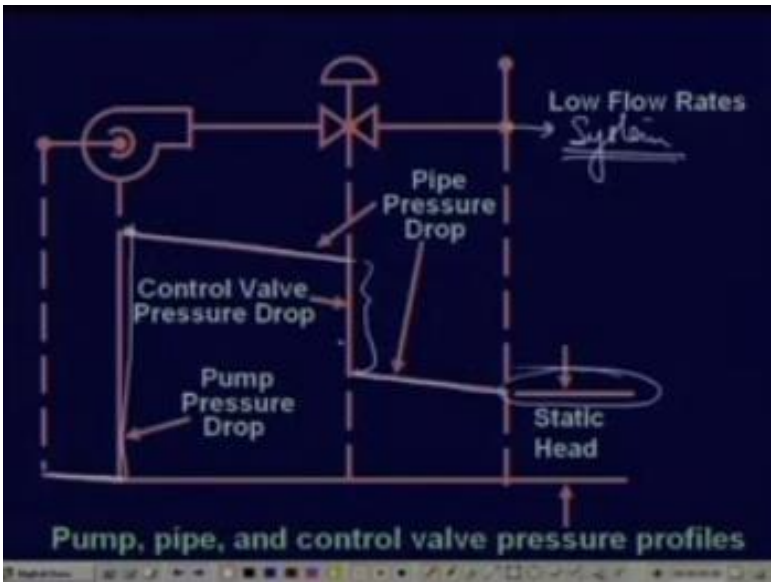
So you see that when you when you are connecting so this goes to the system wherever you want to send this flow and we are just you know arbitrarily assuming that the head of the that the system takes a particular kind of static head so what happens is that during flow there are actually pressure drops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

(Refer Slide Time: 23:20)



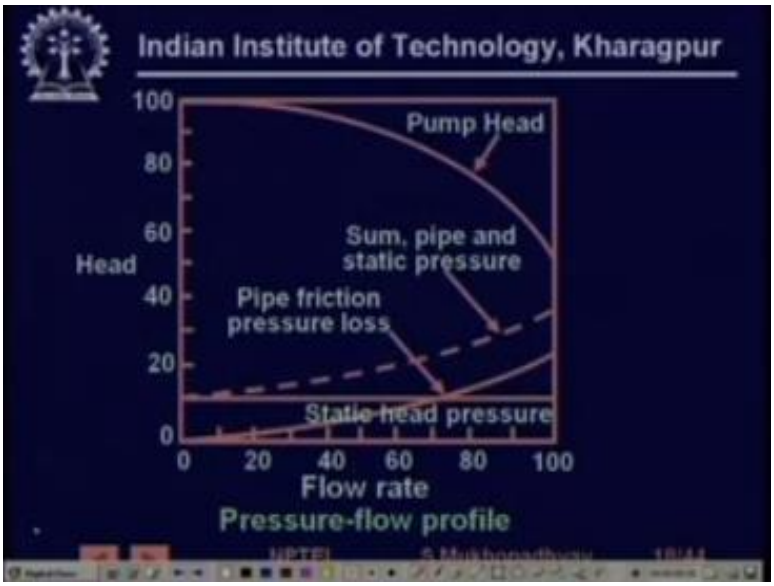
Then this flows through the pipe so again there is a friction loss and there is some pressure head then there is a drop across the valve because all because all valves will have a you know if it has to flow through a no issues there has to be a ΔP.

(Refer Slide Time: 23:36)



