Industrial Automation & Control

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Lecture - 26
Hydraulic Control Systems – 1

Welcome to today's lecture, which is lesson number 26 of the course on Industrial Automation and Control.

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Today, we are going to take our first look at hydraulic control systems and we will review some elementary basic concepts, and then we will first look at the components, which make a, hydraulic control systems. In the subsequent lectures, we shall see some special components and we shall see as to how these components can be used to make a hydraulic control system, so we begin here, before we begin, we look at the instructional objectives.

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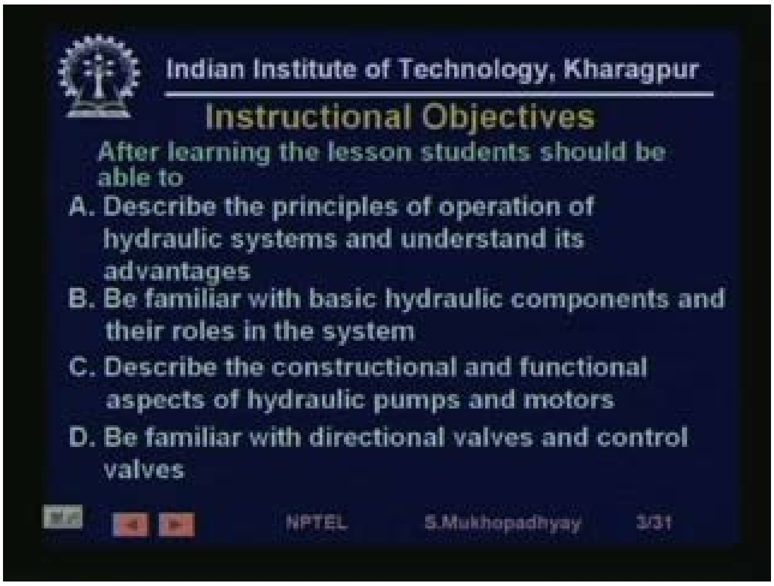

So, the instructional objectives are basically, to describe the principle of operation of hydraulic systems and understand it is advantages, what is involved and why it is, almost irreplaceably used, in certain applications there are certain advantages. Then of course, we have to be, the main purpose of the lesson is to be familiar with the basic hydraulic system components, and their roles in the system, what they do? And, describe the constructional and functional aspects of hydraulic pumps and motors, how they function; and be familiar with directional valves and control valves, they are very important components, so we will take a somewhat detailed look at these.

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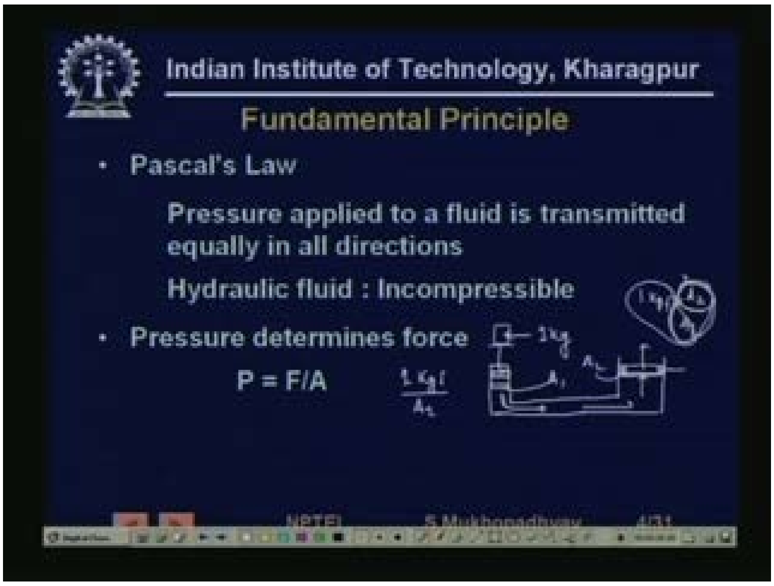

So, we begin with the fundamental principle of hydraulics, which is based on essentially on Pascal’s law, which says that, pressure applied to a fluid is transmitted equally in all directions. So, if we apply pressure in a fluid at a given point, then it that same pressure is transmitted through the fluid, which is supposed to be incompressible and gets applied everywhere else, so we actually use this, property of incompressible fluids to transmit forces.

So, we will apply basically hydraulic control systems are used to create motions, under in various situations very precise motions, against heavy loads, so high force has to be transmitted and precise displacements and velocities have to be created, that is the basic idea, where hydraulic systems find majority of it is applications. So, what we essentially are going to do is that, we are going to apply, pressure to a fluid at one end, and the same pressure is going to get transmitted and act on some other body.

So, when pressure acts on a body it creates force, so we expect that force will, create a motion. Now, as I said that pressure determines force and how does it determine force, pressure is given as force per unit area of the application of the pressure. So, you see interestingly, we should look at this, we have also learnt this in school, that if we, so you see, that if we apply let us take this very elementary example, which we have, which is the basic principle of a hydraulic press, which was one of the hydraulic machines. So, if we have a small piston here and if we have a large piston here, large means, the area is large as you can see.

And, if we place a load, so this is let us say 1 kg, then the pressure here is basically this 1 kg force, by A 1, now the same this is A 1 and this is A 2. So, by Pascal’s law, now this same pressure is going to get transmitted and will act on this area, so the pressure on this is also 1 kg f by A 1 and the force on this is 1 kg f into A 2 by A 1, because this is the pressure. So, what is the force it creates on this body into A 2, so you see that, we apply a 1 kg force here, and we have created a force, which is multiplied.

So, we have created a force, which can now if that A 2 by A 1 ratio is hundred, then by applying a 1 kg f force at 1 end, we have created a 100 kg f force at the other end. So, using this principle, it is somewhat like a fluidic lever, remember levers that we, because of the fulcrum, if we apply a small force at 1 end, we can lift a much higher load at another end, because of movement balance, so here also because of pressure balance the same thing is going to happen.

So, we can multiply, we can create very large forces and that sometimes, it might create an illusion in one's mind, that whether, how suddenly without I mean does it, invalidate any law of physics is energy conserved, energy is indeed conserved, because energy or power is force into velocity.

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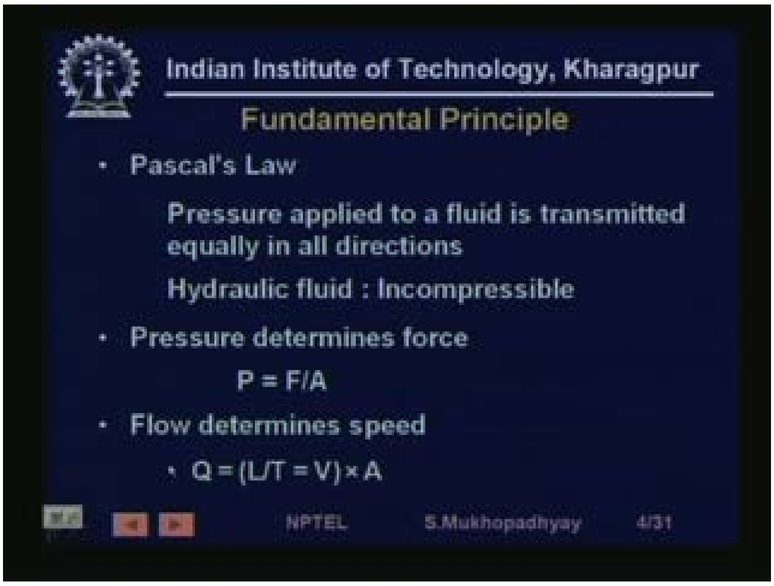

So, we can look at this, so and that velocity comes from flow, so what is a flow, the flow is what is a flow rate, because let us look at the next diagram, then this picture will be clear.

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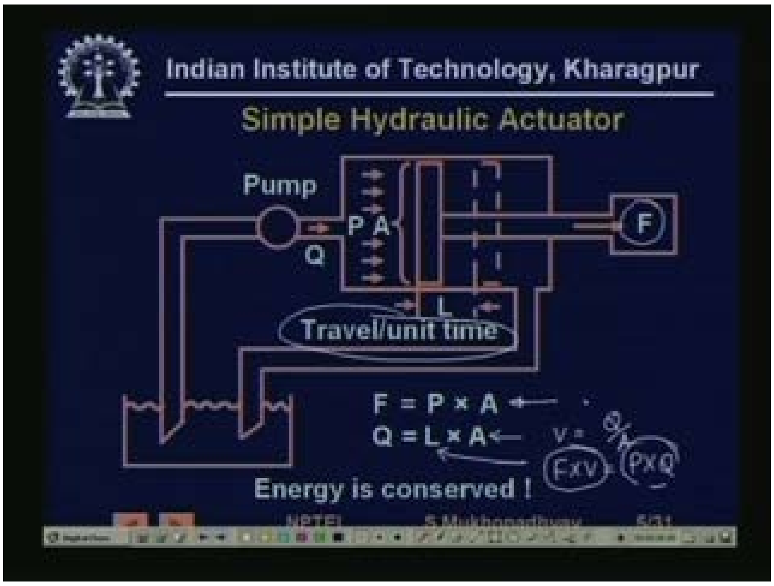

So, let us look at a simple hydraulic actuator, so you see that, we are creating a pressure here, so that creates a force F depending on the area and the pressure, so F is equal to P in to A. Now, let us look at the velocity, what is the volumetric flow rate Q that is equal to the area into L, where L is the travel per unit time, in other words L is the velocity. So, F is equal to P into A and Q is equal to L into A or in other words we can write, that V is equal to Q by A.

