Industrial Instrumentation

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Lecture - 38
Control Valve - I

Welcome to the lesson 38 of industrial instrumentation. In this lesson, we will cover the control valve. In fact, this lesson 38 and 39 both will be dedicated to the I mean control valve 1 and control valve 2. Control valve as you know it is a final control element in a process, and it is most important part of any industrial instrumentation. Now, so far we have studied as you know the many sensors which actually measure the process, variable flow temperature pressure and viscosity pH and so on and so forth. Now, all this actual measurement is basically to control some that particular process suppose in the case of temperatures or in the case of flow we have to control the temperature we have set point. So, we our goal is to I mean to make that whatever the set point. I mean determined by the or fixed by the engineers our system should attain that particular value, right.

So, some of the other we need control valve. Now, control valve is basically is a device which will resist the flow of the fluid either liquid or gases through a pipe, right. This is the basic purpose and directly it is controlling the flow indirectly it is controlling the temperatures and any other process parameters, right. Suppose I have a indirect heating of a boiler. So, we are heating it by a super heated steam in that case by controlling the amount of steam also we can raise the temperature and of the boiler. And directly in the case of flow measurement there is no problems we have seen that by changing the flow. That means, there changing the flow through the pipe, I can control it. I can achieve some set point which is pre-determined.

Now, all this I mean basically is to as you can see that this control valve is basically is a variable resistance. It will offer a variable resistance to flow. And why we to we are telling it control valve? Because and there is a distinct difference between the valve and the control valve, because in the control valve signal will come from some controller. And it will offer some resistance either I mean another open the valve stream or it will down the valve stream. So, that I will achieve the, if the desired flow is more I mean then the, what is actually existing? So, that I have to open the valve if the desired existent existence is I mean is less than the I mean more then I have to close the valve. So, if we can do it manually, but in the case of control valves it is done automatically right. So, let us study this control valve in details. Lesson 38 control valve 1 the contents are.

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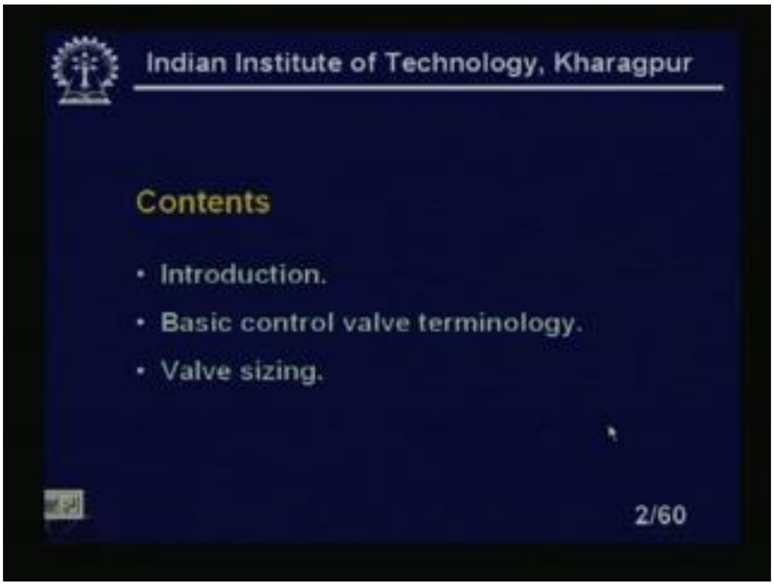

Introduction to the control valve and basic control valve terminology then you have valve sizing, because the valve sizing is also important.

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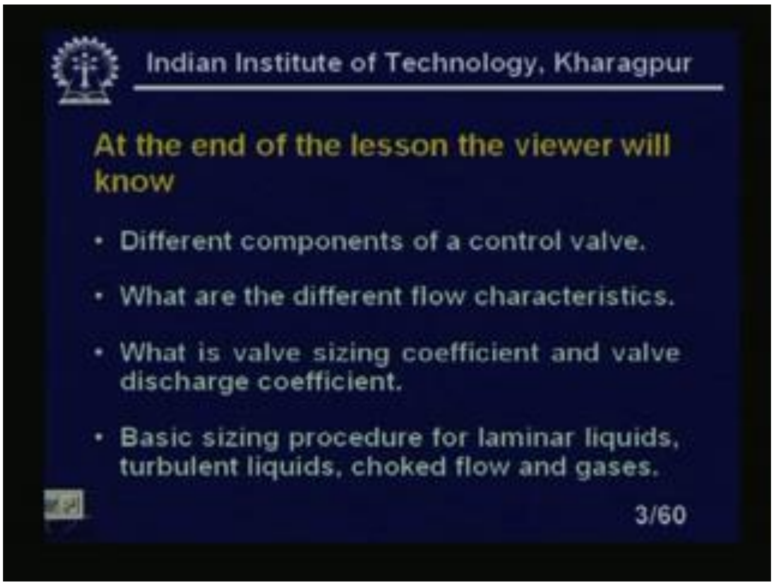

Now, at the end of the lesson the viewer will know the different components of a controller. What are the different components? What are the different terminologies?

You must know first then we will go for the other details construction. What are the different flow characteristics? We can achieve in a control valve we will find there are 3 different characteristics we will achieve in the control valve. What is the valve sizing coefficient and valve discharge coefficient? These are 2 important parameters for designing a control valve. This also we will know basic sizing procedure for the laminar liquids and turbulent liquids and chocked flow and gases. Chocked flow you will find as the most of the cases the flow is chocked. So, it is called chocked flow. And also for the gases because all these thing. We are not considering the solids here we are at best we can consider the suspended particles in the liquid. So, this we will cover in details let us look at the introduction.

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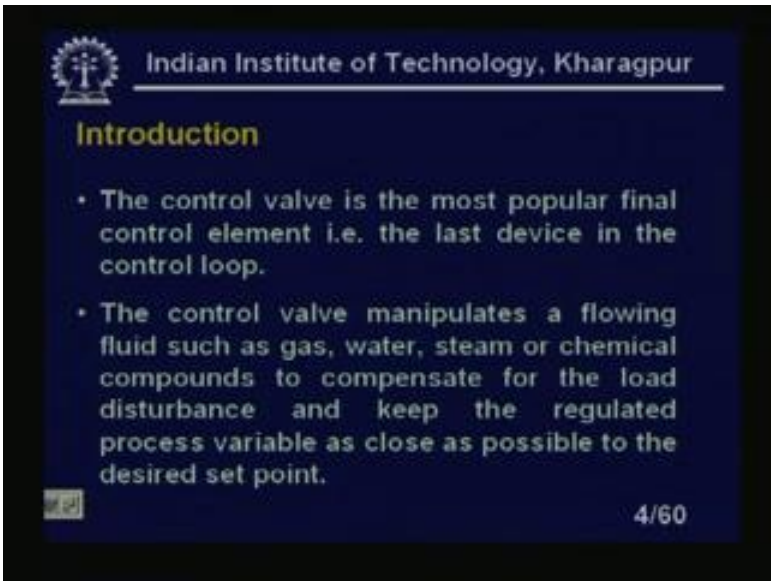

The control valve is the most popular final control element. That is the last device in a control loop right; that means, I am measuring with some sensor, suppose I have a flow meters. So, flow meters in the case of orifice meter, venturi meter or any other meter, but ultimately to control the flow in the pipe I need a valve. So, it is basically a final control element. I will measure the flow actual existing flow it is if it is more than the set point. So, I will I will close the I mean I will reduce the flow through the pipe by the control valve if it is less than the desired value, so I will open it. So, that the more flow can go, so ultimately, so that is the reason we are calling it a final control element in the any process.

The control valve manipulates a flowing fluid such as gas water stream or chemical compounds to compensate for the load disturbance, and keep the regulated process variables as close as possible to the desired set point. Now, this question my come several times I am saying that the if it is more if it is less, why it will be like this one? Because I have a set point it is not a. So, I know that the flow should be suppose 10 to the power 3 liter per hour. So, why should it change? Because I have already set points I have a some pump which is flowing to the I mean which is pumping the liquid to the pipe. So, why should it change? It will change due to the load disturbances, due to the load disturbances if it changes. So, I have to open the control valve I have to close the control valve. So, that the whatever the desired flow of liquid. What are the set points did there? So, liquid should flow accordingly through the point, right.

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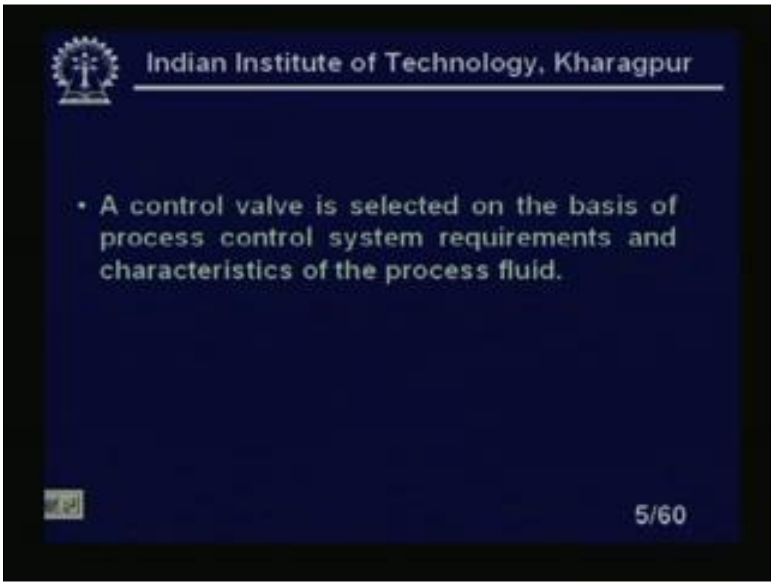

A control valve selected on the basis of the process control system requirements and the characteristics of the process fluid, right. There are different types of control system requirements. First of all you will you have to look at and we have to look at the process. What type of fluid it is whether it is a clean fluid whether it is a dirty fluid whether it is a very highly viscous fluid. So, all this depend I mean considerations we have to keep in mind to choose a control valve, or control valve characteristics I should say.

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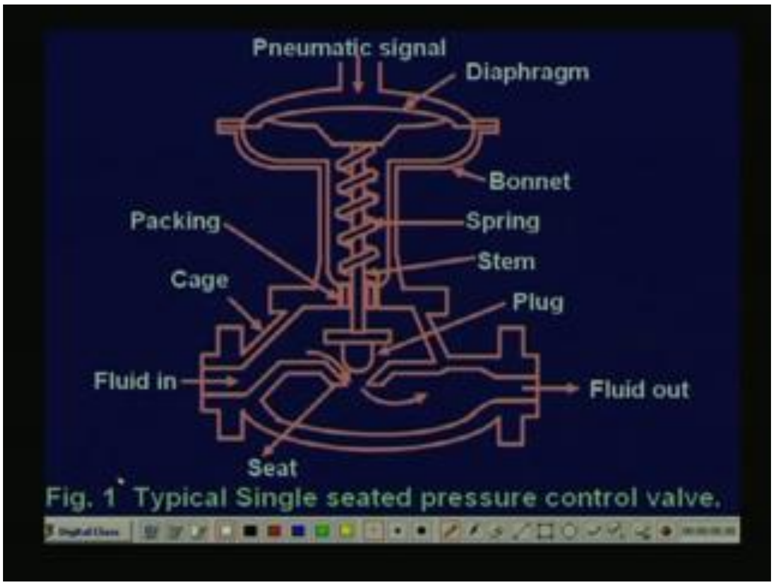

Now, you see this is a basic control valve you can see here, you see this is a control valve. Now, you see here that we have a pneumatic control valve, I mean we have a bonnet here. You see here there is a diaphragm and let me take a different color. I have a diaphragm here, and this is called you see this is called the plug of the control valve. The liquid fluid is coming either gas, I mean or anything is coming through this and it is going out through this one, right. And you there here that there is a there is a plug and this is called the seat of the control valve. This is called the seat this is plug and this vertical I mean this is called the stem of the control valve you see this portions. I am talking about this is this portion this is called the stem of the control valve, you can see here this is called the stem of the control valve.

Here you see there is a packing this packing is necessary. So, that the valve this stem can move only in the vertical directions, as well as it will resist the flow of the fluid through this portion. Liquid will flow from this one according to the opens it will come to this 1 and it will fluid out it will go out like this one, clear? And we have a bonnet here. A spring is necessary, because when you when it is removed when the pressure is removed; that means, when you if you if the pressure from this pneumatic signals is removed. So, valve should this stem should go to it is previous position. This type of valve you can see it is called air to close. Because air is to be come through pneumatic signal will come through this 1 and it will close it. So, it is called air to close valve right and this is a cage and this is a packing as I told you this is the spring which is needed to. I mean move the stem of the control valve to the position when it was normally when there is no pneumatic signal there.

So, this type of say I mean control valve when there is no pneumatic signal. So, the valve will be fully opened. So, to give the full pressures once you give the full pressures air and through pneumatic signal. Because this is totally sealed this is circular in shape. So, the seat will be and the valve stem will sit on will come on the seat of the control valve, right. And this is the fluid and liquid is flowing through this one and it is coming out to this one. This is the total details of a typical control valve. Now, there is different shape of this plug you will find that, I mean if we choose a different set shape of the plug. I can get a I mean different types of characteristics that basically linear characteristics, equal percentage characteristics, quick opening characteristics depends on the plug. What is the shape of the plug? We will go through the details of that one.

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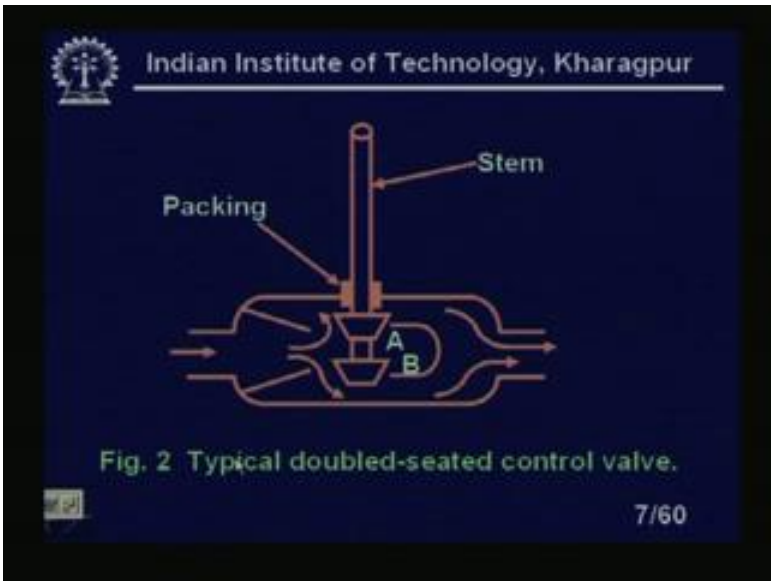

This is the the control valve previously what I have discussed it is called a single seat valve. But here we have a double seat valve, the double seat valve has a some I mean I have not drawn the full. I have drawn only the stem and all these things double seated valve is also necessary for many applications, fine.

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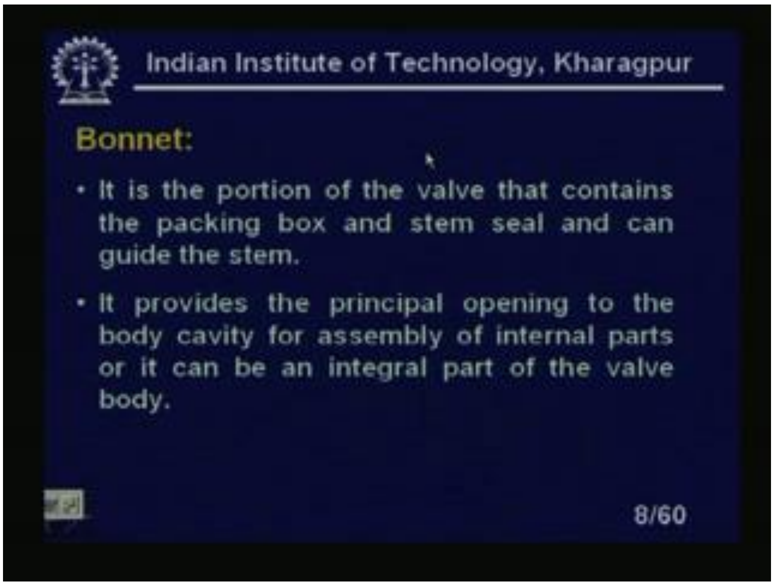

Bonnet it is the portion of the valve that contains the packing box and the stem seal and can guide the system stem, right. As I told you if I look at bonnet, this is the called the bonnet, right. It provides the principle opening to the body cavity for assembly of the internal parts or it can be an integral part of the valve body. It is can be of the integral part of the valve body.

