Fundamentals of Industrial Oil Hydraulics and Pneumatics
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Module03 Lecture08
Different Types of Valves- Features and Operations-ll

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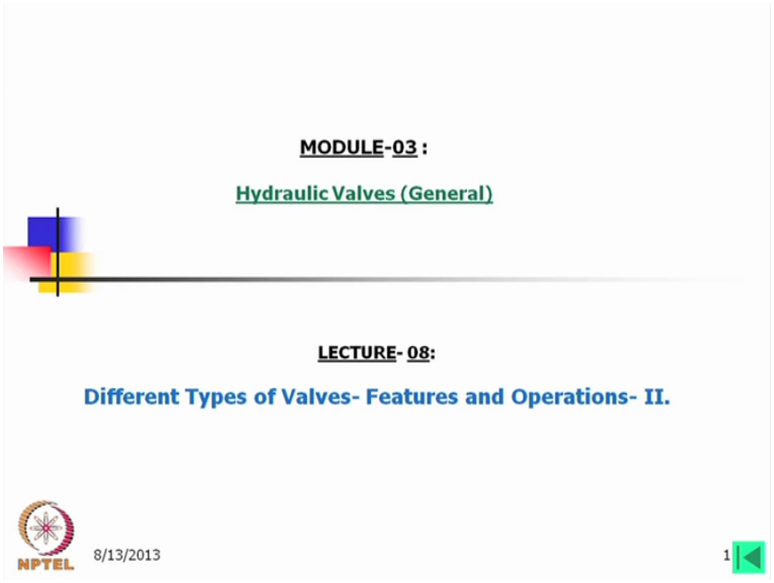

Welcome to this lecture on hydraulics and pneumatics. This is module 3 hydraulic valves general. Today's topic is different types of valves-features and operations 2.

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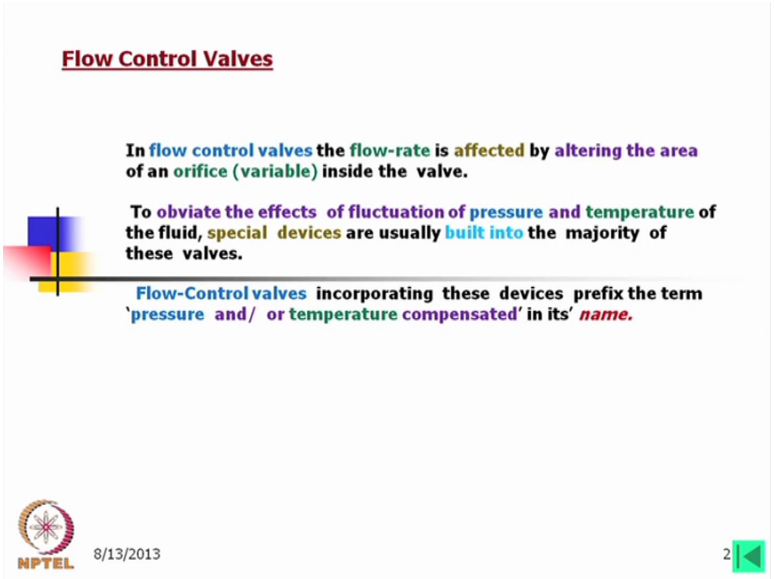

We shall discuss about flow control valves. In flow control valves the flow rate is affected by altering the area of an orifice inside the valve. The orifice is variable. To obviate the effects of fluctuation of pressure and temperature of the fluid, special devices are usually built into the majority of these valves. Flow control valves incorporating these devices prefix the term pressure and or temperature compensated in its name.

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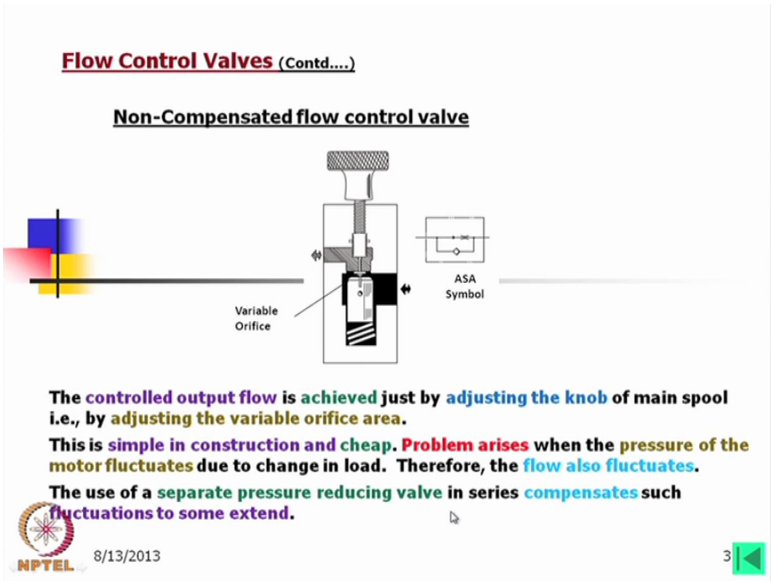

Now if we look into this figure, this is non-compensated flow control valve. This can work in both ways. This means in one way, it is a free flow through a check valve, but in other way it is

flow control valve or throttle valve. Let us consider flow from right side to left side. So this black means this is pressurized. So oil is coming through this and then it is passing through this orifice and going to left side. Here, this orifice is variable the area of which can be controlled by rotating this knob. So depending on the area the flow will be throttle and there will be control of flow that means amount of rate will reduce or increase depending upon the orifice area allowed to flow.

On the other hand, a flow comes from the reverse side that means from left side, then it can go to the other side by moving this poppet against the spring. Now as you see the configuration or the symbol is presented by this. So when the flow is coming from this side from here from the left side then it is going through the throttle valve whereas, the flow is coming from the reverse side; it is going through the check valve. Now this definitely it can be developed the equation for such flow knowing the geometry of this orifices.

Now the controlled output flow is achieved just by adjusting the knob which I have described on main spool by adjusting the variable orifice area. This is simple in construction and cheap. Problem arises when the pressure of the motor fluctuates due to change in load. Therefore, the flow also fluctuates. The use of a separate pressure reducing valve in series compensates such fluctuation to some extend. We have not yet learn what is pressure reducing valve we shall discuss a little later.

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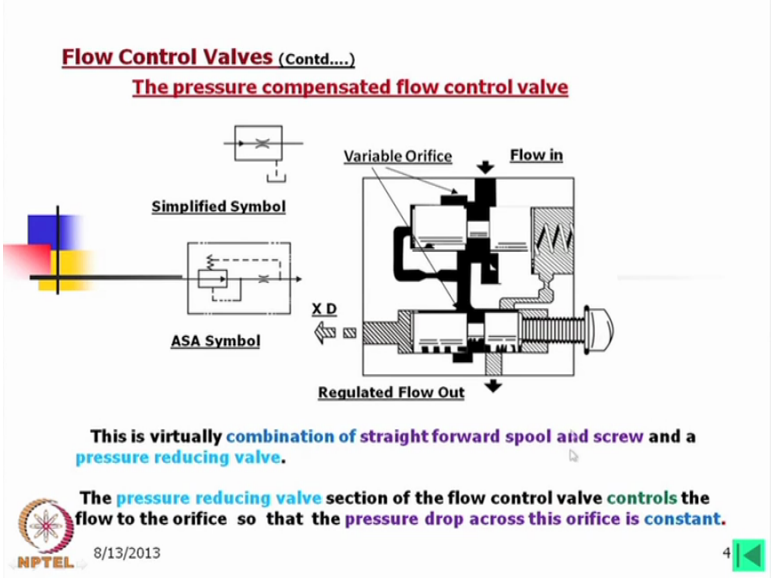

Now the pressure compensated flow control valve. The simplest one what we have seen there will be fluctuation of flow if there is change in pressure of the actuator or motor. Now for that this valve can be modified introducing a pressure compensated device inside it. Now what we look into this there is a spool. This is the main spool and this is the main area orifice area main orifice. Now this spool is supported by a spring flow is coming in and through this orifice, it is going to other side. These figures is not exactly showing that the orifice area. However, this orifice area can be fully closed by compressing this one.

Now this flow while it is coming through this, then there is another spool arrangement. What we find that through this spool this oil can go the other side of the main spool. Also there is another orifice. This can go the left side of the main spool. Now this spool can be adjusted. Now what happens that when the flow is going through this and going out depending on the orifice opening here the oil flow some part of the oil flow is going back to the tank through the relief valve here and the other part of the oil is going to the other side?

Now amount of this flow is a adjusted by this one as well as this is pressure compensated in a sense, suppose there is a increase in the pressure. Once there is an increase in this pressure definitely there will be change in flow, because through this in this orifice, there will be change in pressure difference. Once, this flow is changed then there the flow will occur (this) through this orifice. In normal conditions, if the spool does not move or this does not move there will be no change in flow through this orifice, but once there is a change in flow here there will be change in pressure difference in this orifice also. Suppose this side the pressure has increased automatically what will happen. This will be slightly closed and this area will be reduced and then the again the same amount of flow will be maintained with this pressure difference.

