Control Engineering
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Lecture - 17
Models of Industrial Control Devices and Systems (Contd..)

Well, last time we had taken up hydraulic devices used in industrial control. I hope you will recall the two devices we had discussed in details. One: hydraulic linear actuator and the other electrohydraulic valve. These are the two devices we had discussed.

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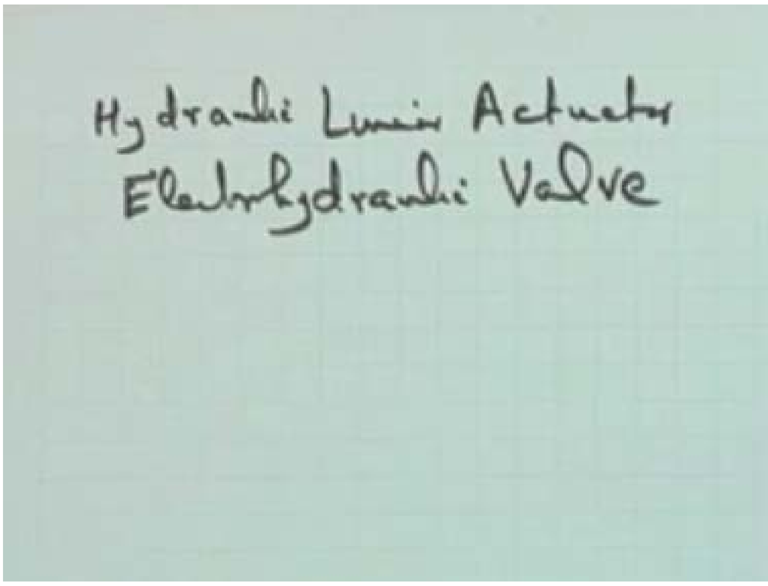

Electrohydraulic valve, as I had mentioned to you is a proper interface between an electronic controller and a hydraulic actuator which is selected on the basis of the power demand and other considerations. Now let me take a system a closed-loop system today using these devices. Particularly the hydraulic linear actuator I will show that its use in industrial control is in abundance and some of the very common applications will come before you.

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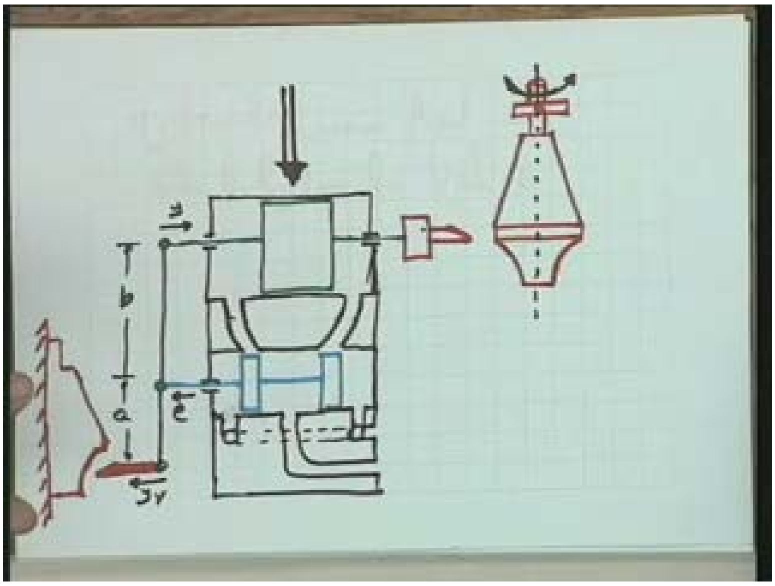

Here I have an example a machine tool control example. You just see, it is very simple, follow up the feedback principle in this particular example. This is the scheme which is used in practice. In this particular case here is my work piece. this is the work piece and this is rotated at a constant speed and here is the tool; the idea is this is that the depth of the tool, you see that, please see the requirement, the depth of the tool should be controlled in accordance with the job to be done and the job to be done is shown on a template.

So, actually I want that this work piece profile should exactly follow this template. So it means the template is a command and this command is to be reproduced on the work piece and in between I have the servo mechanism whose action we have to see. See this requirement, once must be seen; what is your standard way of saying what is command input? In this particular case command input is y r. So how do you set this y r? You set this y r on the basis of this template profile. I can say that this is my constant carriage speed. it means this (Refer Slide Time: 3:28) whole assembly is moving at a constant speed, please see, linear; this whole assembly is moving at a constant speed which is going to set the command signal y r depending upon this profile.

I can say that, well, there is a spring over here whose tension can be suitably controlled. This arrangement is there. Now let us see how does this system work. assume that in this particular case y r is set. But before I give this description I hope this will recall, this is your power piston here, here is a spool valve, this is your high pressure oil and this is going to drain to the reservoir. So, these two are obviously the control ports. So it means the oil to the control ports is going to be suitably controlled by the moment of spool which is going to move the which is going to control the power piston motion and hence the load.

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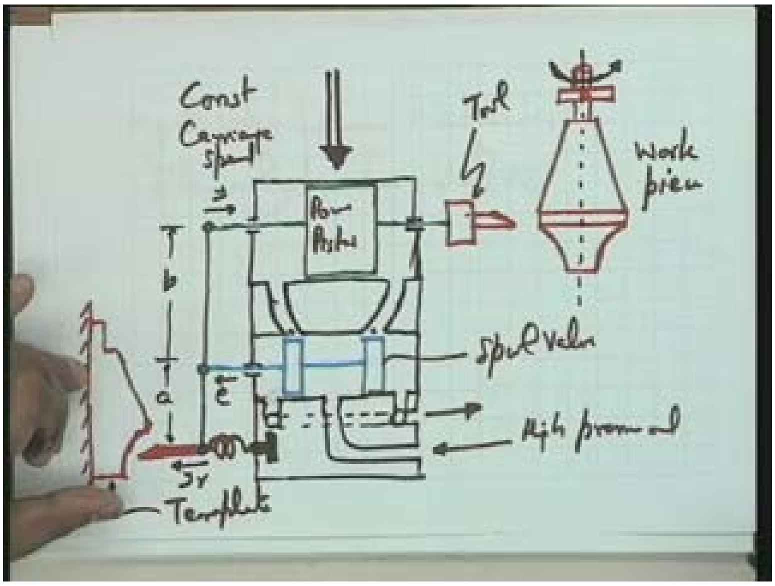

The load in this particular case is the load of the tool the associated friction and how about the disturbance. Please see, the reaction force on the tool is going to provide the disturbance on the system and the reaction force will depend upon the job to be done, the hardness of the material and so many other factors and therefore the reaction force is uncontrolled and will act as a disturbance on the system. I repeat over here that; as far the load is concerned the load is the mass m, the friction frictional environment for this particular moment b and the tool reaction force and the tool reaction force will be considered as a disturbance on the system. This entire carriage is moving with a fixed speed and with this moment of the entire carriage the y r position will change, the y r is your reference displacement for the tool. Now please follow up the action. Yes please.

[Conversation between Student and Professor – Not audible ((00:05:46 min))]
The carriage, yes sir, yes, it is moving in this translational with constant speed and that speed is set depending up on the total the speed of response of the system. This is a constant rotational speed for the job; these points must be clearly understood please so that you get the feel of the system. This is a constant rotational speed for the job so that you get the profile all around. This is a profile only shown y r and here you will be able to get this profile which is cylindrical in nature. This is the constant speed over here and here is a constant carriage speed, it is not in the feedback mechanism this or equivalently you fix this and you move your template. It is you who require the relative motion between the two; between the template and this particular assembly so that y r can be set according to the profile. This is a way of the giving an input and one can have different ways of giving the input. in this particular mechanism I have shown you, well, in this particular case no, you will have to move this and not the template, please see because the tool is to move like this, the tool is to……. any alternative which comes to your mind please, any alternative which comes to your mind help me.

Can I move the template and the job then I can keep the assembly constant. Please see, I will have to move the template and the job in a linear in a linear motion then I can keep this assembly constant because I want this particular tool position this particular tool to cut this particular job as per the template profile. is this alright please with you that an alternative arrangement is possible but this arrangement works better in this particular case, movement of this particular assembly is required.

