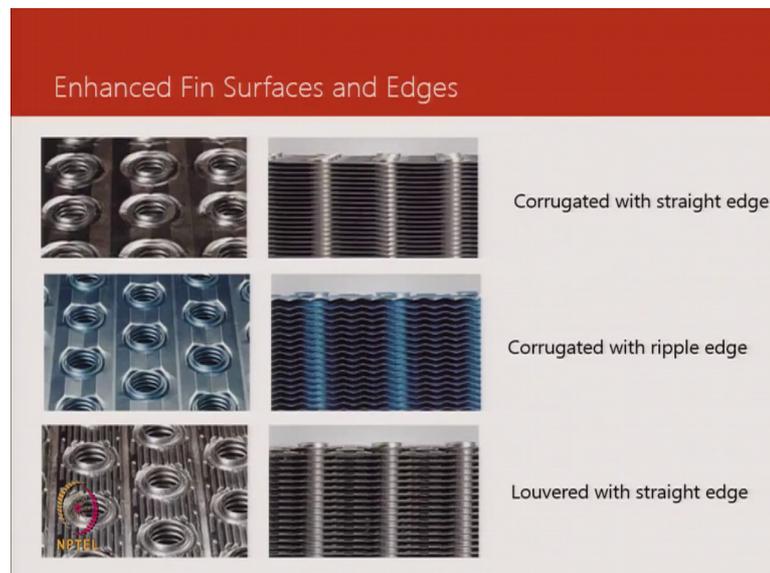


RAC Product Design
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Lecture – 10
Types of heat exchanges and air conditioning systems

So, now we are going to look at some other enhancements for heat transfer.

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So, what can we do to the fin for two purposes? So, one purpose is to improve the heat transfer coefficient on the air side and another is durability. If any of you have friends who stayed closer toward drain, then many times air conditional coils condenser, coils will just crumple and after 2 year period, people have reported losing the condenser totally. So, that is the symptom of corrosion. Some gases containing hydrogen sulphide tend to react with aluminium and cause it to corrode faster than or people staying near the sea many times, I have reported some particular condensers wear off.

So, one way to offset that is to provide a coating and this is a newer problem earlier, say air conditioners manufactured 15 years back, 20 years back, the fin thickness was in the region of 0.2 millimetres there was enough thickness on the fin. So, one would not notice, it would easily last for the 12 years or 10 years life of the air conditioner. Now, with competitive cost fin thicknesses have gone to as low as 0.11 millimetres with that low thickness, if there is any corrosion that begins it is very easily evident and to offset

it, we provide a 1 to 5 micron thickness on the fin and that takes care of corrosion that is one purpose of coating a coil.

When we talking about enhanced fin services and edges. So, how do we enhance a fin? If you have a plane fin, there is a straight flow path the pressure drop is the least of all configurations and we would have a certain part of the air pass through like bypassed because, it would not come in contact with the film. So, to enhance it, we could look at first step is corrugating the film since should having a plane fin. So, the first one that we see on top is a corrugated fin and then you could have variations in the edge of the film.

So, you could have a straight fin or you could have a ripple edge and all these are means of improving turbulence, increasing the turbulence and getting a better heat transfer and finally, we cut the fin. So, before it is assembled make lures in it so, that there is further turbulence generated in the path of air. And, all of these types can be used in evaporators as well as condenses. If you look at characteristics of flat fins, they are the ones which will reduce ice accumulation.

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FINS: SHAPES & APPLICATIONS		
Fin Shape	Characteristics	Common Applications
Flat	Flat fins reduce ice accumulation on fins. They have the lowest resistance to air flow.	Deep freezers Cooling / freezing systems Passive air flow systems
 Corrugated	Corrugated fins improve the heat transfer factor to a lower degree than louvered fins. They also have a lower resistance to air flow.	Used where icing or heavy dust conditions are expected, like condensers for off road vehicles and for heavy dust applications

So, if you are looking at a frost free refrigerator than we normally see plane fins being used, they have the lowest air resistance as we mentioned. And, then applications are deep freezers or free cooling and freezing systems and then passive air flow systems. Corrugated fins improve the heat transfer but, it is less than a louvered fin and they have a lower resistance to airflow in comparison to a louvered fin wherever there is dust. So,

typically condensers way to make use of a louvered fin or if we are looking at off road vehicles in there again louvered fin is a good choice, there have been two fin forms that have been in the market for reasons of some patents.

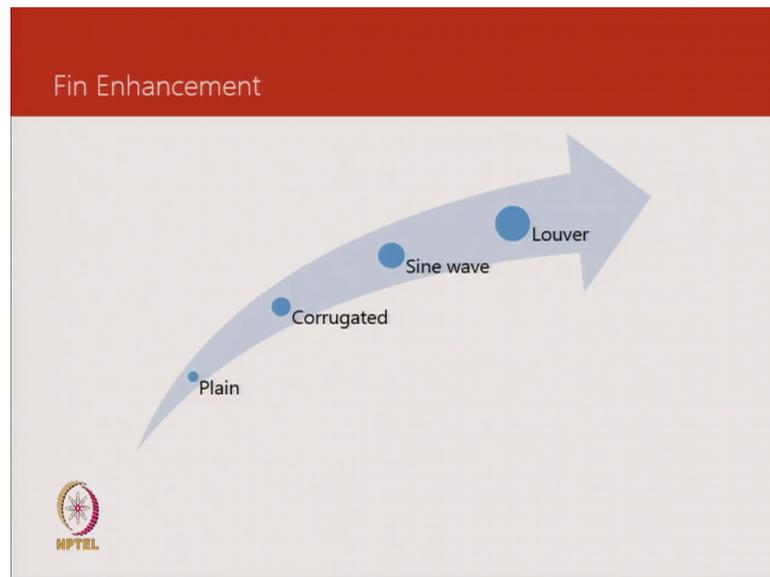
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FINS: SHAPES & APPLICATIONS		
Fin Shape	Characteristics	Common Applications
Sine Wave	Sine wave fins improve the heat transfer factor to a higher degree than corrugated fins. These have about the same resistance to air flow as the corrugated fins.	Good all purpose selection for all types of coils, provides the best output to air pressure drop ratio Default fin shape when not otherwise specified
Louvered 	Louvered fins increase the heat transfer capacity by creating air turbulence which reduces the boundary layer on the fin's surface, but at a cost of increased air-pressure drop across the coil.	Evaporators Heaters and Coolers Condensers operating in areas with light to normal dust conditions

So, someone filed a patent for a particular shape of this fin and there was a sine wave fin with and without lancing for that reason it is protected and therefore, people try to beat that by making a louvered fin. So, there have been 2 fins that have been in use: louvered and sine wave pretty close to each other, but the sine wave has a better heat transfer than the louvered fin. Then the sorry the corrugated fin sorry not the louvered the corrugated fin and then the sine wave is again a general all purpose selection when you are bothered about clogging it is less prone to clogging than a louvered fin.

