Experimental Methods in Fluid Mechanics

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Lecture 24 - Ideal Gas Thermometer, Temperature Measurement by Mechanical and Electrical Effects Contd.

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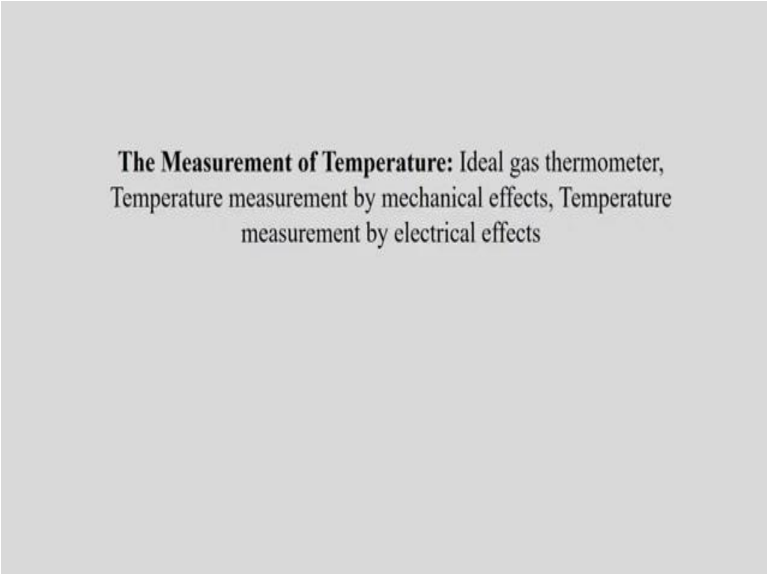

Good afternoon! I welcome you to this session of Experimental Methods in Fluid Mechanics and in continuation of my discussion on the measurement of temperature, today we will discuss that how we can measure temperature, exploiting electrical effects.

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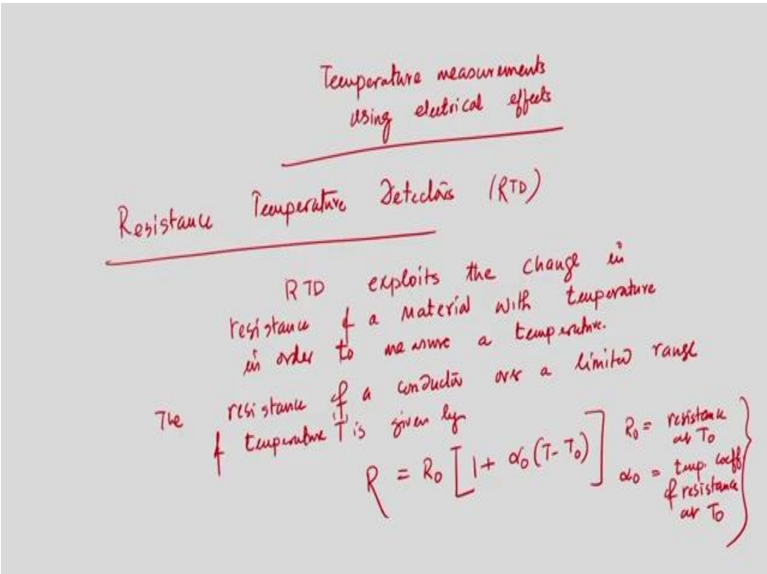

So to start with, we will see that, that is temperature measurement using electrical effects, so that is what would like to know that and to know the measurement technique of temperature using electrical effect, we should discuss the resistance temperature detectors, so, that is resistance temperature detectors or RTD in short. So, the resistance temperature detectors basically they exploit the change in resistance of the material with temperature to detect the temperature difference.

So, the principle of measuring temperature using electrical effect is to exploit the change in resistance of the material with temperature. And from there we can measure what will be the temperature. So I can write that the RTD exploits the, I can say change in resistance of a material with temperature in order to measure a temperature. So, we know that the resistance of a conductor over a limited range of temperature, say T is given by R is equal to R naught, 1 plus alpha naught T minus T naught.

So, this is what we know it is known that the resistance of a conductor for the limited range of temperature can, is given by this expression where we know that R naught is the resistance at temperature T naught and alpha naught is the temperature coefficient of resistance at T naught. So, this is what we know, we should know, if we now try to exploit the change in resistance with a temperature then how we can measure the temperature that is our objective, that is what is our objective.