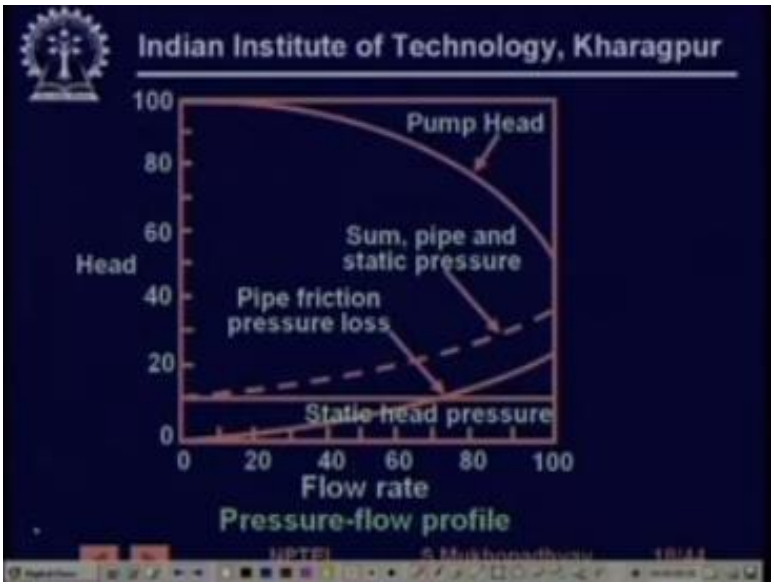
Then again there is a drawback along the pipe and then the available pressure at the system is there so this is the way the pressure drops and actually as we shall see now.

(Refer Slide Time: 23:50)



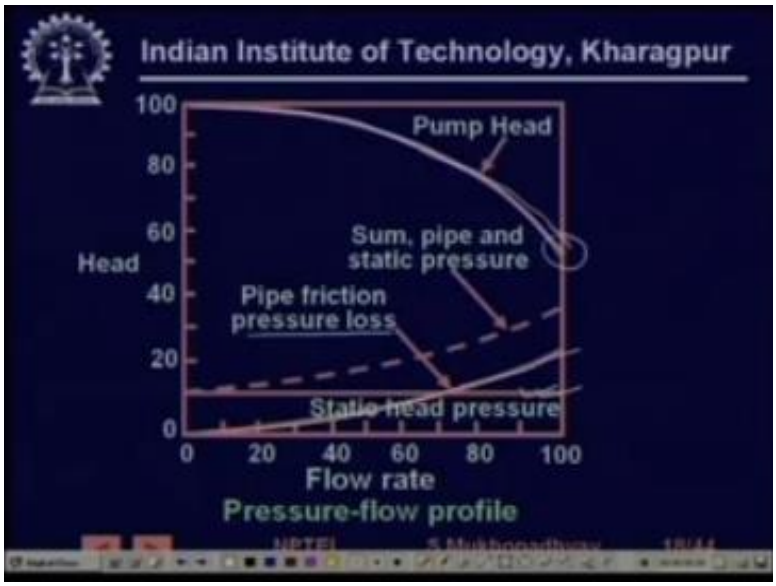
That now as now as we know that these pressure various pressures drops very with flow itself.

(Refer Slide Time: 24:00)



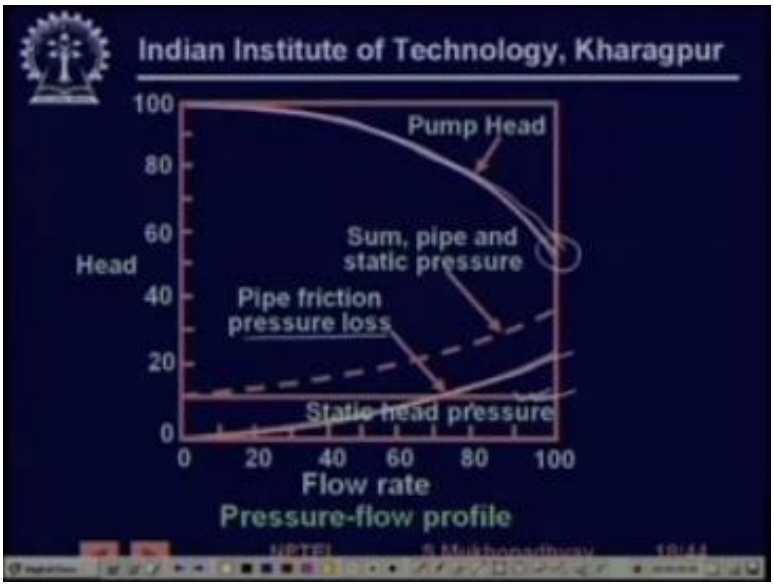
So for example the pipe friction pressure loss will also rise with flow similarly if the pump head because there are pressure losses inside the pump so the pump head available the pump head that will be generated will also be will also be lower.

