

**Electronics Enclosures Thermal Issues**  
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**Lecture - 20**  
**Thermo-electric cooling**

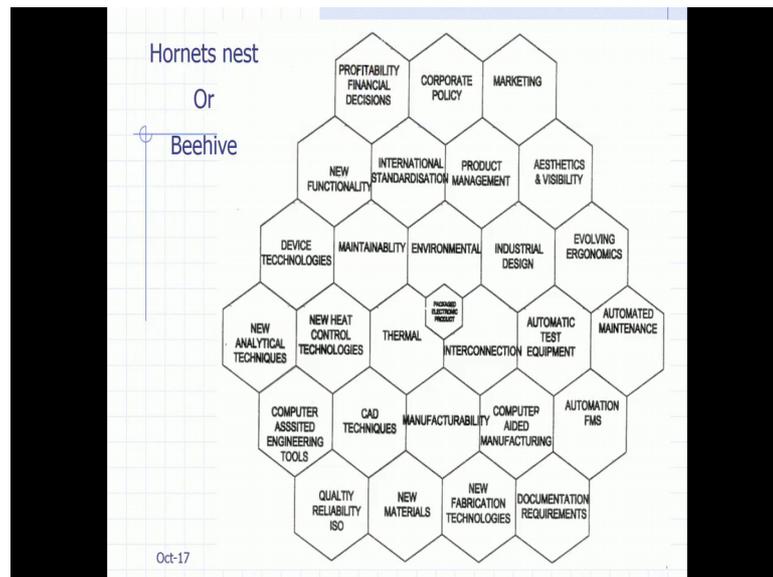
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Hello, allow me to continue and then go back little bit of recapitulation on this thing. So, if you look at my presentation, so can I see the PPT, yeah, if you look at my presentation, you will see there that I have started earlier saying all product design is a beehive of activity. And it is not a pigeonholing, seeing two thing pigeonholing is separately people deal with things; and then the pigeons do not inter-communicate the purposes ok, no problem.

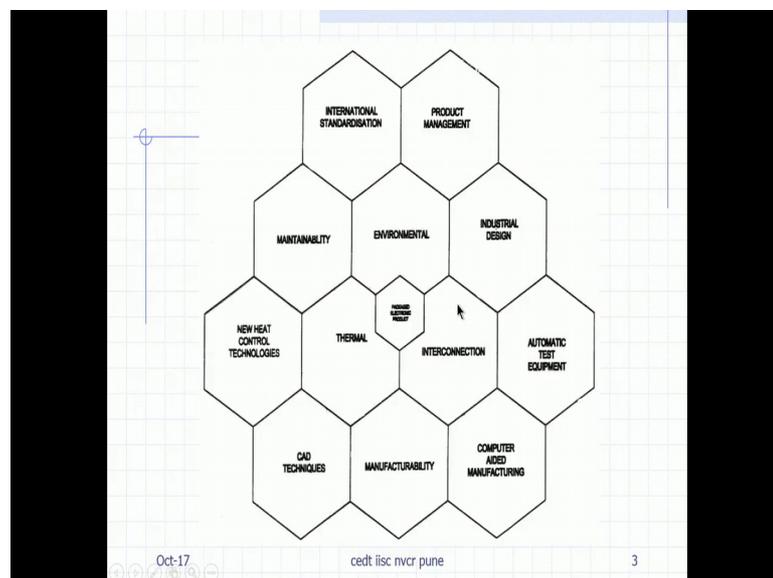
In this case, two things are there one of the first thing is that they have a common purpose; I do not know what it is other than you know I do not steal honey, I make others steal for me, but then I do not take honey, so makes it even. One is making food for its survival and building this beautiful what you call beehive. In case there are some threat we have a stinger, stinger which is you know poised for attack. So, if you are not threat of course, there is no problem, it is good.

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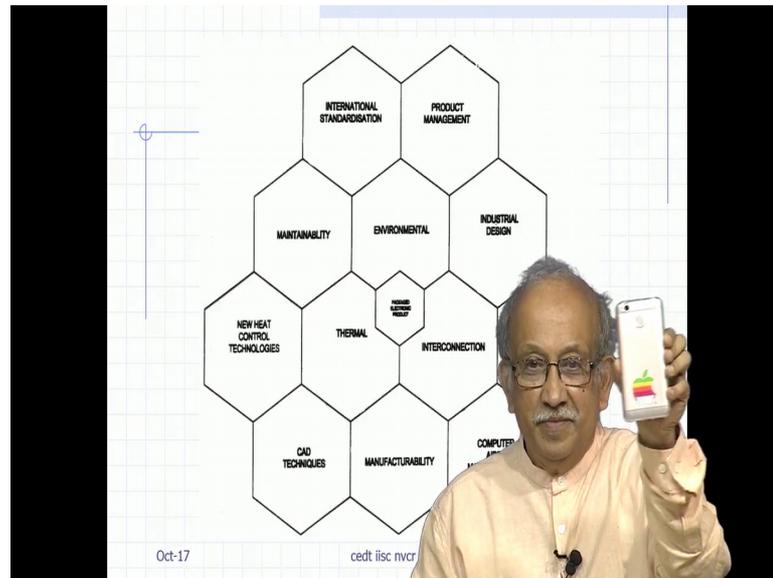
Same thing happens with electronic product design. So, we have here so many of this thing. The core of it is probably the small bit of actual product.

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So, going a little closer we will notice that something which is equally important is probably all this stuff saying there is standards, and there is product management meaning the how do you introduce the product. People are not ready to buy their most advanced product as you like. So, I have here a shameless copy a clone sorry for the words.

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You see here at the moment you look at it you do not need to whether I add this pointless colour bar or not you know very well it does not make any sense at all. But in the original cost probably 70,000 rupees it is a lot of money. This cost 7,000 rupees one-tenth of it. So, I can keep losing them and tracking them. But then you say that there is something to it you know which wants people to copy. So, I will stop; I will now get back to my presentation.

So, the product management or the people you know who decide what is it that way want initially nobody would want a fully what you call all the bells and vessels product, because the market is not ready, and then we do not even know whether somebody will buy it. So, I am sure manufacturers are working about it all the time. Peoples are planned obsolescence the issue is not about planned obsolescence. The issue is how to introduce products to the market, and thus people try a basic product it is unlikely that they would want to go to the fully loaded product.

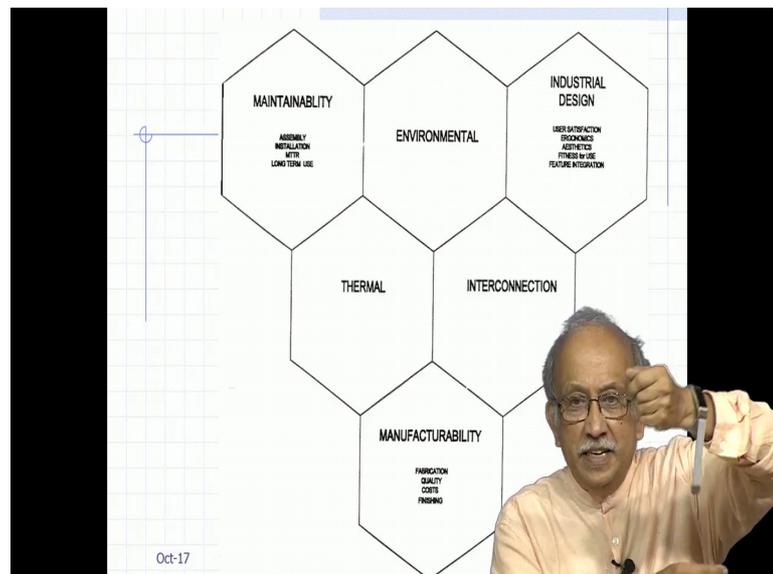
Very much related to this is something called industrial design. When people talk about industrial design, what they mean is long ago once upon a time it was about products which are made in the industry. Right now definition is saying making technology humanizable. And two things traditional product designers especially like me we are caught up in how to make a better product and the technology of it. Well, then user would not want that much of technology there is a RAMs, ROMs and you know all mb

mp and I do not know we are all strong with pixel, but we really do not know what is voxel. So, we are not yet ready for it. Industrial design makes takes the users point of view if they say the whole issue is about experience design. So, I will stop here. I suggest you go to the other things you know same check-up about it.

