

# Chiller and how it work

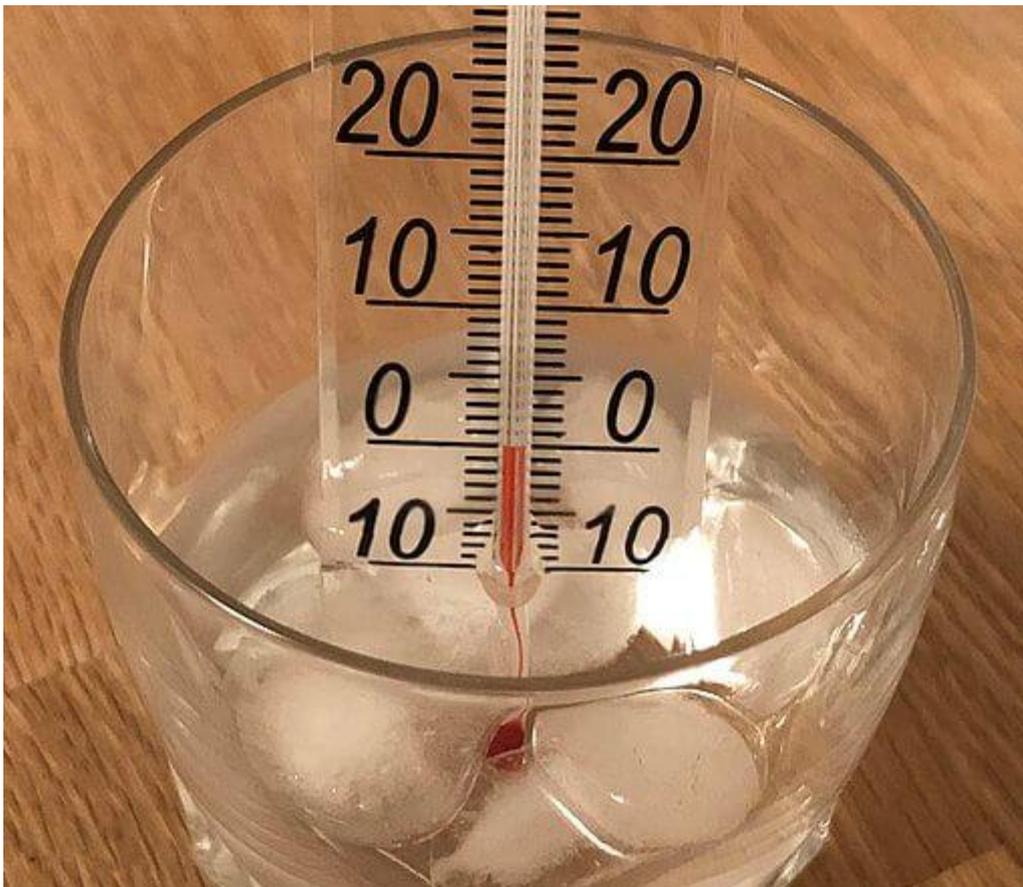
## What Chiller Works Best for Your Process?

Chiller systems range vastly in size and design and are available as small, localized or [portable chiller units](#) for smaller applications or [large central chillers](#) designed to provide cooling for entire processes.

If you are interested in more details on the best cooling solution for your application please contact a Thermal Care specialist.

## Refrigeration Basics

Operating a chiller incorporates three major concepts: heat transfer, fluid circulation, and refrigeration.



*Heat always flows from a higher temperature substance to a lower temperature substance*

