Refrigeration and Air Conditioning
Prof. M. Ramgopal
Department of Mechanical Engineering
Indian Institute of Technology, Kharagpur
Lecture No. # 03
Applications of RTAC

Welcome to the third lecture on refrigeration and air conditioning.

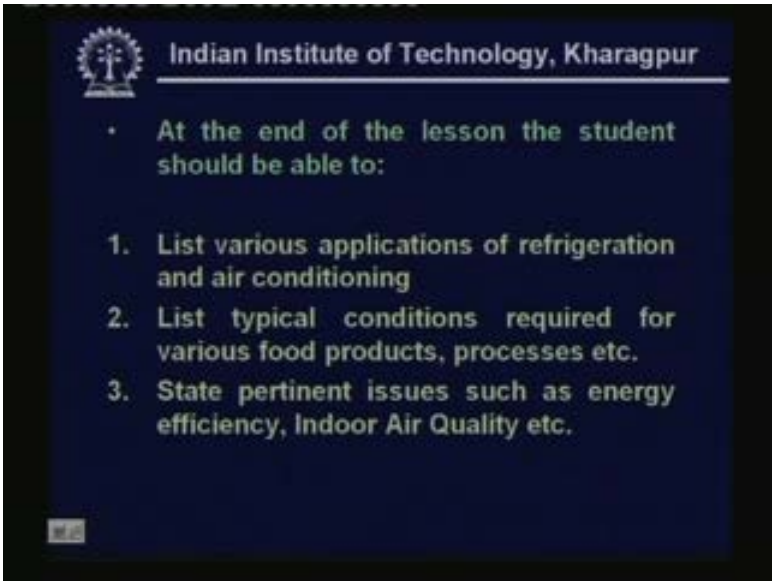
(Refer Slide Time: 00:00:41 min)

In the first two lessons we have discussed the historical aspects of various refrigeration cycles, Refrigerants and compressors. So in this lesson let us look at some of the important applications of refrigeration.

(Refer Slide Time: 00:00:50 min)

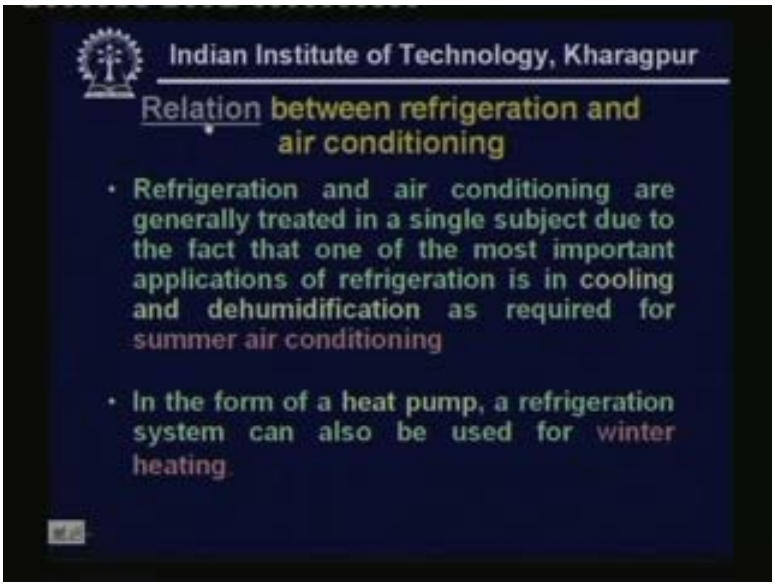
So the objectives of this lesson are to introduce applications of refrigeration. Particularly in food processing and preservation in chemical process, industries and some special applications of refrigeration. And then to introduce the applications of air conditioning. Then for industrial and for comfort applications.

(Refer Slide Time: 00:01:11 min)



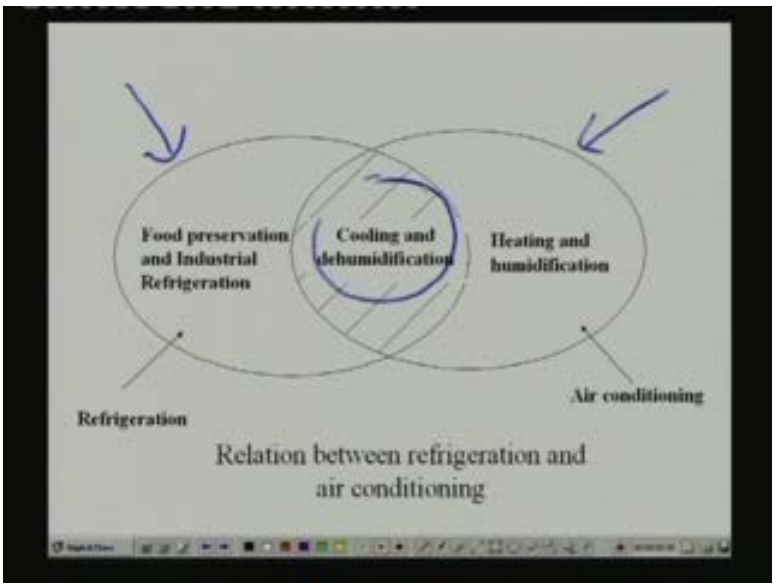
And at the end of the lesson you should be able to list various applications of refrigeration and air conditioning. List typical conditions required for various food products and processes and state pertinent issued such as energy efficiency indoor air quality etcetera.

(Refer Slide Time: 00:01:25 min)



Now before discussing the application in detail let us look at the relationship between refrigeration and air conditioning. Normally they are clubbed together, refrigeration and air conditioning, what is the relationship between them? We clubbed refrigeration and air conditioning because air conditioning is one of the largest; I mean users of refrigeration air refrigeration required in summer air conditioning for cooling and humidification of air. That is the reason why we normally club these two systems together. Refrigeration systems can although also used for winter air conditioning.

(Refer Slide Time: 00:02:06 min)



If we are using the refrigeration systems as a heat pump. This picture here shows the relationship between refrigeration and air conditioning. You can see that you have the area of refrigeration on one side. So this is the field of refrigeration and this is the field of air conditioning and there is a large area of over lapping. This over lapping area is because of cooling and dehumidification in cooling. And dehumidification one has to cool the air and one has to reduce the moisture content of air this requires a refrigeration system. And by far as I said this is the largest application of refrigeration. So this is the relationship between; and as i was telling you can also use refrigeration system in this area. If you are using refrigeration systems as a heat pump okay.

(Refer Slide Time: 00:02:55 min)

So now let us look at the applications of refrigeration can be grouped into four major areas. The first one is food processing preservation and distribution. And the second application is chemical. In chemical and process industries and the third application is as I said, some miscellaneous special application. Which we will see later and the fourth application is in the area of comfort air conditioning. These are the four major applications of refrigeration.

(Refer Slide Time: 00:03:25 min)

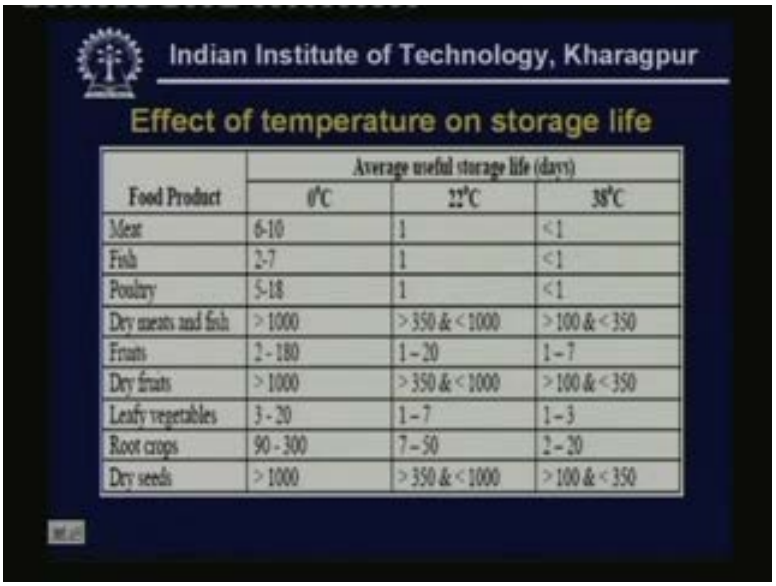
Now let us look at the applications of refrigeration in food processing preservation and distribution. In fact this is one of the classical applications of refrigeration and it is one of the most important applications of refrigeration. We know very well that food products can be stored for a longer time if you are keeping them at low temperatures. So for example our experience tells us that the food products can be stored for a longer time in winter compared to summer. Similarly if we are keeping them inside the refrigerator they can be preserved for a longer time. That means you can do the preservation at low temperatures. This fact is very well known and you can store both live products as well as dead products for a longer time if you are keeping them at low temperatures. Let us see what the live and dead products are. Live products are typically products which can breathe which undergo the process of respiration. These are just like any living beings. And the examples of live products are fruits vegetables etcetera.

