Natural Gas Engineering
Dr.B. Pankaj Tiwari
Department of Chemical Engineering
Indian Institute of Technology – Guwahati

Module No # 04
Lecture No # 16
Measurement of Natural gas

Hello and welcome again today's lecture on measurement of natural so whenever we are dealing with natural gas either we are producing we are processing it or we are transporting it is very much required to know the amount of the natural gas that is being pass through a particular point. It is very much required when a buyer is purchasing natural gas and a seller is selling to understand the buyer and seller relationship constant device or a major technique should be established that is accepted by both the parties not only buyer and seller but that measurement technique should be accepted widely.

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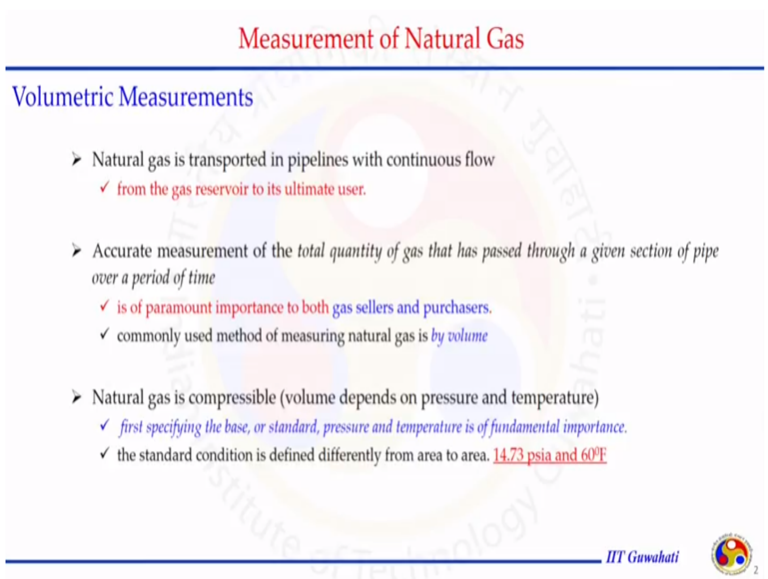

So if we talk about measurement of natural gas we understand the transportation happen in pipeline during the production also even in the processing when we are doing the dehydration sweetening process sending it through the main pipeline, sending it to distributor and from the distributor it travels through the pipeline. Most of the measurement techniques are based on the pipeline concept where we are measuring property like a pressure and converting it into flow rate.

The volumetric measurements of the natural gas is required from it gas reservoir to it ultimate user the accuracy to measure the natural gas is required to understand the quantity of gas pass through a given section of pipe over a period of time. So if we understand how much quantities are passing through a particular cross section of a pipe we can over the time period we can understand the flow rate. It is of para-mounting importance of gas seller and purchaser.

Commonly use method measuring of natural gas is by volume we understand the value of the natural gas is also depend on energy content how much energy it is containing but to quantify the energy content also we need to understand the volume of the natural gas that is purchased or that is sold. Natural gas is compressible by the nature we understand it the volume depends on temperature and pressure.

So when we talk about measuring the natural gas in terms of the volume it becomes (()) (03:18) to understand at what temperature and pressure the volume is measured and if it is different from one location to other location certain corrections should be done in the measurement. So first specifying the base temperature or standard pressure and temperature is a fundamental importance.

Most of the time the standard temperature and pressure conditions are specified but those are depending on the location. So area to area the base temperature pressure they vary accordingly the correction in the volumetric measurement should be implemented.

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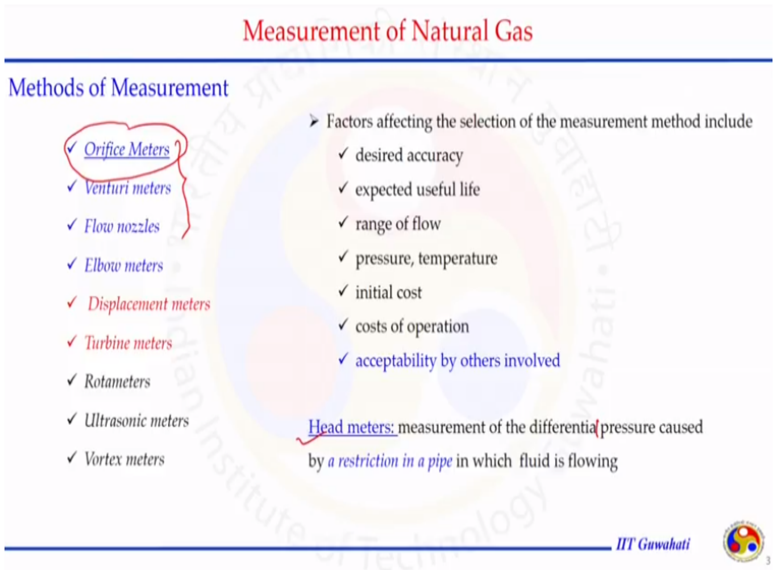

So if we go to understand how to measure the volume there are several methods those allow the measurement to the natural gas directly or indirectly most of the time the direct measurement are not done it is indirect measurement technique where a parameter is measured and converted into volume. So for example the list shown is having several base of measuring it.

So Orifice meter, Venturi meter, flow Nozzles and Elbow meter there could be putative is also there they are based on the head meter concept. So head meter means the measurement of the differential caused by a restriction in a pipe in which fluid id flowing. So if natural gas is flowing through a pipe line we can put certain restriction and changes happening in the pressure can be recorded and the pressure required can be converted into velocity and knowing the cross sectional area we can convert into flow rate it is indirect way of measurement of volume of gas that is passing through that pipeline.

Other method may be displacement meter, turbine meter where the way of measurement natural gas depends on specific device like in displacement meter it is number of stock the piston is making in each stock the slender is the piston is discharging non amount of the gas at the other end. So the number of stocks slender is making over a period of time plus the slender volume that is used to discharge the natural gas can give us the volume that is getting transported from this particular section.

Similar in the turbine meter number of rotations made by the turbine because the natural gas is passing through their we can convert that number of rotation to volume. All these device needs certain calibration because they are designed for considering XYZ type of material or the fluid. But when they are used for the natural gas certain calibration comes should be included into account the changes happening because of the fluid or other conditions.

The rota meter is another device where the cross sectional through which the fluid is passing is getting increase and a float a device in it is just floating depend on the pressure it is facing from top side and bottom side location of the float on a graduated scale can tell us about the volume that is passing through the gas. We will discuss this little later and other several techniques could be there like the ultra-sonic meter Votex meter and now with the advancement of the technique several other techniques are also being used to measure the flow rate or the volume of natural gas.

