Protective Cooling Solution Overview

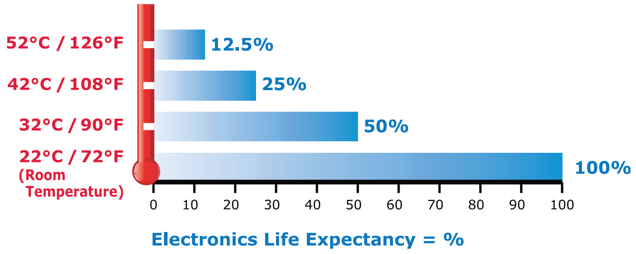
Why Cool Electronics in the First Place?

Keeping your electronics cool is essential to extending their life and keeping your business running.

Heat Ruins Electronics

The life expectancy of electronics is cut in half every 10 C / 18 F they operate above room temperature. Operating electronics above certain temperatures can void manufacturers' warranties, making proper cooling essential. Cooling vital electronics increases service life and reduces capital expenses over the long-term.

Electronics Life Expectancy with Every 10° C Rise over Room Temperature



Sources of Heat

Damaging heat can come from a variety of sources. Inside the cabinet, heat can come from:

- AC power supplies
- Controllers, drives and servos
- Transformers and rectifiers
- Processors and server racks
- Radio equipment
- And other electronic components

Heat also comes from sources outside the enclosure such as:

- Solar heat gain
- Welding processes
- Paint oven
- Blast furnace
- Foundry equipment

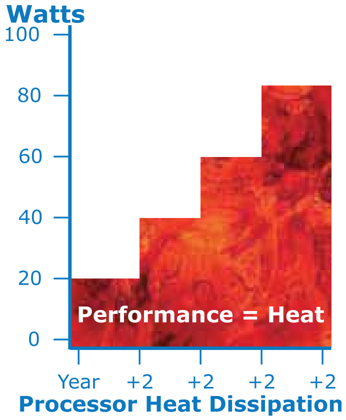
Trend Toward More Damaging Heat

For the foreseeable future, the trend is toward increasing levels of heat in electronics, not less, because the market's thirst for more information processing capacity and speed continues to grow. This trend is known as "Moore's Law."

More powerful data-processing electronics generate extra heat with virtually every new system that is designed. There is no guarantee that an application which did not require much, if any, cooling in the past will not need cooling in the future. The new system likely has more functionality and will probably require some form of cooling as a result.

Moore's Law

Named after the founder of Intel



What Are the Consequences of Damaging Heat?

Heat build-up can adversely affect industrial controls and sensitive electronic systems as follows:

- De-rated drive performance
- I/C-based devices experience intermittent fluctuations
- MTBF decreases exponentially
- Catastrophic failure

The costs when a factory line or electronic system fails can include:

- Productivity losses
- Component replacement costs
- Late shipments
- Customer dissatisfaction
- Lost revenue
- Cell phone tower outage
- Breach in homeland security

Direct costs to a business can be as much as $50,000 per hour of system downtime.

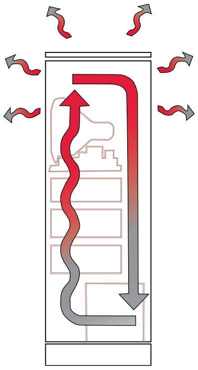
Options for Cooling Electronics

Conductive Cooling

This is a passive way to cool electronics. It simply allows the heat to radiate through the cabinet walls.

Conductive cooling works well with electronics systems that have small heat loads (<50 W) and cool air around the enclosure (<78 F/25 C).

If heat is an issue, one option within this type of cooling is to increase cabinet size to create more surface area to speed the transfer of heat. However, growing cabinet size is often not a practical solution because of space limitations and the greater heat loads associated with today's high-power electronics.

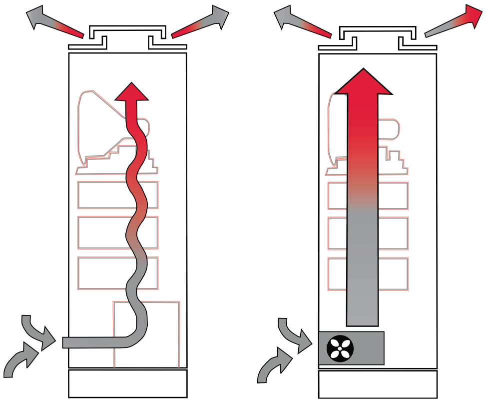


Fresh Air Cooling

This is an active way to manage heat in electronics applications. This type of cooling ventilates fresh air through the cabinet, exhausting heat away from the hot components.

Fresh air cooling may be used when the electronics system is deployed in a relatively clean and cool environment such as an office building, data networking center or light-duty factory. Options for cooling electronic enclosures with fresh air include filter fans, fan trays, motorized impellers and packaged blowers.

Fresh air cooling is known as an "open-loop system" because no significant seal is maintained to protect electronic components from harmful elements such as dirt, water, metal filings and corrosive fumes.



