Electronics Enclosures Thermal Issues
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Lecture – 03
Practical Examples 2

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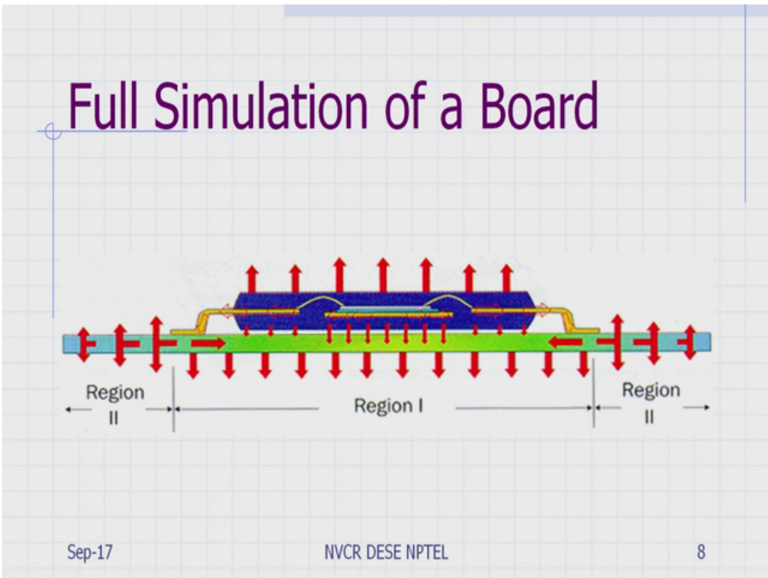

Board, the starting point is the chip. So, chips are depending on the technology and all that they, I think, correct me and because of this gray. I have read about 120 as being the normal thing like that, but now very high temperature chips are being made. I understand which are all you know, 230 degree centigrade and all they can tolerate, you can look it up and if, I have time in the end, I will show you, but typically a chip can withstand up to about 120 degrees centigrade, but not a continuously peak and then, anything about that there is the end of it and reliability comes down.

So, if you see very - very carefully here and top surface of the chip you know; obviously, heat can be taken away, you can mount it, I do not know heat spreader and then, do what all you want to do and then, bottom of it also know occasionally, you have this bottom of it which is there, is heat coming here and then, you have seen the very interesting thing through the leads, lot of heat is conducted away through the leads and then where, it is hot more you know, flux is there and then the flux reduces and then, depending on the what you call the physical profile of it, or the footprint of it, the manufacturers themselves suggest what should be the pad footprint, how should the pads look like. If you follow all that that correctly, you will be able to make things.

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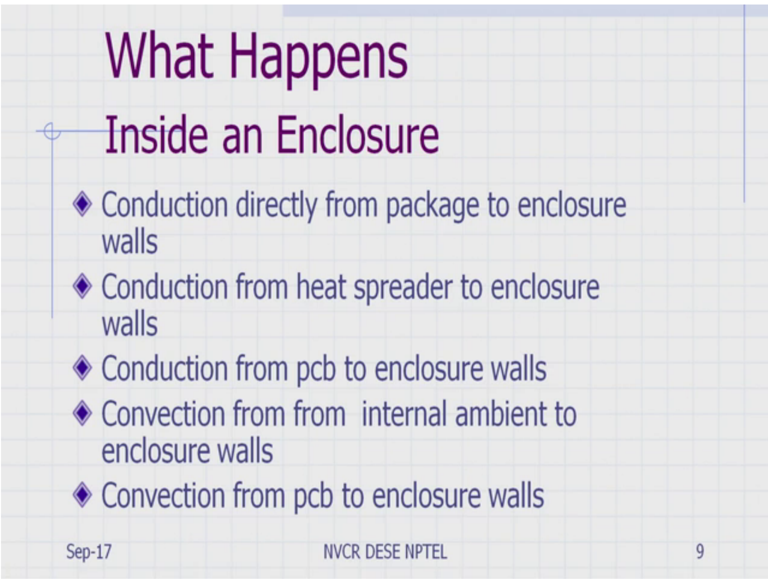

So, what happens typically is the conduction is the predominant thing from package to enclosure walls. That is how the walls get it, conduction from a heat spreader to enclosure walls. Sometimes the packages are directly mounted on the wall or you need a heat spreader, or typically a bridge or something, which I have shown you earlier to enclosure walls. At the amount all these things on another small conductive thermally conductive plate and then, bolt it onto the enclosure and then conductor conduction directly from PCB to enclosure walls.

