Upstream LNG Technology
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Lecture – 17
Temperature and Quality Measurement in Natural Gas Systems

Welcome, today in this lecture, we shall be leaning about the some more measurements, we have already covered the measurement of flow and pressure etcetera. Now we shall look into the temperature measurement and the quality measurement.

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So, let us go to it let us see that what we shall learn in this lecture, we shall talk about some temperature measurement devices in case of natural gas, and some kind of quality measurement methods. Understand this that there are many ways of measurement of this parameters, but we shall be restricting ourselves only to those which are commonly used in the natural gas industries.

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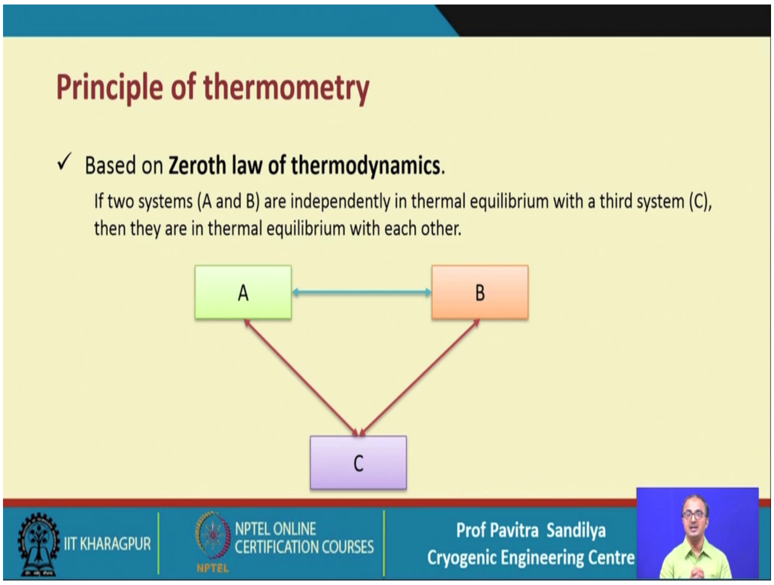

So, first let us understand the principle of thermometry that is the measurement of temperature. Thermo means energy or temperature thermal energy and metry means measurement. So, this measurement principle is based on the 0th law of thermodynamics, which says that if 2 systems A and B are independently in thermal equilibrium with the third system C, then these A and B are also in thermal equilibrium with themselves.

So, this is the principle of the 0th law of thermodynamics, and pictorially we can show that suppose this is system A and system B this 2 systems are in thermal equilibrium with a system C. So, then what happens we say that a the thermal equilibrium means that A and C have the same temperature B and C have the same temperature. So, it also means A and B are also in thermal equilibrium, that is the temperature of A and B are also the same.

Ah now what is the specialty about this? It seems obvious, but you see that if you look at our day to day life, the way we measure temperature for example, when we are fever we use thermometer. Now in this case, how to additive by the thermometer; now thermometer is one system, my body is another system and there may be another thing, which with which I will say that my body is how hot and how cold my body is. So, what I do that if I take a some standard, so, what I will first do? I will take a thermometer just suppose that is system A, and suppose I am the system C with which the thermometer will come to equilibrium, if I keep thermometer for some time with touch with my body.

And now what I do? I system known system whose temperature I know. Now if I adjust that temperature of the system same as my body temperature and it comes to equilibrium with my body, then what happens? I say that the thermometer and the system with which I measure my body temperature they will mutually be in thermal equilibrium. And this particular thing is used for the calibration of this temperature sensors, as you know which will I will not be talking about the calibration part, but as we know that there are many fixed points using which we calibrate all thermometers or the temperature sensors.

So, this calibrated sensors, calibrated ones are ones which are the system B, ok. My thermometer is system A and my body is system C. So, in that way we find that we develop this whole concept of measurement of the temperature.

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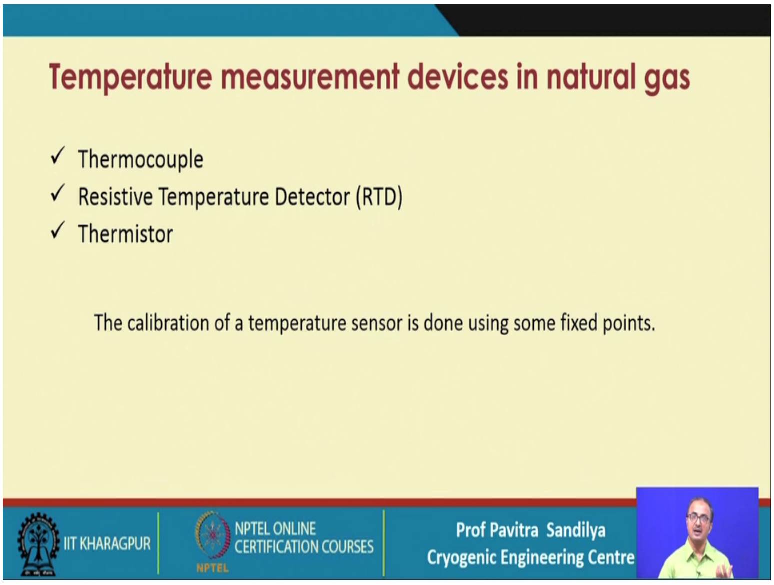

So, let us see the commonly used temperature measurement devices, these are thermocouple, then resistive temperature detector and thermistor. So, I at the end of the lecture, I will also show you a thermocouple and resistive temperature detector.

This now as I told you all the sensors need to be calibrated with some fixed points, and there are many fixed points given in the literature and some of the common ones you know there are steam point and the ice point. That is a temperature at which water balls at one atmosphere, and the temperature at which water condensers to ice at sorry freezes to ice at one atmosphere.

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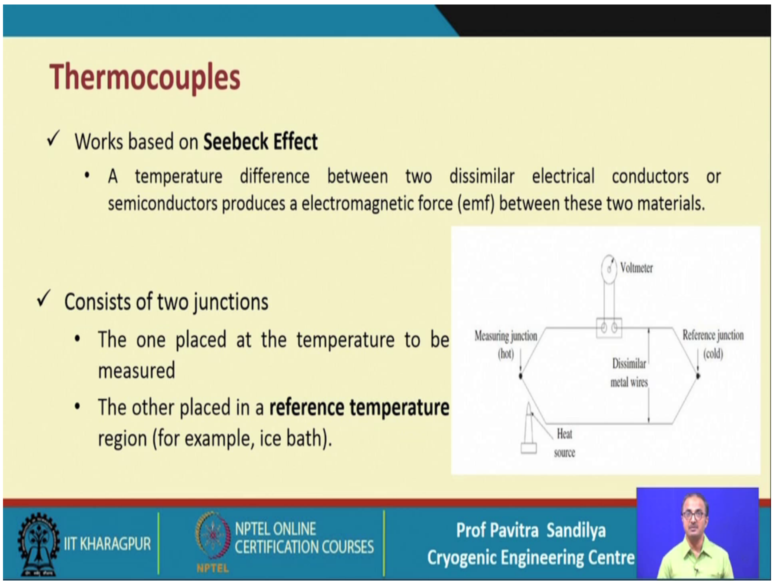

So, let us see the thermo couples, now this thermocouples based or worked on the on the seebeck effect. And this we know that it is an effect which causes a change in the emf between 2 materials with a if there is a difference in the temperature in the materials. Now these 2 materials are joined at some point and we apply 2 different temperatures to these 2 limbs of this material, and then we find there is some kind of a emf generated and we measure the emf to find out the temperature.

