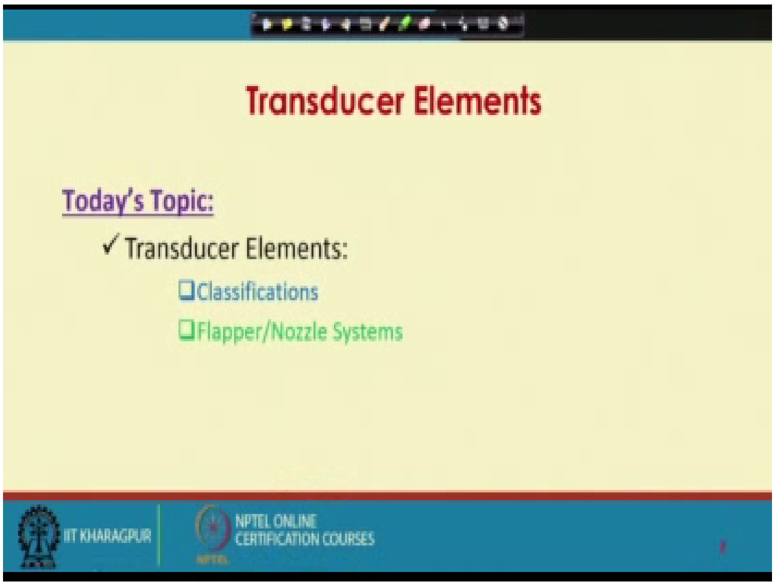
Chemical Process Instrumentation
Prof. Debasis Sarkar
Department of Chemical Engineering
Indian Institute of Technology, Kharagpur

Lecture – 16
Transducer Elements

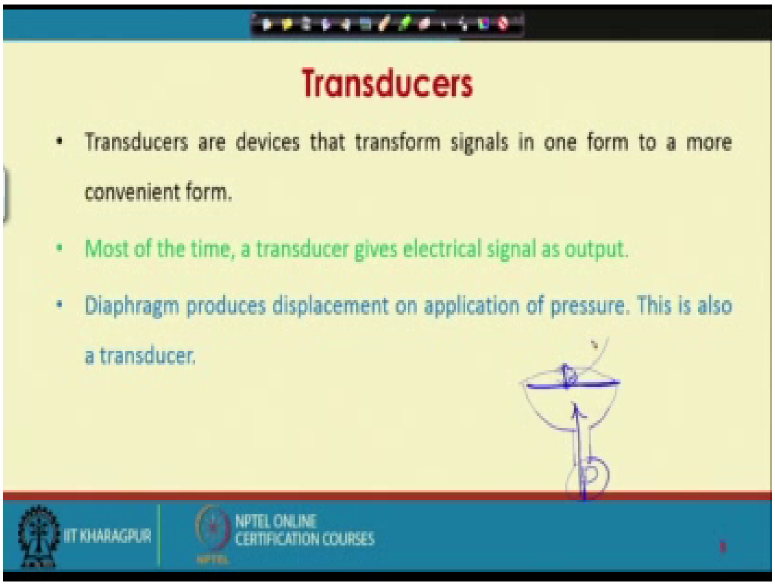
Welcome to lecture – 16. This is the first lecture of week – 4 and in this week we will talk about transducer elements. So, what do you mean by transducer elements? Transducer elements are devices that takes signal input signal in one form and gives you output in some other form which is more convenient for the purpose of measurement. So, essentially the transducer elements will change the nature of the signal. So, input signal and output signals will be different for transducers. So, in this week we will talk about different transducer elements that are useful for chemical process industries.

(Refer Slide Time: 01:24)



So, today's topic a transducer elements we will first talk about classifications of various transducer elements and then we will talk about one particular transducer known as flapper nozzle system. This is essentially a pneumatic transducer. So, we will learn more about it as we move along.

(Refer Slide Time: 01:50)

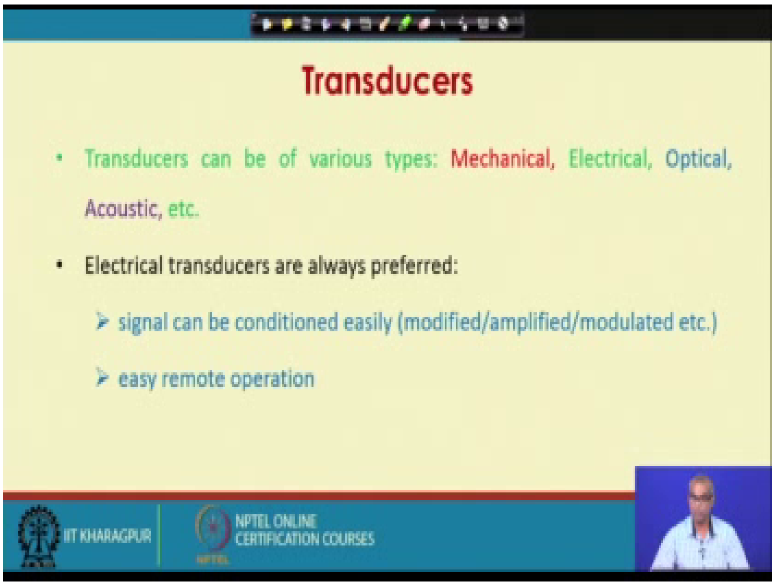


So, transducers are devices that transform signals in one form to a more convenient form. Most of the time a transducer gives electrical signal as output, but remember this is not necessary that the output from the transducer element has to be an electrical signal. Most of the time, we get electrical signal from the transducer because electrical signals are more convenient to handle. For example, it can be conveyed from one place to another very easily. You can easily let us say magnify the signal; that means, the signal manipulation is easy, you can amplify the signal, you can reduce the strength of the signal. So, these things are very easily done with electrical signals.