But the factor those affect this selection of measurement method include the desired accuracy required in the measurement range of low like how much quantity of the natural gas is flowing through the pipe or at what range the measuring device should be able to measure the flow rate is expected useful life of the device that is used to measure the flow rate. initial cost pressure and temperature cost of operation acceptability by others involved so I have chosen a device I understand and I accept it is going to measure very accurate the volumetric flow of natural gas.

But it should also be accepted by the others so instead of going each device we can just go through the most acceptable device that is used to measure the volumetric flow rate of natural gas and definitely it is Orifice meter. And Orifice meter works on the principle of head meter means a restriction in the pipeline create the pressure difference and that is allow us to measure the flow rate.

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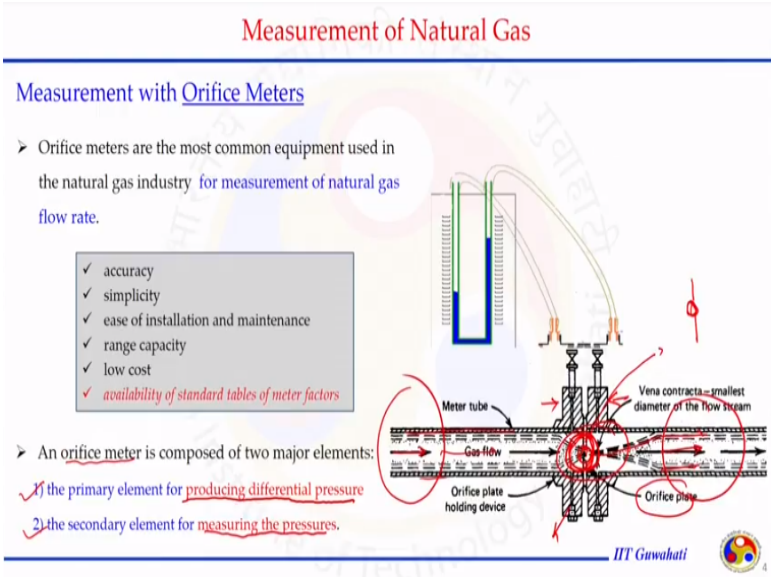

So why using the Orifice meter that is the most common equipment use in the natural gas industry for measurement of natural gas flow rate is having two part primary element and the secondary element the choice Orifice meter as a most common equipment is because of the accuracy the Orifice meter can measure the volumetric flow rate it is simplicity in the design and installation and the maintenance of the Orifice meter is not that tedious and costly range acceptability is there are wide range through which the Orifice meter can function low cost.

Important one is availability of standard table of meter factor as I said when the conditions are changing the device should have a calibration chart to calibrate the flow rate to apply the correction those are required to have the accuracy in the measurement. So if we look on the orifice is meter which qualifies the most common device to use for the natural gas measurement because of certain advantage it offers of because of it is characteristics.

The orifice meter primary element is just to produce differential pressure and the secondary element measure that pressure which is created by the primary device if we look on this symmetric diagram which says the flow is happening in a pipeline and this pipe line is having a restriction here device that is put in the path way of a fluid in the pipeline and this device is called Orifice.

So the Orifice is a circular because this pipe is circular is a circular very fine machine device that is put across the flow with the help if flange or other device which can hold this orifice in the path line it is mostly placed at the center of the pipe so the orifice bore is at the center of this flow line and attach with the flanges and because of this restriction the diameter which is lesser than the pipe diameter the flow which is happening in the pipeline will get converted to another flow regime because of the changes in the pressure and kinetic energy we will discuss that little later.

And the flow will be just go like this to pass through this small diameter orifice and then later on it will again after certain diameter take its position back and flow will be happening in the normal direction as it was happening before this restriction was placed in the path line orifice plate holding device also called the flange or the devices which is holding this fine machine orifice at a constant position and not allowing this to get disturb because of the flow. If that is happening the disturbance are going to affect the position of the orifice plate the correction cannot be done in the measurement and we will getting the wrong measurement.

The orifice plate this is here it should not have a significant thickness the thickness of the orifice plate depends on the diameter of the pipe it is placed and this should be very fine machine the size of this orifice should be very precisely known it should not be having kind of the roughness and any kind of the database through that bore otherwise the calculation will be different. So it is going to calculate?

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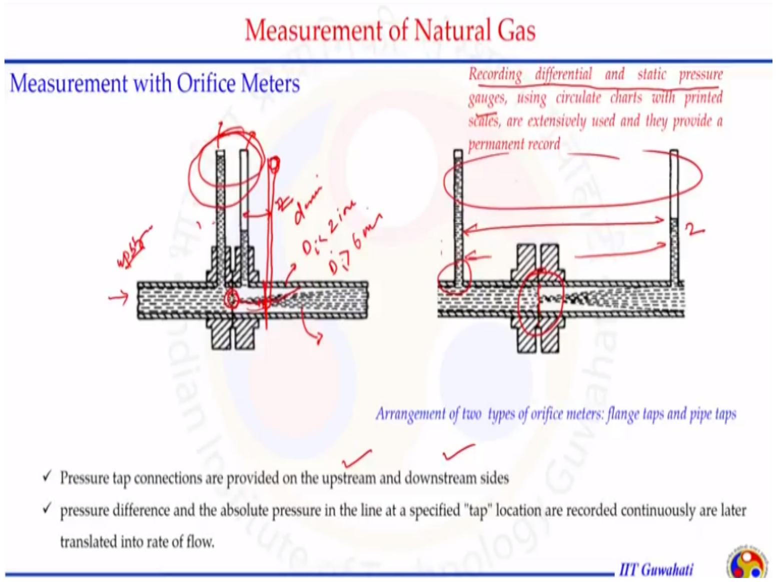

The question is how we can use this device which is having the restriction so we can look more clearly here so this is the pipeline through which the flow was happening suddenly a very small or think plate with the circular hole at the center is placed because of that the pressure energy will get converted into kinetic energy and we will get such kind of the pattern.

And you see here the minimum area where this fluid is going to hit is not at the orifice but at a certain location but at a certain locations is called Vena contractor. This is the smallest diameter of the flow is stream where the lowest stream is passing through this orifice but meeting at a particular point that the smallest diameter of the fluid is same. So the meter which is happening the gas flow the orifice that is creating the restriction or change in the flow rate or in the change in the velocity at that point the device that is holding the orifice plate or the part of primary element device of the orifice.

In this secondary element there should be connecting device to this point let us say it is 1 this is point 2 we will discuss about the location separately. For example here the position of point 1 and point 2 are on the flange so one at the upstream side and 2 at the downstream side and before fluid is reaching to 2 then pass through the orifice. Now the pressure will be different at point 2 then point 1 so the measuring device the can required this data like static pressure means the flowing pressure plus pressure difference because of the restriction is called secondary device.

