ABOUT EVAPORATIVE COOLING

Evaporative cooler

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An **evaporative cooler** (also **swamp cooler**, **desert cooler** and **wet air cooler**) is a device that cools air through the evaporation of water. Evaporative cooling differs from typical air conditioning systems, which use vapor-compression or absorption refrigeration cycles. Evaporative cooling works by exploiting water's large enthalpy of vaporization. The temperature of dry air can be dropped significantly through the phase transition of liquid water to water vapor (evaporation). This can cool air using much less energy than refrigeration. In extremely dry climates, evaporative cooling of air has the added benefit of conditioning the air with more moisture for the comfort of building occupants.

The cooling potential for evaporative cooling is dependent on the wet-bulb depression, the difference between dry-bulb temperature and wet-bulb temperature. In arid climates, evaporative cooling can reduce energy consumption and total equipment for conditioning as an alternative to compressor-based cooling. In climates not considered arid, indirect evaporative cooling can still take advantage of the evaporative cooling process without increasing humidity. Passive evaporative cooling strategies can offer the same benefits of mechanical evaporative cooling systems without the complexity of equipment and ductwork.

Physical principles

Evaporative coolers lower the temperature of air using the principle of evaporative cooling, unlike typical air conditioning systems which use vapor-compression refrigeration or absorption refrigerator. Evaporative cooling is the conversion of liquid water into vapor using the thermal energy in the air, resulting in a lower air temperature. The energy needed to evaporate the water is taken from the air in the form of sensible heat, which affects the temperature of the air, and converted into latent heat, the energy present in the water vapor component of the air, whilst the air remains at a constant enthalpy value. This conversion of sensible heat to latent heat is known as an isenthalpic process because it occurs at a constant enthalpy value. Evaporative cooling therefore causes a drop in the temperature of air proportional to the sensible heat drop and an increase in humidity proportional to the latent heat gain. Evaporative cooling can be visualized sing a psychrometric chart by finding the initial air condition and moving along a line of constant enthalpy toward a state of higher humidity.

A simple example of natural evaporative cooling is perspiration, or sweat, secreted by the body, evaporation of which cools the body. The evaporation rate depends on the temperature and humidity of the air, which is why sweat accumulates more on humid days, as it does not evaporate fast enough.

Applications

California ranch house with evaporative cooler box on roof ridgeline

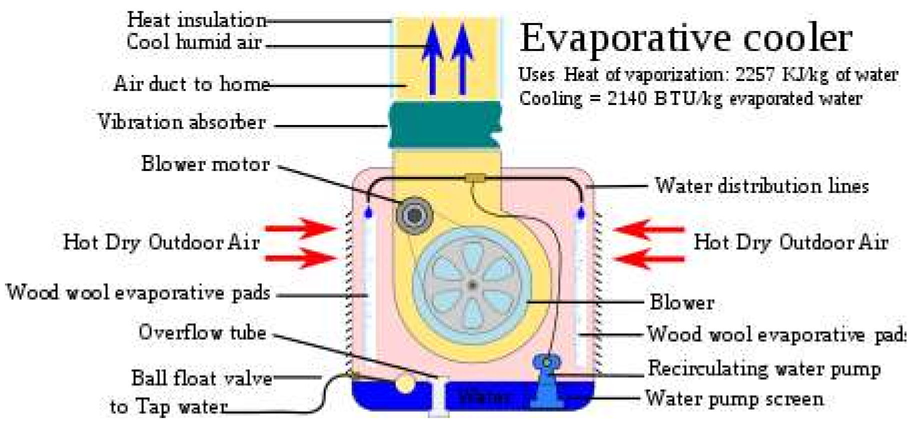
Evaporative cooling is a common form of cooling buildings for thermal comfort since it is relatively cheap and requires less energy than other forms of cooling.

Evaporative cooling is most effective when the relative humidity is on the low side, limiting its popularity to dry climates. Evaporative cooling raises the internal humidity level significantly, which desert inhabitants may appreciate as the moist air re-hydrates dry skin and sinuses.

Evaporative cooling is especially well suited for climates where the air is hot and humidity is low. In the United States, the western/mountain states are good locations, with evaporative coolers prevalent in cities like Denver, Salt Lake City, Albuquerque, El Paso, Tucson, and Fresno. Evaporative air conditioning is also popular and well-suited to the southern (temperate) part of Australia. In dry, arid climates, the installation and operating cost of an evaporative cooler can be much lower than that of refrigerative air conditioning, often by 80% or so. However, evaporative cooling and vapor-compression air conditioning are sometimes used in combination to yield optimal cooling results. Some evaporative coolers may also serve as humidifiers in the heating season. Even in regions that are mostly arid, short periods of high humidity may prevent evaporative cooling from being an effective cooling strategy. An example of this event is the monsoon season in New Mexico and southern Arizona in July and August.

In locations with moderate humidity there are many cost-effective uses for evaporative cooling, In highly humid climates, evaporative cooling may have little thermal comfort benefit beyond the increased ventilation and air movement it provides.

Designs



Evaporative cooler illustration

Most designs take advantage of the fact that water has one of the highest known enthalpy of vaporization (latent heat of vaporization) values of any common substance. Because of this, evaporative coolers use only a fraction of the energy of vapor-compression or absorption air conditioning systems. Unfortunately, except in very dry climates, the single-stage (direct) cooler can increase relative humidity (RH) to a level that makes occupants uncomfortable. Indirect and Two-stage evaporative coolers keep the RH lower.

