Mechanical Measurements and Metrology
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Module - 3
Lecture - 31
Measurements of Heat Flux (continued)

This will be lecture number 31 on the series of the mechanical measurements. Towards the end of the lecture number 30 we were talking about the measurement of heat flux by using a gage in which the heat transfer and the temperature gradient are in a direction parallel to each other. So we call it at the axial heat conduction gage. Let us discuss about axial heat conduction probe and example 33 will show the typical dimension on what we expect from such a proof.

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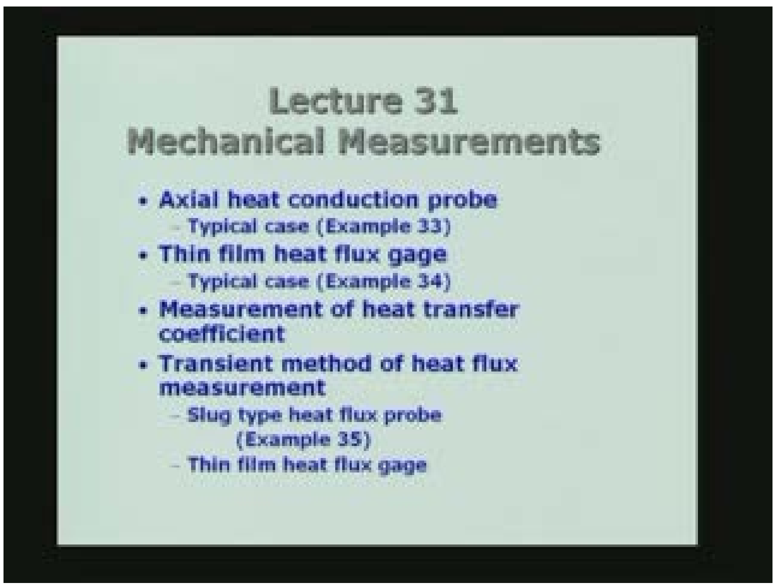

Subsequently, I will look at again a gage in which the temperature gradient or the temperature change or the temperature profile or temperature field and heat flux are again parallel and this is the case of the thin field heat flux gage. And example 34 will indicate the kind of performance you can expect from a thin film gage. Subsequently we will move on to the measurement of heat transfer coefficient which is a very useful quantity in thermal engineering. This is done by using a gage which is a heat flux gage basically and the results are interpreted in terms of heat transfer coefficient instead of the heat flux. Let us also try to look at transient method of heat flux measurement using what is called the slug type heat flux probe. Actually the slide shows the working principle of an axial heat flux gage schematically. If you look at the figure here I have a circular cross section probe or a cylindrical probe.

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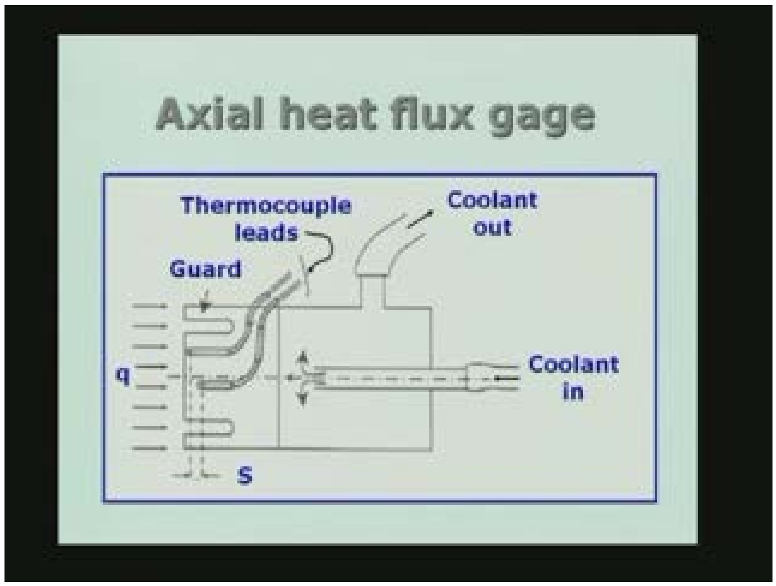

This is the probe part of it which is indicated by this portion and behind that I have some arrangement for cooling the back surface of the probe. The back surface of the probe is cooled by a coolant which comes out in the form a jet and impinges on the back surface and cools this surface and after cooling the fluid goes out through the tube shown here. So the coolant comes axially like this. For example, coolant can be either air or water and in many cases air is a possibility. The coolant enters here axially through this pipe impinges in the form of a jet on the backward surface of the probe and leaves from the tube attached to this side.

And if you look at the probe itself, the probe consists of an inner cylinder with a small gap which is formed by gouging out to the material, so we have an as annulus in other words with a small gap. This gap is very large here but in practice it will be a very narrow gap. The idea is that there should be no physical contact between these two parts. Between the outer annulus cylindrical and the inner cylindrical parts there should be no actual contact. And on the outside I have got a small annular region and the annular region as well as the inner cylindrical region are parts of the same block of the material.

This is the cylindrical block with a small gouged out portion like this and this is the gage and the heat flux is incident here and there are two thermocouples. One is attached very close to the front surface but need not be exactly the front surface but it should be slightly inside so we have a blind hole which is thrilled through from the back and a thermocouple is connected there or placed at the bottom of the blind hole and intimately connected to the bottom by cementing and the leads are taken out like this. Similarly I have a second hole which is drilled but slightly distanced from the front surface. Therefore there is a gap between this thermocouple and this thermocouple in the axial direction.

So this thermocouple lead is also taken outside and I am going to measure the delta T across the two thermocouples by connecting the differential mode. This is the main probe and this is the guard probe, the heat flux is incident here, and what happens in this case is that the heat flux is going to create a temperature gradient along the length because I am cooling the backward surface. That means the surface here is at a lower temperature than the temperature to which this is subjected. Therefore there is a temperature gradient along the length of the probe. And I am going to use the Fourier law of heat conduction to estimate the heat flux from the temperature difference which is measured and by knowing the distance between the two thermocouples I can do that for the point. Now we would like to know the principle involved in the guard and the main probe.