And then something which is very much related to it is new manufacturability. So, I have shown you clone phone which the fact that they are able to sell it 7 or 8000 rupees shows that probably it is made at half the cost. So, I expect the whole thing is a probably you know assembled and it leaves OEM premises for much much less may be around 50 dollars. And then you pay what you call 1000 dollars for it is not my problem, but the issue is manufacturability has ensured two things that things are made within a target cost. We have a target cost and made in sufficiently large volumes. And once the design is ready, it can be made by anybody anywhere.

So, little you know hard to take, but the reality is like that. So, what is manufacturability about saying you should be able to make it anywhere in the world and then you know sell it wherever you like and all that. Related to this and I will I will just I mean go back here something three things are very much related to this, I will come back later.

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Now, when we come to the actual core product, we will notice that the interconnection technology, thermal environmental same to make a lot of difference. So, latest is that this related to manufacturability is computer aided manufacturing saying once you create

certain files followed you know once you create a certain file that same file should be able to be used by the manufacturing people there. Then if you remember I have talked about CAD techniques, advanced is CFD, and all sorts of numerical and what you call finite element analysis. And you see here oh I am trying to look in the monitor and do we have now automatic test equipment in fact, things are so standardised that PCBs are not checked in you know this thing the components are real and they are all checked, components are shorted the PCB.

So, you have a component shooter which at a made at least for a old fellow like me whose suffering from various you know time frame problems there that just shorted the PCB and miraculously they seem to stick to the PCB. And something happens something else in the end and automatic test equipment you know just make sure that it works and I understand they talk about yield saying all the PCB is work all the time and not just then later on also. In case something fails, we have maintainability. You see there we have that maintainability how well things can be maintained both by authorized service people.

Or coming back to my clone phone something beautiful has happened. You do not even need to go anywhere all the time, updates are available, even should you buy the original Apple, it gets updated automatically, it needs your permission only as a formality. And then otherwise you know I do not know if it is real or not, there is a kill switch also. If they want they can shutoff of the phone, but they will never do it that is I understand the kill switch are jail break and all that are not part of this. So, we have these issues of CAD techniques ok. If you start properly you have several things and then you have computer aided manufacturing, automatic test equipment and maintainability. And the moment you start with CAD techniques, you just go up here we come to new type of controlling heat.

So, it is all you know covered here saying in maintainability assembly installation mean time to repair and long-term use. Industrial design user satisfaction, ergonomics say aesthetics, fitness and future integration. So, when somebody buys a designer something including a designer watch I have a funny looking designer watch I am surprised because it does not cost too much it is a fit bit, it is one of the trackers, it is costly.

In India, it is very costly the original I do not know how much it is like so many of the things you see with me are all presented it costs 15000 rupees. But I am very much thrilled that it comes with a metal strap, and even the other straps what I have and then if

you see the metal strap also it is a magnet. And then I very much thrilled what I want is visible what I do not want miraculously goes away that is what is about this integration of features.

And again coming back to product management in the beginning we have to we have no choice, but to have what is called an entry level. Not long ago maybe 50 years back, we just had a car we lived with it forever. While I wants the future is a shock anymore the future is here right now people talk about an entry level car saying first time somebody first time buy a entry level and all that they talk about. Eventually they depending on where they use it if they are using it you know off road or anything they will go into sport cycles and depending on their thing you know you have commuter, segment and so on.

So, design tries to make a tradeoff between various things. So, so you have something which is at an entry level in India when we started cars were having I do not know one stick on the side, some of the time the stick was you know stuck to the steering wheel. And then they had lot of pedals at the bottom you know push it here there and all that we have got used to those things. Now, these days I think it is unlikely anybody buys a car which does not have power steering, assisted breaks, power window, climatizer, SRS airbags then what you call dash cam, and then you have parking sensors you have front everything. And at least what we do not need or I have never been able to use is the cruise control and GPS trackers and so on know this is how features are.

Now, if somebody ask me I crawl lead to thing I live in a place called Bangalore where on good days in bad traffic, we cover 10 kilometres an hour. So, do not ask me what happens on bad days, and what it is. And then yes if you have been able to make it faster drive fast I cannot, I live in. So, thing is what the size of the engine should be that is you know things called hybrids, micro hybrids, and how you store energy all this you know design takes care of this things.

In manufacturability, you come about fabrication the quality, costs and finishing. Something should look good. Even things like a phone you do not look at all the features and order it online it is unlikely. Even if you have to order online, the positioning in your mind is very very critical part of it is this finishing, how well parts fit together, something which looks good, it gives you a measure of quality directly. Something again

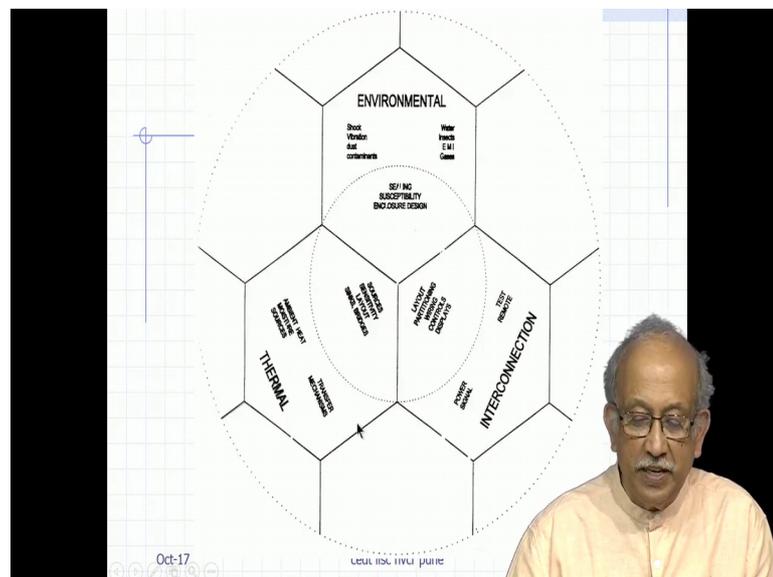
related to various types of costs involved in making things have been evolving.

And in the other extreme you know come here saying maintainability. After installation how do you install things then if you remember you know you are talking about hot plugin. So, happens with power supplies, happens with fans, happens with you know actually bolts, if you want to reliability you end up with that. And then after the failure how quickly can you repair something.

The plumber needs to be on your premises before you get flooded out not a big flood like a cyclone, a normal drip know eventually very irritation. We have the feeling that drips you know are made to make sure that not the drips here, but the I think people call it tap or faucet, faucet dripping in fact Disney made a movie out of it.

And long term use backwards compatible. So, if somebody has what you call a hold rotary dial phone, the new devices must have the way of converting it into pulse dialling phones ok. So, even option between pulse dialling, DTMF, and the new technologies, and then something related to is assembly and disassembly. So, I will not talk too much about it.

