RAC Product Design
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Lecture - 11
Selection of air conditioning systems for hostels

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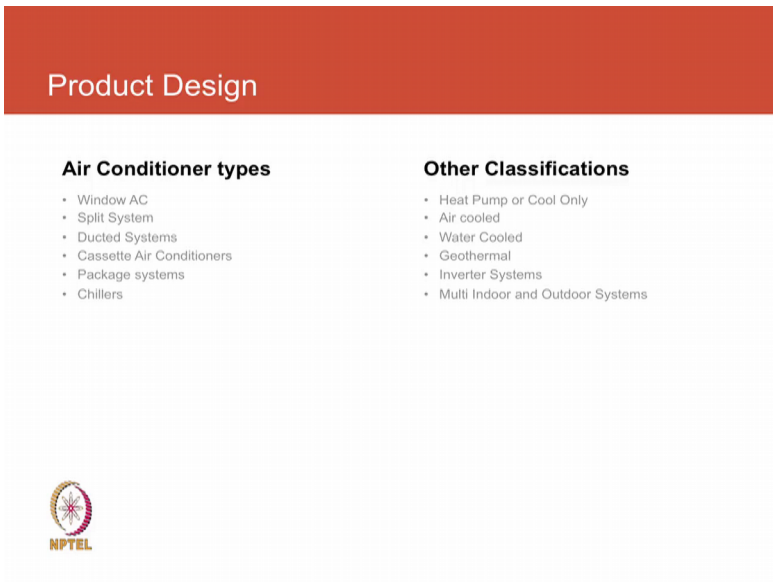

So, we began by looking at 2 different air conditioner types, so I will readied out for you. So, air conditioner types are window we just looked at it using a picture. A split system we saw one outdoor unit and we have all seen indoor units which are hung on high walls. Split systems also include ducted system and they also include cassettes.

And then package systems; so package systems are complete units which have the compressor, evaporator, condenser all the controls housed in one single body. There could be rooftop units, they could be units used for telecom applications, they could be units used for computer room cooling everything else together, and that is why we call it a package and then we have chillers. So, chillers are used for large comfort and process cooling applications. Then we have some other classifications. So, these days if you just have a normal air conditioner it is of no use, but if you had purchased a heat pump you will find that it lowers your electrical power consumption, because the heat pump principle allows for heat to be pumped from the environment into your comfort zone.

So, most of the air conditioning needs in the in Europe and in the U S were around heating and that is how their air conditioners have evolved for heat pumps more than air conditional that we use here. Then we can also classify based on how we reject heat to the environment. So, we could reject heat directly using an air to refrigerant heat transfer surface like, a condenser coil that we saw fan on tube or we could reject heat from the refrigerant to water. And in that water could be cooled using a cooling tower.

So, both have their positives and limitations. Limitations with using cooling towers is the space that we need and addition to the space the fact that we need some water to be replenished. The water that we are losing to the environment for causing the evaporation that is driving the cooling process. When there are also solutions where we reject heat to the Earth; so, it is also a way of rejecting heat to the environment you could take groundwater pump it through the condenser and throw it back to the ground.

Then we have classifications based on whether it is a fixed speed type which means the compressor shuts on and off. Or it is inverter type, where the motor speed is continuously varying. In the latest in air conditioner types is a multi-indoor multi outdoor option. So, where several compressors come together in outdoor units and then multiple outdoor units can be connected in common refrigerant pipes. And then those pipes connect to several indoors. So, prior to this system coming into place it was common to use chillers and have several terminal units.

So, you would have air handling units, you would have fan coil units. Where there is heat exchange between the comfort zone air and the medium which is water. The drawback in that was your so let us look at it with some numbers. So, if you look at it using some numbers we make some assumptions again and let us make an assumption that we are looking at a comfort application. So, comfort application means we are targeting in a d x evaporator or temperature between 7 and 9 degree centigrade. And again for making it simpler to understand let us look at 7 degree centigrade. So, if you look at 7 degree centigrade as the evaporating temperature.

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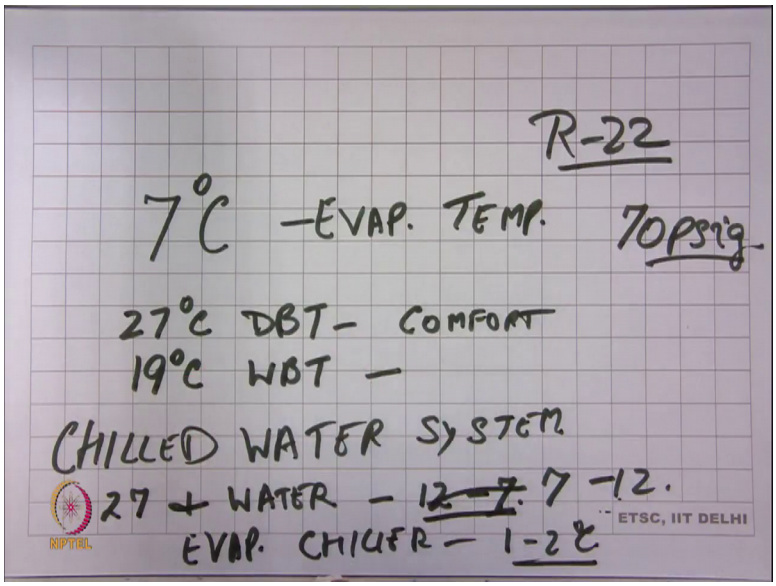

