Chemical Process Instrumentation
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Lecture – 39
Temperature Measurement (Contd.)

Welcome to lecture 39 we are talking about temperature measuring instruments. In our previous lecture we have talked about RTD which is based on changes in resistance with change in temperature. So, we will talk about another instrument which work on the same principle and this is known as thermistor.

So, both RTD and thermistor work on the principle that the resistance of an resistance element will change with change in temperature in a reproducible manner. So, by measuring the change in resistance it will be possible to relate temperature with the change in resistance and the change in resistance can be easily measured using a Wheatstone bridge.

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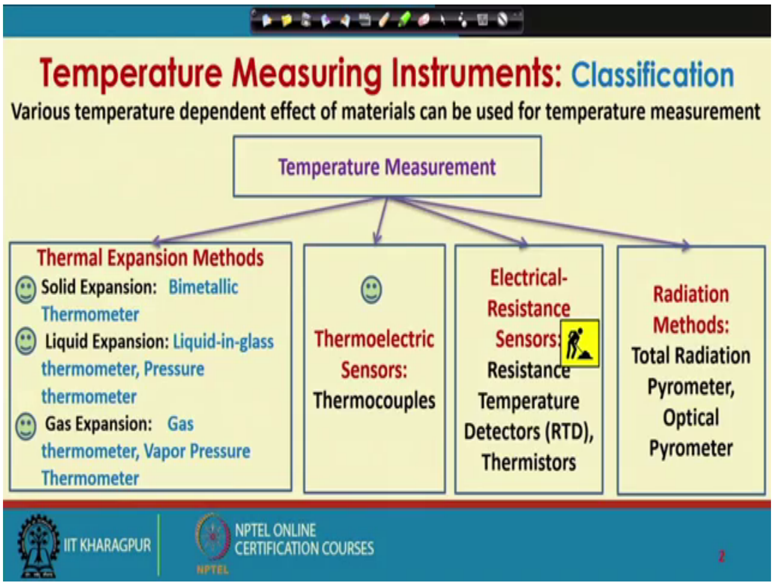

So, we have talked about thermal expansion methods complete, thermoelectric sensors thermocouples have talked about and resistance temperature device or RTD. We talked about in previous class and now we will talk about thermistors.

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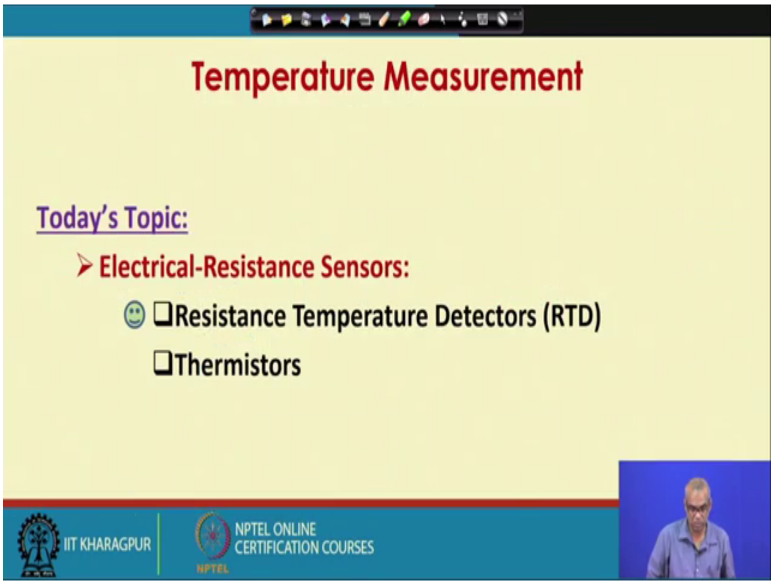

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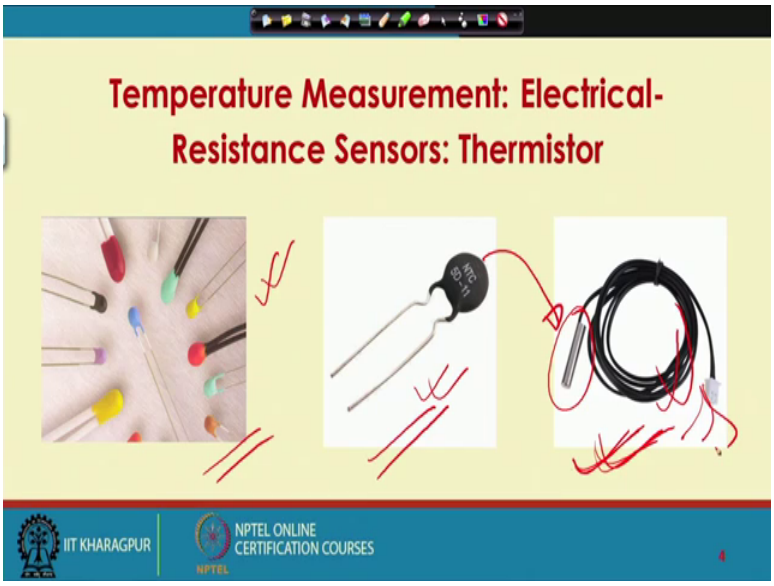

