Chemical Process Instrumentation

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Lecture – 56
Pneumatic Control Valve

Welcome to lecture 56 and this is week 12. So, this is the final week of the course; in this week we will talk about control valve piping and instrumentation diagram. And then as a review of the whole course we will go through some of the gate questions chemical engineering gate questions relevant to our course. So, today we will talk about pneumatic control valve if you remember the block diagram of a feedback control system there exist the final control element after controllers block.

So, final control element implements the decision taken by the controller; in case of chemical engineering processes many chemical engineering processes in petrochemical industries the final element control is basically a control valve. And when you talk about pneumatic control system the control valve is a pneumatic control valve.

So, in this lecture and in the following lecture as well we will see what is a pneumatic control valve? What is the construction of a pneumatic control valve? How it works and also we will learn an important thing called as control valve characteristics. It helps us to select a suitable control valve for our application. So, let us start our discussion on pneumatic control valve.

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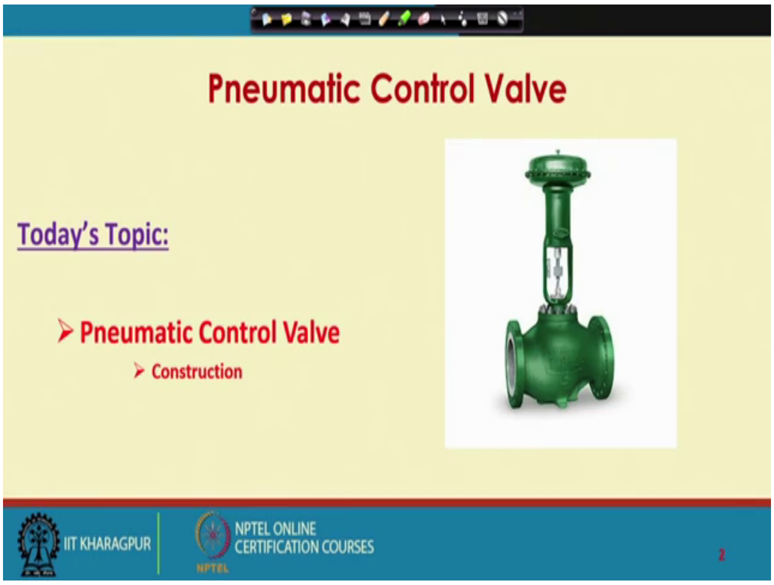

So, today we will focus on the construction of the pneumatic control valve what you see is an image of a pneumatic control valve.

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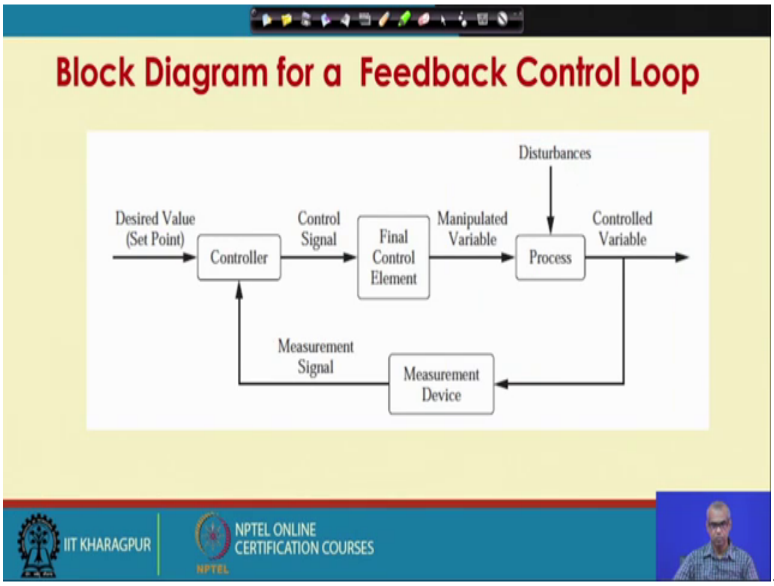

So, this is a block diagram for a general feedback control loop. So, you have the process which we want to control the process needs to be control because there is disturbance. So, the control variable whose value you want to control is measured by a measuring device and that measured signal is fed to the controller.

Controller has information about the desired value which is known as set point. So, controller knows what should be the desired value or set point of the controlled variable that you are going to control. So, controller compares the measurement signal and the set point and generates and error signal. So, based on the error signal the error signal is nothing, but the difference between the measurement signal and the set point value. So, based on the error signal the controller decides what has to be done to the manipulated variable. See to control a control variable you have to manipulate something and the that variable is known as manipulated variable.