The principle of the guard: the idea of the guard is to obtain one D that is one dimensional temperature field in the probe. Suppose I have a piece of material like this a cylinder and I subject it to some amount of heat flux on the surface and this is exposed then what will happen is that the heat transfer will take place like this and some amount of heat transfer will take place like this. Towards the edges there will be some heat leak in the lateral direction. Even though the heat transfer may be more or less one dimensional in the axial region near the axis of the cylinder towards the periphery the temperature distribution is going to be not one dimensional but there will be some radial component of the heat flux. Therefore if you plot the temperature profile, I would like to have temperature profile like this, I want to have uniform temperature profile but if there is heat loss in the lateral direction then what you will get is something like this.

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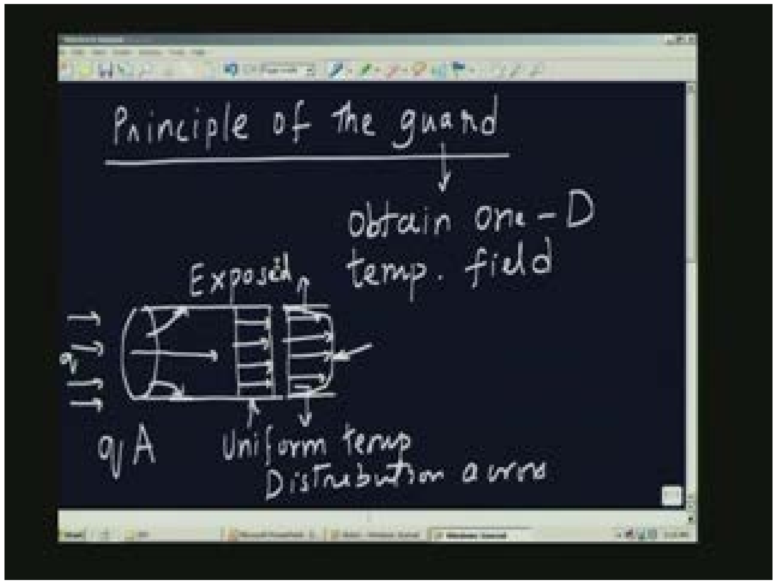

So it is some temperature variation like this I will get which means there is a heat loss from the two sides. So what is the consequence of this? Suppose I assume that all the heat which is entering the front surface is going axially then I can know the total heat transfer simply by the fact q into A and that is heat which is entering the surface. Now if this amount of heat is transferred axially then I can equate it to the amount of heat transfer in this cylinder by conduction if the temperature profile forms this particular pattern that is uniform across the probe, uniform temperature distribution across the probe. However, this will not satisfy that requirement because qA is not equal to the amount of heat transfer axially because it is small amount of leak in the lateral direction.

So how to we take care of this is the principle of the guard. Here I have a cylinder and I have an annulus which is surrounding it. The annulus is like this. This is the cross section. This is the axis of the probe. Now the heat flux is incident here and also on the annular region.

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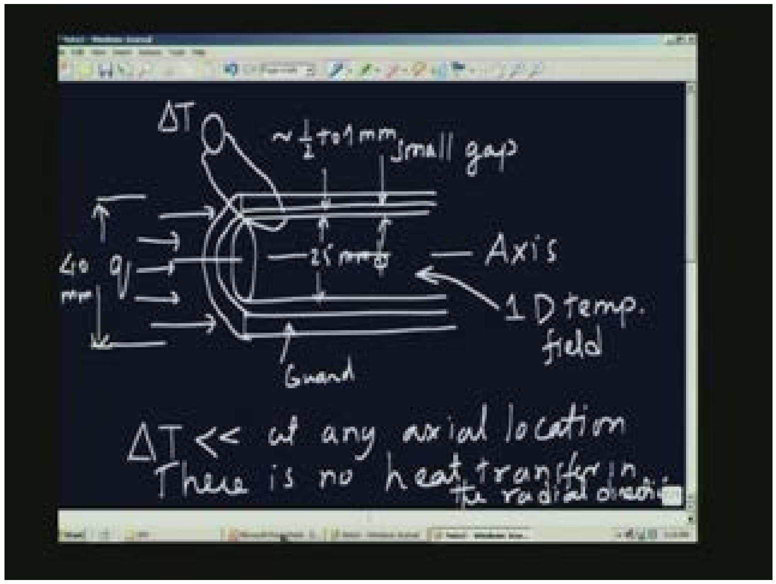

The q is incident both on the central cylindrical portion as well as the annular region and we have a very small gap for example, this may be 25 mm diameter typically. This may be the outer diameter there may be about 40 mm, the gap here between 1 by 2 to 1 mm is a very narrow gap between the inner cylinder and the outer guard. So if the heat is impinging on the front surface both of the cylinder as well as the guard, this is the guard, it will set up the temperature field in the guard as well as the cylinder and if these two are made of the same material then more or less a similar temperature profile would prevail in the two of them.

So, if you work to connect a thermocouple across the gap, if I measure the delta T, delta T is very small at any axial location because the guard probe as well as the main probe both are subjected to the same heat flux at the front. Both are of the same material, they have similar temperature profiles within them. Even though the guard may have a two dimensional temperature field because of the heat loss at the outer periphery and because the two are surrounding each other the guard will have a temperature profile which is more or less similar to the temperature profile within the main probe. Therefore there is no heat transfer and delta T is small so there is no heat transfer in the radial direction. So what we notice is that, by surrounding the main gage by a guard gage of the same material we are subjecting both of them at the front surface to the same heat flux. We are having a small or negligible temperature difference between the periphery of the main probe and the inner wall of the guard probe.

Therefore heat transfer in the lateral direction is completely suppressed. That means in the main probe we have 1D temperature field. This is the consequence of the guard. The axial heat flux gage is schematically shown here. Now I am going to measure the temperature difference between the two locations. One is close to the front surface probe and the second one at a distance away from the front. Therefore there is a small spacing between the two thermocouples. These two thermo couples are going to record two different temperatures. Therefore there is a temperature difference across them and this is what I am going to measure. So the gage output is nothing but the thermocouple reading or the differentiate thermocouple reading is the gage output. If we control the rate of coolant which is being sent into the back of the probe, that is if I control the amount of coolant which is being sent here by having a valve controlled by the temperature indicated by the first thermocouple, this first thermocouple very close to the surface and therefore it is an indication of the surface temperature.

