Industrial Automation & Control
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Lecture - 28
Industrial Hydraulic Circuit

Welcome to lesson 28 of industrial automation and control, course under the NPTEL program. Today, we are going to look at a very interesting topic, in the last two lectures we have seen various hydraulic system components, in this lecture we will see, how they can be joined together to form hydraulic circuits for various kinds of industrial applications, so that is going to be very interesting for me at least to tell you.

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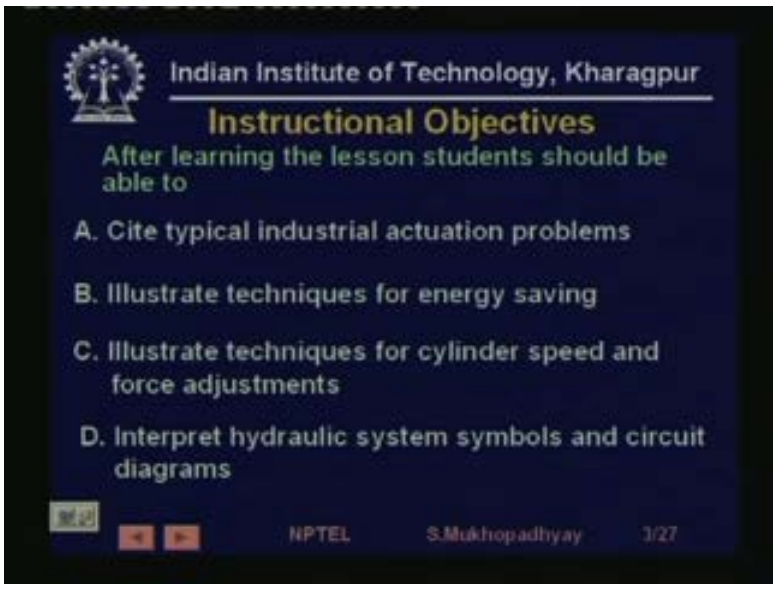

So, looking at the instructional objectives, after this lesson a student should be able to cite typical industrial actuation problems, some very common problems which occur in the case of industrial systems. So, then in many cases, we you know energy is very expensive, so we do, we never like to spend energy unnecessarily, so there are various kinds of energy saving schemes especially hydraulic systems, that are very high power systems, so saving energy is important.

So, we will see how we can save energy, for such systems and sometimes we will find that, we need to you know, we need to create motions using hydraulic systems, so we need to adjust speeds, we need to adjust forces, depending on the requirement of the

load. So, how to do them and finally we, all the circuits will draw using some, using specific hydraulic symbols, so we will see in the course of this lesson, how to interpret hydraulic symbols, how to understand, what components are being used and how to figure out, how hydraulic circuits work from a circuit diagram.

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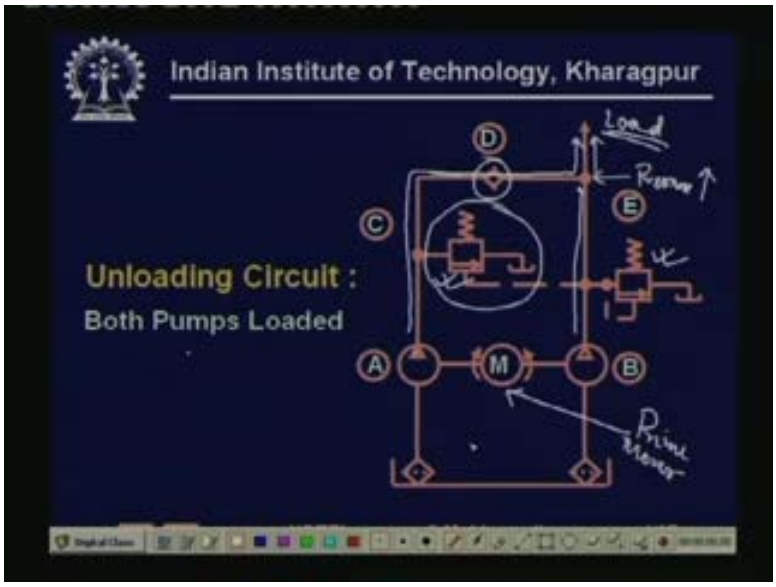

So, if I come to our first circuit what is that, in this circuit, it is called an unloading circuit, so there are, see the circuit there are two pumps, can you realize that this is the, this is actually hydraulic pump, this is a hydraulic pump. This is also another hydraulic pump and they are being driven by a common motor, so this is the prime mover and these pumps are actually connected in parallel, this is where it is going to the load or the system.

So the pump if flow, is going this way, this is the check valve, so this way is free flow for the check valve if you recall, this is flow of pump A and this is flow of pump B. They are being, they are getting joined here and the total flow, that is flow of pump A plus pump B is actually flowing onto the load. Now, you see, we know that what is the hydraulic power requirement, power requirement is force into flow rate or rather pressure into flow rate, which is equal to force into speed.

So, if the load force and finally, we must recall we must realize, that the power comes from the prime mover and the prime mover is designed to handle a certain amount of power. So, if at certain, at a certain point of time, the force requirement in the load goes

up, then just to be able to, so that the power requirement does not go out of the prime movers capabilities, so we need to reduce flow rate right, so for heavy loads we generally moves them slowly, a light loads we can move them fast, right.

So, what happens, if suddenly the force requirement in the system goes up, immediately what will happen is that, the pressure here will tend to go up, so pressure will go up. Now, you see that, there are two relief valves, this is one relief valve and this is another relief valve, now, if we have decided, that if the pressure goes up beyond this setting, remember that we are talking about hydrostatic pumps or positive displacement pump generally.

So, as long as the speed is the same, the volume being delivered is the same and the power requirement is directly proportional to the pressure, assuming that the volumetric efficiency is same, the leakage etcetera are not significant. So, now we, if we want to, the pressure has gone up, because the force requirement has gone up, so we want to reduce flow rate, so what you want to do, so we have this setting of this relief valve as, if the setting is exceeded at some point, then what is going to happen. Is that this relief vale will vent, so the pump flow at that time, let me use the different color, so the pump flow at that times, so this is the case for both pumps loaded. So, let me go to the other diagram, then we will be able to see the case where pump A unloaded.

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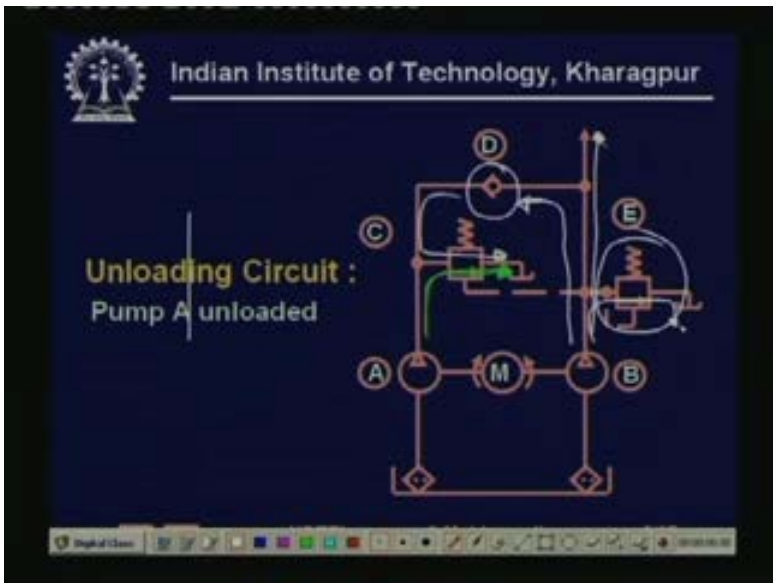

So, then when pump A is unloaded, because this relief valve setting has been exceeded, so this is the flow rate of the pump, right and this so the, so this pump gets unloaded, so therefore, the power demand on this motor reduces and the and now, the system is only fed from this flow rate right. So, you see that, we have we can unload a pump when the pressure requirement goes up, to keep the power requirement, so that if the, if suddenly we put a very heavy load, then it will still be moved but it will be moved slowly.