So, controller this is controller decides what has to be done to the manipulated variable whether the manipulated variable has to be increased or manipulated variable needs to be decreased. If the measurement signal and the set point signal are same; that means, system is under control then perhaps you do not have to make any change to the manipulated variable. Now the controller text this decision, but this decision has to be implemented by someone. So, the hardware that implements this decision is the final control element; in case of chemical engineering processes of end times this final control element is nothing, but a pneumatic control valve.

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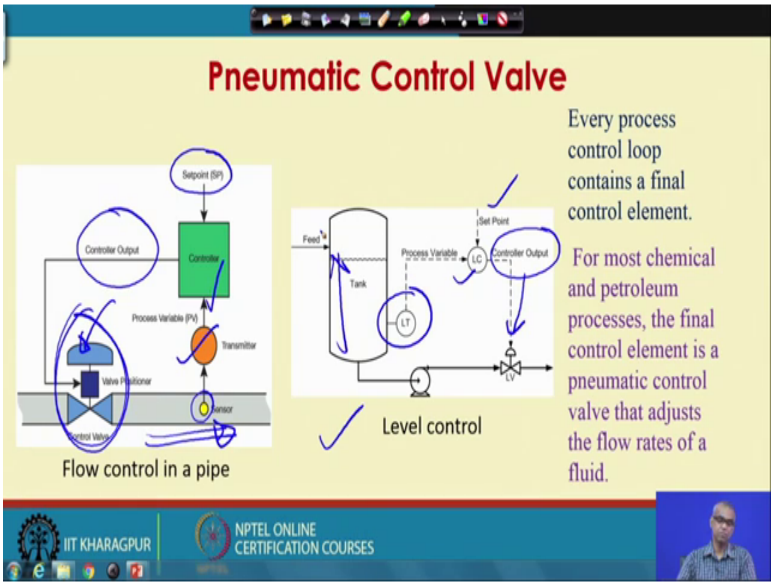

Here let us say there is a flow through this pipe I want to control this flow rate. So, I take a flow sensor measured the value of the flow rate that value is transmitted to the controller using a transmitter the controller has the information about the set point regarding the desired value through this pipe.

So, the controller compares the measured flow and the desired flow and generates a controller output. This controller output is fed to this control valve which is a pneumatic control valve. Accordingly pneumatic control valve which is nothing, but a variable flow resistance increases or decreases the resistance there by change the flow rate through the pipe.

Since this is a pneumatic control valve. So, the controller output is nothing, but a pneumatic signal; that means, it is a pressure signal. So, a pressure signal is applied on this valve top and that increases or decreases the opening of the control valve through which flow takes place. So, that is the flow rate can be increased or decreased by changing the resistance or changing the opening of the control valve and one can achieve a control on the flow rate.

Similarly in this figure you see a schematic of level control in a pan. So, I measure the value of the level and that information is sent to the level controller.

So, level transmitter is indicated by L T; it transmits the information about the level at any point of time to the level controller the level controller has information in the set point; s+o, comparing these two signal it generates a controller output. So, the controller output is fed to the control valve and accordingly the control valve either increases or decreases the flow rate and thereby try to achieve the level inside the tank. So, every process control loop contains a final control element foremost chemical and petroleum processes, the final control element is a pneumatic control valve that adjusts the flow rate of a fluid.

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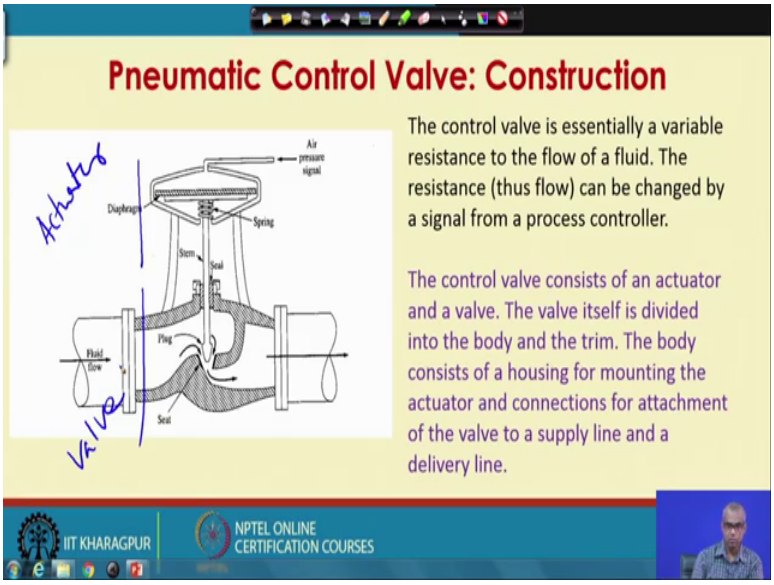

