RAC Product Design
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Lecture – 15
Case Study on a telecom cooling system and Emerging technologies

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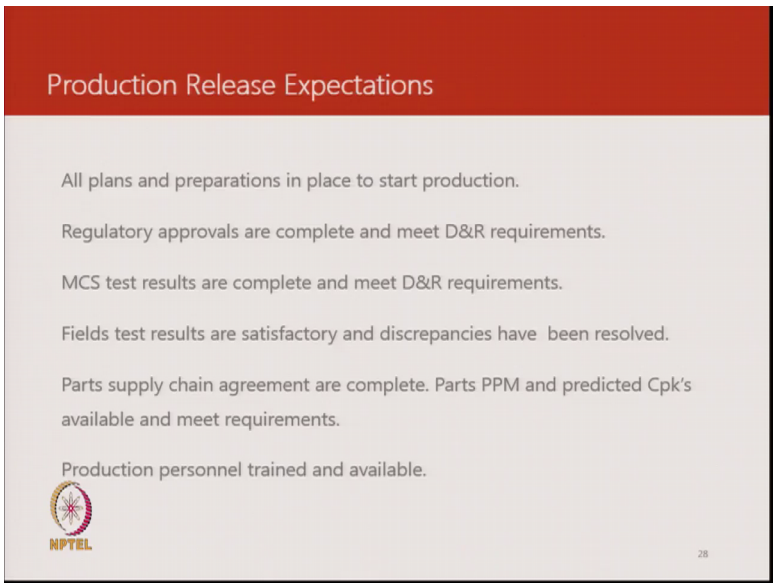

So, now, we look at what are the expectations that have to be met when the product is being released for market. So, at this stage everything that was agreed for design and reliability test is all accepted it has been proven there is no remaining activity. The first requirement, regulatory approvals a product cannot be released without that. So, again evidence of that then manufacturing has made the number of requisite number of batches to verify that they can meet the rate of production.

Field tests are satisfactory there is nothing abnormal being discovered by field test. So, field test is typically a process to discover the unknown if you look at a case study in railways vibration was something that was discovered and it was not through a planned field test, but it was discovered you know running production, but in products of high volume you do a field trial just to be sure that there is nothing that has been left out because of something not being so, obvious at the time of framing of test plans.

Again it is to reduce the risk of the commercial risk of a product launch and then parts the supply chain agreement all that is completed the needed levels of quality in terms of

acceptable parts that may turn out to be defective and all that is predicted accepted supplies of agreed and production personnel are trained and available.

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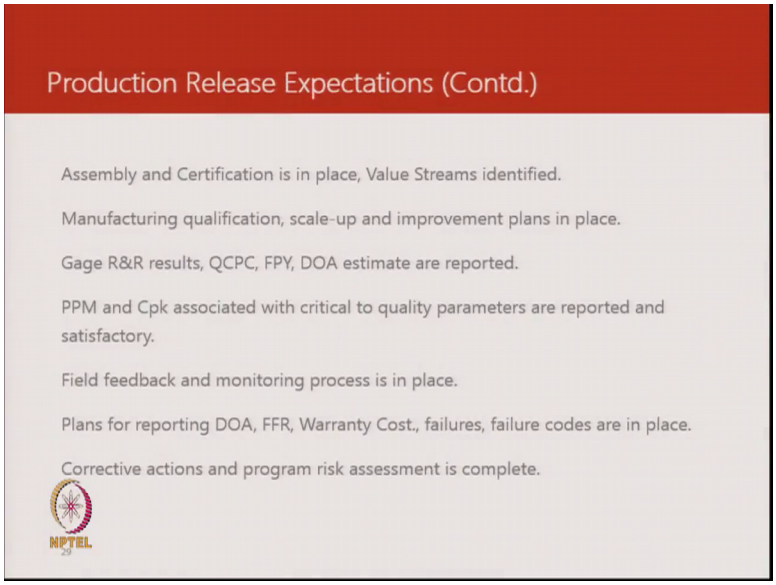

Then there is a whole lot of work that happens in the manufacturing domain which is assembly in certification whether it is training of people value streams manufacturing and then scale up and improvement plans and very often when there is a an external product compliance need which is mandatory like in India we have the star rating program.

So, product can be picked up from the market put to a lab test a third party lab test and if they are not complying to what has been rated on the label of the product then there is a penalty and a risk of reputation for the manufacturer. So, to overcome all those risks at the manufacturing level that has to be Gauge, R and R and then there is a an estimate of any failures of product on a regular ongoing method then process capability is mapped for all the critical parameters. So, in an air conditioner the critical parameters would be energy efficiency ratio and cooling capacity which is a derivative again of cooling capacity and power consumption.

So, all that has to be falling within the defined norm of 3 percent at the manufacturing level if they are to meet an external requirement of 5 percent. So, now, you had asked me for another case study last time. So, the case study is here and the case study we will look at is a product designed for telecom cooling. So, the first case study was something

that I had an opportunity to be a part of in 1995 to 1998 this one is more recent it is in the period of 2008 - 2009.

Some background to this is telecom shelter so, right now technology is changing. So, the air conditioning needs then a telecom shelter are coming down and with 4 G services we do not need to air condition the equipment at the transmission point, but for 2 G services and 3 G services the equipment has to be kept below 30 degree centigrade and that creates the need for some air conditioner or a specific purpose built air conditioner for meeting that need. So, this is very different from comfort. So, comfort we are targeting more in the region of 25 testing at 27 here it is 30 degrees centigrade.

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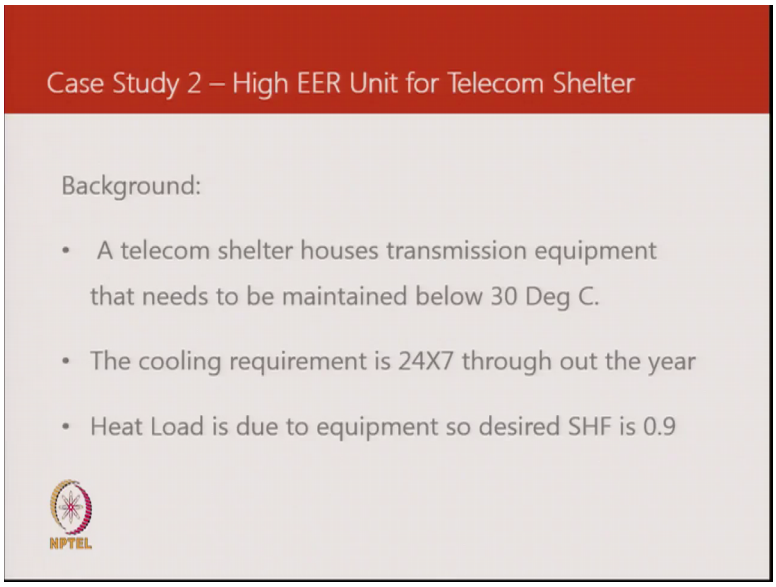

So, and then it is going to be year round operation 24 by 7 throughout the year. So, the energy needs have going to be much more significant and since in India we have power shortages. So, there will be times when this unit will run on or Deg C set. So, the optics will be driven by a combination of cost of power and cost of fuel. So, that is tremendous focus on keeping the energy costs the operational costs low and then the entire heat load is because of I mean it is sensible heat there is no moisture being added in this shelter.

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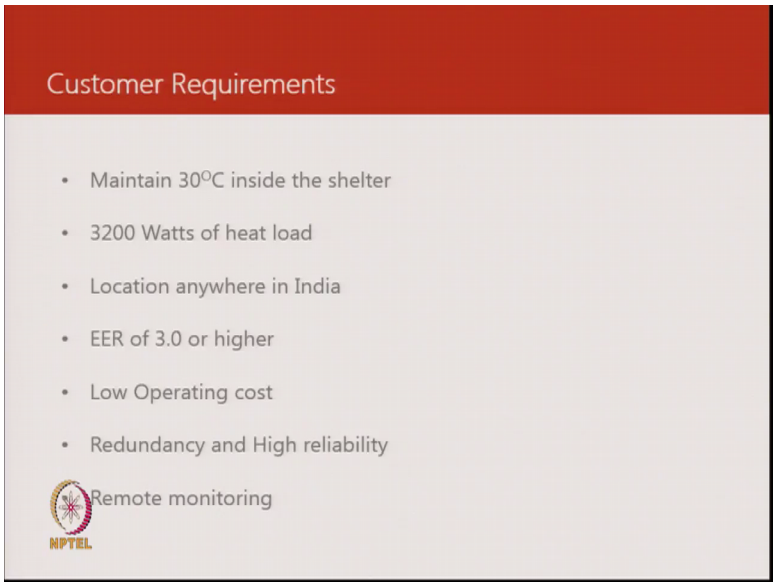

So, if we try and apply this as a you know some way of mapping the customer requirements some things are pretty straightforward where you want to maintain 30 degree centigrade or lower. The heat load comes out as an input because of the equipment that is inside the shelter. So, the customer has no problem sharing this and then the location anywhere in India, which means we can look at the worst operating condition in India and then based on that design the product.

So, just for you to know if we look at the last 30 years temperature data in India we will find that the max temperature ever recorded and this is based on what I reviewed in 2008 the max ever recorded temperatures 50 degrees centigrade by the met department. After that if there have been some instances of it going by a few points above I am not sure that is kind of a number that you can remember.