Suppose I want to maintain the surface temperature of the probe at a value below that at which the probe is going to get damage or at the limiting value of the temperature to which the probe can be supported can be subject to then I have to take the temperature of the first thermocouple as the control voltage and that can be used to control the coolant level such that the temperature is maintained at a constant value less than the maximum possible value which is the allowed value. Therefore this probe does two things. One is, it can maintain the front surface of the probe at a temperature which is desired and secondly, it also gives me a temperature difference which can be use for measuring the heat flux at the same time. That is by controlling the coolant flow rate assuming that the coolant is always available at the same inlet temperature.

In some designs, the heat transfer rate at the back for this size may not be adequate in which case we can expand or extend this by using a cone at the back. That is the only a small change in the probe profile but that is not going to affect the performance of the front portion which is always going to be the uniform cylinder surrounded by a guard cylinder.

Here is example 33:
I will assume that we have a 25 mm diameter main gage and of course for calculation purpose the guard is not going to come into the picture The heat flux is incident here q and I am measuring the temperature axially at two locations, let us say this is T_1 and this is T_2, The temperature difference delta T is T_1 minus T_2 because this end is cooled and we are going to wait till the steady state is reached, that means the temperatures are going to initially change and then finally it will

settle down such that delta T will show a constant output depending on the value of q. Suppose I use a material of thermal conductivity 45 watts by m degree Celsius, I am just choosing a material which has got the value of 45. Actually I can choose different material depending on the maximum temperature you will subject the gage to and secondly the kind of temperature difference you would like to have.

If the thermal conductivity is large, the temperature gradient is will be small and vice versa for given value of q. Therefore depending on the heat flux which you want to measure, depending on the maximum temperature to which the gage can be subjected we can use different materials and I have just chosen the material 45 watts by m to the power degree of the thermal conductivity of this. Suppose the distance between these two is called as S then S is equal to 10 mm that is the distance between the two thermocouples which are kept inside the material. So, a typical case would be, I have got a q of 100000 watts per square meter which works out to about 10 watts per centimeter square because 10000 watts by square meter is equal to 1 watt by cm square so I am talking about fairly high value for the heat transfer rate or the heat flux.

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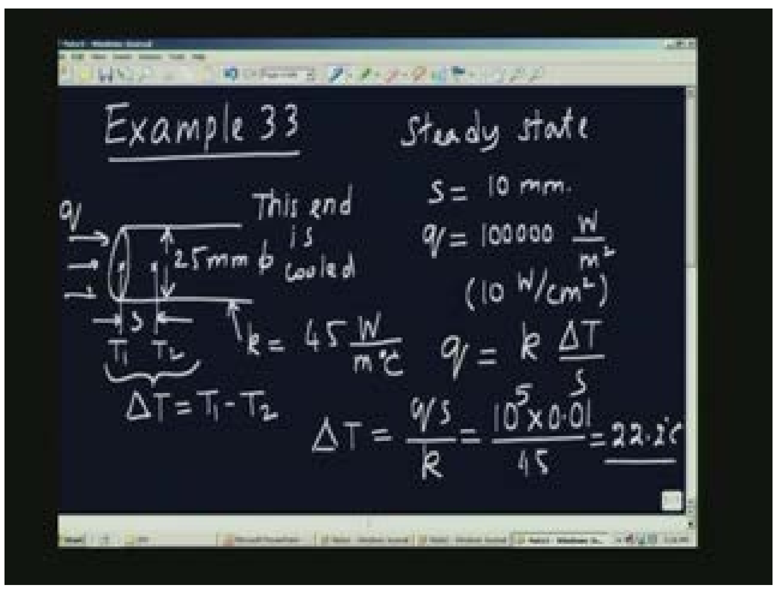

So I can find out what is delta T I am going to get, by using a simple formula q is equal to k delta T by S, the diameter of the probe does not come into the picture because we are having the heat flux and we are not measuring actual heat transfer for which of course you would require the diameter of the probe. From this I can obtain delta T as qS by k which is directly proportional to q therefore it is a linear gage. So qS by k where q is nothing but 10 power 5 multiplied by 10 mm which is 0.01m by 45 and this gives you a temperature of 22.2 degree Celsius and 20.2 degree is a quite good measurable value.

As said earlier if we are using a K type thermocouple or T type thermocouple both of them have similar See beck coefficients that is 22 into 40microvolts, 22.2 degree that is 20 into 40, 600 microvolts so about 0.6 millivolts will be the output. So it is quite a measurable value. Now let us look at the amount of heat which is transferred or heat to be removed. This is done by q into A, q into pi D square by 4 and this will be (10 power 5 into 0.025) whole square by 4 which is so many watts and this works out to be about 49.1 watts so roughly let us say 50 watts to be removed. And this can be easily removed by air with a back area of about circle of 75 mm diameter.

Therefore the probe itself if you remember is 25 it can be expanded to seventy five by using the cone at the back. And if one wants, the cone can be made of a different material whose thermal conductivity may be even higher one can do that, and the heat can be removed from the back easily by using air. Such a heat flux gage is actually used in practice in measuring the heat flux which may be incident on the walls of a boiler plant.

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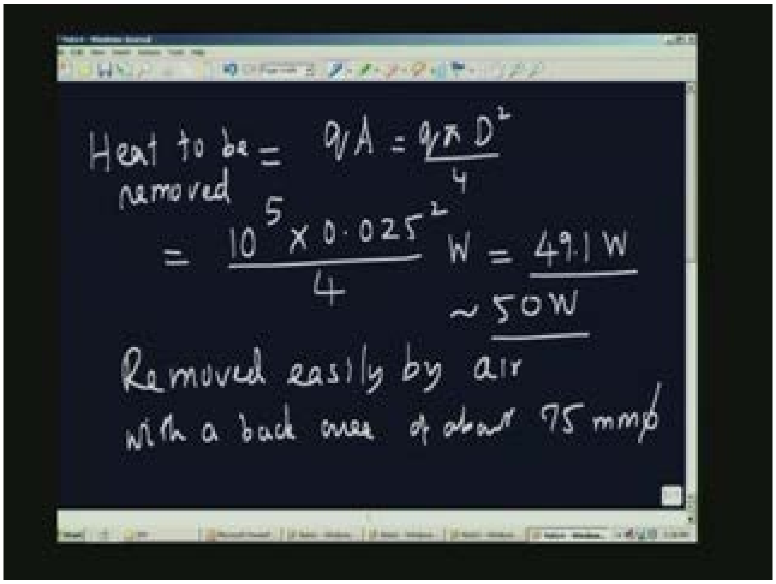

In the boiler plant the walls are covered with tubes which are called water walls where water is flowing through the tubes and all you have to do is make a small hole on the side of the boiler wall and introduce this probe such that the front surface of the probe is in the same plane as of the water wall tube so that you can measure the heat transfer rate at the wall and this will be heat transfer rate at the surface of the water wall if we maintain the temperature of the front surface at a value close to that of the water wall tubes. By controlling the coolant rate, I can actually maintain the front surface at the desired temperature.