So, in the case of certain aircraft equipment and all that, the PCB, it edges. If this were to be a PCB, the edges themselves are made with you know, copper is kept thick places and then, it goes into a mount and then, it is clamp plate like that and some of them are made with metal core. We have something called the thermal core in PCB is where, the metal core is there. So, as the flux then she is keep increasing, we need to play on all these things. So, coming back here, we have this convection from internal ambient to enclosure walls. So, inside the enclosure, things are hot. They will be about maybe 70 - 80 degrees hot. The heat inside itself is not everywhere, but there will be internally, what you call thermals which are there, which will do the convection.

So, from the PCB, heat is picked up, the hot air it cools on the wall and then it comes back. So, we have this conviction. Sometimes to prevent hotspots from building up, you may have a fully sealed enclosure with a small recirculating fan inside, that ensures that all the heat inside the enclosure is smoothly circulated and the wall itself may have fins, inside may have fins - inside and fins outside. So, if you have a typically a wall like this, it is possible for it. They have fins on one side, similarly, fins on the outside, fins on the inside become heat, from there by convection, as I said by having a fan inside fins; outside transmitted outside.

So, this you would have seen in commercial literature, related to air conditioning. The air condition outdoor units and similarly the operator indoor units are often made, this is the special finned tubes, which have fins inside and then fins outside. So, we have an advantage there, because we have the working fluid circulating inside and there is a high powered circulating pump inside. So, the fins will not impede the flow of the working fluid and depending again on the design and all that we can make them of the correct profile because most of the times, the fins are extruded. Similarly, on the outside also, the fins sometimes are attached to further, I am sorry, the tubes are attached to further fins or the fins are directly extruded.

So, if you get a chance, have a look at an old outdoor unit of an air conditioner, especially, the split air conditioners. There, you can clearly see the main copper tubes are something, which are attached to the fins, which happens to that device you see, in the front of the car, the heat exchanger which is kept there. So again there, across the wall we have conduction and we need to analyze the conduction and from the working fluid to those, what you call those fins, the thing is by convection.

Here, slowly the concepts of heat and mass transfer will come to you. Oh, sorry! Let me go back.

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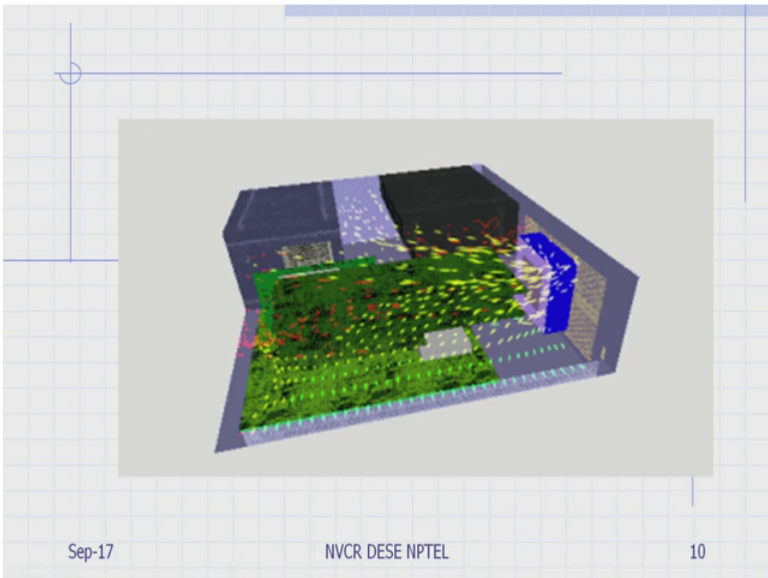

This is one of those beautiful simulations. For some reason it is not working, because I think flash or something is needed and it is not enabled. So, you can go and check on the internet. You see there, these days, there are commercial software that are available, which will help you understand this, other than, what you call extreme expense in acquiring one of these software.

The other issue is also about how well you model your component and your system. So, it is; obviously, a 2 step process. In the first step, you have a rough prototype and you need to estimate and so being, you know completely like what I call an enthusiast or I want to avoid the thing. Now mechanics are much better than me, I can talk and they can do lot of differences there.