And then energy efficiency the customer wanted energy efficiency ratio of 3 or more and the other things are kind of derived because of nature of application you gone have a low operating cost and then high reliability. So, the components have to be looked at differently because they going to be in a 24 by 7 application environment and a need for remote monitoring the nature of spread of these units is such that if a service when I need to visit it would be helpful if he knew what was wrong with the unit.

So, if there could be communication to a central point about possible you know guess he could make us to what is wrong with the unit has a compressor fail fan field or is just a

damper issue. Now in this there is a unique feature opportunity because this unit is going to be operating your round, there is an opportunity in the winter months once to use the cooling that is available from ambient air.

So, you gone to maintain 30 and in winters what are the temperatures you will encounter somewhere in the region of 4 to 24 if you look at months of November to February. So, if you are really looking at it as an opportunity then how would you use this for cooling very unconventional and creates an opportunity for integrating a unique feature. So, what can we do, such that the compressor need not run in the winter months.

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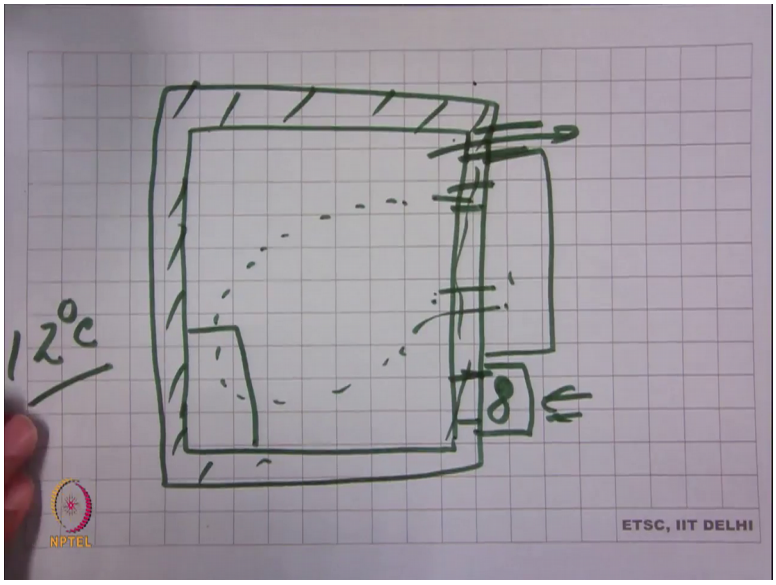

This is an insulated box, this is the insulation and then we have equipment which is generating heat and we have some air conditioners which are cooling. So, we have supply air which is coming here going back to a unit another AC. So, this conventional solution is there and now we are looking at condition where the outdoor temperature is let us say 12 degree centigrade let us take case of Delhi and we want to cool this without using the compressor.

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Right simple and then what do we need to do create an opening.

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So, one simple straightforward thing could be that we create a cutout over here we have a unit which has a fan and then we create another cutout maybe somewhere here. So, when we are taking air from here it is passing over this throwing it out right, now what would it look like if this feature has to be integrated into the AC

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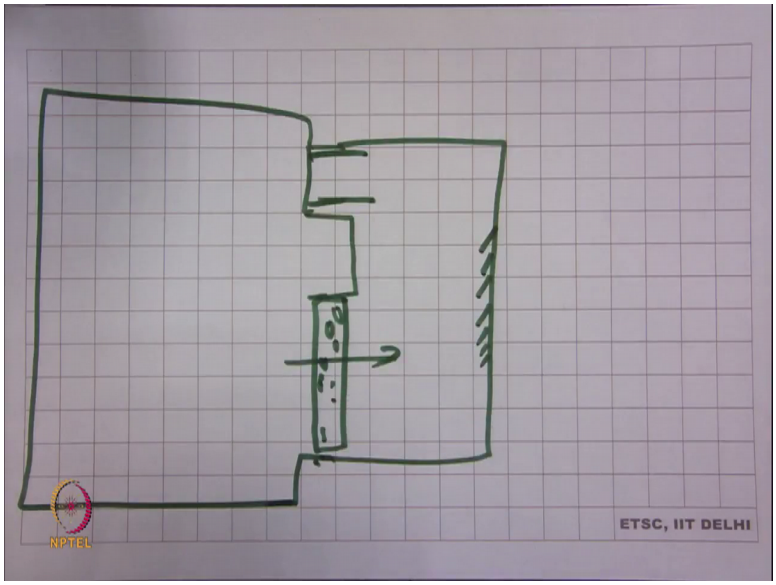

What we said is feasible, but it would require someone manually switching that unit on switching the air conditioner off. So, one of the things we can derive is that if there was a sensor related switch which could switch off and switch on from a technology specter he already provide that and one simple unit so, that air conditioner is unique.

So, the air conditioner we can say is so, this is the evaporator coil and here is a supply air. So, this is normal circulation how could we integrate within the AC some combination of controls, dampers to take outside air when the temperature is sufficiently low. So, the opening that you talked about instead of having it in the shelter we could have it in the AC. So, let us say we create an opening in the AC and then we would need to have a means of blocking this and opening it. So, this is what was created as a feature. So, instead of drawing it all over again I will use this sketch.

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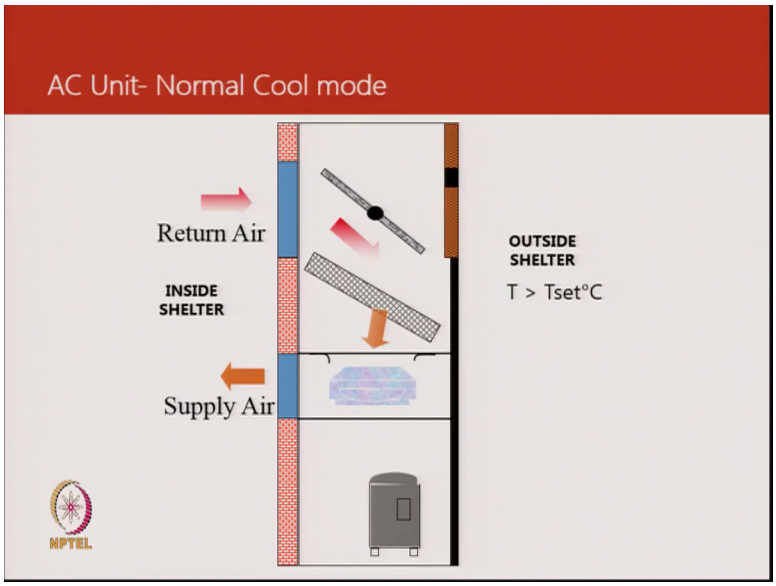

So, in the normal cooling mode return air comes in, this damper in the normal position is actually sealed on this side as well as this side. So, the return air comes over the cooling coil into the blower and soon back into the shelter and this is when the compressor is in operation and the outside temperature is higher than the set point for the free cooling mode.

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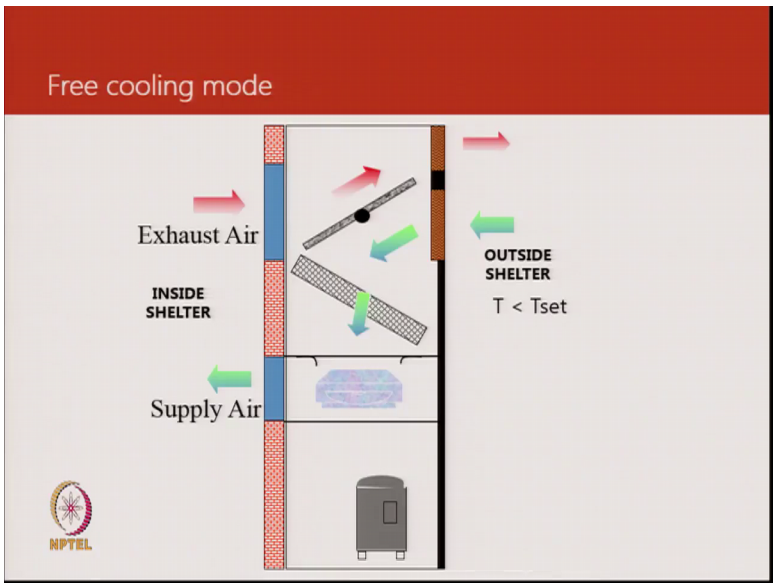

So, in the free cooling mode when the temperature outside the shelter is lower than the set point then what do we have, a damper moves it from it is position and outside air

comes. So, the same blower is used to take air from outside and throw it into the room and the exhaust air goes through another part of the opening into the environment. So, this whole thing gets integrated together and it creates a unique opportunity. Now how big is this opportunity in terms of energy savings.