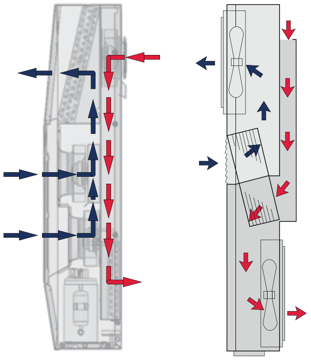
Protective Cooling

This is another active way to cool electrical components. This type of thermal management maintains the seal of the enclosure—using an air conditioner or heat exchanger as examples—to remove heat from inside the electronics cabinet.

Protective cooling is generally required when the electronics application:
(1) operates in high temperatures, typically over 95 F/35 C,
(2) is deployed in a harsh environment such as an outdoor telecom base station, wastewater treatment plant, metal working operation, oil rig platform, paper mill, foundry and/or
(3) generates a high heat load from its own components, usually more than 500 W.

Options for protective cooling include air conditioners, air-to-air heat exchangers, air-to-water heat exchangers, thermo-electric coolers and vortex coolers.

Protective cooling is known as a "closed-loop system" because the seal of the electrical cabinet is maintained, allowing no elements which can damage the electronics inside the enclosure.



Air Conditioner Heat Exchanger

Levels of Electronic Enclosure Protection

Protection Levels

NEMA, UL and CSA Ratings **Enclosure Type Descriptions for Non-Hazardous Locations**

	Type	NEMA	UL	CSA
Indoor	Type 1	Enclosures are intended for indoor use primarily to provide a degree of protection against contact with the enclosed equipment or locations where unusual service conditions do not exist.	Indoor use primarily to provide protection against contact with the enclosed equipment and against a limited amount of falling dirt.	General purpose enclosure. Protects against accidental contact with live parts.
Indoor	Type 12	Enclosures are intended for indoor use primarily to provide a degree of protection against dust, falling dirt and dripping noncorrosive liquids.	Indoor use to provide a degree of protection against dust, dirt, fiber flyings, dripping water and external condensation of noncorrosive liquids.	Indoor use; provides a degree of protection against circulating dust, lint, fibers and flyings; dripping and light splashing of non-corrosive liquids; not provided with knockouts.
Indoor	Type 12K	Enclosures with knockouts are intended for indoor use primarily to provide a degree of protection against dust, falling dirt and dripping noncorrosive liquids.	Indoor use to provide a degree of protection against dust, dirt, fiber flyings, dripping water and external condensation of noncorrosive liquids.	Indoor use; provides a degree of protection against circulating dust, lint, fibers and flyings; dripping and light splashing of noncorrosive liquids; not provided with knockouts.
Indoor	Type 13	Enclosures are intended for indoor use primarily to provide a degree of protection against dust, spraying of water, oil and noncorrosive coolant.	Indoor use to provide a degree of protection against lint, dust seepage, external condensation and spraying of water, oil and noncorrosive liquids.	Indoor use; provides a degree of protection against circulating dust, lint, fibers and flyings; seepage and spraying of non-corrosive liquids, including oils and coolants.
Outdoor	Type 3	Enclosures are intended for outdoor use primarily to provide a degree of protection against windblown dust, rain and sleet; undamaged by the formation of ice on the enclosure.	Outdoor use to provide a degree of protection against windblown dust and windblown rain; undamaged by the formation of ice on the enclosure.	Indoor or outdoor use; provides a degree of protection against rain, snow and windblown dust; undamaged by the external formation of ice on the enclosure.
Outdoor	Type 3R	Enclosures are intended for outdoor use primarily to provide a degree of protection against falling rain and sleet; undamaged by the formation of ice on the enclosure.	Outdoor use to provide a degree of protection against falling rain; undamaged by the formation of ice on the enclosure.	Indoor or outdoor use; provides a degree of protection against rain and snow; undamaged by the external formation of ice on the enclosure.
Outdoor	Type 3RX	Enclosures are intended for outdoor use primarily to provide a degree of protection against corrosion, falling rain and sleet; undamaged by the formation of ice on the enclosure.	Not specifically defined.	Not specifically defined.
Outdoor	Type 4	Enclosures are intended for indoor or outdoor use primarily to provide a degree of protection against windblown dust and rain, splashing water and hose directed water; undamaged by the formation of ice on the enclosure.	Either indoor or outdoor use to provide a degree of protection against falling rain, splashing water and hose-directed water; undamaged by the formation of ice on the enclosure.	Indoor or outdoor use; provides a degree of protection against rain, snow, windblown dust, splashing and hose-directed water; undamaged by the external formation of ice on the enclosure.
Outdoor	Type 4X	Enclosures are intended for indoor or outdoor use primarily to provide a degree of protection against corrosion, windblown dust and rain, splashing water and hose-directed water; undamaged by the formation of ice on the enclosure.	Either indoor or outdoor use to provide a degree of protection against falling rain, splashing water and hose-directed water; undamaged by the formation of ice on the enclosure; resists corrosion.	Indoor or outdoor use; provides a degree of protection against rain, snow, windblown dust, splashing and hose-directed water; undamaged by the external formation of ice on the enclosure; resists corrosion.
Outdoor	Type 6	Enclosures are intended for use indoors or outdoors where occasional submersion is encountered; limited depth; undamaged by the formation of ice on the enclosure.	Indoor or outdoor use to provide a degree of protection against entry of water during temporary submersion at a limited depth; undamaged by the external formation of ice on the enclosure.	Indoor or outdoor use; provides a degree of protection against the entry of water during temporary submersion at a limited depth. Undamaged by the external formation of ice on the enclosure; resists corrosion.