This is our first example, leads to some amount of, you know leads does not get into, now interestingly there is one point to mention, that what is the role of this check valve. See when this pump is getting unloaded, then remember, that this flow cannot go through this valve because this check valve is blocked. So, therefore, this pump really cannot unload through this relief valve, so this pump will continue to deliver, until the setting of this relief valve is also exceeded, you see all pumps have overloads, overload production using relief valves.

So, if for some reason, you have put such a heavy load which cannot be even handled by one pump, in that case, this relief valve will vent and the load will of course stop and the fluid will flow like this, but the motor load, motor will be protected from overloading. So, this is, the way this circuit functions, then we go to the our next circuit, we are going to see a number of such applications.

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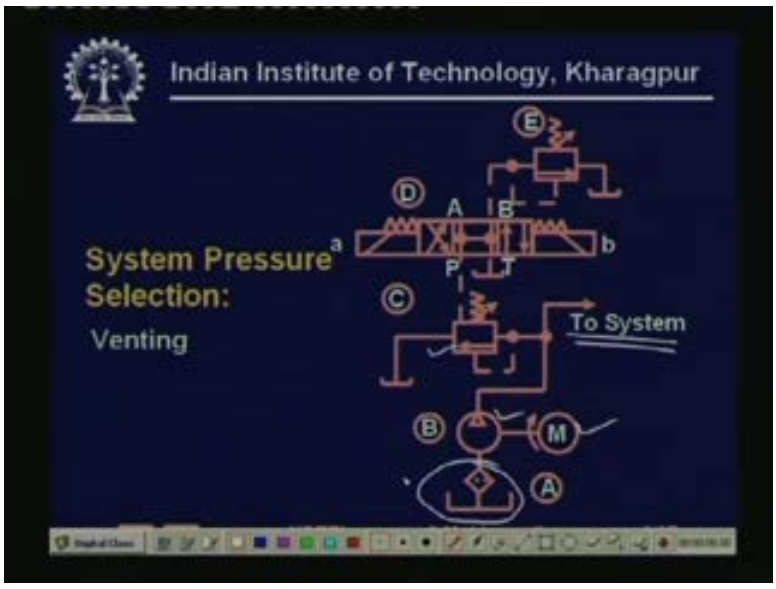

So, the next circuit is where, we want to again, we want to in this case, what was happening is that the pump was getting, if the pressure goes up, then the pump gets unloaded, but now we want a different thing, we want to select the pressure with which we want to drive the load. So, what happens is here, so we have three modes of the system, in the first mode the system will vent, that is pump will be directly connected to the tank, no fluid no flow.

Second is, it will be operated at a low working pressure, thirdly it will be working at a high working pressure. So, there are three modes and we wanted to select the modes, so that happens like this, so here is a circuit first for the vent mode, so in the vent mode, what is happening look at this circuit. So what components do we have the tank and the reservoir here, we have the pump, we have the motor, we have a relief valve and this is where it goes to the system.

Now, the pressure limits, the pressure up to which the system can occur will, obviously be selected by this relief valve and this relief valve actually the… There are this is a pilot operated relief valve, so in this valve at what, what is the setting of the relief valve that depends on the pilot pressure, we have seen such valves before. Now, so actually what we are going to do is, so let us see what happens, so how is the pilot pressure determined, so let us look at the pilot circuits.

So, this is the pilot line dashed, so when there are, this is a directional valve right, there are, it is a solenoid operated valve you can see that from the symbol and there are two springs, so when both solenoids are off then it is spring centered. So, both the springs will push and it will keep it at the center, what is the position at the center, at the center it is the pump port is directly connected to the tank port. So, if A and B neither of them are energized, then this directional valve is at the center.

And therefore, the vent port of this relief valve C is actually connected directly through the central position of the directional valve to the tank. So, actually there is no pilot pressure, the pilot pressure is actually a tank pressure and therefore, this pressure is very low, so directly the pump vents and no fluid goes to the system, so this is the operation in the venting, now what happen in the other modes, so let us go to the other modes.

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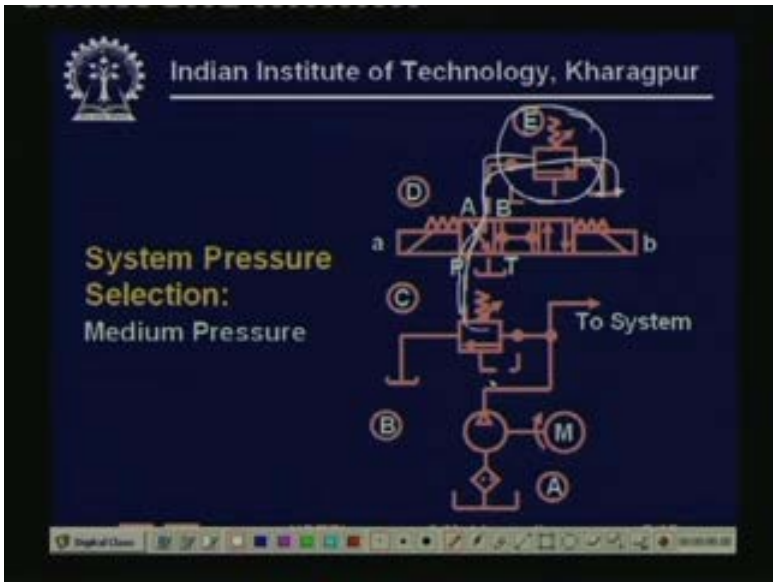

So, in the medium pressure mode, what is happening is the following, so in the medium pressure mode we have energized solenoid A, so where we have energized solenoid A, we will assume that the, this position of the valve is active, so now the pump port is connected like this, through this, through this to this and this. So, now the, what is the pilot pressure, the pilot pressure is actually determined by the setting of this valve E, so whenever the pressure will exceed the setting of this valve E, the vent port will open.

Therefore, the system pressure, gets limited by the setting of E, setting of C, set C, C itself has the setting, it is own setting which is not, it is also a relief valve, so it has a, this is a remote pilot, but it has it is own setting, so that setting is actually higher than the setting of E. So, in that case, what is happening, so in this case the setting of the system pressure is actually limited by the setting of E and E being the lower one of E and C. So, therefore, we have a medium, the limiting pressure is now medium. So, now we go to the, I am sorry we go to the next one, which is high pressure mode.