(Refer Slide Time: 24:24)



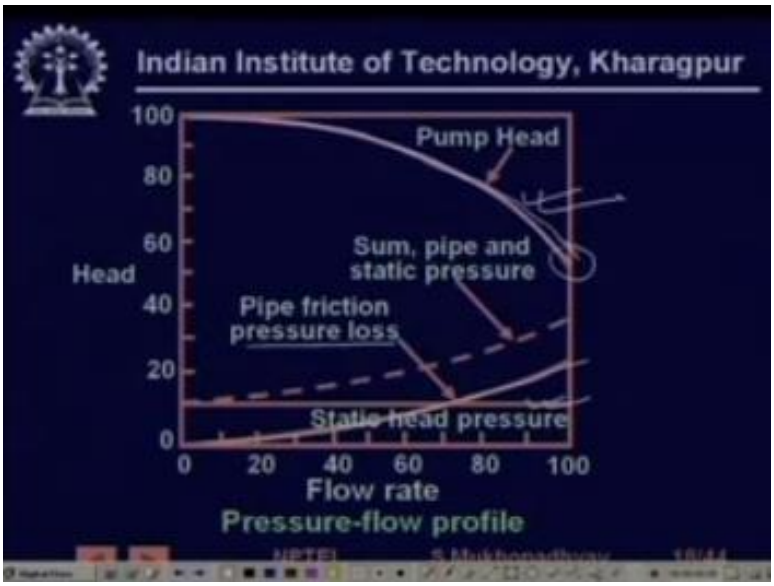
Similarly here we have assumed a static head pressure it may be constant or in some cases even this for example if the fluid is a you know kind of heat exchanger then again the heat exchanger is actually nothing but a intertwined length of pipe so basically the pressure head.

(Refer Slide Time: 24:42)



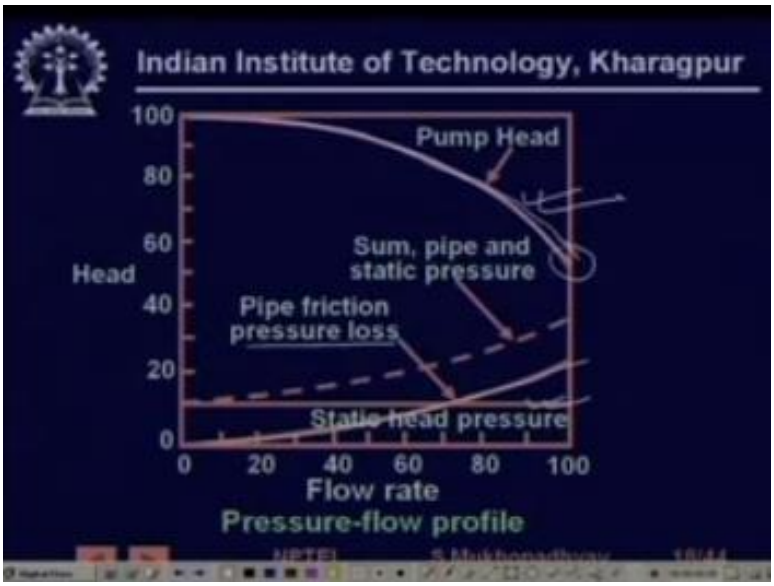
Across the system will also increase with flow so eventually what happens is that see the pump is the prime mover right so the total pump head available is this one.

(Refer Slide Time: 24:54)