So, here we have seen that here in this particular figure we see, there is one hot junction, another is cold junction, ok. So, these are 2 materials this is top one is one material, another one is the bottom material and here we have showing that we are heating it up with some kind of heat source. And another one we are keeping cooled that because reference junction, and this is a measuring junction, and then due to this difference in the temperature there is some kind of emf generated which is measured by the volt meter. So, this volt meter reading becomes an indication of the temperature provided we calibrate it with some standard temperature.

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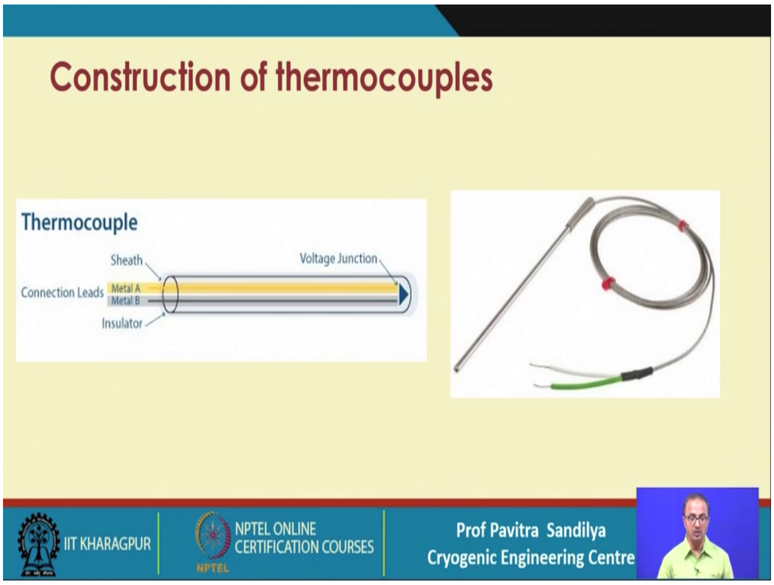

So, this reference temperature may be an ice bath. And here we show that how it looks like in practice here we this is the one which you obtain generally from the market, and these particular limb how it look some inside that in the inside here we have a sheath that is a covering.

And then we have 2 metals A and B, this metals need not be pure metal they may be alloys too. So, this we have this 2 metal thing and this is insulator, and they are producing some kind of some voltage when we put this 2 metals this 2 ends of the metals at 2 different temperatures.

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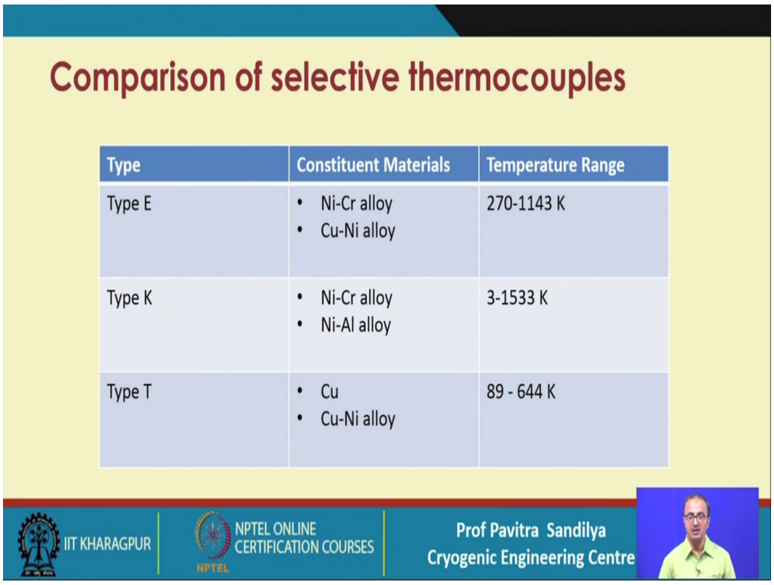

Type	Constituent Materials	Temperature Range
Type E	• Ni-Cr alloy • Cu-Ni alloy	270-1143 K
Type K	• Ni-Cr alloy • Ni-Al alloy	3-1533 K
Type T	• Cu • Cu-Ni alloy	89 - 644 K

Now, here we have compared the performance of a few types of thermocouples, like we have different types of thermocouples depending on the material chosen to make this. So, there is type E type, K type, T many other things. So, here we see that a kind of materials, we are using here we are using in type e nickel chromium alloy and copper nickel alloy in type K, we are using nickel chromium nickel aluminum in type T, we are using copper and copper nickel alloy, and we also find that all this thermocouples are operating can operate at various temperature ranges. So, depending on a choice of the material we have the temperature ranges.

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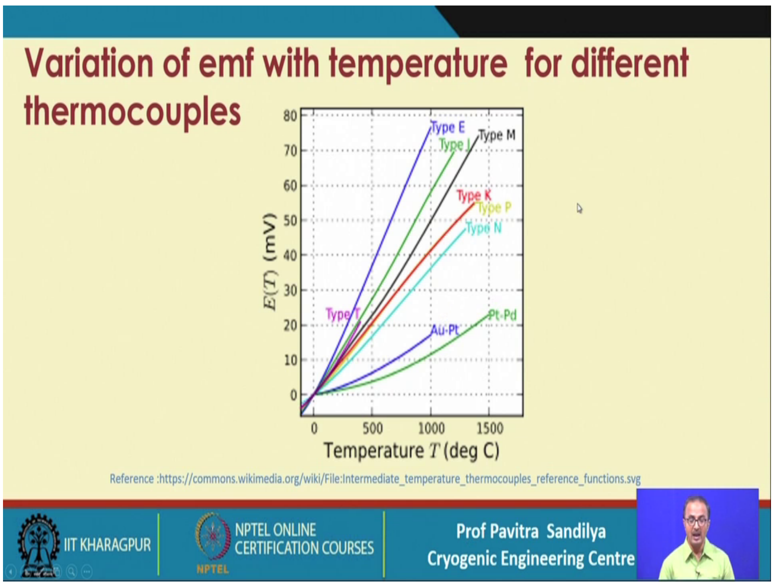

And here I show in this particular figure that how the emf varies with the temperature for different types of thermocouples. Here we see that the slope of the variation of this emf with temperature decides the sensitivity of the thermocouple; that means, we want a measuring device to be sensitive enough; that means, it should be able to sense any change effectively for some small changes in the temperature.

So, if it is highly sensitive; that means, even the small change will be detected very efficiently by the thermocouple, in that respect we find that this gold platinum or platinum palladium thermocouples are less sensitive than the other types of thermocouples. But sensitive sensitivity is one of the parameters to decide the choice of thermocouples there are other parameters also which are used towards the choice.

