INDIAN INSTITUTE OF TECHNOLOGY
KHARAGPUR

NPTEL
ONLINE CERTIFICATION COURSE

On Industrial Automation and Control

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Topic Lecture – 38
Industrial Hydraulic Circuit

Welcome to lesson 28 of industrial automation and control course under the NPTEL program today we are we are going to look at a very interesting topic.

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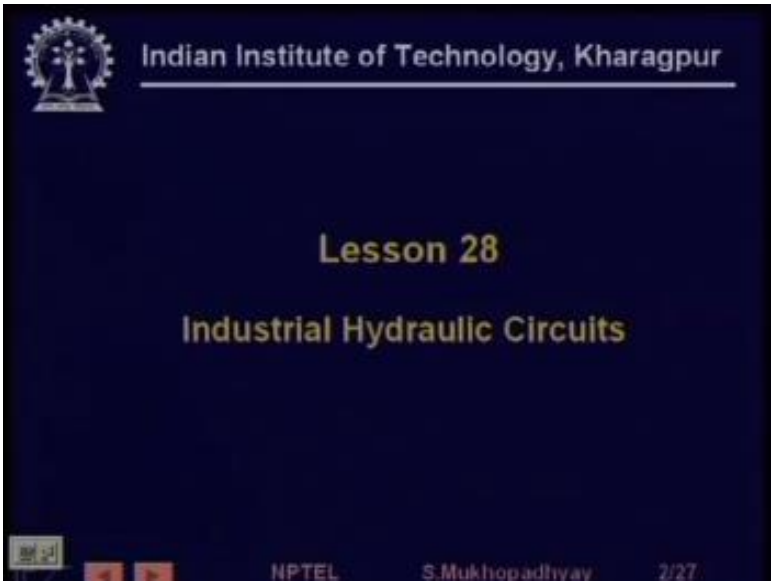

In the last two lectures we have seen various hydraulic system components, in this lecture we will see how they can be joined together to form hydraulic circuits for various kinds of industrial applications so that is going to be very interesting for me at least to tell you.

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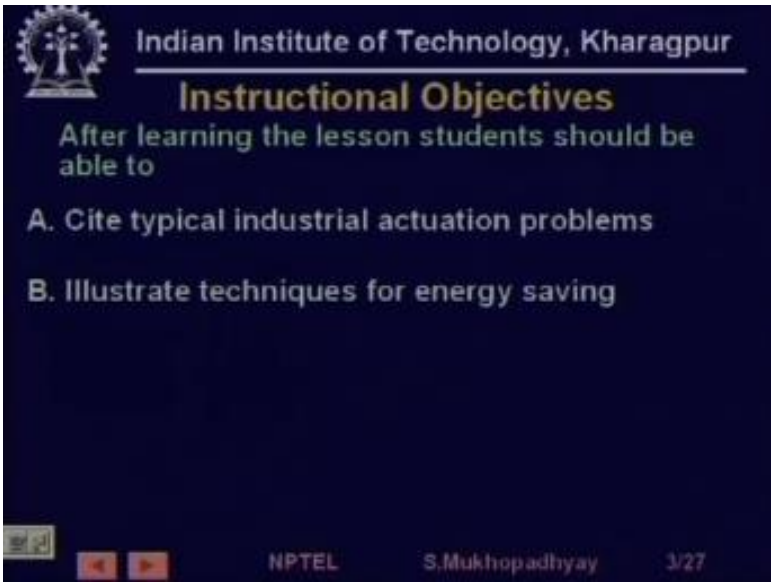

So looking at the instructional objectives after this lesson a student should be able to cite typical industrial activation problems some very common problems which occur in the case of industrial systems, so then in many cases we you know energy is very expensive so we do we never like to spend energy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

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Sometimes we will find that we need to you know we need to create motions using hydraulic systems so we need to adjust feeds we need to adjust forces depending on the requirement of the load, so how to do them and finally we all these circuits we 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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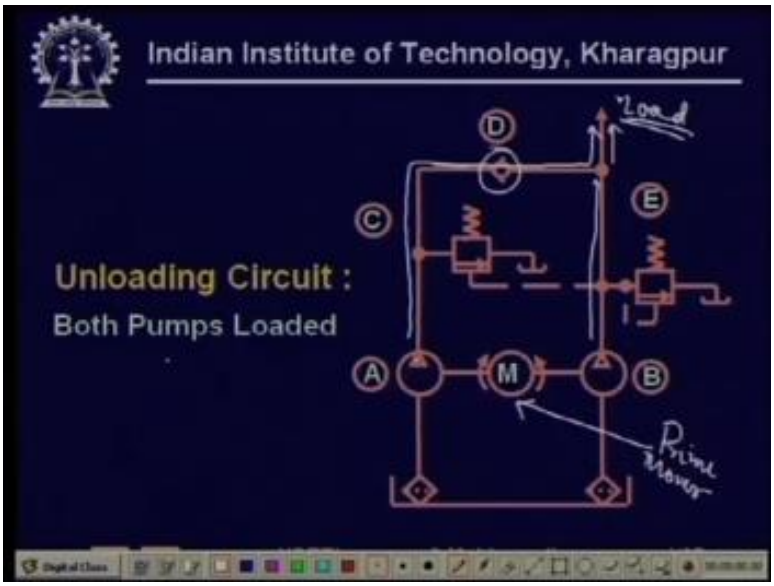

So we first come to our first circuit what is that, in this circuit it is called an unloading circuit so there are see the circuit here are two pumps can you realize that this is actually a hydraulic pump, this is a hydraulic pump this is also another hydraulic pump and they are being driven by a common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

So the pump A flow is going this way this is a 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 there 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 other 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 sudden 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 move them slowly and 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.