# WHAT IS A CHILLER?

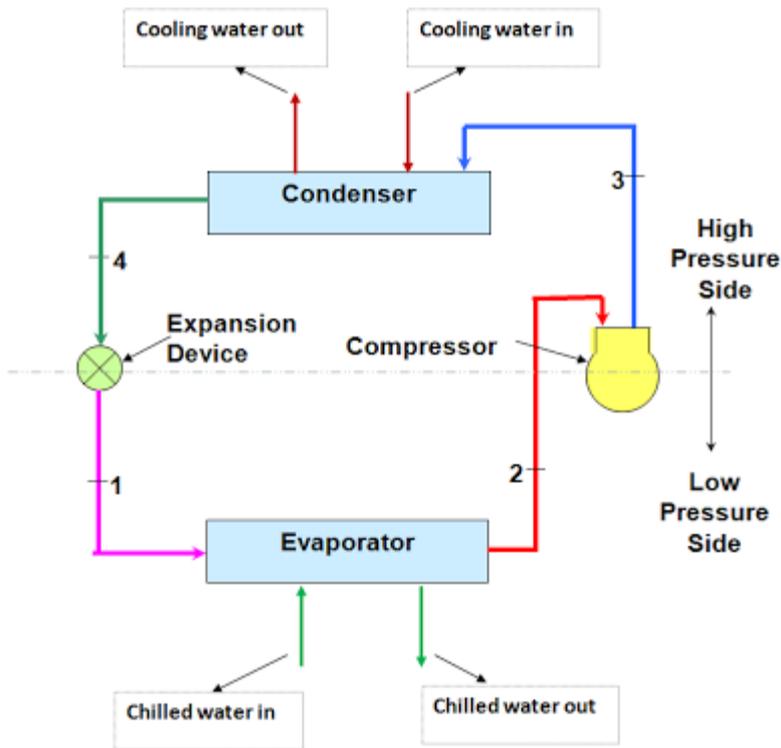
This device **removes heat from a load and transfers** it to the environment using a refrigeration system. This heat transfer device is the preferable cooling machine in power plants and other large-scale facilities.

There are also air-cooled chillers, which **disperse heat-using fans**. These are more recent and common in power plants

Commercial buildings use Heating, Ventilation and Air Conditioning (HVAC) systems to dehumidify and to cool the building. Modern commercial buildings seek *efficient* HVAC systems and components as part of [broader initiatives centered on building performance and sustainability](#). Building occupants similarly carry great expectations, that the HVAC system will function as intended . . . to create a comfortable interior environment regardless of the conditions external to the building.

Chillers have become an essential HVAC component of a wide variety of commercial facilities, including hotels, restaurants, hospitals, sporting arenas, industrial and manufacturing plants, etc. The industry has long recognized that chiller systems represent the single largest consumer of electrical usage in most facilities. They can easily consume more than 50% of the total electrical usage during seasonal periods. According to the [US Department of Energy](#) (DOE), chillers can combine to use approximately 20% of the total electric power generated in North America. Moreover, the DOE estimates that chillers can expend up to 30% in additional energy usage due to various operational inefficiencies. These acknowledged inefficiencies cost companies and building facilities billions of dollars annually.

In general, a chiller facilitates the transfer of heat from an internal environment to an external environment. This heat-transfer device relies on the physical state of a refrigerant as it circulates through the chiller system. Certainly, chillers can function as the heart of any [central HVAC system](#).



## Types of Chillers:

As described, two different cooling mediums (air or water) can facilitate the transfer of the latent heat given up as the refrigerant changes from vapor to liquid. Thus, chillers can use two different types of condensers, air-cooled and water-cooled.

- Air-cooled condensers resemble the “radiators” that cool automobile engines. They use a motorized blower to force air across a grid of refrigerant lines. Unless they are specially designed for high-ambient conditions, air-cooled condensers require ambient temperatures of 95°F (35°C) or below to operate effectively.
- Water-cooled condensers perform the same function as air-cooled condensers, but require two steps to complete the heat transfer. First, heat moves from refrigerant vapor into the condenser water. Then, the warm condenser water is pumped to a [cooling tower](#) where the process heat is ultimately discharged to the atmosphere.



## DIFFERENCE BETWEEN AIR COOLED AND WATER COOLED CHILLER SYSTEM

in the world are grappling with water scarcity. Numerous efforts to desalinate and trade in water are evidence of the magnitude of the problem. The World Bank puts the number of people living with [absolute water scarcity at 2bn](#), a number that **could hit the 4.6bn mark within the next 65 years**.

The [water energy nexus](#) has been a regular subject in recent years. **Power plants that feed most nations consume a lot of water**, either directly or indirectly.

When it comes to the feasibility study of a cooling plant, the debate of consuming water or not is very important. Depending on the results of this study, water-cooled or air-cooled chillers will be selected.

### WATER COOLED CHILLER

Water-cooled chiller systems have a **cooling tower**, thus they feature higher efficiency than air-cooled chillers.

Water-cooled chillers are **more efficient because they condense depending on the ambient temperature bulb temperature**, which is lower than the ambient dry bulb temperature. The lower a chiller condenses, the more efficient it is.