So, most of the times transducers will give us electrical signal as output, maybe a voltage maybe a current, but by definition a transducer element will change the nature of the signal. So, output signal and the input signal will be different. Let us say, diaphragm. Diaphragm will produce displacement on application of pressure. So, if I consider a diaphragm like this, is a diaphragm say theme metallic diaphragm and let us say it is a closed container I apply pressure. So, if I apply pressure the diaphragm will deflect like this. So, it deflects by this amount. Later on, we will talk about diaphragm gauge and we will see that these deflection is a measure of this pressure.

So, for this diaphragm gauge pressure was input and this deflection which is basically a displacement is an output. So, output signal is different from input signal and the diaphragm gauge or a diaphragm is a transducer. So, it is not necessary that the output of the transducer will be electrical signal, but since electrical signals are more convenient will prefer transducers to produce electrical signal for us and in common practice we consider transducers elements will give us electrical signal as output.

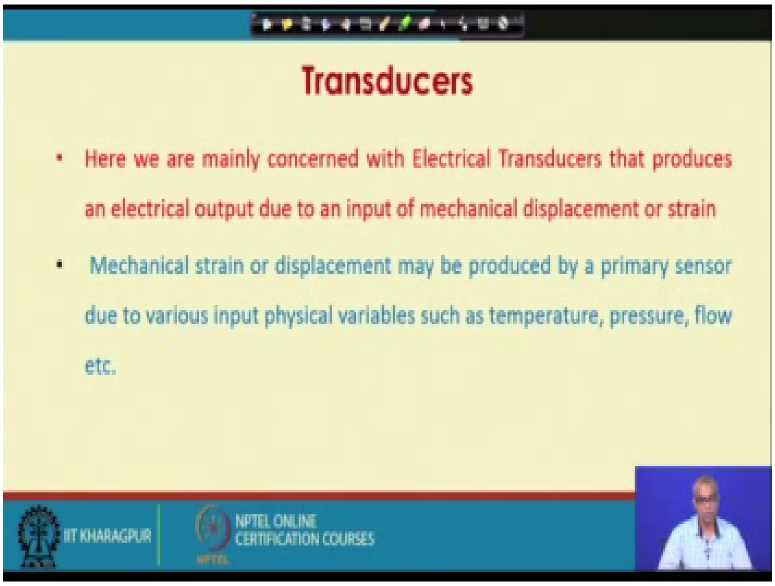
(Refer Slide Time: 05:10)



So, transducers can be of various types; mechanical type transducers, electrical type transducers, optical type transducer, acoustic type transducer so on and so forth. Electrical transducers are always preferred, because the signal can be conditioned easily; that means, signal can be modified, amplified, modulated etcetera. The remote operation is easy; that means, the signal can be transferred from one place to another very easily.

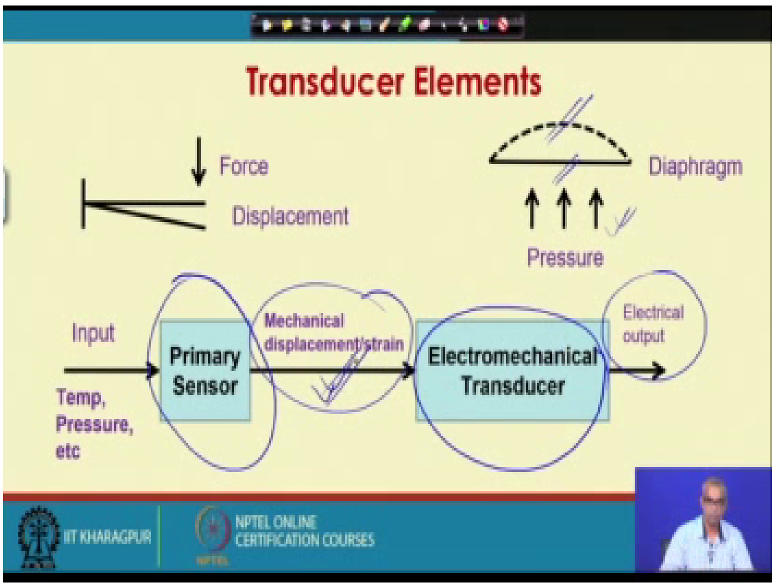
So, it is also possible to transmit a pneumatic signal which is air pressure from one place to another, but of course, transferring electrical signal from one place to another is much easier than transferring a pneumatic signal from one place to another. Electrical signal can be transferred from one place to a very large distant place. Pneumatic signals; with pneumatic signals it may not be so easy.

(Refer Slide Time: 16:30)



Here, we are mainly concerned with electrical transducer that produces an electrical output due to an input or mechanical displacement or strain. So, most of the transducers that we talk about over this week are electrical transducers that produces an electrical output due to an input, which is a mechanical displacement or strain. We will of course, talk about one pneumatic transducer which is flapper nozzle system. Mechanical strain or displacement maybe produced by primary sensor due to various input physical variables such as temperature, pressure, flow, etcetera.