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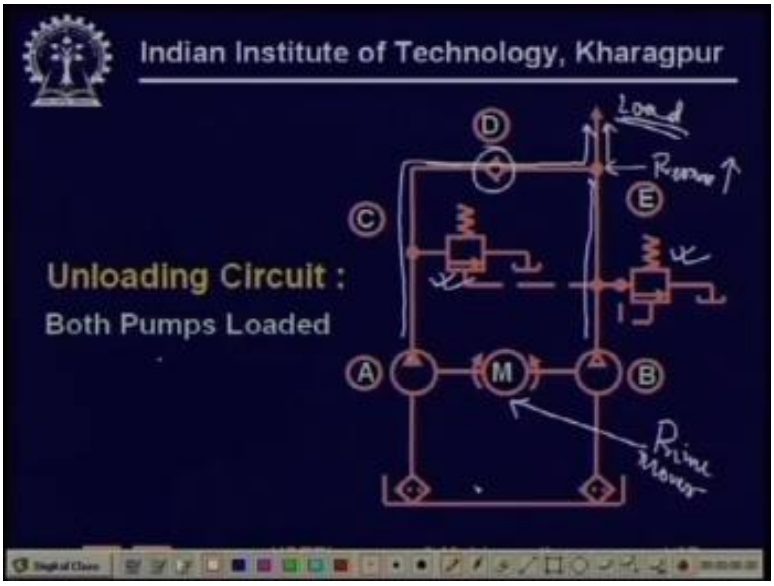

So pressure will go up, now you see that there are two relief valves this is one relief valve and this is another relief valve. Now if we have decided that if the pressure goes up beyond this setting remember that we are talking about.

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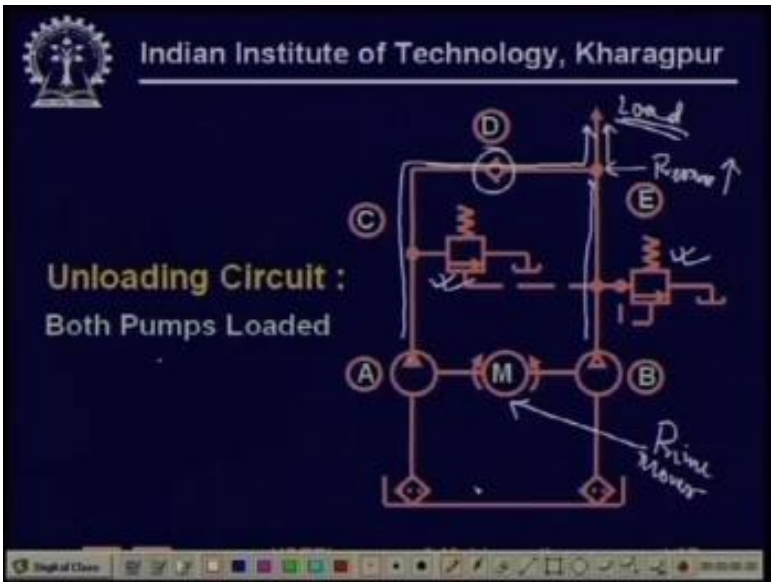

Hydrostatic pumps or positive displacement pump generally so as long as the speed is the same the volume being delivered is the same and the power requirement is directly proportional to the pressure. Assuming that the volumetric efficiency is same the leakage extra are not significant.

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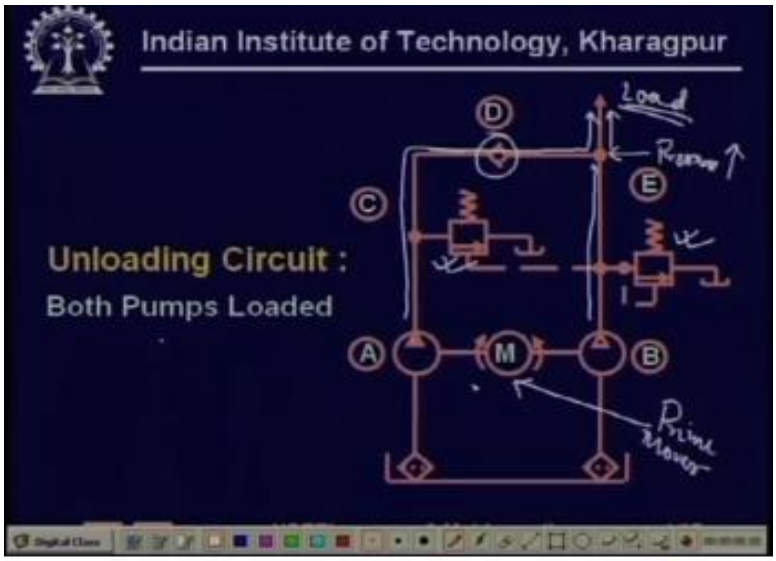

So now we want to the pressure has gone up because the force requirement has gone up so we want to reduce flow rate, so what do we want to do so we have this setting of this relief valve.