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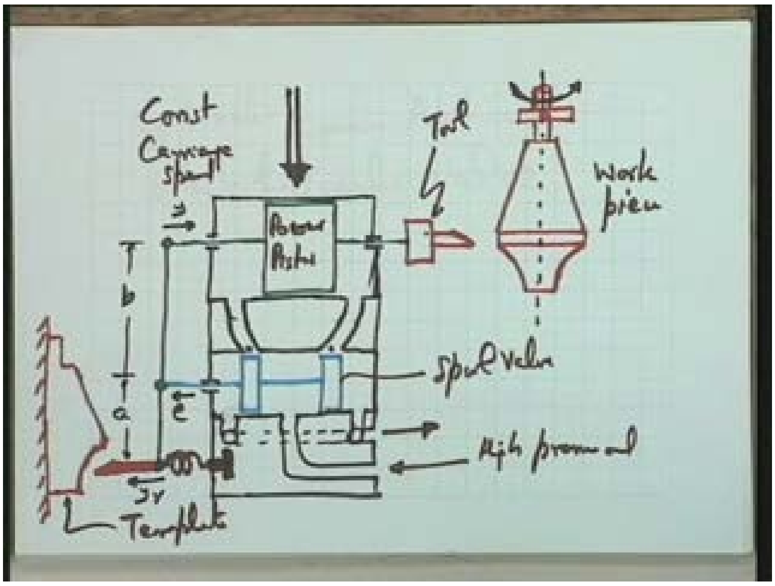

Yes, this assembly will move at a constant speed. So, in this particular case please see, one point must you must note that is why I making a mention power piston. So it means the weight of this piston is going to be much higher than that of this spool. Now help me, if suddenly a y r demand comes on the system let us say from an initial equilibrium position, this let me say as the equilibrium position, from the equilibrium position the y r demand comes on the system what will happen; in that particular case my claim is this that this point (Refer Slide Time: 8:11) will act as a pivot immediately because this is a heavy piston and the movement of this particular point immediately instantly will not be possible.

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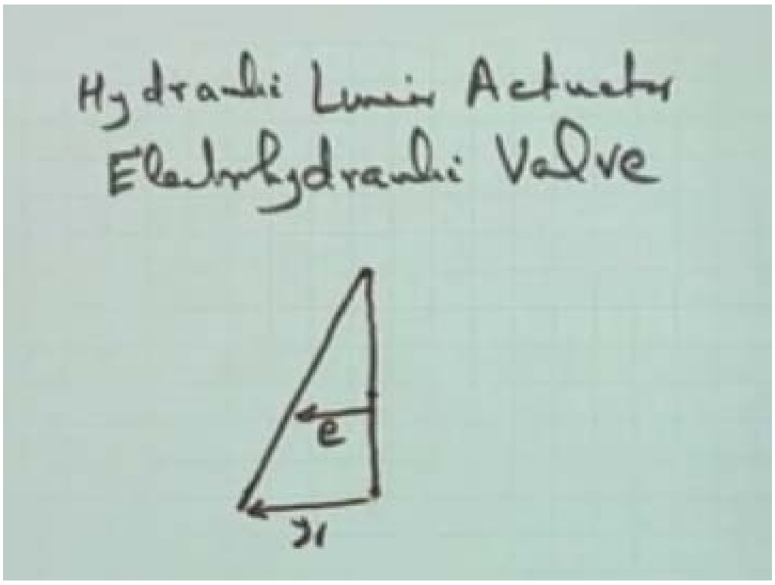

So I will put it this way that, if this is the equilibrium position these are the three points and suddenly a y r comes, this the y r demand and this lever will take up this position instantly because the power piston will await will provide a pivot to this and the movement of the power piston immediately will not be possible. So it means, with respect to this there will be an error e. Now what is this error doing? This point (Refer Slide Time: 9:01) moving in this particular direction it may spool is going to move to the left, help me please what will happen, what will happen to this particular port? When the spool moves to the left you find that this port is opened to the high pressure oil and this port is opened to the drain. So it means, as soon as this moves to the left high pressure oil rushes to the left side chamber of the power cylinder. I can say that this total unit is a power cylinder. So, if the high pressure oil rushes to this particular power cylinder in that particular case the power piston will move to the right and hence a new equilibrium position will come where the forces will balance.

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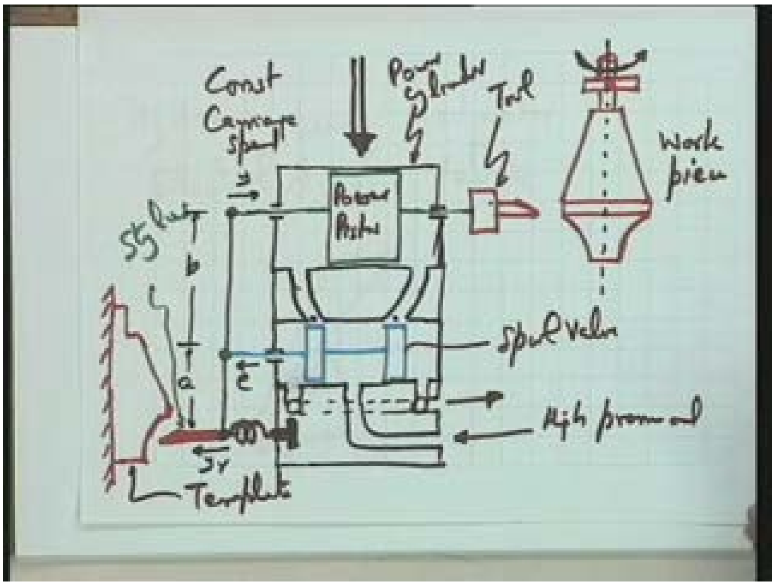

Now let me assume that the new equilibrium position is given by this diagram of the power piston, this diagram of the this particular position of the lever.

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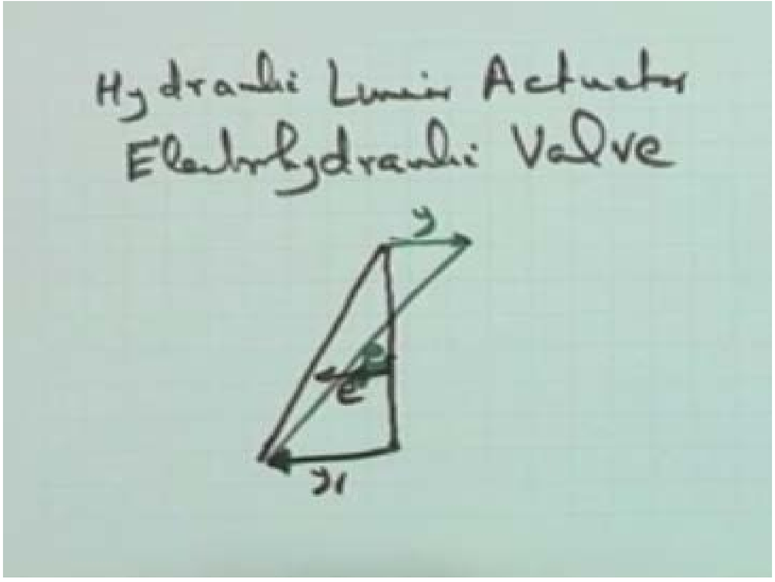

So you can see that this is the net position, y is going to move by this amount, e is going to move by this amount when y r is the input this system by this amount. This point, I again need your attention before i give you the mathematical model of this particular system. As soon as y r because of this, movement of this stylus, this is the stylus, this is the stylus please, as soon as this stylus moment on this template gives you y r this particular point is going act as a pivot and hence the lever will move this way (Refer Slide Time: 10:51) pulling this particular spool this way. As soon as this spool is pulled this way the high pressure oil rushes to this side which moves the power piston this way and hence there are two forces on this particular lever: One force is in this direction and the other force is in this direction. So the net position of the lever will be given by the position where the forces is appropriately balanced and hence I say I assume that this is the balanced position of the lever. And from here I see how the mathematical diagram mathematical model can be obtained.