This system has several essential components including:

- Cooling towers
- Condenser water pumps
- Make-up water pumps
- Chillers
- TES reservoirs

What are the benefits of a water-cooled chiller?

Some users may prefer these chillers because of the **smaller size** they occupy as compared to air-cooled chillers. These chillers also feature **higher efficiency** and last longer than the mentioned alternative. Those who would like the equipment to be placed indoors may find the water-cooled machine desirable.

## **IN THE COOLING TOWERS**

This is **where the unwanted heat in a facility ends up**. A large fan feeds the unit with air. The air meets with the oncoming condenser water. From the direct contact, the condenser water loses heat to the air. The condenser water goes back to the condenser the cycle continues. These open-topped devices come in many designs depending on many factors. Examples are cross flow, counter flow, natural draft and mechanical draft. Stay with us for coverage of these designs in upcoming posts.

This is a good way of settling the cooling tower vs. chiller confusion. However, if you still need **more details about the water-cooled chiller components and operation**, reach out to our team and you will get help.

Now, compare it to the air-cooled chiller discussed below.

## **AIR COOLED CHILLER**

Where aesthetics and environmental conditions or water access restrictions exist, the **air-cooled chiller may be applied**. Both air-cooled and water-cooled chillers depend on an air stream as a means of heat transfer.

The difference is that the water-cooled chillers or rather the cooling towers use a humid air stream (ambient air stream + water spray) while the air-cooled chillers use a **current of ambient air**.

Normally water-cooled chillers are **cheaper and more efficient**, with the disadvantage of **high water consumption**.

Owing to that, the company's chiller plants are very competitive to water chilled chillers in different aspects. For example, these plants are **very impressive in terms of footprint, efficiency, and noise**.

Unfortunately, some people still believe that air-cooled chillers cannot offer quite good efficiencies. What such people only need to check is the performance of these chillers two decades ago is the **progressive increase in NPLV rating of air-cooled chillers** over the years.

Already, many chiller plants in the Middle East and elsewhere have adopted ARANER's air-cooled designs and have expressed satisfaction. When used in part-load applications, these chillers are very reliable.

In summary, here are **the benefits of using air-cooled chillers**:

- No cooling towers
- Better environmental stability-no water wastage
- Low maintenance costs
- Easier to operate and control-tower freezing and tower bypass absent
- Chemical costs avoided
- Water costs avoided, especially in cities
- No water problems to deal with in case of disaster

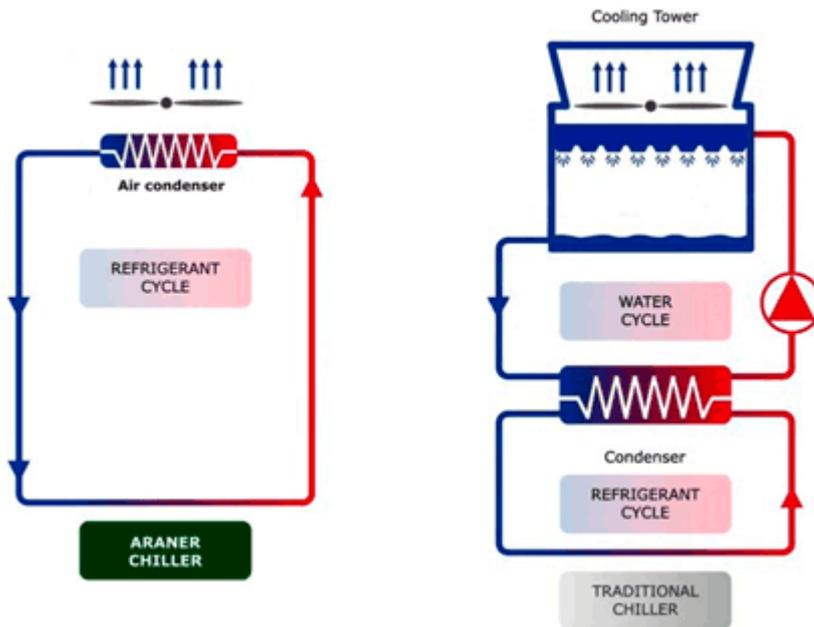


Fig 1: Air Cooled Chilled Alongside Water Cooled (Traditional) Chiller

**Air-cooled chillers** rely on a condenser cooled by the environment air. Thus, air-cooled chillers may find common application in smaller or medium installations where space constraints may exist. An air-cooled chiller can represent the most practical choice in scenarios where water represents a scarce resource.