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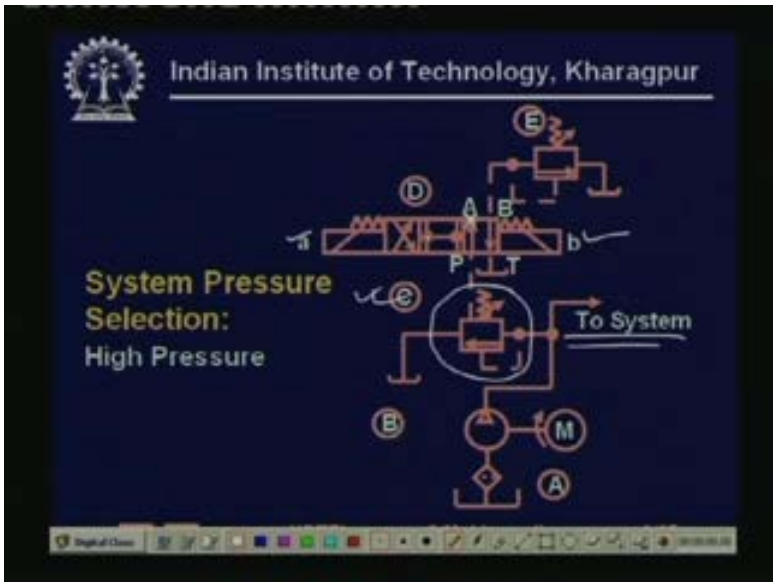

So, what is happening in the high pressure mode, in the high pressure mode, we are now in this position, so in this position what is happening, first see, that this port is actually plugged, this is plugged means that it is sealed. So, therefore, the pilot pressure can go up to any level theoretically, it can go to very high level, so the operation of, so now the operation of this valve is not limited by the pilot pressure, because the pilot is connected to a plugged port, so the pilot does not vent the valve.

So, now it is operated by it is own setting, so now, in this system pressure gets limited by the setting of the valve C itself and since the setting of the valve C is higher than that of E, so we can limit the system pressure to a higher level. So, you see that, we can, we are able to achieve this by, either energizing a or energizing b or energizing none, so we can select the system operating pressure, this is our second example.

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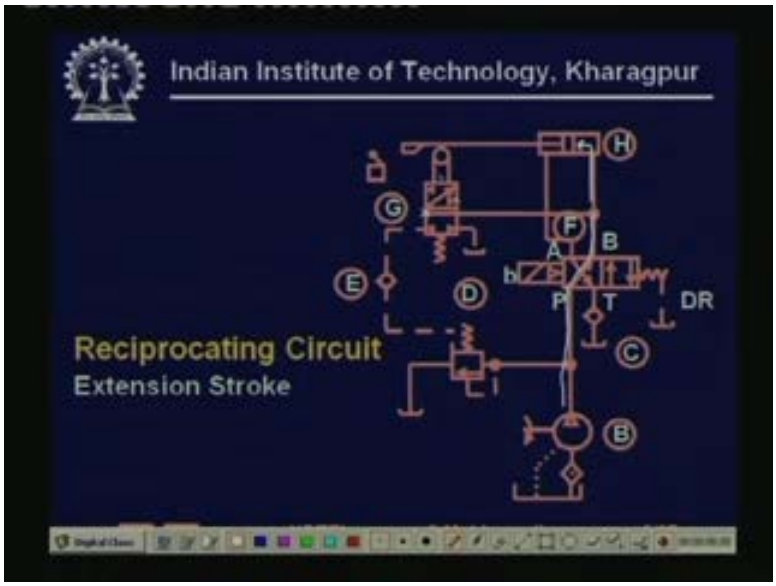

So, in the third example, we have a very common circuit which is a reciprocating circuit, hydraulic circuits are often required to execute cyclic motion, that is suppose you have a cylinder, it will extend, push the load and it will come back, right. So, suppose some conveyor belt has brought a, has some brought some item, there may be a hydraulic arm which will push the item into the bin and then retract. So, there are now various cases, in some cases the pushing forward is under a load, the pushing backward is free.

So, there are various cases that arise and we will see some of these, because this extension retraction, reciprocating movement is a very common thing in hydraulic circuit. So, we first look at a reciprocating circuit and in particular, we look at the extension stoke first, so here is the circuit, so what is happening here, very simple again, always start from the pump. So, here is the pump, the filter, this is a drain line, this is the relief valve which is typically used for overload protection of the pump.

Now, if this case, see look at this valve, this valves has first of all try to interpret the symbol, the symbol has a, it has a solenoid plus it has a hydraulic pilot. So, actually it is probably this direction valve is actually a very big valve, so therefore, it is not operated only by a solenoid, the previous valve was being operated only by a solenoid. In this case, we are having a solenoid, which is operating a hydraulic pilot, which is again in turn operating this big directional valve, right.

And we have, in this case we have only one this thing, only one solenoid and the other side is, so if you switch off the solenoid it will come to, so it has only two positions. If the solenoid is off, it goes to the right hand position, if the solenoid is on, it goes to the left hand position. So, now we are at the left hand position, when the solenoid is on, so the pump flow goes like this, like this, like this and enters what is known as the cap end or the head end of the cylinder, pushes it towards left.

At the same time, look at this line, this line is plugged here, so there is nothing, this valve is a cam operated valve, so unless the cam is, when the cam is operated this is supposed to be in the left position, when the cam is not operated this is supposed to be in the right position, so currently it is in the right position, so this side is off, this side is off mean this, the relief valve port is plugged. So, therefore, the full pressure is actually applied to the load. The pilot port is plugged and this cylinder is moving this way right, so this is the extension stroke, what happens in the next stroke.

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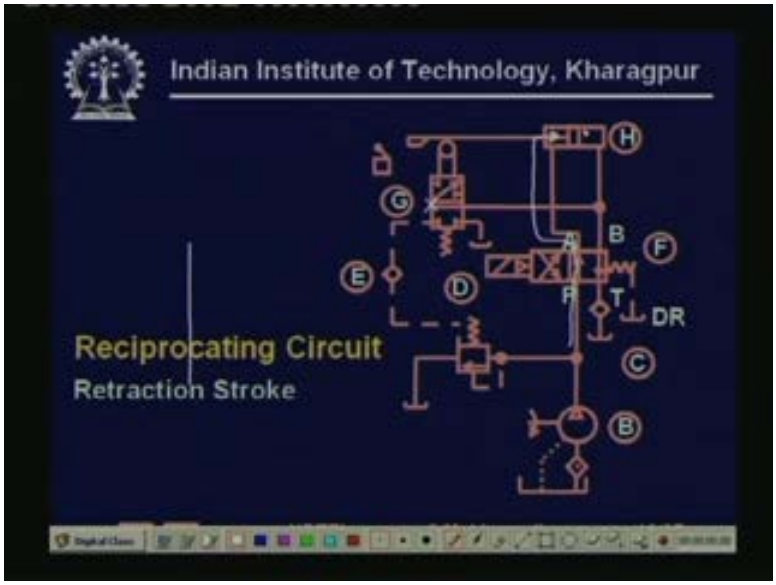

In the next stroke, now we have an, we have a retraction stroke, so what happens is, when it reaches the end, it operates this limit switch at the end, at the extreme end of the extension stroke. That limit switch is actually connected to the solenoid, in such a way that immediately when the limit switch is made or switched on, this solenoid is put off. So, when the solenoid is put off, this directional valve assumes the right position, so what is happening in the position.

In the right position, the pump flow goes like this, so now you see, what is the matter here, so in the right position the pump flow goes like this and enters, what is known as the rod end of the cylinder, so the, now the cylinder moves towards the right. Note that the cam is still not operated, so therefore, this is still plugged and this is also still plugged and the full pressure is being operated, being applied to the cylinder, so the next case.