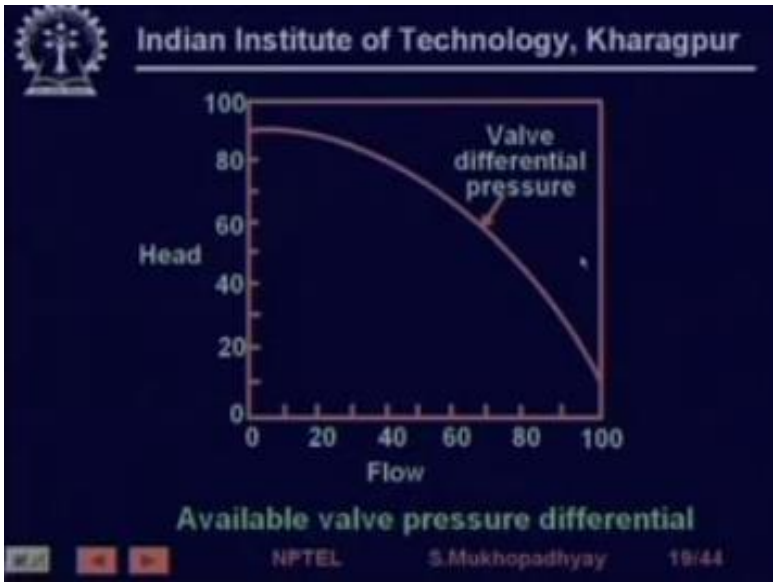
And that must be equal to the sum of the drop in pipes drop in the valve plus drop in the system so as the drop in the valve dropping the pipe and the drop in the system raises here is little less and less ΔP available across the valve and so the flow actually reduces right.

(Refer Slide Time: 25:17)



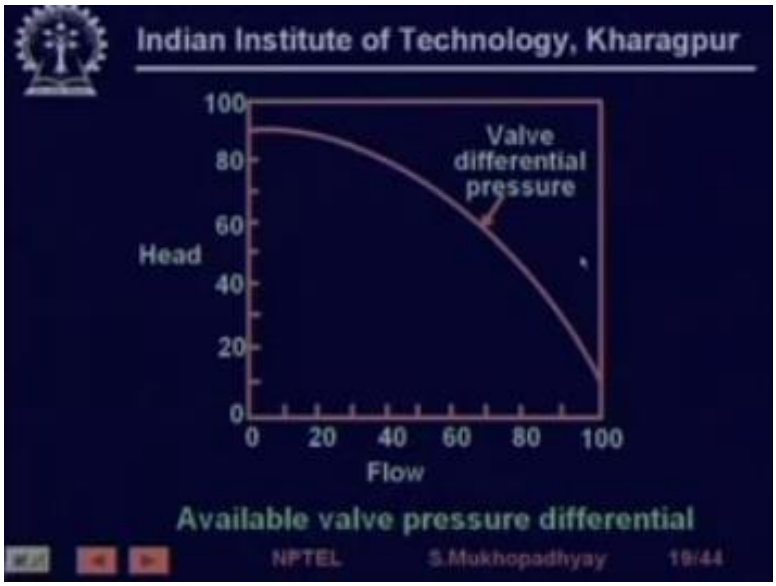
So the operating points that are established will always have ΔP falling.

(Refer Slide Time: 25:25)



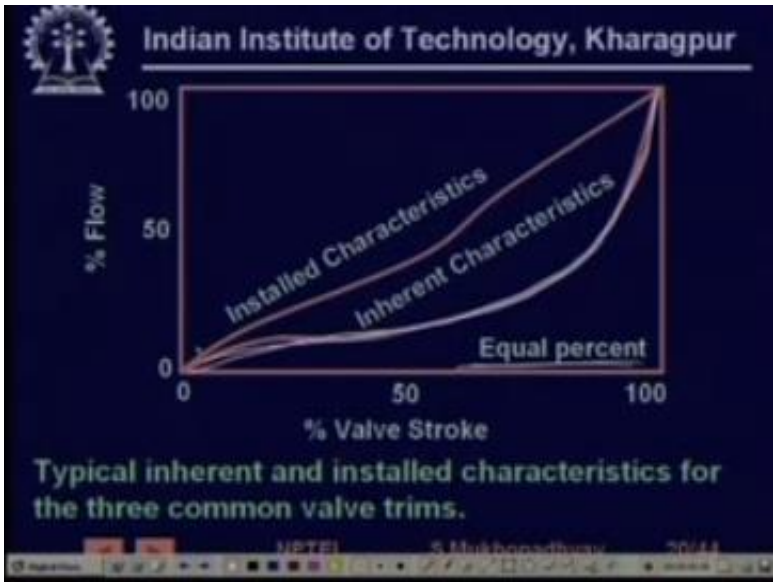
So if all differential pressure available actually falls quite sharply with the flow.

