Reducing Waste with an Air to Air Heat Exchanger

Electrical Enclosures and the Need for a Thermal Management System

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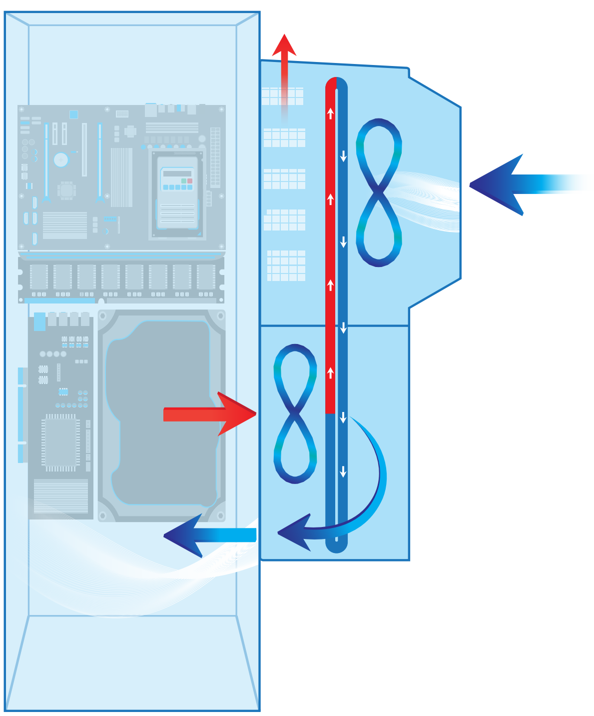
Introduction

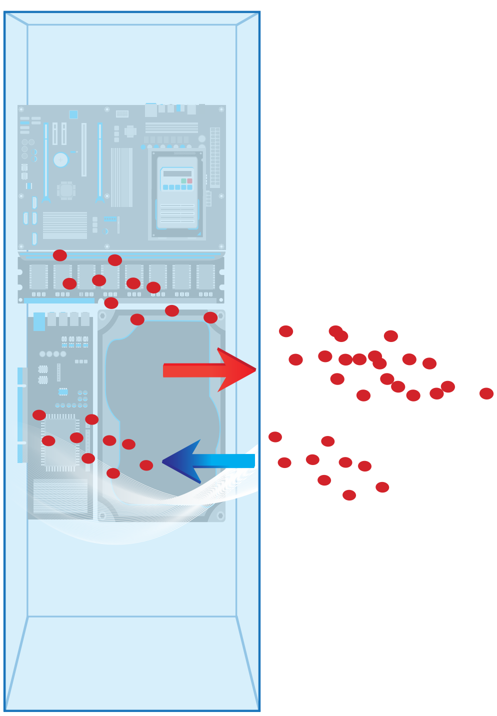
With a global push to reduce energy waste and potllution, choosing a properly sized thermal management system that fits environment conditions is more important than ever. This not only reduces the energy usage of the thermal management system but also keeps electrical components within their optimal temperature and humidity range, increasing their efficiency. Thermal management involves maintaining a temperature and humidity range inside of an electrical enclosure. This is crucial to ensuring the electrical components inside are protected from condensation and overheating, providing continuous uptime and longer lifespans for the components. Depending on environment conditions, target temperatures, and the needs of a particular application, different types of thermal management systems can be used to provide the best protection.

For thermal management systems, there are two types of cooling, passive and active, and two types of loops, open and closed. Heat (energy) can only flow from a higher energy source to a lower energy source. Passive cooling uses the natural path of heat transfer to move energy from a higher energy source to a lower energy source. Active cooling is used when energy needs to be moved from a lower to a higher energy source. This is done by inputting mechanical energy into the system so that the heat has a path to follow. An open loop occurs when the ambient environment mixes with the enclosure environment, and a closed loop occurs when the ambient environment and enclosure environment are kept separate (see Figure 1).

Fig. 1



Closed Loop Cooling:
Complete separation of internal and external air/water circuits



Open Loop Cooling:
Where ambient and internal air/water circuits mix

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Examples of Thermal Management Solutions

1. Passive Cooling

a) Fans & Exhaust (Open Loop)

This simple method uses fans to move cooler air from the ambient environment into the enclosure and carries warmer air out through the exhaust. It uses the least amount of energy to remove heat, with minimal space requirements. However, as this is an open loop solution, outside air will pass through the enclosure. The air moving through the enclosure can carry airborne particulates, contaminating any sensitive devices within the electrical enclosure. Even with the addition of a filter material to the system, this method cannot protect against high humidity environments or fine particulates (5 microns or less).

b) Heat Exchangers

i. Air to Air (Closed Loop)

This technology allows the transfer of heat between the inside of the enclosure and the environment while still separating the two compartments. This is a closed loop solution, which is beneficial for preventing contaminants- whether liquid or particulate- from entering the enclosure.

ii. Air to Water (Closed Loop)

Another type of heat exchanger is an air to water heat exchanger. This method uses cool water to absorb the heat from the enclosure. If cool water is readily available, the technology can be a very efficient.

