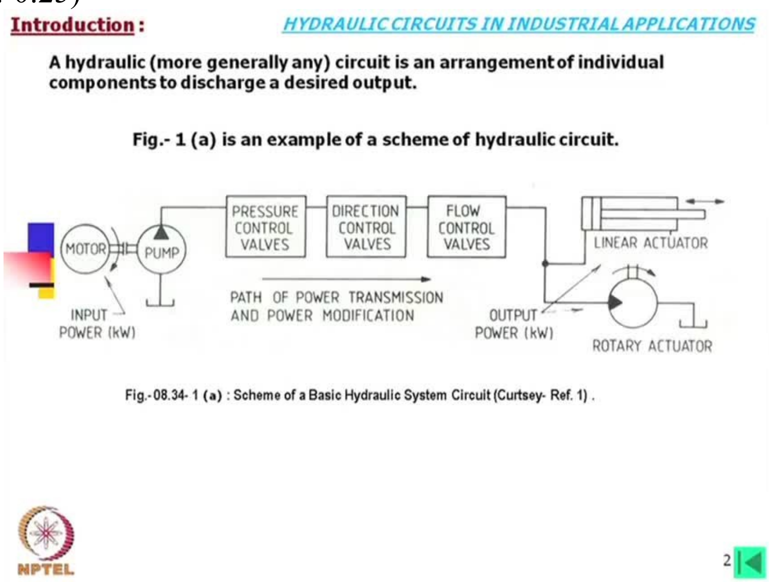
Fundamentals of Industrial Oil Hydraulics and Pneumatics
By Professor R. Maiti
Department of Mechanical Engineering
Indian Institute of Technology Kharagpur
Lecture 34
Hydraulic Circuits in Industrial Applications.

Welcome to today's lecture, this is on hydraulic circuits in industrial applications.

(Refer Slide Time: 0:25)

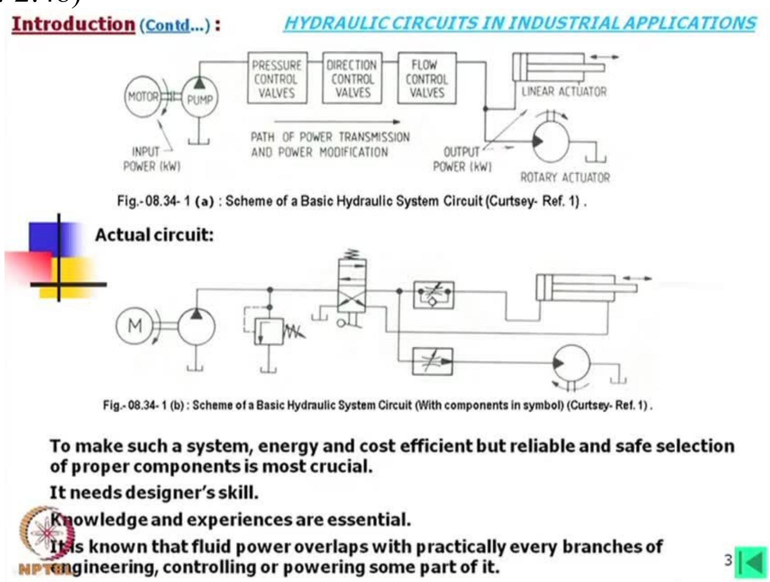


Now hydraulic, more generally, any circuit is an arrangement of individual components to discharge a desired output. Now here what we find, an example, a scheme of hydraulic circuit. Like electrical circuit, we need to draw also hydraulic circuit and mainly, in hydrostatic transmission system or so to say any hydraulic systems, we need to procure the components. These are not individual components are designed, rather circuits are designed and we put together those components connected by the hose or pipes and then it performs for a particular requirement.

In this schematic view, what we find that there is a pump. Pump is driven by a motor and then essentially there is a pressure control valves. Pressure control valves in that groups that may be pressure reducing valves or anything but here, pressure control valve means actually this is a safety valve, that is pressure relief valve is used. Then we need to have direction control valve what we have learnt in 1st lectures. Then flow control valve and linear actuator or maybe their an rotary actuator.

Now in many cases, you will find that this direction control valve and flow control valve may be combined together or a separate flow control valve is used. And some cases, we do not need the flow control valve at all because even if this there is a fixed displacement pump, but the velocity of these actuators need not control, only it should actuate and it should detract also.

(Refer Slide Time: 2:48)



Now with this scheme then what will be the actual circuit? In actual circuit, give this is we use the symbol. This is pump and coupled to the motor and then this is pressure control valves which is nothing but a pressure relief valve. This means that if the system pressure exceeds due to excess load, in that case, the flow will bypass through the pressure relief valve and in that way, it will save the circuit.

Now here, we find a direction control valve. This direction control valve looking into this symbol if you have, if you know this symbol we have already learnt, this is 4 by 2 this means that 4 ports are there and 2 position. This is one position and this is another position. And this spring means, in one side spring means it will assume only one position when we do not actuate this lever.

Now here as shown that in normal condition, it is like this, that means a cross connection is there. Cross connection means, the flow is going in this directions, then this is being retracted. Okay? In that case possibly it will rotate in one directions. It is not possible to indicate by this symbol only. And when we actuate this, this spring is compressed and we get this path. In that way, oil is going through this and then this is actuating.

And oil from this side is being returned to the tank. Now what we find? When this connection is there, oil is coming through this to the tank. In that case, if you look into this, there is a flow control valve. In that flow control valve, what we find, there is a check valve, this means that oil will return by blowing this check valve and it will return to the tank almost without any resistance whereas if we connect this one, in that case, oil is going through this and we can this arrow means we can vary this.

That means, we can control the flow. So there will be a controlled flow for actuation. This means that depending on load, we may control the speed also. So in that case, this is a fixed displacement pump but still this velocity can be controlled. And if we actuate this one, if we use this side, then say this connection is not the connection here, this is just bypassing, I mean this is one line, this is another line, so oil may come this side, again there is a flow control valve.

This means that we can control this speed of this motor also. Now here, this motor in one directional and oil is being returned directly to the tank. There is a, it is possible that we can move this and as well as this but depending on load, we do not know which one will move. Because oil will always flow to the least resistive path okay? So this just to show that how the circuit can be designed.

Now so this is a simple circuit and we can design the circuit like this. And if we have a little knowledge about these symbols, in that case, what we find that this can be regulated as this arrow is there and this is also that depending on the pressure, this will operate. This means that suppose this, here we are working with 10 mega Pascal, this is also maybe the system pressure is 10 mega Pascal due to the load.