Now it is difficult to understand just by these words, but you need to study these valves thoroughly to understand that what is happening. Always you should keep in mind that wherever there are orifice the flow will change and there will be change in pressure drop once the flow begins through these valves and ultimately, these two pressure that pressure difference keep these spool in balance position for longer time. However, (it is) in this configuration it is also possible that we can externally excite this spool and then there will be change in flow which is not flow control valve, which will not act as a flow control valve, but bypass the flow.

So sometimes this external excitation is also required to operate this valve or to driver the flow and if we look into the symbols. This is the ASA symbols more simplified symbol is this one. It is it may not be easy to remember this symbols, but looking into this at least we should be able to understand that this is a pressure compensated flow control valve. Now this is virtually combination of straight forward spool and screw and a pressure reducing valve. The pressure reducing valve section of the flow control valve controls the flow to the orifice so that the pressure drop across this orifice is constant. This means that we can change when there is a change in pressure then this orifice is controlled in such a way again the pressure drops with this remain constant and the spool will come back to in original positions. So the flow remain constant that pressure difference we can change only by tightening or loosening this spool.

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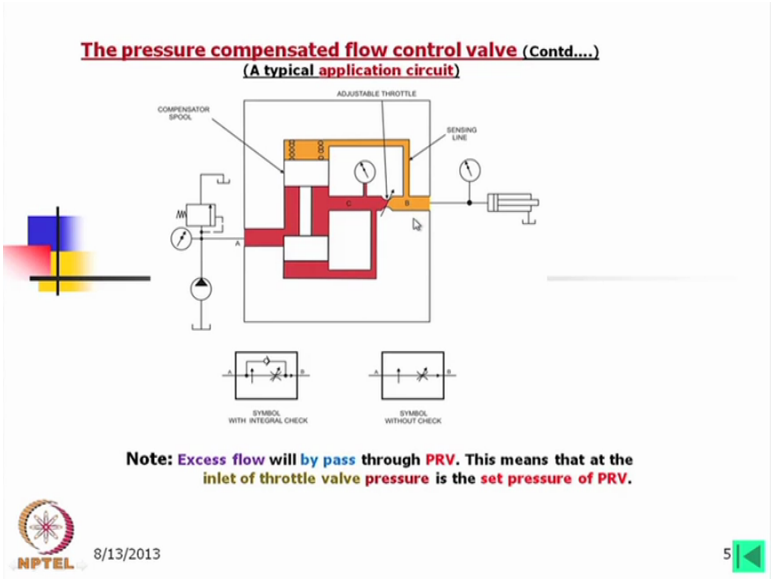

Now this is a typical application of this circuit, as you see (this) there is a pump and there is a pressure relief valve and then this is the pressure compensated flow control valve. The main flow is going through this orifice which can be adjusted and depending on this adjustment, there will be certain amount of flow will go to this actuator and the rest of the flow will go back to tank through the pressure relief valve through this pressure relief valve. Now if there is any change this flow or pressure then this will affect this side as well as this side and this spool will be readjusted to control the flow further and it will again come back to the original flow requirement.

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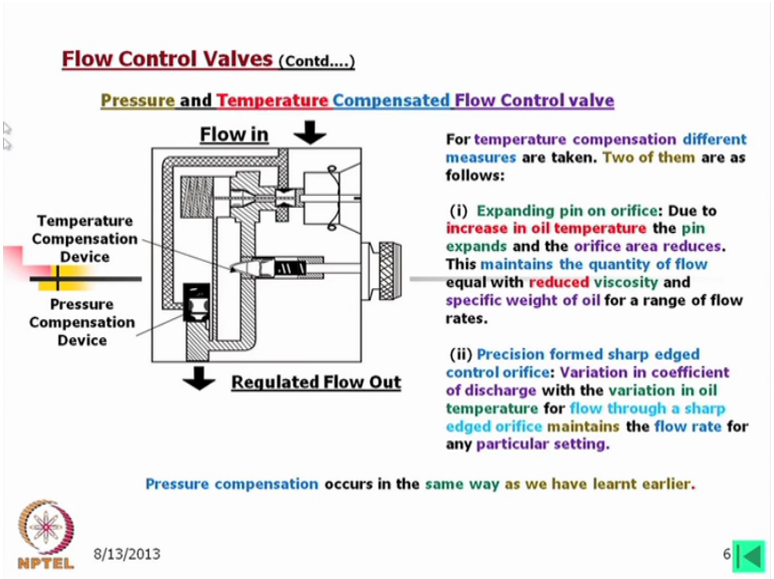

However, this pressure compensation is not enough to keep the flow constant or desire flow, because due to the temperature variation there is also change in the orifice area. To compensate that there is a temperature compensation device which we can assume in the orifice there is a either metallic or non-metallic bellow type thing which expands with the increase in temperature and compressed in when the temperature is lowered. What it does? It changes the orifice area to keep the flow amount same. Why the flow amount will increase in pressure compensation valve. We have sorry, in flow control valve with pressure compensation only there is a possibility that flow will change if the viscosity changes. If the with the increase in temperature the oil becomes thinner or thicker. Now that is compensated by this temperature compensator.

Now here again if we look into this device, the flow is coming over here depending on the orifice open here the flow will come to this side and we can adjust this orifice to decide the amount of flow. Here there is practically no adjustment we can adjust this to have the flow control flow within a range of course. It cannot be make from 0 to 30 liters per minutes, it might be we are controlling this valve depending on it range may be 25 to 30 liter per minutes depending on of the size of this orifice. Now when we adjust this then this flow I coming over here through this orifice and there is pressure in this side as well as through this side the pressure is also in the opposite side and thus, this spool is balanced to maintain a certain orifice area and it is further controlled by this temperature compensation.

This is I have written, the temperature compensation different measures are taken. Two of them are as follows one expanding pin or orifice due to increase in oil temperature the pin expands and the orifice area reduces. This maintains the quantity of flow equal to with reduced viscosity and specific weight of oil for a range of flow rates. Precision formed sharp edged control orifice. The orifice are can also be designed in different way that it can be made it can be made very sharp edged or slightly (())(15:37) edges. Depending on the requirement we make we design such orifices. Variation in coefficient of discharge depending of such orifice edges, there will be change in coefficient of discharge. So variation in that coefficient with the variation in oil temperature for flow through a sharp edged orifice maintains the flow rate for any particular setting. Pressure compensation occurs in the same way as we have learned earlier in this valve.

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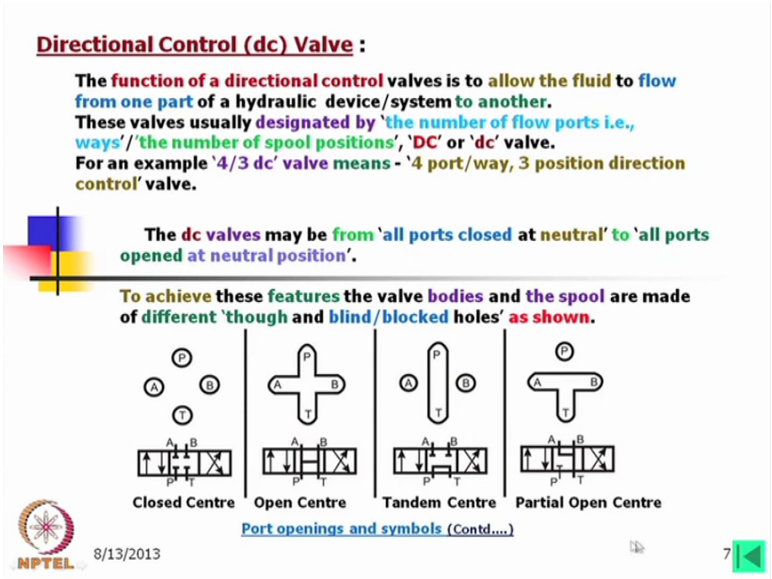

Now we will come into the direction control valve. In my earlier lectures I have already discussed a little bit about the directional control valve. This is most essential component in any circuit any hydraulic circuit. The function of directional control valves is to allow the fluid to flow from one part of a hydraulic device/system to another. These valves usually designated by the number of flow ports that is ways by the number of spool positions. It is simply called either capital DC or small dc valve. For an example, 4 by 3 dc valves means 4 port or way, 3 position direction control valve.

The dc valves may be from all ports closed at neutral to all ports opened at neutral positions. Some valves of course, there is no neutral position, it is simply either one directions or in the opposite directions. There is no such neutral positions, but in most of the valve you will find there is a neutral positions. To achieve these features, the valve bodies and the spool are made of different through and blind or blocked holes as shown below. Now here if we look into the left one the left most one, already we know this is 4 by 3 closed centre dc valve. We have not shown how it is operated.

Now here what we find this 4 ports are closed or blocked at a neutral position. So these ports A, B, P is the pressure port, T is the drain port. It is going T means tank, P means pressure not pump here pressure port. It might be from single pump or from a system. Now A,B is normally in the actuator side these two ports and this is the symbol and whereas we can mention the ports are lying that all are independent at the neutral position. When we come to the right hand side the connections are like that. When we come to the left hand side the connections are like that. This directly indicates that if we move the lever or some actuator to drive the spool if we move leftward this is the straight connection P to A and B to T. if we move rightward directions then P to B and A to T.

