Principles of Mechanical Measurements
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Lecture No. # 25

We have seen until now pressure measurement and the vacuum measurement. Vacuum measurement we know it is again a pressure, it is a low pressure than atmospheric conditions so we call it vacuum. So it's again a pressure measurement, vacuum is pressure measurement. So whatever the technique we used for the pressure measurement we can use it for the vacuum measurement also.

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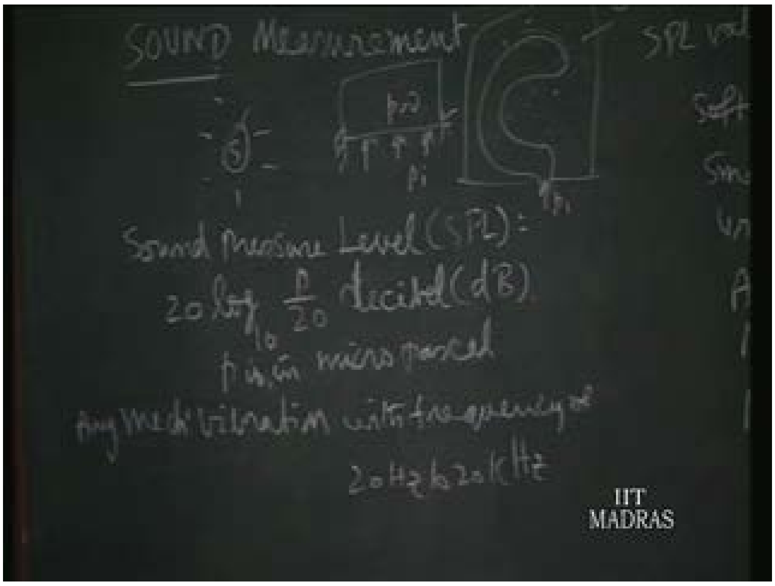

For example bourdon gauge and bellows, diaphragms if you put one side for example if you take bourdon tube this is what you have seen. If we can put this atmospheric condition into a casing and this you evacuate. If you evacuate the surrounding in which the bourdon tube is put then bourdon tube itself can measure the low pressure or vacuum pressure. Similarly a diaphragm when we have got diaphragm and this side if you say p is equal to zero vacuum and here if it is some pressure p_i vacuum pressure then you will find we can measure the vacuum pressure also lower atmospheric conditions. So the bourdon tube, the pressure, the diaphragm or the bellows can also be used to measure vacuum of low and moderate values. Other methods you have seen in detail in the last class that is McLeod gauge and viscous vacuum gauge and pirani gauge are other methods.

Otherwise whatever method we have used for the pressure measurement we can use it provided the surrounding in which the instrument is there is evacuated and by absolute pressure that is vacuum pressure is applied inside the tube that way we can measure it. Today we are going to see another one sound measurement; sound is also a pressure because what is sound? It is a mechanical disturbance taking place in air or liquid or in solid. Sound can be propagated by any one of these medium air, gas or the liquid or sound or the solid, these three can transmit sound.

What is actually sound? When we say light, it is electromagnetic wave. Whereas sound is mechanical wave when we have got a source so this is a source. A source if it produces some sound that means the nearby molecules I mean any vibrations, any mechanical vibration with frequency of 20 hertz to 20 kilohertz is there, then the sound is produced because sound frequency is 20 hertz to 20 kilohertz. Suppose we vibrate now what i am vibrating is 1 or 2 hertz that's all, so no sound is there but if i can vibrate at 20 to 20 kilohertz in the frequency, naturally sound is made that sound is propagated in air. How it is done? When move movement is there the nearby air molecules are compressed and then when the movement is away then the air molecules are rarified.

So you find alternatively compression and rarefaction of air molecules takes place around the sound producing source. So that waviness produced is maintained and it propagates through the medium of air or the gas or liquid or solid that is the propagation of sound. Now we are concerned here with the measurement of sound it is because we consider here sound measurement mainly refers to noise that is noise is unwanted sound. Unwanted sound is noise and when we like that sound we say music, when music frequency is particular or in slow variations, not sudden variation in frequency or tone. When there is all sorts of variations in frequency and tone then such a sound is unpleasant and then we call it noise. Noise is a public nuisance. Why? When there is a noise we have to shout over the noise or when somebody talks and I cannot here because there is some other disturbing source. So that means my hearing is disturbed by the presence of some other sound.

So we know it is a public nuisance, sound and this noises and in order to reduce such noise engineers take many efforts while they design the equipment and we might have noted in newspapers, advertisement as of electronic noise free typewriter. A mechanical typewriter we say for that one good feature is less noise, this typewriter makes less noise like that. So noise free machines, noise free operators have got that is a special specification for many things. So while we design an instrument naturally we have to see that noise is reduced to the extent possible. So naturally whether noise is reduced or not how do you know? Unless we measure the noise we cannot specify or quantify the noise that is what we are learning here how to quantify noise.