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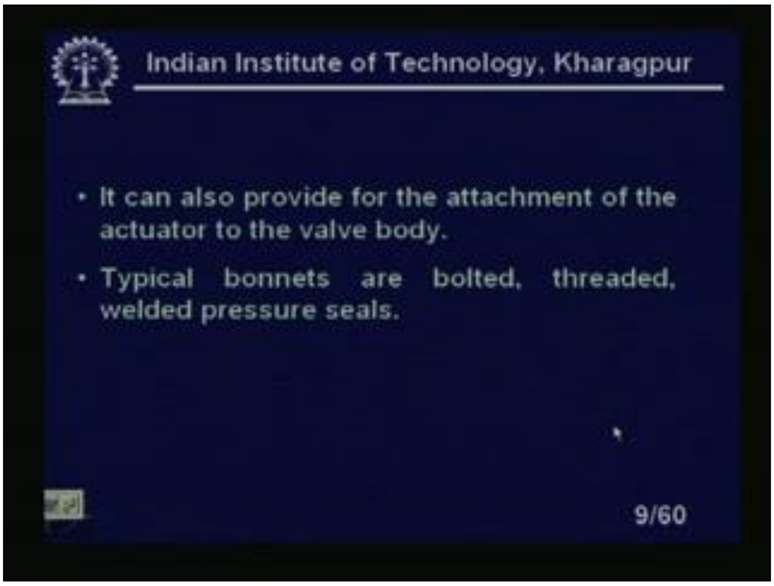

It can also provide for the attachment of the actuator to the valve body, clear. Typical bonnets are bolted threaded and welded pressured seals, because this are totally sealed otherwise there will be a problem.

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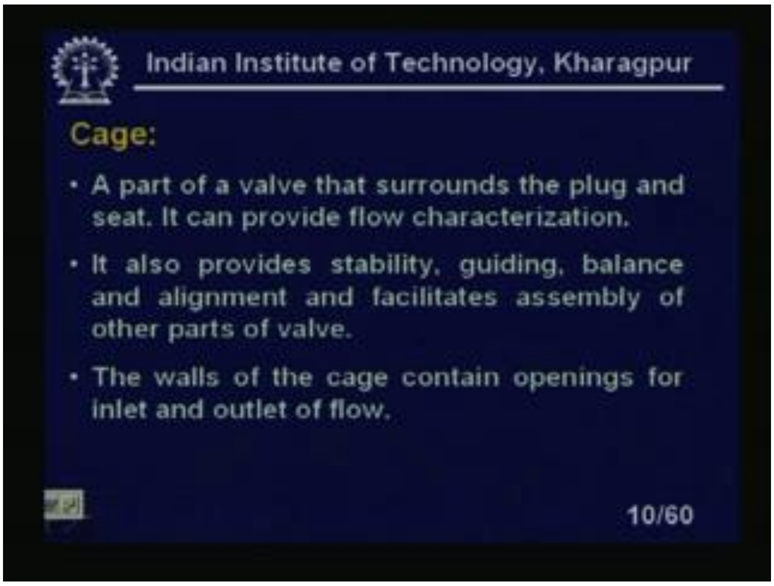

Cage is another part of the control valve. What is cage? A part of a valve that surrounds the plug seat and it can provide the flow characterization, right. So, the plug and the seat, which I have shown several times. So, that is actually contains the that is makes the cage of the control through which the liquid is flowing. It is coming to the coming through the in in path fluid in path and it is going out of the fluid out path, right. So, it can provide the flow characterization what type of I mean I mean characterizations you want that is can be determined by this one. It also provides stability guiding balance and alignment and facilitates assembly of the other parts of the valve, right. The valves of the cage contain openings for inlet and outlet of the valve flow we have shown this one. So, through one it is the inlet the valve is coming and through which the valve is going out.

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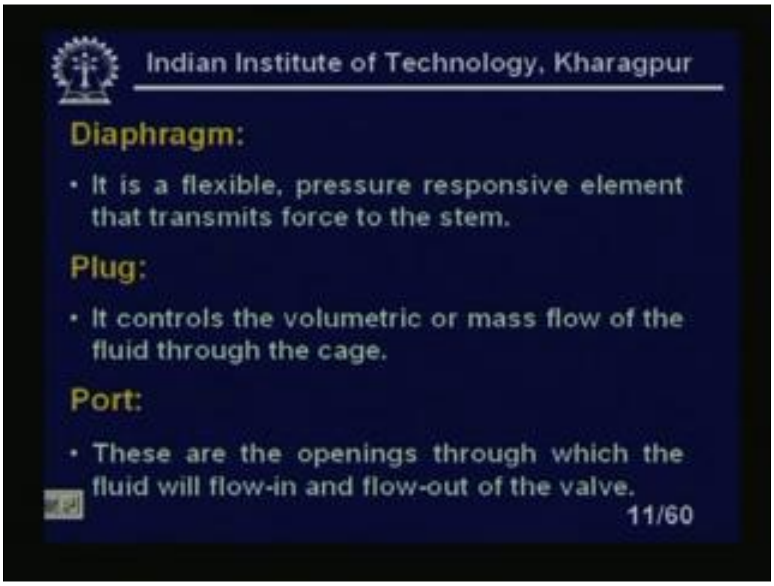

Diaphragm, it is a flexible pressure responsive element that transmits force to the stem, right. It is a flexible pressure responsive element. That transmits force to the stem it is at the top of the control valve, it is steel diaphragm. We have already studied diaphragm gauges all this things. This is basically giving the force to the against the spring which is already in existence to the stem. So, that the stem will move down as well plug will move down it will go and put on the cover the seat of the control valve. Plug; it controls the volumetric or mass flow of the fluid through the cage it controls the volumetric or mass flow of the fluid through the cage. Port; these are the openings through which the fluid will flow in flow out of the valve.

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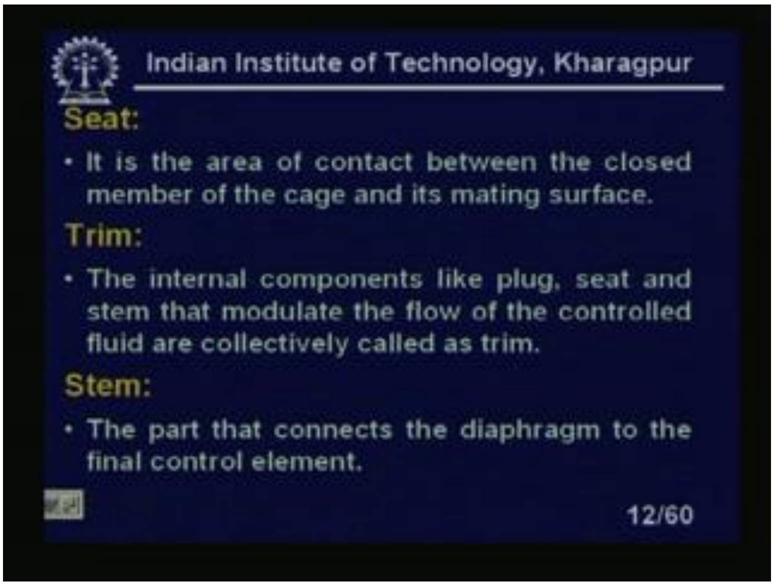

Seat; it is the area of the contact between the closed member of the cage and its mating surface. Already we have shown this seat, actually there is a contact between there is always when the valve when the plug totally rest on the seat that is it is totally closed when it is fully opened. So, that will totally liquid. So, the through the seat actually always the liquid is flowing in between the space in between the space in between the seat and the plug the liquid is flowing through the valve. Trim; the internal components like plug seat and stem that modulate the flow of the control fluid are collectively called as trim. So, the plug seat and the stem of the control valve, that are collectively called as a trim. Stem; the part that connects the diaphragm to the final control element, final control element here in this case of the control valve is the plug. So, the when the plug is connected plug is connected to the diaphragm through the stem. And the stem is surrounded by a spring.

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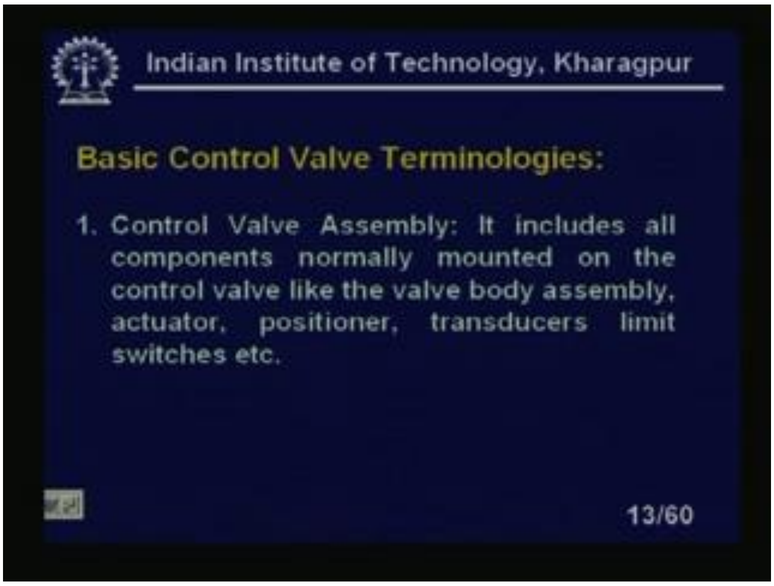

Now, basic control valve terminologies control valve assembly. It includes all the components normally mounted on the control valve like the valve body assembly, actuator positioned, transducers limit switches etc.

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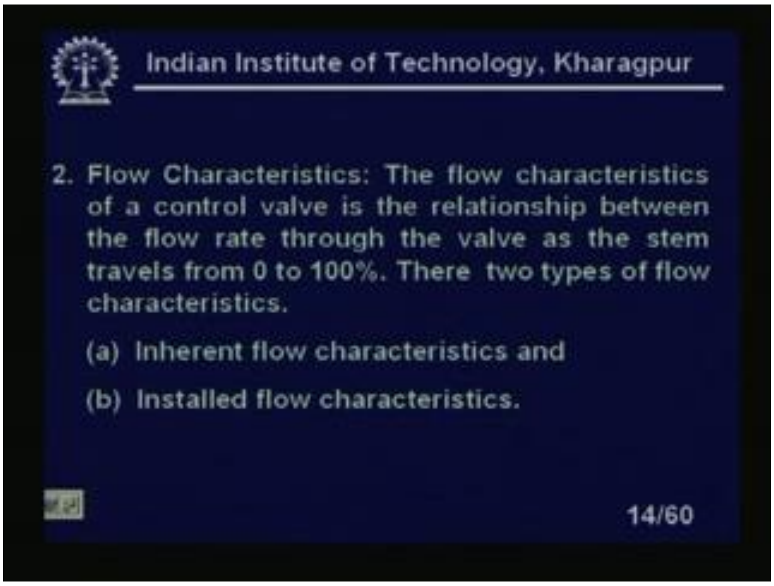

Flow characteristics; the flow characteristics of a control valve is a relationship between the flow rate through the valve as the stem travels from 0 to 100 percent. This travelling of the stem is called in the process control industry we call it the lift of the wall percentage lift of the wall. If the valve is fully opened; that means, it is 100 percent travelled, like this one. That there are 2 types of flow characteristics 1 is a inherent flow characteristics another is the install flow characteristics we will studied this in details inherent flow characteristics we will study more details you will find.

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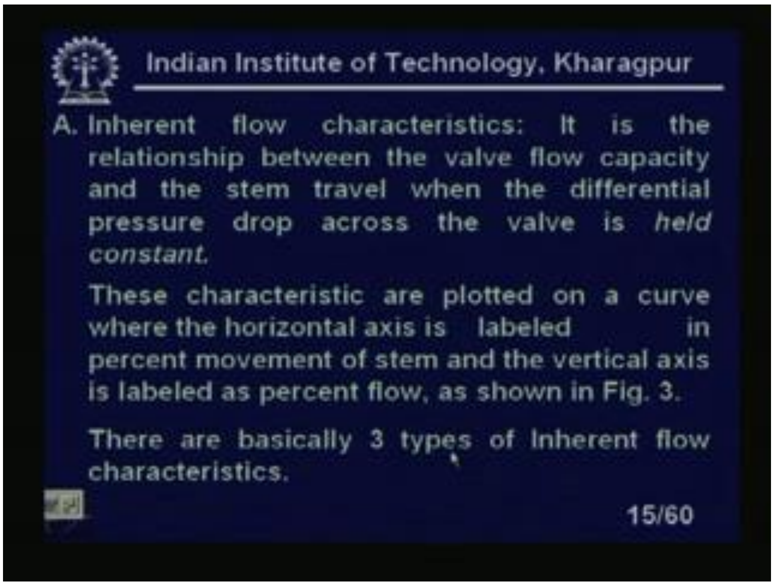

Inherent flow characteristics; it is the relationship between the valve flow capacity and the stem travel when that the stem travel as I told you is repeatedly it is a basically the percentage lift of the stem, right. That is called the stem travel. Stem travel when the differential pressure drop across the valve is held constant, right. I will repeat it is the relationship between the valve flow capacity And the stem travel when the differential pressure drop across the valve is held constant.

These characteristics are plotted on a curve where the horizontal axis is labelled in percentage movement of the stem percent horizontal axis stem and the valve axis. And the vertical axis is labelled as the percentage flow as shown in figure 3. Percentage label or lift as I told you as shown in figure 3.There are basically 3 types of inherent flow characteristics we will find there are 3 types of basic inherent flow characteristics these are equal percentage linear and the quick opening. We will show we will see this in details.

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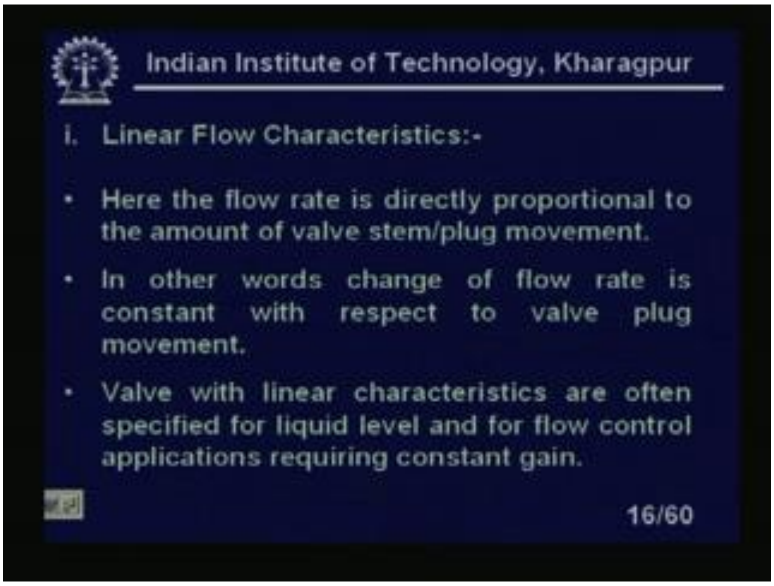

Linear flow characteristics, here the flow rate is directly proportional to the amount of valve stem plug movement. There is no there is a direct I mean relationship it is a linear. In other words change of flow rate is constant with respect to valve plug movement. It is the linear curve there is nothing much to say. Valve with linear characteristics are often specified for liquid level and for flow control application requiring constant gain. If you need a constant gain that type of things in that type of situations I need this type of linear characteristics.