- This material is reproduced with permission from NEMA. The preceding descriptions, however, are not intended to be complete representations of National Electrical Manufacturers Association standards for enclosures nor those of the Electrical and Electronic Manufacturers Association of Canada.
- This material is reproduced with permission from Underwriters Laboratories Inc. Enclosures for Electrical Equipment, UL 50, 50E and Industrial Control Panels, UL 508A.
- This material is reproduced with permission from the Canadian Standards Association.
- Underwriters Laboratories Inc. (UL) shall not be responsible for the use of or reliance upon a UL Standard by anyone. UL shall not incur any obligation or liability for damages, including consequential damages, arising out of or in connection with the use, interpretation of, or reliance upon a UL Standard.
- Some enclosures may have multiple ratings. For instance: 4, 12—Outdoor use; able to be used indoors with modifications; 4X, 3RX—Outdoor use; able to be used indoors with modifications; 4, 9—Can be used in both hazardous and non-hazardous locations

Levels of Electronic Enclosure Protection

IP Rating Descriptions **Example Rating**

If 1st IP number is...	and the 2nd IP number is...	Then the IP rating is
2	3	IP23
(protection against solid objects)	(protection against liquids)	An enclosure with this designation provides protection against touch with a finger, penetration of solid objects greater than 12 mm and spraying water.

First Numeral (Solid Objects and Dust)

IP	Protection of Persons	Protection of Equipment
0	No Protection	No Protection
1	Protected against contact with large areas of the body (back of hand)	Protected against objects over 50 mm in diameter
2	Protected against contact with fingers	Protected against solid objects over 12 mm in diameter
3	Protected against tools and wires over 2.5 mm in diameter	Protected against solid objects over 2.5 mm in diameter
4	Protected against tools and wires over 1 mm in diameter	Protected against solid objects over 1 mm in diameter
5	Protected against tools and wires over 1 mm in diameter	Protected against dust (limited ingress, no harmful deposit)
6	Protected against tools and wires over 1 mm in diameter	Totally protected against dust

Second Numeral (Liquid)

IP	Protection of Equipment
0	No Protection
1	Protected against vertically falling drops of water, e.g. condensation
2	Protected against direct sprays of water up to 15 degrees from vertical
3	Protected against sprays up to 60 degrees from vertical
4	Protected against water sprayed from all directions (limited ingress permitted)
5	Protected against low-pressure jets of water from all directions (limited ingress permitted)
6	Protected against strong jets of water
7	Protected against the effects of immersion between 15 cm and 1 m
8	Protected against long periods of immersion under pressure

SCCR Requirements per UL (Condensed version)

Article 409 of the 2008 National Electric Code (NFPA 70) requires industrial control panels to be marked with a short circuit current rating. As specified in the National Electric Code, UL508A-2001 Supplement SB, the Standard of Safety for Industrial Control Equipment, provides an accepted method for determining the short-circuit current rating of the control panel.

The SCCR rating for our air conditioners and heat exchangers has a default value of 5 kA.

You may use a 5 or 10 kVA isolation transformer between the customer's panel and our air conditioner and not have an effect on the customer's 65 kA rating.

You may use a fuse or circuit breaker with a 5 kA short circuit rating on the line side of the ACU and its branch circuit protective device and not have an effect on the customer's 65 kA rating.

The current limiting fuse or circuit breaker used on the line side of the branch circuit protection for the ACU must have a SCCR => that of the panel rating. Additionally for a current limiting fuse the customer would need to verify using table SB4.2 of UL 508A, that the let through current (Ip * 10^3) of the fuse is <= 5KA. If a circuit breaker is used as feeder protection, it **must** be marked Current Limiting type from the manufacturer, and the panel builder would need to verify based on the manufacturers published curves that it will let through <= 5kA. Examples of these curves are included in UL 508A supplement SB.

You can run separate circuits for the panel and the air conditioner as long as each is labeled with their individual SCCR ratings.
(5 kA and 65 kA)

If the customer does not implement one of the options above, then the resulting SCCR rating would be the 5 kA rating of the ACU, if that is the lowest rated component in the panel.

Testing represents another option; however, if the customer does not implement these options, then the resulting short circuit rating of the panel is based on the lowest short circuit current rating of all power circuit components installed in the panel.