Now if we come to the next one which is fully open centre at neutral position, it is fully open that is represented by the plus sign sort of things, where A,P, B. T all are interconnected at the neutral positions, others are same as closed centre. Now next one is the tandem centre. In that case, in at neutral position pressure port is connected to tank. This to save energy, the flow at ideal condition is going directly to the tank, okay and this one is that partial open centre. In that case, what we find only the pressure ports remain closed at the neutral position where other 3 ports A, B and T are interconnected. Now I have discussed a little bit about the use of such valves, say for example closed centre is used where we would like to keep the oil always ready and we do not one when it is in the ideal conditions, the actuated portion should move in the opposite direction. That means actuator is arrested at the position when the valve is at neutral.

In case of open centre if we keep at neutral positions then all are connected means the load will come down, the actuator will go back to its least resistive position. Now if I compare these two valves closed centre has a first response while we are actuating for operating the load in comparison to open centre. On the other hand, open center is most energy saving all the energy is

not being lost when it is in the ideal conditions. So if there is a frequent operation probably we will go for closed centre and if the operation is not very frequent we can go for open centre and tandem centre is in between these two and in many cases the tandem centre is used. Partial open centre may be a special case.

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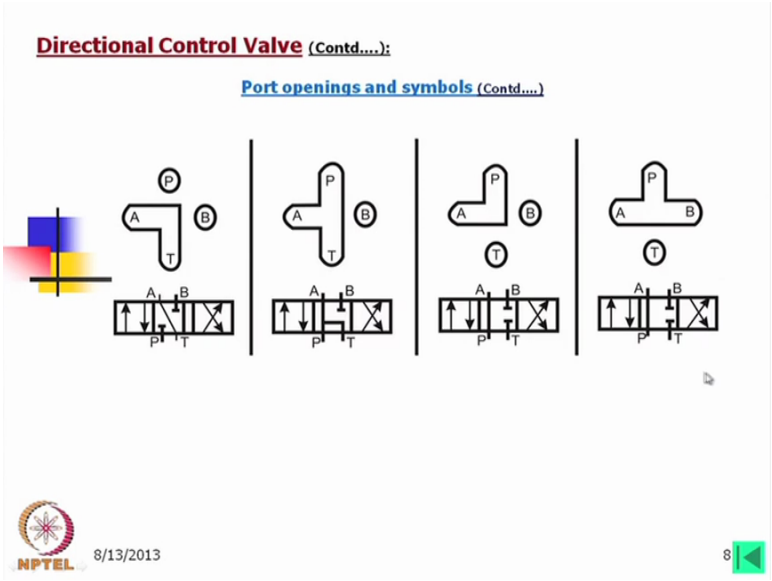

Now I have shown some other all symbols here. So look into this valve, you need to study of your own such symbols and what might be the possible openings, but here it is clearly shown. This means that in this valve left most position this valve is having A to T that A port to T port is connected at the neutral positions. This means when it is neutral positions then one flow to one side which is interconnected, say if we remember our circuit the A port was at the bottom that means when your neutral positions the load will automatically come down, A this oil will put the tank.

Now if we come to that you can understand from this A, P,T are interconnected at the neutral position where B is closed and if we come to this one. Always there is a flow to the A side from the pressure side whereas, B and T remains closed at neutral and here, this also A, P and B are interconnected, but T is closed. Possibly there is a mistake that we have to connect this one we have to connect this one, okay. Actually, in this symbols this mistake is there A should be connected to B. Now these are depending on different type of applications in always the target is that aim is that we should save the energy as much as possible. The first aim of the hydraulic

circuit is to save the energy as much as possible, while we are applying, but in many cases in case of hydraulic operation particularly, where we need very precision operation and time mound operations, sometimes it is not possible, but still depending on the applications we can go for any one of this valves.

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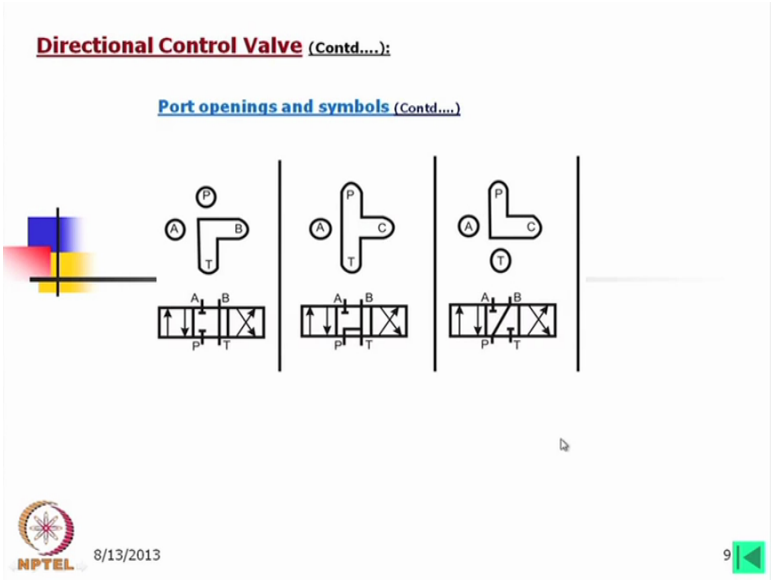

Now the last one valve like that possibly you can study of your own you can see this B to T is connected here P,C,T are connected and here this is P to B is connected.

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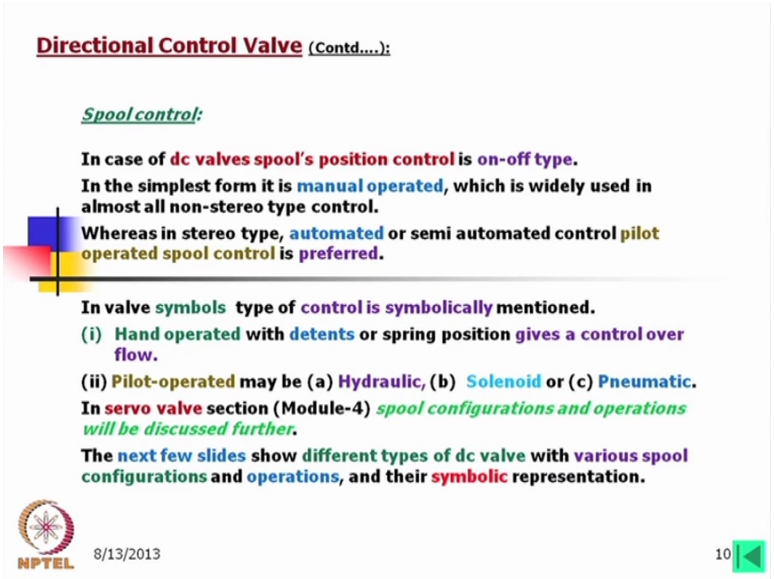

Now we will look into the spool control. In case of dc valves spools position control is on-off type. Once we mean that direction control valve means it is on and off type. In some cases, we can control this valve keeping the spool in intermediate position and we can control the flow to some extent we can also control the pressure, but these are not desired neither the purpose of spool valve is to control the flow rate or the pressure. This means that while we are designing the spool orifice only to avoid the transient dynamics we should design the orifice either very sharp or slightly blind or may be chamfered edged etcetera depending on the applications, but in case of servo valve the same port will be designed very accurately to control the flow any way we will come later when we will study the servo valve.

In the simplest form, it is manual operated the spool is manual operated, which is widely used in almost all non-stereo type control. Whereas, in stereo type that is automated or semi-automated control pilot operated spool control is preferred. The valve symbols type of control is symbolically mentioned. In valve symbols we mentioned also how it is controlled. Hand operated with detents or spring position gives a control over flow. As I have mentioned we can also control a flow little bit by detaining the spool in a position intermediate position. Pilot operated may be a again hydraulic, solenoid or pneumatic. In servo valve section 4 section in module 4 spool configurations and operations will be discussed further. The next few slides show different types of dc valve with various spool configurations and operations and their symbolic representation.

