ENCLOSURES

Practical Guide to Electrical Enclosures for Industrial Applications

ADC-001-Enc

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ENCLOSURES
PRACTICAL GUIDE

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Electrical Enclosures Overview

An electrical enclosure is a purpose-built cabinet designed to house electrical and electronic devices, providing the required protection to keep operators/personnel safe from electrical shock hazards and devices protected from hazardous environments as well as accidental damage. Today's enclosures are built to provide a lifetime of service when the correct enclosure is used to meet the specific needs for a service or application.

Enclosures are designed in a range of shapes and sizes to offer various solutions and serve various applications. The following enclosure types are the most commonly used enclosures. The information is provided with a description of the enclosure design and purpose to better understand how they can be used in applications.

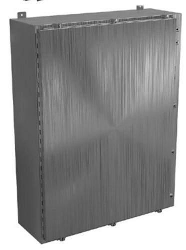
Electrical Enclosure Types

- **Wall-mount:** Designed to mount directly on a wall and to house electrical controls, terminals, instruments and components while providing protection from dust, dirt, oil, and water. This type of enclosure can be used for many applications and are available for various NEMA/IP protection ratings.

- **Floor-mount and Freestanding:** Designed with feet supports that allow them to stand on any hard surface and to be secured/bolted for a permanent and secure installation. These enclosures are commonly used for larger applications involving motor starters, drives, contactors, and PLCs as well as a wide variety of other electrical and electronic equipment.

- **Junction Boxes:** Designed for use as surface-mounted junction boxes, service boxes, switch boxes and cutout boxes. Many of these junction boxes are NEMA 1 and NEMA 3R and include pre-punched knockouts for easier cable entry.

- **Pushbutton Enclosures:** These enclosures are available in various shapes and forms including slope tops, consoles, and more. They are basically enclosures with pre-cut standard 22.5mm or 30.5mm openings that allow easy mounting of pushbuttons, switches, indicators and other pilot devices. Models with blank covers that allow users to determine their preferred configu ation are also available.



- **Disconnect Enclosures:** Specifi ally designed to house and allow operation of disconnects from many popular manufacturers and disconnect products. These enclosures offer NEMA 4, 4X, 12 or 4/12 protection and are usually available in wall-mount, floor mou t and freestanding versions.

- **Consoles and Consolets:** These enclosures house electrical and electronic controls and/or instruments and typically have HMIs, pushbuttons, switches and other pilot devices and controls where operators can access the devices to control and operate machinery and systems. Consoles and consolets are heavy duty constructed enclosures that protect contents from dirt, dust, oil and water, and are available in various types including; freestanding consoles, operator consoles, console tops, pushbutton consolets, writing desktops, pedestal and bases.

- **Wire Through Enclosures:** Similar to junction boxes, wire through enclosures are designed to protect wiring from surrounding personnel, equipment and atmosphere.

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Electrical Enclosures Overview and Types

- **Sloped top Enclosures:** Typically wall-mounted, floor-mou ted or freestanding units designed with a 20° slope on the top portion of the enclosure and door flanges that help prevent accumulation of water and debris on top of the enclosure. Sloped top enclosures are ideal for housing electrical and electronic components for applications in harsh and dirty environments where dust, dirt, oil, water and other contaminants are present and applications requiring washdowns.

- **Windowed and Clear Cover Enclosures:** These enclosures have a window or clear cover to allow a view inside the enclosure without opening the door and exposing the internal components.

- **Dual Access Enclosures:** Designed to protect electrical and electronic controls, components, and instruments in typical industrial environments with dust, dirt, oil and dripping water. Dual access enclosures are designed to provide additional access from the rear side of the enclosure if necessary.

- **Flush-Mount Enclosures:** Wall-mounted enclosures with an external frame that allows it to be recessed in wall. These enclosures are typically used in applications where external space is limited or in high traffic area

Understanding Enclosure NEMA and IP Ratings

Your enclosure's primary function is to protect the equipment inside it from the surrounding environment. Therefore, if you need an enclosure, then you need to understand the environment where the enclosure will be located and select the appropriate level of protection.

The primary method of standardized enclosure protection classifi ation used in North America is the NEMA rating system, established by the National Electrical Manufacturers Association (NEMA). In the rest of the world, Ingress Protection (IP) codes based on International Electrotechnical Commission (IEC) standards are the prevailing classifi ation system, though these ratings are sometimes used in North America. Therefore, in order to properly select an enclosure for an application, we must know what environmental hazards the enclosure must protect against and what NEMA rating or IP code provides the desired level of protection.

Neither NEMA nor IEC actually tests products; they establish the performance criteria for enclosures intended for specific environments. Their standards describe each type of enclosure in general and in functional terms, and specifi ally omit construction details. In other words, they specify what an enclosure must do, not how to manufacture it.

NEMA Ratings

NEMA performance criteria and test methods are used by Underwriters Laboratories (UL) and the Canadian Standards Association (CSA) as guidelines for investigation and listing of electrical enclosures. The tested enclosures are then authorized to carry a label endorsed by UL or CSA to prove it has passed the required tests and meets the applicable UL or CSA standard.

The table below provides descriptions of typical NEMA ratings along with the level of protection they provide. Use this table to determine the level of protection required in your specific environment and surroundings. Keep in mind that it is just as important not to over-specify the protection level of your enclosure as it is to under-specify, as increasing the protection level typically increases the cost of the enclosure.