So, unless the person, who is actually on the field, who does it just by trial and error, you can always put together a simple prototype and then, after carrying out this analysis you can optimize it and while optimizing, you can if you see, you remember that fins, I showed you, that cooler one of them, that fins are not strictly radial. They are all also following a peculiar, what I call tangential like a curved fin, like that in one of them, the fins are radial and then, the heat is being taken away like that. These things can have come out of optimization using these or software.

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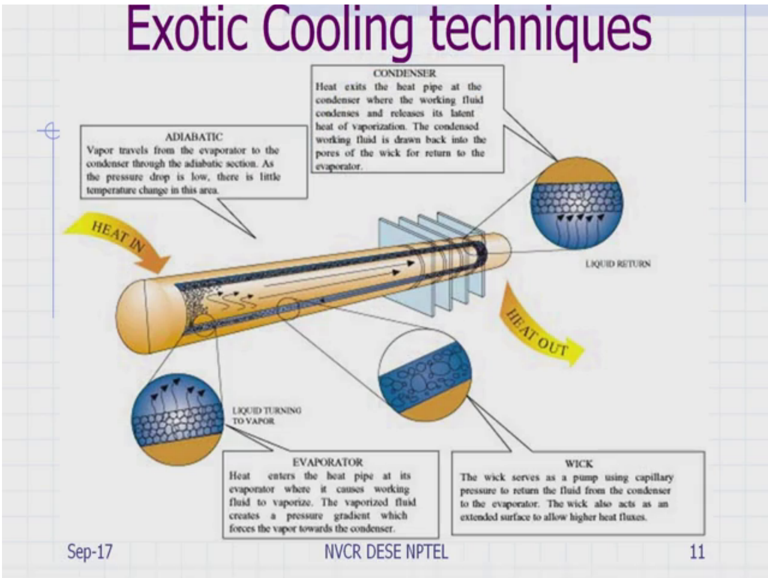

The next picture shows you unconventional things, which are not used often, but they are also used, the thing is, they have practically become proprietary and I think, all of you know about this heat pipe, how we have awake, how we have you know, one end of it. That you will repeat it again, such a beautiful picture, I myself am caught in this. So, invariably they will be a long tube, hollow – it is not a solid. The comparison is always between this solid tube and the hollow tube.

So in this hollow tube, the main components are :- there is a wick, which is close to the wall here, a thin wick maybe I mean a millimeter also, if you take an 8 millimeter tube, the wick maybe only 1 or 2 millimeters and then, and one in the feed, this is attached to the heat generating device. You remember that as some like this thing, that you know aluminum, and this is a copper, things are there for the case of convenience. It does not case of analysis, they have shown it as a round tube.

So, the moment you give it to heat, phase change occurs here. That liquid inside, starts becoming vapor and then, we have a latent heat of evaporation, similar to what will happen when we boil water, which is common practice. If you have to put water in where, cylinder start boiling it, you will notice that the water evaporates by surface, some boiling and all the bubbles escape and vapor is generated to the surface and then, the origin of the vapor, know maybe some because of a nuclear boiling and we have that famous experiment and all that know, the vapor bubbles will start at the probably bottom or wherever it is and come out and though, the issue there is latent heat of evaporation carries away all the heat. Temperature of the liquid does not change; commonly it is used in various things like a milk boiler. Water generally knows it is taken, that water boils probably depending on the ambient and so, on around 95, 97 up to 100 degrees at sea level.

So in Bangalore, where it a elevation, it boils at a what you call lower temperature, I take it that our water boils at 97 degrees, but milk requires a little more than 100 degrees for boiling. Over it forms that the cuisine and then, the whole thing you know comes. So, if you are taking a water jacketed vessel, that is, you take water in a vessel and then put one more vessel inside, put milk in it and start boiling the water inside, it will never reach the boiling over point of milk. This is how, typically a water jacketed vessel works and what is called, a milk cooker also works..

And now, do we need to boil over the milk? That is a thing in, I mean we have been taught as children know it, must you stand there, watch and I know boil over, which is probably how know, this steam engine was invented. When a child was ask, to you know what you call do anything, he did the next thing, what did he do? He pressed on the cover and one small thing, what we may say is, if there is a spout, it would not have developed the pressure, probably it is a close to vessel, then only founded that if you close it, the pressure builds up and so on and then, after that you know, now things have improved dramatically. We are probably are not interested in it.