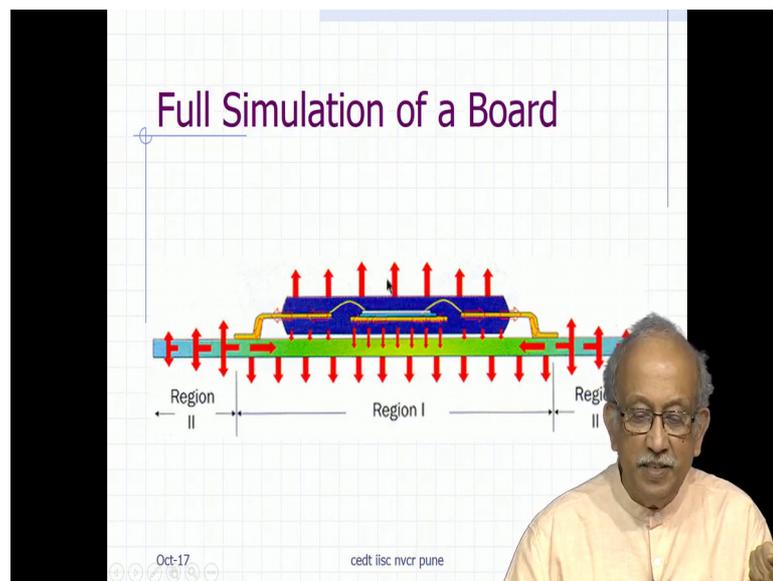
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Next slide talks about the environmental the interconnection, and the thermal aspects which have come nothing from the actually from the decent things. See, here we have thermal environmental interconnection little closer this is the box we are talking about.

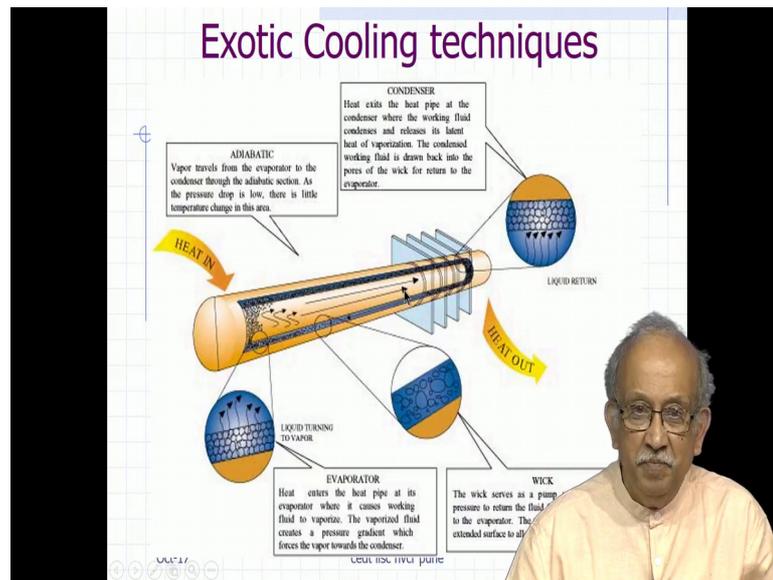
This thermal very peculiarly comes to what looks like a intuitively contrary thing saying if you seal something, you cannot cool it. If you want to cool it, you have to make sure you make also you know you have a dotted line, I will later on I will I come to this things.

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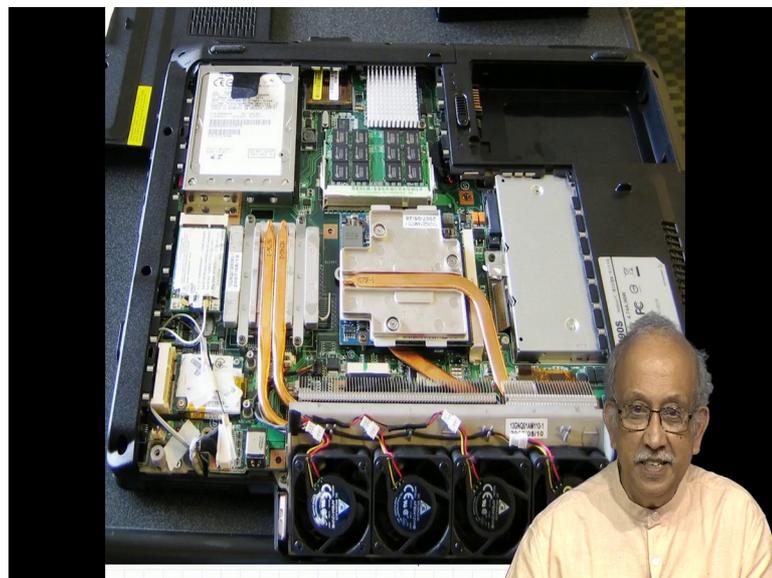
This is what you know early I had shown you saying we have conductivity from here you see here the you know heat is being lost just outside from the precipitates and then something from the leads and then this blue colour. And then you see here something from the case if you have to have a case, which is reasonably conductive, and then it has very good convection and maybe you know you can is there a way of doing it maybe we can do better.

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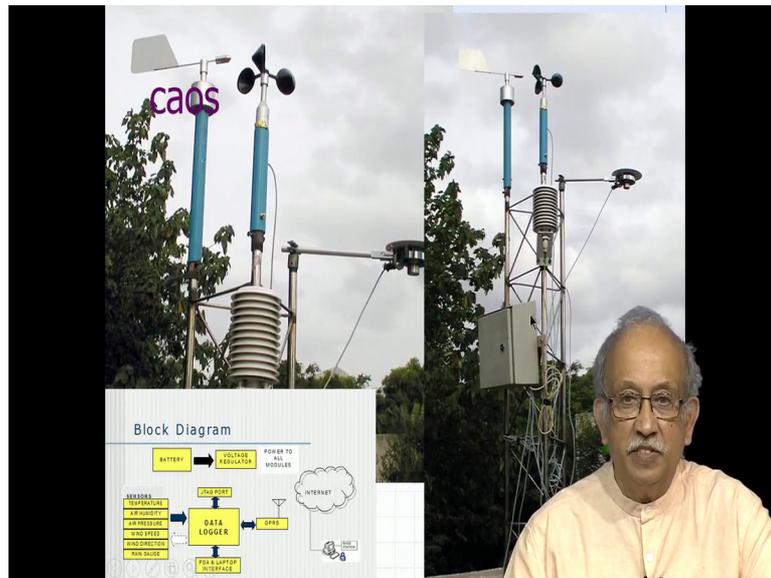
Exotic the cooling techniques include phase change.

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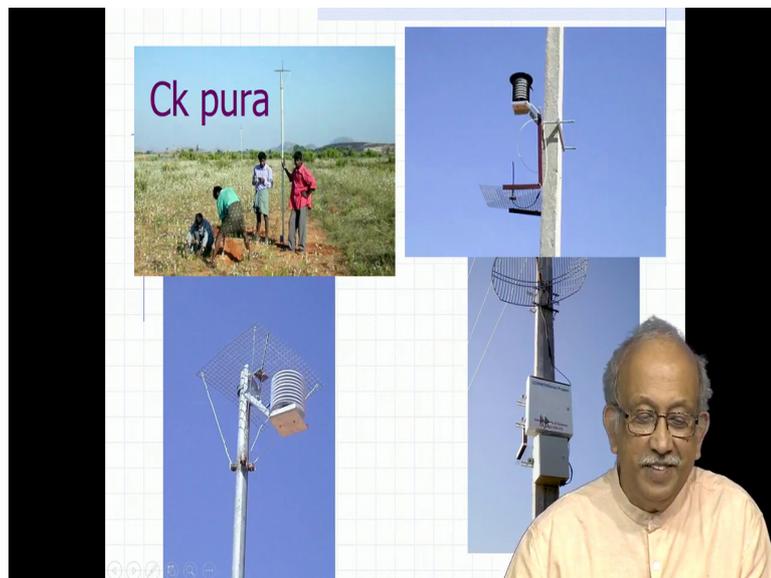
Same thing what looks you know very very say the previous slide shows as a idealised thing. This is a heat pipe. A practical heat pipe is a little more, but I still I am not a much of a fan for it.

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Now, you see whenever we talk about things like that all the time they cannot be in a benign atmosphere. So, you have this is the weather station and something and then this one is a I think you know what it is know right side is a what you call we have a hybrid rain what you call device, and these are all you know things in which I have worked.