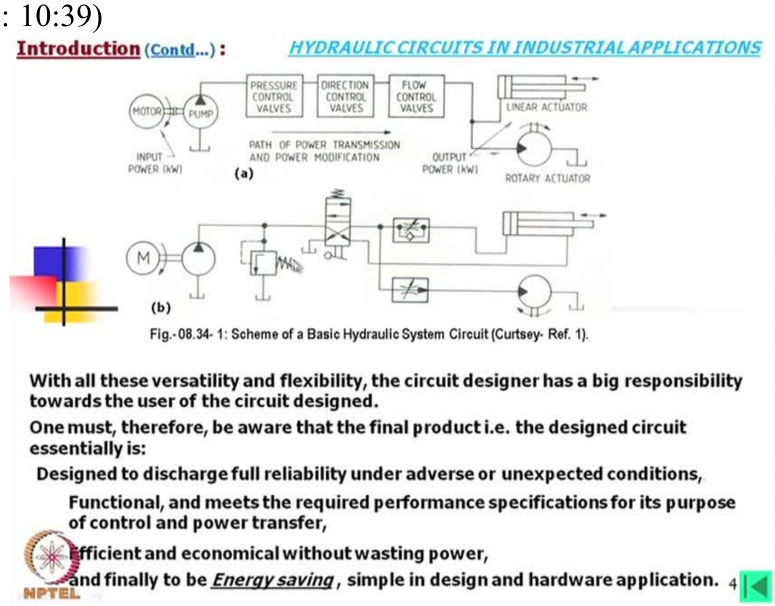
In that case we will probably set 10.2 mega Pascal. Then if pressure exceeds about 10.2, that means above 10, almost above 10, then this will blow and oil will go back to the tank. To make such a system, energy and cost efficient but reliable and safe, selection of proper components is more crucial. Nowadays, with the crisis of energy everywhere, so almost in all design, it is always thought of how the energy can be saved.

For your information, if we want to control say flow control, pressure control, particularly where we use the servo control, always we should keep in mind that there will be pressure drop across the valve orifice and in that way, there will be loss. That we cannot avoid. However, by arranging the system, that where we can, according to load, if we can control this part, then probably we can save the energy.

Now it definitely needs designer skill. There are systematic methods. That means if we have thorough theoretical knowledge and some little bit experience, probably we able to make the energy within circuit but always it is there. You need an experience to make an good circuit. It is known the fluid power overlaps with practically every branches of engineering, controlling or powering some part of it. This means that fluid power is used almost, I mean every say if you go to the production engineering, if you go to the missile, even if the spacecraft, there you will find the fluid power is being used.

It is together that supply of power, I mean power conversion, usually there will be a motor to drive, in this case drive a pump but that power give the translatory motion as well as rotary motion with torque conversion. Okay? And as well, this can be controlled also, say for example we cannot controlling the speed through a flow control valve and fortunately, in this case, this control signal also passes through the oil hydraulics and oil hydraulics in that way the oil medium is very good for transmitting control signals.

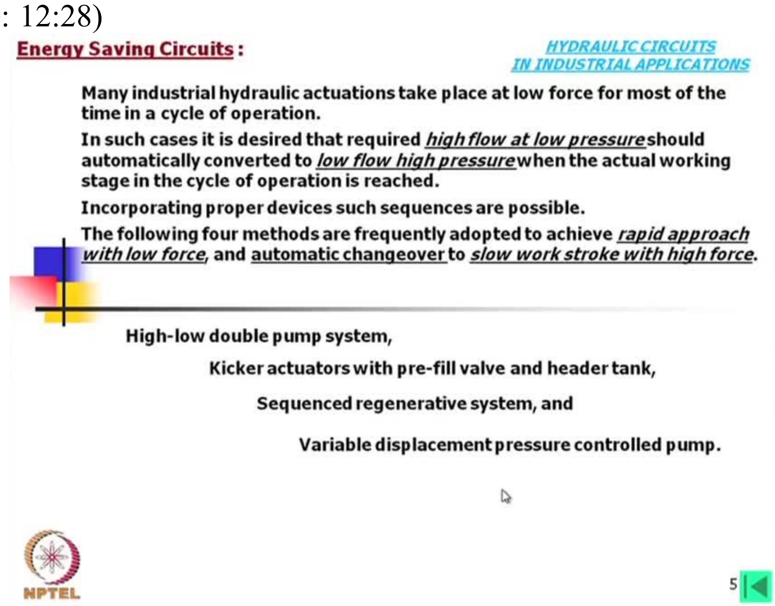
(Refer Slide Time: 10:39)



Now with all these versatility and flexibility, the circuit designer has a big responsibility towards the user of circuit designed. One must, therefore, be aware that the final product that is the designed circuit essentially is designed to discharge full reliability under adverse or unexpected conditions. Secondly, functional, and meets the required performance specifications for its purpose of control and power transfer. Thirdly, efficient and economical without wasting power. And finally, to be energy-saving, simple in design and hardware applications.

This is one is that wasting of power we say, this means that suppose the oil is flowing through the pressure relief valve. In some cases, we will find that when the system is idle, then oil is flowing through pressure relief valve. That is definitely wastage of power. That can be made we can make such system that we can save the energy, either using this oil for some other purpose or we can use this valve such that when this system is idle, the oil is flowing through this valve without much resistance.

(Refer Slide Time: 12:28)



Many industrial hydraulic actuations take place at low force for most of the time in a cycle of operation. Actually while we are designing, we can go for various systems definitely but depending on thus operation cycle, how much we need to operate the circuit within a time period, depending on that, we can design the circuit accordingly. In many cases, if we find that the circuit is almost being used for the full-time with load, in that case, we perhaps can go for a little expensive components so that these are used, the circuit is used efficiently.

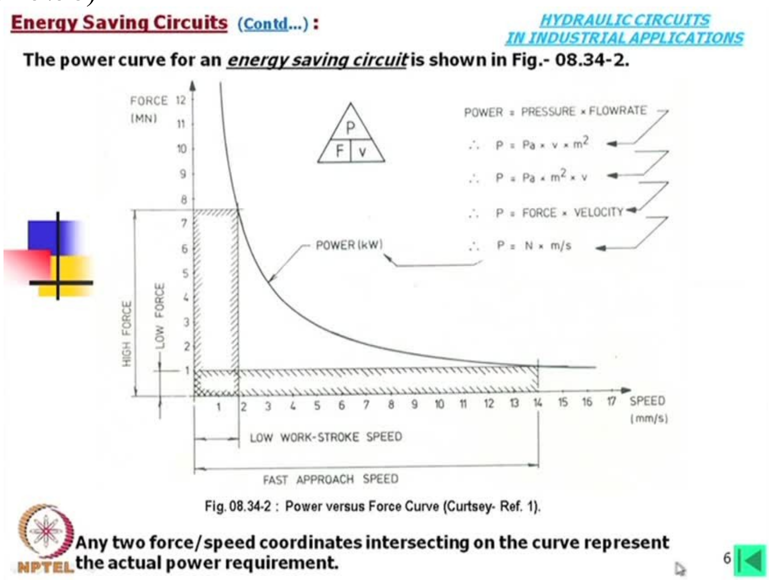
Whereas in case if we find that it is not being used, used say it is being used for 5 minutes and then 10 minutes gap, in that case, we can use a low-cost items but there is such a system when it is idle, the oil is going through the less resistive path. In such cases, it is desired that required high flow at low pressure should automatically converted to low flow high-pressure when the actual working stage in the cycle of operation is reached. Incorporating proper devices such sequences are possible. That we will learn in this lecture.

