Chemical Process Instrumentation
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Lecture – 57
Pneumatic Control Valve (Contd.)

Welcome to lecture 57 of week 12. So, in lecture 56 we have started our discussion on control valve and we have discussed about construction of control valves. In this lecture we will focus on control valve characteristics which we need to know. So, that we can select valve for our applications this is also known as sizing of control valves.

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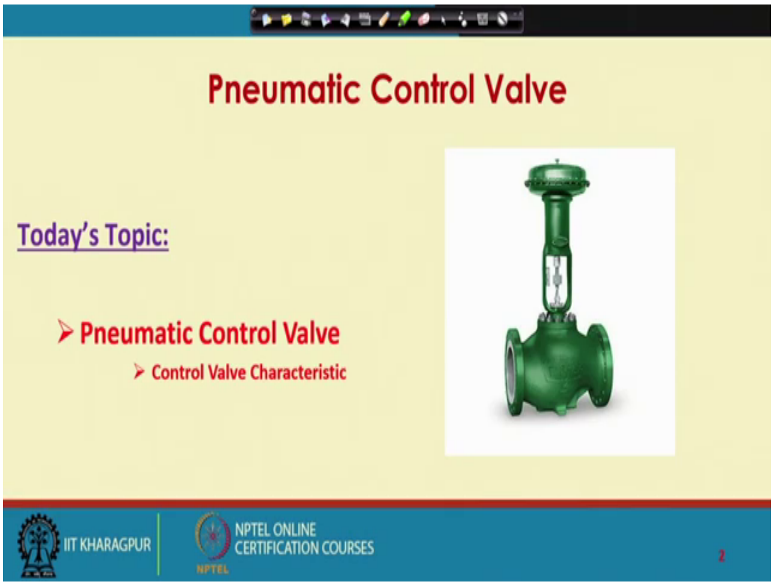

So, today's topic is control valve characteristics.

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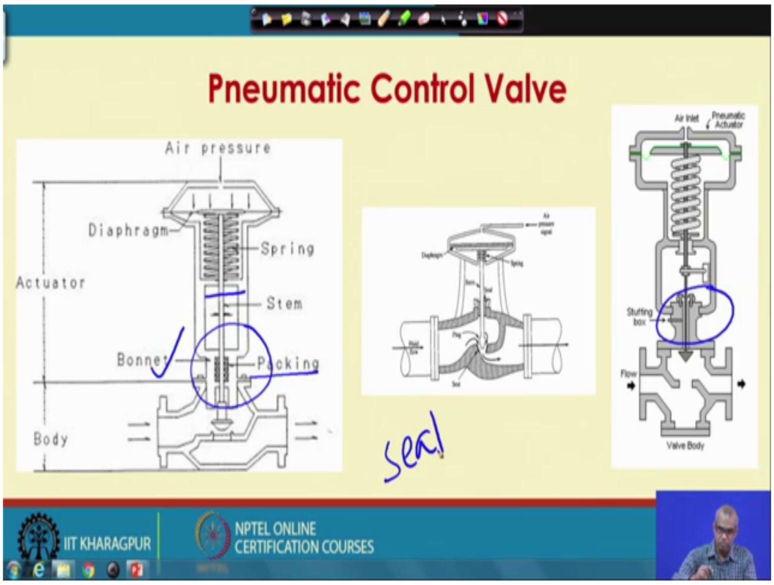

So, what you show; what is see on the screen is the construction of the control valve that we have discussed in our previous lecture. So, I want you to focus your attention on this part this is the packing, we have not mentioned about it while you talked about construction in your previous lecture. So, the packing or the stuffing box is basically a reliable seal it is the seal between the bonnet and the valve stem.

So, this packing or sale does not allow any leakage of fluid. We will make use of this packing will make a reference to this packing later on in today's discussion.

