Industrial Instrumentation

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Lecture - 33
Flapper-Nozzle

Welcome to the lesson 33 of industrial instrumentation. In this particular lesson, we will study the flapper nozzle or rather flapper nozzle system. Flapper nozzle is a very important I mean item in most of the pneumatic systems or pneumatic based instrumentation. Because as you know that even though we are as many sensors or all those things are converted to the electronic domain. But still in some cases we need these pneumatic systems for the safety reason as well as for the large control in the large control for all those things.

And especially in the petrochemical industries, or the hydrocarbon industries where the electronic systems or electrical system is forbidden to use, because there is a voltage rating. It should be not it should be above 45 volt and that system also we should be we need this flapper nozzle systems Now, flapper nozzle system the advantage is that you see that it has a it has a it can be used as a displacement sensor. It can be used as it can be used as differential pressure transmitter and so on, we will discuss all this things in details. Let us look at the content.

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Contents

- Introduction
- Principle of operation
- Displacement measurement.
- A reverse acting pneumatic relay
- Current-to-Pressure (I-P) converter.
- Differential Pressure transmitter.

Introductions then we will go to the principal operation then we will go to displacement measurements and displacement sensors rather we will see that how the flapper nozzles can be utilized to make a displacement sensor we have. A reverse acting pneumatic relay, because I mean I will see that to make to keep this pneumatic sensors I mean flapper nozzle systems in the linear region. We will find that we should make the movement of the flapper very small. So, to do that thing we need a pneumatic relay we will discuss this in details it is called reverse acting pneumatic relay then you will also see the current to pressure convertor or I to P convertor using a flapper nozzle systems. How we can make I to P to convertor? Because in many point the process always we need to do I to P convertors many a cases we will find whether the 4 to 20 milliampere of current you have to convert 3 to 15 PSI of pressure.

So, in that type of situations we need this I to P convertor. Then differential pressure transmitter this also we will discuss in details, because differential pressure transmitter as we know we need it in many process. And though we have now electronic system, but still this differential pneumatic differential pressure transmitter is still used in many process industries. Because as you we have studied in during the flow meter that the flow measurements the flow is calibrated in terms of pressure differential pressure. That is to be transmitted we can transmit four to 20 milliampere, but we can transmit to directly 3 to 15 PSI pressure also. So, we discussed these thing how we can make with the flapper nozzle system I mean a differential pressure transmitters.

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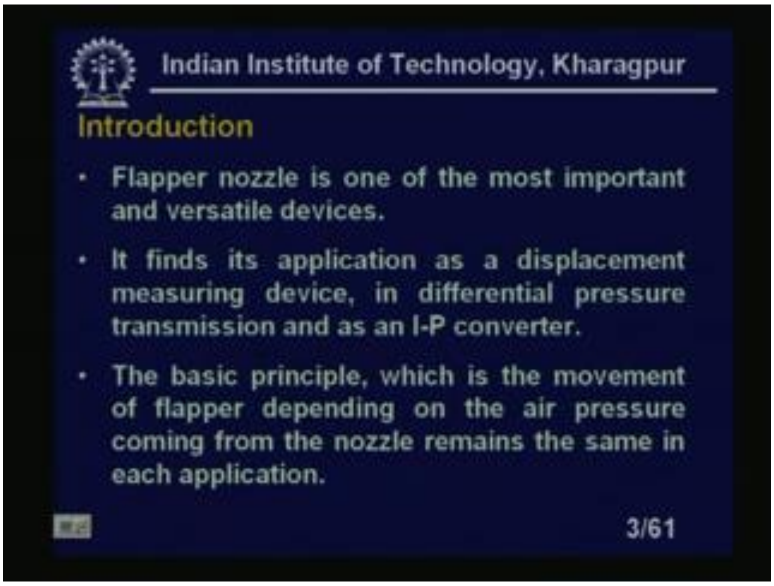

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Introduction

- Flapper nozzle is one of the most important and versatile devices.
- It finds its application as a displacement measuring device, in differential pressure transmission and as an I-P converter.
- The basic principle, which is the movement of flapper depending on the air pressure coming from the nozzle remains the same in each application.

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Basic introduction flapper nozzle is one of the most versatile and versatile device. It finds it is application as displacement measuring devices in differential pressure transmission and as an IP converter. The basic principle which is the which is the movement of flapper depending on air pressure coming from the nozzle remains the same as in each application. In all applications we will find there is a there is a nozzle and through which the continuous air is bleeding through that nozzles and we have a flapper. This nozzle’s position is fixed, but the flapper position is I mean variable. Now, we will find that if the flapper position varies we are getting some I mean ((Refer Time: 04:42)) of pressures or back pressures. So, which can be utilized which can be calibrated in terms of pressure currents and so on, application as a displacement measuring devices.

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Application as a Displacement measuring device

- A flapper–nozzle system is used for the measurement of small displacements.
- A small movement of the flapper can result in a large change in the output pressure, and hence it is treated as a displacement to pressure converter.

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Let us look at the displacement measuring devices how the flapper. Now, to know the displacement measuring devices let us first look at what is this flapper nozzle system looks like? A flapper nozzle system is used for the measurement of small displacement. A small movement of the flapper can result in a large change in the output pressure and hence it is treated as a displacement to pressure converter. Basically I am getting pressure in all the flapper nozzle system. Please note the output is pressure whether it is I am measuring the displacement or velocity or current. Output is in terms of pressure 3 to 15 PSI or is whatever in kg if you say it does not matter. So, it is it is output is pressure. So, that it is treated as you look at the last line and it is treated as a displacement to pressure converter

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- Such transducers are designed for use on both hydraulic and pneumatic power supplies.

Such transducers are designed for use on both hydraulic and pneumatic power supplies. It is used as a pneumatic and hydraulic power supplies. The pneumatic system is operated at an air pressure range of 15 to 30 psi. This is I am talking about the supply pressure, but we will find out the pressure with controlled output which we will get from the or the range of the output which we will get from the pneumatic system our flapper nozzle system is 3 to 15 PSI.

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Flapper Nozzle System.

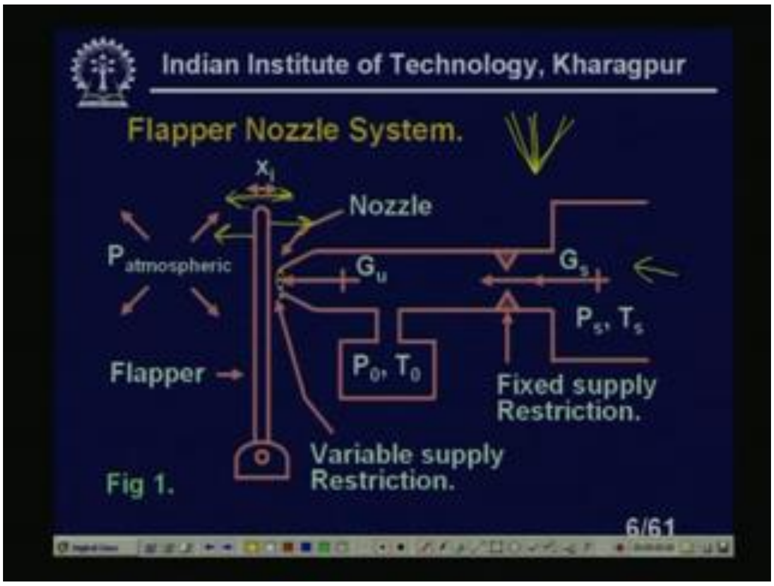

Fig 1.

Flapper nozzle system let us look at them. This is the basic flapper nozzle system you can look at very carefully. You see here that we have one, this is our nozzle. This is small in diameter it is a circular in nature. This is a nozzle and these are the flappers which move in these directions, which moves in this direction as you can see it is written. So, it moves in this direction it moves in this direction. You can see here now, see there is a continuous flow of pressure, which is called the supply pressure of air and there is a fixed supply restriction. These restrictions will make a constant pressured which is constant Ps I mean it will make a restriction, so that you will get a constant bleeding of air through this nozzle. Now, you see that if the if the flapper goes out if the flapper goes in these direction if the flapper moves in these directions we will find the more air will leak through this nozzle.

This is the nozzle, which is in circular in shape this is the nozzle I mean the more air will. So, this will reduce the pressure P naught and obviously, please note that Ps will not change; that means, the supply pressure will not change. But this back pressures or pilot pressure will change this Po will change it has some time by the, it might be different from the supply pressure temperature Ts it does not matter. Now, if it moves in this direction the flapper moves in this direction as in if I use it as a displacement sensor. If it is displacement sensor; obviously, I will put the displacement to the flapper is not a there is a hinge here. So, it moves in this direction. So, either it will go in this directions or it will go in this direction this is a neutral positions what we have in the flapper.

Now, you see that when it moves in this directions. So, it will allow less air to leak through this flapper, because there is a continues bleeding, because supply pressure Ps is coming. So, this will lead to the increase over the pressure Po or output pressure. This output pressures will be calibrated in terms of not the temperature output pressure will be calibrated in terms of the displacement. This is the basic principles of the all flapper nozzle systems you will find that whether it is a temperature current it does not I mean current it does not matter you will find it everywhere. This is the basic principles this is the output Po which is to be calibrated in terms of the process parameters we actually we are measuring here. The process parameters we have taken as a displacement. Now, let us look at the ambient, I mean what are the legends we are talking about?

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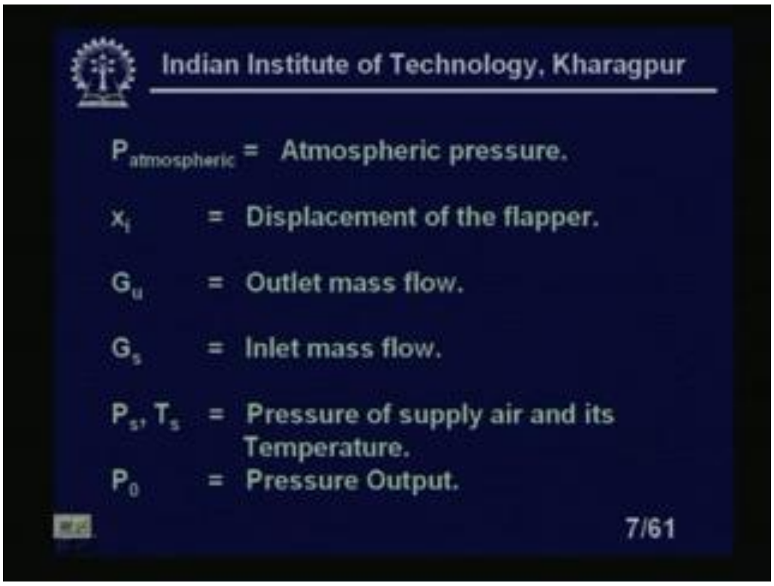

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$P_{atmospheric}$ = Atmospheric pressure.

x_i = Displacement of the flapper.

G_u = Outlet mass flow.

G_s = Inlet mass flow.

P_s, T_s = Pressure of supply air and its Temperature.

P_0 = Pressure Output.

P atmospheric is the atmospheric pressure. Then Xi is the displacement of the flapper if you look at Xi is a displacement of the flapper. Gu is a outlet mass flow we are considering here mass flow also from the volumetric flow the mass flow mass flow of air. Gs is a inlet mass flow inlet flow from the supply pressure which is coming from. Then we have a Ps and Ts is the pressure of the supply air, and it is temperatures pressure of the supply air and it is temperature. Then Po is the pressure output who also weights as the temperature of T naught that we have not mentioned in the legend. So, it is always bleeding to the atmospheric pressure.

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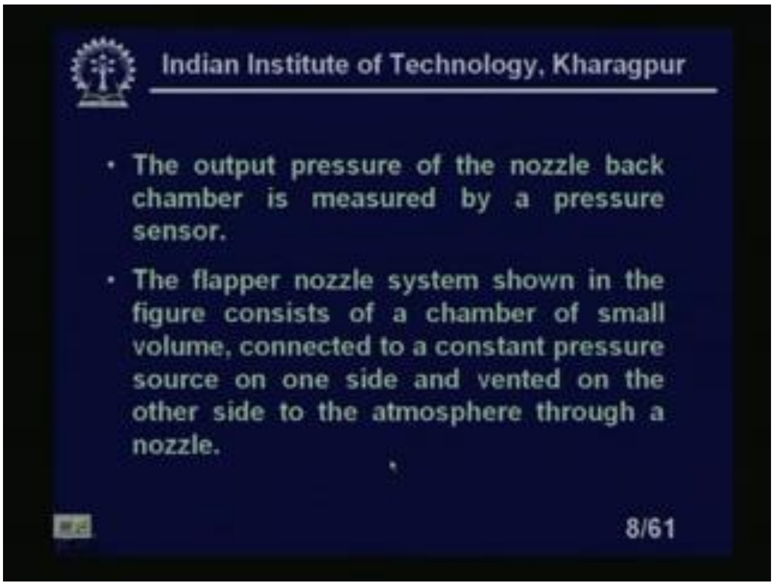

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- The output pressure of the nozzle back chamber is measured by a pressure sensor.
- The flapper nozzle system shown in the figure consists of a chamber of small volume, connected to a constant pressure source on one side and vented on the other side to the atmosphere through a nozzle.

The output pressure of the nozzle back chamber is measured by a pressure sensor. See you can use many pressure sensors we have studied, so many pressure sensors. So, I can use to measure the pressure by any gauges like diaphragm gauges this that we have studied so many. So, we can use utilizing I mean any principles I mean principles we can make a diaphragm is one of the most suitable diaphragm gauge also can be used pressure sensors. The flapper nozzle system shown in the figure; that means, figure 1 consists of a chamber of small volume connected to a constant pressure source which is Ps on one side and vented or bleeded on the other side to the atmosphere through a nozzle. This is a basic principle if you say what is the flapper nozzle system? You must write this line. That means, it is saying that the flapper nozzle which is consists of the chamber of small volume connected to a constant pressure source on one side which is supply pressure and vented or bleeded on the other side to the atmosphere through a nozzle.

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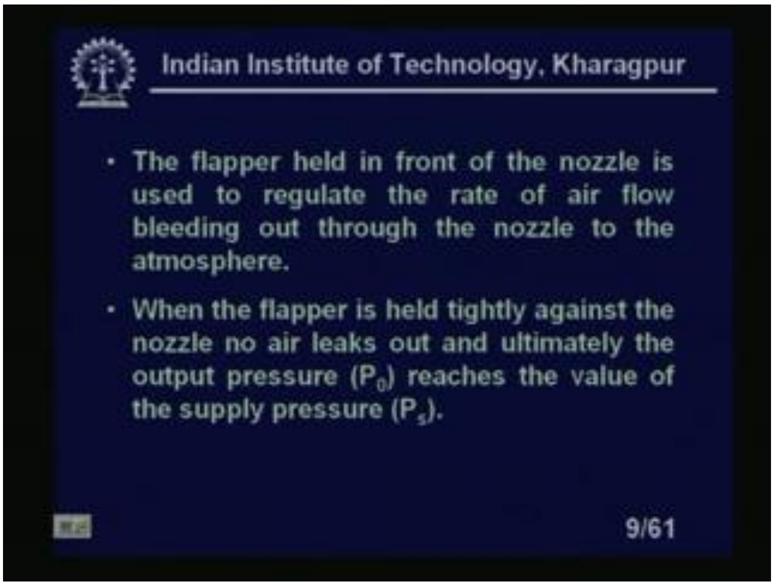

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- The flapper held in front of the nozzle is used to regulate the rate of air flow bleeding out through the nozzle to the atmosphere.
- When the flapper is held tightly against the nozzle no air leaks out and ultimately the output pressure (P_0) reaches the value of the supply pressure (P_s).

The flapper in front of the nozzle is used to regulate the rate of air flow bleeding out through the nozzle to the atmosphere. As I told you we have explained that the how the movement of the flapper will control the regulate the rate of the air flow or air I mean which is bleeding to the atmosphere. When the flapper is held tightly against the nozzle no air leaks out and ultimately the output pressure Po reaches the value of the supply pressure. Obviously, is it not it when I tightly which that situation never arises in a flapper nozzle system. That means if the flapper is suppose I have a flapper here. So, I have my, so if this is the flapper and this is a nozzle through which the air is continuously I have a supply pressure on this side suppose this is I am flapper is now moved and we have controlled we have totally stopped it bleeding. Then what will happen to the Po output pressure? Output pressure will be equal to the supply pressure is not it because nothing is vented to the atmosphere. So, the upload output pressures Po will be equal to the supply pressure.

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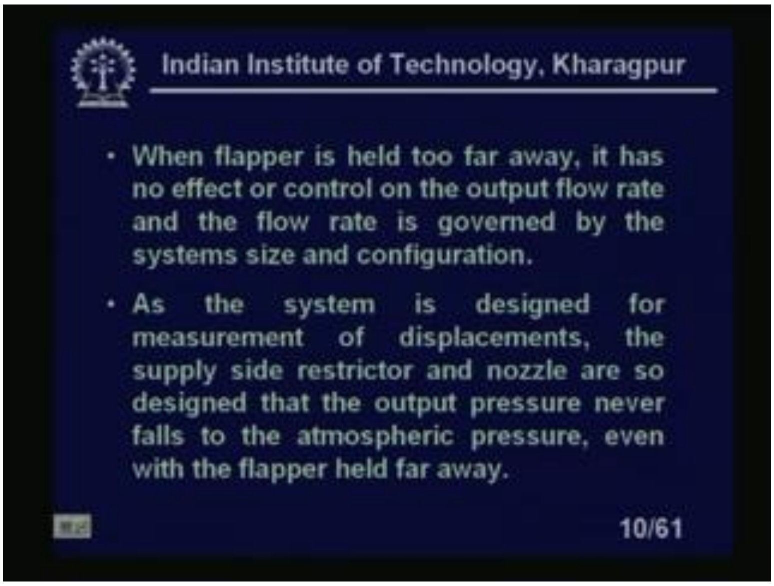

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- When flapper is held too far away, it has no effect or control on the output flow rate and the flow rate is governed by the systems size and configuration.
- As the system is designed for measurement of displacements, the supply side restrictor and nozzle are so designed that the output pressure never falls to the atmospheric pressure, even with the flapper held far away.