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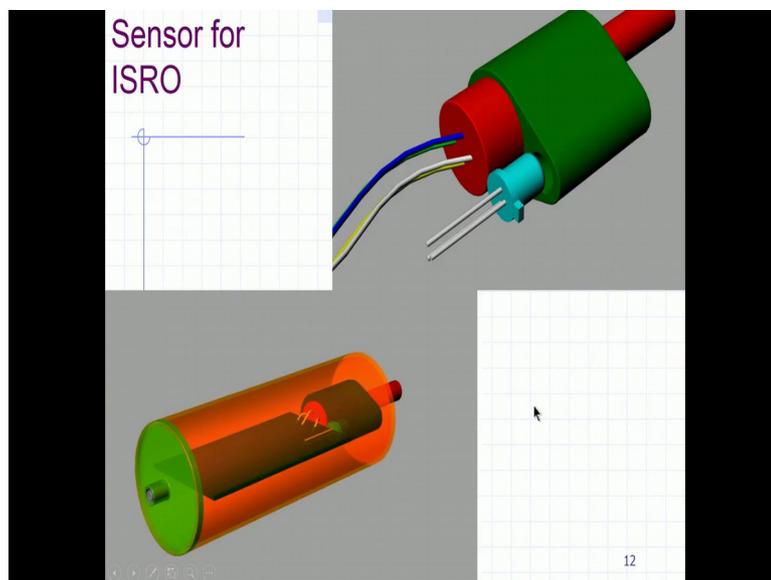
So, we have an antenna here, and I mean actually these are reflector that is an antenna we have various devices all these things you know we end up with.

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What was actually we have seen this know it looks like a you know what you can find inside a lab and then, but you end up with using it outdoors.

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So, you have a temperature compensated pressure sensors here. Some of these things need to be maintained at a constant temperature. You have seen this, the sensor itself you know expected to be maintained at a constant temperature.

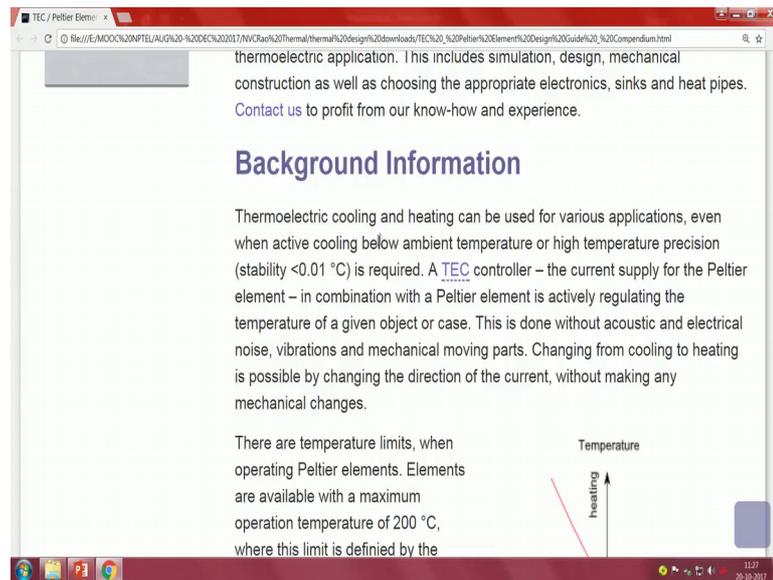
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So, one of the common things while the earlier picture showed you something about heat pipe; This is directly taken from the catalogue of this meerstetter engineering. So, since it is retrieved recently I suggest look for it you understand know meerstetter engineering why it is. Because it is only alloy I have no interest I mean I am sorry I have no pecuniary interest in the whole thing, I am very much interested that you know people understand and instead you are searching this thing, I have read through I would like to tell you about it.

First of all TEC controllers and Peltier elements so, tec subsequently it is explained you should see what it is. So, the contents are all estimated here.

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Thermoelectric cooling understand know thermoelectric cooling can be used for various applications even when active cooling below ambient temperature or high temperature precision in combination and so on and so on is actively regulating the temperature of a given object or a case. You see this where the criticality comes. If you must ensure that precision of the order of fraction of a degree has to be maintained, it is very much possible for us to maintain it if I showed you that pressure sensor which the earlier picture showed you obviously, it does not need it.

But imagine crystals for transmitters they have given I mean very narrow what you call frequency band you cannot afford to make a drift at all. So, the main crystal is maintained in a oven. And typical temperatures around 70 degrees I think most proportional control of main crystals work around 70 degrees.

But imagine inside the enclosure if the ambient goes about that so we have the thermoelectric controllers thermoelectric cooling in combination of the Peltier element is actively regulating the temperature of the given object or case. Then without acoustic and electrical noise vibrations and mechanical moving parts, all other thing you have seen including the heat pipe. They ends up with vibrations and acoustic noise. It may not be directly observable, but the bubbling is not a very comfortable thing.

If you know that here something is bubbling inside you know what it is, so it is not a your what you call tummy growling, but some mild noises changing from cooling to

heating is possible by changing direction of current without making any mechanical changes. So, you must have heard of the air conditioners where which are reversible and can be used as heat pumps. I will say more in what you call they work occasionally. We do have a problem. You got a room inside to be heated when the temperature outside is re-cold something which is outside the thing they outdoor unit has the problem of trying to exchange I will say cold. Trying to pull in heat from outside and passing it to inside, because outside imagine if it is already condensing and the temperatures are really low not much can be done, differential and the absolute temperatures are limited.

But in the case of Peltier it looks like it is not so much of a problem of course, alone very rarely they are use they are always used in conjunction with other things there a temperature limits and operating Peltier elements. Elements are available with the maximum temperature of 20 degree where this limit is divided by the reflow temperature of solder and ceiling.

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The screenshot shows a presentation slide with the following content:

mechanical changes.

There are temperature limits, when operating Peltier elements. Elements are available with a maximum operation temperature of 200 °C, where this limit is defined by the reflow temperature of solder and sealing. When using the Peltier element as a thermoelectric cooler, there is a limit where the temperature will rise again the more current is supplied. This is because of the power dissipation ( $I^2R$ ) within the Peltier element, when drawing more current than  $I_{max}$ .

Designing a thermoelectric application, cooling is the critical part. So we will take the case of cooling an object as example for the design guide.

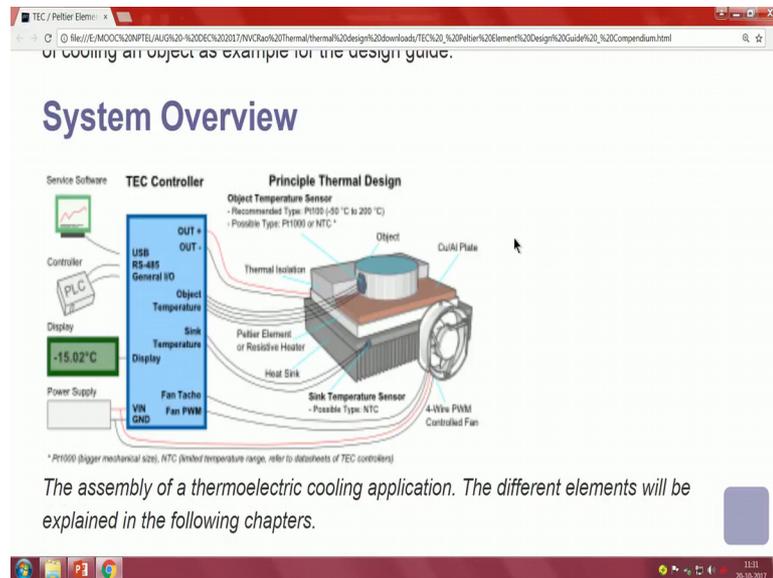
**System Overview**

The graph on the right shows Temperature on the vertical axis and Current on the horizontal axis. The vertical axis is labeled 'heating' at the top and 'cooling' at the bottom. The horizontal axis is labeled 'Current -' on the left and 'Current +' on the right. The origin is marked '0'. A red curve starts at the origin, goes down into the cooling region, reaches a minimum, and then curves back up towards the heating region. A point on the horizontal axis is marked 'Imax'.