(Refer Slide Time: 00:04:26 min)

And the live products get spoiled because of two reasons. One is because of the bacterial activity and the second reason is because of enzymatic processing. These are the two main reasons behind the decay of live products like fruits and vegetables. Now let us look at dead products. A dead product means they do not respire anything and products like fish meat they come under the category of dead products. And dead products get spoiled because of bacterial activity. And it

has been shown that both the bacterial activity as well as enzymatic processes can be reduced at low temperatures.

(Refer Slide Time: 00:04:58 min)



Food Product	Average useful storage life (days)		
	0°C	22°C	38°C
Meat	6-10	1	<1
Fish	2-7	1	<1
Poultry	5-18	1	<1
Dry meats and fish	>1000	>350 & <1000	>100 & <350
Fruits	2 - 180	1 – 20	1 – 7
Dry fruits	>1000	>350 & <1000	>100 & <350
Leafy vegetables	3 - 20	1 – 7	1 – 3
Root crops	90 - 300	7 – 50	2 – 20
Dry seeds	>1000	>350 & <1000	>100 & <350

Now let me show the effect of temperature on storage life. This table here shows how the storage temperature affects the average useful storage life. You can see that, for example if you are keeping storing meat at zero degrees centigrade then the useful storage life is six to ten days. Where as if the temperature is twenty-two degree centigrade then you can store it only for one day. And if the temperature is thirty-eight degree centigrade the storage life is less than a day. So you can see the dramatic change in storage life with temperature. Similarly for other products every where you can see that as you are increasing the temperature the useful storage life is reducing. So this is the principle behind food preservation using refrigeration. One thing usual you can notice here is that compared to products, normal products in dried form can be stored for much longer time.

For example meat at zero degree centigrade. It can be stored for six to ten days. But a dry meat can be stored for more than thousand days. That means you can store meat in the form of a dry meat for more than three years. What is the reason behind this? The reason is like this, the decay depends not only on the temperature but it also depends upon the presence of water in the form of liquid inside the product. So when there is water the bacteria become more active. This is

what is known as water activity. So in the presence of water plus high temperatures the decay will be faster. Where as if, there is no water for example in dried products the decay will be very slow this is the reason behind the drying of food products and storing them for a long periods.

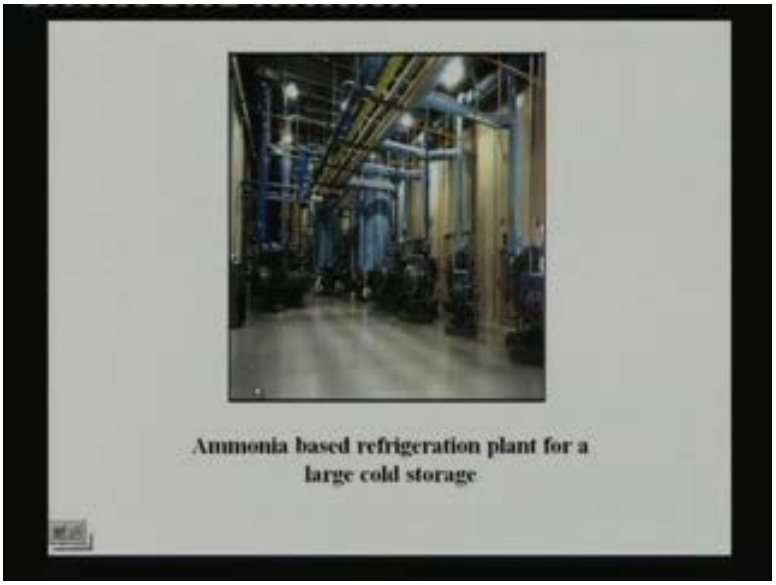
(Refer Slide Time: 00:06:36 min)

well let us discuss A very important aspect called cold chain; if you want to preserve food products effectively you have to maintain what is known as a cold chain. Let us look at a typical cold chain. For fresh products it consists of the following steps. The first step refrigeration is required for post harvest treatment. That means as soon as food products, fresh products like fruits and vegetables as soon as they are harvested they have to be cooled to remove the heat of harvesting post harvest heat. So this is the first step in any cold chain.

And the second step as soon as you remove the post harvest heat you have to transport the food products to a food processing plants and transporting has to be done in a refrigerator truck or a refrigerator vehicle. So this is the second step. The third step during food processing. We find that most of the food processing, processes require refrigeration. So this is the third step in cold chain. And the fourth step is storage of the processed food in large ware houses known as cold storages.

And then the fifth step is after you store them in cold storage for a long time they have to be distributed to the customers. So you first, you take them from the cold storage and send it to retail supermarkets and again refrigeration is required in retail supermarket also. So this is the fifth step in a cold chain. And the last step is when the customer buys the food products from the retail supermarket. He will take them and he will store it in his home domestic refrigerator. So this is the last step in typical cold chain and you have to remember that refrigeration is required throughout the six steps and even if one step is not proper then the food preservation will not be effective. And similar cold chains can also be thought of for frozen food products.

(Refer slide Time: 00:08:38 min)



Let me show you a typical refrigeration plan for a cold storage. This shows the photograph of an ammonia based refrigeration plant for a large cold storage normally ammonia is one very popular refrigerant used in large cold storages. You may be remembering that in the last two classes I have mentioned that ammonia is very good for NOx systems. Because of its excellent properties and also because it's inexpensive and easily available. So most of the cold storages use ammonia as the refrigerant. And here what the photograph shows is a large refrigeration plant for a cold storage system.

(Refer Slide Time: 00:09:10 min)

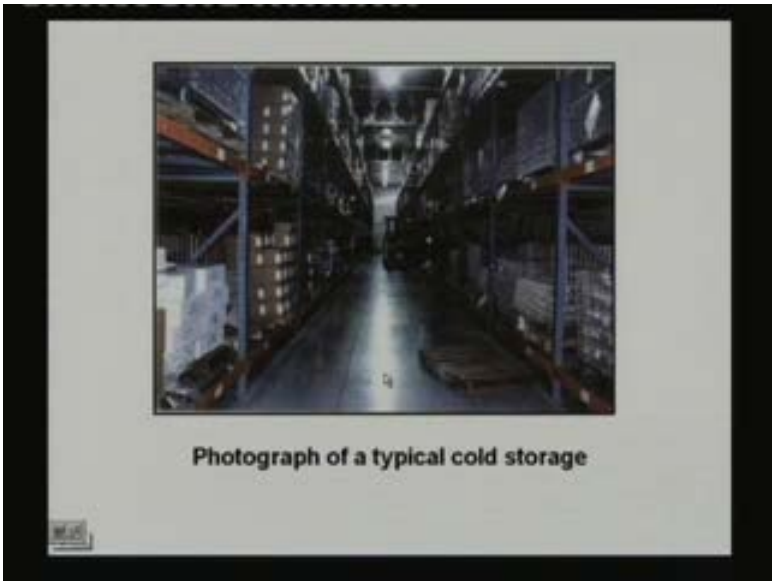
Now let us look at benefits of the cold chain. What are the benefits of a typical cold chain? The cold chain reduces the food spoilage. This is very obvious and excess crop of fruits or vegetables you can store them and you can distribute them during the off season or you can store them for peak demand. So this is the second advantage of any cold chain especially for seasonal fruits. And the third advantage is, you can make these food products available in places where they are not grown and thanks to refrigeration you are able to get apples produced in Australia or in far off countries. So they have to be shift from that place to our country which requires refrigeration. So this is another advantage of cold chain. And the fourth advantage of cold chain is it can, you can avoid distress selling by the farmers that means during the peak season there are no buyers there is too much of supply and less demand this is in the actions of cold storages the farmer has to sell it throwaway prices. So this can be avoided if you have proper cold storage facilities. So that during the season you store the excess crop and you sell them during off season. So that it is very beneficial to the customer.

