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How to Select and Size Enclosure Thermal Management Systems

Follow the steps detailed in this white paper for optimal design for heating and cooling enclosure components and systems.

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Housing electrical components inside an enclosure is a requirement in industrial applications. The enclosure is required to protect the controllers, power distribution components, power supplies and other electronics from harsh factory floor environments. Factories, plants and facilities often experience relatively warm ambient temperatures, and many of the electrical components housed in the control enclosure generate heat, so many enclosures require cooling. In some instances, such as for outdoor installations, enclosures may require heating.

When fluctuating ambient temperatures exist, cooling and/or heating are often required to maintain optimal operating temperatures, keep condensation from forming, and prevent components from overheating or freezing. There are many products available to keep enclosures and the components housed inside within an acceptable temperature range.

Enclosure Thermal Management

Controlling internal temperature is done by transferring heat into or out of an enclosure. The three heat transfer mechanisms used are convection, conduction and radiation. Convection is the movement of heat through a moving fluid, a gas or a liquid, or from a moving fluid to the surface of a solid. Conduction is the flow of heat through solid material, such as the enclosure itself, or between two solids. Radiation is the transfer of thermal energy via conversion to and from electrical energy, such as with an electric strip heater.

This white paper discusses the different types of enclosure thermal management systems used to maintain optimum conditions inside enclosures. The paper will examine the wide assortment of heaters, air conditioners, heat exchangers, vortex coolers, venting devices and control units designed to provide efficient and cost-effective climate control of an enclosure.

Keeping a Consistent Temperature

In most cases, enclosure heating is not used to keep internal components warm. In fact, most electric and electronic components perform better at colder temperatures. The exception is when an enclosure is installed outside in an area where ambient temperatures dip well below freezing. In these situations, heating is required to keep internal temperatures within the operating range of electrical components.

More typically, heating is needed to reduce moisture and related corrosion. The goal of enclosure heating is to keep the relative humidity inside the enclosure below 65%. A consistent temperature inside a control enclosure helps guarantee optimal operating conditions and prevent condensation. In some applications, an enclosure may need to be cooled during the day and heated at night.

If a heater is used, its placement is important. Optimal performance is achieved by placing a heater near the bottom of an enclosure to allow natural convection for heat distribution. Larger enclosures often require fan heaters to distribute the heat throughout the enclosure. Generally, heaters over 150 Watts will include an axial fan to move the heat throughout the enclosure.

Five Steps to Determine Heating Requirements

Calculations to determine the required heater size include the following five steps. Imperial or metric units can be used, but consistency among units must be maintained.

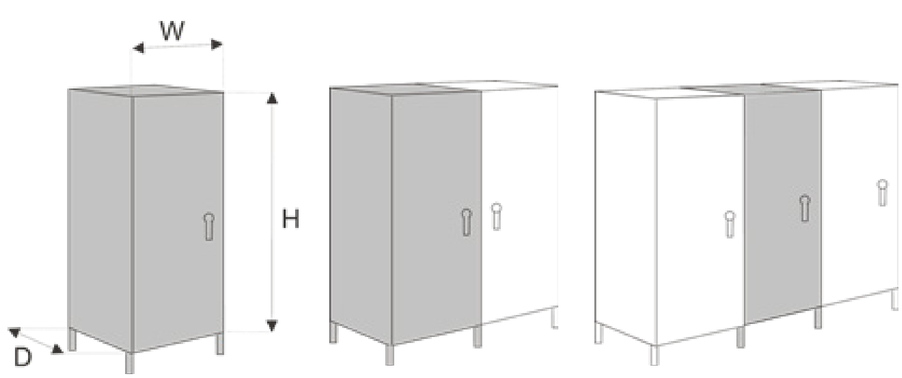
1. Determine the Enclosure Surface Area (A) exposed to open air

   Enclosure Dimensions:

   height = ________feet ________meters
   width = ________feet ________meters
   depth = ________feet ________meters