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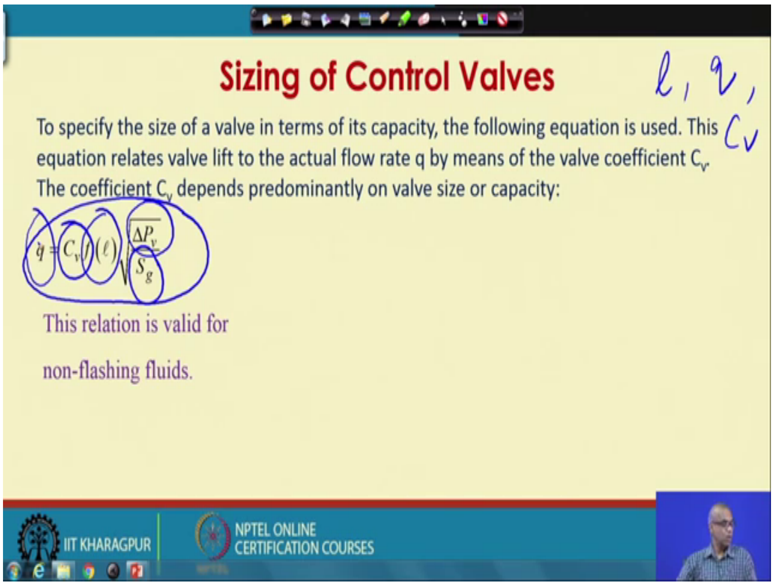

So, let us start talking about sizing of control valves; to specify the size of a valve in terms of its capacity we use this equation the equation is q equal to C v f of l square root of delta P v by S g. This equation relates valve lift which is represented by l to the actual flow rate q by means of valve coefficient C v.

So, the equation relates the actual flow rate q with the lift of the valve represented as l and f l is a function of l; I will come true f l little later delta P v represents the pressure drop across the valve S g represents the specific gravity of the fluid that is flowing through the valve and C v is the proportionality constant known as valve coefficient. The coefficient C v depends predominantly on the valve size or capacity the equation that is written this is valid for non flashing fluids.

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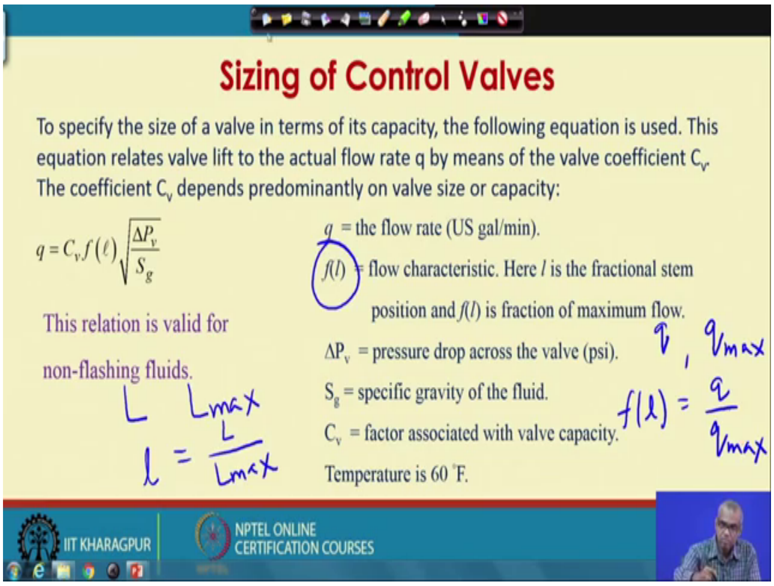

When you use this equation to specify the size of a valve in terms of its capacity; we must use specific units the flow rate q use expressed in US gallon per minute f l represents full flow characteristic; here l is the fractional stem position and f l is fraction of maximum flow. So, l is the fractional stem position; so, if I say L is the stem position and L max is the maximum stem position. So, small l the fractional stem position will be L by L max.

So, the maximum value of small l which represents fractional steam position will be 1 similarly f l is fraction of maximum flow if I say q is flow in gallon per minute and q max is the maximum flow in the same unit US gallon per minute f of l will be q by q max. Delta P v represents pressure drop across the valve in psi S g is specific gravity of the fluid and C v is the factor associated with valve coefficient. When we talk about this flow we consider the temperature is kept at 60 degree Fahrenheit.