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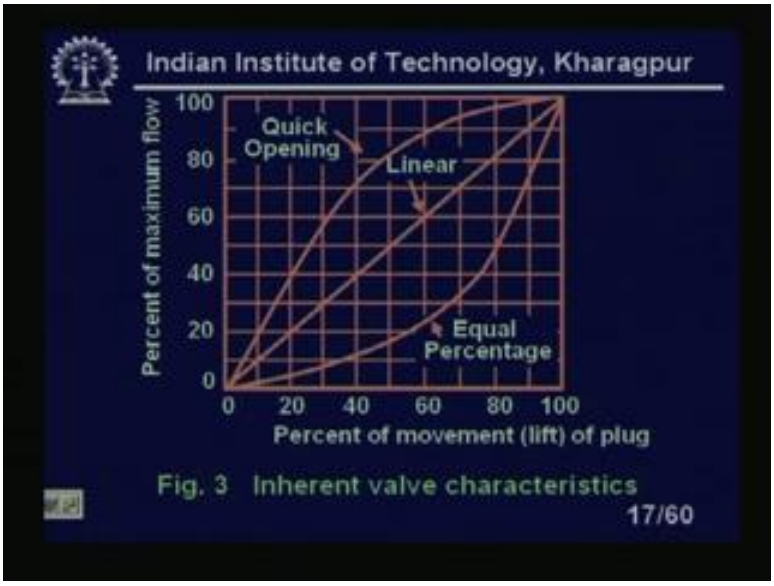

We see here, that is you see it is equal percentage valve equal percentage characteristics. This is a linear characteristics gain is same in all places and where is this is a quick opening characteristics. Here is a percentage percent of movement lift of the plug and there is a percent of maximum flow it is a 100 percent flow this is 100 percent lift hundred percent movement of the plug. So, obviously, when the valve will be fully opened, the stem is fully opened. So, the there should be hundred percent flow of the lift through the valve. So, this is the inherent flow characteristics valve characteristics of the control valve.

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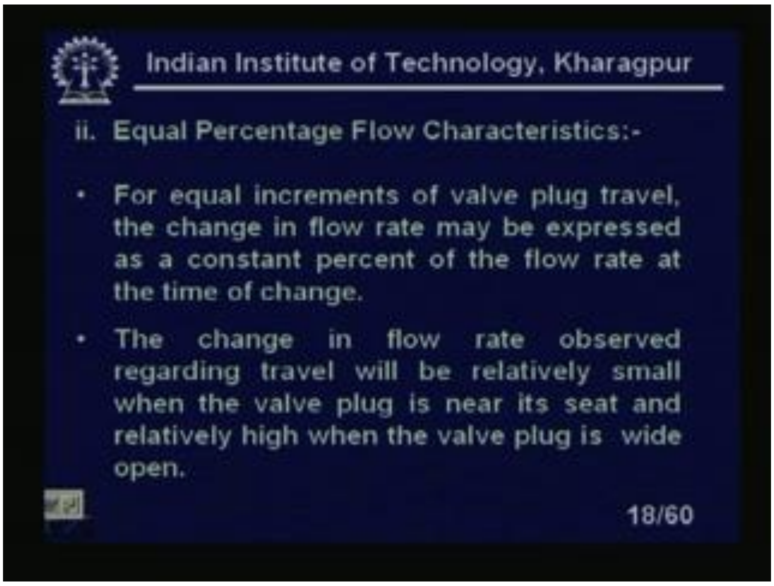

Equal percentage flow characteristics, we have already discussed the linear characteristics let us look at the equal percentage characteristics. For equal increment of the valve plug travel for the change in flow rate may be expressed as a constant percentage of the flow rate at the time of change. Gain is not same, but it is equal increment valve plug travel valve plug travel. The change in the flow rate may be expressed as a constant percent of the flow rate at the time of change. The change in flow rate observed regarding the travel will be relatively small when the valve plug is near its seat, and relatively high when the valve plug is wide open. So, near the seat it is low and when it is valve plug relatively high when the valve plug is wide open.

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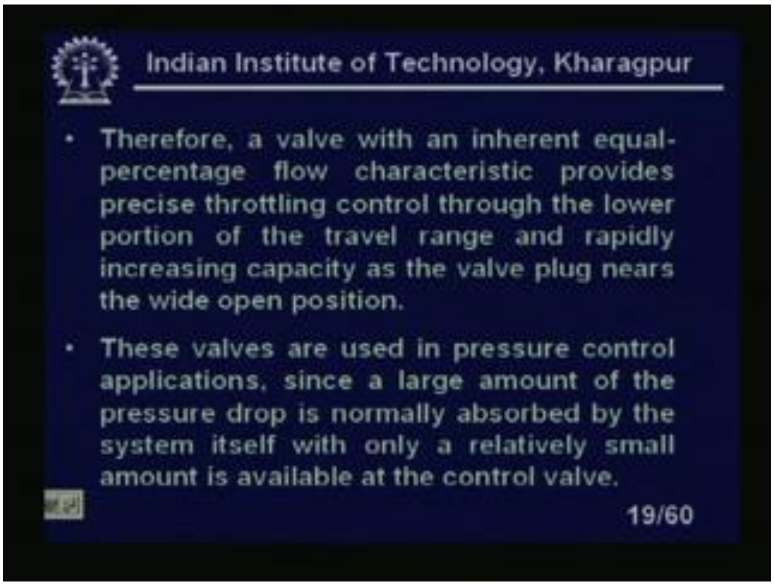

Therefore a valve with an inherent equal percentage flow characteristic provides precise throttling control through the lower portion of the travel range and rapidly increasing capacity as the valve plug nears the wide open position, clear? These valves are used in pressure control applications. Since, a large amount of the pressure drop is normally absorbed by the system itself with only a relatively small amount is available at the control valve. This is applications because there is a various kinds of applications as I told you for the pressure control. So, this type of equal percentage valve will be more acceptable. You can see the characteristics how the characteristics looks like as I told you.

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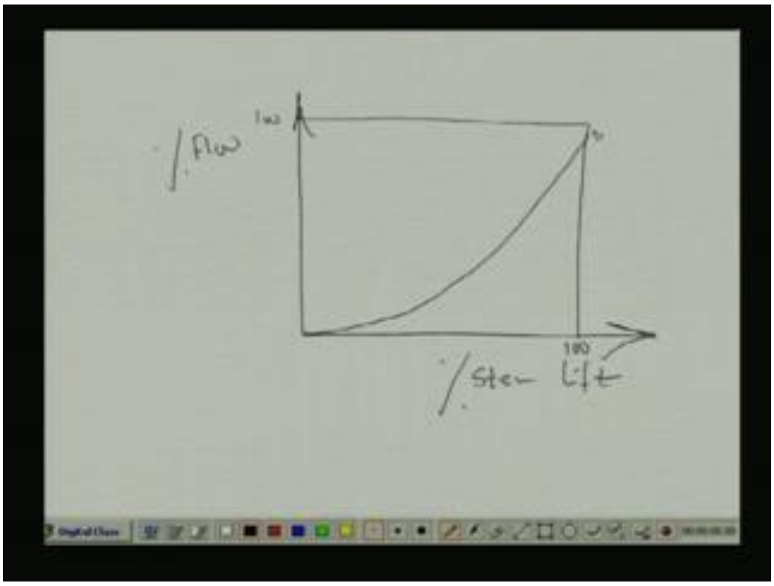

If I take a blank page it will look like, this is our stem movement or stem lift. This is our flow percentage flow percentage lift. So, characteristics will be like this 100 percent, this is 100 percent of the lift 100 percent say characteristics of the lift of the stem. So, that is the reason we call it equal percentage. Percentage will be equal at that point of the stem lift, clear. These valves are used in pressure control applications. Since, a large amount of pressure drop is normally absorbed by the system itself with only a relatively small amount is available at the control valve.

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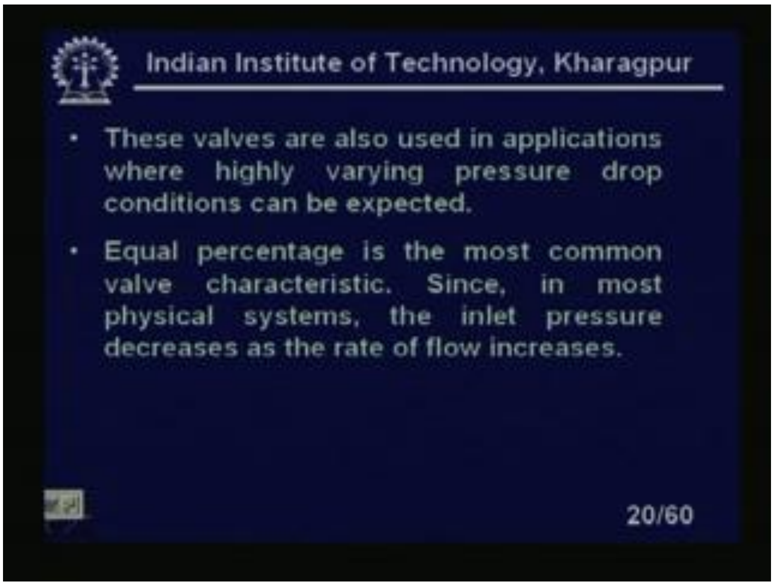

These valves are also used in applications where highly varying pressure drop condition can be expected. So, different applications are there where we are using this type of different types of controller. Equal percentage is the most common valve characteristics. Since, in most physical system the inlet pressure decreases as the rate of flow increases as the rate of flow increases inlet pressure decreases. So, that will be it will be suitable for that type of applications.

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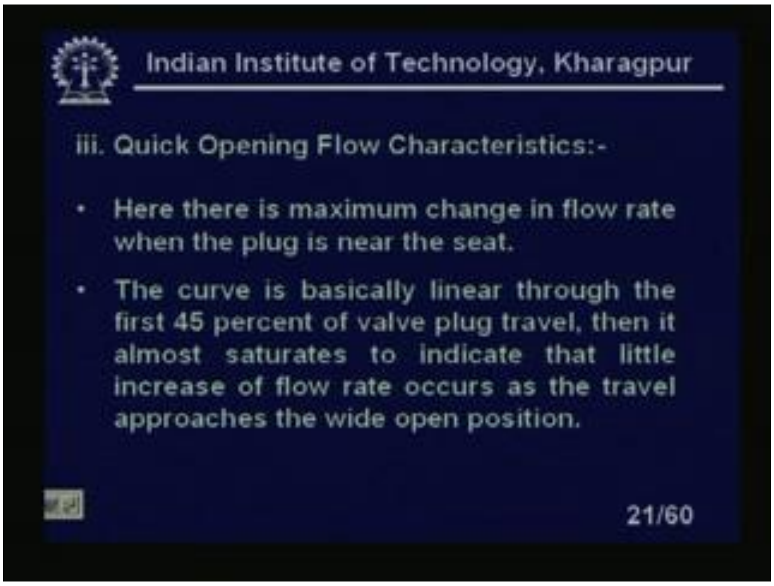

Now, third one is a quick third one of inherent valve characteristics is a quick opening flow characteristics. What is this? Let us look at. Here there is a maximum change in flow rate when the plug is near the seat. And total and slowly it will get saturated, clear. However it is very simple you see here.

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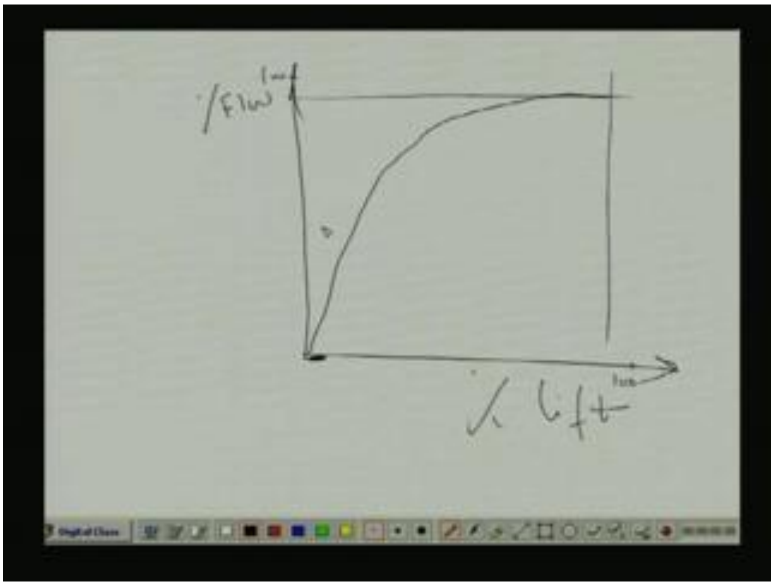

In the case of quick opening I mean percentage lift of the stem and there is a percentage flow is 100 percent this is 100 percent, right. So, at the initially there is a large change slowly it will saturate like this one. For a small change here, if small change of the lift there is a large change of flow slowly it will saturate in many applications we need this type of valve characteristics. So, please note that we have 3 types of inherent valve characteristics one is the linear characteristics in some applications we need it if the gain is equal. Whereas, equal percentage of particular point of lift the percentage the percentage of the valve opening will be percentage of the flow will be I mean equal.

And in the case of quick opening that the initially it is when the valve is very when the seat seat is very near to the plug. Plug is very near to the seat you will find there is a large flow and whenever the plug is coming out going far from the seat as it move as we move the stem upward. So, there will be a little change of the flow, even though there is a change in the stem position. That is basically quick opening characteristics. Here there is a maximum change in flow rate when the plug is near the seat. The curve is basically linear, through the first 45 percent of the valve plug travel. Then it almost saturates to indicate that the little increase of flow rate occurs as the travel approaches the wide open position. All is very nicely drawn in figure three you can look at.

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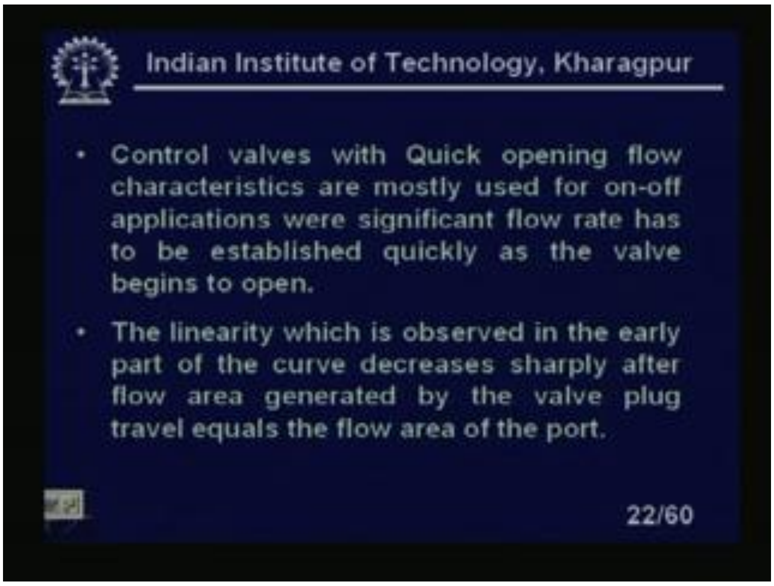

Control valves with quick opening flow characteristics are mostly used for on-off applications were significant flow rate has to be established quickly as the valve begins to flow right in on-off characteristics we need this type of thing. The linearity which is absorbed in the early part of the curve early part of the curve decreases sharply after the flow area generated by the valve plug travels equals to the flow area of the port, right.