There could be different form of the device here it is shown as the (()) (14:48) meter there could be transducer and some other way to monitor this change in the pressure. Position of the connecting tapes could be either at the flange position like one and two points or just at the flange near that one or could be far from this flange. It depends on specifically depend on the accuracy is required depend on the internal diameter of this tube through which is the fluid is flowing as well as diameter of this orifice.

But important point we can keep either this or this arrangement depend on the accuracy and the arrangement we can have. If the diameter of the tube is very less we cannot keep at the flange point because the disturbance will not be monitored with significant changes happening in the pressure line or other way if we keep on so much distance the pressure happening because of the orifice not only the measurement will not only count for that changes but also for the friction losses we will discuss this later on.

So it is like a device where if the diameter of internal diameter of this tube is less than two inches we cannot have this flange tapes there could be another position the dew point placed at the minimum or smallest diameter of the flow stream or the vena contractor and the position 1 and two could be like this that is also having a restriction because it is very difficult to adjust where that exactly the smaller diameter is going to hit certain calculation can be done to find out but it is difficult to adjust and should be suitable when the diameter of the tube is greater than 6 inches.

Pipe tape where the position of 1 and 2 outside this orifice of the left hand side and right hand side could be anywhere but as we increase the distance the uncertainty in the measurement appears and it goes up to 50% error we are getting. As already mentioned the pressure loss because of the roughness of the pipe will also count during the measurement.

The recording difference and that static pressure gauge using circular chart how to read the pressure difference that is happening in the upstream and downstream side this is our upstream and this is downstream. The position where we are measuring the pressure is upstream pressure and downstream pressure so all three type of the arrangement we are having the flanged tapes we are having the Vena contractor tape or we are having the pipe tapes in all three arrangement the position of upstream and downstream will be different.

And based on the difference in the position based on the reading they are recoding there should be a device which is going to record the differential and static pressure or upstream and downstream. Last stream I have shown the mano meter could be for that or the other device that in the form of the chart or electronically we can record that thing.

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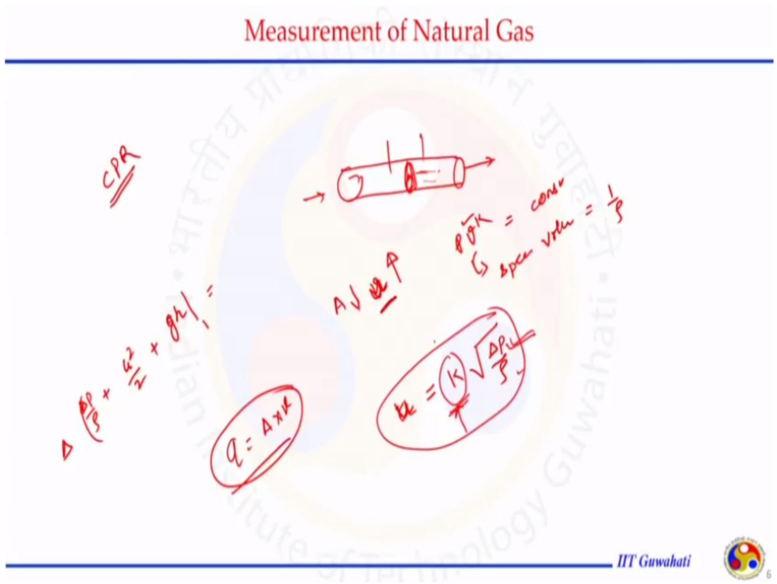

We already understand from our CPR class choke performance class where also there was restriction that was put in the flow line to control the flow rate here we are going to use the same concept the restriction is put we are going to measure what is the flow rate when the fluid is travelling through this pipeline and in that case what we did we considered the pipeline and in that pipeline the restriction was there similar as shown in the last slide upstream and downstream and the flow was happening under the isentropic process condition PV to the power K = constant and this is specific volume or I can say 1 by rho.

The flow was happening we could set up the mechanical balance equation that says the kinetic energy pressure energy and gravitational energy at some one end will be equal to at the second end because we are considering very small difference across this measurement we can say there is no friction losses accounting for that system. And while doing so we could establish like because of area is getting reduced velocity will increase this is velocity u different then this velocity will increase and the flow rate on this side can be calculated by knowing the velocity.

So the pressure energy is getting converted into kinetic energy if the TU is placed very horizontal there is no gravitational component that is going to play a role and in that case if we adjust the things we are going to get the relationship like the velocity = some constant del P / rho the pressure energy + kinetic energy + gravitational form is this elevation head at one point = to the second point.

So when we are going to write the mechanical balance equation for this device and simplified for the case of (()) (20:45) equation which says the pressure head kinetic head plus gravitational head at one point is equal to all three head at the other point plus the friction loss is happening. If there is no frictional loses is happening the sum of all these three energy at one point will be equal to the second point and that happens when we talk about the orifice meter because the pipeline is not that long.

So we can ignore the frictional loss is happening because of the roughness of the pipe and if we do so we can arrange our orifice meter in a long horizontal pipe line it is recommended it should be around 5 times of internal diameter to 45 times of the internal diameter to place the connecting tapes that goes to secondary element of the orifice and within that range the friction losses are not that important.

And we consider the horizontal tube gravitational forces are also not going to important this will be relationship between the pressure energy and kinetic energy. So when the pressure is changing because of the orifice the velocity of kinetic energy will increase and when we can relate the change in pressure with velocity we can get the value of velocity or knowing the diameter we can calculate the area multiplying area with the velocity we can get the flow rate.

And that is we did exactly in our CPR class also then if it is done we will get this kind of the relationship where U = K under root change in pressure divided by density of the fluid. K is the constant that will account for the other things like the unit conversion and some other parameter those may appear as the correction factor for example this chart coefficient and others. But in a simple case it is just a constant and the relationship will appear like this.

Now the rho, the density of the real gas is also not constant it will change with temperature and pressure condition another expression can be written that is summarizes all the changes happening in the system.