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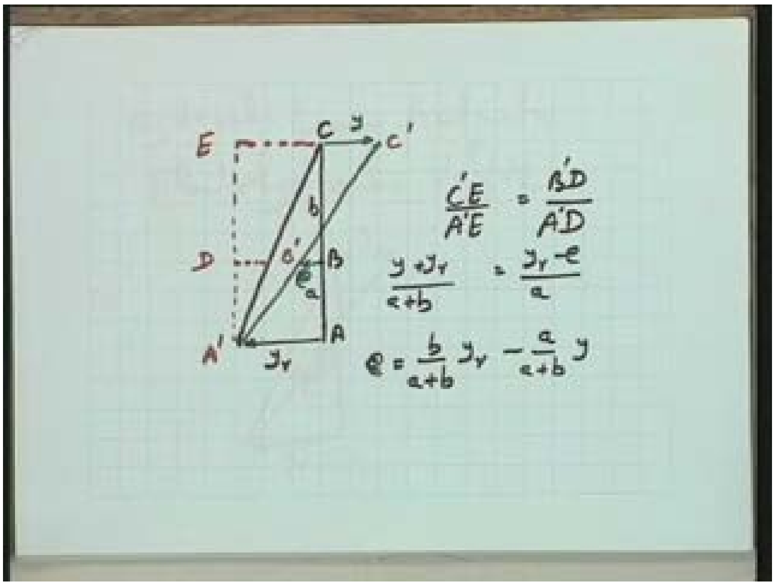

The balanced position of the lever is given as this. You see, from this particular diagram a dash is this position and a dash b dash c dash is the new position of the lever let me say that I call this as position 1, this was the intermediate position, position 2 and this is the final position, position 3 these are the three positions. Look at this triangle now. If you look at this triangle what I have done is c dash e what is this distance divided by this distance is equal to this distance divided by this distance I have taken (Refer Slide Time: 12:04). So what is c dash e? c dash e as you find is nothing but y plus y r; this is y this is y r and how about a dash e? It is a plus b where a and b are the two dimensions of the lever with respect to this spool position; a and b are the dimensions with respect to the spool position. So this is equal to…… look at this quantity please; this quantity that is b dash D is equal to y r minus e should be clear from the geometry; y r minus e is equal to b dash d and about this distance this distance is equal to a and therefore e in terms of y r and y is given by this expression and hence the lever is acting as an error detector.

So far you have seen an Op-Amp acting as an Error detector. So many other devices we have used: a potentiometer acting as an error detector; in this particular case a mechanical system a mechanical unit is acting as an error detector though the constant of proportionality is not the same in this case. In this case you find the error e is equal to a constant K 1 into y r minus another constant K 2 into y where K 1 and K 2 are different and they depend upon the geometry of the lever. I hope this is alright and it does not need any elaboration. I am going to use this particular expression that is this error detector equation in deriving the overall the mathematical model of the system. If there is any question I like to welcome at this stage.

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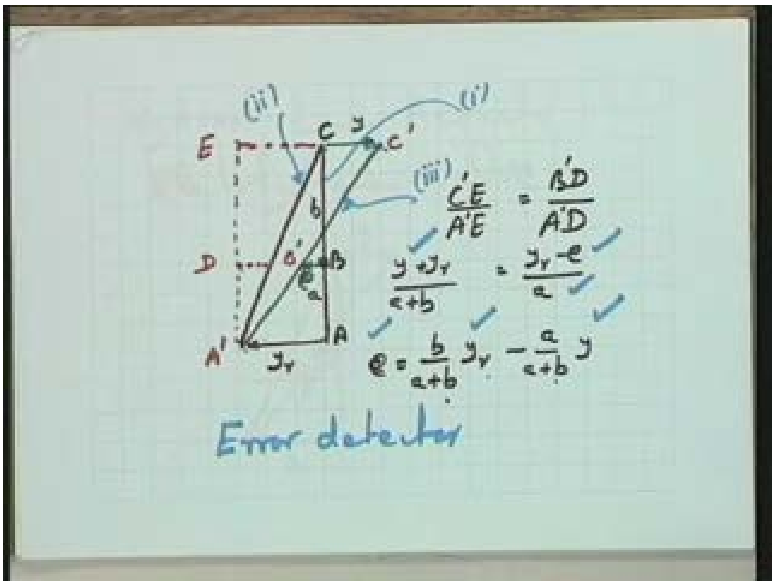

Is it okay please? Fine then.
[Conversation between Student and Professor – Not audible ((00:13:56 min))]
Okay fine. So this error if I write in this expression this particular this thing can be written in this way, here is an error signal e I am putting a block over here b over a plus b and here is the reference command y r, here is a block which is a over a plus b and here is a feedback signal y plus minus this generates the error signal. This is what I am going to use when I give you do overall block diagram of the system. I hope this is okay now. Fine.

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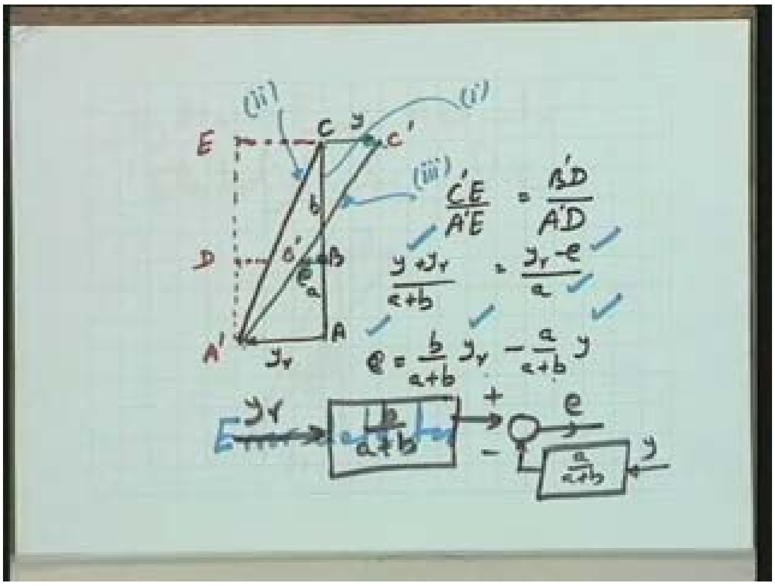

Before I give you the block diagram, rather you should be able to do it yourself now immediately. See the action now again; the error e, let us follow the total signals (Refer Slide Time: 14:59) the error e has been generated on the basis of reference signal y r and the feedback signal y. this error, what is action please; you recall the equation: depending upon the moment of this spool and depending up on the pressure difference across the piston there is going to be a fluid flow; depending upon this particular moment e and the pressure difference del p across the piston there is going to be fluid flow.

Recall the equation, the equation was: K 1 into e where x earlier was taken as the spool movement and now it is e the variable e minus K 2 into del p where del p is the pressure difference across the power piston is equal to…….. come on, let me see whether you recall, come on, recall from your memory what is this expression equal to K 1 e minus K 2 into del p is the total flow in the power cylinder and this flow was taken as equal to q equal to a A into y dot where y dot is the velocity of the cylinder velocity of the power piston, A is the area. This was taken as A into y dot.

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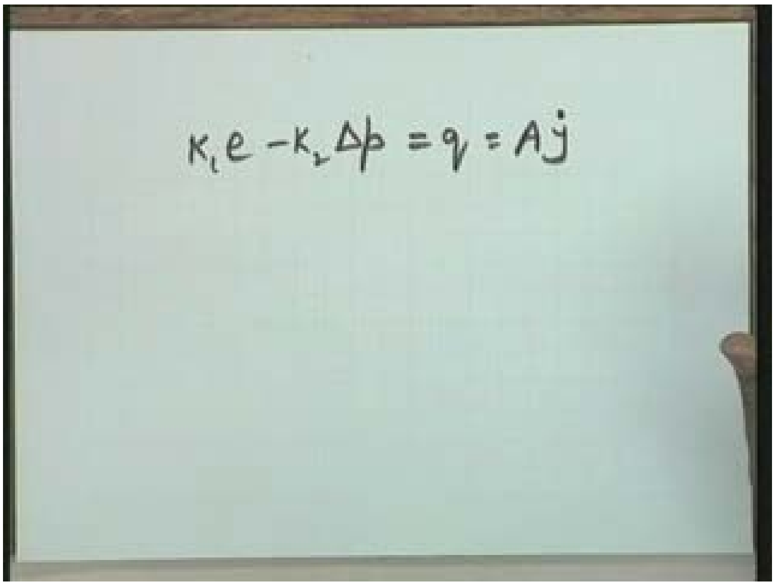

Another equation we had used: A into del p is the force on the power piston; this force is going do the necessary job and that is M y double dot plus B y dot plus F W these are the two equations and in addition today you have derived an equation e is equal to b over a plus b into y r minus a over a plus b into y that is all. These are the three basic equations which describe this particular system and based on these three equations we can now draw the overall block diagram of the system please.