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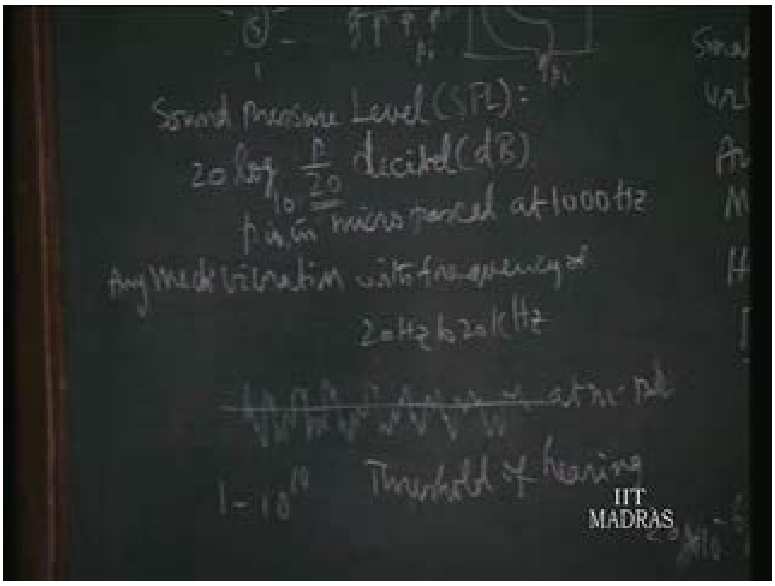

So for that we have this sound pressure level is the unit, simply it's called SPL. It is defined as 20 log to the base 10 p by 20 decibel where p is in micro Pascal that is RMS variation or we know how the sound varies. Sound has got all these frequencies. So when we talk the frequency of sound is varying and that means this is atmospheric pressure. So the atmospheric pressure will be varying when there is a compression, this is a rarefaction. All these random variations within the frequency of 20 hertz 20 kilohertz is taking place, this is the pressure variation. This RMS value of it root mean square value of it, that value that is p is in micro Pascal that value is 20 that value is to be substituted here and that is micro Pascal at 1000 hertz. That is a reference frequency because the 20 represents, 20 micro Pascal at 1000 hertz represents the threshold of hearing, it is called threshold of hearing.

What is threshold of hearing? The necessary pressure to make us hear any sound, if the sound is less than 20 micro Pascal say 1000 hertz then we cannot hear that is the capability of our human ear. So if p produced by a source is equal to 20 Pascal, log one is zero that is it is just when zero decibel means it just near about our capability to identify the sound source, anything more than that we take the logarithmic scale. So why do you take the logarithmic scale? Logarithmic scale normally adopted when the range is very large. If suppose the range is say 10 to the power of 10, can we have a linear scale to represent 1 to 10 to the power of 10 units, even 1 to 1000 units means it's very difficult to represent in linear scale and 10 to the power of 10 definitely we cannot represent in linear scale. So in such cases we go for the logarithmic scale.

Actually you will find the range here, 20 micro Pascal that is 20 into 10 to the power of minus 6 Pascal. That is the lowest value it measures and what is highest value? It is nearly about say threshold of pain 140 rocket engine and atmospheric pressure is 194 that is equal to 10 to the power of 5 Pascal. Atmospheric pressure, the scale range it varies up to 10 to the power of 5 Pascal equal to 1 atmospheric pressure. That means what is total range? Say it is near about 10 to the power of 11 this is the range, 1 to 10 to the power of 11 units represented in linear scale is not possible so we go for the logarithmic scale. So the sound pressure level is always measured by this SPL defined by 20 log p by 20 decibel where p is the sound variations in RMS.

This RMS means you have to square it and then than take root mean square value; this is variation on both sides so that is the sound pressure. So in a sense we are supposed to measure the variation of, sound measurement means a pressure measurement. How the pressure varies around atmospheric pressure, around atmospheric value? That is what we are going to measure that’s why we are learning sound measurement along with the pressure vacuum, also we are measuring this.

Some of the values SPL decibel, sound pressure level in decibel for known sound sources are tabulated here. Soft whisper when two people sit nearby and whispering some information and if we measure 2 meter distance, distance is important. When you measure sound at what distance you measure sound is important because longer the distance sound pressure gets reduced, sound is reduced it is inversely proportional. Suppose we double the distance then the sound pressure is halved, half of the earlier pressure. So that is the case with sound also it is stated this is inverse proportionality it is called inverse proportionality of sound. That is there if we have the distances, minimum distance is 4 times the dimension of the source. Suppose a typewriter say one foot length then away from four feet, later on we can measure the distance. Within the 4 feet we find it is not observing this rule of inverse proportionality.

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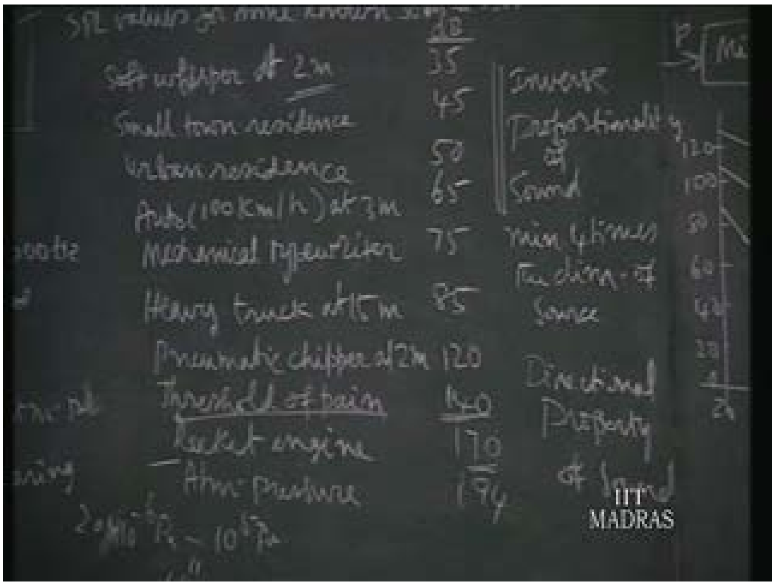

What is inverse proportionality? That is sound pressure will be inversely proportional to distance that is not valid. When we are measuring too near that is one aspect of sound. Second aspect is when we have a sound making body and it is not making equal pressure in all directions in certain directions, it makes larger pressure than the other directions that is called directional property of sound. This is the directional property of sound, both the thing inverse proportional of sound and also directional property of sound will be valid only when we measure the sound in an open space, there should not be any nearby wall. If there is nearby wall what happens, when the sound is made by one object that we are measuring sound hear. We are measuring directly coming sound as well as the sound comes and falls here and reflected, that sound also we will measure. So when there is a reflecting wall nearby then that reflected sound also is measured along with the original sound from the source.