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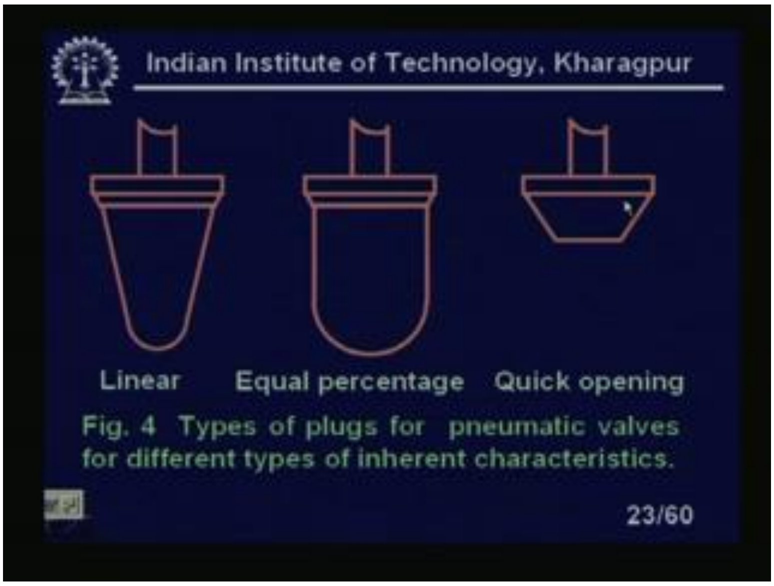

This is the actually the plus as I told you earlier that the, this is the actually shape of the plug. Seat will remain same shape of the plug will give us this different flow characteristics right flow characteristics I mean through the versus the lift of the stem. So, all the flow characteristics are in corresponding to the lift of the stem, actually. And the x axis we have drawn the lift of the stem is basically the movement of the plug is not it. So, the movement of the plug we are plotting in the x axis percentage movement of the plug. We are plotting in the x axis and percentage of the flow we are plotting in the y axis. Now, you see this all this actually basically all this linear equal percentage and as quick opening depends on the type of plug, how will you shape the plug though seat will remain the same. This is the linear you see this is the linear characteristics. This is a equal percentage and this is a quick opening, right. So, these 3 actually characteristics this is different shape of the plug will give us a different flow characteristics inherent valve characteristics, clear?

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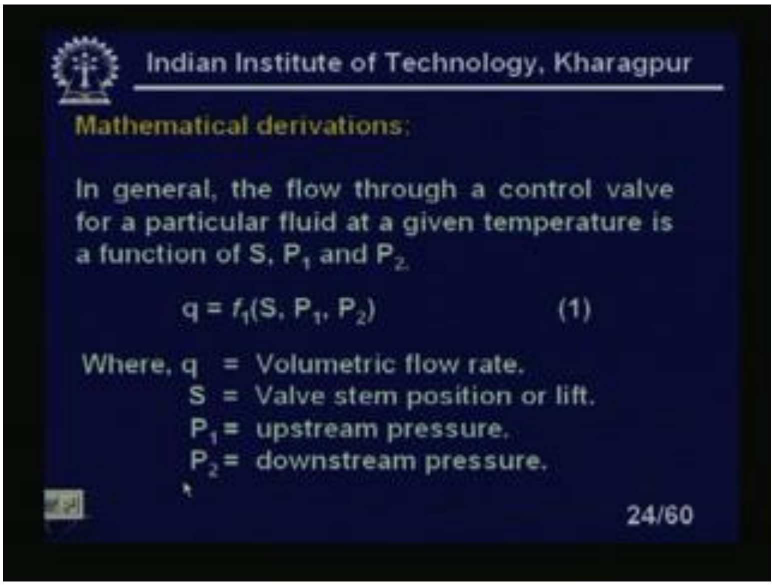

Mathematical derivation; let us look at the mathematical derivations. In general the flow through a control valve for a particular fluid at a given temperature is a function of S P 1 and P 2. Let us look at the legend. Q which I am saying that the the flow at any particular flow rate or volumetric flow is equal to the function of S P 1 P 2. What is S? Let us look at where q is the volumetric flow rate S is the valve stem position or lift stem position stem movement lift. These are all basically same in many process book you will find we have to expressed as a percentage lift or basically here for the use of I mean understanding I am writing as a stem movement, clear? So, stem movement and lift please note these are 2 same thing. Then P 1 is a upstream pressure of the valve, because liquid is flowing through the restriction there will be a pressure drop across the valve please note there is a sufficient I mean pressure drop across the valve. So, in the P 1 and P 2 P 1 is the upstream pressure and P 2 is the downstream pressure. That means that in pressure static pressure of the liquid and the upstream at the inlet. And is, at the static pressure of the liquid or fluid at the outlet of the control valve, right these are we are designating at P 1 and P 2 respectively.

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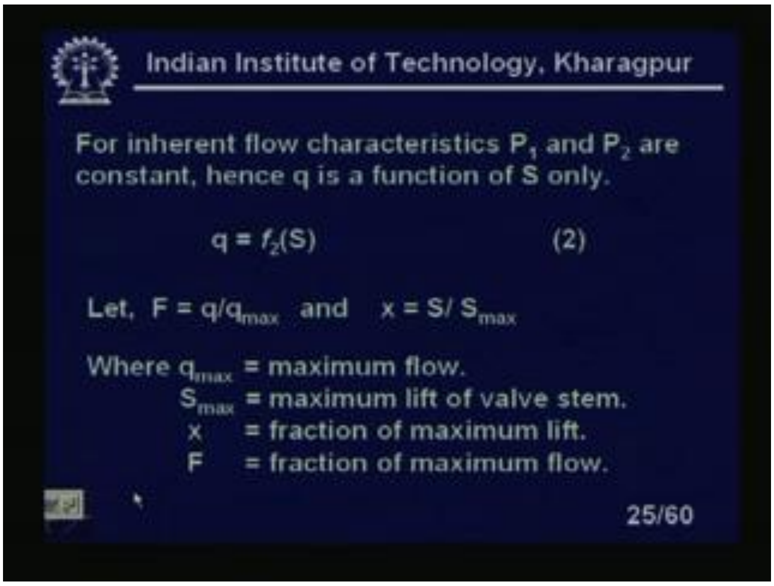

For inherent flow characteristics P 1 and P 2 are constant. Hence q is a function of S only. If the pressure drop is constant, say I can say this is constant. So, q the volumetric flow rate will depend on S; that means, q is a function of S. What is S? S is the valve stem movement or movement of the plug, clear? Now, I suppose that if I introduce a factor capital F equal to q upon q max q q max and x equal to S by S max. So, what is about this? Where q max is the maximum flow and q is a flow at any instant of time.

So, this n is variable depends if it is variable depending on the I mean position of the stem or particular liquid I mean amount of liquid is flowing through that. S max is the maximum lift of the valve stem and x is a fraction of that. So, ratio if you take the ratio. So, it will give you the percentage of the flow right percentage of the lift x is the percentage of lift. And F is actually the percentage of flow right when q equal to q max F will be 100 percent and x when S equal to S max x will be 100 percent. That means, valve has totally open valve is totally open, x is the fraction of the maximum lift and F is the fraction of the maximum flow, clear?

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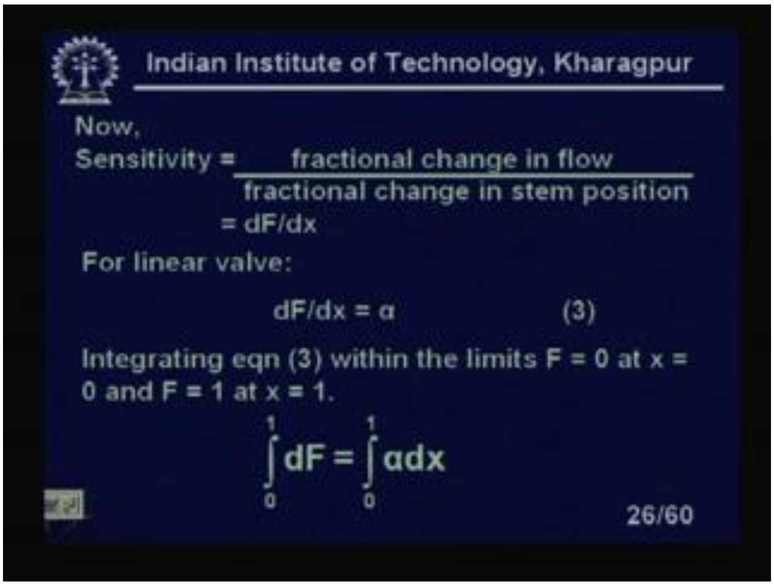

Now, sensitivity we define as the fractional change in flow upon fractional change in stem position. Fractional change in flow upon the fractional change in stem position will give you, the dF by dx derivative of F with respect to x. For linear valve dF by dx equal to alpha, dF by dx equal to alpha for linear valve equation number 3. Integrating equation 3 within the limits F equal to 0 at x equal to 0 we are assuming that that at at 0. That means, when the valve is totally shut off there is no flow and F equal to 1 at x equal to 1. F will be maximum flow when x x maximum value of x can be only the 1, is not it? Because when the totally valve is moved up the stem is moved up. So, that is 1 fully open 100 percent open at that time the flow is 100 percent. So, of F is; obviously, one right. With this limit I can write integral dF 1 integrations of dF derivative of F integration from 1 to 0. Because F can vary dF can vary only from 1 to 0 into alpha in to dx where the limit is 1 to 0 again.

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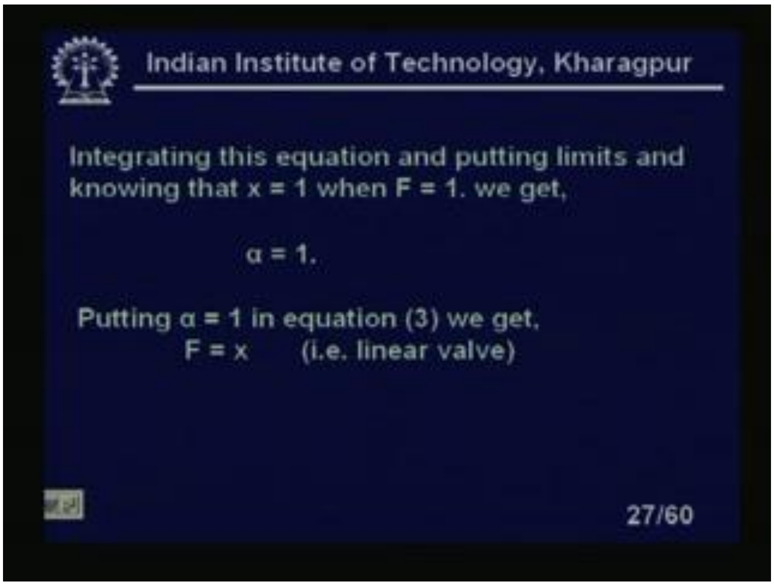

Integrating these equations and putting the limits and knowing that x equal to 1 excuse me and F equal to 1 we get alpha equal to 1, right. Putting alpha 1 in equation 3 we get F equal to x. So, this is the linear valve right. So, this is the relation when the I mean will make like this 1. So, the F equal to x; that means, for any position, whenever I am getting some position. So, F by x is always a constant please note for any position the amount of flow if you divide it. So, the gain will be constant. So, it is the linear valve.

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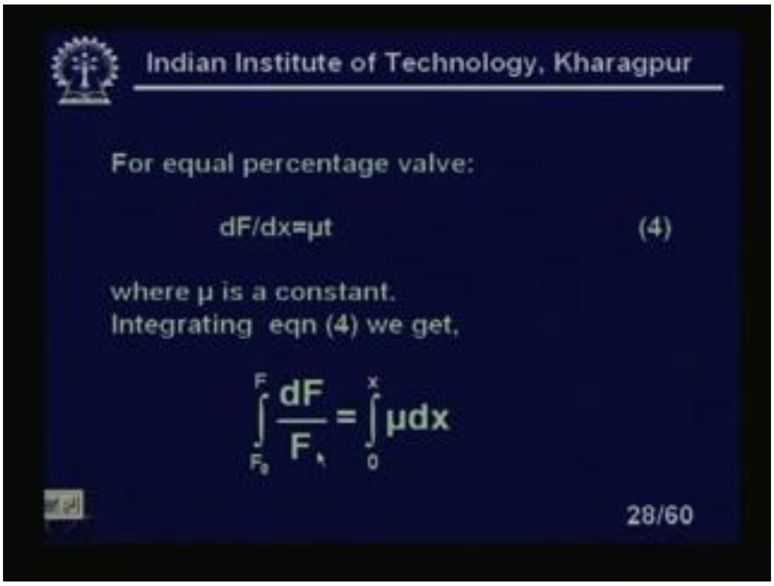

Now, for the equal percentage valve it is slightly different we are defining as d derivative of F with respect to x. That means, derivative of flow with respect to fraction of the flow with respect to fraction of the stem position will be mu in to t where mu is a constant integrating equation 4 we get dF by F where varies from F to F naught and mu into dx when x to 0, right.

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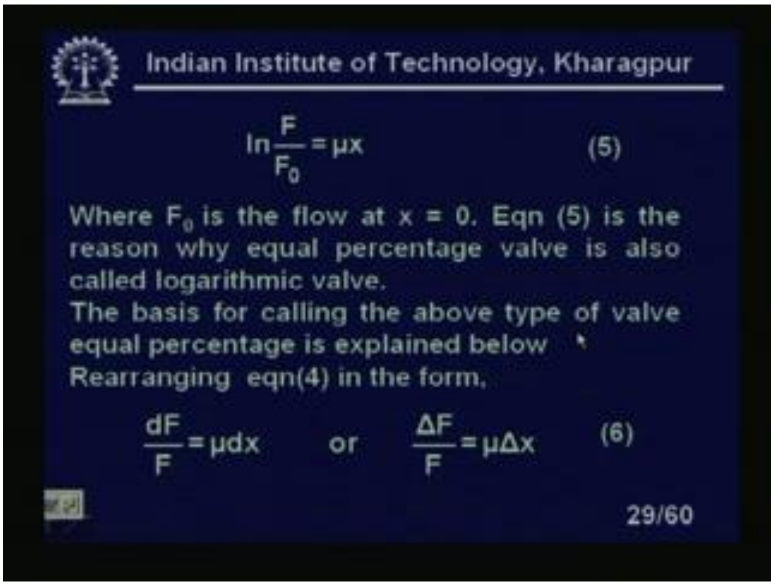

The natural lock if I integrate it will be F by F naught equal to mu into x, right. Where F naught is the flow at x equal to 0. This is very interesting you see the actually the initially the linear valve what we have assumed that is not exactly true. A control valve will never I mean used for totally short of the liquid flow. There will always some liquid flow through the control valve right. So, we are assuming that is special in the single seated valve this always will be true or double seat valve rather I should say this is always true.

That means, x equal to 0 I mean F naught we have to assume otherwise we cannot solve the equation right; that means, at x equal to 0. That means, when the valve is at the minimum position there is still there is not a totally shut off there is a non 0 value of F which is F naught. It is true for most of the practically practically in all the cases of the valve especially double seated valve otherwise we cannot calculate. Equation 5 is the reason why equal percentage valve is also called the logarithmic valve. The basis for calling the above type of valve equal percentage is explained below. Re-arranging equation 4 in the form you see d by dF by F into mu into dx or delta F by F into mu into delta x equation number 6.

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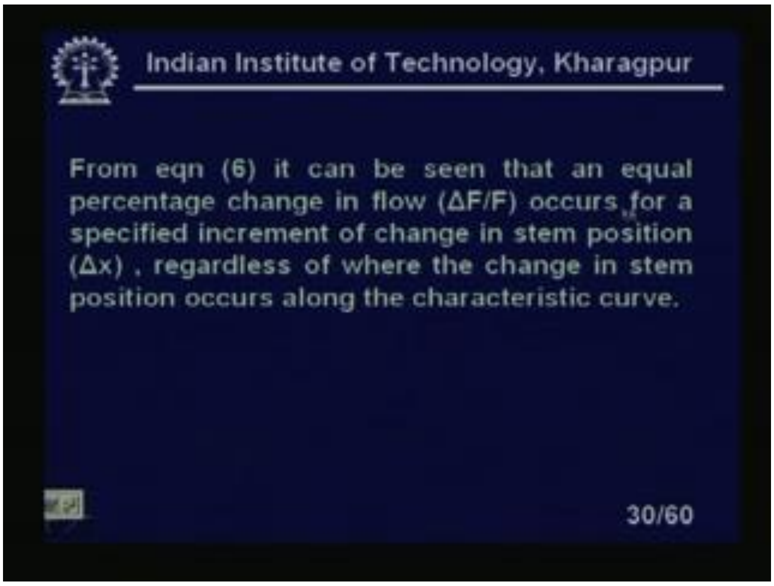

From equation 6, it can be seen that an equal percentage change in flow delta F by F occurs for a specified increment of change in stem position delta x regardless of where the change in stem position occurs along the characteristics curve. It does not matter. So, if I plot it in a similar graph paper what will happen you will find it is a linear characteristics, right. I have drawn in the linear curve, if I drawn in a similar graph paper it will be linear characteristic. That is the reason it is telling that it can be seen that the equal percentage change in flow delta F by F occurs for a specified increment of change in stem position delta x regardless of where the change in the stem position. Let us go back and see.