And if we are looking at a test condition which is 27-degree centigrade dry bulb temperature for comfort. So, today if you look at testing an air conditioner for rating purposes we will use 27 degree centigrade. And we also need to specify humidity which we do indirectly by specifying the wet bulb temperature. So, these 2 together define the cooling space, and if we were to look at direct expansion system then the refrigerant goes to the compressor. So, if you are looking at R 22 corresponding to this you would have a pressure somewhere like 70 P si gauge approx and that is it. So, the compressor is pumping refrigerant from 70 P si to whatever is needed to reject heat in the condenser. Whereas, if you look at a chilled water system, we have 2 levels of heat transfer. The first one is we going to reject heat to water.

So, there is a delta t which is between air 27 and water so the typical chilled water temperatures would be 12 and 7. So, entering water is 12 and 7 and we look at 2 different temperatures in a chilled water system because we not having a 2 phase flow there. So, we not having something like evaporation happening. So, we look at a temperature which is 12 to 7 or let us say inter that 7 leaves that 12, this water again needs to be cooled using a compressor.

So, we will have one more heat transfer which will lower the evaporating temperature in the chiller to somewhere close to one degrees if you are designing it very efficiently right. So, what does it lead to the evaporating temperature in the chiller, if it is 1 to 2

degree centigrade means; we have a penalty from 7 to 25-degree penalty. And that penalty would lead to more energy being required for the same application. The convenience that drives the chiller uses when we have large applications and multiple indoors and what is used.

So, the newer systems overcome this difference; instead of having several indoor units transfer heat to water and then water in another heat exchanger to refrigerant, they use multiple indoors directly transferring heat to the refrigerant. So, the 5-degree difference is not there, and we probably will include this as something that you will evaluate. How much is the penalty associated with a 5 degree drop in evaporating temperature. To give you a clue if you look at a performance curve of a compressor then the power consumption is most sensitive to the suction pressure and therefore, the saturation temperature corresponding to that.

The sensitivity analysis best happens when you look at a compressor performance curve, we look at one temperature and another temperature another temperature and you can see for yourself how much.

So, this opportunity drives the development of newer systems. So, conceptually if you look at why V R V or V R F systems are becoming popular today, it is because they address this part, so far it was difficult to look at long pipe lines. So, if you look at one-kilometer-long pipe you normally would stay away from a split system because you would be concerned about leakages, maintenance and pressure drops and a whole lot of things. So, what technology there is been evolution by which it is possible to have systems which can address such long pipe lines and multiple levels. So you have multi stored apartment complex and you could have units installed at different places connected to the same refrigerant pipe. Also important is to be aware of the risks with such a system.

Since everything is on one pipeline which is interconnected. A leak at 1 place will lead to the whole system come down. The opportunities are far too many, not all rooms that are serviced by this one system will be occupied at the same time and will operate at their full load. The demand diversity is going to be so high that you will mostly operate at part load. And the part load efficiency is further utilized by the control systems to make use

of the entire air to refrigerant heat transfer surface available in the condensing units. And also an opportunity to switch off as needed the multiple outdoor units.

So, it allows for a big benefit in terms of annual energy savings and that is what is; something that we need to keep in mind. Now finally, this is a design course right so if you are going to look at components and you are going to look at product design then how do we begin. So, if someone asked you to design an air conditioner what would come to your mind; how would you translate the need into a requirement document?

