Refrigeration is the process of lowering the temperature of a substance below that of its surroundings. This process is used to produce chilled water for air conditioning and process applications. The basic mechanical components of an air conditioning system are:

- the air and water distribution systems,
- a refrigeration machine, and
- a heat rejection system.

The air distribution system consists of the controls, air ducts, and the heat exchangers between the chilled water and the air. The water distribution systems are the chilled water system and the recirculating water system.

The refrigeration machine transfers heat from the chilled water to the recirculating water. The machine can operate in either a compression cycle (centrifugal cycle) or absorption cycle, depending upon the design. The centrifugal cycle machine uses a fluorocarbon refrigerant (freon) to transfer heat from the chilled water into the freon and then into the recirculating water. An absorption machine uses water as the refrigerant to transfer heat from the chilled water into the recirculating water.

In industrial and commercial refrigeration systems, the heat is usually rejected to water. Once-through cooling may be used, but water costs and environmental restrictions dictate recirculating system utilizing cooling towers to reject the heat into the atmosphere.

Absorption Refrigeration Systems

Cooling capacity is measured in tons of refrigeration. A ton of refrigeration is defined as the capacity to remove heat at a rate of 12,000 Btu/hr at the evaporator or chiller.

An absorption refrigeration system that removes 12,000 Btu/hr requires heat energy input of approximately 18,000 Btu/hr to drive the absorption process. This means that the heat rejection at the cooling tower approximates 30,000 Btu/hr per ton of refrigeration.
Evaporation Rate = Approximately 3 gal/hr/ton

Recirculating Rate = 4 to 5 gpm per ton of refrigeration

Normally, 12 to 15 psig steam is used to provide the heat necessary to drive the absorption process. Hot water can be used in place of the steam.

The key set point is exiting chilled water temperature. This temperature is typically 44 F. A signal goes from the exiting chilled water temperature sensor to the steam control valve. This valve opens and closes as needed to maintain the chilled water temperature at the 44 F set point.

Other than solution and refrigerant pumps, there are few moving parts in an absorption machine. This is an economical design advantage, but the cost of producing the necessary low pressure steam or hot water must be considered. If a facility produces steam year round and has excess capacity, steam absorption refrigeration may be appropriate for air conditioning and process cooling.

**Absorption - Basic Absorption Cycle**

The absorption chiller uses water as the refrigerant in vessels maintained under a deep vacuum. The chiller operates on the simple principle that under low absolute pressure (vacuum), water takes up heat and vaporizes (boils) at a low temperature.

At 0.25 inches of mercury absolute pressure, water boils at 40 F. To obtain the energy required for boiling, it takes heat from, and therefore chills, another fluid (usually water). The chilled water can then be used for cooling purposes.

To make the cooling process continuous, the vaporized refrigerant water is absorbed (assimilated) by a lithium bromide and water solution. The removal of refrigerant vapor by absorption keeps the machine pressure low enough for vaporization to continue.

The diluted lithium bromide solution is then pumped to a separate vessel where it is heated by steam or hot water to release the absorbed water vapor. Relatively cool condensing water from an outside source removes enough heat from the vapor to condense it again into liquid for reuse in the cooling cycle. The reconcentrated lithium bromide solution is returned to the absorber vessel to continue the cycle.
**Absorption - Machine Construction**

An upper and a lower shell (see diagram) contain the four major sections of the absorption machine: evaporator, absorber, generator, and condenser.

The lower shell contains the evaporator section and the absorber section. In the evaporator, the refrigerant water vaporizes and, in doing so, cools the fluid used in the air conditioning or cooling process. In the absorber section, the vaporized water is absorbed by a lithium bromide solution.

The upper shell contains the generator section and the condenser section. The diluted lithium bromide solution is heated and reconcentrated in the generator. The water vapor released in the reconcentration process is condensed to liquid in the condenser section.

The absorption chiller also has a solution heat exchanger to improve operating economy; an external purge system to maintain machine vacuum by the removal of noncondensables; two hermetic pumps to circulate the solution and the refrigerant; and various operation, capacity, and safety controls to provide reliable performance.