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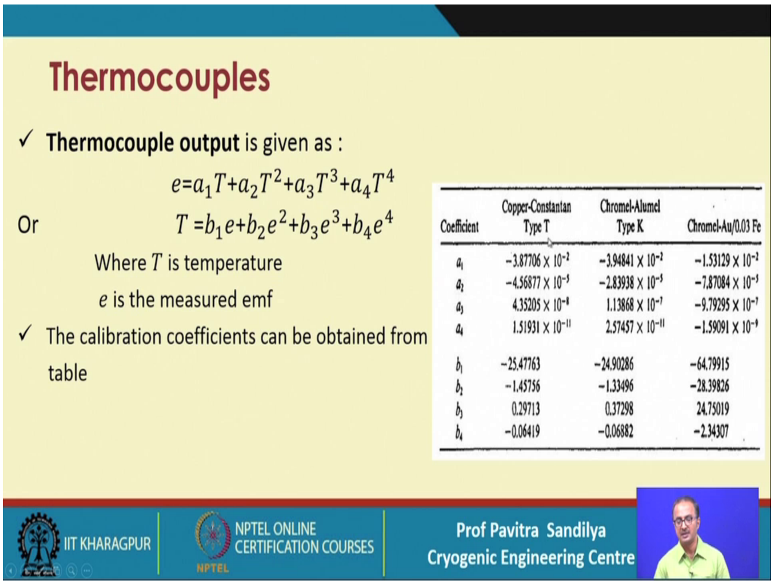

Now, there are various expressions to correlate the emf with the temperature. So, here are some polynomial function in which we find that first expression shows how the emf depends on the temperature, and a second shows how the temperature depends on the emf. These have been obtain empirically from some experimental data.

So, if you know curve fitting or regression you can find such kind of expressions. So, this all this a b ab coefficients they can be obtained from some standard table. And here we show the coefficient values a and b for some few type of thermocouples like copper constantan, and that is type T chromel alumel, that is type K and chromel gold and iron this is another thermocouple for which we show the values of a and b to be used in this particular expressions.

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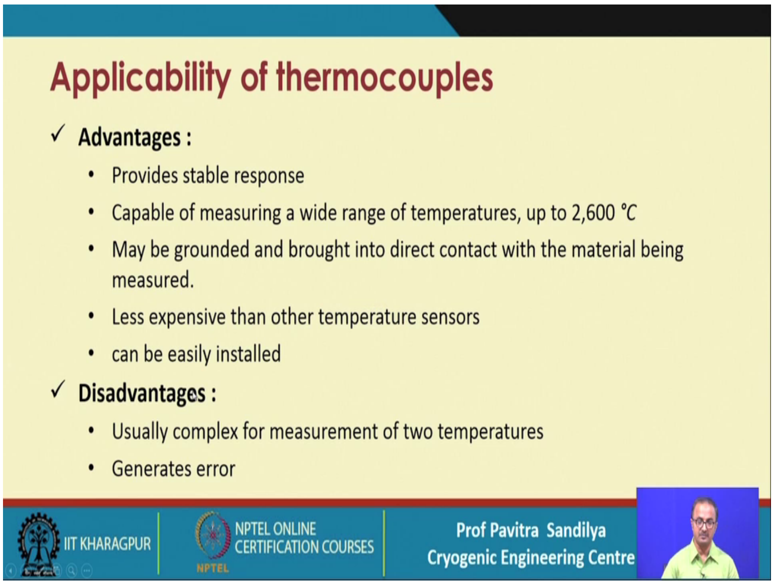

Now, what are the applicability? So, we have some advantages like a thermocouple provides stable response, it should be stable it shown be very unsteady it should quickly come to the particular temperature, the capable of measuring a wide range of temperatures, and may be grounded and brought into contact with the material being measured it is less expensive and can be easily installed.

But disadvantages are that it is when we want to measure 2 temperature, it becomes not that effective and it generates some kind of errors. But by enlarge you will find that this is very, very commonly used in for research also.

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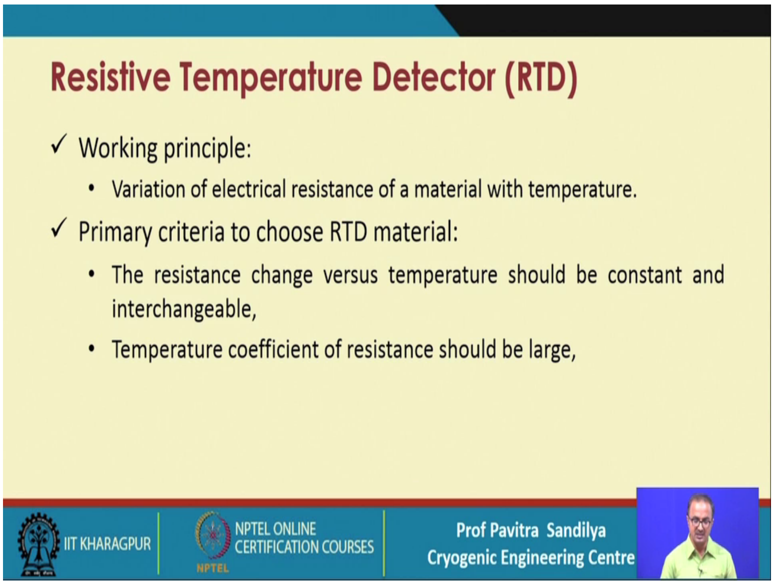

Then we have resistive temperature detector, that is the RTD in short. The working principle is this; the resistance of a material changes with the temperature. Now we generally find that the resistance fluid change for any kind of material with temperature; however, all the materials are not suitable candidates to make RTD's, because we also have to see that the sensitivity should be enough; that means, resistance change versus temperature should be constant and interchangeable.

And the temperature coefficient should be very large; that means, it should be it should respond quickly to any kind of temperature changes.

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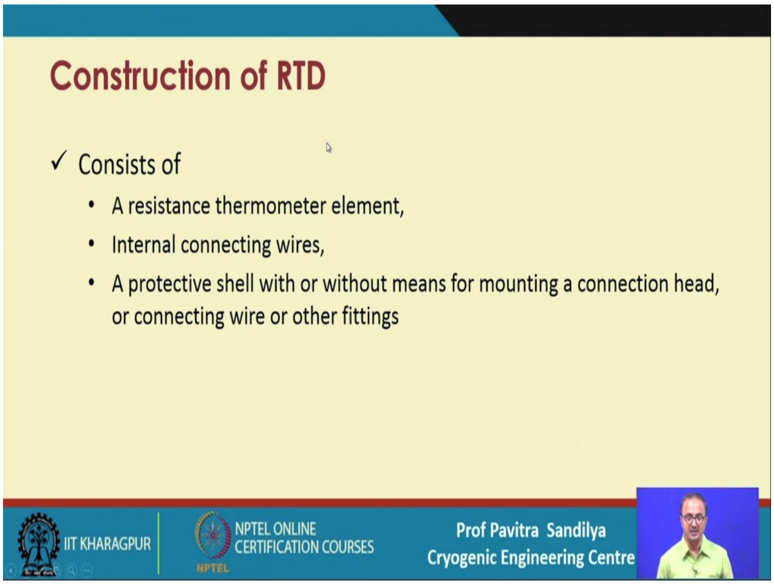

In the construction of RTD is that, it has a measuring element resistance thermometer element, whose resistance will change with temperature, then we have some connecting wires and we protect this particular resistance by (Refer Time: 11:18) kind of some sheath some kind of protection protective layer is used to protect these particular element.

