INDIAN INSTITUTE OF TECHNOLOGY
KHARAGPUR

NPTEL
ONLINE CERTIFICATION COURSE

On Industrial Automation and Control

By Prof. S. Mukhopadhyay
Department of Electrical Engineering
IIT Kharagpur

Topic Lecture – 37
Hydraulic control systems 2
(Condt.)

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How let us come to servo valves there they were typically developed for aviation applications because in aviation you have to make very precise movements of this of these of this control surfaces of the aircraft against very heavy load which is aerodynamic because the aircraft is moving at huge speed through the atmosphere so very precise motion has to be created against high load it is for these purposes that these servo valves are originally developed it is a total closed-loop control technology because you do not want the characteristic to change everything

is very tuned and well you have all the previous advantages like electric drive accuracy computing interface flexibility programmability and hydraulics for high power weight ratio.

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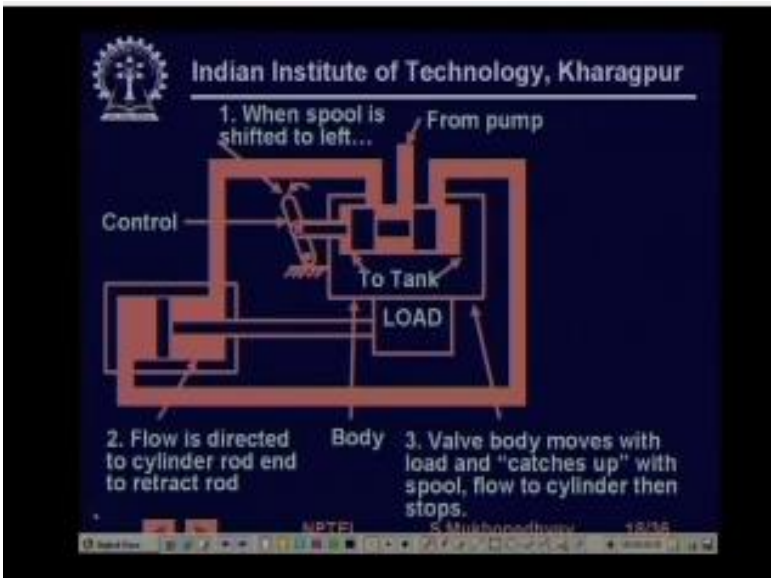

So what is the what is the basic idea see a very typical very simple type of survival so what is happening here is that suppose you shift this this rod okay so if you pull this lever it will move this way as it moves this way what is going to happen that this port it will be connected to this and the tanks are at the end you can imagine the tanks are here.

So the return stroke is going to be controlled going to the tank this is the way the fluid will flow now interesting thing is where is the feedback interesting thing is that the load is connected to the body so if you are pulled it pulled the spool this side the cylinder will move which side remove this side so the load will also move this side and the load is connected to the body so now the body will also move this side this body the not the spool the spool is connected to the lever and the body is connected to the load so the body will move so the movement of the body is actually like a relatively like a movement of the spool in the other direction because the flow the opening is actually by relative motion.

So if the body also moves in this direction again this flow this valve will close so you see there are there is a particular position of the piston or a position of the load this flow will again close till it closes there is going to be flow and there is going to be velocity and this load will keep moving this way so if you move the move the lever the valve is going to move in one direction then finally come and stop that is by feedback okay, so this is thesis this is so this is a typical you know very simple mechanical arrangement servo valve right,

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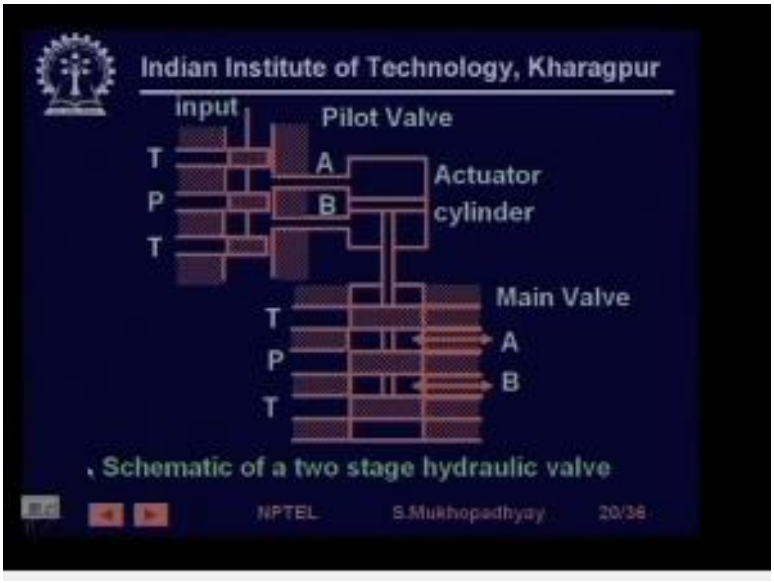

There are various types of server valves for example you one may have a two-stage valve right so what happens in a what happens in a two-stage valve in a thus because you are you are do you want to control huge power so the final stage valve is actually very large so even to move its pool you need another hug the wall so you see what is happening you need an actuator so this is the first stage so this is the first stage.