Selecting the Right Cooling Solution

Cooling Solution

Since heat dissipation is often not a solution, we will limit our choices to protective vs. fresh air cooling.

Use the environmental and electronic system criteria in the table below to determine whether protective or fresh air cooling is most appropriate for your application.

Protective vs. Fresh Air Cooling

Specifying protective cooling that keeps your electronics components sealed from the outside environment versus using fresh air cooling to remove damaging heat depends on the following profile of your system application (check one side or the other for each of the six choices):

	FRESH		PROTECTIVE	
Clean Air / Some Dust / Dripping Water	☐	**SYSTEM OPERATING ENVIRONMENT**	☐	Dirty / Wet / Metal Filings / Outdoors / Corrosive Fumes
Moderate to Low (typically under 95 F / 35 C)	☐	**TEMPERATURE OUTSIDE OF THE ENCLOSURE**	☐	Hot (typically over 95 F / 35 C)
Somewhat to Well-Above Ambient Temperature	☐	**TEMPERATURE RATING OF THE ELECTRONICS**	☐	Below to Somewhat Above Ambient Temperature
Moderate to Low	☐	**HUMIDITY OUTSIDE OF THE ENCLOSURE**	☐	High Relative Humidity
Wide	☐	**TEMPERATURE RANGE FOR THE ELECTRONICS**	☐	Narrow / Precise
Moderate to Low (typically under 3000 Watts)	☐	**SYSTEM POWER DRAW / HEAT LOAD**	☐	Moderate to High (typically over 3000 Watts)

If most of your assessments fell on the fresh air side, then a filter fan, fan tray, motorized impeller or blower is probably the correct cooling solution for your application. However, if most of your assessments were on the protective side, then an air conditioner or heat exchanger found in the McLean Protective Cooling Catalog is likely the right cooling solution for your electronics system.

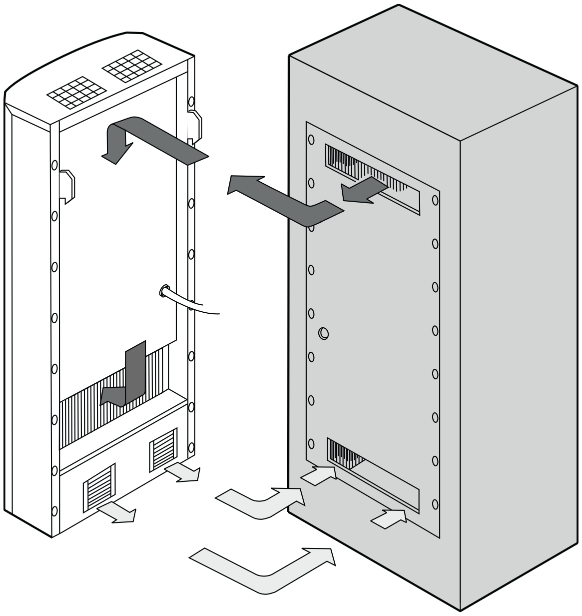
Selecting the Right Cooling Solution

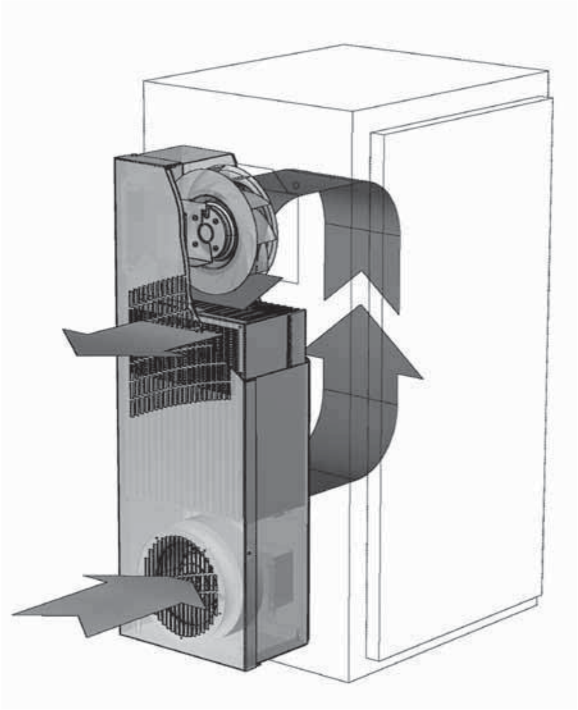
Cooling Solution Choices

Assuming that protective cooling is needed for the application, there are two basic choices—air conditioners or heat exchangers.

An air conditioner should be specified when:
- The temperature inside the enclosure must be maintained at or below the ambient temperature
- Humidity must be removed
- A moderate to high heat load is being produced by the electronic system

A heat exchanger can be used to transfer heat from inside the enclosure to the outside atmosphere when:
- The electronic components can operate at a temperature above the ambient air temperature
- Humidity is not a factor
- A low to moderate heat load is being produced by the electronic system





How to Select the Right Cooling Capacity Air Conditioner

Air Conditioner Cooling Capacity Overview

The cooling capacity of an air conditioner needs to match or exceed the amount of total heat load generated by the electronic system.