**Absorption - Flow Circuits**

The liquid to be chilled is passed through the evaporator tube bundle and is cooled by the evaporation of refrigerant water sprayed on the outer surface of the tubes. This is the chilled water or the process cooling water. Typically, temperatures are 54°F in and 44°F out. The refrigerant water boils at 40°F since the evaporator is kept at 0.3 inches of mercury at 32°F.

The refrigerant vapors are drawn into the absorber section and are absorbed by the lithium bromide solution sprayed on the absorber tubes. The lithium bromide solution concentration is 65% when sprayed upon the absorber. The absorption process is an exothermic reaction at about 105°F.

The heat of absorption is removed by the condenser water flowing through the absorber tubes. Typically, a delta T of about 10°F is experienced in this portion of the recirculation water system.

The 65% lithium bromide solution is diluted to 60% concentration by the absorption of the refrigerant vapors. The 60% lithium bromide solution is pumped into the generator section to be reconcentrated. In the generator, the 60% lithium bromide solution is heated by steam.
or hot water to boil out of the absorbed refrigerant water. The refrigerant vapors are at about 220°F. The generator and evaporator operate at 3 inches of mercury at 32°F.

The resulting refrigerant vapor passes into the condenser section and condenses on the tubes containing cooler condenser water. Typically, a delta T of about 5°F is experienced in this portion of the recirculating water system.

The condensed refrigerant liquid at 115°F no flows back to the evaporator to begin a new refrigerant cycle.

The reconcentrated 65% lithium bromide solution flows from the generator back to the absorber to begin a new solution cycle. On the way, it passes through a heat exchanger where heat is transferred from the 65% solution to the 60% solution being pumped to the generator. This heat transfer improves solution cycle efficiency by preheating the relatively cool 60% solution before it enters the generator and precooling the 65% solution before it enters the absorber. The affinity of the lithium bromide solution for the refrigerant vapors is greatest when the lithium bromide solution is coldest.

**Absorption - General Comments**

1. We do not chemically treat the refrigerant (water) which is internal to the absorption machine.

2. The temperature in the absorber is approximately 105°F (similar to normal condenser temperatures in centrifugal systems).

3. The temperature in the absorption machine condenser is much greater than in centrifugal condensers. This is the major problem area for water treatment programs. Watch the LSI of the water at the skin temperature of the absorption machine condenser which is about 115°F.

4. The lithium bromide solution contains a corrosion inhibitor which should be checked regularly.

5. The preferred method of controlling the machine is on the exiting chilled water temperature. The steam flow is throttled to maintain the chilled water temperature. Reducing the steam flow increases the pounds of steam required per ton of refrigeration. The machine is most efficient when fully loaded.
6. Another method of control is to vary the flow rate of the condenser water. This method is not desirable because cutting back on the condenser water gpm results in lower velocities and hence a greater deposition potential. Additionally, less condenser water flow can cause higher steam demand and produce higher skin temperatures than normal. The higher skin temperatures create a greater scaling potential.

7. The lithium bromide solution can crystallize if it becomes over concentrated. This can lead to system shutdown.

8. The overall delta T for the condenser water is 15°F but will vary depending upon operating conditions.

**Absorption - Summary**

The absorption refrigeration system requires attention to detail just like all water treatment problems. Fouling and the formation of scale in absorption systems reduces operating efficiency. Because the highest water temperatures exist in the condenser, deposition always occurs first in this portion of the system. Under extreme conditions, scale formation can also occur in the absorber.

Absorption refrigeration machines require the same treatment programs that is applied to any open recirculating cooling tower system. Blowdown and treatment to inhibit scale, fouling, and microbiological activity are needed to ensure that the systems operate efficiently.

**Centrifugal Refrigeration Systems**

Cooling capacity is measured in tons of refrigeration. A ton of refrigeration is defined as the capacity to remove heat at a rate of 12,000 Btu/hr at the evaporator or chiller.

A centrifugal refrigeration system that removes 12,000 Btu/hr requires heat energy input of approximately 3,000 Btu/hr to drive the centrifugal process. This means that the heat rejection at the cooling tower approximates 15,000 Btu/hr per ton of refrigeration.