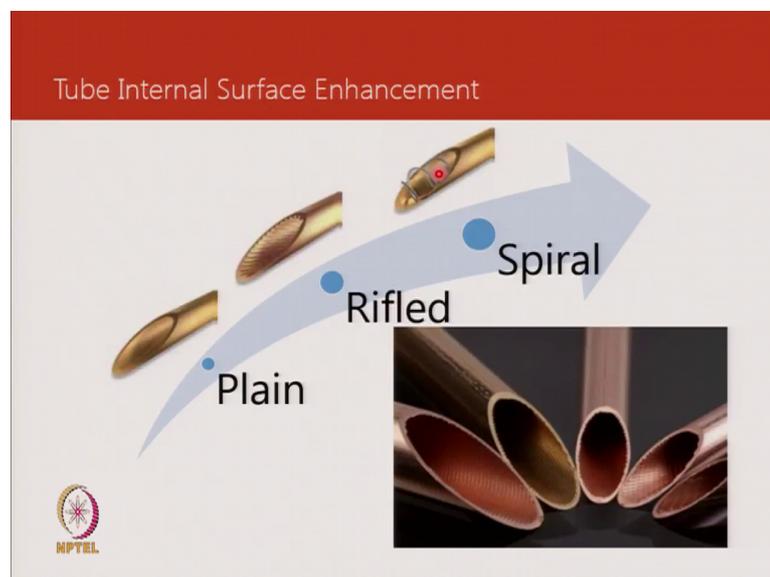
And it is a default fin shape also, if we are not specifying anything, then this could be the default fin shape that we use. Louvered we talked is the highest turbulent generating fin and it is also offering the highest rate of heat transfer on the air side. And, it comes with a penalty which is higher pressure drop, but they have been used so much that the trade off has been accepted. So, when you go to a fin density as high as 18 fins per inch and a louvered fin for evaporators, they have been helping manufacturers build compact indoor units that have been also acceptable to the market in terms of cost and performance.

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So, if you look at a summary, we have the basic plane fin and then we have corrugated fin, the sine wave fin and on top for performances the louvered fin. Just like we can enhance the fin surface, we can also enhance the tube internal surface.

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So, references plane fin and then what we have is a rifled inside. So, we have grooves and these grooves again generate turbulence and improve the inside heat transfer coefficients. The refrigerant side heat transfer coefficient inside the copper tube goes up, I have shown a visual and I do not think this is clear enough or is it I think it is clear on

for your screen I think it is pretty good. So, let me just see if you look at this surface, it is a different internal surface the type of channels, it is a crisscross pattern and there are manufacturers who have protected their patterns and got some mileage out of it getting a premium and then this is having two spiral grooves.

So, it is like double rifle you could use that word and this is a simple spiral groove inside the tube. So, as manufacturing processes for drawing copper to have evolved, it is in possible to make some more complex shapes inside the copper tube and get higher refrigerant heat transfer coefficients the key thing that we must remember is that this becomes necessary only after you have taken the airside coefficient substantially high because otherwise the airside heat transfer coefficient is what is the constrained in the amount of heat that we will transfer and then there could be further turbulence generated by inserting something like a spiral wire inside the tube.

So, this spring kind of a arrangement further enhances the and it is used in different designs differently because if your intention is to enhance the heat transfer coefficient in a certain area of the tube only then because it is a cost and complexity associated with implementing such a enhancement, you would do it specifically for those tubes where you want to benefit from this. Now, I am bring this a live is that there is a region in the evaporator where there is super heat happening when the superheat is happening there is really no major benefit of putting in an enhancement device there because, it is all vapour.

So, suddenly, we know from a mixture of liquid and vapor I mean fantastic heat transfer it goes up to its maximum just before it reaches superheat. So, we need to be careful on what part of the circuit we are adding the now surfacing.

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Fin on Tube Evaporators and Condensers

- Material of Fin Aluminum/Copper/Stainless Steel
- Fin Thickness
- Fin Spacing
- Fin Type
- Fin Coating

 NPTEL

So, now, if we look at everything that we discussed about fin on tube design heat exchanges, then whether it is an evaporator or a condenser we would need to define all of these. So, we need to define the material, when you define the fin thickness, we need to define spacing and in a little while, I will also take you through the coating part. So, these are the parameters that are expected from an engineer when he is designing the evaporator or condenser.

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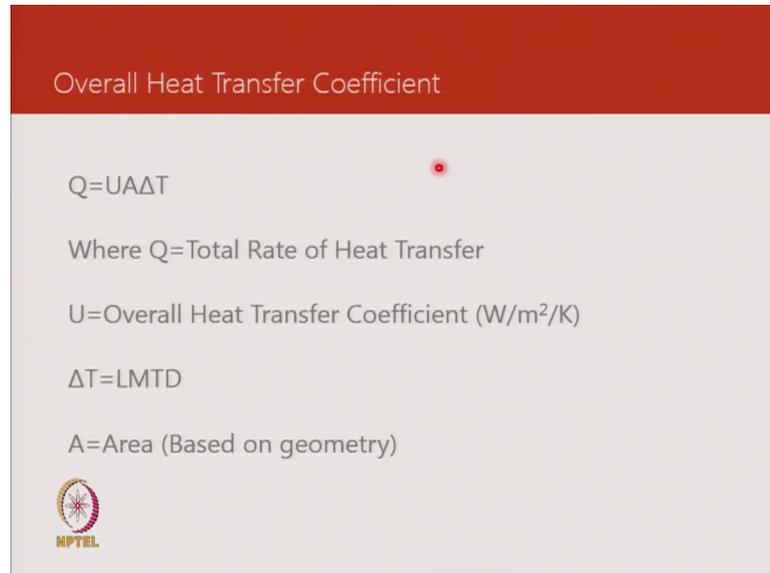
Fin on Tube Evaporators and Condensers

- Material of Tube Copper/Aluminum/Stainless Steel
- Tube Outer Diameter
- Tube Thickness
- Tube Spacing
- Vertical Pitch & Transverse Pitch:
- Tube Internal Surface

 NPTEL

And then similarly, on the tube side what is the material of the tube outer diameter tube thickness tube spacing and we said tube spacing, it is the vertical pitch as well as the transverse pitch and the internal surface type.

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Overall Heat Transfer Coefficient

$$Q=UA\Delta T$$

Where Q=Total Rate of Heat Transfer

U=Overall Heat Transfer Coefficient (W/m²/K)

ΔT =LMTD

A=Area (Based on geometry)



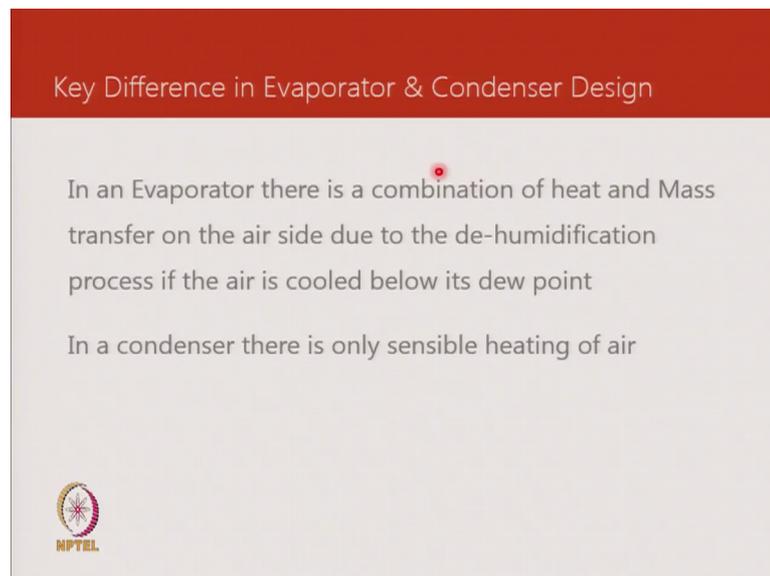
The governing equation is the overall governing equation is the overall heat transfer coefficient and area into log mean of the temperature difference at inlet and outlet. There is a something more complex in this because the evaporator does not have a constant temperature profile. Let us say comfort application return air entering at 27 degree centigrade dry bulb, 19 degrees wet bulb; when it first comes in contact with refrigerant of the bank of tubes which are the first contact point we will have only sensible heat transfer. There is no mass transfer happening till we till that air reaches the dew point, then within that section there could be a certain part which is in the superheat zone. So, the inside heat transfer coefficient is not the same.