So, today's topic is Thermistor. So, what you see is some images of thermistors may come in several colors. This is also a thermistor is written as NTC. So, we will see what NTC stand for now very much.

Similar to RTD like you have seen in your previous class that RTD is nothing but a resistance element. It may be a wire or it may be a thin film. So, essentially a wire or a thin film which work as a resistance element exactly similar to this we also have thermistor which is nothing but a resistance element.

RTD was made of metals; thermistors are made of semiconductor materials. So, their material of construction is different, RTD was made of metals and the alpha value. There is a temperature coefficient was positive because it is positive for metals, but for semiconductor materials the temperature coefficient is negative. So, they are known as negative temperature coefficient resistance element or negative temperature coefficient thermistor so that is NTC

Also PTC is also possible positive temperature coefficient thermistor, but commonly we will have negative temperature coefficient thermistor. So, now what you see here are the images of thermistors.

But if you look at thermistor in lab or industry what do you see is this a term a temperature measuring instrument based on thermistor if you look at you will see this. So, this is the protective case and this is there inside this this or similar resistance element and this is the extension leads.

So, basically from outside it may not be very easy to find whether this one is RTD or thermistor. Because the protective casing may look identical yes, but if it is the three wire connection, if it is a three wire RTD connection then I will see three wires are coming out if it is 2 wire connection only 2 wire will come out..

Thermistor generally 2 wires will come out. So, a 2 wire RTD and a 2 wire thermistor it would not be possible to figure out which 1 is what just by looking at that. So, we need to read the label it will be written whether this is a thermistor or whether it is RTD. Whenever you look at instrument always try to read the label manufacturer supplies several important informations in the level.

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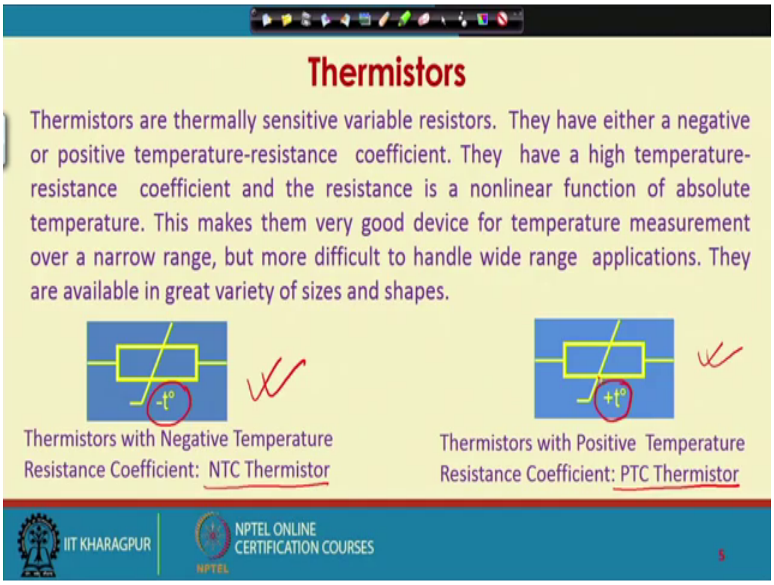

So, thermistors are thermally sensitive variable resistors. They have either a negative or positive temperature resistance coefficient. They have a high temperature resistance coefficient and the resistance is a non-linear function of absolute temperature. This makes the very good device for temperature measurement over a narrow range, but more difficult to handle wide range applications. They are available in great variety of sizes and shapes..

So, this is how we indicate thermistors with negative temperature resistance coefficient. In short we call NTC thermistor and this is how we indicate thermistors with positive temperature resistance coefficient in brief we call PTC thermistor.

Note that the difference lies here minus T degree and plus T degree; plus T degree stands for PTC thermistor or positive temperature resistance coefficient thermistor and minus T degree stand for negative temperature resistance coefficient thermistor or NTC thermistor.

