Building Services III
Lecture 2

Refrigeration and Refrigerant

The term refrigeration may be defined as the process of removing heat from a substance under controlled conditions. We can recall from the previous lecture of how refrigeration is done, it's not about supplying cold air or cooling the space. It's a process of removing the heat from the space. That's what the definition says about refrigeration. Here the heat is being generally pumped from low level to the higher one and is rejected at high temperature. How does this happen and what is the medium that plays this role? It is called the refrigerant. The refrigerant is a heat carrying medium which during its cycle in a refrigeration system absorbs heat from a low temperature system and delivers it to a higher temperature system.

The whole refrigeration process revolves around the refrigerant and this one particular element is very important. Let us see how this refrigerant helps carry out the process of refrigeration.

The refrigerant has a variety used in vapour compression systems. How do we choose a refrigerant? The choice of fluid is determined largely by the cooling temperature required. You can see in the picture here, the different types of refrigerants used in a market. They are from the family of Chlorinated fluorocarbons or CFCs, also known as freons - R-11, R-12, so on and so forth. This is a very schematic sketch or diagram that explains the principle or refrigeration or air conditioning. Let us assume, this system as a space or the place where you want to refrigerate or air condition. R is the air conditioner. The refrigeration or air conditioning system (R) transfers the heat from a cooler low-energy reservoir to a warmer high-energy reservoir. You want to air condition this space which is a system. What does this air conditioning system do? It takes away the heat from the low energy reservoir and it rejects the heat to the surroundings which is nothing but the atmosphere. Basically, the refrigeration which we use in today's context is classified into two types; Vapour Compression Refrigeration and the other is, Vapour Absorption Refrigeration which uses thermal energy. We will be primarily talking about vapour compression refrigeration in our lecture.

This is a schematic work flow or the cycle that explains the vapour compression refrigeration or the refrigeration cycle. Let us quickly look at the different components; the Evaporator, the Condenser, the Compressor and the Expansion device. Let us go step by step and see what happens in each of these components.

Stage 1 - the low pressure liquid refrigerant in the evaporator absorbs heat and changes to a gas. During the process it changes its state from a liquid to a gas and the evaporator exit is slightly superheated. Just a small recap from the previous lecture, we talked about change of

state from a liquid to a gas, a gas to a liquid and liquid to a solid and all of those things, we also talked about subcooled liquid and in the beginning of the lecture, we saw how a refrigerant helps in cooling a space. Here they say the low pressure liquid refrigerant which is coming from this Expansion device, once it goes to the Evaporator, it absorbs the heat and changes into a gas. It is in liquid state, when it passes through the Evaporator, it absorbs the heat and changes into a gas. It is in liquid state, when it is passing through the evaporator, it absorbs the heat from the space. Basically, the evaporator is the indoor unit that is considered to be an Evaporator. This evaporator changes the state of this refrigerant from liquid to gas. By absorbing the heat in the space or the room. This liquid or gaseous refrigerant then moves on to Stage 2 into the compressor. Here, the superheated vapour enters the compressor where its pressure is raised, the temperature will also increase, because a proportion of the energy put put into the compression process is transferred to the refrigerant. This compressor basically compresses the gaseous or superheated vapour refrigerant and thereby, increasing its pressure and also its temperature. After this stage, after it has compressed, it is sent to a Condenser. Here, the high pressure superheated gas is cooled in several stages in the condenser. First the refrigerant went through the evaporator, it changed its state from liquid to gas by absorbing the heat. Then, it went into a compressor, it was compressed, its pressure was increased, its temperature was increased, it was was in a gaseous state. The third step in the condenser is where it is cooled in several stages. The initial part of the cooling process de-superheats the gas before it is then turned back into liquid. The cooling for this process is usually achieved by using air or water. Before it changes its state from gaseous to liquid, this is desuperheater. Basically, at the condenser this high temperature refrigerant gas is cooled down by a medium either air or water. We will look into the details of air cooling in the later part of the lecture. A further reduction in temperature happens in the pipe work and liquid receiver, so that the refrigerant liquid is subcooled as it enters the expansion device. Before entering the expansion device, it is totally cooled down. The last stage 4, the liquid passes through the expansion device, which reduces its pressure and controls the flow into the evaporator. The expansion device reduces the pressure of the refrigerant. It also controls the flow into the evaporator, so that the correct amount of the refrigerant is supplied to the evaporator. Not more or not less. This is the whole cycle or process.

Components of Various Compression Systems

This refrigeration cycle consists of four fundamental changes of state; one is expansion, vaporization, compression and lastly it is Condensation. All these process have change of state happening at different components or parts of the system like- compressor, condenser, receiver, expansion valve and evaporator.