So, you see, that what is the mechanical power, which is developed, that will be force into velocity, so F into V is equal to P into Q. So, you see that the area does not come into the picture, so the power, in the power equation, the area does not come into the picture and even if we try multiply the force, the energy does not get multiplied, how can it get multiplied. So, energy is the same, for a pump as we know, a pump delivers, a fluid at a certain rate, volumetric flow rate and at a certain pressure and the pump output power is simply P into Q.

So, whatever the area the mechanical power is also P into Q, F into V is equal to P into Q, so therefore, energy is conserved and there is no contradiction. So, this, but nevertheless, so actually what is going to happen, is that we will depending on what flow rate we can provide, the load perhaps a very high force, we can create a very high force. But, at the same time, the rate at which that load, which requires a very high force to move is going to be slow, so the energy is going to be conserved, that is the basic fact.

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Then, so having understood this, let us first look at, the first for the better part of this course, we will, we are going to of this lesson, we are going to look at the component, so let us start looking at the component So, the most first component, that comes to mind is the fluid, so the fluid itself transmits the power or the pressure, so you create, you create a you input the power and the power will in a way, that that power travels through the fluid, which is incompressible and delivers the power in a different form, so the fluid power, in terms of pressure and flow, gets converted to mechanical power.

Now, there are certain things to be remembered, that these are, these systems are of very precise create very precise motion and therefore, requires parts of very precise sizes, which move within one another. So, there is an amount of friction involved, because otherwise the fluid is going to leak out, unless the parts are tightly fitting, then the fluid is going to leak out all over the place. So, therefore, there is an amount of friction, which is likely and that is going to create lot of problems, it is going to create heat, it is going to waste energy and it is going to damage the parts.

So, it is of prime importance to lubricate the parts, so that smooth frictionless motion takes place and the fluid itself, one of the big advantages of hydraulics, is that it does not require any additional lubrication, which is often required in electric systems and in pneumatic systems, because they do not have an inbuilt lubricant. Here, we have an inbuilt lubricant, which is the fluid itself, which is used for power transmission.

Even then the, some amount of heat is generated, because of friction and this and so there is a need to cool the components, because enormous pressure exists and the fluid also cools the components. And secondly, it also removes the contaminants, you know as things, move some small small particles may be generated by friction, similarly small, small similarly, sometimes air may, come into the fluid, so all these interrupt air, dust particles these things, have to be removed from the system, and the fluid as it flows it also cleanses these, and brings it to the filter, where they are filtered.

A typical hydraulic fluid is actually petroleum oil, in some cases, one uses you know things like water, with some additives or sometime water oil mixtures. But, the most popular hydraulic fluid is petroleum oil, which is very incompressible, it has a self lubricating property, the only problem it has, is that it tends to be, somewhat hazardous for fire, so that is a drawback. So, it incompressible lubricating and, but combustible, combustible means, the plus point must be considered.

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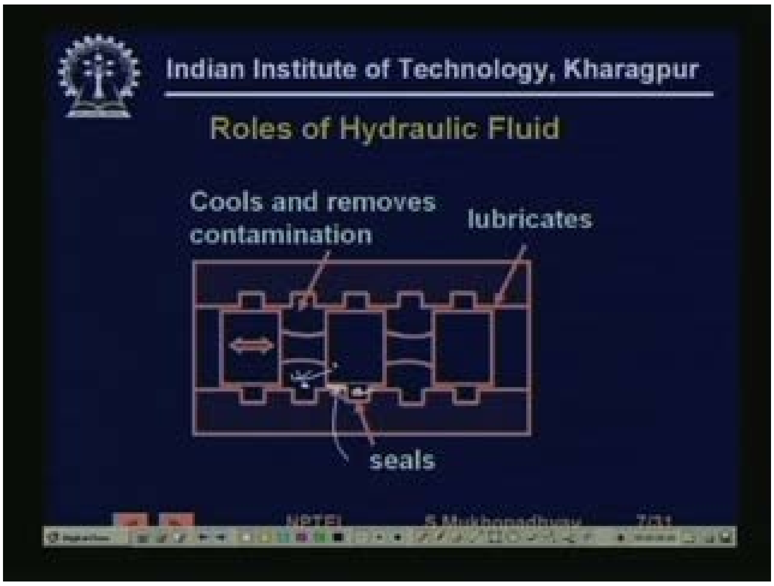

Now, what does a, so this is a picture which says, what the hydraulic fluid does, so you see that, the hydraulic fluid apart from the fact, that it lubricates, it cools and removes contamination, there is one point, that I did not mention, that is it seals also. So, because of the viscosity of the oil, if you have, if you for example, the fluid here and the fluid here, are going to be effectively sealed by this liquid film, so this liquid film here, is going to act as a seal.

So, that, this pressure and this pressure do not, there is an effective barrier created, because if this pressures leak out, then the pressure cannot do effective work. So, it will be lost, so therefore, you need to have seals and in many cases, the liquid film itself creates the seal, in still other places, you have to add additional seals, so that is another thing, that the liquid does.

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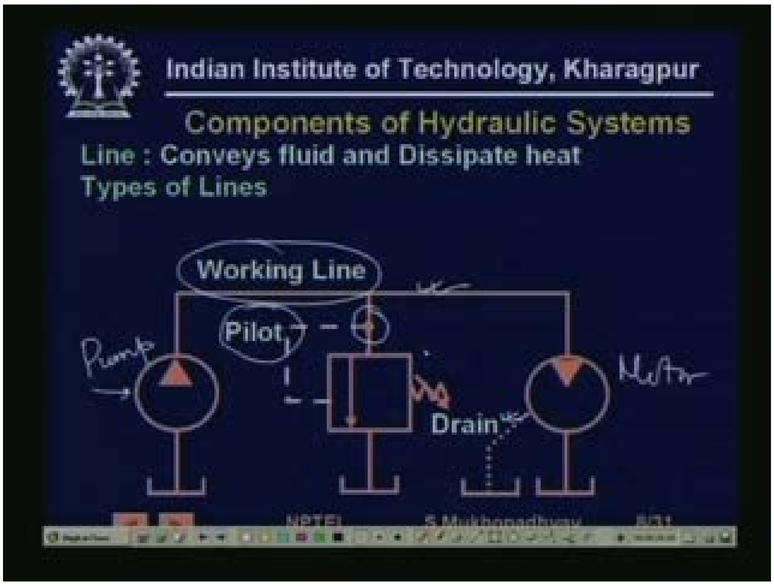

Now, how does the liquid flow, the liquid actually flows in pipes, now this is, you know one of the this is a kind of drawback for the hydraulic system in the sense, that you have to have an, you have to have some piping. And, you not only have to have piping, from the pump to the load, as the liquid is flowing, because it is a liquid, so you need to also have the return line, so that adds some cost and some maintenance.

For example, by contrast in pneumatic systems, you do not need those you do not need the return line. Because, you can release the air into the, after it has done the work and it has come to atmospheric pressure, you can just release the air into the atmosphere, by thereby saving the cost of return line, but that is not the case for hydraulics, you have to have a return line, so there are various kinds of lines, which are used in a hydraulic system.

For example, this is supposed to be a pump and this is supposed to be a motor, so the pump is creating pressure, which is moving the motor and creating the motion. So, you see that, there are some lines, which are shown as form lines, through which the actual liquid flows and transmit the power, they are called working lines. Then sometimes, there are, you have to create some additional pressures at various points, so they, that for control, that is not for transmitting the power, but for controlling the directions, sometimes releasing pressure, so you need to create pressure at different point, so you sometimes, you have to separate lines and these lines are called pilot lines.

In this case, in this particular diagram, the pilot line has been derived from the working line, that may or may not be the case all the time. And the pilot line is shown like, you know in long dashes. Similarly, you have to have some drain lines, because some liquid is going to ge, is going to leak out, so you need to collect them. So that they, you know they, are they do not spill here and there, they are not lost etcetera, so you need to add some drain line, so you also have drain lines, which are shown in short dashes. So, these are the typically, these are the three kinds of lines, through which fluid flows in a hydraulic system.