Total heat load comes from two sources:
(a) the electronic components themselves which is called "internal heat load" and
(b) the ambient heat outside the enclosure which is known as the "heat transfer load."

Most engineers and cooling suppliers determine internal heat load. However, the impact from the heat transfer load is easily overlooked. Heat transfer load can significantly add to the total heat load of the system, especially if the outside air temperature is high and/or the enclosure is located in the sun.

Thus, the **total heat load** to be removed from the electrical enclosure by the air conditioner is the sum of the **internal heat load** and the **heat transfer load.**

TOTAL HEAT LOAD = INTERNAL HEAT LOAD + HEAT TRANSFER LOAD

Part A: How to Determine Internal Heat Load

The internal heat load comes from the amount of waste heat generated inside the enclosure by the electronic components and is expressed in Watts (W).

There are several methods to determine internal heat load, depending on data availability.

Method 1. Heat Load Data from Each Electronics Component Manufacturer

One way to estimate internal load is to gather heat load data from the manufacturers of the electronics components inside the cabinet. They may know the amount of heat their equipment is generating. If more than one control or other electronics components are inside the enclosure, it will be necessary to add together all the estimates of heat load to determine total internal heat load.

Method 2. Component Power – Component Efficiency

A second method is to establish the Watts of power used by each electronic component. Derive Watts of power by multiplying the amp draw of each device by its voltage. Then subtract the efficiency of each component from its estimated power use. Add up the outcomes to get the total internal heat load.

INTERNAL HEAT LOAD =
COMPONENT POWER (W) - COMPONENT EFFICIENCY
(for each electrical device)

Example—

An electronic system uses two components that draw 115 VAC at 15 A. Each has a rated efficiency of 90%. Put another way, 10% of each device is inefficient. Unused power becomes generated heat. Thus the estimated internal heat load is:

Device Power = 115 x 15 = 1725 W
Total Power = 2 x 1725 = 3450
Less Efficiency = 3450 x (1 - .90)
Total Heat Load = 345 W

Method 3. Incoming – Outgoing Power

A third approach is to estimate the power going into the enclosure and the power coming out of it. The difference becomes the estimated amount of internal heat load. The amps and volts of each electrical line going in are multiplied to determine Watts, then they're added together. The same is done for the electrical line(s) coming out of the application. The outgoing Watts are then subtracted from the incoming Watts.

INTERNAL HEAT LOAD =
INCOMING POWER (W) – OUTGOING POWER (W)

Example—

An enclosure has three input lines of 230 VAC at 11, 6 and 4 A. It has one output control line of 115 VAC at 9 A.

Incoming Power = (230 x 11) + (230 x 6) + (230 x 4) = 4830 W
Outgoing Power = 115 x 9 = 1035 W
Total Heat Load = 4830 – 1035 = 3795 W

Method 4. Automated Equipment Horsepower

This fourth method applies only to industrial automation equipment that operates with horsepower (hp) such as variable frequency drives (VFDs). 1 hp = 745.6 W. Thus, the internal heat load from a 3-hp VFD is 2237 W, less its efficiency which is typically 93% - 95%.

Example—

A cabinet has three 5-hp VFDs with 95% efficiency.

VFD Watts = 5 hp x 745.6 x 3 = 11184
Adjusted Watts = 11184 x (1 - .95) = 559
Total Heat Load = 559 x 1.25 = 699 W

1.25 is an assumed "safety" margin for other minor heat-producing components.

How to Select the Right Cooling Capacity Air Conditioner

Part B: How to Determine Heat Transfer Load Overview

Heat transfer load is the ambient heat outside the enclosure conducting itself through the cabinet walls toward the electronics (heat energy travels from the hottest to coldest location).

When an air conditioner cools the enclosure temperature lower than the ambient air outside, additional heat load is drawn into the cabinet which the air conditioner needs to remove. The higher the ambient temperature and/or the presence of solar heat gain (the "greenhouse effect") on the enclosure, the more cooling capacity is required.

Determining heat transfer load requires that you know the **total surface area** of the cabinet, less any non-conductive surface area such as the enclosure side mounted to a wall. It also requires that you determine **ΔT**, which is the difference between maximum ambient temperature and the maximum temperature rating of the electronics components.

There are two methods for determining heat transfer load—the simple chart method and the equation method.