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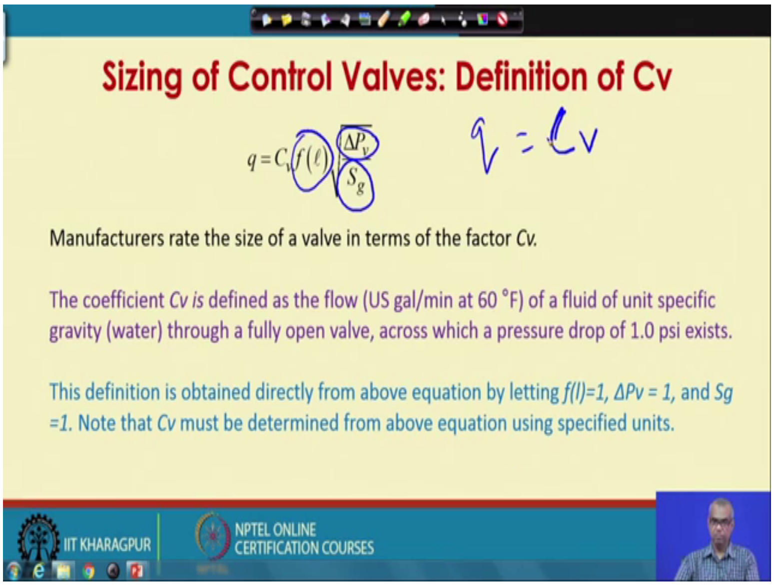

The manufacturer's rate the size of a valve in terms of the factor C v; so, manufacturers will specify the size of the valve in terms of valves coefficient C v. So, let us look at the definition of C v see if I put f l if I put f l equal to 1, delta P v equal to 1 S g equal to 1; then q equal to C v according to the equation. So, the valve efficient can be defined as the flow in us gallon per minute at 60 degree Fahrenheit of a fluid of unit specific gravity there is water.

Through a fully open valve across which a pressure drop of 1 psi exists; this definition is obtained directly from the above equation as I shown you by letting f l equal to 1 delta P v equal to 1 and specific gravity S g equal to 1. C v must be determined from the above equation using specified units meaning q has to be expressed in terms of US gallon per minute temperature 60 degree Fahrenheit delta P v 1 psi. So, I repeat the definition of the valve coefficient C v.

The coefficient C v is defined as the flow in unit us gallon per minute at 60 degree Fahrenheit of a fluid of unix specific gravity through a fully open valve across which a pressure drop of 1 psi exists. So, if you have a fully open valve across which there exist a pressure drop of 1 psi, then if a fluid of unit specific gravity is flowing through the valve then the valve coefficient is the flow rate in ex expressed as us gallon per minute at 60 degree fahrenheit.

So, that is the definition of C v.

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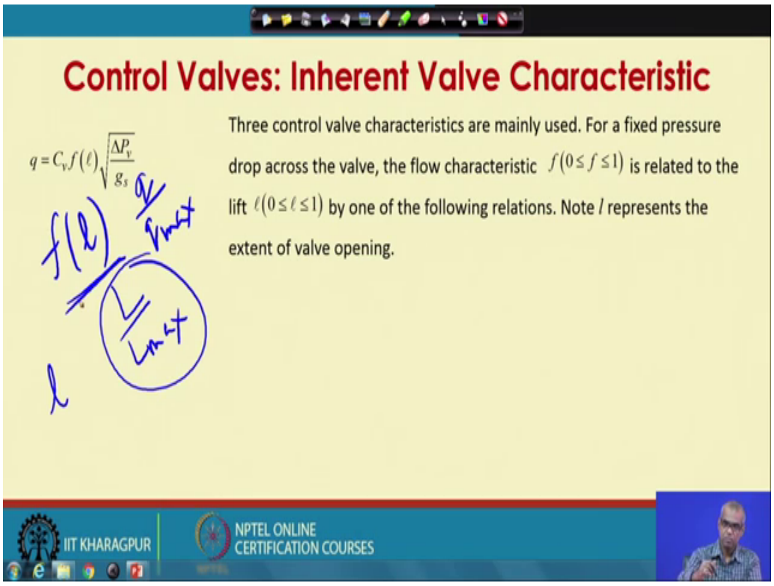

There are two types of valve characteristics f of l as you have seen in the previous example represents flow characteristics of valve characteristics. There are three types of there are two types of valve characteristics inherent valve characteristics and installed or effective valve characteristics. So, the valve characteristics can be of two types.

