Principles of Mechanical Measurements
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Lecture No. # 24

Today we will start the pressure measurement. Pressure is another important variable in process industries, chemical and process industries. We have already learnt the other temperature measurement. Next is the pressure measurement. This pressure is liquid or gas pressure measurement; in machine designing we have another pressure that is called contact pressure. When two solids sits one over the other then the surface pressure is there between the two solids that is called hertz pressure and that is different aspect. So here we are going to see gas and that is fluid pressure. When a fluid is contained in a vessel it exerts equal pressure in all directions so that is the pressure what we are going to measure.

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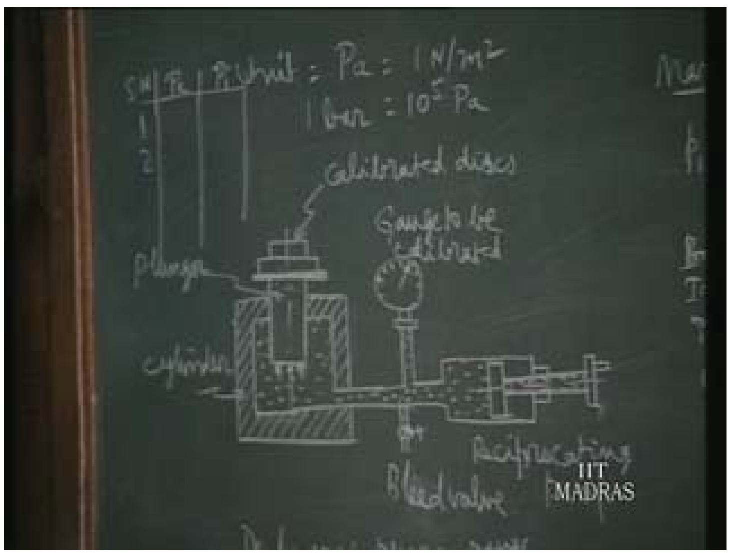

Unit for pressure is Pascal that is equal to one newton per meter square that is the unit for pressure and the one bar, this also used as unit for pressure. That is equal 10 to the power of 5 Pascal, one bar is equal to 10 to power 5 Pascal and one atmospheric pressure is nearly about one bar is strictly speaking 1.01 bar is equal to equal to one atmospheric pressure. So we will say 10 to the power 5 Pascal is around one atmospheric pressures. That is one kilogram force per centimeter square also people call it as atmospheric pressure. So these are the basic units.

The unit normally used for calibration of pressure gauges is dead weight pressure gauge; the principle of functioning is like this. There is a plunger and cylinder and a respirating pump to develop pressure in the liquid and the gauge to be calibrated is fixed here and by rotating this piston, we can move the piston forward or backward and thereby developing the pressure or releasing the pressure in the liquid, in the setup and fine adjustment we can use this bleed wall to take away little liquid so that fine adjustment also can be made. So when there is no pressure developed, the plunger will sit at the bottom and when you rotate this the pressure builds up and when the pressure into this plunger area is equal to the dead weight of the…

This is the dead weight, before adding this calibrated disc only dead weight alone will be there. So by rotating we can make this float when the pressure developed in the liquid into the area of the plunger is equal to the weight of this plunger then it starts floating and some pressure value might have returned to its calibrated piston plunger and whatever the pressure shown is the same pressures indicated by the instrument as well as the true pressure in the liquid which is returned here on the plunger can be noted down. So we can conduct this calibration that is true pressure P_r and indicated pressure P_i. So this is serial number, so whatever we have learnt under static calibration, we can develop different pressures here by adding more and more calibrated disc. Each discs we will have some pressure is retained, 4 or 5 disc means add those pressures together that is total pressure developed and whatever indicated they are written here true pressure and indicated pressure in the instrument and set of readings can be taken.

Again from the high pressure we can go back to the low pressure so that is the way we have learnt the static calibration, it can be done here. So the pressure developed in this liquid is measured by balancing with a calibrated disc and that is used for calibration purpose. The error source here is the static friction between the cylinder surface and the piston and that can be made as small as possible. When you take measurement just twist this piston plunger then as it rotates then you find the static friction is removed and only dynamic friction will be there which will be very small one. So that can be taken care of while we take measurements. Next principle is manometer which is well known so we have a U tube, this is a U tube manometer.

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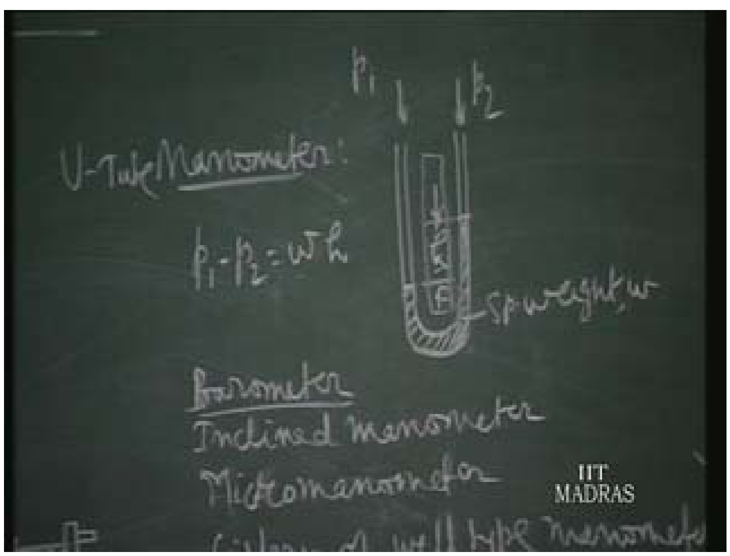

It is in this form so we mostly use it for measuring differential pressure also we can measure the atmospheric pressure by barometer that is having vacuum at one end, the other end atmospheric pressure acts that is the barometer. It is an inversion of the or one of the modifications of manometer so barometer, inclined manometer and micro manometer, cistern or well type manometer these are all different types of manometers. So essentially it measures the pressure difference P_1 minus P_2 is equal to say mostly the liquid used in manometer is mercury, so P_1 minus P_2 is equal to the specific weight of mercury into difference in the height.