A typical air-cooled chiller can feature propeller fans or mechanical refrigeration cycles to draw ambient air over a finned coil to condense the refrigerant. The condensation of the refrigerant vapor in the air-cooled condenser enables the transfer of heat to the atmosphere.

Air-cooled chillers offer the significant advantage of lower installation costs. Simpler maintenance also results due to their relative simplicity as compared to water-cooled chillers. Air-cooled chillers will occupy less space, but will mostly reside outside a facility. Thus, the outdoor elements will compromise their functional lifespan.

The all-inclusive nature of air-cooled chillers reduces maintenance costs. Their relative simplicity coupled with reduced space requirements produces great advantages in many types of installations.

# HOW DO I CHOOSE BETWEEN THE TWO?

The **cooling capacity** is the main guideline for the choice of the chiller. Equally crucial is the **balance between operating costs and capital costs**.

Some clients will base their buying decision on initial costs. However, a value-based option **considers both operational cost and initial cost**. To determine the initial cost of each option, add the costs for both contractors and equipment. For the water-cooled chiller, remember to add cooling tower.

When it comes to life cycle cost, you have to **consider both purchase cost and operating cost**.

When you evaluate each of the two chillers this way, you are able to determine its total cost. What you must note is that water-cooled chillers normally appear more valuable if you ignore first cost and water cost. However, it is only after you look at the **broader costs** that the true picture appears clearly.

## CONCLUSION

Energy cost remains a major consideration in any powered equipment. Energy-saving measures are being implemented everywhere.

While the chiller has direct impact on energy usage, there are **other factors to consider**. While the water-cooled chiller may be more energy-efficient, it receives stiff competition from air-cooled chiller in terms of **installation cost, maintenance cost, number of equipment**, and several other aspects.

Most importantly, air-cooled chillers **avoid water consumption** so they are the ideal alternatives in areas with water scarcity or areas with cheap energy but costly water fees.

## Heat Transfer

Heat transfer is the process of moving heat energy from a substance with high heat energy to another substance with lower heat energy. In the case of the chiller, temperature is the measure of energy and heat is the energy itself. Heat energy cannot be destroyed but can be transferred. Heat always flows from a higher temperature substance to a lower temperature substance. This rate of heat flow is commonly expressed in terms of Btu/hr—the quantity of heat, in Btu's, that flows from one substance to another over a period of one hour.

Chiller operation utilizes heat transfer in two key places: the evaporator and the condenser. In the evaporator, heat transfers from the process recirculating fluid (higher temperature) into the refrigerant (lower temperature). The condenser transfers this heat from the refrigerant (higher temperature) to the cooling source (air or water) at a lower temperature. Each is a part of the refrigeration cycle which will be explained in more detail below.

## Fluid Circulation

Chillers use fluid circulation to deliver the heat from the process to the chiller. This fluid is typically water or a water/glycol mixture. The fluid removes heat from the process, returns to the chiller, transfers heat to the refrigerant through the evaporator, and exits the chiller cold to return to the process.

## Refrigeration

Refrigeration is a thermodynamic cycle. Chillers use refrigeration to extract heat from the process circulation fluid and then ultimately reject it to the atmosphere. This system uses a chemical compound called a refrigerant. There are many types of refrigerants and applications depending on the temperatures required, but they all work on the basic principle of compression and phase-change of the refrigerant from a liquid to a gas and back to a liquid. This process of heating and cooling the refrigerant and changing it from a gas to a liquid and back again is the refrigeration cycle. Changing the physical state of a compound (for example, from gas to liquid) is an extremely efficient means to absorb or expel energy.

The refrigeration cycle in a chiller consists of four key components: evaporator&compressor, condenser, expansion valve, and as illustrated below.

# How does a Chiller Work?

In most process cooling applications, a pumping system circulates cool water or a water/glycol solution from the chiller to the process. This cool fluid removes heat from the process and the warm fluid returns to the chiller. The process water is the means by which heat transfers from the process to the chiller.