So, if you want to do a thorough analysis then a simplistic calculation will not give us an accurate result. So, we would need to look at a software solution where we define small elements of the heat exchanger and do the mass transfer and heat transfer balance equations for each of them using all the knowledge, that we have all theoretical knowledge we have. And, then we would also look at validating some of them by doing some experiments because all our assumptions that need to be validated and then that software becomes useful for simulation for predicting designs and all that fortunately in

the air conditioning there have been so many products developed that there is a set of values that are very handy.

So, you could today look for the heat transfer coefficient inside a tube for $r = 4$ to $r = 22$ and use that as a starting point for your design calculations. Similarly, the air side heat transfer coefficient for certain velocities are available in literature. So, that allows us a good stepping stone to the first design, but today in the competitive world if we are going after optimization in the best performance or the best cost then we need to have a means of iteration. Iterating number of circuits iterating the face area iterating the pipe length and all that and for that we will need to get into more detail about doing some calculations.

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Key Difference in Evaporator & Condenser Design

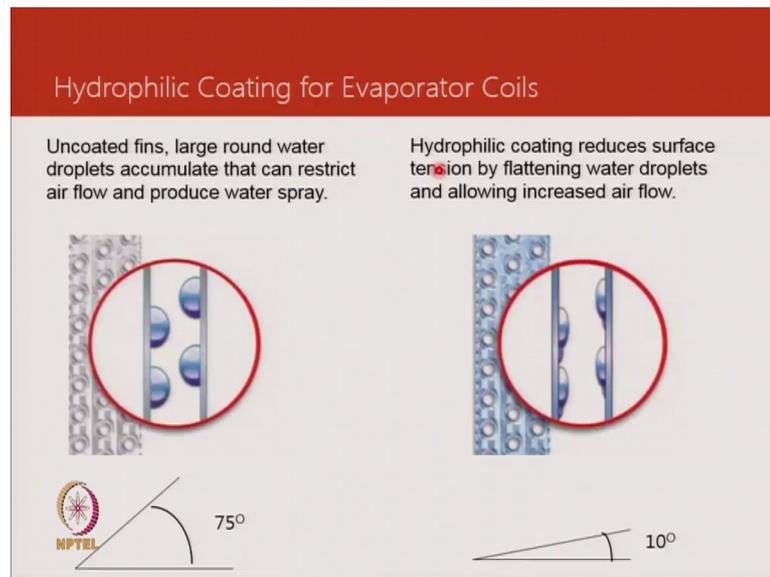
In an Evaporator there is a combination of heat and Mass transfer on the air side due to the de-humidification process if the air is cooled below its dew point

In a condenser there is only sensible heating of air



And now the main difference when designing an evaporator and a condenser is that in the condenser we are increasing the temperature and there is no mass transfer involved. So, if you done an evaporator design then design the condenser is simple, it is just that we are rejecting heat instead of taking in heat to the refrigerant.

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Now, I will go into a little bit about the coating which is different for condensers and evaporators. So, to differentiate the kind of coating that we use one purpose of coating is to enhance the life which means the fins do not crumble, when they are in corrosive environments and we could do that by using stainless steel or copper with tin coating or we could use aluminium with some special coatings.

So, one such coating which is used on evaporator coils which does a combination of things one is to enhance the life it could withstand a salt spray test of say 500 hours and it also changes the characteristics of the surface. So, the wet ability of the fin surface changes and that has two benefits one is the condensate drains faster the film thickness; the vapor film thickness on the film is reduced and carryover of droplets into the supply air is reduced. So, these are the benefits. So, you can see in the two figures when we use the enhancer;

Student: (Refer Time: 13:16).

Sorry.

Student: (Refer Time: 13:19).

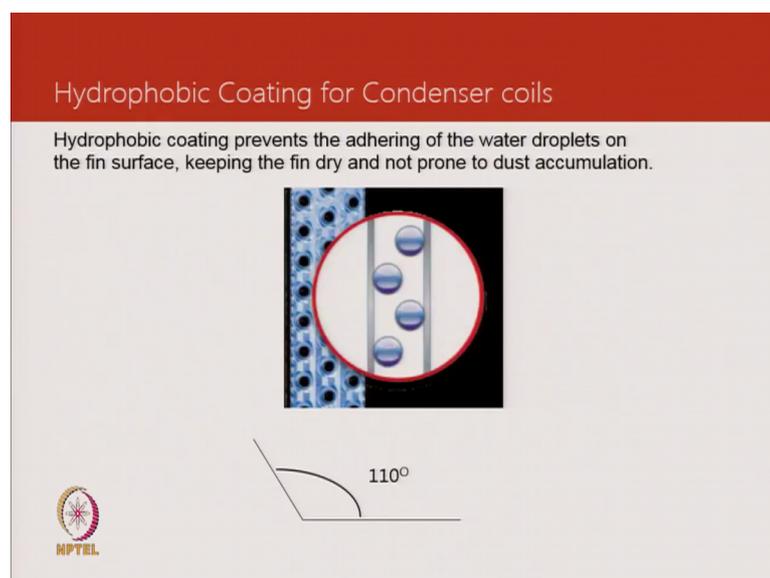
Sir; again.

Student: In infinitely, salt is spirit (Refer Time: 13:22).

There is a salt spirit. So, let us say we go for a coating to enhance the life of a film right how do we measure. So, supply make a claim, but as a manufacturer manufacturing appliance you are tested out. So, you look for a parameter. So, there is a salt spray test. So, in a humid environment where there is so, you use a spray which consists of salty water and you subject that part to 500 hours; so, if it withstands 500 hours, it is considered adequate for the life of the air conditioner. So, it is a robustness test and we will look at robustness tests also in subsequent lectures and we are trying to look at how to make a product robust in field. So, different unexpected scenarios in which the appliance needs to work have we done anything to prove it in the lab at the prototyping stage.

So, so, here is the angle of contact because the surface tension changes. So, the angle of contact changes from 75 degrees to 10 degrees and this leads to better flow of condensate into the drain fan this becomes handy when there is a lot of high air velocity in certain parts of the evaporator the droplets being thrown in a tangential blower because, of the velocity being high in certain part of the coil, it addresses very well. So, split systems would you normally see split systems have a blue coil and that is an indication that are hydrophilic coil has been user in a split system has a tangential blower.

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So, it would have a tendency to pick up droplets more than a window air conditioner or duct ducted air conditioner actually. So, then an exact opposite of hydrophilic and

hydrophobic; so, here we want to repel water from the film so, then it is easily dispersed into the environment evaporated and does not create clogging kind of characteristics and this is useful in condensers here the salt spray test demands are also much higher. So, if you were to test a coating, then we would anticipate it being good for more than one thousand hours of salt spray test that is because outside air is not so controlled they are likely to be more corrosive gases it is subjected to storm dust all that.

So, another claimed benefit of the coating is that the surface remains free of dust. So, the chemical that is being used for coating it has been developed in a way that it does not allow dust to stay like stuck on it and the material is an epoxy material.