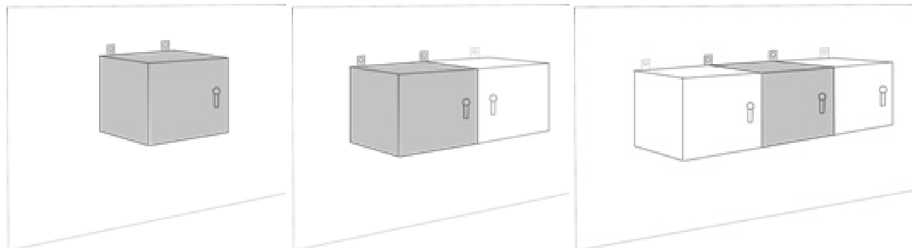
   The enclosure surface area and related conduction varies depending on mounting method such as free-standing or wall mounted. Choose the mounting method using Figure 2, and calculate the surface area as indicated: **A = ________ ft^2 or ________ m^2**

   Figure 2: Enclosure Mounting Types and Surface Area Calculations



a. Free-Standing

Area (A) = 1.8 (H x W) + 1.8 (H x D) + 1.8 (W x D)	**Area (A) = 1.8 (H x W) + 1.4 (H x D) + 1.8 (W x D)**	**Area (A) = 1.8 (H x W) + (H x D) + 1.8 (W x D)**

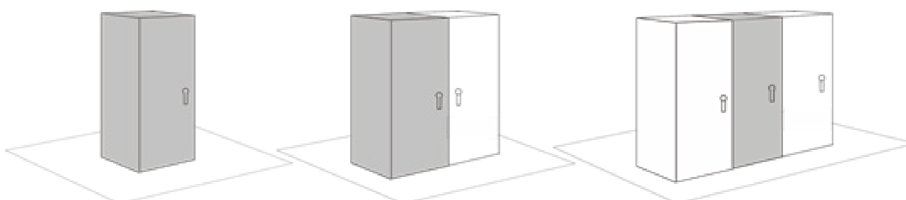


b. Wall-Mounted:

Area (A) = 1.4 (H x W) + 1.8 (H x D) + 1.8 (W x D)

Area (A) = 1.4 (H x W) + 1.4 (H x D) + 1.8 (W x D)

Area (A) = 1.4 (H x W) + (H x D) + 1.8 (W x D)

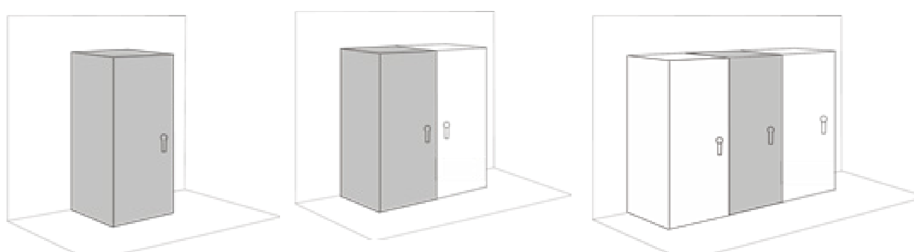


c. Ground:

Area (A) = 1.8 (H x W) + 1.8 (H x D) + 1.4 (W x D)

Area (A) = 1.8 (H x W) + 1.4 (H x D) + 1.4 (W x D)

Area (A) = 1.8 (H x W) + (H x D) + 1.4 (W x D)



d. Ground and Wall:

Area (A) = 1.8 (H x W) + 1.8 (H x D) + 1.4 (W x D)

Area (A) = 1.8 (H x W) + 1.4 (H x D) + 1.4 (W x D)

Area (A) = 1.8 (H x W) + (H x D) + 1.4 (W x D)

2. Choose a Heat Transmission Coefficients (k) value (imperial or metric) from the table below based on the enclosure construction material:

Enclosure Material	Coefficient (W/ft²•K)	Coefficient W/(m²•K)
Painted Steel	**0.511**	**5.5**
Stainless Steel	**0.344**	**3.7**
Aluminum	**1.115**	**12**
Plastic or Insulated Stainless Steel	**0.325**	**3.5**

Coefficient (k) Value selected = (Imperial) ____ W/(ft2•K) or (metric) _____ W/(m2•K)

3. Determine the Temperature Differential (ΔT).
   a. Desired enclosure interior temperature = ____°F ____°C
   b. Lowest ambient (outside) temperature = ____°F ____°C

   Subtract a from b = Temperature differential (ΔT) = ____°F ____°C

   ΔT (°K) = _____ ΔT (°F) / 1.8 or ΔT (°K) = _____ ΔT (°C)

   Note: For these calculations, ΔT must be in degrees Kelvin (°K) so ΔT (°F) is divided by 1.8.