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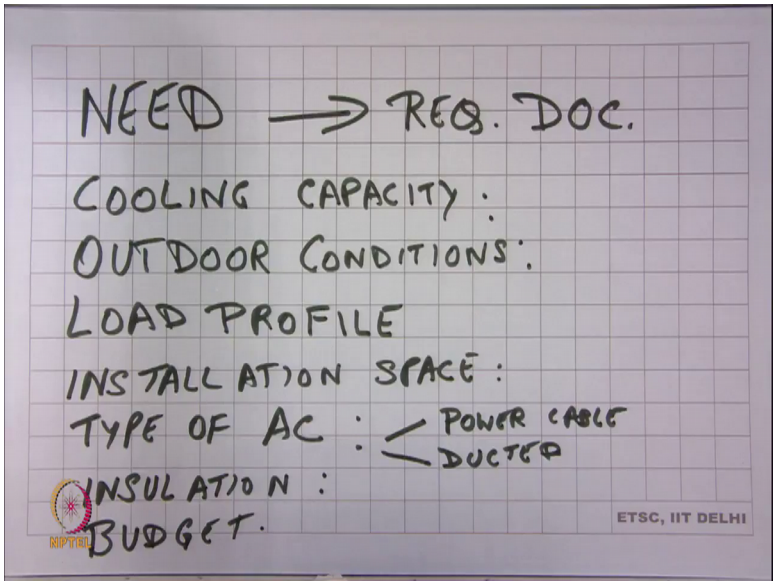

So, this is where you are thinking had to need to now come up, and let us look at this particular example which is alive for many of you. It will not happen before you graduate hostels being air conditioned right. So, if you were to start putting together a document which captures all that is needed, what would come to your mind; how would you go about specifying the air conditioner needed in different hostels? So, I want some participation here.

Student: (Refer Time: 10:35).

Right so, we can say cooling capacity, what else.

Student: Outdoor conditions.

What about the rest? I want everyone to think.

Student: operating (Refer Time: 11:10) what is the load required (Refer Time: 11:12).

So, load profile.

Student: (Refer Time: 11:30).

Would be included in the profile right, load profile would mean that in the afternoon so many rooms will be occupied and it would translate into a load so.

Student: (Refer Time: 11:42).

Right.

Student: Space.

The space that is to be air conditioned.

Student: (Refer Time: 11:48).

Very good, very good so, installation space, that is what you mean right? And good you use the word space because then area and height available everything becomes included there.

Student: (Refer Time: 12:14).

Would it be like a need or would you want to put a limit because you are worried about costs.

Student: (Refer Time: 12:20) slightly limited because if the (Refer Time: 12:27) not be able to (Refer Time: 12:32).

Right, so we can yeah fine the concern is very violent whenever we make this solution we will need, but from a it may not come more as a need it may come out of the complexity of variables that we will manage when we are making the system operational. Like there is an installation related infrastructure that needs to be worked out, but we can put it in a different way whether to have a single system or multiple systems so, that we can plan an infrastructure. So, that way we can include what is your said right.

Student: (Refer Time: 13:14) ducting (Refer Time: 13:18) ducting for the.

So, when again include this here so this will have an impact on power cable. Is it also have an impact on ducting needed or not. So, let us say if we go for a multiple indoor unit d x type units then we need to look at piping. So, we need to make provision for piping if you are looking at air handling units then what you said is correct we need to put ducting.

Student: Insulin.

Yeah. So, when you say insulation you mean whether or not we will add insulation to the walls, to be able to reduce the load right, right you missing one important thing here.

Student: (Refer Time: 14:06).

Ok, but now that is over I had mind, I would say that you would have a budget. So, we can put that as also something so what is the most important thing that I am missing here.

Student: (Refer Time: 14:17) indoor condition (Refer Time: 14:19).

Right.

Student: Comport condition.

That should have been the first thing right.

Student: yeah.

Where will you be, what temperature and would you define only temperature or you want to say something else?

Student: humidity.

What else? So, I will help you here. So, in addition to temperature in humidity you may want to define a certain ventilation air quantity, because it is going to be if it is going to be a single unit then you would want or defined air circulation, so that we get rid of CO 2 and any VOCs and whatever else is there. So, let us try and put together some numbers here.

So, 25 degrees centigrade and 50 percent R H would most of you agree than that will give us a comfortable environment. And then we can refer to some of the known materials available like an ASHRAE handbook to look at how much fresh air per person, yes no.

Student: Yes.

How much? 12 CMF per person is something we can say, and then one of you need through volunteer take some time to look at the ASHRAE handbook, and say see what is the latest recommendation on fresh air quantity. So, you will take that on right? I want you to demonstrate you are a little more interested than others. Find out the pressure quantity per person between now and the next session. So, we will say 12 CFM per person, fresh air; cooling capacity now we can see will be a function of insulation our willingness to alter the rooms. There will be some radiation load coming because of exposure to some rooms to the son.

Student: (Refer Time: 16:39).

Sorry.

Student: (Refer Time: 16:43).

Cubic feet per minute. So, more appropriately I think I should get used to defining it as meter cube per second right. It is a flow rate which so there have been concerns with air conditioning. So, not everything about air conditioning has always been positive when it comes to health concerns. So, when a lot of buildings found a good correlation between productivity of employees and air conditioning there were huge amount spend on air conditioning. As a consequence of that expense it is also noted that the amount of air you get into the building is a direct load and cost.