Inherent valve characteristics and install valve characteristics; install valve characteristics are also known as expected valve characteristics. There are three types of control valve characteristics I am talking about inherent valve characteristics. So, there are three types of control valve characteristics; now these three types of valve characteristics can arise when the control valve is not connected to the pipelines.

Then such valve characteristics are known as inherent valve characteristics; now if these valve characteristics are considered when the controlled valve is used along with other flow pipes and equipment etcetera they are known as installed characteristics.

So, let us first talk about inherent valve characteristics. So, here the control valve is not installed; three control valve characteristics are used. For a fixed pressure drop across the valve the flow characteristics which is expressed as f of l and the value of f of l where is from 0 to 1 because it represents q by q max.

So, the value of f of f of l flow characteristics can vary from 0 to 1. Similarly the lift l which is expressed as L by L max can also taken values from 0 to 1; so for a fixed pressure drop across the valve the flow characteristic is related to the lift by certain set of equations.

There are three equations and corresponding those three equations; we have three types of control valve characteristics. So, note that small l which is L by L max which is the lift of the stem basically represents the extent of valve opening.

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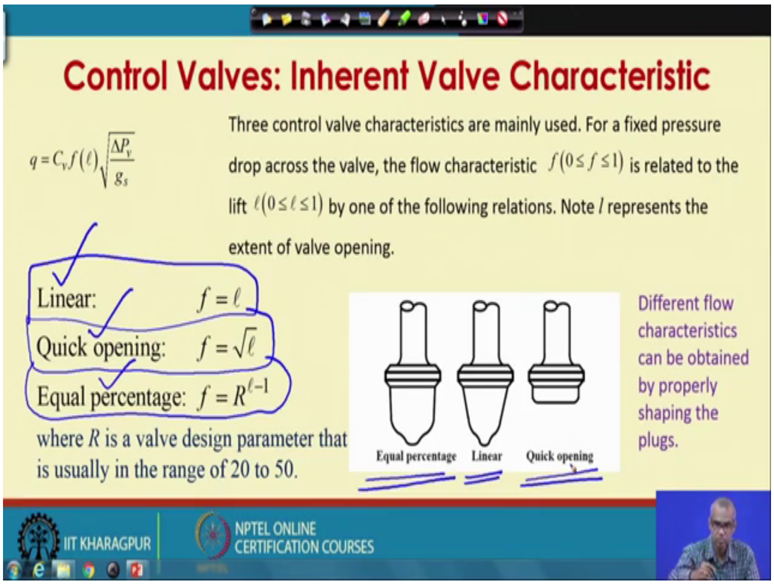

The three types of control valve characteristics are linear, quick opening and equal percentage. The linear valve characteristics is represented as f of l equal to l, quick opening characteristics is represented as f of l equal to square root of l. And the equal percentage valve characteristic is represented as f of l equal to R to the power small l minus 1 where capital R is the valve design parameter that is usually in the range of 20 to 50.

So, the lift of the valve or the extent of valve opening small l is related to flow characteristics f of l by three equations those three equations represent three types of control valve characteristics; they are linear which is f of l equal to l, quick opening which is f of l equal to square root of l and then equal percentage which f equal to capital R to the power small l minus 1 where capital R takes on values in the range of 20 to 50.

Different flow characteristics can be obtained by properly shaping the plugs of the valve. If you remember one end of the stem is attached to the diaphragm which is at the top of the valve control valve actuator. And the other end of the stem there is the plug this plug sits on the valve sit and as the stem goes up; there will be more opening. So, there will be more flow as the stem comes down the plug sits on the valve shape and there will be reduced flow through the control valve. Different flow characteristics such as expressed by f of l can be obtained by properly shaping the plugs.

