Oil Hydraulics and Pneumatics
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Part 2: Remarks on FCV, Flow coefficients, Pressure-compensated FCV, Meter-in circuit, Meter-out circuit
Lecture - 41
Flow Control Valves

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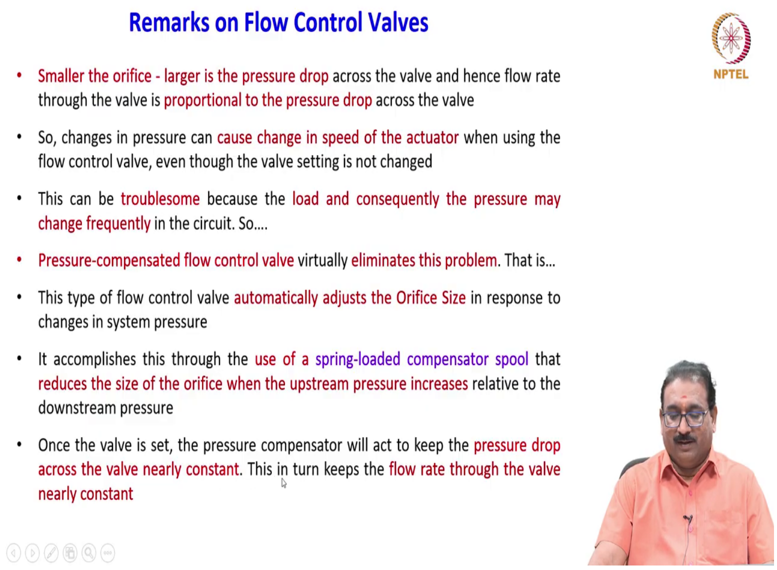

My name is Somashekhar, course faculty for this course. Smaller the orifice larger is the pressure drop across the valve and hence flow rate through the valve is proportional to the pressure drop across the valve. So, changes in pressure can cause change in speed of the actuator when using the flow control valve, even though the valve setting is not changed.

This can be troublesome because the load and consequently the pressure may change frequently in the circuit. So pressure compensated flow control valve virtually eliminates this problem that is this type of flow control valve automatically adjusts the orifice size in response to changes in the system pressure.

It accomplishes this through the use of a spring loaded compensator spool that reduces the size of the orifice when the upstream pressure increases relative to the downstream pressure. Once the valve is set, the pressure compensator will act to keep the pressure drop across the valve nearly constant. This in turn keeps the flow rate through the valve nearly constant.

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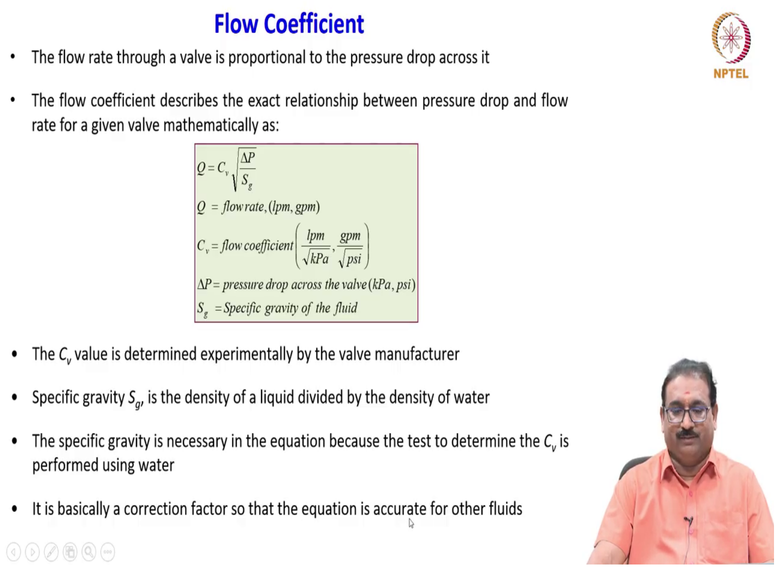

Now, quickly I will show you some of the flow coefficient. The flow rate through the valve is proportional to the pressure drop across it. The flow coefficient describes the exact relationship between the pressure drop and a flow rate for a given valve mathematically as: Q equal to C v into route delta P by S g. Here Q is a flow rate in liters per minute or gallons per minute, C v is a flow coefficient and delta P pressure drop across the valve, S g is a specific gravity of the fluid.