4. Determine Component Heating Power (PV). This includes heat generated by internal components such as transformers, power supplies, etc. Most electrical devices, based on efficiency, add heat to a control enclosure.
   PV = ________ W or ________ W

5. Calculate the required Heating Power (PH) based on the previous values

   If the enclosure is located inside:
   PH = (A x k x ΔT) - PV = __________ W
   If the enclosure is located outside:
   PH = 2 x (A x k x ΔT) - PV = __________ W

There are a wide variety of electrical enclosure heaters for thermal management, providing temperature and moisture control. The AutomationDirect website has touch-safe positive temperature coefficient heaters to prevent the formation of condensation and provide evenly distributed interior air temperature in enclosures. Some selection choices include heater units with or without fans. It is also important to choose an operating voltage compatible with the control system.

Heaters should always be controlled with a thermostat or a hygrostat to turn them OFF when the enclosure internal temperature and/or relative humidity is sufficient to prevent condensation. Controls may be adjustable or preset to fixed ON/OFF setpoints. Control devices may be integrated into the heater, or may be an independent device.

Cooling a Control Enclosure

There are many reasons to add cooling to a control enclosure. Heat may be added to an enclosure from internal components such as drives and power supplies, or from external sources such as ovens, furnaces, foundry equipment, etc. Excess heat decreases life expectancy of control components such as programmable logic controllers, human machine interfaces, and AC drives. Heat can also cause electrical/electronic component problems including overload tripping, change in performance of circuit breakers and fuses, power failures, and more.

The cooling method used depends on the combined internal and external enclosure

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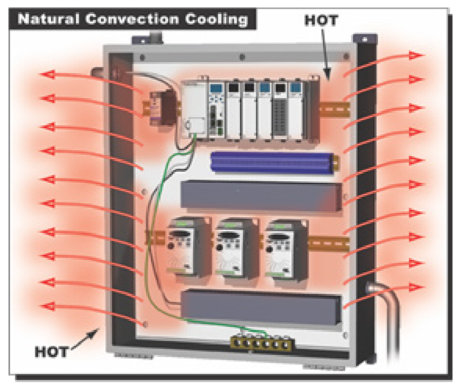
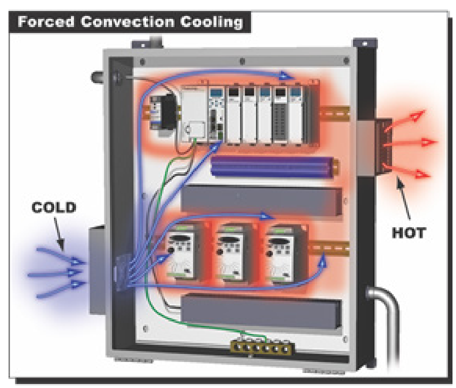
heat load. Heat flows from higher temperature to lower temperatures, so ambient temperature plays a significant role, with higher ambient temperatures adding to the required cooling.

The enclosure protection rating is also important, as sealed enclosures will retain more heat than those vented to ambient. If the heat inside an enclosure cannot be vented while keeping outside contaminants out, then other cooling methods must be considered to maintain the enclosure rating. There are several types of cooling methods including natural convection, forced convection, closed-loop cooling and vortex cooling.

Enclosure Cooling: Natural and Forced Convection

Convection is the primary mechanism used to control the temperature inside an enclosure. The rate of convection depends on the movement of air. The faster the air moves inside the enclosure, the faster heat transfer occurs. Natural convection is caused by hot air rising, which can circulate air inside and can keep many enclosures cool. However, forced convection with a fan provides higher heat transfer rates. In both cases, convection occurs when relatively cool ambient air reduces the internal enclosure temperature. Convection cannot be used to effectively cool an enclosure when ambient temperatures are high.





If cooling requirements are low, natural convection using grilles with filters are often the preferred solution. Proper installation allows cool convection air to enter at the enclosure bottom and exit near the top.