This type of shape will lead to equal percentage control valve this will lead to linear control valve and this will lead to quick opening control valve.

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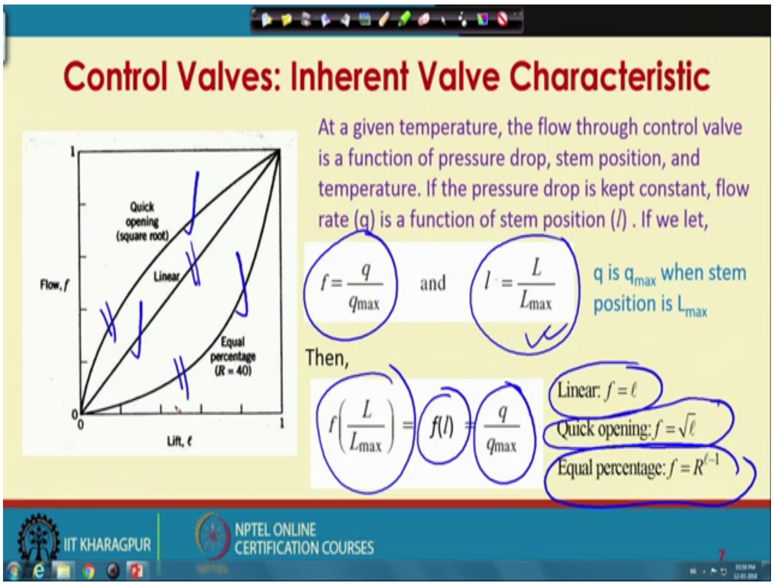

At a given temperature the flow through control valve is a function of pressure drop stem position if the pressure drop is constant at a given temperature flow rate is a function of stem position only. So, if you late f equal to q by q max and small l equal to L by L max; as we discussed f of small l which is nothing, but L by L max equal to f of small l equal to q by q max.

So, both f of l and small l will vary in the range of 0 to 1 for linear it is f of equal to l. So, we will expects a linear relationship as shown in the figure quick opening it is a square root relationship. So, you get the quick opening curve as square root relationship equal percentage valve is f equal to R to the power l minus 1.

So, for a specific value of R let us say R equal to 40 you will expect a curve as shown in the figure. So, this is linear this is quick opening and this is equal percentage what you can. So, what you can see is as the lift increases; the flow linearly increases for linear characteristics.

For a control valve showing linear characteristics as the lift increases; the flow through the valve changes linearly, but in case of quick opening; if you see as the lift increases slightly the flow increases to a large extent. So, quick opening valve can be used as on off controller; a small change in the lift will cause the large change in the flow rate. It is true for increasing lift as well as decreasing lift. So, small change in the lift will cause a large change in the flow rate.

In case of equal percentage the change in the flow rate is low in the beginning as you increase lift, but at very large opening then it increases very rapidly, but in the beginning the flow rate changes minimally as you change or as you increase the lift.

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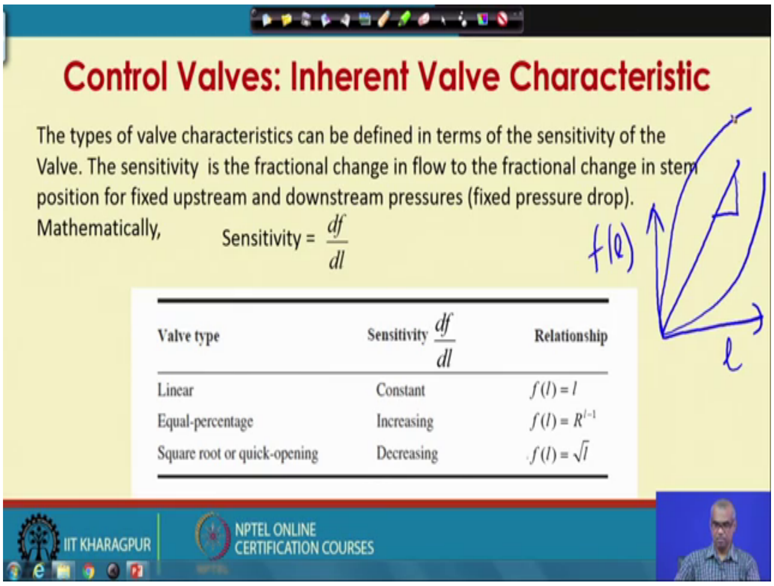

The types of valve characteristics can also be defined in terms of the sensitivity of the valve. The sensitivity is defined as the fractional change in flow to the fractional change in stem position for fixed upper stem and downstream procures that is for fixed pressure drop.