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Then this is a residential duct free split air conditioner coil and here are some openings which would include no passage of refrigerant into the coil and out of it and the complexity in circuiting can be seen from a tripod here. So, this is actually the refrigerant bifurcated into two paths after one paths through the heat exchanger here, we would do that again to optimize the heat transfer. And, most of the literature today has been simplistic in how to predict heat transfer and coils by not accommodating such things which are already in use which is splitting the refrigerant path midway unequal circuiting and all that.

So, with whatever I was trying to even you know in preparation for this class today whatever I saw the there is not enough to predict this kind of behaviour. So, one thing I

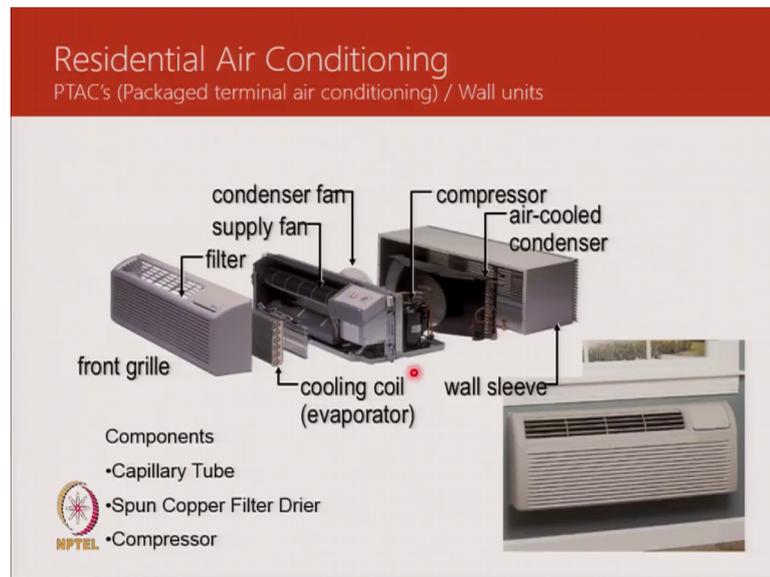
have taken on is to see what is the closest we can get to like if we can get to a single equal circuit, then we would work with that and provide you that information as a means to do the design, but as engineers, we have to do our design, right. So, if formulations are not available if we do not get the exact equations we still need to do a design. So, another approach is to look for known systems with a known performance and then take a look at scaling them. So, if we have a unit which performs well with 5 kilowatts you want to scale it up or down one simplest things to do is to use a correlation and while that looks simplistic in actual design benchmarking is a standard procedure.

So, let us say if today I was working in a my earlier companies before investing on new design I would invest on benchmarking or by competition units compare with the best in class that would be there in the company I work for and see for myself what cost and performance is already available. And, what is it that I can target using the knowledge, it also becomes a good place to test all the known correlations software algorithms and tools that are available to an engineer. Then if there is a constraint of time and you cannot have the most accurate correlation, then you would go with using that information and predicting the first performance the coil.

So, you could for example, make a choice here if we took a coil like this put it through a test in an actual system we could see circuit by circuit superheat, now circuit by circuit super heat will tell us how evenly the coil is designed and one easy balance point would be to add a hairpin to the circuit which has the least super heat or no super heat and remove the hairpin from a circuit which has a very high super heat. So, we would have reduced heat transfer in one circuit and added heat transfer another circuit and that time would be to balance it out. So, that then takes us to the domain of a prototype testing and benchmarking and comparing circuits and when I started working initially this is what nineteen ninety three onwards I did not have very sophisticated design tools available.

But I had test facilities and an opportunity to rig up sensors cyclases liquid indicator basically and check out what is happening inside. So, and then we ran a project of course, with IIT, Delhi and that was to develop some software to predict performance of evaporators and condenses, I think I mentioned once earlier my class that when the founder of air conditioner started designing cause he did not have access to any known literature or correlations as to how he could predict performance. So, he went by the first principle test developed correlations and then use them to design systems.

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Now, if we look at this coil this will typically go into a residential duct free split of this nature and you can see the complexity from evaporator design we would also need to look at several other components and the key component there would be the supply air fan. So, that is a tangential blower which consumes in the region of twenty watts of power and key concerns, there are totally different from heat transfer as you want low noise you want ability to adjust speeds and a certain resistance to carryover of refrigerant droplets in addition to that there would be factors related to aesthetics the coil bear coil by itself would not look very elegant.

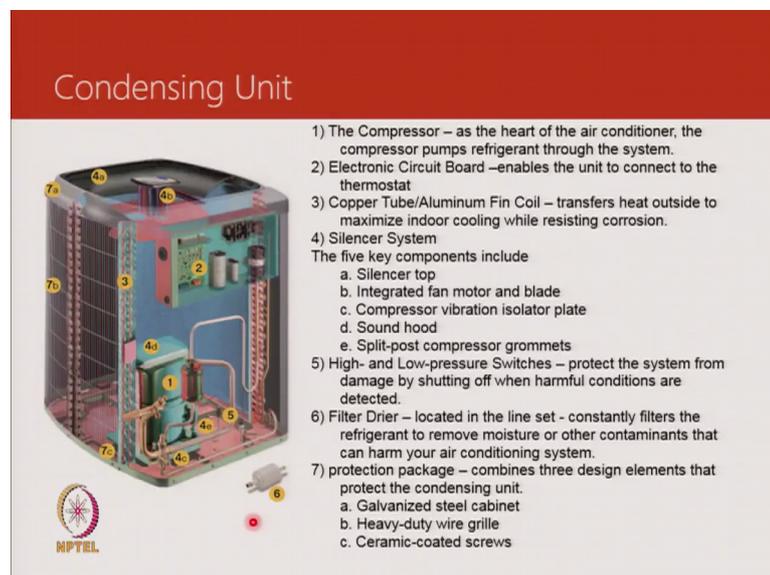
So, we need to cover it up and you need to have some means of having access to the filter because that would need more frequent cleaning. So, from design and selection of an evaporator coil, we would end up looking at the full gamut of components which would need it. So, we looked at capillary before and then there would be a filter drier to ensure that the capillary does not get choked and compress selection you handle before.

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Then we looking at compact heat exchanges a for condensers typically it is common to use circular designs like this or U shape designs.

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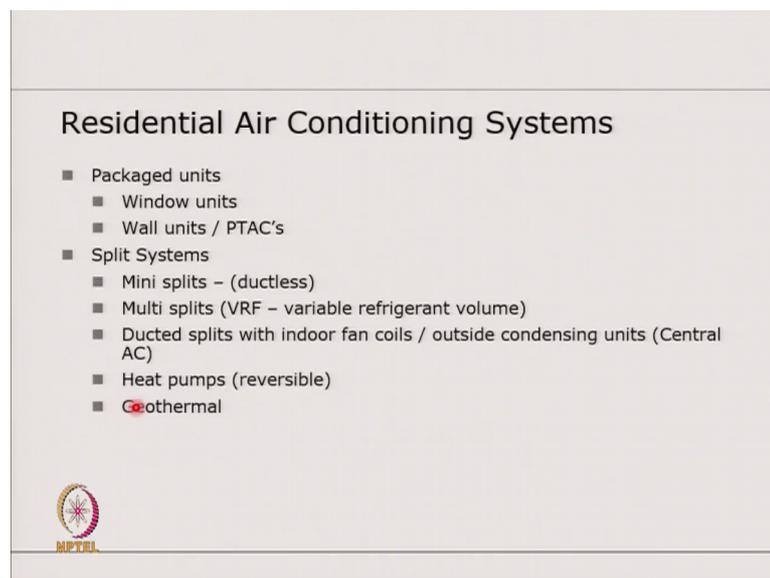


And then this gets into a condensing unit. So, from a condenser we migrate to looking at a full condensing unit where we have the compressor that we earlier looked at how we selected it based on the ambient and the evaporating temperatures and then we want to look at the control components that we need to integrate with that.