Enclosure NEMA Ratings	
Rating	**Protection Description**
NEMA 1	Provides minimal protection. Basically, these enclosures protect personnel from electrical hazard and are used for applications where sealing out dust, oil, and water is not required.
NEMA 2	Used primarily for indoor use and provide a degree of protection against limited amounts of falling water (not under pressure) and dirt.
NEMA 3	Intended for outdoor use and provide a degree of protection against windblown dust, rain, sleet, and external ice formation.
NEMA 3R	Typically used in outdoor applications for wiring and junction boxes and provide protection against falling rain, sleet, snow, and external ice formation. When used indoors they protect against dripping water.
NEMA 3RX	Basically the same as NEMA 3R enclosures, but they provide an additional level of protection against corrosion.
NEMA 3S	Intended for outdoor use and provide a degree of protection against windblown dust, rain, sleet, and to provide for operation of external mechanisms when ice laden.
NEMA 4	Used for applications where occasional wash-downs take place or where machine tool cutter coolant is used. They also protect in applications where a pressurized stream of water is used.
NEMA 4X	Used in harsh environments where corrosive materials and caustic cleaners are used. Applications include food, such as meat/poultry processing facilities, where total wash-down with disinfectants occur repeatedly, and petrochemical facilities, including offshore petroleum sites
NEMA 5	Intended for indoor use to provide a degree of protection against settling airborne dust, falling dirt, and dripping non-corrosive liquids.
NEMA 6	Intended for indoor/outdoor use and to provide a degree of protection against water entry during occasional, temporary submersion at a limited depth.
NEMA 6P	Intended for indoor/outdoor use and to provide a degree of protection against the entry of water during prolonged submersion at a limited depth.
NEMA 12	Intended for indoor use to provide a degree of protection against drips, falling dirt, dripping non-corrosive liquids, and circulating dust, lint, and fibers.
NEMA 12K	Enclosures with knock-outs intended for indoor use primarily to provide a degree of protection against dust, falling dirt, and dripping non-corrosive liquids other than at knock-outs.
NEMA 13	Intended for indoor use and provide a degree of protection against dust, spraying of water, oil, and non-corrosive coolant.

IP Ratings

IP ratings refer specifi ally to ingress of water (liquids) and solid objects, in other words, Ingress Protection, hence "IP". IP and NEMA ratings are defined y different standards so there is no direct conversion between the two.

The rating's numerical portion provides a reference to the type of ingress protection the device provides. The first number refers to the ingress limits for solids while the second number refers to ingress limits for liquids. The letter "K" added after the number reference refers to special testing with high-pressure water jets, originally developed for road vehicles and later adopted by food, beverage, pharmaceuticals, medical and other industries that required frequent high-temperature and high-pressure wash-downs to ensure sanitary conditions.

Just as mentioned with NEMA ratings, keep in mind that it is just as important not to over-specify the protection level of your enclosure as it is to under-specify, as increasing the protection level typically increases the cost of the enclosure.

Use the tables below as reference for IP ratings:

IP Ratings for Solids

Rating	Protects From	Protection Description
0	No Protection	No protection from ingress of objects
1	Objects larger than 50mm	No ingress of objects larger than 50mm (i.e., hands but not fingers)
2	Objects larger than 12.5mm	No ingress of objects larger than 12.5mm (i.e., fingers or similar)
3	Objects larger than 2.5mm	No ingress of objects larger than 2.5mm (i.e., screwdriver or similar)
4	Objects larger than 1mm	No ingress of objects larger than 50mm (i.e., wires, large bugs, or similar)
5	Limited dust ingress protection	No ingress of most dust particles, but not complete ingress
6	Full dust Ingress Protection	No ingress of dust (dust tight), Surpasses previous protection limits

IP Ratings for Liquids

Rating	Protects From	Protection Description
0	No Protection	No protection from ingress of liquids
1	Straight water drops	No vertical water dripping ingress (i.e., 1mm rainfall/minute)
2	Water dripping at 15º angle	No water drop ingress at 15º angle (i.e., 3mm rainfall/minute)
3	Water dripping at 60º angle	No water drop ingress at 60º angle (i.e., water spray nozzle)
4	Water splash, all directions	No water splash ingress from any angle
5	Water Jets	No ingress from a 4.4 PSI (0.3 Bar) water jet at 3m distance from any angle
6	Powerful water jets	No ingress from a 14.5 PSI (1 Bar) water jet at 3m distance from any angle
6K	High power water jets	No ingress from a 145 PSI (10 Bar) water jet at 3m distance from any angle
7	Up to 1m water immersion	No ingress from immersion of lowest part up to 1000mm below water surface
8	Over 1m water immersion	No ingress from immersion of lowest part up to 3m below water surface
9K	High pressure and temperature water jets	No ingress up to 1,100 to 1,450 PSI (80 to 100 Bar) close range water jet pressure with water up to 176º F (80º C). Surpasses previous protection limits.

Enclosure Construction Materials

Today's electrical enclosures have become more advanced, with sealing systems, security accessories, and more. One of the areas where enclosures have evolved is in the construction materials. Today we have metallic and non-metallic enclosures that provide many benefit , ranging from easy and quick installation to resistance to highly corrosive conditions.

To assist in deciding what material might be best for your application, the following list provides information on the most common materials available today, along with their description and benefits

- **Carbon Steel:** Also commonly referred to as low carbon steel or mild steel, these enclosures are very common in many industries and are the most cost-effective choice for metallic enclosures used for indoor applications. These enclosures are not resistant to corrosion so to protect against deterioration, manufacturers treat all carbon steel enclosures with a protective paint covering, consisting of an initial layer of primer, followed by a layer of high-quality powder paint coating that provides a more effici t scratch-resistant finish. However, this doesn't mean that the surface will resist a scratch from a strong accidental collision with another object. In the event the enclosure becomes scratched, the scratch must be repaired immediately with touch up paint to ensure the unit maintains corrosion protection. Finishes range from smooth to textured. The most common paint colors are ANSI 61 gray and RAL 7035 light gray.

- **304 Stainless Steel:** This type of stainless steel is an alloy that contains an iron base with approximately 18% to 20% chromium. This alloy provides corrosion resistance from corrosive solvents, alkalis, and some acids, making them ideal for applications requiring wash-downs with caustic cleaners. 304 Stainless steel enclosures can be used for indoor or outdoor applications.

- **316 Stainless Steel:** This type of stainless steel is an alloy containing molybdenum, which provides additional resistance to corrosion than 304 stainless steel. This alloy provides increased resistance to sea water, chlorine sulfates, bromides, other acids and high temperatures. This added resistance makes 316 stainless steel enclosures ideal for pharmaceutical, food and beverage, marine applications, and inside/outside applications.