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When the flapper is held too far away, it has no effect or control on the output flow rate and the flow rate is governed by the system size and configuration. That is also it is more important this will tell you the range total range of the flapper nozzle system; that means, total range of the displacement sensors, which we are going to design. What I am saying if it goes away from I mean far away from the nozzle itself. So, that suppose I have a nozzle, so flapper goes away this 1. So, that time there is no control; that means, if I move like this 1 there is no control over the bleeding of the air, because ultimately by the movement of the flapper I have to regulate or control the air which is coming out from the nozzle.

If I cannot then; obviously, there is no control. So, whatever where ever position you put it, so it has no output pressure will not change. That time continuous bleeding of the air through the atmosphere. So, it depends on the system geometry or system size and configuration. As the system is designed for measurement of the displacement the supply side restrictor and the nozzle are so designed that the output pressure never falls to the atmospheric pressure even with a flapper held far away it is to be done like that. So, that the you have to regulate the movement of the flapper in such a way, so the output pressure will never come to the atmospheric pressure.

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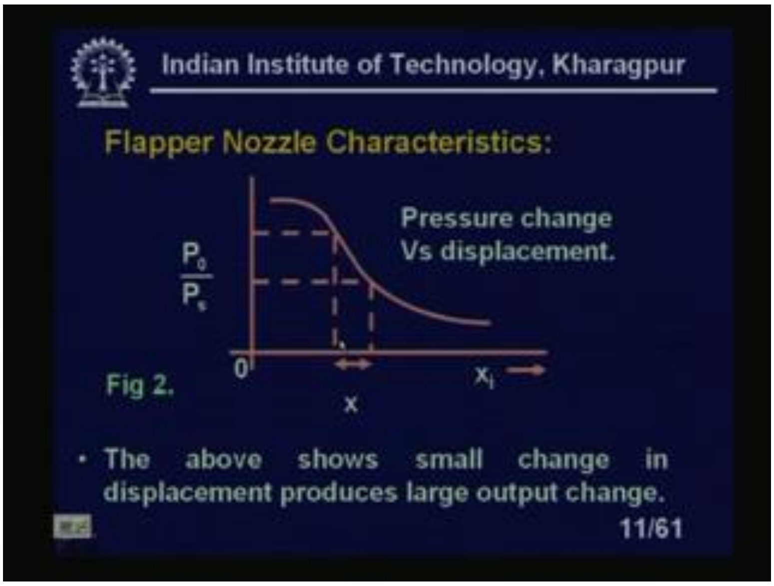

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Flapper Nozzle Characteristics:

Fig 2.

- The above shows small change in displacement produces large output change.

Now, if this is the flapper nozzle characteristics. If you look at we have plotted here on the X axis the P naught by Ps normalized. You see this is normalized I mean I mean we have normalized pressures. We have plotted here in the Y axis and the X axis we have plotted. What we have plotted? We plotted the displacement of the flapper from the normal positions. If you look at you see the graphs looks like this. Ps is constant if the Po increases then what will happen; that means, the distance from the flapper distance of the flapper from the nozzle become getting decreased and decreased. This is side we are avoiding you see this position; that means, it is very close to the tight positions or stopping the bleeding of air.

So, you see it is coming horizontal after that is when it is far away when the flapper is far away you see the Xi is greater and greater. So, it has a constant value of the Po by Ps. So, we will be more interested in this linear region, if you look at we will be more interested in this linear region of the flapper do to the calibrations later on. So, you will find that this pressures with this pressures the Po by Pa will come this will corresponds to a pressure of three to fifteen PSI for a some predicted displacements of the flapper. The above shows small change in the displacement, if you look at the graph the plot; that means fall or the slope the above shows a small change in the displacement produces large output change small change in the displacement produces a large output change.

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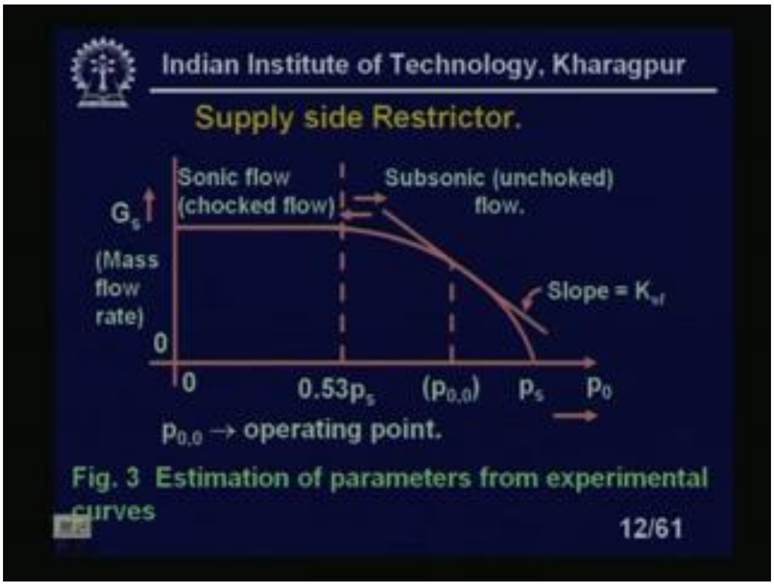

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Supply side Restrictor.

$p_{0,0}$ → operating point.

Fig. 3 Estimation of parameters from experimental curves

Supply side restrictor we have load there are two type restrictors. Where the supply side restrictors we have a load side restrictors load side; that means, on the flapper side; that means. And supply side means which is as restrictors and from the supply of the air which is coming in to the coming in to the flapper nozzle system. You see here estimations of the parameters from the experimental flow. You see here we have mass flow rate we have plotted Gs there is sonic flow or chocked flow and this subsonic flow you see up to this. And after this it is falling down and Ps is a supply pressure Po is some meet position of the flapper systems where the pressure is coming out. Now, what are the legends? Let us look at.

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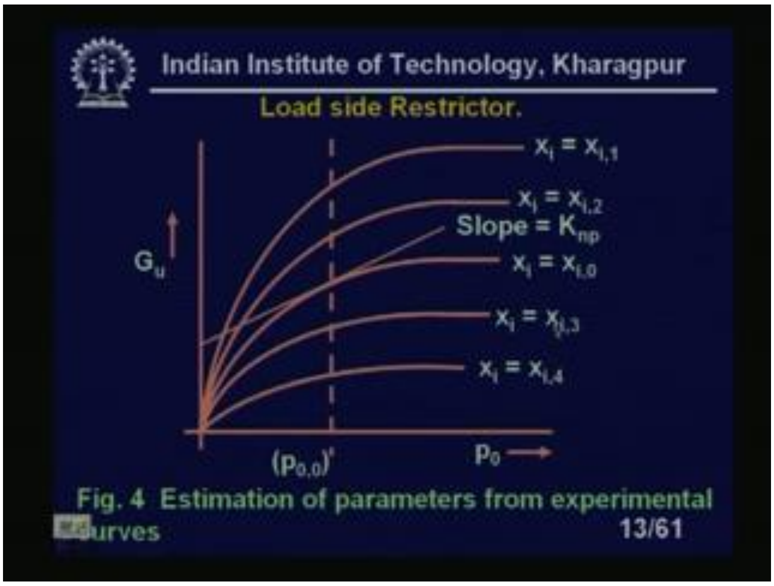

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Load side Restrictor.

Fig. 4 Estimation of parameters from experimental curves

Now, load side restrictor looks like this one. You see here for different position of the Xi for different position of the Xi. If I if I change the Gu, if I change the Po how my Gu will change. So, I plotted like this in this particular graph.

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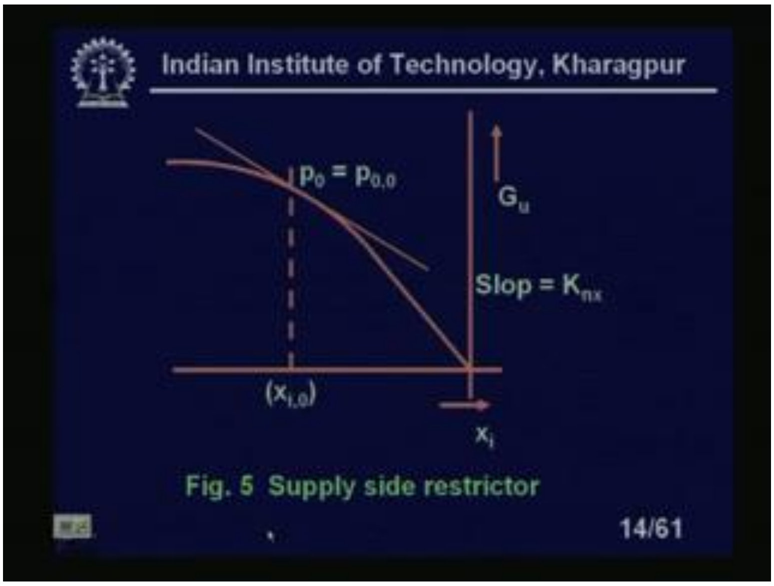

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Fig. 5 Supply side restrictor

This is supply side restrictor same things again we have plotted slope is it is I am sorry, it will be slope Pknx Gu, we have plotted and Xi is the displacement So, what is this legend? Let us look at let us look 1 by 1.

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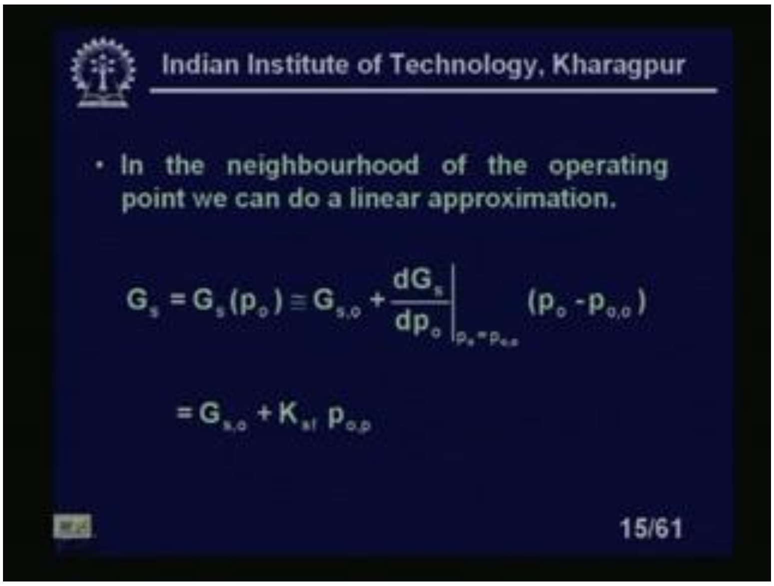

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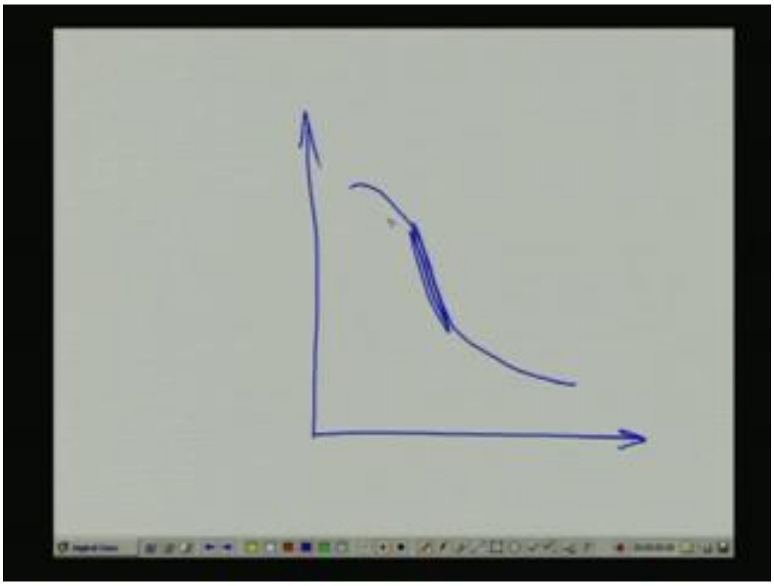
- In the neighbourhood of the operating point we can do a linear approximation.

$$G_s = G_s(p_o) \equiv G_{s,o} + \left.\frac{dG_s}{dp_o}\right|_{p_o = p_{o,o}} (p_o - p_{o,o})$$

$$= G_{s,o} + K_{sf}\, p_{o,p}$$



In the neighbourhood of the operating point we can do a linear approximation; that means, at the linear point; that means. If I look at, that means if I sorry if I look at that means, the plot is I can take some other pages some other colour like this you see. So, that restriction is line. So, I can approximate this positions and I can take this is a linear region this actual operating point of this will corresponds to the 3 to 15 PSI of pressure as a controlled output of the flapper nozzle system. In this neighborhood of the operating point we can do a linear approximation. We can assume that the system is linear system. Now, we are writing Gs equal to Gs Po equal to Ge. So, what are the legends? I will explain plus derivative of Gs with respect to P o at P o equal to P o o multiplied by P o minus P o o, which can be written as G.

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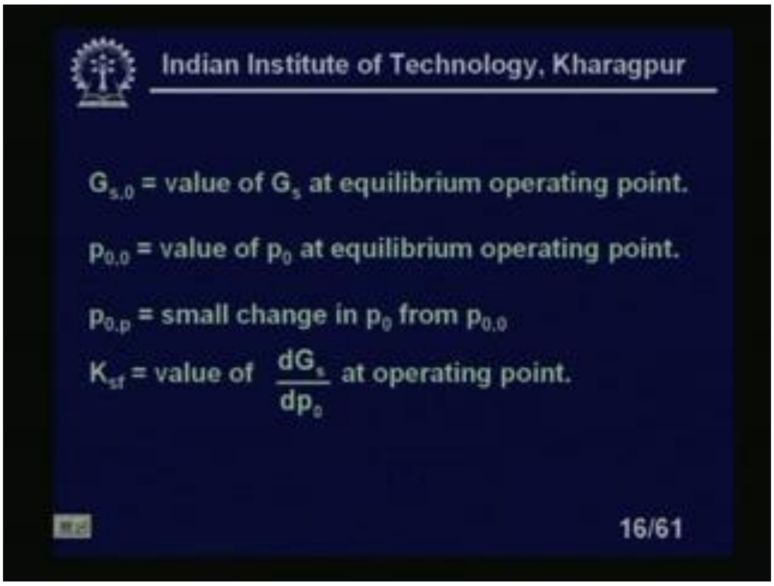

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$G_{s,0}$ = value of G_s at equilibrium operating point.

$p_{0,0}$ = value of p_0 at equilibrium operating point.

$p_{0,p}$ = small change in p_0 from $p_{0,0}$

K_{sf} = value of $\frac{dG_s}{dp_0}$ at operating point.

So, plus Ksf Po, where now the legends we are explaining which corresponds to 3 4 slides which I have shown G. So, is the value of Gs at equilibrium operating point. Po is the value of Po at equilibrium operating point. P o p is the small change in Po from P o o so; there is a small change from the equilibrium point, because now, there is a displacement. So, that is point I am the output pressures we are writing P o p. Ksf is the value of dGs by derivative of Gs supply side I mean I mean restricted d p o at operating point.

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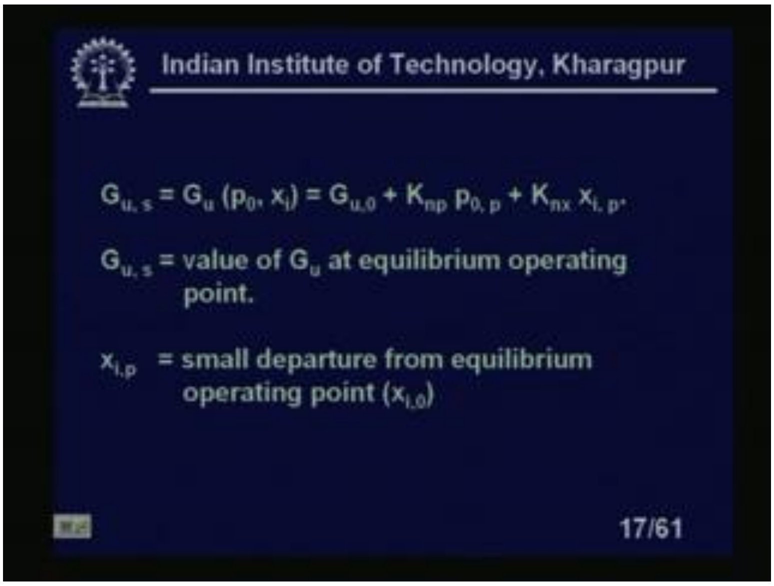

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$G_{u,s} = G_u(p_0, x_i) = G_{u,0} + K_{np}\, p_{0,p} + K_{nx}\, x_{i,p}.$

$G_{u,s}$ = value of G_u at equilibrium operating point.

$x_{i,p}$ = small departure from equilibrium operating point ($x_{i,0}$)

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So, we can write Gus equal to Gu Po Xi equal to Guo plus Knp P o p plus Knx Xi p. Gus is the value of Gu at equilibrium operating point and Xip the small departure from the equilibrium operating point.