So, in a condensing unit other than the coil, we will need some means of mitigating any additional noise and then some pressure switches if it is a large condenser to protect the compressor from operating outside its design limits, we would put in sensors that would signal the controller to switch it off if there was any and toward thing. And, things that we need to be aware of is again clock coils refrigerant leak high discharge gas temperatures all that in terms of choosing materials for making a condensing unit you look at corrosion resistant steel. So, when my steel would be a common choice and then you would look at powder coating it you would look at shapes.

So, that there is a certain quality of manufacturing that is possible certain repeat and component to component and you can see the condenser coil circuiting on this side. So, one end of the coil would have headers, finally, connecting it to a discharge tube and other end would be the liquid line which would go to the split system other end of the split system, this is the hairpin side of the bent condenser.

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Now, if you look at systems in residential air conditioning systems other than window and split there could also be variables refrigerant volume systems where multiple indoors can be connected to a single outdoor and there could also be hydraulic systems where we use water as the heat transfer medium to look at multiple indoor units. And, then they are also options like geothermal air conditioners and heat pumps where we are either

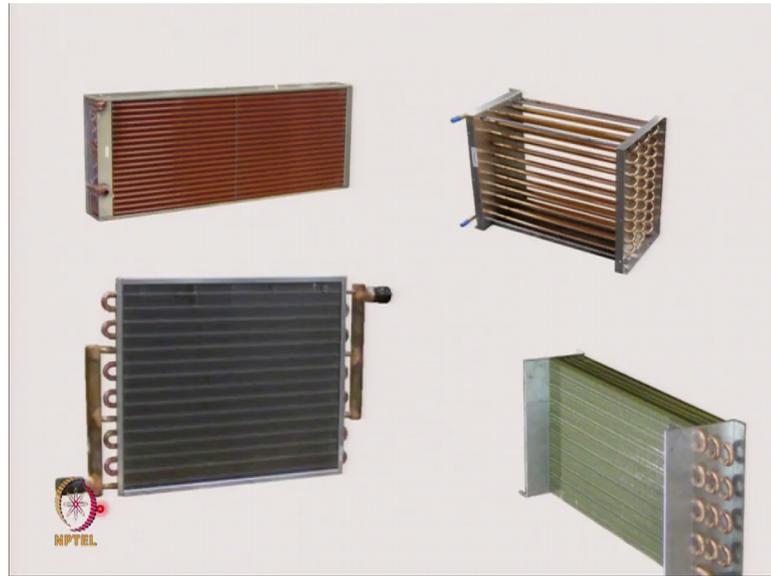
rejecting heat into the groundwater or we are taking heat from the groundwater, if it is a heat pump application.

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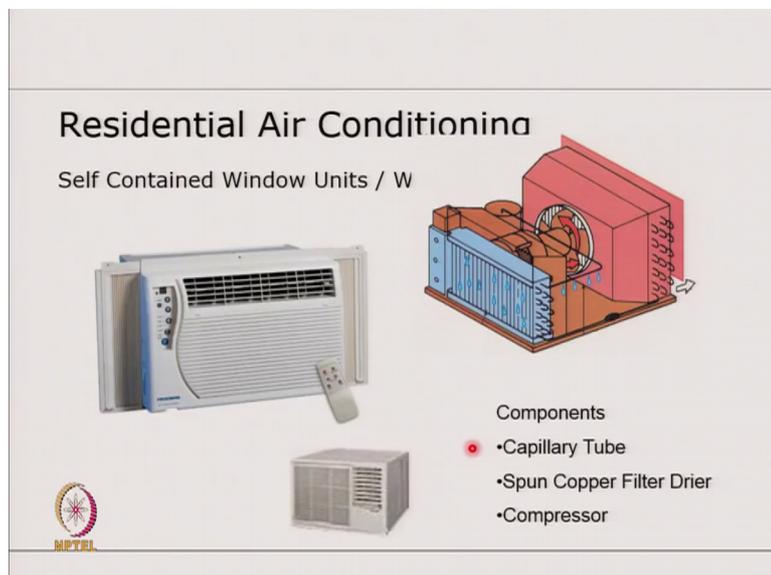
Today residential systems have become so popular that you know this picture says it all each apartment is having several of these units, right, it is more like an exhibition, right and this is growing. So, in India the penetration of air conditioners is still to reach the levels that we see in China and other developed countries. So, we are lagging by about 10 years. So, right now this is going to be tremendous opportunity for air conditioners to grow in India, we just about at a stage where people are beginning to add from one to going to more units in the same household, then we have looked at different coils before already the one unique thing here is a coated condenser coil here and then a bare set of tube banks.

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So, where there is no major enhancement required on the outside and something like this can also be used this and this more typically be parts of a window air conditioner which is again a residential air conditioner like this.

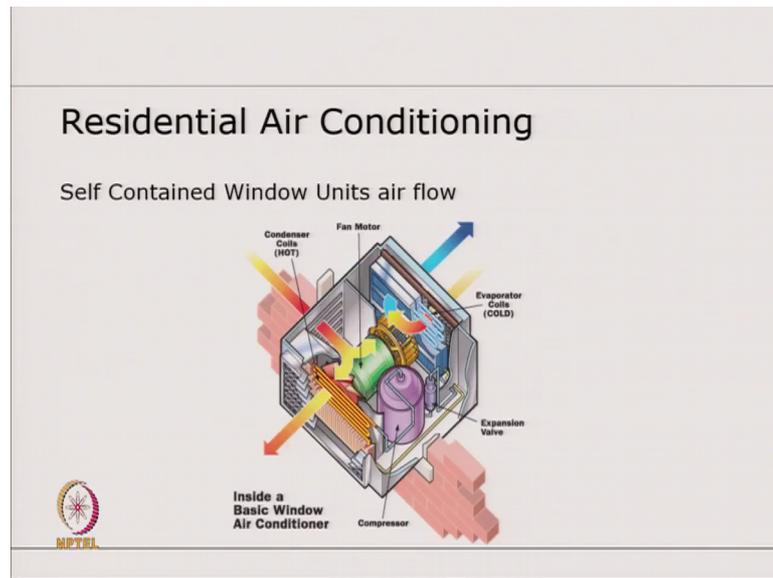
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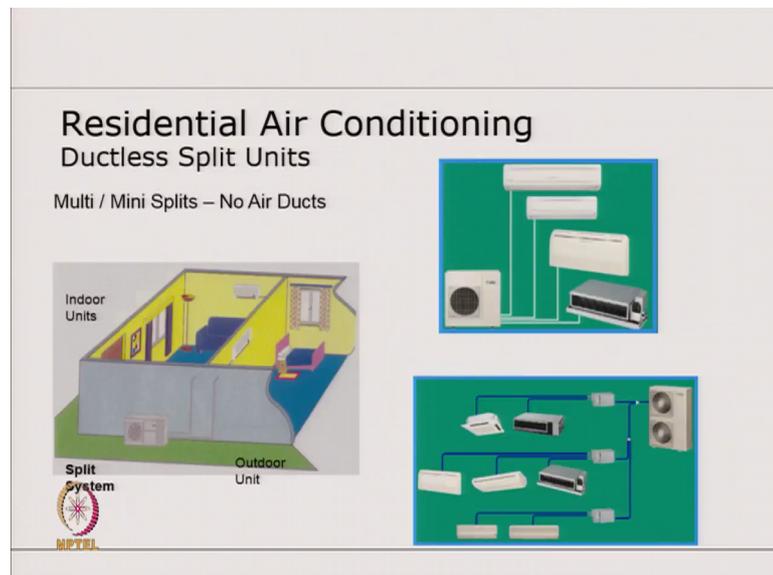
And here you have the expansion device would be a capillary tube because of cost, it would be a low cost device here is the user interface. So, we talked a little about how to change the temperature select on off controls in some display.

