INDIAN INSTITUTE OF TECHNOLOGY
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NPTEL
ONLINE CERTIFICATION COURSE

On Industrial Automation and Control

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Topic Lecture – 43
Pneumatic systems-2
(Contd.)

We have seen different kinds of valves and we have seen how they are actuated we have also seen that you know they that they can be interfaced to for sophisticated actuations especially continuous movements they can be also driven by things like microprocessors now while microprocessors can provide logic sometimes you know simple logic can be provided by also by pneumatic elements.

so this is required in some specific cases especially where you have a big fear of explosion from electric devices like say let us say they said this is a natural gas plant they are using electric devices must be done with lot of precaution because one single spark make cause a big fire hazard an explosion similarly there are certain in some cases there are very hot environments where you know maintaining any kind of electric insulation is a problem.

So therefore in such application sometimes if the if the control logic complexity is not too high one tends to use pneumatic logic.

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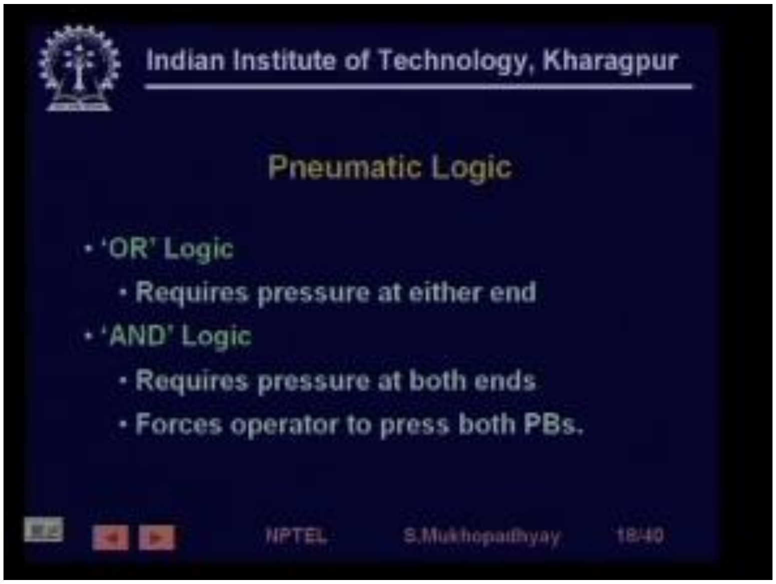

So you know so pneumatic logic no just a moment okay so we are back so okay ,so pneumatic logic means that we are basically trying to have realize you know some sort of a some sort of a digital logic so we need you know elements such as odd we need elements such as and so for example if you we can have all logic which will require pressure at either end for the air to flow into the system pilot pressure similarly if you have an logic then you will require pilot pressure to be applied at both ends simultaneously for the for the air flow to be connected to for the pump to be connected to the load.

So sometimes this and logic is used for safety applications where the operator is forced to press both push buttons so that his hand where it is operating pneumatic systems are very much used to assist operators in in operating various kinds of machines and sometimes you know there are safety hazards for example suppose you have two big roles in which the operator has to put some material typically such things are used in may be used in you know thinning out needing materials like in like in the production of tires initially rubber has to be needed before it can be molded in the in the form of attire.

So in such cases the it is to ensure that when the roll is rotating the operators hand is nowhere near the roll so that can be ensured very easily by requiring that you rotate the role you need to put press to push button simultaneously so you are going to use both hands so you cannot make a mistake.

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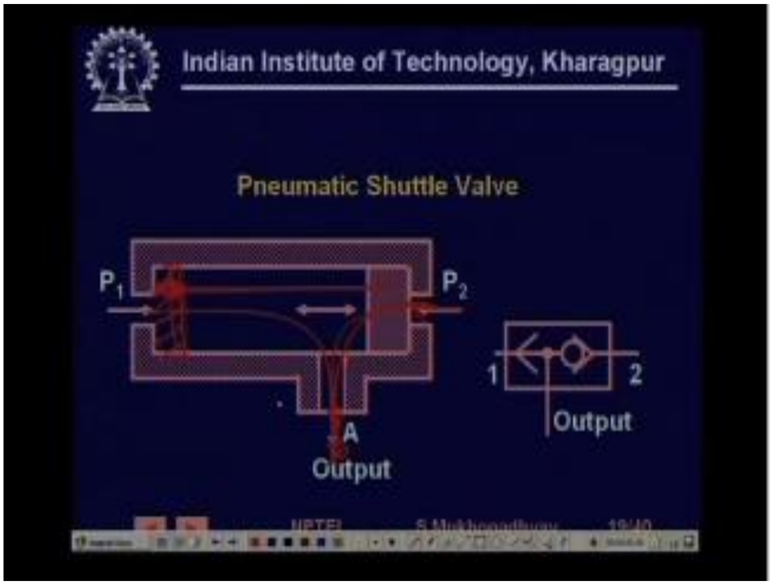

So for such cases so for example let us see or logic first it is a very simple construction pneumatic shuttle valve so you see that you see that output if you have pressure at this end then you are going to get the pump connected to the system on the other hand if you keep pressure at this end also then then also this will shift this way that is why it is called a shuttle this is so this will shift and close this one it will take up this position and air will start flowing so here is all logic where even if we apply one of the pressures then you are going to get the get the air flowing into the system.

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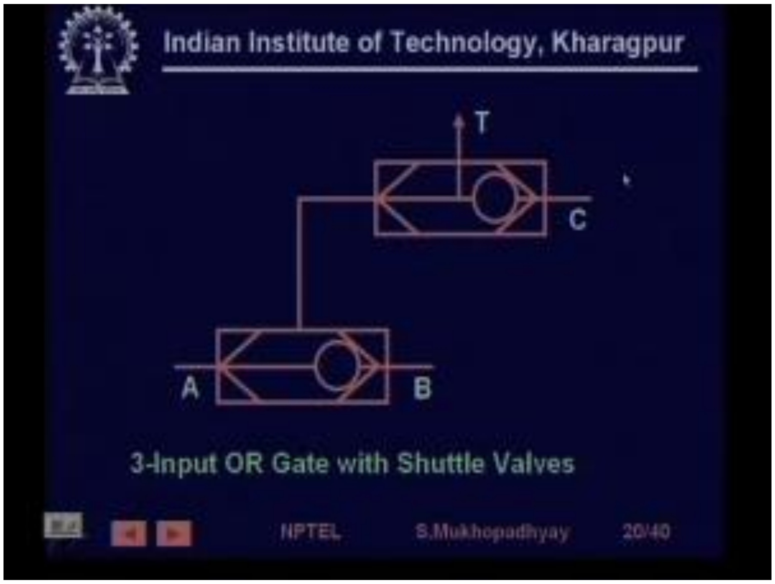

This is just an example which shows that by you know by cascading this shuttle valves you can have a three input or gate also so that so you this at this point you have pressure applied when you went ARB and then that is applied to one port so finally the pressure is applied to the system when you have a or b or c so it is a three input end or it is at here input OR.

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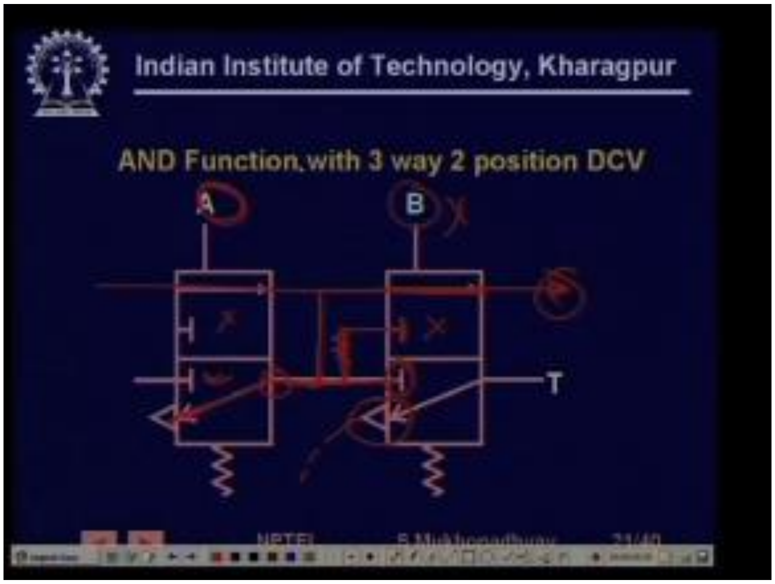

Similarly this is where these are realizations just to just show that how this this this pneumatic elements can be used to generate various podium conditions so this is this is an realization of an and gate using three way to position direction control valves so what happens is that when both these pressures are on then, this is in the box.

So therefore, the supply directly goes to the tank now suppose this is not there which means that now this is the position but here it is there so therefore so therefore you see that in this position this this gets connected to this position or rather this gets connected to actually this position and now right rather this is connected to this position you see this is actually connected to this to this second side so actually it will not go there it will rather go to the left one.

So then so the system will be connected to exhaust if this is taken off similarly if this is taken off then what will happen is that the system will directly be connected to the exhaust this is the exhaust so in if any one of these inputs are taken off then the then the system is going to be connected to the exam even if both are taken off it is still connected to exhaust so it is AND logic.

