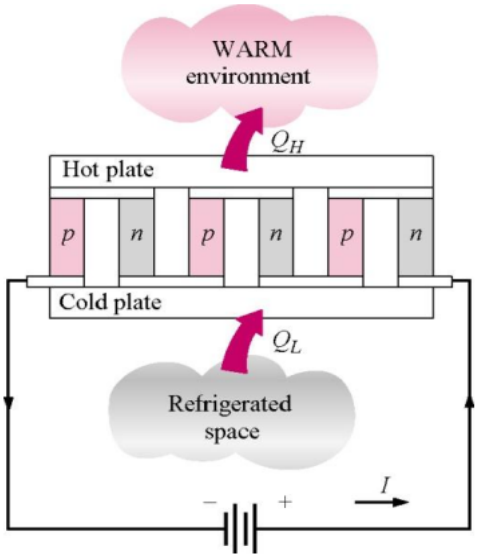
THERMOELECTRIC REFRIGERATION SYSTEMS

A refrigeration effect can also be achieved without using any moving parts by simply passing a small current through a closed circuit made up of two dissimilar materials. This effect is called the *Peltier effect,* and a refrigerator that works on this principle is called a *thermoelectric refrigerator.*

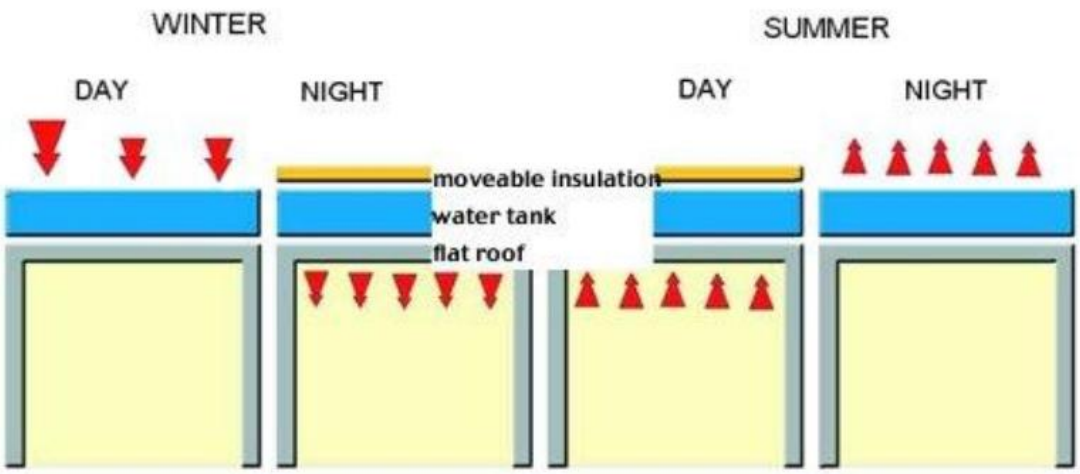


EVAPORATIVE COOLING

Evaporative cooling is a process that uses the effect of evaporation as a natural heat sink. Sensible heat from the air is absorbed to be used as latent heat necessary to evaporate water. The amount of sensible heat absorbed depends on the amount of water that can be evaporated.