The C v value is determined experimentally by the valve manufacturer. Specific gravity S g is the density of liquid divided by the density of water. The specific gravity is necessary in the equation because the test to determine the C v is performed using the water. It is basically a correction factor so that the equation is accurate for the other fluids.

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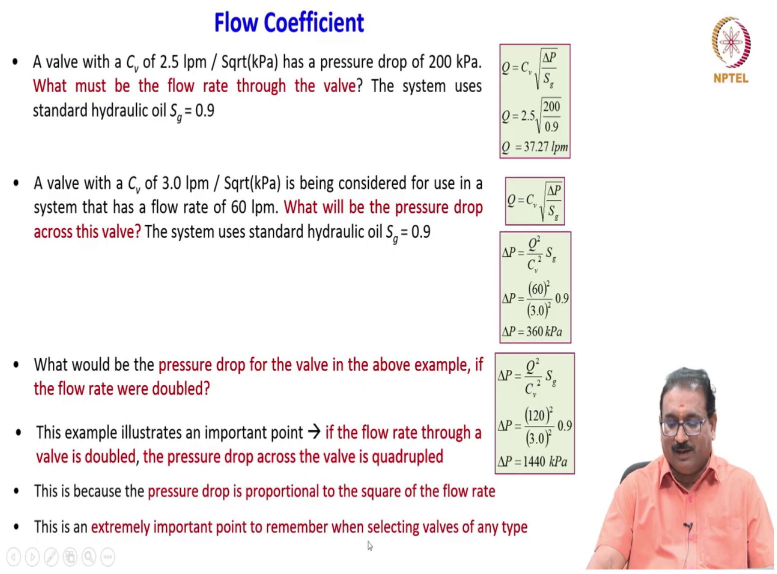

Quickly I will show you the significance of the flow coefficient. A value with a C v of 2.5 lpm per square root of k Pascal has a pressure drop of 200 kPa kilo Pascal. What must be the flow rate through the valve? The system uses a standard hydraulic oil S g equal to 0.9. Very quickly Q equal to already we know that C v into root delta P by S g substitute the given value.

We will get the Q equal to 37.27 liters per minute. Units are very important friends here, similarly, one more. A valve with a C v 3.0 liters per minute per square root of kPa is being considered for use in a system that has a flow rate of 60 liters per minute. What is the pressure drop across this valve? The system uses a standard hydraulic oil S g 0.9, same here Q equal to C v into root delta P by S g, same.

Here delta P is I am squaring out both side. I am getting delta P equal to Q square by C v square into S g, substitute all the value. I am getting delta, delta P is 360 kilo Pascal. Now, we will see, what would be the pressure drop for the valve in the above example, if the flow rate were doubled? Flow rate now here it is 60, if I will doubled the flow rate what happens to pressure drop you will see.

If I will doubled the Q previously 60, now, it is a 120. If you will double it what happens you will see here. This example will illustrates that if the flow rate through a valve is doubled, the pressure drop across the valve is quadruples see here quadrupled. Previously 360 kPa delta P, now it is 1440 kPa which is a quadrupled if the flow is doubled. This is because the pressure drop is proportional to the square of the flow rate correct. This is an extremely important to remember when selecting the valves of any type.