So when we make sound measurement we should be careful that nearby there is no wall. Under this situation only these two rules are valid. So that’s why in many places we find the measurement distance for sound is given. Soft whisper when it is measured at a two meter distance then it is 35 decibel, then small town residence general noise in a small town will be around 45 decibel. In urban residences like Madras or Madurai big cities, you will find a lot of movement traffic and we find 50 decibel is the average sound level. Then auto at 100 kilometers per hour running at 3 meter distance if you measure 65 decibel, mechanical typewriter 75 decibel, the heavy truck lorry with loaded lorry at 15 meter distance if you measure 85 decibel.

A pneumatic chipper because pneumatic will make lot of sound 140. What is threshold of pain? If the decibel is around 140 decibel, if the specific value then your ears starts paining, that paining value is 140 decibel and we find rocket engine when it takes off, it makes 170 decibel. That is the reason the scientists are in a closed housing with glass windows so that they can observe the taking off of the rocket as well as their ear is protected. Otherwise it is more than 170 decibel more than the threshold of pain; your ear will go away in no time so that is very important, the atmospheric pressure is 194 decibels.

So another point is rocket engine pressure is so high, sometimes the rocket panels fail due to fatigue stress produced by the sound at the time of takeoff of the booster rocket. So sound you cannot neglect it, sound produces even failure of some parts so measurement of sound is very important.

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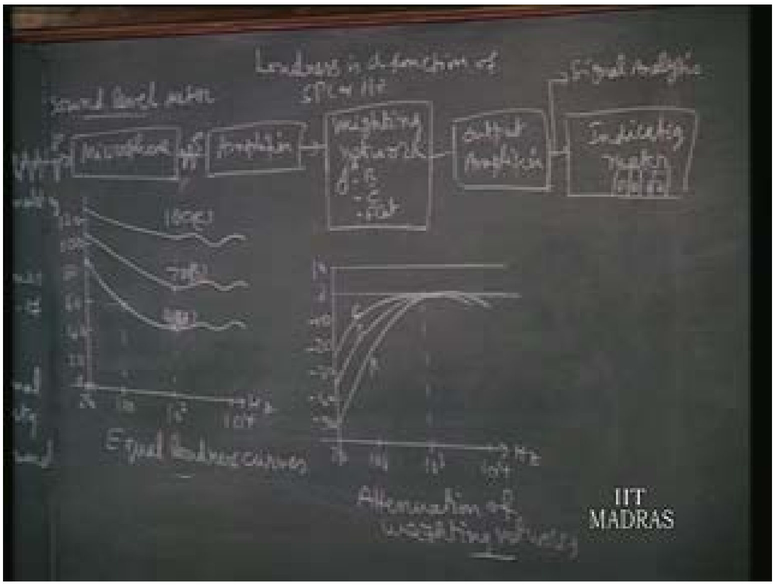

The instrument used to measure the sound is called sound level meter it is here, it is sound level meter. That instrument what we use to measure the sound is sound level meter and it is made up of some basic important units I have put here that is signal flow diagram. First we have got so called microphone, mike is one that is what I have. Here also it is mike, it converts the sound into electrical voltage. What is sound? Sound is nothing but pressure variation we have already learnt, this pressure variation of what I have seen earlier this say pressure variation will be of this nature; this is the pressure variation around atmospheric pressure and it converts into voltage variation of the same nature; it's a voltage variation pressure to sound, that all what it achieves the microphone and 1 or 2 versions are there which we will see little later.

As far as now we will say microphone achieves the changeover of pressure to or transduces pressure to pressure variation into voltage variation then it is amplified that voltage is amplified because it may be very weak it amplifies. Then we call so called weighting network, weighting network is an important unit in any sound level meter. We have got 3 scales A scale, B scale, C scale and another one is flat it doesn't belong to anyone of these things. The weighting network importance is the loudness is a function of SPL and frequency hertz that is important. We have got equal loudness curve, say the loudness phenomena can be explained with this equal loudness curve. We say A scale has got 40 decibel SPL value at 1000 hertz such a tone is called A weighted network and little higher loudness say 70 decibel at 1000 hertz we call it B scale and 100 decibel at 1000 hertz any noise, any sound has got such a decibel at this 1000 hertz they are grouped under this 3 scales, A B C scale. Most of research purposes we go for the A scale. So anyhow these are the 3 scales available in any sound level meter or we can specifically order a meter only with A scale also that is also available in the market.

