Electronics Enclosures Thermal Issues
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Lecture – 14
1972 model paper

Hello, this is the next lecture from where I left of yesterday. You remember there were two things one is from the RAMs burg book and another is from our own perception or just notes and a little bit of sashaying what will happen in case you have a contact resistance problem.

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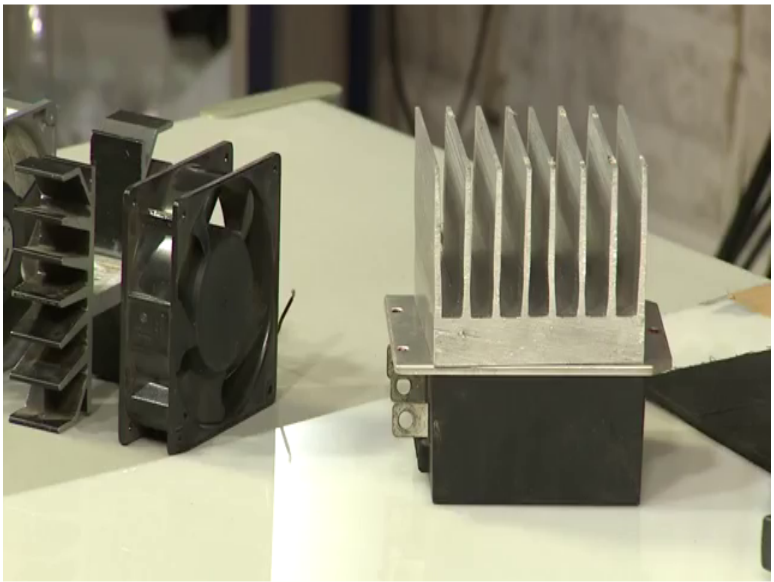

So, if you can kindly look at the sample, which I have given there, some of you not some of you if you just go back you may recollect this is taken from a commercial controller and I think some of you will know and then this is not damaged due to our product design requirements, and to be connected to a big bus for lightning that to bend this to lead a little.

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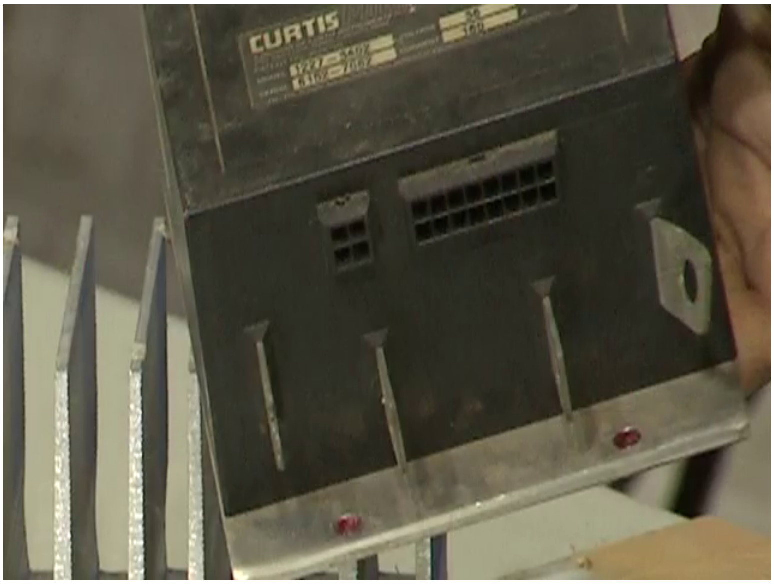

The beauty of this is whatever they talk about at the back, you have seen this we have a solid plate and in general in principal, we are not supposed to alter it or what do you call try to do it. And then here comes the thing what do we do about the surface, do we keep it as stays or to be how do we cool it or whatever it is, this is where all over two levels of analysis is required. One of them is, if you see this heat sink has been made for fan cooling of devices which are mounted on the surface, and then we also have a fan here which as I have told you earlier which approximately covers these areas and then we have this.

But then you will notice here is, if you are starting a design and you have controller the various phases may be you can always use it and then we always have long length, and then you decide using little bit of empiricist a little bit of handbook and suppliers catalogue because what you wanted to do probably he has done it himself seen that.

You know you see the beautiful cross section, this was I trying to tell you and you see the way the fins are tapered to improve the fin effectiveness. And then if you worry about all the other things do not worry if you consider all the other things saying, I have a fan here and then why not make it deeper and all that the consideration about their being deepener spacing, you have only so much control not infinite control as you would do for analytical thing. These things it is a compromise between how much is space is available, for your full module and then what are all you have to mount here?

And then in this case actually it has been removed from where 3 3 t o three packages were mounted here and this was checked for that purpose saying if you just mounted as it is in the fins vertical direction how does it work. Later on can we add a fan directly and what is the effect of this. If you have a thing like this typically what is the effect. And in the case of regular vertical product design, we have this beauty of we will be able to.

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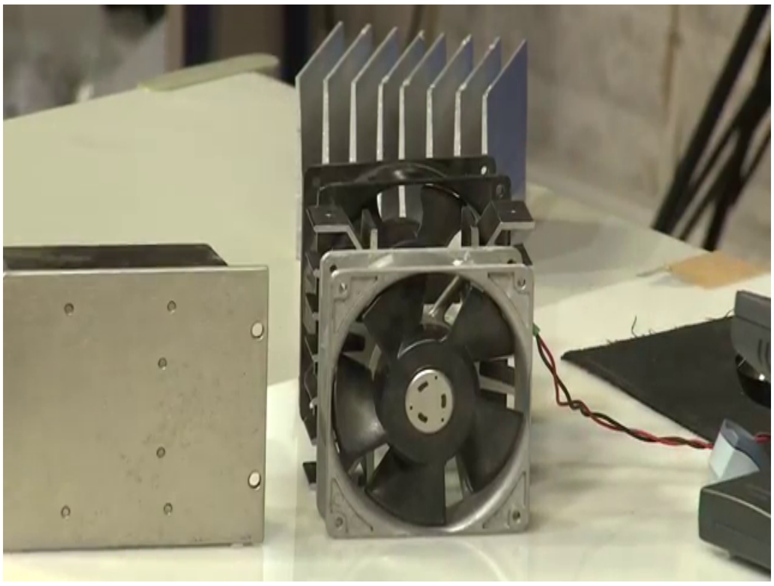

Well I want call it strictly fire fighting, up front I can try to add one more device to improve the air force recirculation this again I would like to what do you call play little on your memory saying a little bit of experimentation a lot of theory, and you next decide how much of spacing how longer big can it be ok. Here the manufacturers should have done whatever data you want to make, and then you make sure that you have a tube like thing along tube light thing. Typically if you have to have an industrial panel rack this is not the 19 inch rack which you talk about, these are all the panels which are directly built they have slightly different dimensions they are not meant for directly mounting.

This is a little like the relay panel (Refer Time: 04:57) which you find on what you call in our science emissions. So, what they do is, fan one of the places fan and then in between heat sink and something to do with the heat sink the length of the heat sink. Now once again because of the leather of devices that is available, we need to start working on these things. This is not every time that you know we are actually starting from scratch and doing things. So, I will now point out to a practical thing this is a as I said know this is a drive which has purchased to be used in a vertical hybrid three wheeler can be used for as an auto rickshaw in our places, they we call it auto rickshaw or it can be used in a any invalid courage having more than three wheels.

Now, having such gerund are people know could locate a nice cute heat sink, gets heavy and they only what do you call a good point of it is, you see somehow it seems to miraculously match and you have enough place for mounting, we have place for mounting holes two of them here and then two place mounting holes here. Now comes to the same thing, why, what are the purposes of the mounting holes and what do we do with this heat sink and what do you do about the imperfections in this?

So, I have a surface you have a surface you have a surface and what are all you have spoken about saying keep this surface at a temperature, keep this surface as temperature still tremendously depends upon the resistance and the air gaps and the contact that is made you avails and valise then you have a harems value of the roughness.