What you see on the screen is a schematic of a pneumatic control valve. So, the control valve is essentially a variable resistance to the flow of a fluid; the resistance and there by the flow rate can be changed by signal from a process controller the control valve consists of an actuator and a valve. So, this part is actuator and this part is valve, the valve itself is divided into the body and the trim the body consists of a housing for mounting the actuator and connections for attachment of the valve to the supply line and delivery line.

So, if you look at the diagram you can see a diag from here which receives a air pressure signal from the controller. So, the air pressure signal comes from the controller and this is fed to the diaphragm with diaphragm a stain is attached. So, in this diaphragm a stain is attached with help of a spring. The other end of this stain is the plug which can sit on the valve seat. So, as the air pressure signal increases the pressure on the valve top increases. So, that pushes the diaphragm downwards.

So, the stem goes downward as the stem goes downward, you can see the plug goes and sits on the valve seat. When the plug completely sits on the valve seat the flow through the valve stops because the flow takes place like this. So, the control valve has two major parts one is actuator, another is a valve; this part is actuator and this part is valve. The valve itself is divided into body and the trim the body consists of a housing for mounting the actuator and the connections for attachment of the valve to a supply line and a delivery line.

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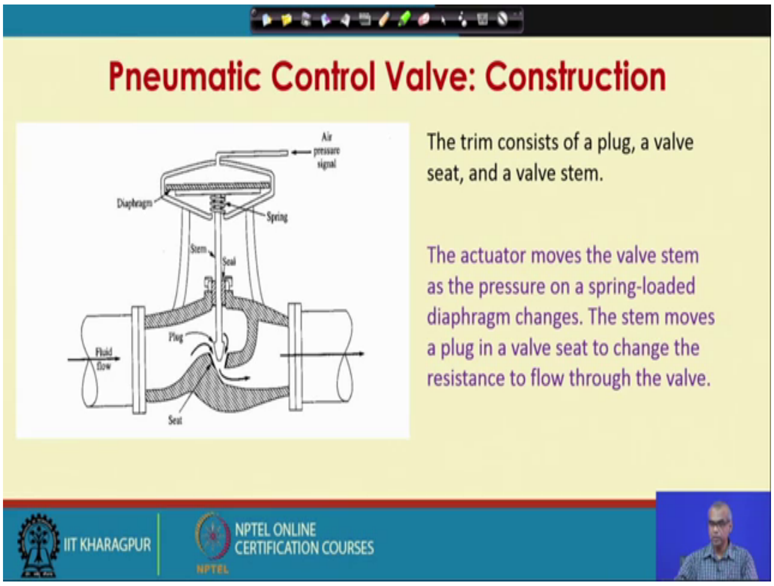

The trim consists of a plug a valve seat and a valve stem. So, valve stem valve seat and the plug. So, trim consists of a plug a valve seat and a valve stem; the actuator moves the valve stem as the pressure on a spring loaded diaphragm changes the stem moves the plug in the valve seat to change the resistance to flow through the valve.

So, as the air pressure signal from the controller increases the pressure on the valve top the diaphragm pushes the stem downward and the valve plug six on the valve seat and the resistance to the flow through the valve increases and the flow rate decreases. As the air pressure on the top of the valve decreases the valve stem goes upward; so, there will be more flow to the valve.

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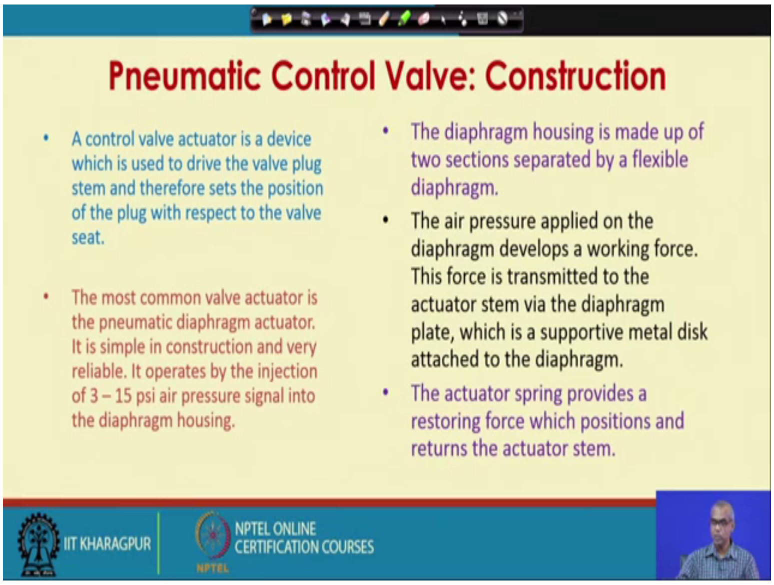

