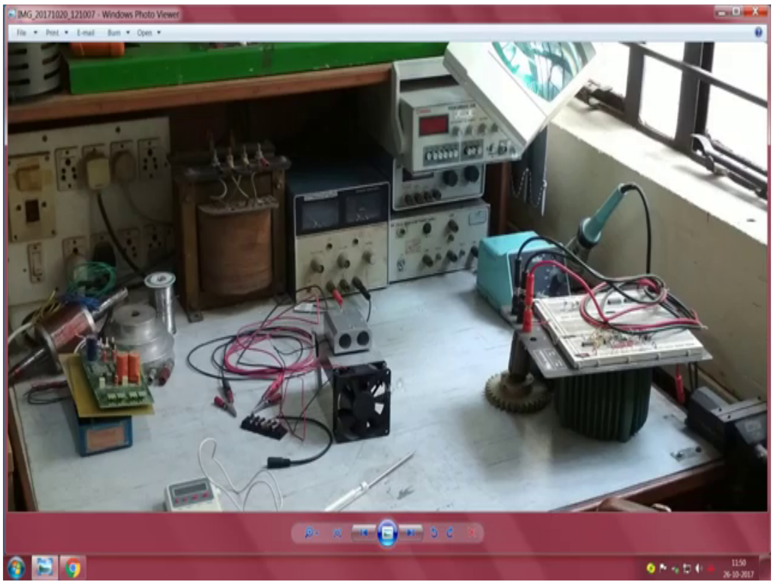
Electronics Enclosures Thermal Issues
Prof. N. V. Chalapathi Rao
Department of Electronic Systems Engineering
Indian Institute of Science, Bangalore

Lecture – 26
CAD detailed design of profiles

So far, I tried to cover somewhat you know I expect to be authentic materials and I had like to acknowledge that they have been taken from the respective manufacturers catalog retrieved in around this time when this is recorded that must have been in October, 2017 and again I leave it to you as things progress that you know you need to what do you call take a call and have a look at the latest thing.

Now, I want you to look at something which I have taken from my; what you call our lab.

(Refer Slide Time: 00:53)



See here this is typically the classroom where they are being recorded. So, I have this what do you call touch PC here, tablet PC then I have this pen and then I need to bring all these small items to have them recorded here.

So, typical recording session know probably, it is a little more cluttered and then we try to show things. Now, I will take you directly to the lab you see here it is a small now what you call like you have shopping shop in a mall it is one of my colleagues genuine desk. The computers on the right side and then he has a small table. On this is typically where everything starts, I have no choice motors back to back, auto transformer, your power supplies, you have huge isolating transformer and then you have all this and this has been brought from there. And, in the initial stages we do not do we do not use too much of instrumentation as much as use one of these simple coolers which are likely to find in your kitchen. This is probably a meat thermometer and, but this is good enough because the overall mass is lower.

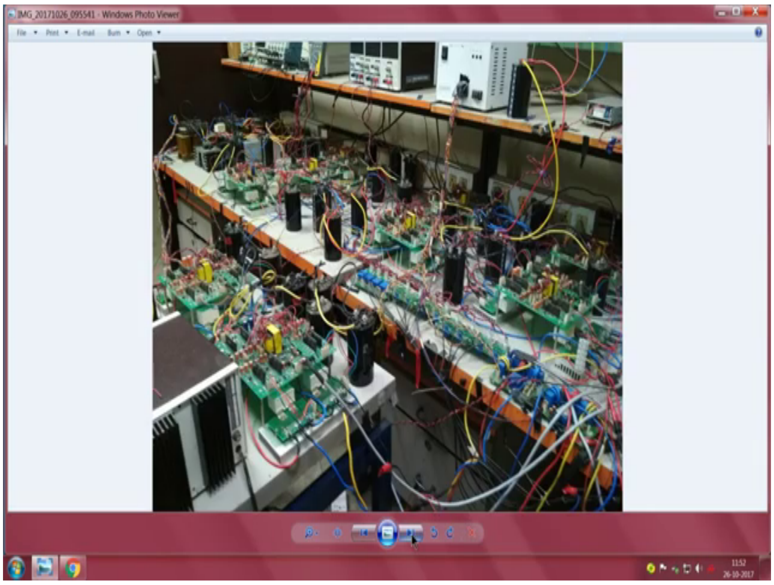
Next picture shows you things a little closer this what I try to show you yesterday that what you call a small isothermal block from various practical purposes we need to create an aluminum block the whole thing is driven by you see here it is power supply is sim critical. So, we still have a problem in case you want to use any peltier we end up with three things one of them is you need a power supply to control the current through this device, another is a way of monitoring the temperature and then you need probably active control otherwise it has a tendency to stay grounded.

(Refer Slide Time: 03:06)

So, these are the two now what you call flame light tech. These two things have been put; they have been kept underneath that block and that I have told you the manufacturers generally give you some idea about which one to choose and so on. You have not much of choice from that. So, they are two ways of it in a mode like this you can make them parallel that is you have more surface area to be contacted I have intentionally kept it like that. Obviously, you know they are kept one next to each other alternatively you can stack them and make them into a series module.

So, it is for you to play around now I will take you back to the actual lab you know which has where which is all these threatening what you call electronics here.

(Refer Slide Time: 03:59)



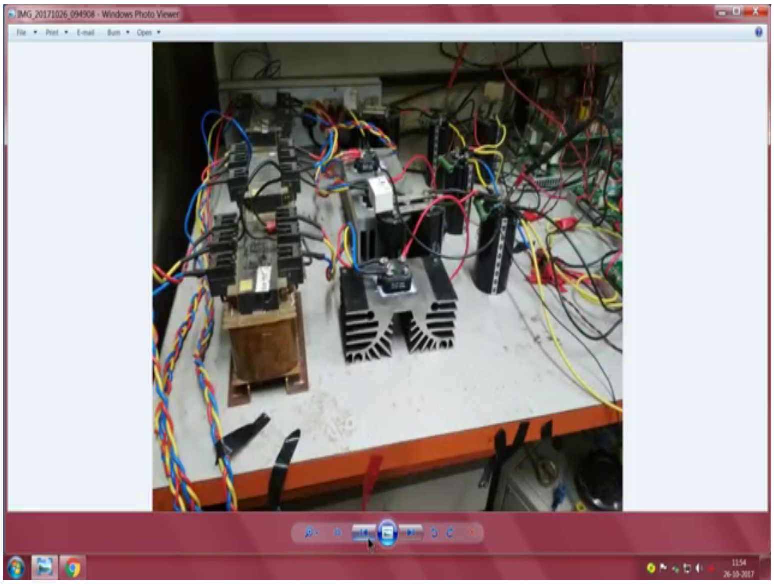
You see that is that is a how typically a power lab is likely to look and except the student for everybody else it is a booby trap, better not touch. If you touch I mean they can they have to get a new processor. So, I will get back to you in the initial stage this maze or what you call what looks like a rats nest of all these things is inevitable and then I will try to take you closer you see here we have a small heat sink and then you see here this is all where the active devices and the capacitors are mounted. You have this DC link capacitors then you have these what do you call permit me to use the word which I do not like heat sinks.

This is how it is if somebody tells unless you happen to be working in a what do you call the firm which has foreign collaboration and somebody already sells you this equipment.

(Refer Slide Time: 05:07)

The reality is this. Not long ago we had this issue of saying heat sinks need to be black. Two things I want to point out, I will ignore heat sink black business. What I had like to tell you is if you see these heat sinks which are narrowly spaced and they have one limb which is you know probably projects into the equipment, you can make out that it is naturally convicted it uses a natural convection anything which does not have this know we will end up with having to make things I will go back here and I will show you.

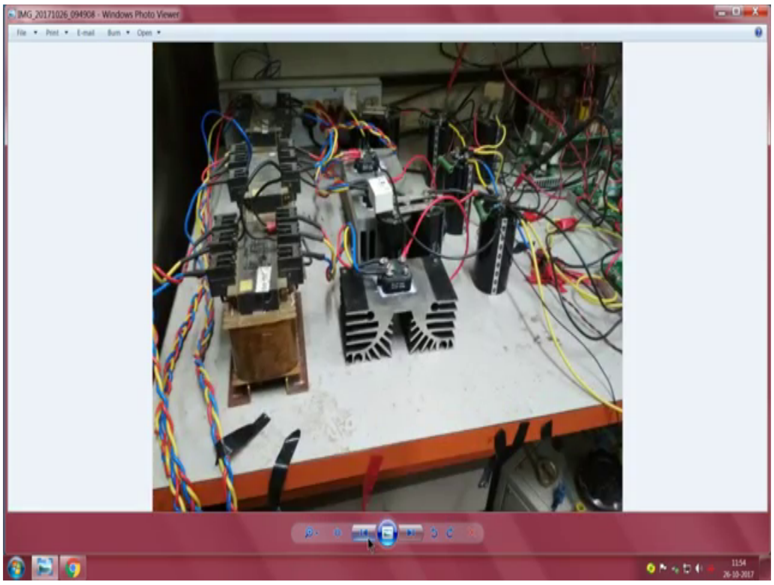
(Refer Slide Time: 05:46)



Have a look at these. These things from here can you see here the first thing here that is probably a bridge rectifier. So, and I am not sure what it is my interest is only the heat sink part of it. Now, you see here you see the very peculiar or very what do you call very characteristic way of putting all these fins and so on. At the moment I will not comment on this saying except that they have all been developed for specific purposes. Why it is like this and whether there is a fan whether four of them are to be stacked end to end and all these that you need to figure out. And, you see we have something else at the back you have seen that is a that fat heat sink I have been carrying around and for convenience sake they wanted one of the available heat sink there is something else which is mounted here.

Now, I will try to asked you to recollect that one solar rack. There if is at the back we had those blowers and usually they probably see this back of this heat sink you see here it is very fat may be the next picture is a little closer, sorry, the next picture again, you see here this is very thick here to help in transient this thing and also in the case of any failure of the fan and all that know the heat can be held over a short time and then you have tapered heat sinks. So, this a large have been made with a little bit of practice then analytics and then later on eventually optimized very very carefully.