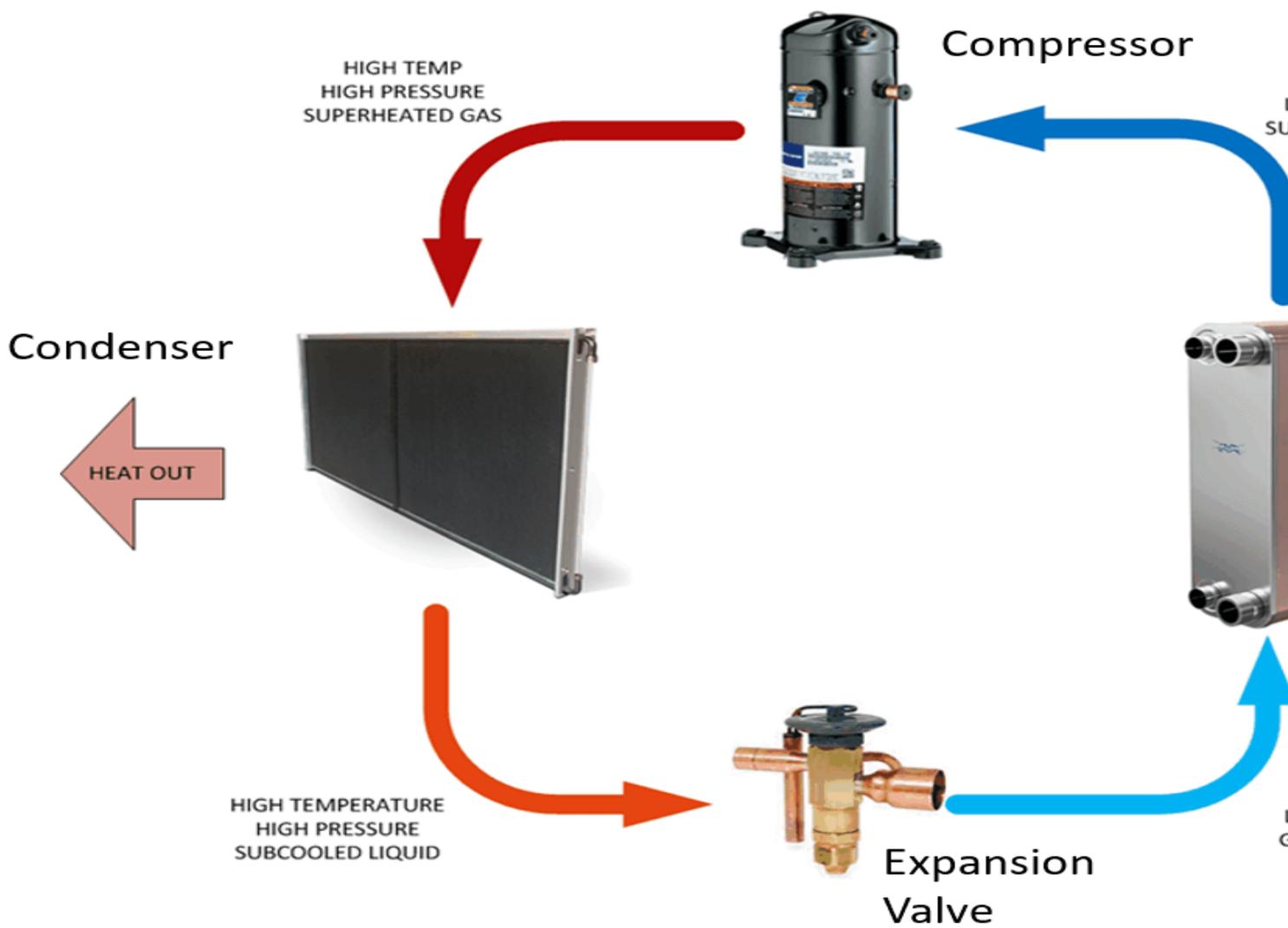
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The refrigeration cycle starts with a **low-pressure liquid/gas mix entering the evaporator**. In the evaporator, heat from the process water or water/glycol solution boils the refrigerant, which changes it from a low-pressure liquid to a low-pressure gas occurs at a constant temperature and absorbs energy. **Superheat** is when the entire liquid refrigerant has evaporated. The low-pressure gas enters the compressor where it is compressed to high-pressure gas. The high-pressure gas enters the condenser where ambient air or condenser water removes (exhaust) heat from the chiller to cool it to a high-pressure liquid to the surrounding. The high-pressure liquid travels to the expansion valve, which controls how much liquid refrigerant enters the evaporator, thereby beginning the refrigeration cycle again.

