Mechanical Measurement Systems
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Lecture - 39
Air Pollution Sampling and Measurement

Hello I welcome you all in this course on mechanical measurement systems, today we will discuss air pollution sampling and measurement.

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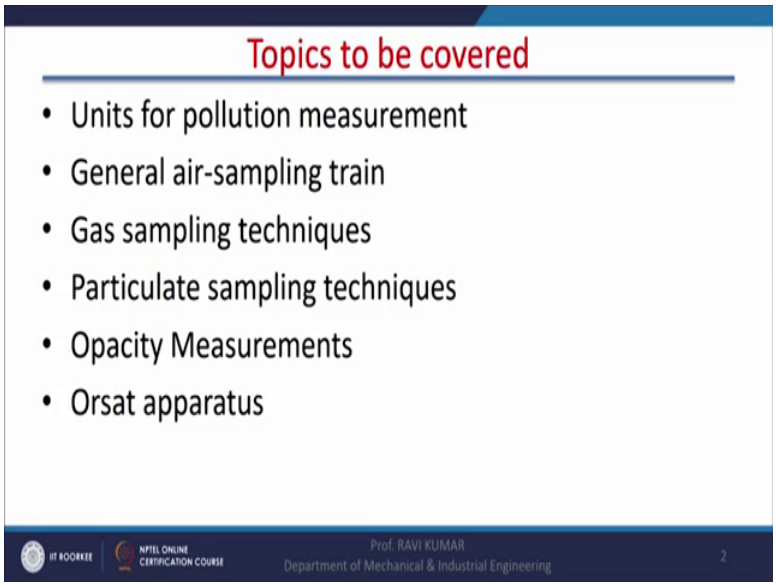

Topics to be covered today are units for pollution measurement first of all followed by general air sampling train, gas sampling techniques, particulate sampling techniques, opacity measurements and offset apparatus. The pollution is everybody's concern nowadays and for the purpose of pollution abatement pollution metering is important. Until unless we measure the pollution, we cannot quantify the pollution, if we are not able to quantify the pollution we cannot reduce the pollution.

So, pollution is expressed in terms of volumetric units, that is parts per million right and parts per million can be defined as, volume of the gaseous pollutant whatever the volume is there right divided by 10 to power 6 volume of the gas plus volume of the air.

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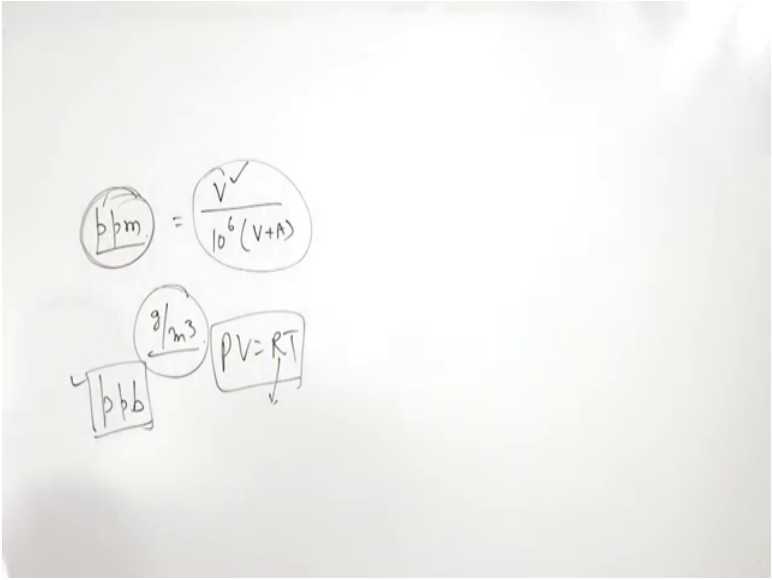

So, it is volume to volume ratio parts per million is volume to volume ratio. Another way of expressing the pollutants is, grams per meter cube that is expression in the basis of unit, which is based on the mass grams per meter cube or it can be expressed in terms of ppm.

Ppb is also there in some of the pollutants like ozone is expressed in terms of ppb parts per billion. But these type of expressions are quite rare normally they are expressed in terms of parts per million and parts per million this volume can always be converted into the mass base type of system using the ideal gas equation P V is equal to RT. Provided we know the value of R for the pollutant right pollute polluting gas.

So, this equation can convert the volume base to the mass base and vice versa mass base also can be converted into the volume base expression. Now local state and nation agencies they set pollution standards certain standards for the pollution, and they have to be adhered and for enforcement of the standards of the pollution, there are 2 ways of doing it I mean first is monitoring the pollution in the air or monitoring the pollution at the source.

So, mon monitoring the pollution in ambient air gives us the gross effect of all the sources, that is also important I mean gross effect of all the sources.