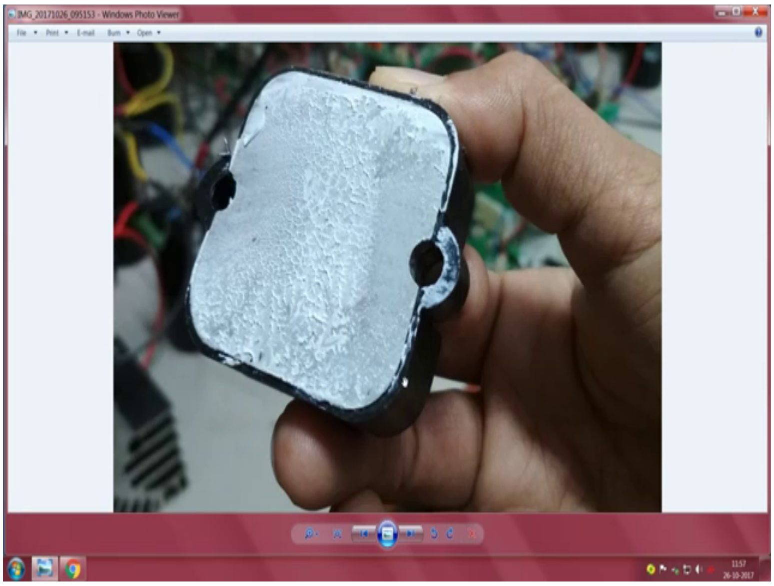
(Refer Slide Time: 07:54)



Now, we come to these things saying what is the reason, why somebody has made this is what do you call your guesses as well as mine. You see this is these are all various I think maybe gate drive circuits and all then and you have this heat sink on which there is a PCB probably there are active components directly mounted on this, ok.

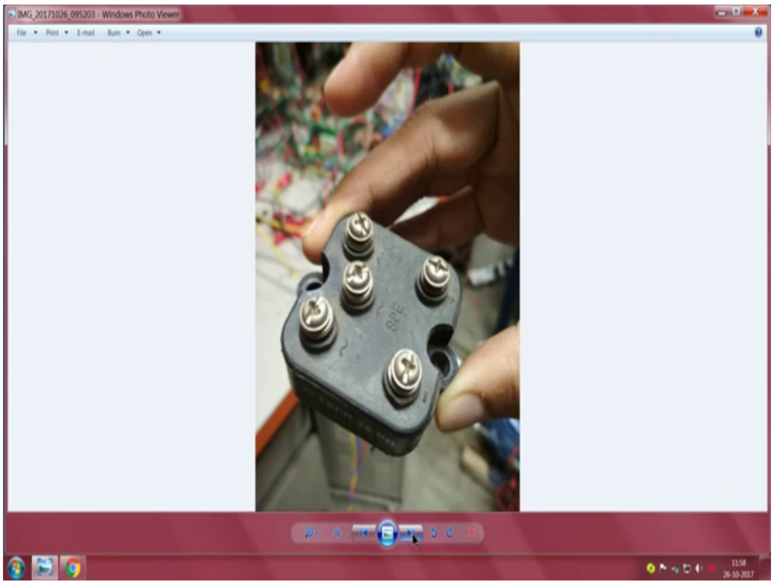
So, well it is convenient for us to talk about concurrent thermal engineering a thermal management somewhere in the beginning somebody has to take a call and do these measurements. There is no equation know it says if you have this much of a what do you call power dissipation and this is a style of equipment this is the heat sink naturally, it still is. While I would not call it trial and error you still have to take an intelligent call on where to start, later on the optimization comes. So, if you if you have some idea of the thickness of these wires now you know what it is, typically something between 100 to 300 amps peak is being handled there hence you have all these things here.

(Refer Slide Time: 09:08)



That is the bottom of the diode which they are showing you it is the student. So, I had like to thank the student about the diode. It was probably removed after the failure. This is where I had like to point out what I had started in the beginning saying the thermal conductivity of air is very very poor. It is only marginally increased by applying this so called thermal paste. Still thermal paste as such know conductivity is not good. If you go back to the earlier lectures in the appendix it is given there. So, coating it with a tremendous amount of this what you call this material or even there are conductive epoxy is not a solution to proper grinding or lapping both the materials and attaching them together.

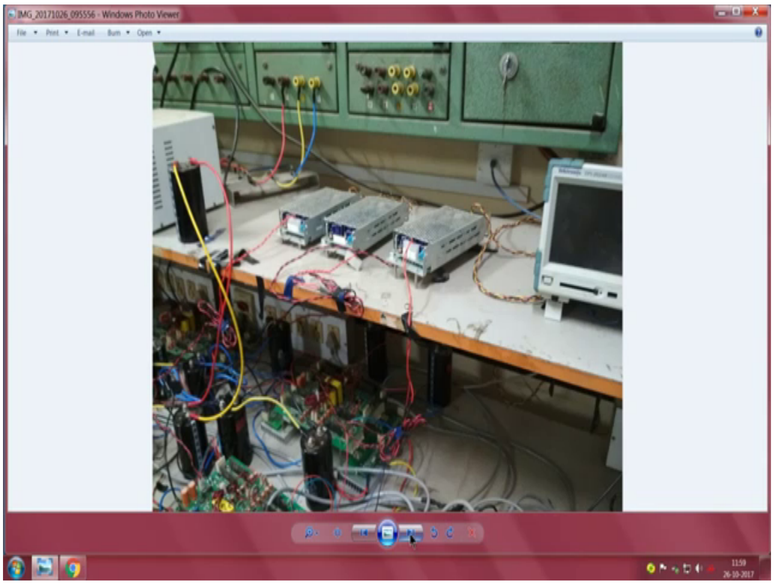
(Refer Slide Time: 10:02)



And you have seen this everything has it is own polarity and then one funny I do not know whether they are visible know that plus and minus here and something else is written here there is some you know one wiggly thing here, wiggly thing here and there is a small offset probably it is a and then I can faintly see U.

So, probably a three-phase rectifier, I have no clue, but my interest is only to say that whenever there is a heat sink and at the that contact surface usually know best lapping has to be done, especially in production especially things are very very critical. Luckily, in our case students are observing only transient phenomena has such you know it probably does not make sense. Otherwise this surface has to be perfectly ground and lapped to meet the other surfaces, ok. So, we can maybe know get out of all this.

(Refer Slide Time: 11:10)



Now, you come to practical things you see this neat power supply here, at one level it looks fine absolutely.

(Refer Slide Time: 11:20)

And, from the packaging point of view you know it is just what is called an open chassis by itself it is not intended to be used as it is, but if you can relate that what you call recollect the solar racks which I have shown you yesterday you will see these power supplies and all directly mounted inside the rack. The rack itself is a IP 55 and dependent the environment know occasionally IP 56 or IP 65 type of a enclosure and for convenience sake it comes with a small protection mesh. One or two things you will notice about it is that while it does not fully protect everything, but any accidental drops of tools or wires or anything know it will not short circuit the PCB or leave them in a damaged condition. So, some physical impacts and all we can avoid.

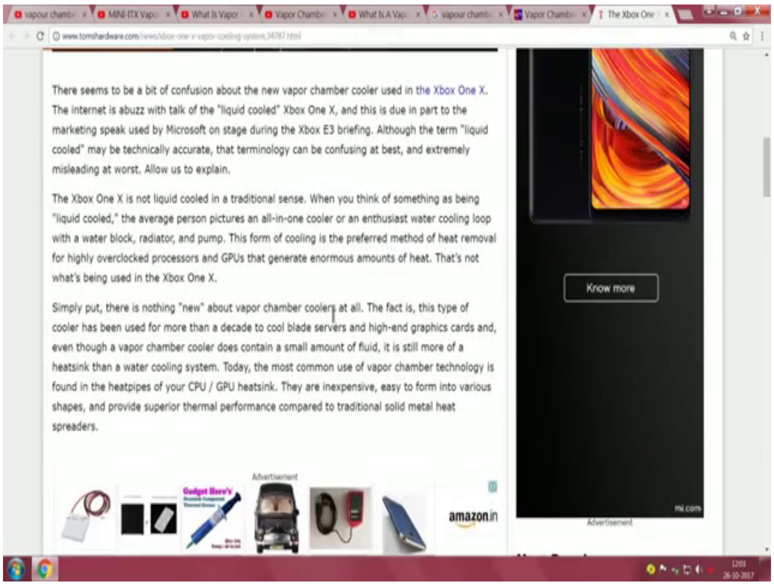
Now, I will see if I can open this and see how it is treated. So, the next picture that has been brought and kept on a table you see here one thing you will notice is we have a some L shaped some mounting plate and my (Refer Time: 12:44) student know he is helping me open the thing.

(Refer Slide Time: 12:52)

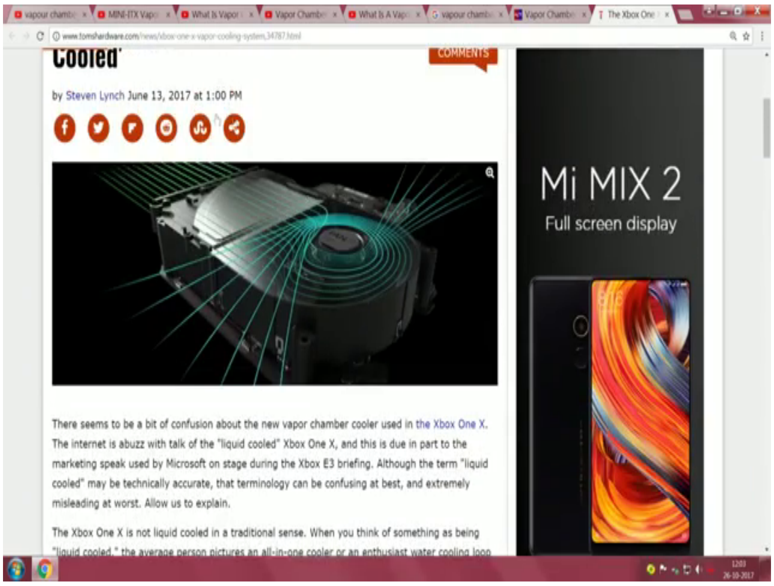
He believes in me he knows very well that you know I am not likely to damage it. You have seen that there just four screws and when you lift it out we have this beauty. I am sure you will appreciate what it is that you know the whole thing is. So, at this corner you can see can you see here. We have two active devices directly mounted on a small aluminum what you call sheet which is all the main purposes of the heat sink and the fact that it is whole thing is open and it will probably in a air stream inside another cabinet this is sufficient absolutely. Absolutely sufficient, same it is here.