Grille: In fiberglass enclosures, a breather vent can be used to provide convection cooling, and a drain vent can be used to remove moisture. These vents maintain a UL 4X enclosure rating.

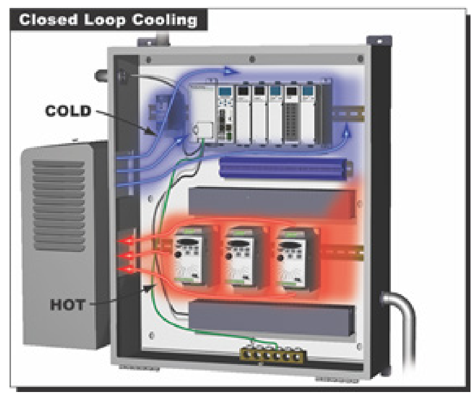
Vent: Forced convection is a good option when clean and cool outside air is available. To force air, a filter fan and grille are mounted low on the enclosure and used to force relatively cool ambient air into the enclosure. An exhaust grille, mounted high on the enclosure, allows hot air in the enclosure to exhaust.

Filter Fan: Forced convection creates a constant air flow through the enclosure to prevent localized heat pockets, and to protect components from overheating. If hot spots are a concern, for example with components generating excessive amounts of heat, compact fans can provide spot cooling to focus air where required.

STEGO enclosure exhaust grilles with filters, filter fans and compact fans, and Hubbell-Wiegmann vents, louver plates and filters, available from AutomationDirect, provide a wide selection of natural and forced convection cooling solutions. These vents & louver plates and filter fans are available for applications where natural and forced convection creates sufficient cooling.

Enclosure Cooling: Closed Loop Cooling

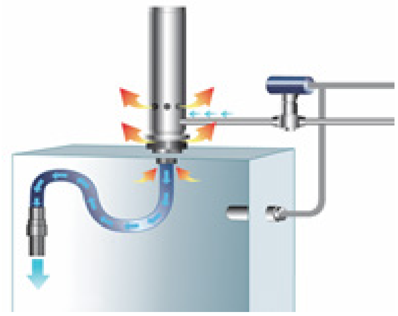
Closed loop cooling is used when the ambient temperature is as high or higher than the desired internal temperature, or when internal components generate excessive heat. It's also used when there is a need to maintain temperature inside an enclosure at or below safe levels for the equipment/components without introducing outside air into the enclosure. Closed loop cooling is typically used in:



- Harsh environments
- Areas where washdown is required
- Areas with heavy dust and debris
- Areas where chemicals are airborne
- Areas with high ambient temperatures
- Enclosures with internal components generating excessive heat

Closed loop cooling options offered by AutomationDirect, which maintain the enclosure protection rating, include Stratus enclosure air conditioners and air-to-air heat exchangers. The primary differences between the operation of an enclosure air conditioner and an enclosure heat exchanger is the refrigerant and how it is circulated through the evaporator and the condenser.

Enclosure Air Conditioners: The high efficiency and effectiveness of an air conditioner does come at a price. The compressor uses much more electrical power than a filter fan or a heat exchanger, but energy-efficient compressors and programmable temperature controllers help keep energy costs in check.



Refrigerant-Free Vortex Coolers: Vortex coolers aren't closed loop because they displace hot air inside the enclosure with cold air from the outside. However, since the cold air comes from a filtered compressed air system, they still maintain NEMA enclosure ratings.

The vortex generator inside the cooler creates a vortex that rotates the compressed air supply at speeds up to 1,000,000 rpm, with the rotation separating the air into hot and cold air streams. The hot air stream is vented to the atmosphere, while the super-cooled air is forced through the center of the incoming air stream through the cold air exhaust port and into the enclosure. Hot air from the enclosure is forced out through a vent. Vortex coolers generate a stream of cold air using nothing except compressed air,with no fans, moving parts, or electrical power required.

Like an air conditioner, a vortex cooler is effective even in high ambient temperatures. Vortex coolers, such as those manufactured by Stratus, are useful when air conditioner or heat exchanger cooling is not possible. This includes small to medium size enclosures, non-metallic enclosures, areas where the size of cooling devices is restricted, and areas where access to electrical power is limited but compressed air is available.