Limit where the temperature will rise again and more current is supplied this is because of the power dissipation within the element drawing more current than  $I_{max}$ . So, we have all this stuff you know heating and cooling and you know how much of what you call cooling can actually be done, because there is a heating inside the hole this thing. So, you are not as if know you can just it is not linear thing like that tremendous amount of first current you put, and it gives cooling down not true. In this case you know maybe it

is possible only for us to operate around 0, because it is still in the linear region partially after you go down a little if we still have a problem. Designing a thermoelectric application cooling is the critical part.

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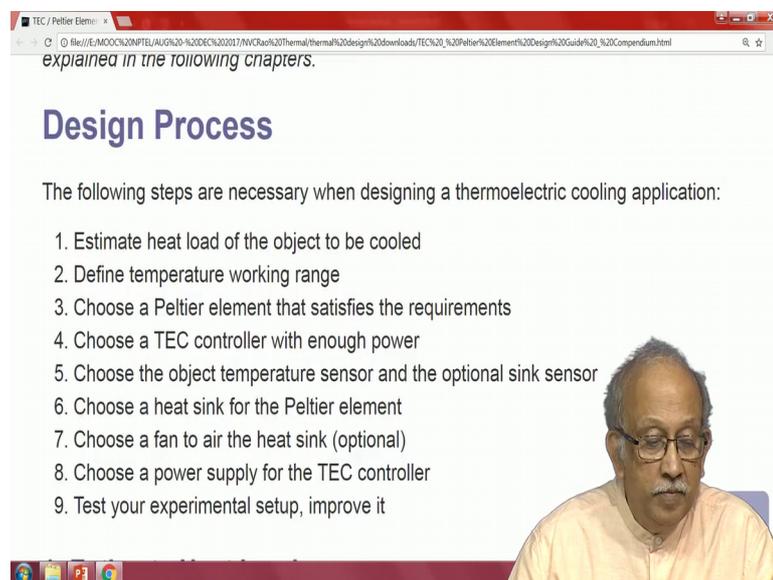
We will take case of an cooling an object and is a example for the design. You see here I will see if I can enlarge in, it does get enlarged. So, we have temperature sensor observed what you call the object itself and then you see here very very important thing is thermal isolation. I am sure some of you have checked on the videos on YouTube, they will show you know a small show me my face sir. They will show you a small plate which is typically around 30 or you know 40 mm square and then you have I mean what you call a power supply pumping in current, and then put a few drops of water and show you how quickly phases.

Reality is while that is it is not a very efficient way of it; instantaneously while the it may work they will always be at short circuiting from heat from the other side to this to isolate it we need to pack it into a proper thermal isolation which is given here. The thermal isolation is very very critical to make sure that there is no short circuiting from the both the sides. And you see this red and you know what you call black. So, I expect that I will put it as a you know out high and out minus there through coloured wire and you have a plate here and then you know we have the monitoring something which monitors the sink temperature. So, usually you have a thermistor or sometimes you know

something else some other sensor.

And then to critical things what you need to do is to spread the heat you probably need a copper or aluminium plate to give a certain amount of stability. Then you have the actually you know the Peltier element then the whole thing of afterwards you know the different elements will be explained in the following chapters and very critical is you also have a fan there. So, depending on the criticality of the design total amount of heat load because heat load seems heat load is critical.

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TEC / Peltier Element explained in the following chapters.

## Design Process

The following steps are necessary when designing a thermoelectric cooling application:

1. Estimate heat load of the object to be cooled
2. Define temperature working range
3. Choose a Peltier element that satisfies the requirements
4. Choose a TEC controller with enough power
5. Choose the object temperature sensor and the optional sink sensor
6. Choose a heat sink for the Peltier element
7. Choose a fan to air the heat sink (optional)
8. Choose a power supply for the TEC controller
9. Test your experimental setup, improve it

Estimating the heat load of the object to be cold so, part of it is make sure you minimise the heat load. So, no point in what you call cooling the a large volume when the thing which needs to be cold as a small volume. So, it is a very huge what you call data centre place, what is valid for the whole room and whole thing it is also same valid in a small chip that needs a close control. Define temperature working range, both the working ranges that is the ambient with which exchange the heat as well as the device which needs to be maintained.

Choose a element that satisfies the requirements, easier said that done little bit of last step test your experiments setup prove it, look, look until you get into a reasonably satisfactory thing. Choose a TEC controller with enough power; this seems to be also equally critical and then this seems the manufacturer here tries to deal with the whole situation. He supply is what has been tested already you know experimental test of set I

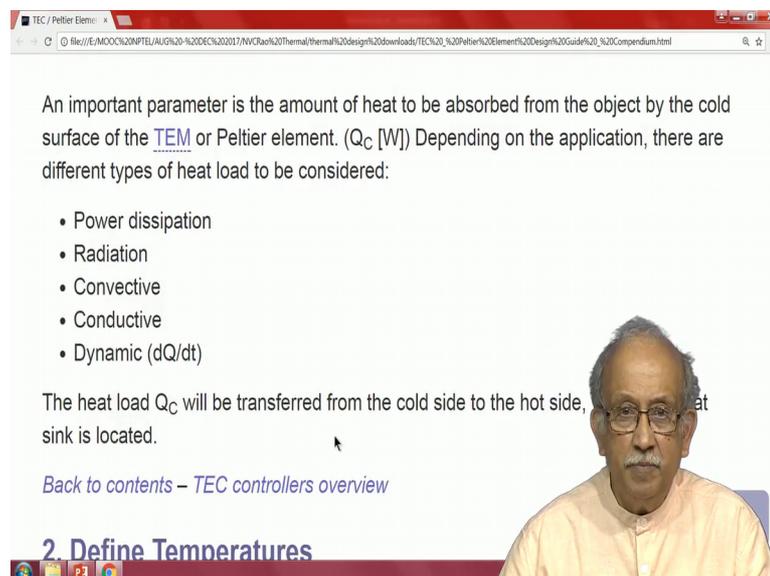
mean experimental setup you know has been tested.

So, in case it requires let us say directly one big connecter which connects to the whole system the Peltier and then the temperature sensor and so on. And maybe something for the fan and then input and something very critical is to have a backup battery saying do you have a reasonably sufficient maybe 12 volts, 20 ampere battery which are likely to find the moment all the stuff is there and then something to keep the battery running, there would not be any runaway that accepts it. So, there do all this. Choose a TEC controller.

Choose the object temperature sensor, and the optional heat sink sensor you see very coolly has written optional. So, I expect that it is probably required that you sense the idea is saying the final ultimate thing is the object temperature the device under control. And if you know the heat sink sensor, you can practically design a few thing. There is a choose a heat sink for the Peltier element which once again know comes to the heat load and the working range.

Choose a fan to air the heat sink meaning due to give convective what you call improve the convective heat transfer coefficient. Again he has given optional depending on if you wanted complicated, you have a fan. If you do not have a complicated arrangement may be a simpler system by which you know natural thing will occur choose a power supply test your experimental setup.

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The screenshot shows a presentation slide titled "TEC / Peltier Element" in a browser window. The slide content is as follows:

An important parameter is the amount of heat to be absorbed from the object by the cold surface of the **TEM** or Peltier element. ( $Q_C$  [W]) Depending on the application, there are different types of heat load to be considered:

- Power dissipation
- Radiation
- Convective
- Conductive
- Dynamic ( $dQ/dt$ )

The heat load  $Q_C$  will be transferred from the cold side to the hot side, at the heat sink is located.