Now, the variation of the resistance that is very important of a temperature which we can, I can say approximate with a quadratic polynomial with the experimental determined coefficient. The RTD the resistance temperature detectors we need to calibrate, but, as I said that the resistance of a material of course, rather I can say the resistance the variation of the resistance with the temperature or with the temperature can be approximated over the wide temperature range with a quadratic polynomial with the experimental determined coefficients.

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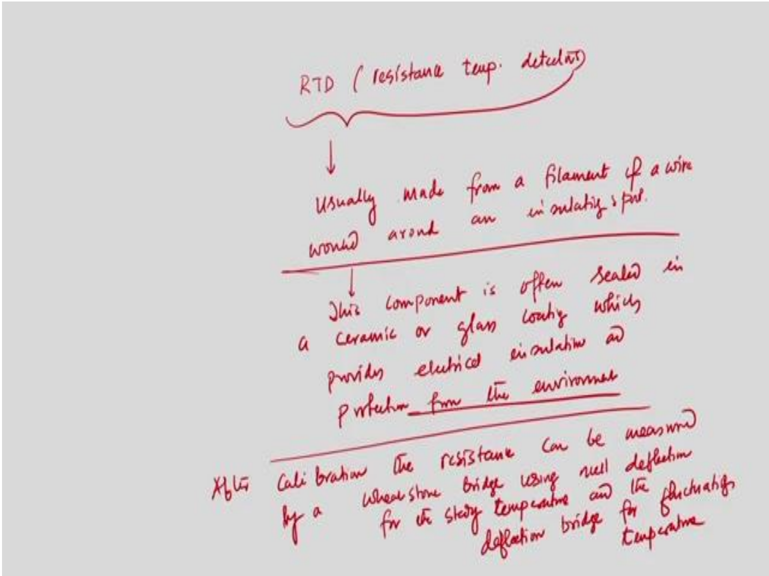

Now the resistance temperature detector we will discuss with the schematic again, this RTD that is resistance temperature detectors. These are usually made of filament of made from a wire wound around an insulating spool. So the RTD which is made from a filament of a wire wound around an insulating spool and this component which is important to know, this component is often sealed in a ceramic or glass coating, which provides electrical insulation. This is important, electrical insulations and protection from the environment.

Now, after calibration resistance can be measured by Wheatstone bridge using null deflection for the steady temperature and Deflection Bridge for the fluctuating temperature. So, the RTD which is easily made from filament of a wire, the component is very often sealed in a ceramic or glass coating which provides electrical insulation also protect from the environment and after calibration we can place this in a Wheatstone bridge using null deflection, of course for the steady current for the steady temperature and the deflection bridge for fluctuating temperature.

So, this is important to know that after calibration the resistance can be measured by Wheatstone bridge using null deflection, of course for the steady resistance, for the steady temperature and the deflection bridge for fluctuating temperature. So, if the temperature is steady or if the temperature is fluctuating, we can still measure the temperature we can measure using this RTD of course, we need to place them in a Wheatstone bridge of either using null deflection or Deflection Bridge.

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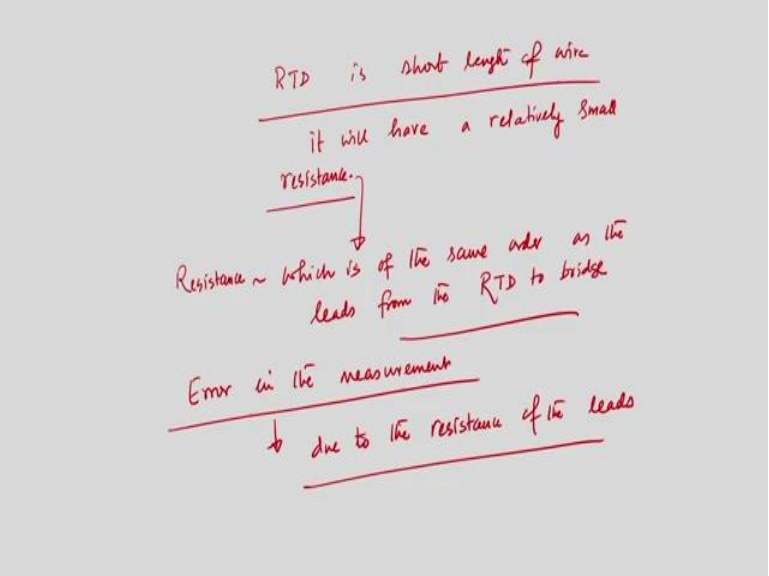