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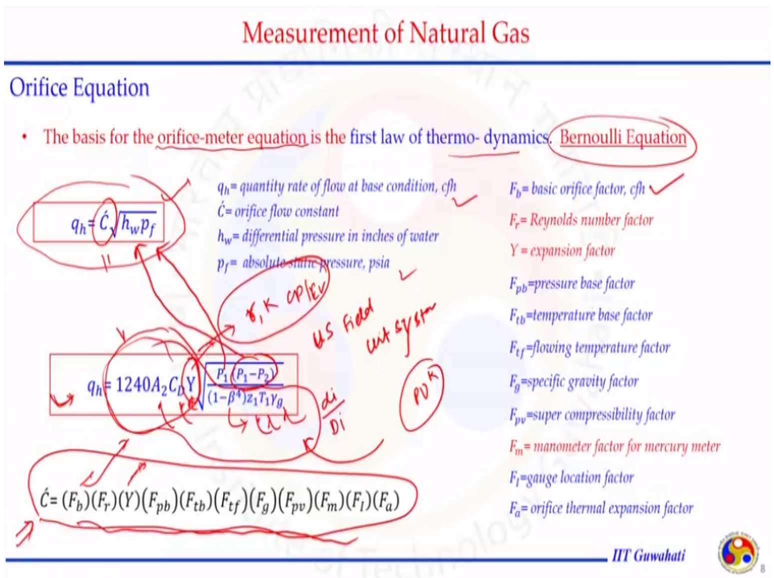

Flow through the restriction in the US field unit system give us this relationship that says how QH is the volumetric flow rate is CFH cubic feet per hour is related to the diameter of the orifice CD discharge coefficient Y is the expansion factor P1 upstream pressure P1 – P2 pressure difference this is beta is the ratio of orifice diameter to internal diameter of tube or the pipe and Zi is the compressibility at one point T1 is the temperature at the upstream side and gamma Z is the specific gravity.

This relationship is a result of performing energy balance equation first law of thermo dynamics simplifying it to (()) (24:07) even in (()) (24:09) case pressure at or the pressure head is related to just the kinetic head and considering this isentropic process we are going to get this expression. In this expression if you see the Y that is having a very big expression that is account for having the changes in pressure ratio or case specific head ratio CP/ CV in that case.

So all those parameter related to the changes happening in gas expansion volume are accounted by Y and CD discharge coefficient altogether if we compare this equation or the basic equation given for orifice meter equation from the first law of thermodynamics considering Bernoulli equation and end result comes out like this that says the flow rate is equal to some constant C prime under root HW PF HW is the pressure difference PF is the pressure or absolute pressure or static pressure or the flowing pressure.

The units are given here if we compare these two equation we can see this P1 – P2 is equivalent to HW just units are different we can adjust for the unit and P1 is here the upstream pressure or the flowing pressure and this C prime is accounting for everything that is appearing here. If we write that in the form of some correction factor considering this equation QH is good enough to represent the flow is happening through the restriction and that can give us the volumetric flow rate just knowing PF upstream pressure and HW the difference between upstream and downstream pressure we can calculate the C prime separately considering the other parameters those may affect.

And that happens when the fluid is passing through the orifice it takes difference form because of pressure energy is getting converted into kinetic energy certain energy at orifice should also be included. So let us see what this C prime is having this C prime include altogether eleven factors we will discuss one by one all those eleven factor some of them is like this the by appearing here is similar to what is by appearing in this correction factor.

The FB is this part numerical coefficient area of the orifice or the discharge coefficient that can be club altogether and can say this is a base orifice factor because it depends on the geometry and dimension of the orifice and some others.

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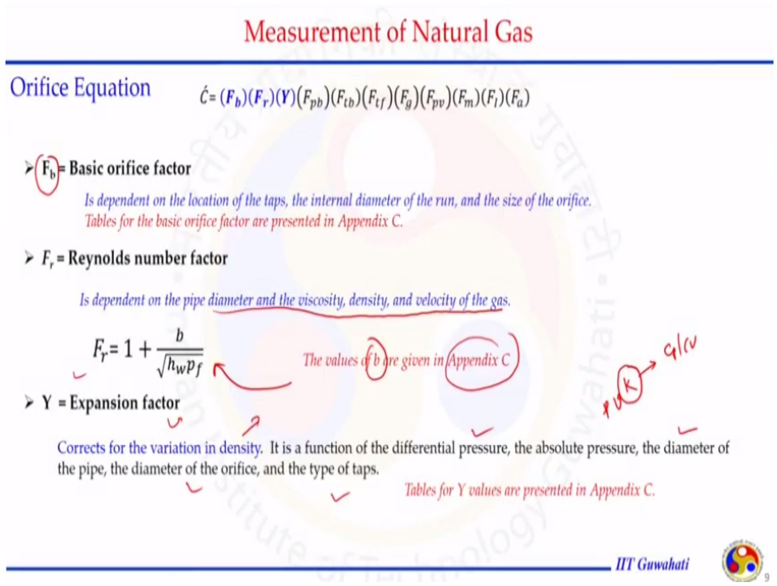

Let us go one by one considering the parameters those are making this C prime. So let us start with FB basic orifice factor it is a quantity that should be included in the correction factor because it depends on the location of the tape we discuss three locations so what where the tapes are connected it accounts for that the internal diameter of the run time and the size of the orifice means the diameter of the orifice.

There are literature the tables are prepared for having such kind of correction considering the diameter of the tube and considering of the diameter of orifice as well as position of the correcting steps like and they are like flange tapes they are like pipe tapes or the they are like vena contractor tapes. The Reynolds number is very much required it should be included because it depends on pipe diameter and the viscosity density and velocity of the gas.

Say if the gas composition are changing it is viscosity is changing or the tube through which the gas is flowing anything is changing Reynolds number value will change and that correction should be included in the correction factor and that in the form of Fr = 1 + B upon under root hwpf there are tables given in appendix C of Gua and Gallumber book those summarizes the value of B rough factor that is required in the Reynolds number correction factor.

The expansion factor this is a correction for the variation in density it is a function of differential pressure obsolete pressure the diameter of the pipe, the diameter of the orifice and types of tapes this is also correct for the type of the isentropic process is happening is the K value that depends on the properties of gas CP / CV. So the gas expansion properties are counted in the form of Y.

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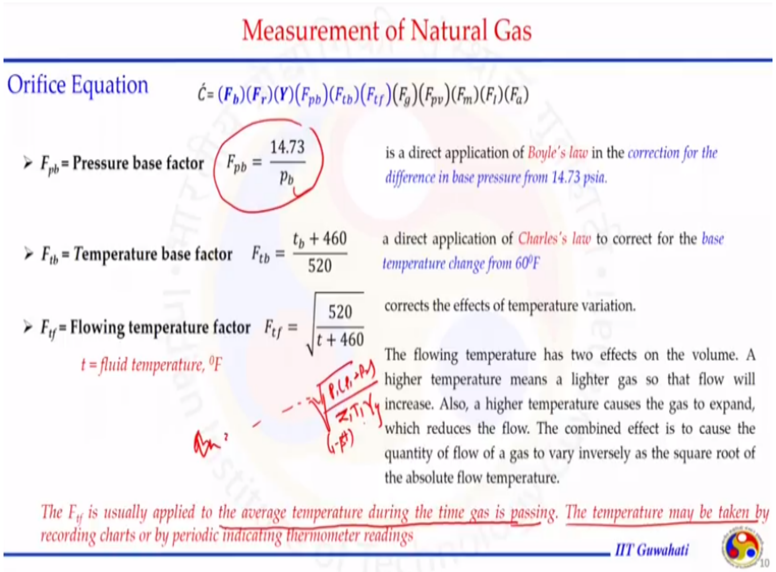

Pressure means factor so in the pressure at that condition the orifice installed may be different so we can use the Boyle's law for correcting the difference in base pressure from 14.73 psia so that for that we can use this 14.73 divided by pb. The temperature base factor is similar to pressure base factor and it is direct application of Charles's that allow us correct for the base temperature changes from 60 degree Fahrenheit.