A control valve actuator is a device which is used to drive the valve plug stem and therefore, sets the position of the valve plug with respect to the valve seat. The most common valve actuator is the pneumatic diaphragm actuator it is simple in construction and very reliable it operates by the injection of 3 to 15 psi pressure signal into the diaphragm housing.

The diaphragm housing is made up of two sections separated by flexible diaphragm, the air pressure applied on the diaphragm develops a working force. This force is transmitted to the actuator stem by the diaphragm plate which is a supportive metal disk attached to the diaphragm. The actuator spring provides a restoring force which positions and returns the actuator stem.

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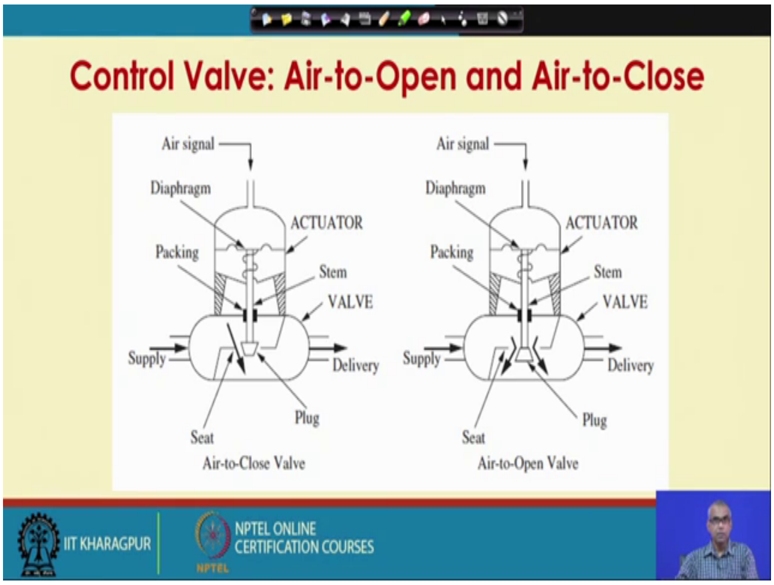

There are two types of control valves we will discuss yet to open control valve and yet to close control valve.

Look at this construction first so, you have this diaphragm and the air signal is acting on the diaphragm. This is the stem which is attached to the diaphragm you have spring as well; as the air pressure increases the stem comes down and the plug completely blocks the opening; that means, as the pressure on the top of the diaphragm or the valve top pressure as we call it increases, the plug completely blocks the flow through the valve.

Look at the shape of the plug as the plug comes down opening decreases and finally, opening is completely closed. So, at that point of time the flow through the valve completely stops; this is known as air to close valve. So, as the air pressure signal on the top of the valve increases; the valve closes this is known as air to close.

In case of air to open valve as the valve top pressure increases; the flow rate through the valve increases because the valve opens more; you can achieve this by simply changing the shape of the plug and without changing anything else. So, now, look at the shape of the plug for this air to open valve; as the valve top pressure increases the stem goes down, but the shape of the plug is such that as the stem goes down the opening now increases and the flow through the valve increases.

So, this is known as air to open valve here the difference between air to close and air to open bulb is only in the shape of the plug. Now again look at this bulb which is yet to close, now instead of putting air signal here if I put air signal here now as the pressure of the air signal increases the stem goes upward and the flow through the valve increases.

So, instead of becoming a to close valve it now becomes air to open valve. So, here I do not change the shape of the plug, but I change the point where I am applying the pressure for air to close valve in this particular control valve or is applying pressure on the top of the valve. Here if I apply pressure below the diaphragm as the pressure signal increases the valve stem goes up. So, that increases more opening and the valve allows more fluid to pass through it. So, it becomes air to open valve.