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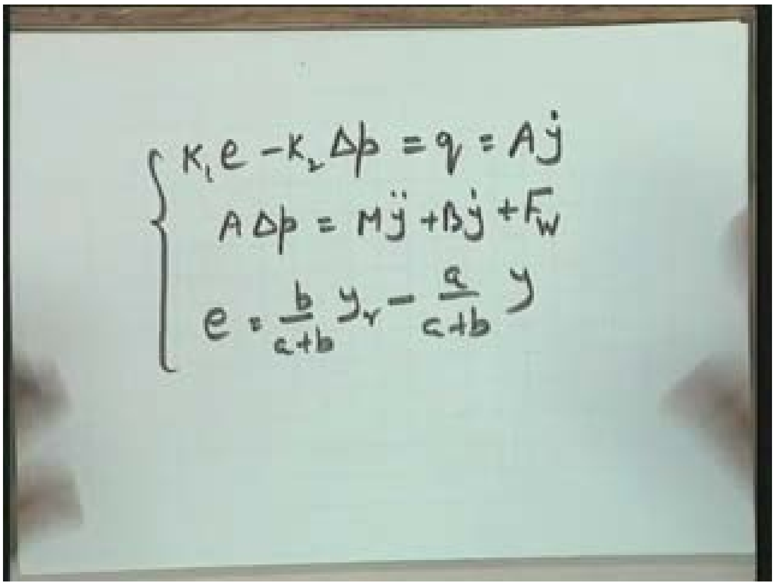

Come on please; make an attempt for the overall block diagram of the system. This is y r here b over a plus b plus minus a over a plus b here this is y I will generate it suitably. this is e signal here, please follow through and tell me if there is an error K 1 e from here I am going to subtract A y dot so let me have an A here and I will bring this signal from y dot keep in mind; K 1 e minus A y dot is equal to K 2 del p. so what I do here, this, I put a block A over K 2 this is going to give me a force; look at the equations you might have written in your notes; if I have a block over here A over K 2 this gives me the force variable. This, I can have a disturbance variable at this point F W (Refer Slide Time: 18:09) this is net force which is being used to move inertia against the viscous friction. so here in this particular block I can have 1 over Ms plus b this gives me y dot this y dot can be picked up from over here from here and I can put it here and here I have 1 over s and this completes the total block diagram please which is identical to the type of systems we had, the type of block diagrams we had in electrical systems.

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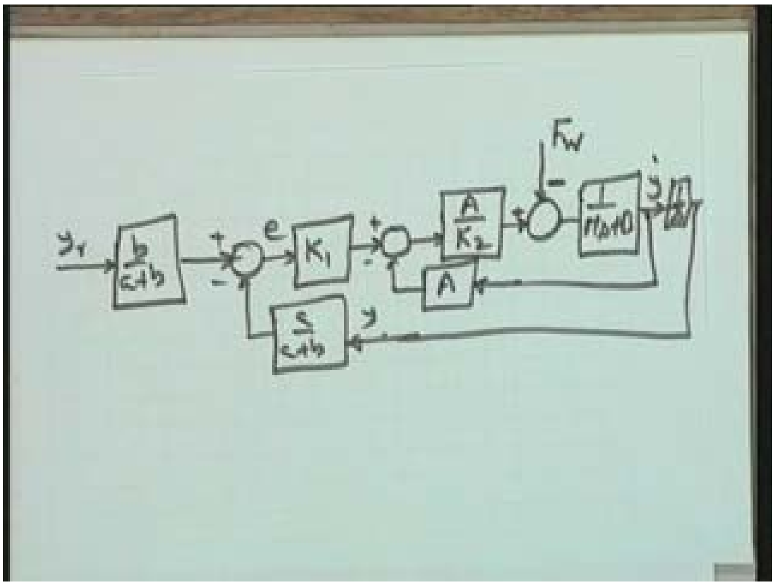

You see that as you know the transfer function of a linear actuator is an integrator and a simple lag: K m over s into tau ms plus 1 we have derived which is similar to that of an electric motor. as far as working of this system is concerned its analysis and design it is going to follow the same pattern but the basic flow of information is different; the basic devices used are altogether different and you must see what are those devices and how they are used in a particular application. Any question on this end on this example please before I proceed further. [Conversation between Student and Professor – Not audible ((00:19:20 min))]

Come on; say it loudly if there is a question. Fine then.

Let us say that, to just give you a feel of hydraulic hardware, this I take as the tool (Refer Slide Time: 19:47) and in this particular case I use an interface the electrohydraulic valve between the actuator and an electronic controller, come on. The purpose now is, in this particular example we have discussed so far there was no interface the electronic controller to hydraulic actuator, in between there was no device. Now I am going to use a device an electrohydraulic device which acts as an interface between the actuator and the electronic controller. I feel there has been some problem in making the nodes it appears. You could make it or there was any difficulty?

[Conversation between Student and Professor – Not audible ((00:20:24 min))]
In that case do you think that you could you go could go to the library and take a look on it or I should bring the xerox copy of the typical drawings? Okay okay okay, I will take care of it next time onwards.

So, in this particular case please see, now I am making it and hence there should not be any difficulty. I am making it just before you. In this case this is the power piston power piston and this power piston I connect to an LVDT. Now, to this particular power piston let me say that I connect, let me say that to this piston I connect a servo valve which is the hydraulic valve and this is an electrical signal coming to this particular valve (Refer Slide Time: 21:55) and to this particular valve you require a hydraulic supply. You recall; you will have to recall the valve now that you had a hydraulic supplied to this particular valve and the signal in this particular case was an error signal which was electrical in nature and the output of this particular case was the spool displacement, the output so these are the two control ports you see for this particular diagram. These are the two control ports; the complete configuration the complete inside of this servo valve is not being reproduced.

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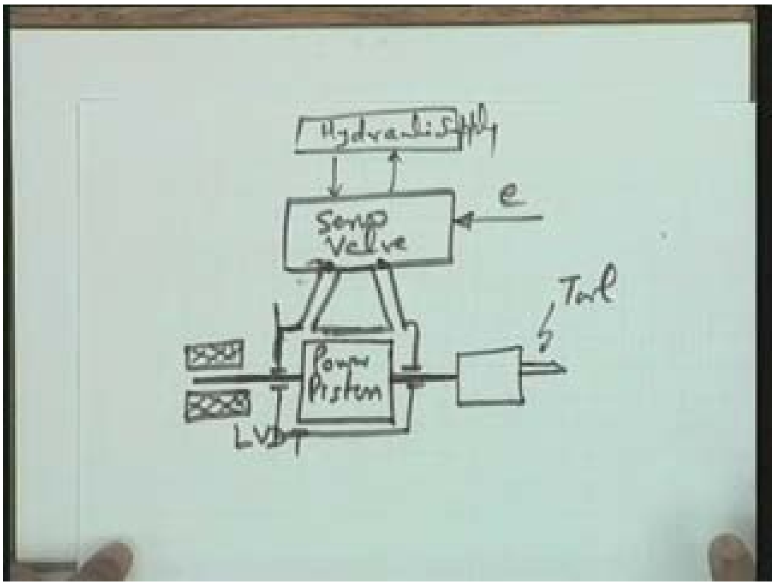

You look at the function of this particular block; an electrical signal a voltage or a current signal is the input which may represent which normally represents an error signal. Corresponding to this electrical signal you have this spool displacement and depending up on this spool displacement you have the power piston movement and this power piston movement is going to move this particular tool.
[Conversation between Student and Professor – Not audible ((00:22:59))]
Yes, I am going to complete it because the feedback part is not yet complete. I am going to complete this diagram now.