In the A scale the sound or the loudness made by 40 decibel at 1000 hertz then another sound having 20 hertz frequency making 90 decibel SPL value both of them that 40 decibel at 1000 hertz and 90 decibel at 20 hertz both will have the same loudness; that is why it is called equal loudness curve. So say for example suppose it is 100 then 60 decibel at 100 hertz will make say a noise equal to 40 decibel at 1000 hertz; that is why I have put loudness is a function of SPL and the frequency. So what we are measuring in this sound level meter is the loudness. So if SPL alone is obtained according to our definition 20 log to the base 10 p by 20 that is not sufficient. After all a human being only is judging the noise source and he will judge only based on the loudness of the machine, so loudness is important for our comparison of the machines. So naturally the weighting network brings the value of SPL to the loudness. How it does? It has got by attenuation of weighting network. What it does? Suppose noise has got 20 hertz and that noise is making 90 decibel pressure variation then what it will do?

Since it is equal to 40 decibel at 1000 hertz it will subtract from 90 that 50 make it 40, so that loudness is seen in indicating meter as 40 decibel because that is equal to 90. So what it does; it subtracts 50 that is attenuation. What it attenuate at 20 hertz whatever be the pressure, whatever the SPL value from that it will subtract 50 and indicate the remaining value. That means if it is 90 decibel at 20 hertz our meter will show only as 40 decibel it is because that loudness of 90 decibel is equal to loudness of 40 decibel at 1000 hertz, so it will show 40. Similarly A and B and C weighting and all, what they will subtract for a given frequency is given here. That is this network electronic network what we have under the weighting network. This electronic unit, it will sense the frequency accordingly it will subtract the value and that remaining value will go there further.

So next it goes to output amplifier and then it can either go to indicating meter where we have the reading so many decibel you may have or we can also take the output of the output amplifier for analysis, especially in machines and equipments where we want to locate because an equipment or instrument is made up of hundreds of parts and which part makes the maximum noise we would like to locate. If you locate that part then probably we will change it to another part making less noise. So for such purposes we have to analyze that signal or for the frequency analysis, it is done with the help of an octave band analyzer, it's called octave band analyzer. What it does octave band means it will have band pass filter, it will have a set of octave for example octave band analyzer will have a set of band pass filter. Center frequency of each band pass filter, subsequent band pass filters will have a ratio of two that is why it is called octave band pass filter, center frequency of subsequent band pass filter will have a ratio of 2.

So we will select one band pass filter measure that SPL value for that for analyses purpose you have to use flat, under the flat because under if you put flat the weighting network will not do any subtraction; it will pass the SPL value as it is without any subtraction that is why it is called flat; under flat condition we have to analyze. So you select one band pass filter with certain center frequency, find the value of SPL and then switch over to the next band pass filter having a ratio of 2 center frequency and again measure the SPL value and then plot it. For example I have got a plot of for a electrical motor how much noise it has made, plot of SPL or I will simply write SPL of a blower measured value, so here it is 63 hertz one center frequency other surface to be 125 then 250 like that it goes 250, 500 so 1000, 2000 that is how the center frequency goes and here we have got 40 decibel 40, 50, 60, 70, 80, 90. So from 75 onwards it goes so at 125 maximum. So 75 it goes like that, so this is the plot after difference center frequency you have got this plot. So from here we know that at 125 hertz it produces the maximum noise probably 125 hertz may be a rotating speed of a gear machine.

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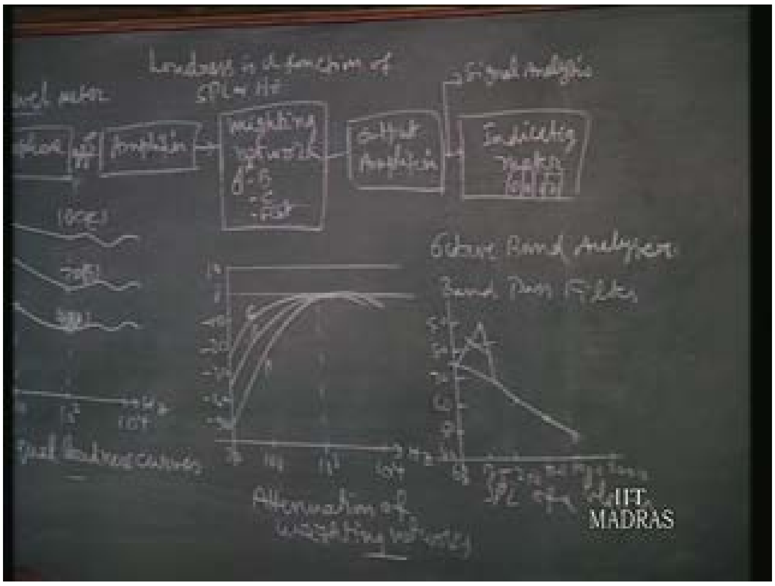

Then we find one of the two machine gears we change it to, if they are metallic we can change it to say one plastic gear. One plastic gear machine with metallic gear will make very less noise then after making that again measure then you will find this will go away like that, we effect improvement in reducing noise in many equipment; for that purpose we can analyze this signal also.