Before we need to know, before we go to discuss about the measurement principle, we need to know that the RTD this resistance temperature detectors basically, is a short length of wire and I cannot say that it will have zero distance but it will have relatively small resistance and the small resistance, this resistance, which is the resistance which is of the order of which is of the same order as the leads from the RTD to bridge. Since we cannot ignore the RTD, also is a short length of wire, but it will still have a very small resistance and which is of the order, which is of the same order as the leads from the RTD to bridge, but, although the resistance is very small rather the lead resistance which leads to error in the measurement of the temperature.

So, the RTD temperature measurements the resistance of the leads creates a special problem and because this will measure the temperature if you would like, rather we are measuring temperature, but the resistance of the leads, which is not 0, but it will, either underestimate or overestimate the measurement. If I can say now that there are but, so, there will be error in the measurement and this error will be due to the resistance of the leads. So, this will lead to error in the measurement. Now, we need to know different scheme rather different wiring scheme by how we can eliminate, we cannot eliminate, but we can reduce the error.

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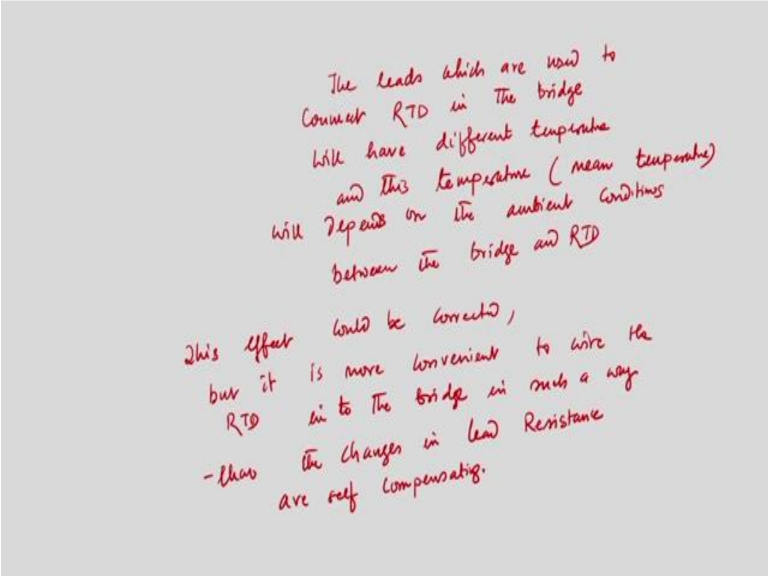

But before that, at least we should know that the leads which are used to connect RTD in the bridge will have different temperature and this temperature I can say the mean temperature will depend on the ambient condition between the bridge and RTD. So, that means RTD when we are placing RTD in the Wheatstone bridge, we need to connect through the leads, but leads will have different temperature, leads will have resistance and that resistance is also I mean equal to the resistance of the RTD. But the leads will have different temperature and this temperature of course, we can say mean temperature, that will depend the ambient condition between the bridge and the RTD.

So, we need to measure whether we are trying to measure temperature using RTD and if the leads between which is there in between the bridge and RTD is having different temperature then there will be error in the measurement and this effect could be corrected but it is more convenient to wire the RTD into the bridge in such a way that the changes in lead resistance are self-compensating. So, what we can say that RTD is placed or connected in the bridge through leads. If the lead is, the resistance of the lead is similar to the same order of the RTD. But, the leads which are used to connect RTD in the bridge will have different temperatures, different wind temperatures that will depend upon the ambient conditions between the bridge and RTD. But, if this is the case then there will be error in the measurements.

So, the effect could be corrected, but it is more convenient to wire the RTD into the bridge in such a way that the change in lead distance are self-compensating. So, that means, the resistance the change, the changes in the lead resistance are self-compensating, so that the correction is not required. So, important clue is that we need to connect, we need to wire

RTD in such a way that the changes in the lead resistance are self-compensating. So, we need not to go for the different correction scheme. So, based on this the wiring scheme of the RTD have been developed essentially to eliminate the error due to lead resistance changes.