Here you will have a scale with which you can take reading between this level and that level and that decides the P_1 minus P_2. The detail of this can be obtained anywhere in the literature. So we will go to the other types which are mainly used in medium and low pressures and high pressures, what are often used here. They can be classified under these 3 groups pressure measurements.

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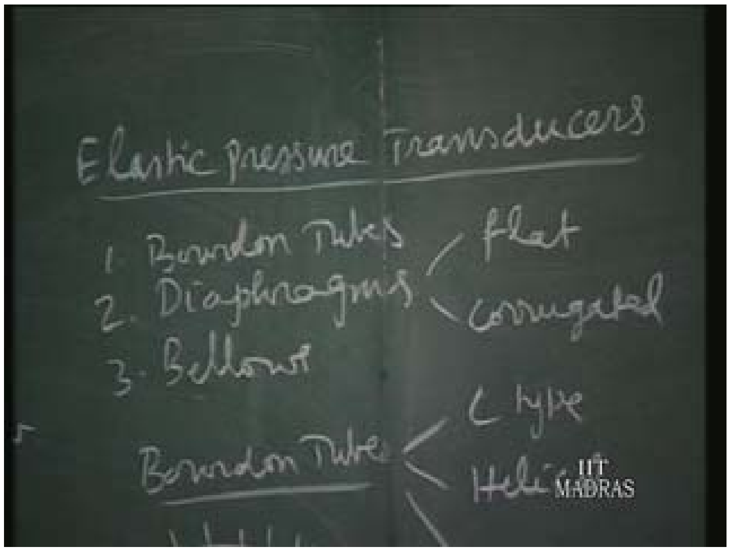

Bourbon tubes, diaphragm types and bellows. These are the three elastic elements made up of say phosphor bronze, beryllium copper, stainless steel these are the material used to make the elastic pressure transducers and the bourdon tube which we have seen in one of the introductory classes is of three types, one is c type, helical type and spiral type and we can measure up to 7000 bar by anyone of this bourdon tubes we can measure up to 7000 bar. The principle is if you take the cross section it is oval cross section.

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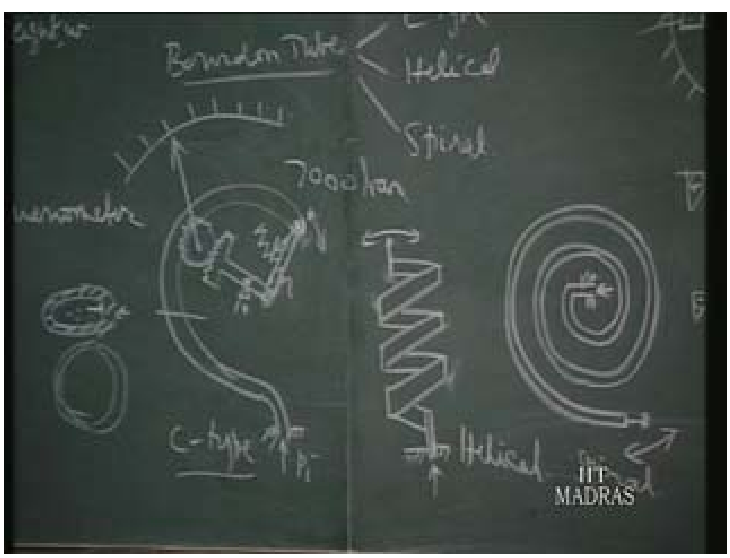

This is the material and the liquid pressure will be allowed inside so it is allowed inside it will occupy. So as the pressure increase this will assume more or less circular cross section, in the process this free end makes a motion. So that free end motion is taken by linkages and given to a rack and pinion mechanism. This lever mechanism printed I mean pivoted here, so the pinion axis given to a pointer which moves over a calibrated scale. So for higher pressures thickness is increased; to measure higher pressure thickness is increased. Also it is more and more of it will be nearing a circular cross section, very high pressures (Refer Slide Time: 08:38). The ovality is small for bourdon tubes for measuring high pressures so when ovality is reduced then the amount of deflection is reduced, to compensate for this people go for helical or spiral type of a bourdon tubes. That is the pressure is allowed here, this is a Bourdon tube in helical form, this is a free and fixed end, closed end and when pressure is there this end will make motions in this direction. So this is also used for very high pressures.

Similarly in spiral type here pressure is allowed and the closed end of the spiral is here so this this end makes to one promotions. So like whatever we have shown, we can have linkage mechanism for reading static pressures. If there is any dynamic pressure probably we can connect a wiper and can convert this wiper motion into electrical signal using potentiometer transducer, we can convert into electrical signal and then we can process it. That’s also possible in this type. It's left to us if we convert this motion into electrical quantity we can use it also for a slowly varying dynamic signal, pressure variations but in dynamic pressures the tube carrying the dynamic pressure, we should be careful because when a pressure fluid flows through any small piping, that frequency is damped out. So whenever we carry dynamic pressure to an instrument, you should have sufficiently large cross section so the pressure variation truthfully transmitted to the instrument end. We have to be careful in this.