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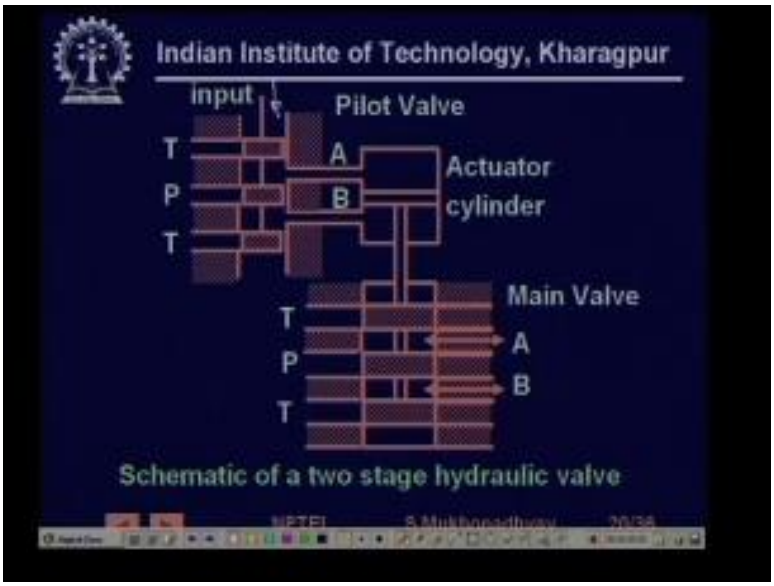

So you give actually your control input here so accordingly if you move it if you push it this way then this port will open and this port will open so the cylinder will move down when it moves down when it moves down then what is going to happen is that this will get connected to this and this will get connected to this, so this is the main valve this is the pilot valve that is it is a valve which drives another valve just like you know a pilot rights in front of a car that is a pilot car the pilot is actually the leader which would drive so in this way this is the driving valve and this is the driven valve and this in turn this sports maybe connected these two ports a and Maybe will be connected to the main actuator which may be a very heavy load right so this way you get power amplification.

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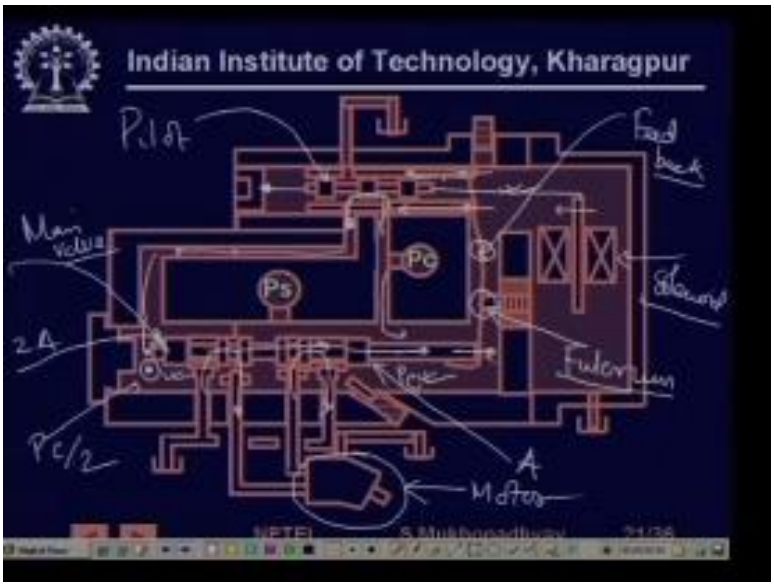

So here is a here is atypical type of two-stage servo valve construction see what is happening you have two kinds of pressure node first so first of all you are where is the main valve and where is the pilot valve so this is the pilot valve and this is the main valve this is the first thing to note who moves the pilot valve this solenoid actually this is connected to the school which is not shown so let us identify the parts right and so what happens is that suppose you tilt the solenoid something like a torque motor arrangement which we'll see what it is, this will push this valve this way now you see that there is a there is a control pressure so the control pressure will come and this valve will move to this end so the pressure will fall here come here and come here and come here and create a pressure here.