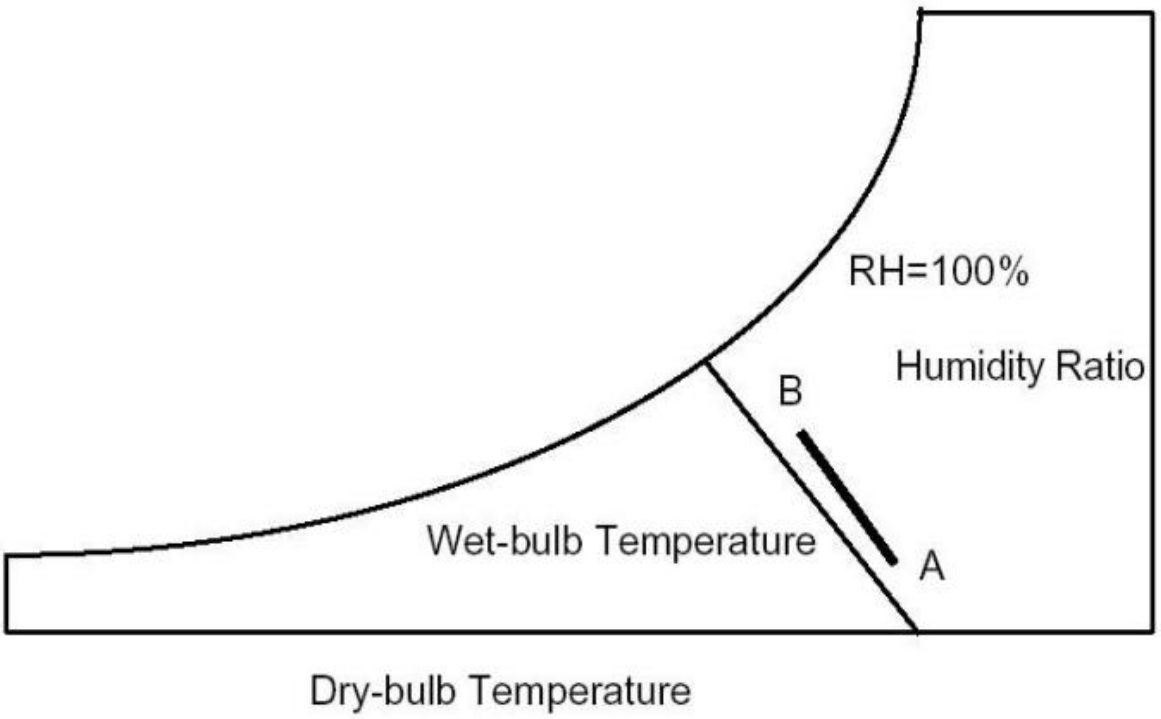
Evaporative cooling can be direct or indirect; passive or hybrid. In direct evaporative cooling, the water content of the cooled air increases because air is in contact with the evaporated water. In indirect evaporative cooling, evaporation occurs inside a heat exchanger and the water content of the cooled air remains unchanged. Since high evaporation rates might increase relative humidity and create discomfort, direct evaporative cooling can be applied only in places where relative humidity is very low.

Where evaporation occurs naturally it is called passive evaporation. A space can be cooled by passive evaporation where there are surfaces of still or flowing water, such as basins or fountains. Where evaporation has to be controlled by means of some mechanical device, the system is called a hybrid evaporative system.