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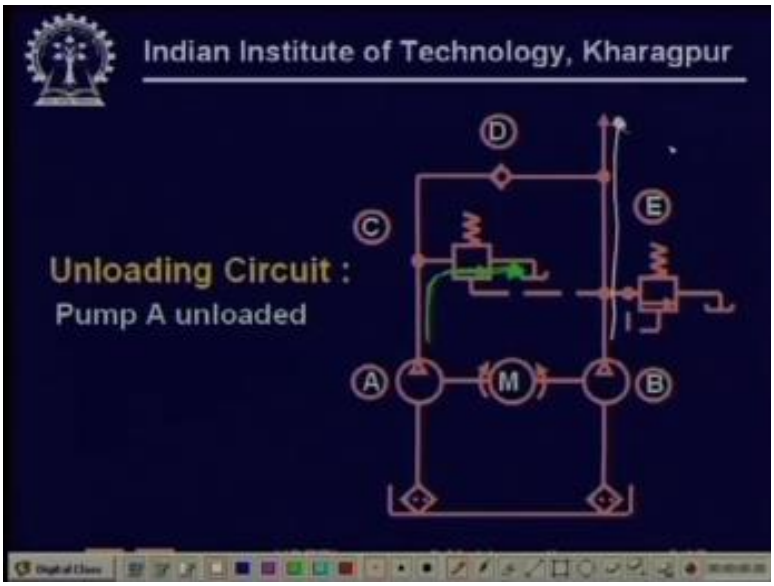

As if the setting is exceeded at some point then what is going to happen is that this relief valve will vent so the pump flow at that time let me use a different color, so the pump flow at that time so this is the case for both pumps loaded so let me go to the other diagram then we will be able to see the case where pump is unloaded. 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 this pump gets unloaded.

So therefore the power demand on this motor reduces 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 suddenly we put a very heavy load then it will still be moved, but it will be moved. This is our first example leads to some amount of you know leads.

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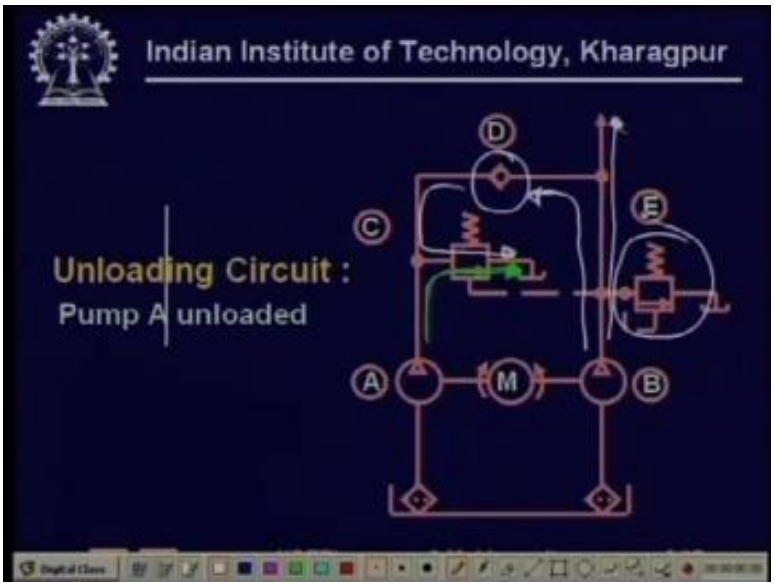

Does not get into now interestingly there is this one point to mention that what is the role of this check valve, see when this pump is getting unloaded then remember that this flow cannot, this flow cannot go through this path because this check valve is blocked. So therefore this pump really cannot 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 overload over load protection 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.

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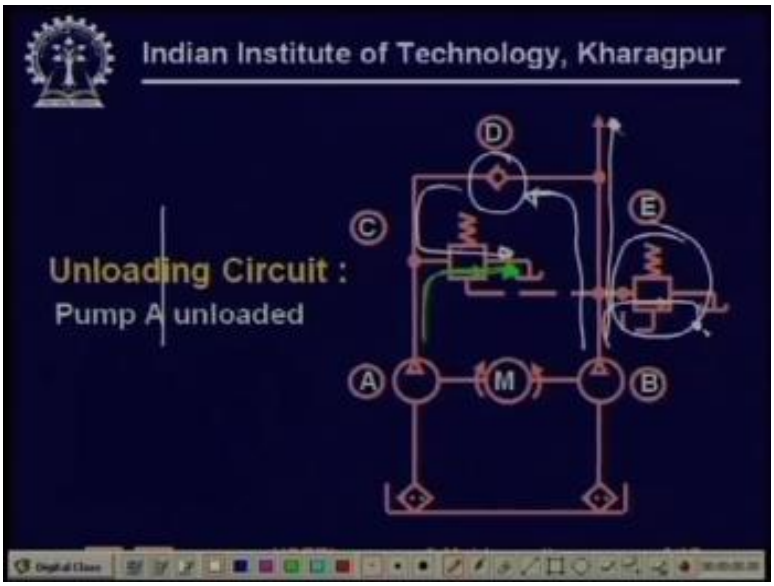

And the load will of course stop and the fluid will flow like this but the motor load motor will be protected from overloading, so this is the way the circuit functions.

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Then we go to the our next circuit we are going to see a number of such applications, 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 you want to select the pressure with which we want to drive the load. So what happens is here.

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So we have we have three modes of the system in the first mode the system will vent that is the pump will be directly connected to 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 want to select the modes so that happens like this.

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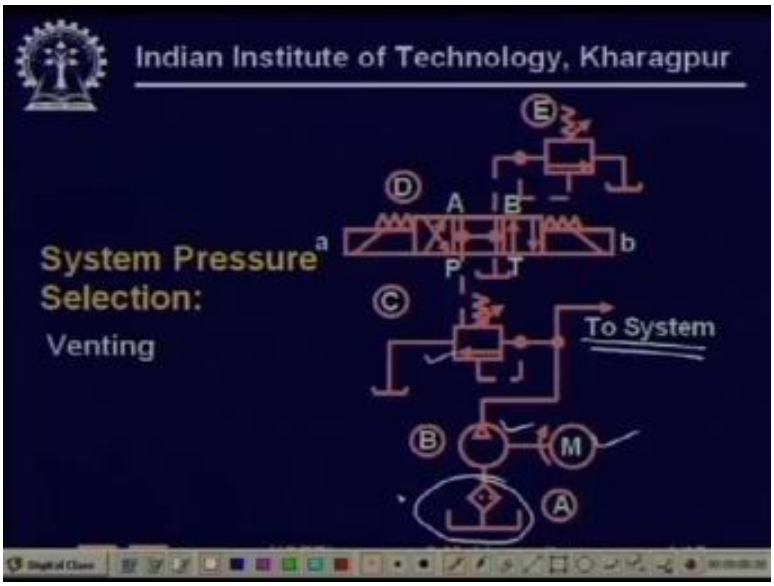