- **316L Stainless Steel:** This stainless steel alloy has a lower carbon content than standard 316 stainless steel, which makes it more resistant to decay resulting from welding on the enclosure or exposure to temperatures over 425 ºC. The lower carbon content increases resistance to very high temperature and highly corrosive applications. It is commonly used for marine and construction applications because of its durability.

- **Aluminum:** Aluminum enclosures are lighter and more economical than other metallic enclosures and are ideal for industrial applications for solar, telecommunications, traffi control, and water and wastewater applications. In addition, these enclosures work well in harsh conditions and high-heat environments, and are lightweight.

- **Fiberglass Reinforced Polyester:** These non-metallic enclosures are commonly described as fiberglass or FRP enclosures. These lightweight enclosures are usually easy to install and modify when drilling is required. However, make sure that if modifi ations are made, all openings are properly sealed to maintain the NEMA rating of the enclosure. These enclosures are considered strong enough to resist normal impacts and can resist corrosive environments, and installations near high-temperature conditions. Some fibe glass enclosure models are designed to be temporarily submerged in water while maintaining the required protection.

- **Polycarbonate:** These non-metallic enclosures are made from thermoplastic polymers. The advantages of polycarbonate enclosures include a higher degree of impact resistance than other non-metallic enclosures, UV resistance, ease of installation and modifi ation since holes and cutouts are cleaner, and no requirement for sanding or finishin . They resist weather conditions better, are available with clear covers or windows for viewing contents without opening, and are ideal for housing instrumentation, controls, and sensitive equipment.

- **PVC:** These non-metallic enclosures are very cost-effici t, have a high degree of impact resistance, are UV resistant, non-conductive, are easier to install and to modify because holes and cutouts are cleaner, and require no sanding or finishin . They are available with clear covers or windows for viewing contents without opening, and are ideal for housing small junction circuits, cabling, and applications requiring watertight and dust-tight seals.

- **Thermoplastic ABS:** Commonly known as ABS enclosures, these enclosures have a high degree of impact, heat and corrosion resistance, are non-conductive, and are ideal for FDA controlled food and beverage (natural beige or black ABS), pharmaceutical and medical applications. These enclosures are also ideal for use for wireless equipment such as WiFi, Bluetooth, and radio frequency technologies, as well as communications panels. ABS enclosures are easy to install and modify because holes and cutouts are cleaner and require no sanding or finishin . They are available with clear covers or windows for viewing contents without opening, and when taken out of service they are fully recyclable.

Important Note: While stainless steels, aluminum, and non-metallic materials are all considered "corrosion resistant," all of them have compatibility limitations. Always check to ensure that the material you select has adequate resistance to whatever corrosive agents or other environmental exposures that you expect your enclosure to be exposed to.

Selecting an Enclosure

When selecting an enclosure there are various factors that should be carefully considered to ensure that the enclosure provides safe, effici t and lasting service. When considering each of the factors, it's important to keep in mind the possibility of future additions to this enclosure and also the possibility of future processes or conditions that will affect the environment surrounding the enclosure.

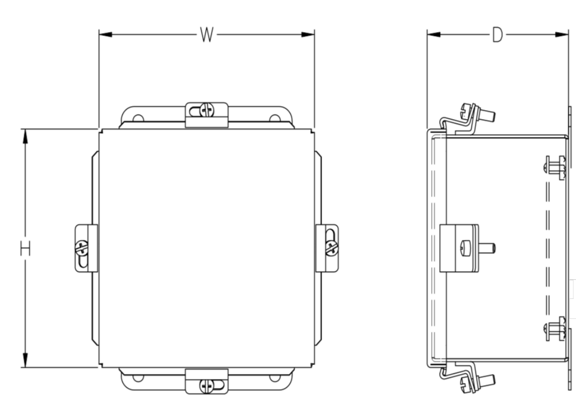
Determine the Enclosure Size

When considering the size required for an enclosure, it is easy to assume that if the enclosure is big enough to fit all your equipment and devices, then the enclosure will work. In addition to the size of the internal components, there is much more to consider when sizing an enclosure. Examples of things to consider are:

- Size of components and devices
- Manufacturers' recommended space tolerances for all devices
- Heat dissipation for heat generated by components and devices
- Adequate space for wires, cables and wiring ducts and conduits
- Adequate space for subpanels, mounts and DIN rails, as these will typically add depth requirements
- Space required to properly fit HM s or any device installed on the enclosure door/cover
- Venting requirements
- Thermal management requirements

The following are recommended steps to take when considering the size required for an enclosure:

1. Create a design showing how the equipment and components inside the enclosure will be laid out. Make sure you don't leave anything out (wire duct, terminal blocks, space for routing wires, etc.) and remember to allow space for subpanel mounting holes, cable entry, protrusions for externally-mounted items like HMIs or air conditioners, and any possible future additions. Remember to place the components and devices with enough spacing between them to prevent overheating, and allow enough space if the device needs to be adjusted. The manufacturer for each device should list any space requirements or tolerances in their manuals or specifi ations.
2. Remember to allow space for heat dissipation. If you have estimated component sizes or heat generation, it's always better to oversize the enclosure when you have the available space. For additional information on thermal management requirements, refer to the thermal management section later in this document.
3. Estimate the height and width for your enclosure from your design. If you are planning to use a subpanel, remember that the subpanel will be slightly smaller than the enclosure.
4. Determine the required enclosure depth. Remember that the subpanel mounting takes up a small portion of the depth. Also, any pushbuttons, operator interfaces, indicators, meters, etc., that you plan to mount on the enclosure door will occupy some enclosure depth. Be sure to account for every component and any wiring that will be included with this enclosure.