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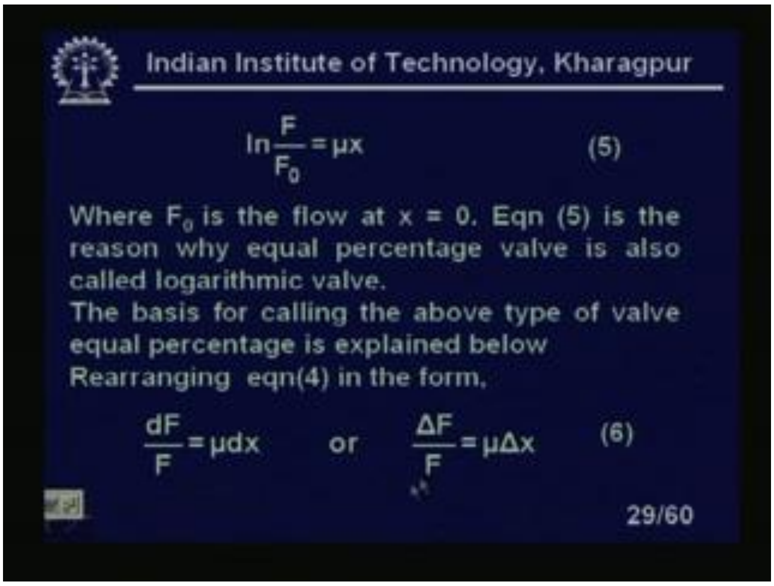

You see here 6 for sorting change in the stem position, percentage change of the flow will be constant mu. Because delta F by F by delta x will be equal to mu, which is a constant, clear? That is the reason we are calling it equal percentage valve, clear?

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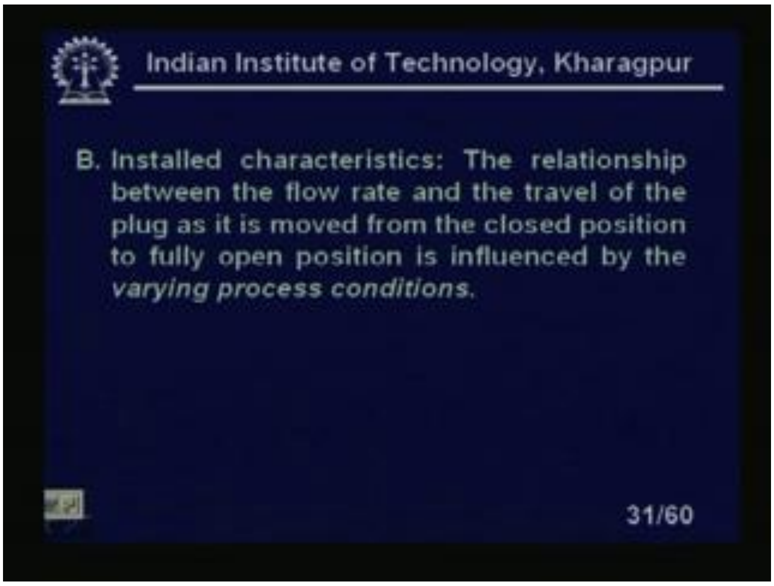

Now, we are talked about the inherent valve characteristics let us come to the installed valve characteristics or install characteristics. The relationship between the flow rate and the travel of the plug as it is moved from the close position to fully open position is influenced by the varying process conditions. This again the process, because so far we have not considered the process condition, but this will also depends on the process conditions, right.

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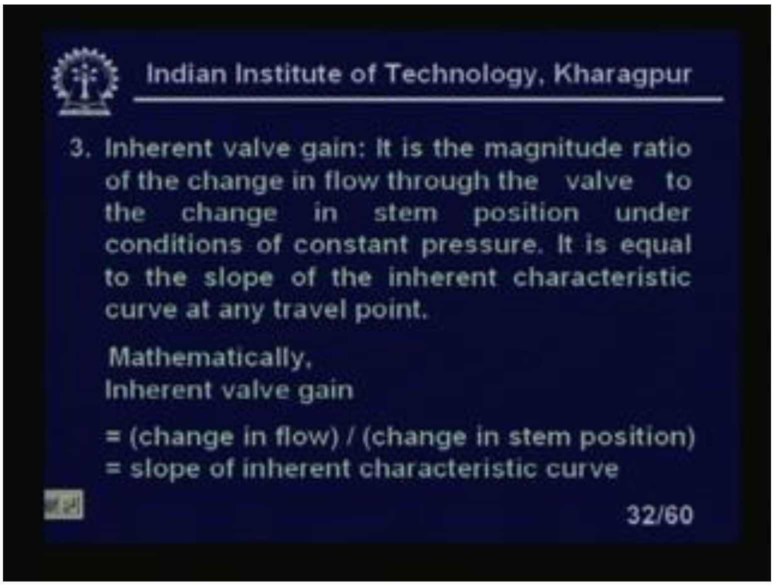

Inherent valve gain, it is the magnitude ratio of the change in the flow through the valve to the change in the stem position under condition of the constant pressure. It is equal to the slope of the inherent characteristics curve at any travel point, right. Mathematically inherent valve gain can be written as change in flow upon change in stem position or change in lift which is the slope of the inherent characteristics curve, right.

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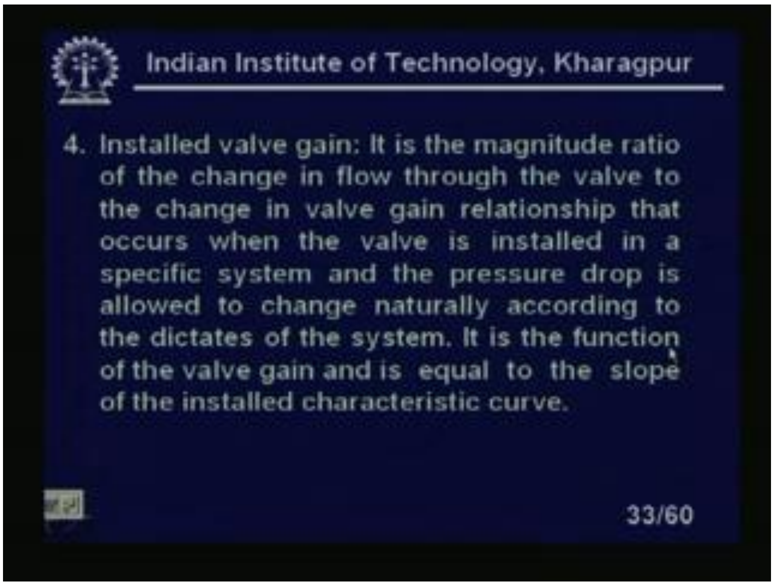

Installed valve gain it is the magnitude ratio of the change in the flow through the valve to the change in the valve gain relationship. That occurs when the valve is installed in a specific system and the pressure drop is allowed to change naturally according to the dictates of the system. Initially we have assumed the pressure drop will remain constant. It is the function of the valve gain and is equal to the slope of the installed characteristics curve.

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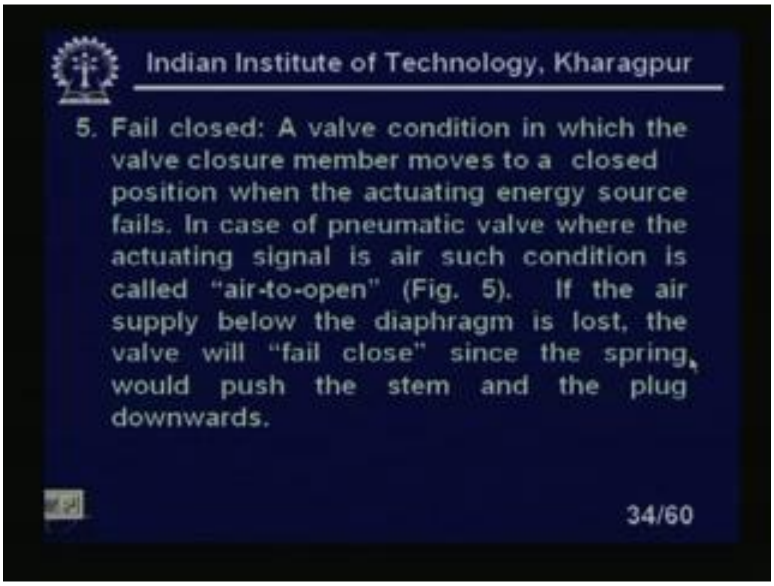

Now, fail closed. So, far we have considered we have seen that the fail open I mean valve, right. So, it is a fail closed a valve condition in which the valve closure member moves to a closed position when the actuating energy source fails. In case of pneumatic valve where the actuating signal is a air such condition is air to open right is called air to open, right. If the air supply below the diaphragm is lost, then the valve will be fully closed fail closed since the spring would push the stem in the valve.

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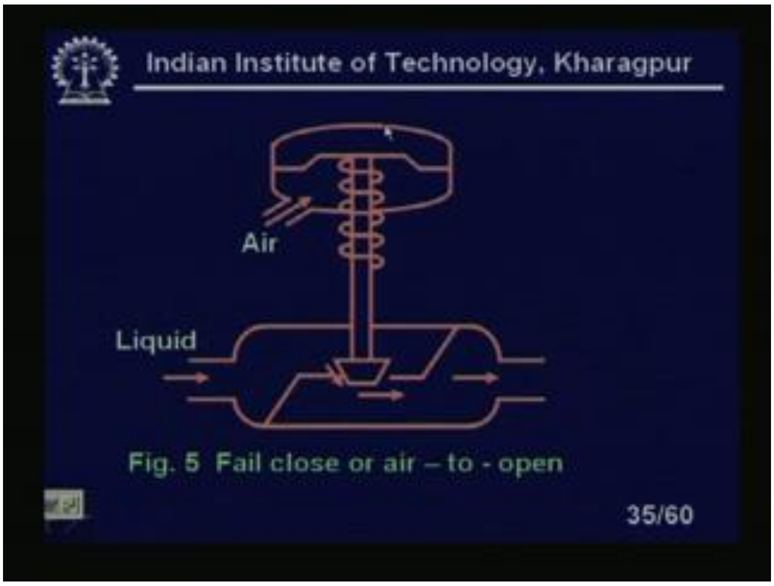

You see here here is spring, so that what will happen you see. If I move the otherwise what will happen you see that valve will always fully open. Sorry if I give a air here, then what will happen this because there is a spring it will try to open, right. So, it is a fail closed or air to open. So, I have to spring will be always closed like this 1. Now, what I have to do I have to give a pressure. So, that it will move up clear? So, this is the air 2 close, because due to spring actions valve will be always closed like this 1 because spring will be always like this one.

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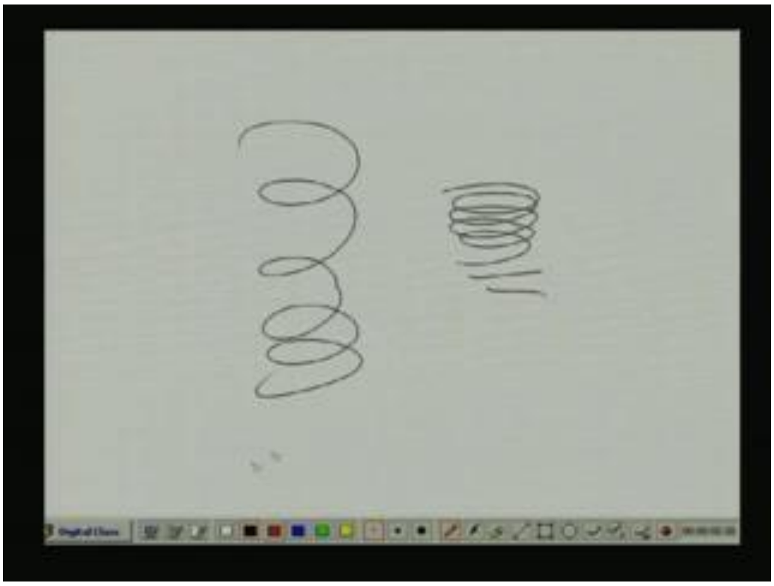

Now, if I put the pressure what will happen? Because the spring will never be in this position it will be always in the squeezed position right, got it like this one spring will be like this one. So, if I give the air spring will be like this one. So, what will happen if this is the position? Let us go back let us see if it is that position what will happen? You see valve will be fully closed now if I put the air. So, valve will be fully open. Now, fail open a condition in which the valve closer member moves to an open position when the actuating energy source fails when the actuating energy source fails the condition. In which the valve close member moves to an open position when the actuating energy source fails. So, it is actually air to close. These are all valve which we have shown and if the air supply above the diaphragm is lost the valve will be fail open. Since, the spring would push the stem and the plug upwards, what how do does it look you see here. What will happen that if the valve if the air supply fails? If the air supply air supply fails the spring will move the valve in the upward position, right. So, it will move in this downward conditions.

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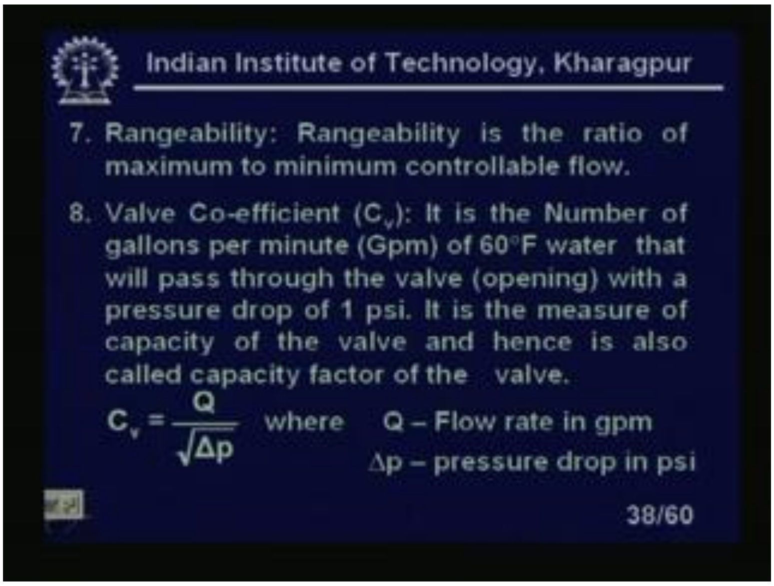

Rangeability; rangeability is the ratio of the maximum to minimum controllable flow, valve coefficient Cv. It is the number of gallons per minute of 60 degree Fahrenheit water. That will pass through the valve opening with a pressure drop of 1 psi. And it is the measure of capacity of the valve and hence is also called the capacity factor of the valve, right. Cv is equal to Q upon square root of delta p where Q will be flow rate in gallon per minute and delta p is the pressure drop in psi.