So, it led to attempts to reduce that to the extent possible, and it led to a sick buildings and room. So, it discovered to be a health hazard because CO 2 levels increase people started not being at the most attentive levels, and out of that came a concern which was addressed by a committee. A committee that rendered details of what amount of air is enough.

So, initially the thought of 20 C F M per person and when they looked at 20 C F M the cost of that was very high; think about afternoon June month's right. If your temperatures are going to be 43 to 46, if you are taking 20 C F M per person you will load the air conditioning system in a big way that cost will become significant, so compliance will become an issue. So, then they were more tests or studies done and I believe the new number is a 12 C F M per person.

So, that gives us an idea of something that is directly impacting the occupants. And we looked at insulation having an impact on the total load. Orientation of the hostel you do not have an impact which rooms are exposed and therefore, we need to look at, differentiating so will have to define different types of rooms that are there.

So, it looks like just defining clearly what is needed will take anywhere between a month to 2 months, provided we put in good quality resources right. So, this gives you a flavour of what I meant in the last session when we are talking about translating a need into articulating it. Articulating it in a way that when we meet it then the target customer will benefit. So, what do we do next; we have got the requirements clearly. As you we have done the work we have talked to people we looked at the solar incidence and we have come to a number.

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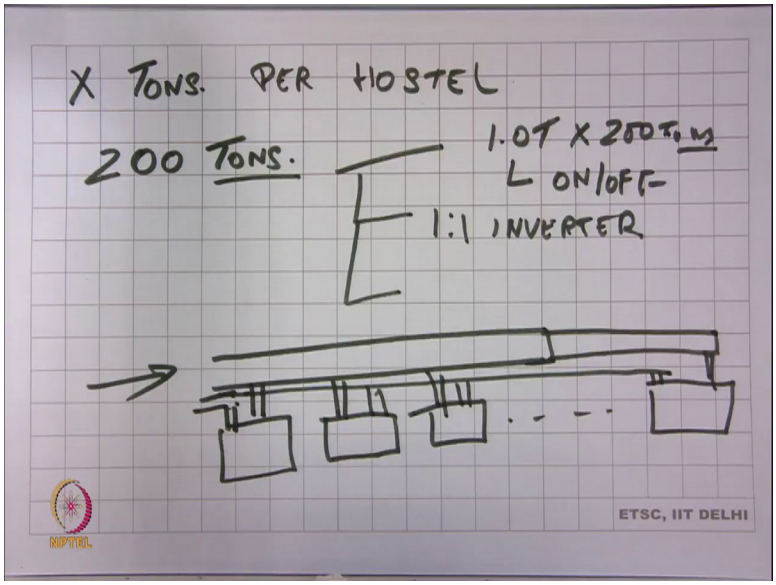

That we need X Tons per hostel and again we need not be a common number it will be different for different hostels depending on their orientation and number of rooms and all that.

So, what do we do next then? So, we are addressing it as a design problem so what is the first component that we go about selecting. So, for purposes of again clarity and making an assumption will say 200 tons, this is just a number it is not based on any calculation that I would have considered. So, we need 200 tons so what are the options that come to my mind, I would say 1 ton into 200 is one clear option. I do not need too much of engineering just define or tender, people will quote and then they will install and everyone will have peace of mind on [FL] off [FL] off [FL] simple right, or I will look at something else.

So, the next least complex system could be what 1 is to 1 inverter system. So, this I was talking about a conventional on off low price system. So, if you looked at differentiating technology and giving individual user a choice then we would go to a 1 is to 1 inverter system. So, one of the things you can do is start looking at some websites where you look at manufacturers get familiar with the different types of air conditioners. As if the first thing is that you have to do this without getting too much of support from me you still could get people comfortable right, with whatever is the known level of technology today it in budget and making a choice.

If you were to buy air conditioner for your room for your home, you would do that by yourself. You would consult a few people and then you would make the decision someone will install and you hold the compress the company supplying it liable in case anything went wrong. So, this part requires very little understanding of design it is just pure connect with what the end user needs. So, do that and in that process you will become familiar. Then what is the next thing that we can do; we can look at every wing. So, we have wings in every hostel right? Like by wing I mean something which allows for a duct to go outside the glass area. And let us say we have room 1 they have room 2 room 3 and so on.

So, something like 20 rooms so all of them have air coming in and then there is a connect to each of them. And there is another duct which takes the return air back. So, you get this principle and that would mean an assumption that when air conditioning is needed

everyone is around it. So, it would a typical wing how many 15 rooms, if you want to have a simple architecture of making the ducts 15 rooms too. And then we could start looking at a 15-ton system, what next we could think of. So, if you go to various air conditioner manufacturer website you will look at chillers.