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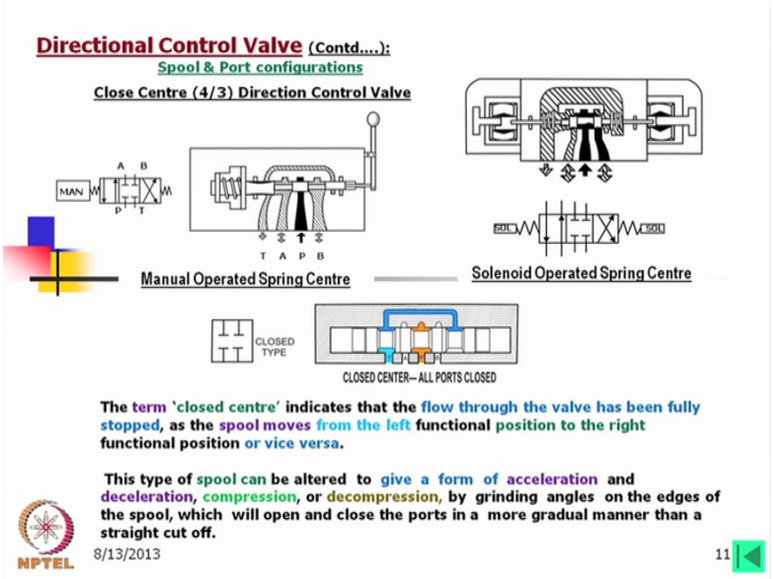

Now here we have shown a closed centre 4 by 3 directional control valves. Now we have studied this symbol. Now looking into this symbol what we find both sides there are spring. So if there is there are springs at both sides then we should call it spring centre that means when the valve when the spool is left un-operated in that case it automatically goes back to neutral position. The meaning is spring centre if there is a spring in one side, then it is called spring return to that direction if we operate it will come back. Now here again in a box it is retained man that means it is manual if we look into this lever of course, the symbol and this figure in the opposite directions if you look into this lever, we operate this lever to push the spool left side or right side, right. in other side spring is not shown here, but as it is called this is a spring return or it might be in one side spring in arrange such a way, it always will come back to this neutral positions. This is also possible, only one spring is used but it is arranged in such a way that whenever the lever is left then it will come back to its positions.

Now we will look into this spool configuration in a little bitter way. Now here another valve is shown which is solenoid operated and it is of course the spring centred. In that case both side solenoids are there. Solenoids again it is a on-off type not a position controlled. So in some cases you will find only one side solenoids, but double acting in other cases you will find single acting solenoid both sides. In this case, it is solenoid at both sides. Now this figure you have already seen earlier, but here if we look into this, this is the spool and these are the ports. If we look into

this the pressure ports is connected like that at neutral positions, but this flow cannot go to the A side or cannot go to the B side neither it can go to the tank side also.

Now if we move in the left side, then P will be connected to A and B will be connected to drain. So oil from the other side will go back to the tank. If we move this is in the right side, then pressure port will be connected to B and A will be connected to tank side. So this is closed centre all ports closed at neutral positions. Here, I have written the definition the term closed centre indicates that the flow through the valve has been fully stopped as the spool moves from the left functional position to the right functional position or vice versa. This means when it will pass through the intermediate positions, all the flow will be disconnected. This type of spool can be altered to give a form of acceleration and deceleration and compression or decompression by grinding angles on the edge of this spool. What I have already mentioned that spool edge, this edge are very important.

In case of servo valve normally you will find these edges are very sharp. Whereas, in case of directional control valve, it is a chamfer is given sometimes a corner is made round, but by changing this spool configuration as well as a slightly the edge of the this ports, but it is very difficult to grind properly these edges, because this is inside the valve body in this bore rather we change the design of the edge. Now if we provide the chamfers or make it round, then the port will open and close more gradually manner than a straight cut off side then a straight cut off and sometimes it is essential, because the straight cut off will give a shock to the system.

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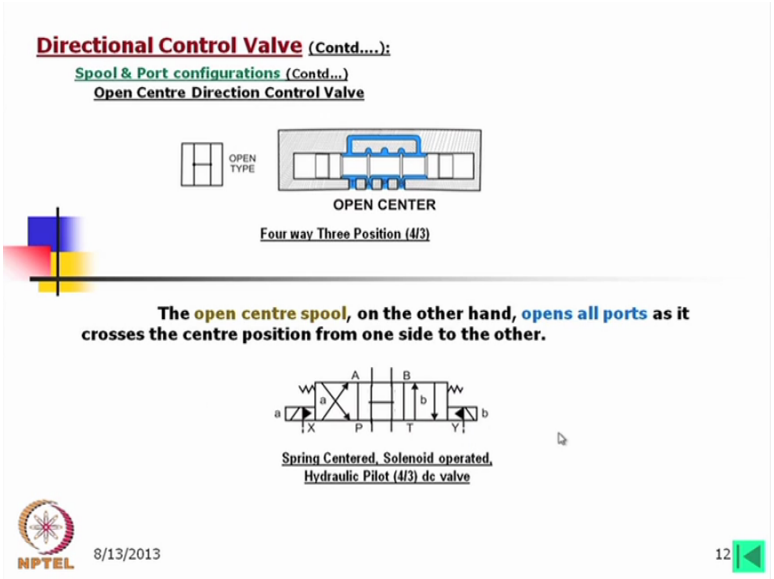

Now again I shall discuss on spool and port configuration. Open centre direction control valve dc valve, look at this. This is open centre as you see that this is the spool and this is the stem and these are the land. The larger diameter is called land and this is called stem as you see here, the two middle lands are very thin not wide and so it is keeping all the ports open at the centre. Now if we move right hand side or left hand side, it will be same as what we have discussed earlier in case of closed centre. The open centre spool on the other hand opens all ports as it (cross) crosses the centre position from one side to other.

Now here I have shown a symbol, but as well I have shown that its how it is operated. In that case what we find that b and a side that a small box with a slanting line. These are solenoids this represents solenoids whereas, this arrow with completely filled in black blacken with x and y, these are two hydraulic pilots. We can also actuate with this. This means that these valve have two features either we can operate by solenoids or we can operate by hydraulically and that hydraulic can be pilot operated means from the circuit, it can sense some pressure and it will be operated.

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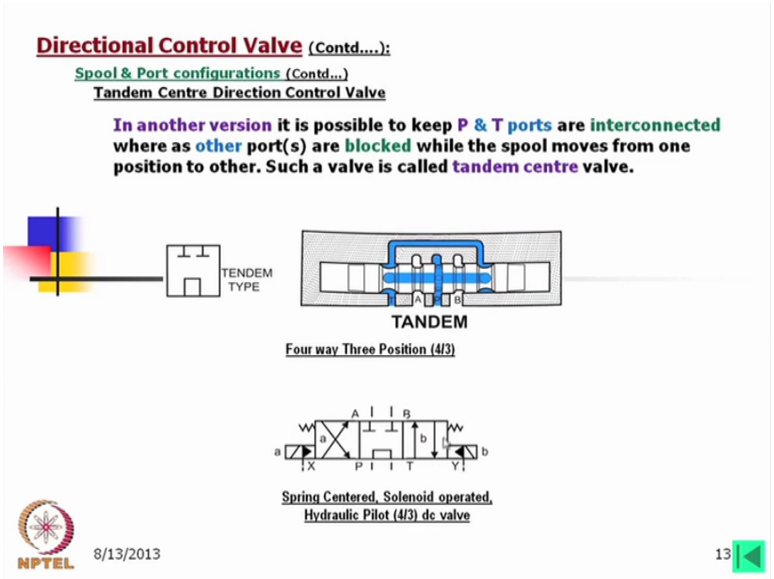

Now tandem centre direction control valve. In another version it is possible to keep P and T ports are interconnected whereas, other ports are blocked while the spool moves from 1 position to other. Such a valve is called tandem centre valve. As you look into this, this spool is having a special configuration. These lands are wider than the fully open centre as well there is a hole longitudinal hole through this in inside the spool, in fact if we look into the manufacture if you think of the manufacture, this hole is made from one side and then it is blocked and from the peripheral side also some holes are made. This means that while this is in the neutral positions A and B ports are completely detached from pressure side whereas, the oil through these holes can go to the inside of this poles and then again it can go out to the drain side, okay and symbolically it is presented by this. Here again I have presented the same valve with the solenoid drive and as well it is the spring centred.

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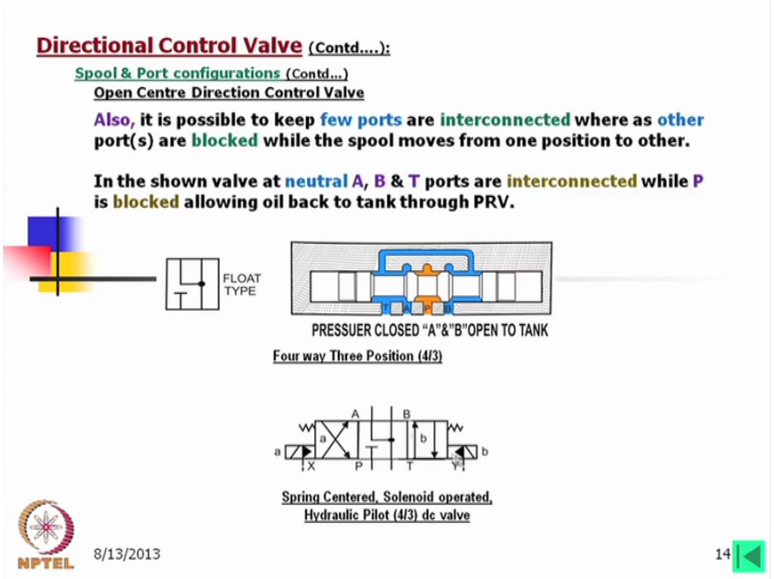

Now open centre direction control valve. Also it is possible to keep few ports are interconnected whereas; other ports are blocked while the spool moves from 1 position to other. This already I have discussed, but in this figure what is shown that how it is constructed. Now in this case what we find than when it is at the neutral positions. This pressure port is completely isolated from A, B and T whereas, these ports are interconnected. This is simply done by say it might be the outer body is what is the completely closed centre. The same outer body we can use only spool we have change we have reduce the thickness of the land at the two middle positions. Of course, it is not thin like what is used for open centre. This means that may be the on the same valve body we can use different spool to make different type of valves. Here is also the symbol is same as that the driving part only the intermediate position. There is change.