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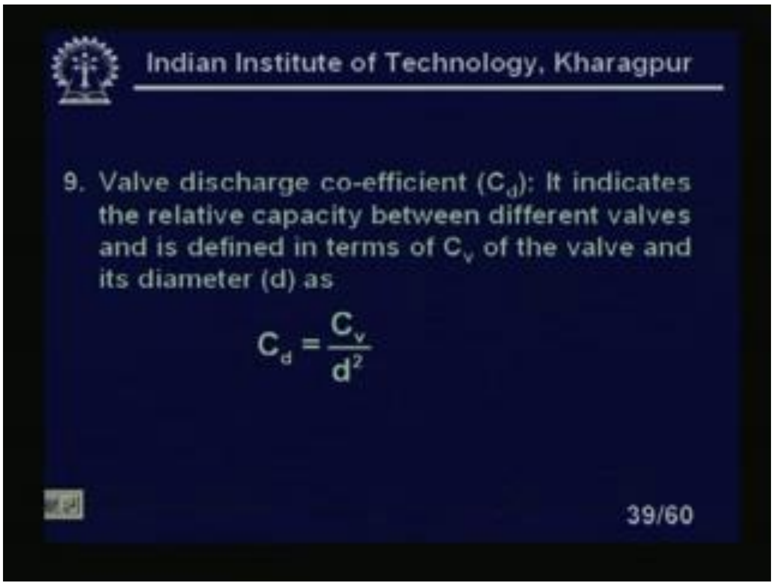

Now, the valve discharge coefficient; it indicates the relative capacity between the different valves. And is defined in terms of Cv of the valve and it is diameter d as Cd Cv by d square. Let us go back I think if you have any confusions. Here what will happen? You see the valve will be always closed like this 1 because, I am sorry, because this spring will always try to open. if it is open, then what will happen if the movement the stem will this seat will this valve plug will always sit on the seat there is a seat. So, valve will always close the flow, right. Normally, if there is no air pressures spring will try to open, clear? This spring will try to open right if there is let me take this 1 the spring will try to open like this one.

Normally if there is no air pressure, suppose there is no air then what will happen spring will try to open. So, what will it will pushed the stem downwards, so that the stem. So, these plug will totally sit totally on the seat. So, there is no flow of fluid air or liquid through the this region. Now, if I put the air then what will happen? So, this stem will move up, if the stem this stem will move up, because diaphragm at that time will be go up. So, the stem will move up, so the liquid will start to flow through this 1. So, this type of thing is called the air to open. And next whatever I have shown is called air to close that we have seen that is if it is normally it is spring will always try to move expand it is like this one. Spring will always try to move in this direction normally when there is no air.

So, it will open it, because if there is fixed here if it is we have a plug here. So, it will move upwards right if the plug it cannot move this direction there is a diaphragm here. So, it will move upwards now, if I want to show the valve is fully open now once we have to give a pneumatic pressure. What will happen? This spring will now start to squeeze the diaphragm is there the spring will start to squeeze and it will totally choke the flow, right. So, this type is called air to close clear let us go back again. Valve discharge coefficient; it indicates that the relative capacity between the different valves and is defined in terms of Cv of the valve and its diameter d as Cd equal to Cv upon d square.

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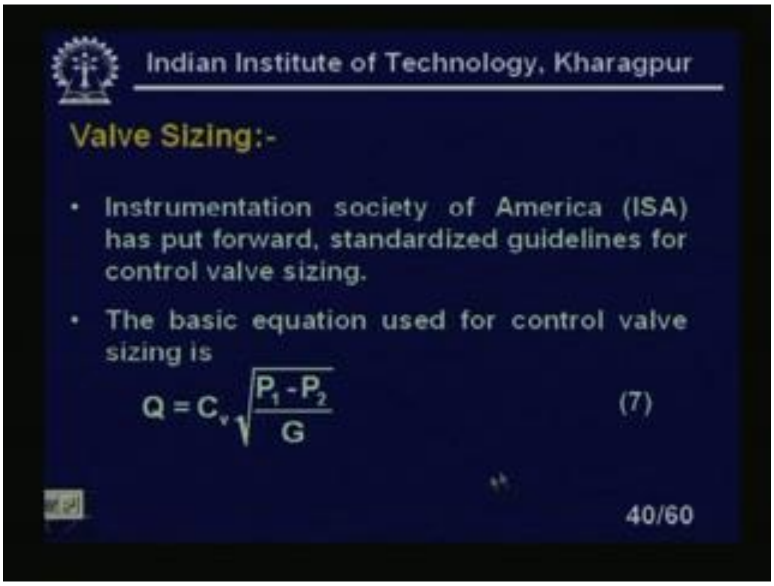

Valve sizing; instrumentation society of America ISA put forward standard standardized guideline for control valve sizing. The basic equation used for control valve sizing is q equal to Cv route over p 1 under the square p 1 minus p 2 upon G under the square route this is equation number 7.

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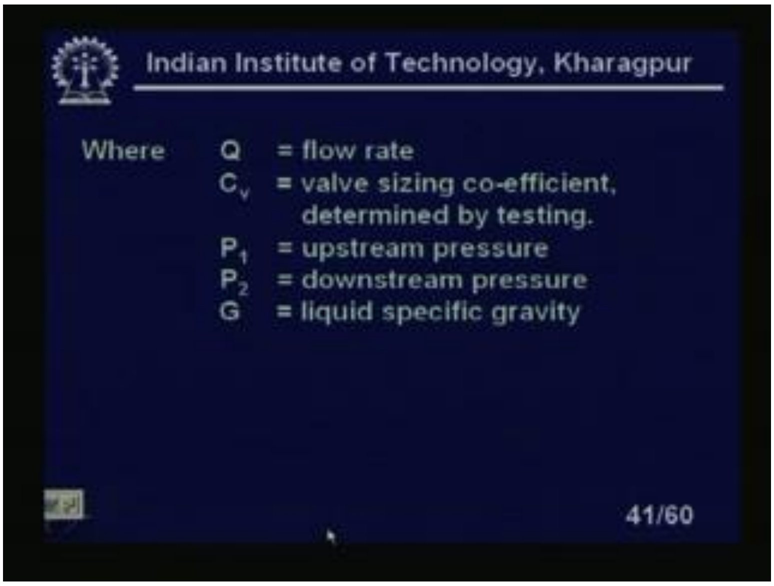

Where Q is the volumetric flow rate, Cv is the valve sizing coefficient determined by testing, P 1 is the upstream pressure, P 2 is the downstream pressure and G is the liquid specific gravity, clear?

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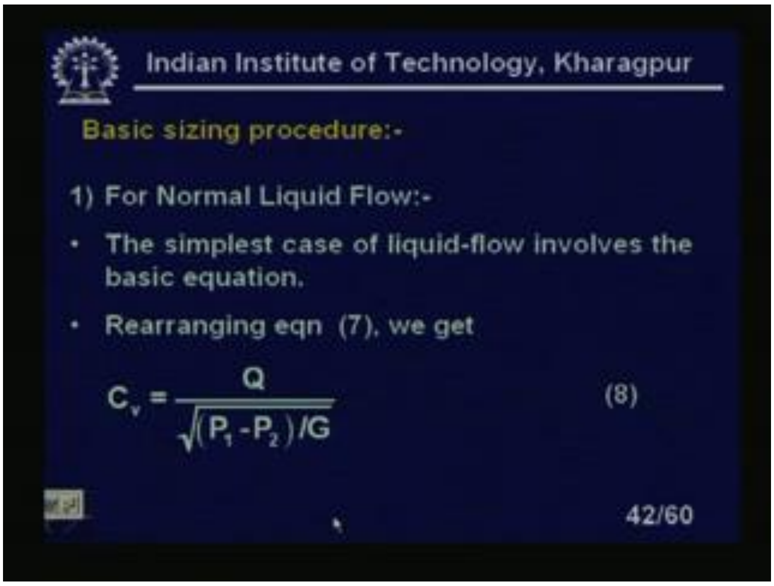

Valve sizing procedure for normal liquid flow you can take the simplest case of liquid flow involves the basic equation. Re-arranging equation 7, we can get Cv equal to Q upon under the square P 1 minus P 2 by G under the square route, right.

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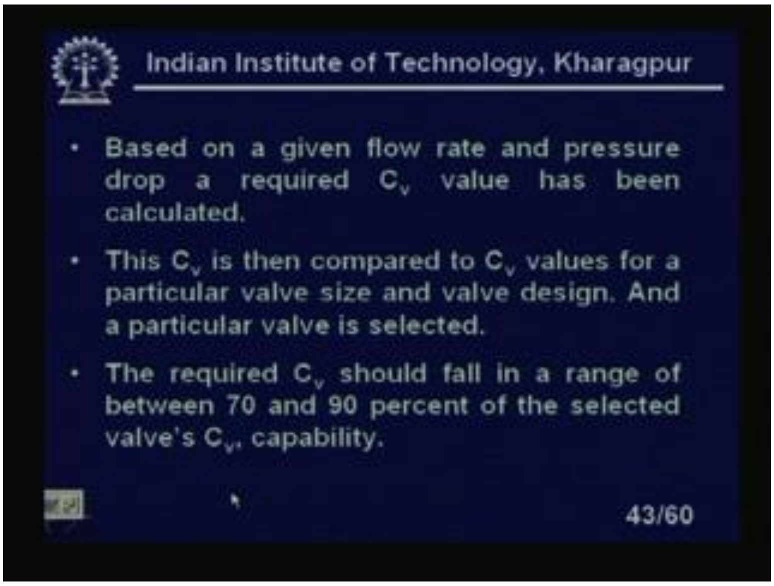

Based on a given flow rate and the pressure drop a required Cv value has been calculated this is very important this is called the characteristics of the valve right. The Cv is then compared to the Cv values for a particular valve size and value valve design and a particular valve is selected . So, that from the series of we have a valve. So, that we have to select a particular valve from that right first we will calculate Cv and compare to the standard Cv of the valves available valves in the process we will choose a particular valve whose Cv will match with the Cv which we have calculated. The required Cv should fall in a range between 70 and 90 percent of the selected valve Cv capability not exactly the same it is within that range. Because ultimately we will find this Cv again, right.

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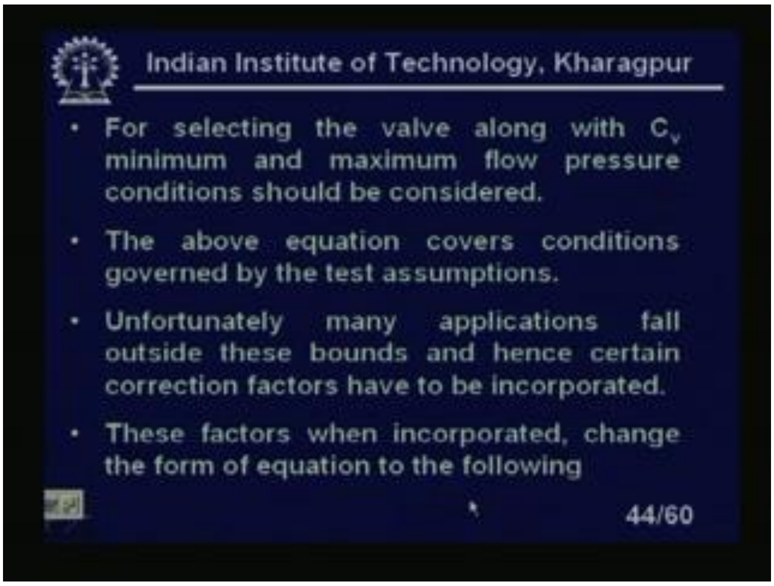

For selecting the valve along with a Cv minimum and maximum flow pressure condition should be considered that is also should be considered static pressure. The above equation covers the condition governed by the test assumptions. Unfortunately many applications fall outside these bounds and hence certain correction factors have to be incorporated. If I include that these factors when incorporated change the form of the equation as follows.

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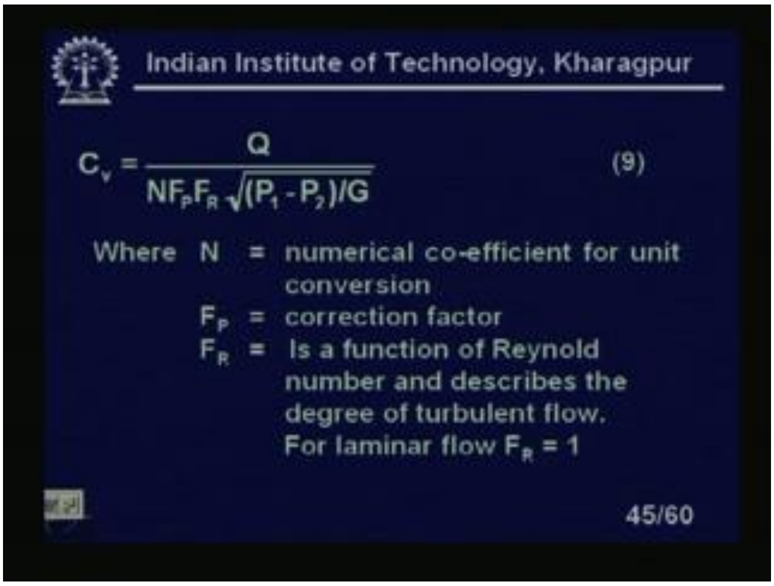

Q Cv valve discharge coefficient equal to Q upon N FPFR under the square root P 1 minus P 2 by G what is that where N is the numerical coefficient for unit conversion FP is the correction factor FR is the function of Reynold number, and describes the degree of turbulent flow for laminar flow FR equal to 1.

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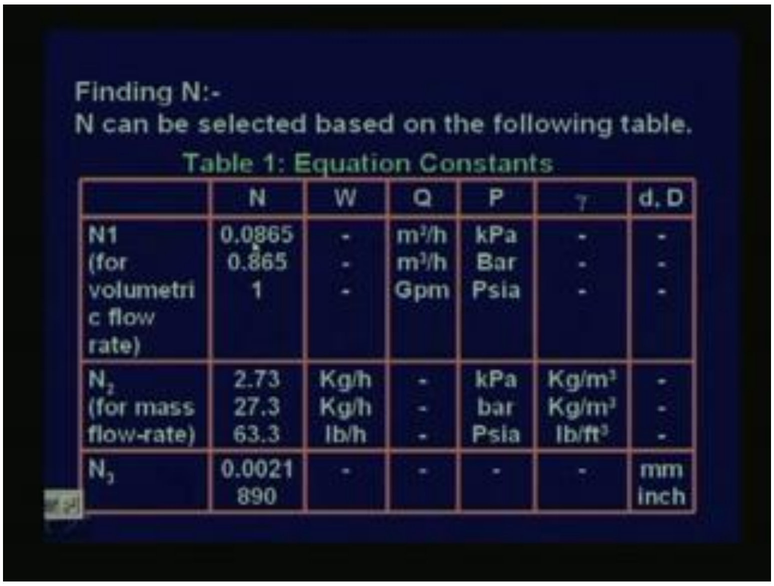
Finding N:-

N can be selected based on the following table.

Table 1: Equation Constants

	N	W	Q	P	γ	d, D
N1 (for volumetric flow rate)	0.0865 0.865 1	- - -	m^3/h m^3/h Gpm	kPa Bar Psia	- - -	- - -
N_2 (for mass flow-rate)	2.73 27.3 63.3	Kg/h Kg/h lb/h	- - -	kPa bar Psia	Kg/m^3 Kg/m^3 lb/ft^3	- - -
N_3	0.0021 890	-	-	-	-	mm inch

And finding N, N can be selected based on the following tables. So, you have to use there is the table from it you can find the value of N. This is the table you see for volumetric flow what is the value of N we have seen different values of N are there. So, as you see this is a correction factor. So, if it is in kilo Pascal Q is in meter cube per hour pressure is kilopascal. So, N will be 0865 and if it is meter cube per hour and pressure is in bar. So, it is 0.86 that is unit conversion nothing else please note it is just a unit conversion and it is 1. If it is Q is volumetric flow is gallon per minute and psi absolute right pressure pounds per square inch. Now, this is for the volumetric flow rate and for the mass flow rate we will choose if it is P is in kilo Pascal gamma which is the I mean density this kg per meter cube then the weight is kg because it is a mass flow rate.

So, it is a kg per hour if the pressure is in bar and is kg per meter cube then the mass flow rate is kg per hour at that time is 27.3 we choose and if it is in FPS unit. That means, if it is in psi pressure is psi pressure drop is psi absolute and gamma is pound for fit cube that time the volumetric flow mass flow rate is pound per hour. So, we are I mean taking 63.3 N 3 value is a small d and capital D this might be either in millimeter or in inch. So, in that case if it is in inch a millimeter it is 0.021 and if it is a inch 0.890 right. So, this will give you the conversion factor. So, which will use for this value N this will simplify our problem solving, because some country is using some if you import some valve form US they have some I mean APS units and from Europe we are using SI units. So, this chart will help you to find the value of N which particular value of N will be use which particular I mean units of Q and P will use.