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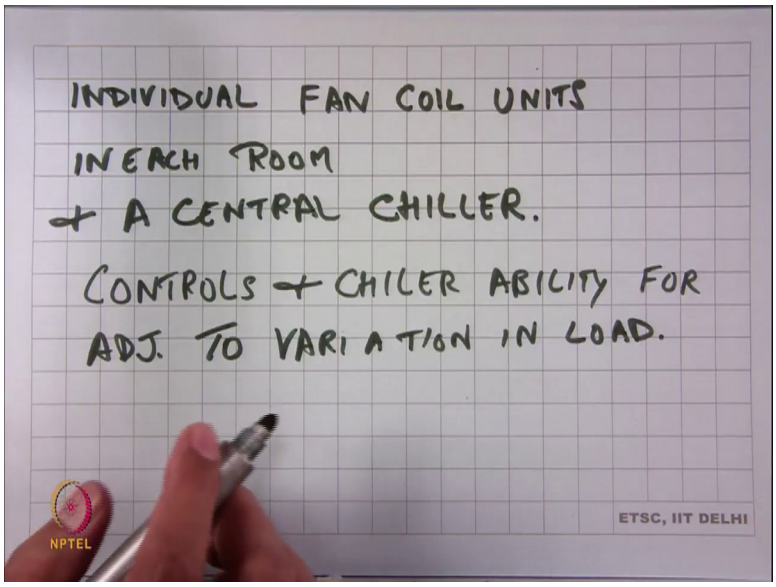

And some very highly efficient chillers and you may want to expert diversity and again give every individual a choice.

So, like in hotel rooms. So, that could be another approach right. So, which means; and what would be the complexity encountered here. So, we look at one is to one systems, some more one is to one efficient system then you look at ducted systems which could end up being fewer and number. Then the individual units and then you are looking at a single central chiller. So, what would the complexity here?

Student: Piping.

So, all the room need to get piping.

Student: Yeah.

But if I was discussing with you I would say piping in any case you have to do because even if you put split systems, you would need piping. So, what other limitations would be there?

Student: (Refer Time: 24:48) estimation of load (Refer Time: 24:53).

Right. So, we need to look at a chiller which is able to address adjusting loads right.

Student: solving air handling units (Refer Time: 25:07).

Sorry.

Student: like for every purely have to install from air handling units have been might not find this space to (Refer Time: 25:18).

Yeah, but know this solution I am talking about is individual fan coil units. So, these are water inside the fin on tube condenser, sorry fin on tube operator. So, you have our terminal unit they not called evaporator because no evaporation happening there chilled water is supplied at 7-degree c leave the 12. And every unit can be switched on and off and then there is a flow controller. So, it is like a hotel or a multi stored central air conditioned apartment complex. The room size is such that 1 ton is a good assumption right. Most rooms will be sufficiently cooled with 1 ton of air conditioning. The only point of caution would be the rooms which are on the top floor which have an exposed roof area.

So, there one the comments are I heard was insulation. So, insulation plus this together would be, what other solution could we have; in the final one would be in the V R V systems, where we have indoor units and common. I would say way from land simply because of issues to do with breakdowns. Given that it is not such a controlled facility, and potential for damage to piping could leave to the entire hostel being at the impact of no air conditioning so, but else, but as an option that is also an option.

So now if you if you make these options and then you have to compare them, what would you compare them on. So, you are the end user you are taking the decision. So now, let us say that you are in the directors chair or the dean chair over is the person responsible for the decision. So, how would you make a decision?

Student: (Refer Time: 27:21) cost.

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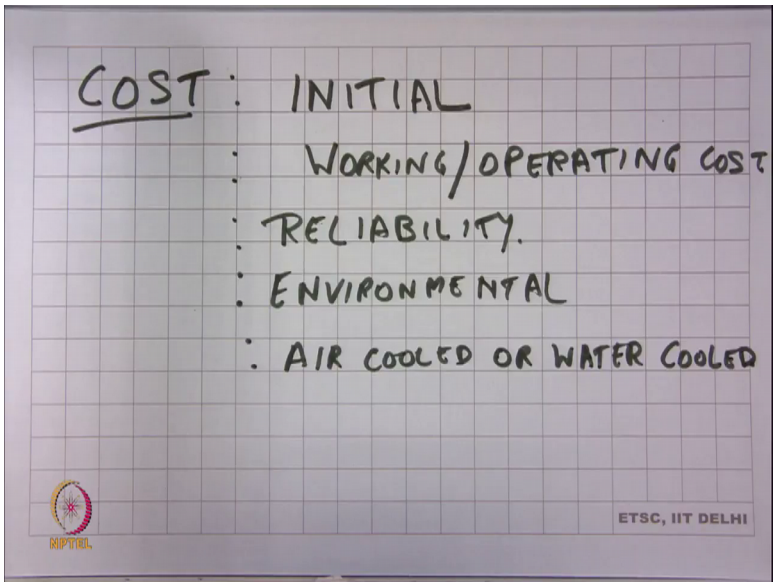

So, cost would be of course, the most important one is cost and you say cost is what; initial cost.