So, sensitivity is the fractional change in flow to the fractional change in stem position for fixed upstream and downstream pressures. So, mathematically speaking sensitivity is d f by d l; so, it is basically represents the change in flow divided by change in stream position for a given pressure drop. For linear valve the sensitivity is constant; so, you get a straight line of constant slow. So, for linear control valve sensitivity is constant for equal percentage control valve; if you look at the graph this is f of l and this is l lift for linear. So, this is the relationship the slope d f d l is constant; so, sensitivity is constant.

For equal percentage you have relationship like this. So, you can check the sensitivity is increasing and for quick opening valve or square root valve shows this relationship between f l and l and here the sensitivity is decreasing.

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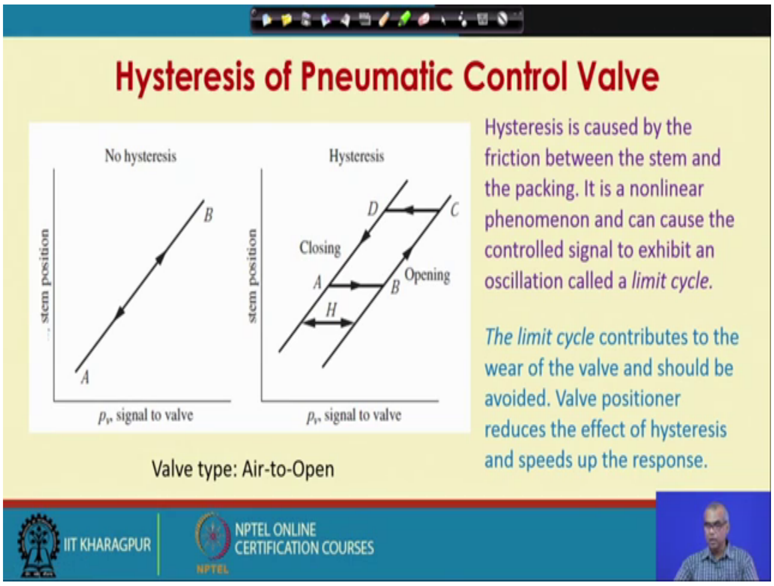

It is increasing or decreasing with change in the lift of the stem l. Next let us talk about hysteresis of pneumatic control valve previously we have talked about hysteresis that you find in instruments when you talked about performance characteristics about instruments.

Generally hysteresis you find in instruments which has elastic member; hysteresis is caused by the friction between the stem and the packing. In the beginning of today's lecture we talked about packing which gives you a reliable seal between the bonnet and the stem and does not allow the fluid to leak. Hysteresis is a non-linear phenomenon and can cause the control signal to exhibit and oscillation called limit cycle.

So, let us try to understand with help of this diagram; what is hysteresis what is hysteresis in a pneumatic control valve. What you see here is the plot between the stem position versus the signal pressure on the valve top. So as the signal pressure increases the stem position increases so, stem position changes as we increase as we increase the signal pressure the stem position changes, as we decrease the signal pressure the stem position changes.

So, stem position increases as we increase the signal pressure, steam position decreases as we decrease the signal pressure. And it follows the same path when it increases and when it decreases. So, there is coincidence of both the paths, but if the instrument or the control valve shows hysteresis then a different phenomenon happens. Suppose I am increasing the signal pressure to the valve; so, stem position increases.

Now, then I decrease the signal pressure to the valve, but you see that immediately the stem position does not change; the stem position remains unchanged for some time, the same the stem position remains the unchanged for certain value of the signal pressure and then it starts decreasing.