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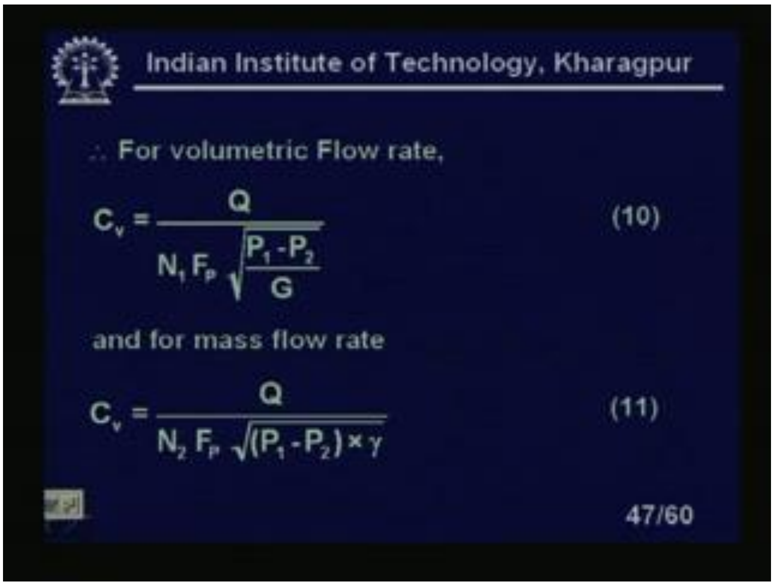

For volumetric flow rate I can write Cv Q upon N 1 F p Q upon N 1 F p under the square route P 1 minus P 2 by G is G is a specific gravity as I told you and for mass flow rate. So, we are writing Q into F p under the square route P 1 minus P 2 into gamma gamma in that case will be density.

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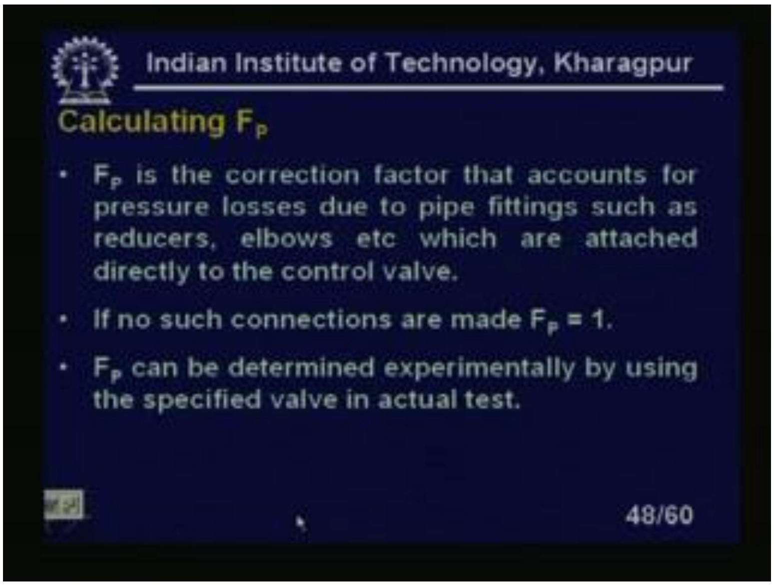

Calculating Fp; Fp is the correction factor that accounts for the pressure losses due to the pipe fittings such as reducers elbows. Because all the valves you know I mean it must be preceded by some elbows some reducers suppose the valve sizing is not matching with the pipe diameter. So, you have to use a reducers which are attached directly to the control valve these are all will be control attached to the control valve, because not necessarily you will get the exactly the pipe diameter and the inlet diameter of the valve same. So, I have to use some reducers if no such connections are made then Fp is equal to 1 if this no connections are made if there is no such reducers elbows. But; obviously, Fp will never will be 1 we use always some reducers some elbows something like that. Fp can be determined experimentally by using the specified valve in actual test. So, if the line test or the length calibrations we have to do alternatively Fp can be determined mathematically using the following equations, what is this equations?

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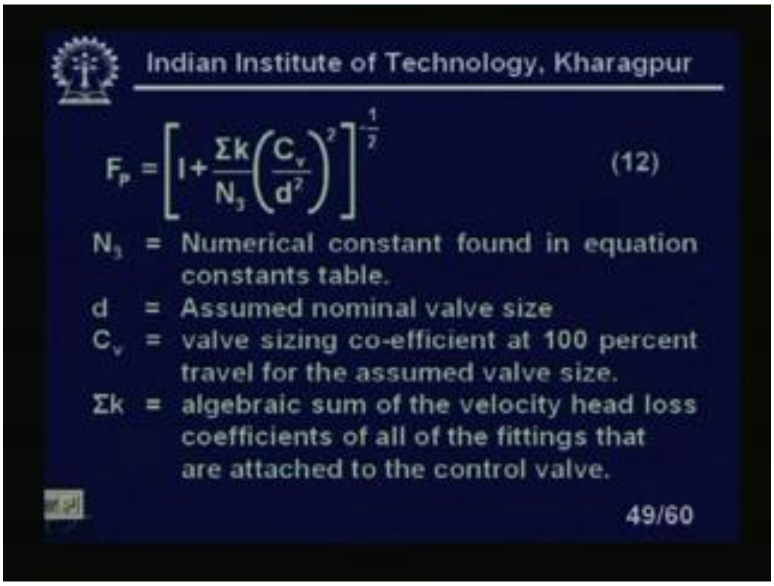

Fp equal to 1 plus summation small k N 3 into Cv by d square whole square under the square route to the power minus half right. So, it is 1 by square route of this 1 right. N 3 is the numerical constant found in equation constant table. We have already seen that N what is N 3 either in millimeter I mean it depends what type of d small d and D. You are using either in the millimeter or inch accordingly you choose the value of N 3. D is the assumed nominal valve size it is always less than capital D which is the Cv is the valve sizing coefficient at 100 percent travel for the assumed valve size right. That means, valve is fully opened Cv whenever you are talking about. Please note it is the valve is fully opened that is stem is totally moved there is a full flow of liquid through the valve. Summation k is the algebraic sum of the velocity heat loss coefficients of all the fittings that are attached to the control valve.

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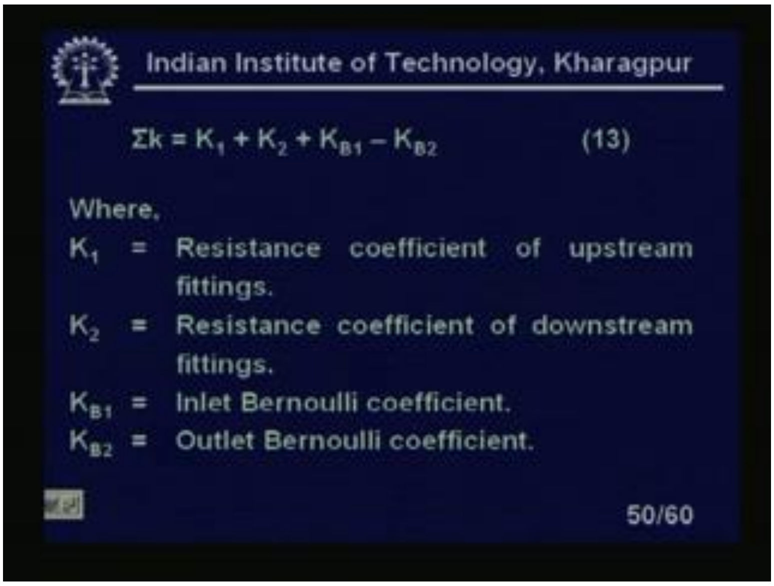

Small k equal to K 1 plus K 2 plus KB1 minus KB 2 this is equation number 13 what is that? Where K 1 is the resistance coefficient of upstream fittings; K 2 is the resistance coefficient of downstream fittings. KB 1 is inlet Bernoulli's coefficient and KB 2 outlet Bernoulli's efficient. So, this will may give summation k, right.

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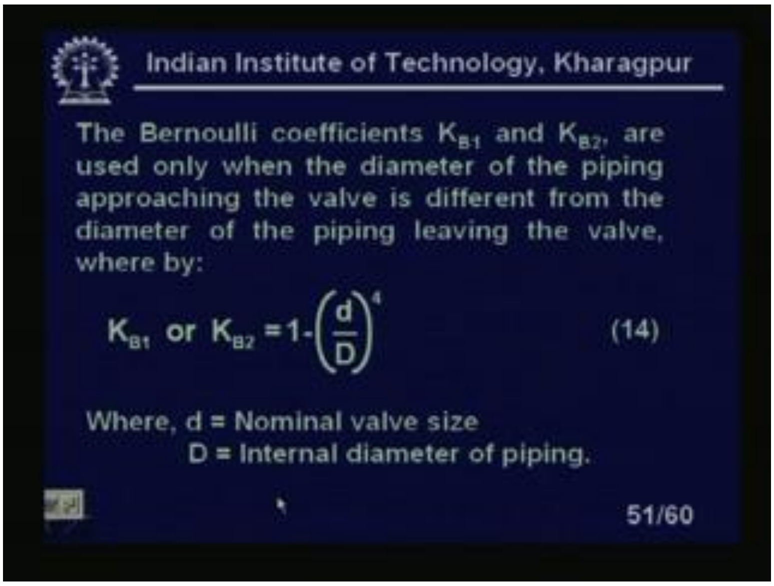

Now, the Bernoulli's coefficient KB 1 and KB 2 are used only when the diameter of the piping approaching the valve is different from the diameter of the pipe leaving the valve. If the 2 valve diameter is same pipe diameter diameter of the pipe I mean same I mean at the inlet and the outlet of the same I do not have to use then KB 1 will be equal to KB 2. Otherwise it will be different, but most of the process cases you will find this will be 0 because KB 1 minus will be equal to KB 2. So, KB 1 minus KB 2 will be 0. So, this 2 terms and the last terms can be calculated whereby KB 1 or KB 2 equal to 1 minus small d by D to the power 4, right. Where d is the nominal valve sizing and D is the internal diameters of the piping, right diameter of the piping; obviously, D is always greater than the small d.

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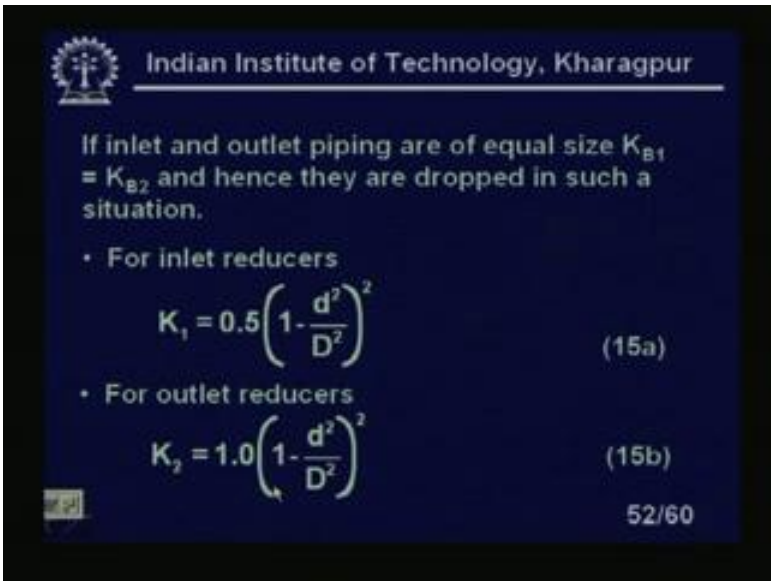

If inlet and outlet pipings are of equal size then we can say inlet and outlet piping to the valve or to and from the valve then KB 1 will be KB 2 and they are dropped in such a situations. So, for inlet reducers I can write K 1 equal to 0.51 minus d square upon capital D square to the power whole square. And for outlet reducers I can write K 2 equal to 1 1 minus small d square by capital D square to the power whole square and it is fifteen point b equations.

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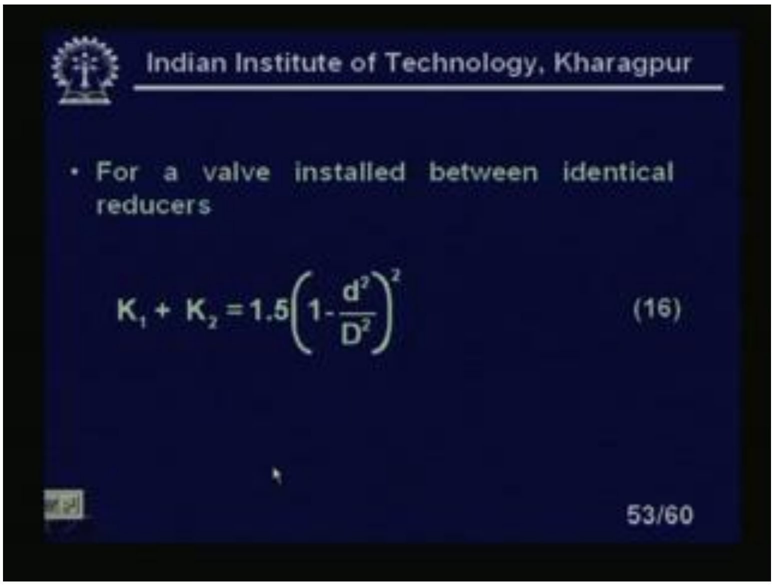

For a valve installed between identical reducers I can write K 1 plus K 2 equal to 1.5 multiplied by 1 minus d square upon small D square by capital square to the power whole square this is equation number 16.

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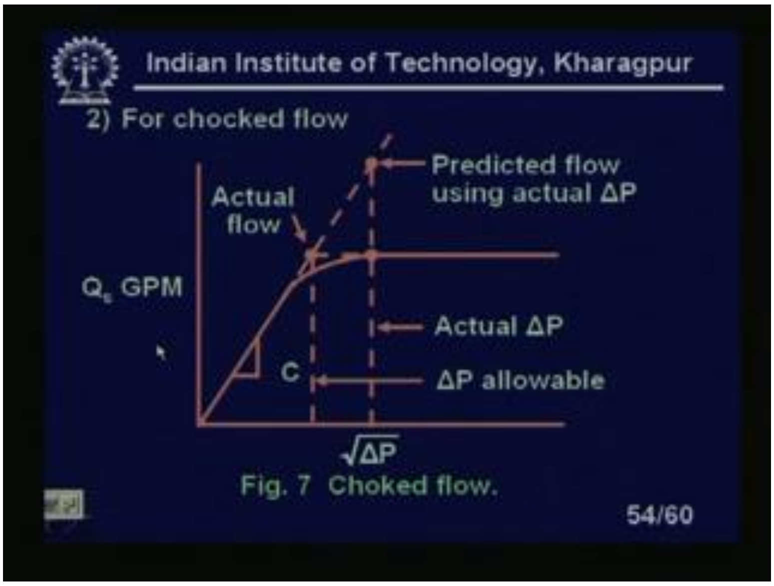

For chocked flow you see that actually in the process we will find there is a chocked flow. That means, even though I am expecting that the flow will be always I mean if I use a delta p if increase a delta p the flow through the fluid and gallon per meter. Whatever it may be I mean the litre per hour whatever the link is it will increase. So, it will saturate. So, that even though increase in the delta p differential pressure will not increase the flow through the pipe. So, this reasons we are calling it chocked flow right is delta p allowable and actual delta p you see to the predicted using the actual delta p this is a chocked flow we are talking about.