The following 4 methods are frequently adopted to achieve rapid approach with low force and automatic changeover to slow work stroke with high force. Number 1 is that high low double pump system. This is high flow and low flow. This means that high flow and low flow. Then 2nd one, this means that when we need low pressure, we can have high flow so that we can use the power fully.

And when there is a high-pressure, that means high load, then low flow. Now kicker actuators with prefill valve and header tank, this is one arrangement, so I shall explain what it is. In that way also, we can save the energy. And the sequenced regenerative system, and fourthly variable displacement pressure controlled pump. Among these, there are a few more components will be there but still, perhaps this one will be the expensive one.

But still, these 4 are the common which are adopted to save the energy. These are just general. There may many arrangement possible and combination of these again gives may give better performance also.

(Refer Slide Time: 15:58)



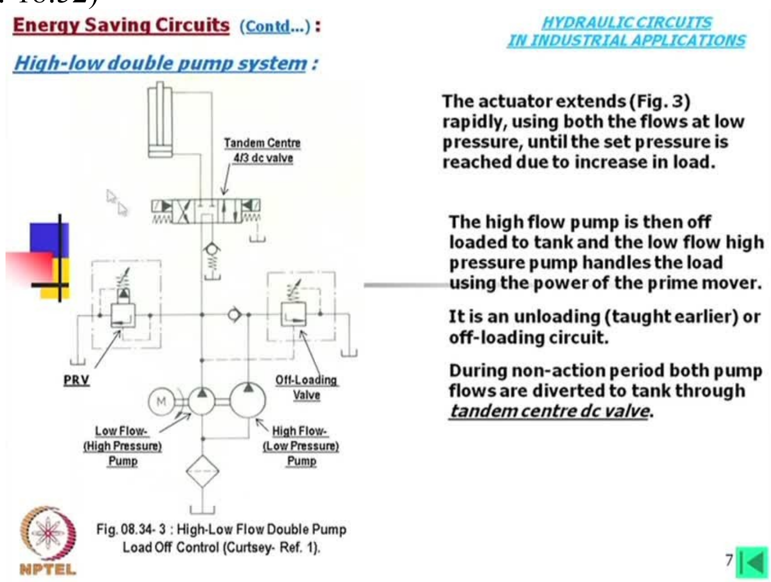
Now 1st of all, it is better to study that how the I mean total mapping of the power utilisation during the operation. So in many cases, you will find the operations are sequenced and may be we can identify one operation cycle. If we study one operation cycle, in that operation, we know what is the speed, what is the flow, et cetera. And from there, we can design our systems. We can have say discreet manner, these are the flow, these are the, this is the pressure, these are the flow and this is the pressure.

And from there, averaging that, we can select a the motor pump and required components. However, if we think that very high force and flow maybe, the speed is less, in that case, we need this much, I mean we can select our, this is one operating zone. On the other hand, this very high-speed but low pressure. Okay. Then this is, we can have this power curve is like that. From there, what we find that in this system, suppose if we use this force, we can go up to this speed. If we use this much force, we can go up to this speed.

So we can now select the devices in such a way that whenever the we need high-speed, we can reduce the force. Or in other words, if there is a less force, then we can move with high speed. This in some cases is it is automatically adjusted. In some cases, you can adjust it manually. In that case, control might be very discreet manner. Suppose if we let us consider we are using for hammering or pressing something. If we see that this pressure, we need less pressure, immediately we can adjust, then probably that it is being done at high-pressure but using low-pressure.

So that adjustment manually we can do like that. And for that study, we need similar graphs. This is any two force speed coordinates intersecting of the curve represent the actual power requirements.

(Refer Slide Time: 18:52)



Now we will study some energy saving circuits. Now here, high low double pump system. This is high low means again, high flow and low flow. In that way, these are named. Now what we find that this is a, we find a bigger circle for the pump symbol, that is for high flow but it operates in low-pressure. And here what we find that this is low flow but high-pressure pump. Now when there is totally low-pressure, it is operating low-pressure, that means say this maximum pressure is 10 mega Pascal but this pump maybe with 5 mega Pascal okay.

Sorry, this pump maximum 5 mega Pascal and this can go up to 10 mega Pascal. This means that at 5 mega Pascal, whatever the flow total flow these 2 pumps can give, that amount of flow into 5 the mega Pascal flow in litre per minute mega Pascals will give us the power. So the motor is selected accordingly. Now when the pressure exceeds above 5 mega Pascal then what we find that this flow is being utilised. This flow is going back to the tank.

And for that flow, very little amount of power is required. So full power is being utilised, the 10 mega Pascal into flow of this. Now how it is operating. Let us study this one. Now essentially in the circuit, the one reserver, the strainer whatever is there and then the common input is there. And here is a common shaft driven by this motor. So when this motor is rotating, both pumps are rotating. It is not that one pump we can off. The impeller inside whatever the impeller or piston actuator, or whatever there, that are moving .

That means it is pumping the flow. And pressure is always experienced by the load. It is not that pump is pumping the pressure. Pump only must be able to withstand with that pressure. To understand my point, say whenever the impeller is moving whatever impeller or piston, whatever is moving, the flow is there. And at low-pressure, there will be less leakage. So flow is full. With high-pressure, there will be leakage but usually that volumetric efficiency of such pump, this common case maybe 90 percent.

So 90 percent of the flow will be always there. And pressure is always experienced by the load. Now these 2 pumps are being rotated. Then what we find? That these are connected here and there is one nonreturn valve. And then what we find, this is tandem centre 4 by 3 DC valve. You know, understand what is? Looking into these symbols, say there are 4 ports, that is why you have written 4 here. And then this is called P port. P is not for the pump. This is for pressure. This one is pressure port and this is T port, that is going back to tank.

And here, one nonreturn valve we can use or we may not use. And but this is at low pressure, this oil can bypass to the tank okay? Then 3 positions, this is usually called neutral positions and this is one position, this is other position. And then, what this symbol means? This symbols means that there is a control by a hydraulic, actuation is there and as well, there is also solenoid valve, electrical control is there.

And what we find, there is spring. This means that if we actuate this way and then if we relieve the actuation load, it will go back to the neutral position due to the Spring shame to this part also. And there is also whatever leakage is there, the drain is there. This is called drain port. Anyway, this valve, why we call it tandem? You will find, this valve will have either 4 loader ports are closed and extreme is that 4 ports are open at the neutral position, that is like a connection capital H .