Otherwise whatever the dynamic pressure taking place in this vessel cannot be carried by a thin tubing to an instrument or we have to mount the instrument itself on the tank itself or pressure vessel wherever you want to measure. That precaution we have to take. So next one is diaphragm, diaphragm we have got two types flat diaphragm and corrugated diaphragm.

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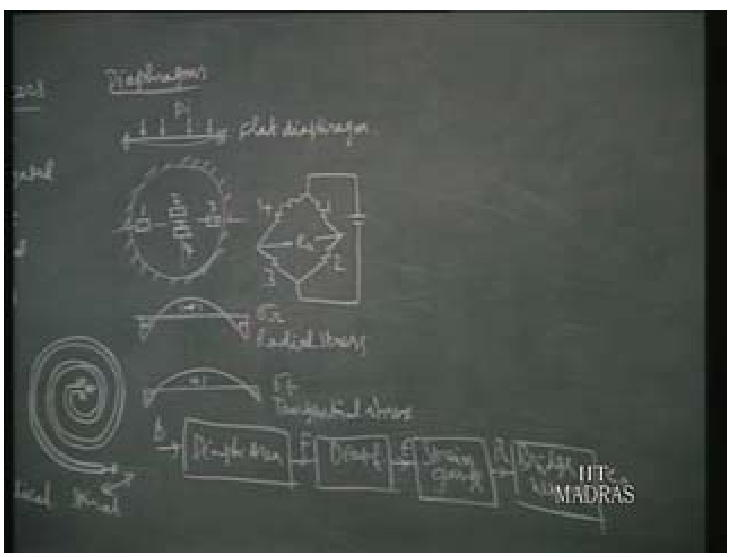

Flat diaphragm is just a thin sheet again made up of spring material fixed at the rim and when you apply pressure one side, you find it is deforming. It deforms like this and that means pressure is converted into force according to this signal flow diagram. This is pressure when we apply it over an area it converts into a force, pressure times the area of the diaphragm that force is deforming the diaphragm material so stress and strain are induced. What are the types strain induced, you can find this radial stress and a transitional stress accordingly, and strain also radial and the transitional strains will be induced. We find near the fixed end of the diaphragm, we have got compressive stress or strain. In both radial and as well as transitional directions we have compressive strain and near about the middle of the diaphragm we have the tensile strain.

So accordingly we fix these strain gauges 1, 3 will pick up the compressive strains 2 and 4 will pick up the tensile strain. So this is 1, 2, 3, 4. 1 and 3 compressive, 2 and 4 tensile so this gives the maximum sensitivity for the bridge network. So the epsilon strain produced is picked up by the strain gauge and R is changed. Resistance of the strain gauge is changed then we find we get an output from the bridge network. This is a DC excitation so we can use the DC amplifier and we get the output voltage X_{o}, this is DC amplifier or we can also use AC excitation for this by using a carrier frequency amplifier which you have learnt already.

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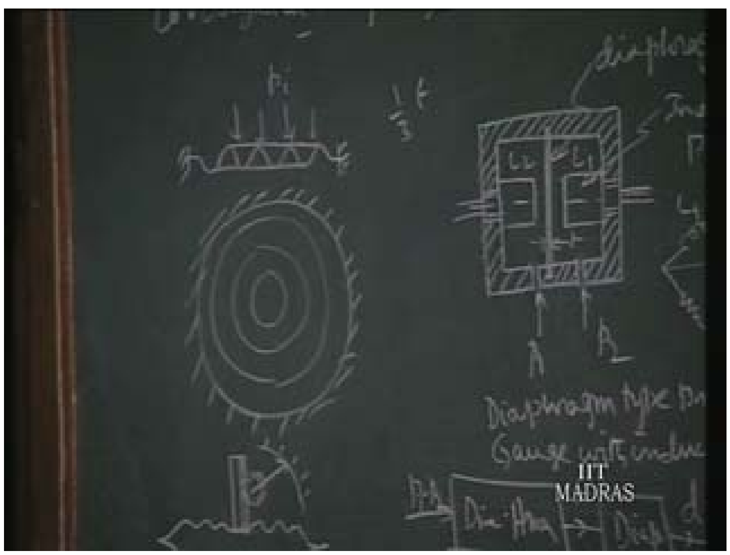

Next type is corrugated diaphragms. The disadvantage of the flat diaphragm is the maximum deformation of a flat diaphragm can be one third, the thickness of the diaphragm. So this is one diaphragm where t is the thickness of the diaphragm, one third the thickness alone it can deform, more than that the deformation is nonlinear to pressure applied. So to overcome this drawback, people go for the corrugated diaphragm. Corrugated diaphragm is somewhat like this. This is c type which we have seen already in one the earlier classes. It’s a Bourdon tube. It’s a c type Bourdon tube, what we have seen just earlier and in place of it we go for helical or the spiral depending upon the pressure range. So that is the Bourdon tube and this is a corrugated diaphragm.

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This is a corrugated diaphragm, you have the waviness, wavy nature in the surface of the diaphragm, and flat diaphragm means it will be flat area. Here you have got the waviness on the surface and this gives rise to much more deformation than what is normally available in the flat diaphragm.

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I will show the other one also which will come later bellows, this is we call it bellows. We find the so called convolutions so everything is made up of spring material but here bellow is shown there, which we will see little later. So the convolutions are produced and the two ends are open as it is shown, the two ends are open here, we have to plug it, if we want to use it but what is available in the market is of this type. So you have to plug one side with turning a piece and fix it properly and the other one, we make a small hole so that through which we can apply the pressure.