2) Active Cooling

a. Air Conditioner AKA a Cooling Unit (Closed Loop)

This is generally a default solution for closed-loop cooling. The electrical enclosure can be cooled even in situations where the ambient temperature is higher than what the temperature inside the enclosure needs to be. This is an active solution in which energy is used to run a compressor in order to compress refrigerant so that it can release heat into the environment, allowing it to absorb heat from the enclosure.

b. Thermo Electric (Closed Loop)

This system operates according to the Peltier effect, in which heat is absorbed when an electrical current is passed through a junction and energy is directly converted from electrical to thermal energy. This solution takes up a small footprint but consumes a high amount of energy, making it very inefficient.

c. Compressed Air Cooling AKA Vortex Cooling (Open Loop)

Another solution is cooling using compressed air. Compressed air is passed through a vortex generator that separates air into a cold and hot stream. Although simple, this solution requires a high amount of energy to compress the air and is also an open loop that requires a clean source of compressed air.

Determining When a Passive Cooling Solution is Viable

A passive cooling system uses the least amount of energy, but certain environmental properties need to be met before one can be used. When selecting a thermal management product, the first property that needs to be considered is the ambient temperature in correlation to the maximum target enclosure temperature. If the ambient is at least 10°C (18°F) lower than the maximum target enclosure temperature, then a passive cooling solution such as filter fans or air to air heat exchangers can be used. If the environment temperature is more than 18°F higher than the target internal temperature, then it must be determined if there is a source of chilled water. If there is a source of chilled water, a passive air to water heat exchanger can be used. If there is no chilled water, an active cooling solution must be used.

Once it is determined that a passive cooling solution can be used, the choice between an open and closed loop solution needs to be made. With a passive open loop solution there is always the possibility of contamination from airborne particulates and corrosive chemicals, reducing the life span of electrical components and increasing maintenance and replacement costs. If an electrical enclosure becomes contaminated from an open loop solution, excessive down time can be expected while components are replaced or repaired if there is no redundancy system in place. With a passive closed loop solution, the electrical enclosure is protected from any possible airborne particulates, chemicals, or humidity. This increases the lifespan and efficiency of electrical components, reducing maintenance costs and decreasing down time.

Sizing an Air to Air Heat Exchanger

Once all environmental properties of the application have been evaluated and it has been determined that an air to air heat exchanger can be used, the cooling capacity of the air to air heat exchanger can be calculated using Formula 1. Looking at how the capacity is calculated, it can be seen that the ratio of capacity to allowable temperature difference is a linear solution. This means that the higher the enclosure internal temperature can reach above the ambient temperature the greater capacity you can get.

$$\{Q_V = q_W x \Delta T\}$$

Formula 1 (Capacity of an Air to Air)

- **Q_V** [Watt]: Total performance of air to air heat exchanger.
- **q_W** [Watt/°C]: Specific cooling capacity of the air to air heat exchanger.
- **ΔT** [°C]: Difference in temperature between the ambient air and the air inside the electronics cabinet.

Pros and Cons of an Air to Air Heat Exchanger

Air to air heat exchangers are a great way to save energy and repair costs, as its only moving parts are the fans. In contrast, an active cooling system requires a complete refrigerant system. Table 1 shows power consumption for 2 kW of cooling capacity from an air to air and an A/C unit as well as the cost to repair the main components (Fans for an Air to Air, Fans/ Compressor/Brazed Joints/Expansion Valve for an A/C Unit). A temperature-controlled environment obtains more savings, as the HVAC system for the environment does not have to remove the excess mechanical energy produced by a compressor. Air to air heat exchangers use either fin and tube technology or heat pipes to provide heat transfer without the mixing of air. A shortcoming of air to air heat exchangers is that the primary method of increasing the specific cooling capacity is to increase the surface area, leading to units that are too large and cannot fit onto electrical enclosures that an A/C unit could fit on for the same cooling capacity. There have been new technological advancements in air to air heat exchangers (Micro Channel Coils, Thermal Siphon, Pulsating Heat Pipes, etc.) that increase their efficiency, allowing them to meet the required cooling capacities without becoming too large for the enclosures. With these advancements, air to air heat exchangers can now fit on more electrical enclosures for higher heat generating applications in climate-controlled plants and work areas, leading to lower power bills and repair costs.

Power Consumption for 2,000 W Cooling Capacity
@ 24°C (75°F) Ambient and 35°C (95°F) Target Enclosure Temperature Δ11°C (20°F)

Unit	Air to Air Heat Exchanger	A/C Unit
Highest Energy Components	2 Fan	2 Fans and 1 Compressor
Power Consumption (W)	353	1,440
Monthly Operating Cost 360hr @ $0.12/kW*hr	$15.25/month	$62.21/month
Replacement Costs for Major Components Average meantime between failure ~ 60,000 hrs	$1,200.00	$4,300.00

Table 1 (Cost of Passive vs Active)

Conclusion

With the global push to reduce energy waste and pollution, air to air heat exchangers are in higher demand. Every two A/C units replaced with air to air heat exchangers is the equivalent to removing the carbon footprint of one vehicle, leading more and more companies to switch to air to air heat exchangers when their environment allows it.

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