Clearing the air on a/c for industrial enclosures

Mis-sized air conditioners can do more damage than the heat they try to remove.

It is true that air conditioning added to an industrial enclosure can significantly prolong equipment life, save energy, and reduce downtime. But this is only the case when the cooling capacity matches the conditions at hand. Unfortunately enclosure cooling is all too often an afterthought. Air-conditioned equipment that runs too hot nevertheless, or is exposed to condensation, may exhibit disappointing reliability.

From the perspective of design, three general areas of concern can affect cooling efficiency. These include the internal heat loads, the way in which air-conditioner cooling capacity is calculated, and the ambient conditions such as humidity and temperature. Air-conditioner performance diagrams and sizing tools are available which can help make educated decisions.

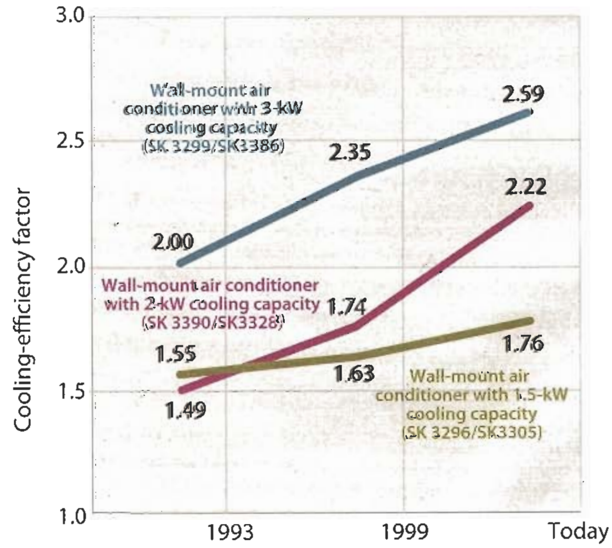
Note that the well-known SEER (Seasonal Energy Efficiency Ratio) standard doesn't apply to industrial enclosure air conditioners. The SEER rating of a unit is the cooling output in Btu during a typical cooling season divided by the total electric-energy input in watt-hours during the same period. But air conditioners for enclosures are not used on a "seasonal" basis. They cool installed equipment year-round. So the "cooling season" mentioned in SEER has no meaning in this context.

Internal heat load is the amount of heat energy that the electronics inside the enclosure produce. This energy comes from the electricity running through the components that is not converted to work. Designers must know how much heat energy (in Btu/hr or in watts/hr) gets created in the enclosure as a starting point for specifying an air conditioner that has enough capacity.

Next comes the determination of how much heat energy the air-conditioning system must remove. There are a number of ways to do this. One way is to add up the heat loads of all installed electronic components as specified by the component manufacturers. Another is to total up the

How cooling-efficiency ratio has risen

(Example: Rittal TopTherm Plus air conditioners)



Cooling efficiency has improved through the years, a point readily apparent from a plot of efficiency over time.

power, P, that the electronics consumes and then multiply it by one minus the efficiency, E, of the system, expressed as a decimal (i.e., $P(1\text{-}E)$). The resulting number defines the need for cooling capacity.

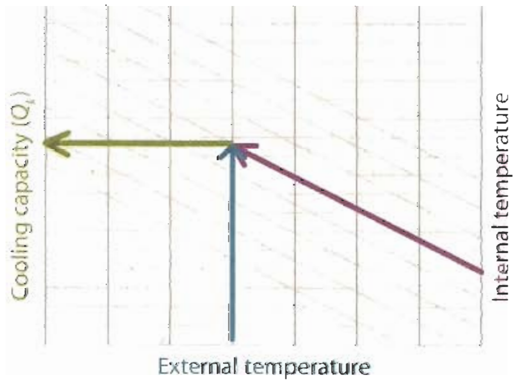
For example, suppose an electronics system consumes 500 W and is 20% efficient. Thus, the system uses only 100 W of power for its actual work. Then $(1 - 0.2) \times 500 = 400$ W dissipated in the form of heat.

Cooling capacity is the maximum amount of thermal energy that a climate-control product can remove. Cooling-capacity units are either watts/hr or Btu/hr (to convert watts/hr into Btu/hr, multiply by 3.413).

Ambient temperature (T_a) can significantly affect air-conditioner performance. An air conditioner provides less cooling capacity if it operates in high ambient temperatures. This is because there must be a temperature difference between the hot refrigerant gas and the surrounding environment. The hotter the outside air, the less effectively the air conditioner transfers enclosure heat energy from its condenser coil. Conversely, when air conditioners operate in cooler settings, heat transfers more efficiently through the condenser coil into the ambient air, thus raising the cooling capacity of the air conditioner.