So, you would have a display here some means of removing the filter and the component inside I am sure by now you are all familiar with. So, we have the evaporator this side the condenser the condenser on the side and then here is a evaporator and this is the supplier region with another view.

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Now, when we are looking at ductless split units, we could look at conventional systems which are fixed speed systems also connected to multiple indoors and there is one example of that inside this unit, there could be a compressor which is either modulated

digitally which means the compressor continues to rotate, but the compression is switched on and off.

Then we looked at compressors we looked at two different ways of variable speed one was true variable speed by the compressor motor changes speed another was we modulate the duration for which the compressor is in compression and then it is offloaded. So, it is unloaded and the stalls just continue to rotate without doing any compression. The key feature of ductless split unit is the very name you do not need a duct to spread air in the conditioned space and for that reason they are simpler to install maintain and service.

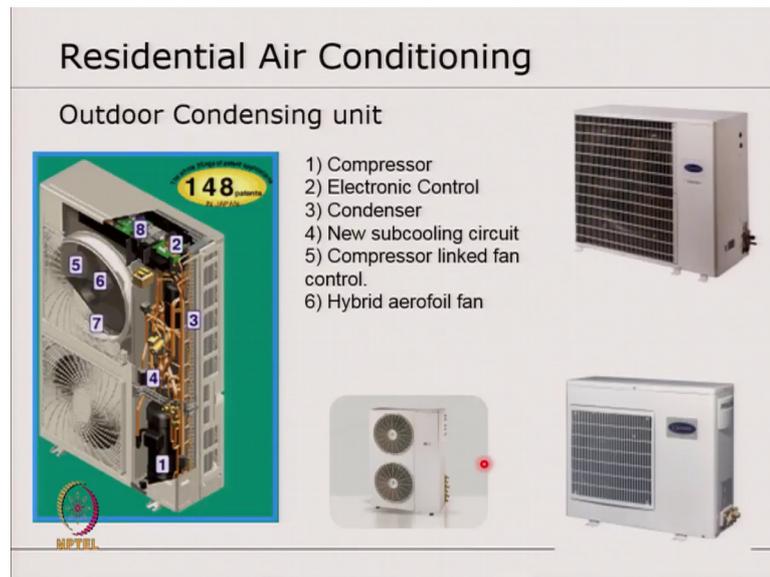
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Then these are some other types of units into which we will end up having evaporators designed for these are becoming less and less popular. But, if it is a large room you could consider unit of this nature, then we have in ceiling cassette units and this is the one's where I was mentioning the need for a condensate pump.

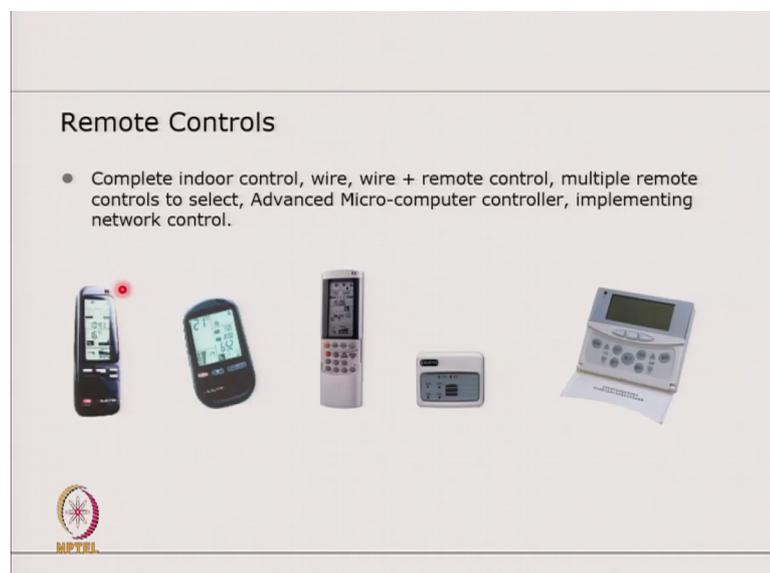
If you need to have it in the ceiling the design is such that you need a pump to ensure condensate is thrown out wall mount I am sure all of us have seen enough familiar with, then I have another picture on the condensing unit where we can see it from another side and here we can look at the fan and the condenser fan is normally a propeller fan.

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So, we would look for a fan which is different from what is used in the evaporator side in the evaporator side we are addressing a heat exchanger which has both simultaneous heat and mass transfer. So, the higher resistance there then there is an air filter we need to a compensate for that. So, we end up using a forward curved the blower in most cases or a tangential blower in that free splits in condenses you would use propeller fans when they have generally made of plastic with a motor and in some more advanced designs they would be driven by a DC motor again the ability to modulate the airflow. So, that we can address varying ambient conditions outdoor air conditions.

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These are some means of looking at the interface between the user and the unit. So, what is it that we would like to see? When you are using an air conditioner ideally what is it that you would like to see or control. So, very basic on off everyone wants; ability to adjust temperature everyone wants, but beyond that what else would we want.

Student: Time (Refer Time: 30:04).

Yeah, the ability to switch it off in after a certain known time, right or switch it on before you come to the home, good, if I were to look at you know my wish list for an air conditioner know is that I should enter a room, I need to do nothing the room should know that I am there. And, what is my preferred setting and everything should be even before I enter the room it should be a conditioning, I should not see it, I should not hear it, I should just feel the comfort and if you look at a lobby, you know bureau 5 star lobby, you do not hear air conditioning, you do not see it, but you pretty comfortable because of the size and the way the air is distributed.

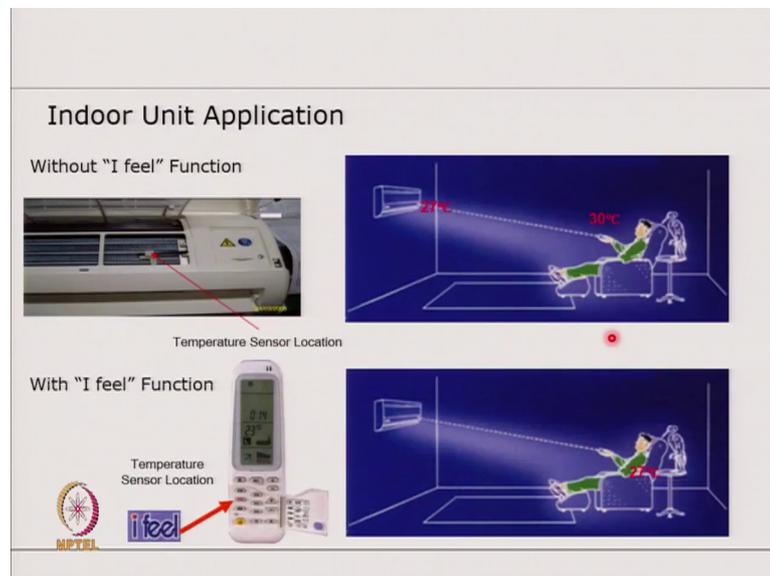
So, ideally that is what we want right we are in the bedroom air should not be coming onto our face, we should not be struggling with you know adjusting the lures, whereas, in the market I mean a marketing gimmick is to sell adjustable lures and positions of lures and a ductless split. So, that you can point the air in a particular direction, if you look at it, you know from a real need perspective where is the need I am standing here, I am comfortable I do not need to see the air conditioner or do anything other, but these are gimmicks and sometimes useful giving because they differentiate one product from another and they actually help put some premium on the product.