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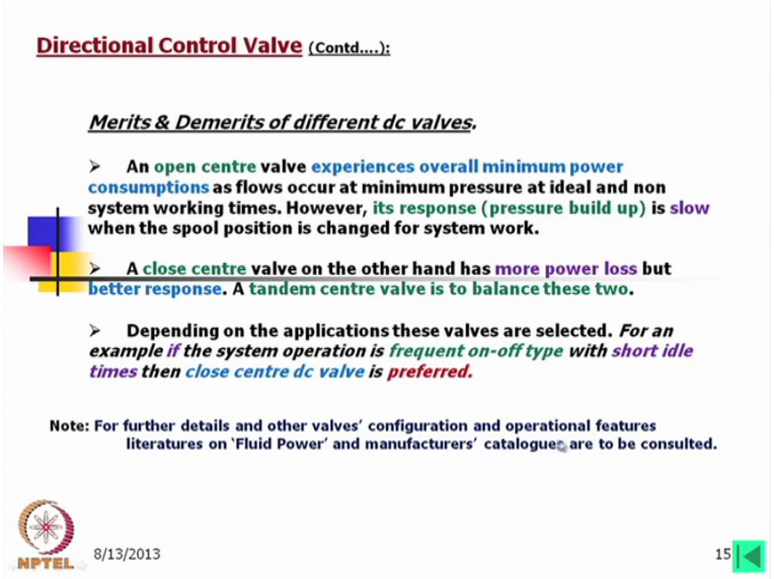

Now merits and demerits of different dc valves. An open centre valve experiences overall minimum power consumption as flow occur at minimum pressure at ideal and non-system working times. However, its response pressure build up is slow when the spool position is changed for system work. A close centre valve on the other hand has more power loss, but better pressure response. A tandem centre valve is to balance these two which I have already discussed. Depending on the applications, these valves are selected for an example if the system operation is frequent on-off type with short ideal times then closed centre dc valve is preferred. Now here I have given a note for further details and other valves configuration and operational features. Literatures on fluid power and manufacturers catalogues are to be consulted.

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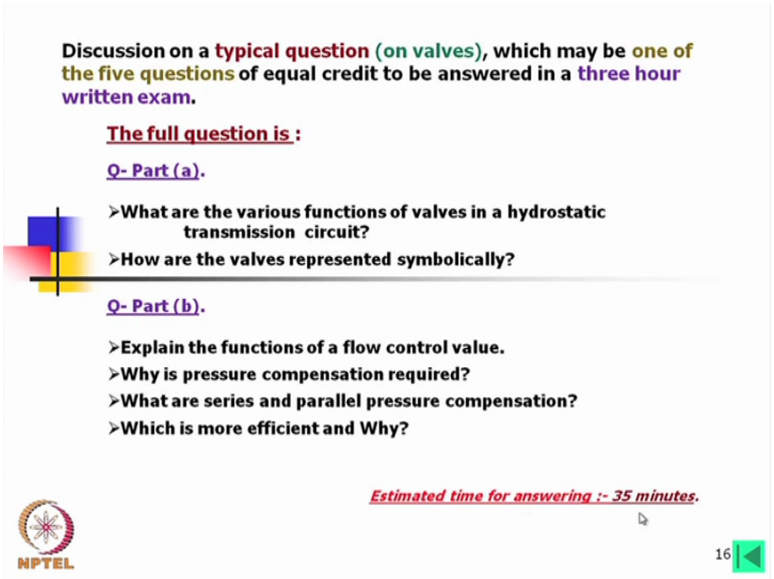

Now I shall discuss on a typical question on valves, which may be one of the five questions of equal credit to be answered in a three hour written exam. This means that if there are 5 questions each credit is 20 marks which you have to answer there hours, then this is a 20 mark question. The whole question is part a, what are the various functions of valves in a hydrostatic transmission circuit? Then it has another sub part, how are the valves represented symbolically. Now in part 2 which is b, it has sub-part explain the functions of a flow control valve. Why is pressure compensation required? What are series and parallel compensations and then which is more efficient and why? Now estimated time for answering will be around 35 minutes, let us see.

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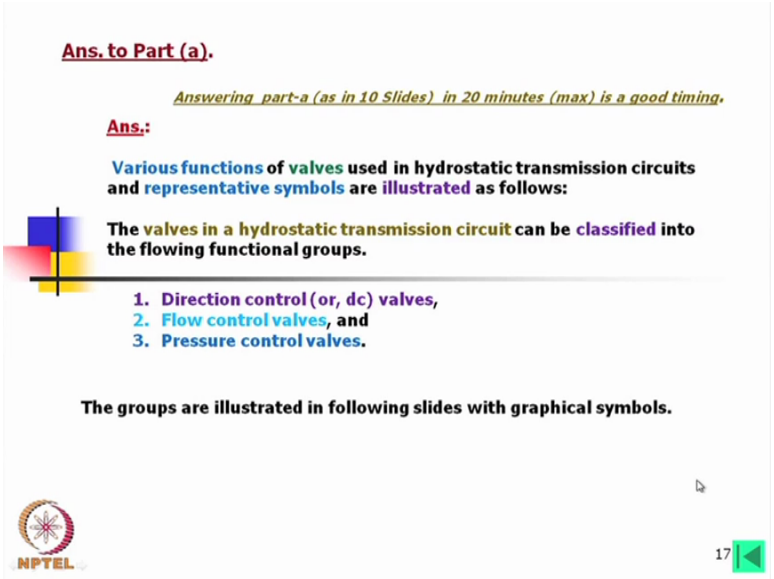

I will discuss very quickly, but you may get 35 to 40 minutes to answer this question. Answering part a. various functions of valves used in hydrostatic transmission circuits and representative symbols are illustrated as follows. The valves in hydrostatic transmission circuits can be classified into the following functional groups, 1 is the direction control valve, flow control valve, third is pressure control valves. The groups are illustrated in following slides with graphical symbols. This is just how to answer, I have shown here how to answer.

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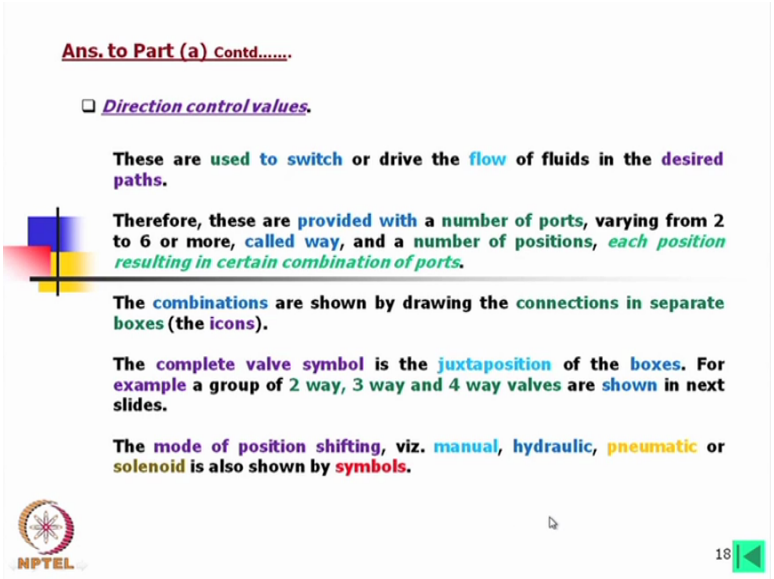

Now direction control valves. These are used to switch or drive the flow of fluids in the desired paths. Therefore, these are provided with a number of ports, varying from 2 to 6 or more called way, and a number of positions, each positions resulting in certain combination of ports. The combinations are shown by drawing the connections in separate boxes, which are also called as icons. The complete valve symbol is the juxtaposition of the boxes that means if you put together these symbols or the icons that will represent a valve symbol, for example, a group of 2 way, 3 way and 4 way valves are shown in next slides. The mode of position shifting that is manual, hydraulic and pneumatic or solenoid is also shown by symbols.