And then when you mount one over there were how well they behave this is all related to that. Just for second cover it in the last time because not to prevent the flow though the things are available, right now I will take it away from here and then get back to.

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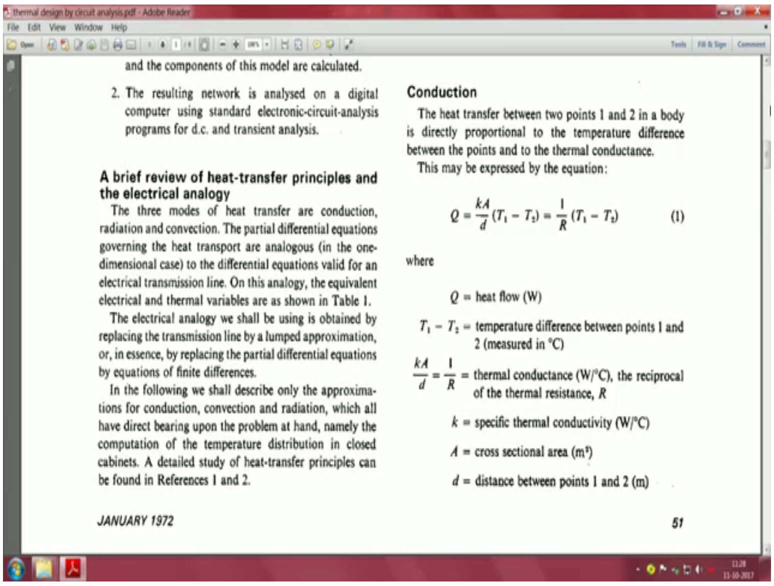

and the components of this model are calculated.

2. The resulting network is analysed on a digital computer using standard electronic-circuit-analysis programs for d.c. and transient analysis.

A brief review of heat-transfer principles and the electrical analogy

The three modes of heat transfer are conduction, radiation and convection. The partial differential equations governing the heat transport are analogous (in the one-dimensional case) to the differential equations valid for an electrical transmission line. On this analogy, the equivalent electrical and thermal variables are as shown in Table 1.

The electrical analogy we shall be using is obtained by replacing the transmission line by a lumped approximation, or, in essence, by replacing the partial differential equations by equations of finite differences.

In the following we shall describe only the approximations for conduction, convection and radiation, which all have direct bearing upon the problem at hand, namely the computation of the temperature distribution in closed cabinets. A detailed study of heat-transfer principles can be found in References 1 and 2.

Conduction

The heat transfer between two points 1 and 2 in a body is directly proportional to the temperature difference between the points and to the thermal conductance.

This may be expressed by the equation:

$$Q = \frac{kA}{d}(T_1 - T_2) = \frac{1}{R}(T_1 - T_2) \quad (1)$$

where

Q = heat flow (W)

$T_1 - T_2$ = temperature difference between points 1 and 2 (measured in °C)

$\frac{kA}{d} = \frac{1}{R}$ = thermal conductance (W/°C), the reciprocal of the thermal resistance, R

k = specific thermal conductivity (W/°C)

A = cross sectional area (m^2)

d = distance between points 1 and 2 (m)

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Have a look at this paper I could retrieve. Most important your notice is you see this the bottom beauty no see when it was made its about the time when I started my professional career 45 years back I did not make it, but I could retrieve it from the what do you call things which have been you know.

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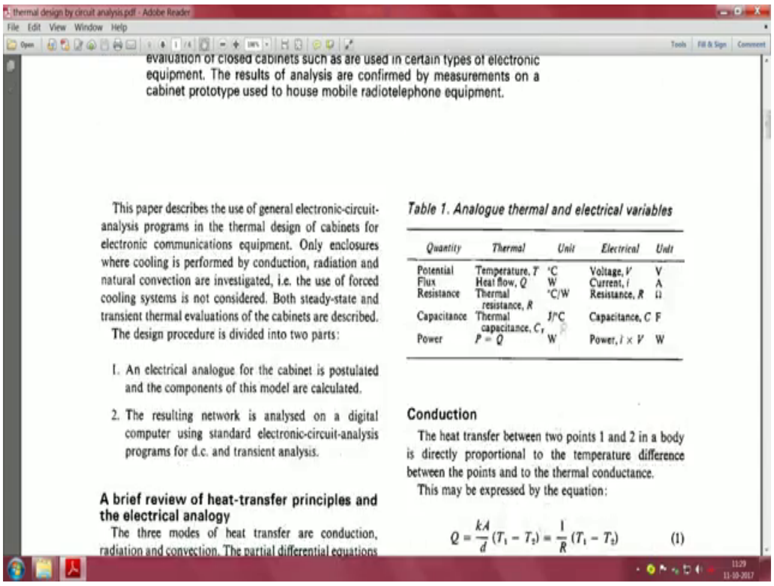
evaluation of closed cabinets such as are used in certain types of electronic equipment. The results of analysis are confirmed by measurements on a cabinet prototype used to house mobile radiotelephone equipment.

This paper describes the use of general electronic-circuit-analysis programs in the thermal design of cabinets for electronic communications equipment. Only enclosures where cooling is performed by conduction, radiation and natural convection are investigated, i.e. the use of forced cooling systems is not considered. Both steady-state and transient thermal evaluations of the cabinets are described.

The design procedure is divided into two parts:

1. An electrical analogue for the cabinet is postulated and the components of this model are calculated.
2. The resulting network is analysed on a digital computer using standard electronic-circuit-analysis programs for d.c. and transient analysis.

A brief review of heat-transfer principles and the electrical analogy

The three modes of heat transfer are conduction, radiation and convection. The partial differential equations

Table 1. Analogue thermal and electrical variables

Quantity	Thermal	Unit	Electrical	Unit
Potential	Temperature, T	°C	Voltage, V	V
Flux	Heat flow, Q	W	Current, I	A
Resistance	Thermal resistance, R	°C/W	Resistance, R	Ω
Capacitance	Thermal capacitance, C_T	J/°C	Capacitance, C	F
Power	$P = Q$	W	Power, $I \times V$	W

Conduction

The heat transfer between two points 1 and 2 in a body is directly proportional to the temperature difference between the points and to the thermal conductance.

This may be expressed by the equation:

$$Q = \frac{kA}{d}(T_1 - T_2) = \frac{1}{R}(T_1 - T_2) \quad (1)$$

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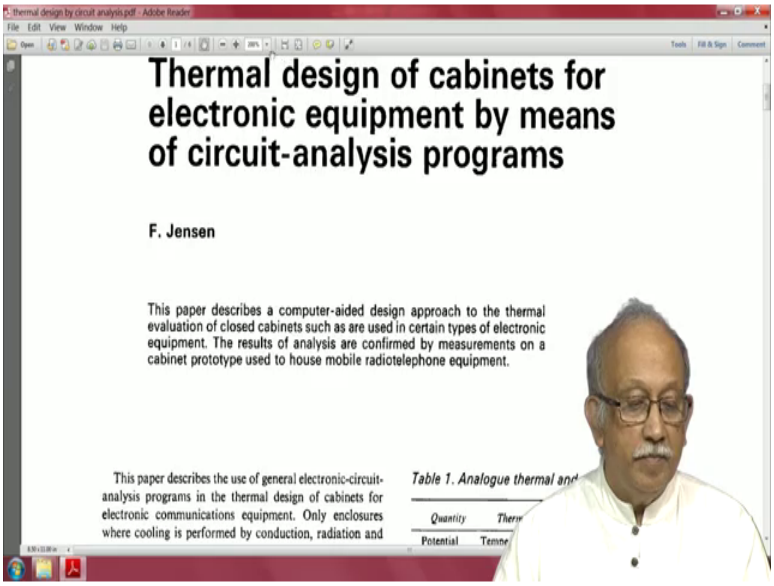
Thermal design of cabinets for electronic equipment by means of circuit-analysis programs

F. Jensen

This paper describes a computer-aided design approach to the thermal evaluation of closed cabinets such as are used in certain types of electronic equipment. The results of analysis are confirmed by measurements on a cabinet prototype used to house mobile radiotelephone equipment.