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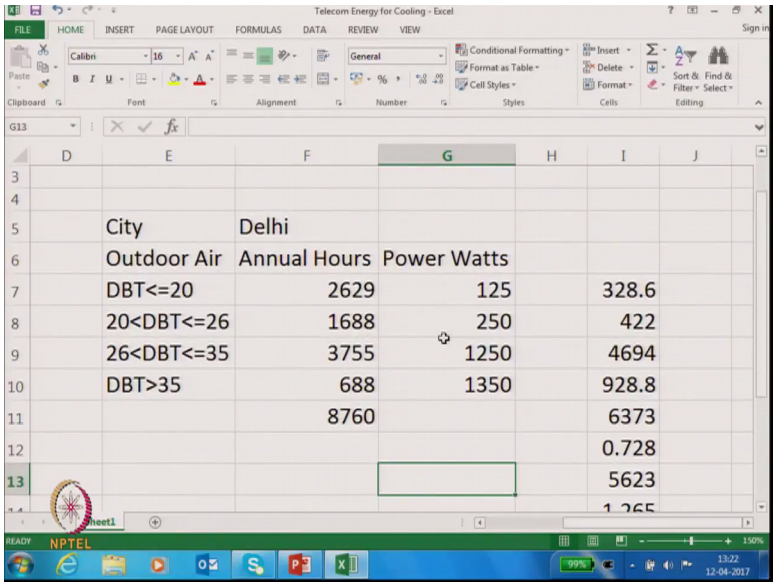

So, if you look at the temperature of Delhi the outdoor air temperature number of hours in a year this is the number of hours in a year when the temperature is below 20 and then this is the number of hours when it is between 20 and 26 and very soon will come to the reason why we have categorized these 2 parts separately and then here is the condition where it is between 26 and 35 clearly the number of hours when the unit will operate with the compressor on and then this is the number of hours when it is greater than 35.

So, when we operate the unit in a free cooling mode for temperatures below 20 the enthalpy of air is low. So, we have much more opportunity for the same quantity of air so, we drop down the CFM of air by just operating one unit. So, this is an example where we are looking at either 2 units so, 2 free cooling units operating or one free cooling unit operating out of a shelter.

And we can come back to this detail a little more after we have seen the design of the unit, but what it translates into is effectively a total average power consumption of 728 watts 0.728 kilowatts versus what it would be is some average of these 2 numbers if we were not using the free cooling mode.

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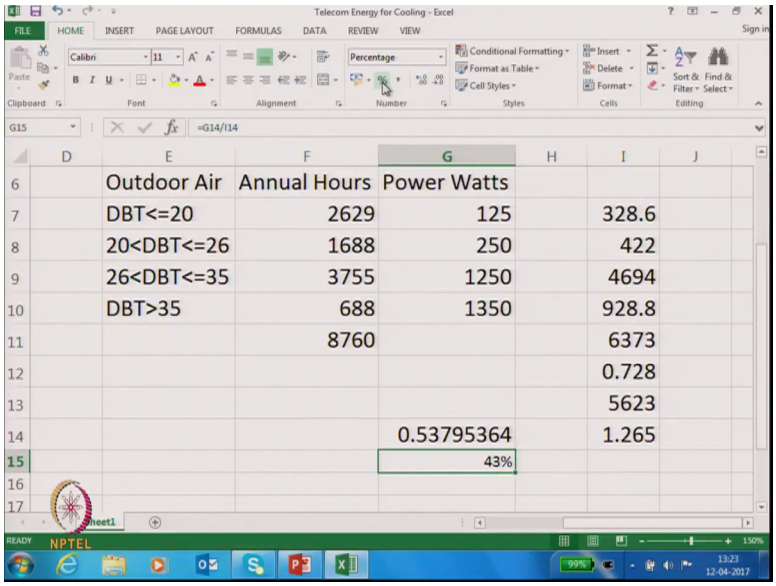

So, this is the number, n is again in kilowatts if we were using just the compressor cooling mode so, the savings that we are generating here. So, 42 percent energy we are saving by integrating this concept and then if you start doing the maths of the number of shelters and all that it becomes a very strong business case.

And that was the reason why a telecom sector was very quick to take these units the specs were formed compute the specs of frame the competition units the benchmark with the each other and orders were placed. And there is one thing which was the roll out of telecom infrastructure and the rollout of these specialized units integrated with free cooling was can wrap it in driven by this particular savings opportunity.

With one of things to remember is that when you do a new product design if you get to something unique as unique as this and you can be sure that if you are among the first to market you have a real opportunity for making good profits if your own companies and for yourself or for the company that you are working for.

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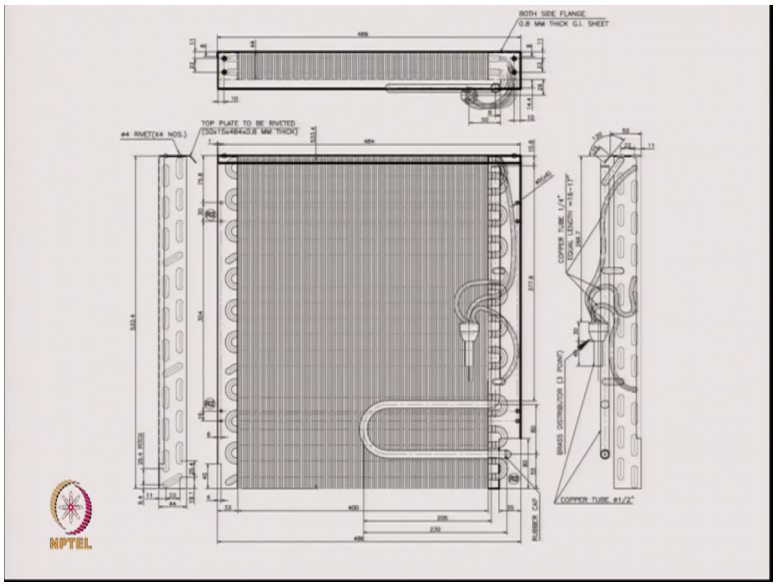

Now, then when we started building this design this is to give you an idea of what kind of components were developed. So, this is the evaporator coil and in the evaporator coil you can now see some of the detailing.

So, this is a distributor here and the function of the distributor if you remember from some earlier discussions is to spread refrigerant equally between different parts of the coil. So, it is a 1 ton or I mean roughly 1 ton unit, but using 3 separate circuits to optimize it for pressure drop and it is a high sensible unit a high sensible heat capacity unit which means the larger surface area again requiring more number of tubes. So, to reduce the pressure drop at least 3 circuits are used they are conventionally even 2 would suffice in a residential unit and then the details of the probably you do not need.

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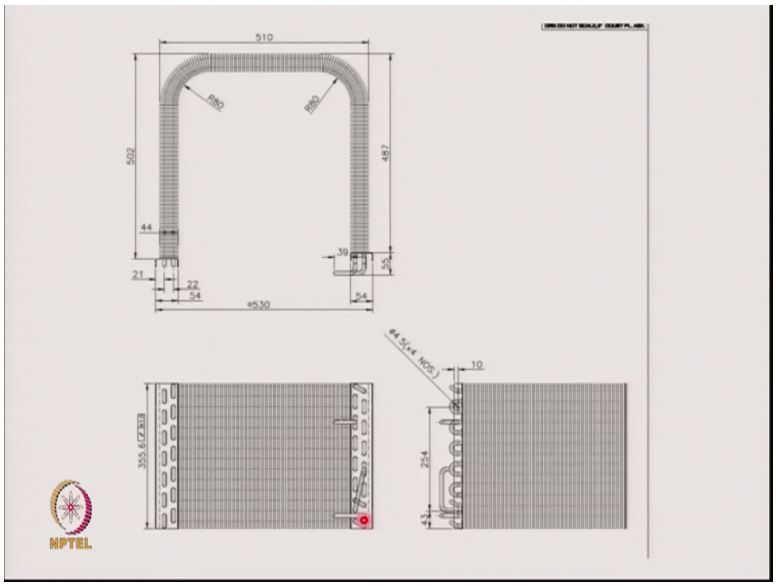

But to get to good performance at high ambient temperatures condenser coil which was bent into a U shape was used and the discharge was kept a vertical. Then there was also a need for looking at a high pressure refrigerant 410 A for some markets and for that there was a new type of a heat exchanger that was considered.

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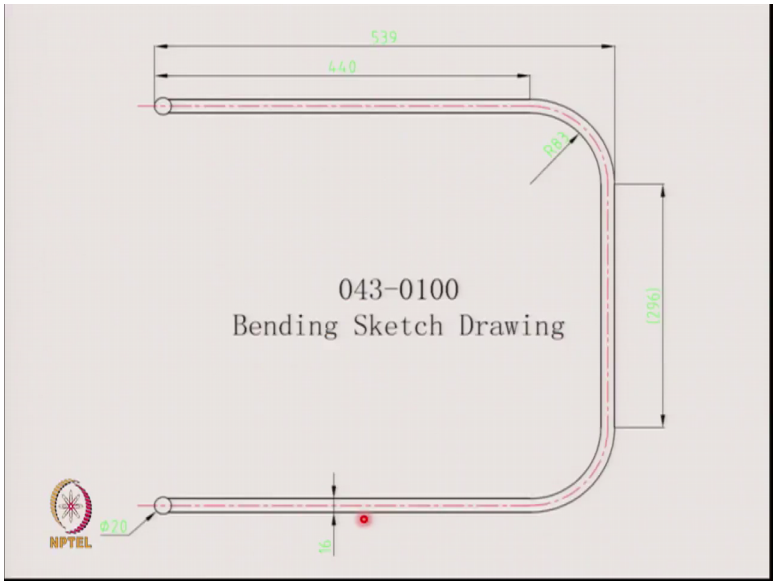

This is a special micro channel heat exchanger with fringe stacked between flat tubes of aluminium it is similar to what you see in car radiators and this is today also being used in the residential sector for lower cost condenser coils.