IMPORTANT: Enclosure descriptions typically include specifi ations of the enclosure's size. These are typically nominal sizes, not actual dimensions. Their correlation to actual dimensions may vary depending on the manufacturer and the style of the enclosure. Even if the dimensions in the description are actual dimensions, you don't know what those dimensions actually mean - the depth dimension may be overall depth, the depth of the enclosure tub (not including the door), the depth from the subpanel to the inside of the door, etc. **ALWAYS REVIEW THE ENGINEERING DRAWING FOR DIMENSIONAL DATA WHEN SELECTING AN ENCLOSURE. NEVER SELECT AN ENCLOSURE SOLELY FROM THE DIMENSIONS IN THE DESCRIPTION.**

Also keep in mind that the design may go through multiple iterations as you work through the selection process, as there may be many different sizes and configu ations (number of doors, mounting, etc.) that suit your application.

Determine the Enclosure Type, Construction Material and Protection Rating

As discussed on Chapter 1 of this eBook, enclosures are designed in a range of shapes to serve various applications, and as discussed in Chapter 3 of this eBook, enclosures are built in various materials to best serve various applications and conditions. When deciding what enclosure type and construction material would be best for your application, it is important to know and understand all the variables that will affect this enclosure. In addition, these variables will also help determine the level of NEMA/IP protection that will be required for your enclosure.

Here is a list of most of the common variables affecting what enclosure type, material and protection rating to select:

- Where will the enclosure be located?
- What type of service will it provide?
- Will it be wall mounted, floor mou ted, freestanding?

Based on the variables listed above, use Chapters 1, 2 and 3 as reference to determine what enclosure type, material and protection level will work best for your installation.

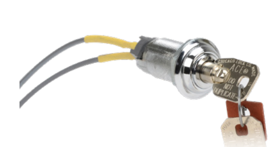
Determine any Security Requirements

Depending on the operation/application, the enclosure may require additional protection against unauthorized access to internal components. An enclosure might require this protection if it contains sensitive control equipment that must only be adjusted by authorized personnel or if it's accessible in an area where you want to ensure no one has direct access to the enclosure contents. To help provide this added protection, enclosure manufacturers offer a wide variety of security devices. For low-risk installations, a screw cover, lift-off cover, or single door with clamps may be suffici t. In higher risk installations, an enclosure with keylocking and/or padlocking capabilities may be needed.

When the enclosure requires added security, a lock or lockable latch can provide the means to latch and lock an enclosure door securely. Every enclosure manufacturer provides various types and styles of locking devices designed to fit and work effici tly with their enclosures. Here's a few examples of locks and keylocks. Refer to the manufacturer's online catalog to find the options vailable for your specific enclosu e.

Other types of latch locking systems are the electrical interlock system and the defeater. These types of locking systems are available from a few manufacturers and are usually made for specific enclosu e models.

The electrical interlock is designed to prevent the door handle from being turned, ensuring no one can access the enclosure when it is activated. This allows designers to wire the lock to only open when some specific actions are taken, ensuring the enclosure cannot be accessed until it is completely safe for the operator or authorized personnel to do so. These interlocks are usually designed to fit handles or specific enclosu es.



A defeater is basically an electrical interlock that operates with a keyed momentary contact switch. When the key is turned, the interlock is disabled, which causes the latch to unlock, allowing access to the enclosure contents.

Enclosure Thermal Management

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 floo 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 flu tuating 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.

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 flui , a gas or a liquid, or from a moving fluid to the surface of a solid. Conduction is the fl w 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. In this chapter we discuss the different types of enclosure thermal management systems used to maintain optimum conditions inside enclosures. We will also examine the wide assortment of heaters, air conditioners, heat exchangers, vortex coolers, venting devices and control units designed to provide effici t and cost-effective climate control of an enclosure.

Enclosure Heating to Maintain 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

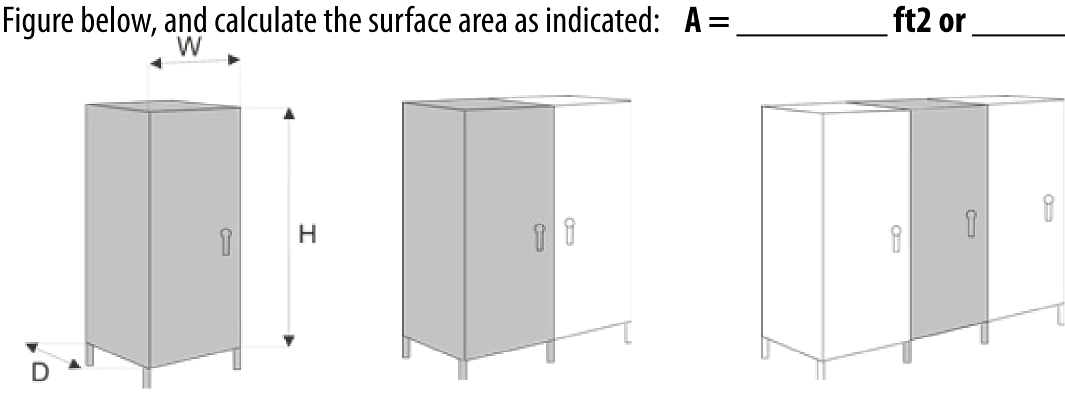
Calculations to determine the required heater size include the following fi e steps. Imperial or metric units can be used, but consistency among units must be maintained.