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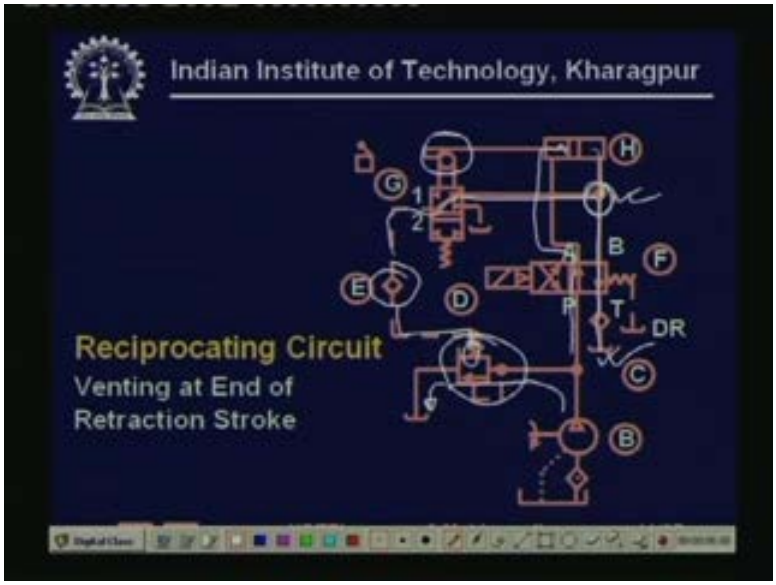

In the next case, a very interesting thing happens at the end of the retraction stroke, that is something special about this circuit. So, at the end of the retraction stroke, when it comes fully to right, this rod is designed in such a manner, that it pushes the cam, so when it pushes the cam, this valve now connects in the top position, as we said, so in the top position what is happening, in the top position, this is the pump and this is the tank, so you see that, this point is very close to tank pressure.

So, now the pilot port of this relief valve is actually connected, this is free flow, direction of the check valve goes through this and comes to this point. So, the positions, the pilot port pressure which is being applied is very close to this, which is in turn very close to this. So the pilot port is now connected nearly to tank, which means that, this relief valve will now vent, so at the end of the retraction cycle the tank directly vent, rather the pump directly vents to tank.

So, the power required by the tank, by the pump is very low, so at the end of the retraction cycle where it is waiting, this pump does not unnecessarily spend power, so it

vents automatically, the circuit is made in a such manner, next what happens, how do you start a new cycle, so you start a new cycle like this.

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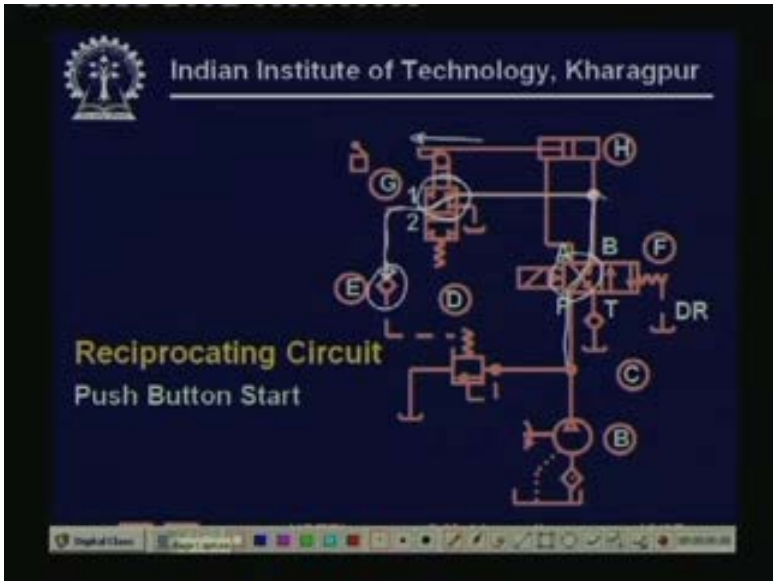

A new cycle is actually started by pressing a push button, so this coil is, has to be connected in such an electrical circuit, such that it can be switched off by this limit switch, as we have seen at the end of the extension cycle and it can be switched on by a push button. So, every time you want to start one extension retraction motion, you need to switch on this solenoid, so when you switch it on, again this shifts to the left, now it is cam is made, so this is in this position and this is in this position.

So, now what is happening, again this connected to pump, this is pump now, this is connected to pump. So, now what, but unfortunately, so now it tries to flow like this, but this is, this pressure is now, so now, you see again, this port is actually, so this is, so the opposing force on check valve is the full pump pressure. So therefore, the pilot pressure, if this valve has to vent, then the pilot pressure has to cross this level, otherwise the there cannot be any flow.

So, therefore this full pump pressure can be applied to the hydraulic cylinder, it will start to move left, the moment it will start to move left, this cam will be released and when the cam is released, it will shift to the lower position and again the vent port of this valve is going to be plugged and the cycle repeats. So, this is the way, that a, this is a conventional reciprocation circuit, only feature that has been added, is that at the end of a

retraction, one full extension under full power retraction under full power. And then at the end, when you have reach the end of the retraction cycle, the pump is unloaded basically it will save power, so let us look at the next example.

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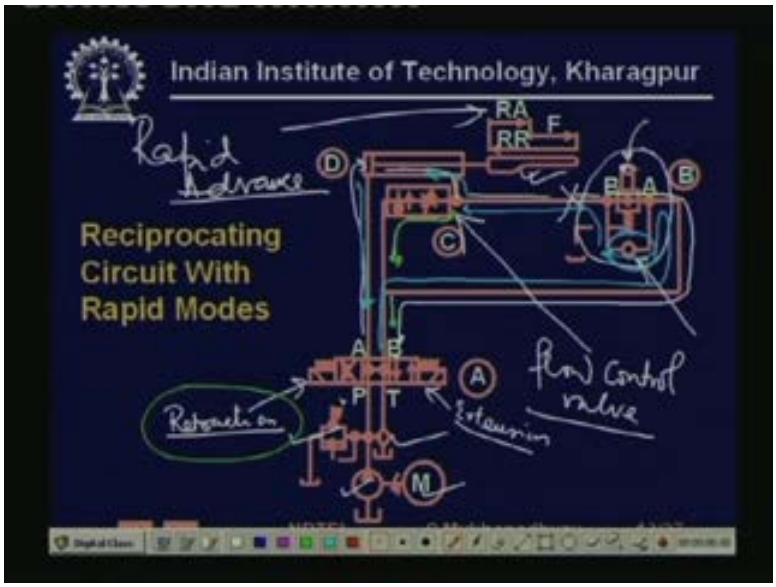

Now, we want to do some special things, that is we want to safe, sometimes it happens, I said that, in the during the extension stroke, you are actually pushing hard against a load, so you want to do it slowly, while the retraction stroke is free, so you want to do it rapidly, because you want to spend, you want to safe time of the operation, right. So, let us see how we can do that, so what we are seeing here you see, again let us identify components, pump, motor, relief valve, this is tank and filter.

This is a three position, this is a three position solenoid, electrical solenoid actuator, spring loaded, valve, so and this is a flow control valve and this is A, again a mechanically operated valve with a property that, if you operate the switch. If you operated the switch as long as you do not operate the switch, then this is a direct short, that this line is open, if you operate the switch, this line gets closed and this switch is mechanically operated by the end of the rod.

So, you see what is happening here, the first what is happening is initially again, when neither of the solenoids are operated, then it is centered, so nothing, no flow pump gets directly to tank. Next you operate it, let us say you operate the left cylinder, so if you operate the left cylinder then pump, first let us look at the advance circuit, which is the

right cylinder, so if you connect it, then port A gets connected to pump, so the fluid flows when this coil is energized.

So, this is for extension and this is for retraction, so during the extension, when this is applied then fluid flows into this end, it comes out of this end and since the cam is not operated, so therefore, this is a short so it returns, directly goes through this, goes through this, returns. So, there is hardly any resistance, direct short, so this starts advancing very fast, that is called the rapid advance, then after a certain distance, this touches this and pushes it.