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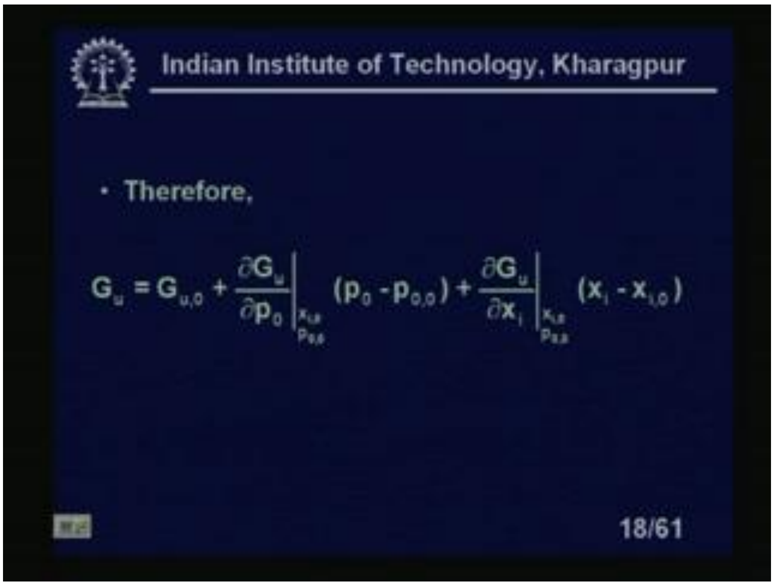

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- Therefore,

$$G_u = G_{u,0} + \left.\frac{\partial G_u}{\partial p_0}\right|_{\substack{x_{i,0}\\ p_{0,0}}} (p_0 - p_{0,0}) + \left.\frac{\partial G_u}{\partial x_i}\right|_{\substack{x_{i,0}\\ p_{0,0}}} (x_i - x_{i,0})$$

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Therefore I can immediately write that Gu equal to Guo plus del of Gu plus d p o d p o. I mean dell of I mean Gu with respect to Po at Xi 0 at P 0 0 multiplied by Po minus P o o plus del of Gu with respect to Xi. One side we are making the derivative with respect to this is our partial derivative with respect to the output pressures and other side with respect to the displacement. So, that is we are multiplying the relative displacement or change of displacement Xi minus Xi naught similarly here the change of pressure Po minus P o o. What is Gu Gs already we have explained.

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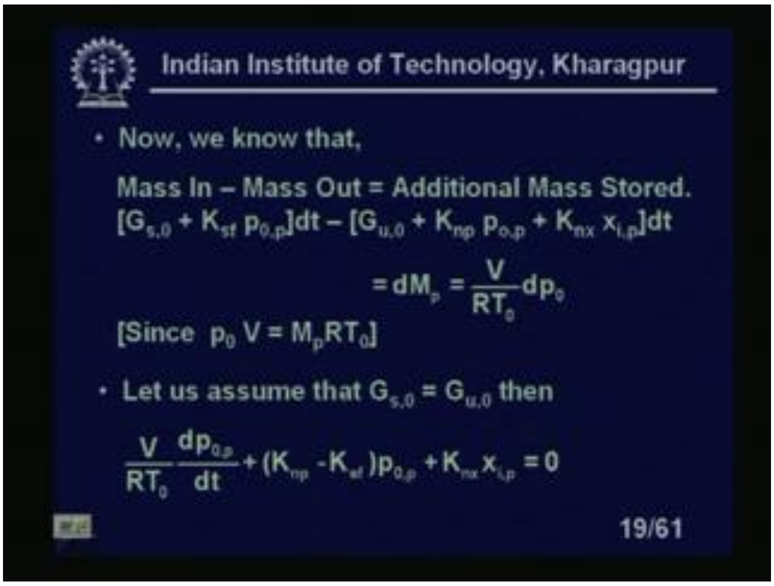

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- Now, we know that,

Mass In – Mass Out = Additional Mass Stored.

$$[G_{s,0} + K_{sf}\, p_{0,p}]dt - [G_{u,0} + K_{np}\, p_{0,p} + K_{nx}\, x_{i,p}]dt$$

$$= dM_p = \frac{V}{RT_0} dp_0$$

[Since $p_0 V = M_p R T_0$]

- Let us assume that $G_{s,0} = G_{u,0}$ then

$$\frac{V}{RT_0}\frac{dp_{0,p}}{dt} + (K_{np} - K_{sf})p_{0,p} + K_{nx} x_{i,p} = 0$$

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Now, we know that, that in a flapper nozzle system mass in which is mass in means mass of air flow which is coming in minus mass out. Obviously, the additional mass stored inside the flapper nozzle inside the nozzle inside nozzle system I should say. If I write that is; obviously, I can immediately write the equations which is Gso plus Ksf P o p dt minus Guo plus Knp plus multiplied P o p plus Knx Xip all multiplied by dt.

Now, from the Gauss theory we know that poV equal to MpRT naught so that we can write immediately V by RT naught equal to dMp. Let us assume that the Gso equal to Gu; that means, at the initially that the supply which is come Gso the mass flow which is coming in and going out mass flow rate is same. See if it is same then; obviously, we can assume that V by RT naught derivative of P o p with respect to dt t time Knp minus Ksf P o p plus Knx into Xip equal to 0.

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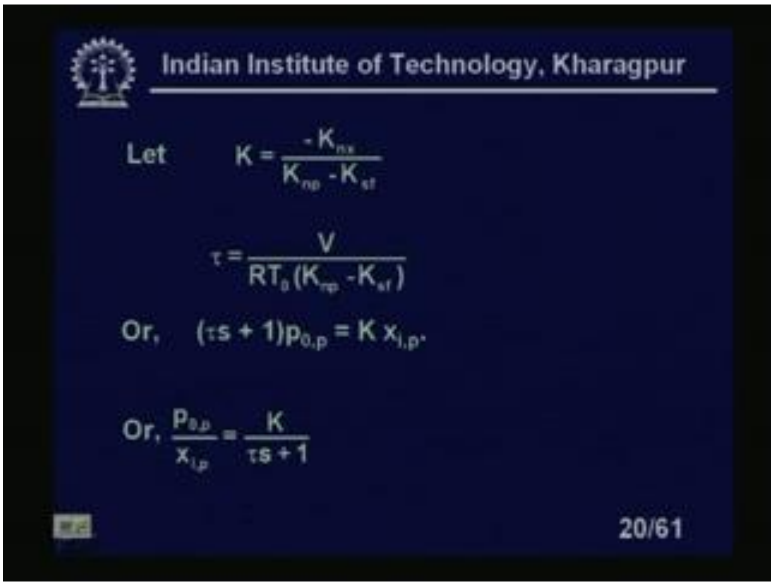

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Let $K = \frac{-K_{nx}}{K_{np} - K_{sf}}$

$\tau = \frac{V}{RT_0(K_{np} - K_{sf})}$

Or, $(\tau s + 1)p_{0,p} = K x_{i,p}$.

Or, $\frac{p_{0,p}}{x_{i,p}} = \frac{K}{\tau s + 1}$

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Let we assume some introduce let us some constant K equal to minus Knx upon Knp minus Ksf. And tau time constant equal to V by RT naught Knp minus Ksf or; obviously, if I make little manipulations. So, it will give you tau s plus 1 P o p equal to Kxip. So, this will lead to a first or a differential equations or the I mean if you look at the response P o p with respect to Xip will be equal to K upon tau s plus 1.

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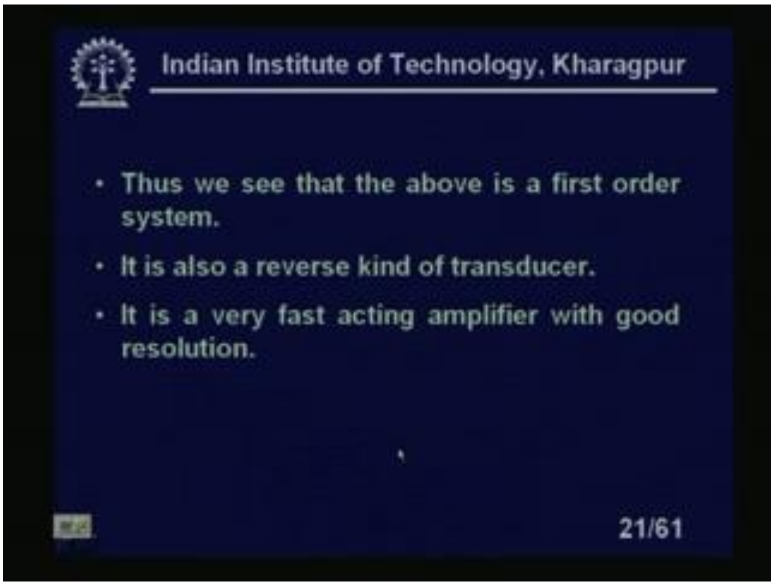

- Thus we see that the above is a first order system.
- It is also a reverse kind of transducer.
- It is a very fast acting amplifier with good resolution.

Thus, we see these above it a first order system. So, I can say that the flapper nozzle system is a we can consider it as a first order system it is also a reverse kind of transducers. That means, that if I forcibly if I change, because if there is a spring action see if I change the pressure, so obviously, change of I mean bleeding pressure there which is coming out. Obviously, the I will get a displacement there that is the reason we call it a reverse kind of transducer.

It is very fast acting amplifier with good resolutions I mean that is if you consider the pneumatic amplifiers. So, it is a fast acting amplifier with good resolutions sensitivity is also quite high that we have already seen. And from the graph also we can predict that it is has a good resolutions used in precision measurement; obviously, for very small displacements I can use this flapper nozzle system. Because we can we have seen that we are getting a large change in the small displacement we are getting large change in the normalized pressure output.

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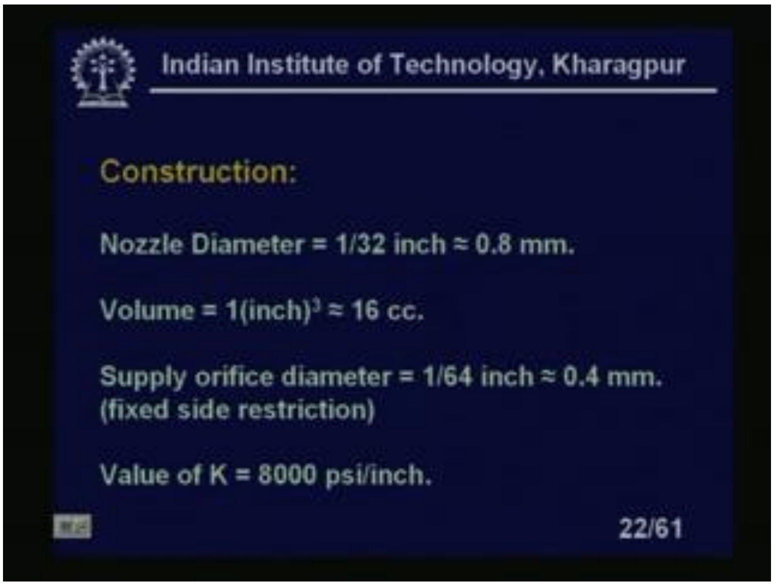

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Construction:

Nozzle Diameter = 1/32 inch ≈ 0.8 mm.

Volume = $1(\text{inch})^3 \approx 16$ cc.

Supply orifice diameter = 1/64 inch ≈ 0.4 mm.
(fixed side restriction)

Value of K = 8000 psi/inch.

Construction nozzle diameter is typically 1 by 32 in inch, which is 0.8 millimeter. Volume is 1 inch cube which is around 16 cc it is quite small. Supply orifice diameter 1 by 64 inch or 0.4 millimeter, which is called fixed side restriction. Value of K is typically 8000 psi per inch, because this will give you a static sensitivity. So, if I draw the electrical equivalent circuit of a flapper nozzle system we can represent it by a simple Rc circuit. So, the analysis will be easier if I can represent by a simple Rc circuit, it is very simple I mean very well resistance with that the…

If you look at the load side restrictor you will find that there is a very well resistance which can I can replace by a potentiometer or a rheostat. And at the supply pressure restrictors we can represent by a simple resistors and the volume we can represent volume of the total volume of the flapper nozzle system, we can replace by a we can capacitor. So, keeping all these mind we got the following electrical representations of our flapper nozzle system which looks like this.

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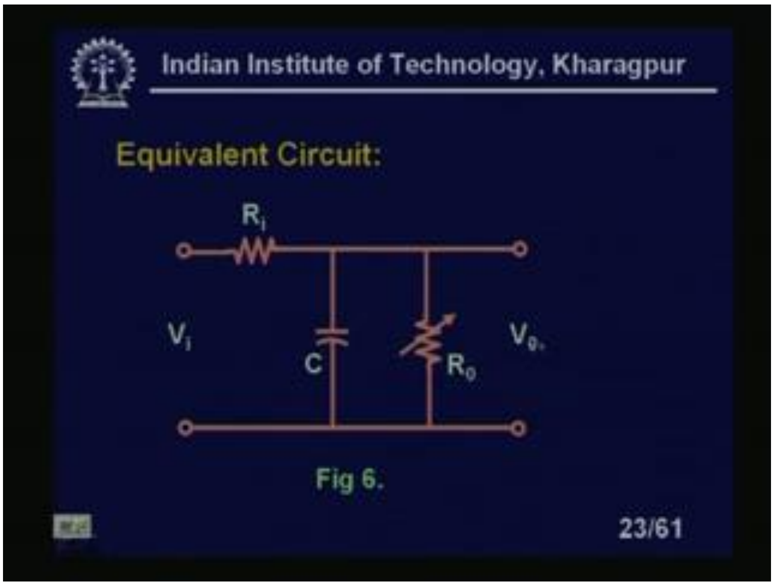

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Equivalent Circuit:

Fig 6.

You see this is out flapper nozzle systems. This Ri and C Ri is the input side; that means, supply side restrictor representing. And this is Ro is the load side restrictors I am giving Vi I am Vo this is a electrical representations of our flapper nozzle system.

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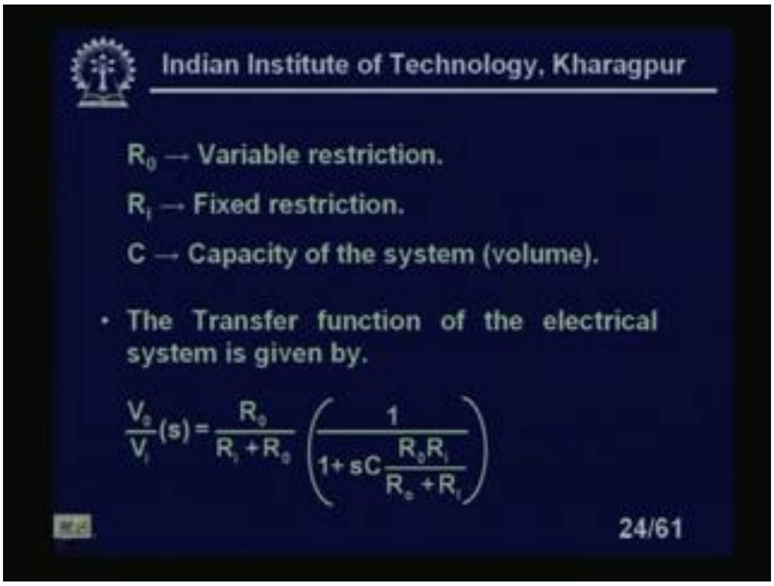

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R_0 → Variable restriction.

R_i → Fixed restriction.

C → Capacity of the system (volume).

- The Transfer function of the electrical system is given by.

$$\frac{V_o}{V_i}(s) = \frac{R_o}{R_i + R_o}\left(\frac{1}{1 + sC\frac{R_0 R_i}{R_o + R_i}}\right)$$

Where is Ro? Is a variable restriction Ri is the fixed restriction. What is the fixed restriction? That is at the input the side the restrictions, which we are getting that is the fixed restrictions. Then C is the capacity of the systems that is the volume, so these actually makes our flapper nozzle system. The transfer function are easily we can find the transfer function of the electrical system is given by V naught by Vi into s R naught Ri plus Ro 1 upon 1 plus Sc multiply by Ro into Ri upon Ro plus Ri.

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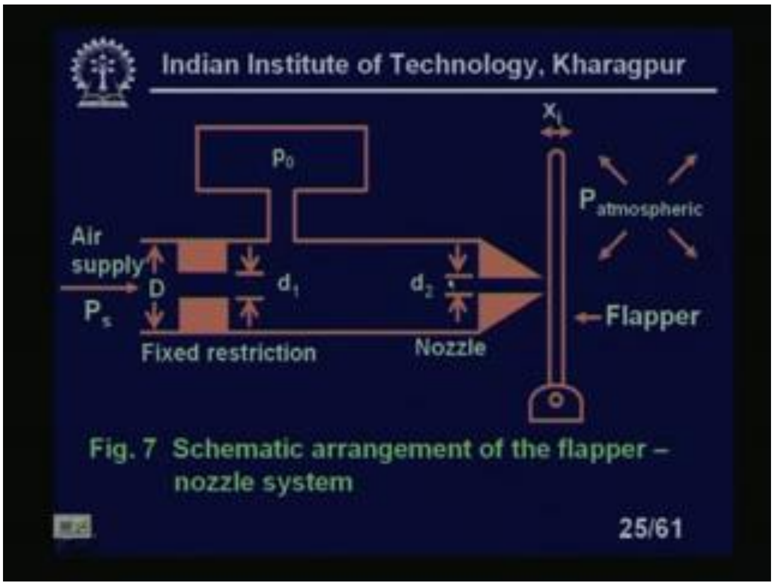

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Fig. 7 Schematic arrangement of the flapper – nozzle system

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You see here let us I mean we can redraw the equation the flapper nozzle systems. We have just redrawn we have change the position it does not matter it can be flapper can be this side this can be that side. I mean the nozzle can be the supply air from this side or that can be that side it does not matter much. You see the same the circuit I mean the flapper nozzle diagram, because we refer to this that is the reason why I have redrawn this in the figure 7.