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

Enclosure Dimensions:

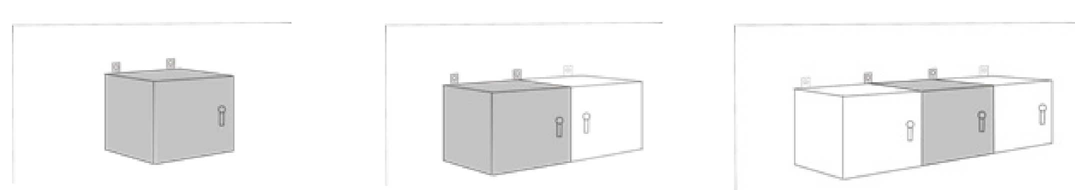
Height = _________feet _________meters
Width = _________feet _________meters
Depth = _________feet _________meters

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 below, and calculate the surface area as indicated: **A = _________ ft2 or _________ m2**



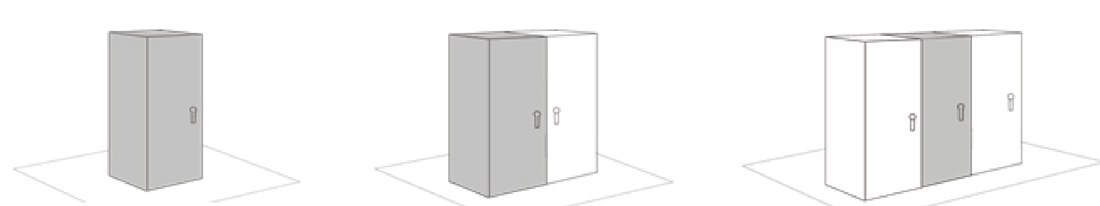
a. Free-Standing

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)**



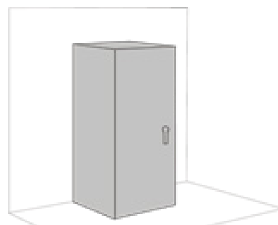
b. Wall-Mounted:

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)**

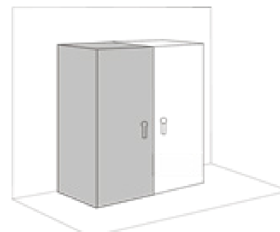


c. Ground:

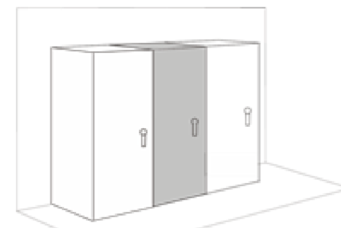
Area (A) = 1.8 (H x W) + 1.8 (H x D) + 1.4 (W x D)	**Area (A) = 1.8 (H x W) + 1.4 (H x D) + 1.4 (W x D)**	**Area (A) = 1.8 (H x W) + (H x D) + 1.4 (W x D)**



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 Coeffici ts (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 efficie y, 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 coeffici t 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 suffici t to prevent condensation. Controls may be adjustable or preset to fi ed 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.

There are two common sources that can cause the enclosure's internal temperature to rise above the devices' recommended temperature ratings:

Internal Sources

The same items that can be damaged by heat may also be the source of the heat. These items include:

- Power supplies
- AC Drives/inverters
- Transformers
- Communication products
- Battery back-up systems
- Servos
- Soft starters
- PLC systems
- HMI systems

External Sources

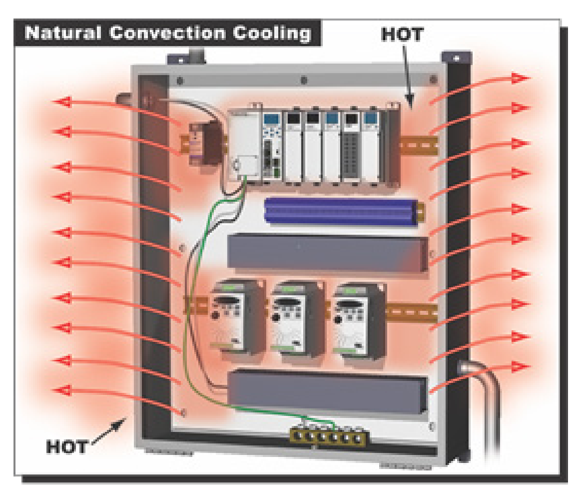
Other sources of heat that can cause the internal temperature of your enclosure to rise above a desired level involve the external environment. These include:

- Industrial ovens
- Foundry equipment
- Solar heat gain
- Blast furnaces

The cooling method used depends on the combined internal and external enclosure heat load. Heat fl ws from higher temperature to lower temperature areas, so ambient temperature plays a signifi ant 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 air. If the heat inside an enclosure cannot be vented while keeping external contaminants out, then other cooling methods must be considered to maintain enclosure cooling.

Enclosure Cooling: Radiation and Natural Convection Cooling



When the ambient temperature outside the enclosure is cooler than the inside of the enclosure, some heat will be radiated into the atmosphere from the surface of the enclosure. In environments where dust and water intrusion is not a concern, louvers can be added to allow outside air to flow through the enclosure via natural convection.

On a large scale, natural convection can be a powerful force - it's one of the primary drivers of our weather. But on the scale of an electrical enclosure, its cooling capacity is very limited. For larger heat loads, a more powerful cooling system may be needed.

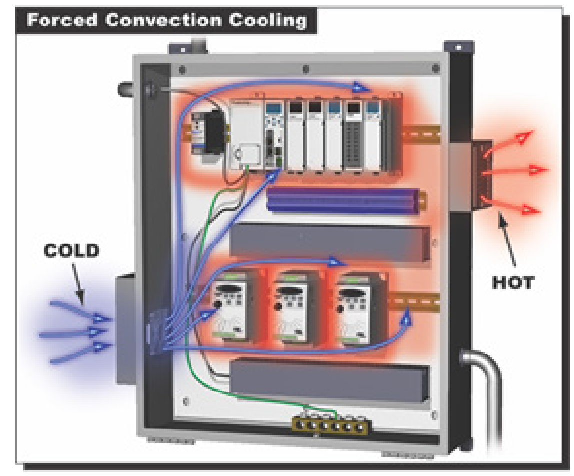
Since they create openings in the enclosure, louvers are typically limited to NEMA 1 and/or NEMA 3R applications. However, some louvers have optional filters that can be added to maintain NEMA 12 protection. If cooling requirements are low, natural convection using grilles with fil ers are often the preferred solution. Proper installation allows cool convection air to enter at the enclosure bottom and exit near the top.

Examples of Devices used for Radiation and Natural Convection Cooling

Vent: Forced convection is a good option when clean and cool outside air is available. To force air, a fil er 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.

Grille: In fibe glass 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 NEMA 4X enclosure rating.