Flowing temperature that correct the effect of temperature variation it means the flowing temperature is different then base temperature the correction is needed because of two reason the high temperature means flow will increase and a higher causes the gas to expand which reduces the flow so the compensation should have the combined effect that is caused the quantity of flow of a gas to vary inversely as the square of absolute flow temperature.

So if we see our equation in that equation like QH = something and then the pressure difference P1 – P2 we were having the temperature here gamma Z and may be some other parameter 1 – beta to the power 4. So the temperature is inversely proportional we should also include that factor as a correction factor the PTF is usually applied to the average temperature during the time gas is passing the temperature may be taken by recording chart or by any thermometer reading that is installed at that location where the orifice is installed.

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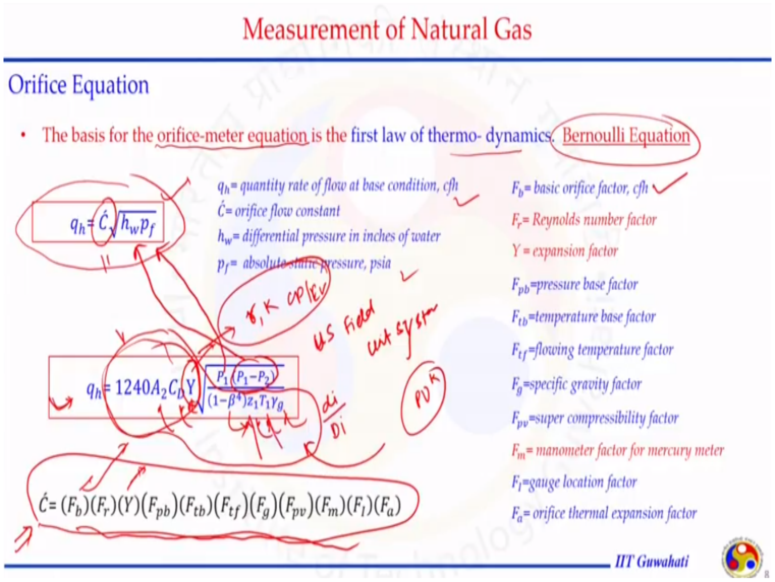

Especially gravity factor so it is used to correct for changes in the specific gravity, and should be based on the actual flowing specific gravity of the gas as determined by the test. So the sample should be taken be taken at the place where the orifice is installed and the correction should be made. From the same expression we can see the Fg is inversely proportional to gamma or square root of gamma z and that is where the correction should be included to have any changes in gamma is appearing.

This factor varies inversely square root of specific gravity with a given force applied on a gas on large quantity of light gas be pushed through orifice then a heavier gas if the gas is having a mixture of lighter and heavy compound if we are not considering this correction factor it means we are just saying everything is passing through same time but in actual scenario happens natural gas which is having the lighter and heavier compound lighter compound will pass through before the gas is heavier compounds are getting change to pass through the orifice that why the correction should be implemented.

Another important correction factor is super compressibility factor that accounts for having a real gas behavior of natural gas compared to the ideal gas and it varies to temperature and pressure and specific gravity and that is why it should be included in that factor. So if look in the big expression this is similar to what we are having here when we go through the energy balance equation we are having the compressibility the denominator under the square root similar we are having for T1 similar we are having for gamma Z.

Either we are using this big expression or for simplicity purpose we are come at all these factor in the form of C prime.

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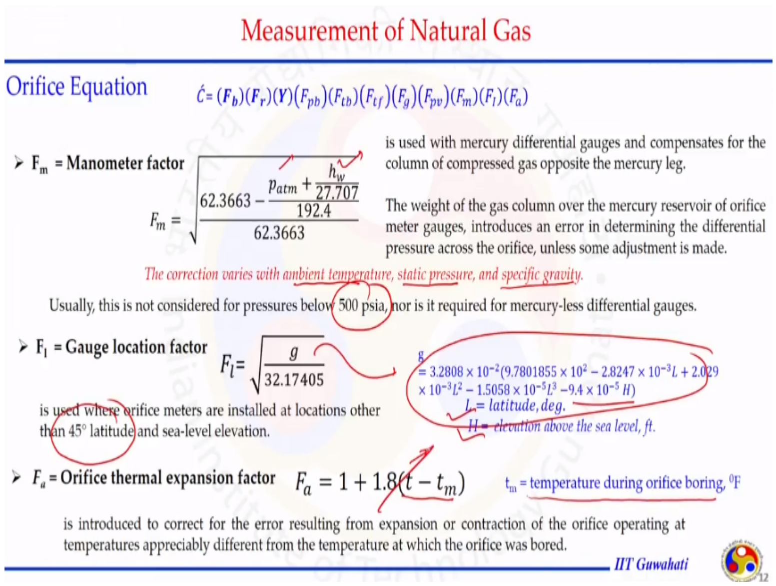

Let us see some other factor how they influence or how this should be calculated like the other parameter manometer factor that is not in that expression is used with mercury differential gases and compensate for the column of compressed gas opposite of mercury leg. So we are having the natural gas which is going to manometer because of the pressure on the static side as well as in the differential side and the weight of the gas over the mercury reservoir of the orifice meter introduction error and determining the differential pressure across the orifice unless some adjustment is made.

So this adjustment which is accounting for the pressure difference pressure and some other parameter for the gas that is entering tin the mercury column should be implemented and the correction varies with ambient temperature static pressure and specific gravity usually this is not considered if the pressure is below 500 psia or when the mercury gas differential gas is are used then it is not required.

Gauge correction factor so the gauge where we are measuring the flow rate or where the horizontal section of the pipe is considered to place the orifice it is location is specific also so if it is not installed at 45 degree or other than 4g degree latitude and above the sea level we have to have the correction for G and at that correction for the G in terms of latitude and elevation from the sea level can be given with this big expression.

This is a polynomial equation in terms of L and also having the H in that expression orifice thermal expansion factor is introduced to correct the error resulting from expansion or contraction of orifice operating at temperature appreciably different from the temperature at which is orifice can be bored. So the orifice was bored was particular at a temperature now it is exposed to different temperature the change that is happening in the geometric of the orifice should also be included in the expression as a correction factor.