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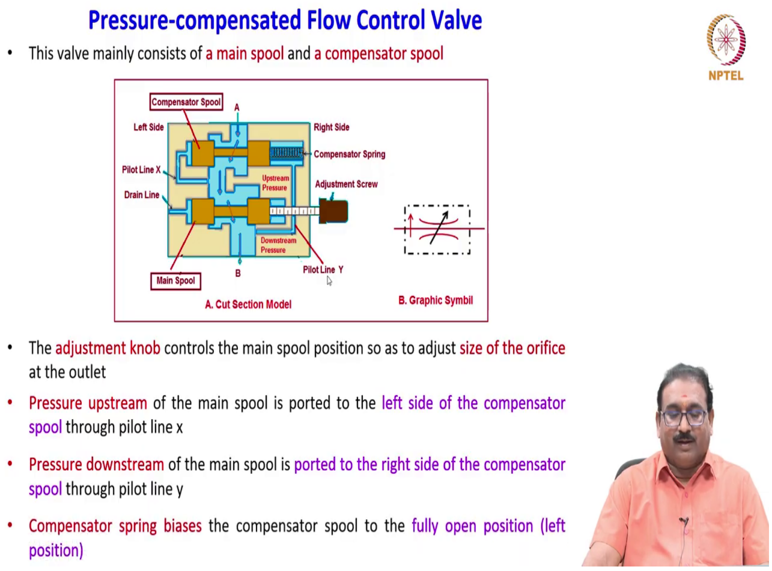

As I have told you pressure compensated flow control valve is a very very important. Automatically it will adjust based on the upstream pressure, how it is there you will see this friends. This valve mainly consists of a main spool and a compensator spool. Schematically shown here, the cut section model here.

It mainly consists of the main spool here. See the main spool and one more is a compensator spool, which are enclosed in the whole valve body. And you will see the adjustment knob is there screw adjustment knob controls the main spool position so, as to adjust the orifice size of the orifice at the outlet.

The pressure upstream of the main spool is ported to the left side of the compensator spool here. Similarly, the pressure downstream of the main spool is ported to the right side of the compensator spool through the pilot line Y. Compensator spring biases the compensator spool to the fully open position always it is left beginning.

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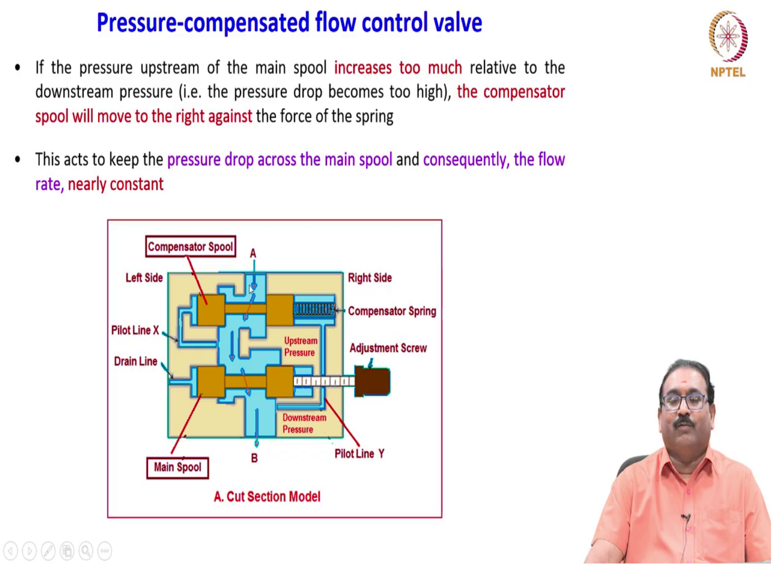

If the pressure upstream you will see the pressure upstream of the main spool increases too much relative to the downstream pressure; meaning, the pressure drop becomes too high the compensator spool will move to the right side against the force of the spring.

If this upstream pressure increases what happened here through the pilot line X this will be pushed against the spring force. This acts to keep the pressure drop across the main spool, consequently, the flow rate, nearly the constant. Always the flow rate across this main pool valve is a constant. This is achieved through the compensator spool very very simple friends it is.