But the starting point is the boiling that takes place here, in the case the phase change occurs here and then, pressure also builds up. As the pressure builds up, it tries to, you know what you call push all the vapor to the other end and the other end is cool, because they put fins here and then, depending on the working fluid usually they have water in propylene glycol and then, probably they evacuate it, also a little and then, other types of what you call alcohol, which boils at a lower temperature, probably most of the times they use propane to all isopropyl alcohol. It boils at much lower temperature, not propylene glycol. Propylene glycol is for something else.

So when they take this, what you call propylene. I am sorry, isopropyl alcohol or anything; the boiling point may be around 50 degree centigrade - 60 degrees. At that point, it starts boiling here and then, when it comes here, when the ambient is say 50 or

60 it will start condensing here. Two things have happened. When it condenses, a lower pressure, the pressure falls strong. So, we have something which is pushing here something which is you know, what you call sucking it out here and then, the condensation is returned by wicking action back. So, again I am sure, all of us thinking people will have the question - does it work in all orientations? You know, what are the critical things? These are all things, which people have worked on very well and then, there are commercial samples, if we just check on the internet you have that thing.

The best example is, you have a tube which is probably 200 mm and then around 800. I am sorry 8 millimeter diameter, 200 mm and then, other side you have a copper rod. Put both of them in coffee and you can feel the difference; obviously, the heat transfer rate and the flux here, can be made to be 10 to 20 times that of is solid rod. Both of them are made of copper. One is copper tube and they have made other inert materials.

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So, the next one, this is what I was telling you about. What looks flat, I mean things very convenient there, is not that easy. In actual modeling, you see here, two or three things are there. Here, once again while the inside is very exotic and then, you have a small what they call a device to, it is a soldered nipple, that is after evacuating it, they crimp it and then they also fuse it, by something by which they know, what is the total material and all that and then, we come back to the original thing – current. From here to here, the mechanism is conduction. In this case, you have a probably, it is a magnesium zinc aluminum casting and then, other side you have copper.

So, from various places including devices here and devices underneath and then, you have seen this small thing is a strap. In this case, we have three clamping screws, but in this case there is a solid strap. So, you need to unscrew this strap and then clamp it. It is clamped and these two are already fitted in the factory. They are probably swaged or otherwise forced in the factory, but main mechanism is conduction which is the reason why it has been included here and it goes back into their device at the back, which is where the condensation takes place.

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And then, that exchanges the heat with the ambient here, using convection.

So, internally you have convection and then, outside you have this beautiful convection again.

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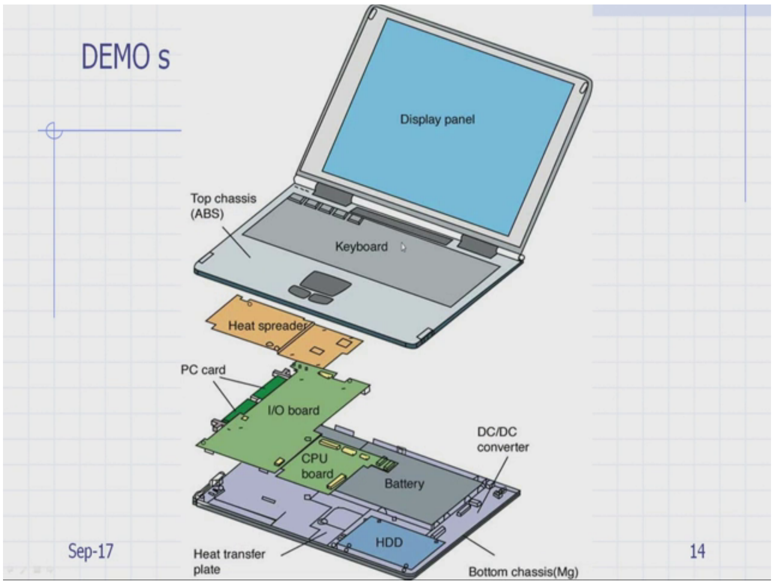

But between these two, conduction seems to be very - very critical. Same thing, even if we were to take a laptop. It is a little old. Very critical component is this - heat spreader. This heat spreader takes all the heat of all the components and then tries to push it inside and you know, makes I am sorry, it will try to collect all the heat and push it outside and then, if we take an average laptop, you only have the top surface and the bottom surface and in the bottom surface these days, if you actually put it in your lab, chances are not comfortable. So, you also have a fan, a small tiny fan which is probably kept an angle depending on the various things. I do not know how the very thin laptops are done. I suggest now, go to tech republic and see how to open various new devices; it will show you how things are done.