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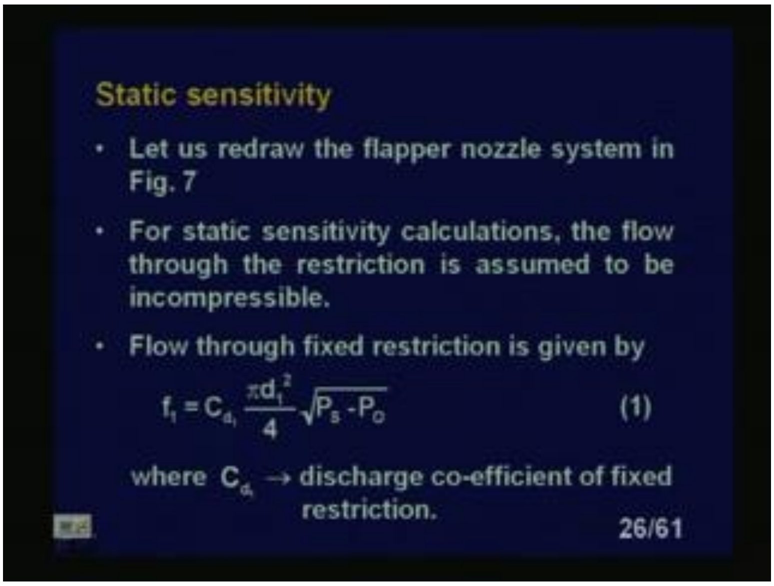

Static sensitivity

- Let us redraw the flapper nozzle system in Fig. 7
- For static sensitivity calculations, the flow through the restriction is assumed to be incompressible.
- Flow through fixed restriction is given by

$$f_1 = C_{d_1} \frac{\pi d_1^2}{4} \sqrt{P_s - P_O} \qquad (1)$$

where $C_{d_1} \rightarrow$ discharge co-efficient of fixed restriction.

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Now, let us how will I compute the static sensitivity of the flapper nozzle systems. Let us redraw flapper nozzle system as I told you in the figure 7. That just we have redrawn the figure it is same as the figure 7 there is no difference. For static sensitivity calculation the flow through the restriction is assumed to be incompressible flow through the restrictor is incompressible in first we have assume. In many field dynamics we thought we have seen that we have assumed like this 1.

Now flow through the fixed restriction is given by f 1 C d 1 pi d 1 square by 4 root over Ps minus Po which is equation number 1. Where did I get this equation very simple I got this equation from our basic orifice I mean orifice principles Bernoulli using the Bernoulli's principles we will get this 1 let us look at what is d 1 what is? You see d 1 is the supply side restrictor orifice diameter and d 2 is the load side restricted I mean restriction diameter which is circular in nature. So, Cd 1 is the flow coefficients on the supply side and Cd 2 is the flow coefficient of at the load side of the flapper nozzle side. If I have that thing; obviously, equation looks like this.

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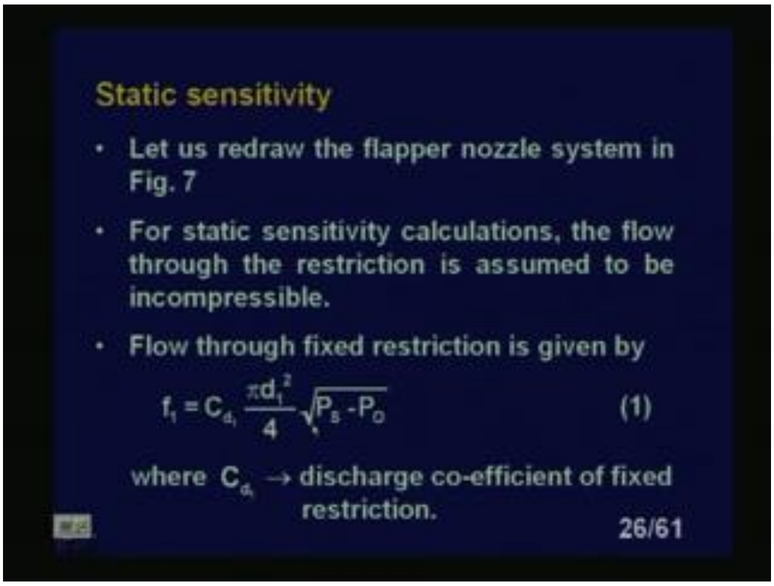

Static sensitivity

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$$f_1 = C_{d_1}\frac{\pi d_1^2}{4}\sqrt{P_s - P_o} \tag{1}$$

where C_{d_1} → discharge co-efficient of fixed restriction.

So, Cd 1 is the discharge coefficient of fixed restrictions; that means, supply side restrictions Ps Po you know there is a output pressures and Ps is the our supply pressure.

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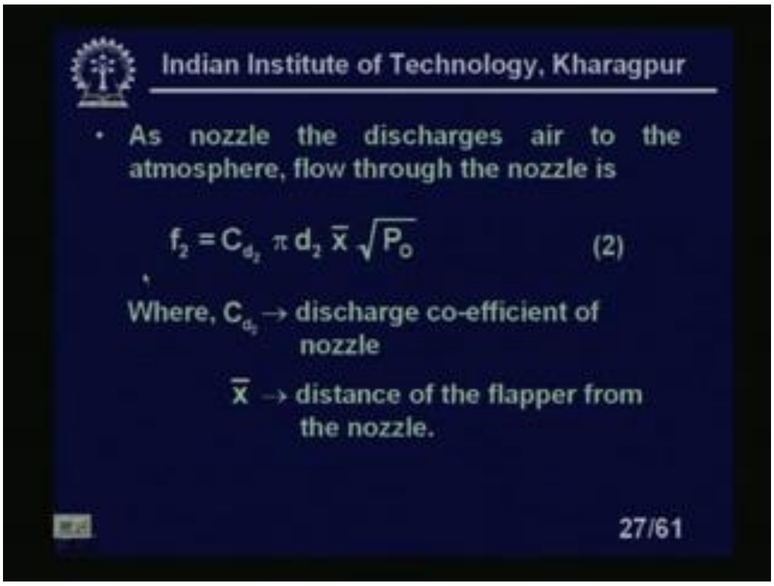

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- As nozzle the discharges air to the atmosphere, flow through the nozzle is

$$f_2 = C_{d_2} \pi d_2 \bar{x} \sqrt{P_0} \qquad (2)$$

Where, C_{d_2} → discharge co-efficient of nozzle

$\bar{x}$ → distance of the flapper from the nozzle.

As nozzle the discharges air to the atmosphere the flow through the nozzle is as the nozzle flow discharges the air to the atmosphere again. The flow rate instead of volumetric flow rate I am talking about is mass flow rate I am talking the volumetric flow rate through the nozzle is look like, if 2 equal to Cd 2 pi d 2 into X dot into P naught. This equation this side is slightly different. We have seen that this is instead of we have taken the circumference multiplied by the x naught. the displacement that we are taking at the bleeding volume. Let us look at a Cd 2 is the discharge coefficient of the nozzle x dot x bar is the distance of the flapper from the nozzle. So, distance of the flapper of the nozzle multiplied by this pi d 2 will give you the flow. If I have that thing so; obviously, this is again I mean is coming in the meter square or something like that.

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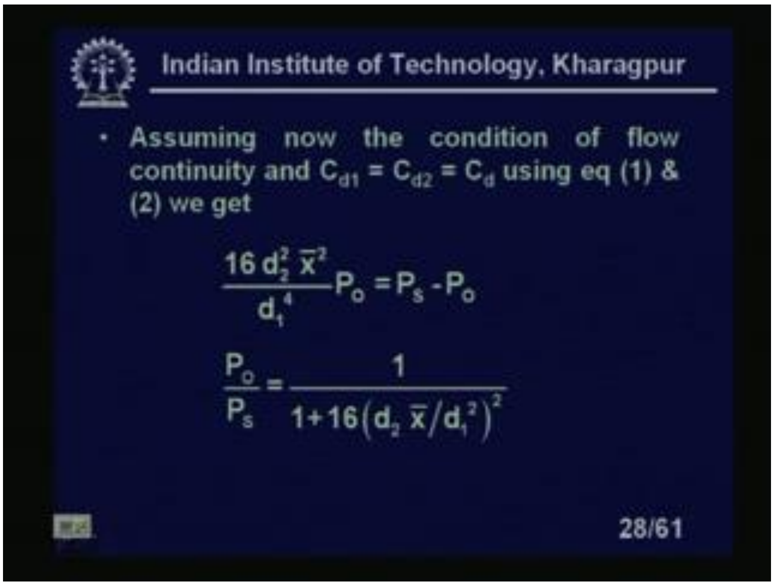

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- Assuming now the condition of flow continuity and $C_{d1} = C_{d2} = C_d$ using eq (1) & (2) we get

$$\frac{16\, d_2^2\, \bar{x}^2}{d_1^4} P_o = P_s - P_o$$

$$\frac{P_o}{P_s} = \frac{1}{1 + 16\left(d_2\, \bar{x}/d_1^2\right)^2}$$

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Now, I assumed that the condition of the flow continuity. What is mean by the flow equation continuity? That means, if 1 equal to f 2 and moreover we assume that the 2 discharge coefficients will be same. Even though there is a lot of an assumption for simplifications of our calculation, let us calculate Cd 1. That means Cd 1 equal to 2 discharge coefficients are same and also assume there is flow continuity is there. Then equation 1 and 2 if I then combine this equation 1 and 2 we will get that 16 d square into x bar square by d 1 to the power 4 equal to Po equal to Ps minus Po. Which will give us Po minus Ps 1 upon 1 by 16 d 2 x bar d 1 square whole square. Let us look at how did I get this thing let us take a blank page or let me take this.

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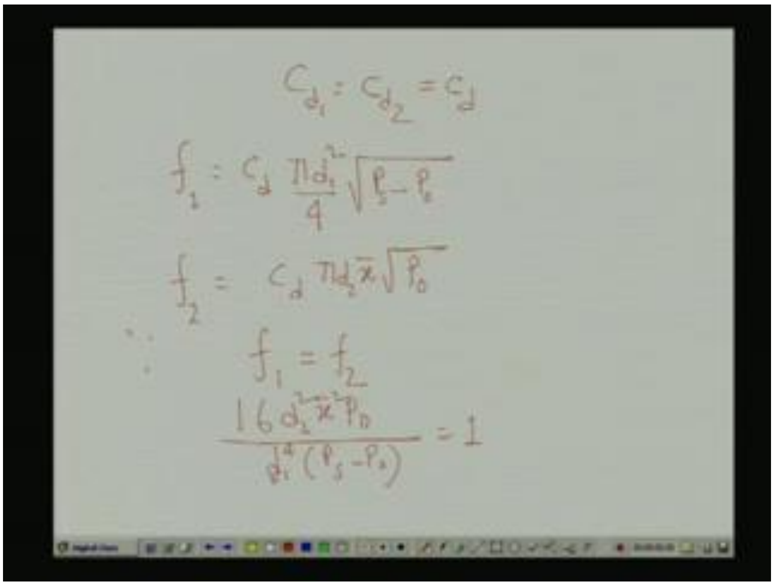

$$C_{d_1} = C_{d_2} = C_d$$

$$f_1 = C_d \frac{\pi d_1^2}{4} \sqrt{P_s - P_o}$$

$$f_2 = C_d\, \pi d_2 \bar{x} \sqrt{P_o}$$

$$\therefore \quad f_1 = f_2$$

$$\frac{16\, d_2^2\, \bar{x}^2 P_o}{d_1^4 (P_s - P_o)} = 1$$

It will look like this, you see f 1 equal to Cd, because we have assumed that Cd 1 equal to Cd 2. We have assumed like this; ((Refer Time: 29:09)) that means, Cd 1 equal to Cd 2 and f 1 from the supply side equal to Cd equal to we write Cd this will be equal to Cd pi d 1 square by 4 root over Ps obviously, will be more than Po, so Ps minus Po. And the nozzle side flow rates we can write Cd again multiplied by pi d 2 2 pi r. So, instead of 2 pi r I am writing pi d 2 in to x bar x bar is the movement of the flapper from the nozzle into Po. Since we know that f 1 equal to f 2, so we will get 16 d 2 square x bar square into Po divided by d 1 to the power 4 Ps minus Po equal to 1 .

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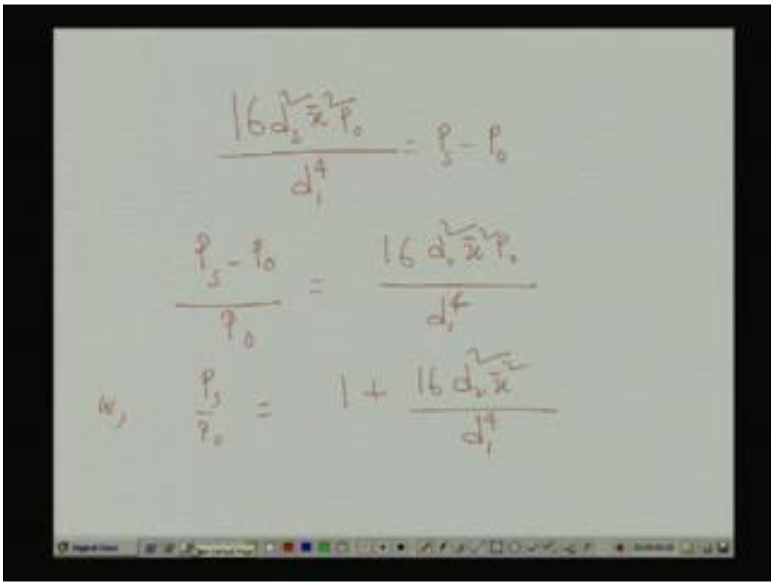

$$\frac{16 d_2^2 \bar{x}^2 P_o}{d_1^4} = P_s - P_o$$

$$\frac{P_s - P_o}{P_o} = \frac{16 d_2^2 \bar{x}^2 P_o}{d_1^4}$$

or, $$\frac{P_s}{P_o} = 1 + \frac{16 d_2^2 \bar{x}^2}{d_1^4}$$

So, this will lead to 16 d 2 square x bar square Po by d 1 to the power 4 Ps minus Po. So, I can write Ps minus Po by Po equal to 16 d 2 square x bar square Po divided by d 1 to the power 4. So, this will lead to Ps by Po equal to 1 plus 16 d 2 square x bar square upon d 1 to the power 4. So, I can write that Po by Ps I can take a new page.

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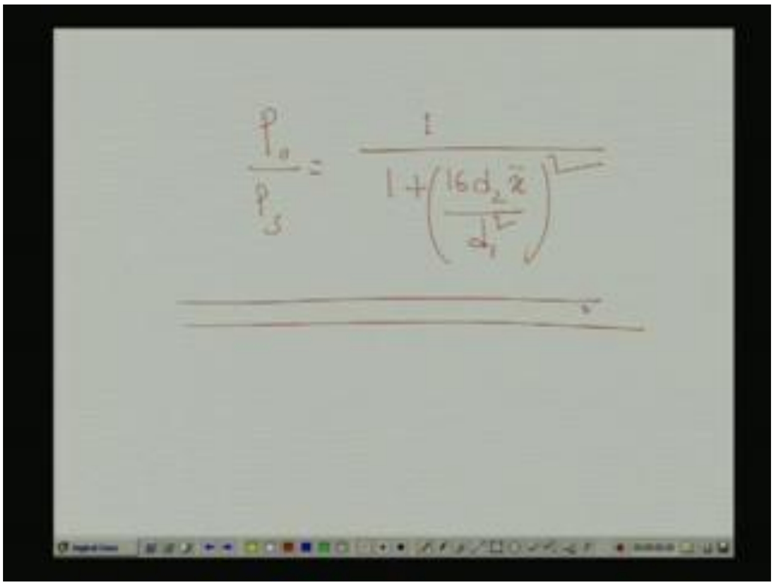

$$\frac{P_o}{P_s} = \frac{1}{1+\left(\frac{16 d_2 \bar{x}}{d_1^2}\right)^2}$$

Po by Ps equal to 1 upon 1 plus 16 d square d 2 here I write x bar here I write by d 1 square to the power whole square this is our equations. This is actually we have explained in our ultimate equations; that means, normalized output how the normalized output is relates to the displacement.