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So that we will come little later, just I want to show you how a bellow looks like when we purchase from the market. These are the three basic elements Bourdon tube and diaphragm and bellows. So that restrictions one third the thickness of the diaphragm alone can deform that is overcome here by going for corrugated diaphragm. So we have got more deformations such an instrument, one is available in aneroid barometer which is in aeroplane and all flying at different heights. The atmospheric pressure at that level it acts over. This is called pressure capsule made up from 2 such corrugated diaphragms. This is one corrugated diagram this is another one, bring both of them together and say at the circumference you solder it or weld it, soon it becomes a capsule. Then when you apply a pressure that the capsule expands that expansion is given to this rack which is formed as part of the top corrugated diaphragm and then when the rack moves up and down, when pressure varies the axis of the pinion is connected to a pointer which moves over a scale.

The pressure reading actually is written in terms of the height at which the plane is flying. That is one of the uses of this corrugated diaphragm. So now we will go back to the flat diaphragm, we have seen how the flat diaphragm deforms and that deformation is picked up by strain gauges. That is one possibility of sensing the deformation of the flat diagram into electrical signal by using resistance, strain gauge is basically resistance. So we can use the other principle also, we know to covert a displacement or stress or strain we can use displacement of any member, we can use resistance or inductance or capacitance. How the inductance capacitances are made use of in sensing the deflection or diaphragm is illustrated in the following figures.

So here we have got two inductive pickups, self-inductance pickup and this is the diaphragm and the pressure difference P_1 and P_2 are allowed to act in this chamber. The P_1 is being higher than P_2 so the diaphragm will deform in this fashion. So the diaphragm is made up of a magnetic material so when it moves nearer, one of the inductive pickups, its nothing but inductive coil so inductance of that will increase.

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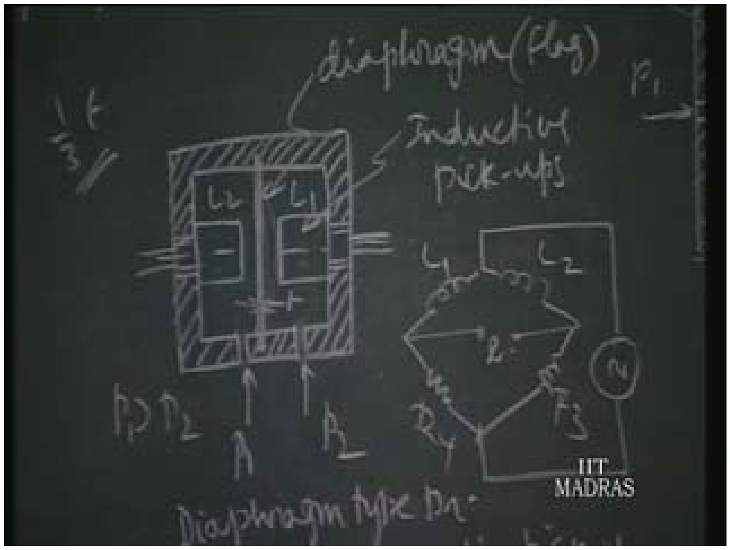

So L_1 will increase L_2 will decrease to the same extent the L_1 has increased from the original value so these two L_1 and L_2 will form adjacent arms often, AC bridge. The other two can be pure resistances; we know the condition for the balancing of AC Bridge. The impedance product of the opposite arms should be same, at the same time that phase angle of opposite arms one opposite arms should be equal to other one. That is well satisfied if you have two more resistances like this pure resistance. So these are the conventional AC Bridge which is used to convert these deformations into electrical signal e. So the full instrumentation diagram I have given here but what is the basic transducer used, how it forms part of the full instrumentation, it is shown in this signal flow diagram. That is P_1 minus P_2 by using diaphragm area the corresponding force is there on the diaphragm that is F, P_1 minus P_2 times area of the diaphragm will be the force. That force again acts on the diaphragm make a deformation D_2, here deformation D. So that deformation is changing the inductance of the coil and that goes into the AC Bridge.

That AC Bridge gives output of e, this is output signal, this is your carrier frequency amplifier, the whole thing forms a part of carrier frequency amplifier. So which you do not see like this but this is what is in a detail which we have learnt earlier. So we get the output signal that is a phase sensitivity demodulator crystal oscillator from where we get the excitation and low pass filter and we get the output signal. So that is how the inductance can made use of to sense the deformation of the diaphragm in the electrical signal. Here there is another version where the deflection of the diaphragm is made use of to change the capacitance of 2 capacitors. This is the diaphragm, so which when acted upon by 2 pressures P_1 minus P_2 so P_1 become larger it deforms like this. So the distance of this two capacitor C_1 is capacitor one, C2 the other capacitor, the common plate is diaphragm and the fixed plate is obtained by having a gold coating on two glass pieces like this.

They will be suitably connected by wires and you will find we can build a bridge network somewhat like this, this plate and this plate is nothing but our diaphragm. This is our diaphragm that is the same diaphragm, same element so both of them is taken as one element and this gold coating is a fixed diaphragm, this is your gold coating. These are the resistances R three and R four so it forms the full bridge.