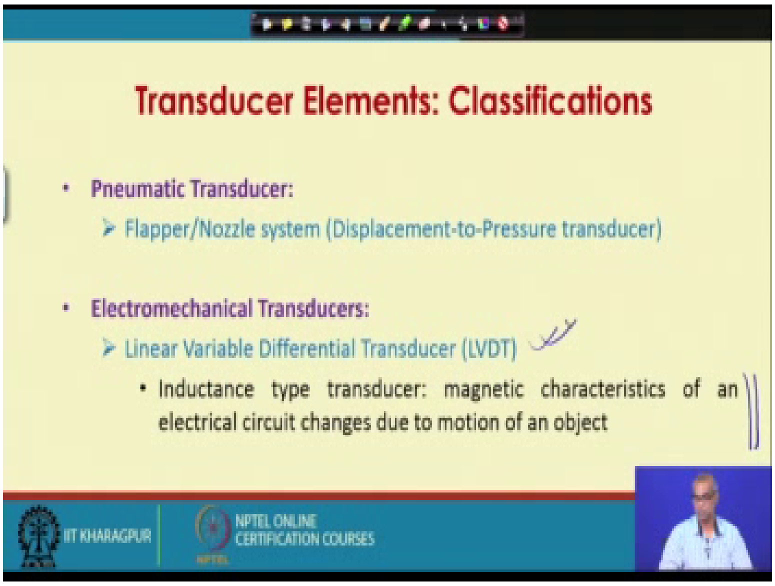
(Refer Slide Time: 07:25)



For example; we have talked about this diaphragm gauge. So, this is the diaphragm, if we apply pressure there will be deflection. So, there is a displacement. This displacement needs to be measured. If you apply force here there is displacement. So, mechanical displacement or strain is output from many primary sensors. Let us say, temperature or pressure say pressure here is goes as input to the diaphragm, but the diaphragm gives you a displacement as output. Similarly, later on we will see that there are temperature measuring inputs where the primary sensor will give you displacement as output.

Now, if this output which is a displacement signal can be converted to an electrical signal, the measurement task becomes much easier and convenient. So, electromechanical transducer serves this purpose. Electromechanical transducer will receive displacement or strain as input and will give you electrical signal as output.

(Refer Slide Time: 09:40)

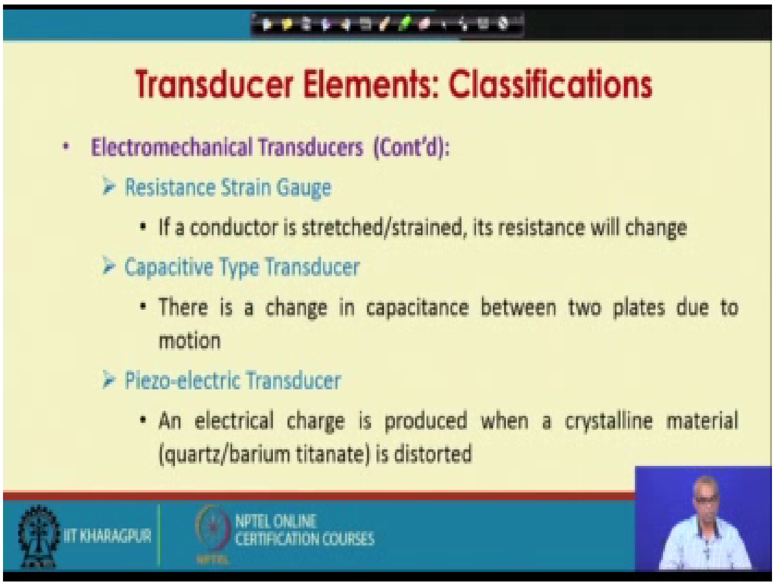


So, let us talk about classifications of transducer elements. So, let us broadly classify them; pneumatic transducers and electromechanical transducers. These are the 2 transducers that we will talk about in this week.

There are others such as acoustics or optical which will not cover in this lecture. Pneumatic transducer; under pneumatic transducer we will talk about a flapper nozzle system which is a displacement to pressure transducer. So, flapper nozzle system will receive displacement as input and will give you pressure as output. This is an important pneumatic transducer.

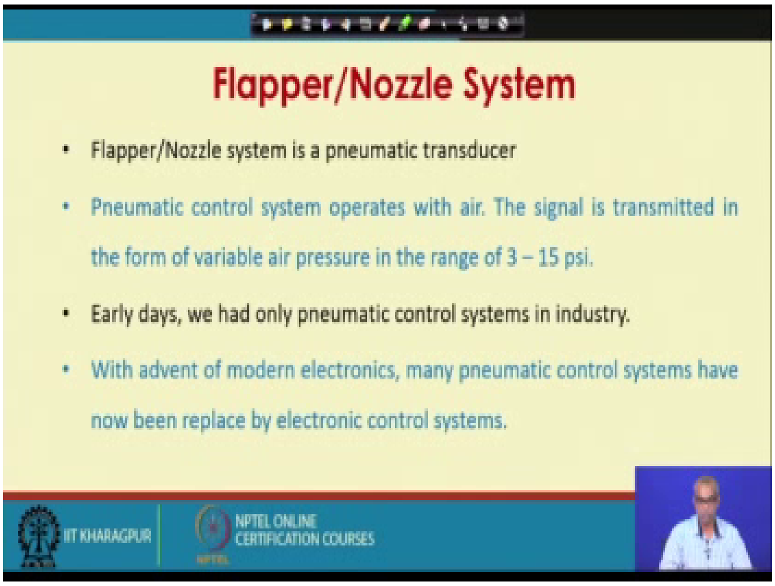
Electromechanical transducers we will talk about linear variable differential transformer or transducer, inductance type transducer magnetic characteristics of an electrical circuit changes due to motion of an object. So, this is the principle that is used in case of linear variable differential transformer or transducer. It is an inductance type transducer: magnetic characteristic of an electrical circuit changes due to motion of an object. So, this is the principle and under which works.