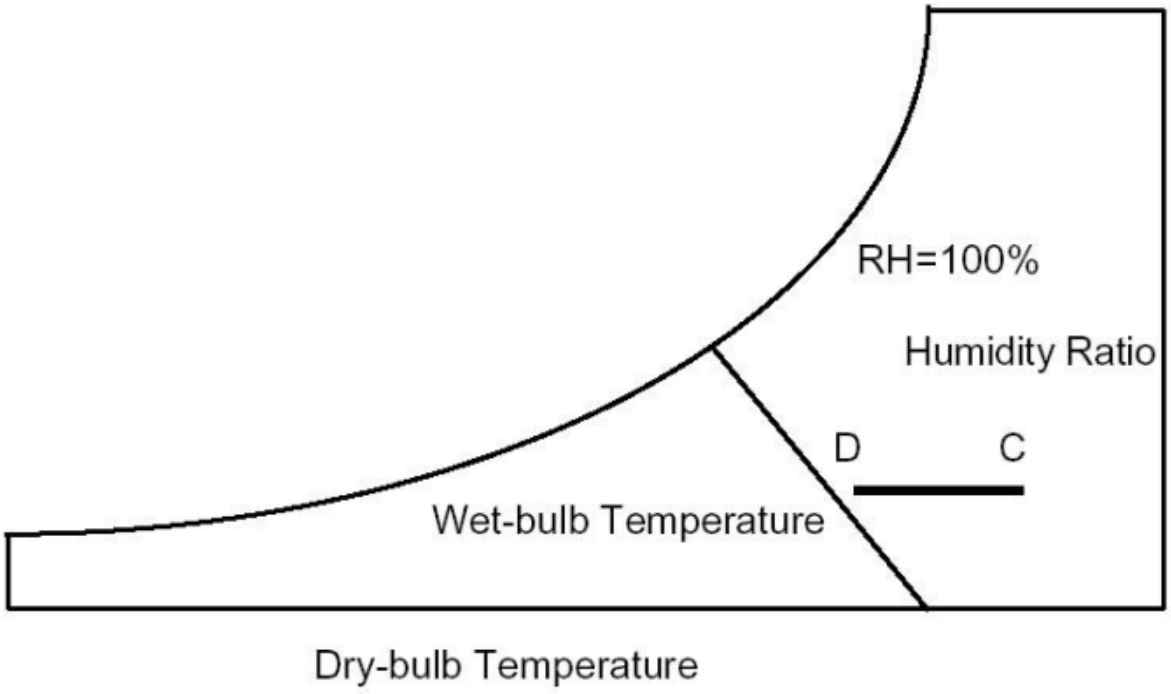


Evaporative cooling is based on the thermodynamics of evaporation of water, i.e. the change of the liquid phase of water into water vapor. This phase change requires energy, which is called latent heat of evaporation- this is the energy required to change a substance from liquid phase to the gaseous one without temperature change. When non-saturated air (i.e. air that does not contain liquid water but only water vapor) comes in direct contact with water evaporation occurs. It is obvious that during this process the moisture content of air is increased. This process is represented on the psychometric chart by a displacement along a constant wet bulb line, AB. The air to be cooled is initially at point A. The air, as a result of the direct evaporative cooling process, reaches point B. This is a constant wet bulb temperature process and therefore line AB is parallel to the wet bulb temperature lines.

When evaporation occurs in the primary circuit of a heat exchanger, while the air to be cooled circulates in the secondary circuit, the air temperature decreases but its humidity ratio remains constant. It must be noted that since the air temperature drops, its relative humidity will increase, but less than during the direct evaporative cooling process. Since the humidity ratio of the air does not change, this process is represented on the psychometric chart by a displacement along a constant humidity ratio line CD. In this figure, the air to be cooled, initially at point C is sensibly cooled by the indirect evaporative cooler until it reaches point B.