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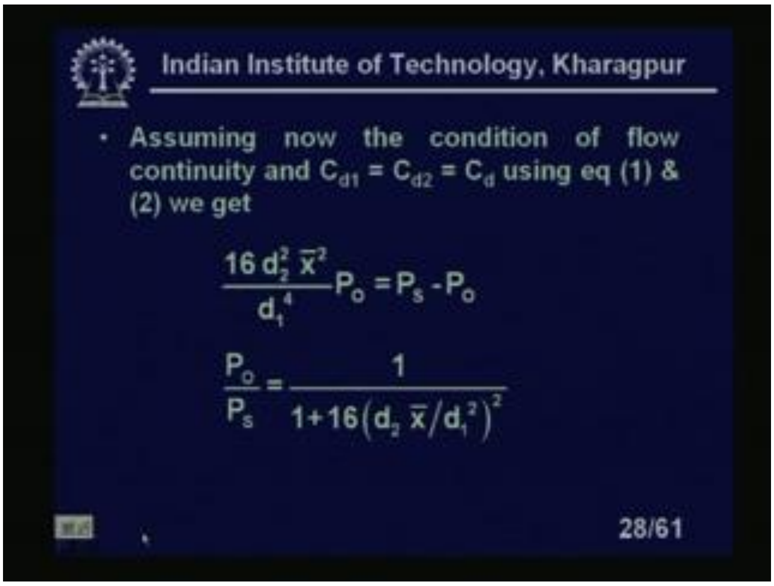

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- Assuming now the condition of flow continuity and $C_{d1} = C_{d2} = C_d$ using eq (1) & (2) we get

$$\frac{16 d_2^2 \bar{x}^2}{d_1^4} P_o = P_s - P_o$$

$$\frac{P_o}{P_s} = \frac{1}{1+16\left(d_2 \bar{x}/d_1^2\right)^2}$$

So, this is our expression 1 upon 1 plus 16 d d 2 plus I am sorry I think that will be 16 d 2 because if I take 16 inside. So, it will be it will be here, it will be 16 if I see it will be here if I take 16. So, this will be…

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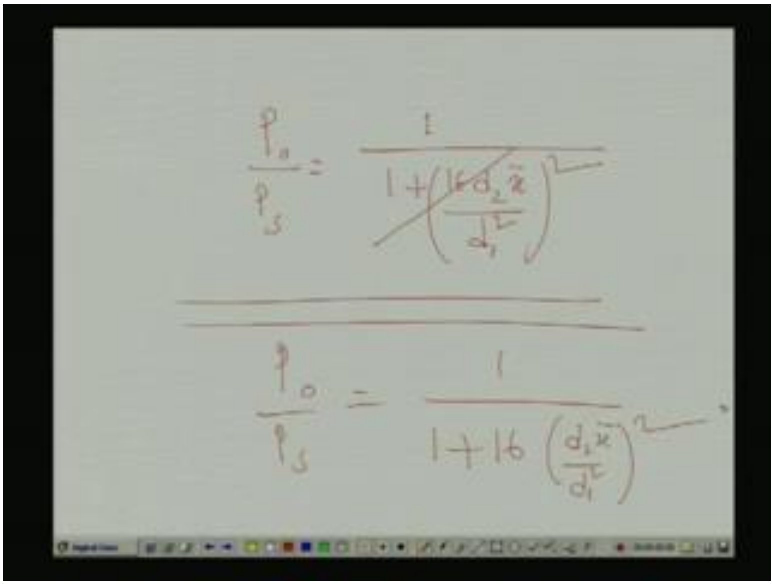

$$\frac{P_0}{P_s} = \frac{1}{\cancel{1+\left(\frac{16 d_2 \bar{x}}{d_1^2}\right)^2}}$$

$$\frac{P_0}{P_s} = \frac{1}{1+16\left(\frac{d_2 \bar{x}}{d_1^2}\right)^2}$$

Anyway let me write down this equation this will be let me take pen. So, this will be like this 1 P naught by Ps 1 upon 1 plus 16, we will take outside. Then I will get d 2 x bar by d 1 square to the power whole square. This is my final equation anyway as you have seen.

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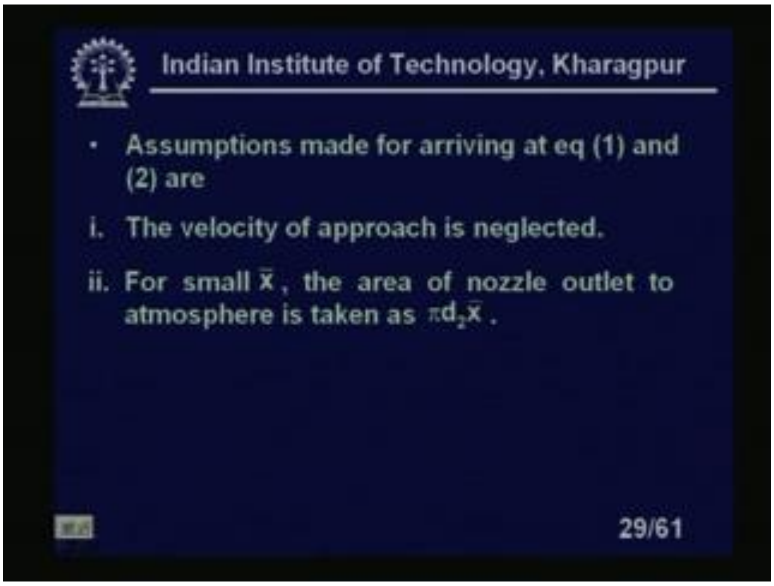

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- Assumptions made for arriving at eq (1) and (2) are

i. The velocity of approach is neglected.

ii. For small $\bar{x}$, the area of nozzle outlet to atmosphere is taken as $\pi d_2 \bar{x}$.

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Now, assumptions made for arriving at equation one and two I mean how there are what are the assumptions basic assumptions. We have taken the velocity of approach is neglected for small x bar the area of the nozzle outlet to the atmosphere is taken as pi d 2 into x bar instead of pi d 2 square by 2 pi d 2 square by 4. We have taken pi d 2 into x bar because we have seen that it is variable. That is the reason we have taken like this 1 where as in the supply side restrictor we have taken pi d 1 square by 4 that is the simple orifice formula. Now, we have taken the normalized response curve shown in figure 8. What is the figure 8? Let us look at these are normalized response curve.

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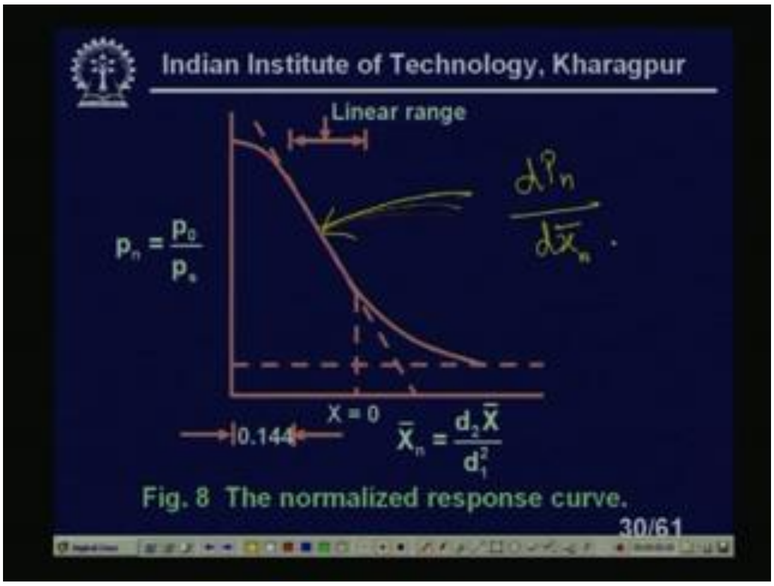

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Fig. 8 The normalized response curve.

Let us look at very carefully this is our plot Pn normalized output by input P naught by Ps X n X n bar. This is also we have plotted in the x axis which is d 2 x bar by d 1 square. This graph is very important this will control the entire position you see here if I come down so; obviously, what will happen? The if I come to the close to the to the nozzle when the flapper moves close to the nozzle; that means, you will find that output pressure is increases which is supposed to be. This is a normalized response curve from this curve we will do, so many other things.

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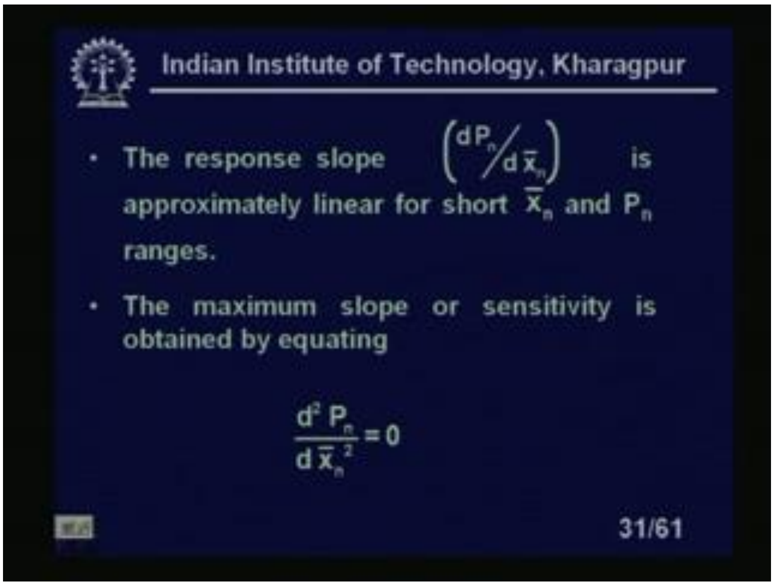

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- The response slope $\left(dP_n / d\bar{x}_n\right)$ is approximately linear for short $\bar{x}_n$ and P_n ranges.
- The maximum slope or sensitivity is obtained by equating

$$\frac{d^2 P_n}{d\bar{x}_n^2} = 0$$

The response slope dPn by dx n is approximately linear for short xn ad pn ranges what is that? You see here, so dPn by Xn; that means, this slope which is supposed to be actually if I say that it is this slope is actually if I take a thicker pen this slope is equal to actually that dPn by dxn. So, this slope is actually will give you the response of the flapper nozzle system approximate linear for short xn and Pn ranges for I mean small ranges we will find it is linear. This very important we need a linear relationship from the beginning we have seen that many all instrumentation cases we needed a linear relationship The maximum slope for sensitivity is obtained by equating the d square pn which 1 basic I mean basic elementary of our calculus. We know d square Pn by dx is x n square is equal to 0.

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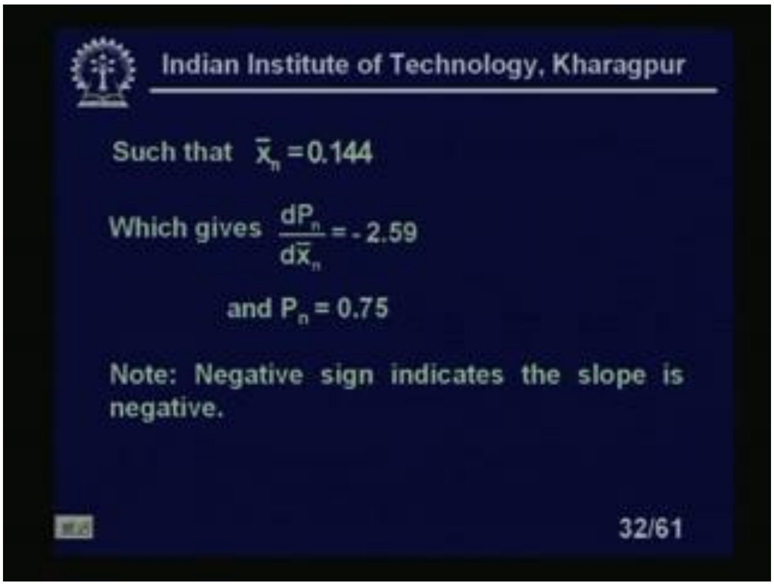

Such that $\bar{x}_n = 0.144$

Which gives $\frac{dP_n}{d\bar{x}_n} = -2.59$

and $P_n = 0.75$

Note: Negative sign indicates the slope is negative.

Such that Xn bar equal to 0.144 that is the value for which we will get the maximum. So, which gives dPn by dxn bar equal to 2 point minus 59 and this need this minus sign signifies that the slope is negative. That we have seen from the graph the slope is negative and Pn equal to 0.75 negative sign indicates the slope is negative.

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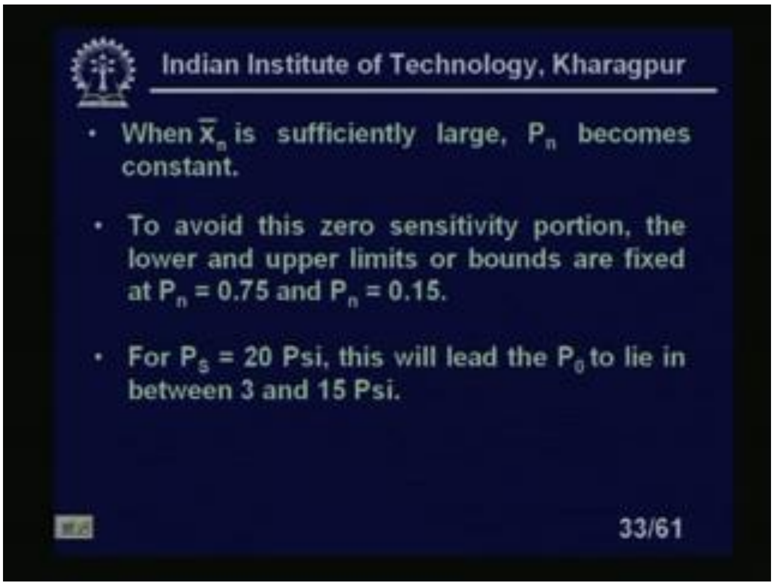

- When $\bar{x}_n$ is sufficiently large, P_n becomes constant.
- To avoid this zero sensitivity portion, the lower and upper limits or bounds are fixed at $P_n = 0.75$ and $P_n = 0.15$.
- For $P_S = 20$ Psi, this will lead the P_0 to lie in between 3 and 15 Psi.

When Xn bar is sufficiently large, Pn becomes constant. That you have seen when it is coming, it is the constant right in Xn bar is how does it look? You see we have seen. How does it look it will look like this 1 see here if I take a blank page. So, the slope will look like.

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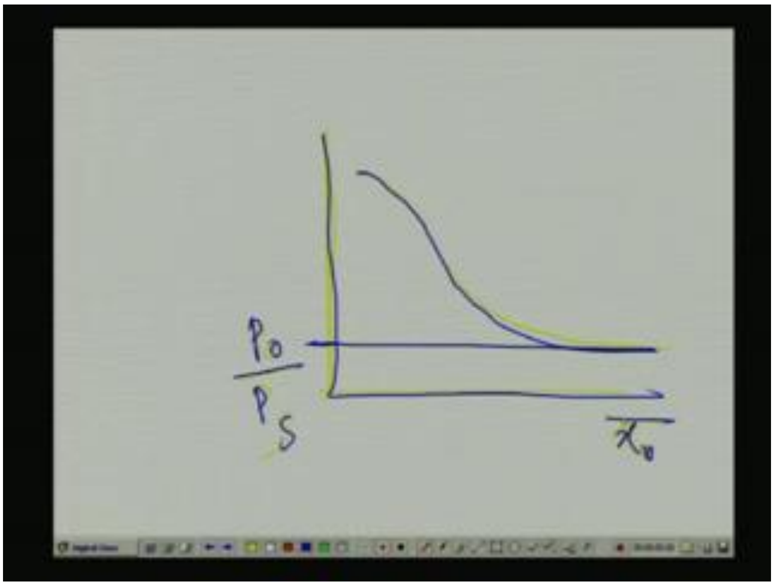

So, if I have take a this 1 that already we have explained we can I mean if we do not take that much. So, it will look like this 1. So, the pressure is Xn is faraway ((Refer Time: 38:02)) is faraway you will find that it is becoming constant. So, it is a pressure is; that means, Po by Ps is constant here. If I take different pen, so right. So, it is coming like this slope is looks like this 1. So, Po by Ps is constant to this value right when Xn is large clear. Is to avoid this zero sensitivity portion that is lower and upper limits or bounds are fixed to Pn equal to 0.75 normalized output is 0.75 and Pn equal to 0.15.

Because I cannot take Pn equal to; obviously, zero I mean I mean it is Pn 0 means it is not possible. That means that these I am talking about um. So, I have taken a I mean range of Pn equal to 0.75 to Pn equal to 0.15. For supply pressure of 20 psi we will find that this will lead to Po to lie between 3 to 15 psi for Pn I can I cannot make it 0. So, if I make it 0 there is a problem. So, that because we need a continues bleeding of air through the nozzle. So, I cannot make it 0.

So, Pn I make the Ps 20 Ps over the supply pressure of 20 Psi this will be 2 3 to 15 Psi. This is the key reason we will find in all the pneumatic system always we are getting this value many a times we calling the industry standards is 3 to 15 Psi of the control pressure where it came from the actually. This is the reason why it is I mean this is the point where it actually came from, so 3 to 15 Psi, because why I want to make it within this in range, because this will make take the linear portion of our graph. So, the flapper nozzle system will be linear in this region that is the reason we are limiting this pressure.

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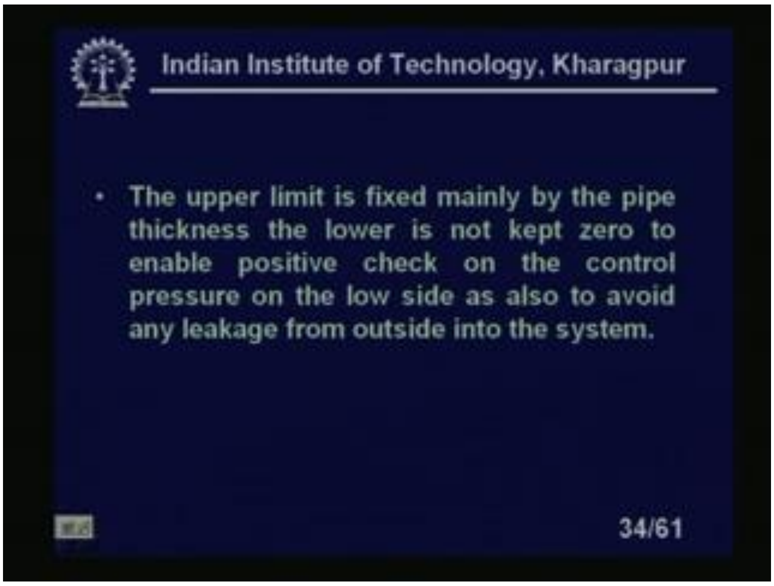

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- The upper limit is fixed mainly by the pipe thickness the lower is not kept zero to enable positive check on the control pressure on the low side as also to avoid any leakage from outside into the system.