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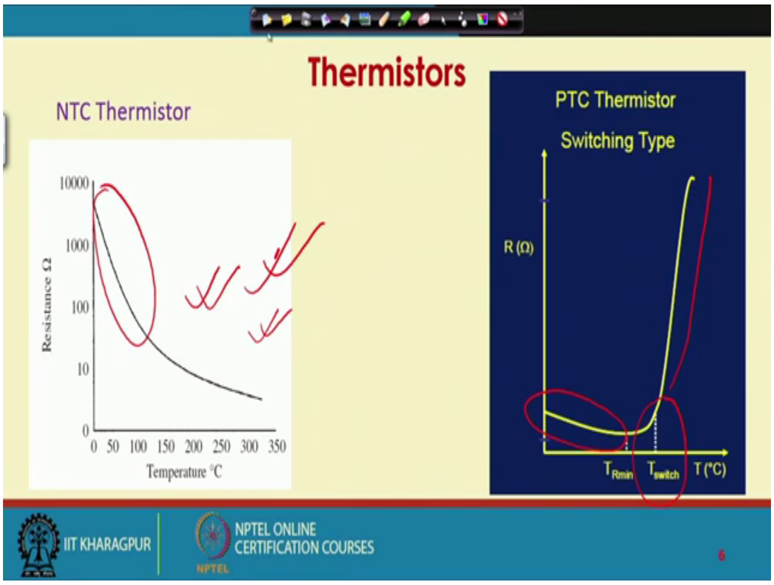

So, this is schematically shown how resistance changes with increase in temperature for NTC thermistor? For RTD, we have seen how the resistance increases with increase in temperature for platinum, nickel, tungsten etcetera. In case of NTC thermistor resistance decreases with increase in temperature and this is highly non-linear relationship and you see the resistance rapidly falls. The resistance rapidly falls for small increase in temperature. So, the instrument become very sensitive, but is highly non-linear. So, calibration will be very very non-linear.

However PTC thermistor for positive temperature with coefficient thermistor is also available. Here you will see that initially the resistance decreases with increase in temperature similar to NTC thermistors, but then there is a temperature which we call switch temperature there. After that switching temperature with increase in temperature the resistance increases similar to platinum, nickel etcetera. So, these are switching type thermistors.

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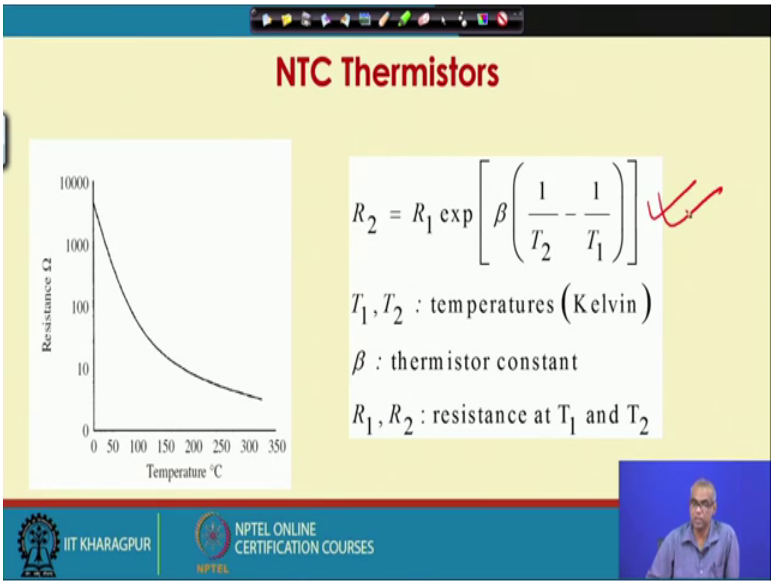

This is a relationship which tells us how the resistance will change with change in temperature for NTC thermistor. You can see the temp relationship is highly non-linear R 2 equal to R 1 into e to the power beta into 1 by T 2 minus 1 by T 1; T 1 T 2 are temperatures expressed in absolute scale. Beta is thermistor constant and R 1, R 2 are resistances is at temperature T 1 and temperature T 2 respectively,