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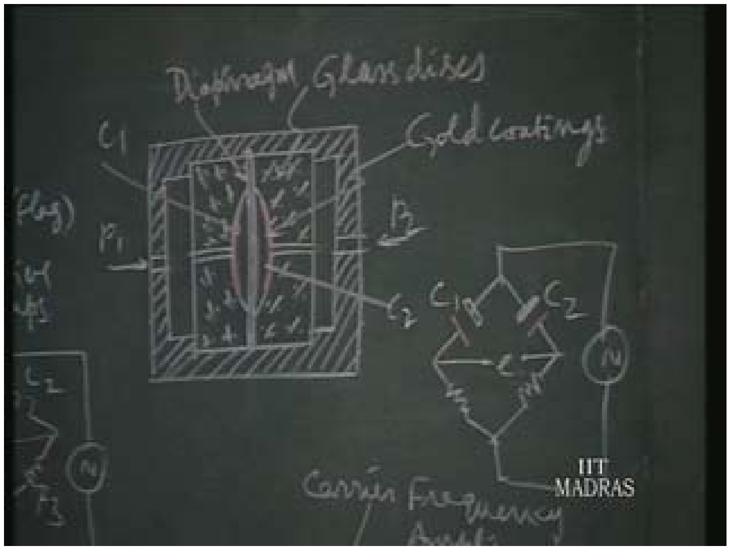

Similar excitation if we give so more or less same, the pressure difference to force in the diaphragm and the diaphragm again deforms to D and here you will have capacitance, in the inductance side capacitance and C will be the end L you write a C and all the other thing remains same, you get the output signal. So this way the deformation can be sensed by using capacitance principle into voltage. Another method also adopted piezoelectric pressure transducers with quartz crystals.

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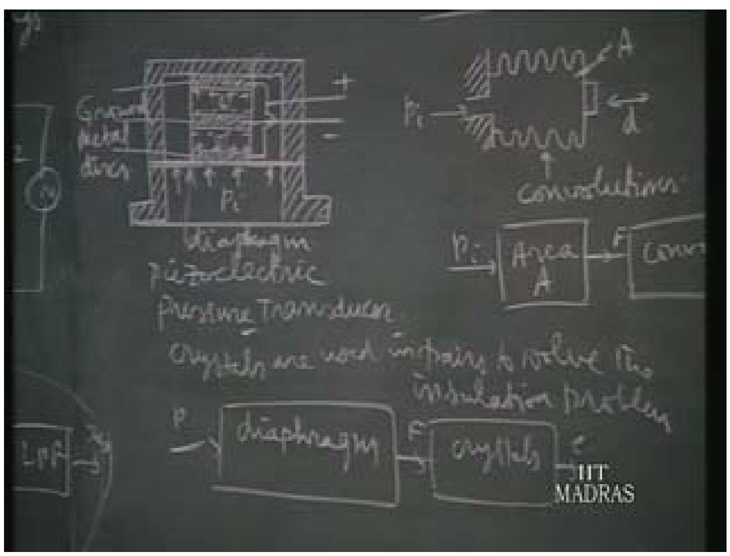

They are normally used in pairs, crystals are used in pairs that is there is some advantage the earthing problem is solved here or for example you find this is crystal one, this is crystal two. One pair we are using and this is a diaphragm over which the pressure is acting. So the signal flow diagram here is the diaphragm, so pressure is acting. So diaphragm area we get the force, by using crystals we convert into charge e, charge or voltage.

So when the pressure acts then force is there and that is compressing the crystals of a piezoelectric crystals. So the crystals can be arranged in a way that top portion of the crystal or bottom portion will develop negative charges and ground pieces, these are the ground pieces, metal pieces, ground a metal discs they will collect the charges accordingly. Some middle disc will collect the negative charges from both the crystals and the outer disc will collect the positive charges so the insulation problem is solved. Crystals are used in pairs to solve the insulation problem because this whole frame will be having only positive charge, negative charge is inside so already insulated if we use in pair.

Otherwise if we use only one crystal this bottom portion will be negative charge, for top will be positive charge in between you have to insulate, in the casing itself we have to insulate. that problem is solved if we use in pairs and correspondingly we have to adjust, you have stack it so that one plate will be positive that is this plate and this plate are connected and finally you take the positive charge here. This plate through this negative charge then we give it to the charge amplifier where it is amplified and voltage output can be obtained. So that is the point in pressure the piezoelectric transducer we have to use crystal in pairs. So that is regarding the usage of diaphragm in sensing the pressure or measurement of pressure.

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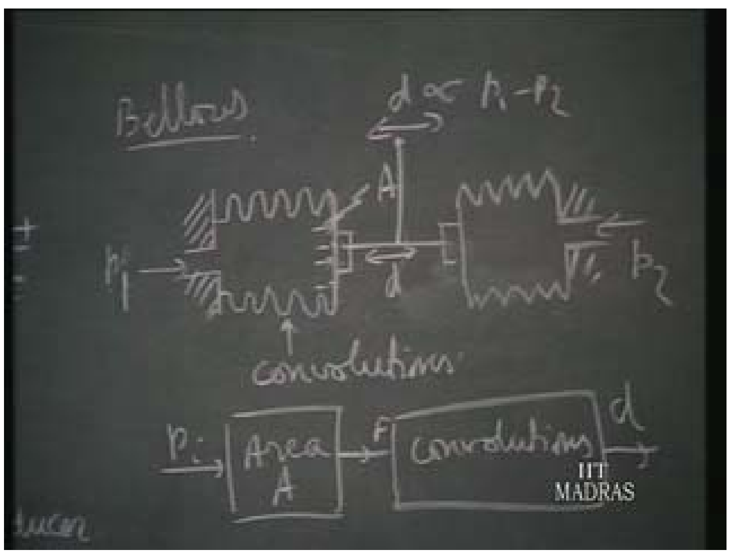

Next one is bellows, this is another elastic element. Here you have a deformation more than even corrugated diaphragm that is advantage because we have so many convolutions here and we allow the pressure here, the pressure acts over this area, end pressure that as I told that end of the bellow should be closed with a plug. so the whole area is used to convert this pressure acting into a force, pressure into area will be force and that force this is nothing but spring material convolutions that gives way. So by using convolutions the F is converted into a displacement d. So this d can be made use of to move over a resistance on a potentiometer resistance and convert that displacement into a corresponding voltage signal. So this is for measuring one pressure if outside is atmospheric pressure, we measure the gauge pressure. By having a vacuum surrounding the bellow we can also measure the absolute pressure so we can arrange bellows in a way we can measure the differential pressure also, 2 different pressures we can give, same arrangements we can have here and here convolutions we can allow the crystals acting there.