See here there are two more devices here and then I am not very sure why it has been you know bent and brought here, same thing here you have many more devices here in just like that hot coffee is spilling on your thing know. You see here this is not about heat this is about a rail being charged, it could be one of them could be a positive rail another could be a negative rail as such now. These are the small heat spreaders used in equipment like this. So, I thought I will stop there and then I will try to come back to an interesting.

(Refer Slide Time: 14:31)

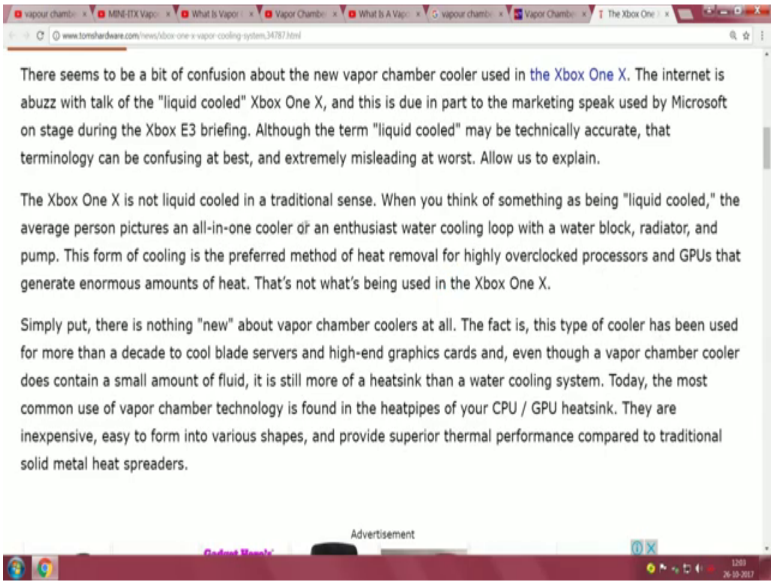


(Refer Slide Time: 14:32)



Some of you may have heard that the latest June, thirteenth it has been you know written.

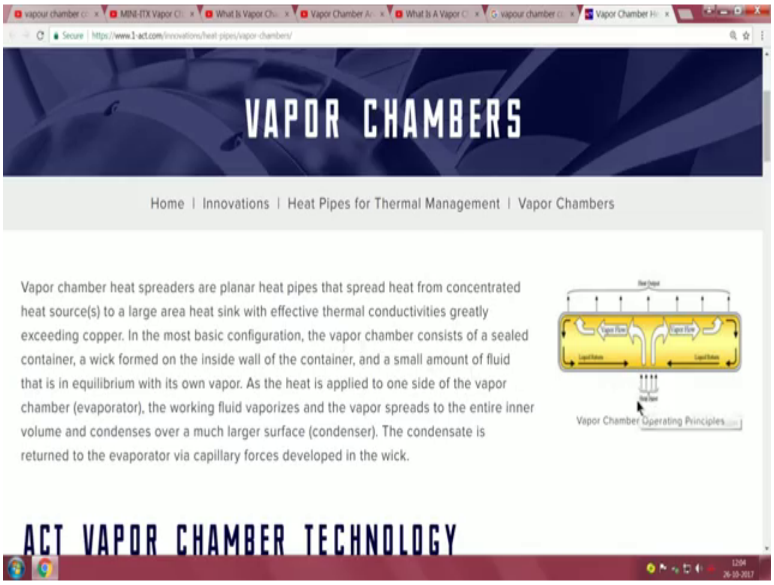
(Refer Slide Time: 14:36)



About Xbox One X. He talks about liquid cooled Xbox One X due to impact to the marketing what you call blitz by Microsoft on stage during the briefing. Although the term liquid cooled may be technically accurate that terminology can be confusing and extremely misleading. Liquid cooled does not mean the same thing as a liquid cooled heat sink or anything is not a liquid cooled in a traditional sense when you think of something is being liquid cooled.

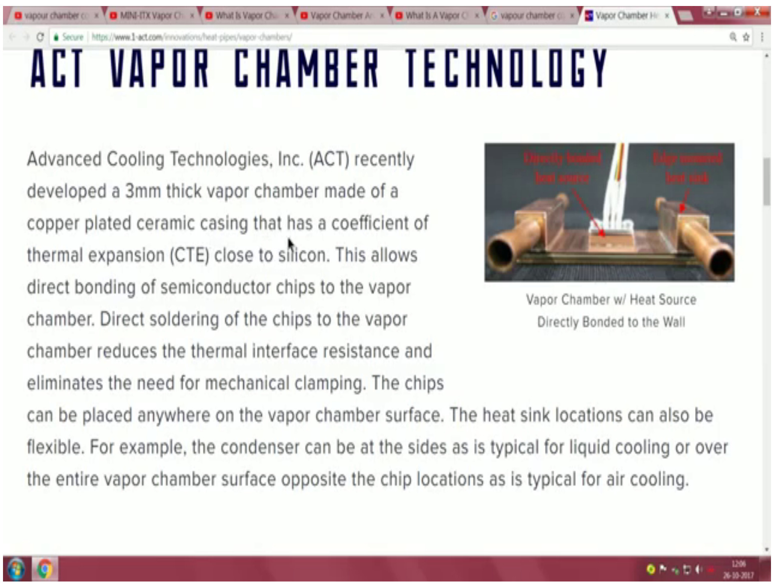
The average person pictures an all-in-one cooler or an enthusiast water cooling loop with a water block radiator and pump. The form of cooling is a preferred method of heat removal for highly overclocked process and the GPU that generate enormous amounts of heat. That is not what is being used in the Xbox One. Instead it uses a vapor chamber. The type of cooler has been used for more than indicate to coal something high end graphic cards and so on.

(Refer Slide Time: 16:02)



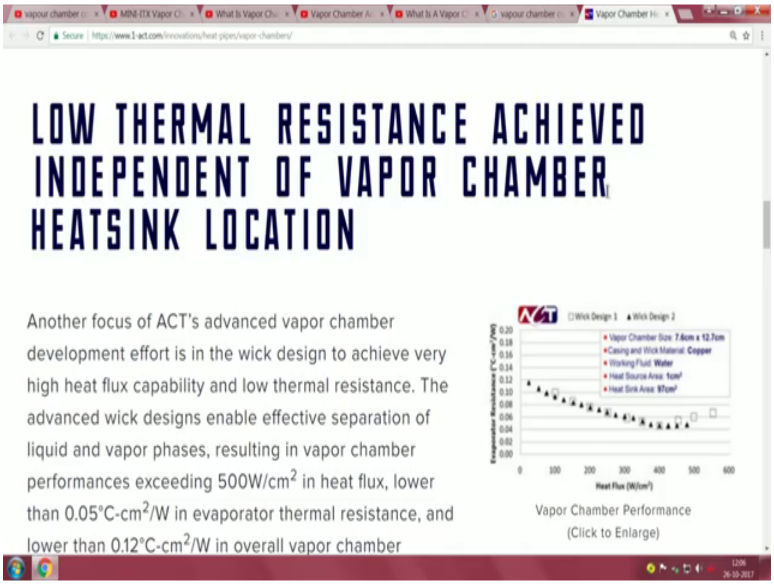
So, I will now stop it here go back to the next this thing in which see what happens in a vapor chamber thing is and the right side you have a heat source then this thing is filled with some liquid which starts boiling or phase changes and that latent heat carries away the heat. That latent heat now makes it condense on another surface usually directly above and then the water is you know I am sorry the liquid gets removed. Heat vapor chamber heat spreaders are planar heat pipes that spread heat from concentrated sources to a large area heat sink effective thermal conductivity is greatly exceeding copper. So, you can read it for yourself with me.

(Refer Slide Time: 17:26)



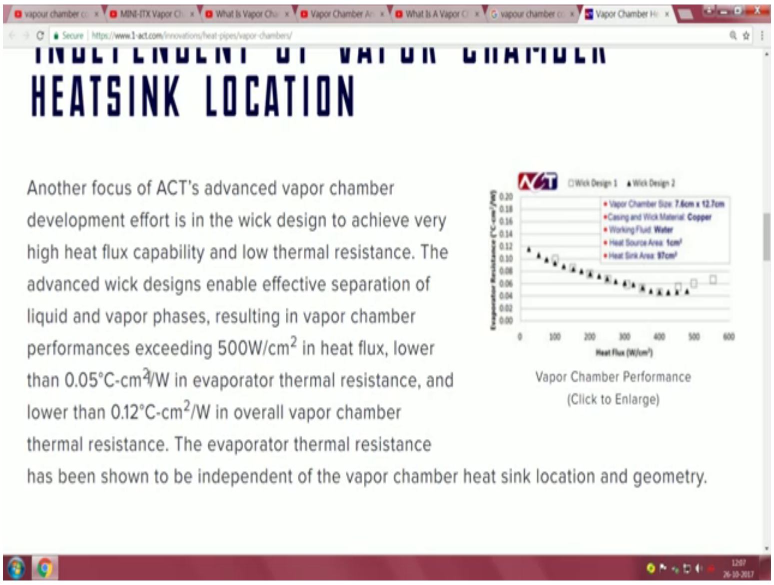
We have all these you know things. Those people developed a chamber made of a copper plated ceramic casing close to silicon. This allows direct bonding of semiconductor chips to the vapor chamber. Direct soldering of the chips to the chamber reduces thermal interface resistance and eliminates need for mechanical clamping. Chips can be placed anywhere in the vapor chamber surface. heat sink locations can be flexible. The condenser can be at the sides of a typical as is typical for liquid cooling or over the entire vapor chamber and so on.