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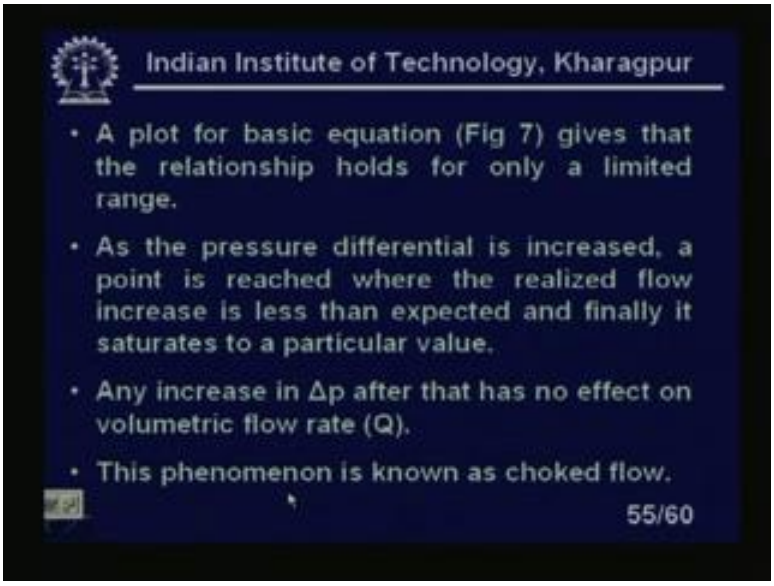

A plot of basic equations of figure 7 gives that the relationship holds this is figure seven a plot of basic equations figure 7 gives that the relationship hold only for a limited range. For the limited range this will happen otherwise it will not at the pressure differential as the pressure differential is increased a point is reached where the realized flow increase is less than the expected. That means, there is saturation or there is value sort characteristics and finally, it saturates to a particular value right. So, as we increase unlike the when stem movement when if you stem movement if you make the change of stem do not confuse with the stem movement x axis. Now, we are plotting please go back x axis we are plotting delta p differential pressure.

We are increasing differential pressure in this direction we are increasing the differential pressure increasing the differential pressure in this directions. We are now in the case the valve characteristics we have seen I mean the valve this seat I mean your plug characteristics. We have seen as we increase the stem movement as we increase the lift of the valve. Obviously, the flow is increased it saturate little bits in the case of quick opening, but in the other case linear and other case equal percent is always increasing right. But that is not the situations here when you are using having a chocked flow. That means, if you increase delta p not necessary it will wait it will saturate after some time. As the pressure differential is increased a point is reached when the where the realized flow increase less than the expected.

And finally, it saturates to a particular value. Any increase in delta p after that has no effect on the volumetric flow rate even if you increase it I mean that will not affect the flow rate of the valve unlike. As I told you several times unlike the stem movement whenever you have a stem movement there is always a change of flow right this is necessary also. This phenomenon is known as the chocked flow this is called the chocked flow of the valve. That means, if I go which ever has a chocked flow this portion is called we are calling a chocked flow. You see this is the choked flow region right even though I am increasing this flow is not increasing it is getting saturated clear? So, this phenomena is known as the chocked flow of the fluid in a control valve clear?

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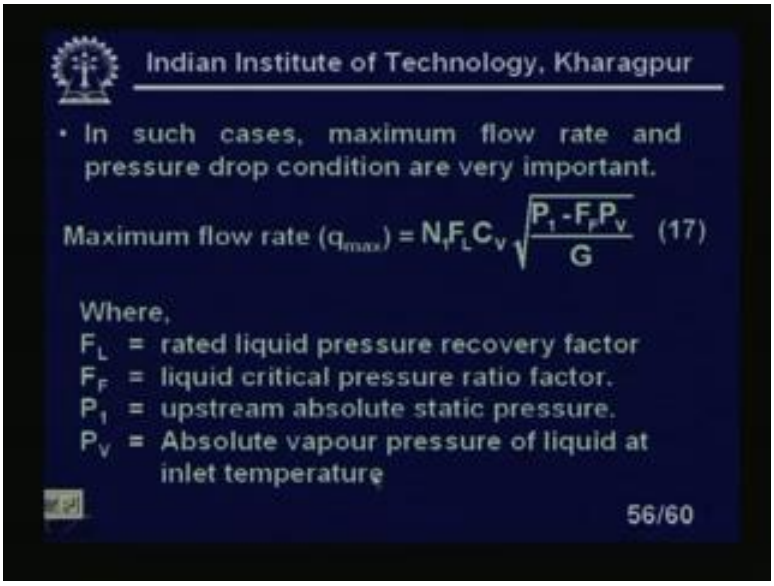

In such cases maximum flow rate and the pressure drop conditions are very important what is the pressure drop conditions and the maximum flow? These 2 we have think on these are very important in this particular cases clear? We have to think of this thing do not confuse the 2 from this let leave them. So, maximum flow rate q max equal to N 1 FL CV and under the square route P 1 minus delta F Ff Pv upon this is equation number 17 where FL is the rated liquid pressure recovery factor which is actually. Because you know the liquid will always the pressure will be recovered recovery factor and Ff is the liquid critical pressure ratio factor and P 1 is the upstream absolute static pressure. This is very important up upstream pressures absolute static pressures I mean it here you see we are not considering the deemed differential pressure. PV is the absolute vapor pressure of the liquid at the inlet temperatures this will make the maximum flow rate q max.

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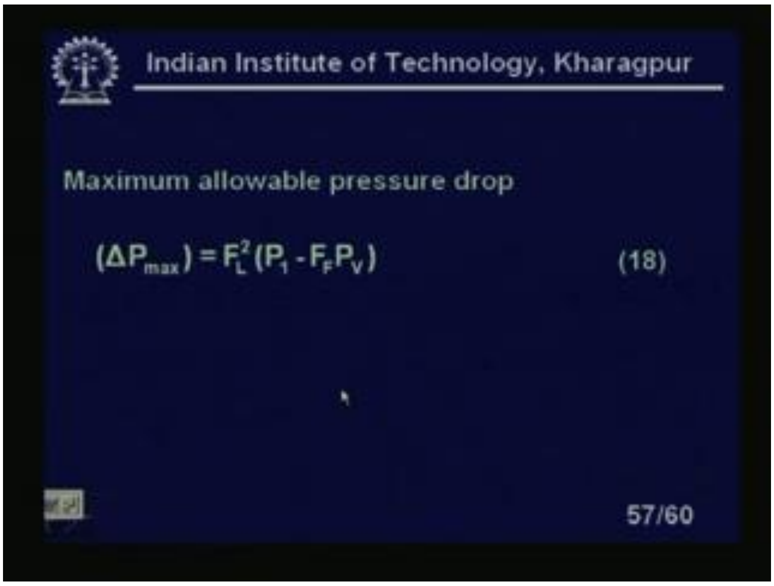

So, maximum allowable pressure drop which is to be calculated delta P max equal to Fl square which is P 1 minus Ff into Pv this is equation number 18.

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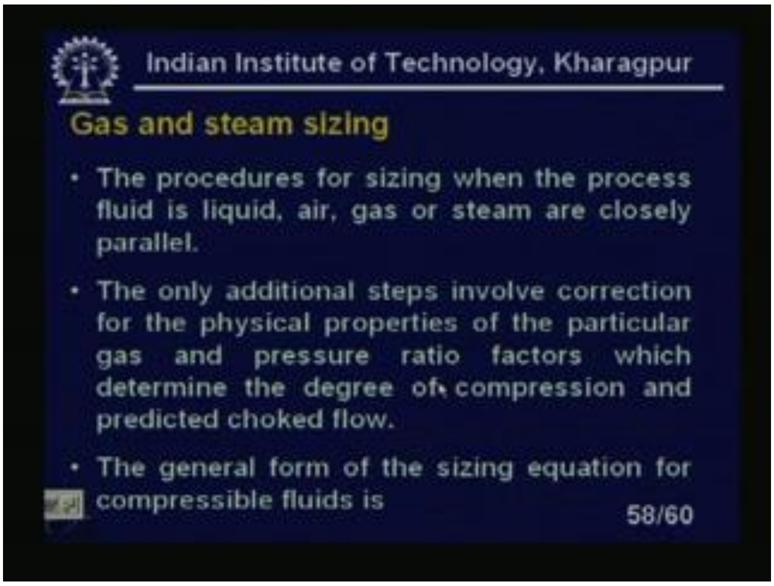

Gas and steam sizing the procedure for sizing when the process fluid is liquid air gas are closely parallel. These are almost same and is not much of difference the only additional steps involve the correction of the physical properties of the particular gas and pressure ratio factors which determine the degree of the compressions and predicted chocked flow. That is I mean these are the only factors which is to be included which I have to think of otherwise not. The general form of the sizing equations for the compressible fluid is.

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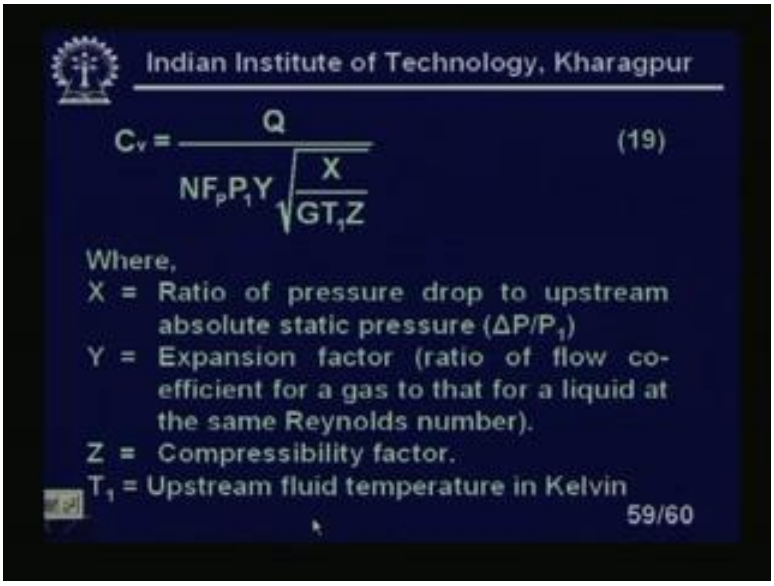

You see Cv equal to Q upon NFp P 1 Y route over X upon GT 1 into Z equation number 19 where the legends are x is the ratio of the pressure drop to upstream absolute static pressure ratio of the pressure drop to upstream absolute static pressure. That is the reason we are interested in P 1 the previous equation number 18 also we have seen that there is a P 1 is important not the P 2. Y is the expansion factor ratio of the flow coefficient for a gas to that for a liquid at the same Reynold number. Z is the compressibility factor and T 1 is the upstream fluid temperature in kelvin. So, all these I mean things all the legends are defined now every time you see that a Cv is the most important thing in the valve parameter there is no other, because if you define Cv or if you find Cv all other parameters will be automatically fixed. There are some parameters like small d capital D.

So, first in the while you are choosing the valve first I have to calculate the, what are the desired Cv you want for a particular applications once you find a Cv? So, from the selected list of the valve, so you try to choose Cv which will match very close you may not get the exact match. It will be 70 to 90 percent of the value of the Cv which you have seen that will be the desired range of the control valve. So, that particular control valve is to be chosen and is to be installed in the process. Now, with this I we will cover this in industrial I mean this control valve we will continue this control valve in the lesson number 39. Also we will go further details and we will solve some problems in the lesson thirty-nine. So, at this with this I come to the end of the lesson 38 of industrial instrumentation

Control Valve-II; Welcome to the lesson 39 of industrial instrumentation. In this lesson we will continue with the control valve control valve we have started in lesson number 38. So, in the lesson 39 also we will continue we will go in the deep details of control valves, because as I told you earlier that the control valves actually means the final control element in any industrial process they are actually the whatever the measurement techniques we have seen or we have studied. So, far like temperature pressure flow pH humidity so many so on and so forth. We will see that ultimately is to all these things are basically and these measurements are necessary to control the temperature control the flow control the process parameter. So, basically I mean the either you can make the heater power control, but most of the cases will find that we have to control the flow whether it is a gas fluid it does not matter. So, we will control the flow. So, by controlling the flow I can control the temperature I can control the flow I can control the level and so on. So, we will continue with the control valves. So, this is a control valve 2 of lesson 39. Let us look at the contents control valve 2.

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Contents are types of control valves we have seen that the we have last time in 38 we have seen that we have considered there the equal percentage valve and quick opening linear. But those are not the types of control valve those are basically the characteristics of the control valve I mean flow characteristics versus the stem movement. I mean if you vary the stem movement how the flow characteristics varies accordingly with the equal percentage linear or quick opening. But the overall the different types of control valves are available in industry. So, we will study those in details in this particular lesson types of control valve.

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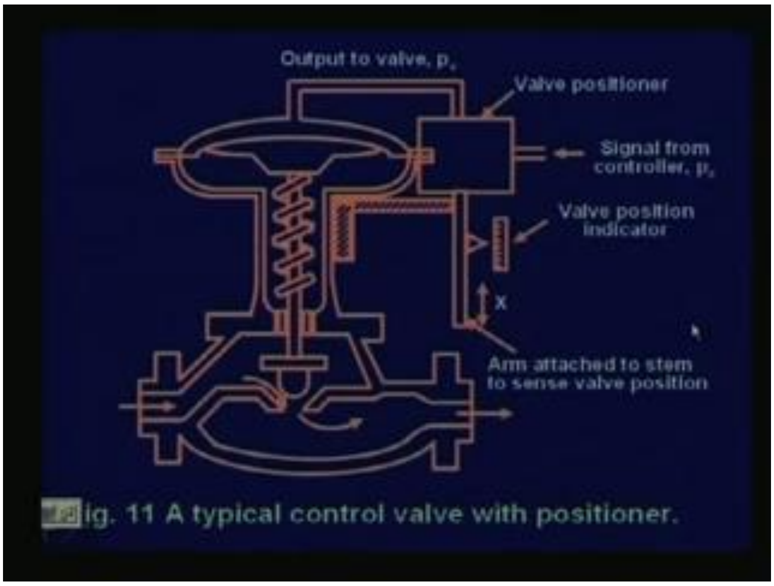

So, this is all about I am talking about this I mean valve positions and all these things you see here this arms attached to stem to sense the valve position. And this is arm it is sense the stem of the valve position this will come to parallel and these are the valve position and signal from the pc will come, right.

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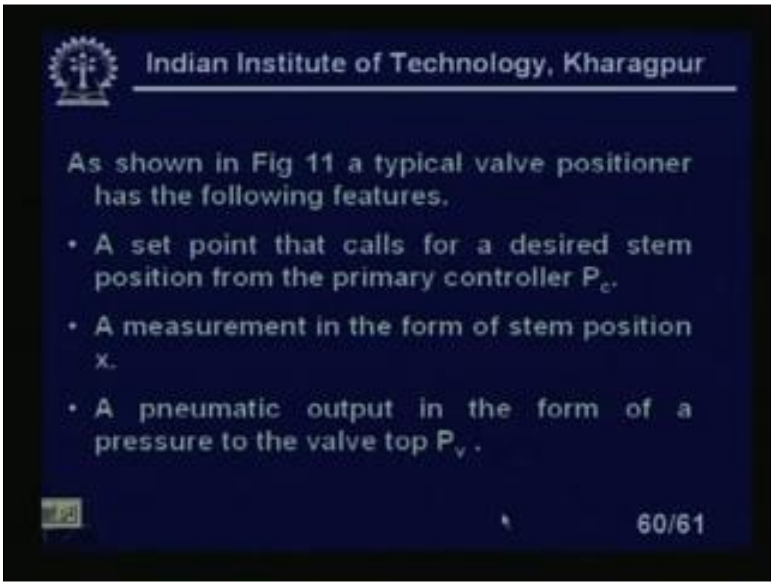

As shown in figure 11 a typical valve positioner has the following features what are the features of the valve positions? Let us look at a set point that calls for a desired stem position from the primary controller Pc. It is coming from the primary controller a measurement in the form of stem position x. So, this 2 will be I mean this 2 will be compared this Pc will be compared with this; obviously, Pc will be compared with x in a valve position. Accordingly it will generate a control signal Pv which will go to the diaphragm of the control valve.

A pneumatic output in the form of a pressure to the valve top Pv will go this will actually give the proper position of the control valve. So, this is all about the positions of the control valves and the control valves I mean and most of the you see the most of the figures. Actually we have taken from the the Fisher's control they are the largest manufacture of the control valve this is available in the web sites. There is no problem those who want to look at the details of the figures. They can go to the, this particular site and you get those figures right. And with this I come to the end of the lesson 39 of the industrial instrumentation.