So, therefore, during that time this operates and this is closed off, it cannot pass through this, this is a check valve, no flow along this. So, now the fluid is forced to flow along this, we should use a different color, so during the forward stroke the fluid is forced to flow along the green line and since this is the flow control valve. So, there is only a certain amount of flow possible not more than that, so the flow is controlled, because we expect load here.

So, again for power requirements we need to reduce speed, so we are doing that by using flow control. Now, what happens, when we want to have retraction, when we want to have retraction, then we will operate this solenoid, when we will operate this solenoid then what happens is, now the, let me choose a different color, so it is a blue one. So, during retraction now, this line B is connected to pump, so how does it flow, so it flows through this path and this path and this.

Now it flows to the check valve, this is the free direction, this is still off, this still made which means that this line is off, but that does not matter, because this side check valve is free flow, so it goes through this and it enters the rod end. So, the retraction and from cap end, it comes straight and it will go to the tank, so during retraction, all the way because of this check valve, fluid will always flow through this and it will have a free flow path and there will be, the flow rate is going to be high.

That does not matter, because the load is not connected, pressure requirements are low and the pump can, with the pump flow you can very well manage. So this is what is happening and you can obtain a rapid retraction, now let us go to the next example, so in the next example, what it happening is that.

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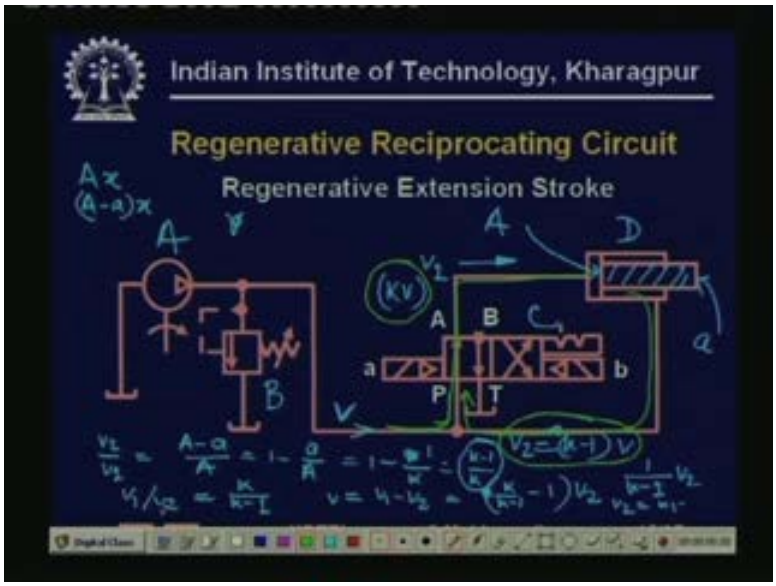

We want to, we are still having reciprocation circuits, but now we want to have a regenerative configuration, what is regenerative configuration, see previously you will recall, that all in, in all your cases when you are trying to move the cylinder, one end, suppose you want to move, extend the rod, so you push in fluid into the cap end and the fluid comes out at the rod end. So, you connect, basically you connect the cap end to the pump and you connect the rod into the tank.

Now, here what we are saying is that, we want to re-circulate some of the fluid, which is coming out of the rod end into the cap end. So, how that is possible, so that is exactly what is being shown here, so you see again identified components first, so you have, this is say A pump, this is B relief valve, this is C directional valve and this is D a cylinder. Now, see that, we have drawn the cylinder rod a bit thick, just to ensure that the rod area is not negligible to the cylinder piston area.

This is the piston area, capital A and this is the rod area, small a suppose, so what is happening is that, now the two side areas are different, also look at this particular directional valve which is two position and it is kind of you ((Refer Time: 31:44)) it is detented in the sense that, so when you, what happens when both the solenoids are off. So, in the both the solenoids are off, then it stays in the position corresponding to the last operation of the solenoids.

So, if last the solenoid A was on then it will, even if you take A off, it will it is going to remain at the left position. So, that is due to a mechanical, you know arrangement, so that is detention, so now what is happening here is, look at this that, suppose the pump flow here is V, so what is happening is that, this part, what is the flow, this part the flow is, this is V see the ratio of the flow into this, suppose it moves by a distance x, then the volume field is A into x and the volume which is expelled is A minus a into x.

So, if this is V 1 and if this is V 2, is coming out, then V 2 by V 1 is equal to A minus a by A, is equal to 1 minus a by A, is equal 1 minus 1 by k, 1 minus 1 by k is equal to k minus 1 by k. So, this V 2 by V 1 and V 1 by V 2 is equal to k by k minus 1, so now what is, now so again V is equal to V 1 minus V 2, is equal to V 2 is equal to V 1, where V is V 1 minus V 2, so it is V 1 minus, V 1 equal to k by k minus 1 into V 2, so it is k by k minus 1 minus 1 into V 2.

That is equal to what, that is equal to 1 by k minus 1 into V 2, k minus k plus 1, so 1 by k minus 1 into V 2 and so V 2 is equal to k minus 1. Let us write it at a different place, so we get two equations, we get V 2 is equal to k minus 1 into V and therefore, V 1 is equal to k into V, these are the two, let me encircle them in a different color, these are the final expressions, so these are the flows, you understand. Similarly, so you see that, so if typical case is, this is the case during extension stroke.

So, actually you see that, though the flow rate is k into V, typically k is greater than 1, but the, actually the fluid drawn is from the pump is small v. Now, what happens in the retraction stroke, in the retraction stroke, so in the extension stroke it is going to go like this, like this, it enters like this and then again part goes this and part go. This is the that the flow patterns and the extension flow, what happens in the retraction stroke.

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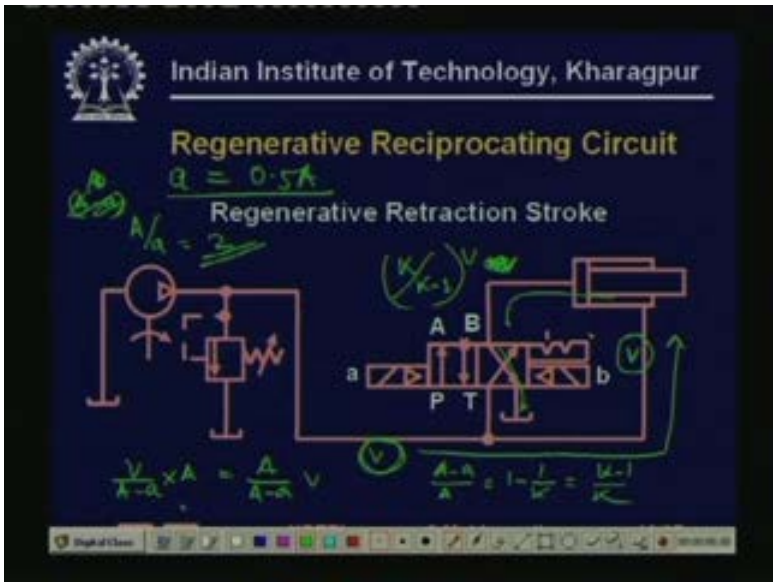

In the retraction stroke, now you are in this position, so now, this simply this is the path, directly this is the path, that is there is no fluid addition or anything. So, now what is happening is that, if this is V, then this is V and obviously, because it directly goes into this and what is going to be this, this is going to be naturally this will be, so A into, rather A minus a into V, suppose it moves distance x, so if this is V suppose the area is half, then this side it will be k into V.