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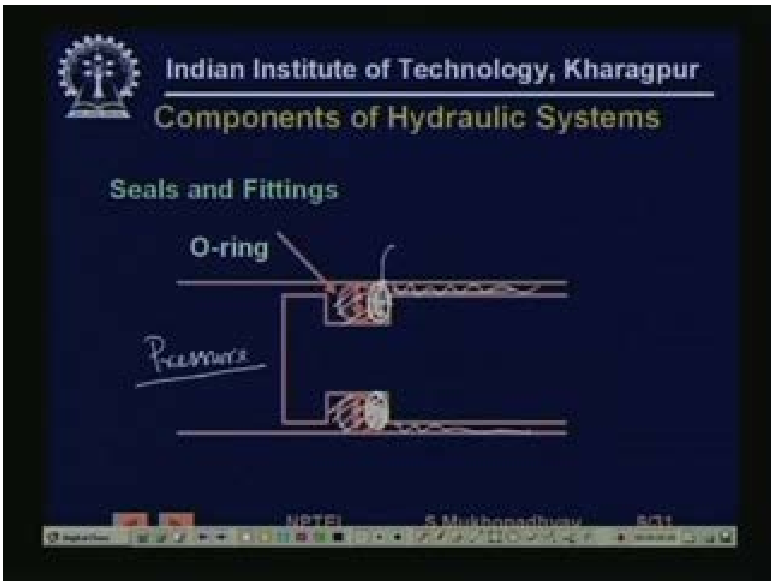

Then, you need some as I said, that you need seals and fittings, sometimes the seal is a natural seal provided by the liquid film. But, sometimes you need to fittings means, whether you have pipe, you have seen, in your own house, in the bathrooms, that whenever, you I mean some fluid is flowing, you need various kinds of fittings, you need various kinds of joints, you need the pipe itself, which can be a, farm pipe typically in the, bathrooms it is sometimes a metal, you know fixed pipe, sometimes we have, we now have polymer pipes.

So, you here also, you can have flexible tubing's, sometimes, you can have hoses, which are you know metal reinforced, polymer pipes. So, various kinds of pipes can be used, and along with that various kinds of fittings and seals, must be used, so this is, we are not going to dwell much on that, only just to show a, just to show what kind of a ring, for example, if you have this is an O-ring, which is a common very common type of seal, so you see, that as this is moving, as this is the, this is when it is moving against pressure, this is a cylinder.

So, what happens is that this seal is going to, be pressured and it will come and settle here. So when, it is, it is actually pressed, so when it will come and settle here, it will effectively settle, it will effectively seal this part, from this part, from this part, so this ring, this is the rubber tube, so it will come and under pressure it will come and, it is a self sealing, under pressure it will provide a seal.

So, such seals are various kinds of seals are used, it is very important, it may not be, we may not be dwelling with it, but unless these things are properly done, your hydraulic system is not going to work, and it will be a lot of problem for the maintenance, so from the maintenance point of view, these things are very important.

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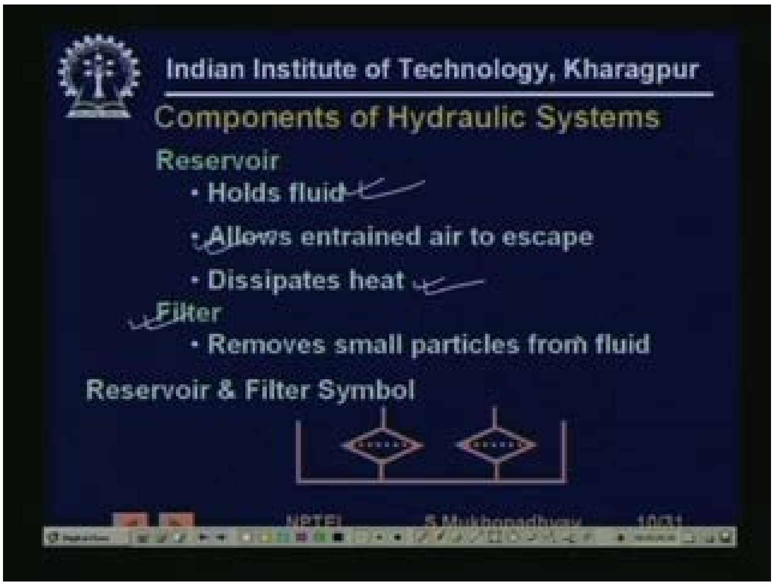

Then, we need a, we have a reservoir, you know oil is continuously circulating, so it is starting from a reservoir, the pump is sucking the oil and then delivering it at a pressure, and then it is flowing through the system, and then it is coming back to the reservoir. So, but apart from the fact, that the reservoir holds the fluid, it actually does many other things, so we will, so it holds the fluid obviously, but it does two other things, for example, it dissipates heat, in the reservoir the liquid gets cooled and it allows entrained air to escape.

So, this removal of contaminants is done partly in the filter, which is also connected closed, on the pipeline closed to the either on the return line, generally on the return line, and, so that removes small particles from the fluid. And, in the reservoir, the entrained air bubbles get removed, removing entering air bubbles is actually very important, because if you have, you can well imagine, that if you have a fluid and in, which if you have entrained air bubbles, then the fluid does not remain incompressible anymore, because if you apply pressure to the fluid, it is the air bubbles, which will get compressed and, so therefore, the fluid itself will get compressed.

So, in technical terms, the bulk modulus of the fluid will can fall drastically, if you have entrained air in it. So, it is very important for as we said, that for effective transmission, and fast quick responding transmission, that the fluid is incompressible, so therefore, it is important that, air bubbles have to be removed and they get removed in the tank. So, this is the, when we will draw hydraulic circuits, we are showing symbol side by side, because in the coming lessons, we will draw hydraulic circuit, so that we understand, so this is a reservoir symbol, in which we have two filters.

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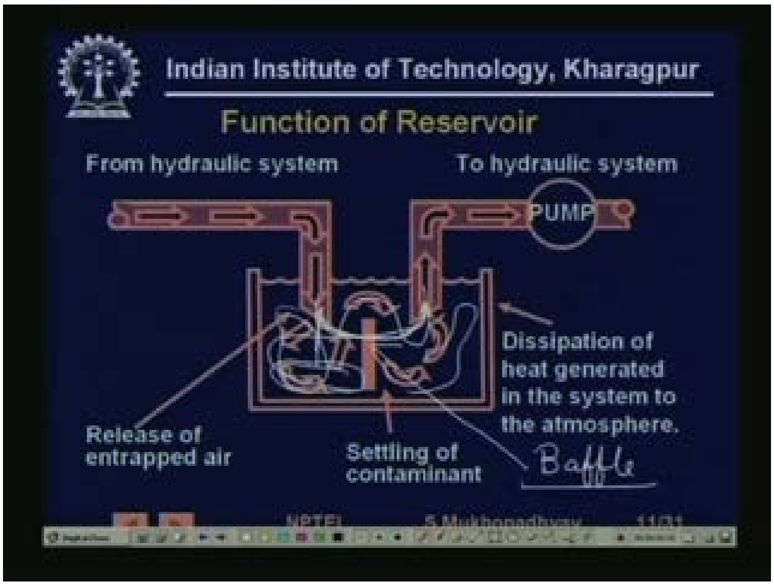

So, coming back, so you see that the functions of the reservoir are shown, so from hydraulic system, there is something called a baffle. So, this is created, so that directly, otherwise if this is not created the, this part of the fluid, because of this low resistance, directly fluid from this will get sucked into the pump. So, therefore, these fluids will not get sucked, and the, these fluids will not spend time in the tank, so therefore, they will not get cooled, they their airs will not get removed.

So, therefore, a baffle is placed, so that the, so the fluid which comes, settles around this point and the, and the fluid, which has come earlier, actually go and enter the pump. So, this is just to create that, so this just shows that, how the pump is, how the reservoir does its job.

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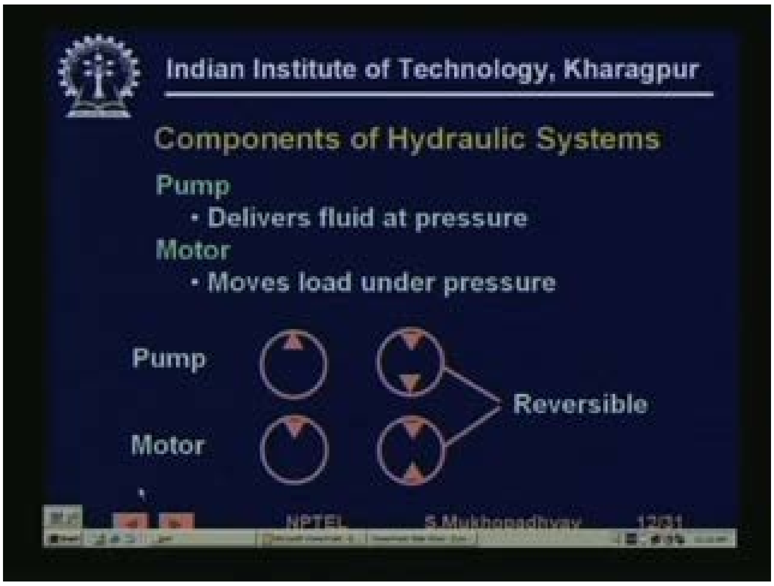

Now, we come to the main component, so firstly, is the pump, as we have seen, that the pump is the generator of the hydraulic energy that is it delivers fluid, at a flow rate, which is determined by the load, and at a given pressure. Now, who drives the pump, the pump cannot generate energy by itself, so the pump has to be generated, again by some other means, sometimes it is an electric motor, which will drive a hydraulic pump, sometimes, especially you know hydraulics is used very much in, aerospace application.

Sometimes, you can couple the engine, along with the, I mean may be bleed some gas, engine gas and then run a special type of motor, which will move the pump. So, in other words, the pump needs a prime mover and creates and delivers fluid at a given pressure. The motor on the other hand is the counter part of the pump, the motor receives the fluid under pressure and creates motion, against the load, so we generally, so the pump is like a battery, while the motor is like a load. And these are the symbols, so you see that the pump symbol is like this, and the motor symbol is like this, and there are some, reversible if the pump and the motor are reversible, that is they can rotate in both directions, then this is the symbol.