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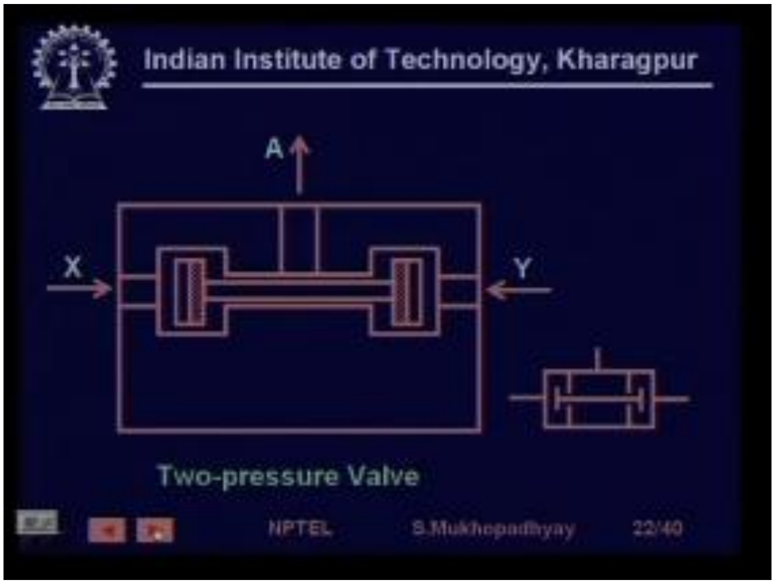

Similarly that was realizing and logic using two directional control valves but you can also have a single element in which you can have AND logic so that this is such a construction basically schematic so in this case if you have either one of them is not there is going to be suppose this is not there then this pressure is going to push this shuttle and bring it in the in to flush with this and this will be flush with this so this will be the position if Y is not there so then you can see that both ports are cut off similarly if X is not there will shift to the left and then again both will be cut off so this will be there this port can get the pressure only if both x and y pressure ports have been applied that is why it is it it's AND logic.

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So as I was saying that this is a you can have a safety application so in this safety application you know only when both these pressures are applied will this cylinder get pressure so therefore it cannot move so for example there is some pneumatic cylinder coming down and probably pressing something stamping something so you need to ensure that that while it is stamping by mistake your hand is not on the your hand does not come on the RAM so you can so if you want to move the RAM which is the movement of the cylinder then you have to press both these switches.

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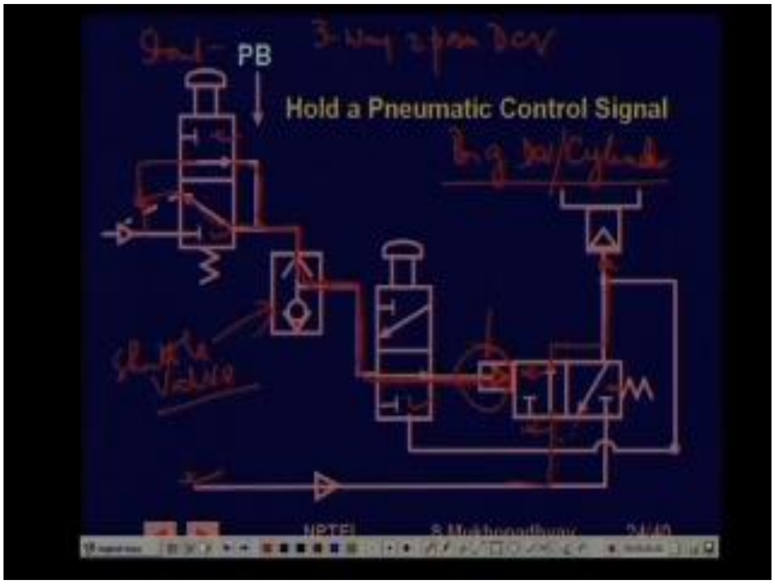

Right similarly have will show another application this is a very interesting application where we are showing something like we are realizing something like a pneumatic latch you know in these electronics we have studied about latches so we are talking about a latch here so then what happens we actually want to move this this this is the cylinder or this is maybe it is a it is a big DCV.

So we want to apply pressure here that is our final objective and the pressure comes from this line now this is a this you can see that this is a it is a three way to position valve DCV and this is suppose of oh this is start PB so suppose press this initially what happens is that see this is the port if this gets pressure this will then the valve will shift and be in this position so in this position the control pressure will go to the final load.

So we have to apply pressure to this one to finally apply pressure to this one now when there is in the in the in the normal position you see when this is this is not pressed and this is not pressed they are actually in this block and this block so this is directly connected through this through this to discharge.

So there is no pressure here so when we went so there is no pressure here when there is no pressure here this is actually here so therefore the this pilot is also connected to exhaust all right now suppose this the start PB is pressed so then it will be in this box so immediately this pressure will be applied through this this shuttle will move this is a shuttle valve this shuttle will be pressed and air will flow in through this and the it'll create pressure the moment it will create pressure this valve will shift and come to this position.

It will come to this position when it comes to this position this pressure this gets connected and therefore this gets pressure now the interesting thing is that this push-button need not be you one need not keep it pressed because once the pressure develops hear that same pressure is going to be fed back and this connection is wrong feedback and it should be connected here this connection is wrong.

So it is fed back here so now when this pressure is there built up now if you release this pressure release this then it will get this this part will immediately get connected to exhaust and since there is pressure here so this shuttle will be will be pushed and it will come to this position and then this pressure itself will go through this and keep the valve in this position note that this Is a spring-loaded valve so if the pressure will be held.

So the pneumatic pressures going to be held even if the start push button has been released right that is the point that we are trying to make now if you want to reset this how do you come out of this so you press this pushbutton this is the stop push button so what happens is that the moment you press this this is going to be this will go this valve is going to be shifted shift here so then this is going to get exhausted so the moment this now what happens is that this gets exhausted and this line which was coming through this gets blocked here this is a normal three position three way to position valve.

So that so the so the pressure will go here and then this valve will now shift to this box which means that this pressure will now drain to exhaust the moment this pressure drains to exhaust then this is no longer in this position but it is free so now if you against press the start push button then again this can move here and energize so basically you see that we can so this is a kind of latch where once the start push button signal is it is something like the auxiliary contact of a PLC logic or a latch in digital logic so even if you release the start push button this this the pressure that this pilot port will be held and therefore this valve will maintain in this position and the pressure at this main load port is going to be maintained.

So this is one application which seems interesting so specifically such things are realized using pneumatic logic.

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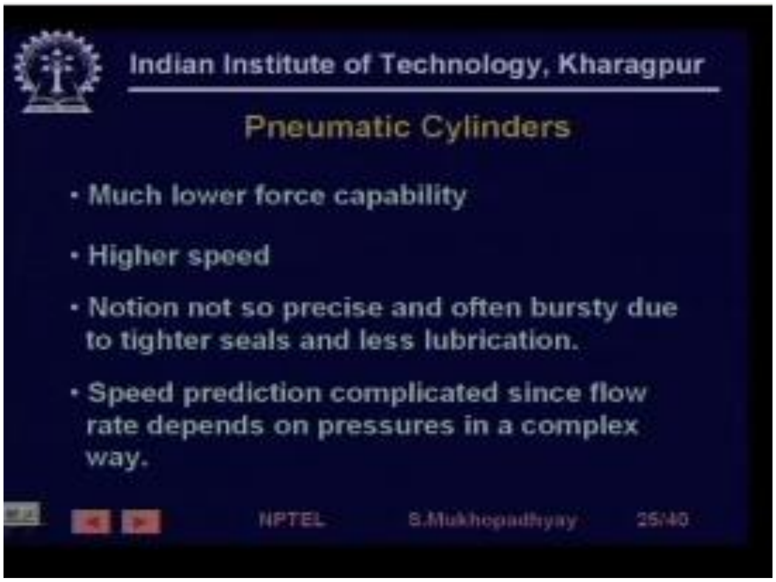

Now we come to the actuator elements or the pneumatic cylinder the pneumatic cylinders have lower force capability and but they have higher they have their they have high speeds because they are generally driven against lower loads also and the this is not notion this is motion so motion is not so precise because of the fact that you know there is the fixture is higher and there is seals are tighter because to prevent air leak so that you know the energy developed by the pump is not wasted so because of the high friction there tends to be you know stick-slip motion so the motion needs to tends to be bursts and precise motion control as is possible in hydraulics is not possible here.

In fact the applications are also less demanding so generally such precise motion control demands are also not there from the application side similarly speed prediction is also complicated because they are actually complicated functions of pressure temperature etcetera because I because we are talking about a gas here so there is a lot of compressibility issues.

So the speed prediction the speed can vary a lot and therefore again that is also another reason why precise motion control may not be possible.