Forced Convection Cooling



The next step up from natural convection is forced convection cooling. The basic cooling mechanism is the same: cooler air from outside the enclosure passes through the enclosure to remove the heat. The difference is that the air is mechanically forced through the enclosure by a filter fan. The fan produces higher air flow rates than natural convection, which in turn increases the amount of heat removed.

As with natural convection cooling, the ambient air temperature must be lower than the desired enclosure temperature for forced convection to be effective.

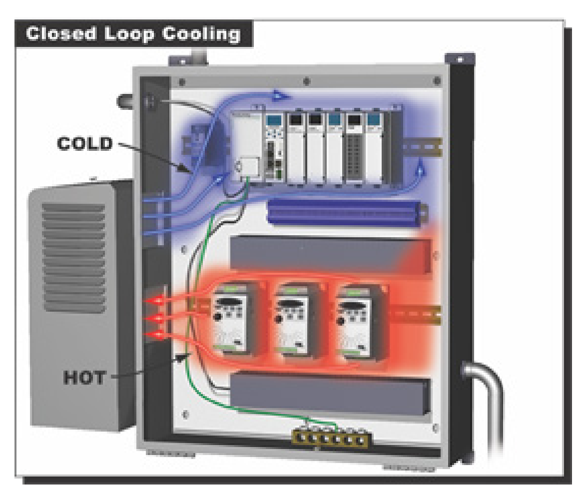
A typical forced convection system consists of a fan and a grille, with a filter on the intake device and either a filter or louvers on the exhaust device. The filters and louvers allow the enclosure to maintain NEMA 12 protection. In NEMA 4 or NEMA 4X environments, hoods can be added to both the fan and the grille to prevent the ingress of water.

Examples of Devices used for Radiation and Natural Convection Cooling

Filter Fan: Forced convection creates a constant air fl w 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 fil ers, fil er fans and compact fans, and Hubbel-Wiegmann vents, louver plates and fil ers, available from AutomationDirect, provide a wide selection of natural and forced convection cooling solutions. These vents & louver plates and fil er fans are available for applications where natural and forced convection creates suffici t cooling.

Enclosure Cooling: Closed Loop Cooling



If the environment is harsh, with heavy dust and debris or the presence of airborne chemicals, or there are washdown requirements, the cooling system must be able to keep the ambient air separate from the air inside the enclosure.

Closed loop systems, which include heat exchangers and air conditioners, circulate the internal air and ambient air through separate chambers connected by a refrigeration system that transfers heat from the internal air stream to the external air stream. Heat exchangers and air conditioners are both closed loop cooling systems. The primary difference in the two is the refrigeration system.

The refrigeration system in a heat exchanger is a set of sealed tubes of alcohol. Heat absorbed from the internal enclosure air boils the liquid alcohol at the bottom of the tube, causing it to rise to the top. The heat is then ejected to the cooler ambient air stream, causing the alcohol to condense back to a liquid and fall to the bottom.

Heat exchangers are very efficient because the refrigeration system has no moving parts - the only moving parts are the two fans. But for the heat to transfer through the system, the ambient air must be colder than the air inside the enclosure, just as it must be for filter fans.

Enclosure air conditioners function in the same manner as a residential or automotive air conditioner, with the refrigeration loop powered by a compressor. The refrigerant absorbs heat from the internal air at the evaporator coil and ejects it to the ambient air at the condenser coil. Unlike heat exchangers, they can provide cooling even if the ambient temperature is higher than the enclosure temperature. They can also be scaled to handle larger heat loads than any other cooling system.

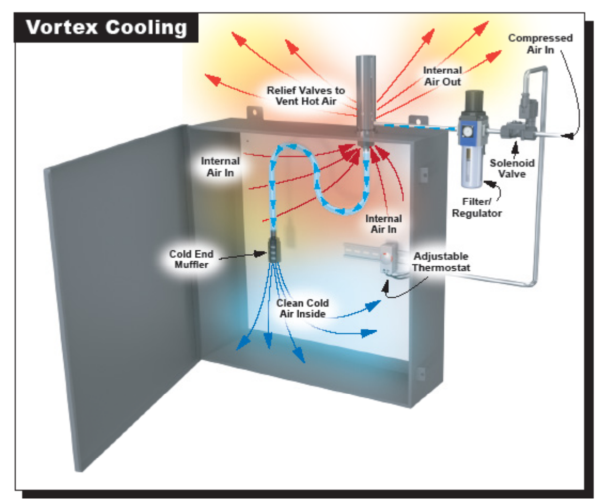
Enclosure air conditioners are available for NEMA 12, NEMA 4 and NEMA 4X applications.

Examples of Devices used for Closed Loop Cooling

Heat Exchangers: A closed loop cooling system that employs the heat pipe principle to exchange heat from an electrical enclosure to the outside.

Air Conditioners: The high efficie y 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 fil ered compressed air system, they still maintain NEMA enclosure ratings.



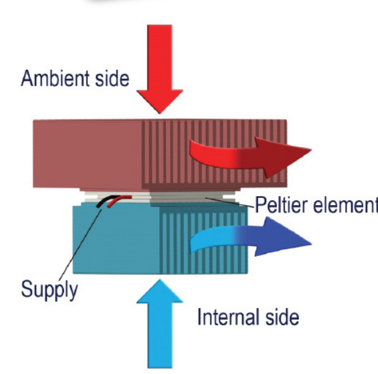
The vortex generator inside the cooler creates a vortex that rotates the compressed air supply at speeds up to 1,000,000 rpm, with the rotation separating the air into hot and cold air streams. The hot air stream is vented to the atmosphere, while the super-cooled air is forced through the center of 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 signifi ant amount of compressed air, which must be accounted for in their operating cost.

Thermoelectric Coolers: Another alternative to a conventional air conditioner is a thermoelectric cooler, which is sometimes referred to as a Peltier cooler. They function in a manner similar to an air conditioner or heat exchanger, with fans inside and outside the enclosure, but with a thermoelectric unit replacing the fluid-based refrigeration system.