So here is the circuit first for the vent mode, so in the vent mode what is happening look at this circuit, so what components do we have, we have the tank and the reservoir here we have the pump we have the motor we have a relief valve and this is where it goes to the system. Now the pressure limits the pressure upto which the system can occur will obviously be selected by this release valve and this relief valve actually the there are this is a pilot operated reliever valve.

So in this valve at 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.

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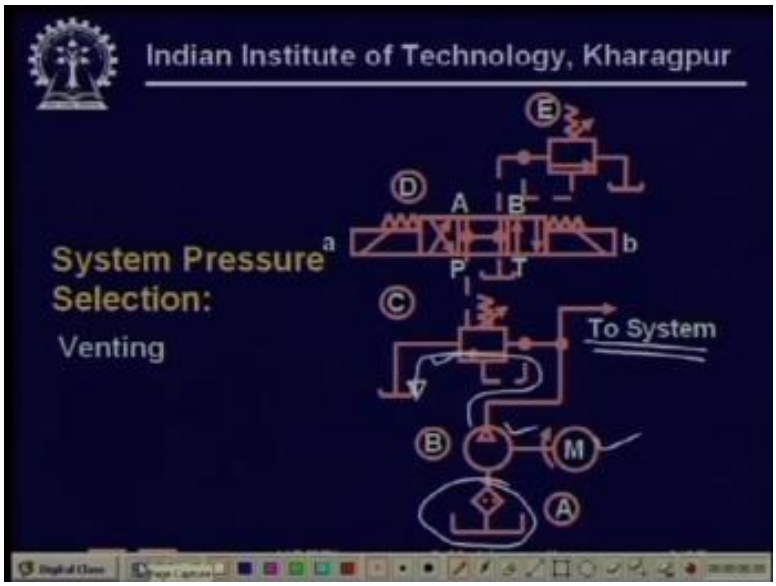

So let us see what happens, so how is the pilot pressure determined so let us look at the pilot circuit so this is the pilot line dashed so when there are this is the directional valve right, there are it is a solenoid operated valve you can see that from the symbol and there are two springs so when both solenoids are off then it is spring centered so both the springs will push and it will keep 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 see 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 vent and no fluid goes to the system, so this is the operation in the venting mode. Now what happened in the other modes, so let us go to the other modes.

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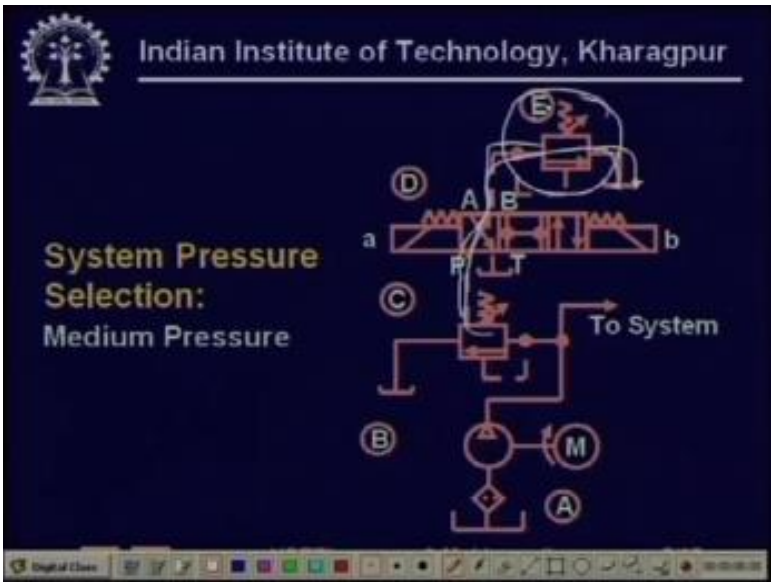

So in the medium pressure mode what is happening is the following, so in the medium pressure mode we have energized solenoid A so where we have energized solenoid a we will assume that the disposition this position of the valve is active, so now the pump port is connected like this, through this, through 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 itself as a setting its own setting which is not it is also relief valve so it has, this is a remote pilot.

But it has its own setting so that setting is actually higher than that 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 a and C so therefore we have a medium the limiting pressure is now medium.

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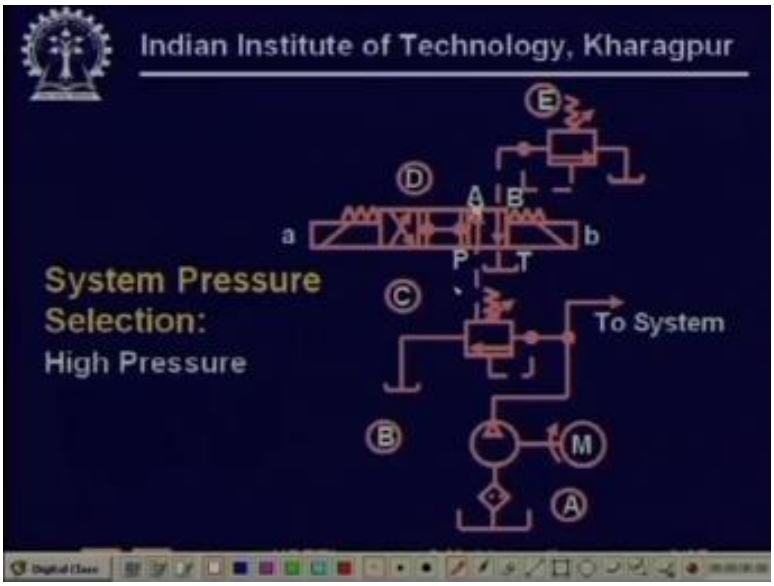

So now we go to the I am sorry, we go to the next one which is the high pressure mode, so what is happening in the high pressure mode, in the high pressure mode we are now in this position, so in this position what is happening first see that this port is actually plugged this is plugged means that it is sealed. So therefore the pilot pressure can go up to any level theoretically speaking can go to very high level.