(Refer Slide Time: 18:03)



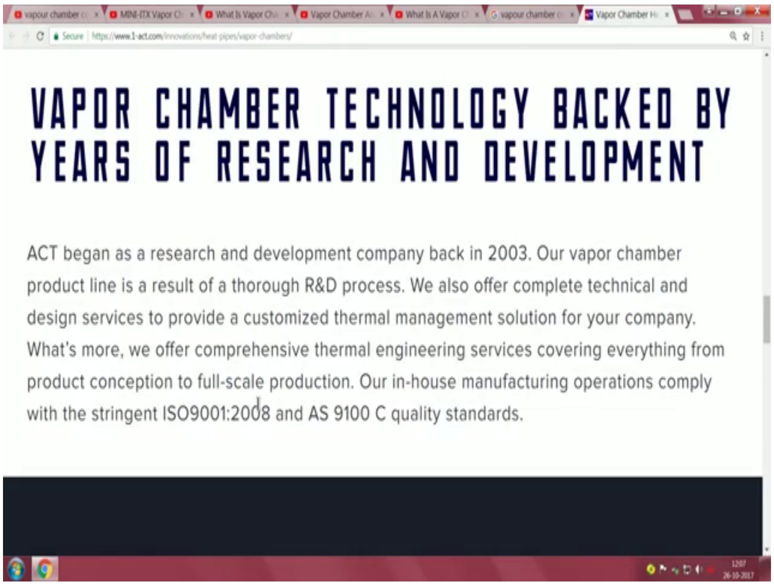
So, lower thermal resistance achieved independent of vapor chamber heat sink location.

(Refer Slide Time: 18:13)



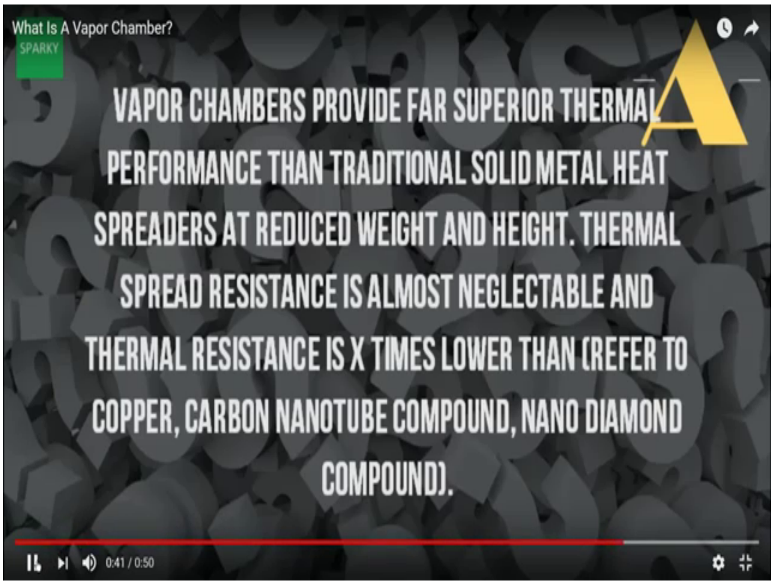
So, we have here if you see what you call the type of heat flux you know term is 100 watts per you know centimeter square, 300 watt centimeter square and so on. So, 500 watts per square centimeter in heat flux lower than 0 in evaporator thermal resistance and lower than 0.12 in overall vapor chamber thermal resistance.

(Refer Slide Time: 18:46)



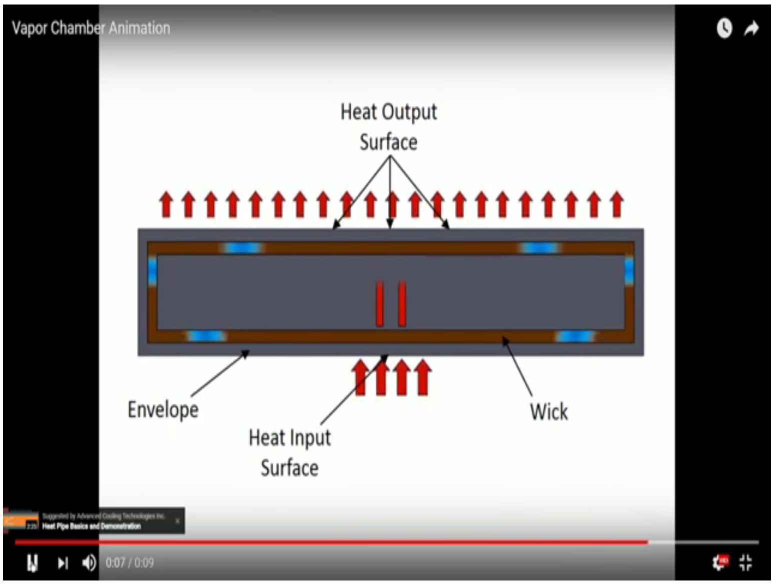
So, my suggestion is you have a look at it, I am just showing you. So, it is very much you know convenient for you to have a look at it. Now, I will see if I can play something which I fully like to acknowledge from the these manufacturers.

(Refer Slide Time: 19:10)



Have a look at this. So, that probably about sums up what is a vapor chamber heat sink.

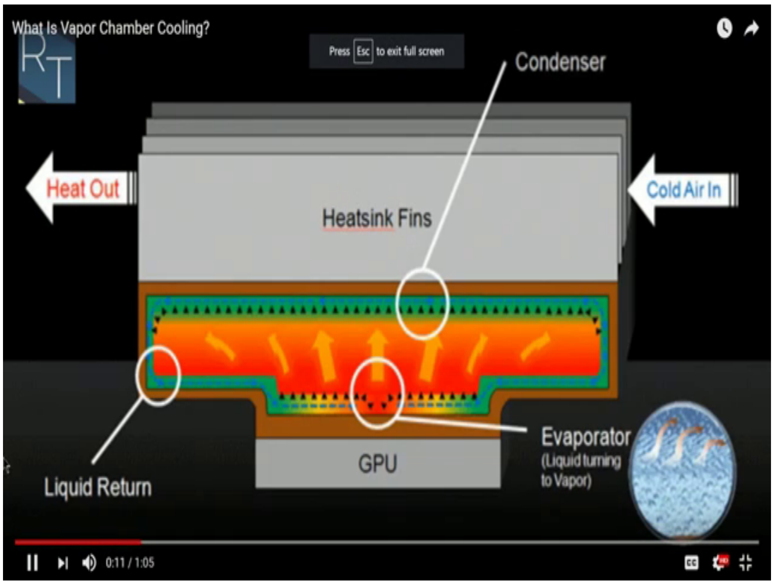
(Refer Slide Time: 20:05)



Now, advanced cooling you know has a similar this thing this is slightly same thing once again know it is it is almost like an animation and it is expected to run again and again you see here it is getting there is all the history.

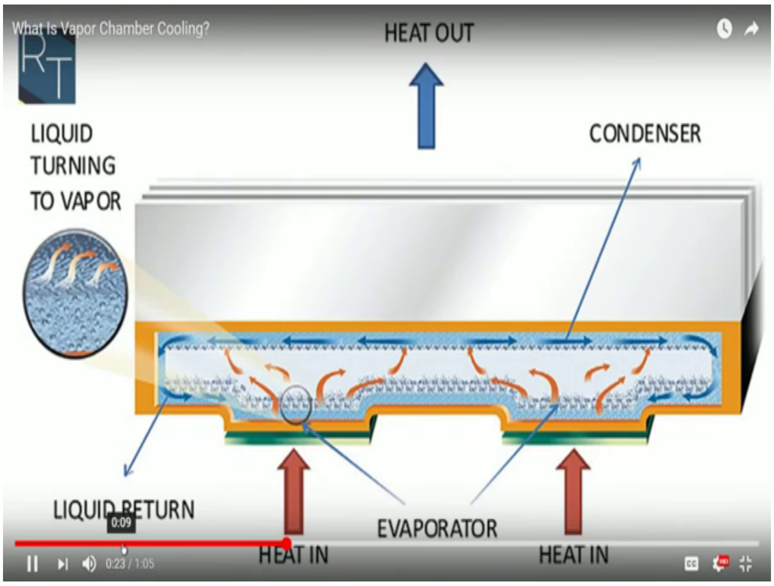
(Refer Time: 20:26) was the first major PC component manufacturer (Refer Time: 20:31) technology contains the working flow of the changes from liquid the gas when the heat is supplied anywhere on its (Refer Time: 20:38).

(Refer Slide Time: 20:59)



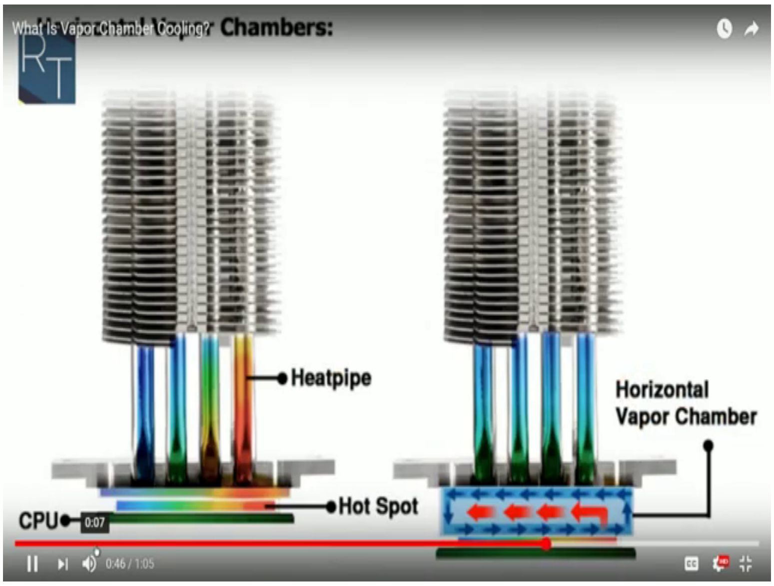
What is vapor chamber heat sink? A vapor chamber heat sink is a much better way of cooling something, rather than using a heat pipe. You will find this type of heat sink in much more higher in graphics cards such as the (Refer Time: 21:07).

(Refer Slide Time: 21:13)



That new X box Scorpio should include this type of cooling method. This is how it will work the vaporized coolants convex freely through the chamber. The molecules that condense on cold surfaces dissipate their heat load and our channel box of the coolant reservoir. Since the rates of condensation depends on the temperature delta of the coolant and the contact surface the coolant automatically streams towards the cooler surface area.

(Refer Slide Time: 21:36)



The coolant stream within the vapor chamber is responsible for its superior thermal properties. As a results it provides stable and evenly spread temperatures on all of it is surfaces, regardless of the location and density of the heat source below the chamber base and that is how a vapor chamber heat sink its surfaces regardless of the location and density of the heat source below the chamber base.