Now let us see that this LVDT what it is doing? Did we not discuss LVDT? I think we have discussed LVDT.
LVDT is a device which gives you an electrical signal an electrical voltage proportional to the linear motion of its core. You see your notes and you will find over there that we have discussed this device. This output of this device if you recall is a modulated signal; we can use an appropriate demodulator so that envelop is extracted. I am assuming that appropriate signal conditioning has been done and I have an electrical signal which is proportional to the movement of the power piston which is the core of this particular LVDT. So, I have an electrical signal here now which is proportional to the tool movement. Now this electrical signal, come on suggest, suggest the completion of this diagram now. Yes, this is a feedback

signal now which is electrical in nature and I want to complete this diagram and make a suggestion as what type of other device is required so that this total system has now an electronic controller and a hydraulic linear actuator.

[Conversation between Student and Professor – Not audible ((00:24:17))]
Yes please, come on. Suggest some devices so that this particular diagram this particular feedback loop could be completed. E-H electrohydraulic valve I have already put, this is electrohydraulic valve. Servo valve I am putting is an electrohydraulic valve which takes electrical signal as the input and generates a spool movement as the output, this i have already used. Electrical signal is the input and this spool movement is the output. come on please with the input given to you should able to give an idea.
[Conversation between Student and Professor – Not audible ((00:24:54))] yes, a differential amplifier will do the job. This is an electrical signal here, what you do is in this particular case you have a reference signal which is electrical in nature. Whatever displacement is needed, for example, please see, your tool movement can be suitably programmed into a computer whatever tool movement is required.

Depending upon the profile of the job, this point may please be noted, this what is done in today's computerized numerical control systems, depending upon the profile of the job you see the tool movement can be suitably programmed. This is stored in your digital computer and using suitable conversion of digital analogue signals you can generate a voltage signal here so that this voltage signal corresponds to the required movement of the tool.

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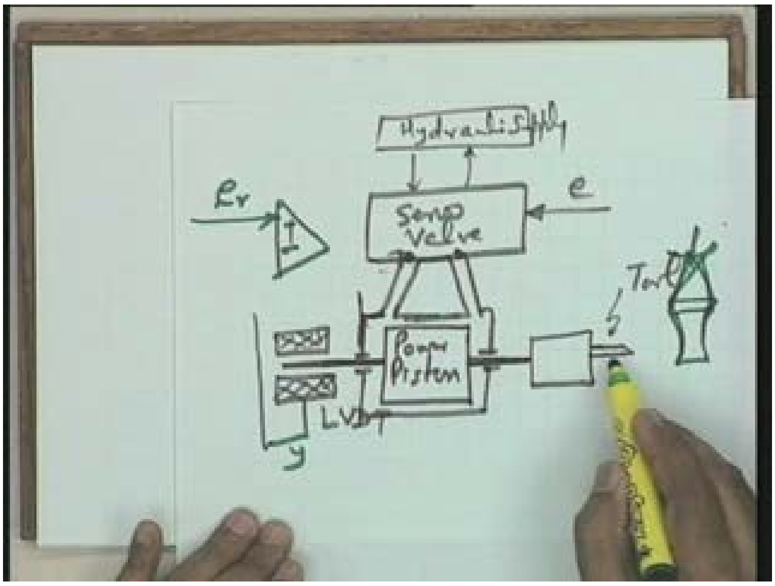

So, whatever may be your method of command signal generation I say that this e r is a voltage profile which corresponds to the desired movement of the tool and hence which corresponds to the desired profile of the job. Here, whatever job is to be done it is translated into e and the requirement of this is this that this particular tool (Refer Slide Time: 26:15) should follow this particular command which has been translated into a voltage. As rightly been said the feedback signal in this particular case is e 0 which is proportional to y. this e 0 is proportional to y, y is the movement of the tool or which is the movement of the core of the LVDT.

Now this signal has been generated, take away this and this signal becomes the input to the servo valve and hence this completes your electrohydraulic control system in which instead of lever, you see, in the earlier case your lever was acting as an error detector and in this particular case an operational amplifier is acting as an error detector. The advantage is not only limited to this that a lever has been replaced by an operational amplifier; the advantage is much more than that. Actually, to have a suitable motion over here you will require a suitable type of PID controller. Realizing a PID controller using a mechanical or hydraulic hardware is going to be less accurate and more difficult compared to an electronic hardware. So you will simply replace this amplifier or you will simply enhance this particular Op-Amp circuit to include the necessary PID features which are required which are appropriately required for a control action, this point be please be noted.

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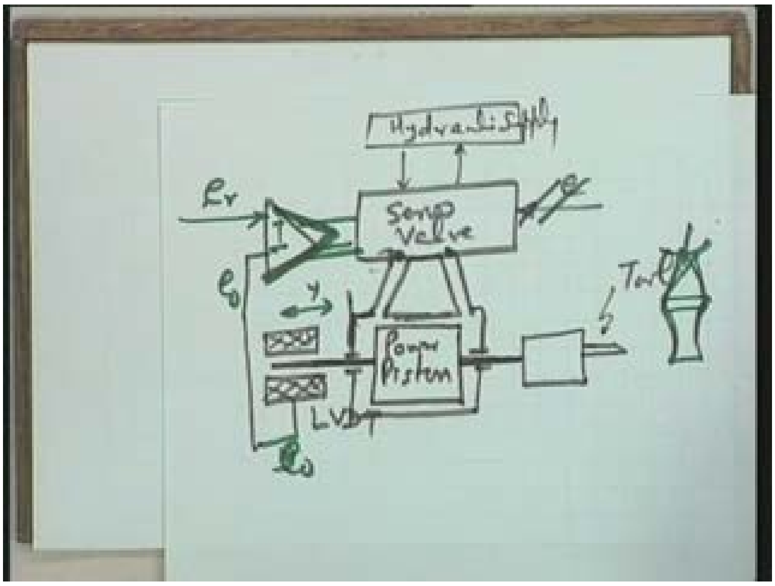

The advantage is not limited only to replacing the lever by an operational amplifier. The advantage really effectively comes when we come to the design of this particular system. This is not the design; this is only a layout giving you the total hardware configuration of the system. This is what will be given to you before you take up this design. That is, I am going to take one more hour tomorrow's hour on the hardware and after that only the true job of the control engineer will start.

You will find that with this hardware configuration available to you your job as a control engineer will start and you will have to design a suitable control function (Refer Slide Time: 28:23) which will act on the error signal and that control function is going to give a suitable control on the manipulated variable so that the output follows the command without any transients and with as good a static accuracy as possible .so the interface of this particular electronic controller and the linear actuator through a servo valve is a very important feature when we come to actual design of the system.

Well, I hope you got the feel of this and the last phase of my discussion on the hardware is to give some feel of the pneumatic devices also. We have discussed electrical devices, electronic devices, hydraulic devices, electro-mechanical devices, pneumatic devices very much used in process industries. By process industry i refer to the applications of temperature control, the pressure control, the liquid level control, the composition control and so on. These are the applications which come under process control applications and pneumatic devices are used in these applications quite extensively.

Let us see the reasons you see. One of the primary reasons is the simplicity. Well, air can be exhausted to the atmosphere you do not need the reservoirs, is available in abundance no problem of hydraulic fluid as you require in hydraulic devices. What else; what could be the other advantages? Probably non inflammable is also one of the important advantages of the system, what else please? Viscosity of air is negligible compared to that of the hydraulic fluid and the viscosity of the hydraulic fluid changes with temperature and hence the performance of the hydraulic devices may change with the environmental changes.

