Overview of Chiller Compressors

An Online Continuing Education Course for Engineers

Course Number: HV-4004

Credit: 4 Hours / 4 PDH / 4 CPD

Overview of Chiller Compressors

A. Bhatia, Mechanical Engineer

Abstract

In the HVAC industry, the refrigeration machine that produces chilled water is referred to as a chiller. A chiller package operates either on the principles of vapor compression or vapor absorption. The vapor compression system uses mechanical energy in the form of an electric motor to drive the cooling cycle, whereas absorption chillers use heat to drive the process. The vapor compression chiller system, which is far more prominent in commercial buildings, consists of four major components: the compressor, evaporator, condenser, and expansion device. All four components are packaged as a single unit. The classification of vapor compression chiller packages is generally by the type of compressor, with centrifugal, reciprocating, and screw being the most common.

Chillers are the largest consumers of energy in commercial buildings. Therefore, it is important to understand the relative benefits and limitations of the various types in order to make the right economic decisions in chiller installation and operation.

This course will discuss the types of compressors used in water-cooled chillers. It will examine the various types of chiller compressors, their advantages and disadvantages, and their applications. Throughout the course, the words chiller and compressor are used interchangeably, as they have the same meaning.

The course is divided into three parts:

Part I: Types of Chiller Compressors
Part II: Comparison of Chiller Compressors
Part III: Economic Evaluation of Chiller Systems

PART I: TYPES OF CHILLER COMPRESSORS

Most cooling systems, from residential air conditioners to large commercial and industrial chillers, employ the refrigeration process known as the vapor compression cycle. At the heart of the vapor compression cycle is the mechanical compressor.

Its function is to pump refrigerant through the cooling system and to compress gaseous refrigerant in the system. This allows it to be condensed to liquid and to absorb heat from the air or water that is being cooled or chilled. Not all air-conditioning applications have the same capacity requirements.

For this reason, chillers are grouped according to the type of compressor:

- **Positive-displacement** compressors physically compress the vaporized refrigerant into a smaller volume and higher pressure, and include reciprocating, rotary, and scroll types. These compressors deliver a constant volume of gas under a constant speed.
- **Dynamic** compressors increase the vaporized refrigerant pressure through the kinetic energy imparted on the refrigerant by a rotating impeller. A centrifugal compressor is a dynamic compressor, and is not a constant displacement type.

Each type utilizes a specific and somewhat ingenious method to pressurize refrigerant vapor.

Reciprocating Chillers:

Reciprocating compressors are positive-displacement machines that use the reciprocating action of a piston inside a cylinder to compress refrigerant. As the piston moves downward, a vacuum is created inside the cylinder. Because the pressure above the intake valve is greater than the pressure below it, the intake valve is forced open and refrigerant is sucked into the cylinder. After the piston reaches its bottom position, it begins to move upward. The intake valve closes, trapping the refrigerant inside the cylinder. As the piston continues to move upward, it compresses the refrigerant, increasing its pressure. At a certain point, the pressure exerted by the refrigerant forces the exhaust valve to open, and the compressed refrigerant flows out of the cylinder. Once the piston reaches its top-most position, it starts moving downward again and the cycle is repeated.

These compressors are available in three configurations:

- **Hermetic:** The motor and compressor are enclosed in a common housing, which is sealed. Because the components are not accessible for repair, the entire compressor unit must be replaced if it fails. The hermetic sealed units are most common in small capacities.

- **Semi-hermetic:** The motor is also part of the unit; however, it is not sealed. Semi-hermetic compressors have an advantage over hermetic compressors in that they can be re-built a number of times if necessary, giving them a much longer service life.
- **Direct drive:** The motor and compressor are separated by a flexible coupling. These types of units utilize older technology, and are not commonly used today.

The main factors favoring reciprocating compressors are low cost and efficient when applied in low capacities. Multiple reciprocating machines can be installed for higher building loads. Further advantages include simple controls and the ability to control the speed through the use of belt drives. These chillers are available from 0.5 to 150 tons of refrigeration (TR*****), and are available in both air-cooled and water-cooled heat rejection configurations.

Reciprocating Compressor

A major drawback of reciprocating chillers is their high level of maintenance requirements in comparison with other chiller types. Reciprocating chillers have more moving parts than centrifugal or rotary chillers, resulting in an increased need for wear-related maintenance activities.