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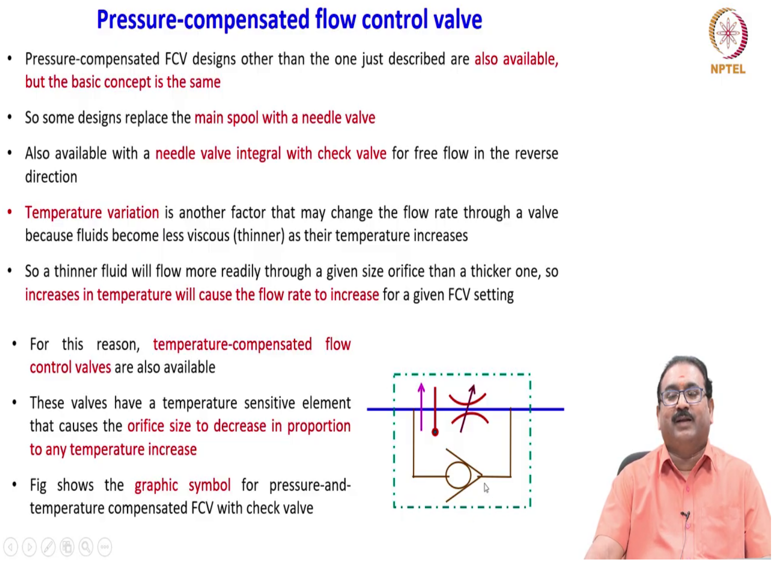

The pressure compensated FCV designs other than the one just described are also available, but the basic concept is the same. So, some designs replace the main spool with a needle valve, also available with the needle valve with integral with check valve for a free flow in the reverse direction. Temperature variation is another factor that may change the flow rate through the valve because fluid becomes less viscous meaning thinner as the temperature increases.

So, the thinner fluid will flow more readily through the given sized orifice than the thicker one. So increase in temperature will cause the flow rate to increase for a given flow control valve setting. For this reason temperature compensated flow control valves are also available like the pressure compensated flow control valves.

These valves have a temperature sensitive element that causes the orifice to decrease in proportion to an any increase in the temperature. Figure shows the graphical symbol of the pressure and temperature compensated flow control valve with a check valve. You will see here only if it is a pressure compensated one arrow mark here across the valve flow control valve.

Now, it is a temperature compensated one temperature sensor. again you will remember from this graphic symbol flow is always taking place from the left side to right side through the throttled metered orifice and from B to A meaning from right to left always through the check valve unrestricted flow.

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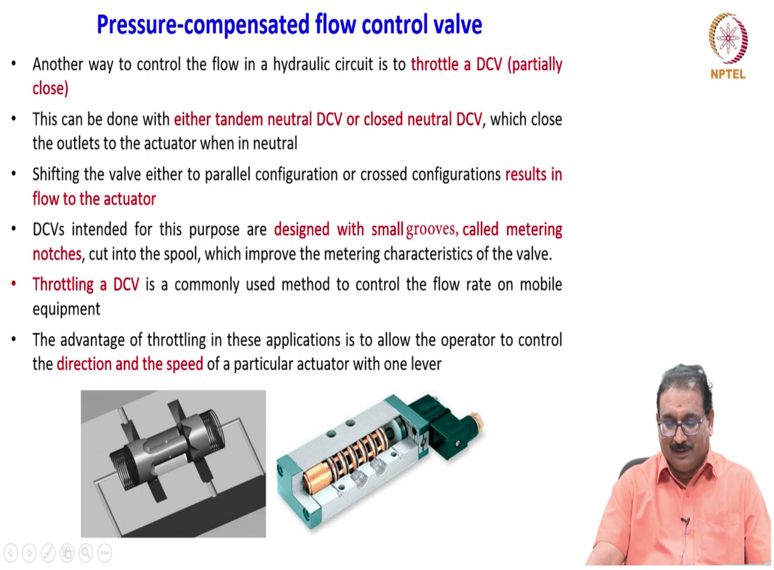

Another way to control the flow in the hydraulic circuit is to throttle a DCV partially closing. This can be done with either at tandem neutral DCV or a closed neutral DCV, which closes the outlet to the actuator when in neutral. Shifting the valve either to parallel configuration or a crossed configuration, results in flow to the actuator.

DCVs intended for this purpose are designed with small grooves, called a metering notches, cut into spool, which improves the metering characteristics of the valve. Throttling a DCV is a commonly used method to control the flow rate on the mobile equipment.