So you see that here what is the pressure here the pressure is PC but here the pressure is not PC because it has to drop through this valve so this is going to be less than PC in fact so then if this side is PC and if there is and if this side is less than PC and still this has to move this way then the net force here has to be more than the net force here therefore the areas must be controlled so the area here is actually twice A and the area here is A so far moving this pressure is only required to be PC by 2 the pressure here is only required to by PC by 2 so the moment this rises above PC by to this valve will shift this winnow when this valve will shift this way.

You see that this is the final actuator this is the motors then when this valve will move this way then what will happen is that probably this port will get connected to here and this port will get connected to hear so then you will get pump and tank connected to the motor now where is the feedback the feedback is here in this thing this is the feedback element, so this pool is going to push this thing this way when it pushes here is a fulcrum. So this will again push the spool not the spool the sleeve so the spool is being pushed by this one and this this one this feedback element pushes the sleeves so it will get going to push the sleeves this way.

So again the relative motion this motion of the sleeve will nullify the relative motion of the spool which was created by the current so again at a certain position at a certain at a certain gap again this will become PC by 2 so now that when the moment it becomes PC by two there is no force on this and it will come to stop.

So it is at that position that now when it comes to stop then there is a certain amount of opening here and depending on that the so when you have a certain amount of opening you have a certain amount of flow of certain amount of pressure or so you are so you're going to drive the motor at that flow rate or that speed so this is the operation of the two-stage survival.

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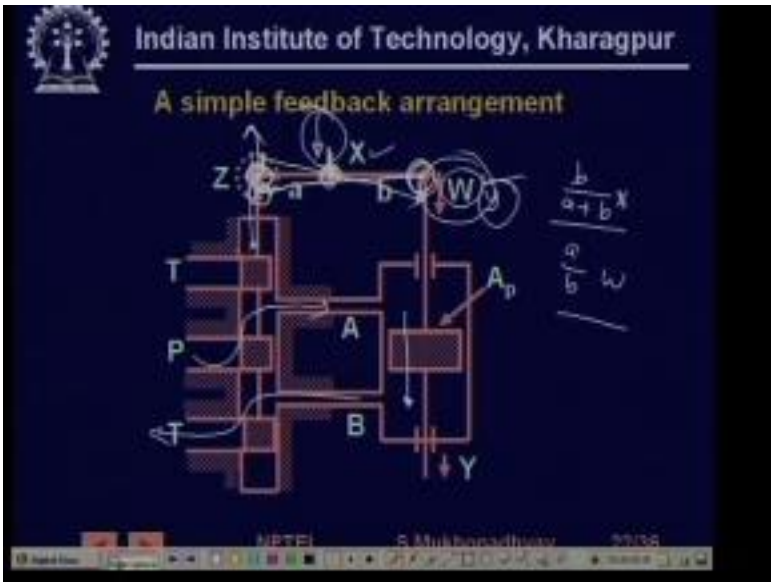

This shows that this this shows this is a slight little analysis of that feedback arrangement that is if the suppose you have this is this is this is this is a valve and this is an actuator and there is a there is a connecting link so you give an input motion here what will happen this will initially shift this way the moment this shift 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 it so the cause that was created the effect will nullify the cause that is why it is a negative feedback situation and 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 were actually two inputs and this is the motion that you want to analyze so first of all you apply superposition 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 a py water 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 on the net motion is going to be a resultant of that so now you can understand so if W is the fulcrum and if X is applied if an amount is applied then what is going to be the motion here, right 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 quick 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 the motion so finally you get so what is the final motion Z ?

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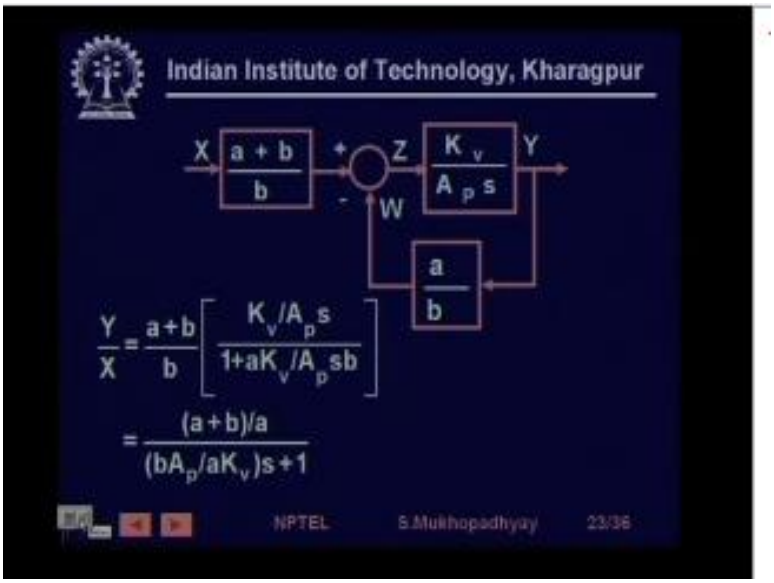

So you have you have an effective feedback arrangement where what is coming this is the motion created by the motion X this is the motion created by the feedback W and this is the net motion Z at any point of time, and that is going to create so motion creates a flow and this is the flow gain so that is going to create a volumetric metric flow that divided AP will give you the linear motion AP is the area of the piston, that integrated 1 by S will give you the motion of the plane, so this is the control system that is effective and here is the transfer function so the transfer function between you can see that now that the transformation between Y by X is actually in the in the steady states X is going to go to 0 so it is going to be A+B/A, and it will act like a first order transfer function.