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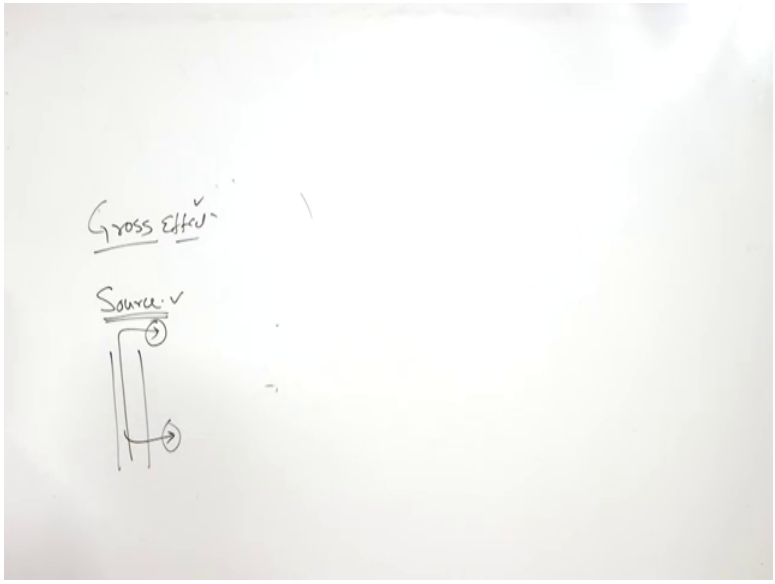

So, ambient air pollution gives the gross effect, this has to be monitored first of all and second thing is pollution at source. For control purpose we have to monitor or we have to meter the pollution at the source because we cannot control the gross effect I mean if ambient air is polluted it cannot be controlled. For controlling the pollution in the ambient air, the pollution has to be controlled at the source for example, chimney in a factory. So, umm. So, so it has to be ensured it has to be ensured by the agencies, that whatever emission is coming out of the chimneys is sticking to the pollution norms or whatever water is being drained off of the industry, it is entering to the pollution norms right.

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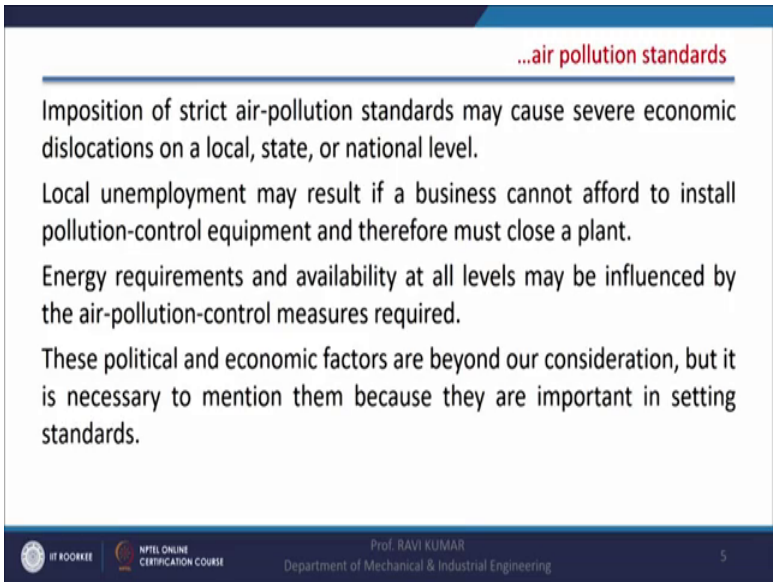

So, the measurement of pollution or pollutants is nowadays a very important activity because it directly affects the human health pollution in the air directly affects the human health, but imposition of strict pollution standards may cause severe economic dislocations on local state and nation level. I mean Taj Mahal is a very good example for that, when the concern was raised for the for the damage of Taj due to the pollutants in the air, many of the industries in Agra were closed especially industries which were coal base industries. And it specifically the casting in the coal based casting either they had to shift to the new technology or they have to closed down they had no other options.

So, it is a I mean severe economic dislocation on local state and nation level, this may result an employment also if you are restrict adhering to the strict pollution norms, it may lead to the unemployment also. Because many of the industries may not be able to install the latest technology in I mean financially it may not be viable for them.

So, they will close down this may cause employment unemployment and, but these are political economic factors, but the fact is at any case we have to control the pollution. If we do not control the pollution it is big it is because nowadays it is becoming a threat for the human race. So, at any cost at any cost the county has to control the pollution and for controlling the pollution it has to be measured first right.

So, there are certain techniques for pollution measurement. So, first of all air sampling has to be done air sampling. Now for the purpose of air sampling we need sample collection equipment.

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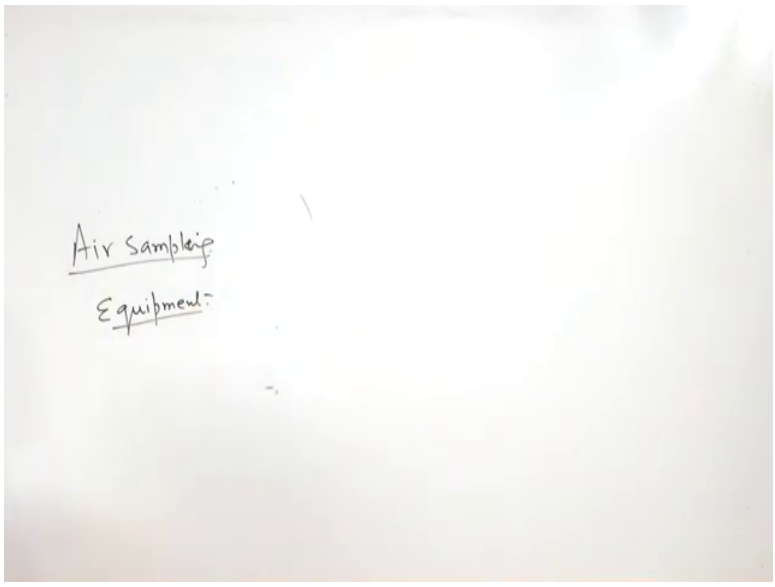

First of all equipment right because we cannot simply pick the air from the atmosphere and or from effluent and I am just measure it. So, there has to be some sampling collection devices, which can collect the air sample. Then some conditioning devices are used which can condition the sample, because there may be some undesired particles or the gases in the sample, which are not required right. So, they have to be filtered out. So, sample conditioning devices, sample collection equipment, metering devices, metering devices are important and then there is a vacuum source. So, vacuum source is required to pull the air. So, it is called a air pollution air sampling train right.