The advantages of throttling in these applications is to allow the operator to control the direction and the speed of the particular actuator with a one lever. See here how the notches they are cut on the spool valve correct this is a different notches are there.

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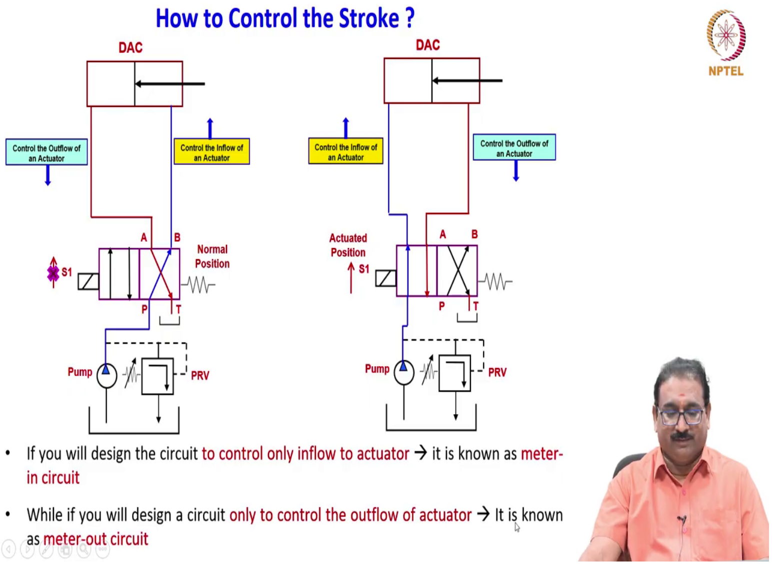

Now, quickly we will see the application of these flow control valves; How to control the stroke here? Now we will see this here this is a Double Acting Cylinder DAC connected to the 4 by 2 DCV solenoid actuation S1. Now it is a normal position is achieved using the stiff spring across the spool, here the pump flow is going to the rod end and whatever the fluid is there and the head side it is going to the tank.

Then can you please tell me how to control the forwards stroke or return stroke? Can you please think me now? Now to control the speed of this actuator we are having the two possibilities, what are those first one you will control the inflow of an actuator or control the outflow of an actuator, you will do either this are either this.

Meaning, you have to control the inflow or control the outflow from the actuator. Also you will see when you will move to the actuated position here also you will see now here the pump flow is now going to the head side, the tail side flow is going to the tank. Now again here you will control the inflow then actuator speed it will be controlled or you will control the outflow, do not control the inflow.

Meaning, there are two possibilities are there to controlling the speed of the actuator. How to do this? Let us we will see if we will design the circuit to control only the inflow to actuator it is known as the metering circuit, while if you will design a circuit only to control the outflow of actuator it is known as meter out circuit.

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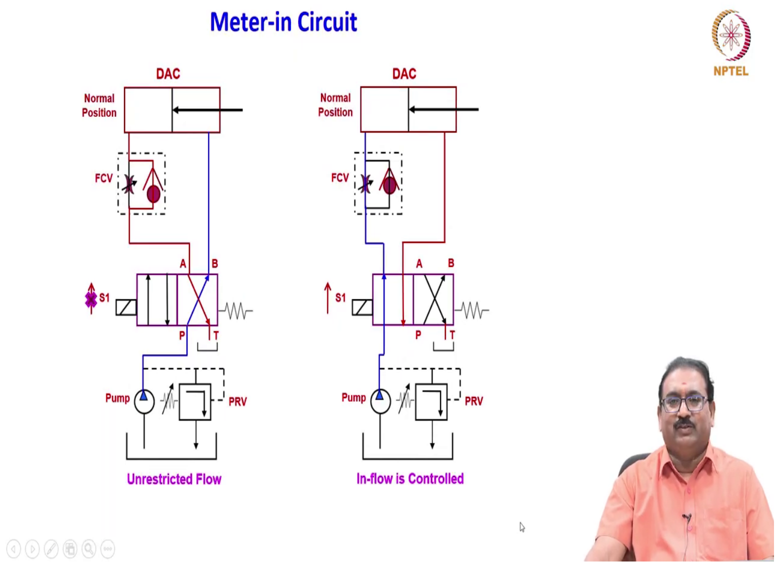

Let us will see how this circuits will looks, this is a metering circuit what I have drawn here, here is the Double Acting Cylinder DAC first one is a normal position meaning always the circuit you have to draw only in the retracted position meaning it is a normal position. Here as usual the 4 by 2 DCV solenoid actuation springs center, here you will see the flow control valve what I have drawn here.