So, now getting back we will notice that if were to use a simple heat pipe and so on. We have this little problem still of if you have a hot spot and if you have multiple heat pipes you still have this problem of some of them getting a little hotter compared to the other thing compared to that if you have a vapor chamber the thing can be equalized. So, it is for you to take a call and what you call wonder now what to call what I will close this now well come back to this again this is slightly what you call longer thing, listen to him.

(Refer Slide Time: 22:43)

Know that the originally call it debay this is the ID COOLING VC 45 and this is kind of unique cooler even though it looks very much like the (Refer Time: 22:54) because it features a vapor chamber built-in. So, what it is like? Go find out. Whoa one thing one thing. So, the last video I purposely chose a CPU that is too hot for the extra mini. The second thing which is really important is that I was using version 28 dot 9 a prime 95 which is what I use for all of my stress testing CPUs, but what it does do very well is generating a lot of heat which is why I used it to compare these coolers or take Doctors able from the century project for asking me to clarify this if I did it any more future heat testing videos. I am also going to use version 26 dot 6 in (Refer Time: 23:35) 5 in this correct bench mark to show you a more accurate stress test that is safe for the CPU at least more safe.

So, with this disclaimer out of the way let us go blow up my CPU. Your job is to stop it from blowing up. Presentation is a not packed well, not much for presentation comes with everything that you need to actually cool your CPU down which is in the end what you pay for.

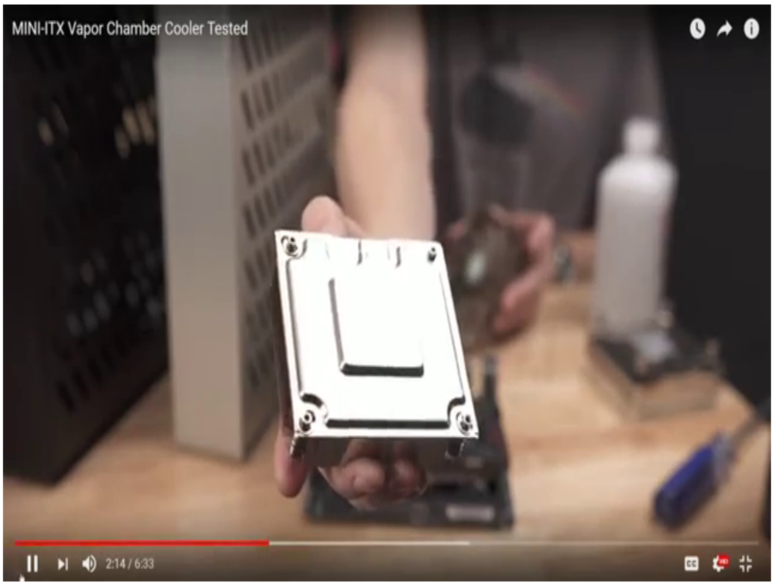
(Refer Slide Time: 24:03)

Also, some weird plastic fibers, box kind of boring, but then again so our am I asked for so many boxes and who really cares, it is about the coolers. Do any test after remove the knob to us from my current test motherboard which is super easy four thumb screws that is all there is to it. So, the VC 45 does come with the thermal interfacing compounds, but I am not going to use it because I want to be consistent with my heat sink tests.

(Refer Slide Time: 24:34)

So, I am using knock to as NT-H1, should I use normal (Refer Time: 24:32) it is good stuff. It works really well I put a pea sized amount, this is what it looks like. It is the pea sized amount. Fading surface the VC 45 is awful as far as finish surface the VC 45 is.

(Refer Slide Time: 24:44)



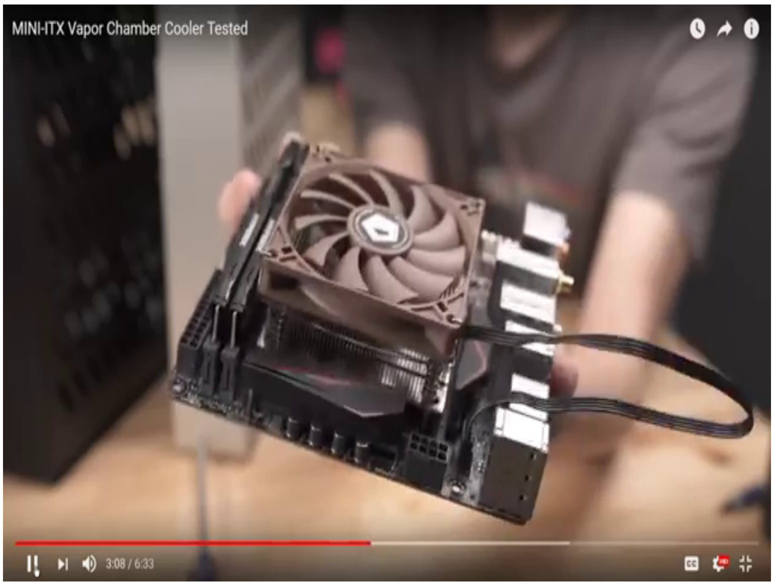
This is probably what was that small device attached to the fan which I brought to you yesterday I need to drill it out drill out the core and see any liquid or anything, but you will notice here that this is slightly different from the conventional simple heat sink with a copper core and something which is spread and top of it now listen to this fully.

Awful its (Refer Time: 25:16) finish, I mean it is one of the roughest surfaces I have seen in a core. I do not think it matters too much, but if you were expecting something lapped and polished just it is not here. The VC 45 does have a just a full mounting system which is really nice.

(Refer Slide Time: 25:36)

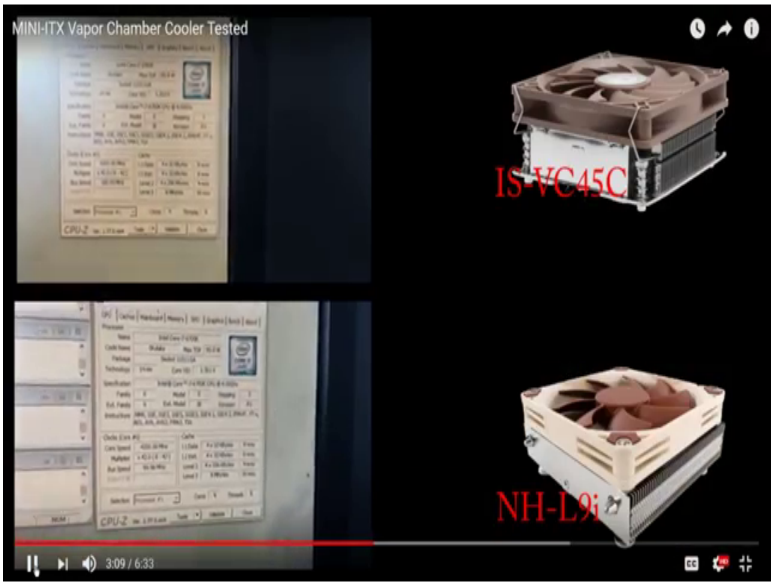
Because you can install it more than one type of motherboard, but it does make it a little trickier to install. You can definitely over tighten it though. So, make sure you do not warp your motherboard and just tighten as much as it needs to be, but not anymore. it is tighten the clips for the fan was really difficult I mean I had to look at the instructions, that is how bad it was and the instructions actually showed a different style clip. So, I was even more confused, but at the end of the day I finally, figured it out and broken the fan clips and I did not shoot my eye out.

(Refer Slide Time: 26:07)

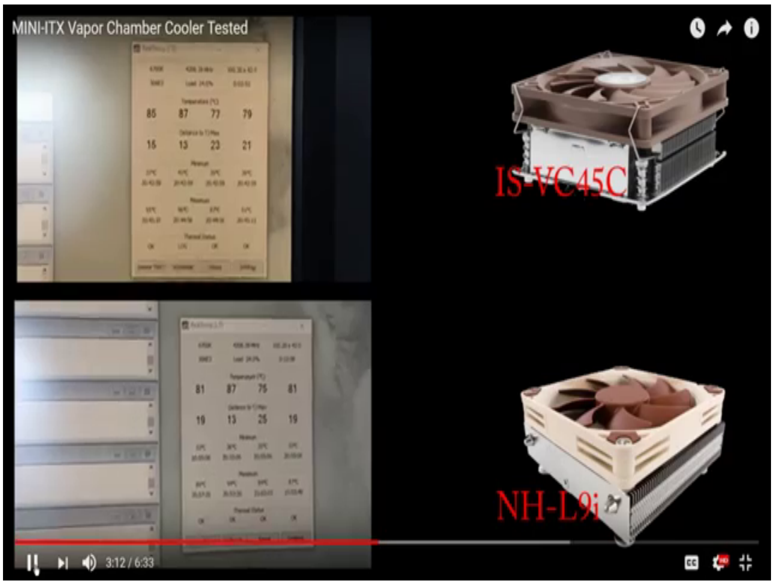


So, there is that. This all bolted up and ready for some testing, ok.