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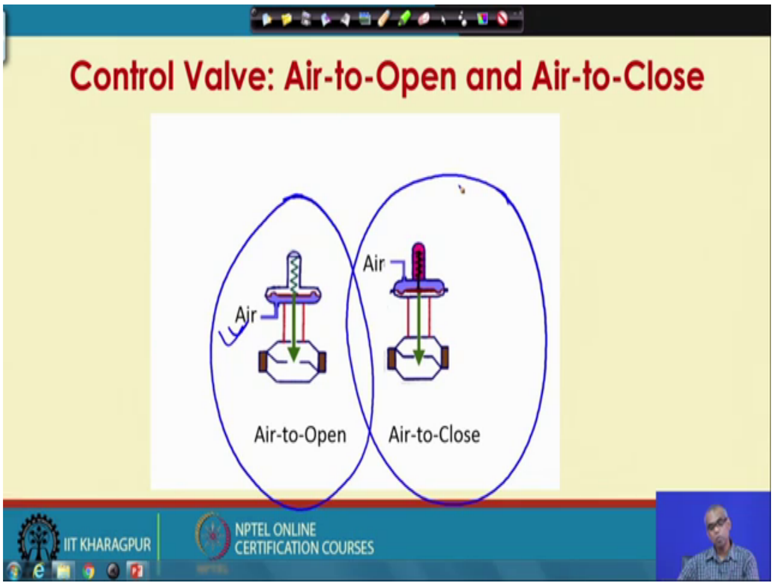

So, this is what is shown here. So, this is air to open where the air signal is being fed to the bottom of the diaphragm where are whereas, this is air to close where the air signal is being applied on the top of the diaphragm.

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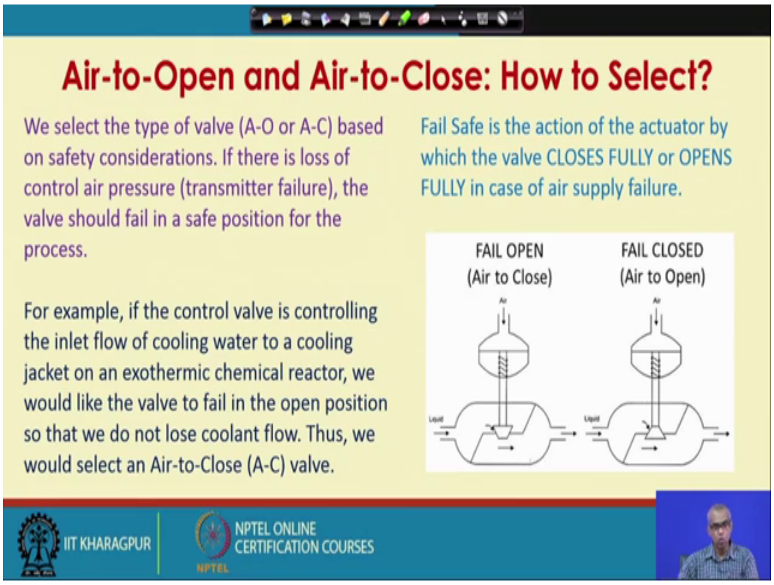

Now, how do I select air to open valve or air to close valve we select the type of valve air to open or air to close.

Based on safety considerations if there is loss of control air pressure; that means, transmitter failure imagine the transmitter fails and the control valve does not receive air signal from the controller in that case a failure happens. So, if there is a loss of control air pressure the valve should fail in a safe position for the process; so, that should be our objective.

So, we have to select the control valve based on safety consideration and the safety considerations will adopt is that in case of a failure. The valve should fail in a position which is safe for the process fail safe is the action of the accelerated by which the valve closest fully or opens fully in case of air supply failure.

So, in case of air supply failure; that means, in case of loss of control air pressure; the failsafe action refers to the case where the valve closes fully or opens fully. So, if there is loss of control air pressure; that means, when there is the failure in the control operation, the failsafe valves will either close fully or open fully. Look at this air to close control valve here as you can see from the shape of the plus as the air pressure on the top of the diaphragm increases the valve closes.

Now, the if there is a loss of air pressure; that means, if there is a loss of the signal the valve will be completely open. So, we call it fail open; so, there is a failure the control valve will open fully. Now look at this schematic for air to open control valve, again from the shape of the plug you see that as the air pressure on the top of the diaphragm increases; the stem goes down which increases the valve opening. So, this is air to open control valve here if there is a loss of air pressure; the valve will completely close. So, this is fail closed because here you need air pressure to open the valve.

So, this becomes a fail closed valve; so, this is fail open and this is fail closed. So, now, how do I choose fail open or fail closed or air to open or air to close? As discussed it depends on the safety consideration for example, if the control valve is controlling the inlet flow of cooling water to a cooling jacket on an exothermic chemical reactor, we would like the valve to fail in the open position so, that we do not lose cool and flow thus you would select an air to close valve I repeat.