Direct evaporative cooling

A *mechanical* direct evaporative cooler unit uses a fan to draw air through a wetted membrane, or pad, which provides a large surface area for the evaporation of water into the air. Water is sprayed at the top of the pad so it can drip down into the membrane and continually keep the membrane saturated. Any excess water that drips out from the bottom of the membrane is collected in a pan and recirculated to the top. Single stage direct evaporative coolers are typically small in size as it only consists of the membrane, water pump, and centrifugal fan. The mineral content of the municipal water supply will cause scaling on the membrane, which will lead to clogging over the life of the membrane. Depending on this mineral content and the evaporation rate, regular cleaning and maintenance is required to ensure optimal performance. Generally, supply air from the single-stage evaporative cooler will need to be exhausted directly (one-through flow) because the high humidity of the supply air. Few design solutions have been conceived to utilize the energy in the air like directing the exhaust air through two sheets of double glazed windows, thus reducing the solar energy absorbed through the glazing. Compared to energy required to achieve the equivalent cooling load with a compressor, single stage evaporative coolers consume less energy.

Materials

Traditionally, evaporative *cooler pads* consist of excelsior (aspen wood fiber) inside a containment net, but more modern materials, such as some plastics and melamine paper, are entering use as cooler-pad media. Modern rigid media, commonly 8" or 12" thick, adds more moisture, and thus cools air more than typically much thinner Aspen media. Another material which is sometimes used is corrugated cardboard.

Design considerations

Water use

In arid and semi-arid climates, the scarcity of water makes water consumption a concern in cooling system design. However, such concerns are addressed by experts who note that electricity generation usually requires a lot of water, and evaporative coolers use far less electricity, and thus comparable water overall, and cost less overall, compared to chillers.

Shading

Allowing direct solar exposure to the media pads increases the evaporation rate. Sunlight may, however, degrade some media, in addition to heating up other elements of the evaporative cooling design. Therefore, shading is advisable in most applications.

Mechanical systems

Apart from fans used in mechanical evaporative cooling, pumps are the only other piece of mechanical equipment required for the evaporative cooling process in both mechanical and passive applications.

Exhaust

Exhaust ducts and/or open windows must be used at all times to allow air to continually escape the air conditioned area. Otherwise, pressure develops and the fan/blower in the system is unable to push much air through the media and into the air conditioned area. The evaporative system cannot function without exhausting the continuous supply of air from the air conditioned area to the outside. By optimizing the placement of the 'cooled air' inlet, along with the layout of the house passages, related doors and room windows, the system can be used most effectively to direct the cooled air to the required areas. A well designed layout can very effectively scavenge and expel the hot air from desired areas without the need for an above ceiling ducted venting system. Continuous airflow is essential, so the exhaust windows or vents must not restrict the volume and passage of air being introduced by the evaporative cooling machine. One must also be mindful of the outside wind direction, as for example a strong hot southerly wind will slow or restrict the exhausted air from a south facing window. It is always best to have the downwind windows open, while the upwind windows are closed.

Comparison to air conditioning

Less expensive to install and operate

- Estimated cost for professional installation is about half or less that of central refrigerated air conditioning.
- Estimated cost of operation is 1/8 that of refrigerated air conditioning.
- No power spike when turned on due to lack of a compressor
- Power consumption is limited to the fan and water pump, which have a relatively low current draw at start-up.
- The working fluid is water. No special refrigerants, such as ammonia or CFCs, are used that could be toxic, expensive to replace, contribute to ozone depletion and/or be subject to stringent licensing and environmental regulations.

Ease of installation and maintenance

- Equipment can be installed by mechanically-inclined users at drastically lower cost than refrigeration equipment which requires specialized skills and professional installation.
- The only two mechanical parts in most basic evaporative coolers are the fan motor and the water pump, both of which can be repaired or replaced at low cost and often by a mechanically inclined user, eliminating costly service calls to HVAC contractors.

Ventilation air

- The frequent and high volumetric flow rate of air traveling through the building reduces the "age-of-air" in the building dramatically.
- Evaporative cooling increases humidity. In dry climates, this may improve comfort and decrease static electricity problems.
- The pad itself acts as a rather effective air filter when properly maintained; it is capable of removing a variety of contaminants in air, including urban ozone caused by pollution], regardless of very dry weather. Refrigeration-based cooling systems lose this ability whenever there is not enough humidity in the air to keep the evaporator wet while providing a frequent trickle of condensation that washes out dissolved impurities removed from the air.

Disadvantages

Performance

- Most evaporative coolers are unable to lower the air temperature as much as refrigerated air conditioning can.
- High dewpoint (humidity) conditions decrease the cooling capability of the evaporative cooler.
- No dehumidification. Traditional air conditioners remove moisture from the air, except in very dry locations where recirculation can lead to a buildup of humidity. Evaporative cooling adds moisture, and in humid climates, dryness may improve thermal comfort at higher temperatures.

Water use

- Evaporative coolers require a constant supply of water to wet the pads.
- Water high in mineral content (hard water) will leave mineral deposits on the pads and interior of the cooler.

Maintenance frequency

- Any mechanical components that can rust or corrode need regular cleaning or replacement due to the environment of high moisture and potentially heavy mineral deposits in areas with hard water.
- Evaporative media must be replaced on a regular basis to maintain cooling performance. Wood wool pads are inexpensive but require replacement every few months. Higher-efficiency rigid media is much more expensive but will last for a number of years proportional to the water hardness; in areas with very hard water, rigid media may only last for two years before mineral scale build-up unacceptably degrades performance.
- In areas with cold winters, evaporative coolers must be drained and winterized to protect the water line and cooler from freeze damage and then de-winterized prior to the cooling season.

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