Simple Chart Method

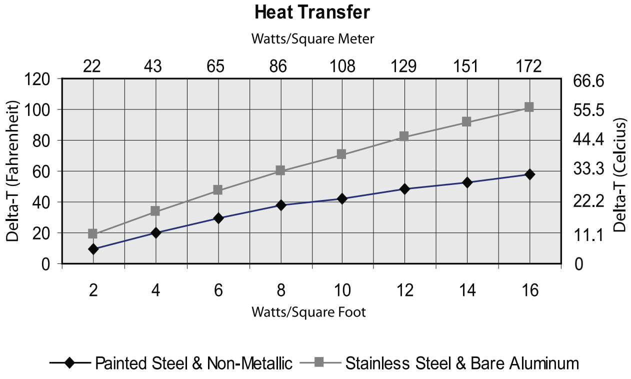
This method is reasonably accurate for most indoor industrial systems where there is no unusual air movement and insulation is not typically used inside the enclosure. The process also provides a ballpark result for outside plant and telecommunications applications, taking into account solar heat gain. However, it does not incorporate the impact of wind or cabinet insulation. If either is present, then the equation method is more precise.

Step A. Determine ΔT in °F or °C.
Step B. Find the heat transfer per ft.^{2} or m^2 on the chart below, using ΔT and the proper cabinet material curve.
Step C. Multiply the heat transfer per ft.^{2} or m^2 by the total surface area of the enclosure that will conduct heat. (Remember to exclude surfaces such as a side mounted to a wall.)

SURFACE AREA (ft.^{2}) = [2AB (in.) + 2BC (in.) + 2AC (in.)] ÷ 144

SURFACE AREA (m^2) =
[2AB (mm) + 2BC (mm) + 2AC (mm)] ÷ 1000000

Total Heat Transfer Load =
Heat Transfer per ft.^{2} or m^2 x Cabinet Surface Area

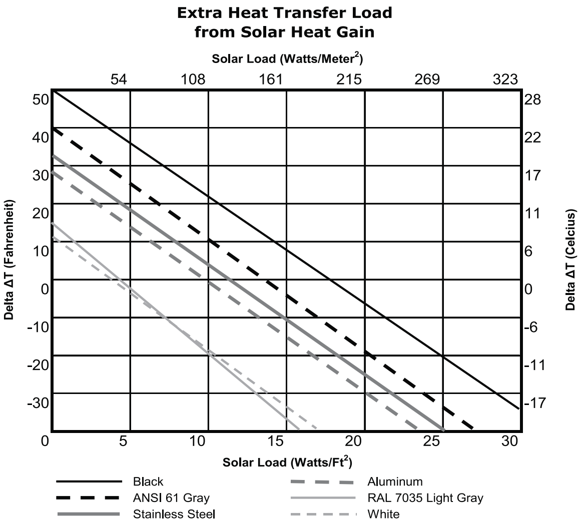


Example —
A painted steel cabinet has 80 ft.^{2} of surface area and will be located in a maximum ambient temperature of 95 F. The rated temperature of the electronics is 75 F.

ΔT = 95 - 75 = 20 F
Heat Transfer = 4 W/ft.^{2} (from chart)

Total Heat Transfer Load = 80 x 4 = 320 W

The estimate for heat transfer load ends here, unless the electronic system will be deployed outdoors. Then solar heat gain needs to be added to the total heat transfer load calculated above. Solar heat gain is determined much the same way as heat transfer per ft.^{2} or m^2, using a similar chart.



Example — The painted cabinet above is in ANSI 61 gray. Thus, 7 W/ft.^{2} need to be added to the heat transfer load which is 560 W (7 x 80 ft.^{2}). Total Heat Transfer Load consequently becomes 720 W.

The result does not include insulation which can significantly reduce heat transfer load.

Equation Method

Heat transfer load may also be determined by equation. This method should be used when at least one of the following criteria are found in the electronic system:

- Moderate to high airflow within the cabinet
- Outdoor applications that involve breezes or gusty winds
- Insulation used within the cabinet to offset the impact of solar heat gain

The governing equations for heat transfer load are:

English System (°F, inches and feet):
$q = (T_o - T_i) \div [(1/h_o) + (1/h_i) + R]$

Metric System (°C, millimeters and meters):
$(q = (T_o - T_i) \div [(1/h_o) + (1/h_i) + R] \times 5.67$

Definition of Variables—
q = Heat transfer load per unit of surface area
T_o = Maximum ambient temperature outside the enclosure
T_i = Maximum rated temperature of the electronics components
h_o = Convective heat transfer coefficient outside the cabinet
Still air: $h = 1.6$
Relatively calm day: $h = 2.5$
Windy day (approx. 15 mph): $h = 6.0$

h_i = Convective heat transfer coefficient inside the cabinet
Still air: $h = 1.6$
Moderate air movement: $h = 2.0$
Blower (approx. 8 ft./sec.): $h = 3.0$

R = Value of insulation lining the interior of the enclosure walls
No insulation: $R = 0.0$
1/2 in. or 12 mm: $R = 2.0$
1 in. or 25 mm: $R = 4.0$
1-1/2 in. or 38 mm: $R = 6.0$
2 in. or 51 mm: $R = 8.0$

$q = (125 - 75) \div [(1/6) + (1/2) + 4]$
$q = (50) \div (.16 + .5 + 4)$
$q = 50 \div 4.66$
$q = 10.7$ BTU/hr./ft.^{2}

Total Heat Transfer Load
10.7 x 72 = 770 BTU/hr. or 770 ÷ 3.413 = 226 W

Since the cabinet is outdoors, and assuming it is painted ANSI 61 gray and located in the sun, extra solar load needs to be added to the outcome above which is 504 Watts (7 W per ft.^{2} x 72 ft.^{2}).