Imagine the control valve is controlling the inlet flow of cooling water to a cooling jacket on an exothermic chemical reactor. So, you have a exothermic we have an exothermic chemical reactor and the controller is controlling the floor of the cooling water that is flowing through the jacket.

In case, there is a failure in the control valve we would like to fail the valve in such a position such that we do not lose the coolant flow. Because if we do not lose the coolant flow; so, that is safe for the process. So, thus you select an air to close because the air to close valve is fail open valve.

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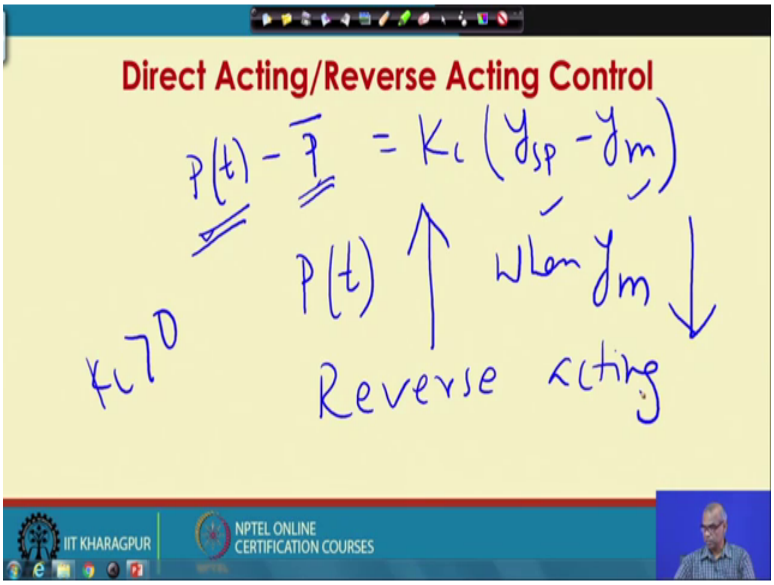

In this connection let me briefly talk about the direct acting and direct acting and reverse acting control. Let us write down how this output of a controller let us say for a proportional controller changes with the error signal which is nothing, but the difference between the set point and the measured signal.

So, this is the output of the controller; so, this is the pneumatic signal output of a say proportional controller and this is the nominal output which will always be there even if set point and measurement measured value or same. So, as the nominal output of the controller; so, that is the output when the controller will be sending when the system is under control; that means, set point is equal to measured value.

So, this P is nothing, but evolved them now let us say we are talking about case when the gain of the controller k c is positive. If the output of the controller increases when the measured value or the input decreases we call this reverse acting.

So, reverse acting control is the output of the controller increases when the measured value or the input decreases. When the output of the controller increases as the measured value or the input increases this is direct acting. So, one is reverse acting another is direct acting in case of divorce acting the output of the controller increases as the input signal decreases in case of direct acting output of the controller increases as the measured signal or input signal decreases.

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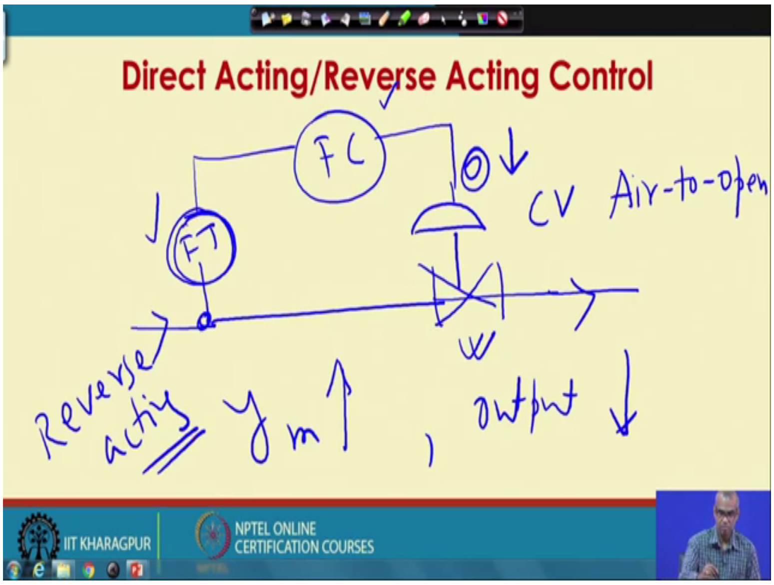

Now, let us consider a flow control let us there is the flow through this pipe; I have a flow transmitter, I have a flow controller and then I have a control valve which is the final control element.