(Refer Slide Time: 26:09)

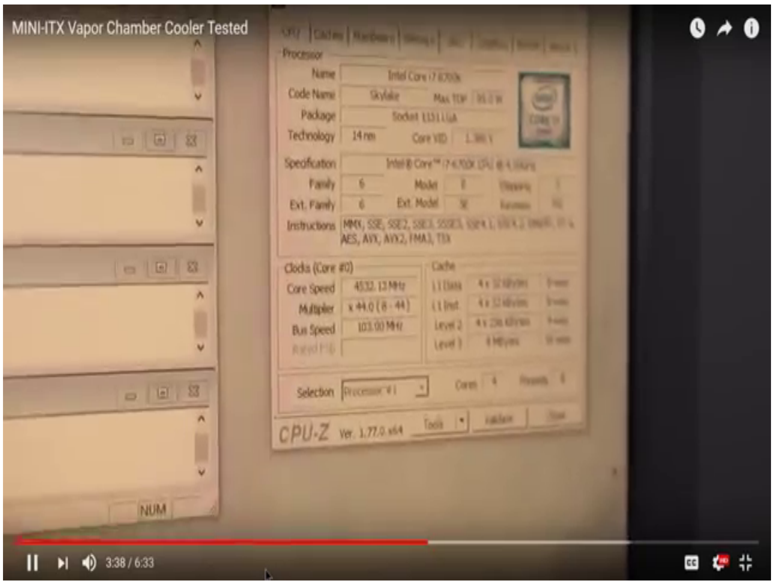


(Refer Slide Time: 26:10)

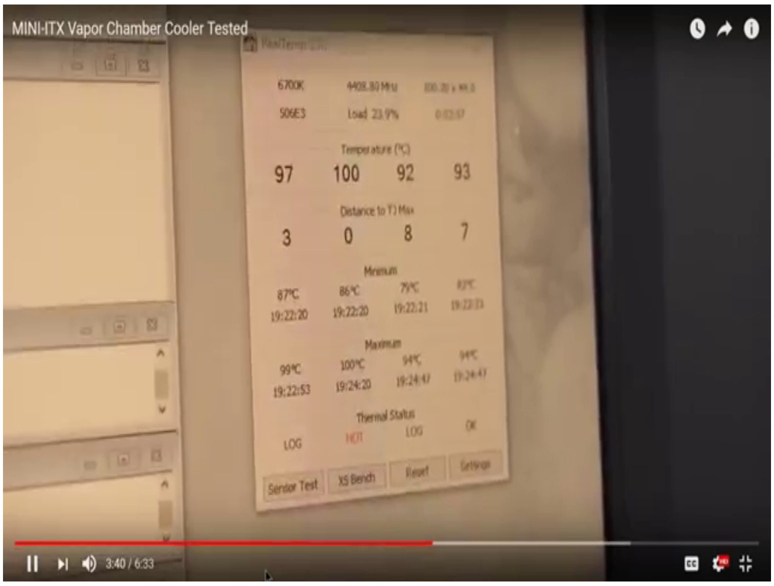


That one is pretty boring stuff (Refer Time: 26:10) stock clock rate Noctua with a little bit cooler a little bit running varying 26 dot 6 prime 95 and the Noctua is actually doing a cycle cooling a little bit more CPU. So, I guess the winner would be the Noctua, but still too boring of a test. So, it over clocked the processor and is 4.5 gigahertz. This is of course, the VC 45 and I am running in the hot version of prime 95, the deadly version.

(Refer Slide Time: 26:36)

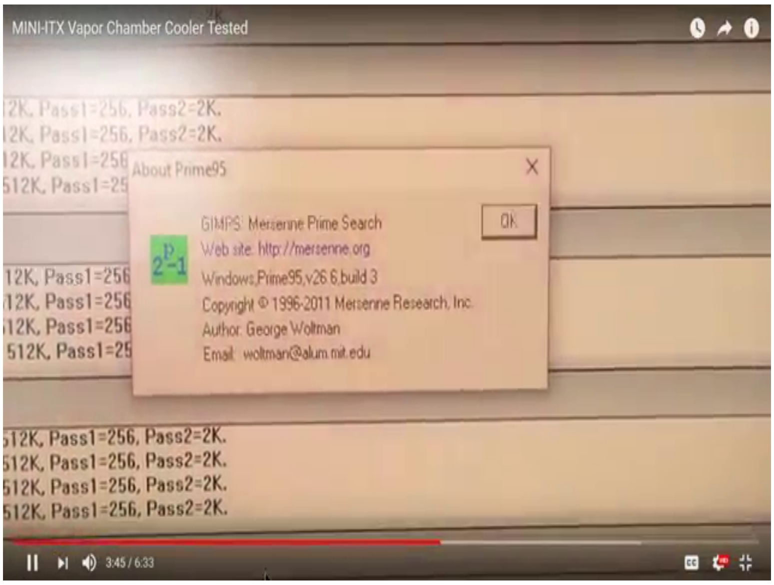


(Refer Slide Time: 26:40)



And, it was pretty hot; it eventually did throttle like after ten minutes.

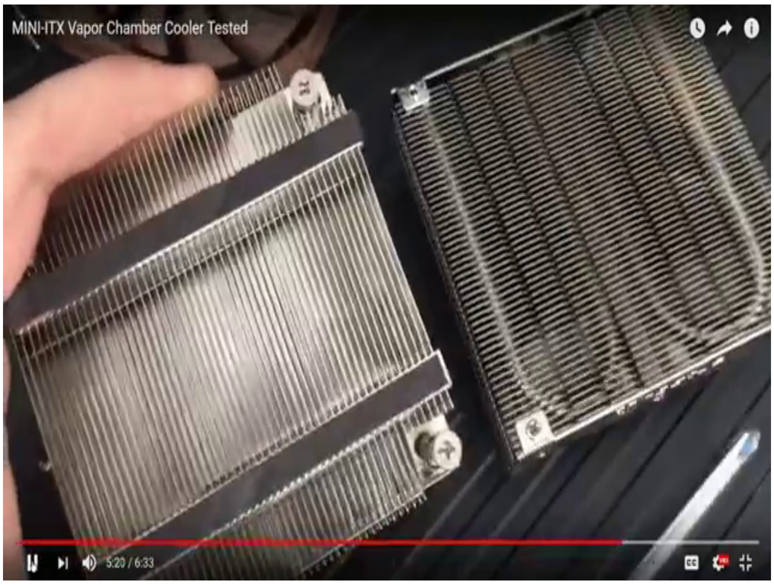
(Refer Slide Time: 26:44)



So, I put back down on the 26 dot 6 version with an over clocked CPU and it throttled, but after like 15 minutes. So, I guess well obviously, the CPU is not for over clocking. So, here is the thing with the VC 45. It is it is pretty loud, louder than Noctua, but listen for yourself. Let us test it against the Noctua fan. Now, I am need a beer to wrangle off this clip, ok.

So, I have the Noctua fan on the VC 45. Let us see which does about the same actually I was actually surprised not seeing much of a difference, except for noise; it is a lot quieter. I made good contact with the VC 45. So, I know that was not the issue both on the CPU and the backside, then a couple runs, but here is the last one it is a confirmation run, stock voltages and looks like the Noctua is a little bit cooler still but, just a teeny tiny bit but, it is quieter.

(Refer Slide Time: 28:18)



So, I think it has to do with the fan because the heat sink design is pretty similar the Noctua has more fins and a heat pipe, but I guess that off sets any advantage that the vapor chamber has on the VC 45. Well, that was pretty close almost too close to call for talking about just the temperature data, but that is only if you are looking at the raw temperatures. There is a lot of things about this cooler that I just do not think holds up to the NHL9I.

So, it is a bad cooler? Absolutely, not, I just cannot to throne the king, but maybe with an update and some heat pipes it could. Over the much lower price tag I would definitely tempted to go with this cooler, but because at least in America it is more expensive than then Noctua, it is no easier than the Noctua, it is not as pretty as the Noctua I would have to go with the Noctua. Thanks for watching this video. Give me a thumbs up or a hate comment if you hated it and frankly I probably deserved it for being negative about a product on the internet. Whatever, you do hope to see you next time.

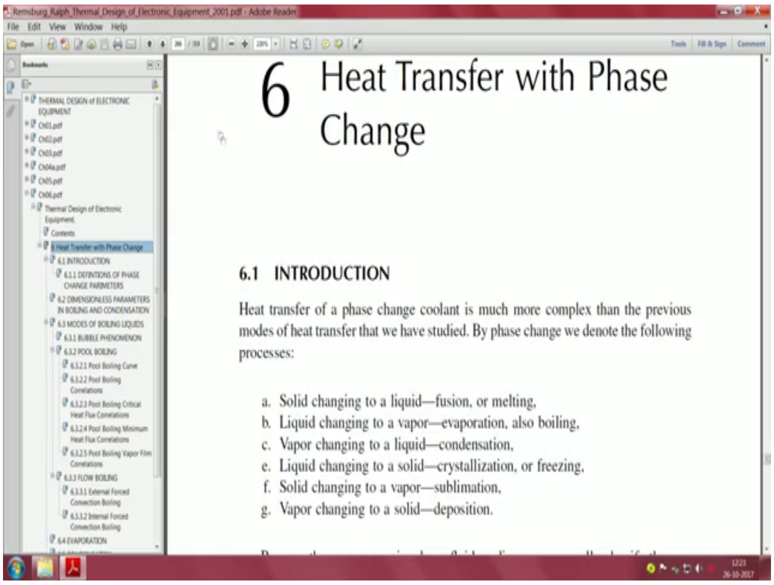
So, coming back here need to probably verify what is being published and the thing is it unless you are in OEM manufacturer or a very serious person or a what I call a researcher it is not possible for us to attempt fabricating any of these things, especially these vapor chambers and all they are all made specifically for a chip set imagine let us say you have a 30 mm by 30 mm external surface on which you can bond this then along with the cooler this makes a neat package. That is not something you attempt to make on your own in your lab or anything same thing a little with your heat pipes also.

Heat pipes it is all well known, but if you have something readymade you can try to use in your other things. So, by default we still end up with simple conduction and how to improve the conductivity between whatever devices being cooled onto a heat spreader which is loosely call a heat sink and then with the available what you call space and geometry how well you can make a heat sink try to use one or you can make one also and then use all your what do you call creative techniques to see how well you can arrange these things on a printed circuit board.

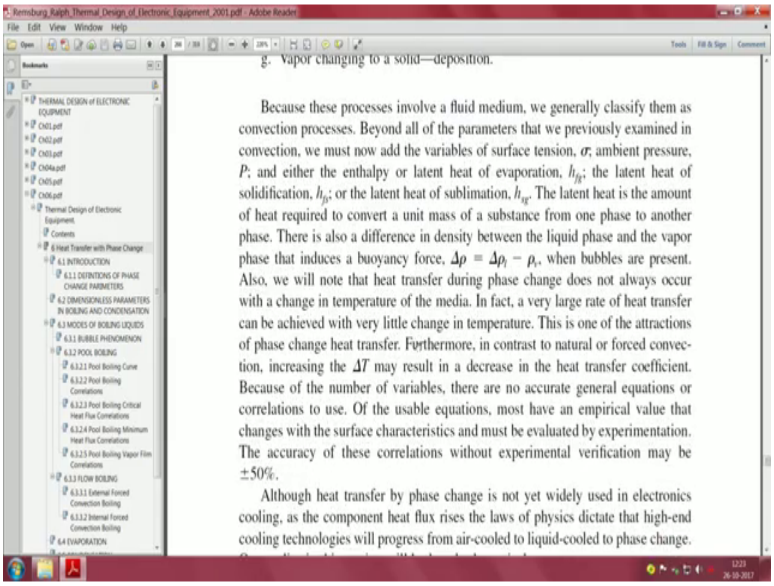
Because, the whole package just needs to be small and then eventually this is at the smallest level then the equipment level one way of dealing it and then finally, we come to the racks and in fact, you have a large installation you are forced to take all the heat out from the last year rack. I think I will pause here for a while and I want you to go back to all the that wherever the question this video has been recorded and read up a little more about the practicality of each of these solutions, that is the reason you do not find these things very what do you call widely used in your equipment.