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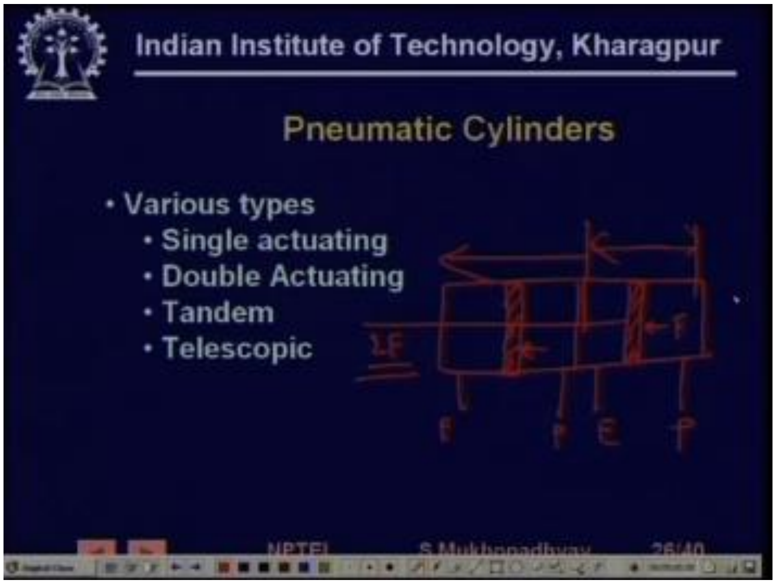

So in such cases one uses you know pneumatic cylinders and they can be of various types they can be single acting where maybe spring loaded so from one side you apply the pressure so it moves only this side retraction is maybe by a spring generally is by a spring so that you actually do not require motion on the other side if you if you have a double-acting cylinder then the connecting rod can move this way that way in both ways and you apply so you apply you can apply pressure on both to both sides of the piston.

Similarly sometimes it happens that you cannot if you want to have higher force then you cannot increase this cylinder area either because of size requirements or because of speed requirements if increases in the area it takes more time for the air to flow.

So sometimes you can you put a you put basically you put two cylinders in tandem like this with a common rod you have a common rod but you have to separate see in this so you apply pressure here and here and exhaust here and here so on this surface some force will develop on this surface some force will develop F and F so total force on this is 2F so two cylinders effectively they are actually two cylinders are put in tandem sometimes such things are done similarly you can have telescopic cylinders where you know separate where you can have large stroke lengths, so there are various such things are possible we will not look at them.

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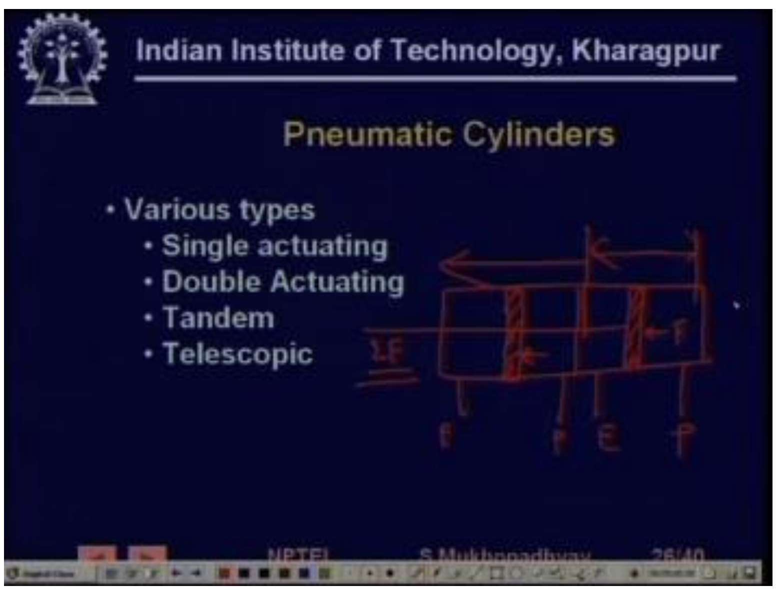

In great detail.

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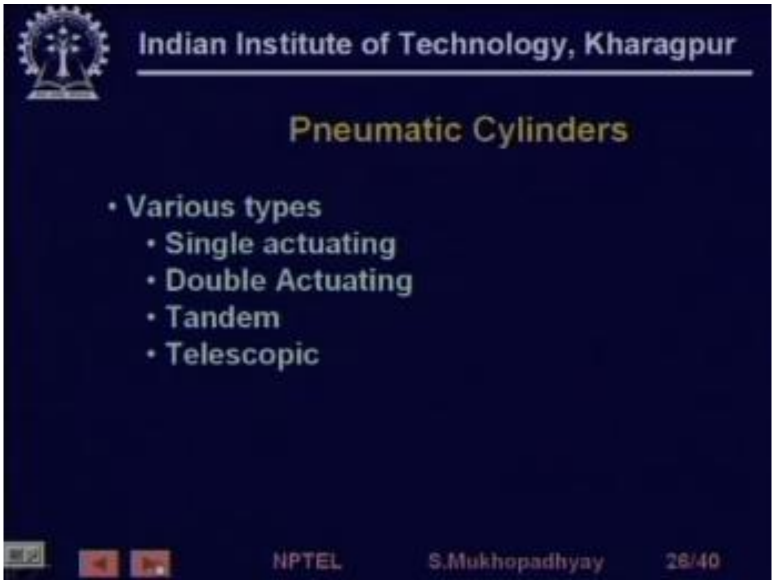

We will just see.

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See a picture of a pneumatic cylinder.

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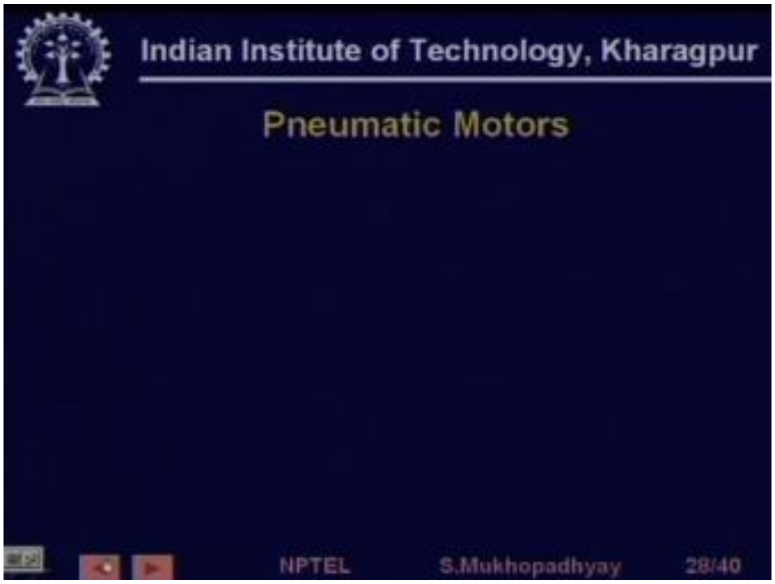

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So it is this is us this is this is a cylinder where this cylinder body you can see the piston and they and the rod which gets connected to the load you as we have seen that you can put a flow control valve here sometimes you can put a quick exhaust valve here so this is a normal pneumatic cylinder.

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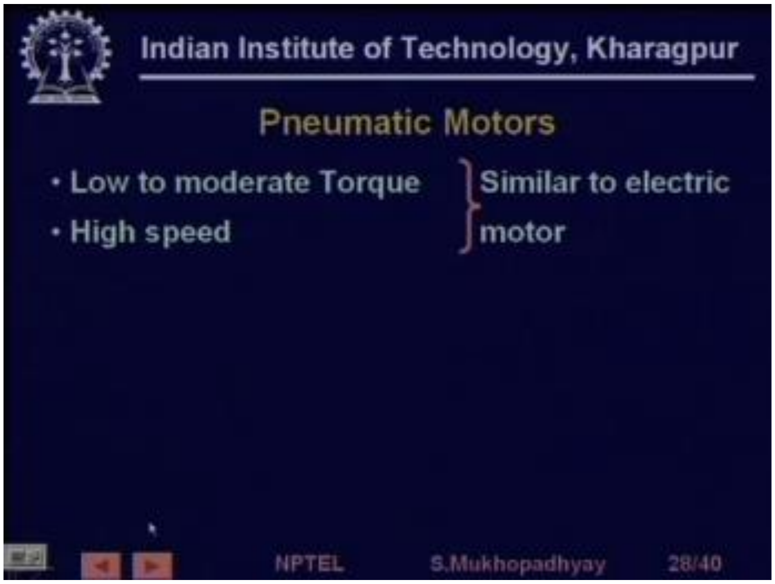

Similarly, you can have pneumatic motors and they can be again of different types positive displacement type non positive displacement type so you can have vane motors or you can a piston motors just like we had in hydraulics so but these are used fear early for low to moderate torque and high speeds somewhat like electric motors.