While vortex coolers are very inexpensive to purchase and install and require no maintenance, they do consume a significant amount of compressed air, which must be accounted for in their operating cost.

Cooler Component Sizing

After choosing the most appropriate cooling method (natural convection, forced convection, or closed-loop), calculations are needed to determine the size/capacity of the cooling components.

Sizing an Enclosure Fan: To calculate the fan cubic feet per minute (CFM) required for a forced air cooling solution, determine amount of heat to be removed (watts) and maximum temperature differential (ΔT).

Cubic Feet per Minute (CFM) = $(3.17 \times P) / \Delta T$ °F
Where: P = Power to be dissipated in watts
ΔT = (max outside ambient air °F) - (max allowable internal enclosure air °F)

Stego offers an online Cooling Calculation Tool to help calculate the required airflow rate for an application.

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Sizing an Air Conditioner or Vortex Cooler: To select the proper size unit, consider the worst-case conditions, but do not oversize. There are two main factors to consider when calculating cooling requirements: internal heat load and heat load transfer.

Internal heat load: Is the heat generated by components inside the enclosure. The preferred method to determine this is to add the maximum heat output specifications that the manufacturers list for all the equipment installed in the cabinet. Load is needed in BTU, but the values are typically given in Watts, so use the following conversion:

BTU per Hour = Watts x 3.413

For example, the Watt-loss chart for and AutomationDirect GS3-2020 AC drive has a Watt-loss of 750 watts. BTU per Hour = 750 watts x 3.413 = 2559

Heat Load Transfer: Is the heat lost (negative heat load transfer) or gained (positive heat load transfer) through enclosure walls from the surrounding ambient air. It's calculated using the following formula:

Heat load transfer (BTU/H) = 1.25 x surface area (ft^2) x (max. outside ambient air °F – max. allowable internal enclosure air °F)

Note: 1.25 is an industry standard constant for metal enclosures; for plastic enclosures use 0.62.

Surface Area (ft^2) = 2 [(H x W) + (H x D) + (W x D)] / 144 sq. inches

Once the internal heat load and the heat load transfer is determined, the cooling capacity needed is calculated as follows:

Cooling capacity (BTU/H) = Internal Heat Load ± Heat Load Transfer

Enclosure Thermal Management Controls

Enclosure heaters controlled with thermostats, humidistats (hygrostats) and hygrotherms provide the consistent temperature and humidity control needed. Many enclosure heaters include integrated thermostats or other controls, and some heaters may allow for or require external controls.

The need for cooling control depends on the type of device. Filter fans and heat exchangers do not typically require a thermostat since they consume very little power, and therefore can be always on, but a control device will prolong filter life.

Stratus air conditioners from AutomationDirect have an integral thermostat, so an external control device is not needed. Stratus vortex coolers should always be controlled by a thermostat to minimize compressed air consumption. In some cases, a thermostat may also be needed to prevent freezing of components inside the enclosure.

Tamperproof thermostats, often DIN rail-mounted, are available. Adjustable thermostats are also available. A normally-closed adjustable thermostat opens on temperature rise above setpoint, and a normally-open unit closes on temperature rise.

Setpoint Thermostats and Hygrostats

Adjustable Dual-setpoint Thermostat: Houses two separate thermostats, allowing independent control of heating and cooling. The normally-closed thermostat (red dial) opens on temperature rise above set point, while the normally-open thermostat (blue dial) closes on temperature rise.

Electronic Hygrostats (Humidistats): Sense relative humidity in an enclosure, and turn on a heater at the setpoint to prevent condensation formation.

Electronic Hygrotherms: Sense ambient temperature and relative air humidity. Depending on the selected contact combination, the hygrotherm will turn a connected device ON or OFF if the temperature is below the setpoint, or if the humidity is above the setpoint. Hygrotherms are typically used to control positive temperature coefficient heaters, fan heaters, condensation heaters or other climate control devices.

Be sure to understand whether you need to keep your enclosure cool, or warm and dry, or both. Once your cooling or heating needs are defined, select a solution and properly size it for the application.

Whatever your enclosure climate control requirements are, AutomationDirect has the solution you need at prices that won't make you sweat!