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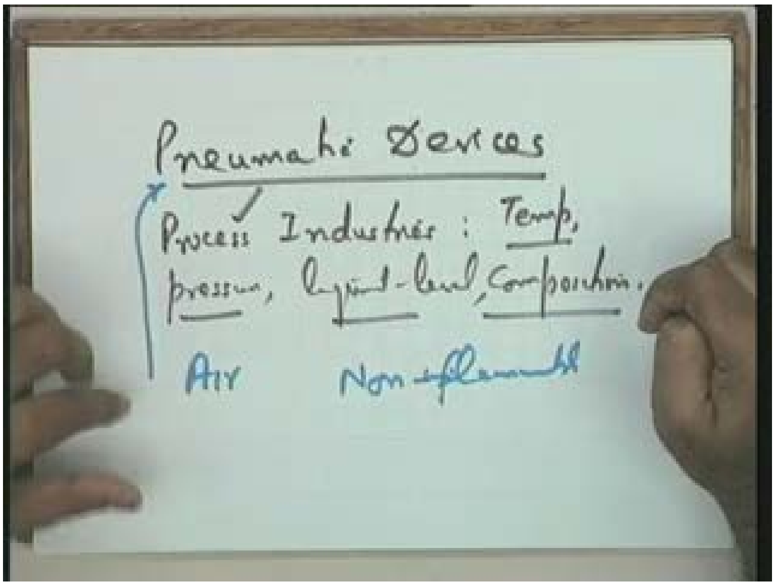

In this particular case, fortunately, that situation does not occur because viscosity is negligible. So everything is really not rosy about the pneumatic devices, there is a problem. Hydraulic fluid is incompressible therefore the force wave can travel very fast and that is why I made a statement that hydraulic devices are fast acting devices. Well, in the case of pneumatic devices compressibility is a very important attribute and because of this time delays occur and therefore pneumatic devices are not fast acting devices. I need your attention please; pneumatic devices are not fast acting devices because of the compressibility feature of the air. So it is because of this you see the pneumatic devices are used primarily in these process control applications because all these applications are slow in nature. And if these applications have got large time constants, if these systems have got large time constants in that particular case on relative basis pneumatic devices can be effectively used.

Your attention may please be needed, here I need; these devices are not used in motion control examples. For example, in position control you do not need, you do not use because these are slow devices. But the process control applications are dominated by large time constant factors and it is because of these reasons that the pneumatic devices are extensively used in these applications.

One of the very simple device though I have a slide but I think I will make it, I will try to make because otherwise you face difficulties. Most common device is this one; please say I am making a valve, flow control valve, I hope the picture may not be very nice but gives you an idea. Let me remove it from here and give a packing here. Well, this is your fluid in and this is the outlet of this (Refer Slide Time: 33:54). Here is a stem the valve stem and this is referred to as the back plate and here is a diaphragm and an error air signal here at a suitable pressure.

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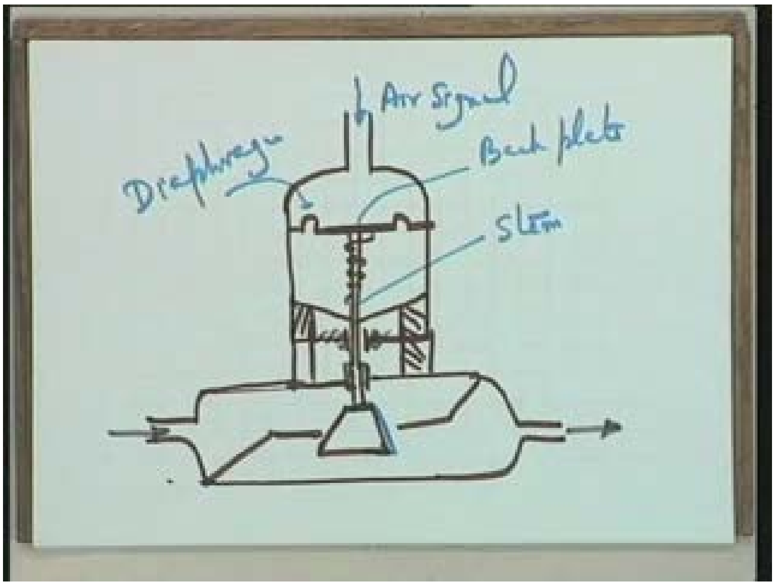

Come on please, you can just see, in this particular case you are simply controlling the opening of this particular valve. This is the control valve; this complete unit as a full assembly is commercially available and this complete unit is so extensively used in the process control applications that your attention is very much needed over here though we will make many approximations to model this particular device. So in this case you just see, the air pressure is the manipulated variable, the air pressure, this is the air signal coming so the flow is being controlled, the output flow in this particular case is being controlled by controlling the air pressure. this air pressure, let us say there is a increase in the air pressure, if there is an increase in the air pressure (Refer Slide Time: 35:16) then this particular stem will move down and the movement of this is resisted by the opposing force due to spring; a balanced situation will come at which this particular stem will have its steady position.

I need you attention please; when there is an increase in the air pressure this particular stem moves down and the balanced force the balanced situation will come because of this spring. When this moves down this particular stem this opening is increased and hence the flow through this will increase, the reverse action. if the pressure decreases in that particular case because of the spring action this particular back plate will move up and hence the opening will reduce and therefore this flow will reduce and therefore you can say that in this particular case this particular valve is acting in such a way that the flow control the flow here is directly proportional to the pressure at this inlet point.

The device is highly non-linear because the flow versus this pressure rather flow verses the stem position and stem versus the pressure these are nonlinear relationships. but if you assume, if you consider that your perturbations are small around the equilibrium point around the steady operating point then a linear relationship is possible and you can say that if the stem position is given by x, if the flow is given by q in that particular case q is equal to K 1 into x and x is equal to K 2 into p where p is the perturbation in the air signal pressure of the air signal and therefore I can say that q is equal to some constant K into p so this air signal pressure is directly controlling the flow q of the control valve.

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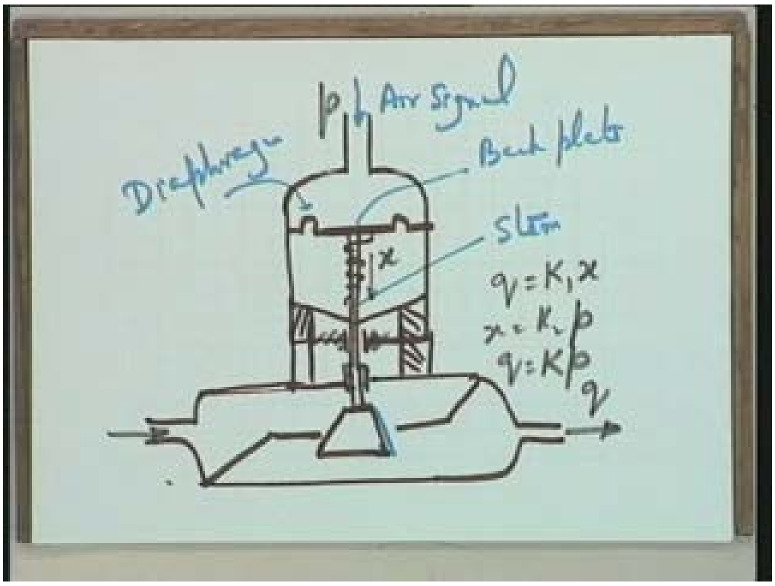

Again, at this juncture, I think I could raise a question. Could you suggest in alternative hardware to realize this objective, an alternative hardware? You see, your purpose is to control the flow and to control the flow you want to control the stem position and to control the stem position you have an air signal. It means a suitable air pressure signal will have to reach this point so that the flow is accordingly controlled. So my question to you is this that any alternative simpler arrangement which comes to your mind to control the flow in this particular case could be suggested. Yes…….
[Conversation between Student and Professor – Not audible ((00:37:58 min))]

Well, I give you an example; you will say it was so easy, surely you will say that. A solenoid, you see that in this particular case instead of having this total arrangement could you not move this particular stem with the help of a solenoid then where is the problem. Why not have a solenoid instead of this control valve? You see that when these control valves are very large in that particular case the power requirement to move this particular stem is high and solenoids normally are not able to provide that power and the air signal that is this particular device is able to provide the required power and in pneumatic in process control applications where large powers are required to move this particular stem normally air operated control valves are used and not solenoid operated control valves.

Any other alternative where the power requirement is also met with? Any other alternative please, recall your test problem. In that particular case in the minor test the problem was given wherein the valve was instead of a linear motion it was a rotary valve. So, in that particular case the required power was being given by an electric motor. So it was an electric motor operated valve, the error signal could go to the motor the motor generates the appropriate torque and that torque then operates that particular valve. The questions which came to your mind that day as to what is the load, please see that movement of this particular stem, the rotary in that particular example, the linear in this particular case itself is a large load. In the process control applications it requires large power and this is the load which in that case electric motor was driving and in this particular case this pneumatic operated device is driving. So it means this particular device has to generate suitable signal so that this stem is operated in a typical process control application (Refer Slide Time: 40:11).