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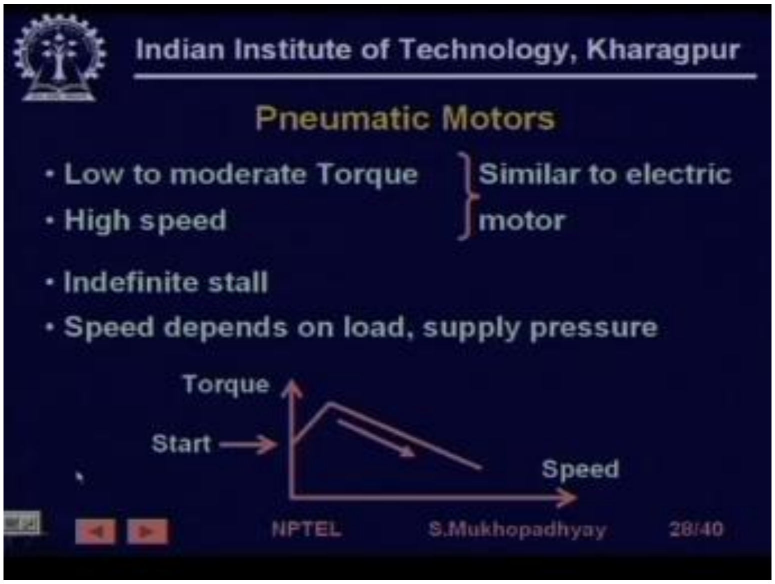

Generally one advantage is that they can be easily stalled you know electric motors cannot be stalled because of that will make a large very large current to flow through these motors they will be heating etcetera and it turns out that you can see that.

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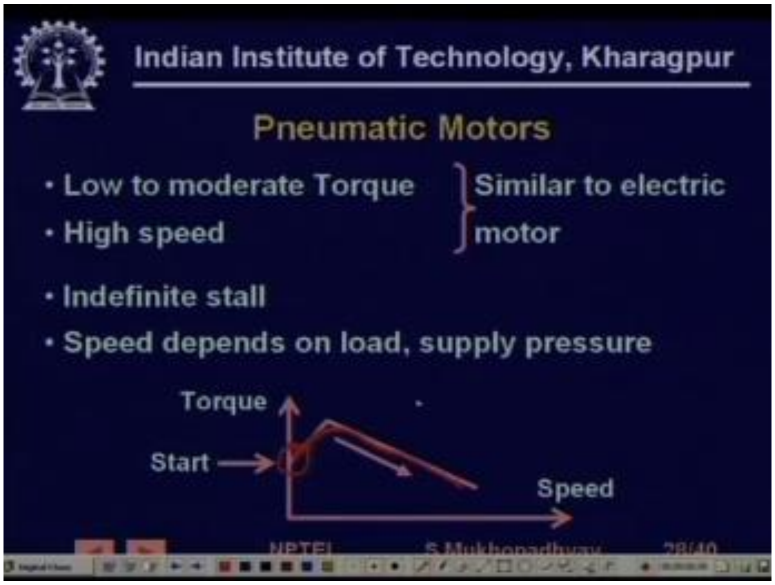

The typical you know typical kind of torque speed characteristics for pneumatic motors so initially the torque is low because of you know the available torque is low because of static friction being high and then at some point of time this as the satisfaction reduces so the torque raises and then after sometimes the so-called you know linear or viscous friction take takes over and then at high speeds again a good amount of torque gets wasted in friction.

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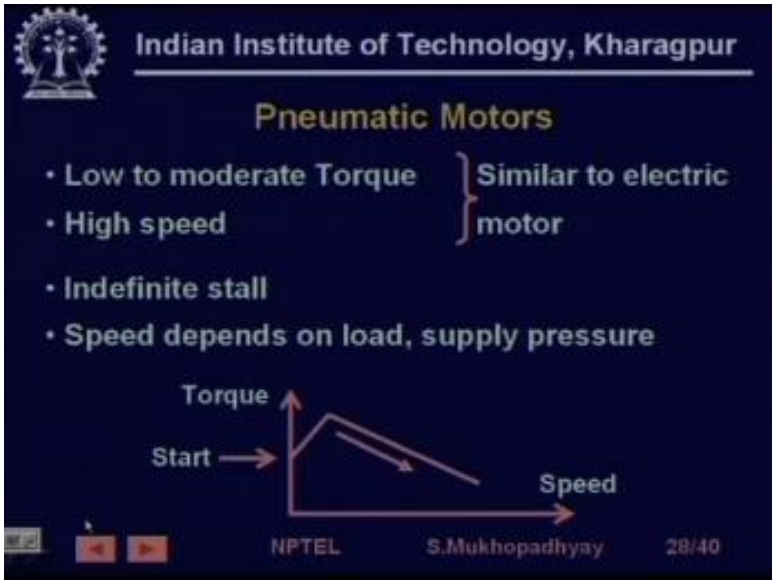

So the overall torque available characteristic falls for a given supply pressure.

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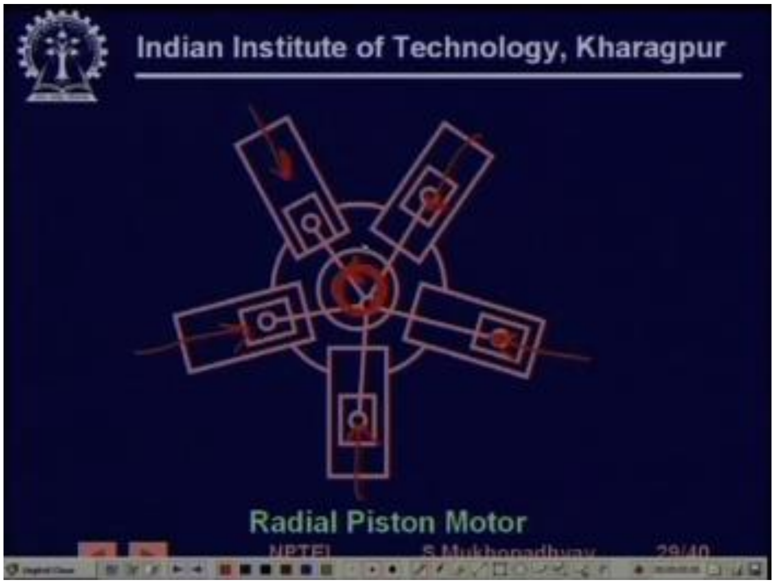

So this is a picture for a radial piston motor so you see that if you apply pressure to these to these pistons in sequence cyclically then this because of this mechanical arrangement there will be there will be rotational motion so this is naturally this is of a positive displacement type that is in every cycle of the piston movement a certain amount of air is here goes to the system.

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Similarly you can have non - positive displacement type here we have not shown a figure but it is exactly similar to the vein motor of hydraulic systems in principle.

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Although there may be constructional differences in design.

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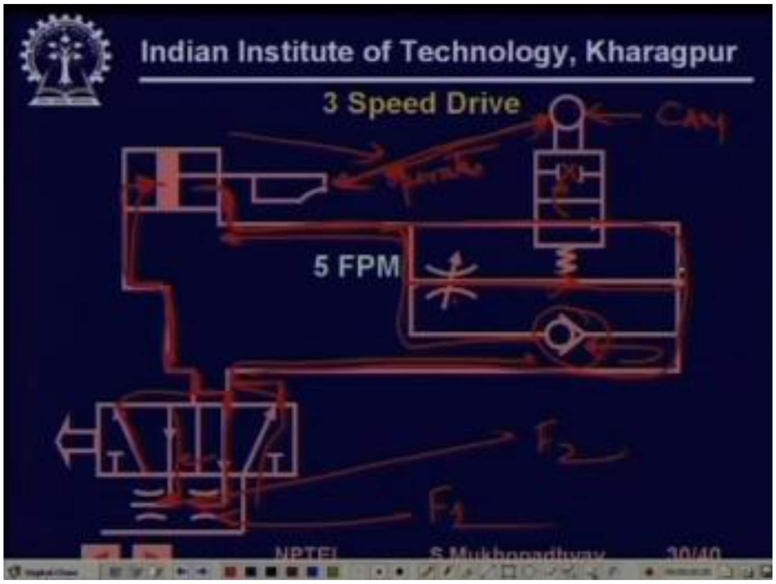

Another application is a three speed drive so in the three-speed interesting so that is a three speed drives we can quickly see what we are doing so you see that when suppose actually this is wrongly connected it should have been here and this one should have been here so when it is in this position then airflows like this like this it goes through this passes through the check valve so it does not pass through this or this.

So it goes like this and flows in and then comes out through this path and we will get connected see this is connected to this path so how much will be the speed depends on the rating of this flow control valve suppose it is f1 on the other hand when it is trying to move this side from left to right that is the position corresponding to this box of the DCV so now the DCV is going to get connected through this and this port will get connected here.

So it will flow through this into the cylinder freely and then while coming out so while coming out initially it will see this is a cam operated this is a cam actually this cam and this these are mechanical linkage so these so initially this is this cam is not operated so therefore this is the position so it flows through the valve and returns and flows out through this path so the flow rate is f2 after sometimes when this actuator moves out this is going to operate the cam so operates this will operate the cam and then the cam will shift.

So therefore this valve will shift and go to this position and then we will get locked at that point of time the flow will pass through this because this is closed and this is also closed this is a check valve so it will pass through this so after a certain time the flow is going to be only five.

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So you see so maybe this setting is f3so you can realize three settings f1 f2and f3 using this circuit right pretty good.