So, this is the flow transmitter, flow controller and the control valve let us say the control valve mean air to open. The control valve I have chosen is air to open now let us consider the measured flow rate is more than the set point. So, we are talking about case when the measured flow rate is more than the set point.

So, what do you want? You want to decrease the flow by closing the control valve. Now this valve is air to open; so, closing the valve will main that the output signal should decrease here. So, the measured value increases, output of the controller decreases that is the requirement to have the control; so, the controller is reverse acting.

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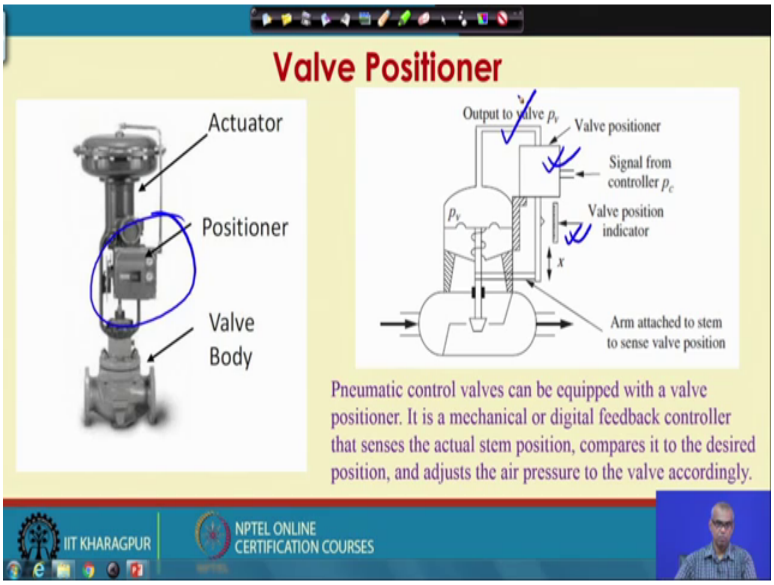

Let us now talk about another important aspect of control valve which is known as valve positioner. Pneumatic control valves can be equipped with the valve positioner it is the mechanical or digital feedback controller that sensed the actual stem position compares it to the desired position and adjust the air pressure on the top of the control valve accordingly.

So, the valve positioner is found here there is the valve position indicator and a valve positioner. So, this valve positioner is nothing, but a mechanical or digital feedback controller that will sense the actual stem position it will compare, it with the desired position and then adjust the air pressure to the control valve accordingly.

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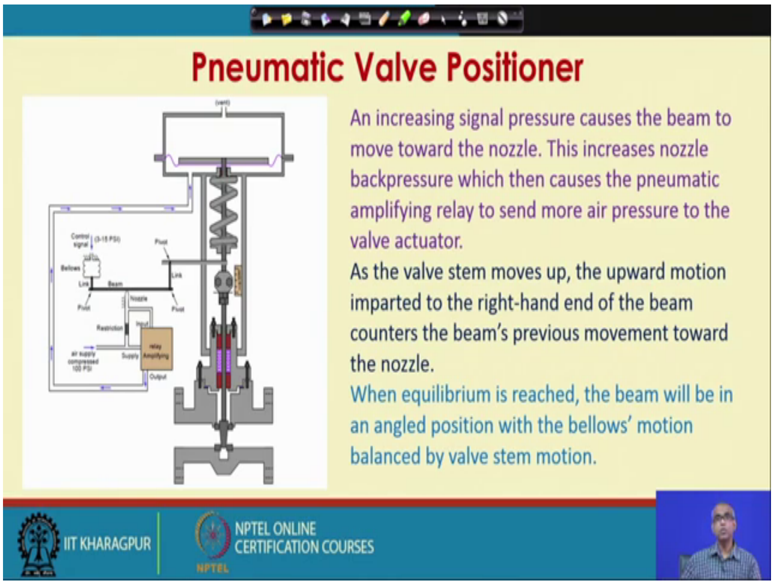

So, the pneumatic valve positioner can work on the principle of flapper and nozzle systems that we have talked about earlier. And increasing signal pressure causes the beam to move towards the nozzle and increasing signal pressure causes the beam to move towards the nozzle. These increases nozzle back pressure which then causes the pneumatic amplifying relay to send more air pressure to the valve actuator; as the valve stem moves up the upward motion imported to the right and right hand end of the beam count as the beams previous movement towards the nozzle.