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Table 1. Analogue thermal and

So, this people they were the sort of pioneers worked on solving these problems long ago. And when first the what do you call the tele communication equipment and all came I had the honor of working with one of the government agency, which is have here and the first our rural automatic exchange rack we try to do this analysis I will say if I can retrieve it and see what best it is.

Now, coming back, I wanted to have a look at the very early on people have try to use cad to thermal evaluation of closed cabinets, such are used in types of electronic equipment. You can I am just reading it along and as I said if my accented this thing is you know little problem you always have the mute button, and then you can read it on and then luckily for us because it's a video lecture we can continue to measurements on a cabinet prototype used to house mobile radiotelephone equipment. So, the what we see here no saying the so, so, called mobile phones or cell phones probably know are much later.

This things are all developed during the era of luxurious car phone system, only the very rich could have a telephone alternatively all the law enforcement and police always had it and probably this was tried in one of those things. So, just read it along with me read the first part. See this one of the thing is enclosures where cooling is performed by conduction, radiation and natural convection are investigated. Coming back tell little this thing not long ago fans and what do you call forced cooling was not construed a really that great a what do you call approach make things easy? One of the first this says what is something fails and we want things to work and then at that time there was not this med what do you call tremendous of you know hotness around.

Seen this electrical analogue for the cabinet is postulated and the components of this model are calculated. Network is analyzed on a digital computer using electronic circuit analysis programs for d c and transient analysis see in that d c is represented by simple potential and the resistances by normal, what do you call heat transfer coefficient transient analysis is wherever heat storage can occur as in the mass and the density of the material. Just to make this paper complete electric analogy will be using is obtained by replacing transmission by lamped approximation, replacing the partial differential equations with finite differences. We describe only the approximation for conduction convection radiation which all have direct baring upon the problem at hand namely temperature distribution and closed cabinets. At the end references are given, I could not what do you call exactly get the references. So, you go by here this I have covered to you yesterday, everywhere we have somehow you need to calculate this k.

And eventually you can make a thermal conductance know as 1 by R R is the thermal resistance. Having all this no from here it is very easy for us to go about making the setting we have repeat it again and again.

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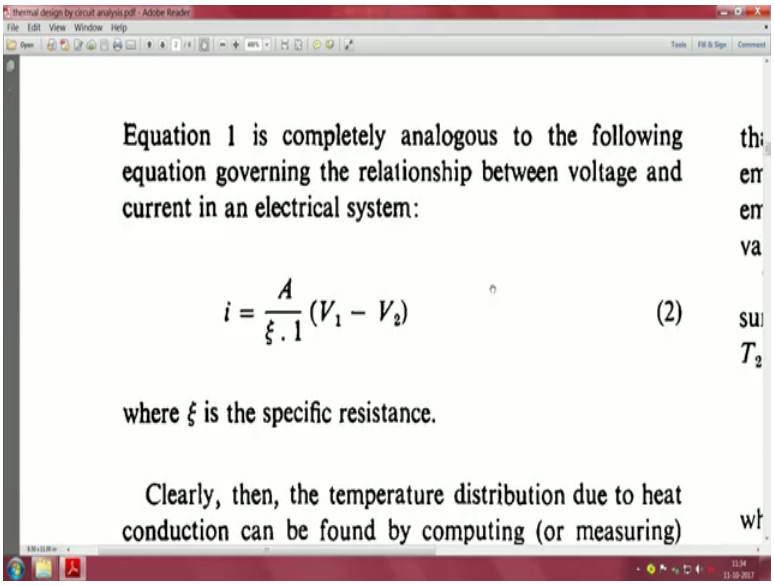

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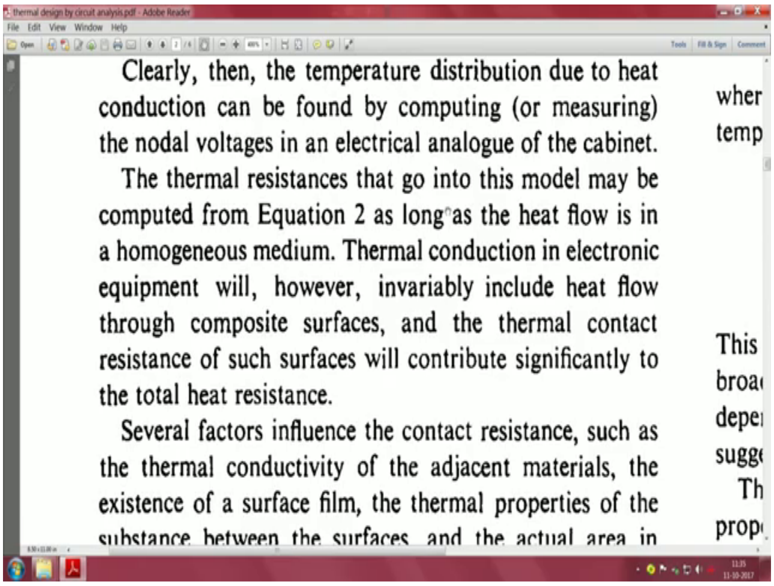

Now, seen this temperature distribution can be found by completing or measuring the nodal voltages and electrical and analytic of the cabinet. See equation 2 one of the first assumptions is heat flow is in homogeneous medium you have seen this here this is what

I wanted to show you thermal contact resistance of such surfaces will contribute significantly to the heat resistance.

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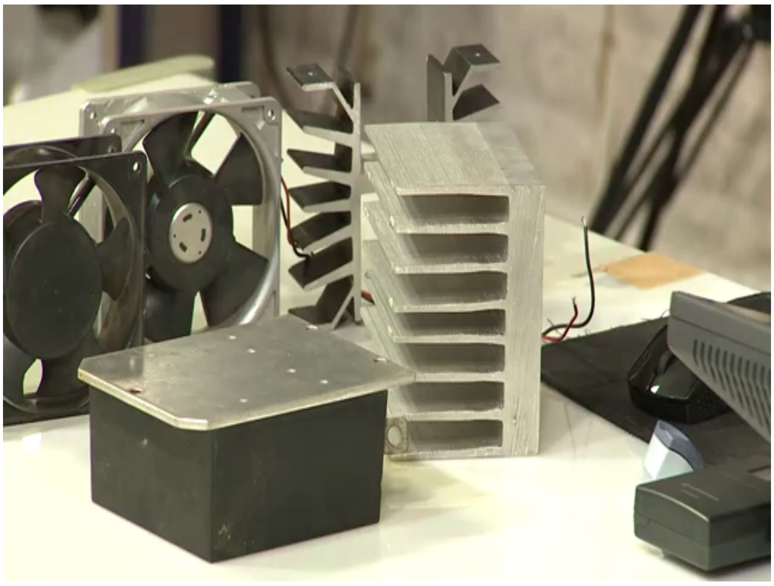

So, coming back to my model, easy manufacturers made this and I would not say as what you can he has made a specified condition saying, if the outer surface of the plate can be maintained at typically around you know 30 or 40 degree centigrade. From there he has given that thing saying typically we can get 3 degrees centigrade per watt 2 degree centigrade per watt directly all the way inside.

Now, comes the question even this manufacturer has mentioned saying this heat spreader has a nicely computed this thing and measured and all that then he has used all the you have seen that you can probably see a little about the gurus that are cut on it. And see one more small thing you can notice is there tapered and base is very thick. If you take the total area of it and then the fact is that then there is the large gap here, there is a gap here it is a little thick here and this whole thing is a generally such a construction when you have a tapered fins and then you have a strong depth and all that probably reverse directly to a heat sink that can be used it in force convection.