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So, you have all those devices. Now, this is taken from what you call sensor insulation, which I have worked with my colleagues. So you have here, do you see typically I am sure you have seen such things outdoors, as part of weather collection. So, I do not know what are these sensors inside, but all that I know is they should not you know, get to gather heat. So in this case, they have reflective shields everywhere to ensure that, the solar radiation does not heat up the components inside.

So, some of these come with you, know fins and all that the fins, have the property of giving away what you call air by convection, not picking up anything by radiation and also, they allow in guiding there to cool things. You see we have something here and then, we have all these antennas and then, in the place where we work, we have; we are in a slightly remote place so we end up with having batteries.

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So you see here, this whole thing is an aluminum case; I think probably this the last slide.

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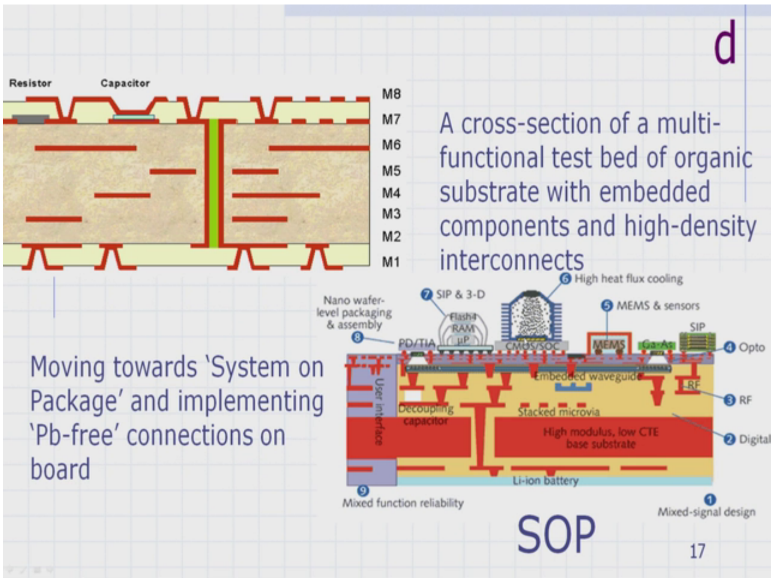

Now, slowly we are coming into the future. The future is passive components in organic substrates with embedded components and high density interconnections. If you see these slides here, you see here fantastic, high heat flux cooling. I am lucky. We have Siemens, what you call system on chip and then we have so many of the thing, wafer level packaging and heat flux cooling which uses the other thing. This I have taken from my colleague DAC who works in the interconnection area. It is not the future, it is a present, already such things exist though, what you call, and it is not as common as you can think of. So, things have progressed tremendously. While I talked to you about the phase change and what you call as heat pipe and all there. Here, you see, already there are devices. No which have this phase change things, built on top of it and then, they are able to take away heat at a high flux.

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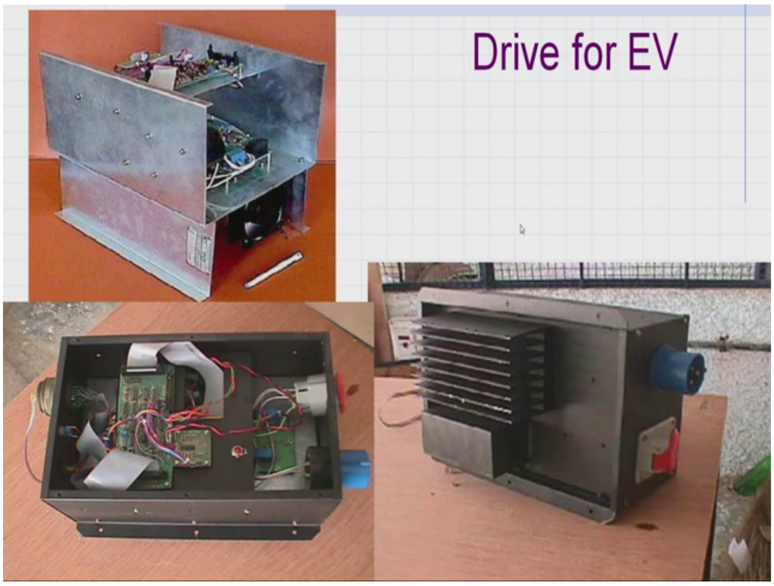

Let me come back for these. You know, what you call, what I showed you already here, all these active components and all are directly mounted on a heat sink which projects out. So, we have conduction.