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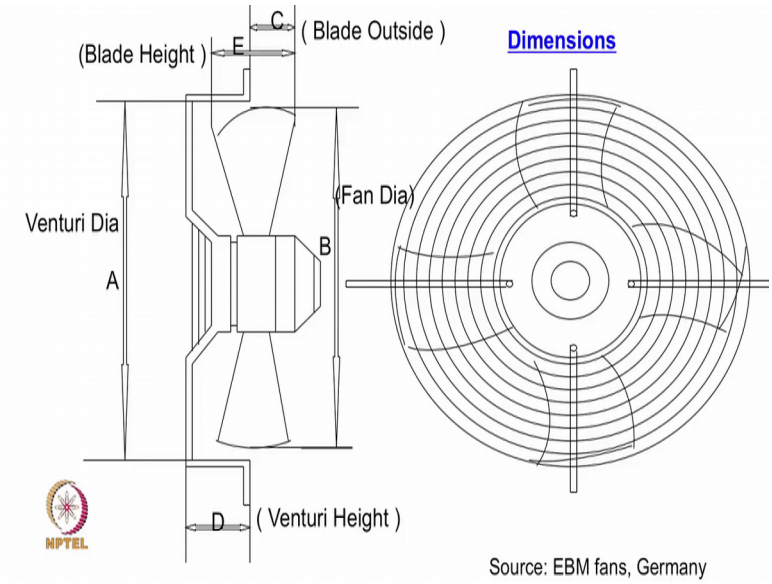

Then here we have the fan. So, for purposes of ensuring high reliability a German fan was utilized for this application such from IBM and again it had to undergo the usual qualification processes for withstanding shower tests. So, that if installed in vertical condition it is not going to have water ingression failure of motors because of that reason.

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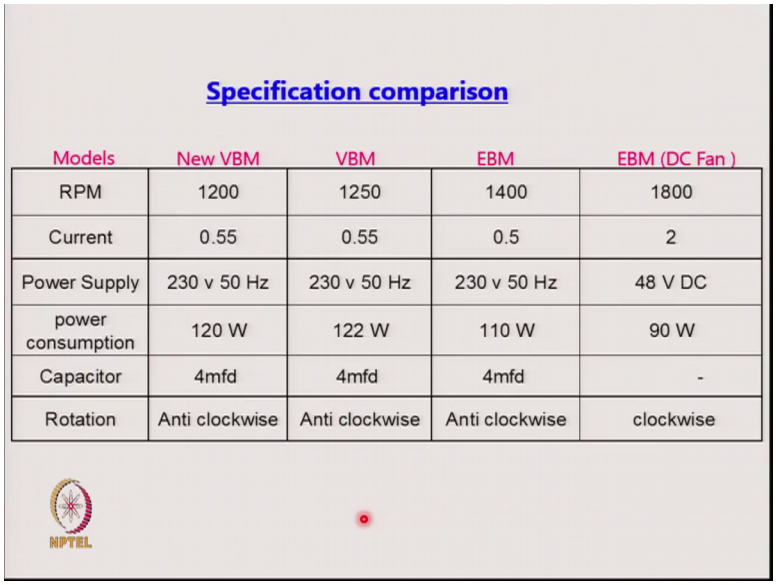

Then to give you a glimpse of the kind of specification comparison that goes in before one invests on a important component of high cost. So, different fans were benchmarked

and before I go forward I must also mention that these telecom shelter unit cooling units need to be performing for short durations on battery. And if there is not enough power available then the blower can be made to operate on 48 volt DC.

So, for that reason by this unique specification for this product that blower would run at 48 volt DC and if there was no power available for short durations the blower itself in the freak willing mode will keep the unit under acceptable temperature conditions it may not stay below 30, but it will still went to the. So, this was a just to illustrate how components are benchmarked and compared so, in addition to performance for cost as well.

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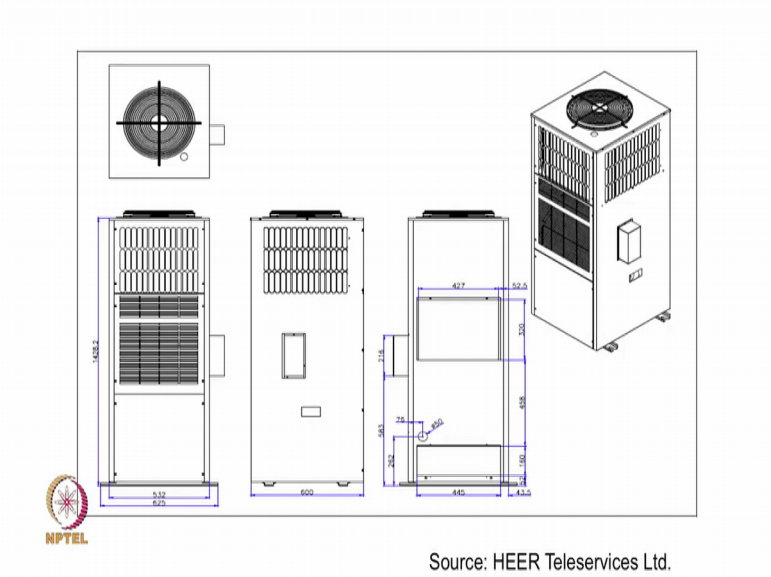

Source: HEER Teleservices Ltd.

And these are the drawings of the final unit you can see the condenser discharging vertically up these are air intake points and this surface is the one which is flush with the shelter. What you see here is a damper so, the damper actuator is outside and this moves the damper from one point to another when we switch from regular cooling to free cooling. Now, there is only this much that I can show you of such productional shape product picture of the real product.

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Source: HEER Teleservices Ltd.

So, this product was called high efficiency energy efficient high energy efficiency unit HEER and it was designed to maintain temperature in telecom shelters, it is all that we already talked about for energy savings ambient temperatures as well as free cooling. So, it was a factory charged unit it did not require any field charging and to that extent was a simple quick and direct installation.

And the emergency cooling that is listed here as a feature is the one I talked about using a DC fan and then there was a controller which would take care of 2 units. So, there is a feature required for onetime equalization you invested on 2 units you might as well get the max out of the units where rotating the duties. So, the second unit is on standby in case one unit fails, the other one will come in operation and in this controller would communicate to the central point for a service the need for maintenance.

Then the features of high pressure low pressure were both built in and they will display to indicate the temperature as well as set point and this also had the high end low voltage protection features and status a lead indicating if there is any fault in the unit. So, between the time this unit was designed and a year 20000 units were installed.

So, it is rapid commercialization once the product matrix desired objective and there was competition so this product was tested you know third party lab where inter tech in a balanced ambient calorimeter there is a second type of test method where in a room you maintain a certain temperature and then the entire heat added in that room is measured.

So, you do not rely on the air enthalpy method for getting the capacity you look at the real heat and moisture addition that is happening the room on both sides.

So, we qualified this product and it was the best of all that was benchmarked based on the customer report and nothing no saying whatever was measured because the lab was independent the customer had his own orders for testing the product and it of course, generated tremendous confidence on the company to supply.

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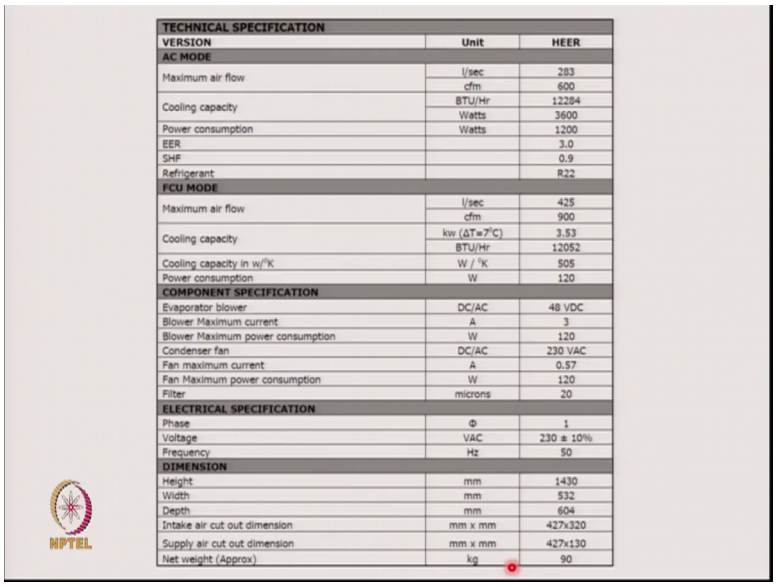

These are some details about the product in terms of how much of airflow; primarily it had 600 CFM of air in the AC mode and 900 CFM of air in the free cooling mode. And that would lead to a certain cooling capacity in the free cooling mode which is 3.53 kilowatt or you could also look at free cooling as a watt per degree Kelvin which is listed 505. So, based on the enthalpy difference or just the dry bulb you can easily calculate the cooling capacity of the unit using fresher.