Again you see, as we had in the electrohydraulic systems in hydraulic systems your demand of hydraulic actuator was there because of the movement requirements because of the mechanical motion requirements and your demand of electronic controller is there because of realization of the control function. Same is the situation here you see. You require a pneumatic signal and air signal because you want to use this pneumatic device for controlling this stem position you do not want to use a solenoid you want to use this particular device while your controller is going to be a digital computer or an electronic device. So it means in this particular case also you require a suitable interface between this particular device and electronic controller and so acting on the similar lines is an Electropneumatic Transducer.

The construction and working is so similar to electrohydraulic valve that I can avoid the discussion please. Electropneumatic transducer I will give you the block diagrammatic description. So this is the device. The input to this electropneumatic transducer is an electrical signal and the output is a pneumatic signal, electropneumatic valve sometimes referred to as electropneumatic valve.

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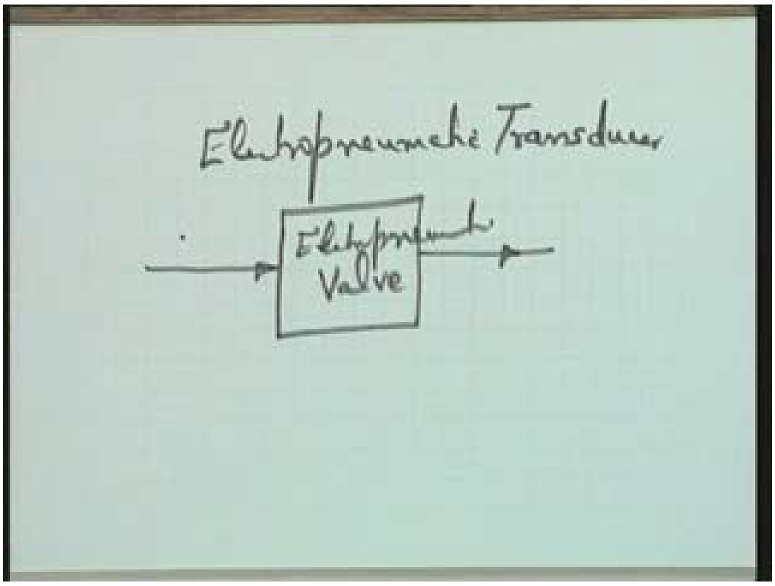

You see that this is again a must you see because if you want to cash on the power of digital computer or Op-Amp circuits for realizing your control functions you really require a compatible device between the control valve which we have discussed and that controller. This electropneumatic valve will accept input signal a voltage or a current signal and an output signal which is a pressure signal.

Now let me give you some industry standards here the type of electropneumatic valves available in the market. This is a device commercially available and we also have in our lab (Refer Slide Time: 42:37). this particular Typical signals are 3 to 15 psi pounds per square inch is the unit which is being used, 3 to 15 is the range of the output. It means, in this particular case, the control valve is also suitably designed after all this is a total unit. So the control valve this particular back plate the diaphragm and other components of this particular device are to be designed assuming that the input to this particular device is 3 to 15 psi, the signal which will be coming from an electropneumatic transducer.

So, accordingly, you see that it is a reverse designing, you require the range of flow, you should know what is the opening range you require here; accordingly you design your system so that with range of 3 to 15 psi g psi with respect to gauge pressure you should be able to realize this objective. So see, this industry standard 3 to 15 psi is a standard input signal which is coming to a control valve. So this is a standard output (Refer Slide Time: 43:50) of the electropneumatic transducer or the electropneumatic value.

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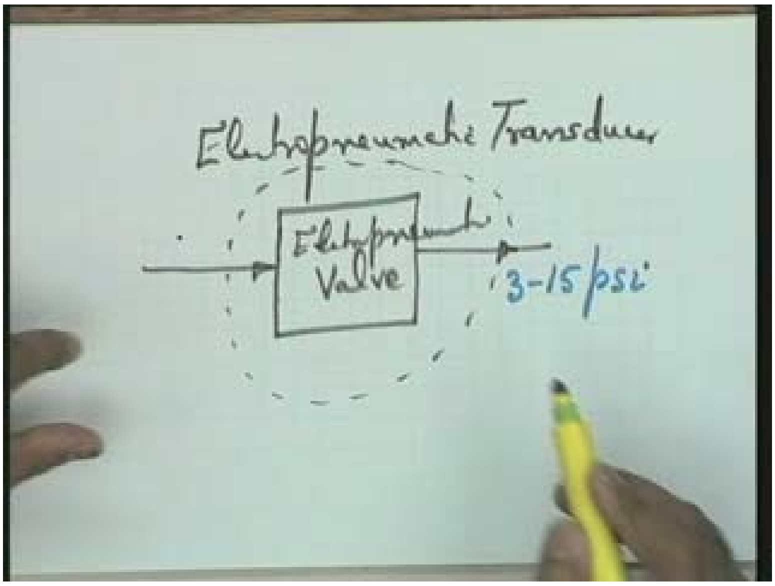

What is the input?
Input is an electrical signal typically let me say which could be in voltage or in current. So now it has been standardized in the process industry to 4 to 20 milliampere. So it is for you to generate a suitable interface if you have a voltage signal, if you have a current signal convert it to appropriate voltage signal in vice versa. So compatible voltage to current converters will be required by you so the industry is going to provide your device which accepts 4 to 20 milliamperes as the input signal and 3 to 15 psi g as the output signal and this is going to be provide suitable interface between the electronic controller and the pneumatic control valve to control the flow through a system.

Come on please; if you have got this very well you suggest the device now for this application. Really it could be a solution coming from you only. This is a heat radiator please. I have given you in a tutorial class the arrangement of heating a chamber with the help of a heater. Now I give you arrangement of heating with the help of steam and the hardware should come from you. A typical process control application please. This is your control valve (Refer Slide Time: 45:36) this is the symbolic representation; actually it is the valve we have now discussed; symbolic representation is like this that is you are controlling the opening of this particular valve so that steam input could be controlled and here is your condensate. So, heater replacement should be clear to you now. So it means this is the heat going into this particular chamber.

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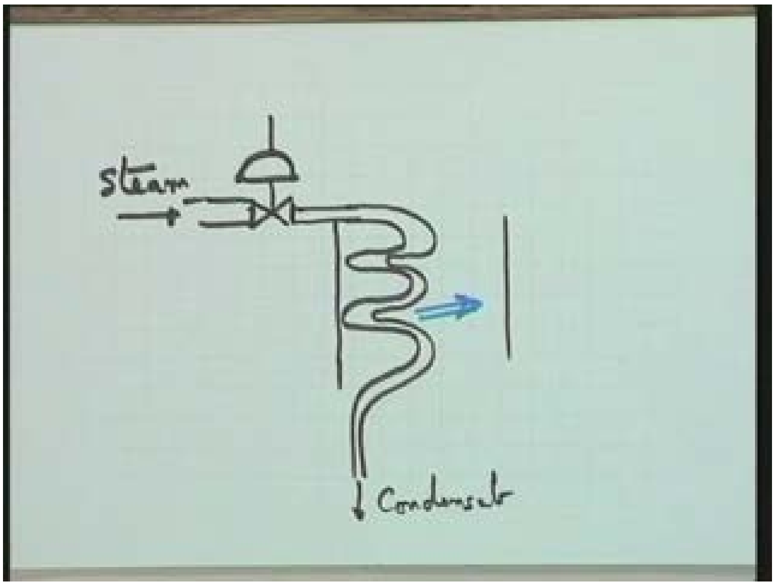

Come on please, suggest the devices. This is your continuously stirred tank reactor; take the input flow, let me take it here and let me take the out flow here and here is your stirrer. Here, let me say Q is the flow rate at a temperature theta i, the desired one Q is the flow rate at a temperature theta, you want to control the temperature theta. So you should give me the mechanism to set the value the command value of theta, theta i is the disturbance on the system; theta i is the temperature variation of the inflow liquid is a disturbance on the system. I want to control this theta and what is the manipulated variable the manipulated variable is this control valve position because controlling this particular position is going to control the steam and hence is going to control the steam flow rate.