So this is the this is the basic dynamics of any feedback of you have seen various kinds of you know link linkage type of feedback arrangements so this is the basic analysis of one such feedback arrangement and in a typical case such analysis can be made ok.

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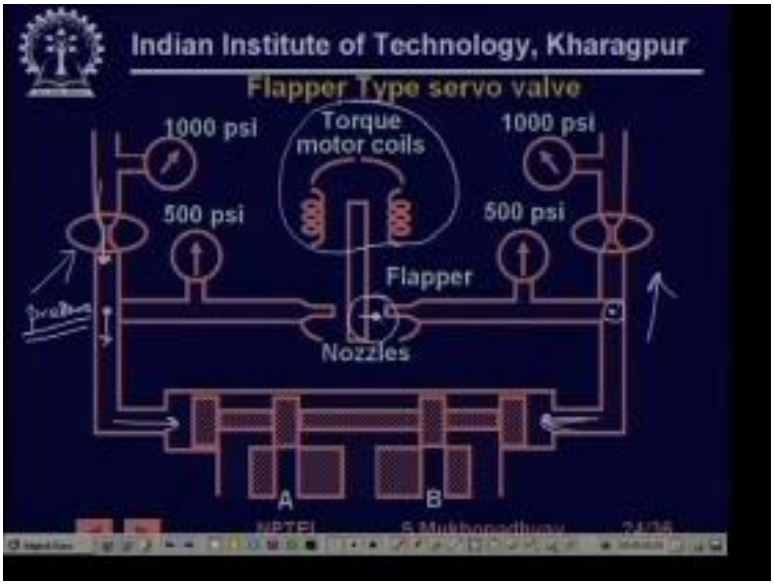

Next we see another type of server valve which is a flapper type turbo valve so you see what is happening here ,what is happening here is that again here the this is the valve the valve is being moved by applying pressure here or pressure here so you have to create a differential pressure how do you create that pressure as such this is also this is a thousand PSI this is a you know restrictor so it is a pressure reducing valve so simply a series obstruction so the pressure will while flowing the pressure will drop here and it will be something like 500 PSI at these two ends when the this is a flapper nozzle okay.

So when if the either the may skew motion of this flapper then the pressure at this point is going to rise if it is this side and the pressure at this side's going to fall so that will create a differential pressure and it will move the spool there is this is the basic principle and how do you create this motion you create this motion by what is known as the torque motor coil, so you have a what

sometimes called is called a torque curve or sometimes called a torque motor, which can create minuscule motion of this flapper.

The advantage of flapper nozzle is that their gain is very high there is very small motion can create a very high pressure difference so that so they are very sensitive devices.

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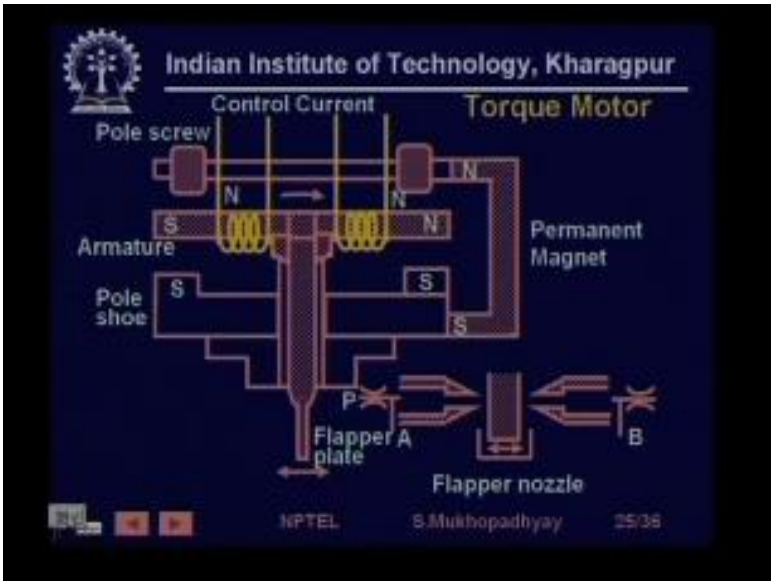

The next user so you here you see get to see the construction of the torque so you see that this is the construction of the torque so when what happens is that you create an S pole here and then N pole here and N pole here is pull that that's the way it is wound so and so what happens is that now you have this pole shoe so if you send currents like this then this is going to repel and this is going to attract so the stalker will slightly tilt it will slightly tilt and it is this tilt which will be this is connected this is the flapper, flapper plate so this is the way you control the flapper.