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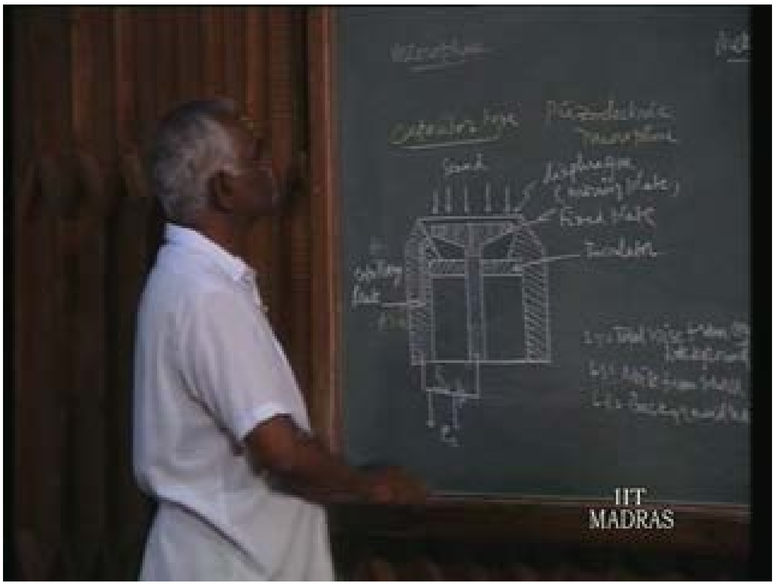

Now we will see how the microphone functions. We have seen in the sound level meter microphone transduces the sound or pressure variation into voltage variation. How this is obtained? We will see one version that is the capacitor type; this is a capacitor type microphone. Here for example for a capacitor we have got two plates whenever we change the distance between the two plates the capacitance varies that can be made use of in suitable electrical circuit and we can get corresponding voltage signal that is what is the principle used here.

The capacitor is made up of the diaphragm on which the sound pressure falling, sound is acting or impinges on that surface and so depending upon the compression rarefaction the diaphragm moves to and fro vibrates that constitutes the moving plate, diaphragm is the moving plate, diaphragm is of the order of the few micron thickness metallic diaphragm fixed over the edges around circumference it is circular diaphragm; below that we have got so called fixed plate it's also a metallic piece with a damping holes because when the diaphragm vibrates at high frequency, if it is allowed to vibrate the diaphragm may break. So to avoid the amplitude, to control the amplitude of vibrations some damping is produced by having damping holes in the fixed plate like this damping holes. What happens when the diaphragm comes down it compresses the air molecule and makes them to flow through this restricted path thereby some damping force is created and the amplitude of vibration is controlled so controlled vibration is there in the diaphragm. That is also achieved by having a capillary leak here atmospheric pressure this is the atmospheric pressure.

The average atmospheric pressures will always find its place below the diaphragm, otherwise the diaphragm may also break and also when we want to have what is the pressure variation due to sound over and above atmospheric conditions, atmospheric pressure we should have the atmospheric pressure here and here. So that is how the atmospheric pressure also is taken here through capillary tubing So now this is capacitor where the distance is varied due to the vibration of the diaphragm and you find with insulator these two are separated, these two plates are separated and the center piece as well as the housing outside where the metallic housing, where the diaphragm is fixed is connected to a battery and resistance R. So it forms a full circuit, with a capacity it forms a full circuit a simple circuit with single capacitor with constant resistance. So whenever the gap changes capacitance changes there is a current flow to and fro and then that current flow through constant resistor gives rise to voltage drop of e_0. Now whatever the pressure variation same variation is around that will take place in e_0 also that means we have converted the pressure variation into voltage variation, this is a capacitor type.

In another one piezoelectric type microphone they are piezoelectric crystal for example quartz is just put below the diaphragm whenever the pressure is varying the quartz crystal is compressed and then you will find a charge is produced that charge is amplified in a charge amplifier then you will have the voltage output that will be varying same way as the pressure variations, that also is available in the market. That is with a diaphragm we convert that pressure variation into force that force acting over the crystal will produce deformation in the crystal and that produces charge, amplified in charge amplifier we get the voltage output. That is these are the two principles for converting the sound pressure variation into voltage variation. Now when we want to measure these noises what are the precautions? The precautions are given by the manufacturer from whom we purchase the sound level meter.

He will say don’t hold the sound level meter like this because for suppose source is there then it measures this directly noise from the source as well as the source sound reflected from the body also may be picked up by the sound level meter. So he will always say hold the sound level meter by extended arm that pointing towards the source. It should be some suppose if mike is here it should point it towards source so we should hold like that only and at a particular distance because distance decides the amount of pressure variations. If we go double the distance the pressure variation is reduced to half the flow. So in all measurements of sound we are supposed to measure the distance at which we are supposed to quote the distance at which sound is measured that is one thing.

Secondly I was telling there should not be any nearby wall and all that will be taken care of if we are using the method of anechoic chamber. Anechoic chamber is one where inside the room or the chamber there is particular construction to avoid any sound reflection, reflection of noise. That is all, suppose there is a chamber it has got 6 walls bottom, top and 4 side walls, all the 6 walls should be filled with the so called wedges made from sound absorbing material. So whenever sound is made by a source, suppose this is a source sound is going and since it's a wedge it gets reflected within the wedge formation once or twice and it gets absorbed within that one or two reflection gets fully absorbed and nothing more can come out to be picked up by the sound level meter.