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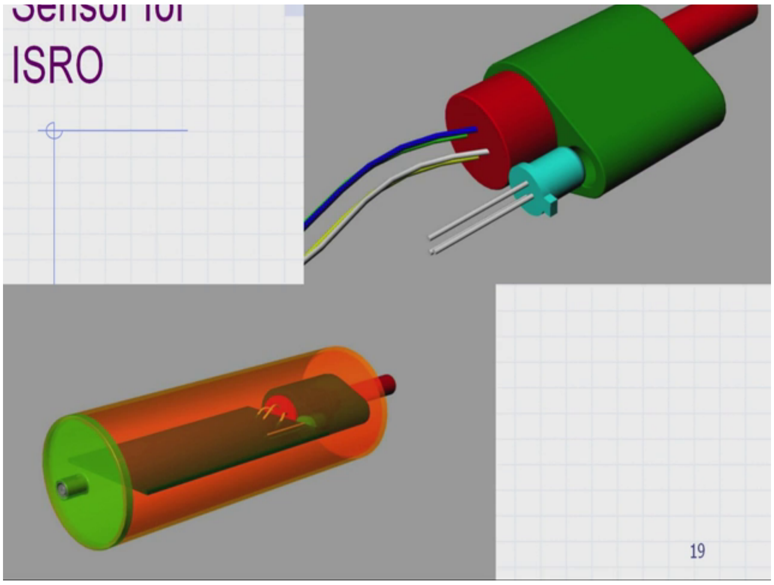

And we have everything. We know about it. Now you see here, in other place, this one is some temperature compensated - some pressure device. So, you have a pipe here and then, you know that, we have that pressure thing here and then, there is a temperature sensor here, which makes sure that the compensation takes place and then the whole thing is sealed in a space grid enclosure, stainless steel in this case and then, we have all the beautiful electronic switches built inside and we have one simple coaxial connector through which, it is expected to receive what you call, all the power and then, also expected to we have a small orifice here, which takes care of the other things.

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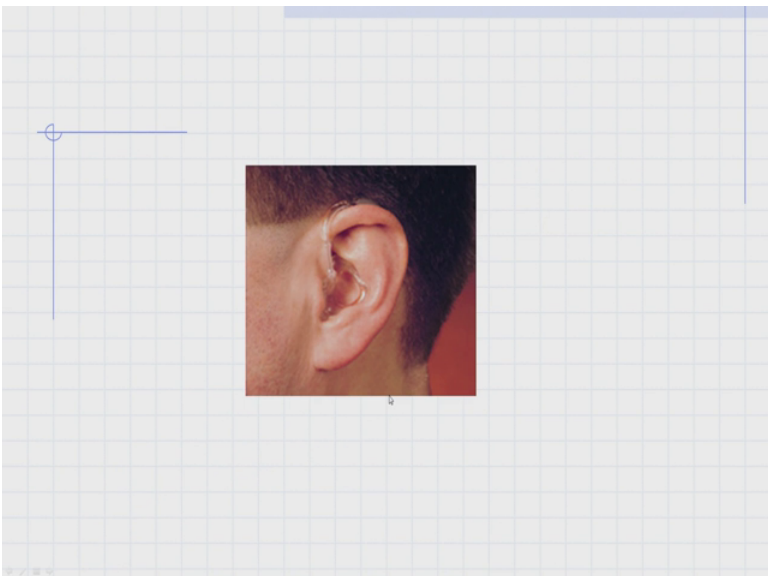

We had two, what you call serious researchers here, who have worked in the place where I work. One professor Shawn Holzer was with us way back in 1980s, who is from I am not sure, I think he is from new technique cum books NTB insists and he has written a small what you call, think here which I have scanned them and this being CDT property and then, he has what you call permitted us to use it. The tables of contents, you will notice here, know it invariably starts with interaction similar to what has spoken then conduction, convection and radiation.