The refrigerant exiting the condenser is a sub cooled liquid. **Subcooling** is when all the vapor refrigerant is condensed and cooled below its saturation temperature.

There are two types of condensers used in chillers; **air-cooled** and **water-cooled**. An air-cooled condenser uses ambient air to cool and condense the hot refrigerant gas back down to a liquid. It can be located inside the chiller or can be remotely located outside, but ultimately it rejects the heat from the chiller to the air. In a water-cooled condenser, water from a cooling tower cools and condenses the refrigerant.

Chillers incorporate two types of heat exchangers – evaporator and condenser



*The Refrigeration Cycle – the process of heating and cooling the refrigerant and changing it from a gas to a liquid and back again is the refrigeration cycle.*

**Condenser** is a heat exchanger that transfers heat from the refrigerant gas to an external cooling source (water or air are typical mediums). This transfer causes a phase change from gas to liquid condensation.

**Expansion valves** reduce high temperature, high pressure liquid refrigerant to a low temperature, low pressure liquid/vapor mixture. This small amount of phase change cools the mixture for a low temperature refrigerant supply to the evaporator. The expansion valve controls the amount of refrigerant supplied to the evaporator by maintaining superheat at the outlet of the evaporator.

**Evaporators** are heat exchangers that transfer heat from the process fluid into the refrigerant causing a phase change, evaporation.

Other common refrigeration circuit components are: liquid line solenoid valve, filter dryer, hot gas bypass valve, and sight glass.

**Latent Heat** is the added heat that results in a phase change- for example to melt ice into water.

**Sensible Heat** is the heat added that results in a temperature increase – for example increase water temperature from 50°F to 60°F.

**Rate of Heat Transfer** is the quantity of heat that flows from one substance to another in a given period of time. This is commonly expressed in Btu/hr (or Btuh) and kW (kilowatts) for SI units.

**Saturation temperature** is the temperature at which a fluid changes phase from liquid to vapor or vapor to liquid. Saturation temperature increases with pressure.

**Superheating** is raising a fluid's temperature above the boiling temperature without boiling. This requires elevated pressures. In the refrigeration circuit, this occurs after the evaporator and compressor.

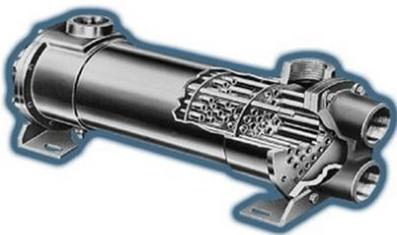
**Sub cooling** is cooling below the saturation temperature. In the refrigeration circuit, this occurs through the condenser before the expansion valve.

**Heat Exchangers** are designed to transfer heat from one fluid to another without mixing. The fluids are physically separated by the heat exchanger allowing heat energy to be between them. The fluids can be a variety of compounds – water, oil, refrigerant, etc. There are three basic types of heat exchangers used within chiller design – plate and frame, shell and tube, and coil.

**Plate and frame heat exchangers** use multiple plates, known as plate packs, to isolate the two fluids from each other. The plate pack mounts on a frame..



**Brazed plate heat exchangers** are a variation of the plate and frame design. The plate pack is permanently brazed together. This eliminates the need for the **frame, gaskets, and end plates**. This design improves **the efficiency over** a standard plate and frame. These are also much more compact but are not easily cleaned. Brazed plate units are often used as **evaporators in chillers**.



**Shell and Tube Heat Exchangers** use an outer **shell** vessel with internal tubes to isolate the two fluids. Large passageways between the tubes inside the shell avoid **clogging** but this reduces the efficiency of heat transfer.. Variations of these heat exchangers are used as condensers in water-cooled chillers.



**Coil heat exchangers** are most often air-to-water or air-to-refrigerant units. These consist of tubes with fins stacked together to form flat pieces. A common example of a coil heat exchanger is a radiator in a car. Forced air through the coil's fins conduct heat from the fluid in the tubes, through the fins and into the air. These are often condensers in air-cooled chillers.

## Compressor types

A compressor is designed to increase pressure (and temperature) of refrigerant and circulate it through the system. By increasing the pressure of the refrigerant, the saturation temperature increases. With the elevated saturation temperature, the condenser easily subcools the refrigerant.