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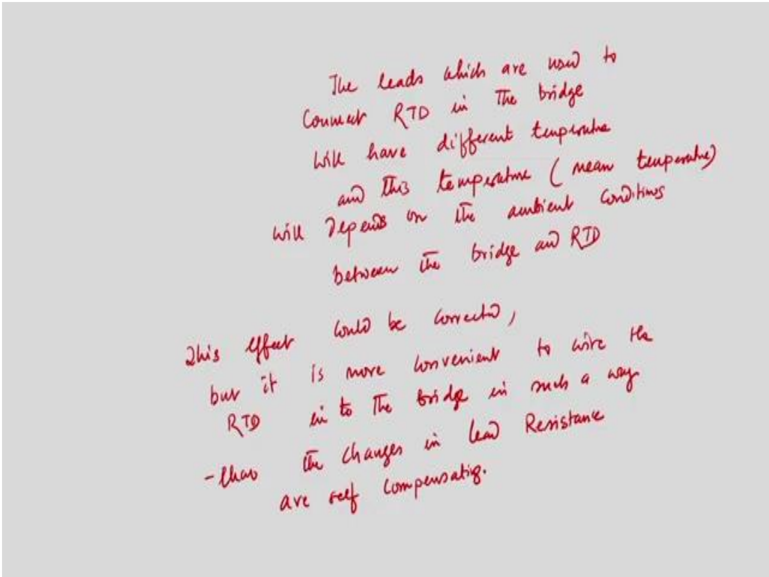

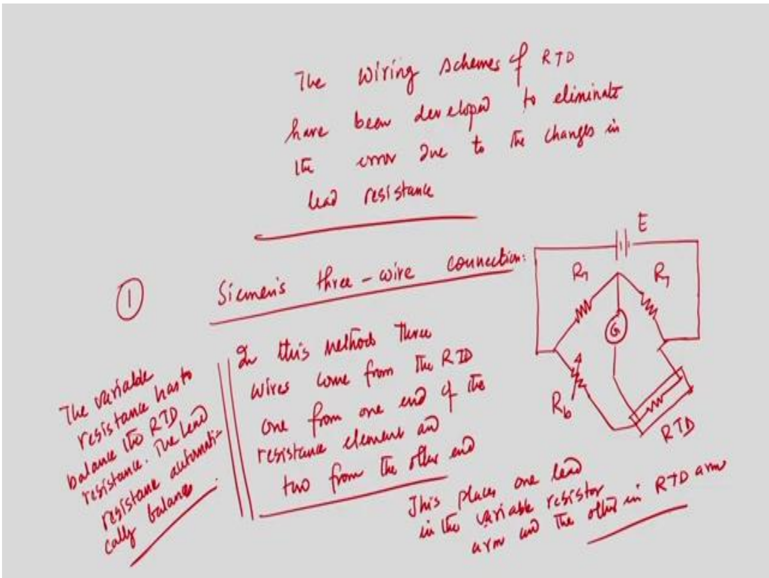

So, we can say that the wiring scheme of RTD, schemes of RTD have been developed to eliminate the error due to the changes in lead resistance. So, that means we have understood that the RTD which you need to place in the Wheatstone bridge through leads, leads will definitely have resistance but depending upon the ambient conditions of the wires of the RTD and bridge, lead will have different temperature and this will lead to error in the measurement techniques.

So, the error can be corrected, but it is more convenient to, that is what I have written in the last slide it is more convenient to wire the RTD to select the scheme of wiring of the RTD to the bridge in such a way that the changes in the lead resistance are self-compensating. So, there are three different, one is known as, there are three different schemes, one is known as Siemens three-wire scheme or I can say three-wire connection. In this method so, let me draw the schematic first then from there we will show, so this is E, this is RT, this is RT. This is RB and this is this is RTD. This is RTD, so this is the schematic.

This is called three-wire connection. So in this method, three wires come from the RTD, one from one end, resistance element and two from the other end. So, these places, this is a schematic. What you can see, in this method 3 wires, so we can see that the resistance element RTD at two ends. So two wires I mean are coming. Three wires are coming, two from one end while one is from other end. So these places one lead in the variable register arm that is RB, variable register arm that is RB and the other in RTD arm. So, what you can see, there are three, one lead in the variable resistance arm and other in the RTD arm.