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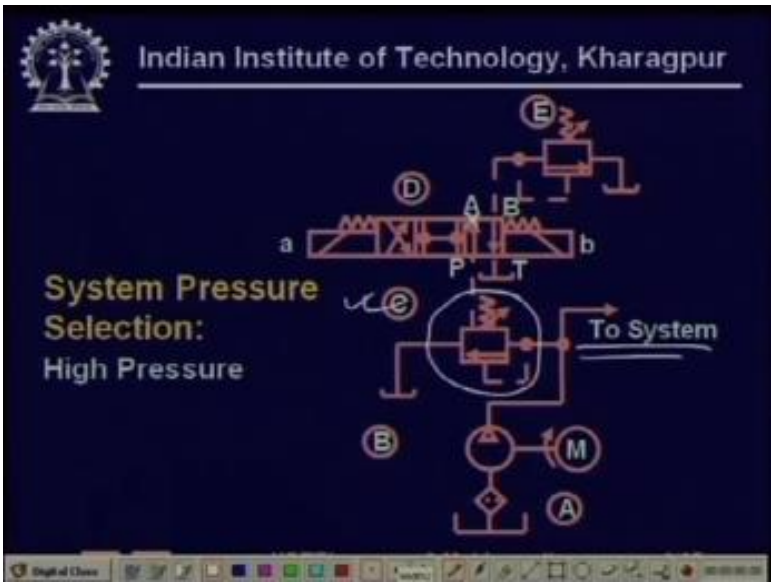

So the operation so now the operation of this valve is not limited by the pilot pressure because the pilot is connected to a plugged port, so the pilot does not vent the valve. So now it is operated by its own setting so now in this system pressure gets limited by the setting of the valve C itself. And since the setting of the valve C is higher than that of E so we can limit the system pressure to a higher level.

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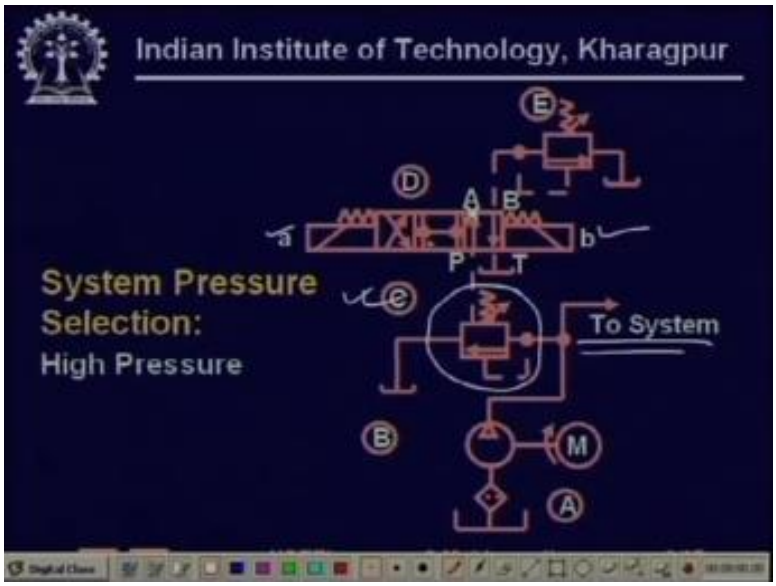

So you see that we are able to achieve this by either energizing A or energizing B or energizing none, so we can select the system operating pressure mode, this is our second example.

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So in the third example, 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 it will push the load and it will come back, right. So suppose some, suppose some conveyor belt has brought some item so there may be hydraulic arm which will push the item into the bill 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 stroke first.

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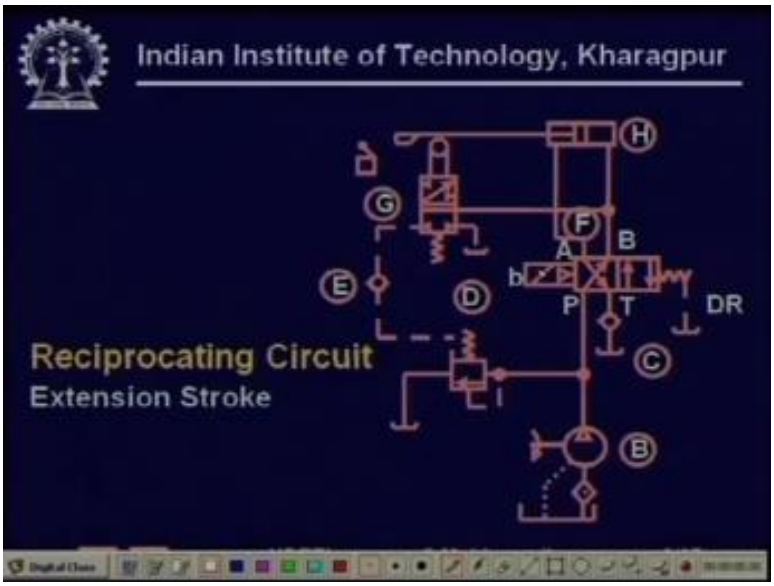

So here is the circuit, so what is happening here very simple again always start from the pump so here is the pump the filter is the drain line, this is the relief valve which is typically used for overload protection of the pump. Now in this case see look at this valve this valve has first of all try to debate the symbol, the symbol has it each has a solenoid plus it has a hydraulic pilot so actually it is a 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.

