Heat Dissipation in Sealed Electrical Enclosures

The accumulation of heat in an enclosure is potentially damaging to electrical and electronic devices. Overheating can shorten the life expectancy of costly electrical components or lead to catastrophic failure.

Enclosure Materials

The following discussion applies to gasketed and unventilated enclosures. Higher temperature rises can be expected with unfinished aluminum and unfinished stainless steel enclosures due to their material's less efficient radiant heat transfer. Non-metallic enclosures have similar heat transfer characteristics to painted metallic enclosures, so the graph can be used directly despite the difference in material.

Enclosure Surface Area

The physical size of the enclosure is the primary factor in determining its ability to dissipate heat. The larger the surface area of the enclosure, the lower the temperature rise due to the heat generated within it.
To determine the surface area of an enclosure in square feet, use the following equation:
Surface Area = 2[(A x B) + (A x C) + (B x C)] ÷ 144
where the enclosure size is A x B x C in inches.
This equation includes all six surfaces of the enclosure. If any surface is not available for transferring heat (for example, an enclosure surface mounted against a wall), that surface's area should be subtracted. *Note: Enclosure volume cannot be used in place of surface area.*

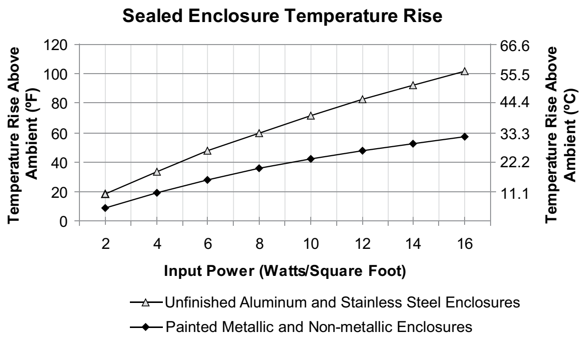
Enclosure Heat Input

For any temperature rise calculation, the heat generated within the enclosure must be known. This information can be obtained from the supplier of the components mounted in the enclosure.

Enclosure Temperature Rise (ΔT)

Research has shown for every 18 F (10 C) rise above normal room temperature 72 - 75 F (22 - 24 C), the reliability of electronic components is cut in half.

The temperature rise illustrated by the curves in the Sealed Enclosure Temperature Rise graph is the temperature difference between the air inside a non-ventilated and non-cooled enclosure and the ambient air outside the enclosure. This value is described in the graph as a function of input power in watts per square foot. In order to predict the temperature inside the enclosure, the temperature rise indicated in the graph must be added to the ambient temperature where the enclosure is located.



Determining Temperature Rise

The temperature rise inside a sealed cabinet without forced ventilation can be approximated as follows.
First calculate the surface area of the enclosure and, from the expected heat load and the surface area, determine the heat input power in watts/sq. ft.
Then the expected temperature rise can be read from the Sealed Enclosure Temperature Rise graph. Find where the input power intersects the line for the enclosure material and read the approximate expected temperature rise at the left.
Example:
What is the temperature rise that can be expected from a 48 x 36 x 16 in. painted steel enclosure with 300 watts of heat dissipated within it?
Solution:
Surface Area = 2[(48 x 36) + (48 x 16) + (36 x 16)] ÷ 144 = 42 sq. ft.
Input Power = 300 ÷ 42= 7.1 Watts/Sq. Ft.
From the Sealed Enclosure Temperature Rise graph:
Temperature Rise = approximately 30 F (16.7 C)

Safety Margins

The graph provides only an approximation of temperature rise. Actual temperature rise will vary due to enclosure layout, internal fan use, air movement in the vicinity of the enclosure, and other factors. A safety margin should be used in critical applications. A safety margin of 25% is recommended.

Outdoor Applications

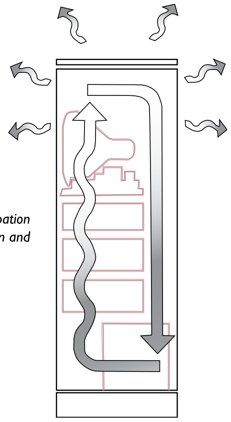
In outdoor applications where an enclosure is exposed to the sun, the temperature inside the enclosure can rise significantly above the estimates calculated. See the Solar Heat Gain section for further technical information.

Heat Dissipation in Electrical Enclosures

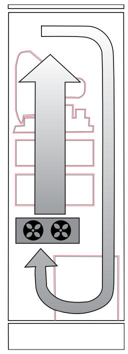
Circulating Fans

The use of circulating fans in an enclosure will improve heat dissipation by as much as 10 percent. Circulating fans are most commonly employed to eliminate hot spots inside an enclosure. The Sealed Enclosure Temperature Rise graph approximates the "average" temperature rise inside an enclosure. However, the temperature in the vicinity of a critical component can be much higher if it is producing a significant portion of the heat in the enclosure or if it is located near a large heat producing device. An internal circulating fan eliminates the resulting hot spots by mixing the air inside the enclosure.