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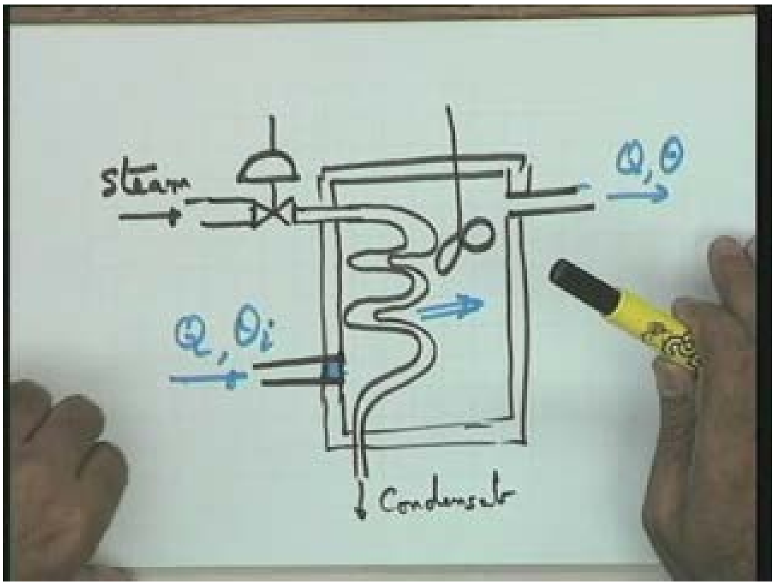

Come on please, suggest the hardware. I particularly want you to give me the flexibility of using a pneumatic control valve for controlling this particular position. So, if I proceed backwards for example, suppose I have decided that I want to go for a pneumatic control valve, so I think this picture is alright, I could take it here. So here I have Pneumatic Control Valve. So please see, this is the in this particular case the stem movement and hence it is controlling the movement of this valve.

What is the input to the Pneumatic Control Valve required?
Input to the Pneumatic Control Valve is a pressure signal p. Input to this Pneumatic Control Valve is p. Now this pressure signal p could come from Electro-pneumatic Transducer. This is the Electro-pneumatic Transducer over here, p the range you must see is 3 to 15 psi the industry standard, the Pneumatic Control Valve is giving you the movement of the stem by x and this x is controlling the flow q, this x is controlling the flow q. Now this p is being manipulated with the help of an electrical signal; this electrical signal is the signal which is coming from a controller the controller is an Op-Amp circuit, the controller in this particular case is an electronic controller which is an Op-Amp circuit.

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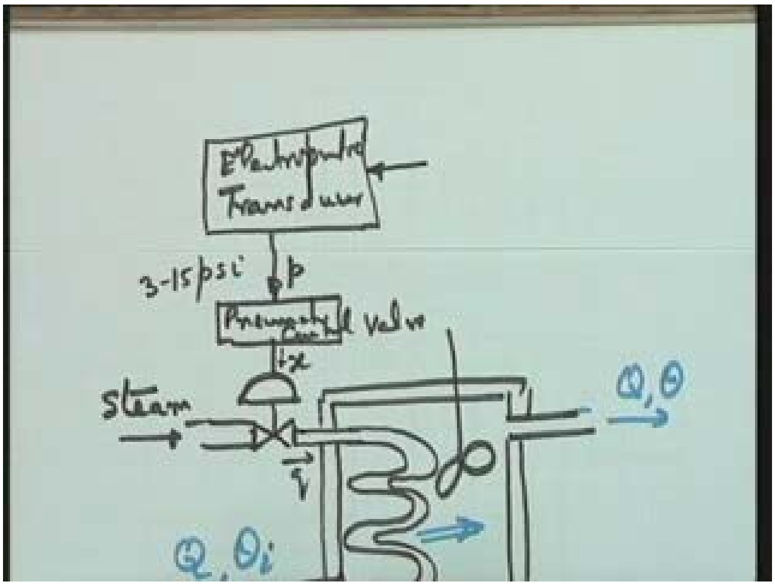

Come on please give me this completion now; come on let us take the sensor point. Thermocouple, thermocouple okay, we could take the thermocouple though the alternatives are there thermistor and other things are there but thermocouple is a very simple device so I am using a thermocouple here. The thermocouple will have to be interfaced to an appropriate signal conditioner because this voltage may be too low and secondly I need a current signal for transmission. So this is a signal conditioner (Refer Slide Time: 49:47).

Let me take this as a current signal; if it is a voltage signal let me convert this to a current signal there is no problem; voltage to current amplifier I can use. I can take this as a current single and the current rate is 4 to 20 milliamperes. So it means that design of this signal conditioner will have to…….. now you see that in the process control application your design is regulated by these industry standards. Depending upon the thermocouple you are going to use you will have to appropriately design your signal conditioner so that the output here is 4 to 20 milliamperes. Now this is going to be going to be compared with a 4 to 20 milliamperes reference signal. Now, again suitable voltage to current amplifier will be required. This effectively is a voltage comparison. But in the block diagram there is no harm if I take it as a current comparison. So this current here is your reference current which corresponds to your command signal.

[Conversation between Student and Professor – Not audible ((00:50:53 min))]
Now, since the signal conditioner constant will be known to me; so, as far as this is concerned this 4 to 20 accordingly will be generated depending upon; that is the signal the generating device over here will be in such a way that the current requirements are met properly; 4 to 20 it means yes you are very right, the signal at this particular point after amplification has to be of this range. So this total system will designed to meet that requirement; total system you are very right, the design of signal conditioner will be guided by other devices as well otherwise it may exceed this valve and this comparison over here is done in this error detector plus minus and let me say that I have an amplifier.

I am taking all in terms of currents suitable voltage conversions and comparisons are possible. So this is an electrical signal to the Electro-pneumatic Transducer which is generating the appropriate pressure signal and hence this becomes the total device which is very much in use in industry as far as process control applications are concerned. I think I am not too wrong in making a statement that almost all the applications today are being controlled this way through a pneumatic control device (Refer Slide Time: 52:34) and Electro-pneumatic Transducer interfacing this device either to an Op-Amp circuit or a digital computer. If not all, most of the applications are having this type of hardware, thank you very much.

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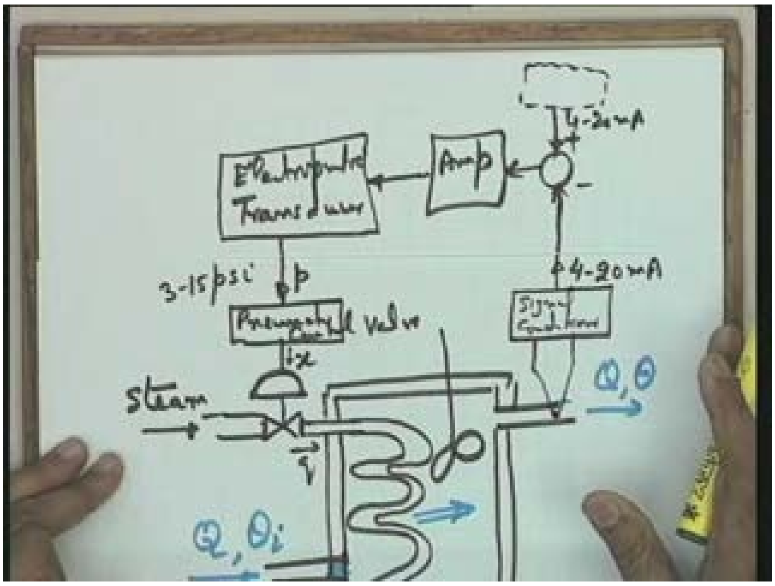

Yes, please………
[Conversation between Student and Professor – Not audible ((00:52:29 – 53:18) min))]
Which device?
It depends you see, most of the device most of these automobiles have hydraulic place which have fast yes…….. no it depends I mean you have to see the total action required, yes compared to the hydraulic or electrical devices they are slow I think in comparison they are definitely slow acting corresponding compared to electronic, electrical or hydraulic devices okay.