Now, having known this status, we have happily one on top of the other and then I will find a way of how to clamp this and may be put a plunge and take that next higher size, imagine this can be brought here. I can take the next higher size drill holes match and drill holes and put anther plate which is what you call which can distribute the load here, and then either tap this whole thing and then insert what are called helicoil inserts. Helicoil is nothing, but a helix with a diamond shaped spring, which sits in this soft materilas. So, if you have a helicoil insert here one insert here one insert here, I can now use probably hexagonal or some other headed screw on the other side, tighten it and hope things fall in to place because in spite of my best understanding of the situation, we still have you have seen this nicely it is rotating here. So, that shows that not in that much in a perfect contact same thing here this is slightly better.

So, I try to apply some heat sink compound and try to apply as much pressure as possible. This is exactly what the Genson has you know was talking about, contact resistances such surfaces will contribute significantly to the total heat resistance.

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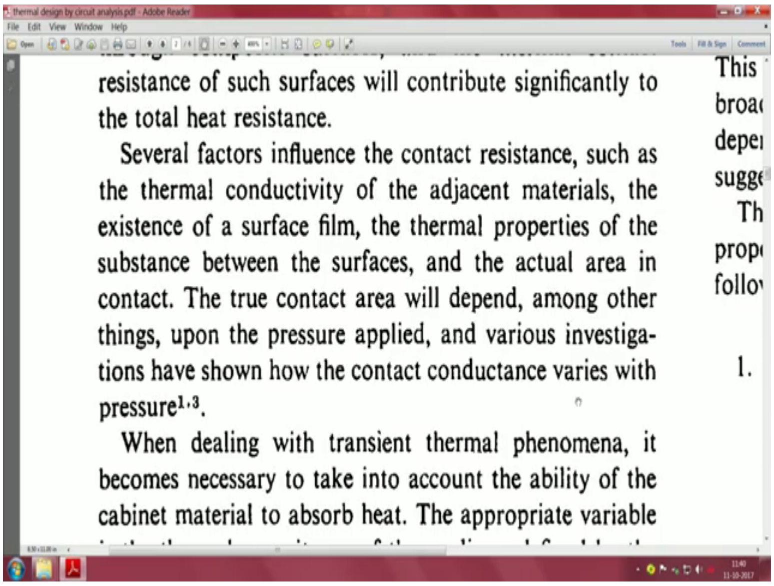
resistance of such surfaces will contribute significantly to the total heat resistance.

Several factors influence the contact resistance, such as the thermal conductivity of the adjacent materials, the existence of a surface film, the thermal properties of the substance between the surfaces, and the actual area in contact. The true contact area will depend, among other things, upon the pressure applied, and various investigations have shown how the contact conductance varies with pressure[1,3].

When dealing with transient thermal phenomena, it becomes necessary to take into account the ability of the cabinet material to absorb heat. The appropriate variable

This is where strictly adhering to specified physical mechanical parameters like they are a the what you call root mean square average of the what you call pits and valise, and also how well you protect it. And even movement between the fabrication shop and this; you have seen this just read it for yourself a little louder saw you have read if a (Refer Time: 18:46) could read, this is exactly from the horses mob a lot depends on the contact resistance, which in turn depends on the pressure. And that is where what I was talking to about how strictly you can I mean how well you can climb the thing and if you use a too much of a thing the chances are too much of pressure, chances are one of the plates will give that will create a problem further down we come to the other thing.

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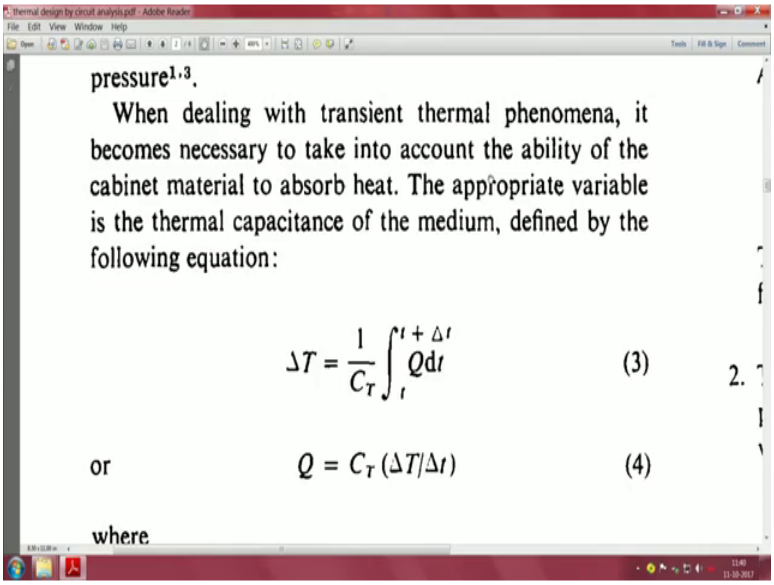

pressure[1,3].

When dealing with transient thermal phenomena, it becomes necessary to take into account the ability of the cabinet material to absorb heat. The appropriate variable is the thermal capacitance of the medium, defined by the following equation:

$$\Delta T = \frac{1}{C_T}\int_t^{t+\Delta t} Q\,dt \qquad (3)$$

or

$$Q = C_T(\Delta T/\Delta t) \qquad (4)$$

where

You have seen that once for the first time we are ending a thermal capacitance of the medium.

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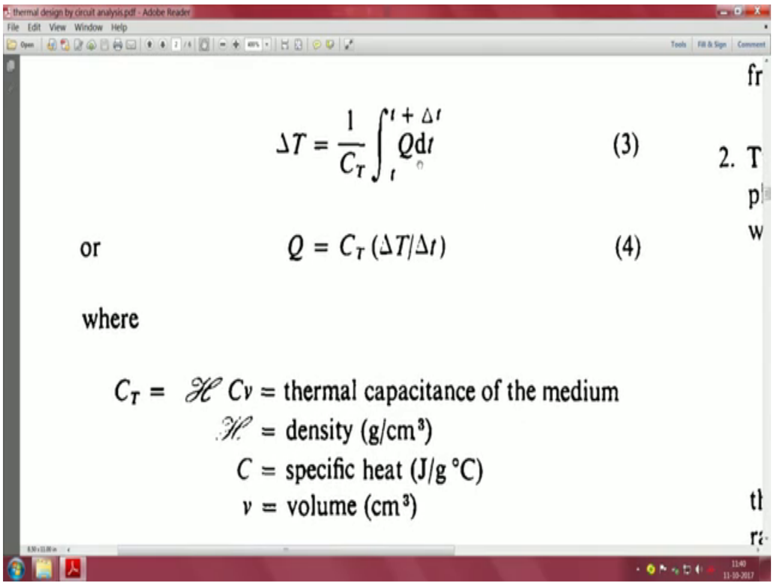

$$\Delta T = \frac{1}{C_T}\int_t^{t+\Delta t} Q\,dt \qquad (3)$$

or

$$Q = C_T(\Delta T/\Delta t) \qquad (4)$$

where

$C_T = \mathscr{H} Cv$ = thermal capacitance of the medium

$\mathscr{H}$ = density (g/cm³)

C = specific heat (J/g °C)

v = volume (cm³)

Densities specifically and the volume that is involved in varies things that we have here.