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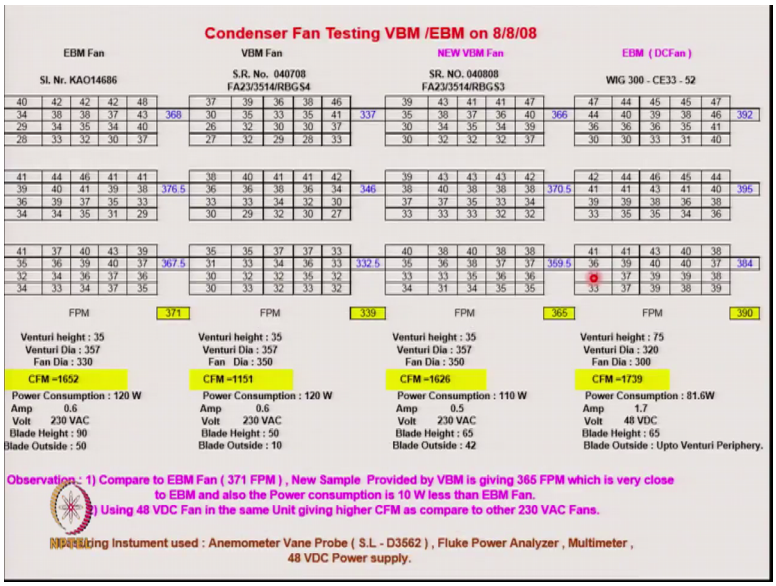

And this is just showing again in the product how the 2 fans performed a locally manufactured equivalent of a German fan and for reasons of reliability of course, the design continued to make use of imported fan.

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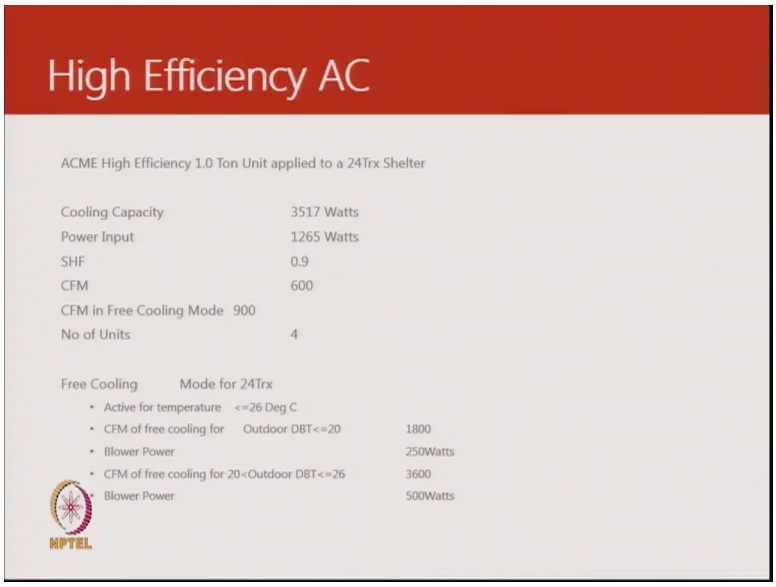

This is a way to look at an application from a unit spec point of view as I was talking to you I will look at some payback calculations using the number of units. So, here we look at in the cooling capacity 3517 watts with 1265 watts of power consumption a sensible heat factor of 0.9 and the CFM in the free cooling mode is 900.

So, for an application which makes use of 4 units of such type, one can look at some energy analysis.

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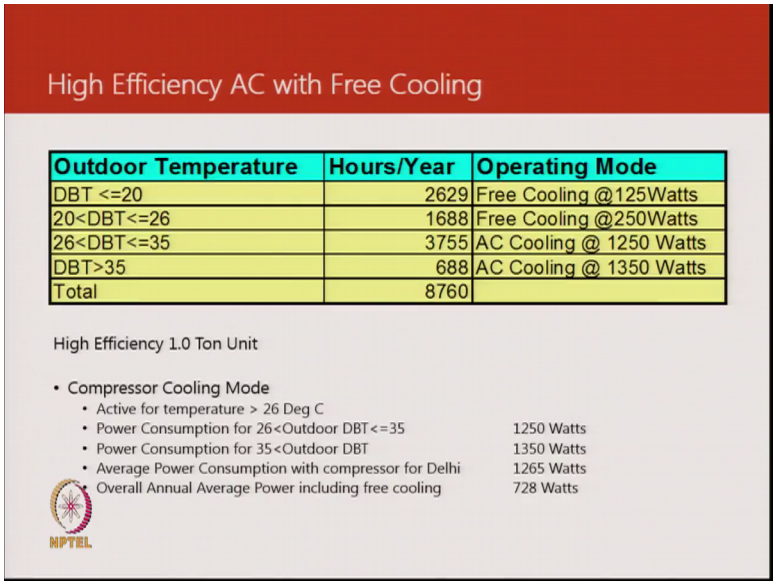

And this is essentially derived from the same sheet that I just shared with you. So, the compressor cooling is eliminated and leads to something in the region of 40 percent energy savings.

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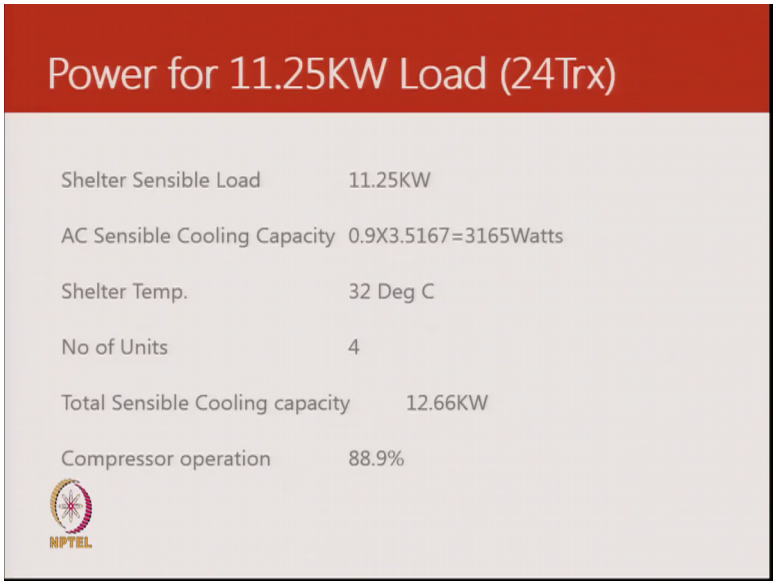

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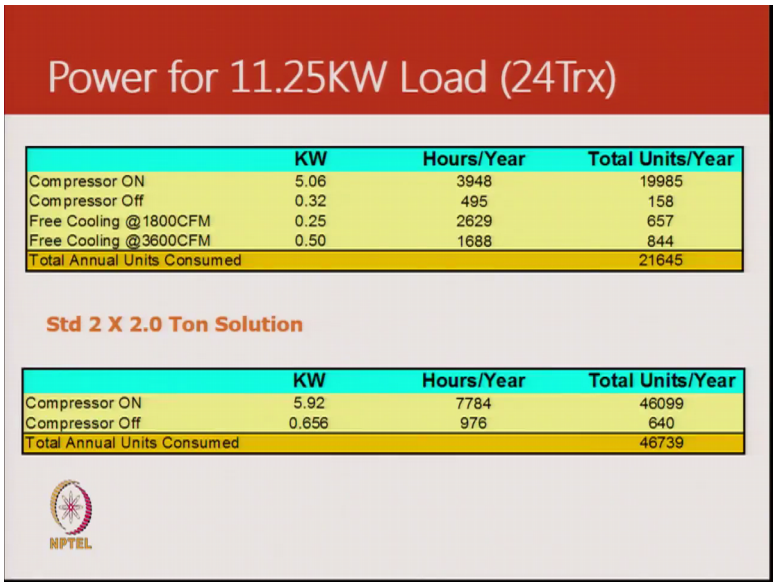

And, if you apply it on different shelters then we can look at the annual savings opportunity you know your versus different alternative scenarios.

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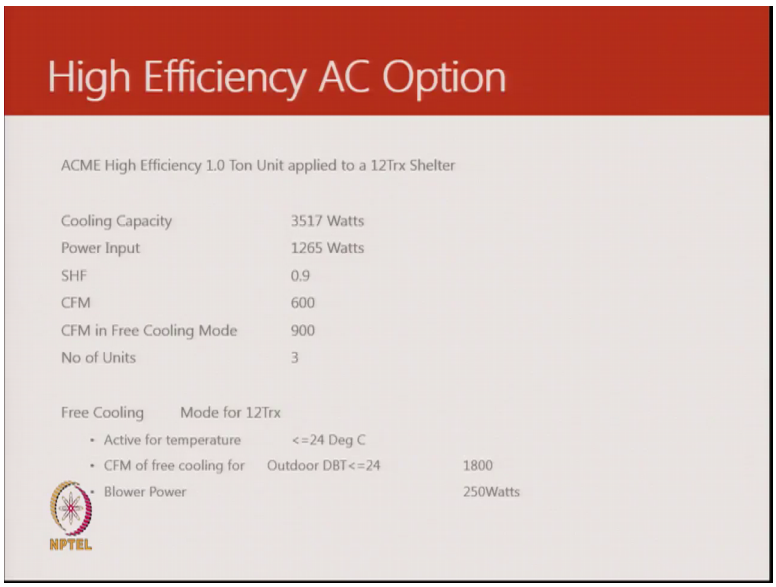

So, with this the case study is more or less complete in the business case the design and the comparison for components. Now we look at some of the emerging technologies that are coming up. So, and one of the newer technologies is an oil free compressor which is used for chillers so, you going to look at that.