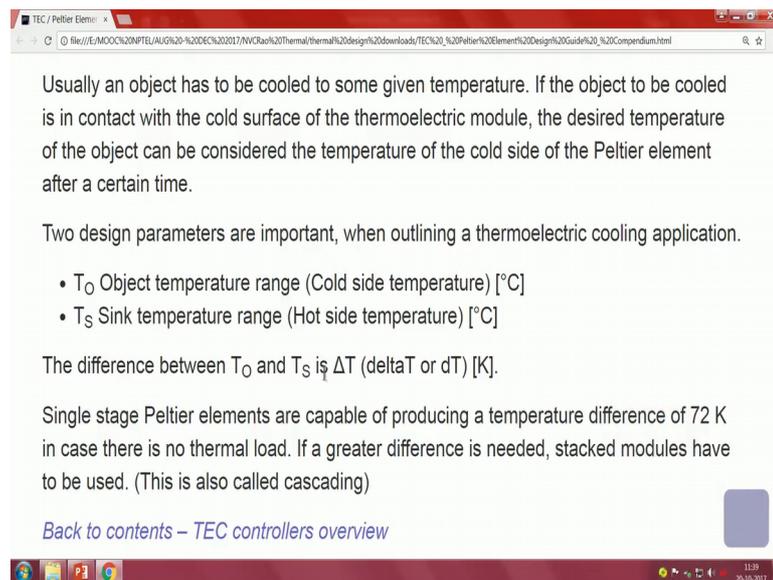
[Back to contents – TEC controllers overview](#)

**2. Define Temperatures**

A video overlay of a man with glasses and a mustache, wearing a light-colored shirt, is positioned in the bottom right corner of the slide.

An important parameter is the amount of heat to be absorbed from the surface of the TEM or Peltier element depending on the application there are different types of heat loads to be considered power, dissipation, radiation and then all this you know. And dynamic the rate at which the total amount of power keeps increasing or decreasing. So, which is likely to be had each load will be transferred from the cold side to the hot side where the heat sink is located.

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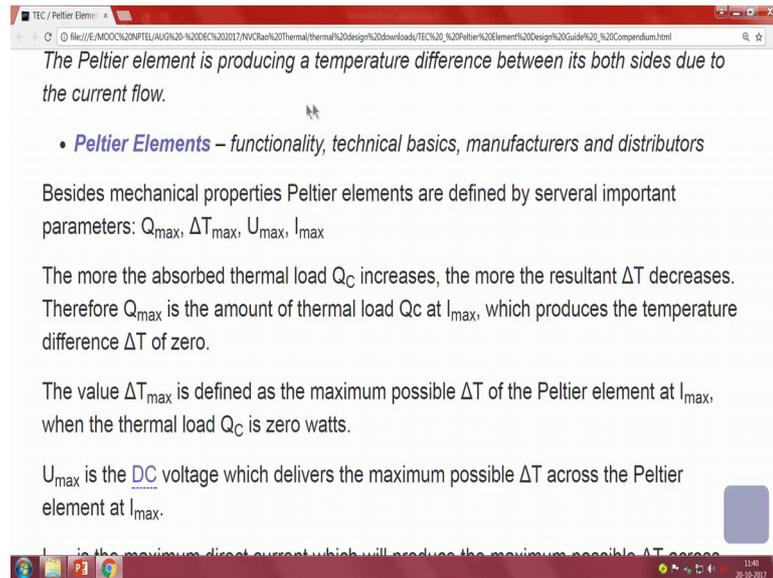


So, in object has to be cooled to some given temperature if the object to be cooled is in contact with the cold surface of the thermoelectric, desired temperature object can be considered as a temperature of the cold side of the Peltier. Two design parameters when outlining cooling application, object temperature range, sink temperature range, this is all a typically a Peltier T is a module maker can guarantee you. From here everything else is yours, so you need to work out saying the delta T that it can come.

Single stage Peltier elements are capable of producing a temperature difference of 72 degrees in case there is no thermal load the greater difference is needed stacked modules have to be used cascaded. While I am happy you know that nice figure like 72 and all is quoted I have never seen it in real life because the load is so much that not easy to maintain such temperatures. So, may be 20 or 30 degrees what is the more practical. You want more your always cascaded like I will show 3, pn, again another p another n p. So, np np np and all that you know they are all stuck together there, you can just you know

what you call literally attach one to the other hot side cold side which will become the hot side of it which will come the cold side of it. Two is very common cascading two is very common with little bit of you know again how do you press them together and occasionally there are also available directly from the manufacturer. So, he gives you all those things.

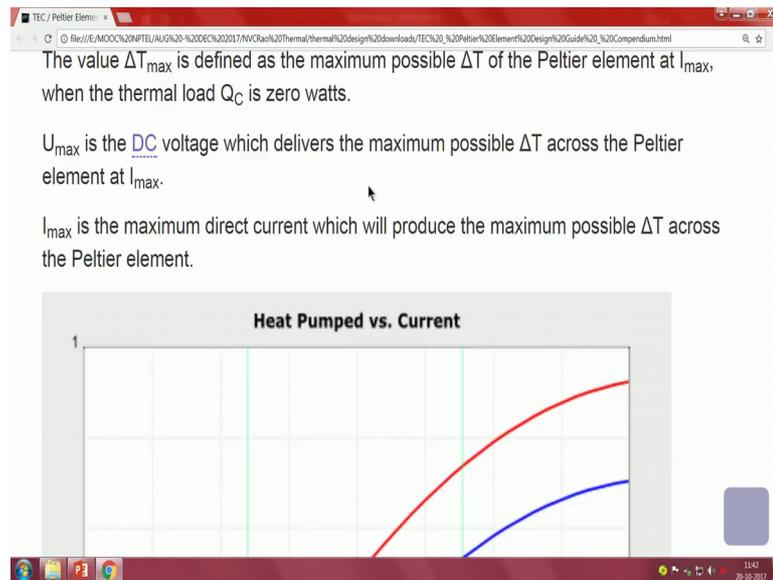
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So, the Peltier element makes produces a temperature difference between both side should be current flow. So, besides mechanical properties Peltier elements are defined by several important things. Total power about handled total what you call voltage maximum that can withstand then the current, and then also the temperature difference it can give.

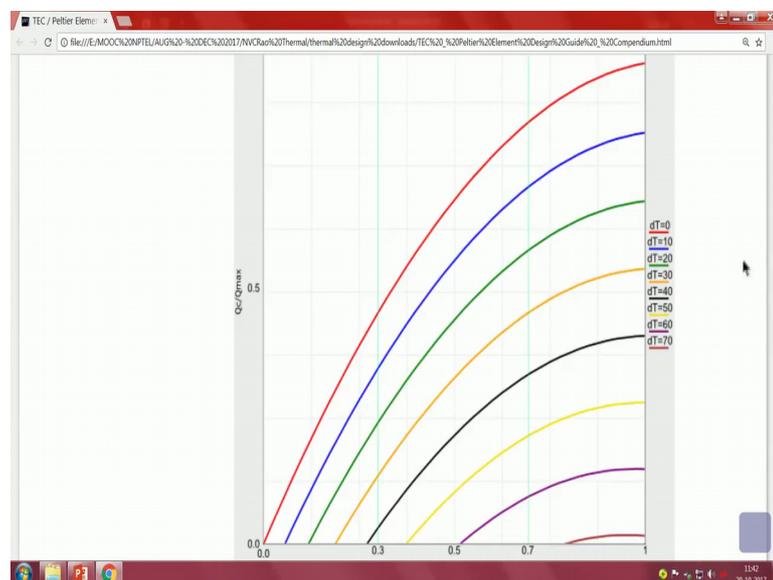
The more the absorbed thermal load increases the more the resultant delta T decreases. So, this is what I was talking to about you know. Q max is the amount of thermal load at I max which produces a temperature difference have practically 0. We will come back to it later. The value is defined as a maximum possible temperature difference of the element at I max when the thermal load is 0 watts which I think you know looks nice more of you know mathematical are you know leading to precision.

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$U_{max}$  is the DC voltage which delivers the maximum possible  $\Delta T$  across the element what you call across the element  $I_{max}$  is maximum direct current which produce maximum possible  $\Delta T$ .