The maximum allowable internal temperature (T_i) is also relevant to the amount of cooling capacity an air conditioner needs. T_i determines how much thermal energy must be removed which, of course, varies by application. Typically, air conditioners operate by maintaining temperatures that do not exceed specified setpoints. A recommended setpoint for enclosure air conditioners lies between 86 and 104°F, depending on the electronics to be cooled. It's best to avoid setpoints below this range to reduce the possibility of excessive condensation.

Typical air-conditioner performance diagram



To read an air-conditioner performance diagram, first locate the vertical line representing the external temperature. Then locate the diagonal line representing the internal temperature. At the intersection of the two lines, draw a line to the left to determine the air-conditioner performance at that point.

Another factor to be aware of is the switching hysteresis, or differential. Operators can often set this parameter rather than live with preset values, as with a home thermostat. For example, suppose the setpoint of an air conditioner is 95°F and the differential setting is 9°F. When the temperature reaches 95°F, the air conditioner begins cooling. At 86°F the unit reaches its differential setpoint and shuts off until the enclosure temperature rises again to the setpoint.

A third factor influencing the cooling capacity is the air conditioner's mains operating frequency. In North America, 60 Hz is the norm, but much of the world uses 50 Hz. When an air conditioner operates at 60 Hz, its fans and compressor actually rotate faster than at 50 Hz, so it cools somewhat more efficiently. (Some units, such as most Rittal TopTherm Plus air conditioners, are dual-rated so they can operate at both 50 and 60 Hz.)

There are no formal standards for testing and establishing cooling capacities in North America. So some manufacturers determine cooling capacity differently than others. Most manufacturers use the maximum internal and external operating temperatures as reference points. These maximum operating temperatures can differ between air-conditioner models as well as among manufacturers.

Typically, a maximum operating temperature is 131°F. If indicated, the rating temperatures could be shown as L131/L131 or T_i 95/T_a 95 or 95°F/95°F. Traditionally, the first number stands for the internal temperature.

Europe uses the DIN 3168/EN 814 part 500 standard (European standard for enclosure climate control). This standard levels the playing field and provides a more-realistic measure of performance by requiring all manufacturers to use the same temperature conditions when they determine cooling.

Helpful tools

Performance diagrams can help determine the cooling capacity of an air conditioner under variable conditions. These charts show the cooling capacity of an air conditioner per the requirements of DIN 3168, as well as under different temperature operating conditions. These charts help determine how any given air conditioner will perform in a specific application.

Sizing software is available to figure out how air conditioners will perform. These convenient tools walk users through the application factors and determine the need for

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Key points:

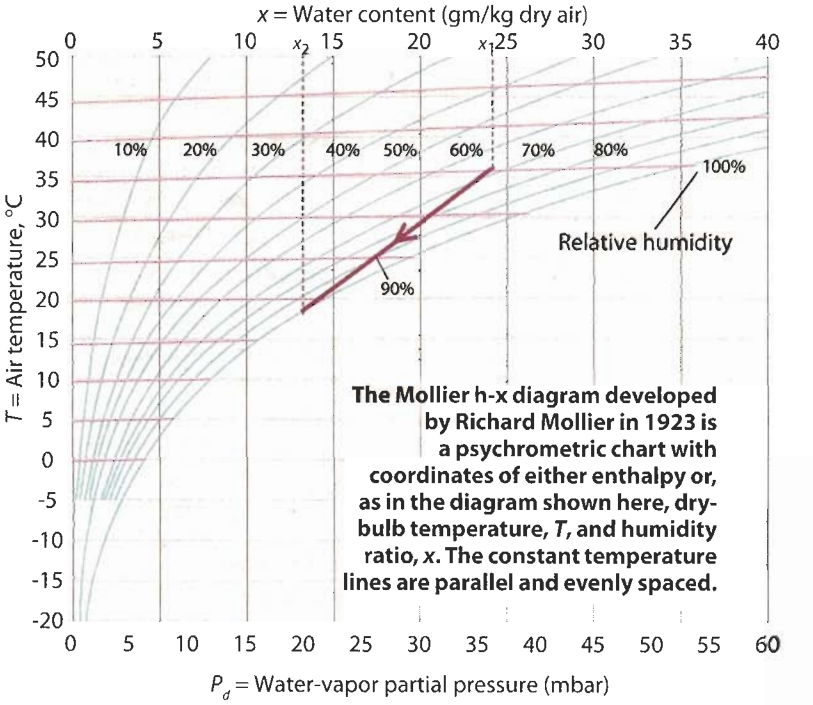
- Even the ac-mains frequency can affect the cooling capacity of an air conditioner.
- SEER ratings are useful for home air conditioners but meaningless for industrial uses.