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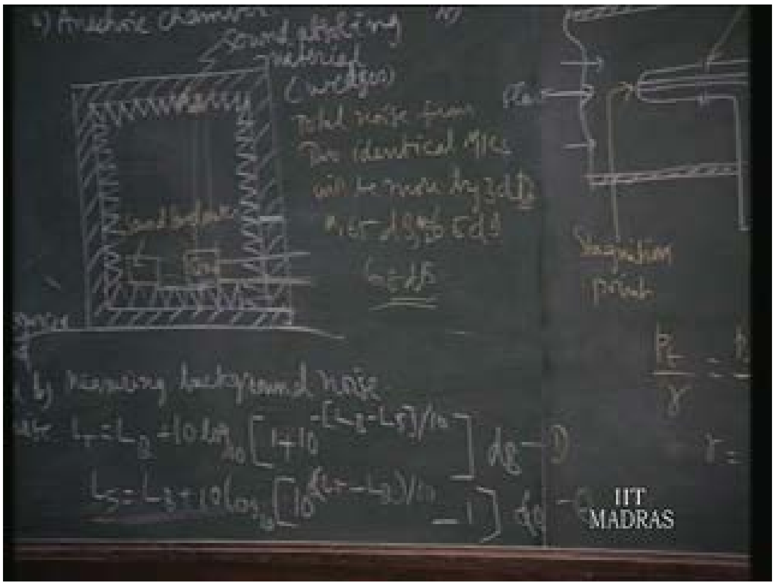

So the sound level meter will measure only the sound produced by the source alone it will measure, no reflected sound will be coming here but normally the size of such anechoic chamber is sufficiently big because we should have a door opening to put our source as well as instrument having electrical connection and all providing all these things it works out to be a big chamber and any laboratory you should have sufficient space otherwise these will occupy a big space and after making one project and until next project after few years you may not be able to keep it there and you may destroy it. So that is second method if you cannot and also if you want to purchase it is costly one, second method is by making background noise also we can measure the noise made by the device that is now you have to make two measurements with the sound level meter.

Suppose source is there making noise and surrounding also will make noise, so we make one measurement called total noise, total noise one measurement where the source is running also atmospheric noise also is there total. Now you switch off the source so it's a running machine so you switch off the power supply so the source will stop, no noise. So you will be measuring the background noise, so you measure the total noise and then after switching off measure the background noise. From these two measurements you can obtain the source measurement by using this equation one, equation two is obtained from one only but it is in terms of our required quantity, we want to measure the source noise so we can use it.

Suppose you have two machines identical machines assuming background noise to be zero if you want to measure the total noise then you can use this one. Equation one total noise equal to L machine one and L_s is a machine two. So L_m 1 and L_m 2 you can put like that and then get the total noise, for that in such instance you can use the first one. Suppose two machines making same noise then you will find the total noise will be increased by two identical machines that is total noise from two identical machines will be more by 3 decibels. Suppose each machine is making say 65 decibel that is machine one and machine two makes that decibel then total noise will be 68 decibel that you can check in this equation also. Two identical machines making same decibel if they are put together total noise will be only 68 decibel it is increased by 3 decibels that you can check in this equation. That is easier way of making measurements of noise instead of the anechoic chamber which is costlier but you should have a control over the background noise that is sometime very tough. That’s why in our laboratory when we want to make such noise measurements we come at midnight so that around there will be less noise, only noise from the birds and the wind may be there but it may be more or less constant and then we make measurements. So you have to select suitable timing to make such measurements. So with this we will complete these sound measurements.

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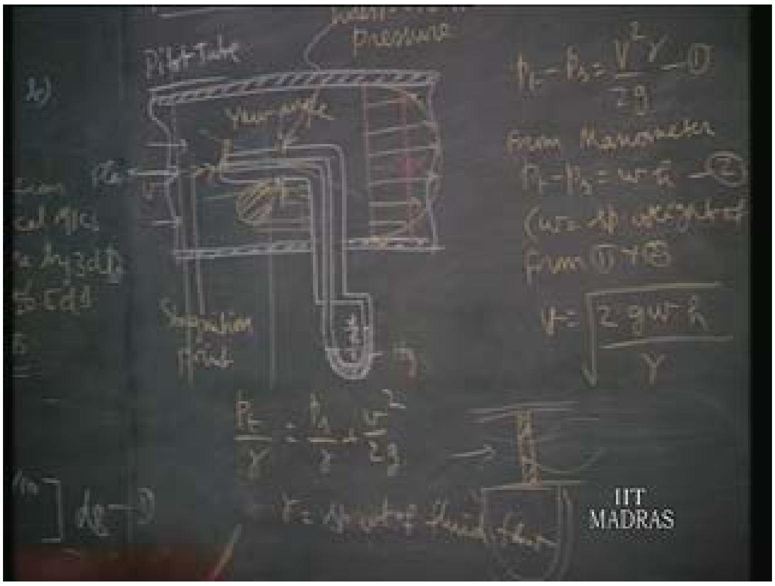

Now we go to the flow measurement, next topic flow measurement. This is also one of the important process parameters. We are seeing now process parameters, first we started temperature, in process and chemical industries temperature, pressure and then flow. These are three important measurements any process or fertilizer industries, chemical industries these are three important measurements because flow is to be controlled precisely to get the required quantities of any product, for that there are many methods and we are not going to see all the methods. For example obstruction type flow meter there is a pipe and you put a obstruction type flow meter so in obstruction this is the obstruction and this is the flow direction, this is here when it flows it will be flowing like this we measure the upstream pressure and the low stream pressure being a contractor and then measure with the help of the monometer and these are what we normally learn under hydraulics and all the positive type flow meters are there to make the measurements.

So all those things I am not going to do it, only few other special methods used for flow measurements alone we are going to see under this topic mechanical measurements. First and foremast we are taking the Pitot tube. Pitot tube is very often used to find out the velocity of the flow at any point. So you can insert it at different heights so that you can get the velocity distribution inside the pipe. Suppose this is the pipe cross section and that pipe velocity may be varying like this; this may be the velocity at boundary layer the velocity will be zero, at the middle it will have maximum this is parabolic distribution of velocity with any cross line cross section of a pipe. So once you get this velocity distribution and you can get later on average velocity, you can find out average velocity for this cross section and this is average V average times the cross section of the piping will give the total flow rate in the pipe. So far you can use the pitot tube also.