Let us go into detail about these components, their primary function and the different types and their applications. First, let us look at the compressor. In all these slides I have given you a flowchart likewise; the circled area in this diagram is the item which we are talking about currently. The low pressure and temperature refrigerant from the evaporator is drawn into the compressor through the inlet or suction valve, where it is compressed to a high pressure and temperature. The high pressure and temperature vapour refrigerant is discharged into the condenser through the delivery or discharge value. Basically, from the evaporator, the low temperature or the low pressure enters the compressor here. It is sucked through a suction valve and once compressed, the temperature and pressure are raised and discharged into the condenser for further cooling through the discharge valve. The compressor is divided into two basic, two major headings or two types, one is the Positive displacement type and the other is Dynamic. The positive displacement type is further segregated into Reciprocating, Rotary. Dynamic is further divided into Centrifugal and Axial. WHat is positive displacement type? In the positive displacement type, a given quality of air or gas is trapped in a compression chamber and the volume it occupies is mechanically reduced, causing a corresponding rise in pressure prior to discharge. It is quite a simple process, where it is trapped and the volume is reduced mechanically. So naturally the pressure increases. One is a reciprocating compressor and the other is a rotary compressor. As the picture here depicts, the reciprocating compressor works like a Bicycle pump. It is used for air and refrigerant compression. Works like a bicycle pump - a cylinder volume reduces while the pressure increases, the pulsating output. Here, the crystals move up and down. Many configurations are available in reciprocating compressors. It is also commonly used in all the air conditioners we use.

The second type is the Rotary compressor, here the pistons are replaced by Rotors. Here, there is a continuous discharge happening which was not the case in the previous, reciprocating compressor. The benefits of this compressor are basically that it's low in cost, compact, low in weight and easy to maintain. Many a times we choose the rotary compressors or the air conditioners. The sizes or the capacity of the rotary compressors will be between 30 - 200 horsepower (hp). There are also further subtypes like lobe compressor, screw compressor and rotary vane/ slide vane compressors. The next type is the dynamic compressor. Here, the dynamic compressor impacts velocity energy to continuously flow air or gas by means of impellers rotating at very high speeds. There we saw pistons or bicycle pumps that reduce the pressure, or reduce the volume but here in dynamic compressors there are Impellers that rotate at very high speeds thereby compressing the gas or increasing its pressure. The velocity energy is changed into pressure energy both by the impellers and the discharge volutes or diffusers. Here, the volume reduction and pressure increase is happening at two stages. The basic types of dynamic compressors are Centrifugal and Axial.

Dynamic compressors are used in large scale air conditioning like industrial applications, big hotels or big shopping malls and such. Here, in the Centrifugal compressors, the rotating impeller transfers energy to move air. Suitable for continuous duty applications where the AC has to run for 24 hours in a day. Designed oil free. High volume applications > 12.000 cfm. Axial compressors are primarily used in aircraft air conditioning, much larger scale. It produces a continuous flow of compressed gas that is the advantage of having an Axial compressor. It has the benefits of having high efficiency and large mass flow rate. We have seen the basic types of compressors, let us see which are the compressors that we normally encounter or use in day to day life like window,split and packaged air conditioners that we use in our residents or offices. Here, the compressors used in window, split and packaged airconditioners are typically hermetically sealed compressors. They are encased in a sealed casey. The hermetically sealed compressors is a gas tight steel shell within which is housed an electrical motor and the compressor unit. These compressors may be of the reciprocating type, the scroll type or the rotary type. Basically, it is a steel shell, it is a compact shell in which you have the compressor and the electrical motor. It is thus a compact element or component in a system. There are different types and we will see how they work; the Reciprocating type, the Scroll type and the Rotary type.

First the, Sealed reciprocating type. These compressors typically have one or two pistons mounted on the crankshaft extension of the motor. As the motor turns the crankshaft, the piston moves up and down in the cylinder. On the top of the cylinder is mounted a valve plate assembly with a suction and discharge valve. Each time the piston moves down, the suction valve opens and the gas is sucked into the cylinder. When the piston moves up, the gas is pushed against the discharge valve which opens to let the compressed gas out. These compressors are available from very small fractional ton capacities up to 10 ton units. From 1 to 10 tons. This mechanism is very simple, it is from our high school physics. This is the picture of a reciprocating sealed compressor.

The next type is the Sealed scroll compressors. The Scroll compressors are a recent innovation. They are inherently more efficient and are capable of producing power savings. Consequently they have become very popular in recent years. Scroll compressors use two interlocked spiral-shaped members which enclose the refrigerant gas in pockets between them. One of the spiral-shaped members are fixed and the other rotates causing the refrigerant to be squeezed into ever decreasing pockets until it reaches the centre from where it is discharged. These compressors are basically used to save power or save energy. They are basically more efficient that the previous type i.e the Sealed reciprocating compressors. These compressors are currently available in small capacities up to 14 tons. The advantages include high reliability, low

maintenance, low noise and vibration and high efficiency. This is the picture of a sealed scroll compressor which we are talking about.