So you can maintain the surface temperature at the value which is close to the value of the temperature of the metal wall of the tubes which are going to be on the water wall. Therefore you are measuring the heat flux under the same circumstances as the water wall tubes are going to be subjected. Therefore it is a very interesting application, where we can measure the heat transfer by axial conducting probe with a temperature of the surface held at about the same value as the surface of the tubes. So the next one we are going to look at is a thin film heat flux sensor and the principle of operation is exactly similar to what we had in the case of axial conduction probe. The only thing is I am going to have a thin thermal barrier; it is a thin film because I am using the barrier of a very small thickness but of known thermal conductivity.

For example, the normal thickness of the barrier will be around 0.25 mm and we are going to have two temperature sensors one on the front surface of the film and the other at the back surface of the film and I am going to simply measure the temperature drop or temperature difference across the barrier. When the heat flux is incident like what is shown here, a temperature field will be developed across the thickness of the sensor, and this temperature difference is measured by a sensor on the top and a sensor on the bottom. This is a thin film of the 0.25 mm, the length and width of this may be 25 mm each. So the film is very small 25 mm by 25 mm, and of a thickness 0.25 plus the thickness of the two sensors which are attached to it.

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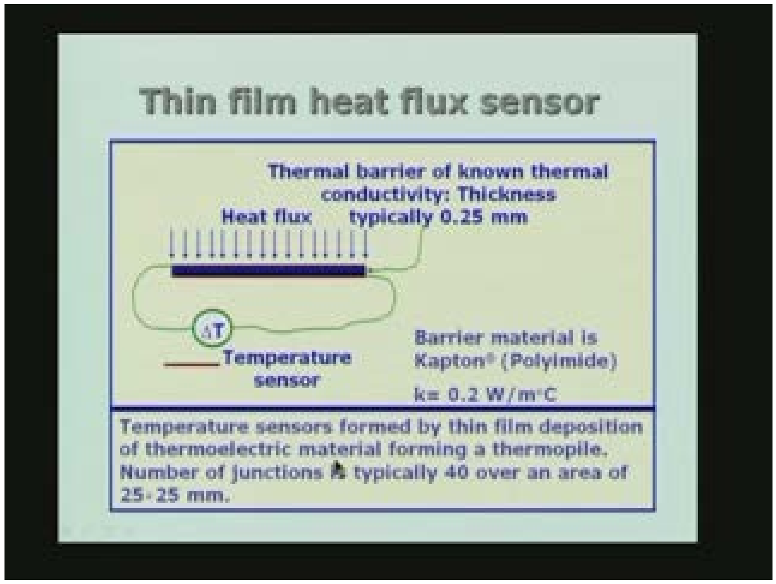

And the sensors are also made by thin film technology by having a thin film deposited of the two thermo electrical materials which are going to form the junctions. And in fact what is normally done is, we have about 40 or so junctions formed on the top and the bottom, and they are interconnected in the differential temperature mode, so that delta T is actually the value which is magnified by the number of junctions which are formed. If there are 40 junctions the temperature indicated here is forty times the temperature across a single thermocouple pair.

So we have forty junctions, this will be forty times the signal and the idea is that we are going to get a good out put with a small temperature difference which may be developed across the film. And the barrier material usually is made up of Kapton a registered trademark of the material which actually is polyimide the chemical name for it and it has got a thermal conductivity of about 0.2 watts per meter degree Celsius. Let us look at the typical behavior of this heat flux sensor. I am going to look at the typical thin film sensor.

Let us see how the thin film sensor is made. we have about 25 mm by 25 mm of Kapton and I am going to deposit the thermocouple material in the form of thin film like this, this is positive, this is negative material and the junction is formed here, this is the junction and in fact I will have a number of them, so many numbers and on the other side also similarly there will be so many junctions and the negative of this and the positive of that and so on and so forth. So you have typically forty junctions. And the thickness is about 0.25 mm and the heat flux is incident along this.

This is a typical case. Let us see what happens. This is numerical example 34: The output of the gage is given to be V is equal to 0.1 volt at the maximum q, to which it can be subjected. How do we determine the maximum q? It is determined by the maximum temperature to which the material can be subjected. If you increase the temperature beyond that the sensor itself can be damaged. What we do is, if we have the substrate of the surface which is subjected to heat flux I am going to mount it by sticking on to it, this is the sensor it is attached by using an adhesive.

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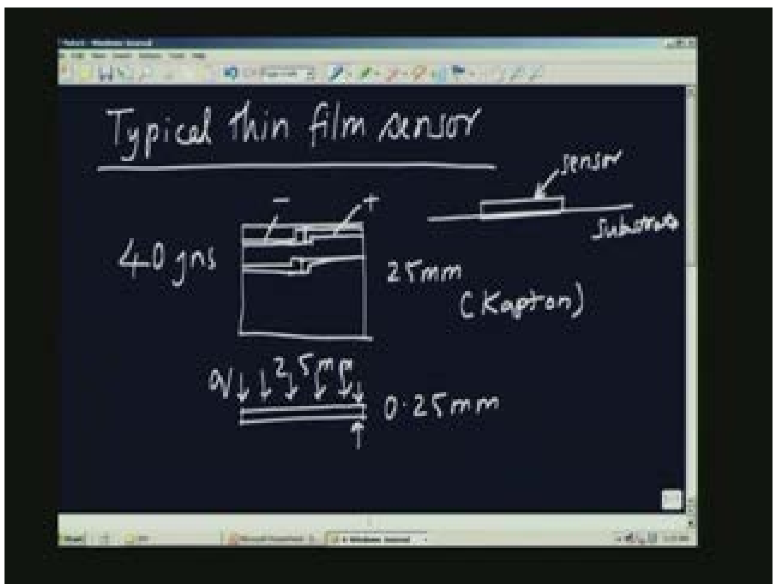

Actually it is as thin as a sheet of paper and it comes with an adhesive layer, all you do is remove the packing and then stick it on the surface on which the heat flux is going to be subjected so you will be able to use it. The two leads will have to be connected to a simple voltmeter in this case of course a microvolt or millivolt capability so that you can measure the temperature directly. It does not require any power because thermocouple will provide an output by itself by thermo electric effect. Now the number of junctions is 40, therefore output per junction is 0.1 by 40 volt at the maximum q, or this will be 0.025 volts per junction ie.,voltage developed is 0.025 volt per junction.