Now, so one lead is in the variable register arm and of course, other in the RTD arms. So, the what you can see in this case importantly, the variable resistance only has to balance the RTD resistance, lead resistance automatically balances. So, the variable resistance has to balance the RTD resistance, the lead resistance balance automatically, automatically balances. So, this is the scheme. So this is known as Siemen's 3 wire connection. Ultimately, what we need to know that we need to know the error due to changes in lead resistance we need to eliminate, so that will automatically balance, that is the objective. So, there are different wiring scheme.

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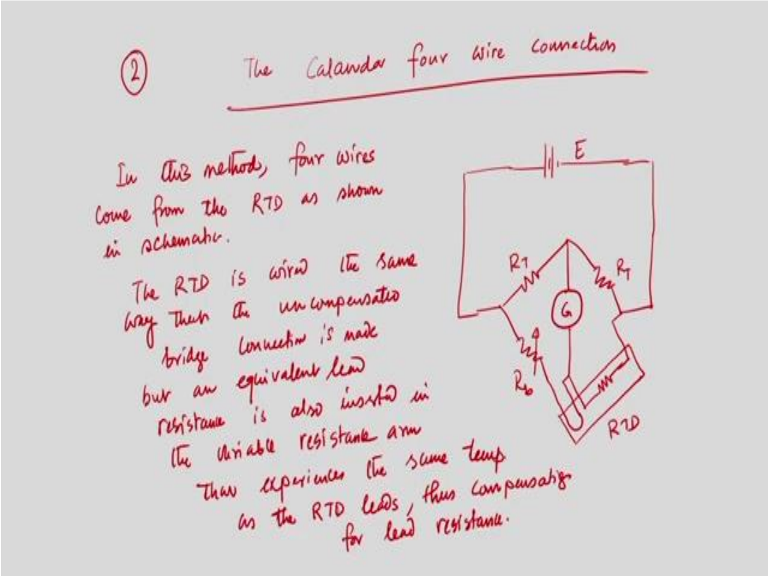

Now, next is 2 is the calendar four wire connection. So, again we need to know the schematic. After drawing the schematic, we will try to explain and that is C, so, let me know draw the schematic. This is RTD, this is RB, this is RT, this is also RT and we need to connect. So, this is E. So this is the schematic we can see that we have 4 wire. From one end one is there and other end there are three wires, so we can write that in this method four wires come from the RTD as shown in the schematic. So here the RTD is wired the same way that the uncompensated bridge connection is made.

But an equivalent lead resistance is also inserted in the variable resistance arm that experiences the same temperature as the RTD leads, thus compensating for lead resistance. So, the RTD is wired in the same way that the uncompensated bridge connection is made but the equivalent lead resistance is also inserted in the variable resistance arm that experience the same temperature as the RTD leads, thus compensating for the lead resistance. So, in this method, we have 4 wire connection, of course, one is from the one end and this is not to, but this is also another one wire from the other arm.

But, the RTD the wiring connection is such that it is I have written clearly the uncompensated bridge connection is made, but an equivalent lead resistance is also inserted in the variable resistance arm and the equivalent resistance will experience the same temperature as RTD leads so, it will compensate so, this is the 4-wire scheme and finally, we need to know the floating point arrangement.

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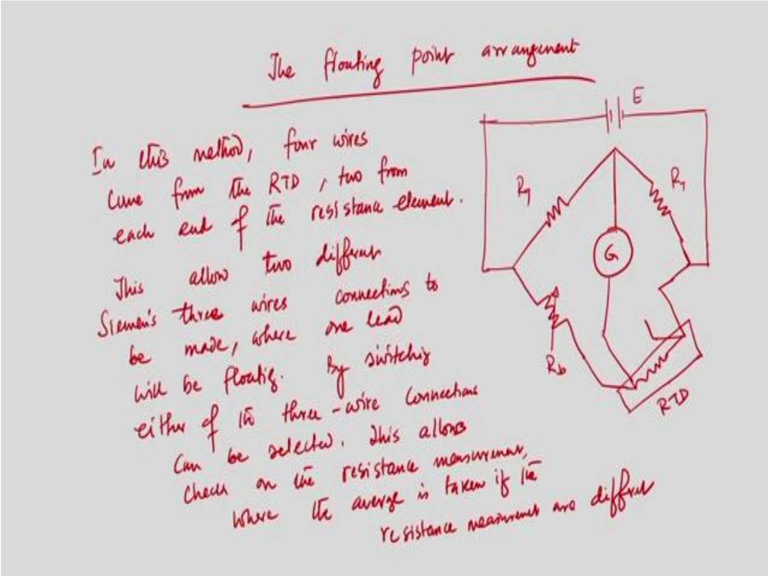