Usually the value may be 1 or this because the expansion is not that much or the temperature condition it is going to face or not different then this is bored. Then the correction says it should include the t – tm, t is the temperature of operation and tm is the temperature during the boring both are same this will go out we will be having just Fa = 1.

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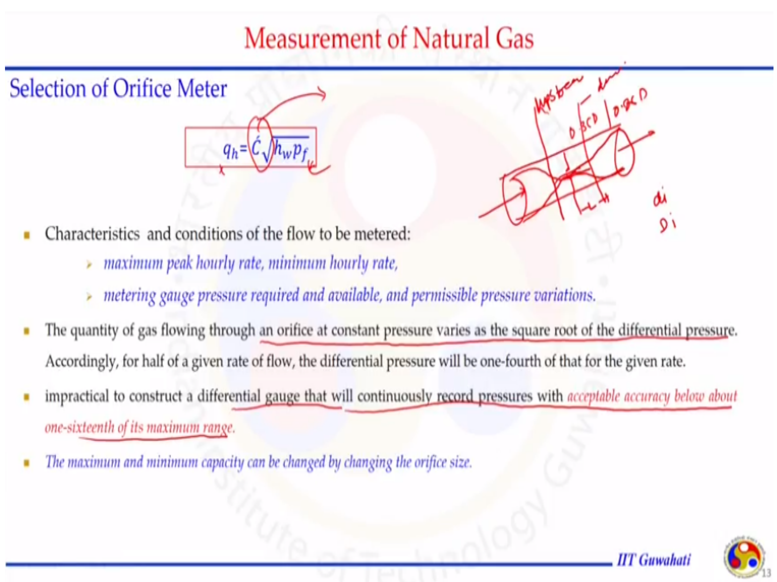

So if we see this C prime that include all this correction factor so instead of correcting for each using the chart table or the appendixes we can just calibrate our device and calculate the C prime value and then C prime value will include for all these correction factor altogether and that is could be done during the standards chart available or a supplier who is supplying us who is providing this C prime value after performance certain experiment.

So the characteristic and condition of the flow to be metered by the orifice device depends further on the maximum peak hourly rate or minimum hourly it means what is the fluctuation is happening in the flow rate also affecter to decide orifice is going to work precisely or not the fluctuation is too much the orifice is not a good idea to have the flow rate measurement accurately.

Metering it is pressure record is available and permissible pressure variation so again the pressure gauge those are going to monitor the or it going to record the pressure changes static pressure as well as differential pressure should be available in the range of we are going to operate the orifice tube measure the flow rate because those should be able to measure the pressure range that is fluctuation or that is even the constant value that may be the low value or high value the pressure is should have that capability.

The quantity of gas flowing through at orifice constant pressure various at the squared root of differential pressure from the expression we know with respect to pressure Q and pressure is having the relationship where the Q is proportional to root of Pf similar q is proportional to root of hw. So it is if any changes in pressure static pressure and difference in pressure is happening that is not directly proportional to qh that is where the sensitivity should also be considered when we are going to measure very precisely what is the flow rate the gas is having through the particular section.

Impractical to construct a differential gauge that will continuously required pressure acceptable accuracy below about one sixth of the maximum range. So whatever the maximum range we had chosen we have chosen the orifice for design the orifice for that range the minimum range or lower range or the lower range could be 116 of that maximum range beyond that it is very difficult to have a very precise measurement.

So the maximum and minimum capacity may be change by changing the orifice plate if you want low we want to go beyond the 116 of the maximum range we have to choose orifice a particular orifice design to measure maximum and minimum flow rate through fixed diameter tube in a horizontal pipe is designed for a particular type of the fluid range if we are going beyond that range we are going to change the orifice or orifice dimension.

In orifice meter when we are having the flow is like this and the fluid that is coming from here going out here the flow behavior will be like this when the effective length L will depend on the diameter of orifice and diameter of pipe thus it might be in the range of 0.35D to 0.85D. So for example we are having the connecting tape just before he orifice like here 0.1 or I should say upstream.

And another is vena contractor here downstream so depend on the size of the orifice this flange is going record very precisely otherwise if we are changing the flow rate to be measured the vena contractor position will also get change and again we have to have a different orifice to have the correction or to have the precise measurement of the natural gas.

So orifice equation is a result of Bernoulli equation when we consider the horizontal scale and the resultant equation is accounting for all the changes happening in terms of temperature compressibility gamma Z basic temperature and pressure conditions, Reynolds number changes, gauge location factor orifice thermal expansion factor. All these are accounted in the form of C prime literature is available we can get the value of C prime and then this selection o orifice depends on some other factor also those are discussed here.

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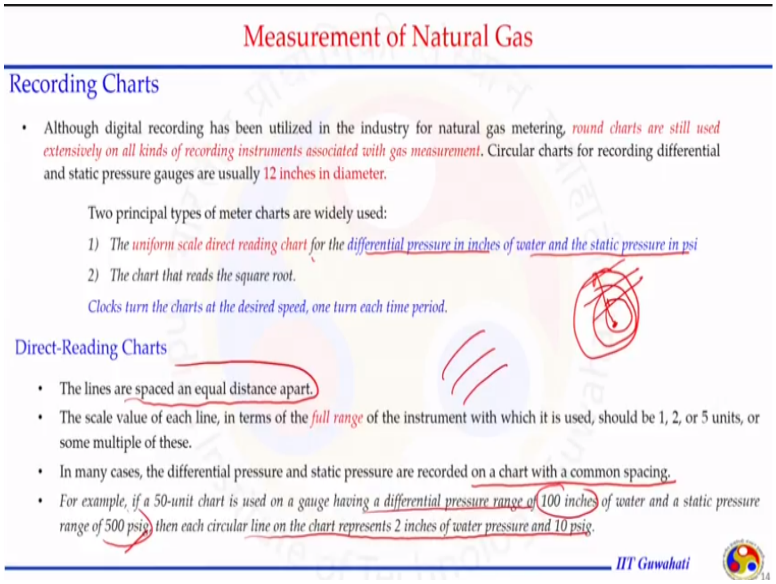

Now all this is on the primary device in the primary device where the restriction is imposed and pressure difference is generated. Now we need the secondary device that can record the data or can monitor the data. Although we are having the distillation we can install several electronics devices at point of interest or the place where the orifice is installed we can record the pressure difference that pressure difference can be converted into flow rate.

But still in the remote area or at several places the chart concept is still in the use in that chart the data differential pressure and pressure are recorded periodically and the chart data can be used convert pressure data into flow rate data and that can be done with the wrong charts those can be of two types the uniform scale or the direct reading chart for the differential pressure inches and the static pressure in psia.