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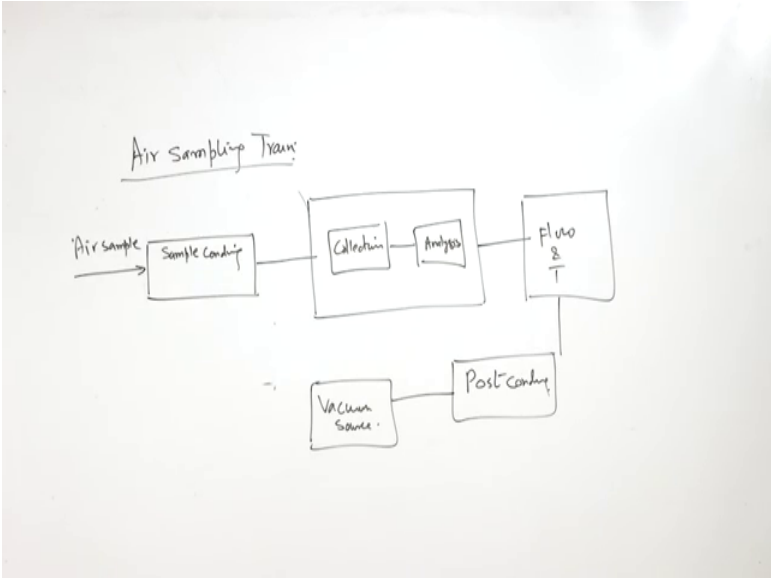

So, in air sampling train the there is one inlet for air sample. Now this air sample will go to the sample conditioning unit sample conditioning right. Now after sampling conditioning it will go to the sample collection unit, and sample connection unit is normally having 2 parts first of all collection and second is analysis; analysis also done here and this is this is a part of sample collection right.

And after sample collection, it goes to the another unit where flow and temperature measurement is done right. Now after metering the flow in temperature post sample conditioning is done, post sample post sample conditioning right and lastly there is a vacuum source. So, this is air sampling train. So, the air sample is entering from this side and leaving from this side and this is how the analysis can be arranged, analysis for the air sampling can be arranged and the first activity here is the filtration. Because whenever we take air into this from the sampling purpose, first it has to be filtered foreign particles have to be removed. So, filtration is the first activity.

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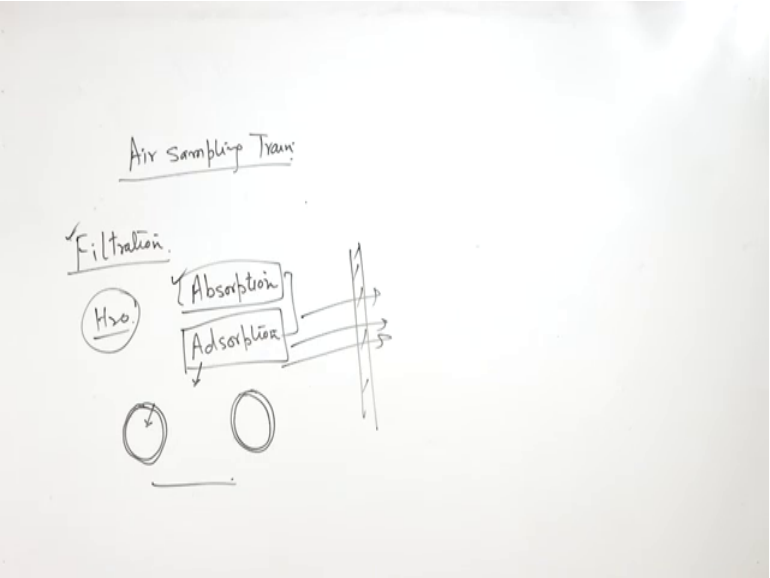

So, air sampling which is coming in it has to be filtered. So, in the filtration, it is also the sample is also dry to remove the vapors of water right. So, the water vapors are removed or we can saturate it entirely with the water vapour for the later reference, that the same air was completely saturated for the later reference in the case of analysis unwanted pollutants are also removed in filtration may be through some reaction. So, unwanted pollutants are also. So, there is a clearing of the sample in the filtration is a sort of cleaning of the sample of air.

Now, for gas collection, now the gas which has entered it has to be collected. Now collection it they can be 2 ways of gas collection 1 is absorption and another is adsorption. Now in process of absorption the gas is absorbed by the liquid or it is simply dissolved in the liquid it is absorption of the gas takes place in the liquid, in adsorption there is the gas remains on the surface it is adsorptions are solids and the gas remains at the surface, it remains on the sir it forms a layer on the surface it does not penetrate the adsorption, but this adsorption process is very effective. Something like if you put a chalk in ink, when you break the chalk you will find that ink is the color of the ink is remaining and the periphery of the chalk only it does not penetrate into the chalk.

So, adsorption activity something like this; however, in the case of absorption the absorption may be through chemical reaction also right. Now the third one is the condensation of the of the vapor. Suppose the gas is coming some of the pollutants can

be removed or so, pollutants have already been removed. So, gas can be absorbed by condensation and freezing out; it is it is put to the low and there can be number of chambers at different temperatures. So, the gases in the mixture are condensed at different pressures sorry different temperatures and they are collected at one place right.