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This is a picture you know move is a very few is a company which is a very well-known manufacturer of such valves so this is just a picture from their website

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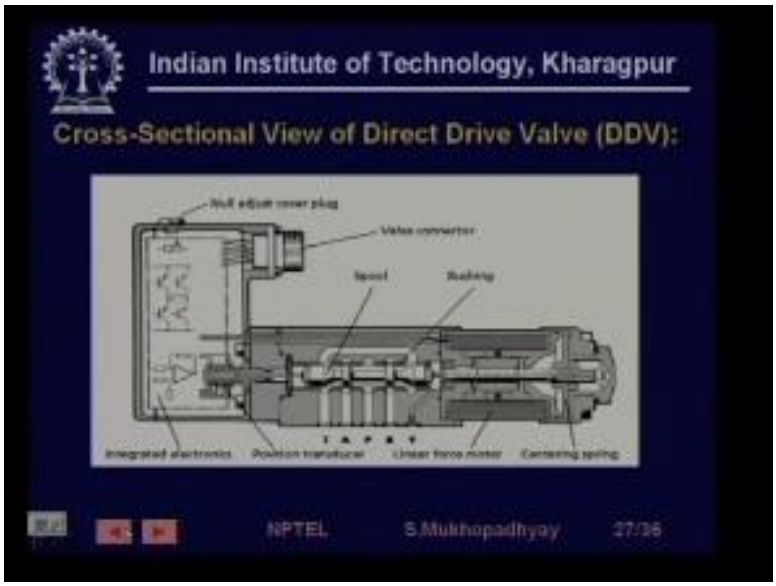

This is a cross-sectional view of a you know direct drive valve so you have so you can see that the various parts this is the electronics this is the actual sir valve and this is the what is known as the coil which will pull the spool and here is the position sensor which is typically an LVDT you sometimes have a spring here and this is where you make the connection so this is just to show you the various parts the actual geometric how they are packed into a vase there these are very compact devices.

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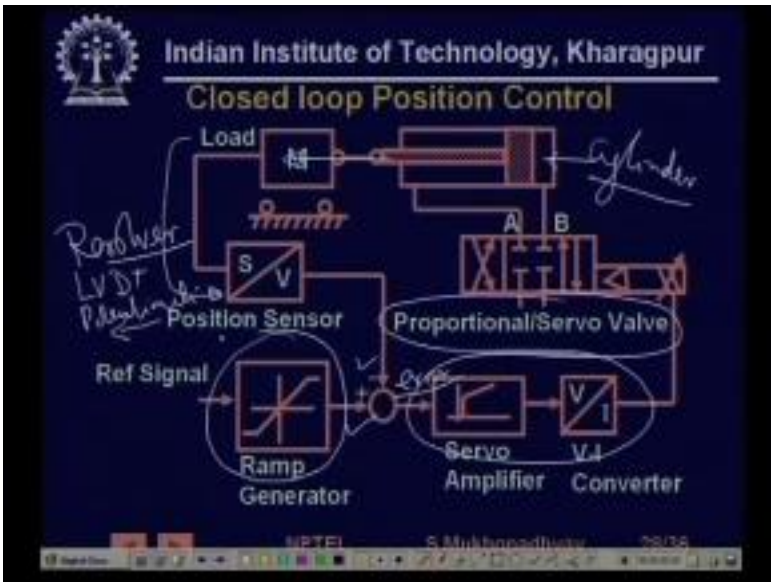

How do you do close to apposition control so very simple this is a say see this is this a position loop so you have a proportional or servo valve here that is driven by this electronics and moves the load this is the cylinder which the position of the load is sensed by the position sensor is the position typically an LVDT, sometimes the potentiometer would be a resolver if it is rotary and these two are compared this and the error is fed a standard position loop, this ramp generator is sometimes used because the fact that I am you do not need to saturate the amplifier and you want to heavy loads should not be you cannot should not give jerks to them that creates might create the damage to equipment might give damage to the loads.

So therefore whenever a position signal has to be changed sometimes you need to control the rate at which it should go you never give step signals generally to this kind of system so you have a ramp generator if you want to go from one system to another you go slowly through a ramp which depends on the velocity level that you want to have on this load.