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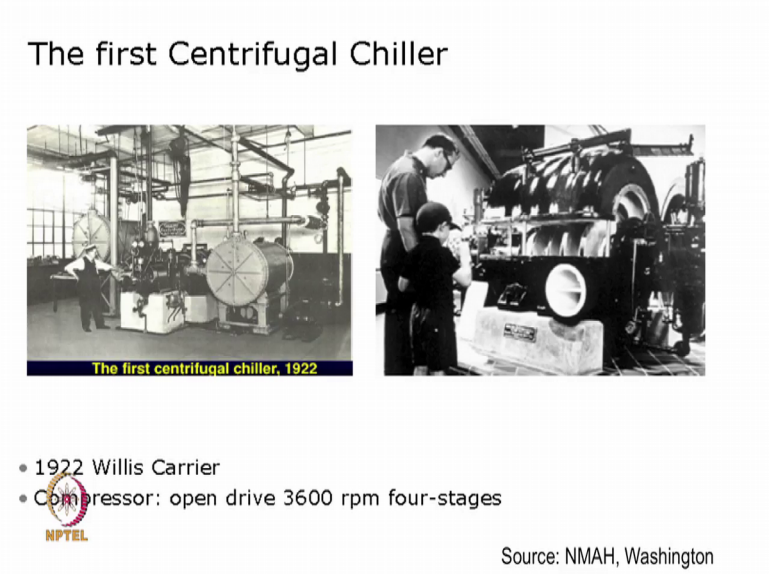

So, before we go there let us start looking at the history of chillers. So, the first Centrifugal Chiller was introduced in 1922 by Willis Carrier, there was an open drive compressor running at 3600 RPM and had 4 stages.

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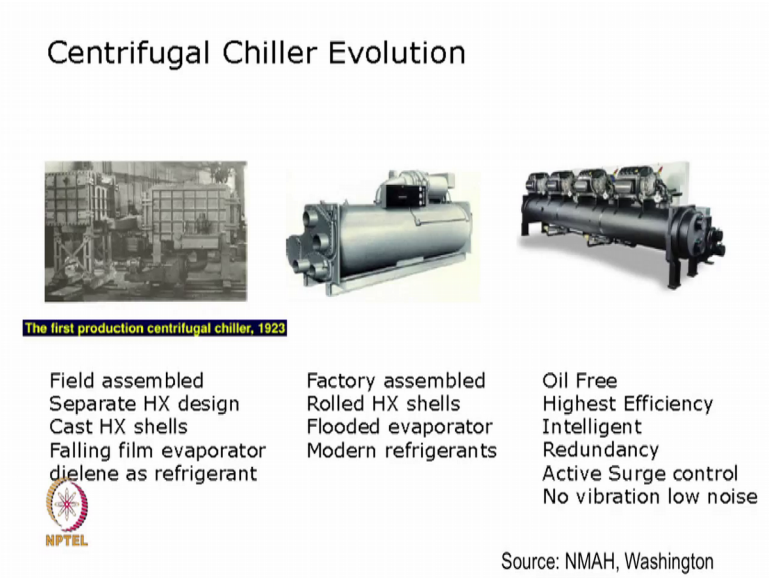

From then there has been evolution and technology. So, from field assemble units so, it is moved to factory assembled units and instead of building it site using cast heat exchangers shells, now we are looking at rolled heat exchanger shells flooded evaporator and newer refrigerants. And the latest is oil free high efficiency compressor system

where there is redundancy and active search control which means capacity control and low vibration and noise.

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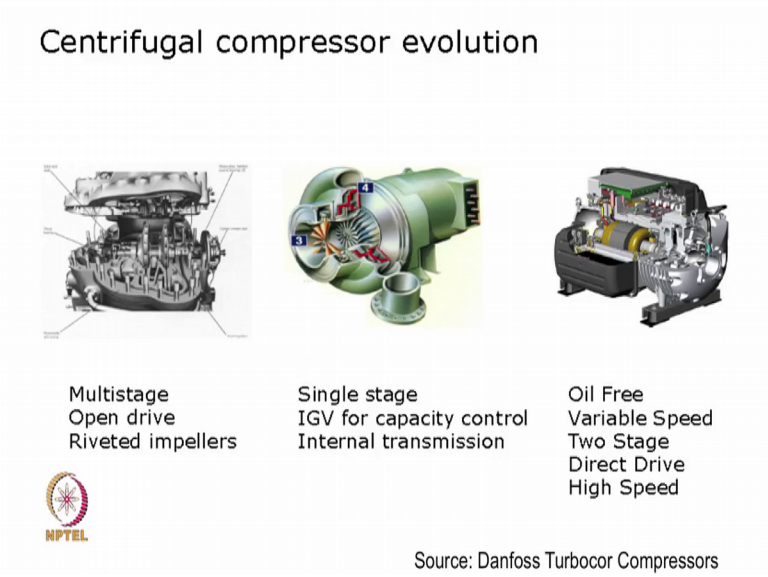

So, here the one on the right is the newer technology. So, the company I worked for Danfoss had has a separate division called Danfoss Turbocor and that is the company to first introduce a oil free barring, where the compressor rotating shaft is magnetically levitated and there is complex electronics to keep it in a fixed distance from the metal surfaces using magnetic forces.

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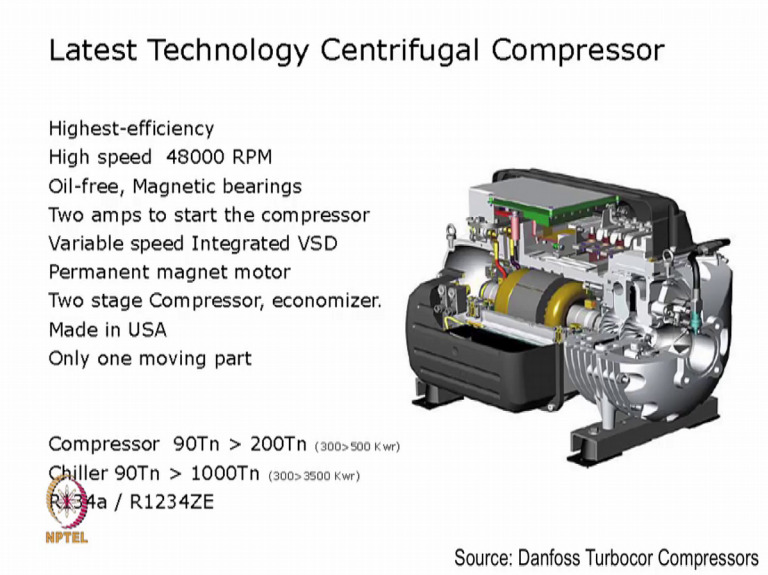

So, what are you going to see here next is so, we looking at about 3600 RPM when it was introduced in 1922 and now we looking at 48000 RPM. So, one can ask this question as to why do we need to go oil free. So, if we looked at some of the reliability concerns earlier it was around oil coming back to the compressor or oil being there in the compressor and that was to address a longer life if we eliminate the need for lubrication we have created a unique opportunity where refrigerant flows without any obstruction, without any real compatibility issues with any oil.

We talked about oils leading to short exposure times or compressors because they are hygroscopic that is eliminated, there would be pressure drops because of oil in the system pipelining that would be eliminated. So, the oil free magnetic bearings are one of the unique things in emerging technologies and the this is finding increasing acceptance and also more companies are trying to find ways to beat any patents that one company has by doing some work around on the technology.

The capacities that are available 90 tons to 200 tons for the compressor, but the chillers can go right up to 1000 tons using multiple compressors and right now, this product is manufactured in the US only.

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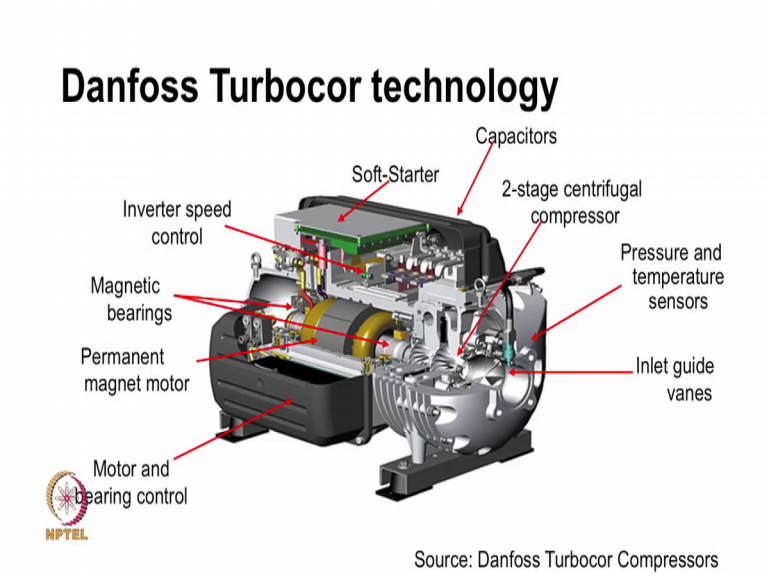

If you look at some of the components this compressor has an inbuilt variable speed control what is written here as inverter speed control. It has a soft start so, big compressor 90 ton compressor just has 2 amperes of start current. A typical residential

compressor may have 40 to 60 amperes of locked rotor current. That is the kind of technology evolution that was happens when it is a 2 stage centrifugal compressor with lot of instrumentation.