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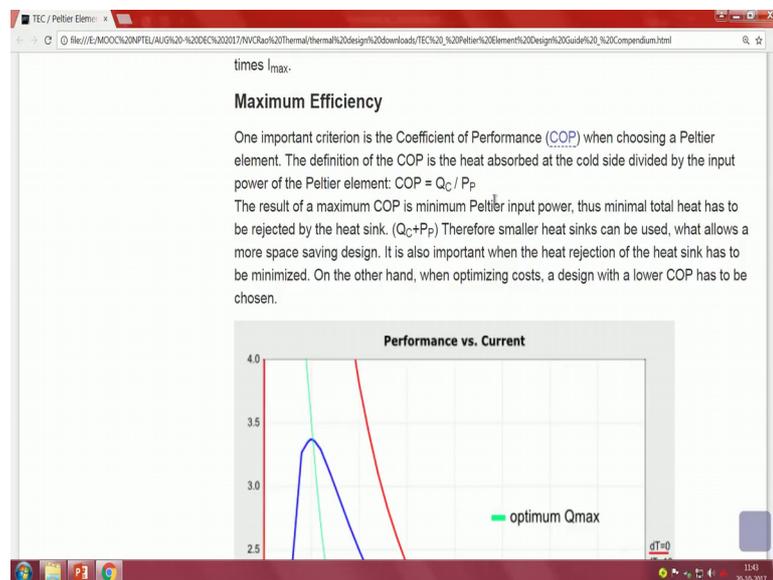


So, you see here heat pumped versus current. So, the what you call maximum  $Q_c$  minus  $Q_{max}$  and as the temperature difference goes more and more know very little you know this can be used. So, both ends since this is useless for us because unlikely well you know we will have such an overrated thing. Similarly, it is unlikely we have these

grossly underrated things also. Operating Peltier elements not at their limits in current and difference yields a greater slope and therefore, more dynamic characteristics of the module and outlining system current of the Peltier element should be 0.3 and 0.7 times,  $I_{max}$  you understood know.

So, something I will you know I will probably prefer at this ok. These are all practical limits understand know around 0.2 times the what you call maximum power it can handle. And similarly what you call the current noise typically about 0.7 to 0.5 or even this you know the yellow cover colours and all that more likely this red is what you will see in this just a mean at the point you know just a median figure.

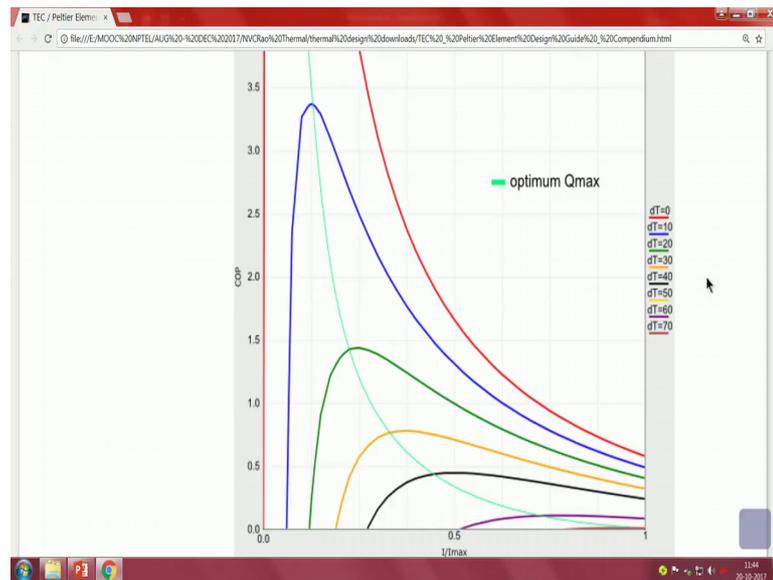
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Another important criteria is the coefficient of performance and choosing a Peltier. Definition of the COP the heat absorbed at the cold side divide by the input power of the Peltier, because when all the small systems are all attach together you have a large number of know small small systems attached together, overall things become very very very poor.

So, for convenience sake they have result of a maximum is minimum Peltier input power minimum total heat has to be rejected by the heat sink. Therefore, smaller heat sinks can be used what allows a more spacing device it is also important when the heat rejection of the heat sink has to be minimised. On the other hand, when optimising costs a design with a lower coefficient of performance has to be chosen.

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So, have a look at it nicely through all the delta t is you know they have drawn a figure which is typically seems to a product of these things. So, once again you see where you would like to know have the optimum power. So, once again know by in this case the product whether you take this or these are approximately same. So, probably one to this you know 0.3 may be a reasonable area by which you know coefficient of performance will be good.

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This graph illustrates the optimum working area for a Peltier element based on COP versus current supplied for a given temperature difference.

**Example**

There are two *thermal* parameters which are necessary to select a Peltier element.

- Maximum cooling capacity  $Q_{max}$
- Temperature difference  $\Delta T$

As an example we assume an object to be cooled to zero degrees. ( $T_C = 0^\circ C$ ) Let's say the sink temperature  $T_S$  is  $36^\circ C$ . Thus the difference  $\Delta T$  is 36 K. There is a heat load  $Q_C$  to be absorbed of 10 W.

As we have a temperature difference of  $\Delta T = 36$  K, a single stage Peltier element is sufficient. We will use one with a  $\Delta T_{max}$  of 72 K.

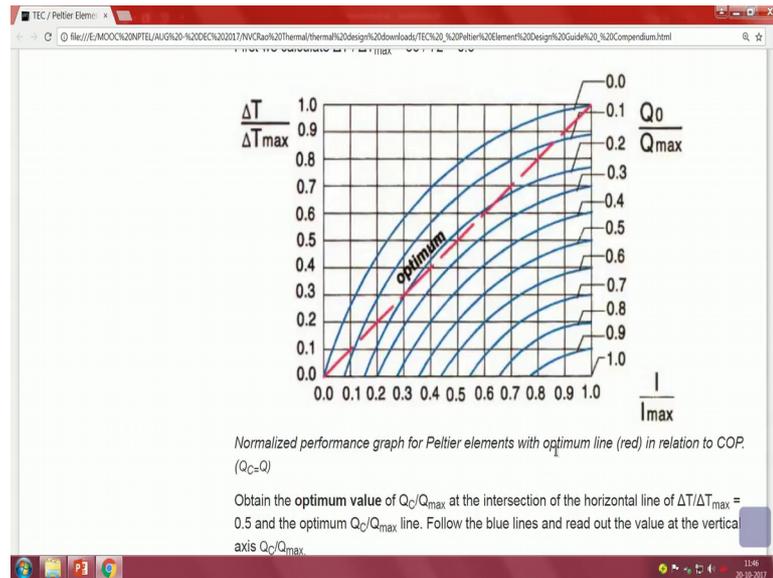
First we calculate  $\Delta T / \Delta T_{max} = 36 / 72 = 0.5$

| $\frac{\Delta T}{\Delta T_{max}}$ | $\frac{Q_0}{Q_{max}}$ |
|-----------------------------------|-----------------------|
| 0.0                               | 0.0                   |
| 0.1                               | 0.1                   |
| 0.2                               | 0.2                   |
| 0.3                               | 0.3                   |
| 0.4                               | 0.4                   |
| 0.5                               | 0.5                   |
| 0.6                               | 0.6                   |
| 0.7                               | 0.7                   |
| 0.8                               | 0.8                   |
| 0.9                               | 0.9                   |
| 1.0                               | 1.0                   |

Two thermal parameters are necessary to select the Peltier element maximum cooling

and temperature. Example: Assume an object to be cooled to 0 degrees let us say this in temperature is 36 degrees centigrade, difference is 36. There is a heat load to be absorbed 10 watts; you see these are very very practical cases. As we have temperature difference of 36 k, single stage Peltier element is sufficient delta t maximum we calculate delta T by delta T maximum 36 by 72 is around 0.5.