So, because they continue to be still a little bit of novelty and very conventional way of selecting a heat sink and then using some way of convective cooling this will help. However, to make this little what you call complete I will take you to old Ransburg book in which a whole chapter has been what do you call if you go to the second part of the this whole book a huge amount of what you call data has been presented and an analysis is presented here about phase change.

(Refer Slide Time: 32:31)

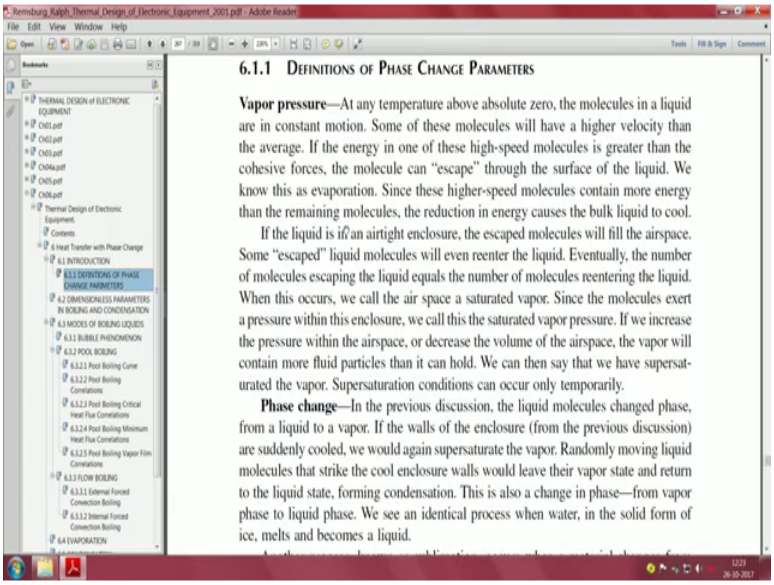


(Refer Slide Time: 32:39)



See it is relatively complex saying heat transfer of a phase change coolant is much more complex than the previous modes of heat transfer. By phase change we denote liquid changing to vapor evaporation. Vapor changing back to a liquid condensation then solid changing to a liquid, liquid changing to a solid, solid changing to vapor sublimation and vapor changing to solid deposition.

(Refer Slide Time: 33:02)



6.1.1 Definitions of Phase Change Parameters

Vapor pressure—At any temperature above absolute zero, the molecules in a liquid are in constant motion. Some of these molecules will have a higher velocity than the average. If the energy in one of these high-speed molecules is greater than the cohesive forces, the molecule can "escape" through the surface of the liquid. We know this as evaporation. Since these higher-speed molecules contain more energy than the remaining molecules, the reduction in energy causes the bulk liquid to cool.

If the liquid is in an airtight enclosure, the escaped molecules will fill the airspace. Some "escaped" liquid molecules will even reenter the liquid. Eventually, the number of molecules escaping the liquid equals the number of molecules reentering the liquid. When this occurs, we call the air space a saturated vapor. Since the molecules exert a pressure within this enclosure, we call this the saturated vapor pressure. If we increase the pressure within the airspace, or decrease the volume of the airspace, the vapor will contain more fluid particles than it can hold. We can then say that we have supersaturated the vapor. Supersaturation conditions can occur only temporarily.

Phase change—In the previous discussion, the liquid molecules changed phase, from a liquid to a vapor. If the walls of the enclosure (from the previous discussion) are suddenly cooled, we would again supersaturate the vapor. Randomly moving liquid molecules that strike the cool enclosure walls would leave their vapor state and return to the liquid state, forming condensation. This is also a change in phase—from vapor phase to liquid phase. We see an identical process when water, in the solid form of ice, melts and becomes a liquid.

So, these things this is what you call textbook gives a huge amount of definitions of what is what is vapor pressure. Above absolute zero molecules in a liquid are in constant motion some of these will have a higher velocity than the average. The energy is one of these high speed molecular is greater than the cohesive forces molecule can escape. This is evaporation if the liquid is an airtight enclosure. The escaped molecules will fill the air space some escaped molecules will even reenter the liquid. Eventually the number of molecules escaping because number of molecules reentering we call the air space is saturated vapor.

So, here you know we need to remember two things; one of them is if you leave something outside in the open. It has a tendency to evaporate at a slow rate which is very different from boiling. In boiling because of the amount of input giving and actually phase change occurs. So, both of them, there is latent heat involved in it; the rate of change is the issue.

So, typically let me get back to your old high school physics; your empty pond. Sometimes we will notice that the pond appears a little cool, too cold in the morning. The same pond some other times does not appear so cold. So, the standard explanation that is given there is one is the evaporation at the surface, the other is the universe is a big black body on a cloudless night all this water loses heat directly to the universe which is dark if you do not have.

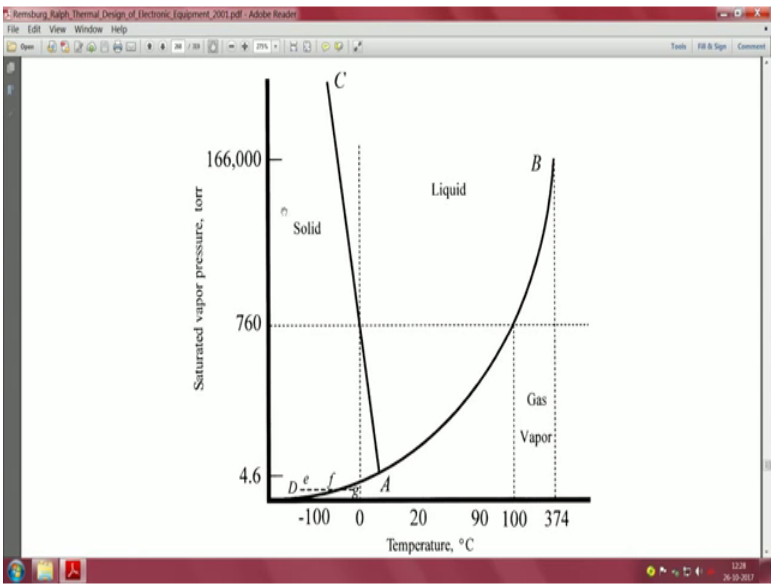
Student: (Refer Time: 35:10).

Any if you do not have any what do you call the stuff about ambient lighting and hopefully it stars of course, star gives light not much of heat and you do not have any of these sources things become extremely cold. So, you have evaporation plus radiation.

Now, down the thing, talks about what is phase change. In the previous discussion the liquid molecule change phase from a liquid to a vapor if the walls of the enclosure from previous are suddenly cold again super saturate the vapor. So, I had like to draw your attention to very common things which we see. If you were to take a hot cup tea cup place it on a horizontal surface like your what you call table or workbench. You will notice that after a while when you take it off it forms a small patch there and you can see condensate on the patch.

In contrast, if you take a bottle having some let us say cold liquid or a glass of cold water you will see that there is condensate all around the outside surface the issue there is this saturated supersaturated this thing for a given temperature. Then if you have a cold surface in the case of a tea cup, example the horizontal surface was cold the cup itself is warm, so, it condenses on the colder surface. In the case of a our what you call tumbler with some cold liquid it is cooler than the ambient. So, it will condense on the walls. So, a lot of it explains what are the phase diagrams and so on.

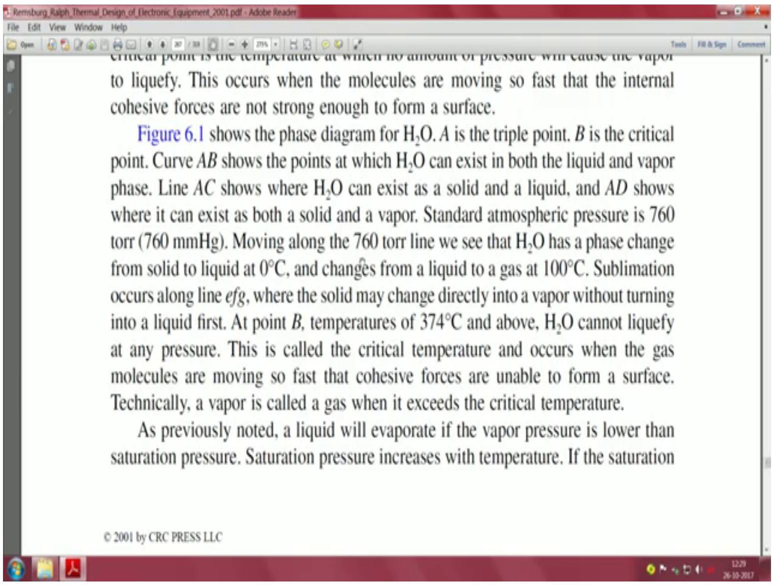
(Refer Slide Time: 37:20)



Probably you have seen this here. So, I suggest you spend a little more time and like me and my you know talking about it. So, at a given temperature what is the you know which part of it is liquid, which part is solid, which part is gas and which is a vapor, this is the diagram for water. So, we all know is depending on the pressure, we all know which is a liquid phase and we all know which is the vapor phase.

So, as you compress the liquid or as you compress the gas how does it behave as you evacuate the gas how does it I mean behave the operation or choice of operation on this is where both your refrigeration, air conditioning equipment as well as our vapor phase coolers will work. Depending on you know when you want it to boil, when you want it to what do you call cool and then what is the pressure at which these things happen, you have a closer look at it later on it is whole thing is explained in the in the text.

(Refer Slide Time: 38:36)



critical point is the temperature at which no amount of pressure will cause the vapor to liquefy. This occurs when the molecules are moving so fast that the internal cohesive forces are not strong enough to form a surface.