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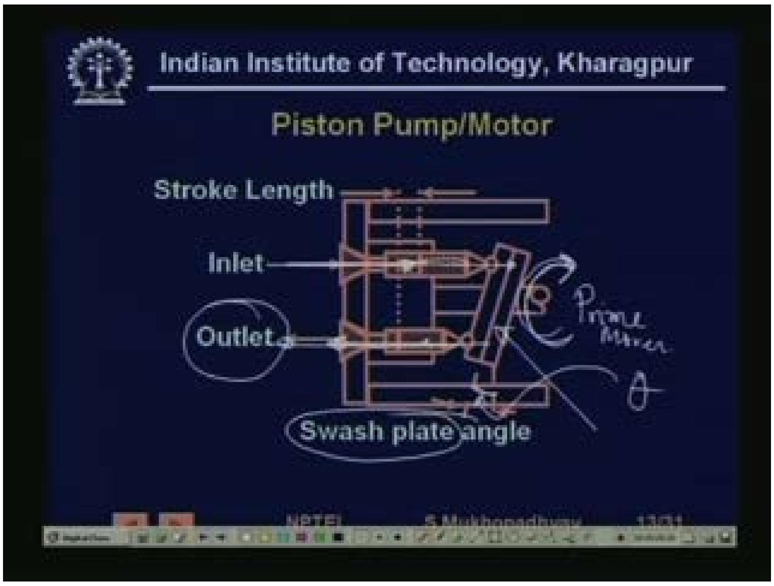

There are various kinds of pumps, which are used we are going to look at three typical types of pumps, so we will first look at the piston pump or the motor. In both cases, the construction is quite similar, only thing is that, in the pump the motion will be created by the prime mover and the fluid will be delivered, while on the motor, the fluid will be will come into the motor and the motion will be delivered, so this is the only difference, that is why we have, we are showing them in a uniform manner.

So, the first thing is the piston the actual piston pump, which operates like this, so you see that, you can imagine, that there are let me show you, let me try to show you, that along the periphery of the motor, along the periphery, there are a number of such pistons. So, you can, if you take a cross section, you can see this diagram, so there are this is one piston, so along the periphery this is one piston, the here there is another piston, here there is another piston, so along the periphery, there are a number of pistons, two of them are being shown.

And these pistons, at the end is actually, connected by a plate, so you see the plate, in the figure, so see the plate in the figure. Now, you see, that the plate is, now you should see the plate, the plate is connected at an angle theta, what does it mean, that let us let us take the case of the pump. So, the pump is being rotated in this way, by prime mover, so one now, while it is rotating, you can imagine, that this is, while it is, while the disc is rotating, here it is pushing and here it is pulling the piston.

So, what is happening is that here, the fluid is being sucked in from the reservoir, and here the fluid is getting delivered into the outlet. So, because of this angle, the fluid is getting sucked here, and then it is getting delivered into this outlet, so this is called swash plate, this is called a swash plate and this delivers pressurized fluid at this outlet. On the other hand, if you apply pressure fluid here and then the fluid will come out, through this outlet and this swash plate will actually rotate in this direction, so that is the function of the motor.

So, this is the way piston pumps move, and naturally the flow rate that you can deliver, depends on the number of cycles of the, what is the total flow rate, that depends on the number of pistons and the, and the number of so at during one rotation, each piston will deliver a fluid, which is equal to it is own volume. So therefore, if the number of rotations per second is x, then x into that number of volume, will actually get delivered in that pressure, so this you can, using this you can compute the volume flow rate, we are not computing anything, our object is to understand only the operation.

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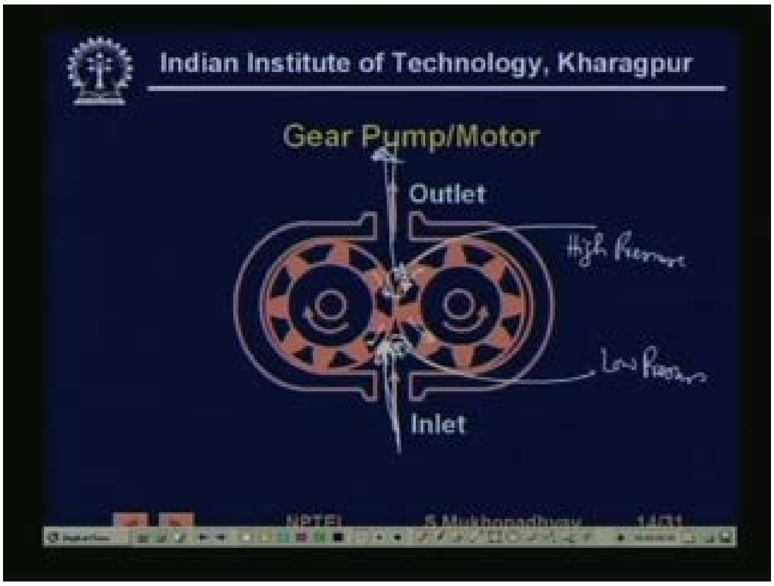

On the other hand, look at gear pumps, in the gear pumps, you have meshed gears, so what is happening, you can you can imagine, that as this gears are rotating, so as this gears are rotating in this zone, as this you see this teeth is moving this way, and this teeth is moving this way. So here, it they are compressing the fluid and some high pressure region is created, on the other hand, here the meshed teeth, I mean the actual drawing is not actually, there has to be much closer meshing of the teeth, so here, the these teeth are actually going away, so they are opening up.

In one place, they are closing they are like this, like this, so in one place they are closing, so when they are closing, they are, they have a tendency of creating a pressure. On the other plate, they are actually opening, so when they are opening, here you have a low pressure region. So obviously, this low pressure region will suck in fluid from the inlet, and this high pressure region will actually, drive the fluid at the outlet, so this is the way the gear pump works.

So, on the other hand, if you in the case of the motor again, if you apply pressure here, and if you, what will happen is that, then it will rotate in the other direction. So, it will move in the other direction, this will get forced and then it will open in the other direction and it will go out. So, this is you see, these two these axial piston pumps, in hydraulics we need to have, the rotational speed and the fluidic rates are, I mean very proportional in the sense that, every time if an axial piston pump or a gear pump rotates at a certain rate. Then, irrespective of the pressure certain volume of fluid will get delivered per second, so the flow rate is directly proportional to the rotational rate of the shaft.

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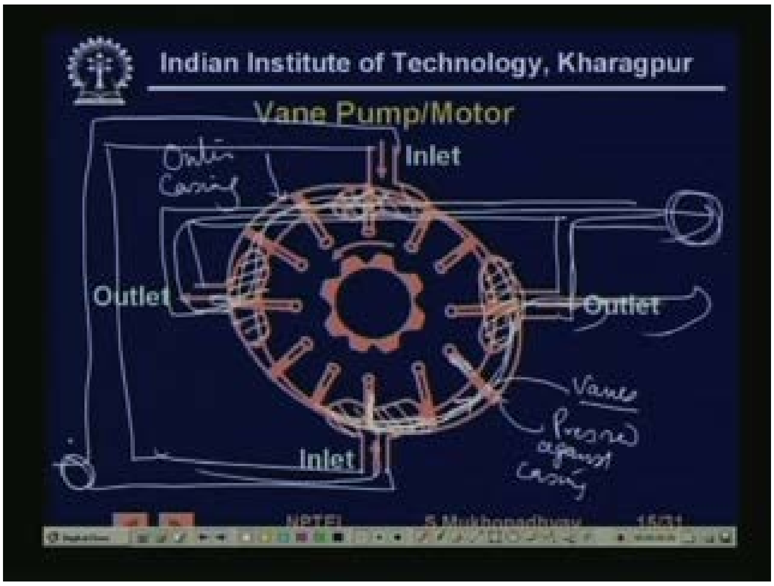

And, this is the third kind of pump, which is called a vane pump, here what is happening is that, you see, that this is the outer casing, this is the port, through which fluid is going out and this is the port, through which fluid is being sucked, in these are the ports. So, you can understand and these are, these are the vanes, these are the vanes, which are spring loaded, actually this is not shown. So, this actually, is pressed against the casing, here there is a spring, pressed against casing, so what is happening you can again see here, that here as it is moving, the vane is always pressed against the casing.

So, it is actually, trying to take the fluid along the casing, so this much of fluid is being pushed, so it is sort of scrapes the fluid and takes it here, and as it comes here, it is getting that is getting compressed, so it gets delivered. Similarly, so that is why here, the fluid goes out and here it gets collected, similarly here it gets collected and here it goes out. So, you see that, in fact, now you can collect, you can actually connect these outlets together and make a make one outlet, and similarly you can have one inlet, so you can have one inlet.

So, then the fluid will get, go this way and from here it will go this way, and I mean rather finally, it will go, so here you will get the overall outlet and here is the overall inlet, so this is the way a vane pump works, very simply speaking.

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So, having seen these three kinds of pumps, we would take a look at, now we will take a look at, now this we have seen that, how the fluid is pressurized and pressurized fluid is generated, we have also seen the motor, which where the pressurized fluid, can be can create a rotational motion. We will see another kind of actuator, where it creates linear motion, we basically need these two kind of things sometimes, we can transfer, I mean we can convert rotational motion into linear motion using, you know things like lead screws.