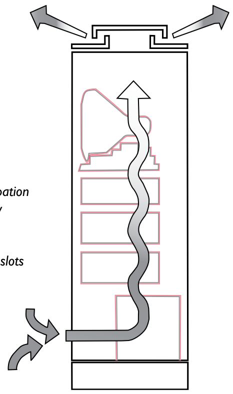
Heat dissipation by radiation and convection



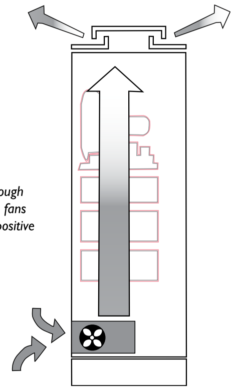
Forced air circulation via fans in sealed cabinets



Heat dissipation by specially positioned enclosure ventilation slots



Airflow through cabinet via fans (negative/positive pressure)



Cooling Options Available

Hoffman offers a full line of enclosure cooling products to meet the unique needs of many applications. These products include fans for circulation and ventilation as well as heat exchangers and air conditioners for closed loop cooling. Hoffman Authorized Distributors, Representatives, and factory technical applications support personnel are qualified to assist you in meeting your cooling requirements.

Glossary

BTU/hour = British Thermal Units/hour. One BTU is the amount of heat required to raise the temperature of one pound of water by one degree Fahrenheit.
Watts = The thermal (heat) load in the enclosure is measured in watts. One watt = 3.413 BTU/hour.
CFM = Airflow in cubic feet per minute ($ft.^3$ /min.)
ΔT = Change in temperature (1.8 ΔT F = 1.0 ΔT C)
°F = Degrees Fahrenheit
°C = Degrees Celsius

Solar Heat Gain

When evaluating the thermal management needs of outdoor electrical enclosures, solar heat gain must be considered. Variables that affect the enclosure's internal temperature rise include the amount of solar exposure, enclosure color and material type, highest sustained atmospheric temperature, heat build-up from internal components and heat reflectance from the surrounding environment.

Exposure to Solar Radiation

Over much of the United States, the approximate peak values of solar radiation striking the Earth's surface is 97 watts/ft.^{2} and the ambient air temperature can reach 104 F. Altitude, humidity and air pollution have an impact on these values, even more so than the location's latitude. In the high, dry climates of the southwest, solar radiation values of 111 watts/ft.^{2} and air temperatures greater than 104 F can be reached.

The extreme conditions the enclosure will be exposed to should be identified. If the internal enclosure temperature is greater than the outdoor (ambient) temperature, wind will provide greater heat transfer and thus cool the enclosure. But, because the presence of wind cannot be guaranteed, it is usually not taken into account when establishing a worst-case evaluation.

Effect of Surrounding Location

Reflection of solar energy from the foreground and surrounding surfaces can impact the total amount of radiant exposure by as much as 30 percent.

Effect of Enclosure Color and Finish

The percent of solar energy absorbed by the enclosure depends on surface color, finish and texture. Absorption values of the finish will increase with age.

Standardized Test Evaluation

Telcordia NEBS™ GR-487 provides a test procedure for evaluating the solar load on electrical/electronic enclosures. The test is run with the internal electronics on, in an environmentally controlled room, and three sides of the enclosure are illuminated uniformly with controlled banks of lights to a measured surface radiant value of 70 watts/ft.^{2} The temperature rise inside the enclosure above ambient is added to 115 F (46 C). This temperature total must not exceed the lowest-rated component within the enclosure.

Evaluation of Solar Heat Gain

To evaluate the heat load on an enclosure, you must take into account:

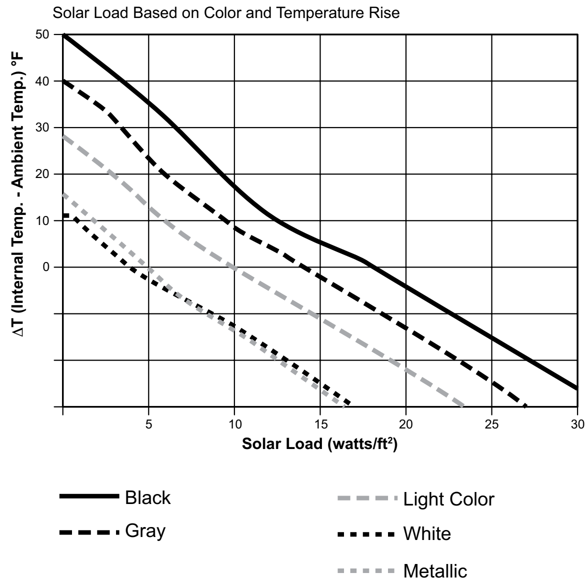
- Total surface area of the enclosure
- Color of the enclosure
- Internal heat load
- Maximum allowable internal temperature
- Maximum ambient temperature
- Solar load