So the cold chain and is very important. Especially because of the large population growth and reduced land for farming and typically it is said that in countries like India about thirty percent of our farm produce and fruits and vegetables are spoiled because of lack of proper cold storage facilities. So this is very important and realizing this, Government has actually given a lot of benefits for setting of cold storage etcetera.

(Refer Slide Time: 00:10:49 min)

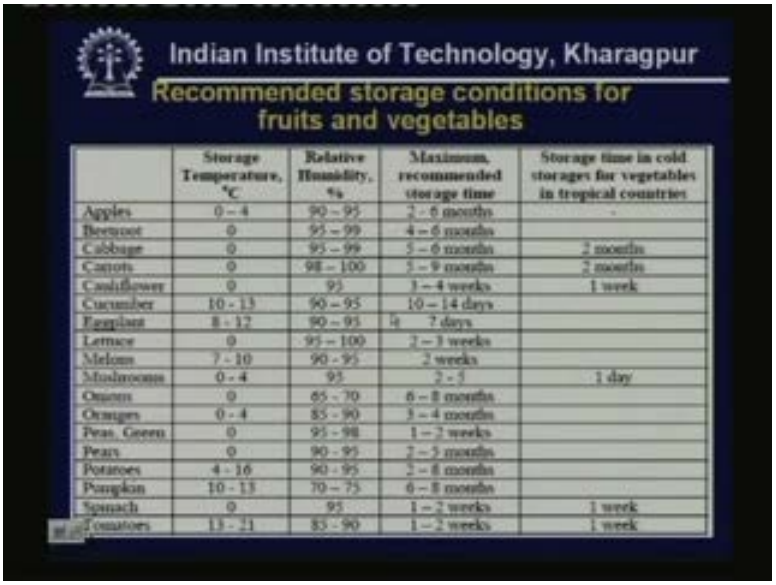
Now what are the conditions required for storage of food products? It is not that all the food products required the same conditions for storage. Every product has an optimum storage conditions and the storage life generally depends on the type of the product stored. The temperature at which product is stored and moisture contents and humidity inside the cold storage and air velocity inside the cold storage. So these are the four factors of course there is one more factor that is the initial quality of the food products. For example the product they which are brought to the cold storage if they themselves are bad then you cannot guarantee a long storage life. So these are the five important factors which decide the storage life of food products. Let me show the photograph of a cold storage.

(Refer Slide Time: 00:12:38 min)



Now this photograph shows a typical cold storage and you can see how products are stand and they are packed and they are stacked typical cold storage look like this. And you can also use this kind of cold storages for storing many fruits vegetables frozen fruits etcetera. In India typically storage of potatoes in cold storage is very popular.

(Refer Slide Time: 00:13:21 min)



	Storage Temperature, °C	Relative Humidity, %	Maximum recommended storage time	Storage time in cold storages for vegetables in tropical countries
Apples	0 – 4	90 – 95	2 - 6 months	-
Beetroot	0	95 – 99	4 – 6 months	
Cabbage	0	95 – 99	5 – 6 months	2 months
Carrots	0	98 – 100	5 – 9 months	2 months
Cauliflower	0	95	3 – 4 weeks	1 week
Cucumber	10 - 13	90 – 95	10 – 14 days	
Eggplant	8 - 12	90 – 95	7 days	
Lettuce	0	95 – 100	2 – 3 weeks	
Melons	7 - 10	90 - 95	2 weeks	
Mushrooms	0 - 4	95	2 - 3	1 day
Onions	0	65 - 70	6 – 8 months	
Oranges	0 - 4	85 - 90	3 – 4 months	
Peas, Green	0	95 - 98	1 – 2 weeks	
Pears	0	90 - 95	2 – 5 months	
Potatoes	4 - 16	90 - 95	2 – 6 months	
Pumpkin	10 - 13	70 – 75	6 – 8 months	
Spinach	0	95	1 – 2 weeks	1 week
Tomatoes	13 - 21	85 - 90	1 – 2 weeks	1 week

So this shows the typical recommended storage conditions for fruits and vegetables. Here are the food products, the storage temperature at which they have to be stored and the relative humidity and the maximum recommended storage time and the storage time for tropical countries. You can see that the storage temperature in general varies between zero degrees centigrade to twenty degree centigrade.

I am talking about the storage of fresh products. That means they are not in frozen condition but they are in condition in which they have harvested. And you can see that for most of the products, the required relative humidity is quite high. That means you have to maintain very high relative humidity inside the storage space. This is required because as a relative humidity is low then food products will lose moisture. That means it will leave to weight loss because of drying. So you have to maintain a high relative humidity. Of course the products like onions and pumpkin you really do not require very high relative humidity. Because they have a thick skin and the moisture loss is very less. And you can also see here that the maximum recommended storage time varies anywhere between few days to a few months depending upon the type of the product. And you can also notice that the storage time in general is less in tropical countries compared to cold countries.

(Refer Slide time: 00:15:26 min)

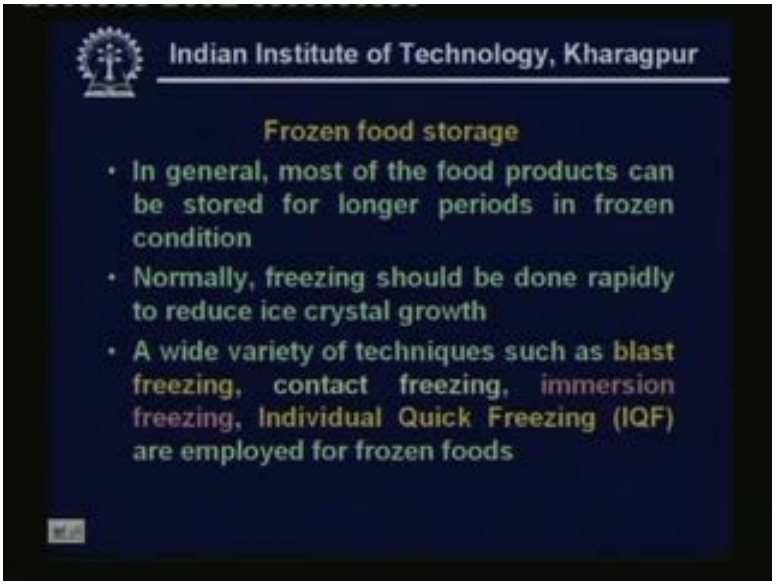
Now let us look at the storage of other food products such as meat, fish, and poultry. They can be stored for longer periods in frozen conditions. The reason behind this is also same as that of a dry product. When you are freezing a food product you are actually temporarily stopping the water activity. Because in frozen conditions water will be available in the form of ice. So the water activities considerably reduced so the bacterial activities also reduced. Thereby you can increase the storage life of food products.