So, there are pressure and temperature sensors to monitor this then inlet guide vanes for modulating the capacity and then there is a motor and bearing control region along with the permanent magnet motor and the magnetic bearings. So, let us look at it a little more in detail as to what this whole technology is around.

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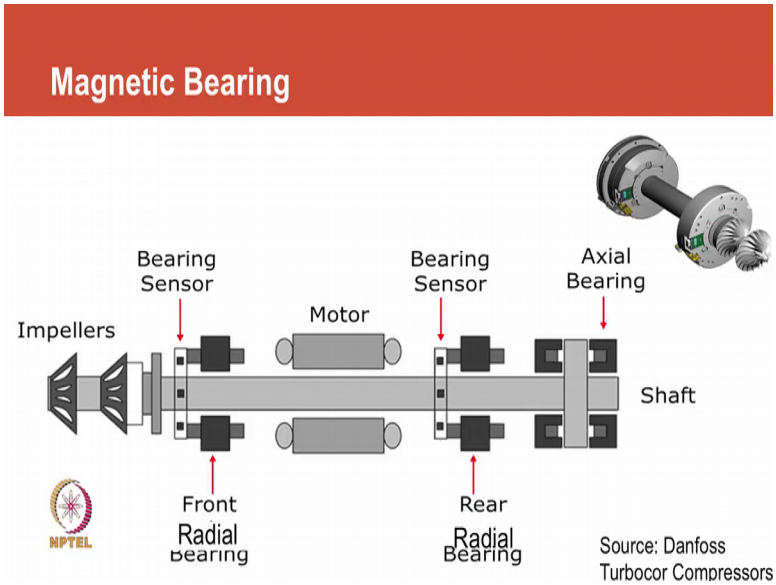

So, here we have the 2 impellers which lead to 2 stages of the compression process and there is one bearing sensor together whether radial bearing you just ignore this radius bearing. It is a radial bearing so, the front radial bearing and the other rear radial bearing and then there is one axial bearing. So, if the whole technology is to pick up the location of the shaft and adjust the magnetic forces.

To centralize it and doing this continuously at a very high rapid speed is what makes this technology feasible. You know like you know you hold this pen and then if you can control the forces. So, you do not let it drop you do not let it touch the top side and do not move it actually if you have done that successfully using magnetic forces then you have an oil free compressor. This is the only moving part in this compressor.

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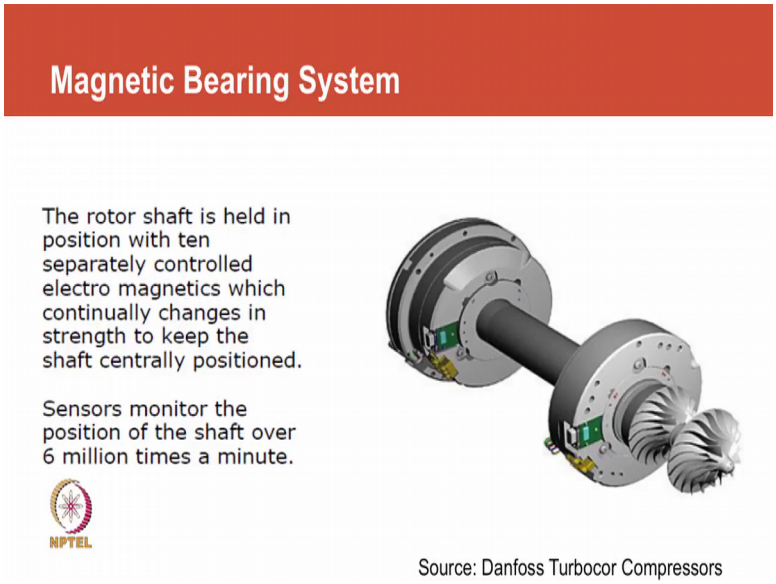

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Well the people who developed this technology who have found it successful with the high speeds and one of the reasons they have used high speeds is to reduce the cost, overall size and cost of the compressor. See when we run a normal motor the governing factor is the frequency that is available. So, you would have 50 hertz in India 60 hertz in the US and more or less that so, multiples of that would determine the rotating speed.

The moments you have converted electrical power into DC and you using magnetic forces then you have an opportunity to run it whatever speeds you want to. So, you can alter the frequencies and if you are doing an r and d program you would like to create a unique value where others cannot quickly catch up with. So, with high speeds and smaller sizes you can make the overall chiller footprint smaller so, that becomes one of the (Refer Time: 30:29)

So, the rotor shaft is held in position with 10 separately controlled electro magnetics which continually change in strength to keep the shaft centrally positioned axially and radially and senses monitor the position over 6 million times a minute. So, look at the level of processing power that would be needed to make this work.

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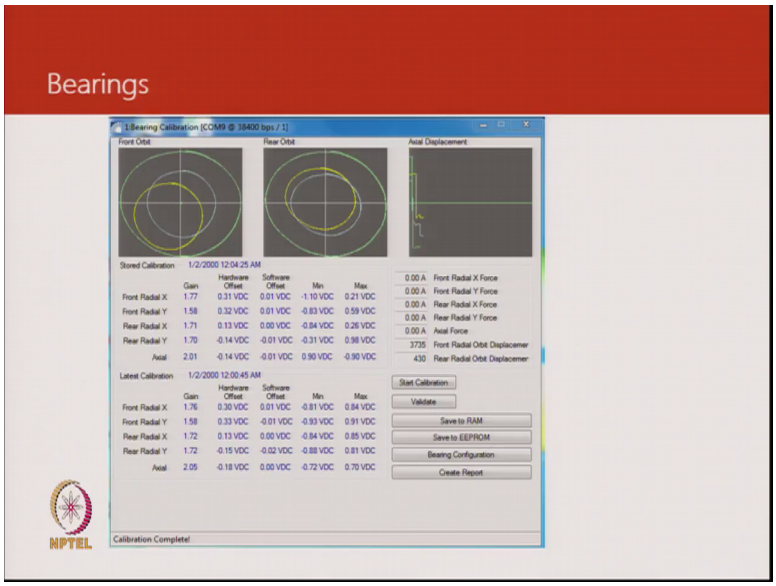

To illustrate whatever saying about centralizing the shaft inside the bearing so, these are some of the details of how the radial axial part is actually the 2 radial bearings and then the 1 axial bearing.

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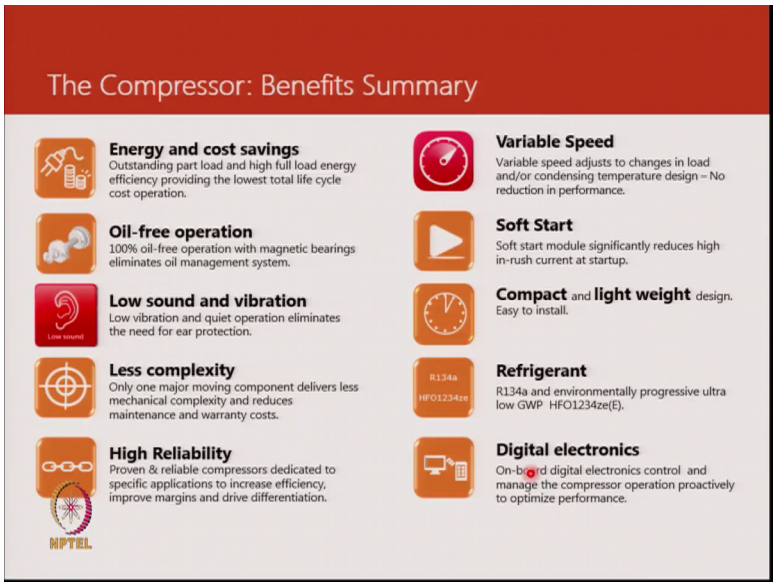

So, if you look at the summary of benefits of this type of a compressor.

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So, when a product is designed using let us say this compressor then the contamination levels that are acceptable in the system would be more demanded they would be more demanding for sure. But in any case in a refrigeration system and there is a lot of requirement for cleanliness even without magnetic bearings because any, let us say there is a metal forming process, you cutting the tube even the current level of specs without using a magnetic cool elaborated compressor require that they are kept within a certain specified limit not for reasons of magnetic, but because they can come between moving parts of the compressor and cause (Refer Time: 32:39)

So, the whole efficiency of a compressor water is driven by how much of a gap you have between the stator and rotor. So, that has already been limiting the level of contamination that is acceptable and a lot of contamination gets generated in the compressor when there is no metal to metal contact then you are actually in this design creating an opportunity of not having this contamination come up. So, because of this higher level of calibration you needed to run the shaft centrally you will have low noise and vibration.