The thermoelectric units consist of an array of semiconductors sandwiched between two ceramic plates. When a DC current is applied to the semiconductor array, heat is driven from one plate to the other, creating a cold side and a warm side. This is known as the Peltier Effect. Fans circulate air across each of the plates, allowing the cold plate to absorb heat from the enclosure and the warm plate to eject it to the ambient air.



THERMOELECTRIC COOLING PRINCIPLE

Like vortex coolers, thermoelectric coolers can be used with NEMA 4X enclosures in harsh, washdown, and corrosive environments, and where the ambient temperature exceeds the enclosure temperature.

Thermoelectric coolers are an alternative to air conditioners in small cooling capacity applications where there isn't adequate space for an air conditioner.

Closed loop cooling options offered by AutomationDirect that maintain the enclosure protection rating include Stratus enclosure air conditioners, air-to-air heat exchangers, and vortex coolers, in addition to Seifert thermoelectric coolers.

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 x P) / ΔT °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 airfl w rate for an application.

Sizing an Air Conditioner, Vortex Cooler or a Thermoelectric 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: Is the heat generated by components inside the enclosure. The preferred method to determine this is to add the maximum heat output specifi ations 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

Sizing a Heat Exchanger

To select the proper size heat exchanger, the worst-case conditions should be considered. For a heat exchanger to work, the ambient air temperature must be lower than the desired internal enclosure air temperature.

There are three main factors in choosing a heat exchanger for an uninsulated metal NEMA rated enclosure located indoors:

- Internal heat load
- (Delta T) ΔT
- 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 specifi ations that the manufacturers list for all the equipment installed in the cabinet. This is typically given in Watts, so use the following conversion:

ΔT = (max allowable internal enclosure air temperature °F) - (max external ambient temperature °F)

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:

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

Note: Only include exposed surfaces of enclosure in calculations. Exclude surfaces such as a surface mounted to wall.

Heat Load Transfer (W/°F) = 0.22 W/°F x surface area

Note: Use 0.22 Watts/for painted steel and non-metallic enclosures. Use .10 Watts/ °F ft^2 for stainless steel and bare aluminum enclosures.

Cooling Capacity: Once you have determined your Internal Heat Load, the Heat Load Transfer and the Delta T, you can choose the proper size unit by calculating the needed cooling capacity.

Cooling Capacity (W/°F) = Internal Heat Load / ΔT - 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 fil er 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 coeffici t 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 define , select a solution and properly size it for the application.

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Determine Required Enclosure Accessories

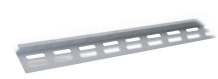
Suppliers like AutomationDirect offer a wide range of accessories for enclosures that help make more efficient installations and provide any feature necessary for your project. The following is a list of many accessories available through AutomationDirect:

- **Subpanels, Swing-out Panels, and Dead Front Panels:** These panels provide a surface to install components in different areas of the enclosure without compromising NEMA ratings and make it helpful to complete installations.

- **Adjustable Depth Mounting Kits, Support Kits, and Central Panel Support:** These kits are made for specific enclosure makes and models. Mounting kits provide a way to mount accessories (i.e., swing-out panels, DIN rails, rack angles, mounting channels and grid straps) at various depths. Support kits provide support for panels housing heavy components. Central panel supports adapt single-wide subpanels, swing-out panels or rack mount frames for mounting in double-door enclosures.

- **Barriers:** Barrier kits for specific enclosures provide partial separation between power and control sections within one cabinet. Barrier kits are available in various sizes and materials.

- **DIN Rails:** Provide a mounting surface for DIN mounted snap-on devices in enclosures. DIN rail is available in various lengths and pre-packaged quantities. Available kits include short precut slotted rails with mounting hardware.



- **Rack Mounting:** Rack mounting accessories allow installation of rack-style equipment in an enclosure. Rack mounts sell separately in various sizes for certain enclosure brands and styles.

- **Terminal Block Strips, Brackets, and Straps:** Provide a strong, versatile means for mounting terminal blocks in specific enclosures.

- **Alternative Mounting:**
  - **Floor Stand Kits:** Kits used to set a wall-mount style enclosure on the floor or to elevate a freestanding enclosure.

  - **Mounting Feet:** Mounting feet kits provide an easy way to securely mount an enclosure on a surface.

  - **Pole Mounting Kits:** Pole mounting kits provide an easy way to mount enclosures to various pole sizes.

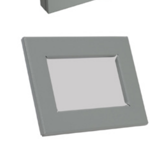
  - **Casters:** Casters can be installed on enclosures to provide enclosure mobility.

  - **Flush Covers:** Flush covers for specific enclosures provide a cover for junction boxes and are designed for flush mount installation requirements.

- **Accessibility:**
  - **Drip Shield Kits:** Drip shields provide additional protection to enclosure doors from dripping water and settling dust.

  - **Deep-Hinged Doors:** Universal deep-hinged doors with concealed hinges for specific enclosures offer a viewing window for clear visibility.

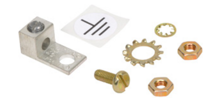
  - **Window Kits:** Window kits are available in various materials are compatible with NEMA 4, 4X, 12 and 13 enclosures. Kits are fully gasketed and include all necessary hardware for installation.



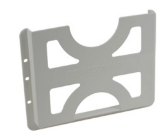
  - **Locks and Latches:** Provide enhanced security options not available as a standard feature.

Determine Required Enclosure Accessories

- **Folding Shelves:** Folding shelves provide temporary support inside or outside an enclosure for equipment weighing 35 pounds or less and fold down when not in use.



- **Grounding:** Ground lugs and wire are often needed to provide proper grounding for enclosures.



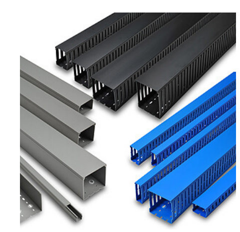
- **Print Pockets:** Print pockets provide storage that can be used to hold documents (i.e., small manual, blueprint). A double-sided adhesive flange all ws for easy installation anywhere inside or outside any enclosure.
- **Cable Entry/Cable Management:**

  - **Cable Entry Systems:** Provide safe cable entry into enclosures or electrical equipment, secure cables and provide strain relief while maintaining enclosure sealing requirements.