So, this is about the gas collection, after the gas collection we have to remove the particulates from the gas. So, filtration is done in singles filtration is also done in signal stage in a multistages this is also done in single stage or it can take place in number of stages. For example, there is a wet cloth right and if you pass air through the wet clothes the number of the particle will be sticking to the wet look that is how the clearing can take place. Wet or die dry impinges can be used for removing the particulates right, sediments will settle and they will also be removed. So, ultimately when the sample is ready after filtration and preparation of the sample or absorption of the gas then analysis of the gas analysis can be done.

In absorption techniques impedance atomizing scrubbers, fretted glasses covers or some type of packed column can be used for absorption type of system and adsorption system it is activated carbon is nowadays is very much used for the absorption process, activated alumina, silica gel and molecular sieves can be used for the adsorption technique of gaps gas sampling.

So, when sample is there, I mean either through absorption through adsorption or by condensation and freeze out techniques, now sample is ready right. Now this sample has to be analyzed and and the level of pollution in the air has to be determined. Now there is a particulate sampling technique, now the range of particulate matter encountered in air is ranges between 0.001 to 500 micrometer the range is quite large.

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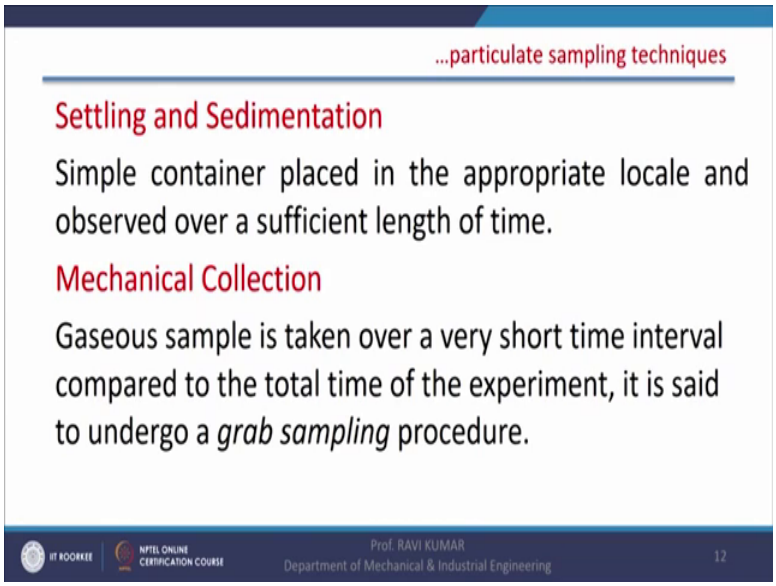

Now settling and sedimentation and there is the 2 techniques, settling and sedimentation and mechanical collection. Separation of the particles first is settling; settling in sedimentation if I said earlier if the particle size is large it will settle and it will and it can be collected at one type if the sufficient length of time is given for the settlement. So, the sample is taken and it is left for a long time left for a long time, let us say 24 hours or 48 hours.

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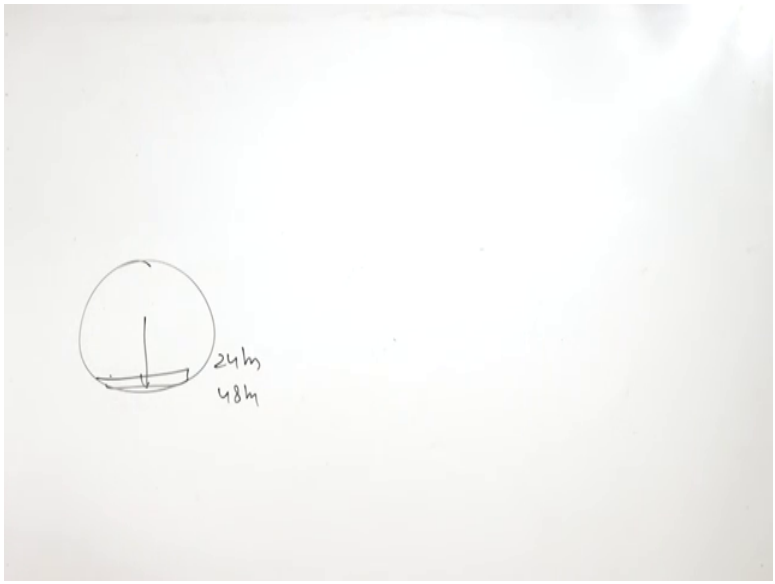

So, particles they will slightly whatever the size is, if the size is 0.1 micron it may not come down the less than 0.1 it may not come down, but particles are those particles will slowly settle at the bottom of the vessel. But we have to give a time period of maybe 24 hour, 28 hours, 48 hours or 72 hours depending it depends upon the size of the particles also. If the size is large settlement will be faster right, but it is difficult to I mean once you take the sample and they leave the pod for 1 or 2 or 3 days and then see how the sedimentation has been done, and still all the particles will not settle down during that duration that is also possible. So, it is a very time consuming into tedious process.