Resources:

Rittal Corp. Industrial Enclosures, *www.rittal.com/products/industrial-enclosures/index.html*

Wikipedia psychrometrics page, *en.wikipedia.org/wiki/Psychrometrics*

Example Mollier h-x diagram



The Mollier h-x diagram developed by Richard Mollier in 1923 is a psychrometric chart with coordinates of either enthalpy or, as in the diagram shown here, dry-bulb temperature, *T*, and humidity ratio, *x*. The constant temperature lines are parallel and evenly spaced.

cooling. For example, Rittal's Therm sizing software can calculate the internal enclosure temperature and suggest an appropriate air conditioner.

The efficiency of an air conditioner is just the ratio between useful cooling capacity and power consumption. The higher the cooling efficiency factor, ϵ, the more efficient the air conditioner:

$$\epsilon = \Theta_k / P_{el}$$

where Θ_k = useful cooling capacity, W; and P_{el} = power consumption, W. For example, consider an enclosure air conditioner with a cooling capacity and power consumption at 95/95, 60 Hz of 2,700 W and 1,500 W, respectively. Then $\epsilon = 2{,}700/1{,}500 = 1.8$.

Both internal and external humidity affect performance. Air conditioners reduce the humidity of the enclosure air as a side effect of cooling. As the air cools, some of the humidity condenses on the evaporator coil. It is important to plan for reliably discharging this condensate from the enclosure. In conventional units, condensate hoses and collection bottles handle condensate. In more advanced products like Rittal's TopTherm Plus, condensate evaporators eliminate this moisture.

The amount of condensate depends on relative humidity, the air temperature in the enclosure, the evaporator coil, and the enclosure air volume. One can get a feel for likely condensation problems from a Mollier h-x diagram, which shows the water content of air depending on its temperature and indicates curves of constant relative air humidity.

A calculation example employing the accompanying Mollier h-x diagram shows how the process typically proceeds. Assume an enclosure air conditioner has a temperature set point of T_i = 95°F and the relative ambient air humidity is 70%. If 95°F air is exchanged over the evaporator coil, the surface temperature of the evaporator coil (evaporation temperature of the refrigerant) is approximately 64°F.

At the outer layer of condensate, water condenses and adheres to the surface of the evaporator coil at the dew point. The difference in water content, $\Delta x = x_1 - x_2$, indicates the amount of condensation that occurs per 2.2 lb (or 1 kg) of air with complete dehumidification. Here x_1 is the water content at the initial temperature and x_2 is the water content at the final temperature.

The degree to which an enclosure is airtight plays an important role in the amount of condensation that will arise in any application. The quantity and humidity of ambient air is limited in a properly sealed enclosure, so condensation will be limited as well.

To solve for water quantity,

$$W = V \bullet \rho \bullet \Delta x$$

where W = water quantity, grams; V = cabinet volume, m³; ρ = density of air, kg/m³; and Δx = difference in water content in gm/kg dry air (from the Mollier h-x diagram).

For this example, assume the enclosure door is closed and all cutouts or openings are properly sealed so ambient air is not entering the enclosure. Then only the humidity trapped inside the enclosure is dehumidified. Assume for the sake of this example that the enclosure is 0.6-m wide, 2-m high, and 0.5-m deep. This gives an enclosure volume, V, of

$$V = W \bullet H \bullet D = 0.6 \bullet 2 \bullet 0.5$$
$$V = 0.6\ m^3$$

Then

$$W = V \bullet \rho \bullet \Delta x$$
$$= 0.6\ m^3 \bullet 1.2\ kg/m^3 \bullet 11\ gm/kg$$
$$= 7.92\ gm$$

If placed into the same calculation example above, an improperly sealed enclosure will see more condensation. Ambient humid air can enter through poorly sealed cable entries, damaged or open enclosure doors, and through damaged enclosure gaskets, causing more condensation. For example, if ambient air enters the enclosure at a rate of 5 m³/hr, the result is a permanent condensation of 2.7 oz/hr (80 ml/hr).

Because of this higher volume of condensation, it's always recommended that control panels operate with enclosure doors closed and that all sides of the enclosure be sealed with gaskets. It is also advisable to use a door switch that interrupts the operation of the air conditioner while the enclosure door is open and to set the internal temperature of the enclosure only as low as needed. **MD**