(Refer Slide Time: 11:29)



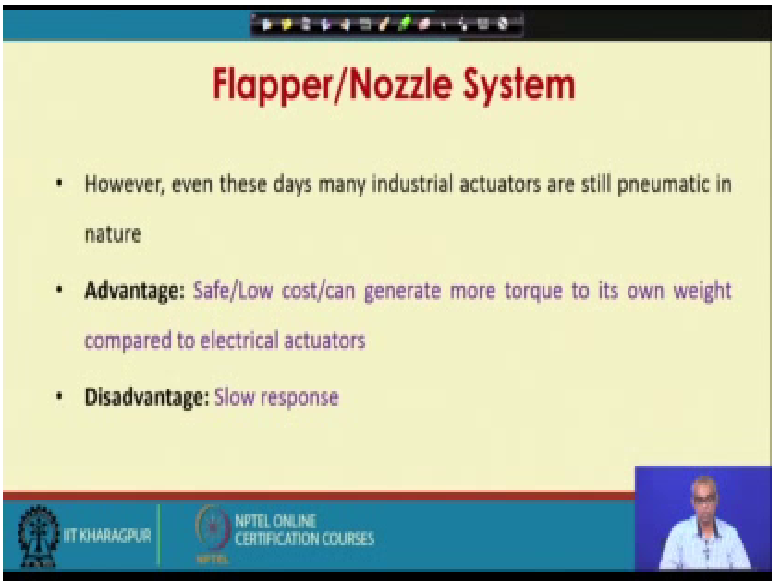
There are other electromechanical transducers that we will be talking about resistance strain gauge; if a conductor is stretch or strained its resistance will change. So, this is the principle that resistance strain gauge uses. Capacitive type transducer there is a change in capacitance between 2 plates due to motion. So, this is the principle that capacitive type transducer uses and Piezo-electric transducer, an electrical charge is produced when a crystalline materials such as quartz or barium titanate is distorted or force is applied. This is the principle for Piezo-electric transducers working.

(Refer Slide Time: 12:22)



So, let us now talk about flapper nozzle system. Flapper nozzle system is a pneumatic transducer. Pneumatic control system operates with air the signal is transmitted in the form of variable air pressure in the range of 3 to 15 psi pressure. Early days, we had only pneumatic control systems in industry. With advent of modern electronics, many pneumatic control systems have now will replaced by electronic control systems.

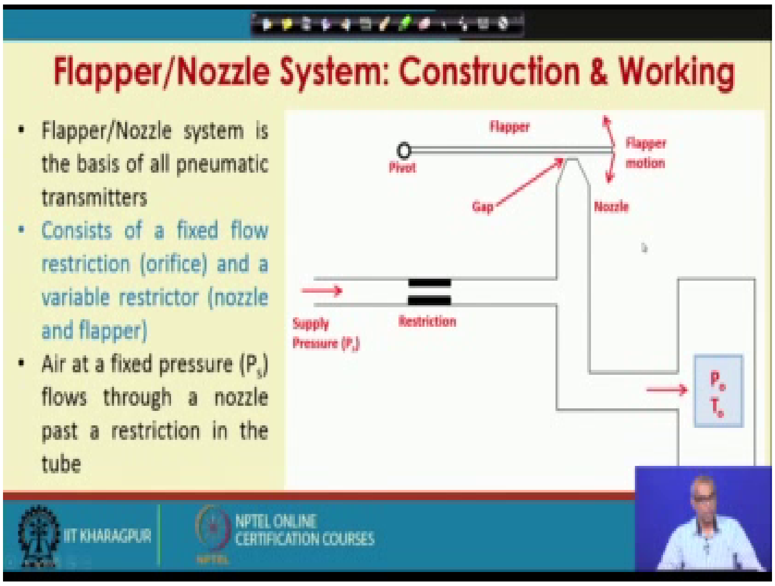
(Refer Slide Time: 13:00)



However, even these days many industrial actuators are still pneumatic in nature. So, pneumatic transducer, flapper nozzle system is important component.

The advantages of flapper nozzle system is safe, low cost and can generate more torque to it is own weight compared to electrical actuators. Disadvantages: it is response is slow compared to electrical actuators.

(Refer Slide Time: 13:44)



Now, let us look at construction and working of flapper nozzle system. The flapper nozzle system consists of 2 restrictions; one is fixed restriction, another is variable resistance that comes from a flapper and a nozzle. So, this is a flapper, this is the pivot and this is the nozzle. So, the gap between the flapper and nozzle determines the restriction here. This restriction is fixed. So, if I supply an air or some fluid most commonly used fluid is air, let us say I supply air with pressure P s, it passes through fixed flow restriction and then depending on the gap between these 2 there is another flow restriction.

