Thermal Edge Inc.™

TEMPERATURE CONTROL SOLUTIONS FOR ELECTRICAL ENCLOSURES

CHOOSING A COOLING SYSTEM FOR ELECTRICAL ENCLOSURES

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Introduction

Selecting a cooling system for an electrical enclosure is an important task that is not always as simple as it might seem. The consequences of choosing the wrong system can be significant, so taking the time to make an informed choice is vital.

To choose the most efficient and cost-effective cooling system you must first consider factors such as the NEMA rating and heat load for the enclosure. These two pieces of information will help you determine whether to use an air conditioner, heat exchanger, or a filtered fan system to cool the enclosure.

However, the choices do not stop there. Once you decide which type of cooling system makes the most sense, you must determine the cooling capacity and the appropriate size to ensure optimal efficiency.

Even with access to resources such as cooling capacity calculators, selecting the right cooling system can be challenging, especially if you have never gone through the process before. The financial consequences of choosing an improperly sized system are not insignificant, so it is important to make your purchase with confidence.

The aim of this white paper is to help you simplify the process of selecting a cooling system for an electrical enclosure. Although the details provided are comprehensive enough to help you narrow your choices, it is always best to consult an expert before making an investment in new cooling equipment for electrical enclosures.

Common Environments for Electrical Enclosures

Electrical enclosures can be found in areas as diverse as factories, windmill farms, and coalmines. The National Electrical Manufacturers Association (NEMA) creates industry standards for the performance of electrical enclosures based on the surrounding environment. The NEMA enclosure type will help inform which kind of cooling system is appropriate for your application.

NEMA 1

A NEMA 1 rating is the least stringent designation for an electrical enclosure. The enclosure will always be indoors and the surrounding environment will be similar to normal atmospheric conditions. Although some dust protection is provided with a NEMA 1 enclosure, it is not a watertight solution and does allow some dust and other airborne contaminants to enter the system.

NEMA 3R

An electrical enclosure with a NEMA 3R rating is intended for outdoor use so it must protect against rain, snow, wind, ice, rust, and other environmental conditions that may be encountered. NEMA 3R enclosures can also be used in indoor environments when falling debris is a consideration.

NEMA 4 N

NEMA 4 enclosures must be weatherproof for outdoor applications and able to withstand more extreme indoor conditions where water or other liquids are present. Examples of potential applications for NEMA 4 enclosures include telecommunications, or freshwater marine environments.

NEMA 4X

A NEMA 4X rating is similar to a NEMA 4 rating, but the 4X designation must also include protection against corrosion. Applications where a NEMA 4X rating is common include wastewater treatment plants, paper bleaching, food processing, and saltwater marine environments. Exposure to corrosive elements such as saltwater or chlorine will typically require an enclosure to have a NEMA 4X rating.

NEMA 12

An enclosure with a NEMA 12 rating is intended for indoor use, such as manufacturing plants, and must meet certain standards for protection against dust, dripping liquids, and falling debris. Unlike a NEMA 4 or 4X rating, enclosures with NEMA 12 ratings are not designed to protect against water infiltration from splashing or direct hose spray.

Enclosures of NEMA types 1 and 3R can often be cooled with a simple filtered fan system that does not provide protection against water spray, dust, or other airborne contaminants. The other types of enclosures require a closed loop system that can be achieved with either an air conditioner or a heat exchanger depending on the ambient temperature, the heat load of the enclosure, and the sensitivity of the equipment.

Determining and Managing Enclosure Heat Load

The heat load of an electrical enclosure is primarily the amount of heat generated by the equipment inside the unit. Too much heat in an enclosure can cause damage to equipment and shorten its life, which is why it is so important to select a cooling system that has the capacity to lower the temperature adequately.

Understanding the sources that contribute to the heat load and how that heat is transferred is one of the first steps in selecting an appropriate cooling system.

The two primary factors that contribute to the heat load of the enclosure are the internal and external heat sources:

Internal Enclosure Heat

Any number of heat sources might exist in an electrical enclosure. Some examples of common components include:

- Motor drives
- Transformers
- Communication equipment
- Servos
- Power supplies
- Control boards
- Programmable logic controllers
- Servers and other networking equipment

It is also worth noting that many of these same heat-generating components are the same ones that require protection from damage due to excess heat. Most components come with specifications that outline the highest expected heat output. You can use this information to help calculate the heat load of the enclosure.

Ambient Heat

Ambient heat refers to the temperature in the environment surrounding the enclosure. In an outdoor environment the ambient temperature is generally comparable to the air temperature, although solar heat gain must also be considered.

However, in an indoor environment, the ambient temperature can be affected by factors such as:

- Industrial ovens
- Kilns
- Furnaces

When ambient heat is high enough to impact the internal temperature of the enclosure, it must be factored into the heat load calculation.

The combination of internal and external heat sources will help you determine the heat load, or just how much heat must be removed from the system, but how do you actually achieve the desired cooling?