Then here a pump with a pressure relief valve, this pressure relief valve always to control the system pressure maximum system pressure. Now we will see in this position what happens friends? In the null position without any actuation the pump flow is going to the rod side, the head side flow will come here; see now it will not pass through the orifice.

It will bypass correct friend it will bypass, meaning here you no need to worry here the inflow is also not controlled outflow is also not controlled in this direction correct meaning cylinder will be retracted back. When once you will operate the solenoid S1 what happens you will see, the pump flow is going to the head side. How it is going friends?

It is going through the throttle; the metering how much you are provided here only that much fluid is going to the head side of the double acting cylinder, the tail side fully going to the tank, but how much flow is coming here will matters to control the speed of an actuator. Here what I am controlling here in actuated position I am controlling the inflow that is why it is called meter in circuit.

In null position no need to worry, if you want to control here also how to do it, I will tell you. Now in this circuit what I have drawn using the one flow control valve at the head side, in this figure it will control only the in actuated position the inflow to an actuator.

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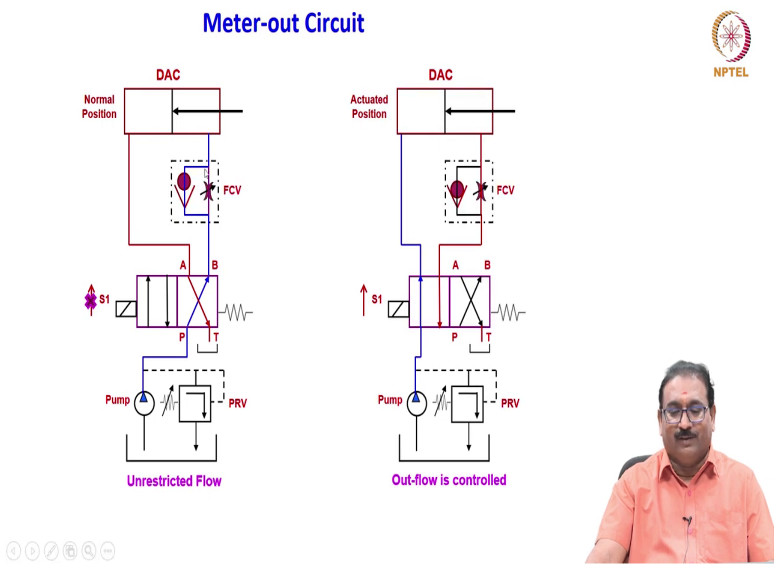

Similarly, outflow how to control friends you will see here now, now same figure it is now I have used at the tail side meaning rod side I have used as a flow control valve. Now we will see the pump flow is coming here P to B it will go, then you will see here valve will be lifted up because the path of resistance path of least resistance is only through the check valve; then it will enters to the rod side whatever the fluid is there and the head side it is going to the tank.

Meaning what? The flow inflow is not controlled here. Once you will operate the solenoid now what happens you will see now here; once the solenoid actuated the pump flow is connecting to the head side and the tail side fluid is coming here it will not pass through the check valve.

It will pass only through the metered orifice, then it will go to the tank meaning I am controlling outflow of the actuator it is known as the meter out circuit. See here if you are controlling the inflow of an actuator it is a meter in circuit; if you are controlling the outflow of the actuator it is known as meter out circuit.