And in this case, 2 are closed, that means load side is closed but this side is open. So that is why it is called a tandem valve. Okay, then that means in normal course, if we do not actuate this valve, this flow will go to this and it will go back to the tank. Now this is called offloading value, this is called pressure relief valve and also it is called offloading valve. What is there that a connection is from here to this side. That means, if and again it can be adjusted here.

Then if the pressure exceeds, then this will connect this part to tank. And what is there looking into this connection that this is works on somewhat differential pressure. That means from this side also, pressure is being sensed and this is called offloading valve. This valve is called offloading valve. Okay? And this is a pressure relief valve. This is when the total system pressure say 10 mega Pascal, so when this pressure will exceed 10 mega Pascal, then this will the oil will flow through this valve.

Now we can even if we omit this valve and if we are sure the pressure is not exceeding 10 mega Pascal, then also this circuit will work. So this is basically for safety valve. Now how it is being operated? Now the actuator extends rapidly using both the flows at low-pressure until the set pressure is reached due to the increase in load. Now here, say suppose this is is pressing something okay, then what will happen? Initial pressure is low, so both flow, flow of both pumps will mix together and this is giving the pressure to that and it is moving very fast.

Now pressure is increasing. Say suppose it has increased above 5 mega Pascal, in that case if we need to move at the same speed, we need more power here. But if we use a motor of more power, then initial stage, it will the power will be lowest because we do not need that much pressure, that much power. Now in that case, what will happen? Say pressure has exceed that much, then this will open.

So oil of this will instead of going this way, it will go this way and go back to the tank. Whereas flow of this and pressure is high, so it is keeping this closed, it is not going this way, it is going directly to this side and this is moving with slow speed. The high flow pump is then offloaded, this is offloaded to tank and the low flow high-pressure pump handles a load using the power of prime mover.

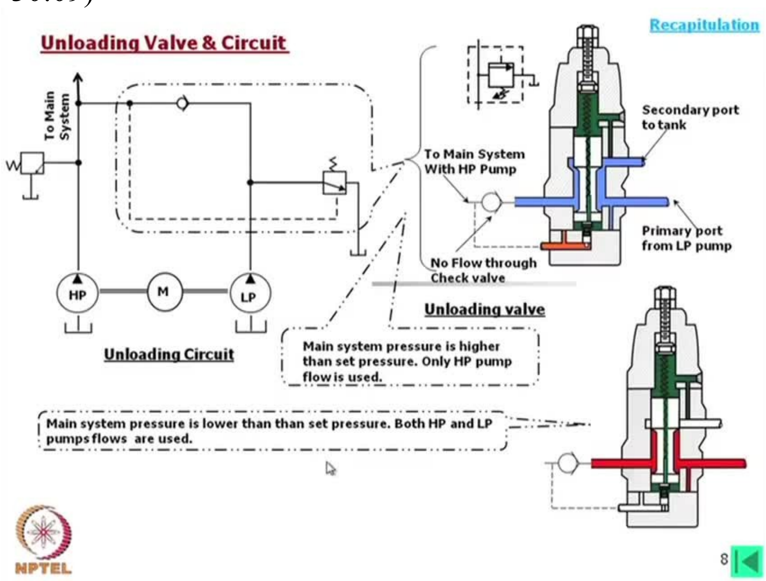
It is an unloading. This is earlier we have learned what is unloading valve. Unfortunately this is for the other class. Or offloading circuit, I shall discuss a little bit about this valve also. So just looking into symbols you see this what are the names of such valves. Then during non-action period, both pumps flow are diverted to tank through tandem centre valve. This means that we are saving energy in that way when it is not being operated.

Now there is a, you may think that if we use suppose it is a closed centre, that means, 4 ports are closed at neutral position. What will happen? In that case, this this flow, say pressure will initially increase up to 5 mega Pascal, then say suppose this is blocked and in that case, this oil will go through go back to this tank here, at 5 mega Pascal, this pump will be off but unless the pressure is increased to 10 mega Pascal, this will not be blown.

Then in that case, this means that this pump will operate with 10 mega Pascals and then this pump will operate at low pressure and oil will go back to the tank. But still, if we think of 10 mega Pascal of this flow, almost the full power of motor will be used. In that case, say power is being wasted. But the question is that, still there are closed centre valves. Why we should use the closed centre valve?

Closed centre valve is used that where we need the frequent operations and we would like to keep the oil ready for operation always. In that case, we go for closed centre valve. However, for such operations, usually will find that this is a tandem centre and this is a very good energy-saving circuit.

(Refer Slide Time: 30:09)



Now this unloading valve and circuits what we have learned earlier, say this is the same, this is a very schematic view of that system. This valve was also pressure relief valve. If you look into this valve and this valve, there is not much difference. This is pressure relief valve whereas this is we are calling unloading valve. In that case actually the control pressure line is connected in such a way, when pressure exceeds some limit, then only this operates.

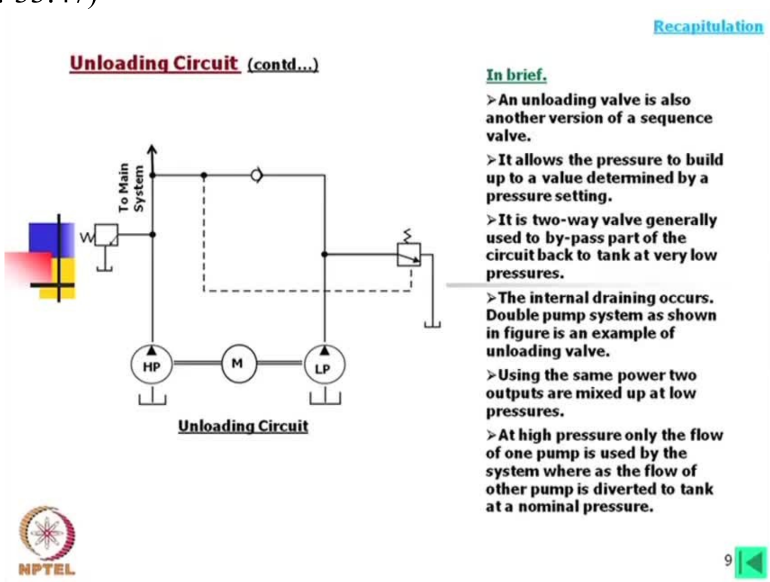
So that is why, it is called unloading valve. Now how it looks like? It is something like this. You will find that in normal case, the pressure is coming over here, this is from the pressure side and this oil is also coming over here and then at when this pressure exceeds, then this opens and then all the oil flow through this. It is like that, this is one pressure line if you remember the other sign, this side and this is also another line, the oil is coming like this.

And when this exceeds some pressure, then this opens, all the oil goes back to the tank. So this is called unloading valve. So this you can compare with this low-pressure high flow pump connection, this side is from the main loading system and this is the control pressure and this is the spoor, normally this remain closed. When this pressure exceeds some limit, then this opens and oil go back to the tank ok. The symbol is like this.