The upper limit is fixed mainly by the pipe thickness the lower is not kept zero to enable positive check on the control pressure on the low side as also to avoid the leakage in any leakage from outside into the system. There should be always some bleeding. So, that is the reason why we are saying there. So, there is no if there is not bleeding there is a chance of the output pressure will come output atmospheric air will come inside the system. So, that you do not allow. So, that is the reason here always leakage to always there will be some bleeding of the air from the nozzle to the atmosphere.

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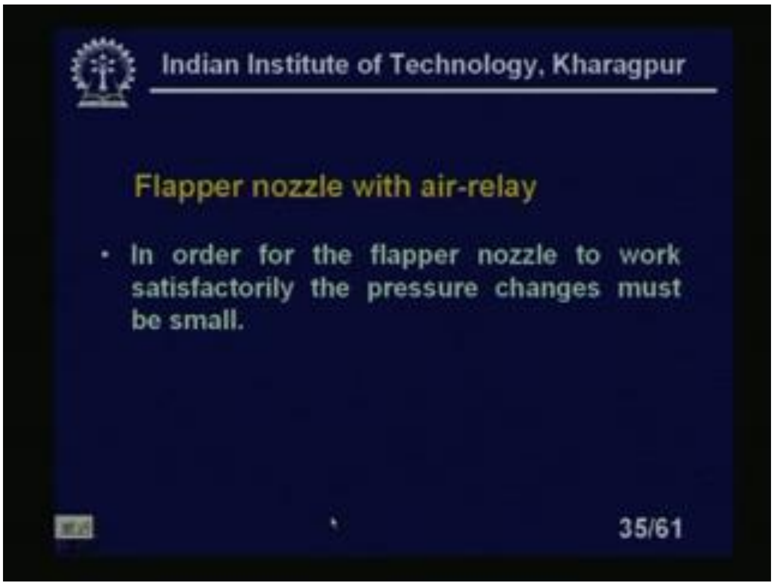

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Flapper nozzle with air-relay

- In order for the flapper nozzle to work satisfactorily the pressure changes must be small.

Flapper nozzle with air relay this is another important thing in order for the flapper nozzle to work satisfactorily the pressure changes must be small. We have seen that the pressure change must be small I mean very small. This is by using an air relay an excellent thing you see the how it works?

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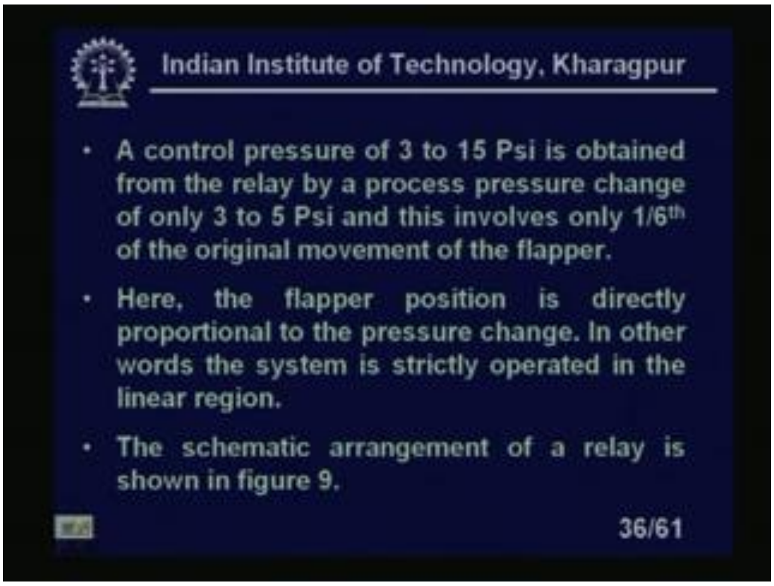

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- A control pressure of 3 to 15 Psi is obtained from the relay by a process pressure change of only 3 to 5 Psi and this involves only 1/6th of the original movement of the flapper.
- Here, the flapper position is directly proportional to the pressure change. In other words the system is strictly operated in the linear region.
- The schematic arrangement of a relay is shown in figure 9.

A control pressure of 3 to 15 Psi obtained from the relay by a process pressure change of only 3 to 5 Psi and this involves only one-sixth of the original movement of the flapper. So, I will strictly I am bringing the I mean, because I am saying that 3 to 15 Psi, but I am saying that if I can even reduce the movement of the flapper to a smaller to this value then what will happen I will get a less pressure. We will find that the pressure changes in this type of situation say will be 3 to 5 Psi, but with the relay I will make it 3 to 15 Psi which is a industry standard. How it looks like? Let us see here the flapper position is directly proportional to the pressure change. In other words, the system is strictly operated in the linear region the schematic shown in the relay is…

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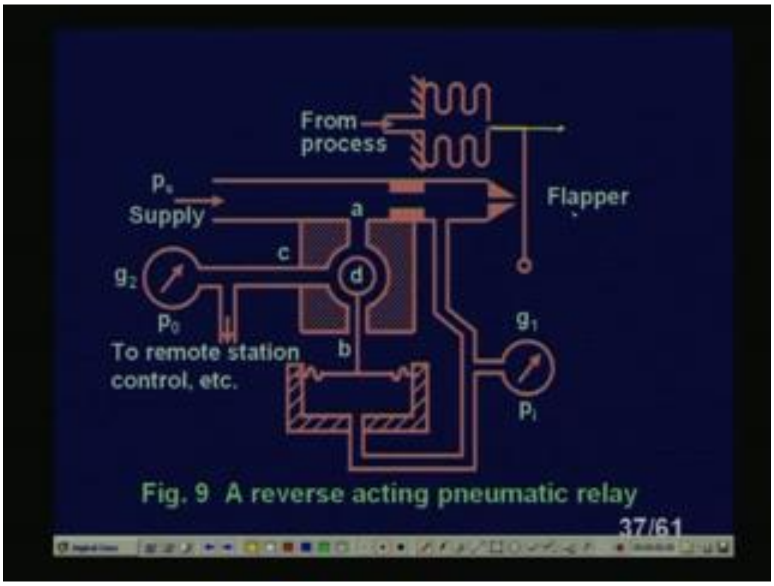

Fig. 9 A reverse acting pneumatic relay

You see this is the relay position this is from the process there is a bellow you can see here there is a bellow. So, if the pressure increases this flapper will move further here in this direction. Let me take it this bellow will move in this direction the flapper, because this is a fixed end of the below I mean the bellow the flapper will move in this direction. Vertically it will move in this direction I mean horizontal If it moves in what will happen? You see the more air will leak out more air will leak this will reduce the pressure here. If we reduce the pressure this will what will happen? You see that ultimately it will reduce the inside pressure inside this diaphragm gauge.

So, this diaphragm will come down if the diaphragm will come down what will happen? You see diaphragm will come down. So, this ball will come down. So, allowing the more pressure I mean the allowing the. So, allowing the more pressure to indicate so; that means, the more I mean signal to the remote station. So, this is the basic principle like other way if I if the flapper moves in this direction this will increase the flapper. So, it will move this in this direction. So, it will move in this direction the supply less air will come to the gauges it will show less, right.

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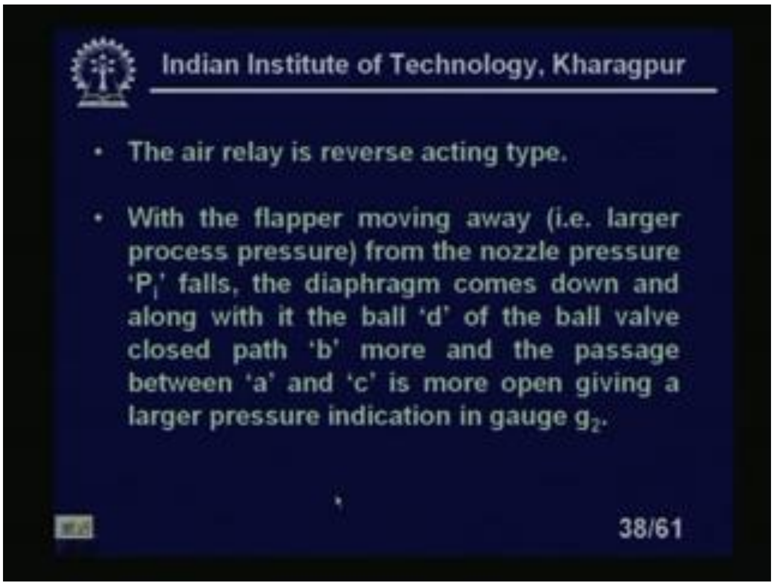

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- The air relay is reverse acting type.
- With the flapper moving away (i.e. larger process pressure) from the nozzle pressure ‘P_i’ falls, the diaphragm comes down and along with it the ball ‘d’ of the ball valve closed path ‘b’ more and the passage between ‘a’ and ‘c’ is more open giving a larger pressure indication in gauge g_2.

Let us look at the air relay is reverse acting type. With the flapper moving away the larger process when the process pressure is large from the nozzle the pressure Pi falls when the diaphragm comes down along with the ball d. Pressure Pi this is the pressure Pi, because it comes down the pressure Pi falls along with the ball d. So, it is closed the path b again if I if I go that back it closed the path b. So, this path will go because this will now valve since the pressure increases this will move out. So, this path there is a no chance of air to come close the path b more and the passage between a and c is more open. What is look at sorry passage between a and c is more open.

So, this will come down if the valve is coming down sorry if the valve is coming down then what will happen? So, there is a less path. So, that less if the valve is I mean coming down. So, what will happen? So, there is a less path to come here, but the more path a and c will be more and more open. And the passage between a and c is more open giving a larger pressure indication in gauge g 2. So, when the Pi falls when the g 1 is showing some I mean lower pressure g 2 will show the larger pressure.

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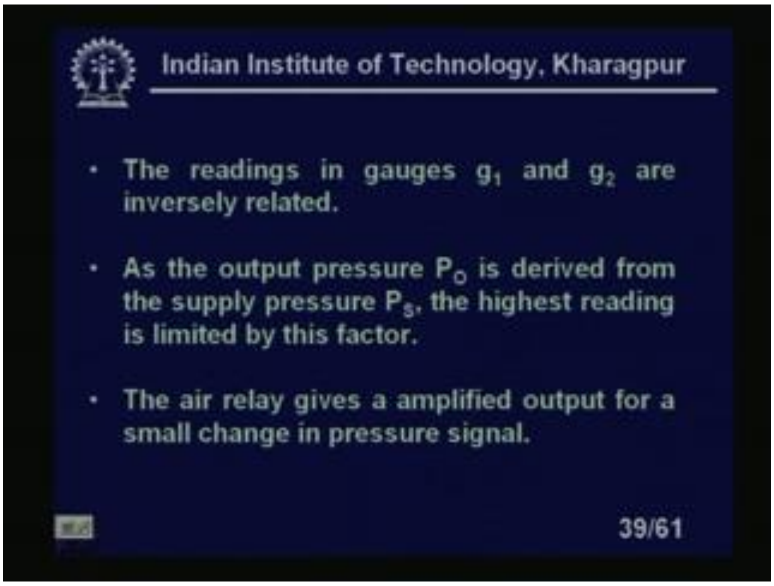
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- The readings in gauges g_1 and g_2 are inversely related.
- As the output pressure P_O is derived from the supply pressure P_S, the highest reading is limited by this factor.
- The air relay gives a amplified output for a small change in pressure signal.

The readings in gauges g 1 and g 2 are always inversely related. It is the other way also when the flapper is coming close when the system pressure is less then what will happen? Flapper will come close then the valve will move the g 2 pressure will be high pressure showing by g sorry pressure showing with the g 1 will be high. So, what will happen? That the diaphragm will go up if the diaphragm goes up; obviously, it will show the less I mean less it will restrict the air passage to the gauge g 2. So, that is the reason we are telling that the g 1 and g 2 will be always inversely related.

So, g 1 and g 2 will be g 1 and g 2 will be this is g 1 we can see here this is g 1 sorry g 1 and g 2 will be inversely related this is g 1 and g 2 will be inversely related. With the flapper moving away that is already we have explained. Now, as the output pressure Po is diverted derived sorry derived from the supply pressure Ps the highest reading is emitted by this factor. The air relay gives us amplified output for a small change in pressure signal. Air relay will gives amplified output for a small change in pressure signal that is the reason from 3 to 5 psi is I am getting a signal from 3 to 15 psi.

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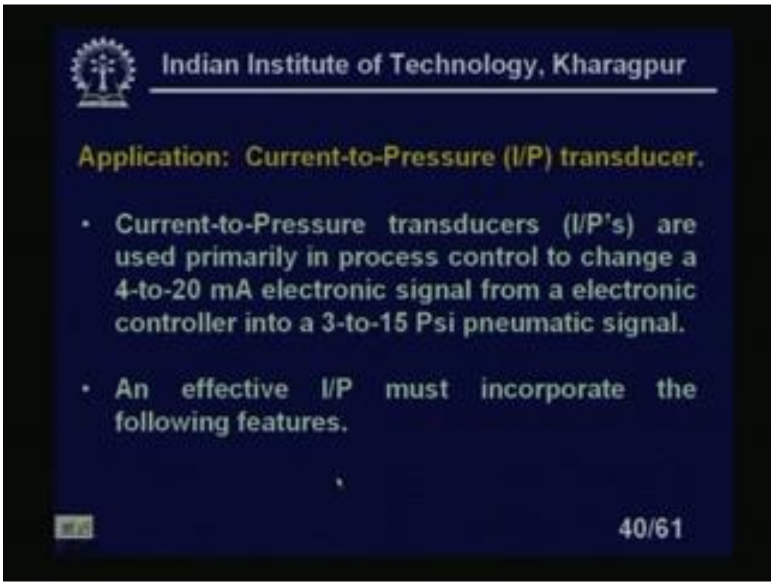

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Application: Current-to-Pressure (I/P) transducer.

- Current-to-Pressure transducers (I/P's) are used primarily in process control to change a 4-to-20 mA electronic signal from a electronic controller into a 3-to-15 Psi pneumatic signal.
- An effective I/P must incorporate the following features.

Now, current to pressure convertor I to P convertor as I told you this is very widely used in industry. Current to pressure transducers are used primarily in the process control to change a 4 to 20 million ampere of electronic signal from a electronic controller into 3 to 15 psi for a pneumatic controller. An effective I and P most incorporate the following features.

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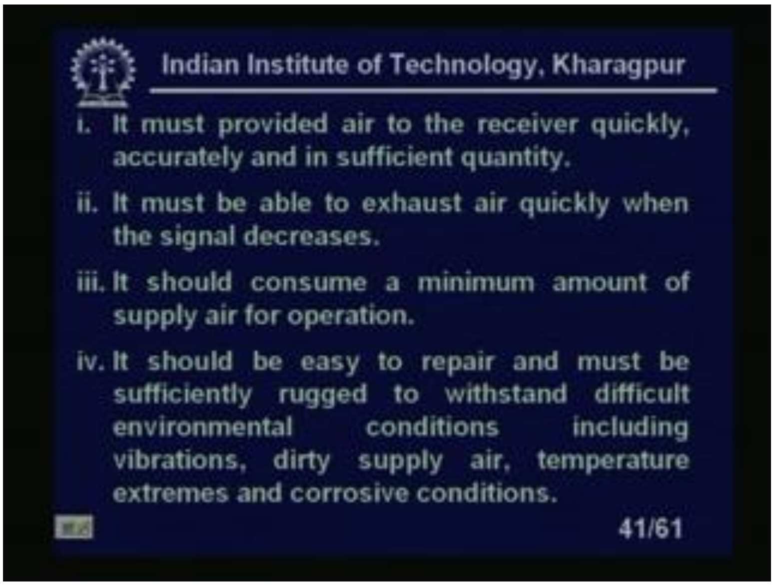

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i. It must provided air to the receiver quickly, accurately and in sufficient quantity.
ii. It must be able to exhaust air quickly when the signal decreases.
iii. It should consume a minimum amount of supply air for operation.
iv. It should be easy to repair and must be sufficiently rugged to withstand difficult environmental conditions including vibrations, dirty supply air, temperature extremes and corrosive conditions.

What are the following features; it most provide air to the receiver quickly accurately and in sufficient quantity. It must be able to exhaust air quickly when the signal decreases sorry It must it should be consumes it should consume a minimum amount of supply air for operation. It should be easy to repair and must be sufficiently rugged to withstand difficult environmental conditions including variations dirty supply of air. That is not very important usually we can filter the air temperature extremes and corrosive conditions.

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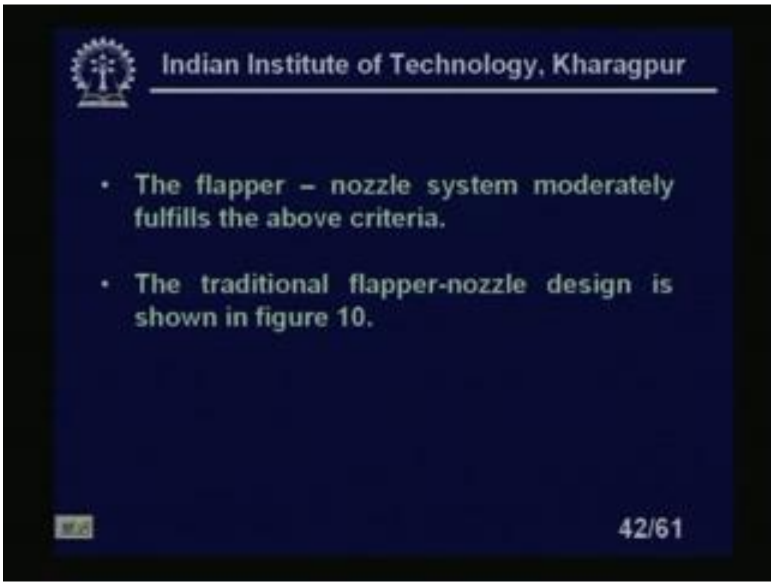

- The flapper – nozzle system moderately fulfills the above criteria.
- The traditional flapper-nozzle design is shown in figure 10.