Examples:

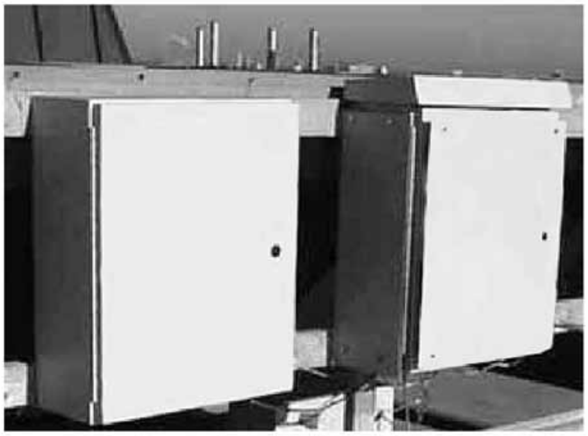
1. What amount of heat energy must be removed from a 24 x 20 x 12 (surface area = 14 ft.^{2}) ANSI 61 gray enclosure located outdoors and without any heat dissipated internally, to maintain the enclosure temperature equal to the ambient (temperature rise = 0 degrees)?
From the chart below, at 0 F temperature rise we find the solar load is approximately 14 watts/ft.^{2} 14 ft.^{2} x 14 watts/ft.^{2} = 196 watts. This is the heat energy that must be removed to maintain the enclosure temperature at ambient.

2. If the same enclosure has internal equipment dissipating 200 watts of heat, what is the amount of heat energy that must be removed to maintain the enclosure at a temperature rise of 20 F above the ambient temperature?
From the chart below, at 20 F temperature rise we find the solar load is approximately 6 watts/ft.^{2} 14 ft.^{2} x 6 watts/ft.^{2} = 84 watts.
All of the internally dissipated heat of 200 watts must also be removed. 84 watts + 200 watts = 284 watts. This is the total amount of heat energy that must be removed to maintain the enclosure at 20 F above the ambient temperature.

3. What is the expected temperature rise above the ambient temperature due to solar heat gain for an enclosure with ANSI 61 gray finish?
From the chart below, the temperature rise due to solar heat load can be found by locating the intersection of the data curve for the given finish and the 0 Solar Generated Heat Load axis. For ANSI 61 Gray, the temperature rise due to solar heat is about 40 F.



The Benefits of Shielding Enclosures

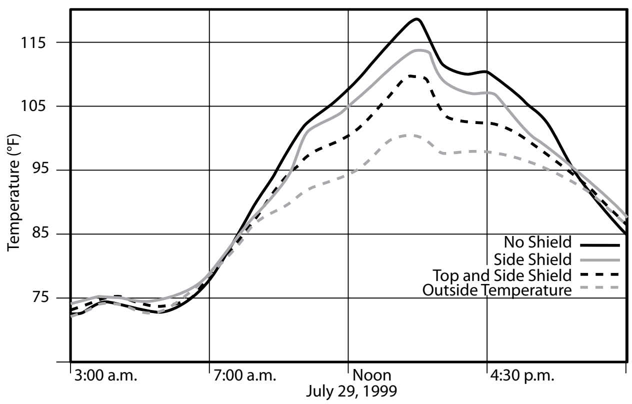


Hoffman's research on the effects of solar radiation on enclosures has shown the positive benefits of utilizing shielding to decrease temperature rise. Shielding has been found to be an effective, low-cost method of reducing solar heat gain in outdoor electrical/ electronic applications.

A test to compare the shielding effect on internal temperature rise was performed on similar enclosures exposed to the sun. The enclosures are the same color (RAL 7035 light gray) and material. The enclosure on the left is unshielded; the enclosure on the right is shielded on top and applicable sides.

The results of the test show the enclosure with top and side shields to have approximately a 46 percent reduction in temperature compared to the unshielded enclosure. The reduction in temperature is approximately 25 percent with the solar top shield only. Hoffman offers top shields as an accessory for Hoffman COMLINE Wall-Mount Enclosures. Hoffman can provide side shields as a customer-ordered modification.