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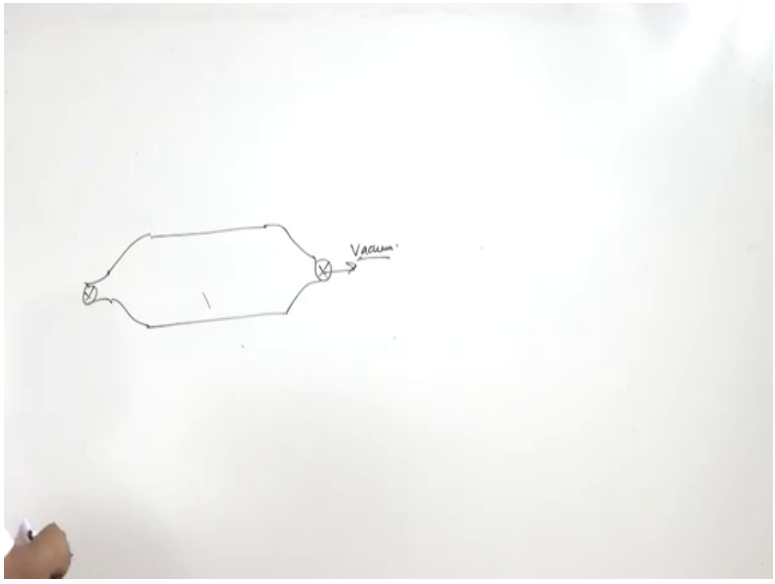

Another is mechanical collection. In mechanical collection there is a there is a grab volume and is a simply tube and having walls on both the sides right and this grab to you this side is connected to the vacuum some vacuum pump right and this the whatever the air is coming from this side it is connected in the tube. But the issue remains that consultation is disturb or it is not disturbed when we are taking sample because already air is there inside this tube right. So, consultation has disturbed or it has not disturbed if it is disturbed. So, what we can do? We can flush the sample filtration techniques now in some other filtration techniques.

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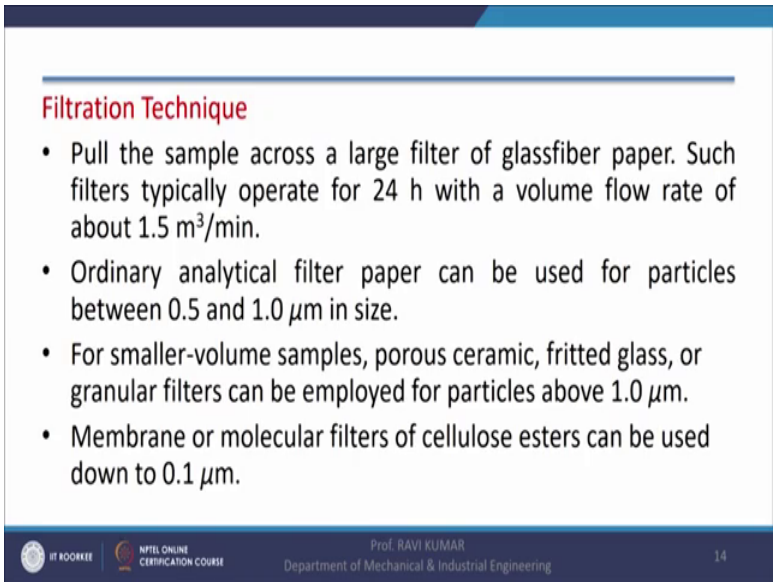

A glass fiber paper can be taken a glass fiber taker paper can be taken and this glass fiber type of paper the sample is pass through this paper for 24 hours right.

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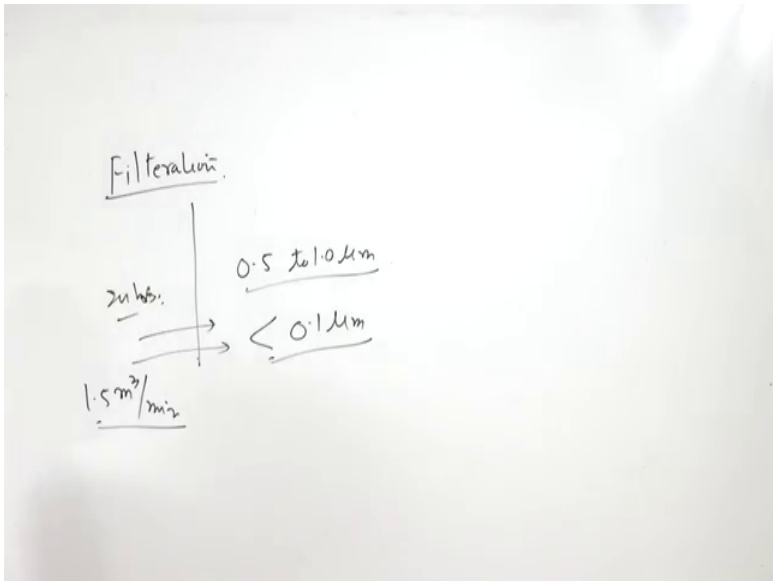

And the flow rate is about 1.5 meter cube per minute right and for ordinary filter paper can also be taken for the particle size at the range of 0.5 to 1.0 micrometers. Now if we want to have I mean the particles are of the size of the 0.5 to 1 micrometer ordinary filter paper can also work, and for a small volume samples porous ceramic fretted glass they can even we can use different type of filters for the purpose of filtration, suppose

filtration is less than suppose the particle size is less than 0.1 micrometer right. So, in that case membranes or molecular filters can also be used, but normally we do not require measurement of the particles less than 0.5 0.1 micrometers right.

Now, result of such measurement is expressed now that this filtration result is expressed in terms of coefficient of his COH.