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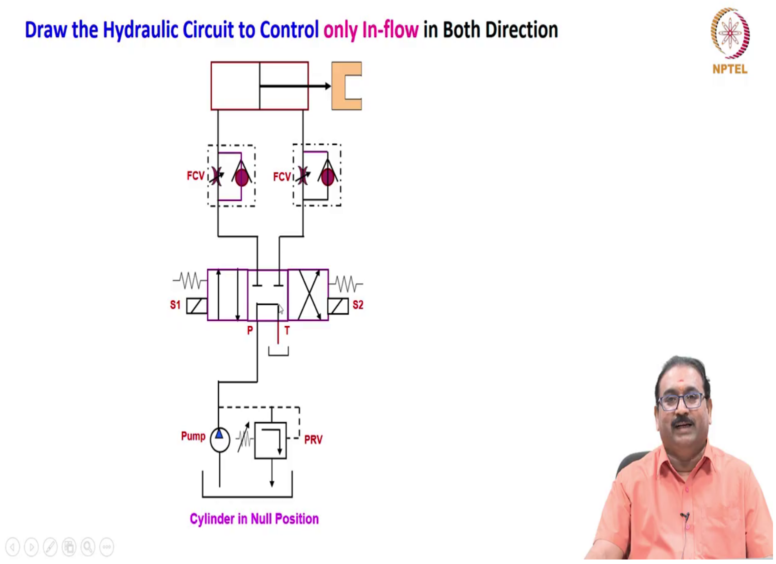

Now, we will see draw the hydraulic circuit to control only inflow in both directions, you will see now inflow in both direction; now only way is I am using the flow control valve head side as well as a tail side. Now we will see always you will draw the circuit in the null position friends.

You will see this is now it is a now I have drawn here the 4 by 3 DCV tandem center correct P is connecting to T and A and B are blocked always in the null position you have to draw the circuit. Now you will analyze, If I will operate the solenoid S one what happens? If I will operate the solenoid S 2 what happens?

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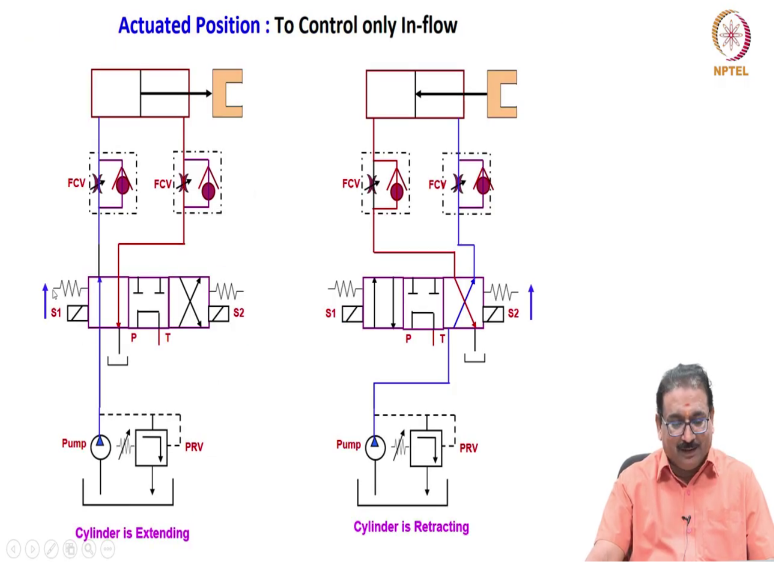

Let us will see here if the S1 is operated what happens? You will see the pump flow is coming here and it will not pass through the check valve, because position you will see here only it will pass through the orifice how much you are opened meaning the inflow is controlled. Then whatever the flow is there at the rod side it will bypass through the check valve meaning inflow is controlled when S1 is operated.

Similarly, when you will operate the S2, now we will see friends what happened, the pump flow is coming here it is going here then it will not pass through the check valve, it will pass through the orifice how much you are opening; again you will see here the inflow is controlled.

Now we will see the outflow at the head side it will come here it will bypass and going to the tank. You will see if the head side and tail side if I will use the flow control valve, see the direction of the check valve very very important because valve looks same. Please see if you want to control the inflow the position of the check valve will please see here.