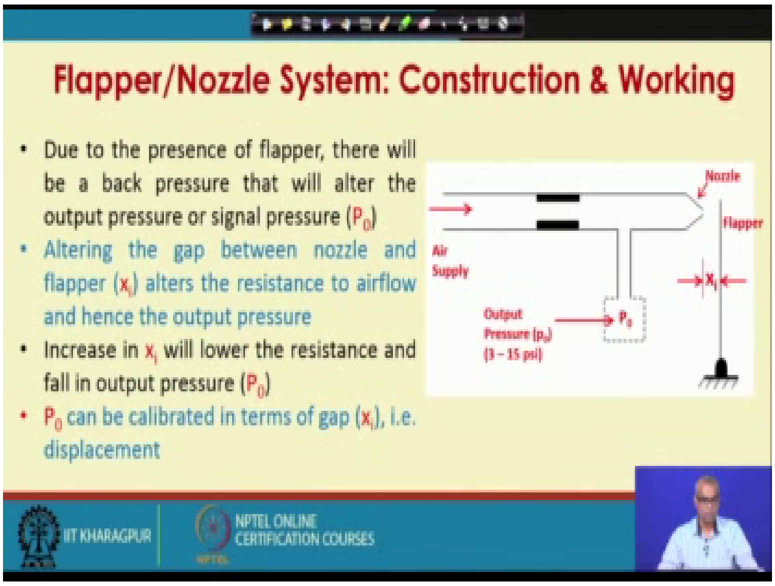
So, if I now, a back pressure will be developed which depends on this gap between the flapper and nozzle. If I measure the output pressure here with an independent pressure gauge, this pressure will be a function of the gap between the flapper and nozzle. If the gap between the flapper and nozzle is reduced there will be more back pressure, this pressure will increase. If the gap between the flapper and the nozzle is increased; that means, flapper is away from the nozzle, there will be less back pressure. This pressure will decrease. So, by measuring this pressure I can relate the gap between the flapper and nozzle with this pressure.

Now, imagine that there is a moving object whose displacement I have to measure. So, I attached that object with this flapper.

So, in the motion of the object the flapper will move. So, the motion of the object the flapper will move and the movement of the flapper will determine the gap between the nozzle and the flapper and the gap between the nozzle and the flapper will decide the pressure here. So, by measuring the pressure it is possible to measure the gap between the distance between the flapper and nozzle which in turn will give me an indication of the motion or displacement of the object.

So, let us now look at the constraints cannot work working of the flapper nozzle system one more time. Flapper nozzle system is the basis of all pneumatic transmitters. It consists of a fixed flow restriction orifice and a variable restrictor which comes from nozzle and the flapper. Air at a fixed pressure P s, flows through a nozzle past a restriction in the tube.

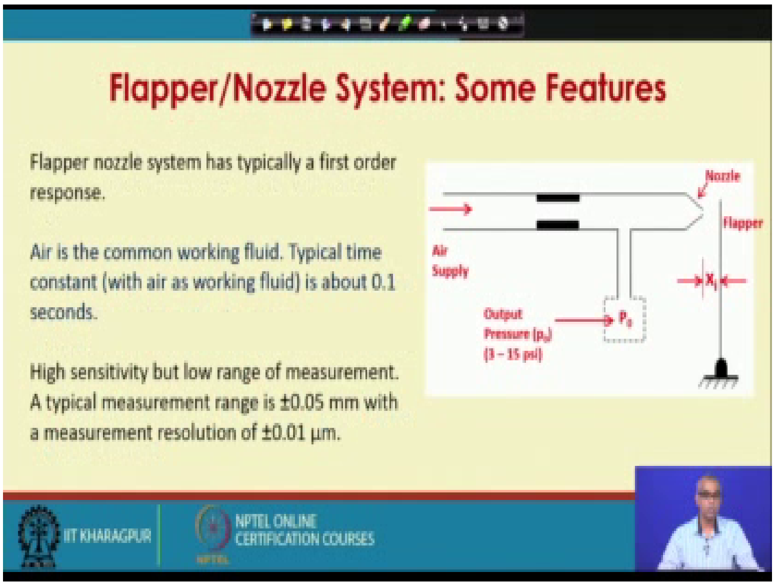
(Refer Slide Time: 18:27)



Due to the presence of flapper, there will be a bad pressure that will alter the output pressure or the signal pressure. Altering the gap between nozzle and flapper alters the resistance to airflow, hence the output pressure. Increasing in x I, which is the gap between flapper and nozzle, will lower the resistance and fall in output pressure.

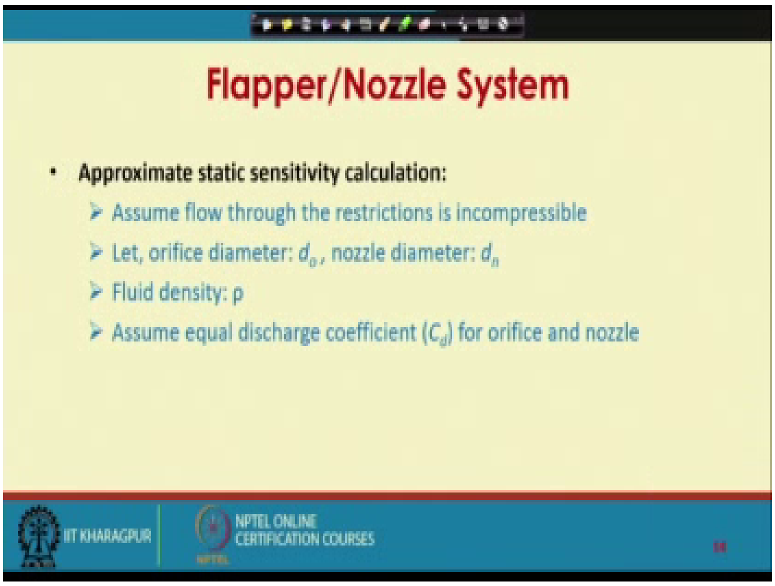
So, the output pressure P 0 can be calibrated in terms of gap x I, that is, between flapper and nozzle which is displacement.