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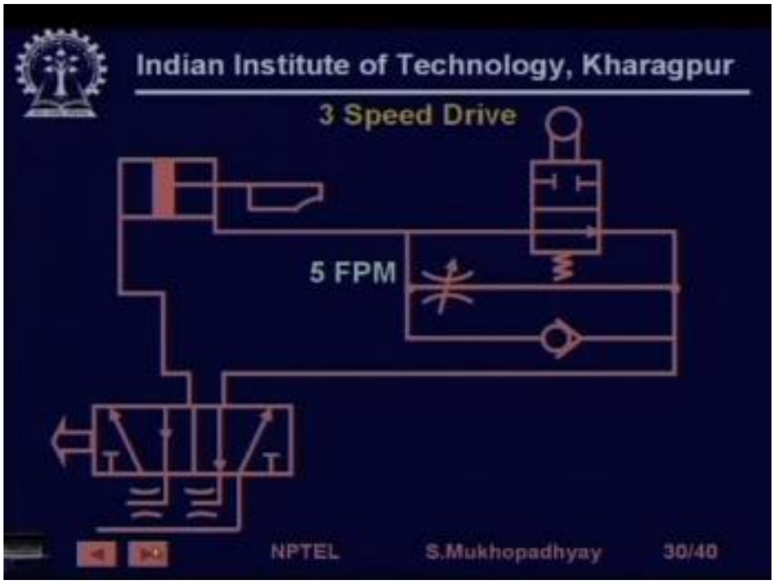

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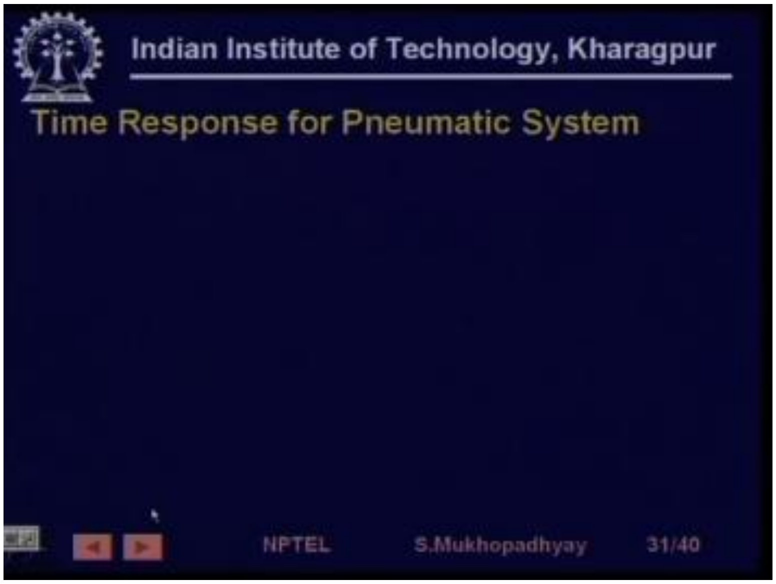

So as we have seen that pneumatic systems have main one of the main drawbacks is that the time responses are slow and basically happens.

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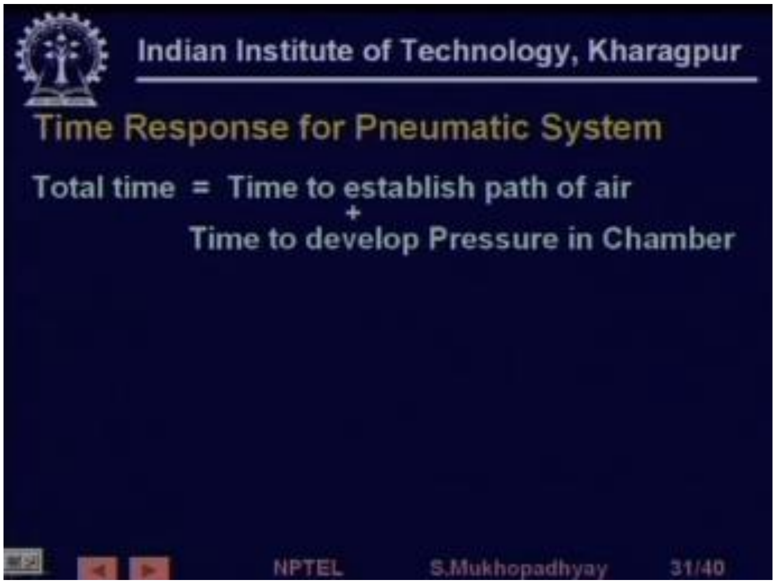

Because time is required to establish path of air by air must flow into the final chamber and then time to develop pressure in the chamber so from the air source to the chamber air must air path must be established and then pressure in the chamber must develop before something will move.

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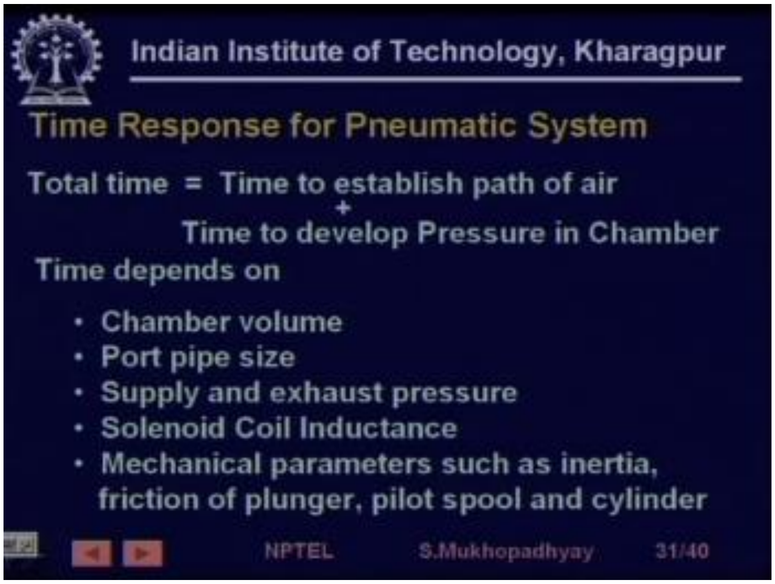

So these times depend on lot of factors like chamber volume port pipe size supply exhaust pressures what is called the ratio of these upstream and downstream pressures similarly there are also you know these are times required solenoid coil inductance inertia etcetera they are generally smaller compared to you know the pneumatic part but these all these factors will affect the time response of a pneumatic system.

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If you see the pressure for example if you see the pressure flow characteristics of pneumatic valves it turns out that it depends on a number of factors so for example for example it will depend on this is the weight flow rate it will depend on discharge coefficient and area that is standard for any flow but because it is compressible flow it is going to also depend on the upstream and the downstream pressures which particularly the upstream downstream pressure ratios it will also depend on the temperature. So these are special influencing factors for pneumatics.

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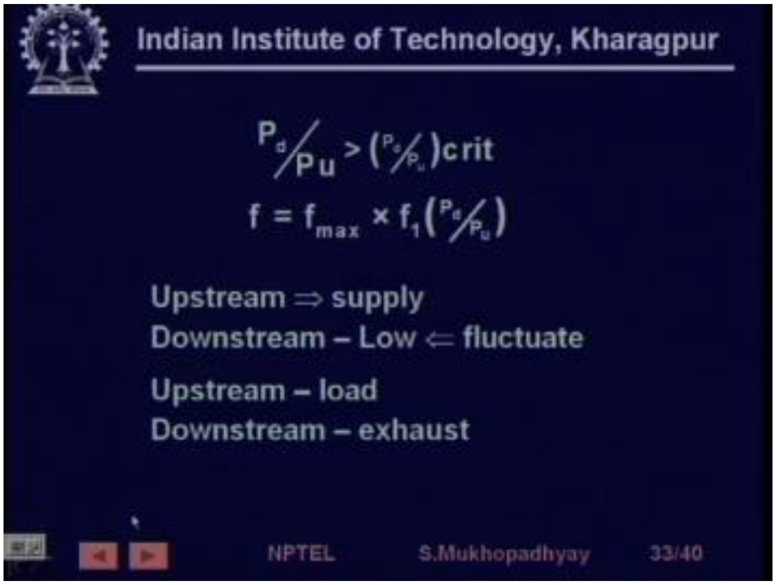

You know so it turns out that the in fact in this depends depending on the valves configuration these upstream downstream pressures keep varying for example you know in a given situation it may be so that the upstream is actually connected to supply.