But, we can also create direct linear motion, using what are known as cylinders, now in between these two, that is where the between the pump and the actuator, which can be a motor or which can be a cylinder, the fluid has to pass, and there are, it has to pass in various ways, pressure has to be controlled. So, various types of components have to be put, in it is in the path of it is journey, from the pump to the actuator, so we need various kinds of typically, we need various kinds of valves for this.

And, one of the major category of valves are called directional valves, whose job it is, to control the direction of the flow, so which way it will move, will it move, from the, that is the flow direction, because the flow direction is very much related to the direction of motion. Now, we want to create motion in various ways, sometimes we want to create back and forth motion, so if you want to create back and forth motion, then we have to continuously, change the direction of flow automatically. So, for using doing these, valves are required, so we have various kinds of directional valves, we are going to look at the, these three. So, the first one is a one way check valve, the second one is a two way valve and the third one is called a four way valve.

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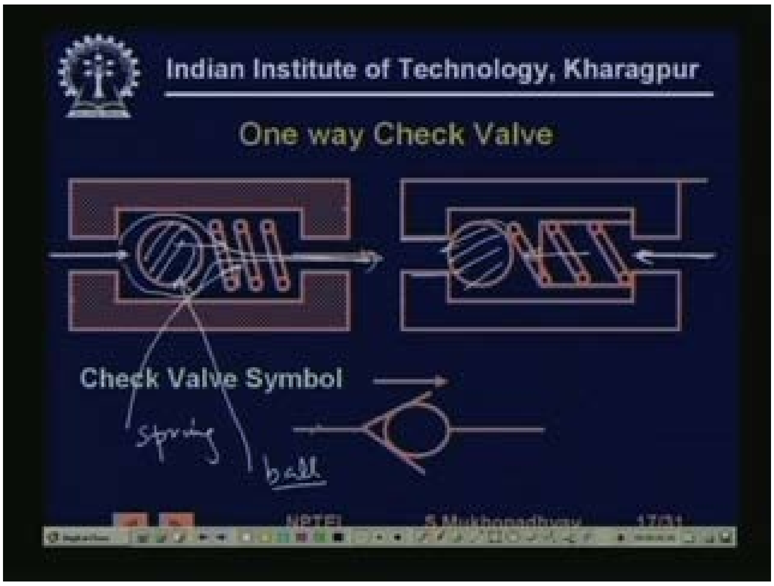

So, first the check valve, so the check valve what does it do, it will allow flow in one direction, but not the other direction, and it is, so you see, how it works, very simple, this is a, this is one of the constructions, there are various kinds of check valves. In fact, the mechanical design of hydraulic systems are, very complicated, they require very precision manufacturing, and, so there are various constructions possible, but we are going to see mainly schematic, so this is one schematic, where we use a ball type check valve, we can also a poppet type check valve various kinds.

So, here what is happening is that, this is a spring, this is a spring and this is a ball, this is actually a ball, solid ball may be all balls. So, what is happening, is that, if you, if the flow is in this direction, then the ball will be pushed along the spring, and it will be, the water the fluid will flow through the like this through the spring. But, when it will be, when the flow will be in this direction, then the ball will be pushed in this direction, and it will come and settle and close this pour, this pour.

So, fluid cannot, flow from this direction to this way, while it can flow freely through this, so this is a symbol, which shows that the flow direction is this and this way, it cannot pass.

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Having seen, one way check valve sometimes, we need valves, you know we will demonstrate a case of a, of you know pilot operated valves. Because, sometimes, we also want, that in the normal condition, the flow will be in this direction, but under certain special conditions, the flow can be made in the reverse direction also, so how do you ensure that. So, sometimes we, because remember that, these all these hydraulic equipment, can actually be quite far away from the operators, where the operator is working, they can be, you know near the machine, etcetera.

So, there are needs, by which the operator, from a relatively remote action, it can operate, it can change the mode of working of the valve. So, for this reason, pilot operated valves are used, whereby applying an external pressure, possibly from a remote source, one can change the mode of operation of the valve. So, let us, give an example, so here you have a valve, you can see that the, this is the port and this is a, this is a my, you know the member which controls the flow, this is a spring and this is a cylinder, which separates these two, this is my pilot port and this is a drain port.

You know in these valves, remember that, suppose a pump is trying to deliver fluid, through a load and the load is moving. Now, suppose suddenly the load gets mechanically jammed, then what is going to happen, the pump is trying to drive fluid and the load is not moving. So, the fluid will immediately tend to get pressurized, because it is a incompressible very high pressure will generate, and this very high pressures, can actually be very detrimental, they can open they can damage seals, fittings they can create explosions etcetera.

So therefore, pressure has also always to be, in all these equipment, if the pressure suddenly tends to very high, because it is you see, because it is incompressible, so the pressure can very quickly rise to high values, sometimes if there is jamming. So, therefore, there are always mechanisms, such that, such pressures can has to be released, so here is a, so that this is the, that mechanism brain, so now, what is happening, is that initially, so this is also a part and this is the port.

This is, so initially normally what is happening is that the, this spring is pressing, so this is, so this port is, these are actually solid parts, these are not which one, this is the hollow part, where the fluid exists, these are solid parts, metallic parts. So, normally what is happening, is that, this is the position of the valve, what is that called stem and the, so now, when the fluid is coming here, the fluid is pushing and this will come down, if there is certain amount of pressure.

So, there will be certain amount of force, on this and this, spring force will be overcome and the fluid will flow out, through this is the normal flow direction. On the other hand, if the pressure becomes too much, here then it may happen, that the force is also here, so the force on the, so the now because of the spring force, so if you see, free ball diagram, the spring force is here and the pressure forces are here also on this.

So, now if sometimes it may happen, that the pressure here, may move the spring up, in which case this will be, this will open, this will suppose the fluid may pass out, from in this way, through the drain. In other cases, now suppose you apply a, suppose you apply a pilot pressure, then what will happen, now that will come later. So, we can see that, if we apply fluid flow here, the fluid will freely pass on in this direction, now what happens, but it cannot pass in the other direction, why it cannot pass in the other direction, because if let me let me change the color, to mark the other direction.

So, if the fluid now tends to tries to enter this port here, then this is going to get pressed and this will close, this will close, so fluid cannot pass, in this direction that is why, it is a check valve. On the other hand, if we in certain conditions, we want that, under certain we want to, convert this valve from a, we also want reverse flow, so in that case, we can apply pilot pressure here. If you apply pilot pressure, then this whole thing, by pilot pressure will come down, so the, so this thing, now that that, I think we have a diagram, we have a separate diagram for the pilot pressure, so we will show that.

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So, when we have pilot pressure then this is the pilot port, so you have pressure, so this spring will be pressed and this will actually come out, at the bottom, not exactly aligned, may be somewhere over here. So, now the fluid, now this opening is opened, these openings are opened, so the fluid will pass and can flow through these, they can also, still open they can also get drained, so you see, so this is a typically pilot operated check valve.

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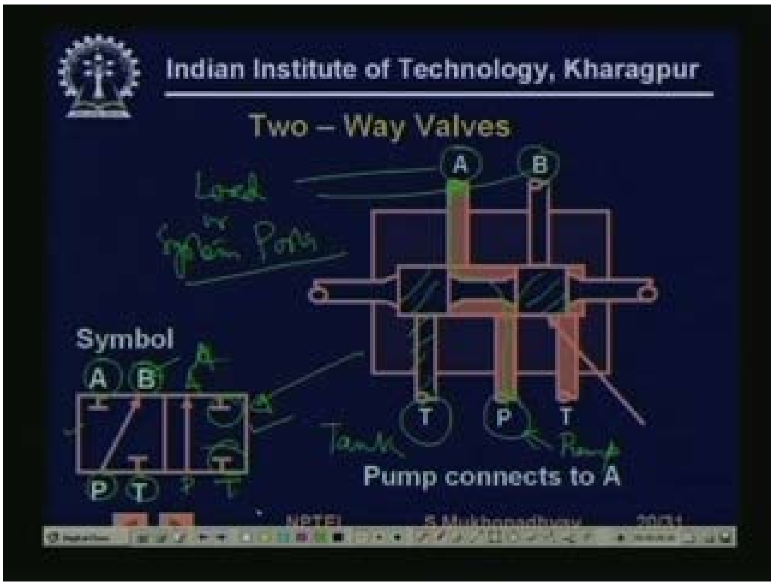

Similarly, there are situations, where we need to change flow direction, so typically, we have two way and four way valves, and we must see, so these are this T means tank, this P means pump, and this A and B are the load ports, load or system ports. So, now you see that, this valve has two positions, so if in this, in this position, you see that the pump, is actually connected to the port A, how it is going to come back to the tank, is not through this, but through some other path, which is not shown.

So, you see, that we draw it, there are two positions, so we draw it by two boxes, sometimes you may have three boxes, in which there is a central position neutral. On one side we have pump and tank, on another side we have the load ports, and this arrow indicates, that in which in, each of these positions, by which port is connected to which port. So, in this position, pump is connected to B, in this particular position actually, this should have been A, if you correspond to this, and this should have been actually, so this means, that this diagram actually corresponds to this particular box. Where this is P, this is A, and this is tank is sealed, so the tank is sealed and B is also sealed, so these are sealed, as you can see.