The flapper nozzle system fulfills the above all criteria that is the reason we are using it because it is not very much effected by the temperature that is the most important thing in the flapper nozzle system. Now, traditional flapper nozzle system is shown in figure ten you see here.

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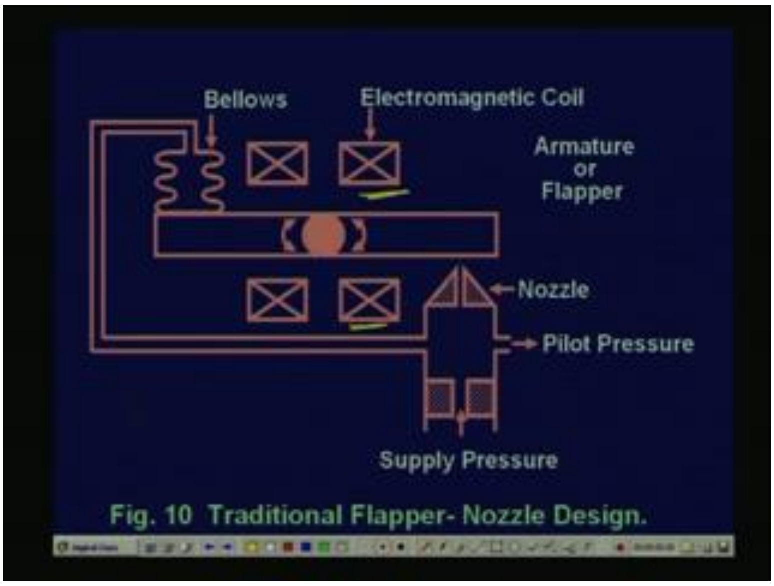

Fig. 10 Traditional Flapper- Nozzle Design.

So, this is the traditional flapper nozzle system. You see the current is coming through the electromagnetic coil here current is coming here current is coming here right. So, there is a bellows you see the, what will happen the pressure it will if it comes down? So, this will increase the pilot pressure here or back pressure. So, the flapper now the position of the flapper depends on the position of the flapper depends on the current. I want to make I to P convertor ultimately the position of the flapper will be corresponds to the pilot pressure this is the pilot pressure should be a function of the current. But the current actually will control the position of the flapper right. So, this there is a hinge you see here at the center point there is a hinge here the flapper can go this way or that; that means, it can go this way or that way like this one. So, if it go moves like this and; obviously, what will happen you see this is a flapper position will change clear.

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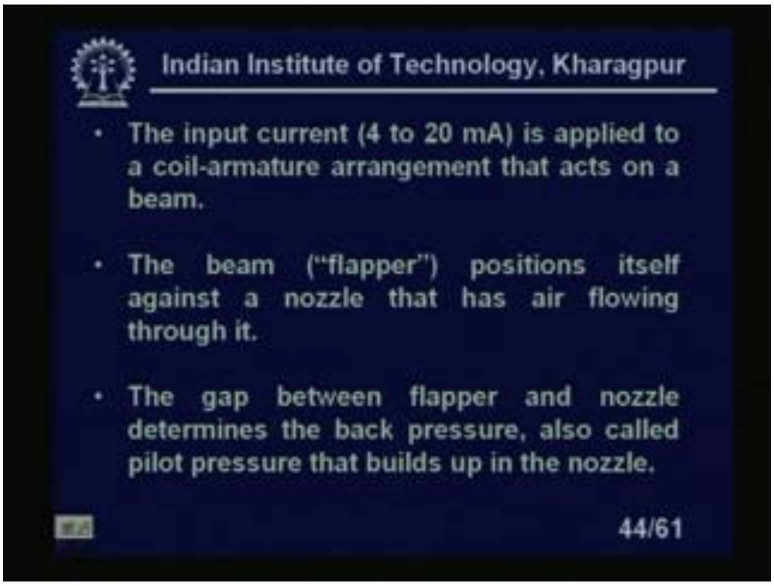

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- The input current (4 to 20 mA) is applied to a coil-armature arrangement that acts on a beam.
- The beam ("flapper") positions itself against a nozzle that has air flowing through it.
- The gap between flapper and nozzle determines the back pressure, also called pilot pressure that builds up in the nozzle.

The input current is four to 20 milliampere is applied to a coil-armature arrangement that acts on a beam. Beam is now the armature or flapper whatever you call we are no more calling it flapper we are calling it a beam. The beam positions itself against a nozzle . So, positions itself a nozzle that has air flowing through it. The gap between the flapper and the nozzle determines the back pressure also called the pilot pressure that builds up in the nozzle. So, this is the pilot pressures the in the nozzles we have seen what is that pilot pressures you see here the pilot pressure. So, this gap will control the pilot pressure the same thing we have seen that it can be supplied to a relay to get a higher. I mean that 3 to 15 psi of pressures also you have a feedback relay also bellows also to neutralize.

The gap between the flapper and nozzle determines the back pressure also called the pilot pressure and builds up in the nozzle right. You see the reason of the feedback, because it is working like a spring, because if comes very close, if the bridge comes, because I have a supply pressure, if it comes to very close to this one. So, this will increase the back pressure because pilot pressures and this pressure is same. So, this will increase the more pressures in the bellow. So, it will make the make the system. So, that it will restrict the nozzle to come very close because it will work as a spring there right that is the reason we have used a bellows here also. So, the gap between the flapper and nozzle determines the back pressure also called the pilot pressure that builds up in nozzle.

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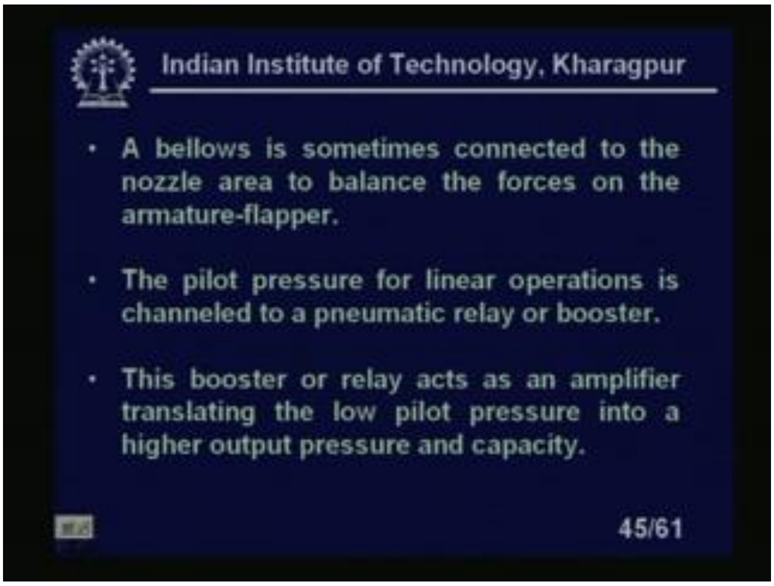

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- A bellows is sometimes connected to the nozzle area to balance the forces on the armature-flapper.
- The pilot pressure for linear operations is channeled to a pneumatic relay or booster.
- This booster or relay acts as an amplifier translating the low pilot pressure into a higher output pressure and capacity.

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A bellows is sometimes connected a bellow I am sorry is sometimes connected to the nozzle area to balance the forces on the armature-flapper. As I told you it is just like a spring instead of spring I am using the bellows there which will control the position of the forces on the flapper nozzle system armature-flapper or armature is a instead of flapper. We are calling it armature or bar whatever you call it basic principle is same the nozzle remains fixed only the armature is moving. The pilot pressure for linear operation is channeled to a pneumatic relay or booster the pilot pressure or back pressure which is coming that is going to relay for boosting operations right.

That means, it will be with the pressure is less three to fifteen psi will make a small movements where the more linear region this will lead to after the once it goes to the relay. So, I will get a three to fifteen psi of pressure. The pilot pressure the booster or relay act as an amplifier translating the low pilot pressure into higher output pressures and capacity. Because the capacity is also important, because if the capacity of this system might be very, very small in this case. We have capacities we can use both of the capacity and range I can go to the a booster circuit or relay circuit.

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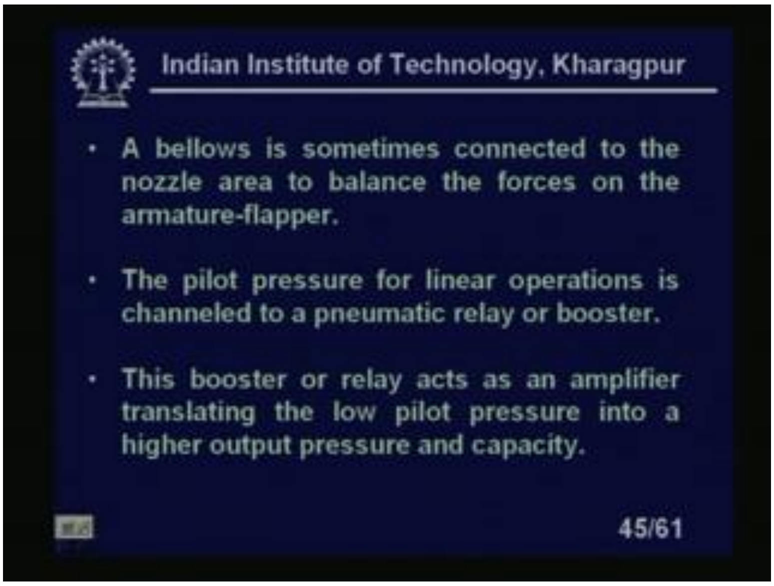

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Mechanical I to P convertor; that means, current to pressure convertor that use a flapper nozzle and which do not use electronic feedback sensors face some difficulty in dealing with the environmental factors what are those factors let us look at. The flapper is susceptible to vibration, and traditionally has forced users to mount the I P and current to pressure convertors separately on a pipe or rack. This requires additional tubing to carry I to P output signal to the valve the additional cost nullifies the benefit from mounting the I to P convertor together in a common location.

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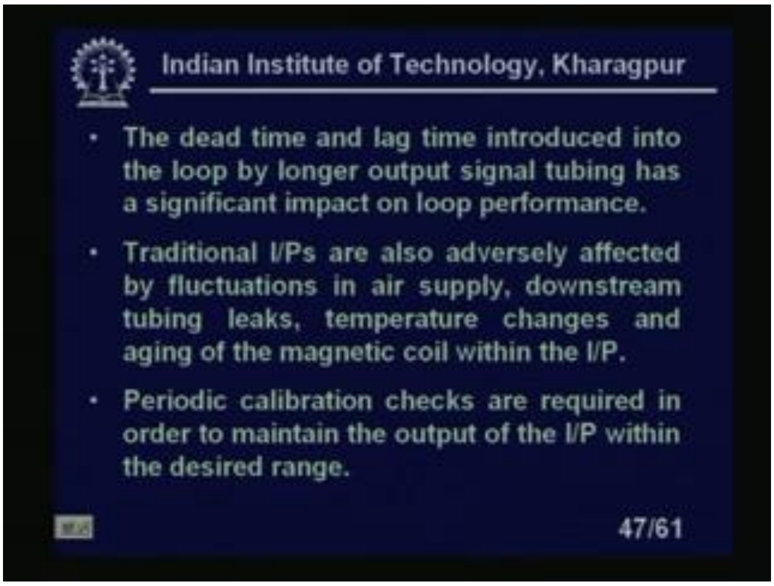

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- The dead time and lag time introduced into the loop by longer output signal tubing has a significant impact on loop performance.
- Traditional I/Ps are also adversely affected by fluctuations in air supply, downstream tubing leaks, temperature changes and aging of the magnetic coil within the I/P.
- Periodic calibration checks are required in order to maintain the output of the I/P within the desired range.

The dead time and lag time introduced into the loop by longer output signal tubing has a significant impact on the loop performance. Because whenever we are using some tubing in pneumatic systems it is not very I mean predominant in the case of electrical systems. But a pneumatic systems when using more tubing; obviously, this will increase the the lag in the system as well the dead time in the system. Traditional I to P converters are also adversely affected by fluctuations in air supply downstream tubing leaks temperature changes and aging of the magnetic coil within the I to P convertor. Periodic calibration checks are required in order to maintain the output of the I to P convertor within the desired range.

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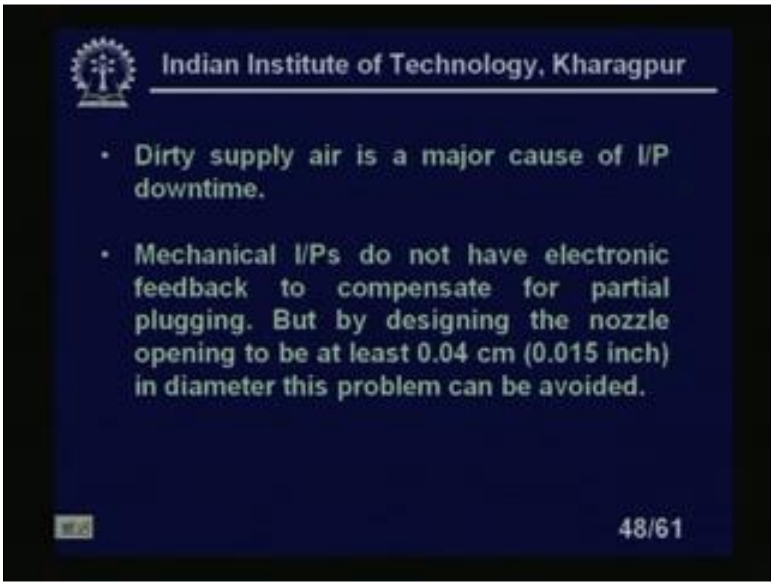

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- Dirty supply air is a major cause of I/P downtime.
- Mechanical I/Ps do not have electronic feedback to compensate for partial plugging. But by designing the nozzle opening to be at least 0.04 cm (0.015 inch) in diameter this problem can be avoided.

Dirty supply air is the major cause of I to P downtime mechanical I P's do not have electronic feedback to compensate for partial plugging. But designing the nozzle opening to be at least point 0 4 centimeter; that means, 0.015 inch in diameter this problem can be avoided.

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New I/P Converter

- Several new concepts have been introduced within the I/P.
- These new concepts have changed the nature of the pilot stage and have incorporated sensor-based electronics.

  It includes some tradeoffs like between efficiency and cost or improvement of one factor which leads to the degradation of the other.

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Now, there is new type of I to P convertors has been introduced let us look at that I to P convertors thought there is basic principle is again the flapper nozzle system. But with the help of peiso-electric systems they are used. Several new concepts have been introduced these new concepts have change the nature of the pilot stage and have incorporated sensor-based electronics systems. It includes some tradeoffs like between efficiency and cost or improvement of one factor, which leads to the degradation of the other one such important device piezo-ceramic bender nozzle. So, piezo-ceramic bender nozzle is fine that piezo is you know that there are I mean we can your I mean natural systems we have an natural piezo electric systems. We have a synthetic we have a piezo ceramic also this are some advantage of a piezo-ceramic systems. So, let us look at that.

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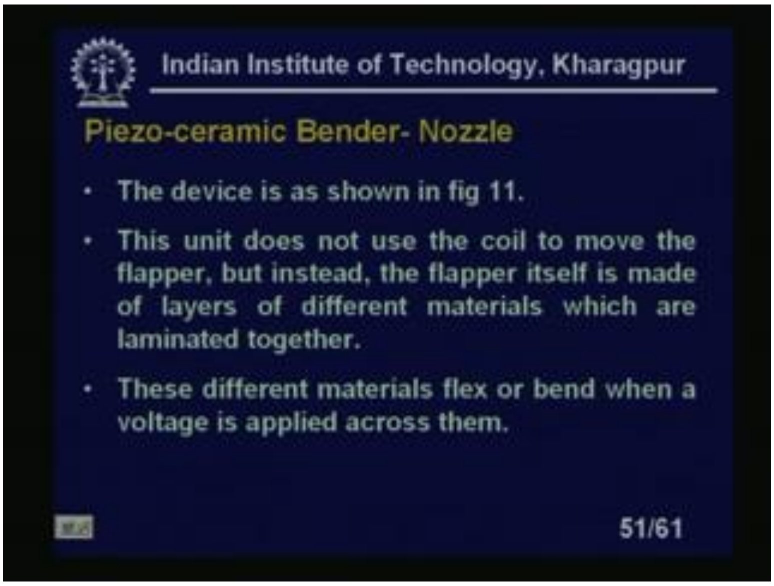

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Piezo-ceramic Bender- Nozzle

- The device is as shown in fig 11.
- This unit does not use the coil to move the flapper, but instead, the flapper itself is made of layers of different materials which are laminated together.
- These different materials flex or bend when a voltage is applied across them.

Now, piezo ceramic bender nozzles you will find that its device is shown in figure 11. The unit does not use the coil to move the flapper which are used in the I mean conventional I to P convertor. There is a coil actually which energizes and which current is coming to that coil and it is giving the movement of the flapper. But instead the flapper itself is made of layers of different materials which are laminated together these different materials flex or bend when the voltage is applied across them, right.

