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Heat Rejection Equipment at High Altitude

Heat Rejection Equipment

There are many different heat rejection equipment configurations available on the market. It's important to understand the nuanced differences and terminology that characterizes each one. Below are brief descriptions of four different types of heat rejection equipment and how they function. In addition to the equipment descriptions, there is discussion about the given equipment's capacity reduction with respect to altitude.

A **cooling tower** is a specialized heat exchanger that removes heat from water through evaporative cooling. Hot water is sprayed over fill media which provides additional surface area for increased air contact. As air moves across the fill, heat from the water is absorbed causing a portion of it to evaporate.

An **evaporative fluid cooler** is a closed loop cooling tower. A working fluid, typically water or glycol, flows through a coil while cold water is sprayed over the outside of the coil. As the cold water is sprayed, the water evaporates as it absorbs heat from the working fluid.

Dry cooling is a method of removing heat through sensible heat rejection. In a typical application of dry cooling, a process fluid, such as water, flows through finned tubes. A mechanical unit, typically a fan, then works to draw air across the system. Heat is transferred from the process fluid to the air passing over the tubes through a conductive and convective process. The process fluid is then cooled to a lower temperature.

Adiabatic is a specialized dry cooler, which precools air before drawing it across a coil. Water is sprayed over media where the air is cooled prior to reaching the coil. Adiabatic configurations typically operate in warm climates with spray pump on a small percentage of the year, otherwise they behave just like a dry cooler. This makes the system more efficient than a dry cooler at peak times, while also using less water annually than an evaporative system.

Physical Traits of Air with Altitude

Cooling processes are influenced by their environment, specifically altitude. As elevation increases, temperature, water vapor, air pressure, and moisture in air decrease. We can observe how the properties of air influence each other within a given volume of air using the Ideal Gas Law.

The Ideal Gas Law can be understood using an example of a jar filled with air and by varying the volume using a lid. Pushing the lid down, the volume decreases causing the fluid to compress and the pressure of the fluid to increase. Alternatively, pulling the lid out of the jar increases the volume which lowers the pressure of the fluid. This is comparable to altitude because as elevation increases, volume increases in the expanding atmosphere. This drives the barometric pressure of the air down in addition to the air density.

Air density is directly affected by its element composition. The atmosphere contains various elements but is mostly composed of Nitrogen and Oxygen. Referring to Avogadro's Law, as water vapor fills a cubic foot of air, some of the Nitrogen and Oxygen get displaced and are replaced with the water vapor. This is because the total amount of molecules must remain constant within the given volume. As water vapor replaces the gases, the weight of the air decreases which results in less dense air. This occurs because water has a lower molecular weight than Nitrogen and Oxygen. Contrary to popular belief, humid air is less dense than dry air, as proven by the phenomenon mentioned above because the molar mass of water vapor is less than that of dry air.

The difference in density between humid and dry air can be observed in varying climates and altitudes. Higher altitudes generally have a cooler climate because there is less atmosphere. Again, this prompts a decrease in barometric pressure and a lower air density. Cold air holds less water vapor than humid/warm air, which results in higher altitudes having dry air. Dry, thin air can heat up and cool more rapidly causing large temperature shifts from day to night. These principles start the discussion about the performance of heat rejection equipment in high altitude applications.

Evaporative vs. Dry Cooling with Elevation

Evaporative cooling systems cool towards the wet bulb temperature. As altitude increases, the evaporative cooling system has an easier time evaporating water at the lower barometric pressure and air density, as mentioned above. For this reason, evaporative cooling systems do not experience a capacity reduction at higher altitudes.

Alternatively, dry cooling systems cool towards the dry bulb temperature. As altitude increases, the lower barometric pressure and air density cause dry cooling systems to lose capacity directly tied to reduction in air mass flow. Fans move a relatively constant volume of air at a fixed speed. Lower density air means less mass flow of air through the system. For this reason, dry cooling systems experience a capacity reduction as altitude increases. To note, dry bulb temperature varies throughout a day cycle, so dry and adiabatic cooler capacity fluctuates as well.

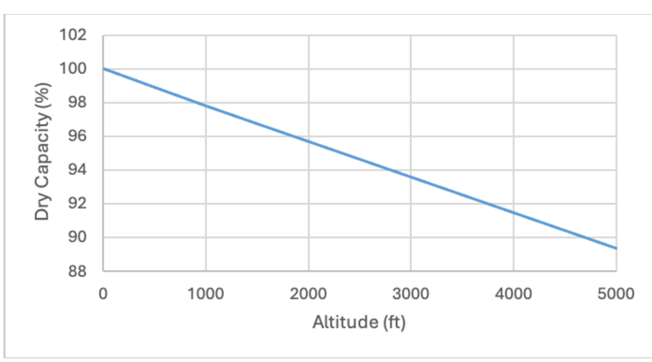


Figure 1 – Dry or Adiabatic Capacity vs Altitude

See Figure 1 for capacity relative to altitude. This general trend is supported across many different equipment manufacturers. Note the impact is significant and shall be considered when making thermal selections of either Dry or Adiabatic units.

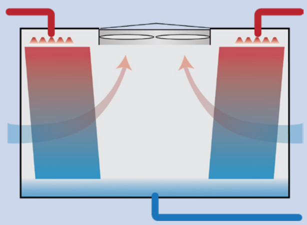
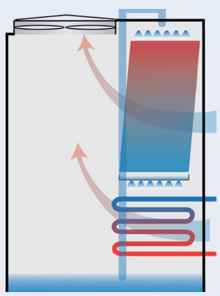
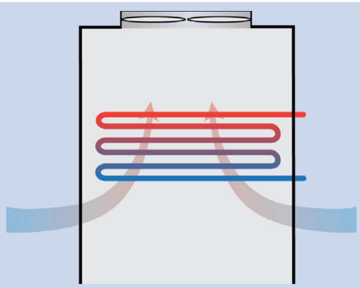
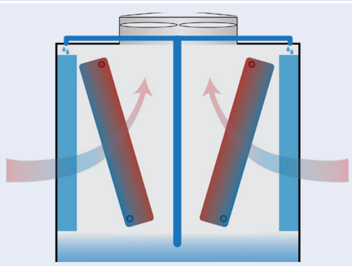
Motor Considerations

NEMA and IEC standards typically require electric motors rated up to 1,000 meters (3,300 feet) above sea level. Above that elevation, heat dissipation decreases due to lower air density. Contact the supplier for proper motor selection at altitudes exceeding 1,000 meters.

Key Takeaways

- Evaporative cooling has negligible impacts tied to altitude
- Dry and adiabatic coolers have poorer capacity at altitude due to low barometric pressure and air density
- When using CoolSpec Product Selector:
  - OlympusV adiabatic or Dry – Enter correct altitude for installation site
  - Evaporative products – Do not consider altitude in thermal selection

Heat Rejection Equipment Summary Table

Equipment Type	Operation Image	Altitude Capacity Impact	Cooling Baseline	
			Wet Bulb Temperature	Dry Bulb Temperature
Cooling Tower		N/A	✓	
Evaporative Fluid Cooler		N/A	✓	
Dry Cooler		✓		✓
Adiabiatic Cooler		✓	✓*	✓

**During peak ambient conditions (small % of year), Adiabatic cooler media is wetted to pre-cool air between the entering wet bulb and dry bulb temperature before reaching the coil.*

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