Shielding E ec tiveness



Enclosure Type	Temperature (F)	Temperature (C)	Percent Temperature Reduction
Unshielded	119	48	—
Top shield only	114	46	25
Top and side shields	110	43	46

Fan/Blower Selection and Sizing

Selection Procedure

The following selection process will help determine the size of the fan required for your application.

Application Guidelines

- Forced air systems can provide much greater heat transfer rates than those available with natural convection and radiation, therefore internal electronic packages have lower hot spot temperatures with forced air systems. The amount of cooling air flowing through an enclosure determines the temperature rise inside the enclosure due to the heat input. The more air that flows through the enclosure, the lower the temperature rise.

- Fans can be used at the exhaust to draw air through an enclosure, or at the inlet to blow air into the enclosure. Generally, a blowing fan at the air inlet is recommended for the following reasons:

1. A fan at the inlet will raise the internal air pressure within the enclosure, which will help to keep dust and dirt out of an enclosure that is unsealed or opened frequently.
2. A blowing fan at the inlet will produce slightly more turbulence, which improves the heat transfer characteristics within the enclosure.
3. Fan life is prolonged since it is located in the path of the entering cooler air.

- The air inlet to the enclosure should be located as far as possible from the air outlet in order to prevent the airstream from short cycling. In a short cycling condition the air leaving the enclosure through the air outlet re-enters the enclosure through the air inlet. This condition results in a reduction in cooling efficiency. In general, it is recommended that the enclosure air inlet be on the side of the enclosure near the bottom and the air outlet be located on the opposite side and near the top.

- Fans should not be located adjacent to an area that restricts the free flow of cooling air. The use of a plenum in front of the fan is a good practice since it improves fan performance. The air velocity must be allowed to develop in order to effectively overcome the flow resistance. When the fan blades are located at the downstream end of the plenum housing, the air has a longer flow path. This improves the air velocity profile and fan performance.

- The enclosure fan system should have an air outlet area at least equal to the air inlet area.

- The system cooling efficiency changes with altitude because of reduced air density. Air flow through an enclosure should be increased when the air density decreases.

- If more than one fan is used in parallel, in the same enclosure, then both fans should be identical.

Fans and Blowers

Determine the required fan/blower size (volume airflow):

Step 1

Select the product family that best fits your application:

- Compact Cooling Fans

(economical fan with no filter)

- Cooling Fan Packages

(economical fan package with low density filter)

- Type 12 Cooling Fan Package

Step 2

Determine the internal heat load in watts.

1 Watt = 3.413 BTU/Hr.

Step 3

Determine the ΔT (°F)

Step 4

Plot your application using the selection graph to the right.

- Find Watts (internal heat load) on the vertical scale
- Draw a horizontal line across to the intersection point with the diagonal line representing your ΔT
- Extend a vertical line down to the horizontal scale to determine your CFM requirement

The red line on the chart shows the airflow requirement for a 400 watt heat load and a ΔT of 20°F.

Or calculate using the formula:

CFM = (3.16 x Watt) / (ΔT °F)

Where:

Watts = Internal Heat Load in watts

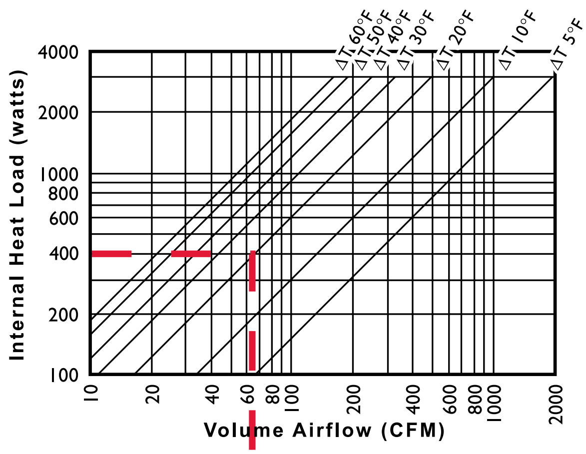
ΔT = Internal Temperature minus Ambient Temperature in °F

CFM = Required airflow in ft^3 /min.

Example:

An internal heat load of 400 watts requires airflow of about 63 CFM to maintain the enclosure at a ΔT of 20°F above the ambient temperature.

(3.16 x 400 watts) / (20°F) ≈ 63 CFM



EX:
An internal heat load of 400 watts requires airflow of about 63 cfm to reduce cabinet temperature 20°F.

Fan/Blower Selection and Sizing

Thermal Management Sizing and Selection Software

Designed to assist you in determining the most suitable choices of air conditioners, heat exchangers or fans for your application. Download a free copy of our selection software by visiting our web site: hoffmanonline.com.
Click on **Thermal Management** chapter.