Student: Initial cost (Refer Time: 27:45).

We use the word operating cost is one the same thing what you mean, what else?

Student: (Refer Time: 27:56) efficiency.

Efficiency indirectly included in the operating cost.

Student: (Refer Time: 28:00).

Ok and now how would you measure reliability.

Student: (Refer Time: 28:08).

So, some something you can analyze straight away like, we talked about the multi indoor outdoor. You know that there is a better reliability with the one to one system because at most how many 2 percent, 5 percent will go down, but everyone else will have so that is the factor that you will consider.

But how about the reliability of the complete system, how do you address that. In fact, when I was in my initial few jobs reliability was one of the difficult things to address

because you cannot really measure it. When you are making a purchase decision you cannot you rely on the manufacturers, commitment and whatever is historical data available for other customers using same equipment right.

There is a mathematical way of defining reliability, if you were to know each component reliability then you could stack them all together and you could predict the reliability of the system. What else would you consider, what about environment? So being our technology institute, premier technology institute you would like to set a good example right? So, the moment you would take on here, then is water in short supply in IIT.

Student: (Refer Time: 29:30).

It is right.

Student: yes.

So, you would therefore, look for an air cooled solution over a water cooled solution right, but we will put it as a consideration right. So, having put this all together and let us say that out of all deliberations and everything else, the final conclusion reached is that it is going to be a 1 is to 1 system simple; and that too without any modulation like on off. Because with whatever deliberation you did with potential users all students it came out that the maximum use was night time use. Night time temperatures are pretty constant, daytime people are going to be in the institute the estimated running hours are only the weekends. And therefore, it does not make sense to incur a high initial cost for the advantages small advantage that is there in the operating cost.

So, then what would we do? Let me share you know my own experience because you some of you feel. When I was fond of design you know when I joined Fedders Lloyd, which is a not so well known company, then the company I work for which was imperial chemical industries and then before that I was not talking gamble. So, each of these companies I got opportunities to apply what I knew, but in a very different way that things are known just execute. And I felt somewhere constrained in expressing myself and ability or opportunity to do something new.

So, I opted for a job where I got the opportunity to be a manager in design and development for Fedders Llyod and I was very excited. When I went there and the first

problem thrown at me was design and air conditioner for Indian railways. It is going to be a roof mounted air conditioner for Indian railways and must work. And I was at my wits end as to how do I start. Because any theory that I had had been exposed to an IIT was not giving me a straightforward way to start solving the problem.

Student: (Refer Time: 31:41).

I knew what is Reynold number, I knew how it relates to heat transfer, but where to start. Totally you know other state and then I was not reporting to anyone like, they thought a person from IIT comes in he will be able to do magic you know we do not need anything else.

So, now the thing was that they were systems working before I was having to face a design problem. So, there were systems working as package units split systems and all that. And the one thing that help me a lot was the ability to conceptualize and build designs using parameters.

So, there is a design known it works at 35 degree centigrade, it does a certain lot of heat transfer. And then I had not known how carry learnt air conditioning, but later on when I got to know I ended up doing almost something similar that whatever is known you put together a system and test it out. When you test it out you would get the performance, you get to know how much it cools, what are the issues, what power consumption, what cost, which components are reliable, which are not because you stress it out. And that is how I learned and then some of it that I learned was; I am going to discuss in one of the case studies, but what I learnt was having sent the units to Indian railways they were installed on Rajasthani train.

And they were moving between Delhi and Mumbai. And there were no problems and I was quite excited design, but I not learned noise and vibration. I in fact skipped that course altogether in IIT because it was too mathematical. And I thought you know whatever I like is what I should do not you know what is needed. So, what I discovered and my job is that that was the part that was missing. So, when the same design went in on a different track between Delhi and Amritsar. The track conditions were not the same as a well maintained track between Delhi and Mumbai.

So, there were failures happening every trip, and suddenly from position of glory and prestige I was a target to Bhupinder does not know how to design a product. Everyone became a design; you know project vibration eliminator. A whole lot of things were being thrown as to you know why this did not work. And what help was me recognizing that there is an area where I am not strong, which is analysis of the root cause this.

So, it was I was in Delhi, and I approached 2 professors here and I had a consultancy project signed up. And it was a petty amount like 25000 rupees for a project that gets so much business to a company is nothing, but it will design the whole thing was designed in a way that; the know-how, the knowledge part comes to my IIT, the measurement equipment comes to my IIT and the experimental part happens you know industrial scenario.