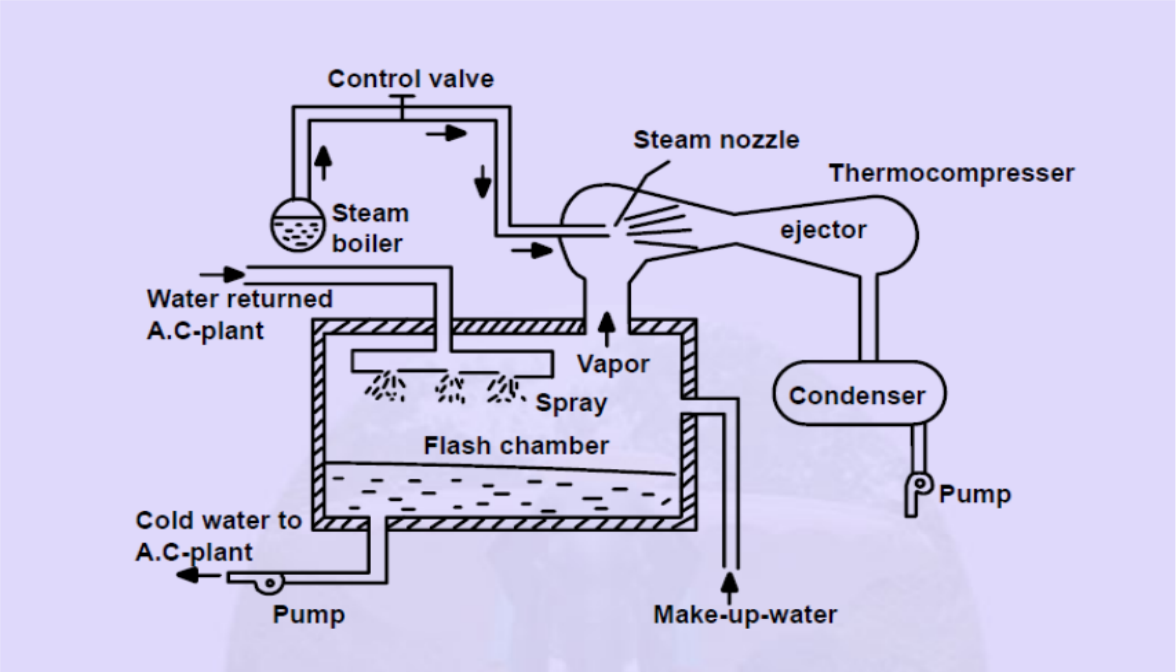


direct evaporative cooling"



indirect evaporative cooling"

STEAM JET REFRIGERATION



This system uses the principle of boiling the water below 1000 C. If the pressure on the surface of the water is reduced below atmospheric pressure, water can be made boil at low temperatures. Water boils at 60 C, when the pressure on the surface is 5 cm of Hg and at 100 C, when the pressure is 6.5 cm of Hg. The very low pressure or high vacuum on the surface of the water can be maintained by throttling the steam through jets or nozzles. The general arrangement of the system is shown in the Fig.6.8. Consider a flash chamber contains 100 kg of water. If suddenly 1 kg of water is removed by boiling, as pressure is reduced due to throttling of steam through nozzles. Approximately 2385 kJ of heat will be removed from the water, which is equivalent to heat of evaporation of water. The fall in temperature of the remaining water will be,

Evaporating one more kg of water reduces the remaining water temperature by 5.7 degree C further. Thus by continuing this process, the remaining water can be made to freeze. Water is the refrigerant used in the steam jet refrigeration system. As water freezes at 0 degree C, then either refrigeration has to be stopped or some device is required to pump the ice. Operation: High pressure steam is supplied to the nozzle from the boiler and it is expanded. Here, the water vapor originated from the flash chamber is entrained with the high velocity steam jet and it is further compressed in the thermo compressor. The kinetic energy of the mixture is converted into static pressure and mass is discharged to the condenser. The condensate is usually returned to the boiler. Generally, 1% evaporation of water in the flash chamber is sufficient to decrease the temperature of chilled water to 60 C. The chilled water in the flash chamber is circulated by a pump to the point of application. The warm water from the load is returned to the flash chamber.

The water is sprayed through the nozzles to provide maximum surface area for cooling. The water, which is splashed in the chamber and any loss of cold water at the application, must be replaced by makeup water added to the cold water circulating system.

Advantages: a) It is flexible in operation; cooling capacity can be easily and quickly changed. b) It has no moving parts as such it is vibration free. c) It can be installed out of doors. d) The weight of the system per ton of refrigerating capacity is less. e) The system is very reliable and maintenance cost is less. f) The system is particularly adapted to the processing of cold water used in rubber mills,, distilleries, paper mills, food processing plants, etc. g) This system is particularly used in air-conditioning installations, because of the complete safety of water as refrigerant and ability to adjust quickly to load variations and no hazard from the leakage of the refrigerant.

Disadvantages: a) The use of direct evaporation to produce chilled water is usually limited as tremendous volume of vapor is to be handled. b) About twice as much heat must be removed in the condenser of steam jet per ton of refrigeration compared with the vapor compression system. c) The system is useful for comfort air-conditioning, but it is not practically feasible for water temperature below 40 C.