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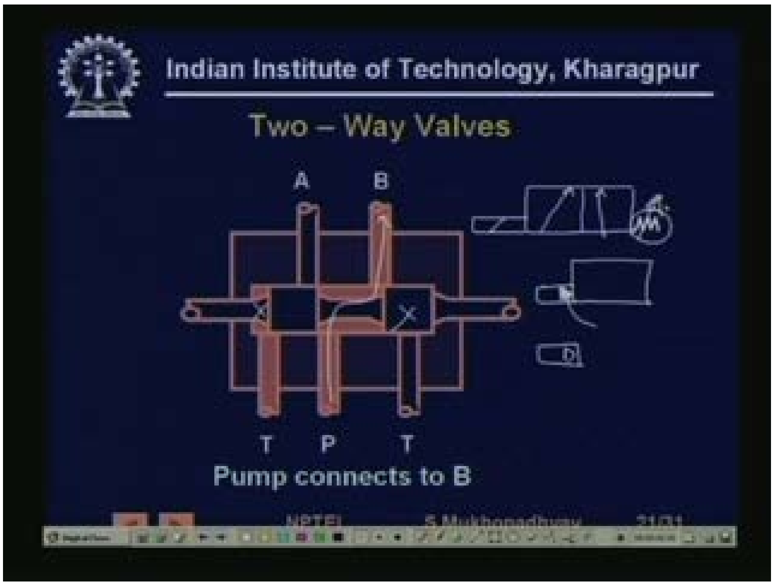

On the other hand, in the next position, see just the reverse, so just the reverse, that is now, it is in the right position, so in the right position, pump is connected to B, and A, and tank are sealed, so you have the other box of that diagram. So, you see that, a particular what have we achieved, that by moving the spool, just by moving the spool of the valve, you can, connect either port A to pump or port B to pump, this is what you have achieved, and how do you move the spool, there are a variety of ways to move the spool.

So, for example, the spool may be moved, sometimes you know when we draw the symbol, suppose we draw the symbol, then how do we move the spool, we may be moving the spool by a solenoid. So, we may be moving, if we write like this is a solenoid symbol, sometimes we may be using, if there are if these valves are big, it requires force to move the spool. So, the spool may be moved, by either a, so this triangle means, they are moved by hydraulics and pneumatic, if this is filled up, this is a hydraulically moved spool.

So, the sometimes these directional valves can be very large, and to move the spool itself, you need another hydraulic force. So, this is a hydraulically moved spool triangle filled, if the triangle is hollow, then it is a pneumatically filled, pneumatically operated valve. Sometimes, so these are very a typical situation, sometimes we may have an, we may have this means, that there is a spring, so you only need to pull it in this direction, then return is by spring, sometimes we may have an adjustable spring, so there are all kinds of, spool moving actuation mechanisms are there with this valve. You may, also like to move it mechanically just by hand or by pushing something, draw or pulling a lever.

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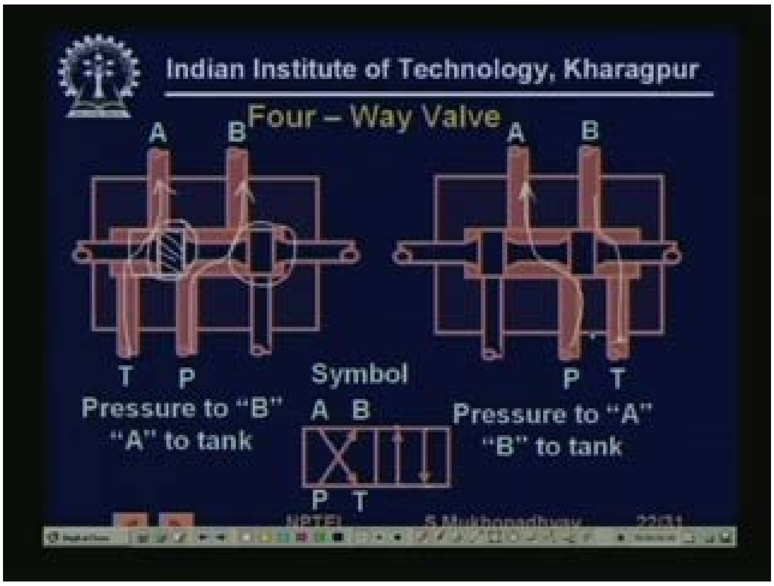

So, coming to, then we come to four way valves, so in four way valves, it is exactly similar, only thing is that now, in each position both A and B are connected to pump and tank. So, in this position, pump is connected to B, tank is connected to A, while in this position pump is connected to A, and tank is connected to, B is connected to tank, so you see that, now by construction, this is exactly similar, so the same valve is becoming two way or four way., basically depending on the geometry, that is how wide is this.

This is the same type of figure only thing is that previously, we had this one as very wide, so therefore, A was sealed. Now, we have this one as a narrow one, so in this position pump is connected to B, and tank is connected to A, while on the, if you move it to the left, then pump is connected to A and tank is connected to B, so this is a four way valve.

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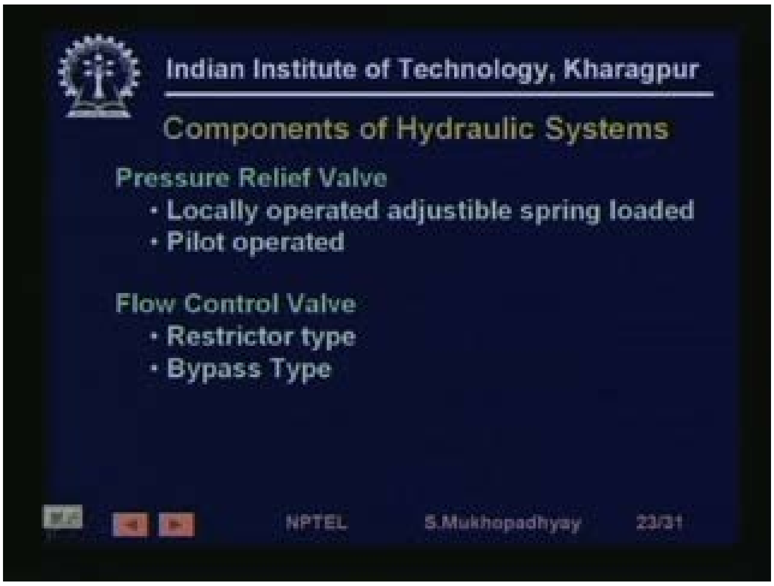

Now, as I said that, you in many cases you need, to control the pressure or the flow through the valve, sometimes you know velocity has to be controlled, if you are moving a very high load, sometimes we want that, it moves at only at a certain speed, so for that you have to do flow control. If you want to, and pressure control is very much needed, so we have another the other kinds of valves, which are called pressure relief valves and flow control valves, so we will look at some of them.

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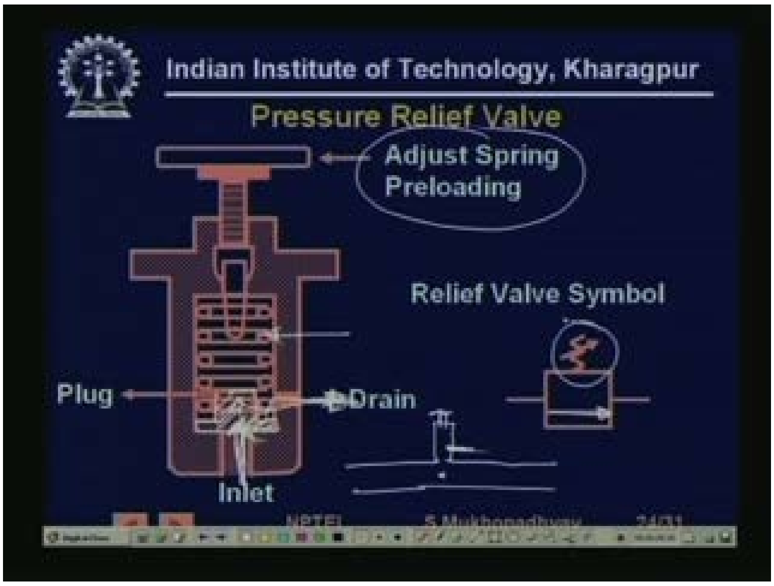

So, this is a simple pressure release valve, so you see that, this is the inlet, this is the inlet, so very simple, this is the drain, so actually this valve, can be connected across a pipeline, if you connect it across a pipeline, this is your drain. So, if the pressure here increases too much, then this particular poppet, this will push, this will be pushed up, and therefore, the fluid will pass through the drain, so since the drain is at a low pressure immediately pressure will fall, so high pressure cannot be created.

And, at what pressure this poppet will start moving and will open the line to the drain, that depends on the spring and this pressure can be adjusted, by tightening this screw, so if you tighten the screw, there the spring can be preloaded to a value. And then at that adjusted value, if the pressure goes beyond that, then the fluid will be connected to drain, so this is this is shown by this symbol, that this is the relief direction and the this shows, that there is an adjustable spring here. So this is a very simple pressure relief valve, then we have a pilot operated relief valve.