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So, you have seen this you know typically any of these things in relation to COP obtain the optimum value of  $Q_c$  by  $I_{max}$  at the intersection of the horizontal line of delta T and delta T maximum at 0.5 you have seen that know somewhere here. Follow the blue lines and read out the value at the vertical axis. So, optimum up to 40 watts can be done obtain the maximum value of  $Q_c$  max at the right vertical axis they correspond to 0.5 maximum  $Q_c$  is 20 watts. A Peltier element with  $q_{max}$  between 20 and 40 has to be chosen.

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( $Q_C = Q$ )

Obtain the **optimum value** of  $Q_C/Q_{max}$  at the intersection of the horizontal line of  $\Delta T/\Delta T_{max} = 0.5$  and the optimum  $Q_C/Q_{max}$  line. Follow the blue lines and read out the value at the vertical axis  $Q_C/Q_{max}$ .

Optimum  $Q_C/Q_{max} = 0.25$  (in the middle of the blue lines 0.2 and 0.3)

Optimum  $Q_{max} = Q_c/0.25 = 10 \text{ W}/0.25 = 40 \text{ W}$

Obtain the **maximum value** of  $Q_C/Q_{max}$  at the right vertical axis that corresponds to  $\Delta T/\Delta T_{max} = 0.5$ .

Maximum  $Q_C/Q_{max} = 0.5$

Maximum  $Q_{max} = Q_c/0.5 = 20 \text{ W}$

So a Peltier element with  $Q_{max}$  between 20 and 40 W has to be chosen. If a Peltier element with  $Q_{max}$  near to the optimum  $Q_{max}$  is chosen, a high COP and therefore maximum efficiency is achieved. An Element with  $Q_{max}$  near to the maximum  $Q_{max}$  will yield less cost but less cooling capacity. The Peltier element will be operated near its limits.

The ratio  $I/I_{max}$  is given by the diagram as well. At the intersection of  $\Delta T/\Delta T_{max}$  and the value of  $Q_C/Q_{max}$ , plot a vertical line. Record the value at the intersection of the vertical line and the bottom axis. In the optimum case  $I/I_{max}$  is 0.5. Using the value  $I_{max}$  of the Peltier element, we can calculate the resulting current  $I = I_{max} * (I/I_{max})$

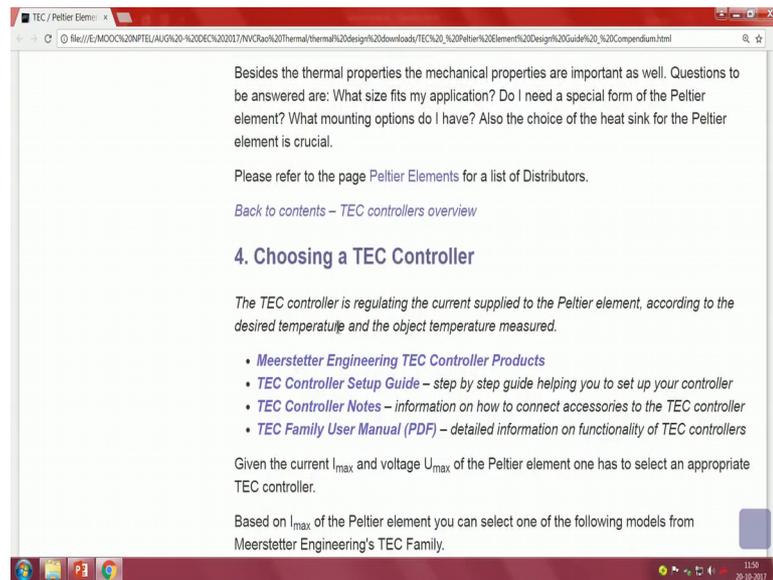
Besides the thermal properties the mechanical properties are important as well. Questions to

Though we started with only 10 watts that needs to be dissipated you understand know something much bigger saying 20 to 40 watts has to be chosen I will go for the higher thing only because initially if something fails we are in a problem later on fixing it is a problem. Once your experiment is succeeded in all that know may be reducing it a little or leaving it where it is. Because you see while the cost is I here, the size approximately will be the same there no at monstrously big or anything there not as if there four times aspects there only slightly bigger.

The Peltier element near to the optimum is chosen a high COP, and therefore, maximum efficiency is achieved. Element with near the optimum will yield less cost, but less cooling capacity which is also true. Peltier element will be operated near its limits which is a serious problem you have seen that know ending up with a limits is a problem. So, reason why this 40 watts I would prefer to choose is at the intersection and so on, the value plot a vertical line record the value at the intersection of the vertical line in the bottom axis.

Without optimum is 0.5 using the, we using the value  $I_{max}$  of the Peltier element we can calculate the result current. Visit the thermal properties of the mechanical are also importance.

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So, having decided this I suggest you go over this you take the 40 watts thing and so on. So, we end of with a good starting value for these things. And as I said depending on your own available expertise that your area, you can always make your own electronics or try to say you can integrate the same this control and all on your printed wiring board which you already have if you have a wiring board probably and you already have a supply somewhere you are getting rail which will give allow its rail. And getting let us say around 80 or 100 watts is not impossible for you.

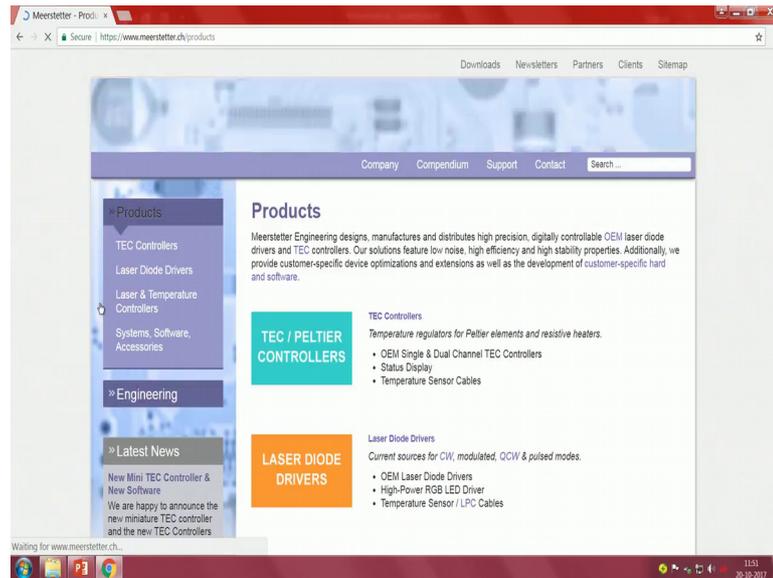
So, you can do something to include all these things here because very rarely you know you may be giving the 12 volts into 3 or 4 amps may or may not be required actually around the operating point, it will be just hunting around the small value probably around half of it. So, if you can integrate it onto your remain design as a designer, you have the choice of calling the shots.

Now, we come to what is the size for my application do I need a special form of the Peltier what mounting options to have the choice of heat sink for the Peltier. So, we have this issue saying how do you what are all the Peltier that are available. And as I told very roughly I told you that we have a 40 mm by 40 mm and so on. So, as you go down here this various you know controller centre are listed here.

So, I suggest you go through this a little more in detail. And make sure that the things like you know who are all the fans. So, what are fans you do what are power supply

requirements you do and then test setup. So, we have here basic what you call things about these are basically things relating to the controllers only you understand know because we are talking about the electronics control about at the elements the form factor and all that know. Right now I have no access to the internet as such it will only; even if I click here nothing will happen, it will just what you call.

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Kindly you must go back to the, what you call other manufacturers look for the what you call Peltier controllers and so on. I will try to close this here at this point and go back to the old what you call the master book about, stuff about how to deal with oh I mean I am sorry we do not have it here elsewhere I will try to conduct it. So, probably I will what you call stop here at this point, and see start with that you know sample we have and see what we can do here.

So, thank you for this session.