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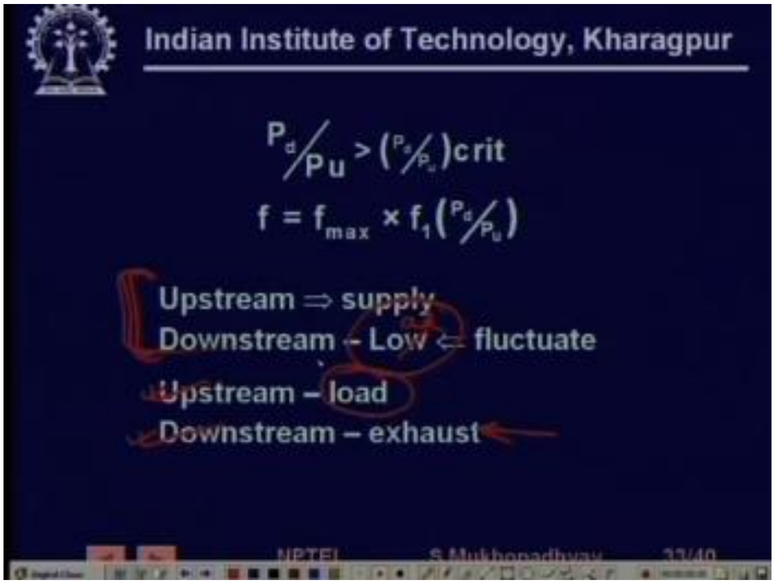

While the weather well the downstream is actually connected to load this is load so the load pressure ferry is this ratio is going to value it may also happen that the upstream is connected to the load and the and the downstream is connected to exhaust the in this case this is constant but then this may that so again the pd /pu relationship will vary. So in such cases but what is said is that if you want to have a, you know a constant flow characteristic then you should maintain.

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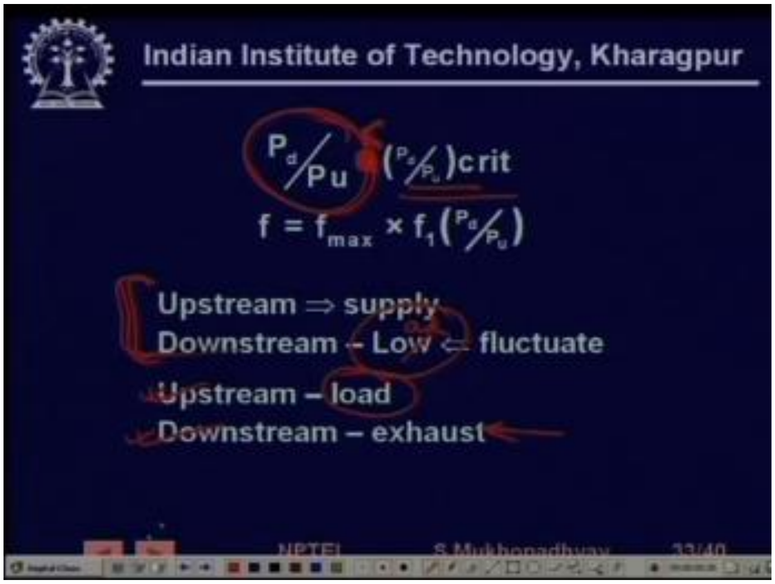

This pd / pu ratio beyond a critical value actually it should be less than a critical value not greater than this is this greater than is wrong so it turns out that.

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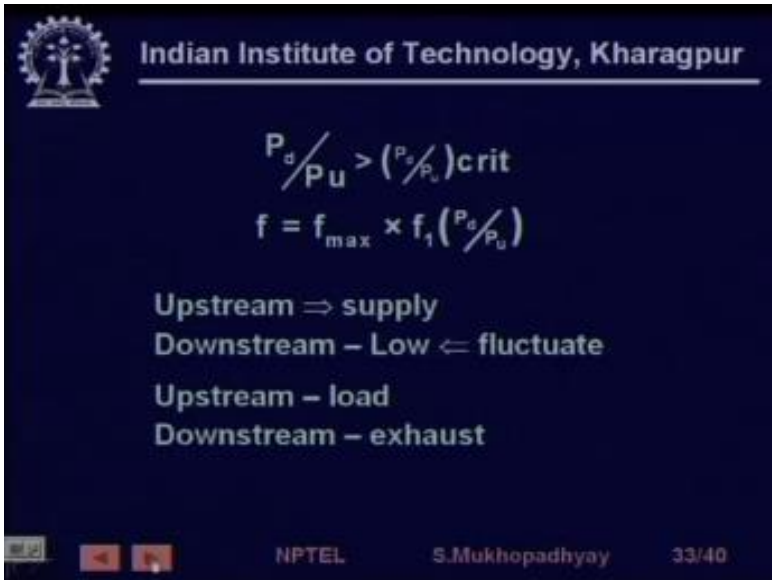

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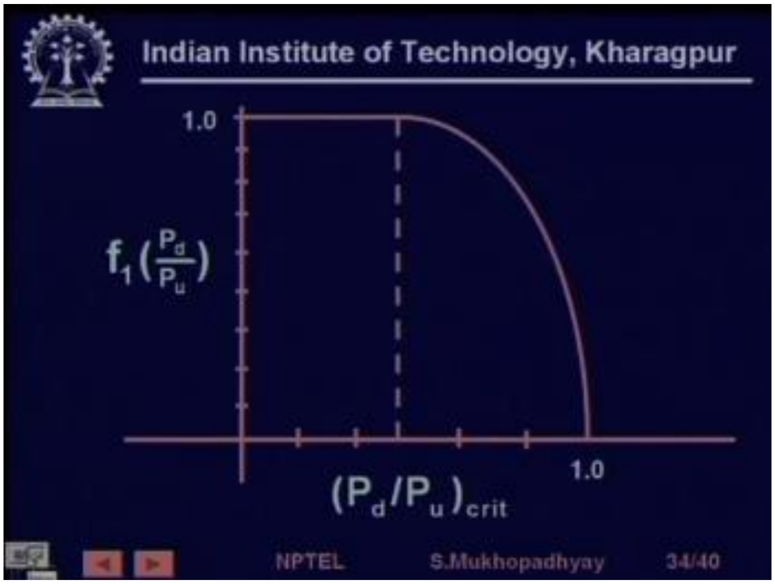

So for example you see that.

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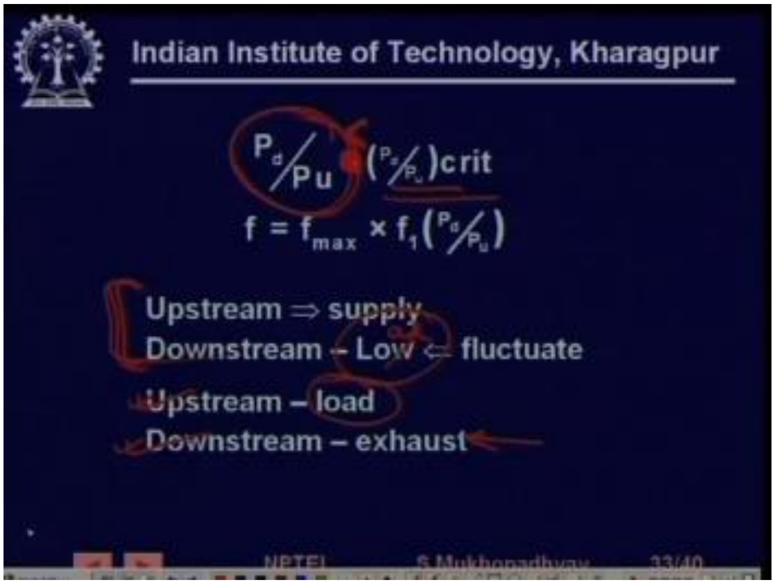

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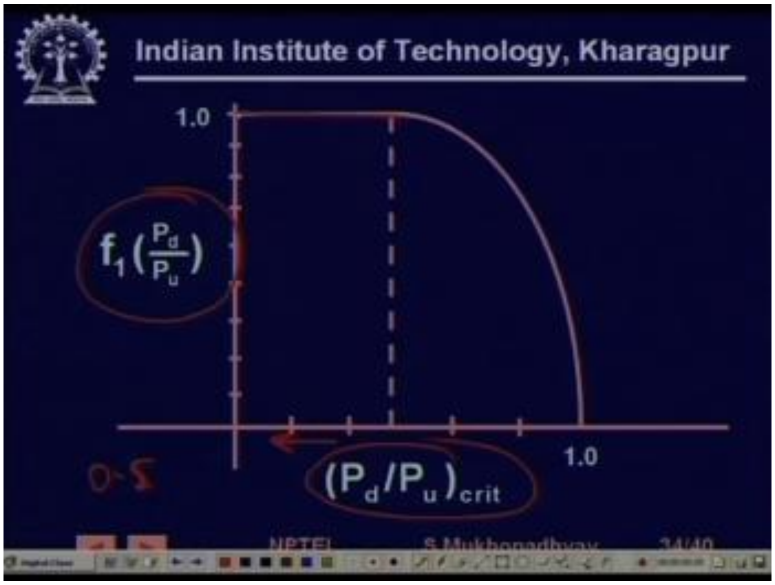

Depending on the pd / pu if the pd/ pu this function for a given this function causes fluctuations in the flow rate depending on pd / pu so but if you keep the pd / pu ratio below a certain factor like you know something like 0.5then what happens is that this function becomes constant and then the flow rate will only depend on you know things like1 pressure discharge coefficient area etcetera that is the flow fluctuations will be less. So sometimes this pd/pu pressure is needs to be maintained.