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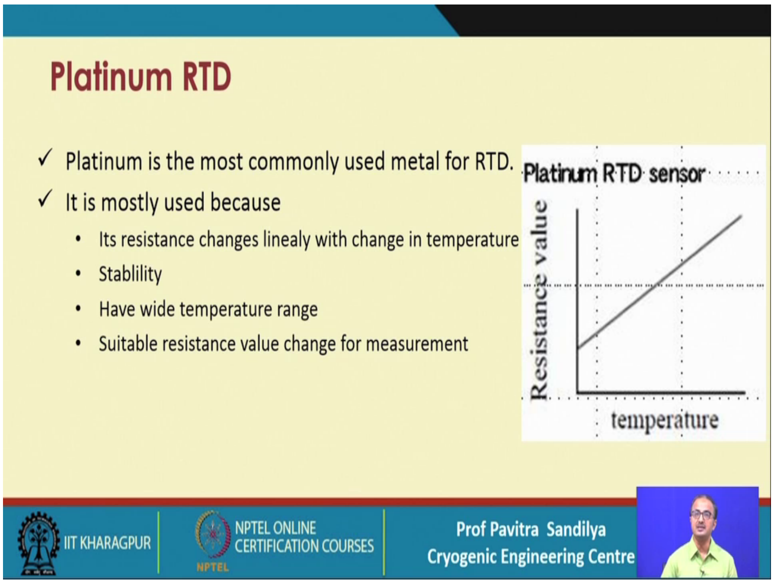

And platinum is very commonly used RTD, we call it in short pt pt RTD the platinum RTD and it is used very common because it is resistance changes almost linearly with temperature. And as we can see in this particular diagram, that the resistance of the platinum RTD is changing almost to linearly with temperature. It is quite stable and it can handle a wide range of temperatures, and it is suitable for measuring the resistances effectively.

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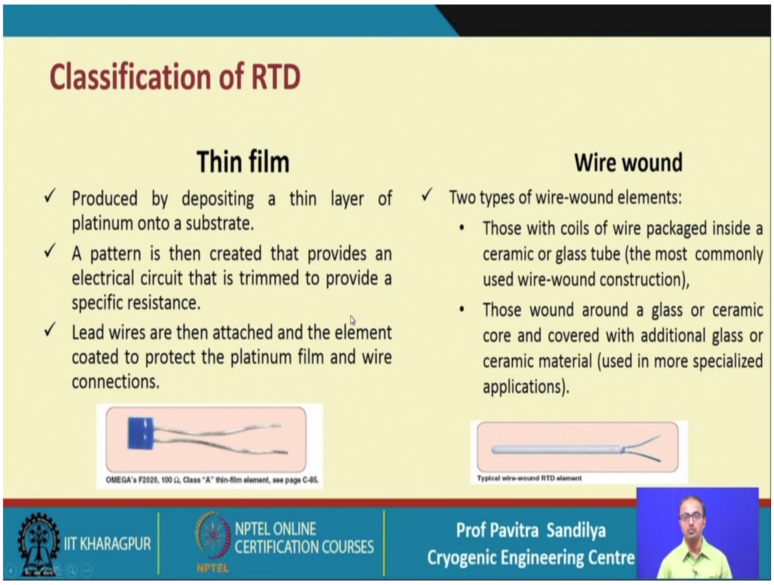

And this comes in 2 verities, that one can be thin film, and one can be wired wound that in thin film we are you show you at the end of the lecture this that it is a very, very thin film is used here to protect the element. And there we have the wired list attached to it, and this kind of things is used when we want to measure some point temperature in some devices. At a given point we want to measure temperature.

And this wired wound is used when we are not able to put this thin film tied inside some system it, you will find it when in practice in some, some cases we are not able to put this fix this one. So, what we do? Then we take this particular thing inside a long limb, and this limb can be inserted in the system, and then we can take out the lead wire from the end to measure the temperature. So, depending on the system we choose one of this 2 configurations.

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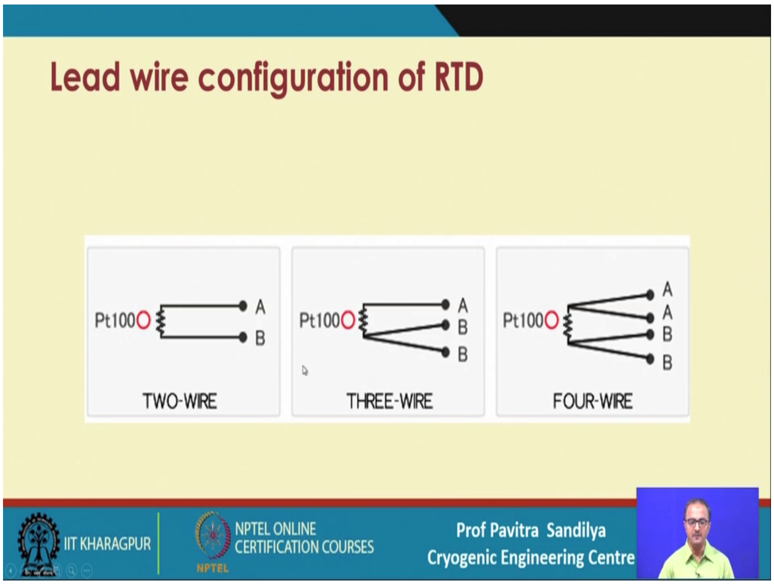

And here we have some lead wire configuration 2 wire, 3 wire, 4 wire, I will not go into detail of this things just to tell you that there some resistances also involved at the junction. So, to nullify the effect of the resistance at the junction, we use more than 2 wires also, and depending on system we go for to 2 wire that is simplest in construction to the 4 wire which is very, very accurate. So, we have different types of configurations of the lead wire.

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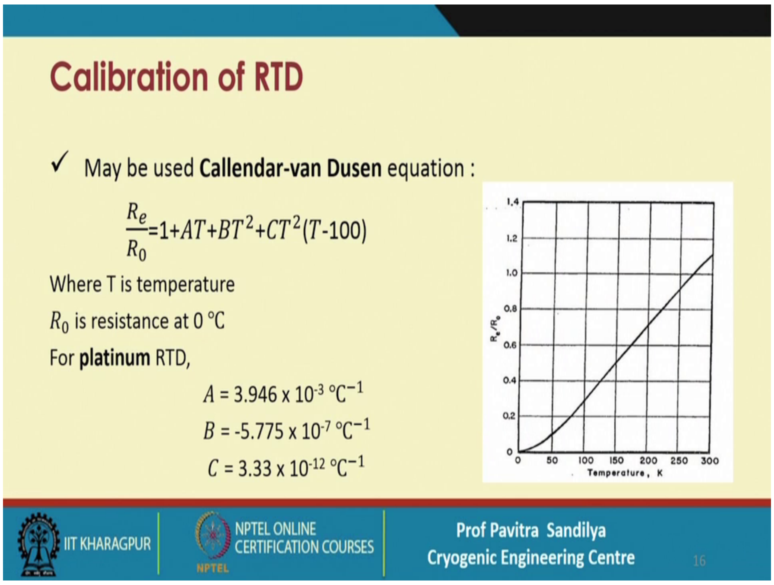

And now we go for calibration, in the calibration again we can see that we are calibrating basically the resistance with the temperature, and in case of the thermocouples we were calibrating with respect to the emf, emf and temperature here it is resistance to temperature, and this expressions very common and this is the callendar van dusen equation.

And this is for the platinum RTD this a B C values are given here. And the R 0 is resistance at 0 degree centigrade, and here we find that how the callendar van curve looks for the resistance on the y axis, and temperature on the x axis then we find; that for most part of this of our interest we find that it is linear. This is coming from a very low temperature up to about say 70 k, and going to the 300 k almost near room temperature. So, it is a for a very long range for a very low temperature also this RTD can work very well.