What is the principle function of pitot tube? We have got so called stagnation point that is it is a tubing like this, we have got a center point you have one tubing and annular another space is there where the opening is made to the flow say at the 4 times distance from this tip end we have to diameter of this support we have to provide holes, here only static pressure will enter. So here at the stagnation point both velocity head as well as static pressure will be available here because velocity also becomes zero, pressure is static pressure already is there. So total pressure P_t by gamma, gamma is the specific weight of this gas or liquid whatever it flows, P_t gamma that pressure head is equal to P_s static pressure by gamma plus V squared where V is the velocity of the flow, V squared over 2 g. So this is the total heat available at the stagnation point that is taken through a tubing to a manometer where a mercury manometer is available.

The other limp of the manometer is connected to the static pressure this is the static pressure. So we have to ensure it is only static pressure is there for that you should see this axis of this pitot tube and the flow direction coincides. Otherwise suppose it is tilted somewhat like this I have shown exaggerated suppose it is tilted then you will find through this hole some of the velocity head also will enter. So static head shown by this pitot tube will be larger once there is a tilting this angle is called yaw angle, yaw angle should be zero for correct measurement. That is the angle between the pitot tube axis and the flow direction is called yaw angle and that should be zero. So when zero means only static pressure alone will come here that is shown here.

The difference between these two things static pressure and this you will get the P square over 2 g that is P_t minus P_s by gamma, gamma gone this side we get this V square over 2 g into gamma and now the pressure difference in this two limps is also given by P_t minus P_s equal to w into h, w is the specific heat of the mercury. So comparing these two equation you can find V is equal to that is velocity is equal to 2 gwh by gamma, gamma is mercury specific heat, gamma is the specific weight of the flow, gamma by g also we can say row, density of the flow medium both are same. So by this we can get the velocity at any given point and later on we can find out the total flow rate in this medium. The one problem here is the error source is at this cross section if you compare these two cross sections, you find in this cross section this much area is occupied by this pitot tube.

Naturally the flow in this section, flow of velocity will be more; flow velocity will be more than this cross section that means when total heat rate same, flow velocity increases the P_s or this static pressure here will be smaller than the static pressure undisturbed static pressure that is called something like loading effect, process of measurements disturb the parameters of measurement.

So to avoid it what is done is there is another thing this is a support side of the pitot tube, it also obstructs the flow, obstructs the flow means the static pressure increase. By suitable distance of this limb to the hole you will find the static pressure drop and the pressure rise both can match equally and then you can nullify that effect but proper dimensioning is important. That is this error source which can be properly thought and then it can be nullified but these are the some of the error sources.

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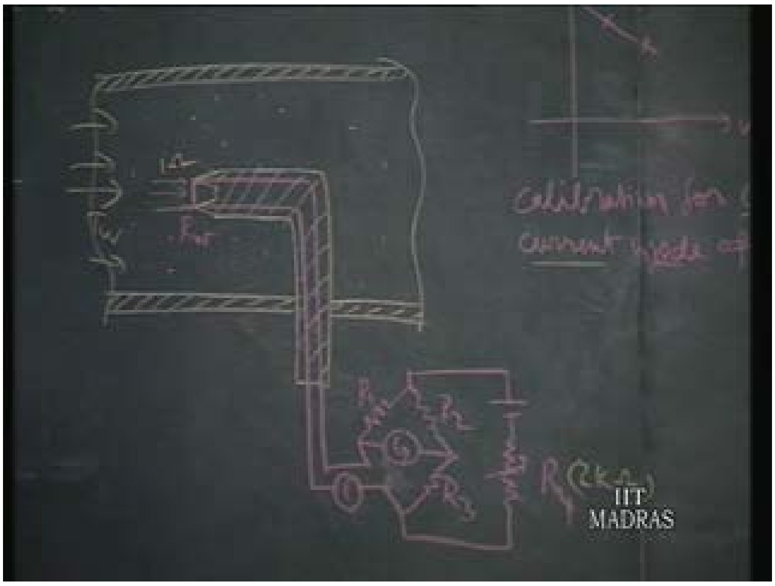

Next method we are seeing is hot wire anemometer. The construction of hot wire anemometer is somewhat like this. So this is the support, so there is a wire very thin wire of few microns diameter of about a few mm, 1 or 2 mm length fixed there in the support. So whenever the flow is there the heat is dissipated from the wire to the flowing medium so this is the wire its resistance is changing depending upon the flow velocity. So that resistance forms part of a 4 arm bridge, Wheatstone bridge and where each other arm will be of the same order of the 1 ohm. So then output impedance we know we have learnt already will be order of 1 ohm and this is excitation voltage for the bridge and the resistance series will be of the order of 2 kilo ohm.

So naturally you will find the current flow through the whole circuit is controlled by the adjustment of the series resistance R_4 because it is order of 2 kilo ohm the whole resistance gives an equivalent resistance only 1 ohm so the current can be controlled by this. This is the construction of a hot wire anemometer. What is the governing equation for this heat dissipation? The i squared R_w, i is the current flow through this wire, exposed wire that this wire R_w equal to h into A into T_w minus T_f where h is the heat transfer coefficient, film coefficient of heat transfer in watt per or joule per second per degree centigrade per meter square. So into area, surface area of this wire into difference between the, this is flow temperature, gas flow temperature and minus T_f, wire temperature is the T_w, flow temperature is T_f because from higher temperature to a lower temperature the heat flows so the wire will be at higher temperature. When we switch on the power supply to the bridge network again due to current flow the temperature is raised to a high level and from there the heat is dissipated to the flowing fluid this is the governing equation for this.