Then food products like dairy products like milk butter ice cream etcetera, they require refrigeration at various temperatures during processing and also during storage. For example milk. As soon as milk is taken from the cow simi they require precooling. That means immediately after cow is milked the milk has to be precooled. And then in that precooled condition it will be sent to a dairy plant or dairy farm. Where it has to be heated to seventy-three degree centigrade for pasteurization. Then after, it has to be cooled to four degree centigrade and it is stored at four degree centigrade. So you require about thirteen to fifteen degrees centigrade for precooling and about four degree centigrade for storing milk. Whereas milk products like ice cream and all require much lower temperatures. For example the optimums are recommended storage temperature for ice cream is about minus thirty degree centigrade and other milk products like butter they require slightly higher temperature.

They require about seven to ten degree centigrade so you can see that different milk products require different temperatures. And a dairy plant which produces all these milk products requires refrigeration plants which can provide different temperatures on different conditions.

And refrigeration is also required in breweries and all. And also for processing and storage of cold drinks for fruit juices for wine beer etcetera. And drinks like wine, beer etcetera the refrigeration required because they involved the process of fermentation. And fermentation is an exothermic process. So heat is released during the making of wine or beer. So that heat has got to be taken out that is the reason why we require refrigeration in the breweries.

(Refer Slide Time: 00:17:40 min)



Let us look at frozen food storage. As I mentioned earlier frozen foods can be stored for a longer time. Compared to fresh foods this is because of the reduced bacterial activity. And normally freezing should be done rapidly to reduce the ice crystal growth. This is very important that means not only the final temperature is important but also the rate at which the food products has to frozen.

You have to rapidly freeze the food products. So that this ice crystal growth can be minimized. Now what happens if you freeze it slowly the ice crystals inside the food products they become bigger and they damage the cellular structure of the food products? So to avoid this we have to freeze food products very fast so typically any freezing food freezing equipment must provide large refrigeration capacities. So that the moment you bring the products they can be frozen fast.

So let me show some of the well or let me name some of the freezers used in industries for freezing food products.

We have what is known as blast freezing. Blast freezers using the blast freezing technique. And we have contact freezers, we have immersion freezers and also known as another one what is known as individual quick freezing. These are the techniques employed in industries for freezing those food products.

(Refer Slide Time: 00:19:02 min)

Normally as I was mentioning you require large refrigeration capacities as the process has got to be rapid and sometimes instead of using a refrigeration system liquid nitrogen or solid carbon dioxide is used for rapid freezing the food products. It is also quite effective and there is another process of food preservation is known as freeze drying. In freeze drying what is done is you first freeze the food product. That means once you convert all the water in the food product into ice then you dry the product by sublimation. That means this freeze drying process involves two steps. First freezing the food products then the process of sublimation. During which all the water stored in the food products in the form of ice will be sublimated. So finally you end up with a dry product devoid of any water. So this is a technique used for producing products like instant coffee milk powder etcetera.

And this is very effective technique. Because the quality of the product will be generally good compared to normal freezing or normal drying. And since this is the costly process this process is generally used for special applications such as in space or military applications. Where weight is a very important factor. So what is done in food products are freeze dried so you have a very light food product and which can be stored for longer time. And when the user wants to consume it all he has to do is he has to add water to the product and then you can consume it. So this is a very popular technique for this kind of special applications.

(Refer Slide Time: 00:20:41 min)

Now of course as you know very well domestic refrigerator thanks to the development in vapour compression refrigerant technology. Domestic refrigeration for food preservation at customers place has became so popular that it is one of the most important or necessary appliances in any home in all developed countries and also in developing countries. And of late particularly in developed countries and also in big cities the supermarket refrigeration has become quite popular.

Supermarket refrigeration means as I was mentioning earlier food products will be stored in cold storage. And from the cold storage you have to bring them, you have to store them in a supermarket. So that customers can buy them. And the supermarkets also required refrigeration otherwise they get spoiled. So supermarket refrigeration is again different. You required a different design methodology for supermarket refrigeration. Because a large variety of products are stored and these products required different storage conditions and all. And the refrigerant systems used for supermarket refrigeration have got to be very reliable. Because of the cost of the products stored. So this is actually a challenging job to ensure an efficient at the same time very reliable system for supermarket refrigeration.

I will just show a typical photograph of a supermarket.

(Refer Slide Time: 00:22:10 min)

So this shows the section of a supermarket with refrigerated display cases and all. You can see that how different products are stored and all these products are under refrigerated conditions. And refrigeration is also required in areas like remote and rural areas for storing farm produce and dairy products etcetera. And one problem with remote and rural areas is they may not have access to bit power that means they may not get electricity from the grid.

(Refer Slide Time: 00:22:26 min)

So you have to have systems which do not depend on grid.

(Refer Slide Time: 00:22:49 min)

But which are also reliable. So now let us look at applications of refrigeration in chemical process industries it is used for separation and liquefaction of gases in petrochemical industries and refineries. Refrigeration is also required for removal of heat of reaction in various chemical industries. It is required for dehumidification of air process, air in pharmaceutical industries and it is also required for recovery of solvents and storage of low boiling liquids in various chemical industries.

(Refer Slide Time: 00:23:16 min)

And let us look at some of the special applications of refrigeration required manufacturing. Because in manufacturing cold treatment of metals and precision parts and cutting tools as carried out to improve the dimensional accuracy of the precision parts. And to improve the hardness wear resistance and tool life of various materials and tools. So this is one of the very important applications of refrigeration in manufacturing. And refrigeration is also required in medical as you know it is required for storage of blood plasma tissues vaccines and etcetera. And it is also required for manufacture and storage of a wide variety of drugs and sometimes refrigeration also used for local anesthesia.

(Refer Slide Time: 00:24:05 min)

And in construction refrigeration is required for two purposes. The first purpose is during the setting of concrete and mixing. And setting of concrete is an exothermic reaction that means heat is released during setting of concrete. Now if you look at huge walls for example the walls of the dam and all, when their during setting lot of heat is released because of the exothermic process.

And this heat has to rejected from the wall. And if the heat rejection is not efficient what happens is these temperature gradients will develop inside the wall. And this will lead to thermal stresses which will finally lead to cracks so to avoid the cracks thick walls require artificial refrigeration techniques.

So what is done normally is in large walls of the dams and all pipes are buried through which either a refrigerant or chill water flows which take the heat of the setting process and keeps the temperature gradients small. So that there won't be any appreciable thermal stress developments.

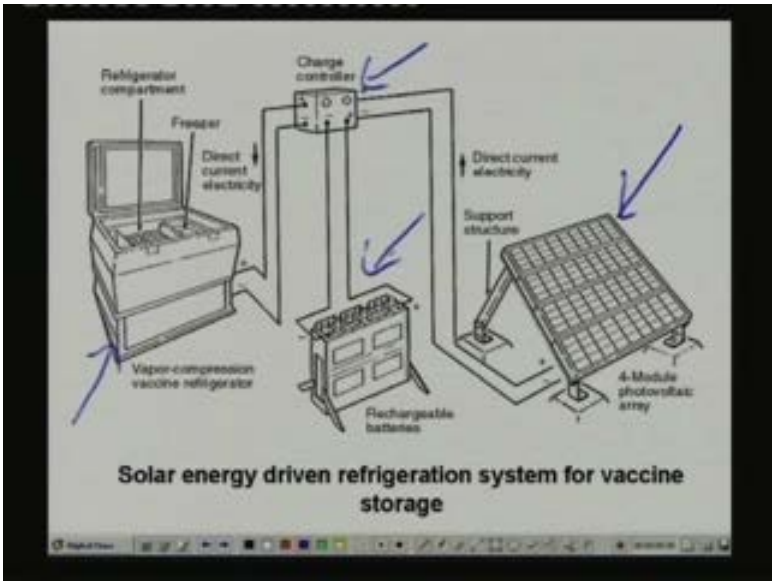
So this is one of the applications of the refrigeration in construction. And appliqué refrigeration is also used sometimes for freezing of wet soil to facilitate excavation and this particularly happens in cold countries. Where the soil becomes frozen and if you want to excavation you have to freeze it first and then do the excavation.