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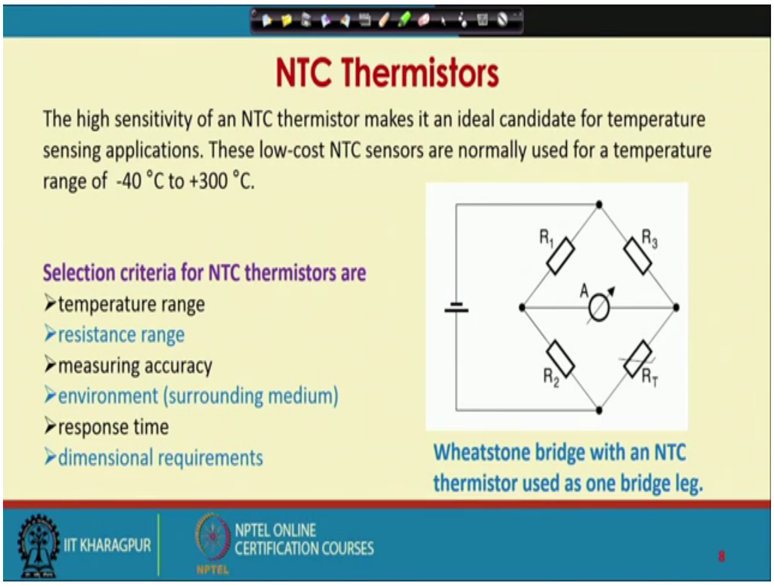

The high sensitivity of an NTC thermistor makes it an ideal candidate for temperature sensing applications. These low-cost NTC sensors and normally used for a temperature range of minus 40 degree Celsius to 300 degree Celsius. Please note that the temperature range is not very great, but in this temperature range the thermistors are extremely sensitive instruments and also it is low cost inexpensive because these are made of inexpensive semiconductor materials.

Another important aspect is that they come in various sizes and shapes. So, the selection criteria for NTC thermistors are temperature range, resistance range, measuring accuracy, environment, or the surrounding medium, response time and dimensional requirements. So, these are the factors which will govern the selection of NTC thermistor.

What is the range over which the temperature is vary? What is the resistance range? What accuracy is required? What kind of environment in which you have to perform the temperature measurement? What is the response time and what is the dimensional requirement. So, the change in resistance of NTC can be measured as usual by Wheatstone bridge principal. So, here the NTC thermistor is used as 1 leg of the Wheatstone bridge.

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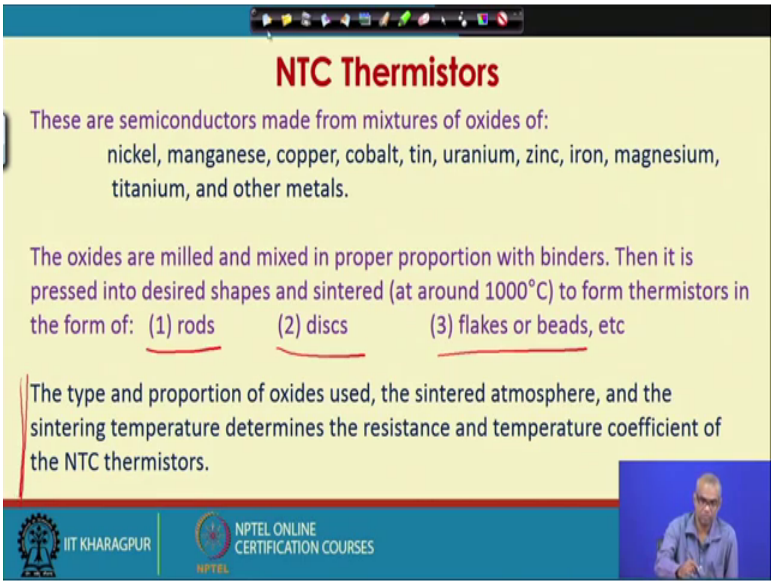

Now, the NTC thermistors are made from semiconductor materials. So, NTC thermistors are basically semiconductors and they are made from mixtures of oxides of nickel, manganese, copper, cobalt, tin, uranium, zinc, iron, magnesium, titanium and other metals. So, they are made from mixtures of several of oxides such as nickel, oxides of nickel, manganese, copper, cobalt, tin, uranium, zinc, iron, magnesium, titanium and other metals.

The oxides are milled and mixed in proper proportion with binders then it is pressed into desired shapes and sintered at around 1000 degree Celsius to form thermistors in the form of rod, disc, flakes or beads. So, these are the common shapes. So, as you see the materials it is made from are oxides or nickel, manganese etcetera. So, they are all in a made from inexpensive materials. So, these oxides are mixed in various proportions they are milled and mixed in various proportions and they are also mixed with binders and then it is pressed to get different shapes the shapes commonly are rods, disc, flakes or beads etcetera.