The last type will be the Sealed Rotary compressors - the rotary compressor has a turning rotor eccentric to the cylinder housing, and blades which slide to form a continuous seal for the refrigerant gas. At the beginning of the stoke a volume of refrigerant gas enters the chamber. As the stroke progresses the nature of eccentricity squeezes the gas thereby compressing it. Rotary compressors are quieter compared to the Reciprocating compressors. However, owing to technical constraints, the Rotary compressors are far more successful in capacities up to 2 Ton. By virtue of being far quieter, they have become more popular in window air conditioners and to some extent in split air conditioners. These are the three basic types that we encounter day to day in our lives. Here is a picture of the sealed rotary compressor.

Condenser

The next important component of the Vapour compression cycle is the condenser. The condenser consists of coils of pipe in which the high pressure and temperature vapour refrigerant is cooled and condensed. The condenser already reduces the volume and increases the pressure in temperature and once it enters the condenser, the refrigerant is cooled and condensed. The refrigerant while passing through the condenser rejects its latent heat to surrounding condensing medium which is normally air or water. It rejects the heat just gained in the compression process. This, hot refrigerant vapour received from compressor is converted into liquid form in condenser. Naturally, we know the law of change of state, when the heat is removed, it changes from one state into another, from gaseous to liquid state.

Once again, condensers also have two basic types. As saw in the previous slide, the heat is rejected by the refrigerant, it is either air cooled or water cooled. They are precisely the types. In air cooled condensers what happens is, these types of condensers eject heat to the outdoors and are simple to install. Most common uses for these condensers are in residential packaged air conditioning units. Air cooled condensers are quite common, all of you might have seen. Whenever we install the split air conditioner in our house, e have an indoor unit and the outdoor unit. The outdoor unit is nothing but the condenser unit. Here the heat is ejected out into the atmosphere, there is a blower fan that pushes out the heat into the atmosphere.

In water cooled condensers, they are very common in commercial and industrial applications. Water flow is opposite to the refrigerant flow and is called the counterflow method. Through counterflow method, the cooling of the condenser happens here, in water cooled condensers. There is one specific type; Tube-in-a-shell type in water cooled condensers that have tubes and shells outside covering the tubes. The water is passed through the shell to cool down the pipes where the refrigerant is present. There is another type that is called, Evaporative Condenser

which is once again water cooled in which the condenser is inside a cooling tower like setup where water is sprayed from top and water drips on the pipes, removing the heat and there is a fan which blows or sucks the hot air from the water. This is an evaporative condenser.

The next component in the vapour compression cycle is Receiver and the expansion cycle. This receiver and expansion valve is located between the condenser and the evaporator. First is the receiver which receives the cooled refrigerant and then passes to the expansion valve before it reaches the evaporator. Let us see what are their functions. First the receiver - the condensed liquid refrigerant from the condenser is stored in a vessel known as a receiver, from where it is supplied to the expansion valve or refrigerant control valve. It is nothing but a storage vessel which collects the liquid before it is pumped into the expansion valve. What is expansion value - the function of this valve is to allow the liquid refrigerant under high pressure and temperature to pass at a controlled rate after reducing its pressure and temperature. Some of the liquid refrigerant evaporates as it passes through the expansion valve, but the greater portion is vaporised in the evaporator at the low pressure and temperature. Next comes the Evaporator, the final component in this cycle. What does the evaporator do? The evaporator consists of coils of pipes in which the liquid vapour refrigerant at low pressure and temperature is evaporated and changed into vapour refrigerant at low pressure and temperature. Here, the evaporation process happens on the inside, happens in the room or the space to be air conditioned. During evaporation process, the liquid vapour refrigerant absorbs its latent heat of vaporization from the medium which is to be cooled. Thereby, with the removal heat, it becomes cool. The evaporators are of two types; Shell-and-tube and the other is direct expansion tube type. The spray shell-and-tube type evaporators spray refrigerant evenly over a distributor, where it receives energy from the warm condenser water returning from buildings that are flowing through the tube bundles. This is used in large scale applications where you use cooled water cycle or chilled water cycle, that is why they talk about the refrigerant evenly over evaporates, shell-and-tube. This refrigerant receives the heat from the condenser, the warm water running through the pipes and it cools. Thereby cooling the water and the cooled water helps in air conditioning the different spaces in the building. The water passes through the tube bundles in a defined number of passes and is expelled at a low temperature used for building air conditioning. Basically, in this evaporator, water is passed through the tubes on which the refrigerant is sprayed and this refrigerant changes state by absorbing the heat from the water, in the process the water gets cooled and then this water is circulated in pipes throughout the building that has to be air conditioned and naturally the cooled water helps in conditioning the different spaces. The next type of evaporator is the DIrect expansion, shell-and-tube. Here, the direct expansion shell-and-tube evaporator is designed with refrigerant flowing through the tubes and chilled water flowing through the shell. Pretty much the same but in the previous case the water was flowing through the tubes and the refrigerant was sprayed on the tubes but

here, its the reverse. The water is in the shell whereas the refrigerant flows in the tubes. Thereby, the same result occurs here also.