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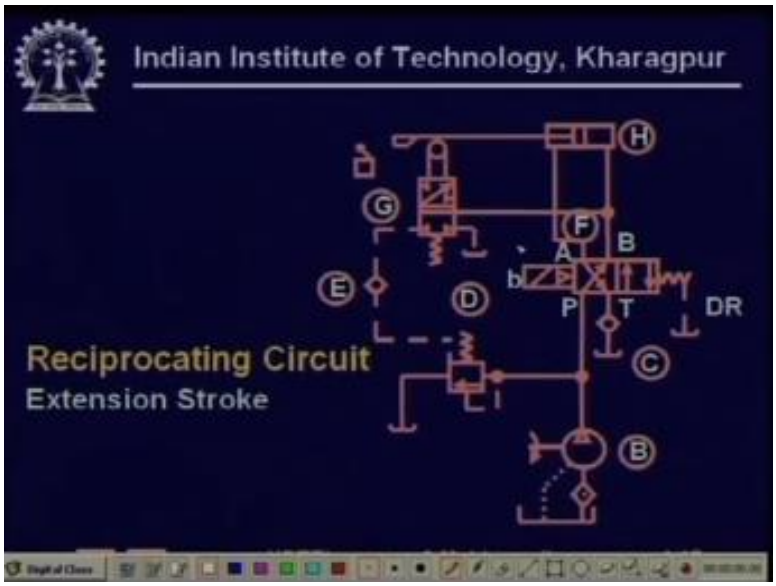

And we have in this case we have only one this thing only one solenoid and the other side is so if you switch off the solenoid it will come to, so it has only two positions.

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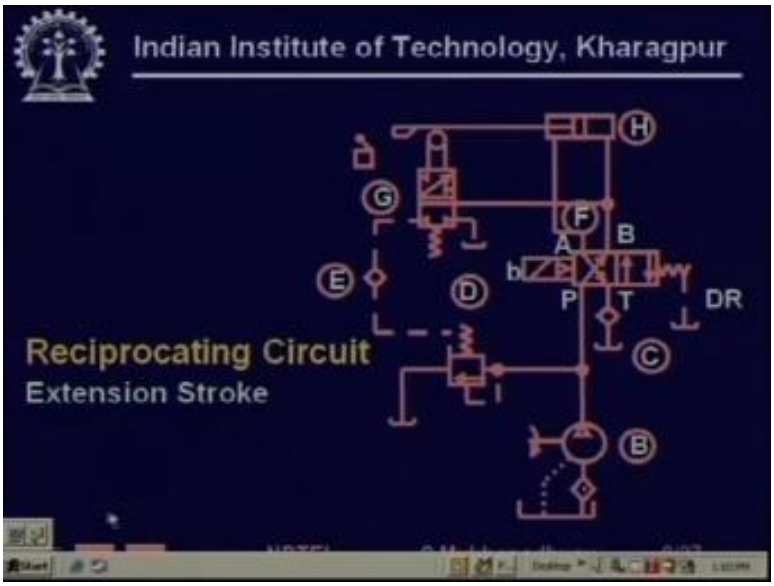

If the solenoid is off it goes to the right hand position if the solenoids on it goes to the left hand position. So now we are at the left hand position when the solenoid is on so the pump flow goes like this, like this, like this and enters what is known as the cap end or the head end of the cylinder 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 up when the cam is operated this supposed to be in the left position, when the cam is not operated is supposed to be 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 plug and this cylinder is moving this way, right. So this is the extension stroke what happens in the next stroke.

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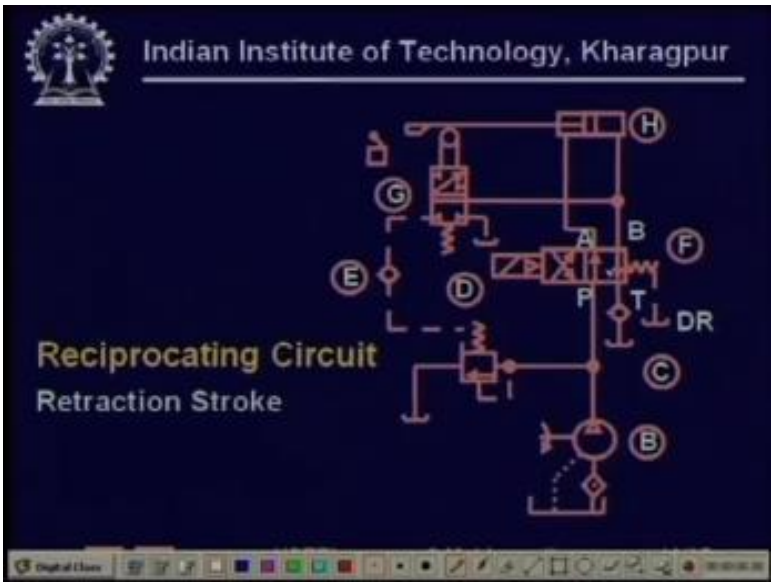

In the next row, now we have a retraction stroke, so what happens is when it reaches the end it operates this limit switch at the end at the extreme end of the extension stroke that limit switch is actually connected to the solenoid in such a way that immediately when the limit switch is made or switched 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 right position.