The type and proportion of oxides used the sintered atmosphere and the sintering temperature determines the resistance and temperature coefficient of the NTC thermistors. So, this is important.

The type and proportion of oxides use the sintered atmosphere and the sintering temperature determines the resistance and temperature coefficient of the NTC thermistors. So, these are two important variable for the thermistor.

One is the resistance of the element and the temperature coefficient and you can have a control on these two variables by changing the proportions of oxides sintering atmosphere, and the sintering temperature.

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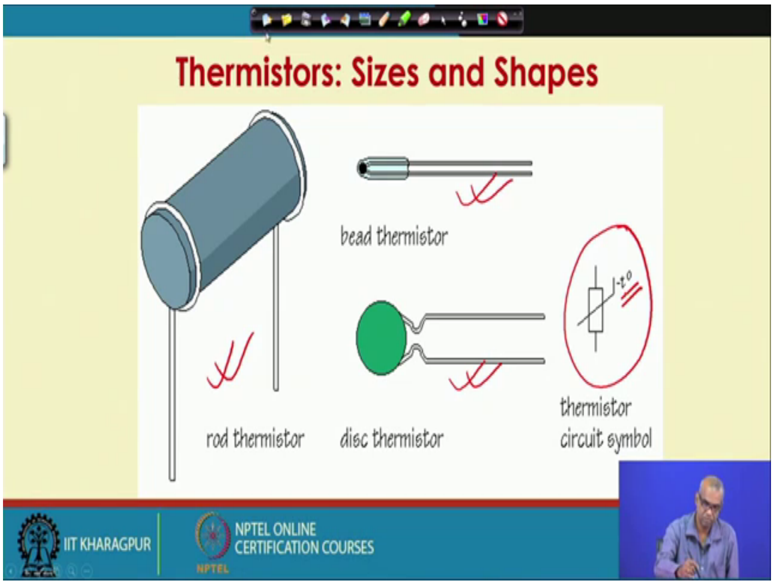

So, this shows various sizes and shapes thermistors. So, rod type disc type and bead type we have seen this is the symbol for thermistor and as it is minus T degree. So, this is a NTC.

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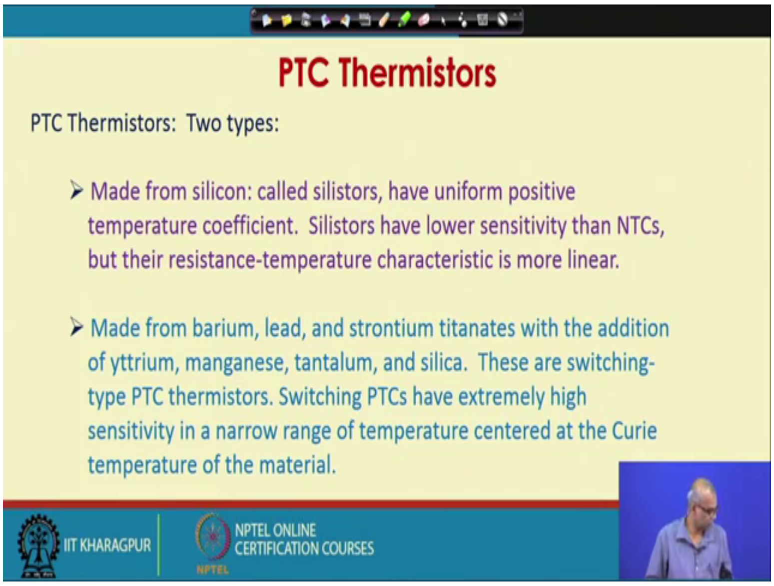

PTC thermistors are of two types made from silicon. They are called silistors have uniform positive temperature coefficient. Silistors have lower sensitivity than NTCs, but their resistance temperature characteristic is more linear. So, thermistors made from silicon known as silistors have uniform positive temperature coefficient.

The other type made from barium, lead, and strontium titanates with the addition of yttrium, manganese, tantalum, and silica. These are switching type PTC thermistors. Switching PTCs have extremely high sensitivity in a narrow range of temperature centred at the Curie temperature of the material.