Figure 6.1 shows the phase diagram for H_2O. *A* is the triple point. *B* is the critical point. Curve *AB* shows the points at which H_2O can exist in both the liquid and vapor phase. Line *AC* shows where H_2O can exist as a solid and a liquid, and *AD* shows where it can exist as both a solid and a vapor. Standard atmospheric pressure is 760 torr (760 mmHg). Moving along the 760 torr line we see that H_2O has a phase change from solid to liquid at 0°C, and changes from a liquid to a gas at 100°C. Sublimation occurs along line *efg*, where the solid may change directly into a vapor without turning into a liquid first. At point *B*, temperatures of 374°C and above, H_2O cannot liquefy at any pressure. This is called the critical temperature and occurs when the gas molecules are moving so fast that cohesive forces are unable to form a surface. Technically, a vapor is called a gas when it exceeds the critical temperature.

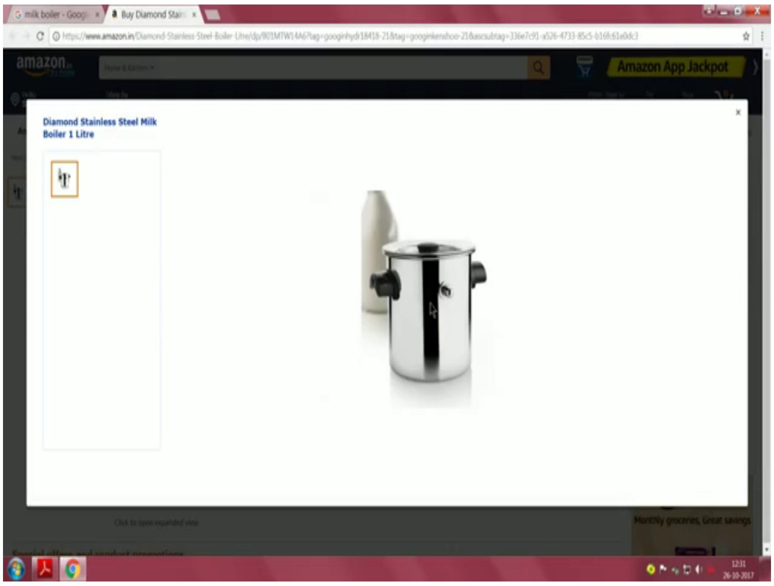
As previously noted, a liquid will evaporate if the vapor pressure is lower than saturation pressure. Saturation pressure increases with temperature. If the saturation

© 2001 by CRC PRESS LLC

Phase diagram for this thing; A is the triple point, B is the critical point curve AB shows the point at which water can exist in both liquid and vapor phase.

So, you have seen this A and B is where we work with in all over this thing. So, depending on the what do you amount of you know pressure you apply how much of gas you fill and all that. Standard atmosphere pressure is 760 what you call torrs at 760 millimeters which is you know equivalent to something. Moving along the torr line we see that H2O has a phase change from solid to liquid at 0 degree centigrade standard things, changes from liquid to gas at 100 degrees centigrade. Typically, this is used in your milk boilers. So, if we take a milk boiler it is nothing, but a water jacketed vessel left to the atmosphere. So, I will see if I can go to the internet and look for a milk boiler.

(Refer Slide Time: 40:17)

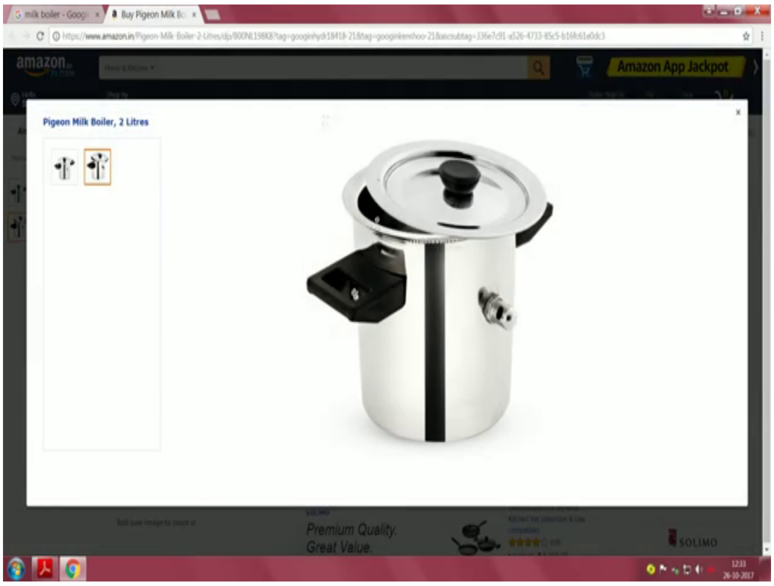


I am sure some of you have seen this device. Madam show me this thing. This is typically a milk boiler, we know we have this serious problem with the milk this thing. If you keep milk on any what you call hot plate stow gas or anything first thing is as long as you keep looking at it nothing will happen. Even momentarily you look away and then it will boils over. So, is that a way of avoiding it, so, what generally people do is, put it in this water jacketed vessel which is called a milk boiler.

So, there is nothing outside as a small opening here you fill it with water and then you keep it on your hob or gas or anything. As long as this is getting heated up and even when it is boiling especially at a low temperature it you keep condensing on the inner jacket, you have an outer jacket and a inner jacket. The liquid from the outer know keeps condensing on the inner jacket or if they are directly in contact it will not boil, which is the beauty of it. Usually this is filled probably about between one third and half the way.

So, the advantage is as long as you are heating in by conduction and if the milk inside is still you know in the normal condition, you will notice that it will not boil over. The moment this boiling will start is probably when inside temperature is you know approximately reached a few degrees below the ambient boiling point and one more important thing is it must be left open to the atmosphere. Then the moment is boiling starts there is a whistle attached to it. So, the whistle whistles and you know take out.

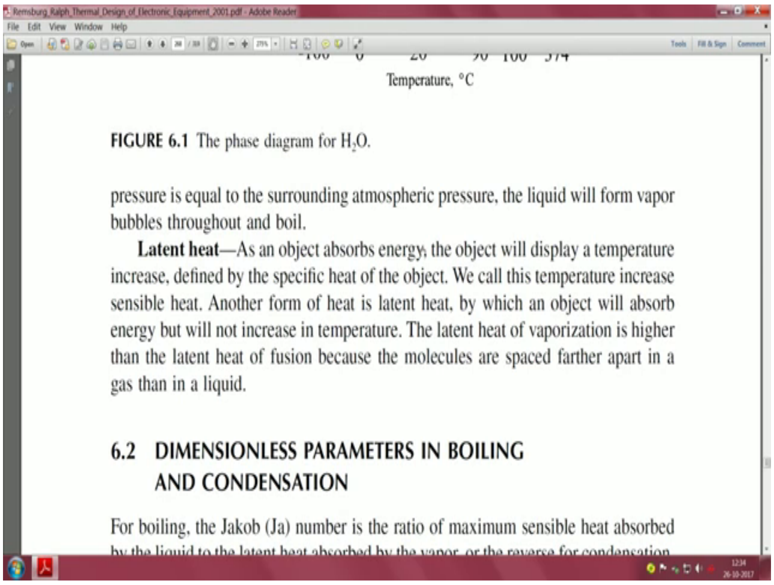
(Refer Slide Time: 42:11)



And, so, we have any of this beautiful you know milk boilers. Main principle is milk boiler is its simple water jacketed vessel. You have an inside container and then you have this outside container you see here. You have a lid and it is a double walled thing where the container is filled with water. This is all there is to it any of the vapor chamber coolers which are talking about. Why I keep giving you this a common examples are is that you may not be working in a lab besides you can always make an experiment.

So, we will notice that H2O has the phase change from solid to liquid at 0 degrees centigrade and changes from liquid to gas at hundred degrees and so on and so on. So, this is typically what will happen even inside your so called vapor chamber what you call, devices.

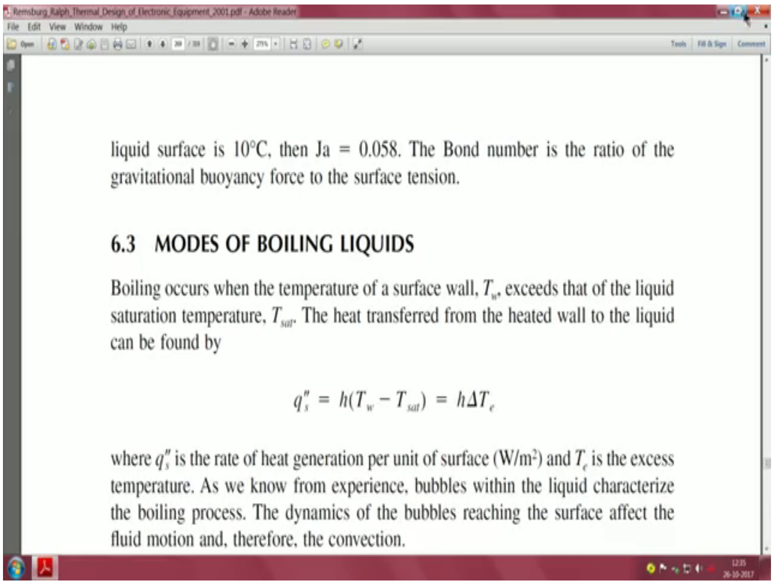
(Refer Slide Time: 43:04)



So, as an object absorbs energy, the object will display a temperature increase defined by the specific weight of the object we call this temperature increase sensible heat another form of heat is latent heat by which the object will absorb energy, but will not increase in temperatures that latent heat of vaporization is higher than the latent heat of fusion.

Now, the molecules are spaced so on and so on and all the advantage is in boiling until the last drop of liquid gets evaporated the temperature does not change which is exactly what is the principle used in the water jacketed vessel and it looks like milk and then with the that little you know temperature drop across the container will never boil over in the that water boiler which I was in the milk boiler, which I have showing you.

(Refer Slide Time: 44:12)



I leave you here for you to you know talk about this Jakob number and so on and so on. So, thank you, I will just stop here, and I will continue with the theory in the next class which I have this is probably I already covered a little time.

Thank you.