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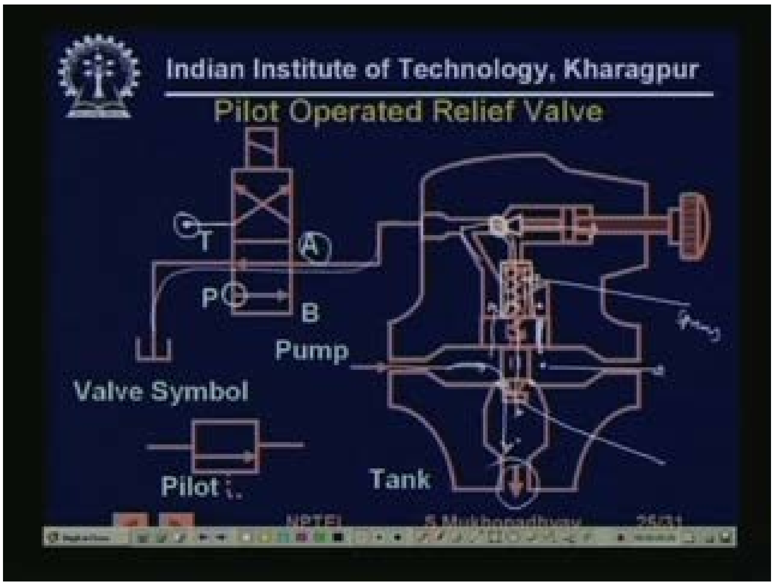

See, so that is more complex, so what here what we are doing, is that whereas, this operation is interesting, so initially what happens, is that by this spring action, you see here, there is actually a small orifice, which is not drawn, in the diagram the person, who drew it missed it. So, normally, because the fluid pressure here, for steady pressure and the fluid pressure here are same, so therefore, this is being pressed by this spring, and this is actually closed, this comes and sits on this, so the fluid is passing like this.

Now, if there is a suddenly, very suddenly pressure rises, then what will happen, is that because this is a narrow orifice, so that the pressure here, and here will not be same, so suddenly, if the pressure rises high here, this will be pushed up, by that force. And, naturally this opening will be opened and fluid will drain to tank, this is tank, so therefore, sudden pressure rises can be controlled.

Second things, is that, if that, if now the pressure suppose the pressure the rises slowly, then that phenomenon will not occur, but then at a certain value, suppose this place is sealed. For example, in this position it is connected to tank, but in this position, suppose this is a this valve in this position, therefore this is connected to the pump, this is the pump port, so therefore, when it will be in this position, that is then this is connected to some pressure.

So, suppose we or we might have sealed it, then what happens, is that as this pressure rises, this pressure will also keep rising, and they will balance each other. At a certain point of time, the pressure here will be too much, for this needle valve to resist, so the needle valve will open. And, then the fluid this is actually a hollow, see the dotted lines, so there is a hollow opening through this, so then this fluid will flow through this, through this and will go out to the tank, so even steady very high pressures, cannot be sustained.

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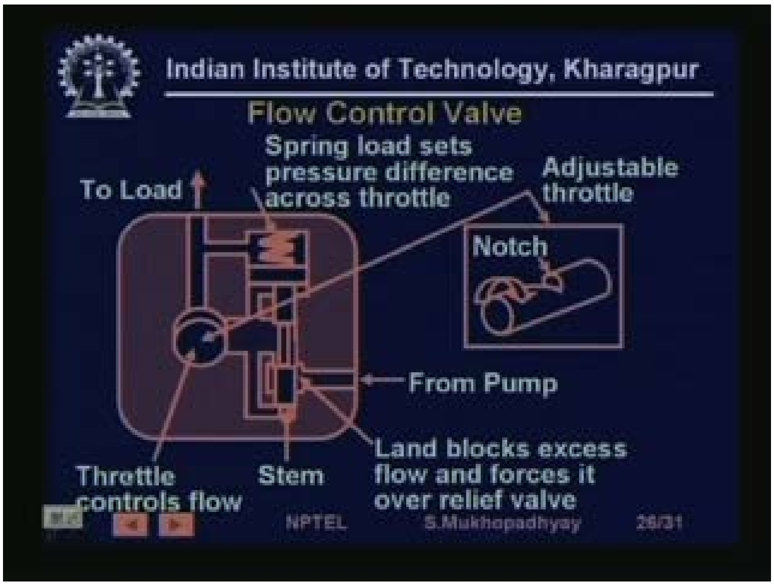

So, lastly we have a flow control valve, now what is happening here, is that the here, we want to control flow, so you see, what we will do is, we are actually running out of time. So, we will consider the flow control valve, in the next lecture, so in the next lesson, we will actually begin with the flow control valve, so I will skip this, for the time being.

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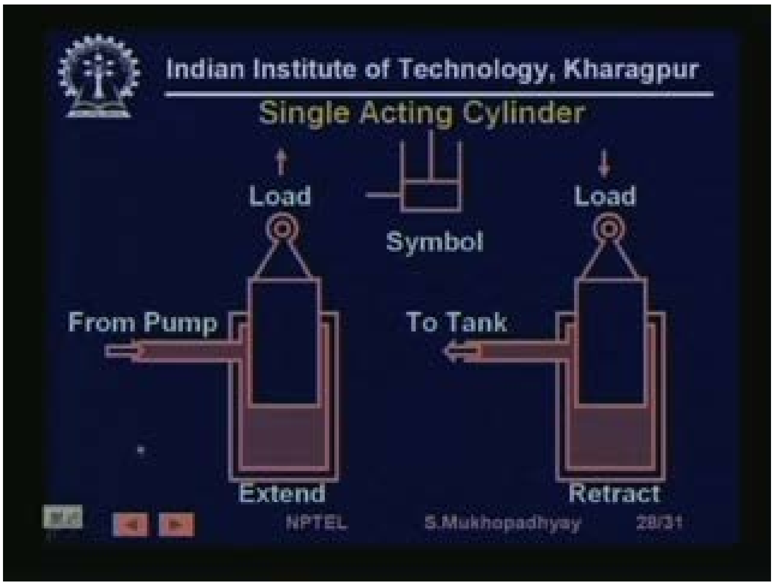

This is cylinder, so we can talk about the cylinder later.

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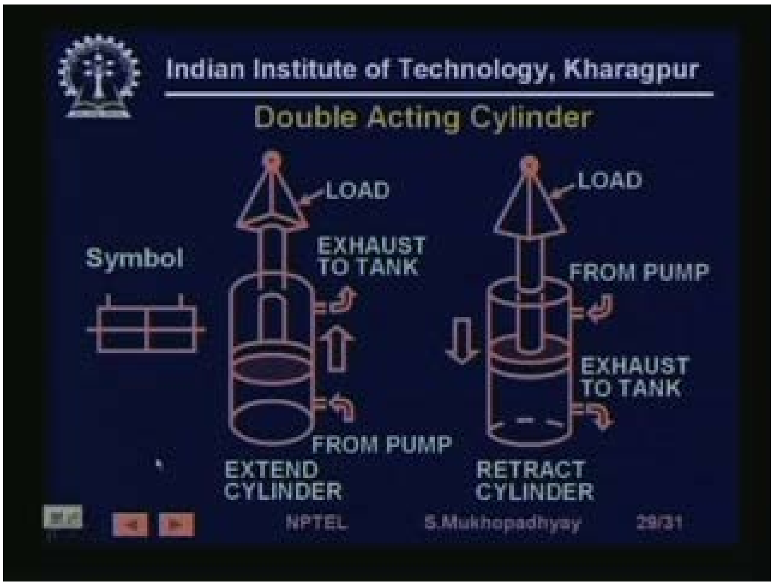

So, this from the last three four slides, we will take up in the next lecture.

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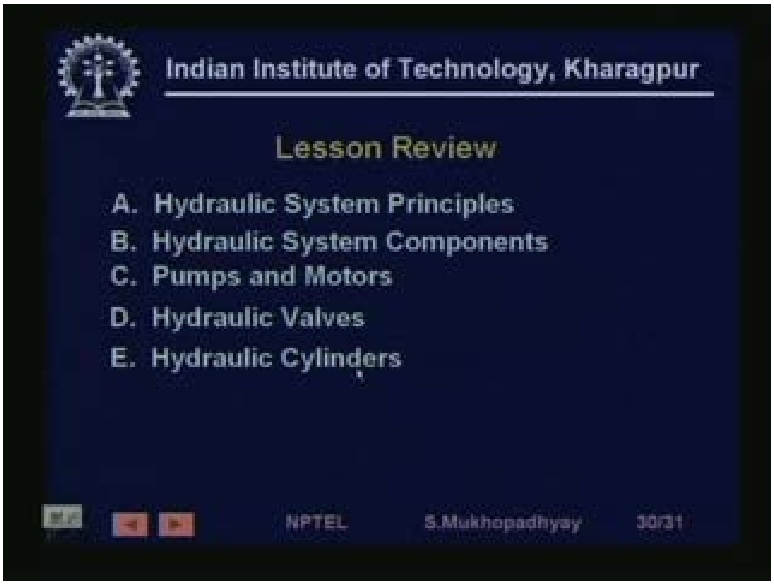

So, now let us come to the lesson review, so what have we done today, so we have, today we have, seen the basic hydraulic system principles, that some pressures pressured fluid is created using a pump, and that fluid flows, through the that pressure is transmitted by taking the fluid through lines, and is applied on the load to create various kinds of motion. And we see that, it is possible to amplify force, but at the same time energy is conserved, so therefore, the velocity that we can create gets limited by the flow rate that can be delivered by the pump, at that pressure.