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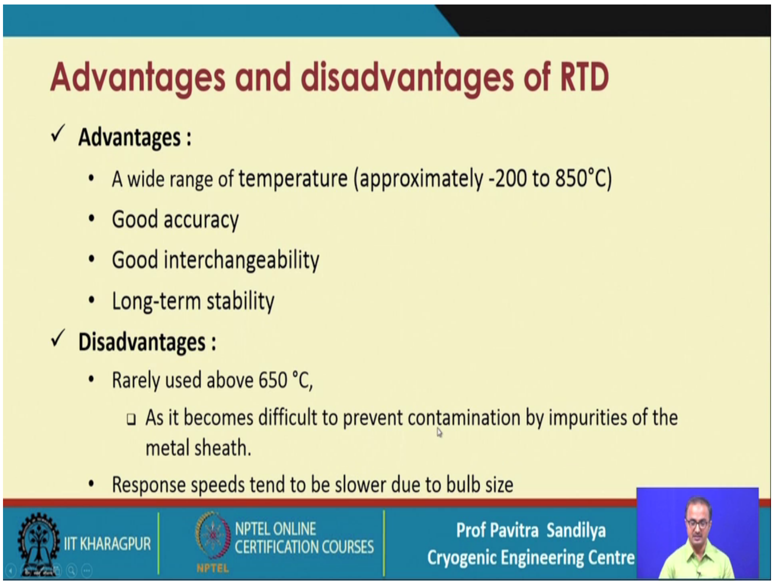

Advantages of RTD are that it can traverse a wide range of temperatures, this temperature range is not very peculate it is typical temperature range, and it, then we minus 200 means we are going in a cryogenic regime. And it has a very good accuracy very good interchangeability, and it has a longs term stability.

This advantages are that it is rarely used for a very high temperature, generally above 650 degree centigrade, because it becomes contaminated by some impurities. And it has a commendable and very good response due to a bulb size and, but the response starts decreasing with the bulb size.

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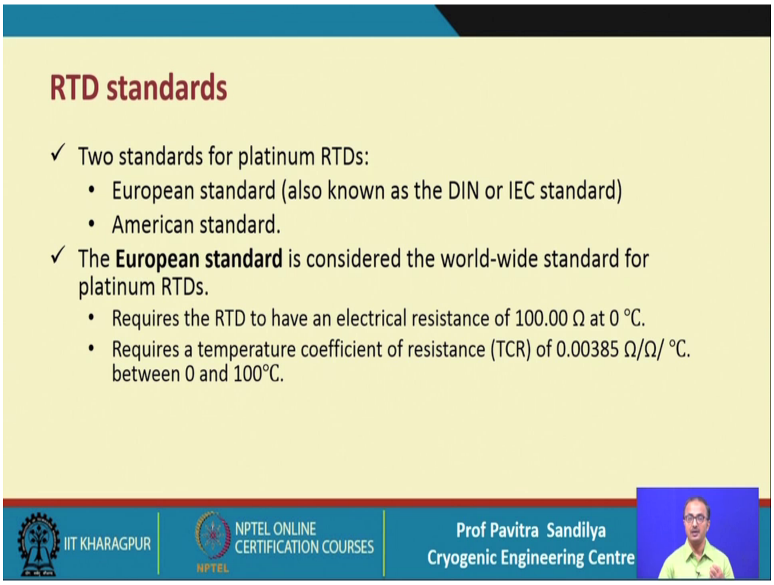

Now, the 2 standards are there for the RTD's, one is the European standard, one is the American standard, and this European standard is used in more frequently, and it requires that the RTD to have an electrical resistance of 100 ohm at 0 degree centigrade. And this is generally satisfied by a very commonly used RTD that is the platinum RTD we sometimes we call it pt 100. Pt 100 means that this particular RTD can will be showing 100-ohm resistance at 0 degree centigrade, but please understand this pt 100 is not unique there can be other pts also.

And the temperature coefficient is about this; that means, the how much we will be the resistance how much it change in resistance per unit change in the temperature.

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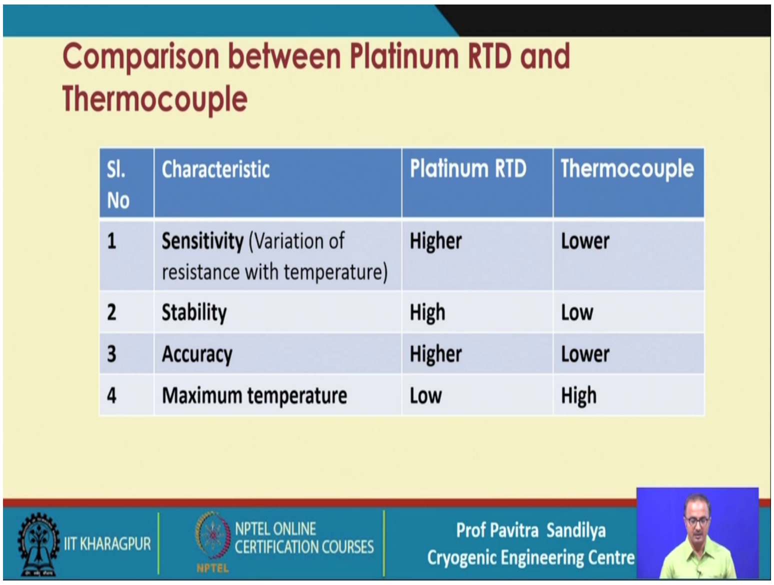

Next we have this comparison between the platinum RTD and thermocouple. We find that the sensitivity device pt RTD gives better sensitivity then the thermocouples, stability wise we get higher stability then the thermocouples in the accuracy wise we get higher accuracy then thermocouples and for maximum temperature, we find that thermocouple you can go higher temperature then the RTD.

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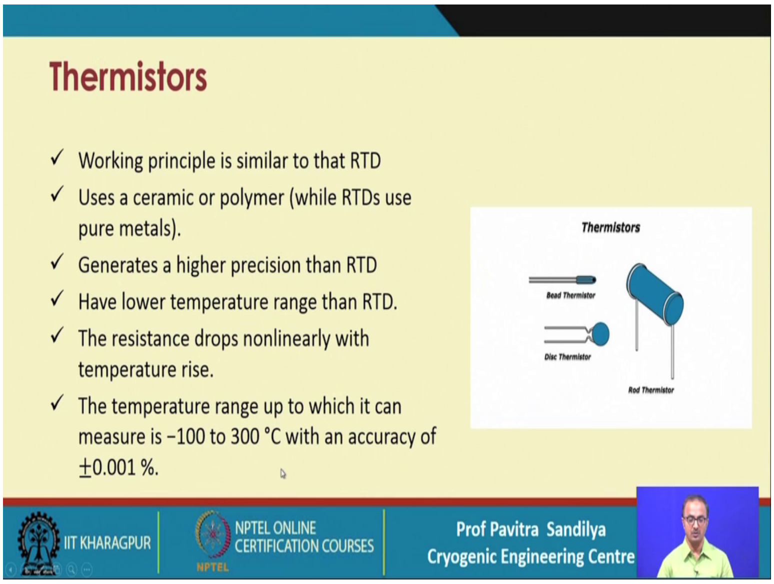

Now, lastly we shall be talking of thermistor now thermistor in principle is similar to RTD only change is that here in the thermistor we use some ceramic or polymeric material unlike RTD which is based on metallic material.