The floating point arrangement, so for that again we need to know the schematic. This is RT. This is a schematic and this is known as floating point arrangement. So we can say that again in this method I will write first then I will try to explain, in this method four wires come from the RTD. The four wires come, two from each end of the resistance element. Now, this scheme this allow two different Siemen’s three-wire scheme, this allows two different Siemen’s three-wire scheme or rather three wire connection to be made, where one lead will be floating. So, that is why it is known as floating.

Now by switching either of the three-wire connections can be selected and this allows check on the resistance measurement where the average is taken if the resistance measurements are different. So this is known as floating point arrangement. So in this method, four wires come from RTD we can see from the schematic, two from a chain of the resistance element. This allows two different Siemen’s three-wire connection can be made where one lead will be floating and by switching either of the three-wire connection and by switching either of the three-wire connection can be selected.

Now, this allows check on the resistance measurement where average is taken if the resistance measurements are different. So, this is what is and, since one lead is always floating, so this is, that is why it is known as floating point arrangement.

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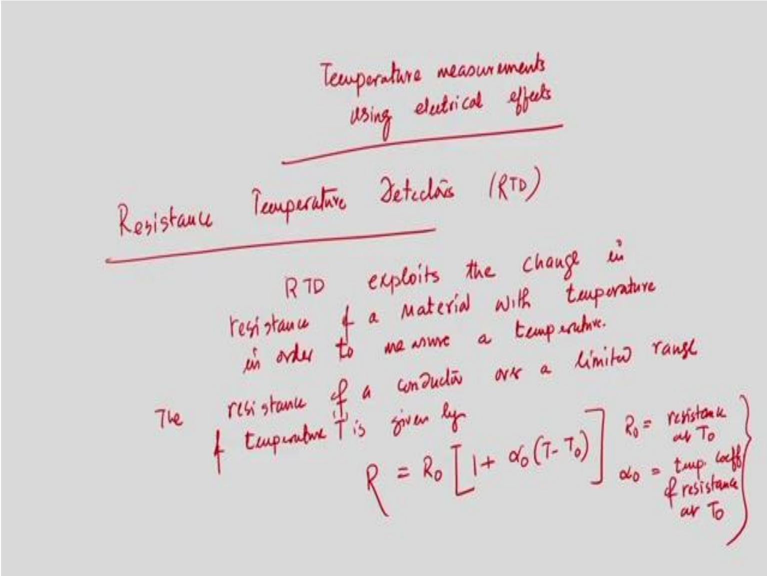