So, some of these fancy remotes would mean that the air conditioner would be sold at a higher price also and I have myself contributor to adding features in some of the companies that I work for we have added features. So, that we can differentiate and it is becoming more like if everyone in the market is doing then you also need to do, but look at it from a need perspective, when you connect to where the air conditioning what is it that you need, I agree there are time when you need to just have humidity louvered, then it should be known because human comfort is defined twenty 5 degrees if you maintain 50 percent more or less some adjustment fine, you know user a needs 22, user b needs 26, done it and then it is over.

But then for whatever it is worth's these units will allow for settings that can make the compressor run for de modification and it is typically an algorithm. So, instead of honouring the set point, then the compressor is switched on and off in response to a particular cycle. So, you want to de notify the room without respecting set point, you will probably over cool it, but then you will cause the compressor to continuously run and then stop and then run at the lowest fan speed. So, that reduces the sensible heat factor and increase the later need factor and then that would address that you could also have some things like reminding your it is time to change the filter.

So, you get an indication on the unit sometimes have multiple units. So, you want to define which remote will switch on which unit. So, you can again play with that functionality you could program that fine, this is a unit which will operate units on the left hand side this operate on left all these. Then, these are this is an example of a central controller if you have multiple units at home and you want to control all of them from one place, then this would be wired and it would have some algorithms to communicate with the multiple set of units which you could assign addressing systems and all that.

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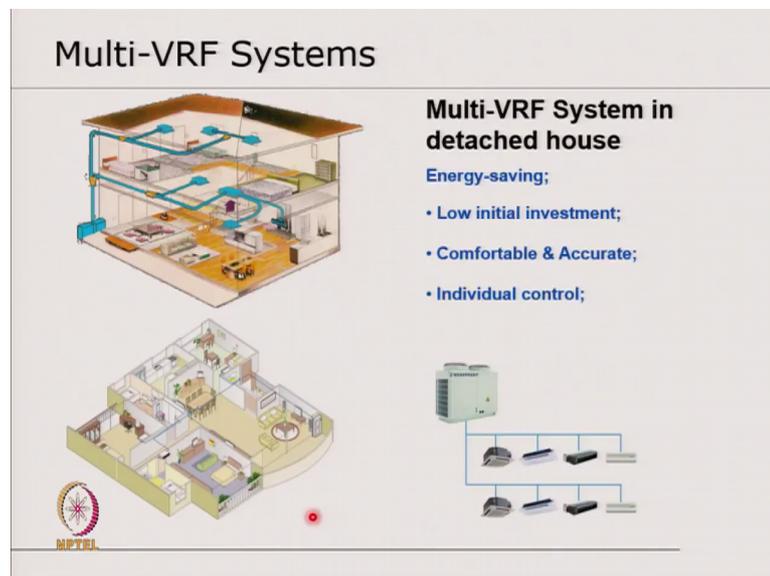
This is an example of selling a feature, again, some time back, it is be the I feel comfortable or I feel warm or I feel cold. So, you just give that as a signal to the unit and then the set point is altered and responds to that. So, if I am standing here and I am feeling slightly cold, I would press a button and it would alter. So, as it would not be you

know the user is not pushed into determining what temperature he should maintain, you simply giving a signal on how he is feeling.

Student: (Refer Time: 34:02).

Yeah, the key thing in the previous slide sorry about that was that the temperature sensor which is controlling the compressor on off is located in the return air path very close to the evaporator coil over here. So, when we are altering the set point, we are actually altering the temperature here and the key difference in this feature is that you are making the conditioner respond to temperature where you are again that feature is not needed.

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If the entire space is at a uniform temperature, then we look at multiple VRF systems and the whole value proposition for a VRF system is the ability to get annual energy savings. So, in this figure we can see multiple indoor units. So, we have several of these terminal units all connected through a common piping and distribution of refrigerant you know residence not all rooms need to be air conditioned all the time. So, that is the basic value proposition that gets built in multiple VRF systems.

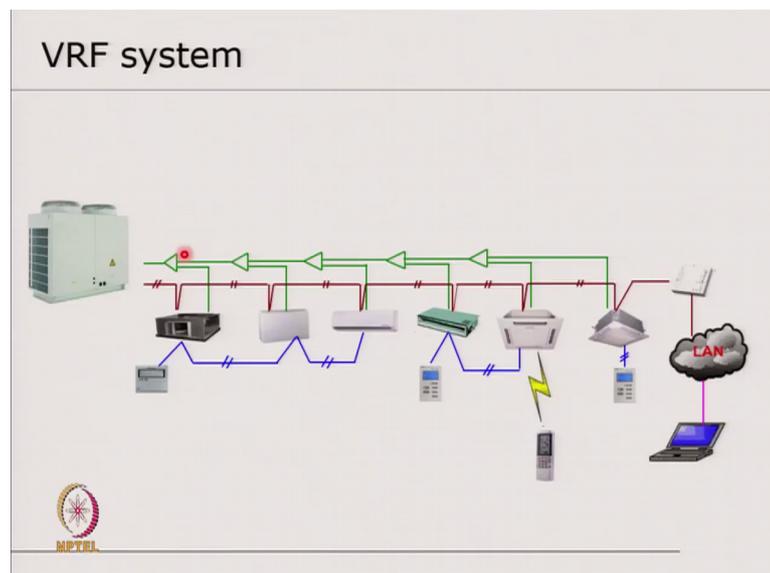
So, first is you get to downsize the total required capacity of the air conditioning and to relate to it think about your own homes do you need to air condition the drawing room and all the bedrooms at the same time most likely not right, but when you have guess you would want all the air all the bedrooms air conditioned and when you are having and

get together like an evening at together the bedrooms do not need. So, much air conditioning, but the living room has a lot of guests. So, you need air conditioning there.

So, a system like this will allow for the variation like they would adjust to those needs at an intention is that it should happen at a lower installed cost, but if you look at figures, today, we have not reached that yet. So, very simple when I was buying air conditioners for my home I was looking at could I buy a 6 ton unit which would take care of 3 rooms plus the living room and I found that no the cost was going almost double or two and a half times and that time.

So, did not make sense, but if you look at it from a pure engineering point of view the total installed capacity there is an opportunity to get it down and also to get benefit of annual energy savings. So, when we have a system of 6 tons which is coupled to just 2 indoor units of 1.5 ton which guess would be a normal residential air conditioning need, then the condenser coil is oversized and it can be used to run the compressor at a much lower condensing temperature allowing for a higher EER; a higher part load EER. So, this benefit is only a optional and available if we use VRF systems or some system similar to that.