So, that the parts of about speed you know, you know how difficult it is to run an experiment and IIT getting all parts together the time required there is an industry you can really make it much faster because it is urgent. So, that combination helped us reach a point that we could address that issue. And now the units run details that I will share more when we have that particular session, but when you do not enter an area where nothing is known it is still possible to make progress.

So, you today are in a scenario where there is so much advancement 100 years of legacy we have an air conditioning designs. And there was a time when there was not much happening in the area of design because it was consistent taking for granted, at design our air conditioner simple thumb rule this it can be made. Only when there was concern for the environment, need for changing refrigerants that things began to move. And then energy efficiency became a big the moment people recognized that 70 percent of the energy is being used for comfort and cooling purposes. There was a lot of emphasis that came back because it meant money.

And then today it is area where there is a lot of R and D happening, in terms of evolving new systems and making them work, analyze them, look at newer technology. Scroll compressors came into being because of the need for energy efficiency and reliability. The number of parts got cut down phenomenally. So, if any of use feeling a little you know lost to came discuss it is fine know. You know in a design role you will sometimes have unknowns; you will need to grapple with things that you not done before.

So, let us start grappling with designing your one-ton air conditioner [FL]. We have the design conditions so we said 25 and 50 percent R H.

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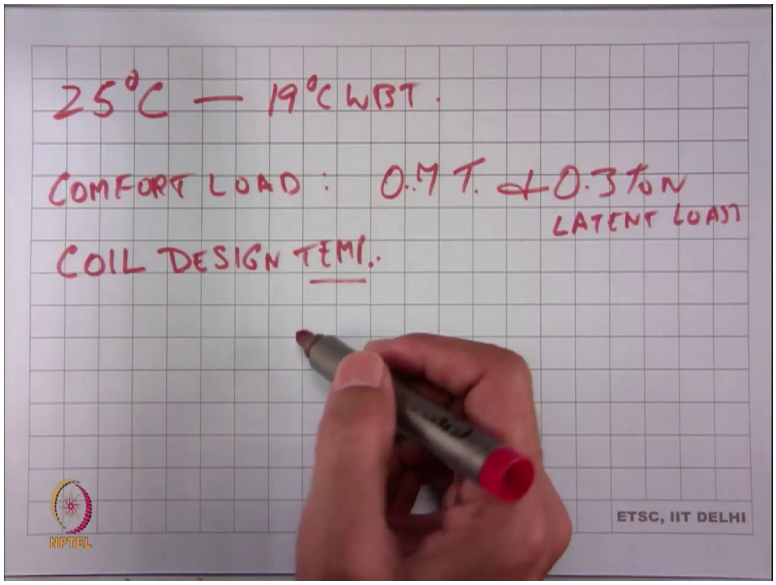

So, 25 degrees C and 19 degrees C W B T. So, we look at comfort load; it is a combination of sensible and latent. And for you would appreciate that all of us are breathing right. So, we are adding some moisture in the environment that here.

So, we need to remove that moisture. So, they will be comfort load which will be let us say 0.7 tones and 0.3 tones of what we term as latent load. And then we look at the psychometric chart, and define an evaporating temperature that we need in the coil. This design temperature will pretty much be a function of these 2.

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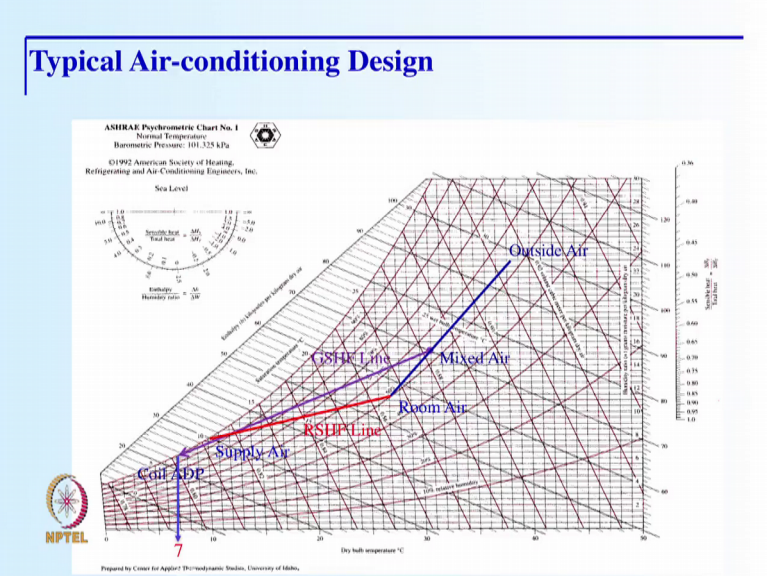

So, let us say we come to a conclusion that this is a 7 degree centigrade. So, at 7 degrees centigrade we are able to meet the ratio of latent and sensible load. And then what do we do next? So, we could do one of the 2 thing, we could look at the evaporator heat exchanger design or we could look at choosing the compressor, my typical approaches to look at compressor selection.