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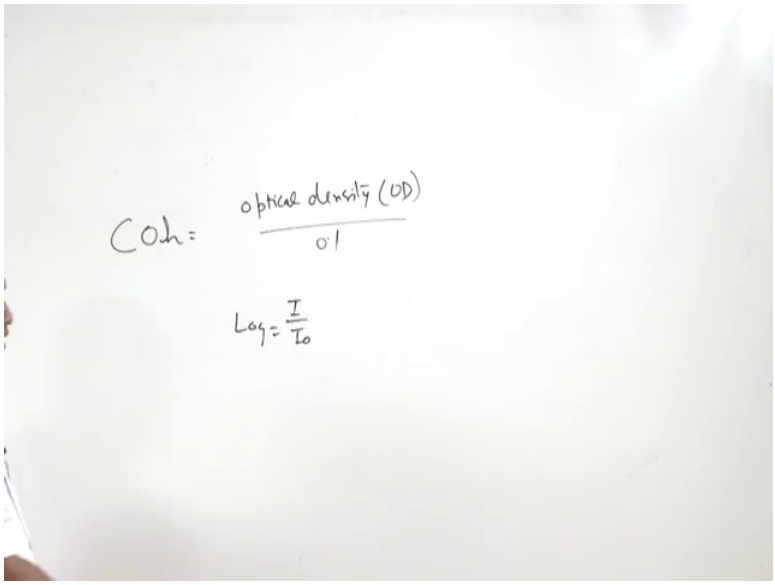

COH coefficient of his. Now coefficient of is his is expressed in terms of optical density oOD divided by 0.1 now what is optical density? Optical densities log I over IO intensity, when before the use and intensity after the use I over I O that is intensity of the light before use and this is after the use right.

And opacity this is known as I by IO is also known as opacity of the paper. So, it is simply just passing the sample over the paper the transparency of the paper will reduce or right and paper will tend to become more and more opaque if the pollution level is high and this is quantified by coefficient of his. Now after the coefficient of his we can we can discuss when very important device which is used for especially flue gas analysis and for the purpose of flue gas analysis offset type of apparatus is used offset apparatus is used.

So, for the purpose of analysis of flue gases, orsat apparatus is used right. So, orsat apparatus. In orsat apparatus in those in the flue gases the mean pollutant at the flue

gases are this carbon dioxide, carbon monoxide and we have to find the level of oxygen also in order to find the axis air right. So, in orsat apparatus there are 3 tubes filled with the different regents.

So, they have the flask actually they are not tubes they are flasks, they are filled with different regents and in fact, they are bent backward. If you look at the side view the side view is going to be like this and they are filled with the glass tubes also glass rods also just to increase, they are filled with the I mean number of glass tubes just to increase the surface area of the contact right.

So, it is filled up to here and this is the front which we are seeing, on the back side there is an oil so, that the reagent does not evaporate from the back side.

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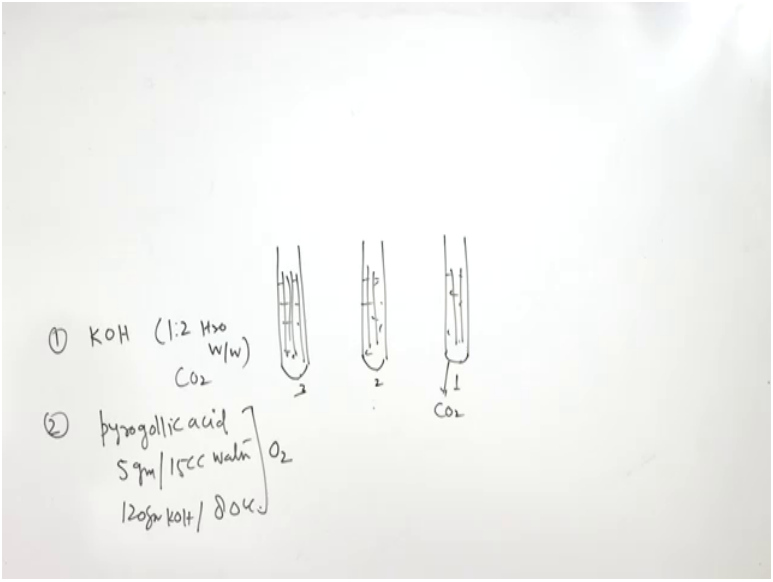

So, it is a from elevation it appears to be a single flask, but it is a combination of 2 flasks right and on the backward in the backside flask there is it is filled with the oil. So, that there is no evaporation of these regents and let us label them flask 1, flax 2 and flask 3. Now flask 1 consists of KOH potassium hydroxide and it is in 1 2 ratio of water mass to mass or weight to weight ratio with water. I mean 1 let us it is a 10 grams of KOH it is mixed with the twenty grams of water. So, this mixture is present in flask 1 and this is used for absorption of CO 2. So, this is for absorption of CO 2.

Now, another one is parabolic acid this is flask 2 parabolic acid and parabolic acid is 5 grams in 15 cc of water 5 grams of parabolic acid in 15 cc of water with 120 grams of KOH in 80 cc of water. So, they say it is a mixture. So, it is present here for the absorption of oxygen right and in the third one is q plus chloride right q plus chloride is dissolved in 1 is to 20 weight to weigh ratio of sel till it becomes colorless. So, these are 3 the chemicals filled in this flask and they are connected by a common header, a common header is here and all are connected to common header.