And it also gives very high precision and it works very well, but only thing is this the span of temperature with in which it works is lower than the RTD’s, that restricts is used and the resistance also drops non-linearly with temperature rise. Which is not the case with RTD, and we always try to have the device which will be as linear in it is response as possible.

So, that way RTD seems to be the best of the lord, because it gives almost a linear variation of the resistance with temperature. So, in that case, what happens that by in the calibration we can choose only 2 points to calibrate the particular sensor, but if it is non-linear then we need more standards to make the calibration curve. And this is how a typical thermistor looks like.

The temperature range is about from minus 100 to 300 degree centigrade with an accuracy of quite good accuracy 0.001 percent, the accuracy is quite good.

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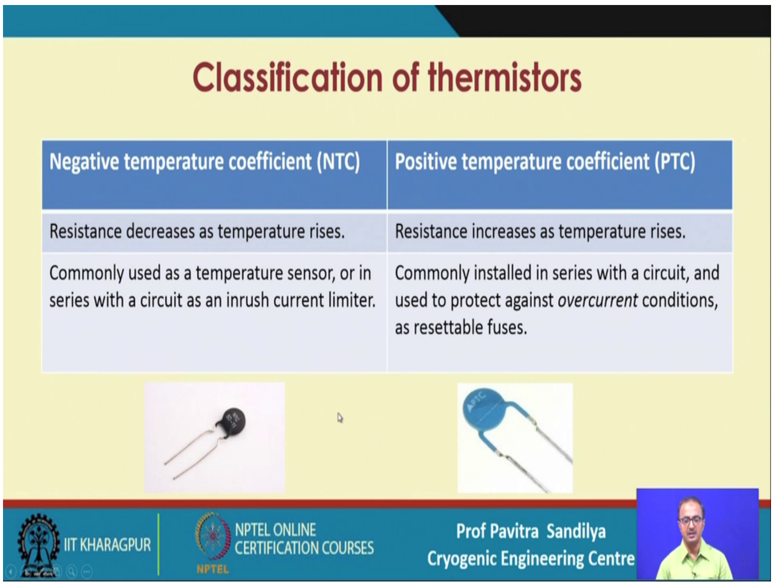

And then we have some classification of this ah thermistors, some of negative temperature coefficient and positive temperature coefficient, it is simplys tells us that whether the resistance will decrease or increase with an increasing temperature. Negative means, the slope is negative that is with increase in the temperature resistance will decrease, whereas, positive means that is increasing temperature resistance will increase.

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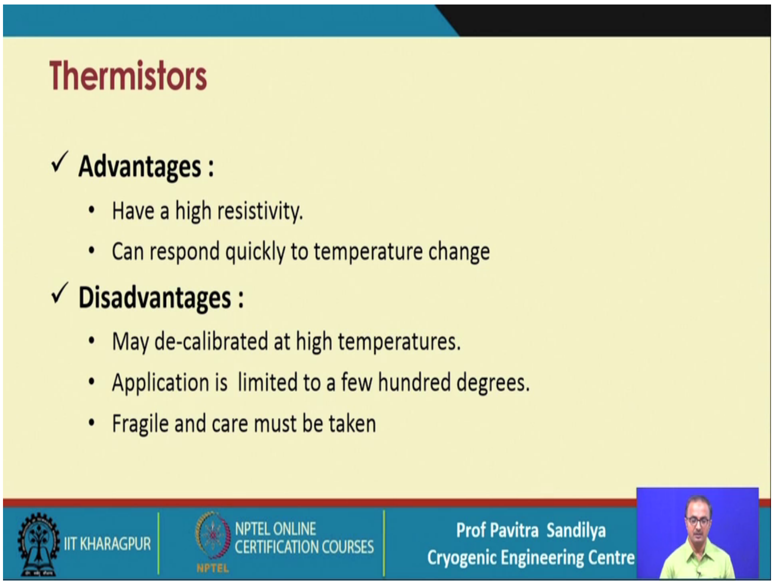

And advantages are that it has high resistivity can respond quickly to some temperature change, disadvantages are that it may be may the calibration get destroyed at high temperature, and it is application is limited by the temperature range and it is very fragile. So, that it will break easily so, we have to take more care while we handle this kind of this thermistors.

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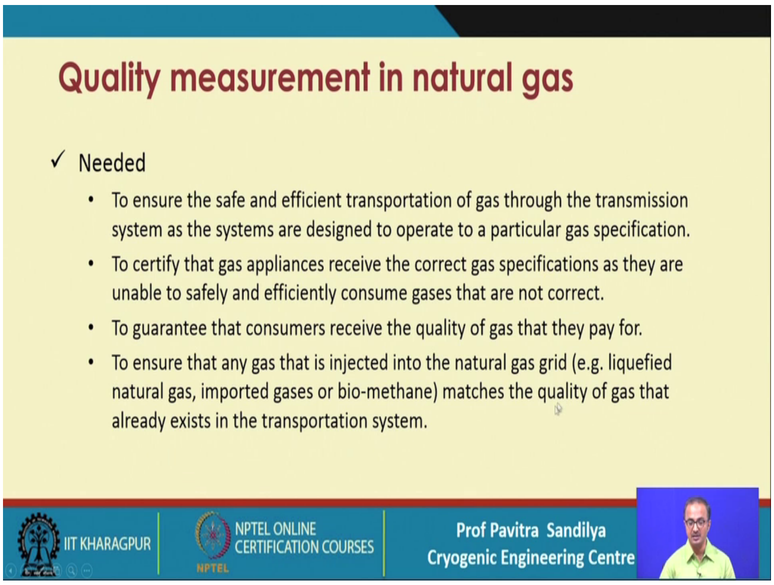

Next we come to quality measurement. Now quality measurement is needed for various results, that whenever we are supplying the natural gas, we have to see that whether the natural gas is in only vapor form or in liquid form or in mixer of that and it needed for safe and efficient transportation of gas through some translation systems to operate a particular gas specification.

Then to certify that the gas appliances receive the gas at some given configuration. And so, that the they can be handled safely. And the consumers should get the right quality of the gas for which their paying and to ensure that the gas is injected because natural gas grid with and the quality matches with the specified quality, there should go in the grid for transposition of the natural gas.

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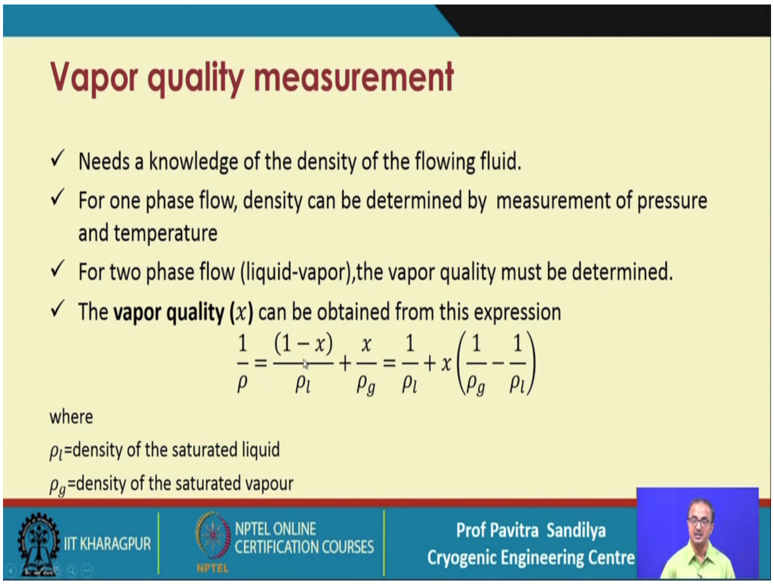

So, this quality is basically the amount of vapor and amount of liquid present in the natural gas. So, first we see that what is vapor quality, how we find the vapor quality the vapor quality ah? For this we need the information about the density of the flowing fluid, for single phase flow we know that we can calculate the density by knowing the pressure temperature from some equation of state as we learnt earlier.