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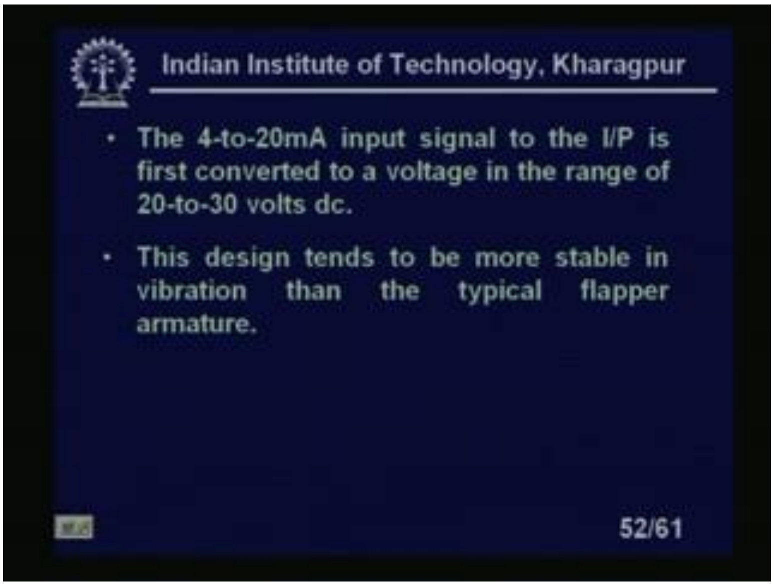

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- The 4-to-20mA input signal to the I/P is first converted to a voltage in the range of 20-to-30 volts dc.
- This design tends to be more stable in vibration than the typical flapper armature.

The 4 to 20 milliampere of current input signal to the I to P is first converted to voltage in the range of 20 to 30 volts dc right. Now, this voltage is actually given to the flapper this design tends to be more stable in variations vibration. Then the typical flapper armature and some of the drawbacks of this new concepts are…

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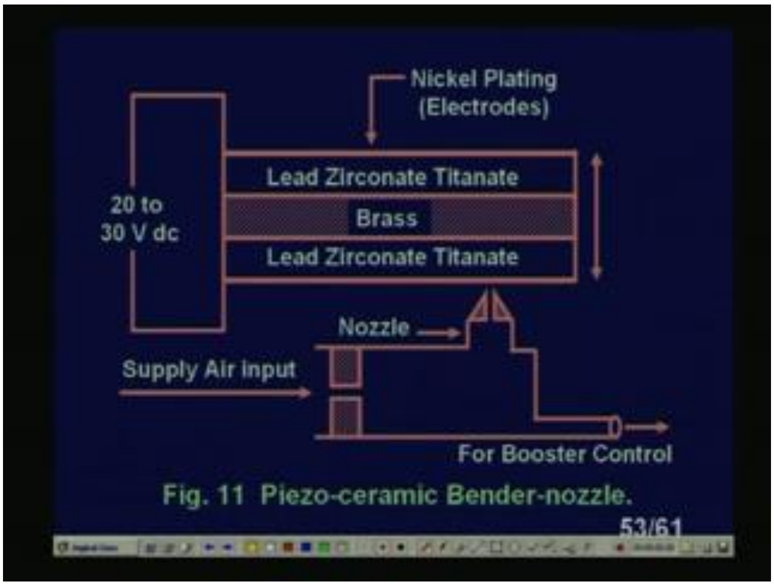

Nickel Plating (Electrodes)

20 to 30 V dc

Lead Zirconate Titanate

Brass

Lead Zirconate Titanate

Nozzle

Supply Air input

For Booster Control

Fig. 11 Piezo-ceramic Bender-nozzle.

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You see that is will come later on, let us see this one this is our figure you say you see here. So, we have a lead zirconate this is our ceramic piezo electric systems. So, now first the 3 to 4 to 20 milliampere of currents we are converting to 20 to 30 volt dc is applied. As you know that the piezo electric system is reversible systems if you apply the pressures I will get a voltage if you apply the voltage I will get change in I mean pressure. So, this since it is lead zirconate and brass we are using. So, it will try to bend and this bends will be sensed by this you see this lead zirconate and brass. And this will make the, this will work as a flapper that time and it will come to the either to the close to the nozzle at pay off.

So, this will give you this booster this output this is the pilot pressure which is sensitive to the, which is this pilot pressure or booster pressures or booster control. This pilot pressure will be a function of this dc voltage we have applied to the flapper nozzle at this ceramic. And this voltage again its I mean controlled to this function of the current which is coming right. So, this will lead to you see the whatever the pilot pressures or back pressures I am getting here that is the proportional or that is a function of exactly the current which you are getting. So, many other I mean point of the I mean those we have eliminated here in this because there is no coil as such. So, directly applying and due to this bimetal sort of this is ceramic and brass; obviously, this will bend in one directions or the other. So, when the voltage is applied due to piezo electric effect, so obviously, this will make the this flapper close to the nozzle or not or away from the nozzle.

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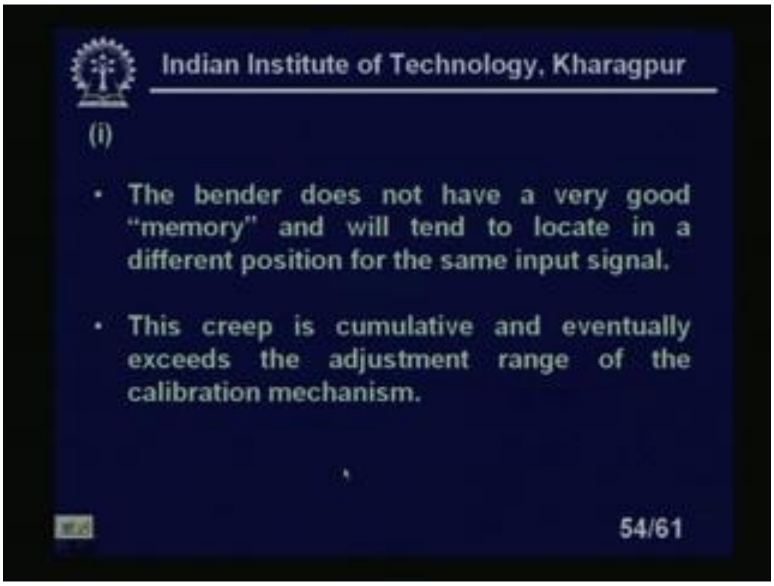

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(i)

- The bender does not have a very good "memory" and will tend to locate in a different position for the same input signal.
- This creep is cumulative and eventually exceeds the adjustment range of the calibration mechanism.

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The bender does not have a very good memory; that means that it has a creep which memory means it is called in the systems and will tend to locate in a different position for the same input signal. That means, creep is cumulative cumulant and eventually it exceeds the adjustment range of the calibration mechanism.

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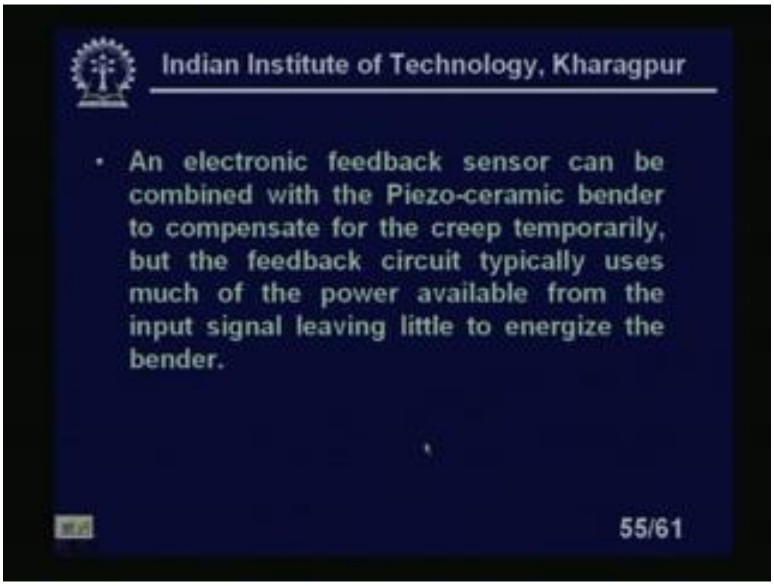

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- An electronic feedback sensor can be combined with the Piezo-ceramic bender to compensate for the creep temporarily, but the feedback circuit typically uses much of the power available from the input signal leaving little to energize the bender.

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An electronic feedback sensor can be combined with the piezo-ceramic bender to compensate for the creep temporarily for the… But the feedback circuit typically uses such more power available from the input signal having little to energize the bender.

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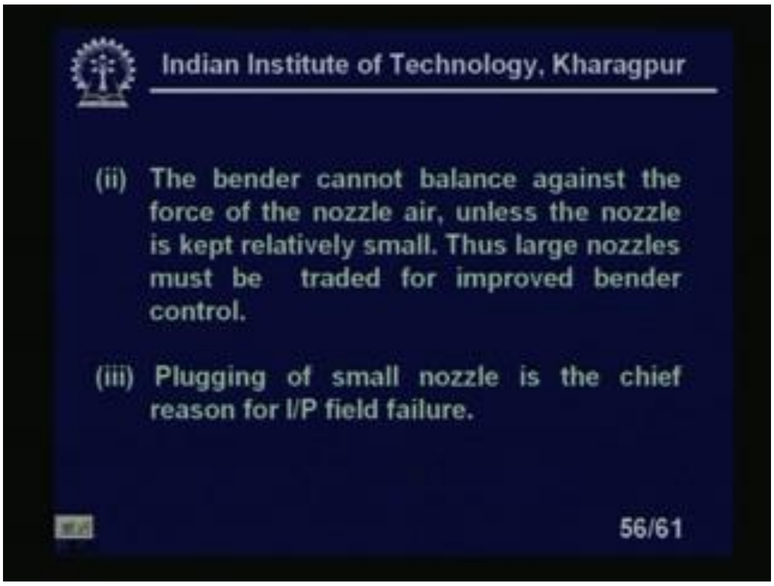

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(ii) The bender cannot balance against the force of the nozzle air, unless the nozzle is kept relatively small. Thus large nozzles must be traded for improved bender control.

(iii) Plugging of small nozzle is the chief reason for I/P field failure.

The bender cannot balance against the force of the nozzle air unless the nozzle is kept relatively small thus large nozzles must be traded for improved bender control. Plugging of small nozzles is a chief reason for I to P field failure.

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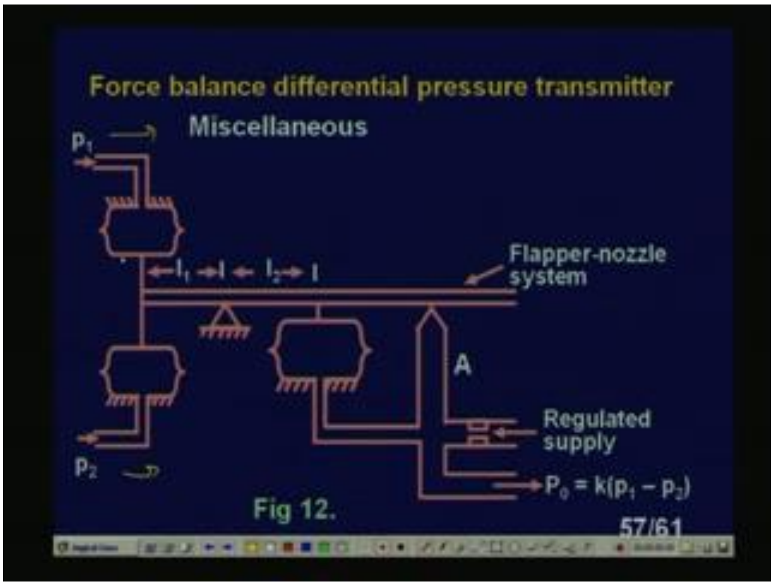

Force balance differential pressure transmitter

Miscellaneous

Fig 12.

Force balanced differential pressure transmitter; you see this we have seen the 2 pressures are coming this side. You can see here two pressures I mean P 1 sorry this P 1 and P 2 is coming here from the process and which is coming for the from the flow. So, this actually from this I am getting a supply pressure which is function Po after all function of k P 1 minus P 2. Because always in the flow measurement we have seen that in all differential pressure are based I mean flow meter. So, this type of output pressure this will be this P 1 minus P 2 or Po will be calibrated in terms of flow. So, that we can use a total pneumatic systems you can see this is you see there is another. This is the feedback bellows we have used this is the bellows please note feedback bellows we have used.

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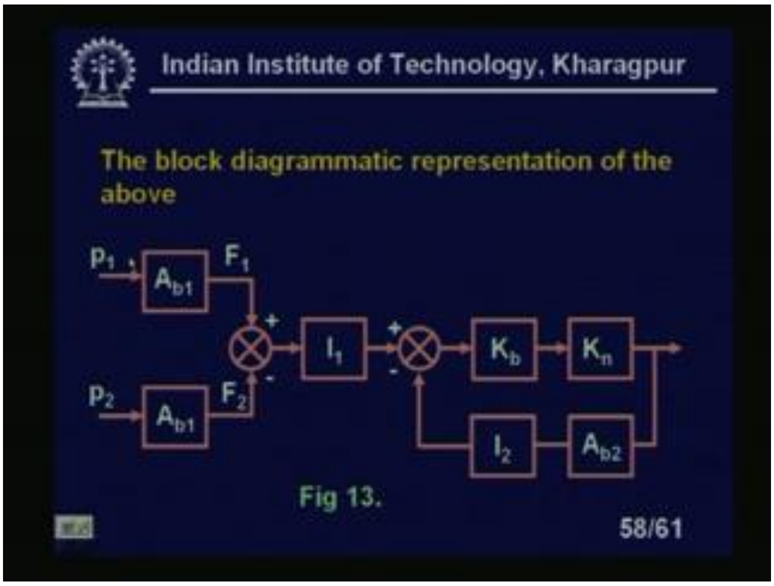

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The block diagrammatic representation of the above

Fig 13.

To block diagram this if I draw the block diagram it looks like this one. So, all the significance is P 1 and P 2 the output pressure. And the output pressure is coming here 2 pressures on the upstream and downstream is coming here which is combined. So, we are giving the relation like this one.

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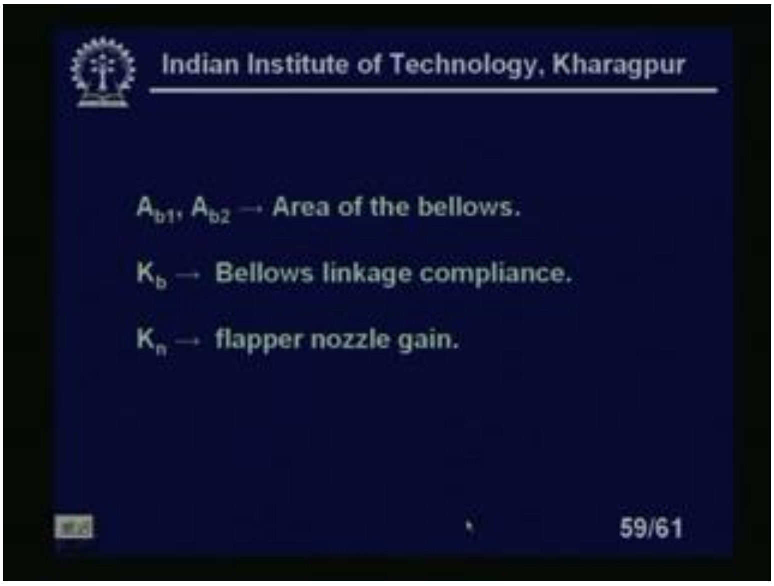

A_{b1}, A_{b2} → Area of the bellows.

K_b → Bellows linkage compliance.

K_n → flapper nozzle gain.

Say 1 Ab 1 Ab 2, the area of the bellows Kb the bellows linkage compliance Km the flapper nozzle again.

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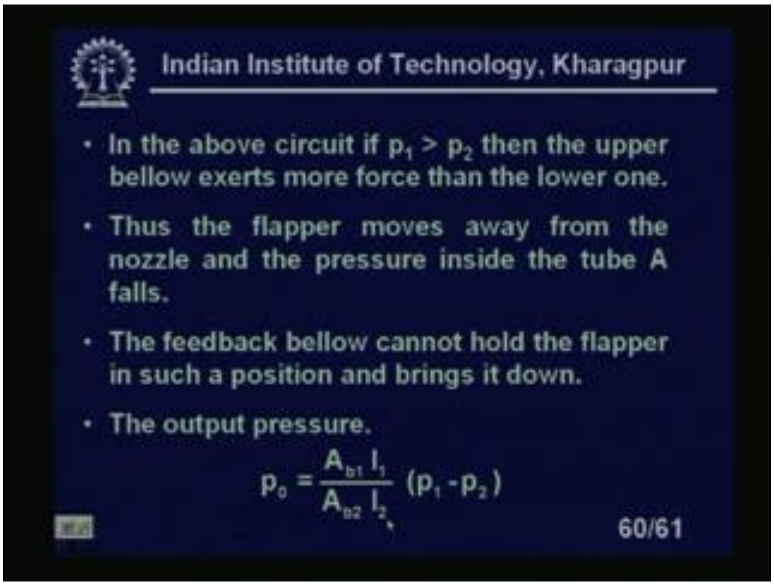

- In the above circuit if $p_1 > p_2$ then the upper bellow exerts more force than the lower one.
- Thus the flapper moves away from the nozzle and the pressure inside the tube A falls.
- The feedback bellow cannot hold the flapper in such a position and brings it down.
- The output pressure.

$$p_0 = \frac{A_{b1} l_1}{A_{b2} l_2} (p_1 - p_2)$$

And in the above circuit P 1 is always greater than P 2 then the upper bellow exerts more forces. Then the lower one always it will be greater because upstream flow is higher than the. Thus the flapper moves away from the nozzle and the pressure inside the tube A falls. The feedback bellow cannot hold the flapper in such a position and brings it down. So, the output resist pressure will come P naught equal to Ab 1 by Ab 2 I 1 by I 2 P 1 minus P 2 right. So, this actually will give you the direct this you see the output pressure is again the function of P 1 minus P 2 which is actually calibrated in terms of the flow. So, with this I come to the end of the flapper nozzle system.