The distance moved in unit time is actually V by A minus a, if V volume is flowing, this is the distance traversed, so that into A will be the volume, which will be expelled. So, it is going to be, A by A minus a into V, which is equal to A minus a by A, is equal to 1 minus 1 by k, is equal k minus 1 by k. So, A by A minus a is going to be, k by k minus 1, so it is going to be k by k minus 1 into V, this is the rate at which the fluid will get expelled, this is the, see this will be the flow rate.

So, what are we achieving by doing this, similarly if you look at the pressure, if you look at the pressure then you will you find that. So, you see that, suppose the one interesting thing that happens, is that suppose a is equal to 0.5 of A or rather A by a is equal to 2, so then what happens is that, you can see that the, for example, with the same pump flow rate V, the distance travelled per unit time is going to be, if this is V this is going to be the flow into, this is going to be V and in the previous case what was happening.

In the previous case what was happening is that, if you go to the previous case, let we go to the previous case, I came a little fast. In the previous case, we were having, so you can actually find out, that we have ((Refer Time: 40:54)) taken, we can actually find out that the, the interesting point is that, you can work it out. In fact, this can be a nice exercise, that there are two things that will happen, the first thing is that, you will find that number 1, two points, number 1 is that, say let us say 2 is to 1 area ratio.

Then you will find that, the extension and retraction speeds are same, but they are not going to be same for other area ratios, that must be remember. Similarly, you will find that, so you see we can find that, at a smaller if we directly connect it to tank, say in the case of the extension stroke, if it directly connected to, connected these two pump and that two tank, then we would have had a slower motion, with the same pump flow rate we would have got a slower motion, which we are.

So, the advantage of regeneration is that, with the same flow rate rating pump, we are able to generate faster motion, but at the same time we will see that, we will require higher pump pressure. So, what happens is that, I mean basically for, that is when will require higher pump pressure, if we want to drive a load which require the same force to be driven, then in the regenerative circuit we need higher pressure.

So, basically we are trading of pressure with flow, that is we are we can use a lower flow rate pump to achieve a certain speed, but at the same time if you want to achieve a certain force, then we have to give higher pressure. So, this is the basic feature of a this regenerative retraction circuit, so moving on to the next one.

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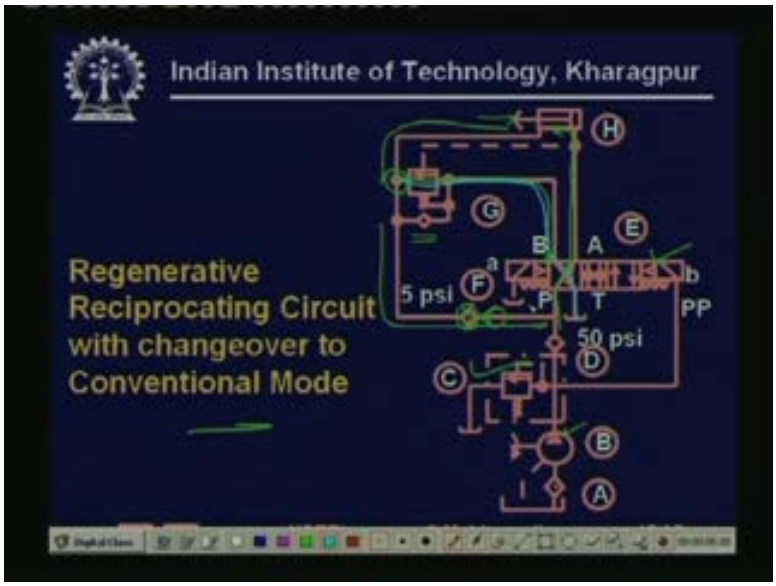

This is a regenerative reciprocating circuit, with changeover to conventional mode, so what is happening here, basically the same type, only thing that is happening here is that. Here you see, initially we have again pump, I am sorry what is this happening here, again you have pump, you have relief valve, you have three position direction valve, with solenoids and hydraulic pilot and so. In the first case in this position that is shown, flow is like this, like this, to the cap end starts moving, goes this way and this is wrong actually, you should draw it like this.

So, comes freely and there is a regeneration, so initially there is regeneration, so with the given pump flow rate, speed will be higher. Now, if at the end, there is a higher force encountered which cannot be supported by the prime mover at that flow rate, then what is going to happen, is that the pressure here will build up. Whenever, this faces resistance the pressure here builds up, when the pressure here will build up and this is opposite, so this is going to be connected like this.

So, now you see that, it will be after the pressure builds up, it will connect like this and flow through this, so now, across this there will be a full pressure and there is no regeneration, so therefore, the speed will fall and therefore, it will be, it will still be handle the pressure. Now, so at the end, if there is a higher force requirement, it will change over by this valve from a regenerative circuit to a conventional reciprocating circuit.

What will happen in the other position, in the other position it is very simple, in the other position it will be here. So, then what will happen, is that the, this is this will be the flow, so it will directly flow through this check valve straight and it will come back directly, it will actually come back here and it will get connected to tank. ((Refer Time: 45:39)) So, that is a very conventional mode, so in this case it will, that is there is no pressure requirement and it will come back.

So, on the only advantage is that, since we are we have higher force requirement, so as long as the force requirement is manageable by the pump, we are going for a regenerative circuit having, so with the pump flow rate. We are achieving a higher speed, but whenever the force requirement goes up, so we are immediately switching over to a it, the I mean the system automatically switch switches over to a conventional circuit, pressure is now full applied. So, we can manage and the flow rate falls, with the flow rate we have a lower speed, so that is the advantage of the circuit.

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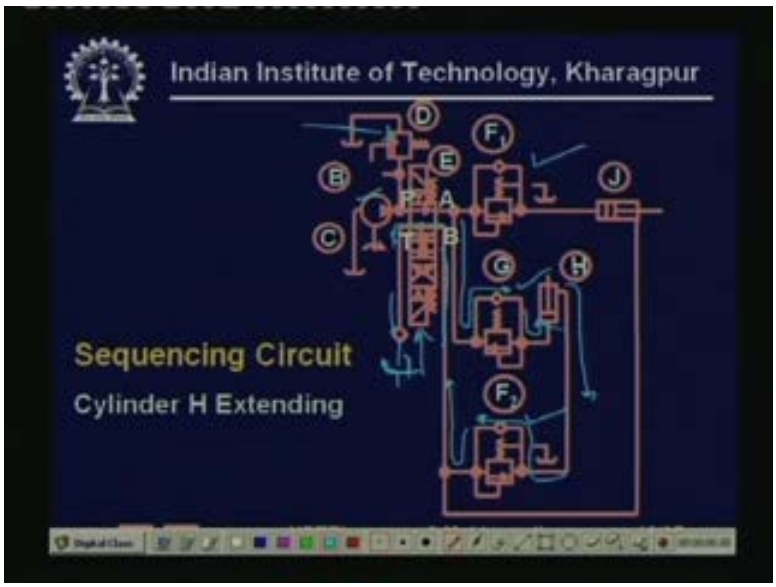

Next we have a sequencing circuit, so in the sequencing circuit what is happening is that, here now, in this example, we have more than one cylinder. So, far what we have been doing is that, we are we have handled only one cylinder, but sometimes it happens that, you need to operate multiple cylinders and for example, suppose you have a wood working machine, you have a plaining machine. So, before you plain the machine, before you start moving the plaining cutter, you have to hold the job.

So, the sequence is that, first operate the holding cylinder, then start moving the plainer, so the plainer extends, then the plainer retracts, then remove the clamp cylinder. So, you see that, we are we have every time we operate, we have to operate it in first clamp, then extension of plaining cylinder, then retraction of plaining cylinder, then unclamped. So, this is a particular sequence of two cylinder which have a, which have to be operated, so now, we will see how we can achieve this one.