So this means that this is the valve. This together usually you will find this nonreturn valve is also incorporated here. So together is called unloading valve and the symbol is like this. This is the primary port low-pressure pump, this is the secondary port to the tank and this is main system with HP pump. Main system pressure is higher than set pressure. Only HP pump flow is used. No flow through this check valve at that condition.

So this is another view. Main system pressure is lower than set pressure. Both HP and LP pump flow are used. In that case, flow will be through the check valve. Oil is coming here and check valve is blown and oil is going to the main system.

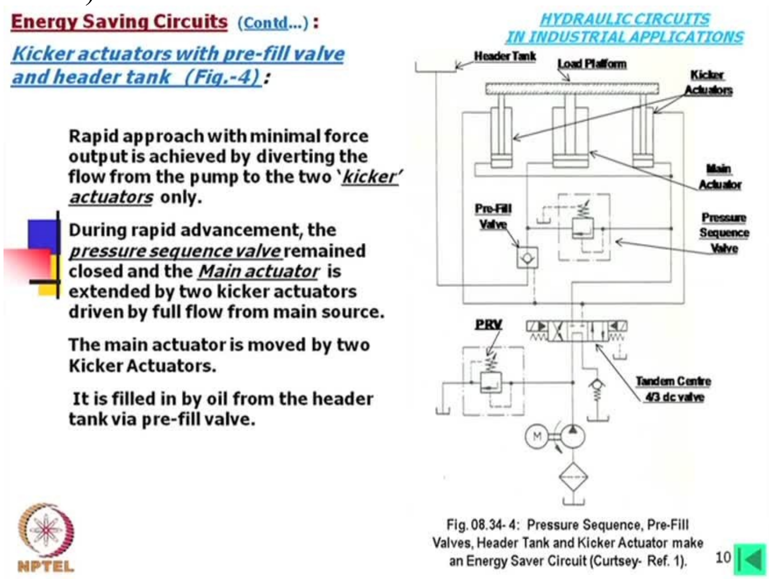
(Refer Slide Time: 33:47)



This is another example of I mean if we summarise this, we can write an unloading valve is also another version of sequence valve. Now sequence valve will come a little later. This sequence valve and the unloading valve, their features are more or less same. Only thing, this by the control pressure, this valve is operated in a different manner, then we call it sequence valve. It allows the pressure to build up to a value determined by a pressure setting.

It is two-way valve generally used to bypass part of the circuit back to tank at very low pressure. The internal draining occurs-double pump systems as shown in figure is an example of unloading valves. Using the same power two outputs and mixed up at low pressure. At high-pressure, only the flow of one pump is used by the system whereas the flow of other pump is diverted to tank at a nominal pressure.

(Refer Slide Time: 35:11)



Now so far what we have discussed, say if it is say unloading circuit and receiving circuit, so this may if it is a short note, you may use the answer, a brief description, how it is working and then these few points, that will be a short note type question. But otherwise, describing of such thing, you may expect that this is a full question, how this unloading valve is works and how it can be used for energy-saving with flow flow and high flow pumps. Then discuss the 2nd point if you remember, we talked about kicker actuators with prefilled valve and header tank.

Now let us see the circuit 1st. In that case, we find this pump and then as the arrow is not there, then we should call this is a fixed displacement pump. That means when we run this motor, it will rotate at a fixed rpm, fixed speed except we can control the motor outputs. But the pump displacement is fixed. What does it mean? If you have the idea of swept volume, that is volume displaced in one revolution, that remain constant for this pump.

This flow may be varied by varying the speed of the motor which is not usually done. Then in that case, we have one fixed displacement pump and then this is the pressure relief valve. It is not only pressure relief valve, as we find that this is the pilot line from this side and pilot line from other side also. Usually with this some symbol, it is we should say that pressure reducing valve, that we can also control the reduced pressure.

But anyway, this system will work if we use ordinary pressure relief valve here also. Then again, this is tandem 4 by 3 DC valve, the same valve what we have discussed. After that, what we find? That there is 2 cylinder. This is the load platform. The load will be let us consider it is uniformly distributed in a sense, then when this is we set is a press, then this pressure over this platform is uniform let us consider for the clarity.

Now we find these 2 cylinder of smaller area, these are called kicker actuators whereas this, this is the main actuator okay? Then what we find? That there is a header tank and from this header tank, through a nonreturn valve which is called prefill valve, that is connected to the main tank. And then, what we find? In this nonreturn valve which is called prefill valve, this is also pilot operated.

That means, by controlling this, we can allow the flow from this side to this side also. When this symbol is there with these dotted lines, that means this can be operated I mean flow can be allowed from this side by actuating through this signal. This is the control line. Now this is called a pressure sequence valve. If we look into the unloading valve and pressure sequence valve, symbols are more or less same, only you can say that by slight, minor operational change, operational feature, the name is different.

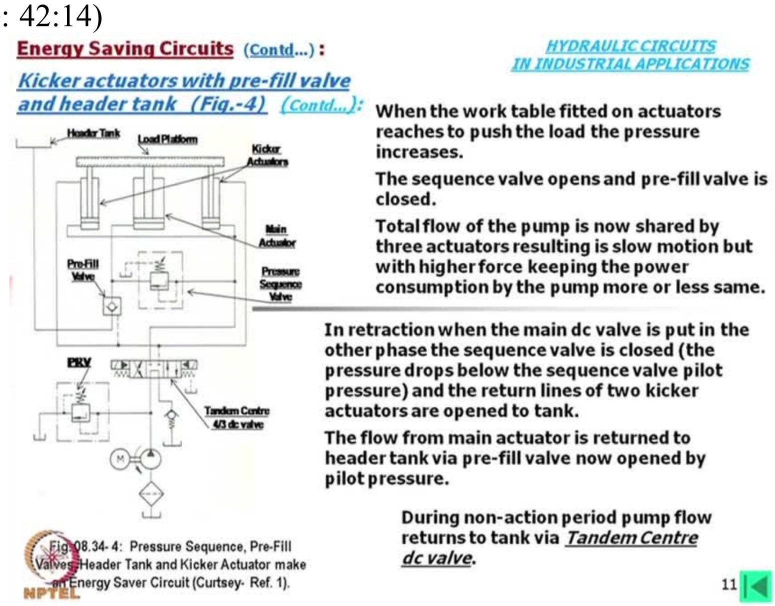
So how it operates? Rapid approach with minimum force, output if achieved by diverting the flow from the pump to the two kicker actuators only. So when there is a little force, then what is happening? So we have connected this one. Connected this means, this path is connected. That means it has actuated this side. It is connected like this. So oil is going like this and then here it is it is coming over here, it is coming over here.

Then what will happen? This with the low load, this is moving upwards. The kicker actuators is moving upwards with high speed. All the flow are being used. Now one thing I would like to mention here, when a crossing lines with a dot means these are connected, pipes are connected. If there is a crossing without such dot, it is not connected. Actually in some cases, for careful design we just put it line like this.