One Refrigeration Ton (12,000 Btu/Hr) + Work of Compression (3,000 Btu/hr) = One Cooling (Tower) Ton (15,000 Btu/hr)

Evaporator Rate = Approximately 2 gal/hr/ton
Recirculating Rate = 3 gpm per ton of refrigeration with a 10°F Delta T across the cooling tower

Electricity provides the energy for the process. An electric motor is used to turn the compressor. A steam turbine, gas turbine, or a gas engine can be used to turn the compressor.

The key set point is exiting chilled water temperature. This temperature is typically 44°F. This set point is generally a manual set point.

A centrifugal refrigeration machine has more moving parts than an absorption refrigeration machine. Centrifugal refrigeration can be installed when steam or hot water is not available.

**Centrifugal - Basic Cycle**

The centrifugal chiller uses freon as the refrigerant. Compression cycle refrigeration is based upon the vaporization and condensation of a volatile refrigerant. Water is cooled in the evaporator by the evaporation of the refrigerant. The refrigerant vapor is compressed and passes to the condenser where heat is removed by the cooling water and the refrigerant becomes a liquid. The liquid refrigerant is then returned to the evaporator through a metering device and the process repeats.

**Centrifugal - Machine Construction**

A centrifugal refrigeration has three major components (see diagram). These are the evaporator, condenser, and the compressor.

The lower shell contains the evaporator section. In the evaporator, the refrigerant freon vaporizes and, in doing so, cools the fluid used in the air conditioning or cooling process.

The upper shell contains the condenser section. The compressed refrigerant gas flows into the condenser where it is cooled by the recirculating water from the cooling tower system. The gaseous freon condenses into a liquid and flows into the evaporator.

The upper and lower shells are connected by connection pipe and a compressor. The compressor is turned by an electric motor.

Additionally, various operating, capacity, and safety controls are installed to provide reliable machine performance.
Centrifugal - Flow Circuits

1. The liquid to be chilled is passed through the evaporator tube bundle and is cooled by the evaporation of freon liquid in the shell of the evaporator. This is the chilled water or the process cooling water. Typically, temperatures are 54°F in and 44°F out. The freon liquid boils at 30°F to 35°F since the evaporator is kept at 1.5 inches vacuum at 40°F.

2. The freon gas passes into the compressor where it is compressed. Compressors may have multiple stages to further compress the freon gas. Compression raises the temperature of the freon gas above the temperature of the water flowing through the condenser. Typical freon gas temperatures are 90°F to 110°F. The compressor places heat into the freon gas. This heat 3,000 Btu/hr is the heat of compression.

3. The compressed freon gas passes into the condenser. Heat is removed by the condenser water flowing through the condenser. The heat is transferred at a rate of 15,000 Btu/hr/ton. The freon gas condenses into a liquid and flows back to the evaporator. Typically, a delta T of about 10°F is experienced in the recirculating water system.

Centrifugal - General Comments

1. Centrifugal refrigeration machines are commonly used for air conditioning systems.

2. The temperature in the recirculating water is in the range of 85°F to 95°F but varies with the ambient temperature.

3. Watch the LSI of the recirculating water at the skin temperature of about 110°F.

4. You will get blamed if the chiller (centrifugal refrigeration machine) does not operate correctly. Check the following areas:
   - Noncondensable gases in the freon (e.g., air)
   - Fouled condenser tubes (waterside)
   - Incorrect water flows (cooling tower)
   - Too high an inlet water temperature (cold well)

Centrifugal - Summary

The centrifugal refrigeration system requires attention to detail just like all water treatment problems. Fouling and the formation of scale in centrifugal
systems reduces operating efficiency. Deposits typically occur in the condenser tubes. Typically, the evaporator tubes do not have scale deposits, but corrosion byproducts can foul the tubes.

Centrifugal refrigeration machines require the same treatment programs that we apply to any open recirculating cooling tower system. Blowdown and treatment to inhibit scale, fouling, and microbiological activity are needed to ensure the systems operate efficiently.