So, here we are, so here is the circuit, so what are we going to do, look at this circuit, so we have here we have two cylinders, one is J another is H and we have normal pump, this is the main valve, which is being operated, there is a relief valve D and these are the three valves which actually cause the sequencing. So, now what happens is that, initially cylinder H extending, so it is in this position.

Look at the position, then what is the flow cylinder H extending means, it flows through this check valve, open direction, flows into cap end, goes out through this, flows through and returns, ((Refer Time: 49:08)) this is here is tank. So, this is the position and so the cylinder H is extending going up, this is the first phase of the cycle, after sometime what will happen is that, cylinder H will stop, it has to it comes across a mechanical stop. Now, now what happens?

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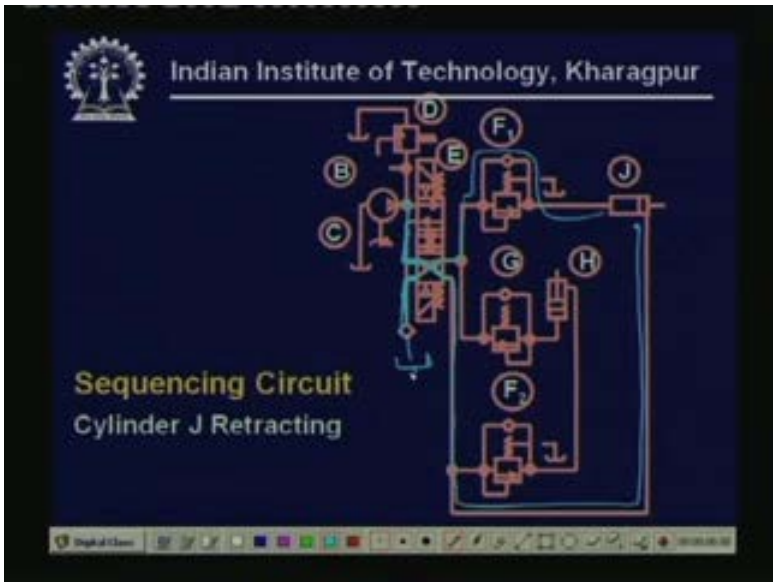

So, the moment it comes to a mechanical stop here, this pressure will now build up, because there ((Refer Time: 49:49)) cannot be any further flow through this, flow is

stopped. So, immediately this point rises to pump pressure, that will operate this valve, cannot go through this at this point. So, it goes through this and starts pushing valve J, so flow goes like this, like this, like this, so cylinder J extends, all through this, remember that this pressure there is a pressure on this.

So, this pressure is holding, this is pressed, cylinder H is pressed up, so there is an, if you want if you are using it for clamping, there is a clamping pressure. Next, ((Refer Time: 50:48)) cylinder J retracting, next what happens, is now here you move the solenoid, so here, you move the solenoid and it is now actually this is wrong, actually this should be, this is wrong, this should be connected to this point and this pump should be connected to this point.

So, now the pump flow is connected like this, goes through this, goes through this, cylinder J retracts, flows out through this flow, flow free flow check valve and goes through this, goes through this to pump tank, cylinder J retracts. Next, last point now J cylinder has retracted fully, so now this pressure cannot, so now, the pressure here builds up, so the pressure here builds up, so the pressure here also builds up and this now pushes the cylinder down.

But this time, note that it has to pass through this, so therefore, while the cylinder H is coming down, there is a there is always a back pressure, this is not connected to tank, because it is not passing through this, it is passing through the relief valve. So, the cylinder is coming down, it is actually being, here the net force is actually being controlled. So, it is coming down slowly, because sometimes when you have vertical coming down etcetera underweight, you want that the coming going up, is can be fast but going down has to be at a low force. So, this is what we have achieved by, so we have achieved the sequencing, so these are some of the circuits.

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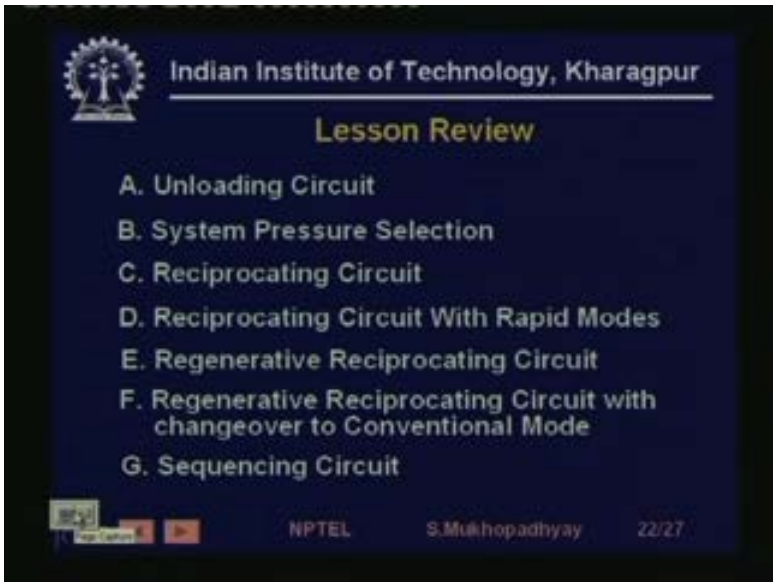

And what we have seen in this lesson, we have seen unloading circuits, system pressure selection circuits, various kinds of reciprocating circuits, reciprocating circuits with rapid modes, reciprocating circuits with regeneration, reciprocating circuits with regeneration plus conventional. And finally, we have seen sequencing circuits, which are basically reciprocating circuits with multiple cylinders, so that brings us to the end of the lesson.

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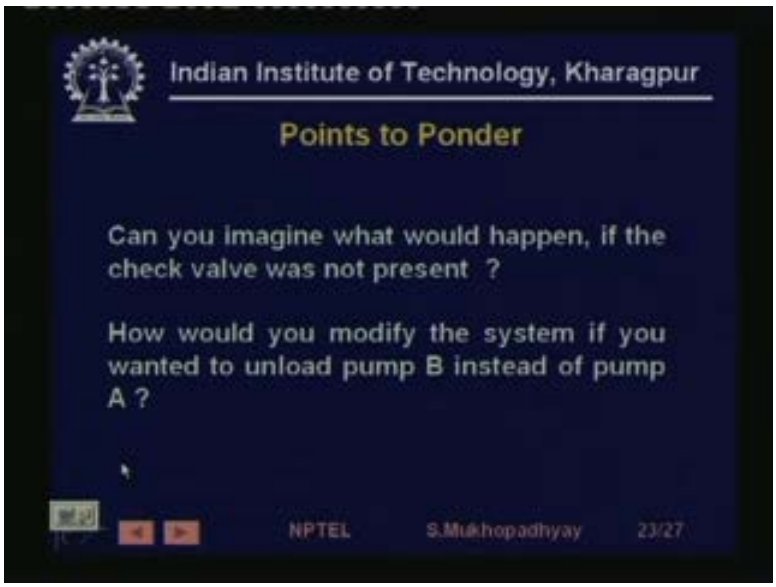

Points to ponder, many questions you can think of, for example, can you imagine what would happen if the check valve was not present in the first unloading circuit, there will

be problem, how would you modify the system, if you wanted to unload pump B instead of pump A in that first system, that is very simple. If the circuit is very symmetric, so you will have to, whatever you did for pump A, you have to move for pump B.