(Refer Slide Time: 19:14)



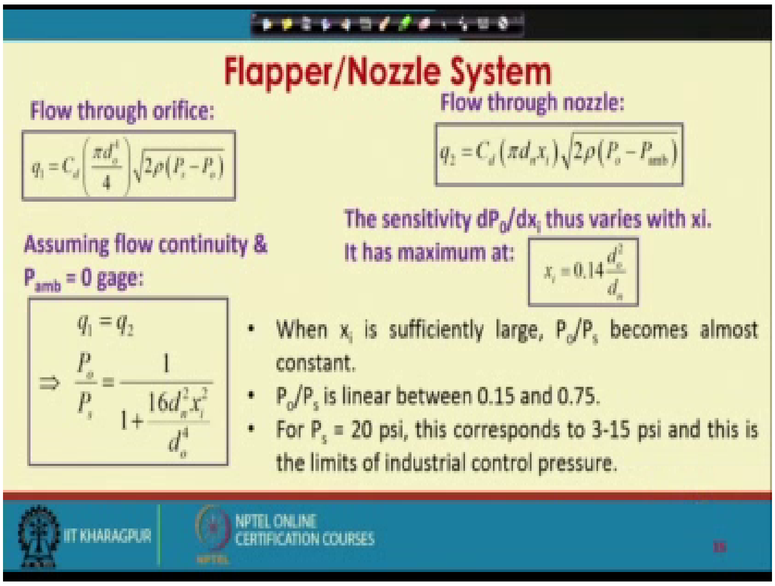
Flapper nozzle system has typically a first order response. Air is the common working fluid. When you use air as working fluid, typical time constant is about 0.1 seconds. Flapper nozzle systems have high sensitivity, but low range of measurement. A typical measurement range is plus minus 0.05 millimeter with a measurement resolution of plus minus 0.01 micrometer.

(Refer Slide Time: 19:49)



Now, let us see how we compute approximate statistic sensitivity for a flapper nozzle system. Assume flow through the restrictions is incompressible. So, we consider incompressible fluid flow. Let the orifice diameter be represented by d o and the nozzle diameter be represented as d n. Fluid density equal to rho. Let us assume equal discharge coefficient C d for orifice and nozzle.

(Refer Slide Time: 20:30)

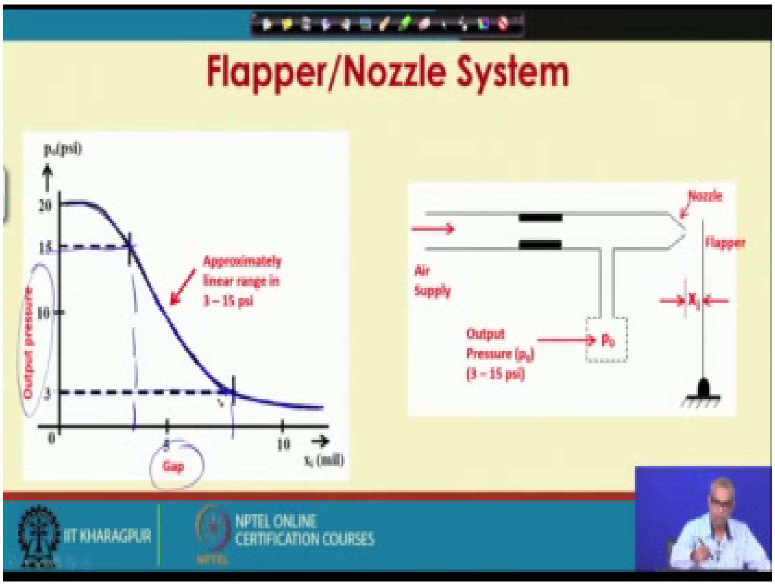


So, flow through orifice can be expressed by this equation. So, we consider flow through orifice as q 1 and q 1 can be expressed by this equation. P s is the supply air pressure and P o is the output pressure. So, P s and P o represent the pressure drop across the fixed flow restriction which is orifice.

Similarly, flow through nozzle can also be expressed by similar equation. So, the pressure difference across the nozzle or the variable restrictor is output pressure and ambient pressure. So, q 2 the flow through nozzle can be expressed by the equation as so. Assuming flow continuity and ambient pressure is 0 gauge, we can equate q 1 equal to q 2. So, if I equate q 1 equal q 2, I can find out the ratio of P 0 and P s which will be computed as P 0 by P s equal to this.