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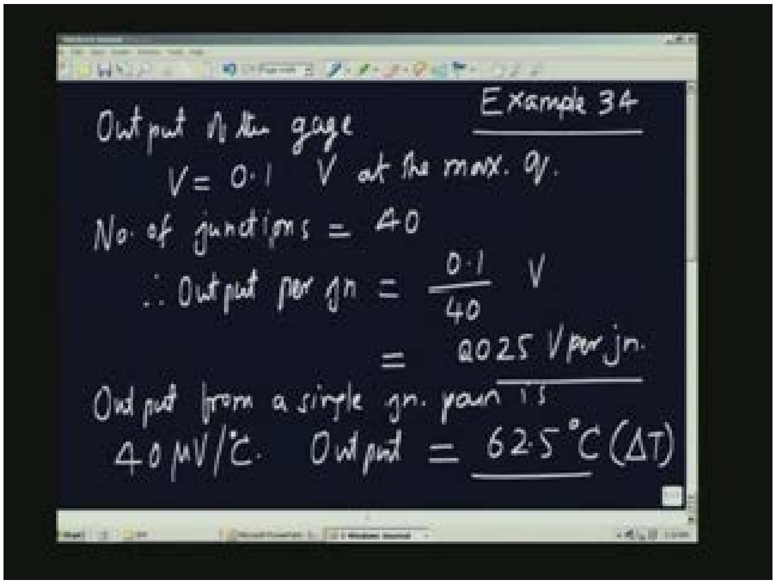

If we assume that the output from a single junction pair is some 40 microvolts per degree Celsius, the output given here will correspond to about 62.5 degree Celsius. That is the output from a single junction. In fact,this is the delta T which is developed by the sensors. Therefore now I can find out the heat flux by using the simple Fourier law of heat conduction k delta T by the thickness of the film delta, k is 0.2, delta T is 62.5 and delta is now 0.25 mm, this will be so many watts per square meter and it comes to 50000 watts per square meter. So a typical thin film gage which is subjected to a heat flux of 50000 watts per square meter will developed about develop about 0.1 volt or 100 millivolt of output. So, q equal to this corresponds to 100 millivolt output which is very easy to measure. So here is the summary of what we are going to use.

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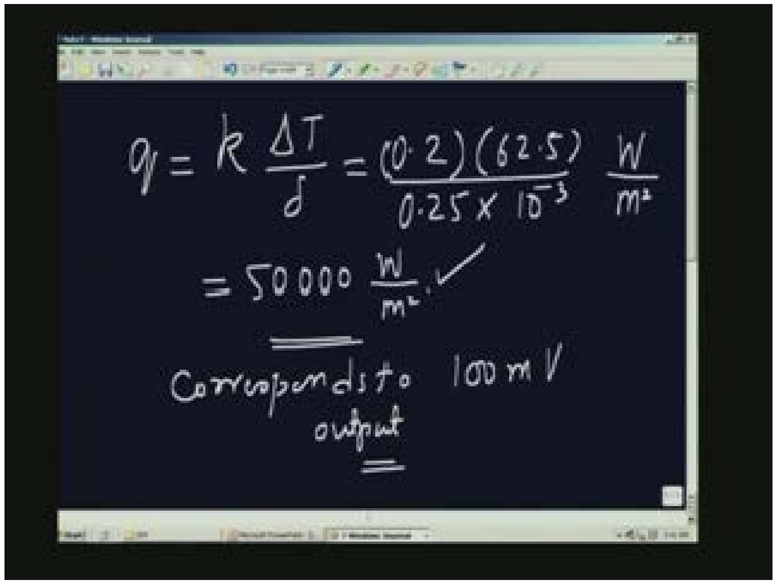

We are going to use a very thin film of material of known thermal conductivity in this case Kapton which is a plastic material whose thermal conductivity is 0.2 watts per meter degree Celsius which is very little in the operating range of temperatures and the two sides of the film we have several junctions formed by thin film technology of dissimilar materials like copper and constantan or some other material also is possible, and the delta T is amplified or the signal is amplified by having large number of junctions so that the output from the thin film sensor is a sizable value which can be measured using a simple millivolt meter. And you can see that about 50000 watts per square meter will correspond to a maximum of 100 millivolts which is the output of the instrument.

So this is the case where the heat transfer or the heat flux and the delta T are in the same direction similar to what we had in the case of the axial probe. Let us now look at the measurement of heat transfer coefficient. So a film coefficient transducer is an instrument, which can be used for measuring the heat transfer coefficient and let us see what is involved in this.

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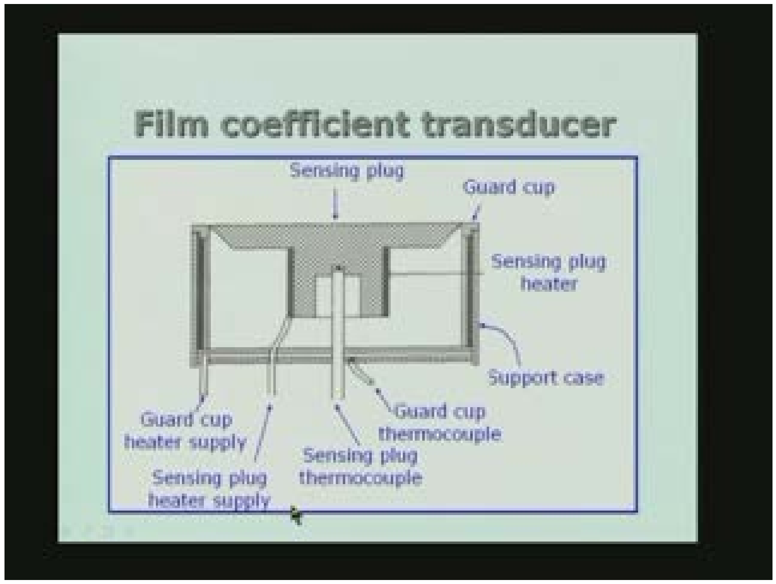

So if I want to measure the heat transfer coefficient which is a very important quantity in studies involving heat transfer especially convective heat transfer.