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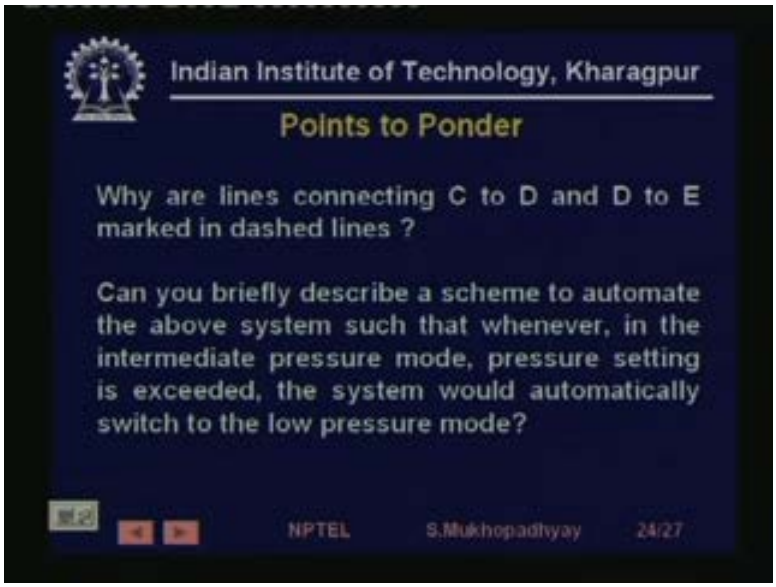

Why are lines connected connecting C to D and D to E marked in dashed line, this is the second one, that is system pressure selection, because a pilot lines. Sorry, I have already given an answer, you are supposed to think about, can you, one thing I wanted to mention is that, in many cases you will find that, I have said that some limit switch operates and that operates some solenoid, so how does that happen. So, you have to have a scheme for that.

Sometimes, you can have a purely electrical scheme, sometimes you can have a simple, you know sometimes you can have a simple ((Refer Time: 54:14) VA type scheme or sometimes you can have a plc based scheme, so various special arrangements are needed. So, for example, I have given one, can you briefly describe a scheme to automate the above system such that whenever, in the intermediate pressure mode, pressure setting is exceeded, the system would automatically switch to the low pressure mode. Previously it was being done manually, as it is shown in that, so you can devise a some control mechanism, by which it will sense the pressure and it will switch on.

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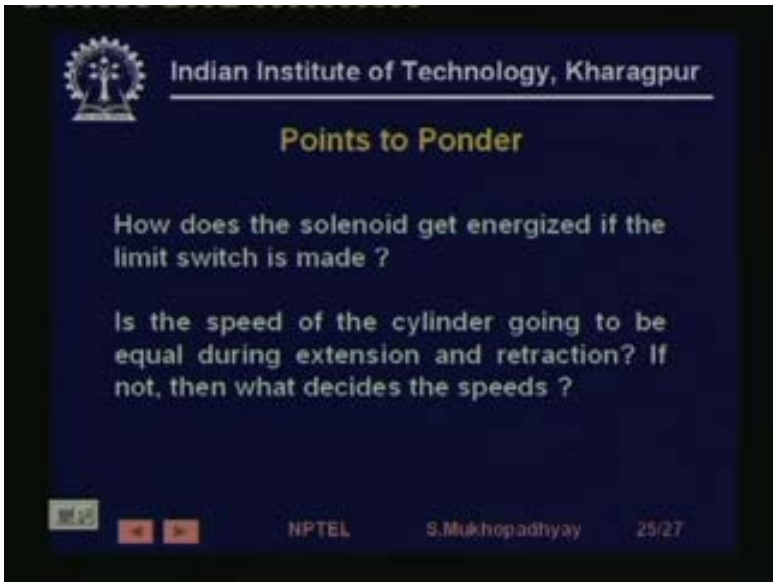

How does the solenoid get energized if the limit switch is made, same question, is the speed of the cylinder going to be equal during extension and retraction, when you have a regenerating circuit, if not, then what decides the speeds. We have analyzed this, it is the area ratio, but how does it decide that you figure out.

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Explain all parts of the symbol of the directional valve C basically, same except for a very something special, this is about the regenerative reciprocating circuit, only the directional valve has a detention, that was the only special thing. This is we have

discussed, regarding the issues regarding pressure and flow, so that brings us to the end of the lesson 28.

Thank you very much.

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Lecture - 30

Energy Savings with variable Speed Drives

Welcome to lesson 30 of industrial automation and control, in this lesson, which is entitled energy savings with variables speed drives, we are going to explain and demonstrate, that for a kind of application, which is very predominant in the industry very common, how what are the firstly, we are going to see.

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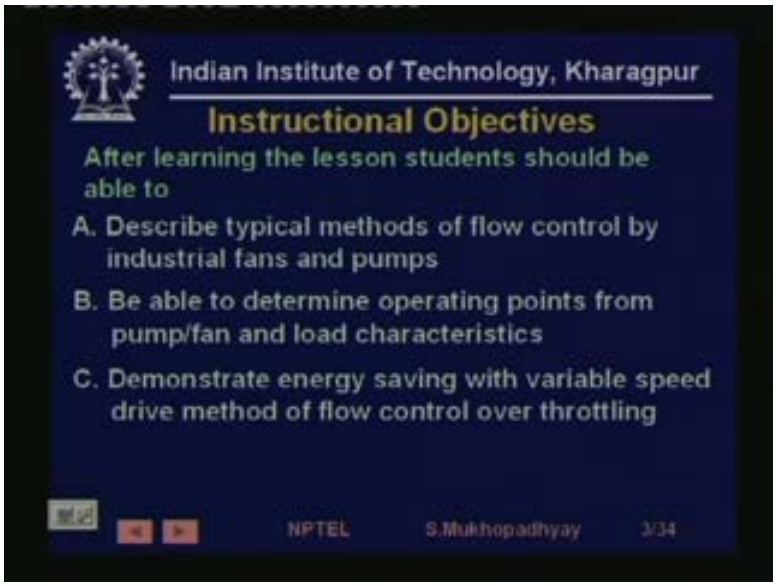

What are the various kinds of flow control applications, that is the application that we are trying to consider, so if flow can be of gas or liquid, so accordingly we have either, what

are known as fans or blowers or we have pumps. Fans, blowers and pumps constitute an enormous, a very significant fraction of loads which are driven by motors and motors which consume a large amount of electrical power in the industry. So, they are very common and common applications and very significant from the energy point of view.

So, we are going to see that, in such applications how flow is to be controlled and then we are also going to see that if you, flow is typically controlled by driving a pump, by a motor, but if you drive a pump, by a motor, then it will drive a certain amount of air. Let us say, if you have a pump it could be water, now the demand for this air or water is not the same all the time. So, the flow has to be controlled, now there are so firstly, how do we, when we connect a machine to the pump, what is the amount of flow that is established.

That depends on the pump characteristics, that depends on the machine characteristics, so we are going to see that, how when you connect a pump or a fan, with the so called load, how is the operating point established, what will be the pressure, what will be the flow, it is actually much like, you know establishing an operating point when you connect a battery with a circuit or a load. So, we are going see that and we will see that, depending on how we can vary this operating point.

See, we have to vary this operating point, because we need to vary the flow, now the flow can be varied by various ways of varying the operating point and it is. So, some of these ways are may be very simple, but may be, may not be efficient in from energy point of view. While others may involve more complex technology, but possibly would be more energy saving, so we are going to look at two of the most common techniques and show that, how their energy characteristics are going to be different In fact that will motivate ((Refer Time: 59:02)).