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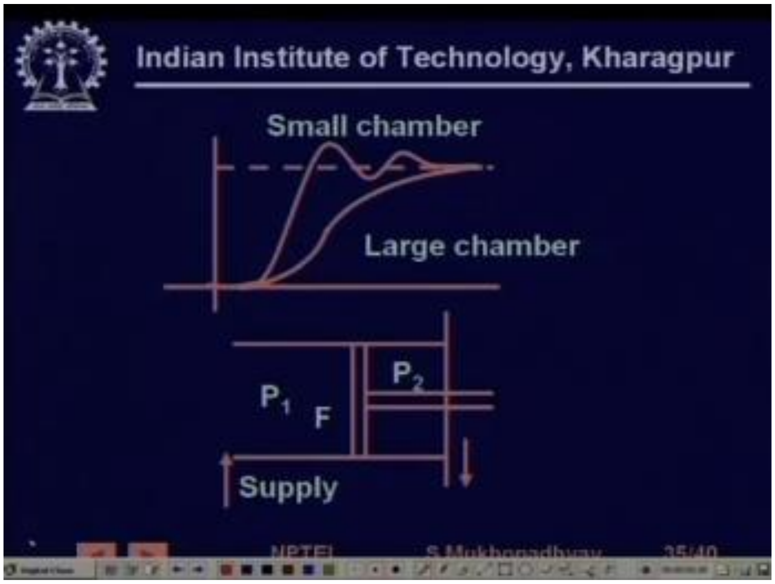

Similarly, if you see time response then what happens is that see the whole air mass moves into the cylinder chamber and depending on the capacity of the cylinder chamber and the flow rate and the air mass rate you can have different kinds of you know issues if you measure the pressure after the valve is suddenly opened then if you measure the pressure variation with time.

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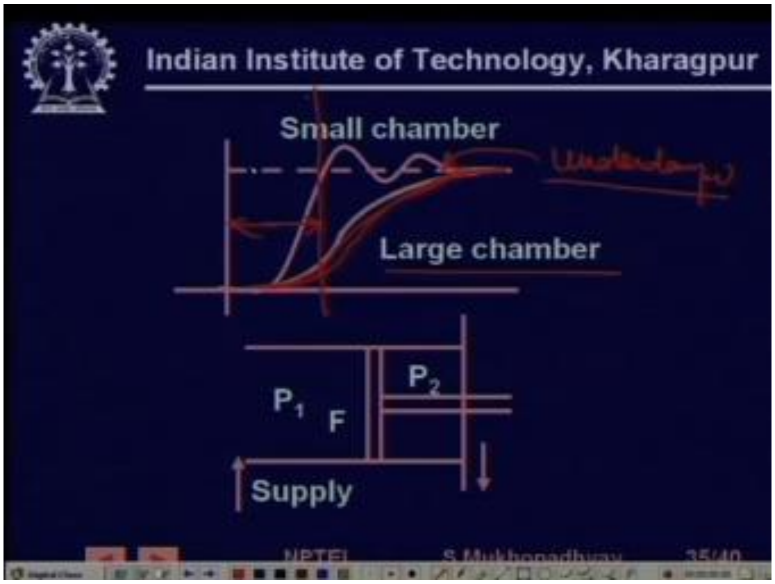

You can get various kinds of response for example for small chambers it is going to be an under damped response so the pressure will build up then it will overshoot and gradually settle to the real pressure while if you have large chamber sometimes this can be an over damped response but in any case a certain amount of time is gone for example let us say the sets so this much of time will be required before the actuation will take place.

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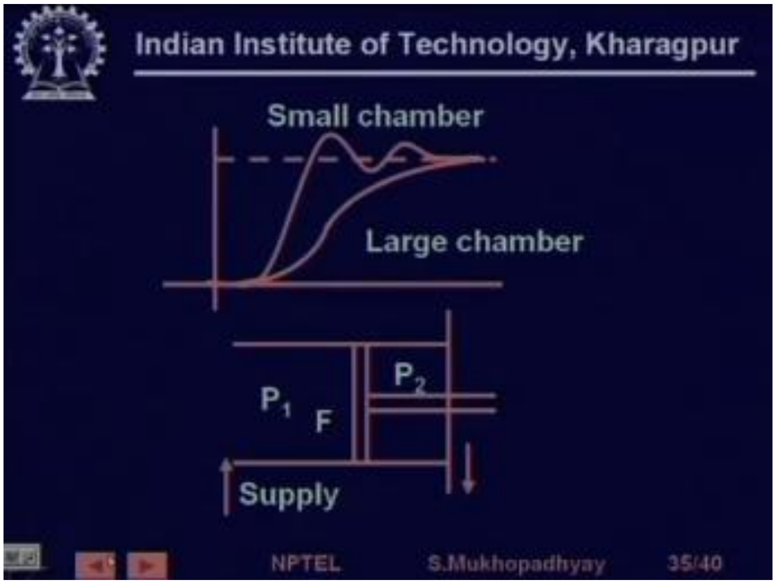

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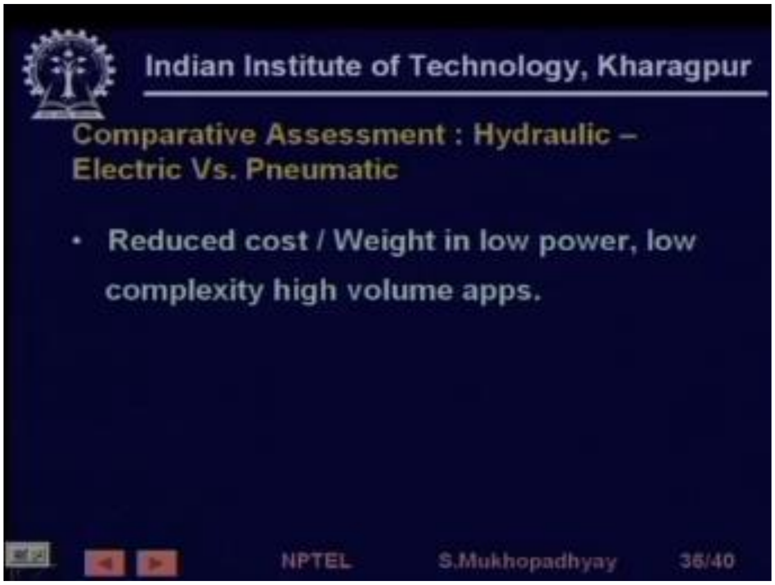

Now we come to the last topic which is the comparison of hydraulic and hydraulic electric and pneumatic systems so turns out that for low power low complexity high-volume applications of course generally pneumatic systems sometimes tend to give you an advantage that is why it is used in you know things like in using pneumatic tools in large you know assembly shops like in a like in an automotive factory.

So there you see these individual tools do not require low power there is no complexity general jobs are like you know screw driving clamping etcetera but there are large number of operated stations so what happens is that you can have you can have a very low cost implementation of controls because of the fact that the major equipment that is a compressor regulator etcetera they can be shared over this number of applications.

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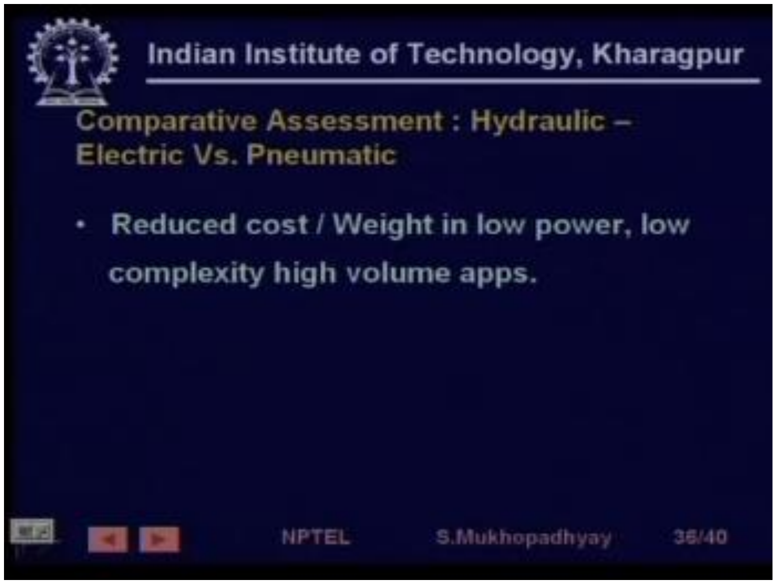

So you have you must have a high volume application and the requirements are.

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Performance requirements are very ordinary some of the cost advantage comes because this there is as we have said that there is no return line so mean I mean that that saves a lot of cost half the tubing cost is gone just like hydraulics and pneumatics there is no stalling problem when in electric there is in pneumatic there is no fire hazard in hydraulic there is because the oil itself is prone to fire.

While in the case of electric if the if the environment is if the hazardous then there can be fired but in pneumatic there is the there is no fire hazard generally in electric and pneumatic one has reduced temperature sensitivity because why then hydraulic because in hydraulic there is a the oil viscosity can change and give you know performance variations the in electric there is the no question of viscosity and in pneumatic the air viscosity change is not that predominant.