**Scroll compressors** (تعشيقولوجي احدهما غطاء ثابت والأخر متحرك) use positive displacement to compress the refrigerant from a low pressure gas to a high pressure gas. The compressor motor is cooled by refrigerant passing over it. Oil is a critical component of a scroll compressor for lubrication. Scroll compressors are hermetically sealed and often replaced rather than repaired



(خروج)

(دخول)

**Screw compressors** (حلزوني برغيان كبير و صغير متعشقان و يدوران معا) also use positive displacement to compress the refrigerant. The compressor uses two meshing screw-rotors. These rotate in opposite directions to increase the refrigerant gas pressure. Screw compressors require oil for lubrication. Screw compressors can be disassembled for maintenance and repair.

(دخول)



(خروج)

**Centrifugal Compressors** are dynamic and raise the refrigerant pressure by rotating an impeller. This creates centrifugal force which compresses the gas. Certain centrifugal compressor designs, like those on the Thermal Care TC and TCF series, use magnetic bearings and do not require any oil for lubrication. Centrifugal compressors can be disassembled for maintenance and repair.

**Filter Dryer** is installed in the refrigeration circuit. It filters any particles of dirt, metal or other debris. This protects the operation of the components especially the expansion valves. The dryer absorbs any residual moisture remaining in the system after evacuation and charging the refrigerant. It is important to remove moisture to prevent possible freezing. Moisture can also form acids when in contact with the oil in the system.



Loose desiccant



Steel housing



Solid core molecular sieve



**Hot gas bypass valve** is used for capacity control of a chiller. It provides an artificial load on the evaporator by introducing high pressure, high temperature gas to the evaporator. This prevents the compressor from short cycling the system when the demand for cooling is low. Additionally, the hot gas keeps the evaporator from freezing and prevents low refrigerant pressure alarms.



**Liquid Solenoid Valve** prevents liquid refrigerant migration to the compressor when the system is shutdown.

**Process cooling** is a method of removing heat from where it is not wanted (the process) and moving it into the air outside a manufacturing facility.



**Refrigerant sight glasses** provide a visual indication of refrigerant as it flows through the system. The sight glass includes a moisture indicator. Visual bubbles in the system can indicate a clogged filter-dryer or low refrigerant charge.

**Reservoir** is the tank where water or water/glycol mix is stored.



**Sensors** measure pressure in the system.

## Ongoing Maintenance

Chiller systems will operate more efficiently through proper ongoing maintenance. Most organizations recognize this value and have taken steps as part of their day-to-day facility management best practices. Some common best practices for chiller systems include:

1. Inspect and clean condenser coils. Heat transfer has a large effect on chiller systems and remains fundamental to producing efficient chiller operation. Routine maintenance should inspect condenser coils for clogging and free air passage.
2. Maintain refrigerant charge. A chiller's cooling quotient depends on proper refrigerant levels in the system. Maintaining proper refrigerant charge can greatly impact energy efficiency by reducing cooling costs by nearly 5-10%.
3. Maintain condenser water: Condenser water loops used with cooling towers must maintain proper water flow as designed. Any debris like sand, erosive solids and contamination materials can affect the condenser water loop. Fouling or scaling can inhibit water flow and greatly impact the chiller operating efficiency.

## Predictive Maintenance

Artificial Intelligence (AI) continues to advance in everyday practical applications. Machinery such as chiller systems will benefit from AI algorithms that can detect potential failures before they occur. Predictive maintenance leverages the collection and analysis of chiller system operational data to determine when maintenance actions should be taken prior to catastrophic failure. As chillers systems represent the heart of most modern HVAC systems, the prevention of catastrophic failures that produce significant "downtime" will save on emergency repair costs as well as reputation. The critical role played by a chiller system warrants the increased scrutiny. Big Data and AI will minimize downtime and maximize productivity.

The Internet of Things (IoT) provides the data collection tool that can enable AI applications such as predictive maintenance. In fact, the [future of HVAC is AI and IoT](#). IoT enables the collection of real-time data from a chiller to enable continual analysis of its operation. The granular IoT data collected from a chiller will go far beyond that obtained by visual inspection. [IoT connects building engineers to real-time visibility of critical HVAC assets](#), thereby enabling informed monitoring of actual operating conditions.