Again if I want to increase again for some value of pressure it does not change. So, basically when I increase the signal pressure and the decrease the signal pressure, it does not go like this, but what it does is it goes in a loop like this. And in this loop for this part and this part the stem position does not change.

In fact, should draw a better figure like this should be horizontal to show that it does not change. So, a loop forms like this; so, this is an oscillation and this hysteresis can cause the control signal to exhibit and oscillation called a limit cycle. The limit cycle contributes to the wire of the valve and should be avoided, valve position that reduces, the effect of hysteresis and speeds of the response.

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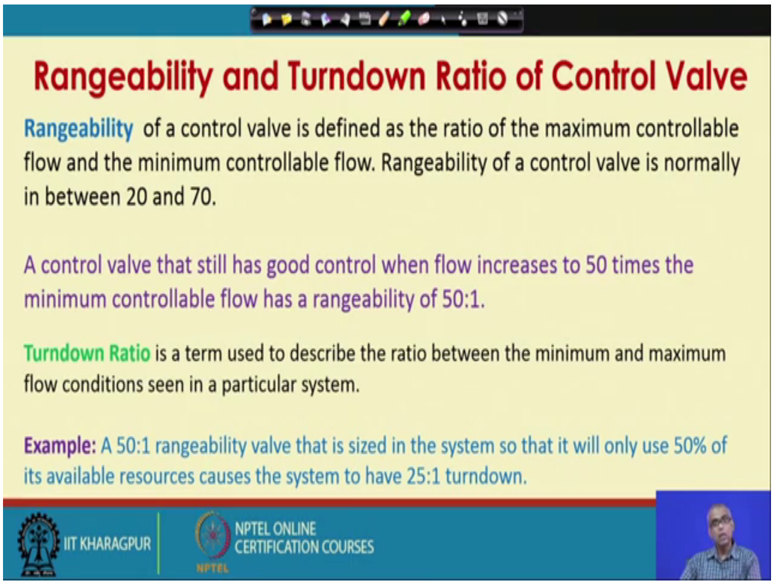

Next we talked about two important terms known as rangeability and turndown ratio of control valve.

Rangeability of a control valve is defined as the ratio of the maximum controllable flow and the minimum controllable flow. Rangeability of a control valve is normally in between 20 and 70 a control valve that still has good control when flow increases to 50 times the minimum controllable flow has the rangeability of 50 is to 1.

By definition rangeability of a control valve is the ratio of maximum controllable flow and the minimum controllable flow. So, rangeability is equal to maximum controllable flow divided by minimum controllable flow. A control valve that has the good control when the flow increases to 50 times the minimum controllable flow will have rangeability as 50 is to 1.

A control valve that is the good control when flow increases to say 40 times the minimum controllable flow will have a rangeability of 40 is to 1. Generally the rangeability of a control valve is normally between 20 and 70; turndown ratio is another similar term and this is used to describe the ratio between the minimum and maximum flow conditions seen in a particular system. So, turndown ratio is used to describe the ratio between the minimum and maximum flow conditions in a particular system. So, when the control valve is installed the ratio of maximum and minimum flow is known as turndown ratio. For example, 50 is to 1 rangeability valve that is sized in the system. So, that it will only use 50 percent of its available resources causes the system to have a 25 is to 1 turndown.

So, we can say that rangeability is something like inherent characteristics and turndown ratio is something like install characteristics. So, rangeability if a for a valve if it is 50 is to 1 and when it is installed you use only 50 percent of the say available resources. So, the turndown ratio is 25 is to 1 50 percent of 50 is 25; so, 25 is to 1 is the turndown ratio.

So, this completes our discussion on the inherent characteristics of the control valves. So, we talked about linear valves, we talked about quick opening valves, we talked about equal percentage valves and we talked about inherent characteristics in the next lecture we will talk about install characteristics. So, in other words we will talk about the same characteristics, but the valve will now be install. So, there will be other flow resistances like such as the control valve will be installed in a pipeline.

So, how these inherent characteristics will be changed when the control valve is actually installed in practice we will be described by installed characteristics. So, that will see in our next lecture.