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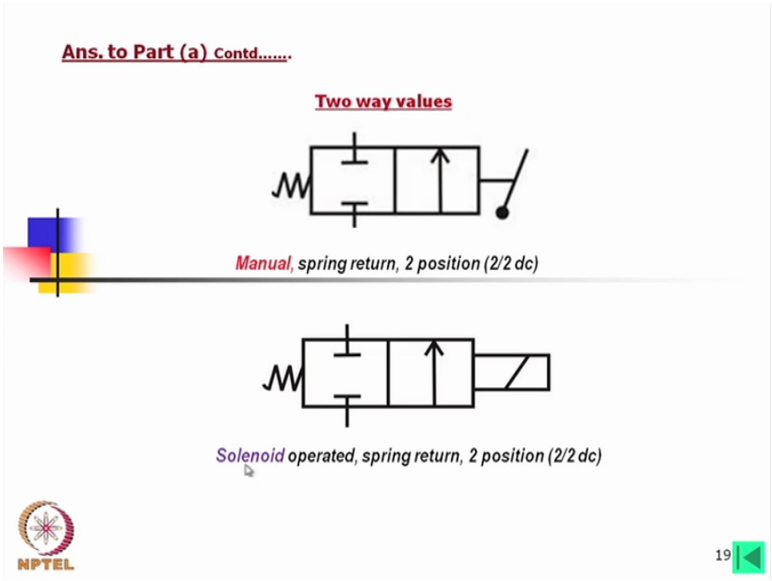

Now two way valves. This is a symbol of two way valves it clearly indicates this is a spring return and manual control 2 by 2 dc. Now here this is also 2 by 2 that is 2 way valves as well as it is 2 by 2 solenoid operated and spring return.

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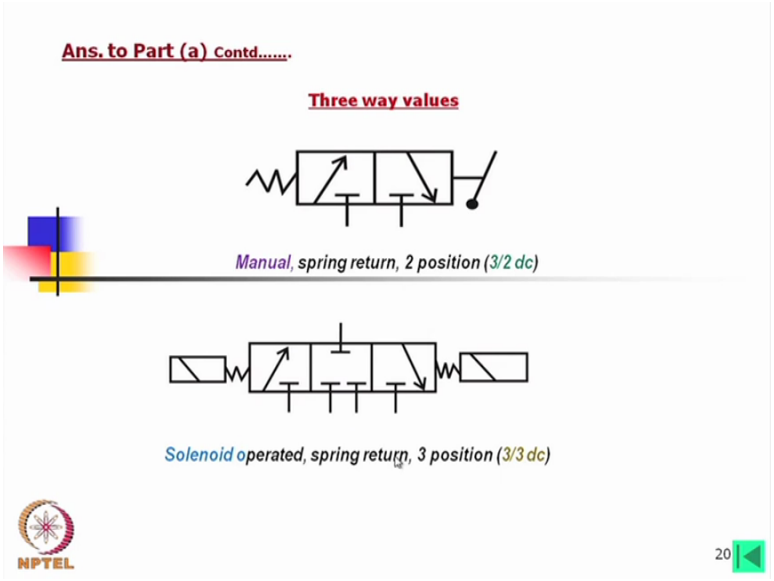

Now 3 way valves, 3 way valves means there are 3 ports. One side spring means again it is spring return and 2 positions. So 3 by 2 dc valve, there is no as such neutral positions either right side or left side. Now in this case, there is a neutral position. This is 3 position and solenoid operated. Here we should call the spring centre. So this is not sprig return rather we should use the word spring centre.

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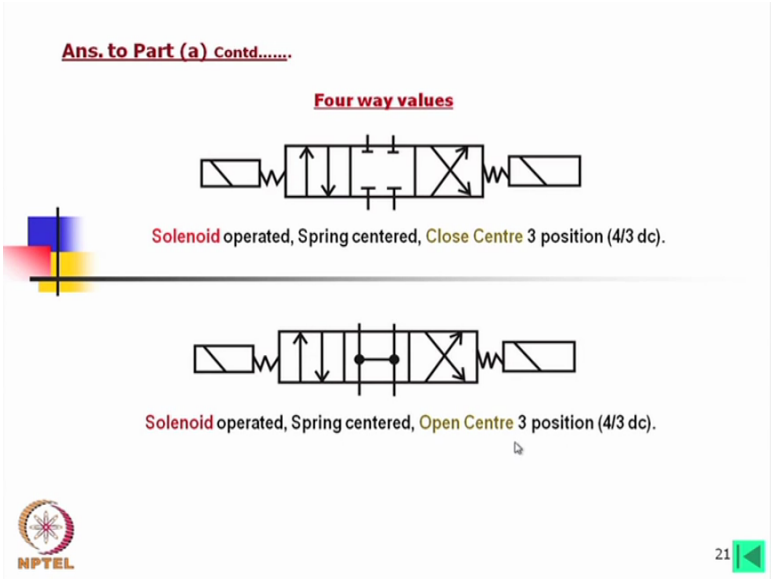

Now in case of 4 way valve, this is again solenoid operated spring centered again it is a closed centre 3 positions. So 4 by the 3 dc valve. Now again solenoid operated spring centered again open centre and 4 by 3dc valve.

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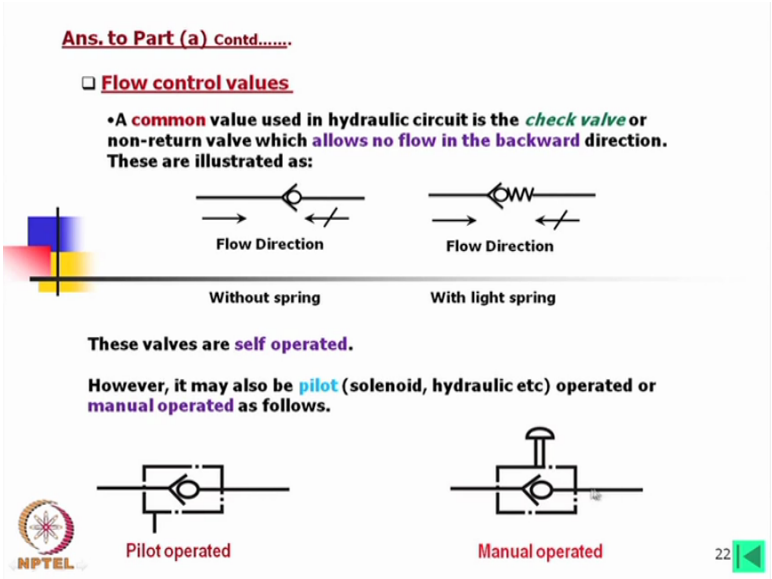

Now we shall discuss about the flow control valves. A common valve used in hydraulic circuit is the check valve or non-return valve which allows no flow in the backward directions. Now the check valve what we call check valve that is also a flow control valve. It is controlling the flow in one directions only. These are illustrated as the simple sign is like that flow directions this way not this way. Here also flow directions from this way not this way and this is without spring and this is with light spring. With light spring it is preferred that because this valve you can keep in any directions even if upward directions also. Whereas, this valve may malfunction (())(45:46) if we keep in the upward directions. These valves are self-operated that means we do not operate from externally. However, it may also be pilot solenoid, hydraulic etcetera operated or manual operated as follows. Now this is the pilot operated that means once this signal is here then oilcan flow from this side also. Do you understand? Oil can flow from this side whether we operate this pilot or not, but if we want the flow from this side we can operate by this pilot and this is manual operated. Simply if we rotate this knob this will open and flow will be allowed from the reverse side.

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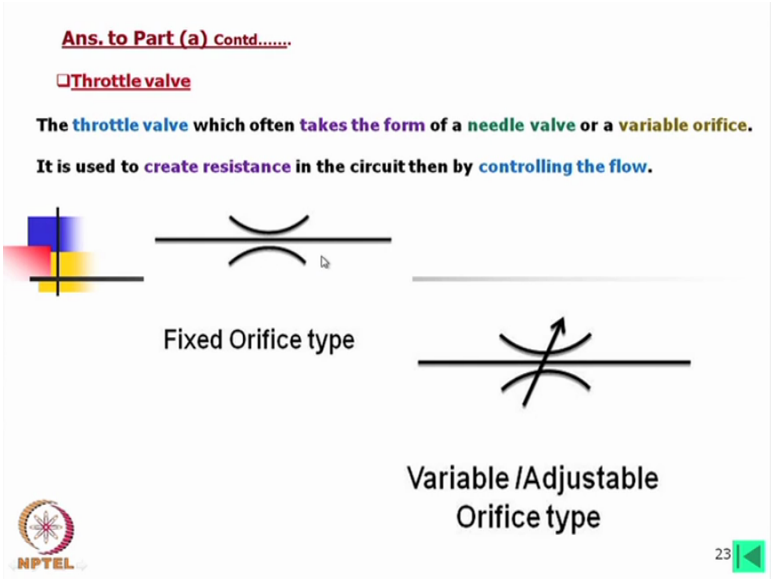

Now throttle valve, which is also called as flow control valve. The throttle valve which often takes the form of a needle valve or variable orifice. It is used to create resistance in the circuit then by controlling the flow. Now the symbol is very simple. It is a fixed orifice type. Now if it is variable or adjustable orifice type then we put simple a arrow on that. That means here with a knob we can adjust these orifice area and by this we can change the flow control, but you should remember always, this fixed orifice means that flow will vary depending on the pressure, but definitely flow will be controlled.