And refrigeration is also required sometimes; it is also used for desalination of water by freezing. As you know desalination can be done in two ways either you can boil the water and collect

them and then condense the water vapour or the other method is used you can freeze the salt water. So when you are freezing the salt water what happens is the salt does not freeze first. So first the water part freezes. So what you get out of the frozen salt solution is comparably pure water. So this is one of the methods by which you can do the desalination. And of course refrigeration is also required in for manufacture of ice cubes ice flakes etcetera. Nowadays commercial ice makers are available using which you can produce ice in a wide variety of ways like in the form of cubes or flakes etcetera. And refrigeration is also required in preparation of ice skating rinks for example in summer season if you want to have a ice skating rinks then using artificial refrigeration you can provide ice skating rinks for skating purposes. So what is generally done is refrigeration pipes are buried inside the water and when the refrigeration systems runs the water freezes and a ice is formed and which can be used for skating purposes.

And refrigeration is also required very important application for storage of vaccines in remote and rural areas, vaccines like polio vaccines etcetera.

(Refer Slide Time: 00:27:44 min)



Let me show a photograph of storage system for vaccines. This is the solar energy based system. Yeah this picture here shows a solar energy driven refrigeration system for vaccine storage. What we have here is a photovoltaic array. This photovoltaic array converts solar energy into direct d c current electricity and this d c current can be used for running a vapour compression

refrigerator here. And of course you can also use a d c current for running a thermoelectric refrigerant system but in this particular schematic a vapour compression refrigerator is used. This is connected to photovoltaic array here.

This is the photovoltaic array and sometimes solar energy may or may not be available or sometime excess solar energy may be required. So to take care of the variations in solar radiations. We have here a charge controller and also a storage battery. That means a typical photovoltaic raven refrigeration system requires photovoltaic array a charge controller and a rechargeable battery plus a refrigeration system. In this particular picture a vapour compression refrigeration system is used. Of course you can also use solar energy directly instead of converting it into heat. You can also use directly or have a vapour absorption refrigeration system. Of course in general absorption systems are bulky are compared to refrigeration vapour compression refrigeration system. So either a thermoelectric refrigeration system using p v modules or a vapour compression system using p v modules are popular. Of course nowadays people are also developing absorption systems using solar energy for remote and rural areas.

Now let us look at applications of air conditioning.

(Refer Slide Time: 00:29:43 min)

So air conditioning is basically required for two purposes. One the very important application of air conditioning is in the area of what is known as comfort air conditioning. And the second application of air conditioning is for industrial applications. And what is the purpose of comfort air conditioning? As the name implies the objective of any comfort air conditioning system is to provide thermal comfort to the occupants. And what is the objective of an industrial air conditioning system. An industrial air conditioning system is required so that you can provide the required conditions for process is to be carried out in an efficient way or products can be produced in an efficient way. So you have comfort air conditioning and industrial air conditioning.

(Refer Slide Time: 00:30:29 min)

Now let us look at comfort air conditioning as I was telling the objective of comfort air conditioning system is to provide thermal comfort. Now how do we define thermal comfort thermal comfort may be defined as the state of mind? This expresses satisfaction with the surroundings. So this is the definition of thermal comfort. And thermal comfort generally depends upon maintaining certain temperatures of a human body. For example the core of a human body has to be maintained at the temperature of about thirty-seven degree centigrade.

If this temperature varies by even one or two degrees. Then human beings feel very uncomfortable. And if the temperature variation becomes large then it can become fatal or it can

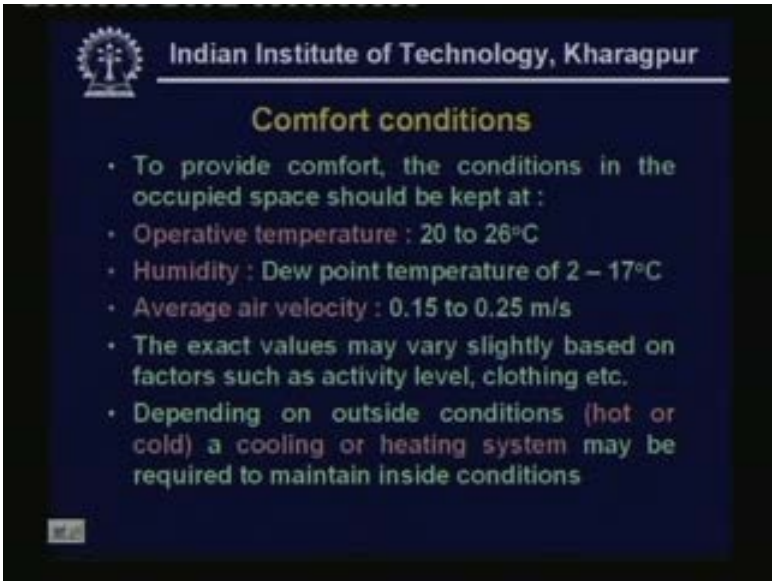
meet to irreparable damages. Normally the comfort air conditioning is used to maintain the temperature at about thirty-seven degree centigrade.

(Refer Slide Time: 00:31:29 min)

So without doing any extra effort the people, the person can feel comfortable. Now let us look at a little bit of physics behind a comfort air conditioning. A human body for all engineering practical engineering purposes can be treated as a heat engine. That means a human body consumes food and the chemical energy stored in the food is converted into heat and work. And the work part is used for certain bodily functions and the heat part is used for maintaining the human body at certain temperature level. And what is excess heat is there has got to be finally rejected to the surroundings so any living human being will be continuously rejecting heat produced inside the body to the surroundings. And the rate at which heat is rejected depends upon the external conditions.

So as I was telling the condition of the surroundings affects the temperature of the body. And the basis of the comfort air conditioning system is to maintain the right surroundings. So that human body can reject heat in a comfortable manner.

(Refer Slide Time: 00:32:31 min)



Let us look at the comfort conditions. What are the requirements for a typical occupied space so that the person can feel comfortable in the occupied space? Generally the temperatures what is known as operative temperature of the condition space should be between twenty to twenty-six degrees centigrade. And the humidity or moisture content should be corresponding to a dew point temperature of two to seventeen degree centigrade. So you can see that for humidity there is a larger band width. And you also have to maintain certain air motion or certain velocity of air inside the occupied space. So that human being can feel comfortable and this required air velocity falls in the range of about point one five meter per second to about point two five meter per second.

If the air velocity is too low human being feels stagnant and may he will have an uncomfortable feeling and if the air velocity is very high then he will have the problem of draughts. So air velocity also has got to be maintained within a range. And the exact value have been what I have given here is a range of values. So the exact value depends upon several factors. For example it depends upon the type of clothing a person is wearing. For example if a person is wearing very heavy clothing then he required a lower temperature is required in the condition space. And if a person is wearing light clothing then you can go for a higher temperature in the condition spacing. So ultimately the optimum temperature to be maintained depends upon several factors.

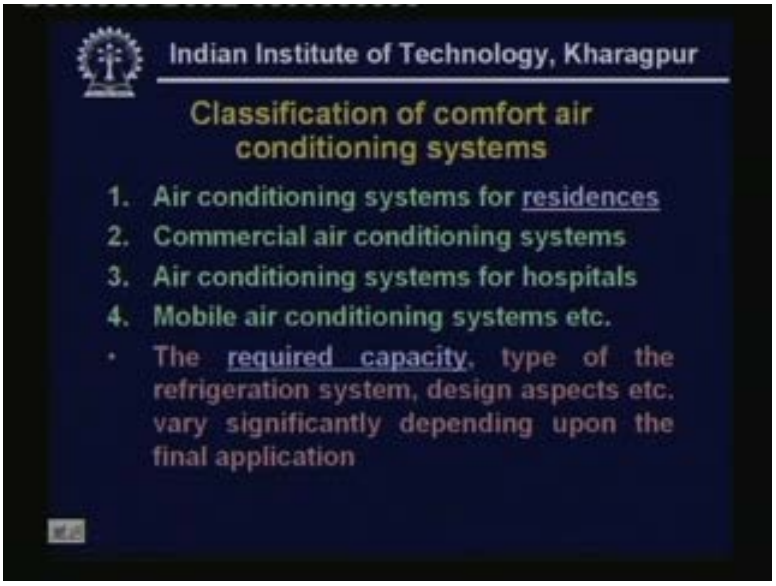
another important factor is activity for example a person is doing very light activity then the required temperature will be higher and if the person is doing very vigorous activity for example in gyms etcetera then you have to maintain low temperature.