Total Heat Transfer Load with Extra from Solar Heat Gain
226 + 504 = 730 W

How to Determine Total Heat Load

Total heat load to be removed from the electrical enclosure by the air conditioner is the sum of **internal heat load** plus **heat transfer load**.

TOTAL HEAT LOAD (C) = INTERNAL HEAT LOAD (A) + HEAT TRANSFER LOAD (B)

Thus, one adds together the result from Part A to the outcome from Part B.

Example—

The internal heat load from one of the examples above was 3795 Watts. The heat transfer load from the other example above was 730 W. Therefore, total heat load is 3795 + 730 = 4525 W.

To convert Watts into BTU/hr. to determine air conditioner capacity in the English system, multiply by 3.413.
4525 W is then 15444 BTU/hr.

Power input, protection level and dimensions of the air conditioner also need to fit system requirements.

Caution! Do not simply match the nominal cooling capacity of the air conditioner model with the total heat load result above. Be sure to know the maximum ambient temperature outside the enclosure as well as the rated temperature of the electronic components. Apply these temperatures to the performance curves provided by the cooling manufacturer to select an appropriately sized air conditioner. Failure to do so may under-size your air conditioner as much as 20% - 25%, thereby under-cooling the electronics and making the application vulnerable to potential over-heating issues.

How to Select the Right Cooling Capacity Heat Exchanger

Heat Exchanger Cooling Capacity Overview

Cooling with an air-to-air heat exchanger assumes the electronic components in your system are able to operate **above** the ambient temperature outside the enclosure. If this is not the case, then an air conditioner must be used.

Selecting a heat exchanger is similar to specifying an air conditioner in that the cooling capacity of the unit must remove the **internal heat load** from the electrical enclosure.

However, since the conductive cooling nature of the cabinet itself removes some of the heat from the system, **heat transfer** should be subtracted from internal heat load (versus added in the case of air conditioners).

Because the cooling capacity of heat exchangers is expressed in terms of Watts/°F or Watts/°C, an extra step is necessary to convert net heat load into a result used to select the appropriate heat exchanger. Divide the net heat load by the **ΔT** which is the difference between the maximum ambient temperature outside the enclosure and the maximum temperature rating of the electronic components.

HEAT EXCHANGER CAPACITY (C) = [INTERNAL HEAT LOAD (A) – HEAT TRANSFER (B)] / ΔT

How to Determine Internal Heat Load

Internal heat load stems from the amount of waste heat generated inside the enclosure by the electronic components and is expressed in Watts.

To determine internal heat load, follow one of the four options outlined in the air conditioner “How to Determine Internal Heat Load” section on page 12.

How to Determine Heat Transfer

In air-to-air heat exchangers, heat transfer is actually cabinet heat loss because the heat inside the enclosure is conducting itself through the cabinet walls toward the cooler temperature outside the enclosure. That is why heat transfer is subtracted from internal heat load to arrive at total net heat load.

To determine heat transfer you need to know the **total surface area** of the cabinet, less any non-conductive surface area such as the enclosure side mounted to a wall. You must also determine **ΔT** which is the difference between maximum ambient temperature and the maximum temperature rating of the electronic components.

There are two methods to determine heat transfer—the **simple chart method** and the **equation method**. The simple chart method may be used for nearly all indoor heat exchanger applications. The equation method needs to be applied when air movement outside or inside the electrical enclosure is high, or for outdoor applications.

Here are the steps for the simple chart method:

Step A. Determine ΔT in °F or °C.
Step B. Find the heat transfer per $ft.^2$ or m^2 from the Heat Transfer graph on page 13, using ΔT and the proper cabinet material curve.
Step C. Multiply the heat transfer per $ft.^2$ or m^2 by the total surface area of the enclosure that will conduct heat. (Remember to exclude surfaces such as a side mounted to a wall.)

SURFACE AREA ($ft.^2$) = [2AB (in.) + 2BC (in.) + 2AC (in.)] ÷ 144

SURFACE AREA (m^2) = [2AB (mm) + 2BC (mm) + 2AC (mm)] ÷ 1,000,000

Heat Transfer (Cabinet Heat Loss) = Heat Transfer per $ft.^2$ or m^2 x Enclosure Surface Area

The estimate for heat transfer ends here, unless the electronic system will be deployed outdoors, or airflow inside or outside the enclosure is high. Then the equation method needs to be used to determine heat transfer (cabinet heat loss).