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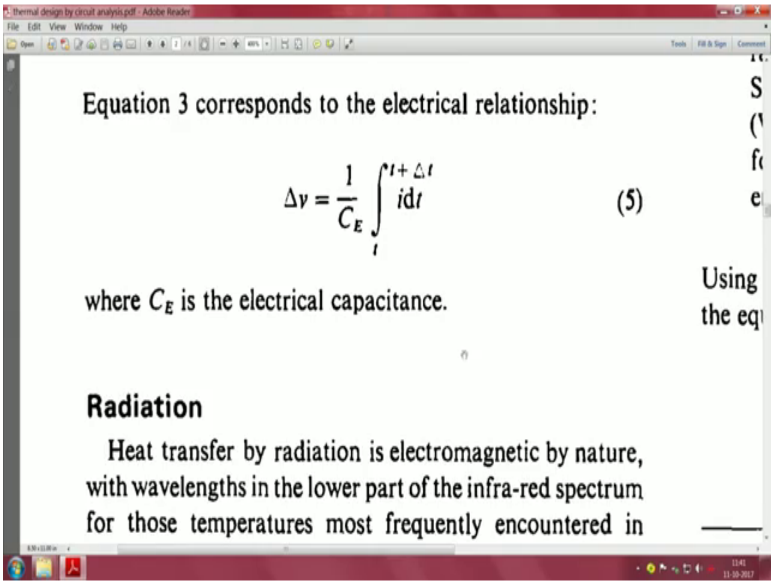

Corresponds to the electrical relationship one more you somehow you can lamp the whole thing to an equivalent electrical capacitance, we can directly use it.

Now, it will come back to the good hold question and then especially two types of people are very curious, one of them is students are working towards their some thesis and practical works. Secondly, practicing engineers saying is that somewhere I get this data. My constrained opinion not readily available you need to approximate take something, which is about near as equivalent and check. So, this is exactly what this people have also done and at the end they have reported the results.

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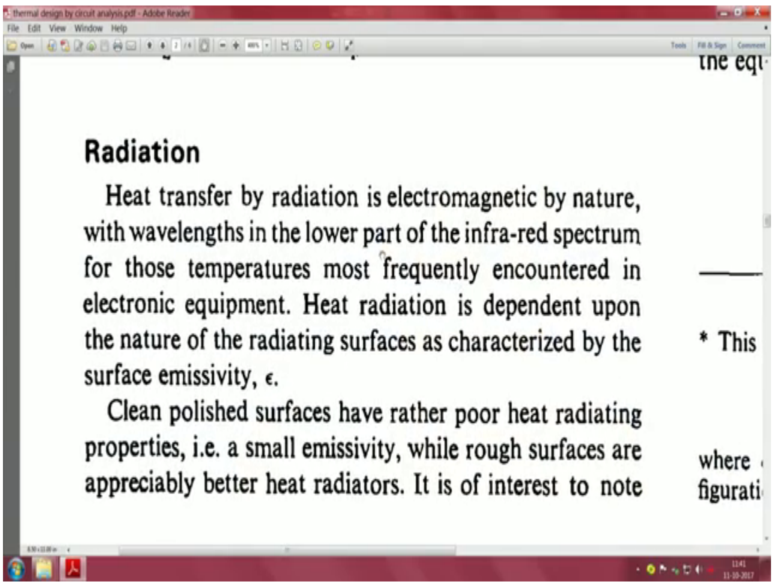

Now we have all this transformer radiation I mean you can read it.

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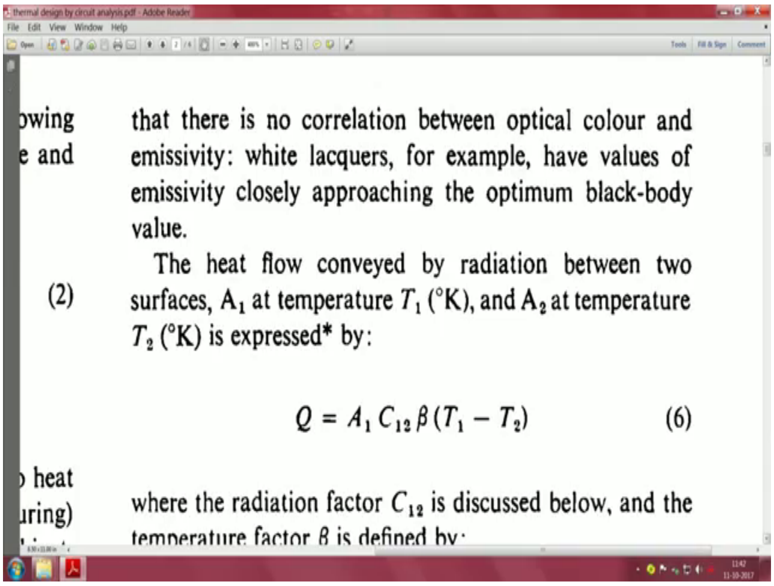

Sorry for the little bit of a jumping I am not used to these things there is no correlation between optical color and emissivity.

So, when I talk to you about a this thing sorry for repeating, it really does not matter. So, if you go to the web and check on all the practicing I will say I will use the word hacker without the bad name hacker is you know not longest in our time no, it meant somebody who will mess up with trying to find things out. They are not jail breaking, it is not you know trying to create malware and so on it is about trying to understand which I am sure some of your curious should have tried it. So, if somebody says black is better than white, as I said if is a teacher who has to grade you whatever you told you repeat it, but then the original is does not make any difference.

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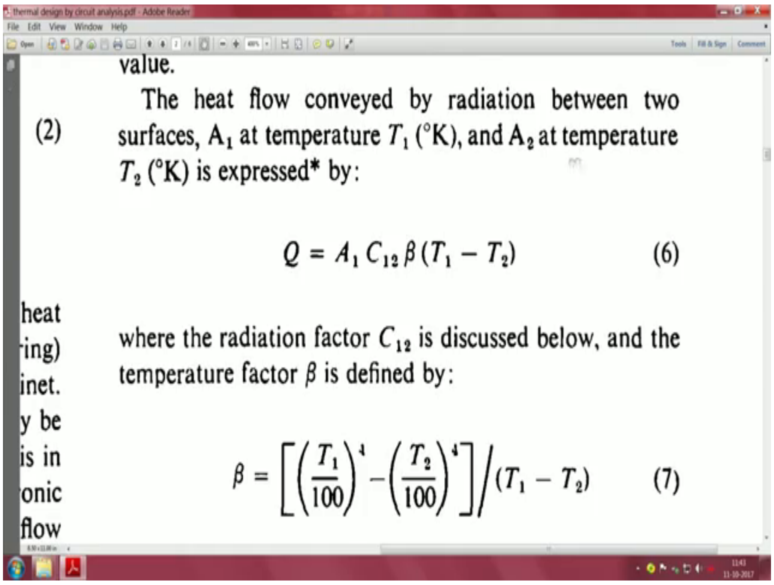

Between two surfaces A 1 and T 1 and the A 2 at T 2.

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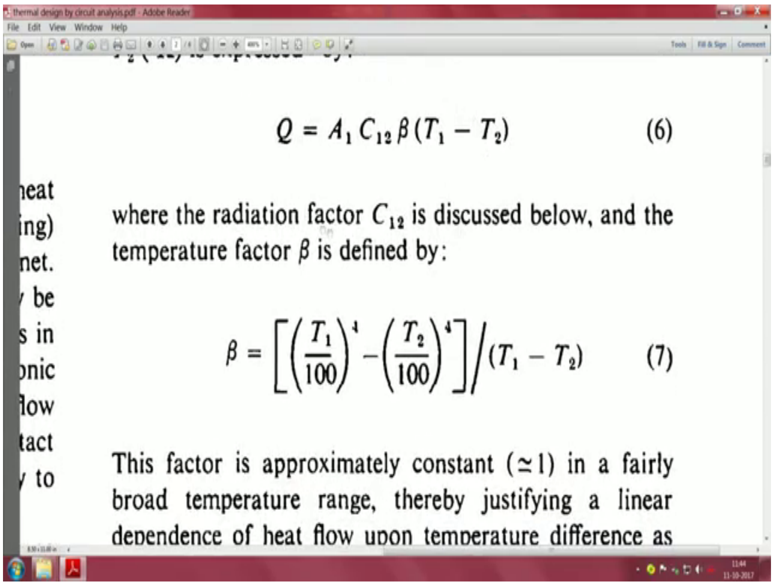

We have this beautiful thing in which we have again end up with temperature factor another what do you call saying is there something we can use directly and after if you take this various temperatures and so on know.