So, as the valve stem moves up the upward motion imported to the right and end of the bean counters the beams previous moment towards the nozzle. When equilibrium is reached the beam will be in an angle position with the bellows motion balanced by valve stem motion.

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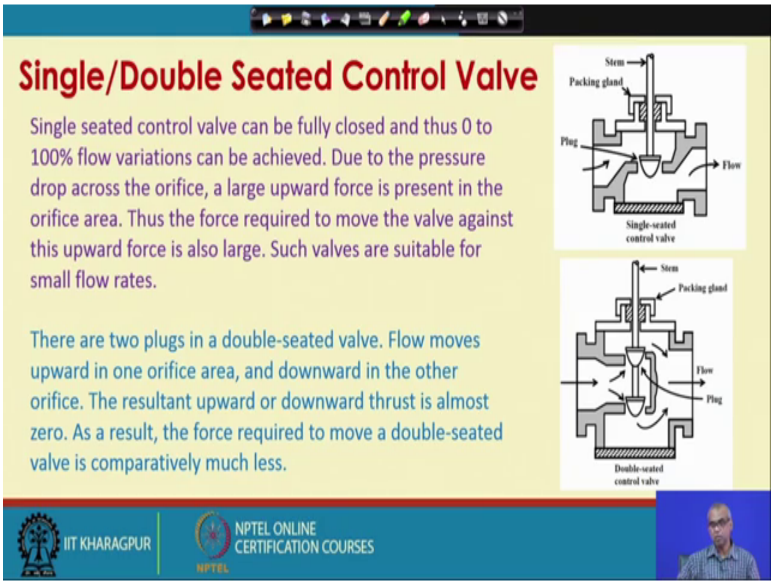

We can have valves with one plus or valves with two plugs we called single seated control valve a double seated control valve. This is an example of a single seated control valve where is this is a double seated control valve schematically represented. Single seated control valve can be fully closed and thus 0 to 100 percent variations can be achieved.

Due to the pressure drop across the orifice a large upward force is present in the orifice area; thus the force required to move the valve against this upward force is also large. Therefore, such valves are suitable for small flow rates; on the other hand there are two plugs in a double seated valve flow moves upward in one orifice area and downward in the other orifice the result and upward or downward thrust is almost 0. As a result the force required to move a double seated valve is comparatively much less. So, in case of single seated valve the force that is required to move the stem is much more compared to the double seated valve.

But the single seated valve can be used to completely shut the control valve.

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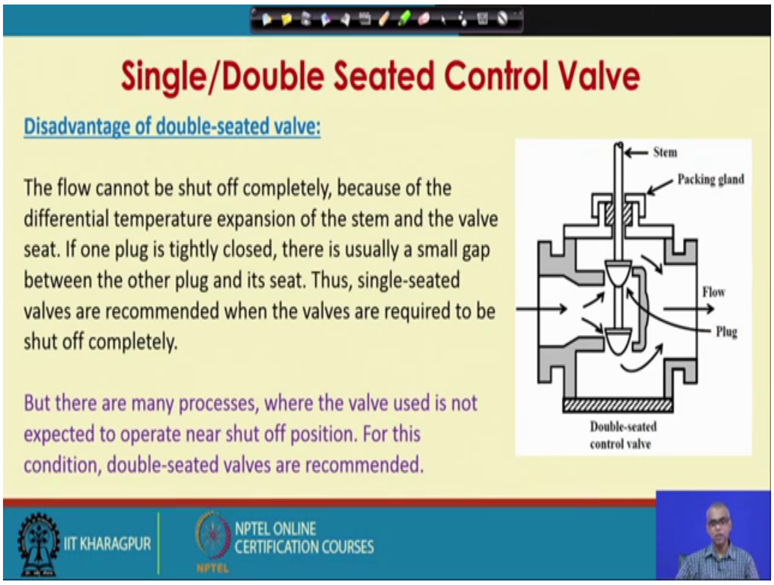

In case of double seated control valve the flow cannot be shut off completely because of the differential temperature expansion of the stem and the valve seat. If one plug is tightly closed there is usually a small gap between the other plug and its it thus single seated vales are recommended when the valves are required to be shut off completely, but there are many processes where the valve used is not expected to operate near shut off position for this condition double seated valves are recommended.

So, this completes our discussion on the construction of the control valve. So, as of now we have highlighted the key issues regarding the construction of the control valve. In the next lecture we will talk about control valve characteristics. So, we will stop our discussion here today.