(Refer Slide Time: 25:35)



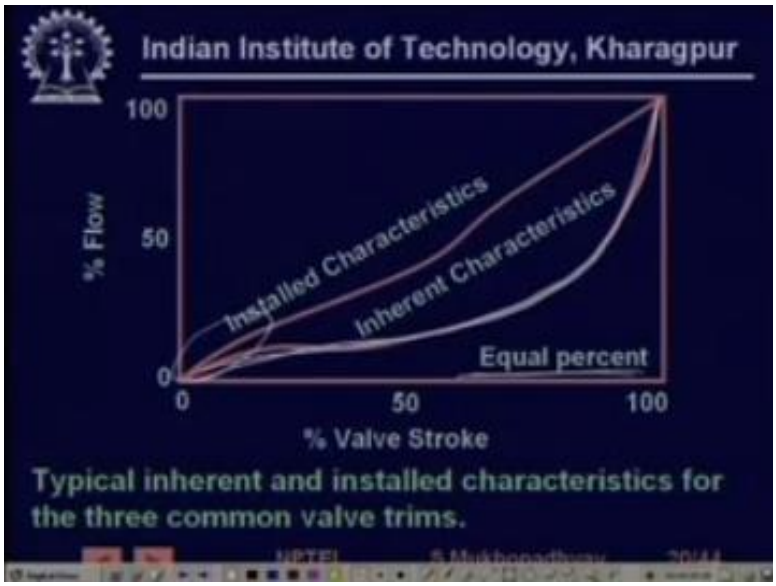
So it is not constant.

(Refer Slide Time: 25:36)



In effect what happens is that for example this is the case of an equal percentage valve at some ΔP so you see that the inherent characteristic is almost like alike 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.

(Refer Slide Time: 26:02)

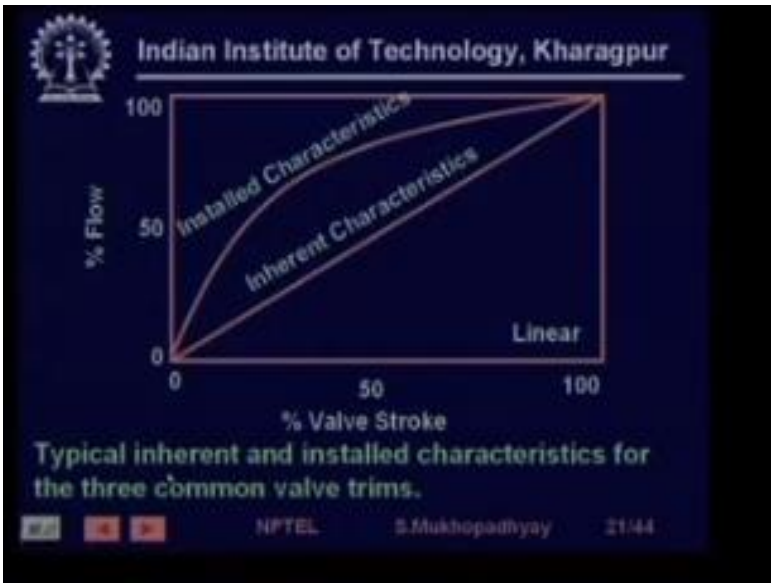


Then initially there is a lot of fresh ΔP available because they will hardly any drop in the flow is low so there is hardly any drop in the system. So the pump so this valve flow with change in lift because δP Available across the valve is now quite high at this stage so the so there is a for a sudden 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 characteristic because of the fact that now the δP has come down so if the δP has come down then for a then for a given change in the lift now so much change which was available she previously when δP held constant I mean a lot of change could be possible by changing a certain part of the lift but now since the dead since the δP is going to fall so therefore so much change is not possible and we get a different characteristic that characteristic is called the installed characteristic and this must be remembered because it is the install characteristic finally which is going to decide the decide the characteristic in the process control.