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Now h is a function of velocity I have told, when higher flow means higher heat will be transferred so that is governed by this h is equal to c_1 plus c_2 where c_1 and c_2 are constants into root v. So its incorporating this equation here and obtaining this equation i squared R_w is equal to now this is in terms of h. Now this equations indicates two mode of mode of operation, one mode is called current constant current mode of operation under that i squared is constant. So when Vg is changed T_w wire is changed when i is kept constant for a increased velocity T_w has to come down that is the constant current mode of operation in that and another one is, constant temperature mode of operation that is wire temperature is always kept constant. Whenever the flow increases to maintain the wire temperature i is increased because when the flow is increased naturally the wire temperature will come down because larger heat is taken, to bring it back you have to send more current.

That is the second mode of operation that is called the constant current constant temperature mode of operation that is constant temperature mode of operation. These are the two mode of operation in which hot wire anemometer is made use of. Now the calibration procedure is as follows. First keep the keep the hot wire anemometer in still gas that is zero velocity and adjust the value of R_4 so that maximum current can flow through the wire so it doesn’t burn out. So under that condition whatever the current flow through the galvanometer that’s imbalance current, so when there is zero velocity means no heat is taken out practically that means it will achieve maximum temperature and hence maximum resistance also. So maximum imbalance and then you will have the higher current this is the, for zero velocity what is the current flow through the galvanometer. Then send gas at known velocities so that is where V_1 and this is where V_2, for known velocity find out the imbalance current flow through the galvanometer.

So it is we call it constant current mode because once we adjusted this later on current through this cannot be changed that the current flow through the circuit is controlled only by adjustment of R_4. Once that is adjusted for the maximum current flow later on we are not touching current flow flow more or less remains same.

So due to R_w changes, imbalance current is changing that is what you are making use of here to plot it for known velocities and for any unknown velocity from the current we can get it, we can get the velocity that is the constant current mode of operation. In constant temperature mode of operation the equation, same equation one can be written like this and you will find i squared is equal to c_3 plus c_4 where all these things because T_w is going to remain constant that is a constant temperature.

so you will find c_3 plus c_4 in to root v. So if y is equal to mx plus c format that is root v, so having root v as x axis, i squared as y axis then you will find it is a linear relation. again here also the calibration is similar that is we still have the still gas, adjust the current flow to have the maximum and find out the current flow through the R_w that is this meter of current you have take, you have to note down that is the current flow for zero velocity.

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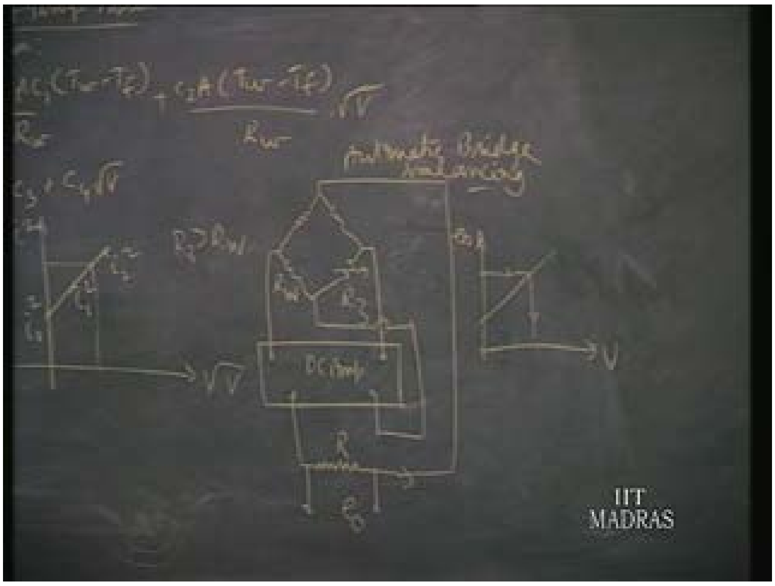

Then at different velocities gas will be flowing and adjust the R_4, for another velocity adjust R_4 so that g will be brought back to zero but what is the current flow through this you can find out when necessary current flow through this. To bring the balance back what is the current flow that you can find out that is i_1 for velocity one similarly i_2. So you plot this curve for the current through the R_w and for any unknown velocities from i squared from i measurement you can get the i squared then to get the root v from that v we can find out. So you find the constant temperature mode of operation you have to make adjustments for because current we have to change that is manual.

So a constant temperature mode of operation can be used for only static measurements whereas constant current mode of operation can be used for static and dynamic but switching over to automatic bridge balancing we can use this constant temperature mode of operation even for dynamic measurement also that is done like this. That is R_w wire temperature so to start with R_3 is made larger than R_4 and again same procedure at zero velocity of the gas, you fill it up and then you switch on immediately we know R_3 is larger than R_4. So immediately imbalance will be there that imbalance voltage will be amplified and current will be sent back so that R_w is brought near about R_3. Whatever the current flow required to bring R_w to R_3 and that flow through capital R, a constant resistance gives rise to a voltage output e.

So for zero velocity what is the current required? Similarly for any other velocities what is the current required to bring the R_w to near about R_3 that will be the current flow through this and by plotting similar curves we can find out say for e_o versus velocities we can have somewhat like this and then for any unknown velocity from the measured voltage we can get back the velocity of the flow A.