Or the other form of the chart is where the chart read the square root so in the first time we are having the chart circular chart and they are equally spaced and full range of the pressure that can be meet when the gas is flowing the chart is designed for that the maximum rate and minimum rate entire reason can be classified in a equal space and those equal space is having the location where the static pressure and the differential pressure can be monitored.

And in this kind of system actually they recoding chart are somewhere very remote area where just guy or a service engineer or service man is going and placing a chart and that chart is having some mark on it like our watch dial and where the mark is from 1, 2, 3, 4, 5, 6, 7, 8, 9, 10, 11, 12 three types of needles are there those just move with a specific rotation speed and give us the timing.

Similar thing is in the recording chart so a clock touch the this needles type of the thing with a specified period that could be just like the watch or could different depend on the operator who is going to use it we can have those chart those are recording the data for one month, one week, one day or just for 12 hours. And the chart is indicated with the position and in this particular needle is particular pointer is getting some pressure on it.

It will move like this it in the direction or it is kind of a spring kind of the things where the position will depend on the pressure it is facing and the needle position that is moving in a circular motion also will leave the foot print on the chart and those foot print are actually the static pressure and the pressure different we will see in the next slide. So the chart could be two types just on the actual scale or second one on the square root scale.

So on the direct reading chart where we are having the actual scale and this scale is spaced and equal distance apart the lines are created in that region those are equally space and in many cases the differential spaces and the static pressure or recorded on a chart with the common spacing the example is here the 50 unit chart is used on a gauge having a differential pressure of 100 inches of water and a static pressure of 500 pisg.

Remember the pressure different unit is inches of water and the pressure unit is or the static pressure is psia psig that is being recorded on a equally spaced direct reading chart then each circular line on the chart represent 2 inches of water pipe and 10 inches psig it means a chart is placed at the location where we are having the orifice and that chart is equally spaced based on the range it is having 100 inches of water if we are having the 50 lines on the chart each line will represent 2 inches of water and if the maximum static pressure range is 500 psig each line will represent 10 psig as the pressure position.

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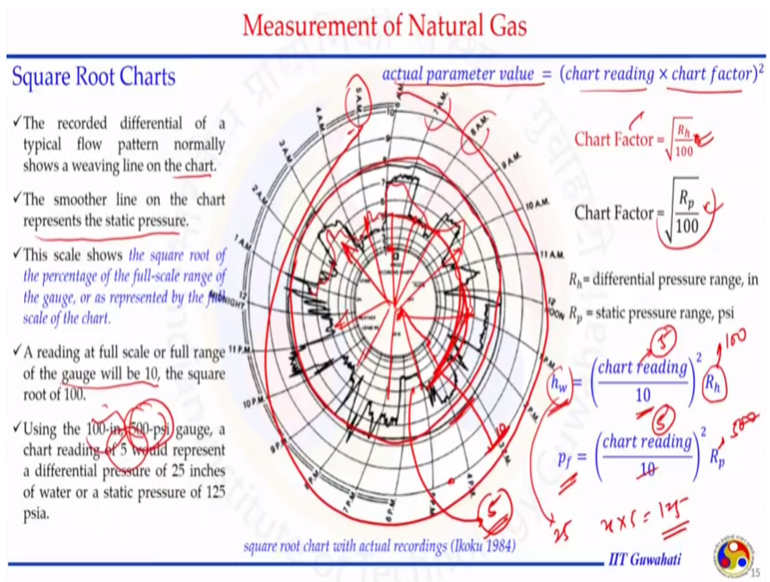

We can see for the square root chart but this is equally good or the direct chart also if we are just ignoring these scale that is put on it. These scale in our hand generally but it is designed on the square root form and the if we look from here this is the center and we are having kind of a needle here and the chart is fixed and the needle is moving with respective time that is specific to this chart like this.

And it might be moving with just in the concept of 1 week or 1 month just one day and when the pressure is there like this is a static pressure the smooth line you are seeing this is static pressure which is almost smooth and the waving lines here those are the pressure difference that is recorded at a particular time you can see 5, 6, 7, 8 at a different time as a the needle is moving we can get the reading of differential pressure.

So the recorded differential of a typical flow pattern normally follow a waving line on the chart the smoother line on the chart represent the static pressure as I just mentioned the scale shows here it is a difference between the direct chart and the square root chart. The square root of the percentage of full range of case or as represented by full scale of the chart it is in our hand we can design this chart or reading at full scale or full range of the gauge will be 10.

So if it is from here the position says if the needle is moving up to this point for example from this center needle this up to this point it is 1 line this is 2, 3, 4 and 5 and finally the line is 10 actually when it is at 10 it means the maximum and the maximum value in 10 inches means it is 100 inch of water. For static pressure that is 500 psi if we are having a particular location somewhere here is given at rate of 5 if the reading is at a 5 and our 5 is here this is our 5 if we can see this is our this is 5 position.

And if the position of the needle at that point of static pressure and pressure difference we can calculate the actual value and that can be done just knowing reading chart value and chart factor. So chart factor is defined because it is a square root chart it is defined as square root Rh / 100. So whatever the factor we are having on this scale we can get that thing pressure difference and similar for the static pressure and the value hw and Pf can be calculated with the help if this chart.

For example here we are having this 100 inch full length and 500 psig full length chart and the position of the needle is at 0.5. So we can use this expression to calculate the pressure difference hw and Pf static pressure. So the reading chart we know is 5 this is also 5 and the Rh the value is 100 and for Rp it is 500 and if we do this calculation we will get hw is as actual value 25 inch water and Pf we will get 125 multiply by 5 is 125 pfw 125 psi when the needle is going at 5 position.

So we can use such kind of the chart to have actual measurement or converting the needle position to pressure reading and knowing this pressure reading we can put in the orifice equation to get the value of Q the flow rate.