Here if we call P_1 and you can allow P_2 and connect both of them by a rod, the rod portions this will move this d is proportional to P_1 minus P_2. So bellows can be arranged in different ways to measure absolute pressure or gauge pressure or the differential pressure. We will learn now the vacuum measurement. Vacuum is low pressure, any pressure lower than atmospheric pressure we call it vacuum. Atmospheric pressure is in another unit 760 millimeter of mercury or we can call it 760 Torr.

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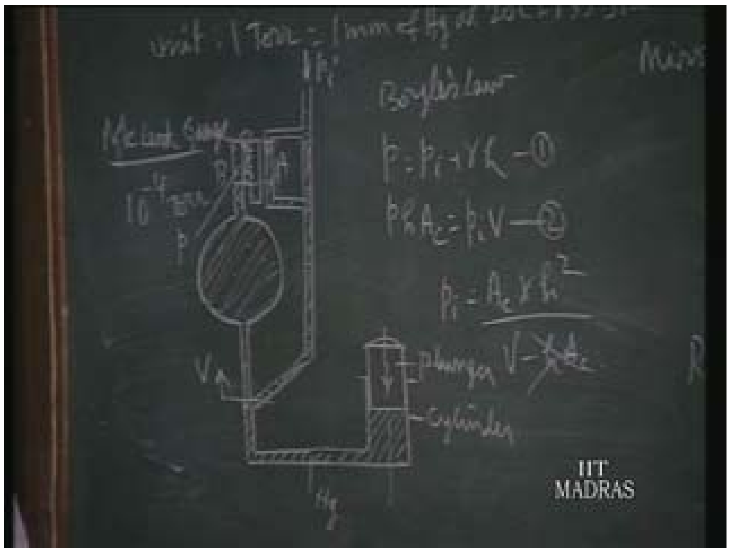

One millimeter of mercury is one torr and that is at temperature 20 degree centigrade whatever the pressure felt at column of one millimeter of mercury that is equal to 133.3 Pascal that we call it one torr. So the atmospheric pressure we say 760 torr. So anything lower than that we call it vacuum. Vacuum is nowadays very widely used in industries in manufacture of vacuum flask and television tubes and breaking system in railways and in metallic coatings say glass pieces and also simulators in order to simulate the space condition, any chamber has to be evacuated to simulate that vacuum condition in space at very larger heights. So when we create vacuum naturally we have to measure the vacuum how much we have created in a chamber. Hence we find vacuum measurement is also an important a parameter. For calibration purposes people go for this McLeod gauge where which can measure up to 10 to the power of minus 4 and this is mainly used for calibration purpose because the measurement principle based on the Boyle's law. That is P_1 V_1 is equal to P_2 V_2 that is what is made use of here, so it’s used for calibration purpose.

The principle is like this, here we have a plunger and cylinder assembly, by withdrawing the cylinder we can bring down, this is mercury is filled up there. By withdrawing the plunger up, moving the plunger up or withdrawing it we can bring the mercury column in this capillary, these are all capillary tubes with a bulb, the spherical bulb connected. So when we withdraw up to this point, now the vacuum pressure can enter into this column, the volume and the capillary tube it can enter. So thing is we have to wait for sufficient time until the vacuum pressure uniformly get dissipated because to occupy a full space it takes some time at very low pressures. We wait for sometimes 5 minutes or 10 minutes and then now the measurement process starts. You push down this plunger down now the mercury will start rising.

The moment it comes here then from this point onwards, up to this that is entrapped. Further rise entrap this vacuum molecules, the gas molecules and here it will rise and rise the mercury level by pushing the plunger down, until it comes here, this is zero mark. Zero mark in the scale until it comes there you rise, so up to here (Refer Slide Time: 29:05). So this will be mercury, mercury column is raised, until it reaches. Suppose it is capillary A, this is capillary B, in capillary B this full volume of V from here it is given, manufacture will give you what is volume, it may come here, up to here the mercury may be occupying the full volume. Now take this height this is we call it measurement height h that is what you are supposed to measure after making the mercury column come to zero level and find the height of the compressed molecule column in the capillary B. Let call it heights h (Refer Slide Time: 29:54). Now by considering this initial volume and later volume, that is later volume is if we call this P the compressed molecules, if we call that pressure P, P into the volume is equal to the capillary area into heights. That will be volume so P_2 V_2 is equal to the P_2 V_2 condition, initial condition is P_i occupying the full space into V, that is P_1 V_1 is equal to P_2 V_2 like that.