Reciprocating chillers also generate high levels of noise and vibration. Special precautions must be taken to isolate the chillers from the facility to prevent the transmission of machine-generated vibrations and noise.

Finally, reciprocating chillers are not well suited for applications with cooling loads in excess of 200 tons. As the units grow in capacity, their space requirements and first costs exceed those of other chiller types. In addition, the energy requirements for larger units exceed those of other chiller types.

Screw Chillers:

Screw compressors are positive-displacement machines that use helical rotors to compress the refrigerant gas. The rotors rotate they intermesh as they rotate, alternately exposing and closing off interlobe spaces at the ends of the rotors. When an interlobe space at the intake end opens up, refrigerant is sucked into it. As the rotors continue to rotate, the refrigerant becomes trapped inside the interlobe space and is forced along the length of the rotors. The volume of the interlobe space decreases, and the refrigerant is compressed. Compressed refrigerant exists when the interlobe space reaches the other end. There are two types:

- A **single-screw** compressor uses a single main screw rotor meshing with two gate rotors with matching teeth. The main screw is driven by the prime mover, typically an electric motor.
- A **twin-screw** compressor consists of accurately matched rotors (one male and one female) that mesh closely when rotating within a close tolerance common housing. One rotor is driven while the other turns in a counter-rotating motion. The twin-screw compressor allows better control and variations in suction pressure without much of an effect on the operation efficiency.

Available in air-cooled and water-cooled configurations, screw chillers are available for up to 750 tons of refrigeration.

Screw Compressor

With a relatively high compression ratio and few moving parts, screw chillers are compact, smaller, and lighter than reciprocating and centrifugal chillers of the same cooling capacity. They also offer quieter, vibration-free operation, and are well known for their robustness, simplicity, and reliability. They are designed for long periods of continuous operation, and need very little maintenance. Screw compressors can overcome high lift when speed is reduced, allowing energy savings without the possibility of surge as the compressor unloads.

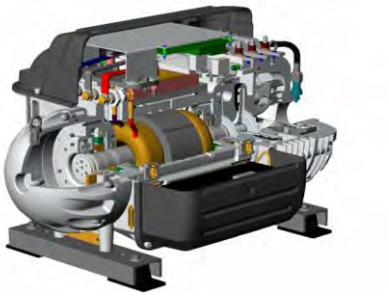
The major drawback of screw chillers is their high first cost. For small cooling loads, reciprocating chillers are less expensive to purchase and install; for large loads, centrifugal chillers cost less.

Centrifugal Chillers:

A centrifugal compressor is a **dynamic** machine that uses the rotating action of an impeller wheel to exert centrifugal force on refrigerant inside a round chamber (volute). Refrigerant is sucked into the impeller wheel through a large circular intake, and flows between the impellers. The impellers force the refrigerant outward, exerting centrifugal force on the refrigerant. The refrigerant is pressurized as it is forced against the sides of the volute.

Centrifugal compressors are well suited to ... of refrigerant to relatively low pressures. The com... s small, so chillers that use centrifugal comp... eel, arranged in series. Centrifugal compress... oving parts. Centrifugal chillers are categorize... machines, depending on the evaporator pressur... ler using refrigerant R-22 and R-134A is a po... a negative-pressure machine. Some key fac...

- Mass flow rates ... proximately 3 lb/min ton. However, du... volumetric flow rate (cfm/ton) is over... rate. Compressors using R-123 typi... nately 40 inches in diameter.
- Compressors usin... t are about 5 inches in diameter. The l... n constraint on the compressor. To re... impellers in series or stages to produ...
- Compressors using ... motors that, on 60 Hz electric supply, turn at 3600 rpm. Comp... g R-134A typically use a motor coupled through a gearbox or speed increaser, and can operate at speeds approaching 30,000 rpm.
- Since the compressor using R-123 operates in a vacuum, it leads to possible contamination from the atmosphere, water vapor, or air-oxygen. This induces high chances of corrosion and wasteful energy consumption (kW per ton penalty) due to the compression of non-condensable gases. Continuous purge is required, and it takes longer shutdowns for maintenance.



Centrifugal Compressor