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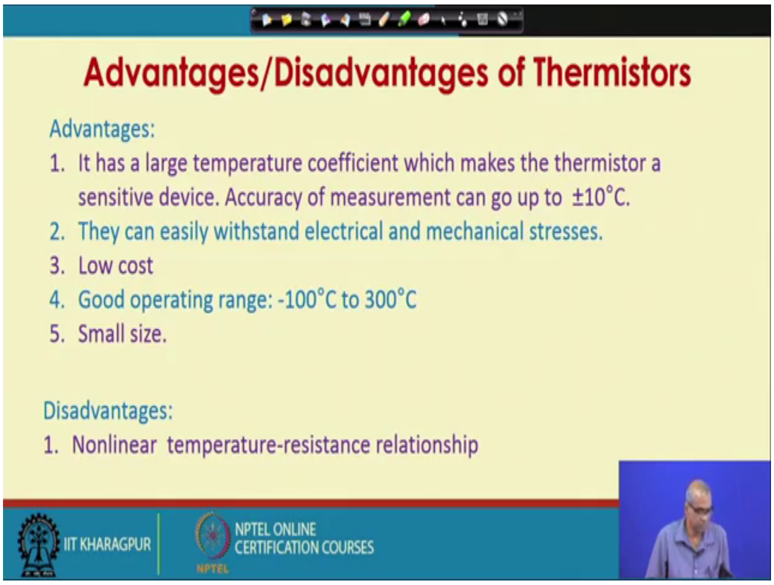

The PTC thermistors finds applications in self regulated heaters, overload protections, and also in introducing delays. Here are some advantages and disadvantages of thermistors. The advantages of thermistors have large temperature coefficient which makes the thermistor a sensitive device. Accuracy of measurement can go up to 10 degree Celsius plus minus 10 degree Celsius. They can easily withstand electrical and mechanical stresses, low cost, good operating range minus 100 to 300 degree Celsius of course, not as large as thermocouples or even RTD has much higher range.

Another advantage of thermistors is they can have small size. Small size further adds to improved sensitivity. Disadvantages mainly the temperature resistance relationship is non-linear. So, the calibration is highly non-linear.

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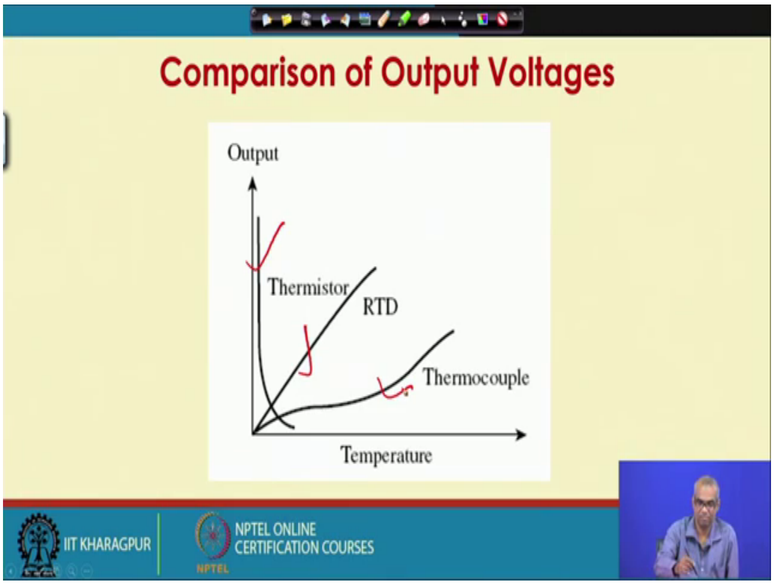

This shows a comparison among the output voltages from thermistor, RTD, and thermocouple. Among these you see that RTD is most linear.

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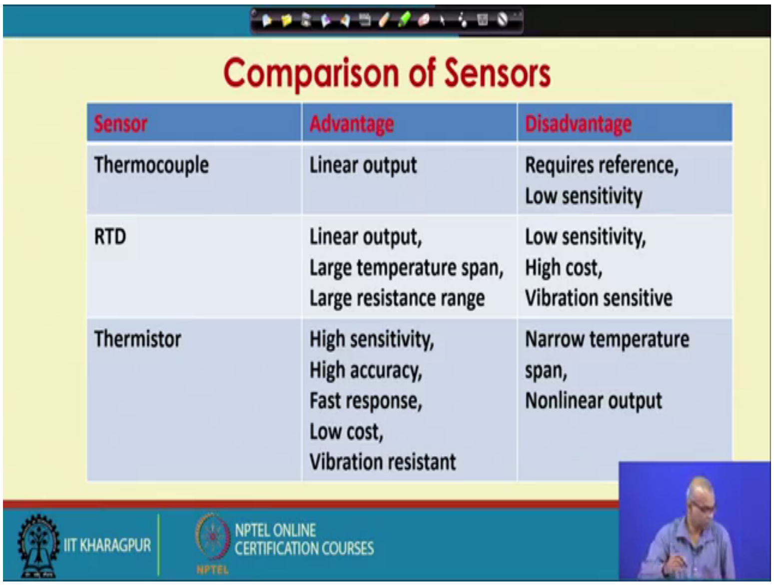

Finally we will put some comparison of various sensors and summarize their advantages and then disadvantages. Thermocouples has linear output it requires reference and has low sensitivity. RTD output is linear, large temperature span, large resistance range. Disadvantage low sensitivity, low cost, and vibration sensitive.