Now we know from hydraulics at this point pressure here are same and at that this point P_i is there at the top plus the pressure due to the liquid column so P is equal to P_i plus gamma h where gamma is the specific weight of the mercury. From these two equation we can eliminate P and get an equation for P_i that is what you have got here, AC gamma h square over V minus h into AC. Now V is very large one when we compare with the small capillary area, we can forget it. So now P_i is obtained here by measuring heights, since all the other terms are constant given by the manufacturer, by measuring heights substitute in this equation we have got the P_i. So this is principle of measurement, we can measure up to; this device is used up to 10 to power of minus 4 torr. That is unknown may compressive we can give it and calculate the pressure there, vacuum pressure.

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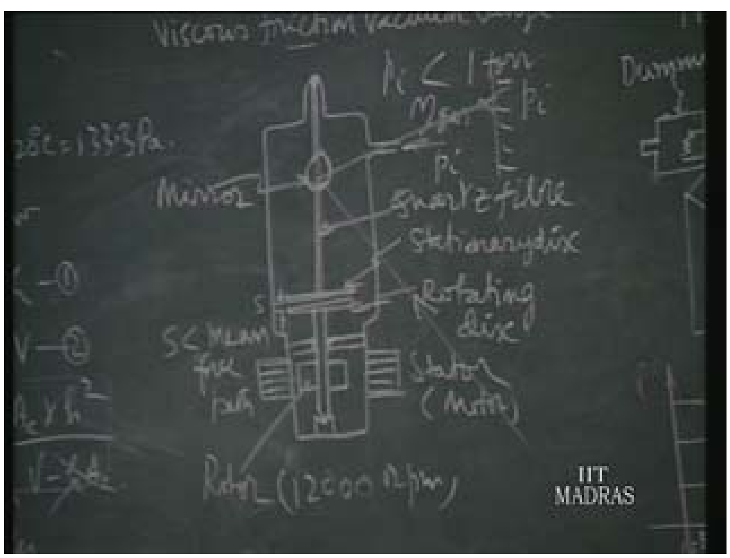

Second method is viscous friction vacuum gauge. Whenever the pressure is less than one torr, when P_i is less than one torr that viscosity of the gas is proportional to the pressure, the viscosity eta of gas is proportional to the pressure P_i. Higher the pressure higher will be this viscosity, absolute viscosity of gas is proportional to P_i. Higher the pressure, higher will be the viscosity that is what is made use of here.

There is one disc rotated by a motor, this is a glass casing. It can be glass casing, outside we have got the stator of the motor, this is part of the motor and to the inner disc that's how we connect the rotor, that is inside. So when you send current here this rotor will rotate at very high speed may be of the order of 1200 rpm in a one given setup. So now the distance between the two discs, one is stationary disc another rotating disc should be less than suppose this is s, so s should be less than mean free path of the molecules then only the viscosity is proportional to the pressure. So it is more or less very near and now due to this presence of molecules there is some viscosity, due to viscosity the torque from the rotating disc is transmitted to the stationary disc. So due to the torque it will tend to twist that is we have got a quartz fiber with its elasticity, it will tend to twist and you have a light ray from source and it will be reflected to an optical scale.

So for optical scale is written in terms of vacuum pressure that is how for different pressures we can get the reading and for each gas we have to calibrate this instrument, after calibration we can use it. Also this instrument is used in finding this principle; the viscosity is proportional to pressure. The torque transmitted to the disc is proportional to viscosity that principle is used in viscosity meter also. Viscosity meter for measuring viscosity of the liquids we find similar arrangement is there. The rotating disc there, the liquid at different temperatures it will be kept there. Whatever torque transmitted is proportional to viscosity. That is same principle used there but here we are using the principle for vacuum measurement.

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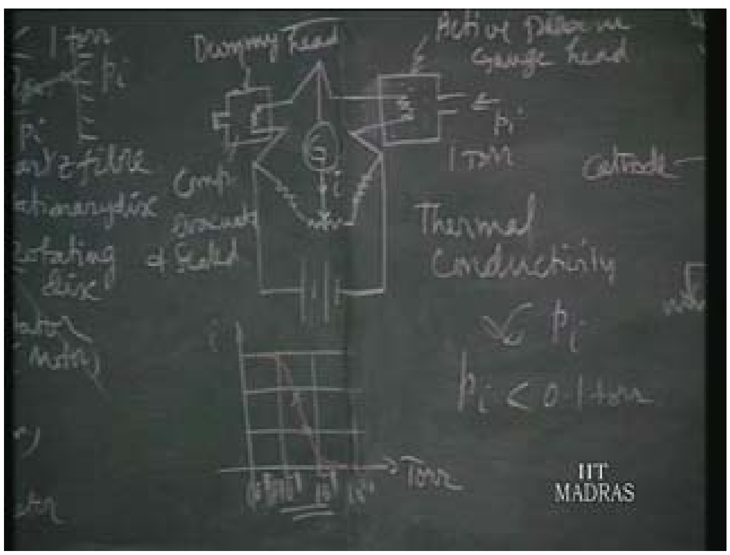

Another one this thermal conductivity this pirani gauge is based upon thermal conductivity that is proportional to again pressure. That is when P_i is less than point one torr, this is the physical property what is made use of there, for that you have the resistance element in the middle of this casing. It may be metallic cylinder or glass cylinder. So the filament made of tungsten's some good conducting material will be put at the middle of this case of the cylinder. So when you switch on this, when you give supply to this circuit or the bridge circuit you will find it is being heated up. This heat will be taken to the casing by the molecule which presents; higher number of molecules will carry a large amount of heat I mean proportionately larger heat. Then the temperature will come down and then at proportional temperature it assumes a resistance.