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However hydraulic is mainly preferred when you have very precision motions and very high forces are required that is not the case of pneumatic you know lower is used for lower force and pressure ratings for a given size response is slow for pneumatic definitely slower than hydraulic comparable to electric in pneumatic there is a there is a problem of leak and leak is not so easy to determine.

But it will you know reduce the efficiency of the system this in turn will cause if you want to prevent leak you have to that will increase maintenance costs it will also make the seals tighter and will increase will increase friction which in turn will cause further fall in efficiency so leak is a big problem for pneumatic systems.

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Interface costs may be prohibitive you know sometimes you may have to interface with electronics and other elements so very so therefore for very sophisticated controls sometimes you know electric actuators maybe preferred.

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Because they can be driven in using an all electric system lubrication is additionally required while in hydraulic it comes along with the oil so lubrication is required.

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And obviously motion control is less precise in pneumatics than either hydraulics or electric.

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So we come to the end of the lesson we have seen pneumatic valves and actuators we have seen some elements which are used in pneumatic logic we have seen some new typical pneumatic applications and we have seen comparison with hydraulic and in some cases electric systems.

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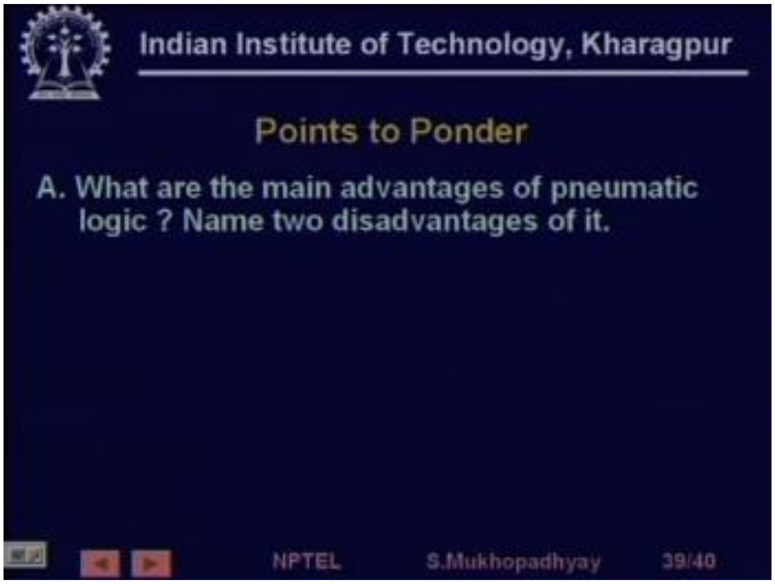

So points to ponder there are some questions like what are the main advantage of pneumatic logic so we have already stated that and what are the disadvantages obviously disadvantages in terms of speed and complexity.

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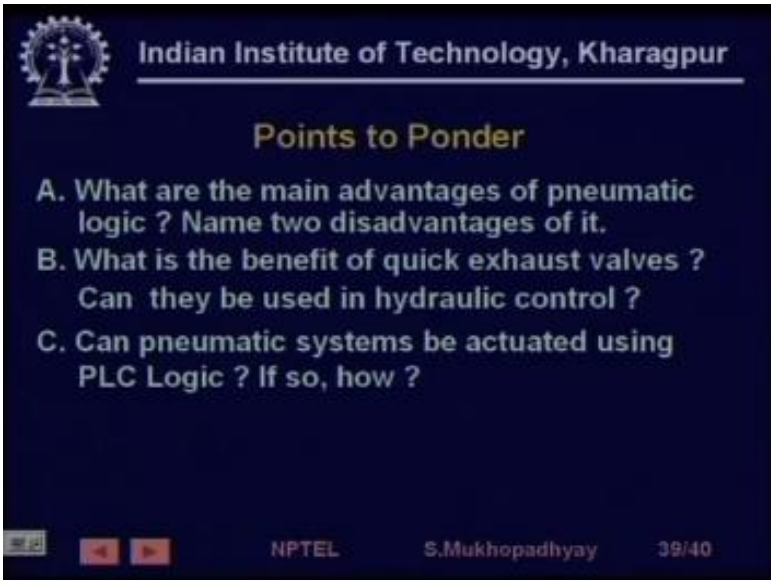

What is the benefit of quick exhaust valves we have and can they be used in hydraulic control of course can they of course they cannot be a pneumatic systems be actuated using PLC logic if so how actually they there are in many cases actuated using electric logic actually this pilot actuation is typically as you have said that you know we have seen how our microprocessor can actually control a pneumatic system. So PLC is actually nothing but a microprocessor as we know so it can surely be used.

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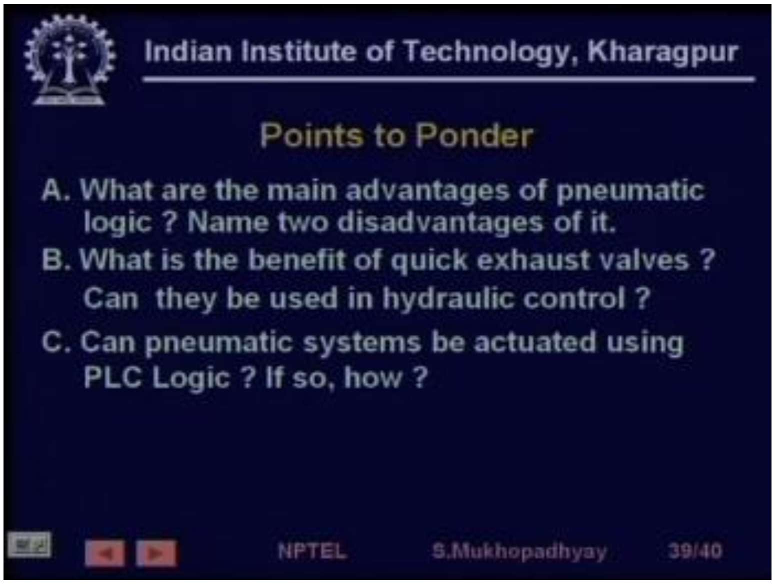

To control but we might need if you need if you have an air pilot we may need and need an eye to be converter that is all.

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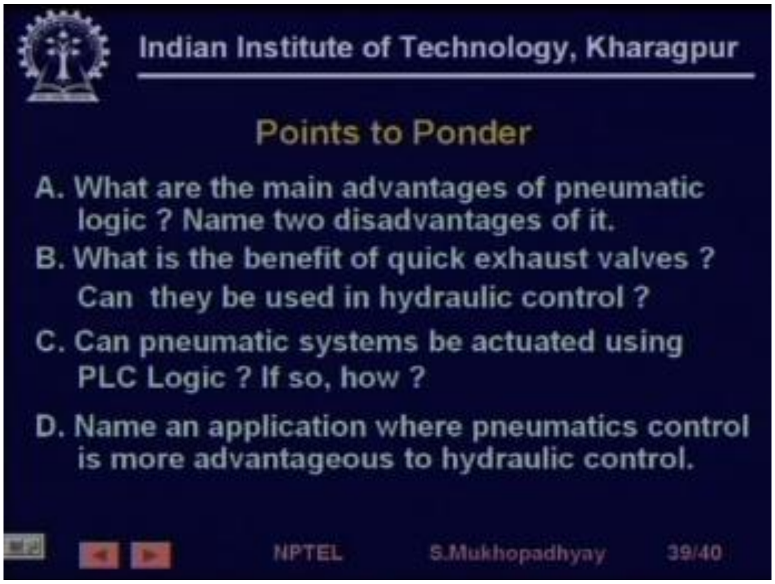

Name an application where pneumatic control is more advantageous to hydraulic control so I have given an application which is assembly to link you can think of others.

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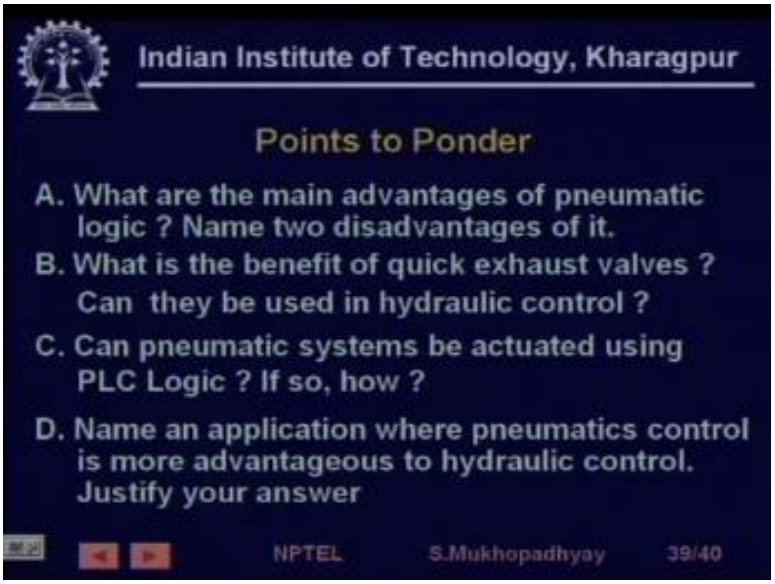

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So that is all for today, thank you very much.