The reason for this is of course when the activities high more heat are produced. So more heat has got to be loss from the human body. That means higher amount of heat transfer which requires higher temperature difference.These aspects will be discussed in detail when we discuss thermal comfort in a later chapter. And depending upon the outside condition it is not necessary that you always require a refrigeration system for providing thermal comfort. For example if the outside conditions are very cold and dry then you require not a refrigeration system but a heating system.

You have to heat and humidify the air and then supply that hot and humidified air to the conditions space. So that the conditions space can be maintained at the required conditions irrespective of the outside cold and dry conditions. So you this is what is known as winter air conditioning. And the other opposite is when the outside condition is very hot and humid typically this is the scenario in countries like India and all where the outside conditions are hot and humid in summer. So you require a refrigerant system which cools and dehumidifies the air and supplies this cold and dehumidified air to the conditions space. so that you can maintain the required temperatures .

So you have a summer air conditioning system and a winter air conditioning system. And if you remember I was mentioning that refrigeration system if you are using it for cooling purposes is required for summer air conditioning. And if you are using a refrigeration system as a heat pump then you can use it for winter air conditioning system also. That means a single refrigeration system depending upon the design can function as an all year air conditioning system provide cooling and humidification in summer and heating and humidification in winter.

(Refer Slide Time: 00:36:05 min)



Now depending up on the a news comfort air conditioning systems can be classified as residential air conditioning systems, commercial air conditioning systems, air conditioning systems for hospitals and mobile air conditioning systems. And the required capacity and what is the type of refrigeration system to be used and what is the design strategy. What kind of controls is required all these things depend up on the final applications. That means you cannot you do not have a unique solution for all these applications depending up on the news you have to suggest a suitable system.

For example if you have a system which has to cater to a house. Then the exact temperature requirement is not there. For example one degree plus or minus one degree is okay.

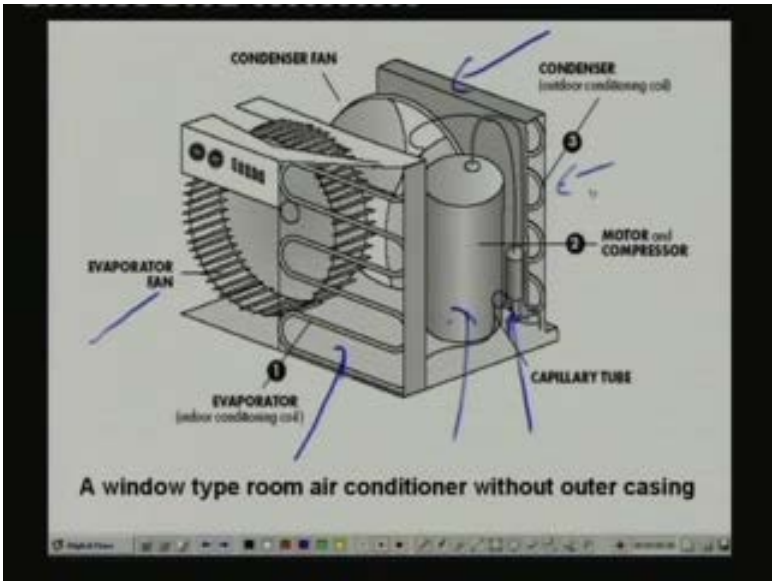
Whereas if you are using it for other applications where the temperature is very critical then you have to have very good control system, which will maintain the temperature exactly. Whereas in residential air conditioning system you may not require such very sophisticated control systems.

Also typically residential air conditioning systems are of low capacity. Whereas large commercial air conditioning systems are of very high capacity. And one special case is the case of mobile air conditioning systems. That means air conditioning systems used in cars trains air craft’s etcetera okay.

They require a totally different design method design strategy because one typical problem with any mobile air conditioning system is the outside conditions may vary continuously. For example a train is moving from let us say Kashmir to Kanyakumari then it encounters all kinds of weather all kinds of outside conditions as it moves from one place to other place. So whatever be the outside condition the air conditioning system must maintain the frame comfort conditions inside. So irrespective of outside conditions you have to have the same inside conditions. So this is one peculiar aspect of mobile air conditioning systems.

Let me show one typical residence air condition system used in residences.

(Refer Slide Time: 00:38:17 min)



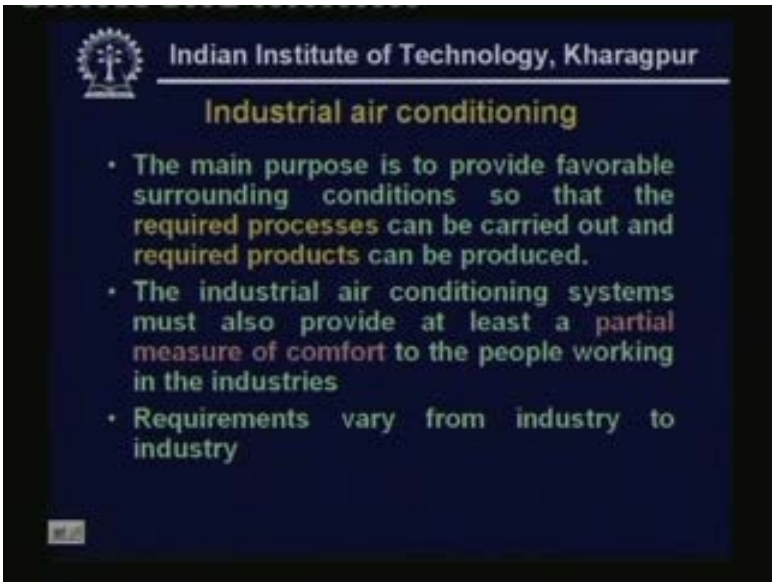
This is a an air con room, what is known as a room carry air conditioner and if you take it out of the casing. So what you have here, if you recollect typical air conditioning system requires a compressor here and a condenser and an evaporator coil here and an expansion valve. So it is nothing but a refrigeration system. And it also uses some accessories such as an evaporator fan and a condenser fan for improving the heat transfer rate and for distributing the air. So this is a typical window type air conditioning system. Of course you are also have what is known as a split type of air conditioning system. Where the condenser and compressor are separated from the evaporator and the expansion valve.

That means you can keep the condensing unit consisting of compressor and condenser outside the occupied space where as this window air conditioner you have to mount it in a window.

And the required capacity normally the required capacity of any refrigeration system is given a unit called tonnes of refrigeration system. You might have heard people saying one point five tonne of refrigeration air conditioning system or two tonne air conditioning system etcetera.

What is this tonne? This tonne is a classical unit of refrigeration capacity and one tonne of refrigeration is equivalent to about three point five one kilo watt of heat. That means if a air conditioning system having a capacity of one tonne will be able to extract three point five kilo watts of heat from the occupied space. This is the meaning of tonnes.

(Refer Slide Time: 00:40:12 min)



Now let us look at industrial air conditioning systems. The main purpose here as I mentioned earlier is to provide the favorable surrounding conditions. So that the required processes can be carried out and required products can be produced. Of course the industrial air conditioning system must also provide at least a partial measure of comfort to the occupants. Because typically all industries will have lot of people working there. So you cannot really look a look at only the product or process point of view. You also have to look at the people that mean

industrial air conditioning system. At least provide some amount of comfort to the workers so that they can work efficiently.