Say electrical circuit we put it like this but do not be confused looking into this. Wherever the connection is there, dot will be there, okay? So what is happening? This is moving. But as you see, this is crossing not connected. Then during rapid advancement, rapidly it is moving upwards, the pressure sequence valve remain. This is the pressure sequence valve remain closed and the main actuator is extended by 2 kicker actuators driven by full flow from main source.

All the flow is moving this whereas this this is closed, this is not being operated. No flow is going through the sides. Now as this is moving upwards, this is a this is these all 3 are coupled to this load platform. So we need to have some oil here also. That means this should not the no no air should be there. Oil should come over there. For that, this header tank is there and from this header tank, oil is coming into this cylinder. This is simply being filled. The main actuator is moved by 2 kicker actuators in this situations. It is filled in by oil from the header tank by a prefilled valve.

(Refer Slide Time: 42:14)



And then, when the worktable fitted on actuators reaches to push the load, the pressure increases. Actually, any press you will find initially this say suppose it is squeezing say cotton let us consider. So initially you will find that cotton is put in between and there is no load. Or if you think of a the paper cutting machines, that is on the paper, this actuator is moving. Say it is applying the load but initially you will find these papers are with a gear. No load, almost no load. Now when they are pushed and this, all this material will come, it will be squeezed.

In that case, pressure will be failed and the sequence valve opens and pre-fill valve is closed. Now the pressure has increased. In that case the with this setting, the pressure setting is such that because this whatever oil is going this side, the kicker actuators, that is also is going to the pressure sequence valve but this pressure is low. So it is closed. Now when the pressure is increased, this will open, then oil is going to this side and due to that, this will be closed.

And then, this oil will go to all 3 cylinder actuator. Through this path, it is going through this way and to these 2 cylinder, it is going as it is. But the flow will be automatically divided and this is one interesting point is there, total load is distributed over there. So total load divided by the area, that will give the pressure. Now what we would do? Suppose this load, it will be distributed in such a way that in these 3, pressure will be same.

That means, suppose this area is just double of these 2 cylinder, that means this will take 1 load 1 I mean 1 unit load, this will take another unit load and this will take 2 unit load. It is like that. Automatically this load will be distributed over the platform. Now still there is a problem. Suppose the load is in such a way that it cannot balance. In that way, you will find that one will move 1st and then the other.

But definitely, there is some system to utilise the load . That is interesting. If you calculate numerically, when these 3 are moving and performing some operations with load, then the pressure will be distributed well over that. Total flow of pump is now shared by 3 actuators resulting in slow motion but with higher force keeping the power consumption by the pump more or less same.

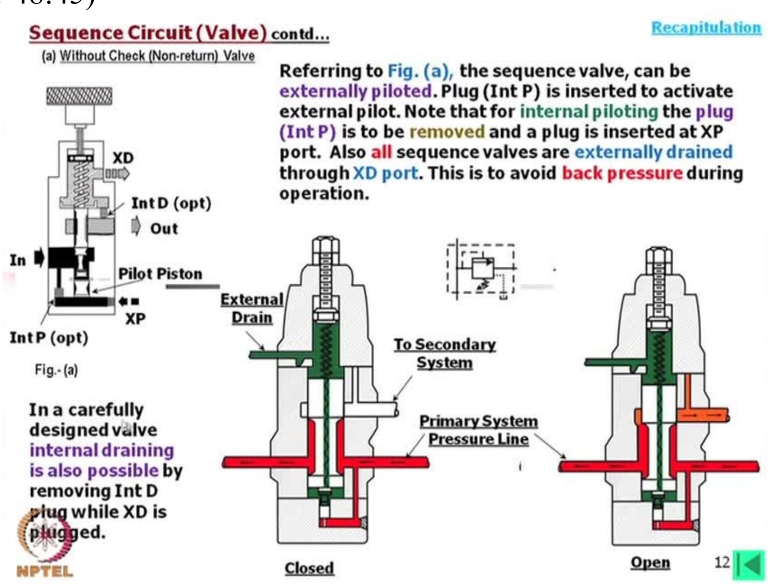
In retraction, when the main DC valve is put now retraction has started is DC valve, direction control valve is put in the other phase. That means we have now connected like this, the pressure drops below the sequence valve pilot and the kicker line of 2 kicker actuators are opened to tank. Say now we have connected this way. Say this cross okay? And then this path is connected to this. Then this oil is going like this and it is going other sides okay?

And oil from this side is going back to the tank. So oil is coming from here, here. Now this oil cannot come to this tank. What is done in that case? The sequence valve is closed again. Due to this, sequence valve is closed because we do not have sufficient pressure and the return line of 2 kicker actuators are opened to this tank okay? This much we have learned but we still do not know what is happening to this main cylinder flow.

The flow from main actuator is returned to the header tank via prefilled valve is because now this is actuated and then oil is again going back to the prefilled I mean header tank. So this pilot pressure will open this one but this path is closed. So oil has to go back to the tank. There is no way. During non-active period, pump flow returns to the tank via this tandem valve. As this is a tandem valve, we when it is in neutral position, all the oil is going back to the tank.

So this is a very good example that when we use such pressure load and these things with a this kicker actuators and prefilled valve, we can save the energy. Only thing, as there is a tandem valve, the operation will be slightly sluggish than if we can use closed centre valve. But really, that does not matter because we are using some pressure, we have to keep the material, we have to move the material. So if there is a time delay for such operations, this really does not matter. So this is one example of the power saving systems.

(Refer Slide Time: 48:45)