But for 2 phase flow we can know the density by knowing the quality, and this is the expression to know the density of the 2 phase mixer with respect to the quality, here x is the vapor fraction that is the amount of vapor present per unit amount of the mixer, and x is the 1 minus x is therefore, the liquid fraction. So, here we are doing the 1 minus 6 by liquid density, when a vapor fraction divided by the vapor density, and this how we are able to correlate the density with the vapor fraction.

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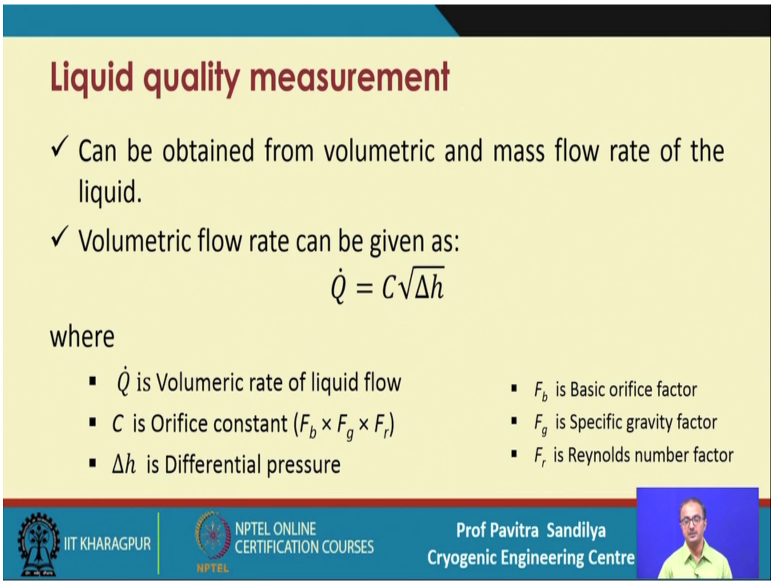

Similarly, we have liquid quality measurement, in this it is obtained from the volumetric or mass flow rate of the liquid, and volumetric flow rate is given in this way that some parameter C into the delta h delta h is the manumetric height for the pressure drop. And here we find this C is again given in terms of some kind of other parameters, and this parameters ah we know this parameters from our knowledge of the orifice meter flow rate in the earlier lecture.

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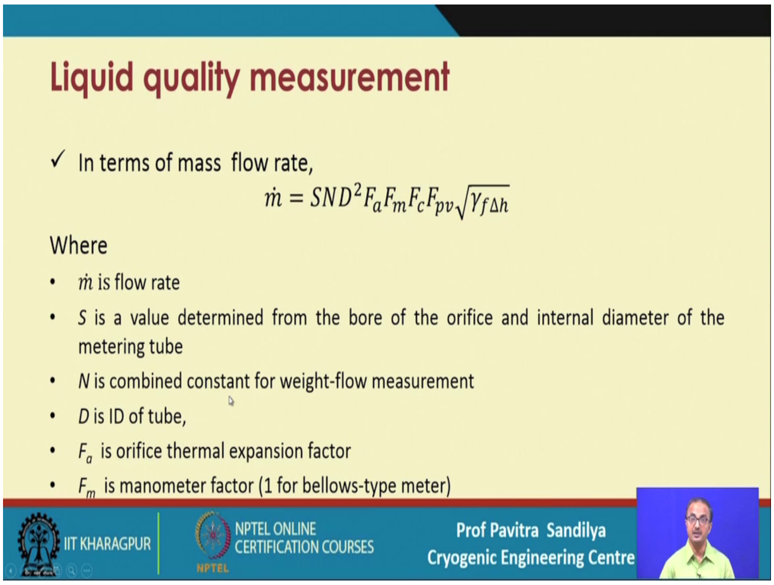

And in terms of mass flow rate we get this kind of an expression. Now in this expression the S is a value determine from the bore of orifice, and internal diameter of the metering tube, and N is a combined constant for weight flow measurement, and D is the inner diameter of the tube, and Fa are some kind of factors. Fa mm there are some kind of correction factors about which we learnt in earlier in the flow measurement for the orifices.

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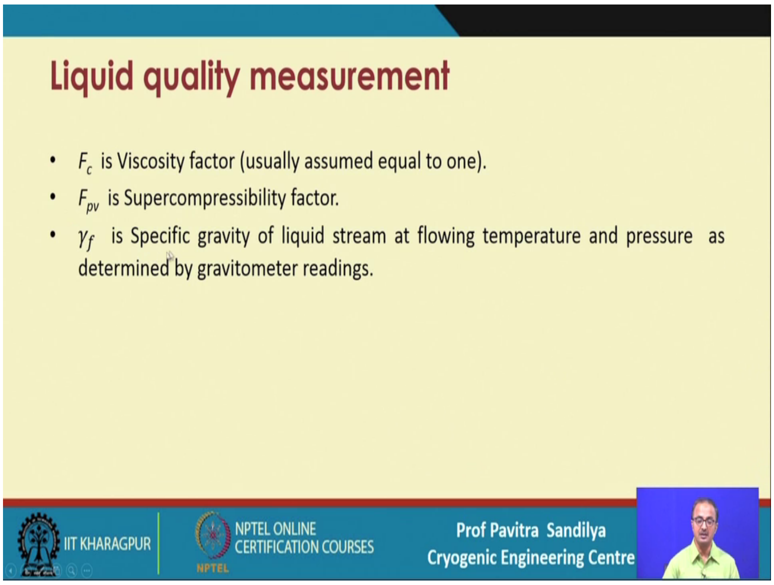

And that is why I am not going to explain this terms to you, and we also learnt how to get this values there are some tables given to find out some of these correction factors, those tables have been presented in the measurement of flow through orifice, and gamma f is the specific gravity of the liquid streams.

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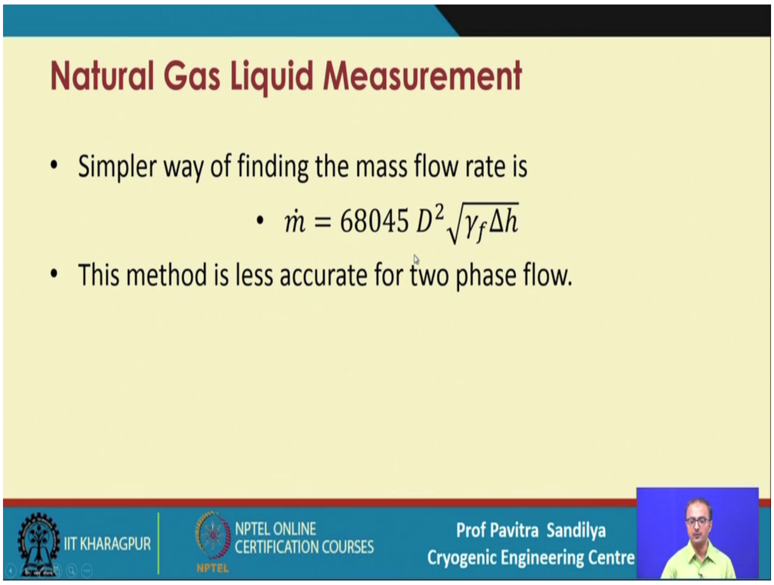

Now, here we have simpler way of finding the mass flow rate of natural gas systems, here we have some this already all this things have been obtained by fitting some experimental data, but this method is less accurate for 2 phase flow. For single phase flow, it works well but not for 2 phase flow.