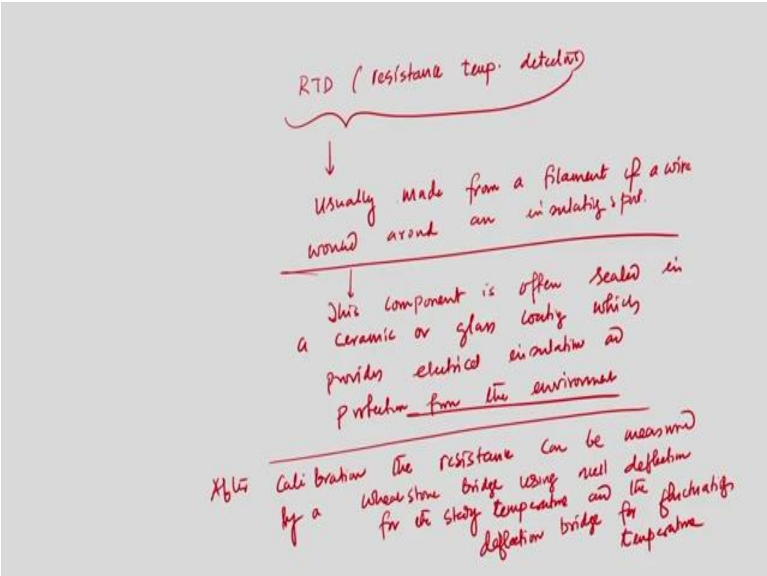

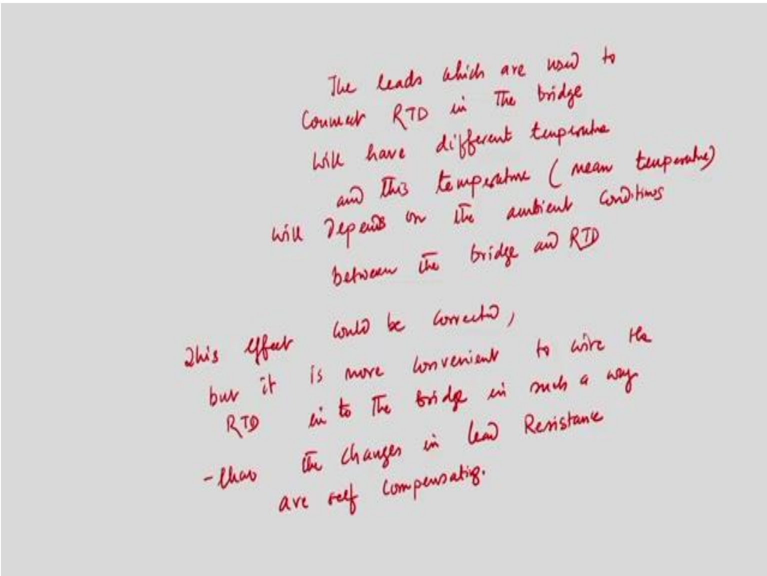

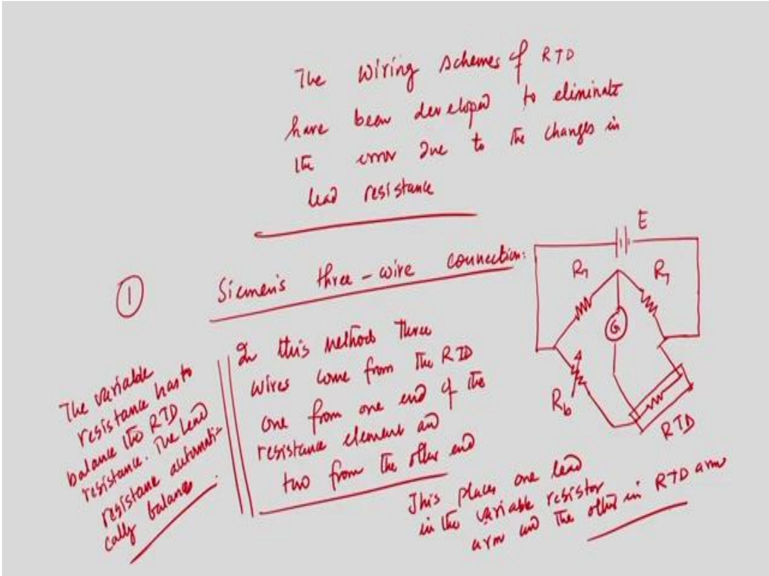

Now, if we go to the previous slide, I mean first slide, we have seen that the resistance temperature detectors essentially, I mean exploits the change in resistance of the material with a temperature in order to measure the temperature. Now, I know the resistance at T naught R, which is R naught and alpha naught is the temperature coefficient of the resistance at T naught then this expression which is, which can be given for the over a limited range of temperature of course, then we have seen that the RTD which are very small filament of wire and the component is often sealed in a ceramic or glass coating, which provides I can say electrical insulation, also it prevents from the environment.

Now, very important to know that, that the RTD we need to connect in a Wheatstone bridge using null deflection if it is a steady temperature or the deflection bridge if it is fluctuating temperature, but RTD is a short length of wire. So, it will have resistance, but the resistance is very small and the order is the same order as the leads from the RTD. Now, when we need to connect RTD in a Wheatstone bridge then we have to connect through the leads. So, leads will have resistance, the resistance in the leads will leads to error in the measurement and I mean now because of the leads, which is having resistance, whatever I mean although very small, but because of the resistance, the temperature will be different between the RTD and the bridge.

Now, we are interested in to measure the temperature of the RTD through the bridge, but in between we have a lead now, lead is having resistance because of this resistance although the resistance is of the order of the RTD resistance, but because of this small resistance, the temperature between the bridge and RTD that will be different. So, that will, that needs to be corrected. Now, instead of correcting that, it is rather it is also another way of correcting that correcting the error that it is more convenient to add the RTD in such a way that the changes in the lead resistance can, are self-compensating. So, I mean that will that, that the balance resistance will balance automatically.