Thermistors advantages are high sensitivity, high accuracy, fast response, low cost, vibration resistive. Disadvantage narrow temperature span compare to other and output is non-linear. Next I want to show you a bimetallic thermometer, a thermocouple, a RTD, and a thermistor.

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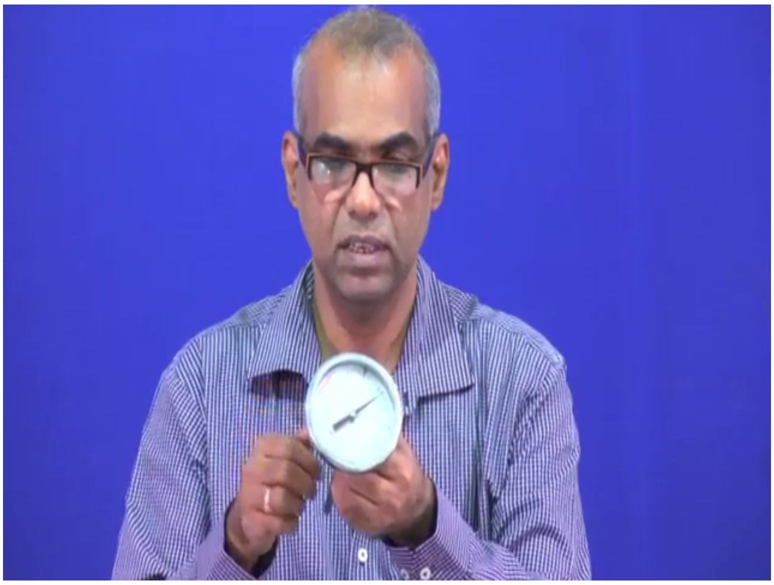

So, let me first show you a bimetallic thermometer. So, this is a bimetallic thermometer. So, what you see is this is the dial. So, this is the dial you can see the pointer and scale. So, the scale will be calibrated directly in terms of temperature units. And you see this is the protective case inside there is a bimetallic strip. In fact, most likely there will be a helical coil made of a bimetallic strip. So, this is completely encapsulated. So, this will be inserted to the medium temperature and measuring.

So, this end of the bimetallic strip is rigid inside the protective case, and the other end of the bimetallic strip is connected to this pointer through some here and linking mechanism inside. So, when this part goes to the medium temperature and measuring, the bimetallic strip this is the temperature shows the deflection which will cause the movement of this pointer against the scale and you can have a direct reading of the temperature.

You can see this scale is 0 to 100 degree Celsius. So, by so this bimetallic strip so this bimetallic thermometer will measure temperature from 0 degree Celsius to 100 degree Celsius.

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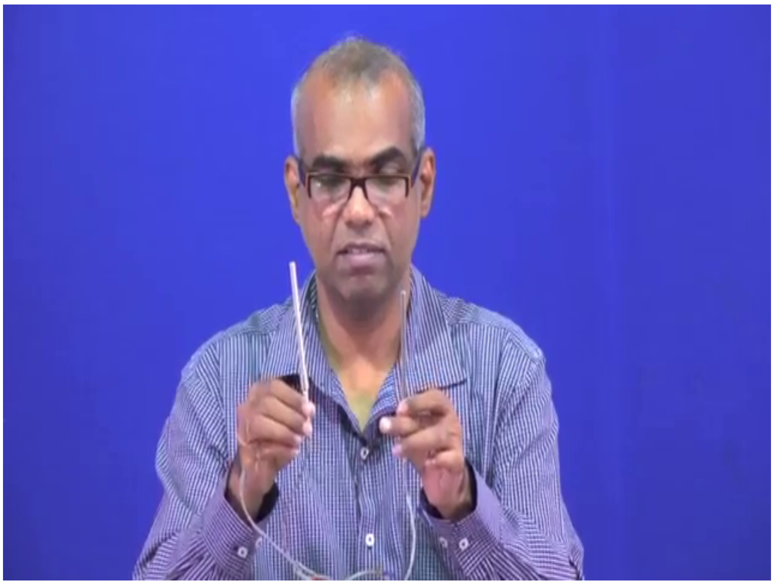

So, from ice water to boiling water so next let us come to electrical Method of temperature measurement and what you see now is a thermocouple. So, you see two identical protective cases. So, you have we have already seen that the thermocouple is made of two dissimilar metals and they are joined end to end to form two joints or two junctions. One we call cold junction or reference junction and the other one we call hot junction or measuring junction.