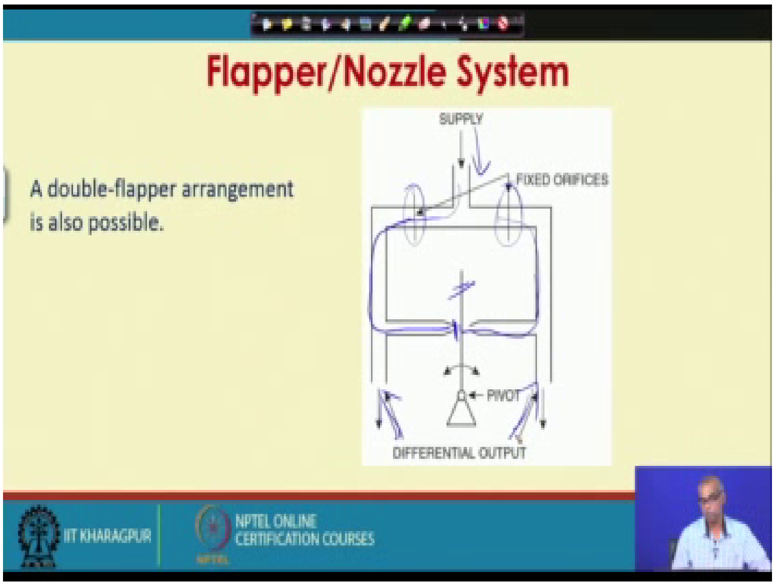
The sensitivity dP 0 by dx i thus varies with xi. It has a maximum at x i equal to 0.14 d 0 square by d n, when x i is sufficiently large P 0 by P s becomes almost constant. P 0 by P s is linear between 0.15 and 0.75. For P s equal to 20 psi this corresponds to 3 to 15 psi and this is the limits of industrial control pressure.

(Refer Slide Time: 23:00)



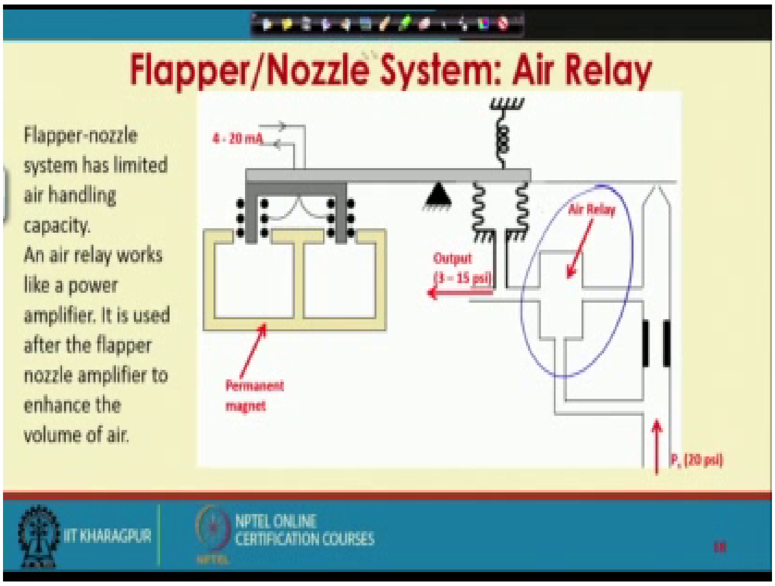
So, if you plot the output pressure versus the gap between the flapper and nozzle with 20 psi supply pressure which is constant, the output pressure varies with the gap between the flapper nozzle systems as this. If you look at this curve carefully between 3 to 15 psi pressure this is approximately linear. So, the response of the flapper nozzle system is approximately linear in the range of 3 to 15 psi pressure. So, in the output pressure is in the range of 3 to 15 psi, the flapper nozzle system shows a linear relationship between the output pressure and the gap between the flapper and nozzle. So, that is why 3 to 15 psi pressure is used for control system in industry.

(Refer Slide Time: 24:39)



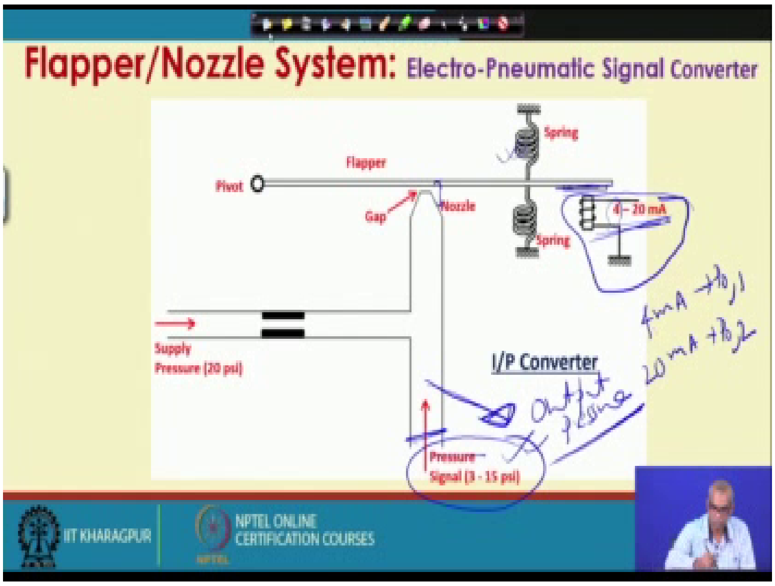
A double flipper arrangement is also possible as of now we have seen only single flip single nozzle. So, it is also possible to have a double flipper arrangement. So, your supply pressure is this. So, we have 2 fixed flow restrictions. So, the supply pressure goes through this fixed restriction and goes through this nozzle and you have a flapper here. So, this gap is variable. Similarly, this is the fixed flow restriction and this gap is variable. So, the output pressure is differential output. So, you will measure differential pressure. So, we will talk about pressure measure instruments we will talk about how to measure differential pressures, but this arrangement is also possible when you have double flapper arrangement.