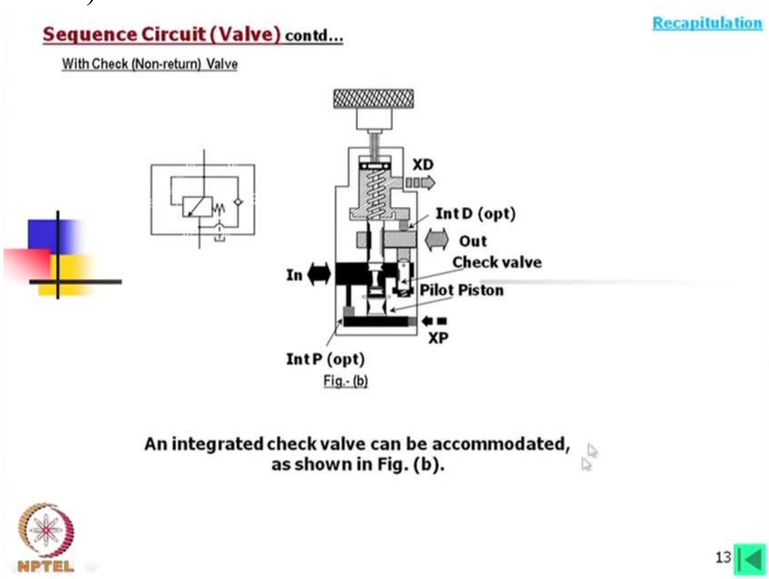


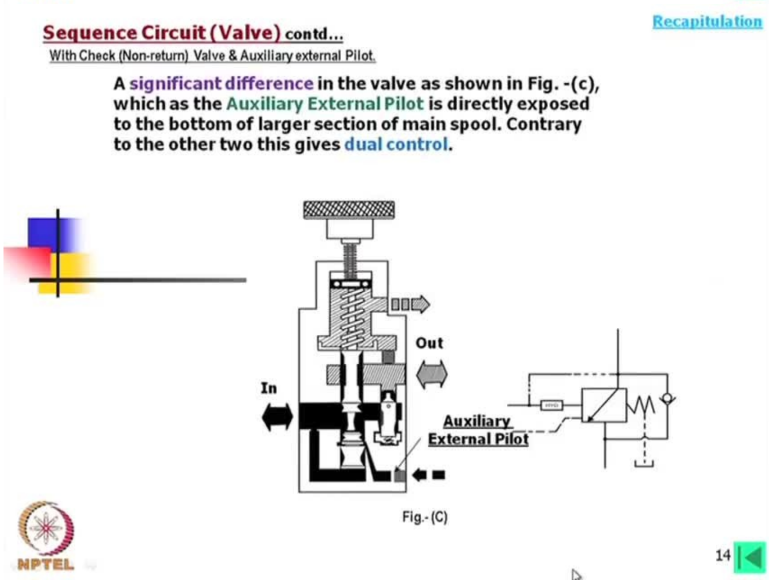
Now how this valve look like. This is the sequence circuit as you find that the oil is coming in and oil is going out through this valve. And then this is the pilot pistons through which it can be opened also externally. Say for example this if we this signal is there then this will open and this oil will go. Otherwise, if there is a certain increase in pressure, this will open and this oil will flow out. And also, if you can study this primary system pressure line is here and then with this when the pressure exceeds some amount, then this open to the secondary system okay?

So high I suggest that you should see this figure and you should study this valve. Here, this how written how it operates. The sequence valve can externally piloted. The plug B is inserted to activate external pilot. Note that for internal piloting, the plug is to be removed and a plug is inserted at XP port. I mean, here if you put this plug it, then not it is externally actuated, it will be actuated internally, internal pilot is caught.

Also all sequence valve are externally drained through XP ports. This is to avoid the back pressure. Say this where there is a possibility of back pressure, then draining is essential. In a carefully designed valve, internal training is also possible by removing internal D plug with XD is plugged. So it is also possible some internal draining through this port.

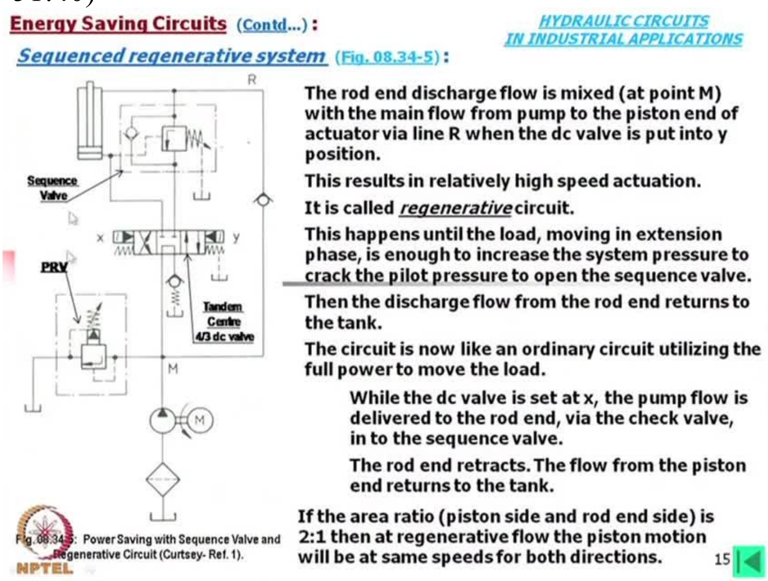
(Refer Slide Time: 51:19)





This is another view of this valve and there is auxiliary external pilot is there. This is just to improve the performance of such valve.

(Refer Slide Time: 51:40)



Now if we look into the other circuit, the sequence regenerative circuit, in that case, we have one sequence valve here. And again this is 4 by 3 DC valve and this is a simple pressure relief valve and fixed displacement pump. In that case, the rod end discharge flow is mixed at point M, this side flow is mixed here and with the main flow from pump to the piston end actuator via line R the return line, when the DC valve is put into y position. If we put into this positions, then the flow is going through this and from here, the flow is coming over here and this is being mixed.

It is possible in regeneration and this sequence valve this results in relatively high-speed actuation system. It is called regenerative circuit. This happens until the load moving in extension phase is enough to increase the system pressure to cut the pilot pressure of this sequence valve. Suppose it is moving at fast speed but the load is now increased. In that case, there will be increase in pressure.

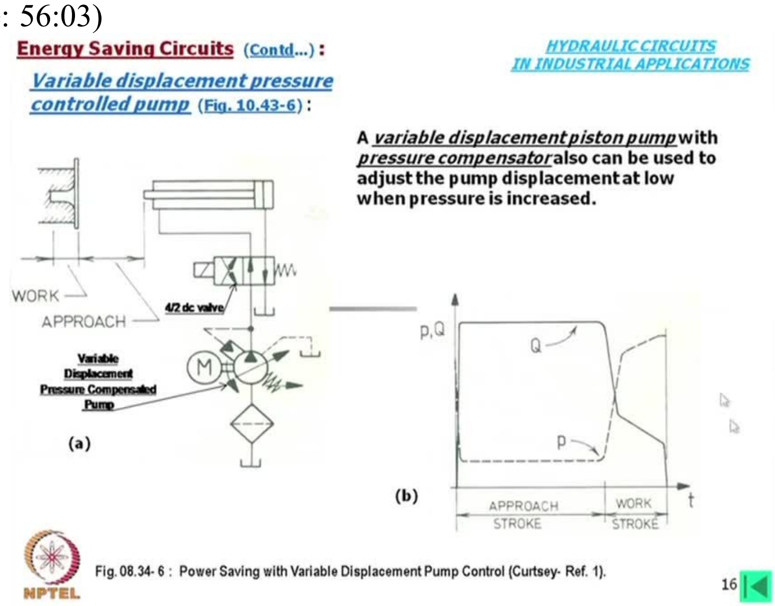
Once the increase in pressure is there, then this valve will open, this valve will be operational and then the discharge flow from the rod end returns to the tank. Then what will happen? This flow instead of being mixed, it will be back to the tank through this valve, through this line. It will not come this way. This will directly come to this way and it will go back to the tank. So in that way, what we find?