So these are the two main objectives of any industrial air conditioning system.

Now let us look at some of the typical industries which require air conditioning and as I have mentioned in case of refrigeration the requirements here vary from industry to industry. That means depending up on what kind of products you are producing or what kind of processes are being carried out the required conditions will be varying.

(Refer Slide Time: 00:41:18 min)

Some of the examples are textile industries. Textile is one of the oldest users of air conditioning.

The yawn used in the textile is very sensitive to temperature and humidity. So if you want to have a very high output you have to maintain the humidity and temperature within certain limits.

So that the yawn can move at high speech without breaking. This is the reason why it was used in early days and how the output was increased using an air conditioning system. And air conditioning is also required in printing presses. In printing presses what happened is, typically, for example you look at a colour printing press the ink will be deposited in stages so and when paper moves from one stage to the other stage the ink has to dry off before it reaches the other stage.

For example let us say that first stage you are depositing red ink and next stage is black ink by the time the paper moves from the red ink stage to the black ink stage. The ink has to dry if it does not dry then there will be problems and there will be mixing of the colours and all. So you have to again maintain certain humidity. So that drying can takes place take place within the required time. So all printing press is required a very good air conditioning system. And also the paper used is sensitive to the humidity. So you have to maintain humidity in certain levels. So that the paper can you can prevent the curling of the paper etcetera. And as I mentioned already refrigeration is also required or air conditioning is also required in manufacturing of several precision parts. And this is particularly, so in case of watches wrist watches or in case of semi conductor elements and all where the cleanliness temperature humidity are very important.

For example the humidity is not right. And if the people start sweating and when they handle the parts with sweating hands then water gets deposited on the parts which lead to rusting since here the dimensional accuracy is very important. You have to prevent any variation in the dimensional accuracy that means you have to maintain both temperature as well as humidity.

In fact all electronic industries semiconductor making industries and other electronic industries. The air conditioning is a very critical requirement and in those industries in addition to the temperature and humidity the cleanliness of weight is also very important. That means there should not be any dust particles or any other solid particles in the air. So in addition to a good air conditioning system they also have a variety of filtration equipment which will be filtering air and provides clean air to the conditions space.

Then as I said the semiconductor industries is one of the largest users of air conditioning and in pharmaceuticals several pharmaceuticals involves several chemical reactions and all and they require controlled condition of temperature and humidity. So when they are being produced and when they are being stored you require certain temperatures and humidity. In fact you might have seen many of the medicine bottles and all they write that they store in a cool and dry place that means the medicine is sensitive to temperature.

You have to store it at any cool place and it is also sensitive to moisture that is why they say cool and dry. Then photographic materials photographic materials are also very sensitive to moisture and to some extent to temperature also. So again they require air conditioning. In fact if you

remember Eastman Kodak is the first companies to use air conditioning for storing its photographic products were back in nineteen hundred.

And air conditioning is very much required in computer rooms especially in large computer centers and all there is a large amount of heat reception. So which has got to be taken out? So you require an air conditioning system also in large computer centers there will be lot of heat generation. Because of people so which also needs to be taken out. So all computer centers require good air conditioning systems also the computer centers require clean air also because you should not have any dust particles floating around. So typically you have to maintain not only the temperature and humidity but also the cleanliness of air.

Then air conditioning is also required in mines, for example in mines as you go down the temperature will increase. So it will terribly hot underground and inside the mines and for the workers they have to do a hard work inside the mines that means they will be rejecting lot of heat. And outside temperature is very hot very high and lot of heat generation is there. Then if air conditioning is not provided then the miner will be subjected to what you known is heat stress and he cannot work properly. So all mines require good air conditioning and another important requirement is the air conditioning systems for mines have to provide fresh air also that means ventilation is also important.

So you have to again have systems which can provide right temperature conditions and also the right amount of ventilation inside the mines. And air conditioning is also required in large power plants. In large power plants inside conditions will be typically hot because the presence of boilers and other equipments etcetera. So the workers will be generally under some heat stress

So you have to provide some amount of comfort by way of air conditioning this is also true in case of steel industries. Steel industries are also inside conditions will be very harsh. So you have to have some kind of an air conditioning system. One problem with large power plants or steel mills etcetera is, it is not possible to air conditioning the entire power plant or you cannot air conditioning in entire steel mill.

So that is not commercially feasible. So what you have to do or what is generally done is they reserve to what is known as spot cooling that means certain areas. Where the workers are only

those areas are cooled and rests of the areas are not cooled. So this is what is known as spot cooling so by using spot cooling you can provide some measure of comfort to the workers.

(Refer Slide Time: 00:47:53 min)

Now let us look at one very important aspect of air conditioning what is known as indoor air quality. We will see in later lectures that an air conditioning system there were energy consumption of an air conditioning system depends upon how much amount of fresh air or how much amount of ventilation that you are providing.

So in the olden days to reduce the energy consumption what people used to do is, they used to reduce the amount of fresh air. That means they used to recirculate the same air again and again so as to reduce the energy consumption. But later it was observed that people who were spending lot of time in air conditioning buildings were suffering from several problems and this is known as a sick building syndrome. That means people working in air conditioning buildings experienced certain sicknesses and this is known as sick building syndrome. And later they found that not only temperature in humidity and air motion but also the quality of air that you are supplying to a conditions space is very important. This is even more so in nowadays people are spending a large part of their life inside the buildings.

It is estimated that about eighty percent of the time is spend in conditioned space. So if the condition space is not cleaned and the air quality is not good then people will fall sick. As a result of which as a separate branch of air conditioning this indoor air quality or IAQ it is called as IAQ has emerged as a separate branch of air conditioning and it requires different techniques and all to ensure air quality. So this is one pertinent and important issue of indoor air quality and as I said any air conditioning system must provide not only required temperatures and all but also clean and healthy environments.

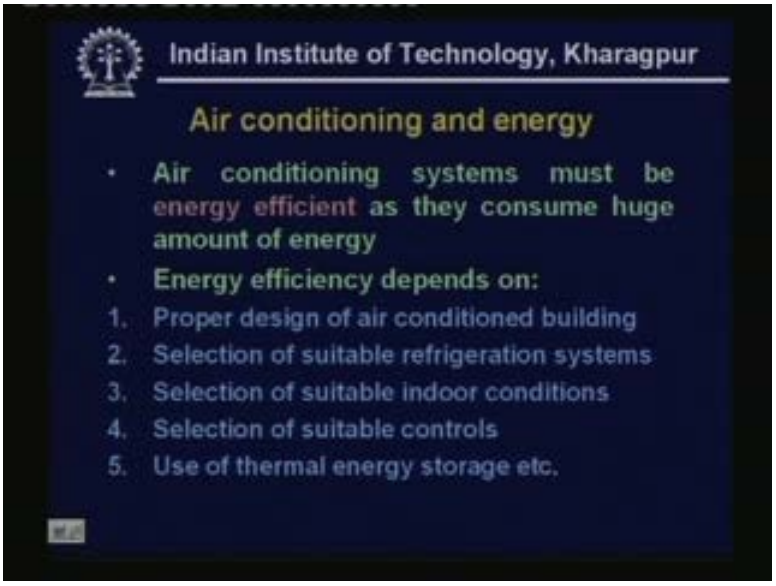
In the olden days the people were very sure that an air conditioned space provides comfort but they were not really sure whether it is good for health or not. And subsequent studies it have shown that if we do not desire air conditioning system it in fact; it can be very unhealthy.

So nowadays the Infosys is not only on comfort but also on healthy environment. So this is the area which is dealt with by IAQ or indoor air quality.

As I mentioned the sick building syndrome is very common in especially in places. Where the outside it is dirty and the designer of air conditioning system provides very less ventilation to save energy.