So this you have to calibrate it so for calibration purpose we fill this volume with the vacuum gas say at one torr and the adjacent arm is similar unit, dummy gauge it is completely evacuated. Similar head but completely evacuated and sealed, it's an adjacent arms. We can have similar resistance but it is easy to have either dummy head and fix it as adjacent arms, this is completely evacuated. Now fill this volume with a gas with one torr that means you will have enough amount of molecule to take the maximum amount of heat from the filament to the casing then temperature will be low and resistance also will be low accordingly. We have learnt the resistance is proportional to the temperature under resistances thermometers. So the resistance is low, now you adjust the potentiometer so that current here is zero, imbalanced current is zero. So at one torr we will have more or less zero reading here, i is zero through this.

Now you can apply known vacuum because it's a calibration process then when we apply vacuum that is less than one torr, the temperature will be increased because less number of molecule taking the heat from the filament and then temperature will increase, imbalance will come and you will have some current value here. So that is for one pressure, similarly you can use it for different vacuum pressures. So at this 10 to the power of minus 3, 10 to the power minus 1 to 10 to power minus 3 is the normal range for pirani gauge. Pirani gauge is often used in conjunction with vacuum pumps. When you order a vacuum pump that manufacture also supply a pirani gauge to measure the vacuum created by the vacuum pump, so this is the principle. The range is 10 to the power of minus 1 to 10 to the power minus that is the range. It's a short range because if the vacuum falls below ten to power minus 3 what happens the heat is conducted not by gas molecules but by the support.

Support of the wire will carry the heat to the casing and hence the principle is after very much affected. That's why pirani gauge work within the limited range of 10 to the power minus 1 to 10 to power minus 3 torr. So as the vacuum is increased the imbalance increase because the resistance is keep on increasing though current is increasing, this is the calibration curve later on for the same gas unknown vacuum pressure can be found out by this. So the arrangement of the circuit is like this so it forms one of the four arms on the wheat stone bridge, a dummy head is adjacent arm these are all constant resistances we call R_1 this is R_2, R_3, R_4.

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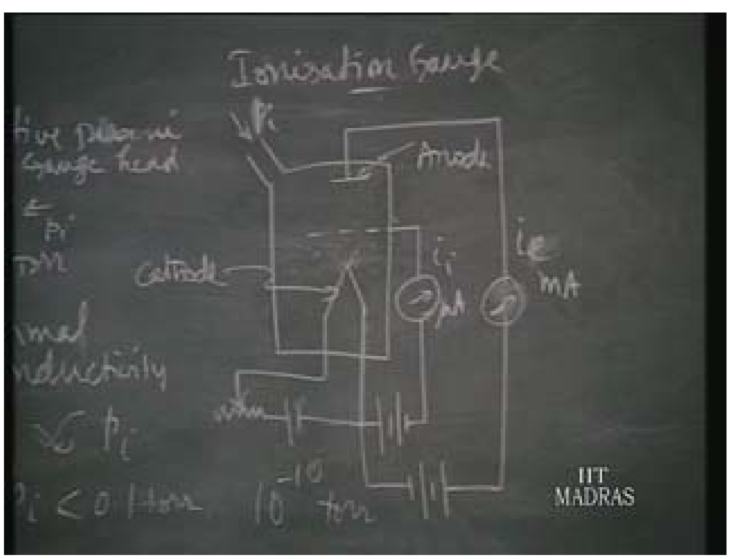

This is for initial balancing of the bridge for the calibration purpose. The last method for the measurement of vacuum is... (Refer Slide Time: 38:23). This is we can use it for pirani gauge. Pirani guage range is 10 to the power minus 3 but here this one is going to 10 to the power of minus 10 torr, very high range. The principle is like this, it is somewhat a triode tube, electronic tube it resembles electronic tube where you have a cathode and its own circuit, heating circuit. It is a battery and this grid circuit has its own circuit and cathode to anode also you have another circuit. So the anode is positively charged with reference to cathode and grid is negatively charged, this is negatively charged with reference to cathode. These are the circuits and this is independent, three independent supply we have got.

So the gas molecule or the vacuum pressure is allowed here and it will occupy this space, inside the tube and when we heat this cathode element the number of electrons will be coming out, millions of electronics. When they hit the gas molecule, the gas molecule is made into positively charged and negatively charged ions. So the positively charged ions are attracted by this grid which is negatively charged with reference to cathode and there is a current flow through this grid circuits in terms of microamph. The negatively charged ion will travel with the other electrons and it will form very small part of it and it will be attracted by anode and it will go through this circuit, the ion current ie but that ie will not be changed by number of hits. The resisting electrons hitting the gas molecules and that number of molecules hit decides the current flow. That is number of positive ions decides the hit or the number of a particles hit by the resisting electrons. So that again in another terms it indicates the vacuum pressure. More and more pressure means more molecules come here that's why it indicates the vacuum pressure. So this reading in this grid circuit, the ammeter in the grid circuit is calibrated in terms of the vacuum pressure. When the vacuum pressure falls down then less number of molecules less current will flow here. So that means vacuum is more like that this is calibrated and it can go up to 10 to power minus 10 torr, its sensitivity is up to that.

The one drawback is suppose this is a heated element cathode, suppose we allow without knowing large amount of molecules or larger pressure then this may be burnt. To avoid this situation what they do, they go for the hot cathode, this is a hot cathode; go for cold cathode then to pull the electrons we should have the high, this will be of the order of 5 kilovolt. If you have cold cathode then this battery will be in terms of kilovolt then you can pull this electrons and as it rises, it hits the molecules proportionately you have current and accordingly we calibrate in terms of the vacuum. So that completes the methods of measurement of vacuum.