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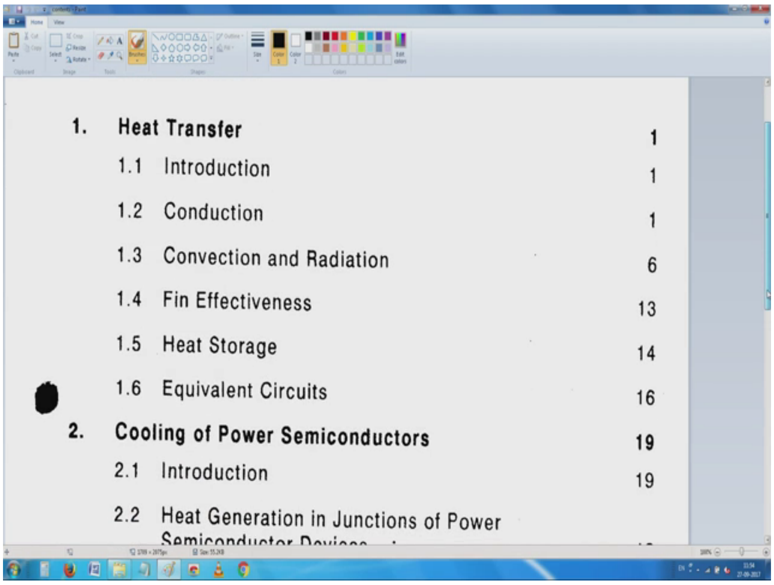

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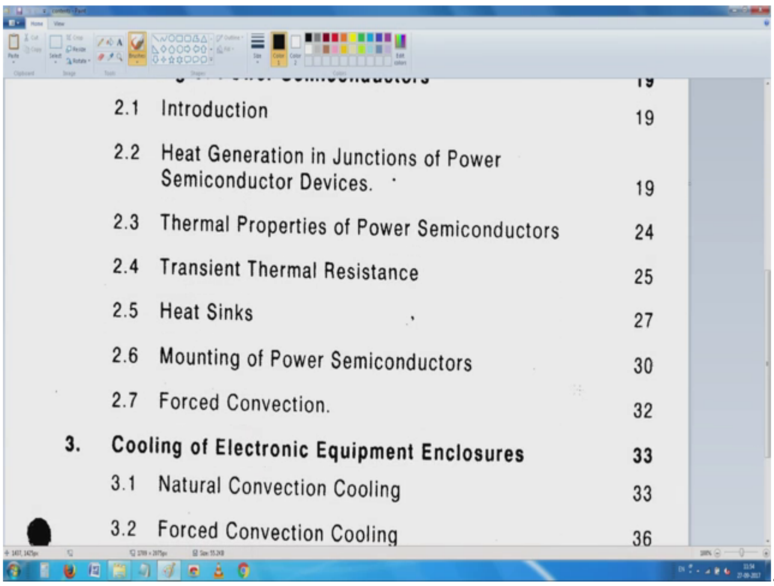

And then, something which I was talking about finally, the next slide is going to take you to something which we both like and we do not like it so much.

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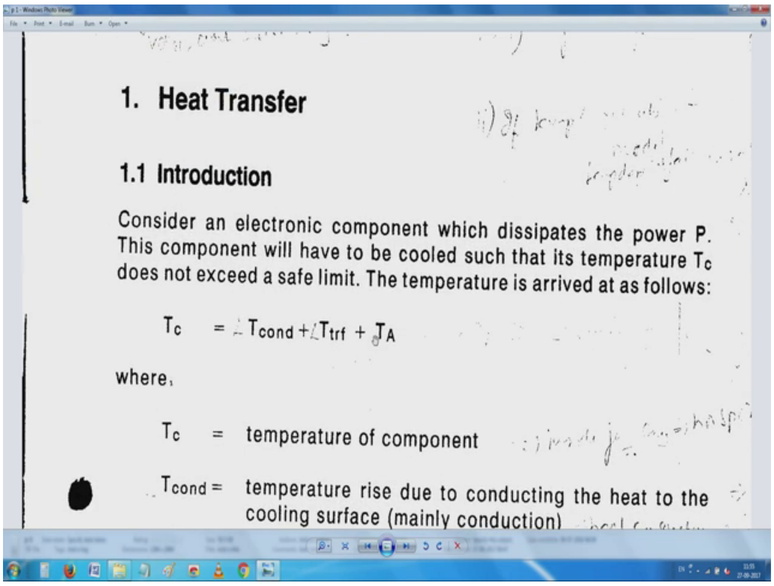

So, very simple thing is how we came about to these correlations. You understand know? Generally, what is heat transfer and how did these correlations come about. If you break them down, which will come to finding out temperature of a source, temperature of a what you call a sink and in between, how to find the transfer coefficient and then, well the heat transfer coefficient is known physical parameters, like the physical dimensions in the case of conduction area of cross section and how it varies and in the case of convection, the surface area that is required and rarely in the case of radiation, what is the area that is exposed to the source from the source to this thing.