So in these and the materials used typically the indoor air quality depends on the amount of ventilation that is provided. And what is the quality of outside air or the fresh air that we are supplying and also what kind of materials we are using inside the conditioned space. So these three parameters ah decide whether an environment is healthy or not. And generally any indoor air quality study recommends the required ventilation qualities and also recommends what kind of materials should be used within the conditioned space. And how to treat the air. The fresh air outside air itself may be dirty then you have to treat the air before you supply into the condition space. so all these aspect come under the indoor air quality.

(Refer Slide Time: 00:51:14 min)



Now let us look at another very important issue that is energy. All air conditioning systems consume a large amount of energy and now because of the requirements in all industries and then many office places residencies etcetera. The installed air condition capacity is increase in tremendously and all these systems require energy. So the energy consumption by the air conditioning system is also increasing tremendously. And in the olden days people did not care much for the energy consumption of air conditioning systems. So they were designing the system without optimizing them. As a result they were consuming lot of energy.

So nowadays the focus has shifted. Now people say that they want a system which provides not only comfort but which is also energy efficient. So this is second issue of any air conditioning system. So energy efficiency has to be guaranteed by the supplier and by the designer and the energy efficiency of any air conditioning systems depends not only on the air conditioning system but also on other factors.

Let us see what is the factors which decide the energy efficiency of an air conditioning system. It depends upon the design of the air conditioned building itself. For example if the building is not designed to properly then it consumes lot of energy. And one nowadays if you might have seen a lot of people use lot of glass. So use of glass actually is will lead to larger loads and air conditioning system. That means we require a bigger air conditioning system which will ultimately lead to larger energy consumption.

So here the architect has a role to play. So the architect with along with the air conditioning engineer has to do the complete system design. So that the total energy consumption is reduced and people also use names like intelligent buildings etcetera. With reference to the energy consumption and the second important aspect is selection of suitable refrigeration systems.

Already refrigeration systems are not equally good for all applications. So you have to depend upon your requirement. You have to select suitable refrigerant systems. For example there are in area as where you have lot of waste treaties are available. Then it makes sense to select a vapour absorption system. Which uses he waste heat and not an electrical energy or mechanical energy?

So depending upon the situation you have to select a required refrigeration system and the third factor is a selection of suitable indoor conditions.

As I mentioned as I have shown the optimum indoor temperature varies from anywhere between twenty-two to twenty-seven or twenty-six degree centigrade. And you will see later that, if you are trying to maintain lower temperature inside the condition space that will lead to higher energy consumption. That means a lower conditioned space temperature means in general higher energy consumption.

So if it is not absolutely required we must try to may keep the temperature on the higher side to reduce the energy consumption. And several factors again come into picture here. For example you are designing an air conditioning system for summer. And let us say typical office building. Let us say and everybody in the office is wearing very heavy clothing. So as I mentioned if everybody is wearing heavy clothing like suits etcetera then you have to maintain lower conditioned space temperature.

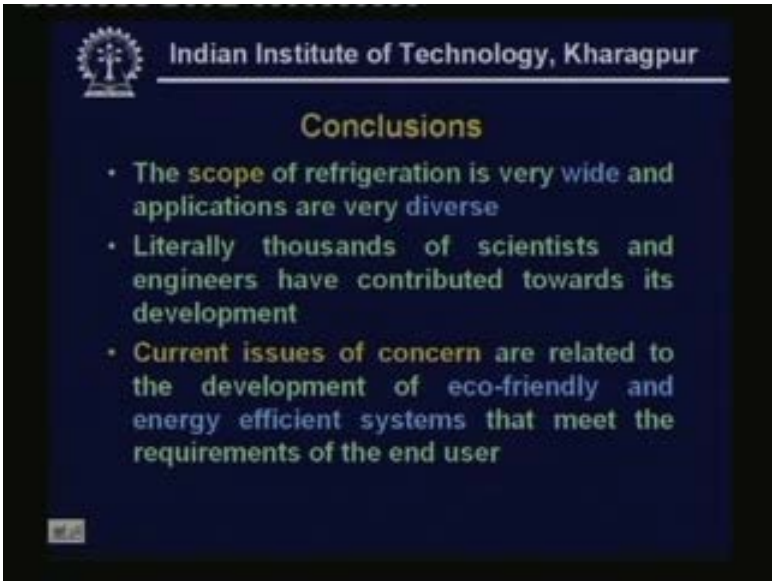
So that he can detect the heat that means lower temperature in the condition space and higher energy consumption. And if the same person is wearing light clothing then you can have a higher temperature in the condition space and thereby you can reduce the energy consumption. So the selection of suitable temperature, this is also very important of course sometimes this can be psychological aspect also. People may think that lower temperature is better. But it is the job of the air conditioning engineer to convince that it is not necessarily, so and the required comfort temperature is not a single point but it is a range and selection of suitable controls. You can also reduce the energy consumption of air conditioning building by using suitable controls. Now for

example, if you have air conditioning system which uses a variable speed compressor so you can reduce the energy consumption in using an efficient variable speed compressor so you require a control which will be able to vary the compressor speed. Then other aspect is the use of thermal energy storage systems.

The concept here is like this. And if there are many places where the night temperature can be very low the day temperature can be very high. For example places like deserts where nights are very cold and days are very hot. So in such cases you can use the concept thermal energy storage. That means you can store the cold in the night and you can use the part of it to offset the heating in the daytime. In fact this is also the reason why all buildings like old temples forts etcetera they are comfortable even in summer. Because there the walls are so thick that they store lot of thermal energy and thereby they provide comfort even without any artificial air conditioning system.

So the thermal energy storage can be provided by way of the walls itself or you can also have other means of providing thermal energy storage. So these are the ways by which you can control the energy consumption and improve the energy efficiency of an air conditioning system. Now let us conclude this lesson.

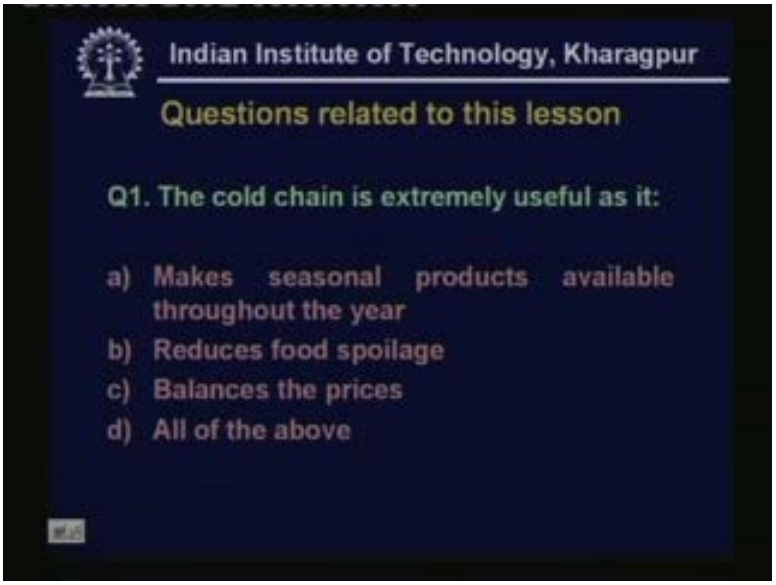
(Refer Slide Time: 00:56:55 min)



We have seen that the scope of refrigeration and air conditioning is really very wide and the applications are very diverse. And it has grown tremendously thanks to the efforts of thousands of scientists and engineers over period of say hundred to hundred and fifty years. So it is not the result of a single man effort but it is the effort of many people and right now as I mentioned the issues of the concern are first is energy efficiency and second important issue is eco friendliness.

That means the refrigeration systems that you are using should be eco friendly they should not create any damage in the environment. Now these are the important concerns and people are working on to develop systems which are both eco friendly as well as energy efficient.

(Refer Slide Time: 00:57:53 min)



Thank you, and based on this lesson I have given some questions and the answers to this will be provided in subsequent lessons.

Thank you.