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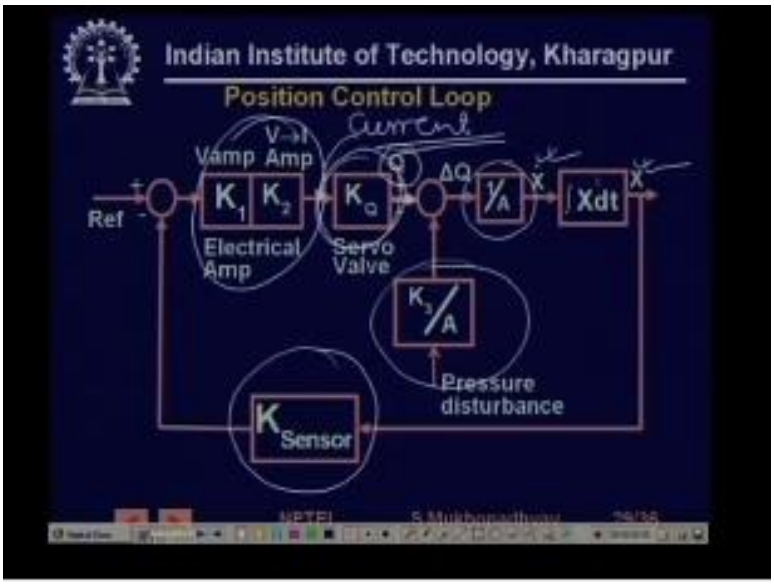

This is a block diagram arrangement of the of the valve of that loop so you see that this these are the these are the these are the electrical gains these are the electrical circuit gains this is the sensor gain this is the valve gain so this is this is current this is the current to flow characteristic KQ of the valve so when you have a certain flow then that flow is going in so flow by area will give you velocity and velocity my integrated will give you position.

This is like a block diagram similarly the flow that you are having this which was fine assuming that is going through because of your nominal value of KQ that you know sometimes that this this flow can be slightly changed if the supply pressure of the pump changes so to model that they have put a pressure disturbance block so if you want to because these are you know I am sorry.

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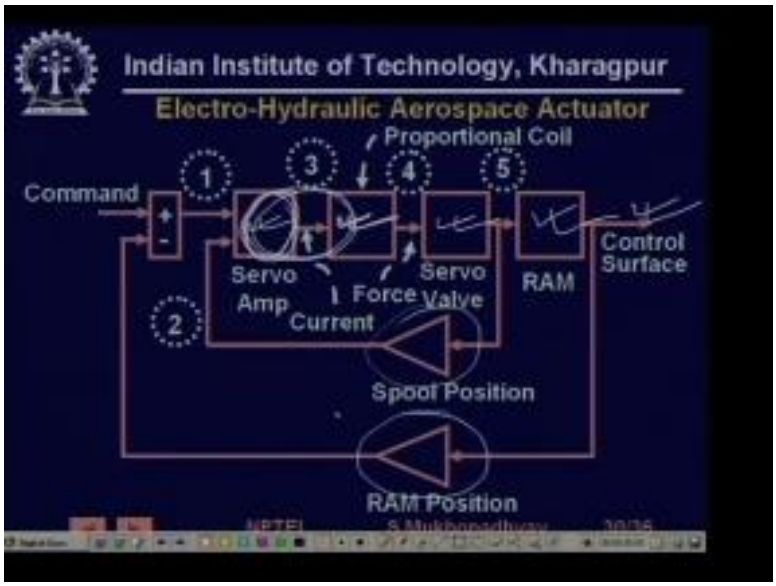

Because these are very precision control devices generally so this it is important to understand the dynamics because there is so much load acting on it that so much force acting on it that this dynamics can actually affect for example in an aircraft the dynamics of the act is very important. So in an electro-hydraulic aerospace actuator you have you have a you have a similar block so you use you can see that you have this is the final say control surface this is a typical actually used in aerospace very precision actuators this is the cylinder which is sometimes called a ram this is so the cylinder is driven by a servo valve the servo valve is driven by a force motor and the force motor this is the coil which drives the spool of the valve and that is driven by a but the electronics, and the servo amplifier.

So there are various feedbacks there is a current feedback which is which is inside this which is inside this force motor current is sensed and fed back Bo here then there is a spool position feedback of the hydraulic servo valve spool and finally there is a ramp position feedback of the of the actual control surface.