The single rotating component makes the manufacturing less complex and the reliability is higher because of fewer components is very simple, variable speed becomes possible because of the investment made in an inverter. So, capacity regulation is the key benefit soft start I talked to you about low current 2 amperes and then it makes use of an environment friendly refrigerant R 134a which is non ozone depleting, but it has a global warming potential and then we have a new refrigerant HFO1234ze and that is a new refrigerant with a very low global warming potential as well as 0 ODP and of course, the benefits of digital electronics.

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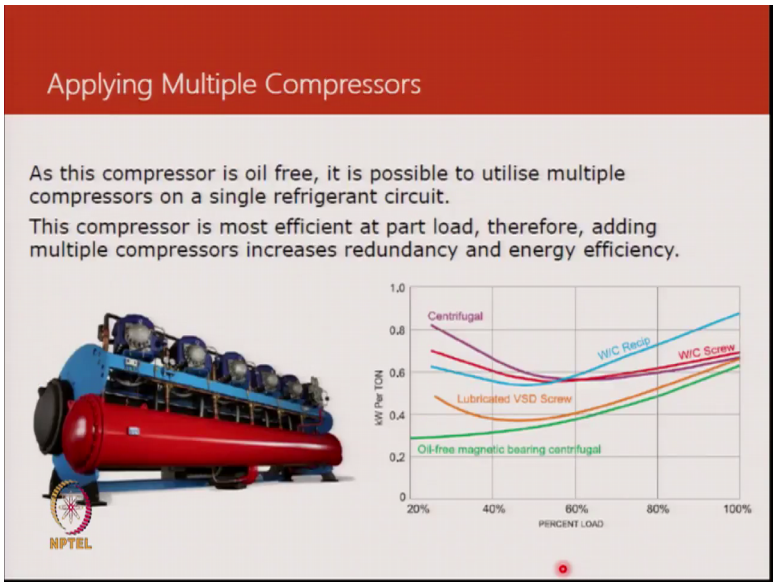

Then because of it is being oil free it is possible to run it slower when conventional compressors which rely on oil for lubrication below a certain speed oil will not return back to the compressor when you need a certain pressure drop pressure buildup for lubricating oil to flow. So, all those things are eliminated and then you can use multiple compressors together, allowing a lower part load operation.

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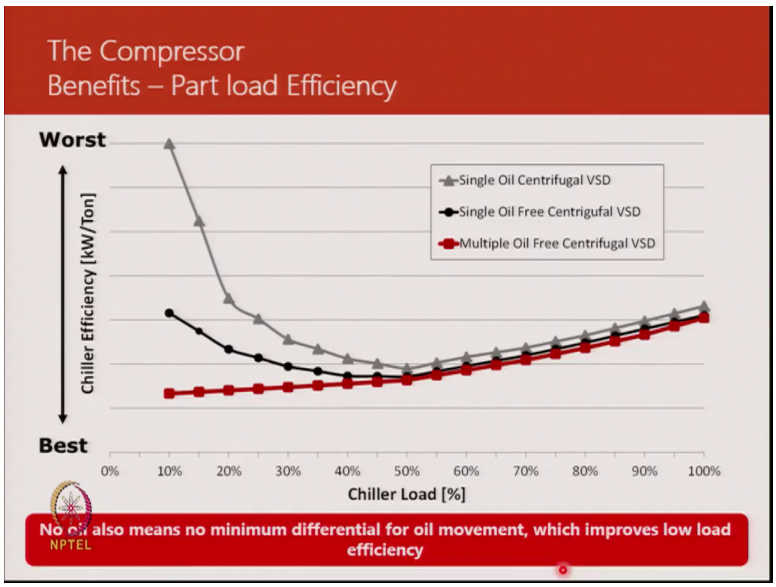

This is a comparison between a single centrifugal variable speed compressor which is the first one.

And then a single oil free centrifugal variable speed compressor and multiple oil free centrifugal variable speed compressors. So, as you can see the multiple oil free centrifugal variable speed compressors all offer the highest part load efficiencies.

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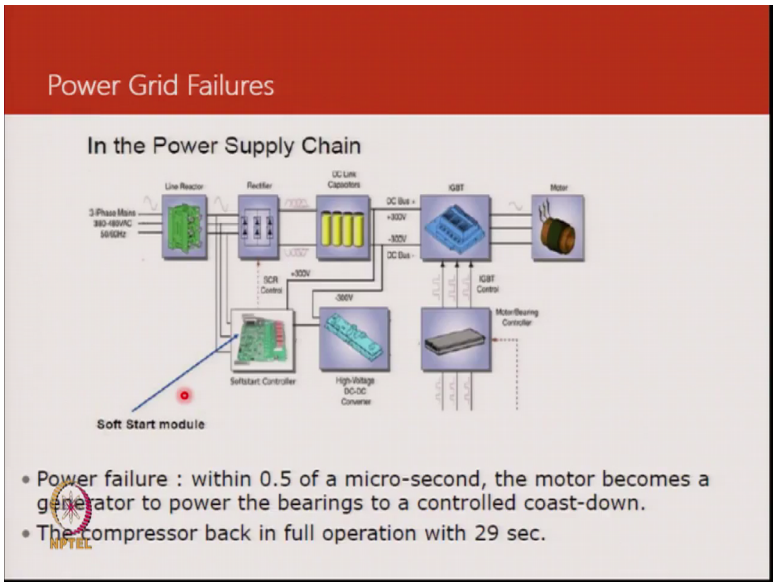

Then we can look at some robustness issues so, we looked at failures that happen because of power delay things. So, what happens to this compressor? It has been made so, sensitive, it is dependent on electronics and suddenly you have no power what is going to happen.

So, that is been built into the design so, within half of a microsecond this compressor would begin to generate power. So, it switch from being a power consumer to generating power and that power is used to slow it down so that it gradually comes to rest, it done bang on the thing in the absence of and then when power resumes it is back in operation in 29 seconds.

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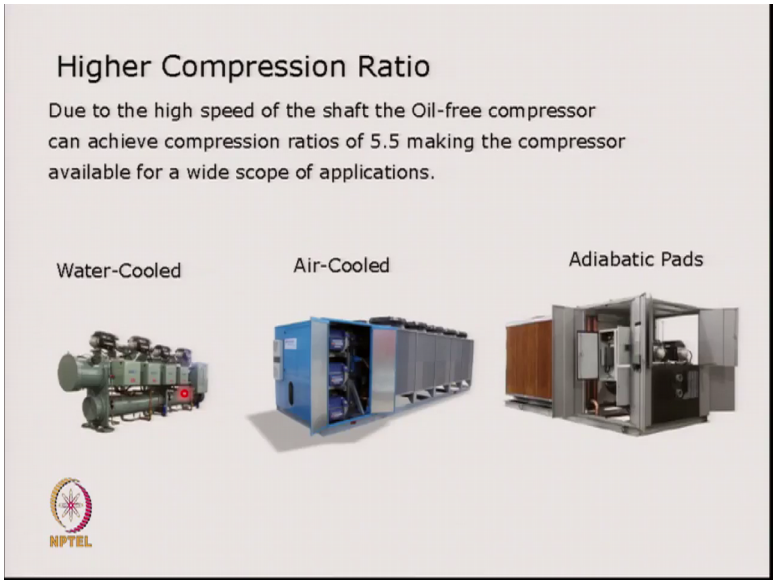

Now, this high speed of shaft of oil free compressor can achieve compression ratios of 5 and a half making the compressor suitable for a wider set of applications, wider meanings can be used for a cold in addition to water cooled and there is an increasing trend of using adiabatic pads with some condenser coils. So, I do not know too much of detail about that, but it is one option.

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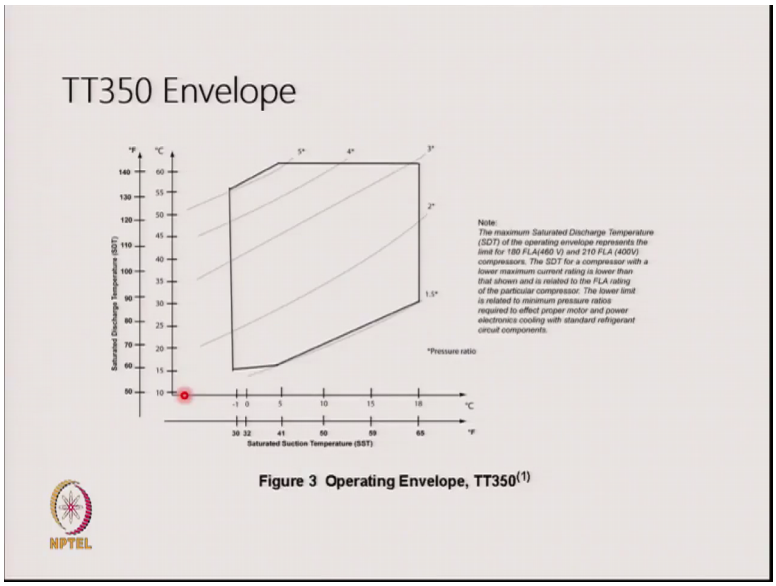

This is a little bit on the operating envelope of this compressor. So, there are different models and TT350 is one of them, but this I would like to close the lecture and also it is the final session. So, I open up.

Thank you