For the equation method, follow the steps on page 13 in the air conditioner selection section. The result will be a negative number; the negative sign should be ignored when deducting heat transfer from internal heat load.

Caution! If the result of the equation method is a positive number, then this means that you want the electronics temperature inside the cabinet to be lower than the temperature outside the enclosure. In this case, an air conditioner should be specified for the electronics system.

How to Select the Right Cooling Capacity Heat Exchanger

How to Determine Heat Exchanger Capacity

Air-to-air heat exchanger capacities are not provided in terms of Watts or BTUs/hr. of cooling like air conditioners. Instead, they are expressed in terms of Watts/°F or Watts/°C. Thus, the final step in determining heat exchanger capacity is to divide the total net heat load by ΔT. Then select the heat exchanger with the same or higher Watts/°F or Watts/°C as the outcome of this process.

—Indoor Industrial Example—

An electronic system uses two components that draw 230 VAC at 7.5 A. Each has a rated efficiency of 90%. They are protected in a painted steel cabinet that is 60 in. (1524 mm) tall, 36 in. (914 mm) wide and 18 in. (457 mm) deep. The system will be located in a maximum ambient temperature of 80 F (27 C). The rated temperature of the electronics is 95 F (35 C).

HEAT EXCHANGER CAPACITY (C) =
[INTERNAL HEAT LOAD (A) – HEAT TRANSFER (B)] ÷ ΔT

Internal heat load (A) may be determined using the “Component Power – Component Efficiency” method on page 12, given the available information. In this example, the estimated heat load is:

Device Power = 230 x 7.5 = 1725 W
Total Power = 2 x 1725 = 3450
Less Efficiency = 3450 x (1 - .90)
Internal Heat Load = 345 W

Heat transfer (B) is derived using the simple chart method, since this is an indoor industrial application. Both cabinet surface area and ΔT are needed to determine heat transfer. Cabinet surface area is 54 ft.^{2} or 5.02 m^2 (from surface area formula on page 13). ΔT is 15 F (8 C)—the difference between ambient temperature and the rated temperature of the electronics.

Heat Transfer (Cabinet Heat Loss) =
Heat Transfer per ft.^{2} or m^2 x Enclosure Surface Area

Using the painted steel curve on the Heat Transfer chart on page 13, heat transfer per ft.^{2} or m^2 is 3 W/ft.^{2} or 32.5 W/m^2.
Heat Transfer = 3 W/ft.^{2} x 54 ft.^{2} = 162 W

Now that we know internal heat load, heat transfer and ΔT, we can determine heat exchanger capacity as follows:

HEAT EXCHANGER CAPACITY (C) =
[345 WATTS (A) – 162 WATTS (B)] ÷ 15 F (or 8 C)

HEAT EXCHANGER CAPACITY (C) = 12 W/°F or 22 W/°C

The result is **minimum** heat exchanger capacity. If no heat exchanger model is similar to the result, choose the next largest size to ensure adequate electronics cooling.

Power input, protection level and dimensions of the heat exchanger also need to fit the system.

—Outdoor Example—

A telecom system draws a total of 5,000 W; its efficiency is 85%. It is protected in a steel cabinet that is 72 ft.^{2} (6.69 m^2) and painted with RAL 7035 light-gray paint. The enclosure walls are lined inside with 1 in. (25 mm) of insulation. The application will be deployed in a maximum ambient outdoor temperature of 104 F (40 C) with occasional winds reaching 15+ mph. The rated temperature of the electronics is 114 F (46 C). Air circulation inside the cabinet is moderate.

HEAT EXCHANGER CAPACITY (C) =
[INTERNAL HEAT LOAD (A) – HEAT TRANSFER (B)] ÷ DELTA ΔT

Internal heat load (A) is determined using the “Component Power – Component Efficiency” method on page 12. In this example, the estimated heat load is as follows:

Total System Power = 5000 W
Less Efficiency = 5000 x (1 - .85)
Internal Heat Load = 750 W

Heat transfer (B) is derived using the equation method, since this is an outdoor application. For brevity, we will assume the English system (°F, inches and feet).

$q = (T_o - T_i) \div [(1/h_o) + (1/h_i) + R]$

“q” is heat transfer per surface area. For an explanation of the other variables, see “Equation Method” on page 14.

$q = (104 - 114) \div [(1/6) + (1/2) + 4]$

q = -2.14 W/ft.^{2}

Total Heat Transfer = 2.14 x 72 ft.^{2} = 154 W
(negative sign is ignored)

ΔT is 10 F — the difference between ambient temperature and the rated temperature of the electronics.

HEAT EXCHANGER CAPACITY (C) =
[750 W (A) – 154 W (B)] ÷ 10 F

HEAT EXCHANGER CAPACITY (C) = 60 W/°F

As in the indoor industrial example, the above result is **minimum** heat exchanger capacity. If no heat exchanger model is similar to the result, choose the next largest size to ensure adequate electronics cooling.

Power input, protection level and dimensions of the heat exchanger also need to fit the system.

Notes