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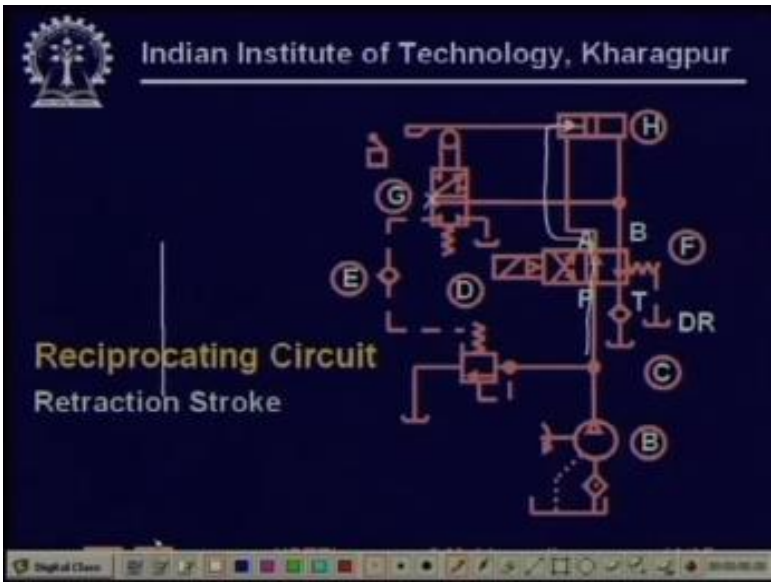

In the right position the pump flow goes like this so now you see what is the matter here, so in the right position the pump flow goes like this and enters what is known as the rod end of the cylinder, so that now the cylinder moves towards the right note that the cam is still not operated so therefore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

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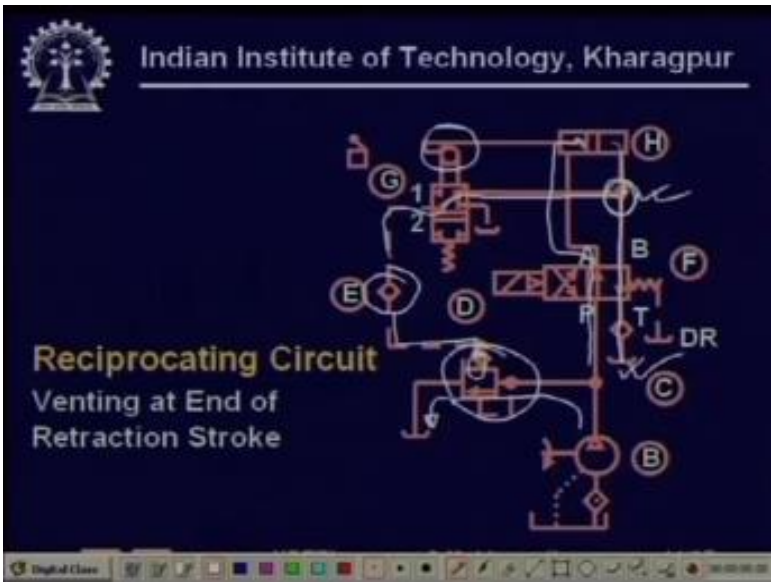

Alright so the next case, in the next case a very interesting thing happens at the end of the retraction stroke that is something special about this circuit, so at the end of the retraction stroke when it comes fully to write this rod is designed in such a manner that it pushes the cam, so when it pushes 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 the direction of the check valve goes through this and come to this point, so the positions of 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 as 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 while it is waiting this pump does not unnecessarily spend power so it went automatically the circuit is made in such a manner.

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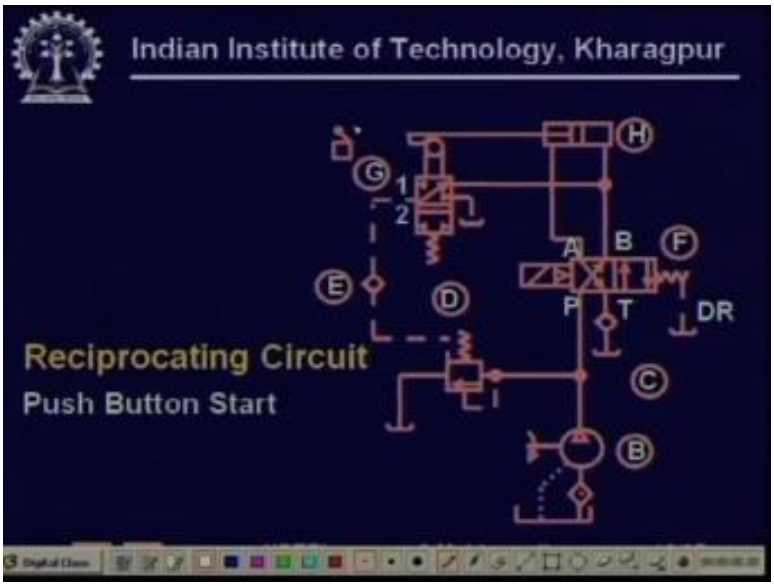

Next what happens how do you start a new cycle so you start a new cycle like this, a new cycle is actually started by pressing a push button, so this coil is has to be connected in such an electrical circuit such that it can be switched off by this limit switch as we have seen at the extent at the end 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.