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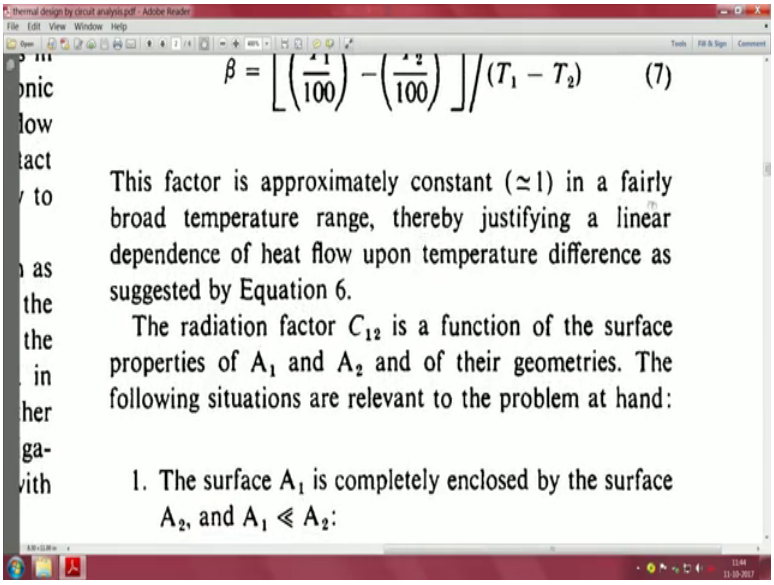

Is approximately constant in a broad temperature range, there by justifying a linear depends of heat flow upon temperature difference as suggested by the earlier equation. Radiation factor is definition of function of the surface properties and of their geometries following situations are relevant completely enclosed by the surface, it is approximately equal to this.

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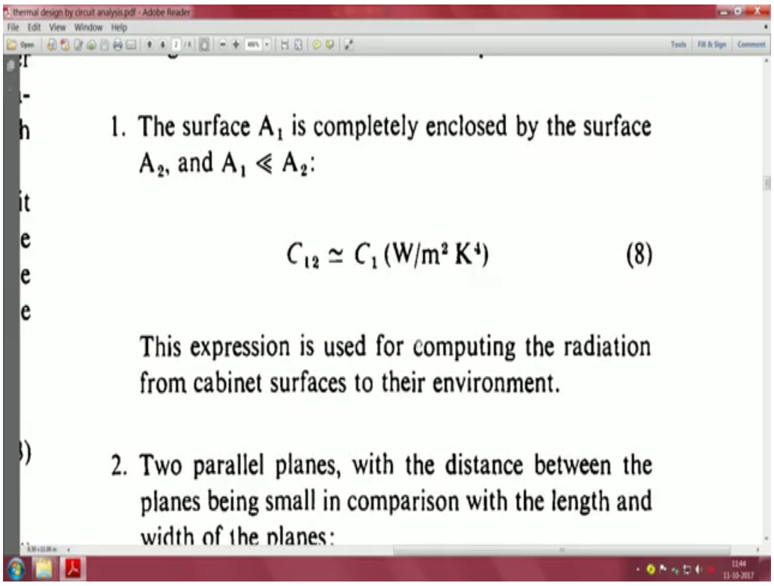

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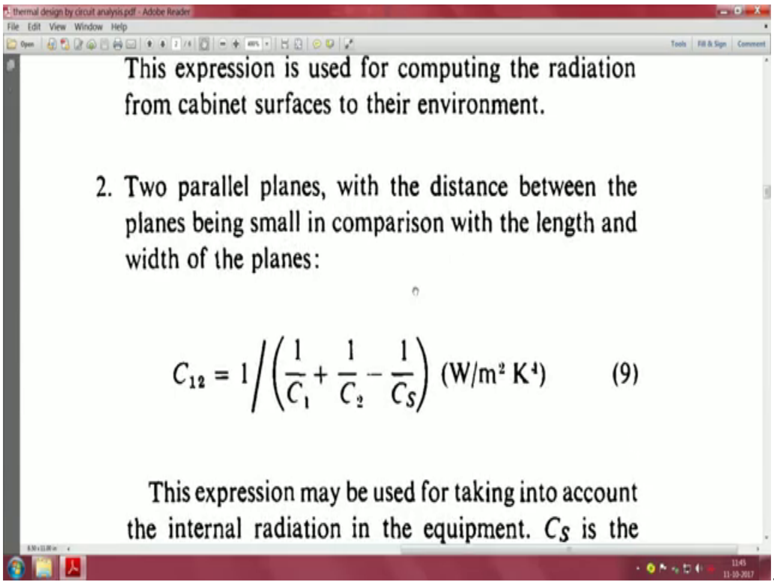
This expression is used for computing the radiation from cabinet surfaces to their environment.

2. Two parallel planes, with the distance between the planes being small in comparison with the length and width of the planes:

$$C_{12} = 1 \Big/ \left(\frac{1}{C_1} + \frac{1}{C_2} - \frac{1}{C_S} \right) \text{ (W/m}^2\text{ K}^4\text{)} \qquad (9)$$

This expression may be used for taking into account the internal radiation in the equipment. C_S is the

Competing radiation from cabinet surfaces to the environment to parallel planes with the distance between the planes, in comparison with the length and width of the plates we have all this may be used for taking into account internal radiation in the equipment.

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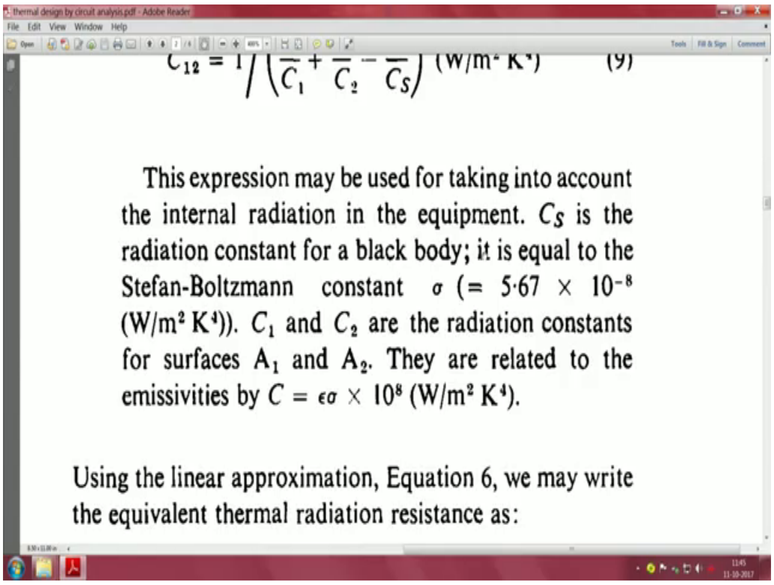
$$C_{12} = 1 \Big/ \left(\frac{1}{C_1} + \frac{1}{C_2} - \frac{1}{C_S} \right) \text{ (W/m}^2\text{ K}^4\text{)} \qquad (9)$$

This expression may be used for taking into account the internal radiation in the equipment. C_S is the radiation constant for a black body; it is equal to the Stefan-Boltzmann constant σ (= $5{\cdot}67 \times 10^{-8}$ (W/m^2 K^4)). C_1 and C_2 are the radiation constants for surfaces A_1 and A_2. They are related to the emissivities by $C = \epsilon\sigma \times 10^8$ (W/m^2 K^4).

Using the linear approximation, Equation 6, we may write the equivalent thermal radiation resistance as:

Is radiation constant for a black body it is equal to the Stefan-Boltzmann constant and C 1 and C 2 are constants for surfaces they are related to the emissivity and so on.