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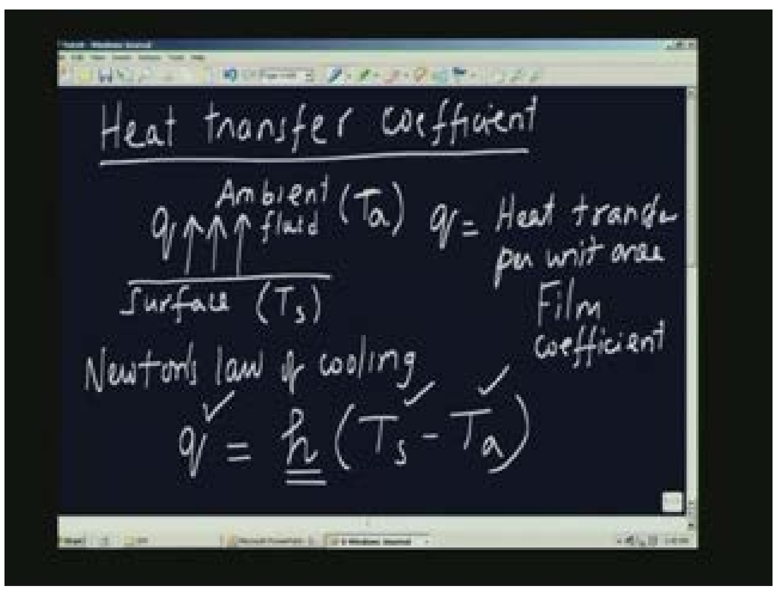

Suppose I have a surface and we have an ambient fluid which may be moving, if the surface of the temperature is T_s and the temperature of the ambient is T_a and, if I measure the heat flux at the surface, if T_a is less than T_s it will be in this direction q and q is nothing but heat transfer from per unit area, the fundamental equation is called the Newton's law of cooling, it says that q will be equal to some quantity called heat transfer coefficient h into(T_s minus T_a). So immediately you see that h is a derived quantity. It requires the measurement of q heat transfer or unit area and requires the temperatures T_s and T_a to be mentioned. I need to measure three quantities q, T_s and T_a or T_s minus T_a can be directly measured the temperature difference between the surface and the ambient then I can obtain the h as the ratio of q by T_s minus T_a. Therefore if I am going to use a probe to measure the heat transfer coefficient I must make arrangement for measuring the heat flux q and I must have an arrangement to measure the temperature of T_s, I also should have arrangement for measuring the ambient fluid temperature. If I do that then I will be able to estimate the heat transfer coefficient.

The heat transfer coefficient is also sometimes called the film coefficient. The reason why we call it film coefficient is that, there is a thin film of fluid next to the surface which is getting cooled or heated in which there is conduction heat transfer. So the idea is that even though the fluid is moving at a distance far away from the plate, at the plate surface itself it is going to be at rest. Therefore we are assuming there is also a small film of the medium which is present right next to the surface in which conduction is the mode of heat transfer. Therefore we call at the film coefficient.

This is just a description of what is happening in the surface. Therefore all I have to do is measure the q, measure the T_s, measure the T_a and how I am going to do that is going to be shown in the slide the film coefficient transducer. So the principle of the film coefficient transducer is the following. What I am going to do is I am going to have plug of material which is shown here, this is a cylindrical thing, this is the axis of the cylinder. I have got the plug material (Refer Slide time 37:16) which is surrounded by a heater placed here so that I can heat the sensing plug to a temperature of desired value and it can be measured using a thermocouple which is inserted into the sensing plug.

The sensing plug is surrounded by sensing plug heater which is heated by electrical power supplied through the leads here and it can be maintained at a constant temperature. And to guarantee that all the heat supplied to the plug is only leaving from the front what I have to do is, I have to surround a sensing plug by a guard cup which is independently heated and of course there is a very small gap between the sensing plug and this which means there is no physical conduct between the guard cup and the sensing plug. And if I heat the sensing plug and the guard cup independently, and maintain the same temperature for the guard plug as I maintain the sensing plug ahead that means that the temperature difference between this and this is 0. That means I measure the guard cup heater temperature and the sensing plug heater temperature and I maintain the same value by controlling the heater input such that the delta T is 0 then you can see that all the heat I am in putting into the sensing plug must be leaving from the top because there no heat transfer from here to here because these are the same temperature. So if these are at the same temperature there is no heat transfer from the sensing plug to the guard cup. The guard cup is surrounding the sensing plug in all the directions except the top. The only available direction for the heat transfer is from the sensing plug from the top and this will of course go to the fluid which is flowing over the sensing plug. So I am measuring the temperature of the sensing plug, I am also measuring the heat transfer heat input into the sensing plug by electrical heating. Therefore the Q, the amount of heat transfer to the plug is measured and we can immediately work out the formula for the heat transfer. So suppose the sensor plug area that is frontal area (Refer Slide time 46:37) is equal to A the electrical power input Q is nothing but e square by r or e(I) then q is nothing but Q by A. And I am measuring temperature of the sensor plug and, I am also measuring the temperature of the ambient therefore h will be nothing but Q by A(T_s minus T_a).

Unlike the heat plug measurement the h measurement is not direct but it is done by measuring Q separately by finding out what is the amount of heat supplied in the form of electrical energy then area is calculated by measuring the frontal area of the sensor plug then T_s and T_r is measured. Therefore four measurements are involved in this one and in these two temperatures are measured and this is identified as the heat transfer coefficient, it is a very useful instrument.