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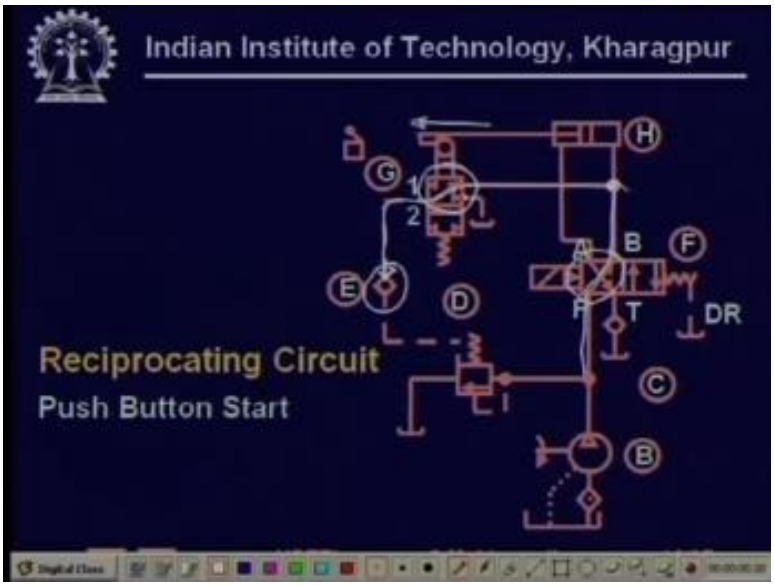

So when you when you switch it on again this shifts to the left, right now it is cam is made so this is in this position and this is in this position, so now what is happening again this connected to pump this is pump now, this is connected to pump. So now what but unfortunately so now it tries to flow like this but this is this pressure is now, so now you see again this port is actually so this so the opposing force on the check valve is the full pump pressure.

So therefore the pilot pressure if this valve to vent then the pilot pressure has to cross this level otherwise they cannot be reflow, so therefore this full pump pressure can be applied to the hydraulic cylinder and 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 get plugged and the cycle repeats.

So this is the way that, 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 will reach the end of the retraction cycle the pump is unloaded basically to save power.

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So let us look at the next example, now we want to we want to do some special things that is we want to save sometimes it happens as 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 your to save time of the operation right. So let us see how we can do that.

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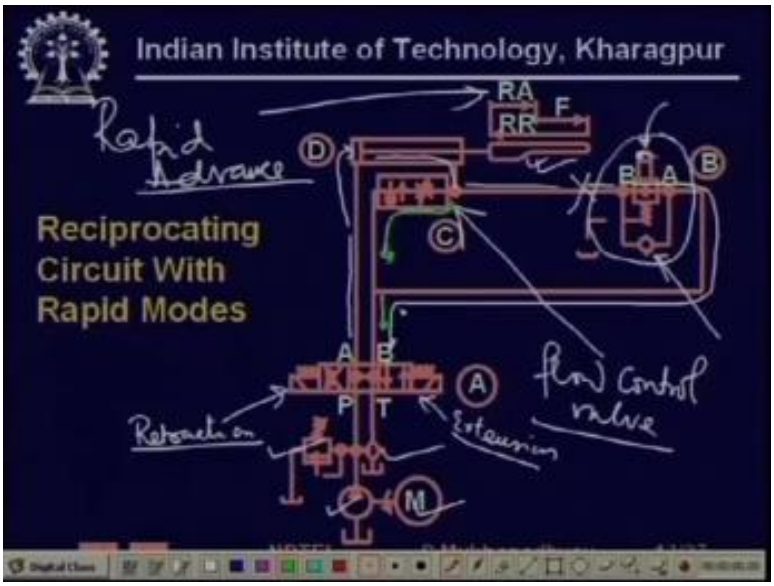

So what we are seeing here you see again let us identify components pump, motor, relief valve this is tank and filter this is a three-position solenoid, electrical solenoid actuated spring-loaded valve, okay. So and this is a flow control valve and this is a again a mechanically, so mechanically operated valve with a property that if you operate the switch, if you operate the switch as long as you do not operate the switch then this is a direct short that is 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, right. 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 now 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, okay first let us look at the advanced 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 shot so this starts advancing very fast that is called the rapid advance.

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 the check valve no flow along this, so now the fluid is forced to flow along this should use a different color so during the forward stroke the fluid is forced to flow along the green line and since this is a flow control valve so there is our 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.

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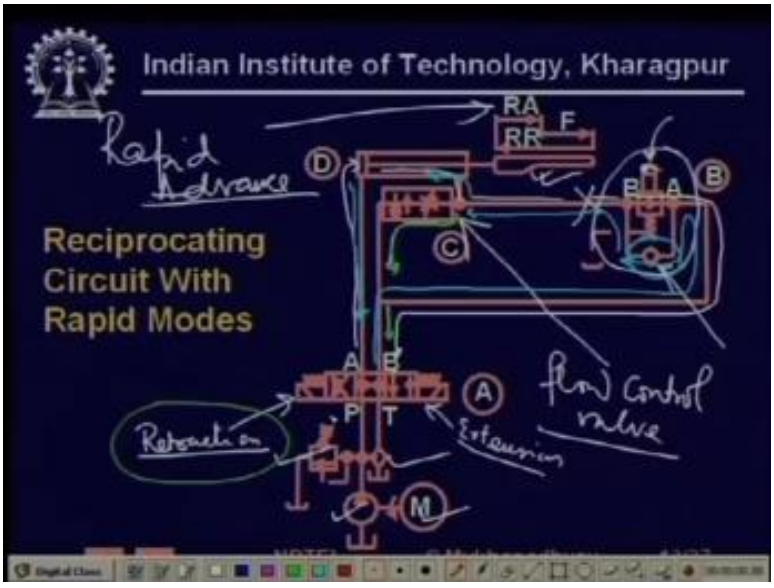

Now what happens when we want to have retraction when we want to have retraction then we will operate this solenoid, when we will operate this solenoid then what happens is now the, let me choose a different color for the blue one so during retraction now this line B is connected to pump so how does 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 may 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 managed right. So this is what is happening and you can obtain a rapid retraction.