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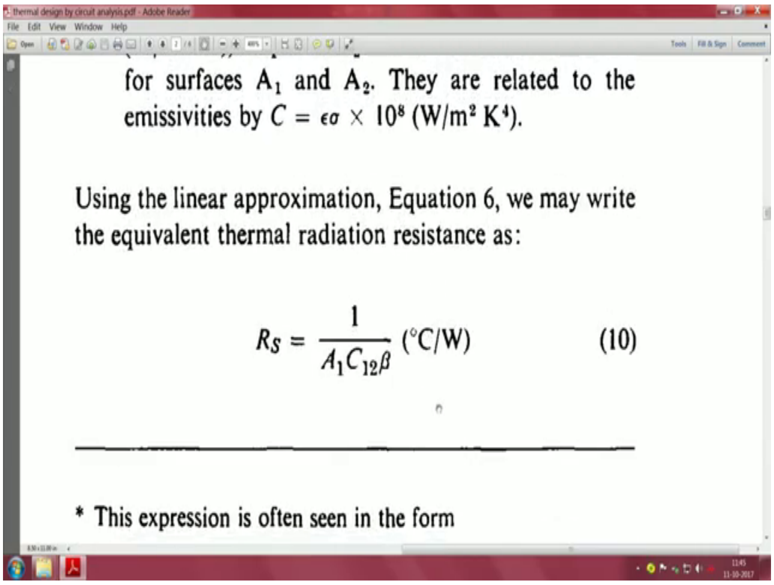

for surfaces A_1 and A_2. They are related to the emissivities by $C = \epsilon\sigma \times 10^8$ (W/m² K⁴).

Using the linear approximation, Equation 6, we may write the equivalent thermal radiation resistance as:

$$R_S = \frac{1}{A_1 C_{12} \beta} \; (^\circ\mathrm{C/W}) \qquad (10)$$

* This expression is often seen in the form

So, finally using all this we have simplified things as much as possible.

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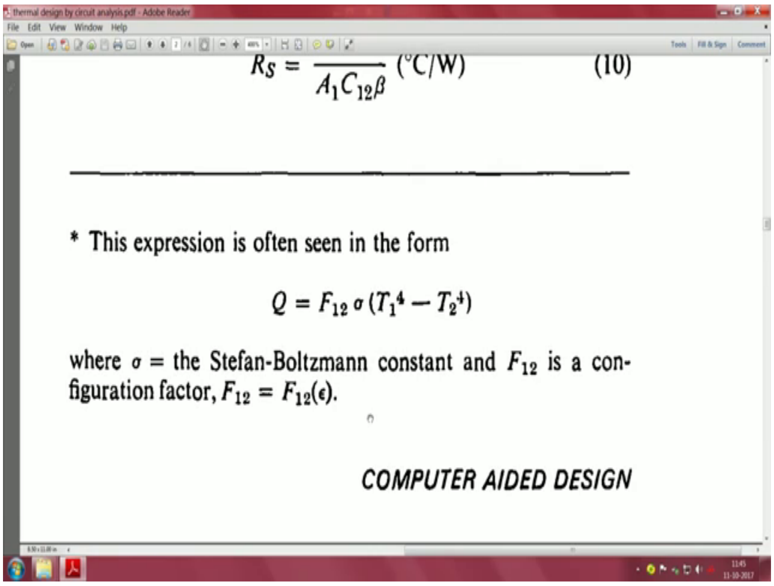

$$R_S = \frac{}{A_1 C_{12} \beta} \; (^\circ\mathrm{C/W}) \qquad (10)$$

* This expression is often seen in the form

$$Q = F_{12}\,\sigma\,(T_1^4 - T_2^4)$$

where σ = the Stefan-Boltzmann constant and F_{12} is a configuration factor, $F_{12} = F_{12}(\epsilon)$.

COMPUTER AIDED DESIGN

Now, let me go back to the next page.

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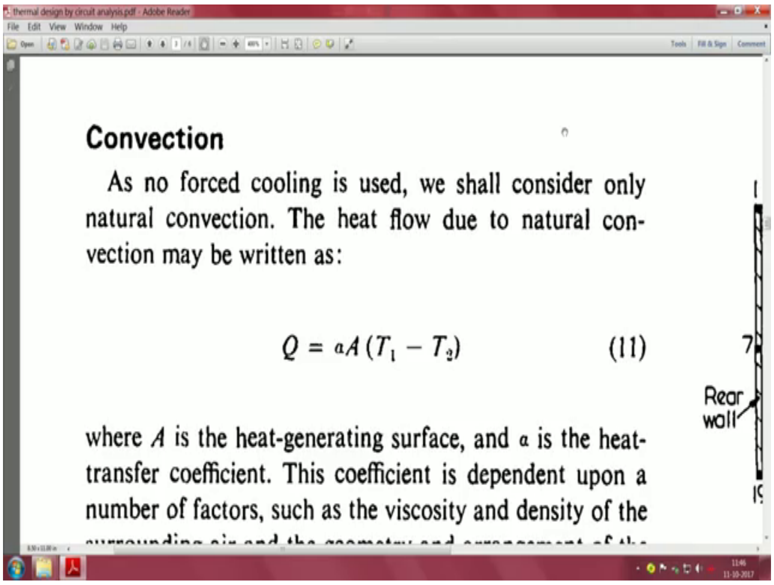

Next page shows you after going towards the conduction I mean the after finishing conduction and radiation, we come to the convection the same way we shall consider only natural the heat flow is due to natural this thing which you come across last time.

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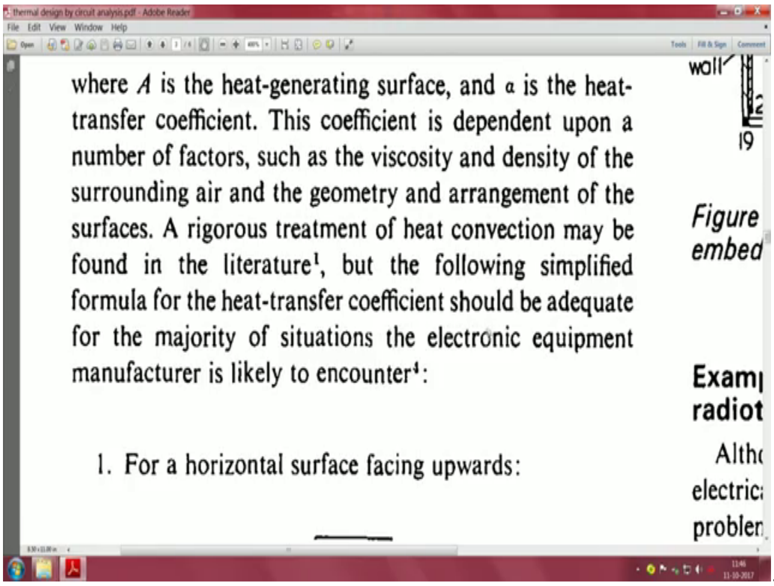

A is the heat generating surface and alpha is the heat transfer coefficient dependent upon a number of factors such as viscosity and density of the surrounding air, and the geometry and arrangement of the surfaces. Rigorous treatment of heat convection may be found in literature, but the following simplified formula for the heat transfer coefficient should be adequate majority of situations. This is what show us that also I talk about you read it for yourself again.