So, we all know sitting in the shade is cooler than standing in the sun, but then remember sun is at a very high temperature we are not that hot. So, starting in the next lecture, I will, what you call try to, I would not say read out from here, see as well how I can explain these things. So my suggestion is, kindly go to the NPTEL HRD lecture series, go for simple heat transfer. Heat and mass transfer is little complicated. Simple heat transfer in the things like this conduction formulae and how they have come about are already explained by the other lecturers.

But the process of continually, I will be talking to them here and then, you can also go to the look up on the internet, because these are all relatively very simple and ok?

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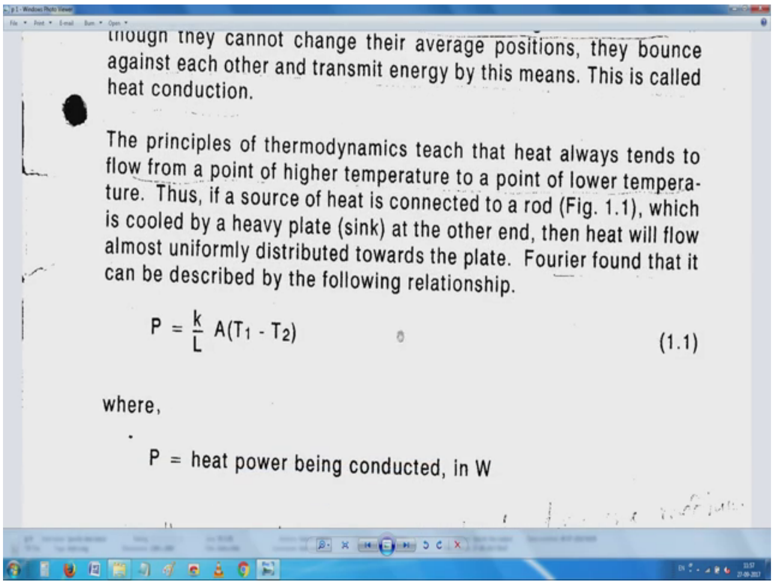

though they cannot change their average positions, they bounce against each other and transmit energy by this means. This is called heat conduction.

The principles of thermodynamics teach that heat always tends to flow from a point of higher temperature to a point of lower temperature. Thus, if a source of heat is connected to a rod (Fig. 1.1), which is cooled by a heavy plate (sink) at the other end, then heat will flow almost uniformly distributed towards the plate. Fourier found that it can be described by the following relationship.

$$P = \frac{k}{L} A(T_1 - T_2) \qquad (1.1)$$

where,

P = heat power being conducted, in W

Things like this are what the other slide which I have shown you in the beginning, taken from the YouTube link. Everybody talks about B is equal to small these things, these things and so on like this and the only problem is, where do we get this K. It is dependent on the situation. It depends on not just the material, the condition of the material is the trip, is what you call material heat treated, is it material extruded, is it what you call - how compactor, all the principal I mean the particles inside.

It is a very specific characteristic at that point of time and finally, conduction only talks about one place to the others place and then everything else needs be mounted. No chip needs to be mounted and then, similarly heats product needs to be mounted inside. So two things, one is the material and then, even a very routine thing like our aluminum, I think I am sure, all of your bicycle enthusiasts, when people talk about 6,000 series and 70-70 bike and all that, you know it can be complicated and there lot of material on the internet which you need to study carefully.

You cannot say aluminum is lighter, saying 7 7, I mean 70 you know, some 65 stronger like that. Know you need to see various other things. So, two things we do not know here, is while this area of contact and the temperature coefficient in conduction. Both of them, we are not very clear; however, we have guidelines, if you go to the catalog, so you can easily get it. So, permit me to stop here and start in at next tomorrow and try to see how I have understood it so.

Thank You, we will meet again.