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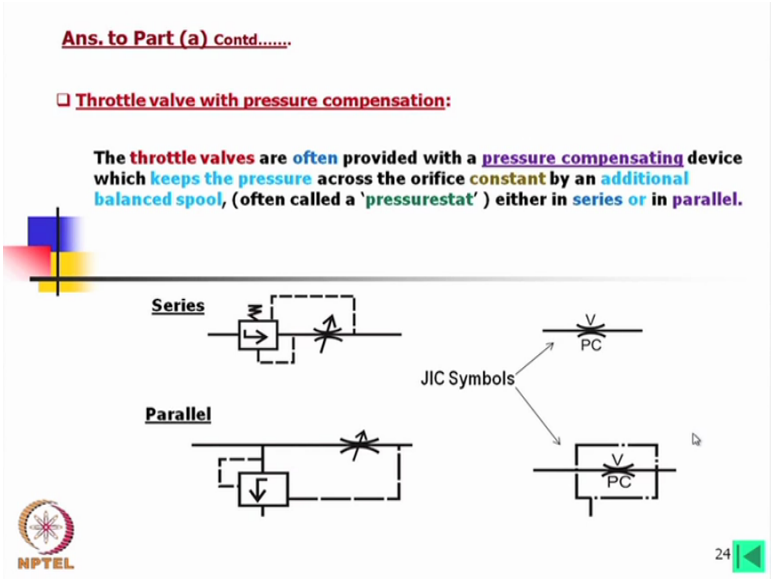

Throttle valve with pressure compensation. The throttle valves are often provided with pressure compensation device which gives the pressure across the orifice constant by an additional balanced spool, often called a pressurestat either in series or in parallel. This is interesting what we have discussed in earlier in the pressure compensation we have not use this term series or parallel. In this case what we find the series connection is like this. In the same line, there is the throttle valve as well as a pressure control valve. Whereas, in case of parallel we find this pressure control valve is in parallel. Essentially at the upstream of both sides there is another pressure relief valve which is system pressure relief valve. However, the symbols are like that which you can see.

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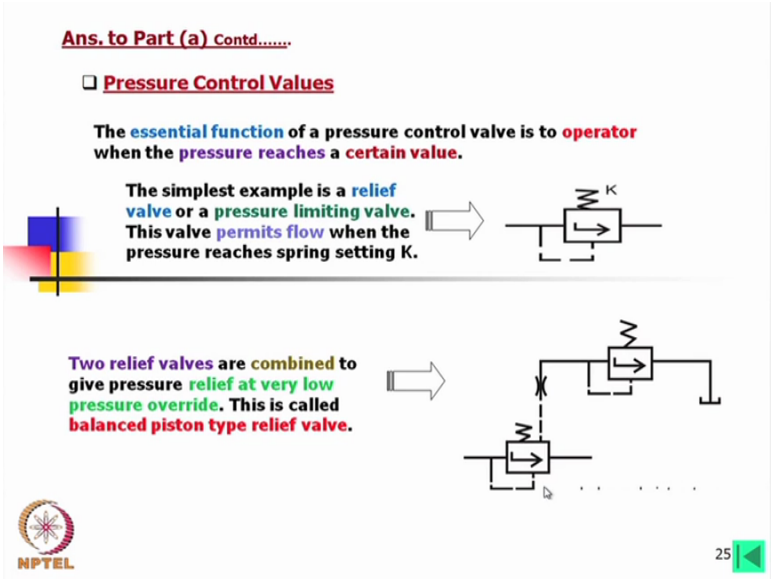

Now pressure control valves with essential function of pressure control valve is to operate when the pressure reaches a certain value. Now the simplest example is a relief valve or a pressure limiting valve. This valve permits flow when the pressure reaches spring setting K. pressure relief valve and two relief valves are combined to give pressure relief at very low pressure override. This is called balanced piston type relief valve. In fact if we look into the balanced piston type pressure relief valve what we have already studied. There are two pressure relief valves, one is main and another is pilot. What we do we control the pilot valve which is direct operated pressure relief valve in terns that maintain a very low pressure override, which means it balances the spool of the main valve to keep this pressure relief valve open for longer time and in stable condition, no chattering or very small chattering will be there.

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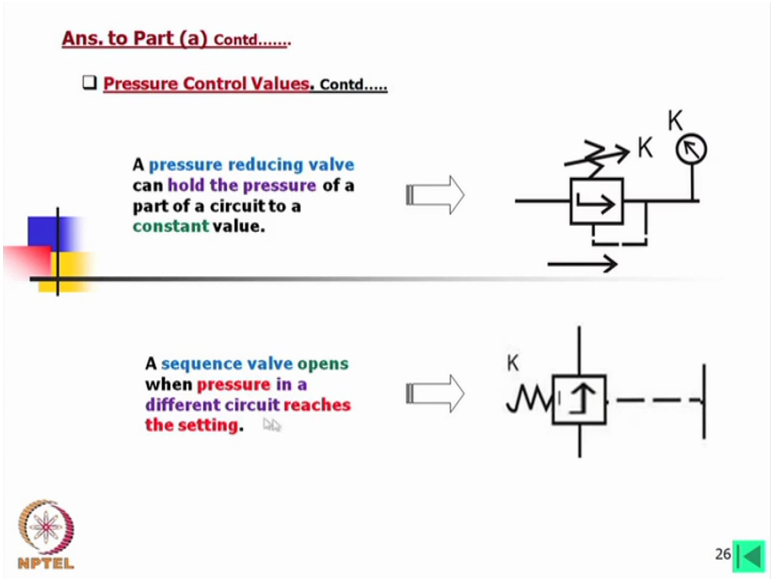

Pressure control valve, again it is we are continuing with this. The pressure reducing valve can hold the pressure of a part of a circuit to a constant value. Now as you see this is looks more or less same, but this is basically a pressure reducing valve. This reduces the pressure, but keep in mind in the upstream side, there is a relief valve without that this will not work. A sequence valve opens when pressure in a different circuit reaches the setting. It is like that, it is it looks like a pressure relief valve, but this is operate by the another system the flow is open and it operates another circuits. So thus a sequence is maintained.

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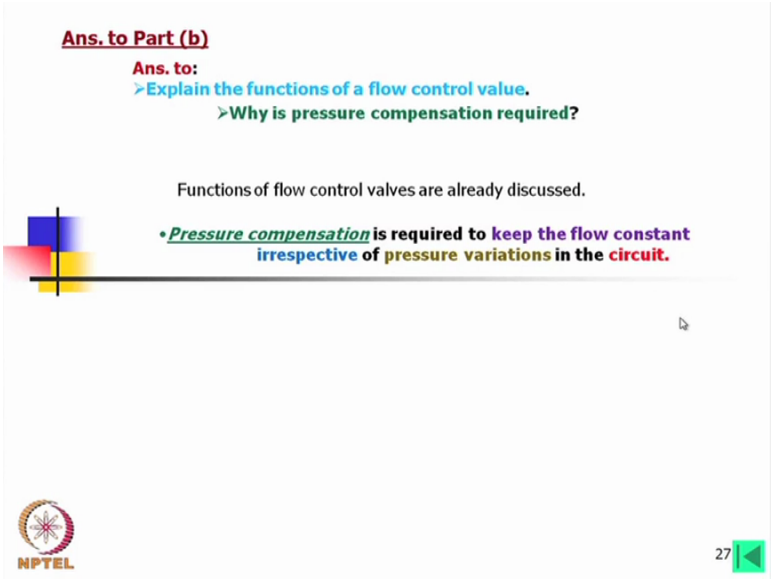

Now the answer to explain the function of a flow control valve. Why is pressure compensation is required? Functions of a flow control valves are already discussed. Now pressure compensation is required to keep the flow constant irrespective of pressure variations in the circuit. What we have discussed earlier while you are answering you have to write in this way.

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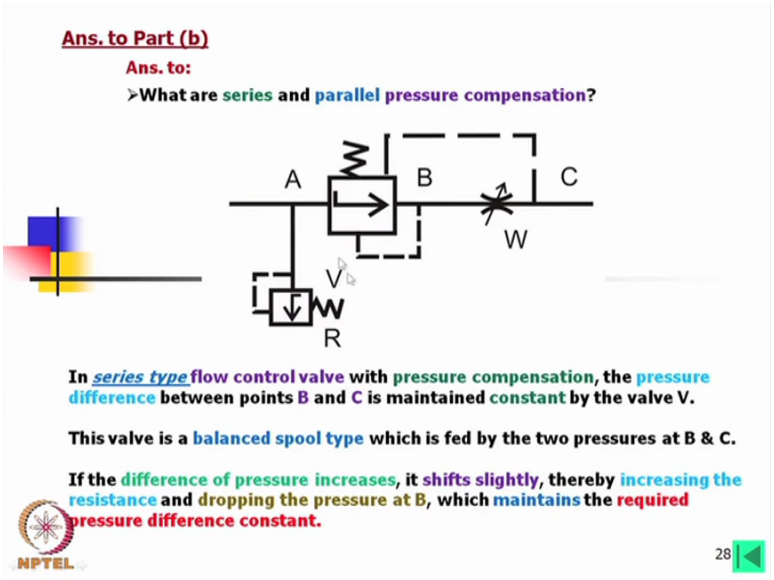

Now what are series and parallel pressure compensation? Now this is in series and there is a pressure relief valve and a series type flow control valve with pressure compensation, the pressure difference between points B and C is maintained constant by the valve V. if we adjust

the then this pressure difference will remain constant here. This valve is balances spool type which is fed by the two pressures at B and C. If the difference of pressure increases, it shifts slightly, thereby increases the resistance and dropping the pressure at B which maintains the required pressure difference constant. Now here I would like to mention for this type of question you need not draw the detail schematic figure rather you should go for the symbols.