So, look for a compressor that will give me 1 ton at 5 degree centigrade or 7 degree centigrade sorry. So, we choose a compressor and in choosing a compressor we need to look at refrigerant choices, so far design was pretty simple use R 22 and go forward. Now, for environmental reasons we will look at 410 a. And we will look at 410 a not for a very long time because you look for a refrigerant which will also not have a high global warming potential right, sorry say again.

Student: R 1 3 4.

1 3 4 is typically going for refrigeration applications not so much for air conditioning. And there is actually no prevalent alternative 2 410 a at the moment. So, most designs that are happening today like if you are designing today then you will just opt for 410 a. And you could consider propane for a small size air conditioner like 1 ton.

So, one of the manufacturers in India, Godrej had some assistance from a German company. And they have produced and sold 20000 plus air conditioners using propane. I

am a little sceptical about that because when you install air conditioners with exposed pipelines using a flammable gas. When people are going to address it for in case of a risk like fire, in case of you are not having enough knowledge about how to handle a flammable refrigerant. And those are things that have not been fully discussed and addressed in a standard. And in the though kind of limitation that we face in India is that there arents strict regulations that are in place to prevent such even quality.

So, China has taken a long time before they have said you know they will go ahead with us. Europe is still not clear whether or not, the only thing that has happened so far is at in U S refrigerators with propane are accepted, in Europe they were accepted for a long time in India they have been sold for a long time. So, for small systems where the charge quantity is really low, propane butane have been accepted as refrigerants. And they are so the reason to bring in this conversation is that they have no risk both for global warming or for ozone depletion.

So, for those environmental reasons they are safe, but they have a flammability risk, which for smaller systems is addressed by technology the way you see the system they will manufacture it. And finally, an evaluation of the overall risk if there was to be a leak in the system.

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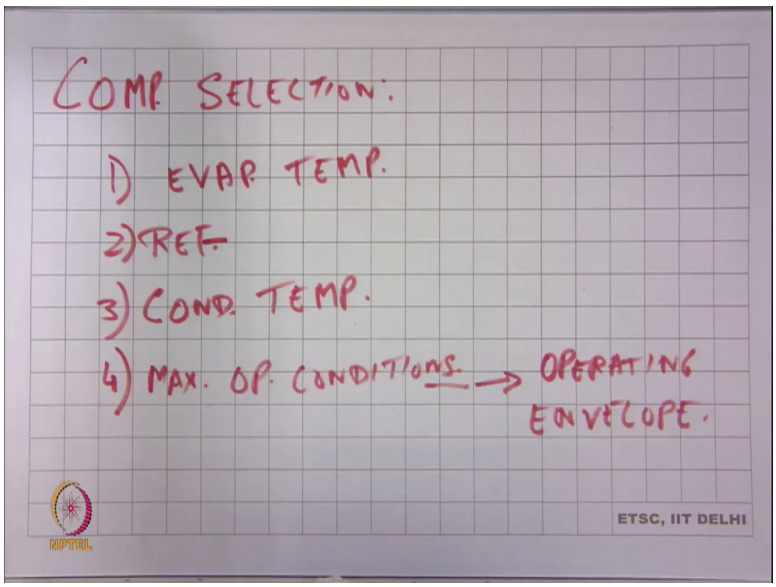

So, compressor selection will require a combination of evaporating temperature, refrigerant and then condensing temperature. We want to pump heat so and the max operating conditions.

So, max operating conditions is something like defining an operating envelope. While we will do a design at a fixed point we need to keep in mind what are the extreme conditions in which this compressor must operate. So, if we have all this, we would go to a compressor performance curve. We look at available compressors from different manufacturers and then look for one which delivers 1 ton with a reasonable cost as well as good performance; mean a good energy efficiency ratio. So, it is pretty.

So, when I was talking about my experience of compress selection came easy, you know so long as I could relate what railways wanted unfortunately that a customer which was clear on what amount of cooling load they have. So, no issues on the requirements part, it was straight translated into a compressor choice. And it was a reciprocating compressor at that time which was about no it was exactly 4 point 3 tons at rating conditions.

But then the reason we do this exercise is that we are not always concerned with the rating condition, we are looking for the design condition and the design condition for railways was 5-degree centigrade evaporating and 60 condensing. It was 57 at one time then increased to 60. So, under those conditions we had to guarantee 3.3 tons per compressor. So, that came I mean for that not too much of work except get to the right compressor performance curve.