We have also seen that, for making an effective system, we need to have various kinds of components, we need the fluid, we need the lines, we need the sealing, of course, we need pumps and the actuators the motor. We also need to, control the flows, flow of the fluid we need various kinds of valves and among the valves, there are some valves which control the direction of flow, there are some valves, which control the pressure and the flow. So, we will continue with this, we have seen pumps and motors, and we have seen part of the valves, some bits are left and finally, we will see the cylinders, in the next lecture.

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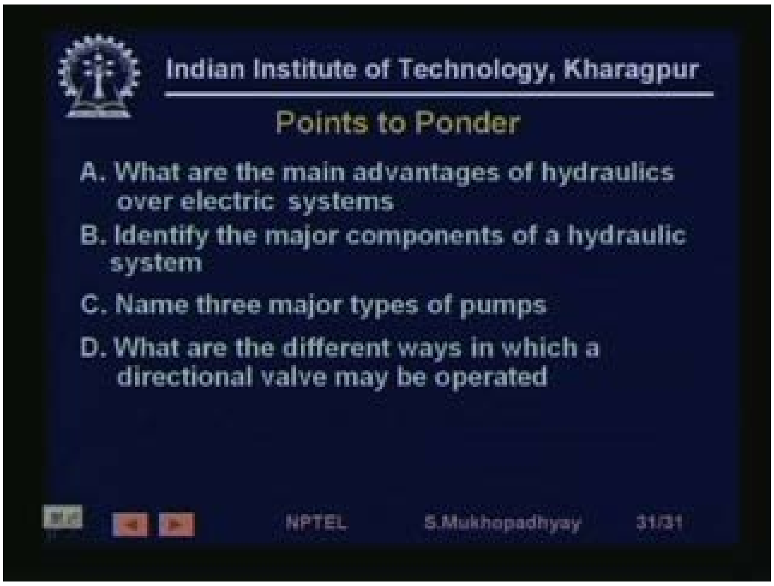

So, you may ponder, what are the main advantages of hydraulics over electric systems, there are some advantages, I have already told, the major advantage of hydraulic systems is that, they can handle, much more power, at using much more low sizes therefore, they are for prime importance and there are used in aerospace. We will discuss this, in the next lesson, we have you can identify the major components of hydraulic system, if you want to build one, and three major types of pumps, we have discussed it.

And, what are the different ways in which directional valves may be operate, so there are various types of the directional valves one way, two way, four way. So, that is all for today, thank you very much, we will continue with this in the next lesson.

Industrial Automation and Control

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Lecture – 27

Hydraulic Control Systems - II

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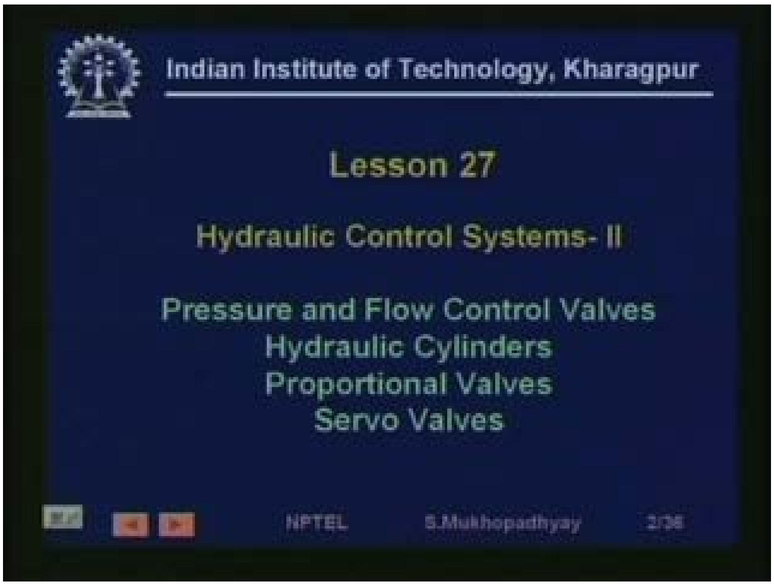

Welcome to lesson 27 of industrial automation and control. In this lecture, we will first look at pressure and flow control valves, something which is spilled over from the last lecture. Then look at hydraulic cylinders, proportional valves and servo valves, and finally, we will look at, the structure of a full, you know hydraulic actuation system, so we look at the instructional objectives.

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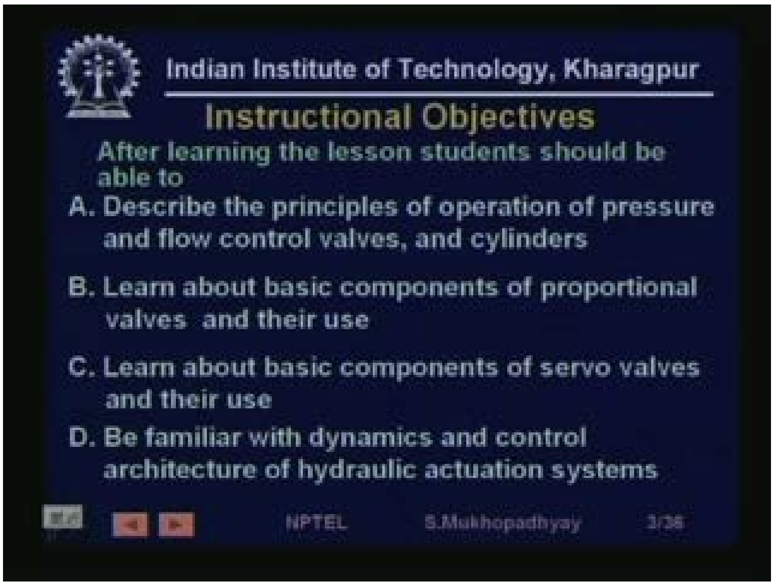

Describe the principles of operation of pressure and flow control valves and cylinders, basic components of proportional valves learn about basic components of servo valves.

And be familiar with the typical, you know control architecture of hydraulic actuation systems, these are the instructional objectives of this lesson.

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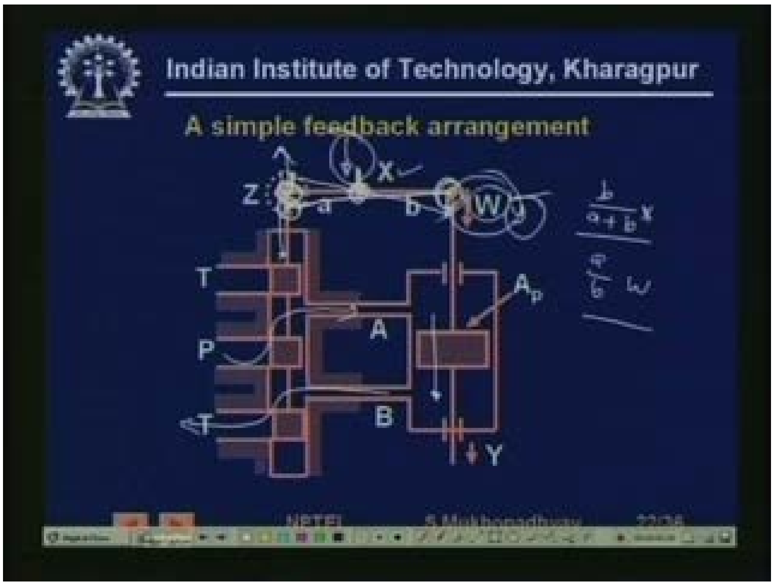

This shows that, this shows, this is a slight a little analysis of that feedback arrangement, that is, if the suppose you have, this is a valve and this is an actuator, and there is a, there is a connecting link, so a given input motion here. What will happen, this will initially shift this way, the movement this shifts this way, what happens is that the pump connects to this, and the tank connects to this. So, the actuator moves this way, when the actuator moves this way, the W moves this way and that will tend to, keep it put it up, so the cause that was created, the effect will nullify the cause, that is why it is a negative feedback situation and it is stable.

So, if you want to analyze the motion of this Z, which finally, creates the flow, then you have to understand, that then you have to look at it like this. So, you see, that first when you imagine, that first there are there are actually 2 inputs, and this is the motion that you want to analyze. So, first of all, you apply super position, so first of all, you apply assume that W is 0 and X is applied, so then the, this rod is going to move about this, because W is 0, so is pivoted to this, that will create some motion.

Next you imagine, that X is fixed and W is moving, so now, you imagine, that it is moving like this, about X. So, this is, so if you can for small motions, you can imagine, that that these two motions are the motions, which will be created and the net motion, is going to be a resultant of that, so now you can understand. So if, W is a fulcrum and if X is applied, if an amount X is applied, then what is going to be the motion here, so that is going to be, that is going to be b by a plus b into x. On the other hand, if you apply fix it here and apply a motion y here, this is y, then what is going to be the motion here, it is going to be a by b into w, suppose w is a motion. So finally, you get so far what is final motion Z.