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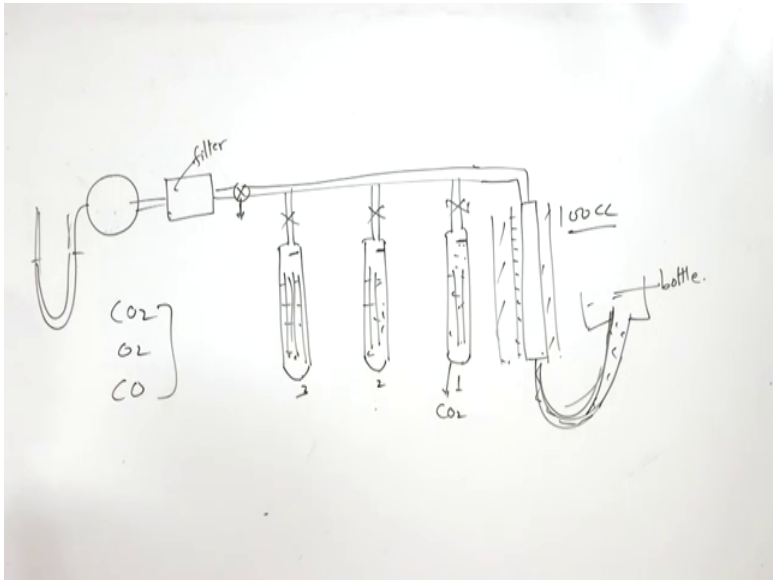

After connection to the common header and there is a wall here. So, anytime it can be opened and it can be closed this is a common header.

Now, sample has to come from this side right and for before sample, there is a cotton wound filter to remove the foreign particles filter right. Now before filter there is a aspirator bulb here which sucks the sample and it comes from a U tube which is filled with the calcium chloride in order to remove any moisture in the. So, it is a dry sample dry sampling entering the header and from header it can be sent to different jars ok.

Now, on the side on this side, there is a eudiometer and which has mormon it or the scale is fixed next to eudiometer and then there is aspirator bottle filled with water there is a aspirator bottle there is a 3 way valve is also somewhere here 3 way valve 3 way valve is also there right.

Now, there is a flexible hose flexible hose is here this is water and these have all jars have a mark at the top. So, initially what we are going to do we are just going to lift this jar. So, all the air will be replaced first of all setup is clean all the walls are checked and then this bottle is lifted, and this is also put under a cooling water jacket because flue gases will be hot. So, this is put under cooling water in jacket. So, temperature remains constant here. So, for initially the glass is lifted this bottle is lifted and all the air inside the system is removed these walls are closed right and then flue gases are sucked in right and this process is carried out by just opening wall base 2 3 times so, that all the air inside the system is removed then finally, a sample is taken in.

First this wall is opened right and this jar is opened 2-3 times is moved to 3 times so, that there is a proper movement of or proper absorption of carbon dioxide here right and then jar is lowered or up or moved up when this is this liquid touches this mark the valve is closed. So, initially so, first of all initial volume is noted here, initial volume normally it is idolizes 100 cc, but it can be 95 90 cc also or hundred and 5 cc also.

But ideally it should be 100 cc. So, constant valve is sucked in after absorption here again the volume is noted naturally the volume is reduced it may reduce. So, let us 100 cc to 90 cc then again this valve is opened this (Refer Time: 28:11) jar bottle is lifted the entire volume from here enters here, the oxygen gets absorbed here then again the bottle is lowered and when this fluid touches this mark this valve is closed. Sieve is the process repeated here and every time you will find that there is reduction in volume.

And this reduction in volume is noted and this reduction in volume ultimately leads to the finding out the concentration of CO 2 O 2 and CO in the flue gases and this is a volumetric analysis, we get the volumes and through this we can also find the access air in the flue gases because when the fuel is burnt it is rare that the fuel entire fuel is burned with a stoichiometric ratio the stoichiometric air what happens? Even if we supply excess of air 10 percent or 20 percent some of the fuel remains unburned and that is why the CO is formed right.

And we can take one example for better understanding of the working of orsat apparatus in a in orsat apparatus the readings I will write on the blackboard on with readings I will write on the board, now suppose initial volume is 95 cc.

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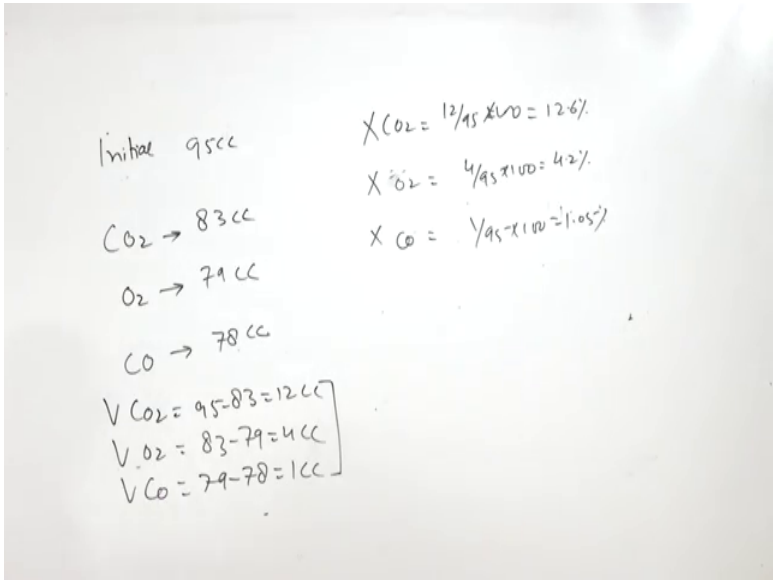

after CO 2 absorption the volume is reduced to 83 cc, after oxygen absorption the volume is reduced to 79 cc and after CO absorption the volume is reduced to 78 cc. So, in an orsat apparatus initial sample volume is 95 cc and these are the volumes after absorption. So, the volume of CO 2 is 95 minus 83 is equal to 12 cc, volume of oxygen is equal to 83 minus 79 is equal to 4 cc and volume of CO is equal to 79 minus 78 is equal to 1 cc right.