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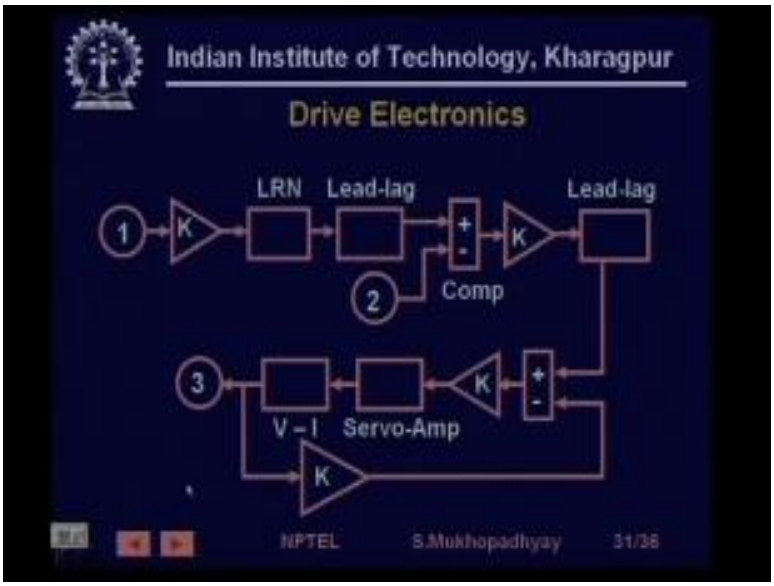

So these are connected in cascade loops you can see there we will not do it in much detail but the typical drive electronics so you use all that i wanted to show is that you have to certain elements for example you have to use servo amplifiers and v2 I converters and then you need variouskinds of filters because specifically because you do not you want to avoid giving inputs to your system which may cause things like resonance so for that from that point of view you have to you have to cut out certain frequencies in your input and that is why you need various kinds of notch filter so this is this name is a load resonance notch.

So if you are carrying molten steel using a hydraulic system then there is not natural frequency if you give input at that frequency than the molten steel with spillover so to cut out that frequency is that as you are transferring there will be no there will be no waves created in the liquid steel or whatever for these purposes certain frequencies of inputs must be cut out so this is a typical loops.

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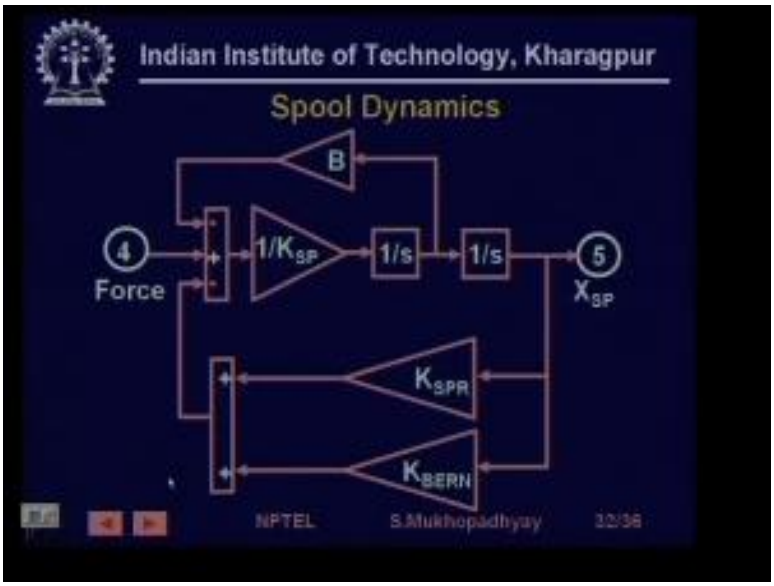

If you see the spool dynamics it is very simple there is some force acting on the spool which is created by the coil this creates a certain amount of acceleration so this is acceleration this velocity so you have friction feedback and then this final is full position and you have two kinds of feedback wise that you can have a spring sometimes we have seen that we have centering Springs connected so you have spring force and you have a Bernoulli force which is which is occurring on which is a force on the spool because of that fluid flowing through the valve so then some force acting on the spool so these act as feedback elements, So this creates the motion of the spool.

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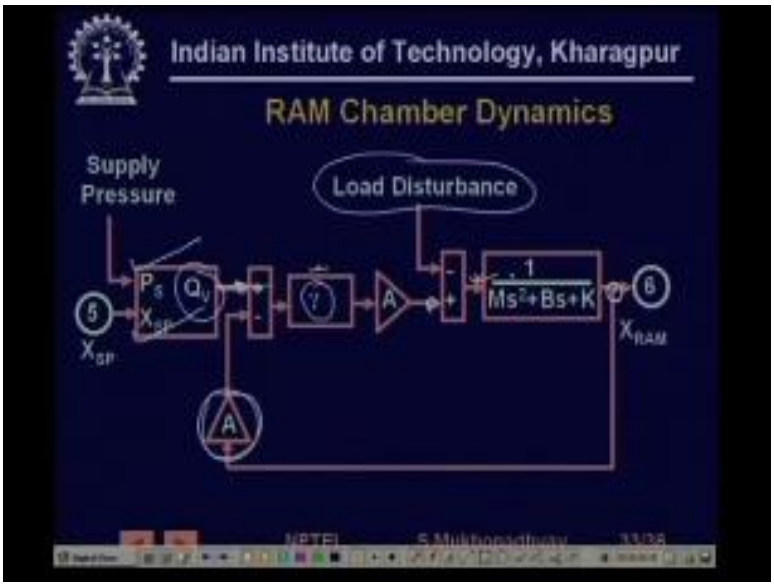