  - **Cable Glands:** Provide cable entry into enclosures or electrical equipment, securing cables or wires and providing strain relief while maintaining enclosure sealing requirements. Available in plastic and metallic.

  - **Gland Plates:** Gland plates are designed to provide easy cable entry into the enclosure while maintaining a NEMA 4 or 12 rating.

  - **Electrical Connectors:** Connectors and fittings provide transitions between components of wired or piped systems.



  - **Wire Duct and Accessories:** Used to route, protect and/or organize electrical cables and wires, typically within a control panel. Rigid and fl xible duct in a variety of sizes and styles offer installation fl xibility; spiral wire wrap and braided sleeving allow easy wire grouping and protection.

Enclosure Cutout Considerations

Selecting electrical enclosure features based on the required size and environmental conditions is the starting point of the design. The design phase includes panel layout, enclosure layout, and thermal considerations to determine how the enclosure must be customized to meet requirements. The main customization step usually is making cutouts in the enclosure, a procedure that can be performed in-house or by the manufacturer.

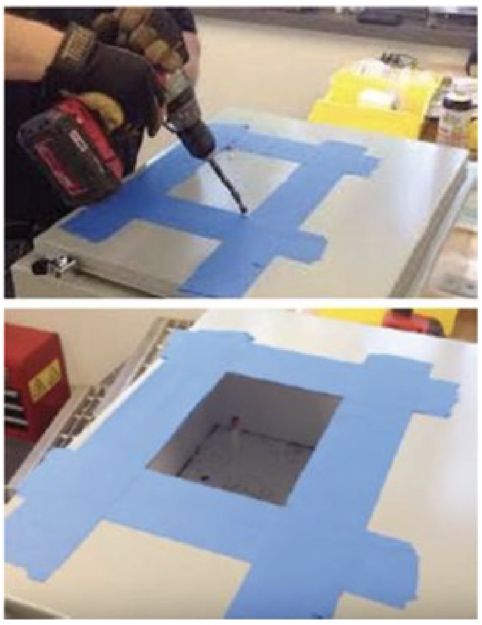
Customizing the Enclosure

In some cases, it can be advantageous to have the manufacturer provide an enclosure with customized cutouts. The types of enclosure cutouts include:

- Human-machine interface (HMI)
- Gauges and meters
- Pushbuttons, switches, and lights
- Potentiometers and thumbwheels
- DIN controllers

Cutouts made by the manufacturer reduce end-user labor costs and can improve quality. If the same type of enclosure and cutouts are repeatedly required, as is the case for many OEM machine builders, the manufacturer often can provide a part number to simplify ordering. When a manufacturer makes cutouts, they can use their manufacturing and fabrication facility's resources to ensure all work is done correctly and precisely, and without compromising the enclosure.

Do-it-yourself (DIY) cutouts can be made in the electrical enclosure after delivery, but this requires several steps. Each cutout needs to be carefully measured and marked (see Figure 2), with care to avoid any scratches, which may require taping. With the cutout's shapes properly aligned, spaced, and marked, drilling and cutting can begin. Cutouts often take signifi ant time to lay out, drill, and cut. In many cases, there is little room for error. Crooked or oversized cutouts present a poor appearance and compromise the enclosure rating. Touch-up paint may be required after cutouts are made, further adding time and expense.



While polycarbonate, PVC, ABS and aluminum can be easy to cut, steel and fibe glass enclosures quickly consume cutting blades, and special tools are needed to make large holes. Once the holes are cut, they must be smoothly filed to remove burrs and rough or sharp edges. Cleanup of cutting debris, oil and tape and removal of cutout markings is also required. After cleanup, the bare steel edges, exposed by cutting, must be painted to inhibit corrosion. At this point, the actual panel build and assembly can begin.

Despite the care required when making DIY cutouts, this can be the best option if just a few simple cutouts are needed, particularly for polycarbonate or fibe glass enclosures. Another scenario where DIY cutouts are the best option is when the OEM or end-user has signifi ant machine shop resources on-hand for cutting, grinding, and painting.

To get to the build and assembly stage faster, purchasing a customized enclosure directly from a manufacturer is another option. This does not eliminate the design phase, and cutouts still may need to be added. But it does signifi antly simplify the build phase, especially if multiple, duplicate enclosures are produced. The result is a customized enclosure, with accurate cutouts to exact specifi ations.

Many enclosure manufacturers offer customized enclosures with factory cutouts per the end user's or OEM's specifi ations. Some of these manufacturers also offer an online graphical configu ation utility that can be used to select several cutout types and sizes, which the user can place in one of several standard enclosures.

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Conclusion

Enclosure layout and selection is often an iterative process, with many draft versions leading to the final design. lways make sure you have covered all required needs and allowed for any future expected additions. Once you have completed your design, always make one last check to ensure that your design fits our enclosure before placing an order.

ALWAYS REMEMBER that even if the dimensions in the description are actual dimensions, you don't know what those dimensions actually mean - the depth dimension may be overall depth, the depth of the enclosure tub (not including the door), the depth from the subpanel to the inside of the door, etc. **ALWAYS REVIEW THE ENGINEERING DRAWING FOR DIMENSIONAL DATA WHEN SELECTING AN ENCLOSURE. NEVER SELECT AN ENCLOSURE SOLELY FROM THE DIMENSIONS IN THE DESCRIPTION.**

In most cases, you will find th t there are many available enclosures that will meet your requirements. Keep in mind that manufacturers often have different specific eatures for otherwise identical enclosures that meet your requirements - thinner or thicker materials, different types of latches and hinges, different finishe , etc. These aspects may or may not be important to you, but you should familiarize yourself with the differences.

One last important variable that should be considered is the availability of the enclosure. Enclosure availability varies considerably between manufacturers and suppliers. If there is an immediate need for the enclosure, it is best to use a supplier that stocks most of their enclosures or has fast drop shipping available. Make sure to review and consider lead times when making your decision.