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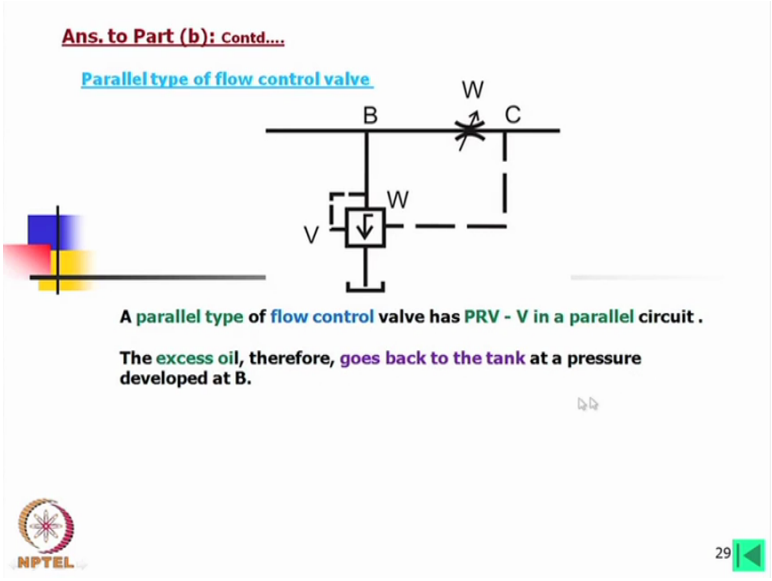

Now this is parallel type as you see there is no pressure control valve here. A parallel type of flow control valve has PRV in a parallel circuit. The excess oil therefore goes back to the tank at a pressure developed at B.

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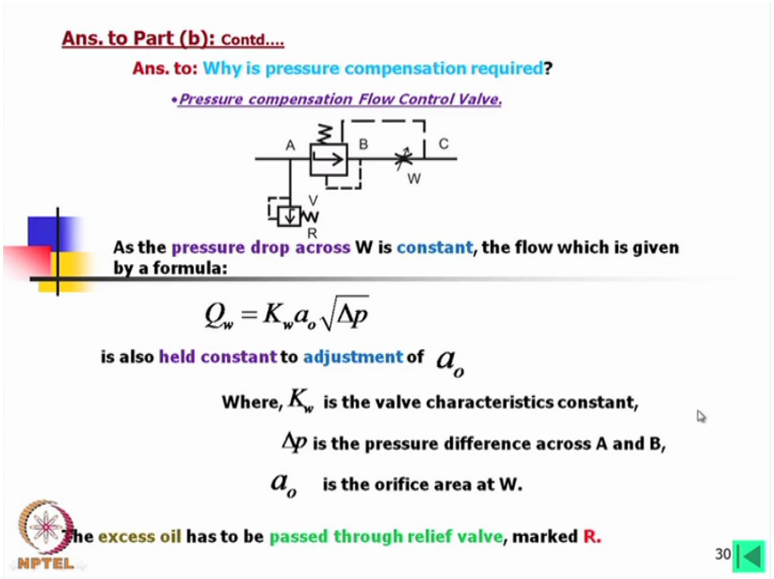

Why is pressure compensation required? Now pressure compensation fowl control valve which we have already discussed. The pressure drop across W is constant to maintain this is a constant we need pressure compensation. The flow which is by a formula, Qw the flow here is Kw a0and del p where, Kw is valve characteristics constant, del p is the pressure difference and a0 is the orifice area and with this pressure compensation valve, this a0 is adjusted. So it is always kept a constant area so that pressure difference kept constant as well as the area kept constant to give a desired flow we can change only that by changing this area here. The excess oil has to be passed through the relief valve, marked R.

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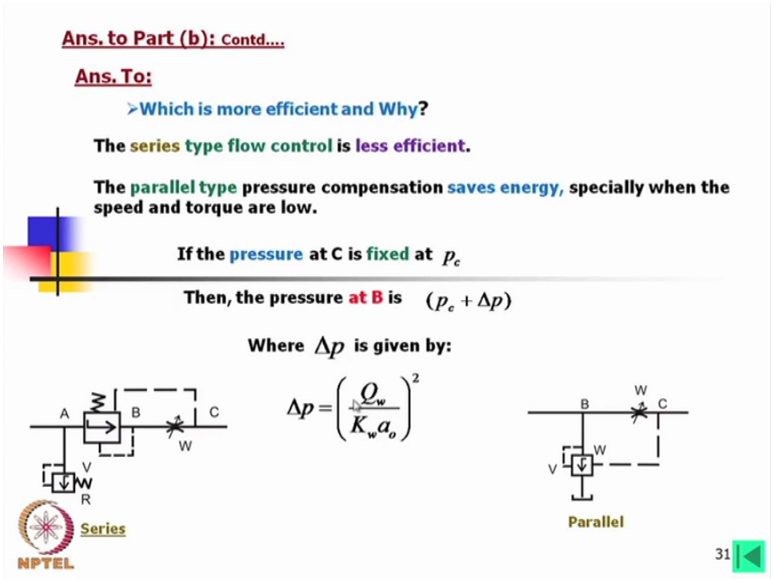

Now which one is more efficient? The series type flow control valve is less efficient. Here we have shown. The parallel type pressure compensation saves energy specially when the speed and torque are low. If the pressure at C is fixed at Pc then the pressure at B is Pc plus del p. where, del p is given by this equation.

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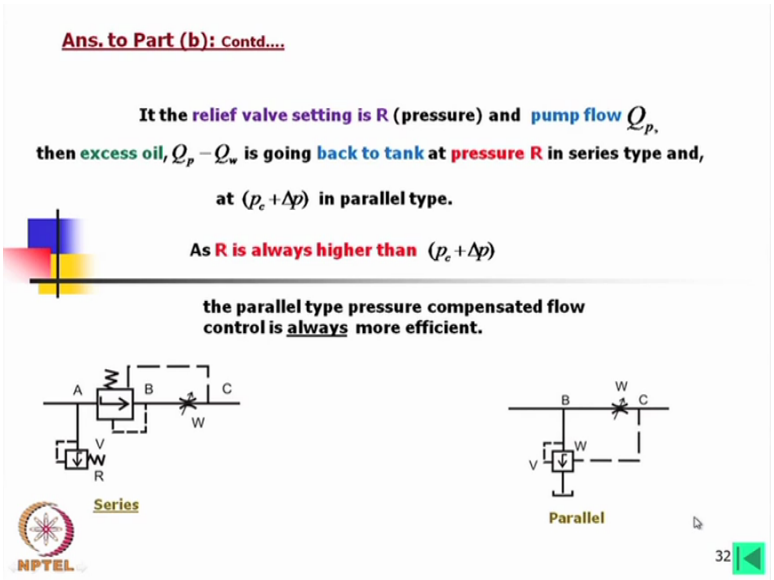

If the relief valve setting is R and pump flow is Qp, then Qp minus Qw is going back to tank at pressure R in series type. Whereas, it is going back to tank with only this pressure drop and this R is always greater than this. This means that in case of series connections, this bypass flow will

always be at a higher setting pressure than this. On the other hand, this is suitable for low pressure whereas, this where the pressure is high as well as the flow is also high we have to go for series type valve irrespective it has more losses. The parallel type pressure compensation flow control is always more efficient.

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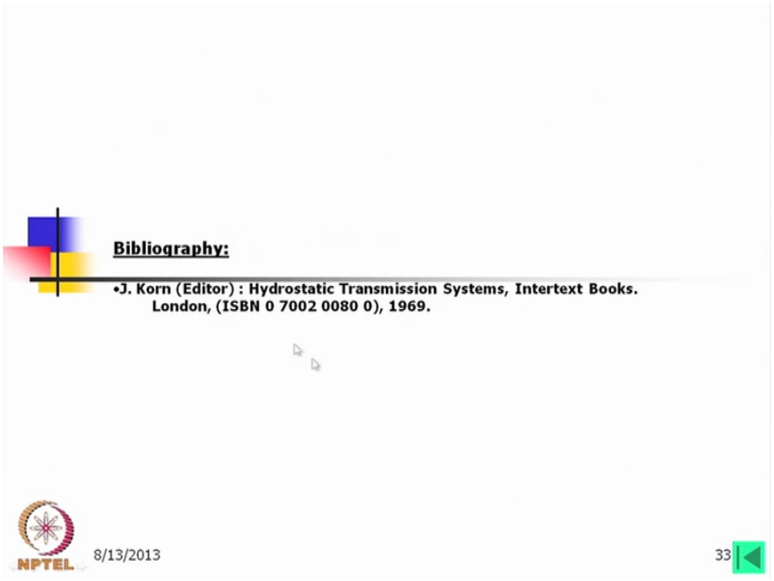

Now for the valve configurations you can follow this book. Thank you.