(Refer Slide Time: 26:00)



Here, please look at this component. A flapper nozzle system has limited air handling capacity. So, for practical works, for practical applications we need more air we need flapper nozzle system to handle to have more air handling capacity. So, an air relay works like a power amplifier. It is used after the flapper nozzle amplifier to enhance the volume of the air. So, an air relay is used in connection with the flapper nozzle system to enhance the volume of the air.

(Refer Slide Time: 27:08)



This is how you can use a flapper nozzle system to convert an electrical signal to a pressure signal. We know the flapper nozzle system receives displacement as input and it gives us pressure as output. How do I use a flapper nozzle system as an electro pneumatic signal converter? The schematic shows how I can convert an electrical signal to a pressure signal by flapper nozzle system. Like 3 to 15 psi pressure is used for industrial control system or industrial pneumatic control system 4 to 20 milliampere current is used for electrical signals in case of industrial electrical control systems 4 to 20 milliampere current.

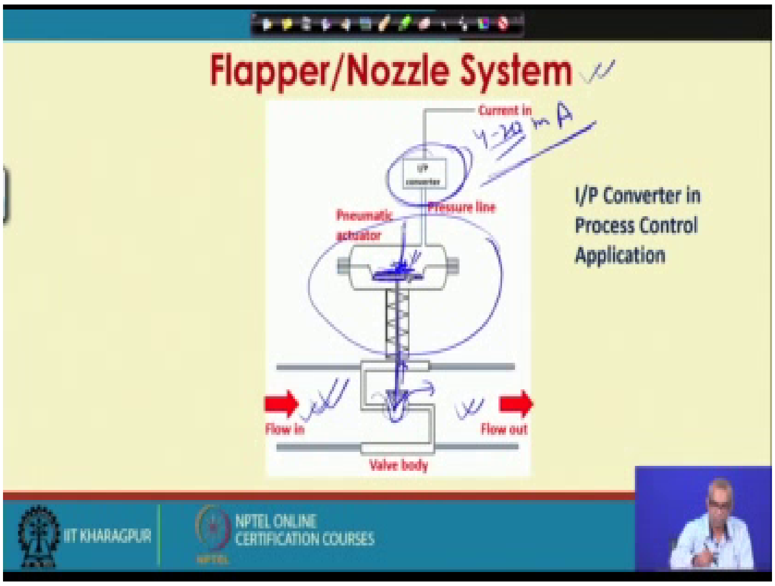
Now, look at this schematic, I send a 4 to 20 milliampere current which is coming from an electrical controller, let us say and let us send it through let us say soft iron core. So, when this current passes through these this becomes this behaves like a magnet. So, it will attract the flapper towards it. The flapper may be magnetic in nature or a magnetic strip or magnetic material stream may be attached in this part of the flapper so that when 4 to 20 milliampere current passes through this soft iron core it becomes magnet and attracts the flapper towards the magnet. The flapper can also be spring restricted for better performance.

Now, the magnetic strength will depend on the strength of the current in the range of 4 to 20 milliampere. On the lower range it is 4, on the higher range into it is 20. So, the strength of the pool will also be low when 4 milliampere current is being passed and it will be high when 20 milliampere current is being passed. So, depending on that the gap between the flapper and nozzle will be decided. So, the gap between flapper and nozzle when 4 milliampere current is being passed, it will be more than the case when 20 milliampere current is being passed. It depends on the strength of the magnetic field.

So, corresponding to 4 ampere current, a particular gap will be present and accordingly a particular pressure will be produced as output pressure, sorry this is signal pressure, this is output pressure. So, this has to be measured as output pressure. Depending on 4 milliampere current or 20 milliampere current, the gap between the flapper nozzle will be decided and that will decide the output pressure. It is possible to convert the current in the range of 4 to 20 milliampere to different output pressures here.

So, if 4 for 4 milliampere current the output pressure is say P 0 1 and for 20 milliampere current the output pressure is P 0 say 2, in between we will have values for output pressure corresponding to in between values for the milliampere current. So, it is possible to convert these electrical signals to pressure signals using flapper nozzle system.

(Refer Slide Time: 33:02)



So, such an I P convertor finds wide application in process controls. Let us say, the electrical controller is being used in my process industry and I want to control the flow through this pipeline. So, I am making use of a pneumatic control valve. So, pneumatic control valve has a diaphragm here. So, if I apply more pressure this valve seat is pushed down and this opening through which flow happens will be closed. So, by changing the gap between this plug and the valve seat it is possible for me to have a control over this flow.

So, the electrical control system, electrical controller sends an electrical signal, but that has to be converted to a pneumatic control, pneumatic pressure, because the diaphragm of the pneumatic control valve we will only receive pressure as input signal. So, a flapper nozzle system can be used as I P converter or electrical signal to pressure converter and can be used in conjunction with the electrical controller.

So, electrical controller will send a signal of 4 to 20 milliampere current depending on this 4 to 20 milliampere current, the I P converter will generate a pressure signal. So, that pressure signal will go through diaphragm of the control valve and accordingly it will push this down or it will pull it a little bit, that means, depending on the current that is being seen by the electrical controller the I P converter will generate an appropriate output pressure and that output pressure will decide the gap for the flow.

So, this flow can be controlled by controlling this gap and to control this gap you have to apply an appropriate pressure here and that pressure will come from the flapper nozzle systems which will receive current from the electrical controller and produce the pressure as output signal for the diaphragm of the control valve. So, this is how an I P converter can be used in conjunction with pneumatic control valve. So, we will stop lecture – 16 here.