Similarly, in the ram the motion of the spool the flow into the ram depends on this the depends on the supply pressure and the spoon so you see that this is the inlet fluid into the ram and what is the outlet fluid if the motion of the ram is x ram and this is the area of the cylinder then this is the fluid which is going out so there is a little difference finally and that difference actually causes what creates the force the force is created by the compression of the fluid so initially there is a little fluid filled fleet compression and because the bulk modulus is so high.

So that immediately creates a lot of pressure and that multiplied by area so you get the force that is the acting force on the cylinder there is a load on the cylinder also so the difference actually accelerates the cylinder and creates the motion. So this is the kind of dynamics that you have on hydraulic cylinders and they have to be precisely controlled.

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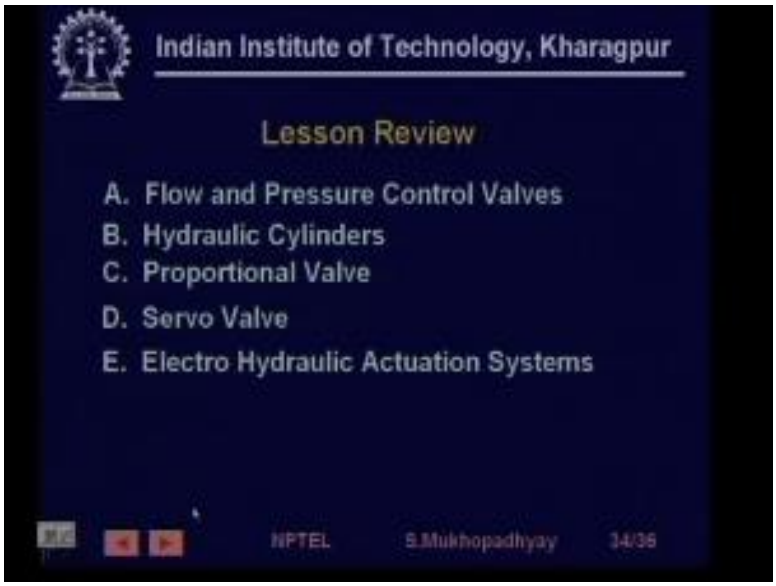

So we have come to the end of the lesson we have seen flower pressure and control valves we have seen hydraulic cylinders proportional valves servo valves and some hydraulic actuation systems.

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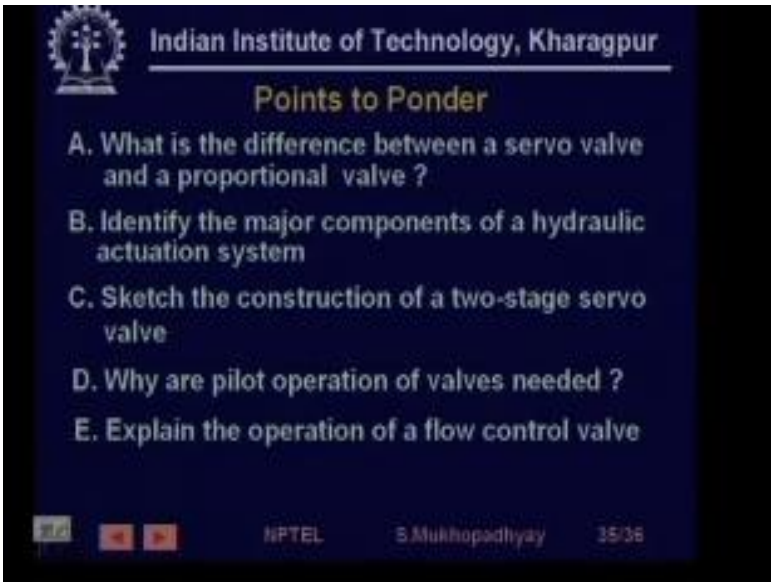

Last points to ponder yeah what is the difference between a salvo valve and proportional valve is it in terms of feedback is it in terms of performance accuracy returns in terms of structure drive what identify the major components of a hydraulic actuation system this is one of the major this question you should be able to answer because is the base one of the basic purposes basic instructional objectives sketch the construction of a two-stage servo valve this is going to take some time but think about it how it works.

Especially how the feedback come works why our pilot operation of valves needed can you think of some actual application and explain the operation of a flow control valve that is interesting how the flow is controlled irrespective of pressure variation by a mechanical arrangement so that brings us to the end of our lesson today thank you very much.