If there is less load, the regenerative circuit function will be operated and this will move at a faster speed. When there is a pressure, then this flow through this valve will go back to, sequence valve will go back to the tank and this will operate at low speed but high pressure. The circuit is now like an ordinary circuit utilising the full power to move the load. While the DC valve is set at X, the pump flow is diverted to the rod end via a check valve into the sequence valve.

The rod end retracts. The flow from the piston end returns to the tank. This is again like an ordinary circuit. Now the thing is that only here, that if we omit this sequence valve, then this will operate at the same speed. The full flow will be mixed and it will go there. In that case, power will increase. So without this, this whole circuit is an regenerative circuit. With this, we should call this is a regenerative circuit with energy-saving.

And with the area ratio, this is another interesting thing that area ratio is 2 is to 1. That means, if this area is 2, then this area is 1. But keep in mind, that does not mean that rod diameter and the piston diameter is 1 is to 2. The area is 1 is to 2. In that case, we can have the same speed in the regenerative.

(Refer Slide Time: 56:03)

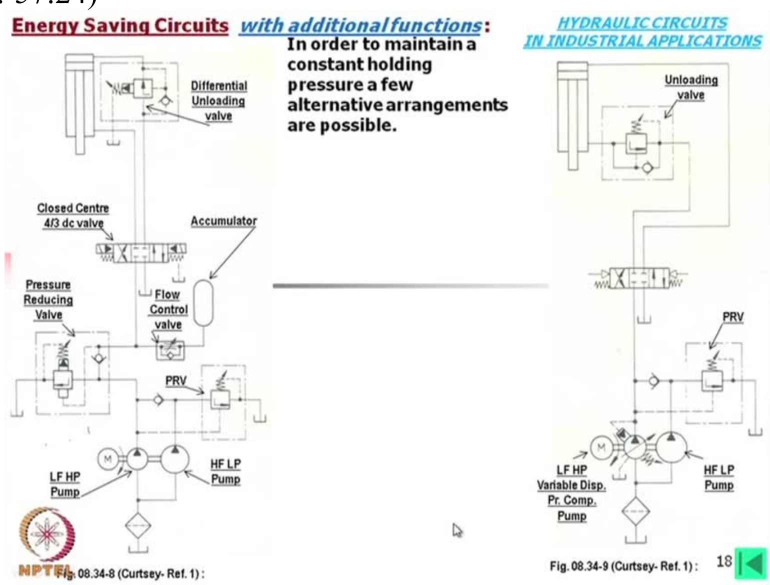


Now this is another circuit I think we can continue later, also we can study the circuit. Maybe in the next lecture we will study this. So this is with the variable displacement pump we can have the same energy-saving system. Only thing, this such variable displacement pump is very expensive. Say for example, if we the same pump, same feature, except this pressure compensation and the variable displacement part, the cost maybe if it is a cost of this pump is

5000, with such variable displacement system, it will be at least 15,000, 3-4 times more than this pump.

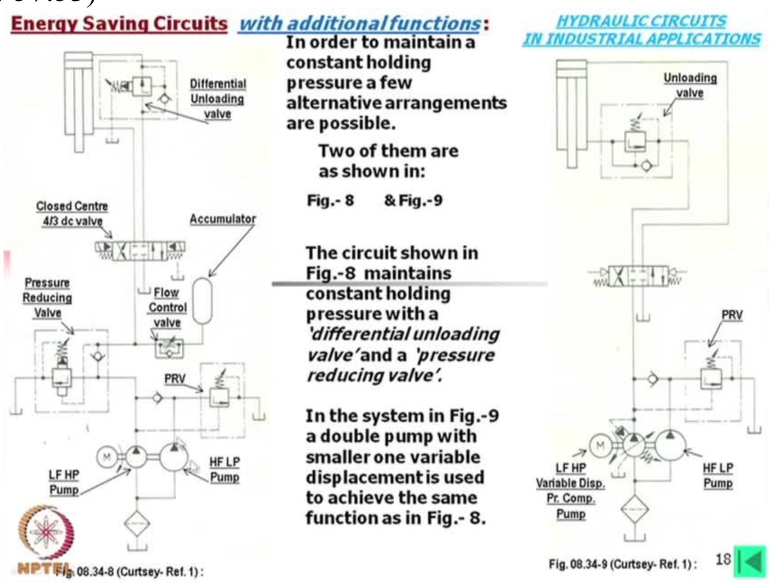
That is why, if we go for such a system, we have to be very selective. But in using such variable displacement pump with a proper control system, the energy savings will be more assured and we can say, more fine control will be there. Now we can study this circuit maybe in the next time.

(Refer Slide Time: 57:24)



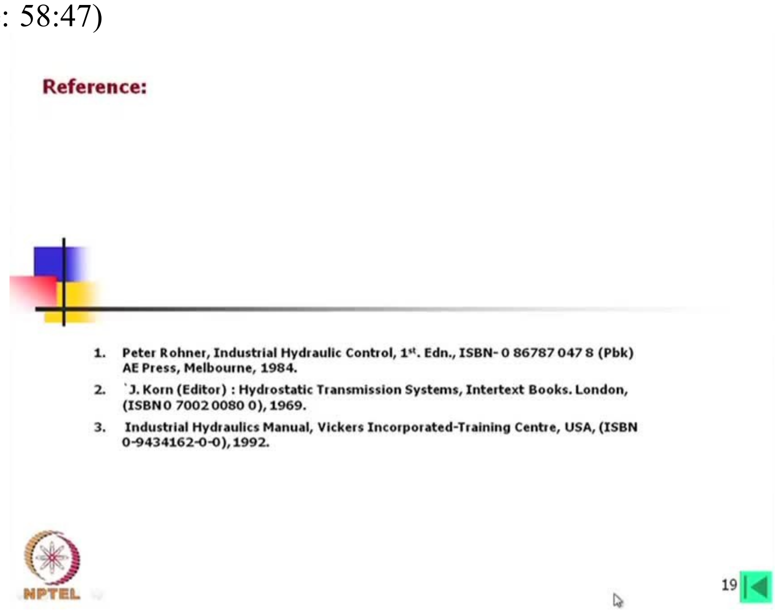
And this is again this is kicker circuits with an accumulator. This, the same operational but with this accumulator, it further saves the energy. And in this case, we do not use the open tandem centre, we have used a closed centre valve here.

(Refer Slide Time: 57:53)



This other 2 circuits with unloading valve. So in this circuits, what we differential unloading valve and pressure reducing valve. In this case, we have only simple one unloading valve. These are more or less you can find that here we have used one accumulator, here without any accumulator but we have used a variable displacement pump. This function and power saving more or less same. Here we can have finer control but this is more expensive than this.

(Refer Slide Time: 58:47)



And this we have followed. This book will not be available in the library. This is out of print also, same as this book and this is also very expensive book and I do not think our library is having. Anyway, I will, this note will be available to you. Thank you for listening.