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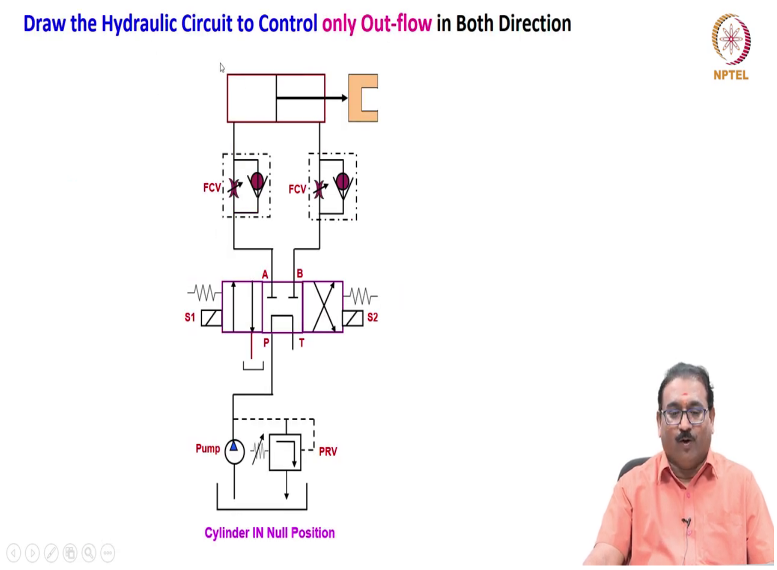

Now, similarly you will see here draw the hydraulic circuit to control only the outflow in both direction, see the position of the check valve very important here friends, because how we are connecting that will matters always as usually you have to draw the circuit in the null positions; again it is a tandem neutral correct the pump PRV all are same S 1 and S 2 are solenoid actuator valve.

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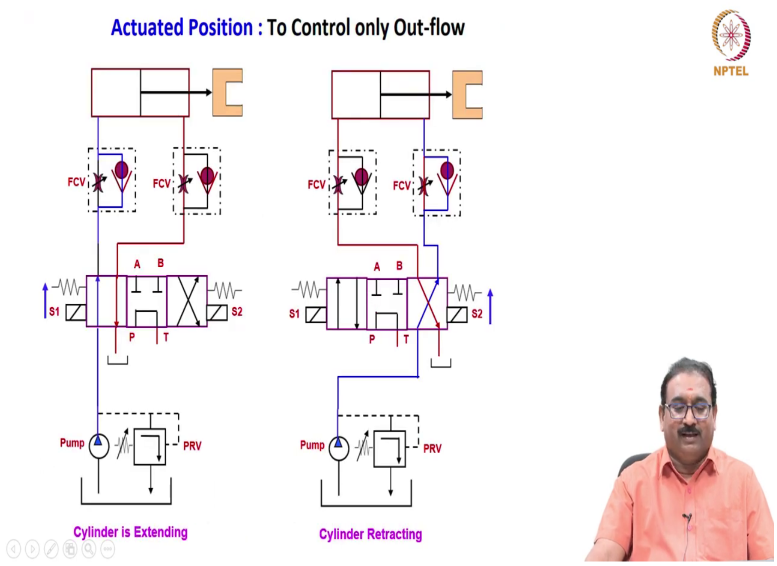

Now we will see in the when S 1 is operated, what which flow is controlled you will see now; pump flow is coming here, then you will see now friends here it will not pass through the opened orifice, it will bypass because the ball will lifted up from the valve seat, it will enters here flow is not controlled. Then from the rod side flow will come here it will pass through the metered orifice.

Meaning which flow I am controlling? Outflow I am controlling you will see in the forward direction. Similarly, when I will operate S 2 same thing you will pump flow is coming here, going here, then it will bypass inflow is not controlled then you will see the head side the outflow is coming here and pass through the metered orifice and then it is going to the tank.

See here friends, the flow control valve when you are using be careful by seeing the position of the check valve is very very important, whether you are controlling the flow into the actuator or flow out of the actuator, this will matters the meter in and meter out circuits.