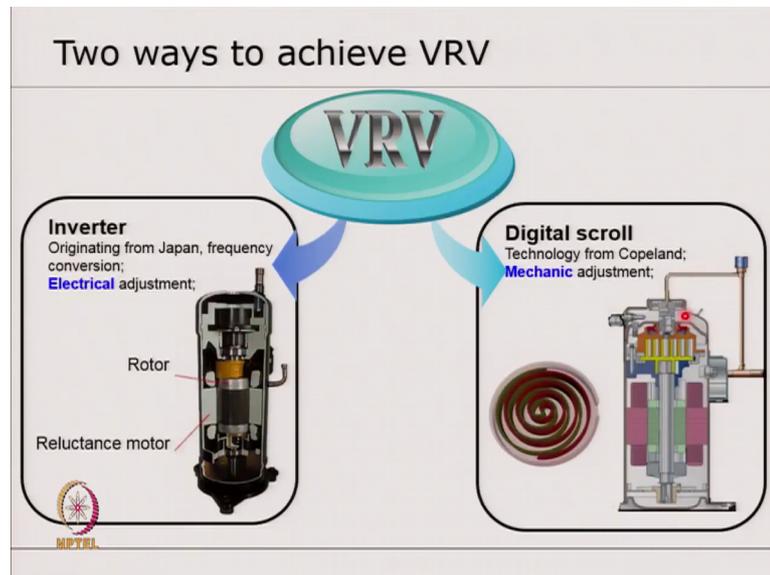
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If you look at just the systems, then here this is what an outdoor unit would look like in the outdoor unit, then is connected to several indoor units both through the refrigerant piping and also through the controls and if you look at the complexity, we need to know;

what is the cooling demand in each of these indoor units it needs to be consolidated at one point and then determine what compressor speed should be operated to address that cooling demand.

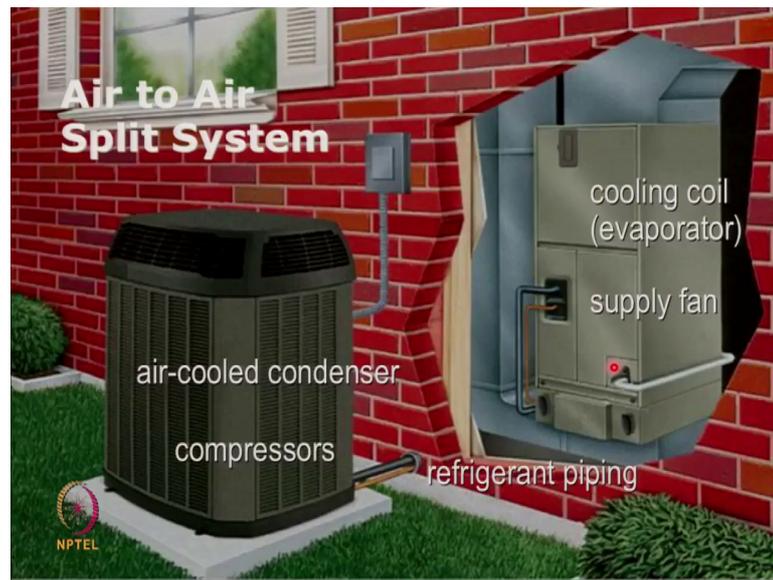
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And then the compressor speed variation or the refrigerant flow variation can be done in two ways; one is using a true variable speed compressor we would offer much higher part load efficiencies or using something like this which is equivalent to bypassing hot gas. But in effect what we are doing is we are unloading the compressor by moving one of the scrolls up. So, that there is no compression happen. So, the origin of the inverter technology is Japan and now it is spread across the world and if the prices are coming down because more manufacturers have developed the capability. So, particularly after some of the major manufacturers in china have come mastered the VRF that prices have become more reasonable and it is not so premium now, then it was 5 to 6 years back.

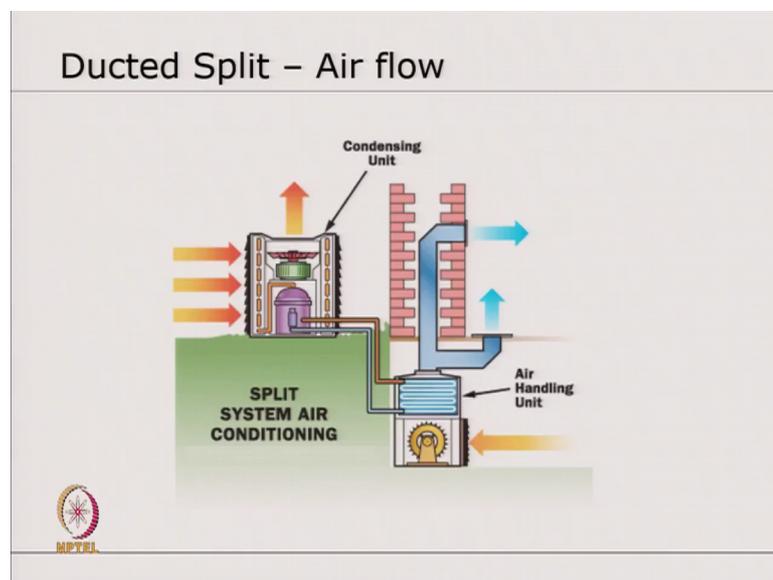
So, the digital stall technology is from Emerson. So, Copeland is a brand of Emerson and we touched upon how this is unloading it is found to be effective if the part load does not go below forty percent for a substantial period of time, then this seems to be giving some energy savings, but if you really want to go down to thirty percent of load then variable speed drive is the right solution here you have a DC motor. So, the losses at low speeds are minimized we could have a much higher part load efficiency with the DC motor, then you could have with a AC motor.

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Here is an example of a ducted system. So, very large a cooled condensing unit with compressors here and then is connected to a cooling coil supply air fan and then we see the ducts which would be servicing the home.

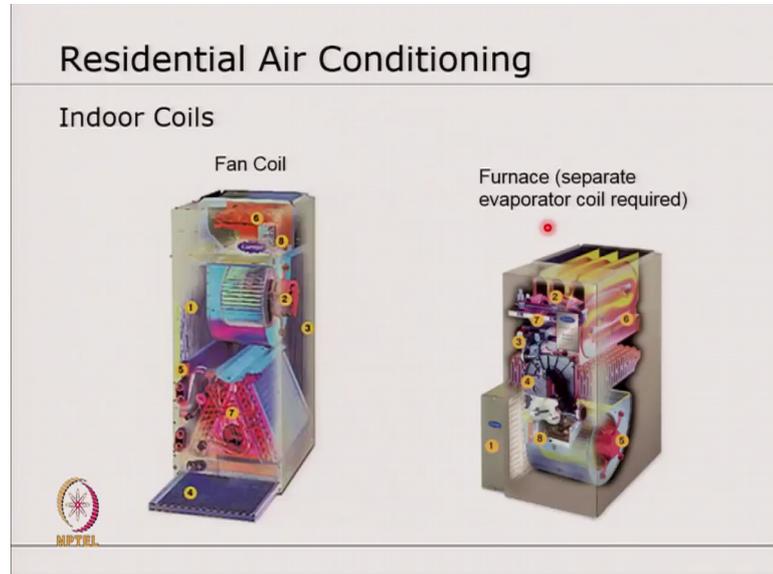
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Now, here we do not have as much of complexities surrounding distribution of refrigerant to different rooms and indoor units is to complete the ducted to split the airflow is something of this nature and this example actually is more of a US home

where in the basement, you have the air handling unit the indoor part of the air handling unit and then it is directing duct through different parts.

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So, if you want to look at the components that we discussed then here is the evaporator in the blower and if you were to put in a furnace if there is a heating need, then the furnace part would also be included ok.

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So, here closer to what we started with evaporator designs including the expansion, the condensate drain fan and the inlet outlet connections; so, all that is the so for today, we will close here.