So, one of them is hot junction or measuring junction, another on is cold junction or reference junction. So, I can let us say this is the cold junction or reference junction I can put this into ice water or known 0 degree Celsius and can put this to the medium of temperature and measuring..

And this will be these are the extension leads which will be connected to the a millivoltmeter. So, millivoltmeter that is output from the thermocouple that reading has to be compare from the therm from the thermocouple EMF table. You now look at the thermocouple emf table and see the output of the millivoltmeter corresponds to what temperature..

So, you are already putting this into 0 degree Celsius so no correction is needed. If it is not put to 0 degrees Celsius but some other temperature then a correction is needed.

So, what correction will be added? The EMF that will be produced when the two junctions are kept at the reference temperature you are talking about now and the 0 degree Celsius. So, this is a thermocouple. So, thermocouple remember will have always 2 such elements. So, inside these two protective cases they are at two joints; one is hot junction or measuring junction, another cold junction or reference junction. So, next I will show you this.

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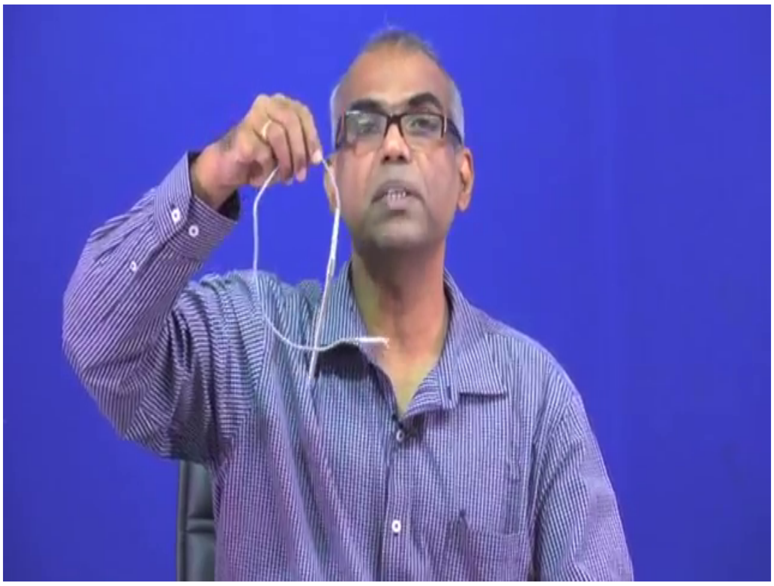

This is another temperature measuring instrument again electrical methods and this was thermocouple. So, you cannot find out any difference at all. Now you see here I have three wires coming out so 2 red, sorry 2 white, and 1 red. So, three lead wires are coming out from this device. So, this is a resistance temperature device this is a three wire RTD this is a three way RTD. So, inside you have a resistance element let us say a platinum wire wound around some select some say glass supported ceramic support and then this three wires shows tells me that this is a three wire RTD.

Finally I will show you exactly another one in look, but this is a thermistor, this is a thermistor. So first it was thermocouple this thermocouple is actually k type thermocouple. So, this thermocouple is k type thermocouple and you know the k type thermocouple is chromel alumel thermocouple. So, you have a chromel metal you have an alumel metal and they have made 2 junctions. So, there is one chromel alumel junction here..

There is another chromel alumel junction here. So, in these two protective cases they are at two junctions which you have formed by joining a chromel and and alumel and this three wire RTD is basically a Pt 100 RTD.

This is a pt 100 RTD. So, if I put this into ice water mixture or 0 degree Celsius water or 0 degree Celsius source the resistance that we will measure here is 100 ohm. So, this is a Pt 100 RTD. So, with this we stop our discussion on thermistors.

So, as of now we have talked about temperature measuring instrument based on principle of thermal expansion of material, then we have talked about thermocouples which is based on thermoelectric principles, then we have talked about thermistor and RTD which are based on the variation in resistance with change in temperature.

So, in the next class we will conclude our discussion on temperature by after discussing temperature measuring instrument based on radiation principles.