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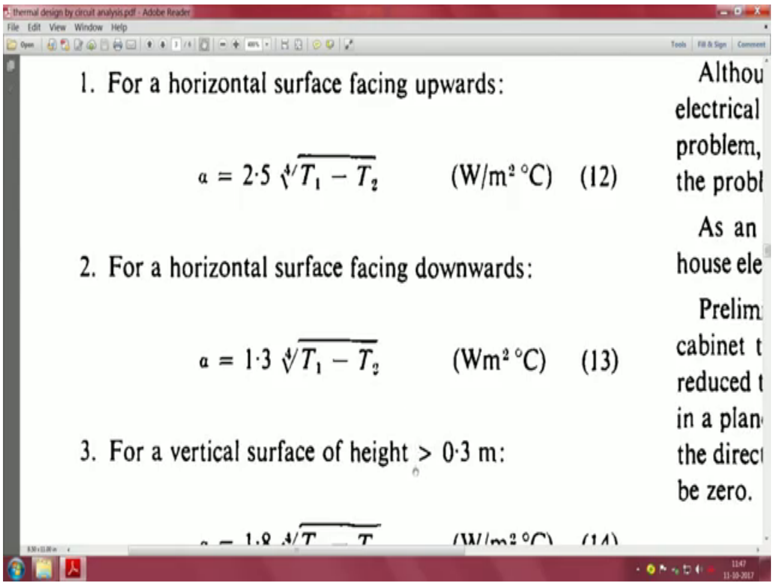

If you remember I had shown you something, which was 0.6 1.3 1.6. So, he has some somewhere else no, he has got these figures saying, if a horizontal surface is facing upwards surface facing downward and if the vertical surface of height is so much for a vertical surface I have stuff think so much and all these.

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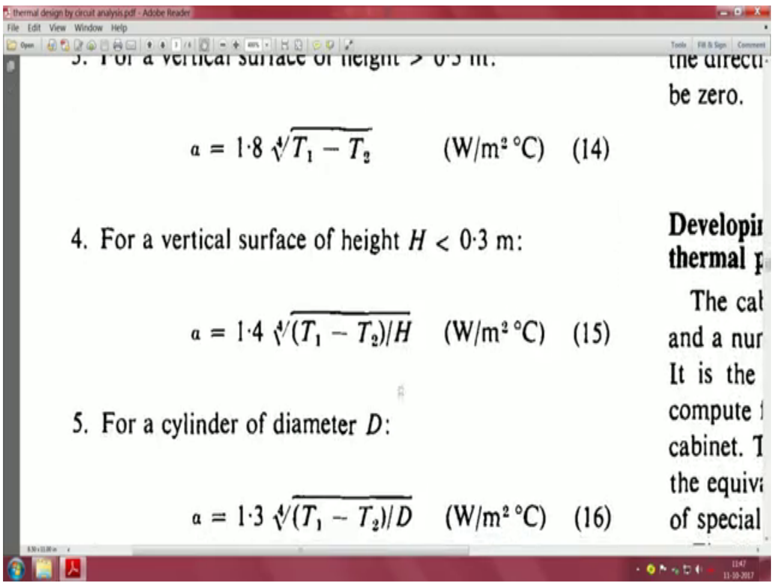

So, depending on which are the places when you can compare, saying that the bottom surface of the cooling and the top surface of the cooling and so on, you can apply this things, but all of it depends again once upon and your specific condition and then how do you try to.

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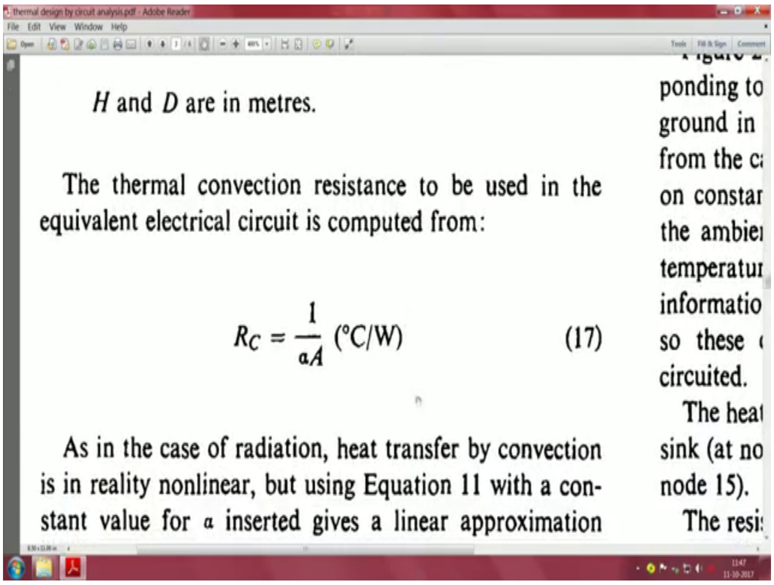

Get into this.

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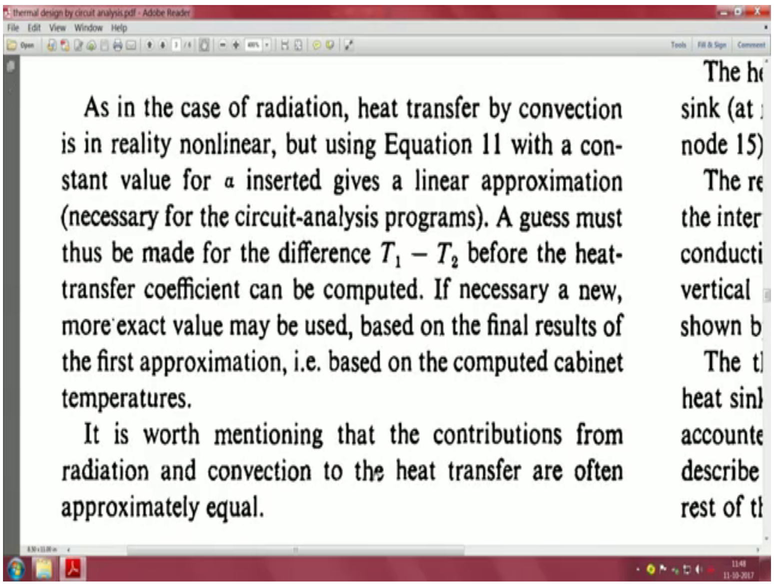

In the case of radiation heat transfer by convection is in reality non-linear, the constant value for alpha gives us a linear approximation, I guess must be made the difference before the heat transfer coefficient can be computed. If necessary new more exact value may be used based on the final results of the first approximation you have seen this.

So, all the people who actually wrote the books, they all talk about there is no one short way of solving anything. You need to probably its a little like your Newtonian methods of trying to find a route, you have to start a the initial route find the difference and keep working back on words for a new exact value may be used based on the final result of the approximation based on the computed cabinet temperatures and then here we get a very difficult or you know force temporisisum on it.

And here he has written saying contribution from radiation and convection to heat transfer are often equal. So, I contested and you can prove whether him or me right.

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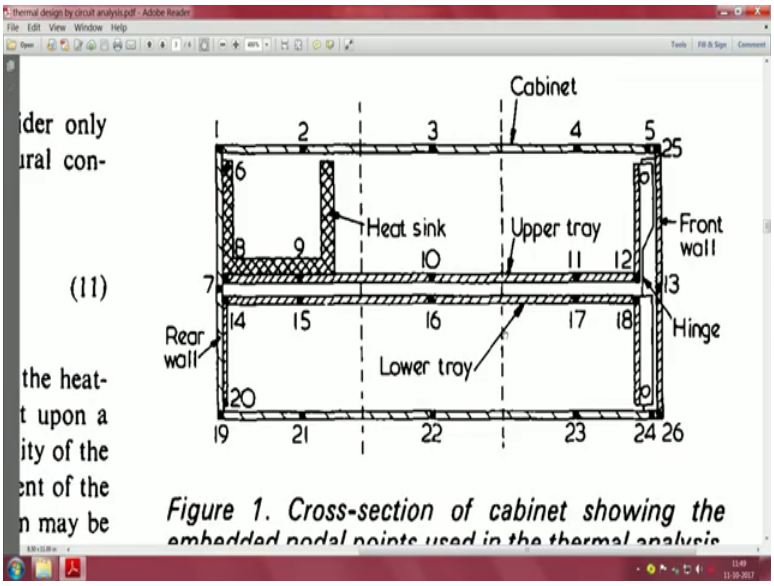

Have a look at the picture try to understand; what the picture can be saying.