And after this after doing this, we will try to find the volume friction of this. So, volume friction is will lead to the mole fiction also. So, mole of CO 2 is equal to 12 by 95 into 100 is equal to 12.6 percent for oxygen it is going to be 4 by 95 into 100 it is going to be 4.2 percent and for sorry CO it is going to be 1 by 95 into 100 is equal to 1.05 percent.

Now, I want to find the excess air which is supplied. So, for excess air we will have to write the equation the combustion equation right and it is the fuel, which is burnt is methane.

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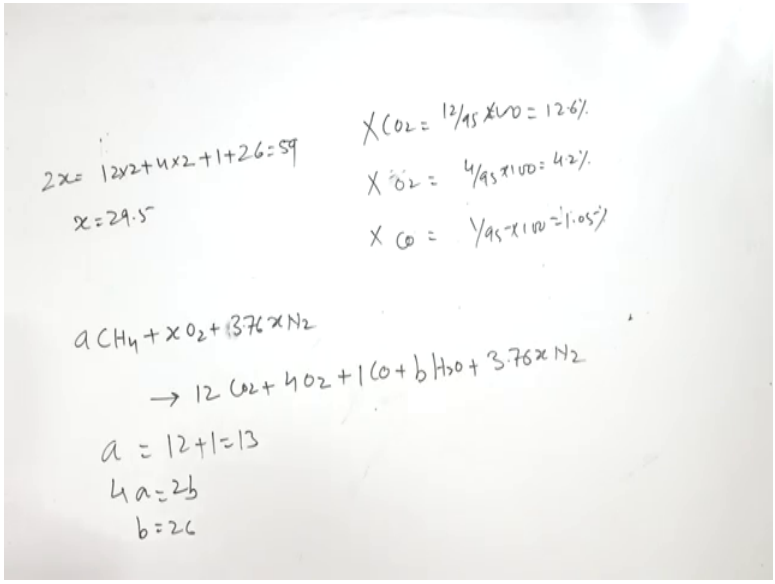

So, fuel which is burnt is methane means suppose a moles of methane are reacting with x of oxygen and plus 3.76 of x of nitrogen when x is oxygen than 3.76 is nitrogen and it is making now let us say 12 of CO 2, 4 of O 2 plus 1 of CO plus some water and water is also let us some constant for water also.

So, water is b H 2 O plus 3 3.76 x nitrogen. Nitrogen will not participate in the reaction. Now if we make the balance then a carbon a is equal to 12 plus 1 is equal to 13 right. And for hydrogen balance 4 a is equal to 2 b. So,. So, b is equal to 26 this is from hydrogen balance and then oxygen. So, 2 x is equal to 12 into 2 plus 4 into 2 plus 1 plus oxygen 12 into 2, 4 into 2 plus 1 plus b, b is equal to 26 right and this is going to be equal to 59.

So, x is equal to 29.5 ok. Now we can put the value of a b and x and we can balance this equation. Now this equation the air fuel ratio.

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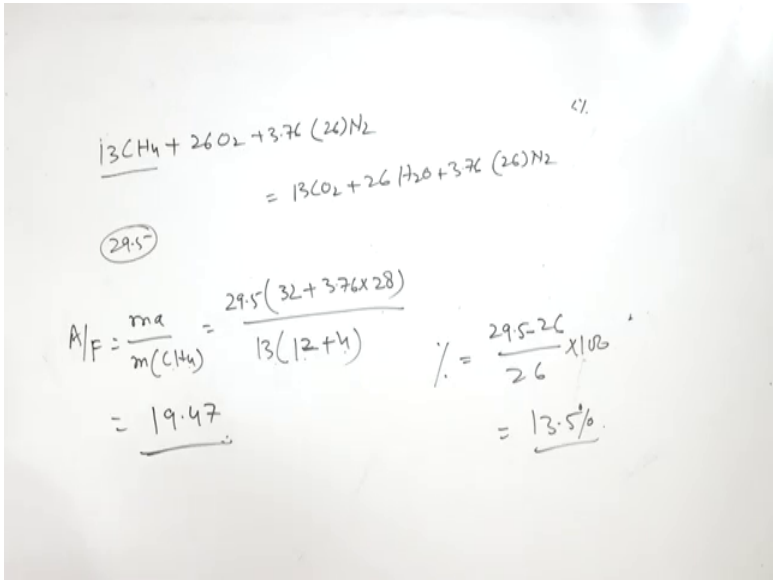

Air fuel ratio air fuel ratio is going to be mass of the air divided by mass of ammonia sorry this methane. Mass of air is 29.5 oxygen plus 3.76 nitrogen. We are considering air is a mixture of oxygen and nitrogen and mass of ammonia the value of a was 30. So, 30 12 plus 4 mass of this methane. So, mass of the methane CH 4 CH 4 the c 4 12 for c and for h 4 right and this will give the air fuel ratio as 19.47.

It means 19.47 kg of air is supplied to burn 1 kg of methane, but actually how much air is required. So, actually (Refer Time: 34:59) required. So, we will have to write the combustion equation again for the burning of methane that is 13 CH 4 plus 26 O 2 plus 3.76 into 26 and 2 is equal to13 CO 2 plus twenty 6 H 2 O plus 3.76 26 into this is the minimum re oxygen requirement this is a minimum oxygen requirement for burning of the methane.

And for this an actual oxygen supplied was 29.5 if you remember. So, if you want to have excess of air and that is going to be percentage excess of air is going to be 29.5 minus 26 divided by 26 into100 and that is 13.5 percent. So, with the help of this orsat apparatus analysis for the flue gases, we can find we can also find how much excess air is supplied for the burning of the fuel that is all for today.

Thank you very much.