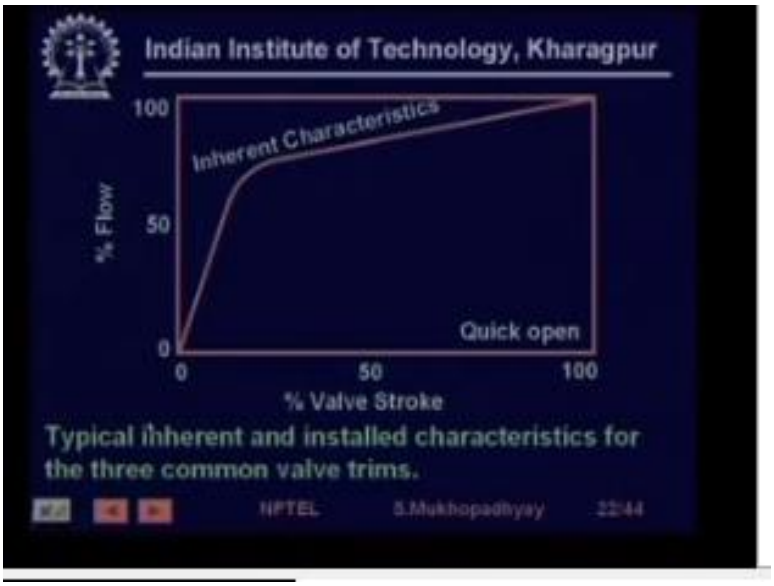
So therefore we must understand that the inherent characteristic gets changed because of pressure drops and the resulting characteristic is called the installed characteristic so the same thing happens for linear valves.

(Refer Slide Time: 27:58)



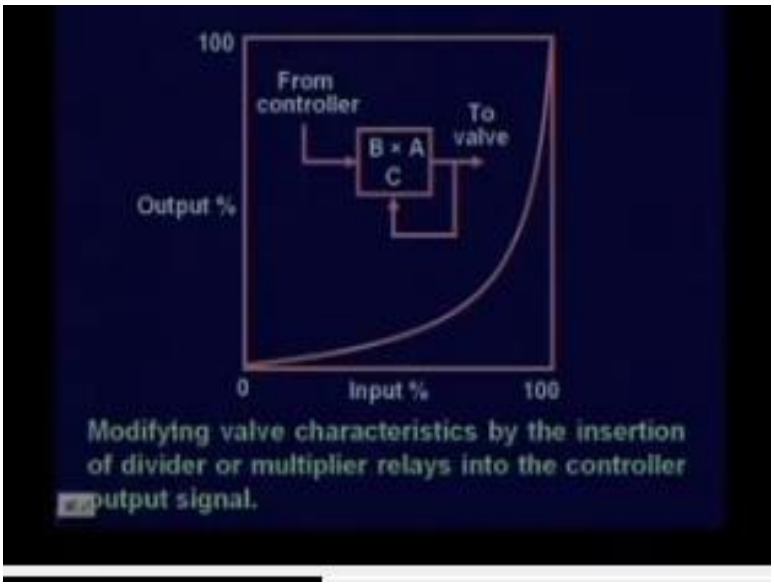
Again there is a high higher than inherently we are assuming the inherent characteristic δP will be will be maintained you know somewhere in the middle of the δP de inch so initially you have high you have a higher δP so therefore the rate of rise is high later on the rate of rise lower than the internet characteristic this is what happens.

(Refer Slide Time: 27:59)



This is the characteristic for inherent characteristic for a this thing and they are not so much used so the install characteristic is actually not drawn.

(Refer Slide Time: 28:07)



Now these characteristics sometimes you know especially when you are trying to design process control application the valves gain the valve gain also comes along with the process game so if so when we want to decide the decide the controller gain then sometimes it is e it is desirable 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 the year this may be a requirement for designing a good controller.

So what I am trying to say is that from the you know there is there is an electronic controller from which output is 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 controller 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, right.

So what we are achieving here is that the see the signal available at the airport is a multiplication of B to C port so suppose this is this is increased so immediately this will increase then, then this will this will also increase and therefore this will increase sharper so what happens is that if you

if you if you change this linearly if that is if the if the input is changed in a linear fashion over time then the output will change in this fashion.

Right so what happens is that effectively actually so if you if you put this really now then what will happen is that a linear valve will start behaving like an equal percentage form so what we what is the message is that by putting such signal processing blocks we can change the valve characteristics I mean depending on the availability sometimes it may not be it may not be easy to locate a valve of that appropriate characteristic on the market but by signal processing after the controller we can always change the valve characteristics right.