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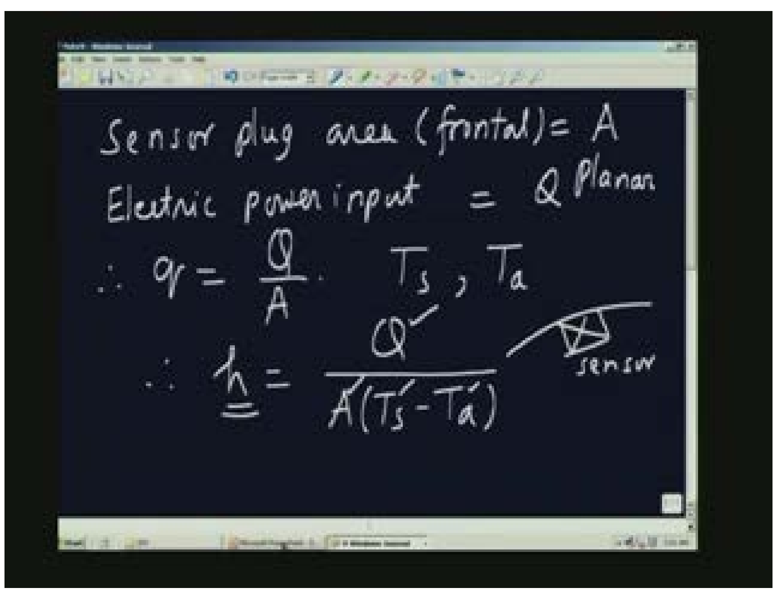

In this case I have the sensor plug surface as a planar area, so this is the planar area. And the sensor itself can be mounted on the surface and it could be placed such that if the rest of the surface is there you can make sure that you can place your sensor here. This is the surface and this is the sensor, a second arrangement is sometimes useful. It is again for the measurement of heat transfer coefficient. I use the heater in the form of a cylindrical tube.

Anyway before we come to this stage here we notice that the heat transfer coefficient is measured by actually allowing heat transfer to take place from the sensing plug to the ambient. So sensing plug is losing heat to the ambient. In this case fluid is cold and the surface is hot. Normally we assume that in the case of convective heat transfer if the surface is cooled compared to the hot fluid it will also be the same as the heat transfer coefficient which you obtain by keeping the sensing plug at a temperature higher than the ambient. So whether the heat transfer takes place from the sensing plug to the ambient or from the ambient to the sensing plug the same heat transfer coefficient will be obtained. And the advantage of using a film coefficient transducer which is heated is that you are doing the experiment with the cold stream of air or cold stream of fluid. So you are not heating all the fluid, the bulk of the fluid is not heated, it is only small amount of heat which is sent from the sensor to the fluid. Continuing the same way we can also use the sensor in the form of a cylindrical plug.

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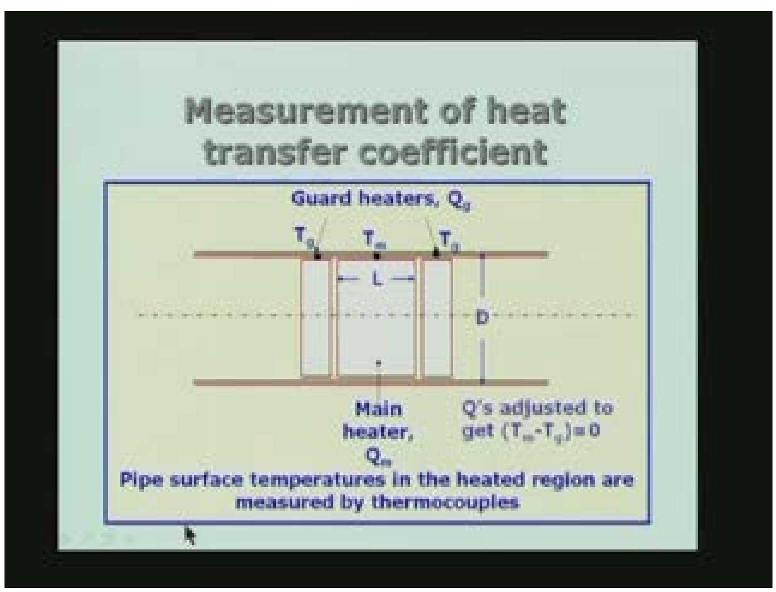

The schematic of the arrangement is shown here. we have a pipe which is shown by these lines here, diameter equal to D a thin walled pipe and then what I have done is, I have main heater shown here with length equal to L and there are two guard heaters of equal width placed just before and after the main heater. So you can see that the temperature of the pipe close to the main heater will be T_m. The temperature close to the region where the guard heaters are placed is equal to T_g. What I am going to do is I am going to do adjust the power which is given to the two guard heaters such that T_m minus T_g is equal to 0. That means there is no temperature difference between the region here and the region here.

So three thermocouples are there, the temperature difference between these two thermocouples and these two must be adjusted to 0 by adjusting the heater power which is supplied to the guard heaters by having some kind of a controller. The heater power is controlled such that these two temperatures are in the same value. Now you realize that all the heat supplied to the main heater must leave the surface of the pipe. Therefore we know how much Q we are supplying and the heat which we are supplying in the form of electrical energy. We are measuring the temperature T_m. Of course at the same time we are also going to measure the temperature of the ambient fluid which is flowing over the cylindrical surface and again the principle is exactly the same as what we had in the earlier case the pi D into L. This is the pipe, main heater, length is L, diameter is D so Q by pi DL is the q, T of the surface is measured, T ambient is measured therefore I can say the heat transfer coefficient is nothing but Q by pi DL by T_s minus T_a.

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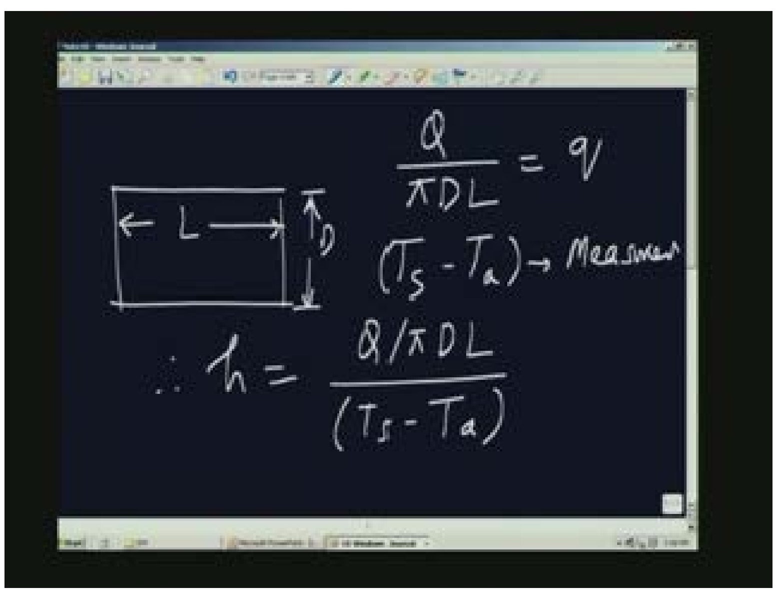

The principle is same as the gage we had earlier which was a planar gage but in this case I have got a cylindrical gage. In fact let us just look at the cylindrical gage in a slightly more detail. This is the cylindrical gage and the fluid may be moving like this, and like this across the gage and I am supplying heat as shown here, this is Q. What I am assuming is that the temperature of the pipe surface is T_s and the temperature of the ambient fluid is T_a so this is your pi D and the heater length is L.