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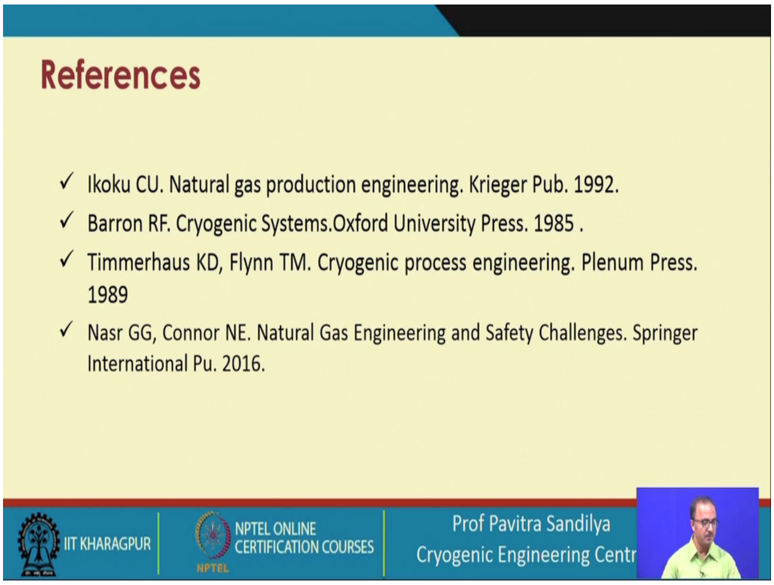

Now, these are the reference before we end I would like to show you some of these temperature measuring devices. First let us see how the one we are using this is normal thermometer, we use in our day to day life. So, we have the bulb here; here bulb and then we have the thermometric liquid which is changing it is position as per the temperature this is quite common, ok.

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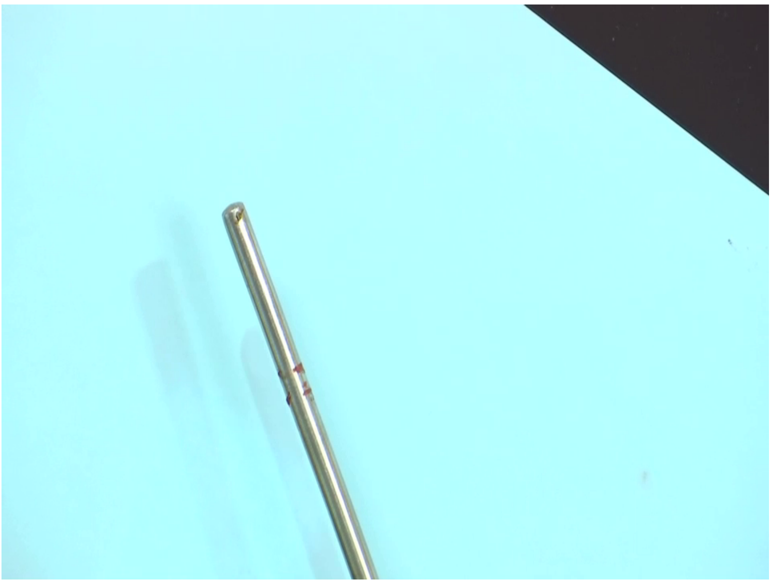

Now, let us come to the another one. This is what I shown in the thermocouple, here we cannot say what is inside, but this is how we get it from the market? And this thermocouple is there inside this particular sheath and there are some cables you can see which are joined with this read.

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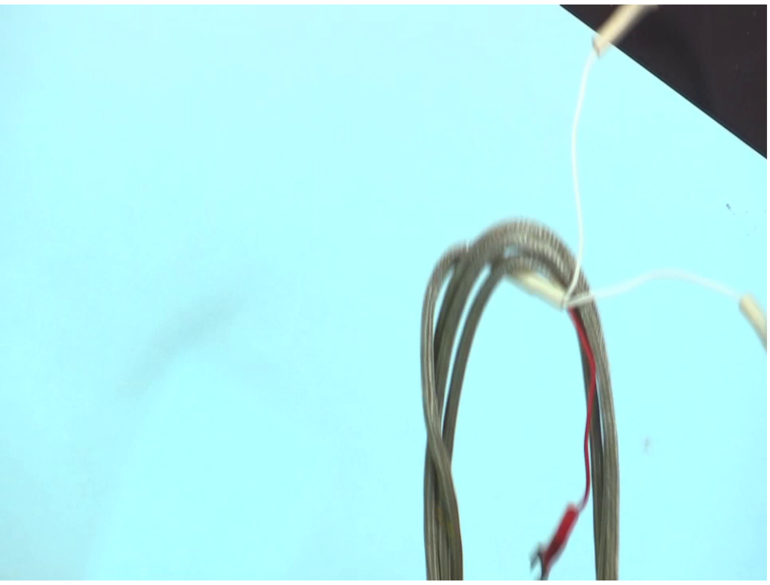

And this cables are used for the for connecting it to some data logger.

And lastly we have this ah pt 100 sensors the RTD.

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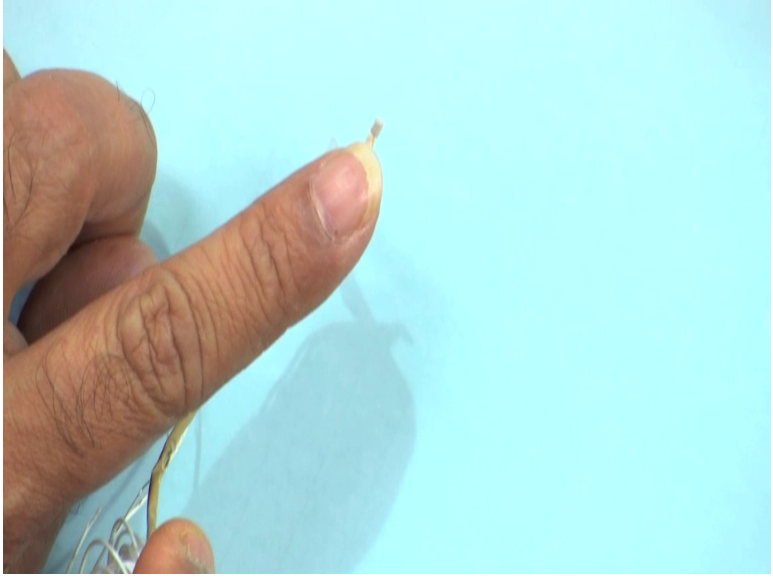

That here we find that, in this RTD we have at the tip we have this thin film. In this thin film is the one in which we have this metal that pt 100 this case metal is there inside this particular protection this is a thin film RTD. And here we find the wires which we are using along with this thing the lead wires which we use to connect it with some kind of data logger so, that is how the whole system looks like. With this we come to the end of the lectures.

Thank you.