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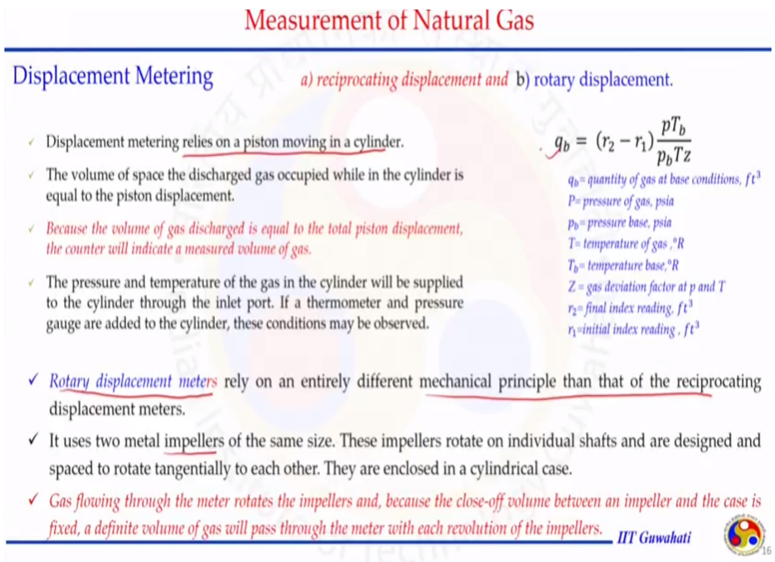

Other than the orifice meter or head meters those are like LO meter (()) (51:36) and something those work on the principle of the restriction the displacement meter those are used for the measurement of the natural gas the reciprocating displacement or the rotary displacement as already discussed in the introductory slide the reciprocating displacement or the positive displacement depends on the movement piton movement.

So in displacement metering relies on the piton position on the cylinder the volume of the cylinder discharge gas occupied while in the cylinder is equal to the piston displacement and knowing that value knowing that number of piston we can calculate the value of natural gas that is flowing through that point and this expression can be used for that purpose. In rotary displacement meters they rely on a entirely different chemical principle then that of the reciprocating displacement it uses two meta impellers of the same size.

These impellers rotated on the individual shaft and that design and spaced to rotate tangentially to each other and when they are rotating they are in closing in a cylindering case and in each rotation they are discharging non amount of the gas on the other side knowing the number of rotation knowing the impeller dimension we can calculate the volumetric flow rate.

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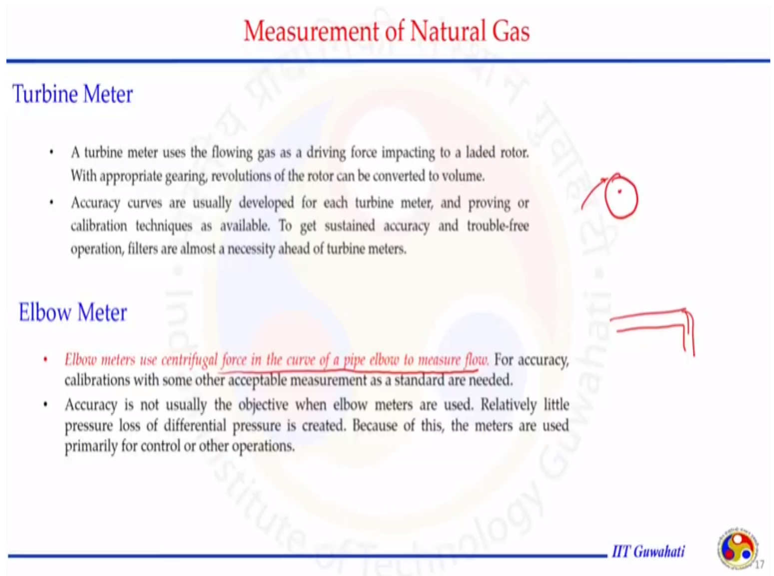

In turbine meters for example this turbine the gas is rotating this turbine we can convert the number of rotation of the turbine using some calibration chart in to the amount of the natural gas that is flowing to have those many rotation of this turbine. In elbow meters use a centrifugal forces in the curve of a pipe elbow to measure flow like this is kind of a point where we are having the elbow and the centrifugal force that is appearing at the elbow we create the pressure difference and that pressure difference can be used as like orifice meter to measure the low rate.

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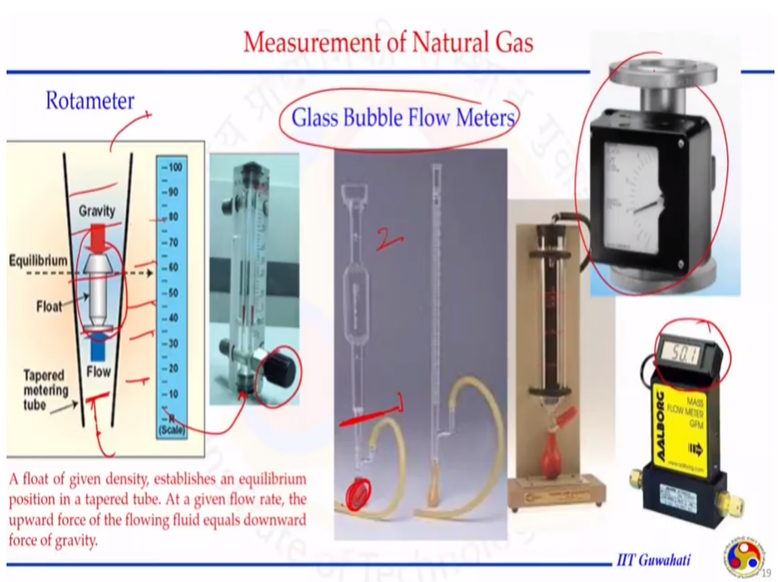

Other measurement device is a rotor meter that use the very well area concept the area here is different and as going up the area is increasing temperedly and the gas is flowing from the bottom this is float and the position of the float in this column can be calibrated on the scale to calculate the volumetric flow rate of the gas passing through the section. In Rota meter a fluid of given density establishes the equilibrium position in a tampered team in a given flow rate the upward force of the flowing fluid it quest down the force of the gravity with the help of the calculation we can establish the relationship that will give us the Q value.

This is widely used for a not very high flow rate just in the medium flow rate range or in the laboratory or pilot plant this is the picture of how this Rota meter looks like this is the needle at the bottom part to control the flow rate gas bubble kilometer then also be used but it is used in the laboratory where we are having just a connecting tube gas is passing through bubbles can be created with some sour and the bubble will travel because of the gas flow rate from non-position one to another position two we know the volume of this the time the bubble needs to travel from point one to point two can be used to calculate the volumetric flow rate.

Some other devices are also shown here like the mass or volumetric flow meter that digitally provide the value directly when the gas is passing through it or the pilot plant or filed scale pressure gauge those can monitor the gases flow rate. But the more important is the orifice meter is the device that is widely used for considering the volumetric flow rate in a wider range however we do not consider certain other parameter like the compressor position if those are nearby the orifice meter they will create a problem in the pressure fluctuation certain fitting turn in the pipe we also disturb.

That is why the orifice meter in installed in a location when there are no disturbance from the compressor or delivery end there is no disturbance from the fittings on that otherwise we have to apply the correction factor for all of the, with this brief idea of how the natural gas can be measured with different methods as well as the details discussion of orifice meter that is a head meter similar Reynolds equation can be established for other head meters also I would like to end my lecture here thank you very much.