So, we have discussed about three different schemes, Siemen's three-wire connection, we have discussed in details that and ultimately, we need to know using this connection scheme, wiring connection scheme how we can ignore, rather how we can automatically balance the resistance of the leads. So, that is why different connections are made, using the Siemen's three-wire connection, we have discussed that 3 wires come from the RTD, one from one end of the RTD resistance, other of filament and 2 from the other end. Now, we have seen that the variable resistance has to balance the RTD resistance and the lead resistance balance automatically.

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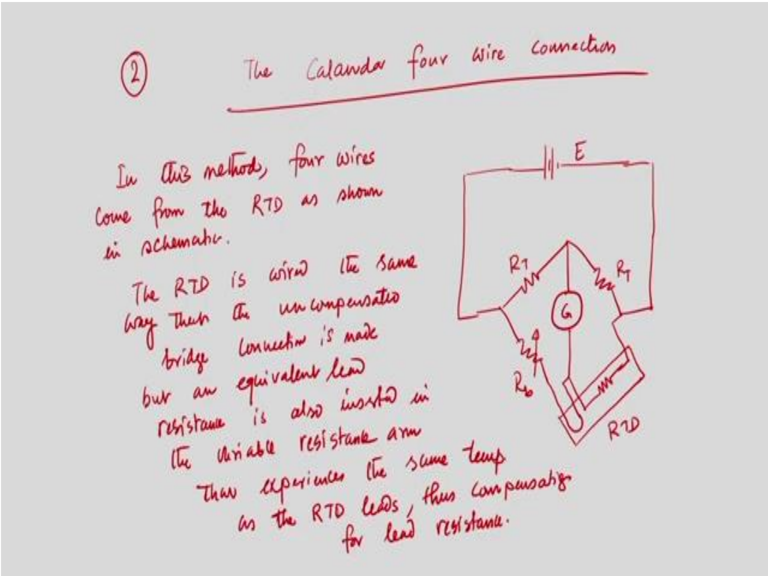

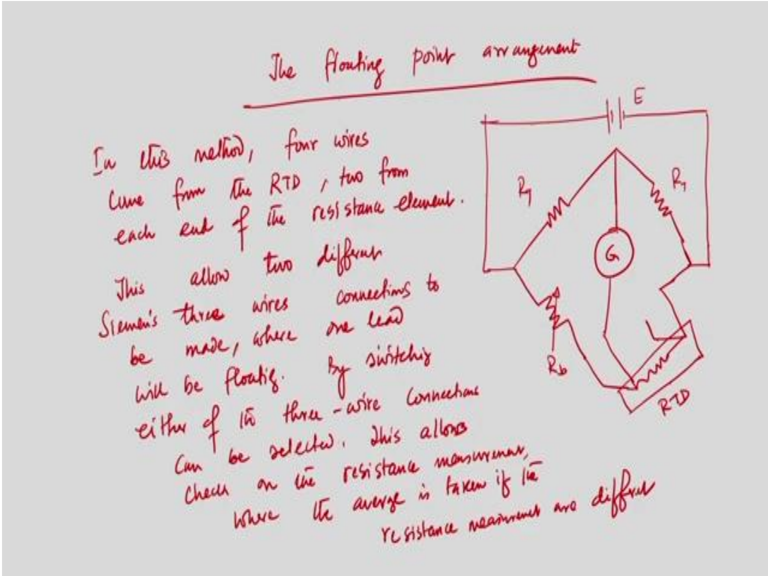

And then we have also discussed about the four-wire scheme and we have seen how using the scheme we can ignore the resistance rather the lead resistance, the error due to the lead registers and finally, we have discussed about the floating point arrangement, also we have discussed that how we can check on the resistance measurement, where I mean resistance due to the leads can be, I mean can be compensated.

So, today, we have discussed about the temperature measurement using electrical effect and we have discussed about the possible sources of error and if we need to eliminate the error what are the remedies we need to have, we have discussed and we have discussed such, one of such remedies is that different wiring scheme and also, we have discussed about different wiring scheme and we have discussed that using this different wiring scheme, how we can compensate, how we can balance the resistance due to, resistance of the lead so that the measured temperature will not be affected. So, with this I stop my discussion today and we will continue our discussion in next class. Thank you.