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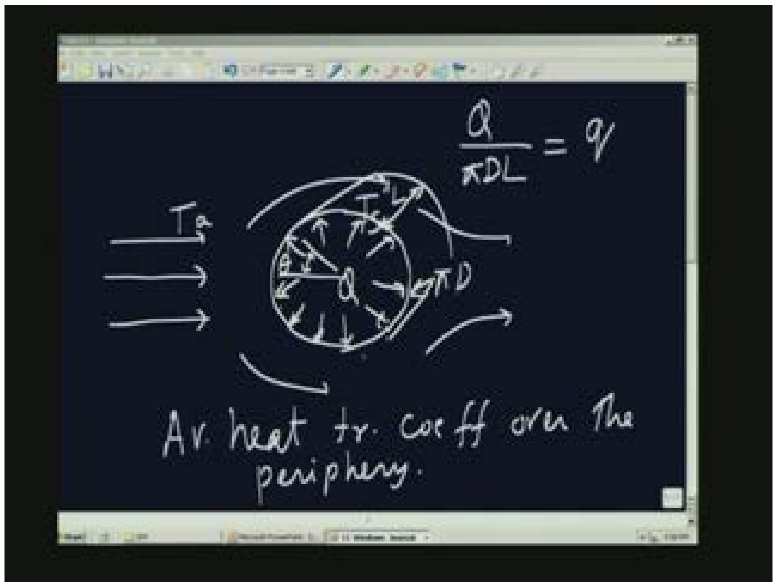

So Q by pi DL is the heat flux of the surface of the pipe. So in practice, what may happen is that there may be temperature variation. In this case, what we are doing is we are supplying the heat over the entire periphery and in other words,we are integrating the effect of heat transfer at the surface so we will able to get only the average heat transfer coefficient over the periphery. For example, if it varies with respect to theta the angle then we will not able to measure it. So this will give you only the overall heat transfer and the average heat transfer coefficient for entire periphery of the pipe.

What is the typical application for this?
Suppose I have a tube caring air I may have a bundle of tubes like what is shown here. It is tube bundle and to find out the heat transfer coefficient variation within this tube bundle, this can be a cylindrical gage. I am not heating the air, this is cold air. And by putting small amount of heat through the gage I am measuring the temperature of this gage and the ambient fluid and knowing how much heat I am

supplying I am getting the value of heat transfer coefficient for this particular location.

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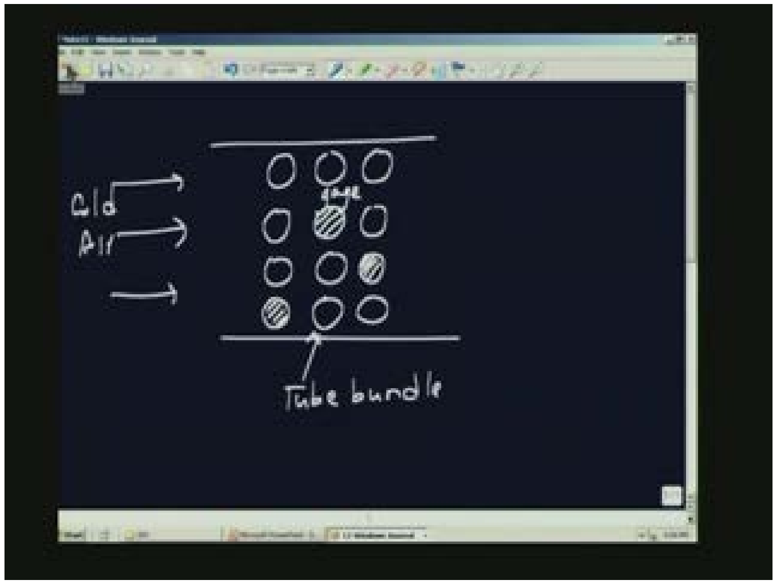

In another experiment I can change the position of the gage here and I can put it here. Or if I have enough money I can have several gages like one here, one here, one here simultaneously so that I can measure the heat transfer coefficient at different locations within the tube bundle. This is one application where the heat transfer coefficient is measured simultaneously at different locations within a bundle. Let us look at the measurement of heat transfer by using transient machines. Consider for example a slug type transducer.

What is a slug type transducer?
It is simply a piece of material which is shown here, this is a slug, slug is simply a piece of material a block of material which in this case is a cylinder or a slab or cylindrical slab of some given diameter with thickness delta. What I am doing is, I am exposing this slug of material to the heat flux which is impinging here as shown. And I am preventing heat transfer from this slug in any other direction. So if there is no heat loss from this slug, if, I am going to heat it with a constant heat flux, if the specific heat of the material is constant,what will happen is the temperature of the piece of material if it is thin enough if the delta is small enough then the temperature of the slug will uniformly go up through the slug at a linear rate q into t is the total heat transfer from the outside to the slug q into t is equal to m into c mass of the slug the specific heat of the slug multiplied by the delta T.

Delta T(t) is the temperature difference between the temperature time t and the temperature with which started. So what I am looking at is the piece of material (Refer Slide time 59:16) mass is equal to M, c is the specific heat and I am subjecting it to constant heat flux q over the area of the surface and it is insulated which is shown by this curve this is insulated and all these sides. That means, if I expose it to certain amount of time qt you see that q into t into A is equal to M into c into T at time t minus T at 0. Therefore q is equal to Mc by t into A to T at t minus T_o. So this is what is measured and this is inferred.Thank you.

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