PRODUCTION OF CRYOGENIC TEMPERATURES

There are essentially only four physical processes that are used to produce cryogenic temperatures and cryogenic environments: heat conduction, evaporative cooling, cooling by rapid expansion (the Joule-Thompson effect), and adiabatic demagnetization. The first two are well known in terms of everyday experience. The third is less well known but is commonly used in ordinary refrigeration and air conditioning units, as well as cryogenic applications. The fourth process is used primarily in cryogenic applications and provides a means of approaching absolute zero

Heat conduction is familiar to everyone. When two bodies are in contact, heat flows from the higher temperature body to a lower temperature body. Conduction can occur between any and all forms of matter, whether gas, liquid, or solid, and is essential in the production of cryogenic temperatures and environments. For example, samples may be cooled to cryogenic temperatures by immersing them directly in a cryogenic liquid or by placing them in an atmosphere cooled by cryogenic refrigeration. In either case, the sample cools by conduction of heat to its colder surroundings.

The second physical process with cryogenic applications is evaporative cooling, which occurs because atoms or molecules have less energy when they are in the liquid state than when they are in the vapor, or gaseous, state. When a liquid evaporates, atoms or molecules at the surface acquire enough energy from the surrounding liquid to enter the gaseous state. The remaining liquid has relatively less energy, so its temperature drops. Thus, the temperature of a liquid can be lowered by encouraging the process

of evaporation. The process is used in cryogenics to reduce the temperature of liquids by continuously pumping away the atoms or molecules as they leave the liquid, allowing the evaporation process to cool the remaining liquid to the desired temperature. Once the desired temperature is reached, pumping continues at a reduced level in order to maintain the lower temperature. This method can be used to reduce the temperature of any liquid. For example, it can be used to reduce the temperature of liquid nitrogen to its freezing point, or to lower the temperature of liquid helium to approximately 1K (-458°F [-272°C]).

The fourth process, adiabatic demagnetization, involves the use of paramagnetic salts to absorb heat. This phenomenon has been used to reduce the temperature of liquid helium to less than a thousandth of a degree above absolute zero in the following way. A paramagnetic salt is much like an enormous collection of very tiny magnets called magnetic moments. Normally, these tiny magnets are randomly aligned so the collection as a whole is not magnetic. However, when the salt is placed in a magnetic field by turning on a nearby electromagnet, the north poles of each magnetic moment are repelled by the north pole of the applied magnetic field, so many of the moments align the same way, that is, opposite to the applied field. This process decreases the entropy of the system.

REFRIGERANTS, COOLING MEDIA, AND LIQUID ABSORBENTS

Refrigerants. A refrigerant is the primary working fluid used for absorbing and transmitting heat in a refrigeration system. Refrigerants absorb heat at a low temperature and low pressure and release heat at a higher temperature and pressure. Most refrigerants undergo phase changes during heat absorption—evaporation—and heat releasing—condensation.

Cooling Media. A cooling medium is the working fluid cooled by the refrigerant to transport the cooling effect between a central plant and remote cooling units and terminals. In a large, centralized system, it is often more economical to use a coolant medium that can be pumped to remote locations where cooling is required. Chilled water, brine, and glycol are used as cooling media in many refrigeration systems. The cooling medium is often called a secondary refrigerant, because it obviates extensive circulation of the primary refrigerant.

Liquid Absorbents. A solution known as liquid absorbent is often used to absorb the vaporized refrigerant (water vapor) after its evaporation in an absorption refrigeration system. This solution, containing the absorbed vapor, is then heated at high pressure. The refrigerant vaporizes, and the solution is restored to its original concentration for reuse. Lithium bromide and ammonia, both in a water solution, are the liquid absorbents used most often in absorption refrigerating systems.

OPERATING CHARACTERISTICS

Leakage Detection: Refrigerant leakage should be easily detected. Leakage of refrigerant from the refrigeration system is often detected by the following methods:

***Halide torch**:* When air flows over a copper element heated by a methyl alcohol flame, the vapor of halogenated refrigerant decomposes and changes the color of the flame (green for a small leak, bluish with a reddish top for a large leak).

Electronic detector: This type of detector reveals a variation of electric current due to ionization of decomposed refrigerant between two oppositely charged electrodes.

***Bubble method**:* A solution of soup or detergent is brushed over the seals and joints where leakage is suspected, producing bubbles that can be easily detected.