Understanding Heat Transfer

The second law of thermodynamics states that heat always transfers from an object or region of higher temperature to one of a lower temperature. For example, when ice is added to a glass of water, the warmer liquid actually heats the ice, and as a result, the temperature of the liquid is lowered. The same concept can be applied to electrical enclosures in three different ways:

1. **Natural Convection Cooling**
   The flow of heat from a warmer environment to a cooler environment occurs

naturally when the ambient temperature surrounding an electrical enclosure is cooler than the internal temperature. The heat from the enclosure will naturally radiate through its walls and the internal temperature will be lowered accordingly.

Although this method is by far the most simple, it is also the least effective because the temperature difference between most enclosures and their ambient environments is not large enough to sufficiently cool the components inside the enclosure.

2. **Forced Convection Cooling**

   The amount of heat that transfers from a warmer area to a cooler area can be increased with addition of a fan or blower to decrease the thermal resistance of the barrier between the two areas.

   In the case of an electrical enclosure, filtered fans can provide affordable forced convection cooling to reduce the internal temperature. But what happens when the outside air has contaminants like dust and dirt or oil? The filtered fan may provide the cooling you need, but it will deposit these contaminants on electrical components at the same time. When air contamination might be a problem, the best solution is a closed loop air to air heat exchanger.

   However, just as with natural convection cooling, the amount of heat that can be transferred away from the components inside the enclosure is limited by the ambient air temperature.

3. **Active Cooling**

   When natural convection or forced convection do not provide enough heat transfer to adequately cool the components inside the enclosure, an air conditioner may be required. An air conditioner also provides a closed loop system which is needed when the components inside the enclosure must be protected from environmental factors such as dirt, dust, or liquids.

Selecting the Right Cooling System

After you have identified the NEMA rating of the enclosure and calculated its heat load, you have enough information to decide whether you need a filtered fan, a heat exchanger, or an air conditioner.

Air Conditioner Sizing and Selection

An air conditioner is necessary when the internal temperature of the enclosure must be lowered below the ambient temperature outside the enclosure. Air conditioners are suitable for enclosures of NEMA types 4, 4X, and 12.

Selecting a properly sized air conditioner is critical for achieving optimal performance and efficiency. An air conditioner that has insufficient cooling capacity will not be able to adequately cool the components inside the enclosure. On the other hand, an over-sized air conditioner will cycle on and off too frequently, making it less efficient, increasing operating costs, and potentially shortening the life of the equipment.

Calculating Cooling Capacity

Calculating the required cooling capacity is an essential step in selecting a properly sized air conditioner. The required cooling capacity of an air conditioner, which is expressed in BTU/hour, is based on the internal heat load and the heat load transfer.

- **Internal heat load** – Each component in the enclosure has a maximum heat output specification, typically provided in Watts, which can be converted to BTU/hour. Adding the maximum heat output specifications for every component in the enclosure will give you the total internal heat load for the system.

- **Heat load transfer** – The heat that transfers between the inside of the enclosure and the ambient air outside is referred to as the heat load transfer. When the temperature inside the enclosure is higher than the ambient temperature, the heat load transfer will be negative. When it is warmer outside the enclosure than it is inside, the heat load transfer will be positive. The calculation takes into account factors such as:

    - The surface area of the enclosure
    - The enclosure material
    - The maximum ambient air temperature
    - The maximum temperature allowed in the enclosure
    - Whether the enclosure is insulated
    - The location of the enclosure
    - Industry standard constants

The internal heat load and the heat load transfer are added together to determine the required cooling capacity for the air conditioner. Cooling capacities for enclosure air conditioners range from 1,000 BTU/hour to 20,000 BTU/hour, so you can see that an accurate calculation is a critical step in selecting the right unit for your application.

Enclosure and Air Conditioner Dimensions

In addition to calculating the cooling capacity, you must also consider the physical size of both the air conditioner and the electrical enclosure to ensure that they are compatible. Enclosure air conditioners come in a variety of shapes and sizes, including narrow units that are designed to fit on enclosures as small as only seven inches deep.

Heat Exchanger Selection

Like air conditioners, heat exchangers are suitable for enclosures of NEMA types 4, 4X, and 12. However, a heat exchanger can only be used when the ambient temperature is lower than the temperature inside the enclosure.

Heat exchangers are most commonly used in relatively low ambient temperatures when a closed loop system is desired to keep contaminants out of the enclosure. They have the advantage of providing highly efficient cooling without the need for filters.

Calculating Cooling Capacity

The required cooling capacity for a heat exchanger is expressed in Watts/degree Celsius (W/°C). It is calculated in a similar way to air conditioners, but with the addition of another factor: Delta T.

- **Internal heat load** – Just as with air conditioners, the internal heat load is calculated by adding the maximum heat output specification for all of the components in the enclosure.

- **Heat load transfer** – Using the same concepts as those described for air conditioners, the heat load transfer for a heat exchanger is calculated using the square footage of the surface area and an industry standard constant that varies depending on the enclosure material.

- **Delta T** – Delta T is calculated by subtracting the maximum ambient temperature from the maximum allowable enclosure temperature.

Dividing the internal heat load by Delta T, and then subtracting the heat load transfer will provide the required cooling capacity for a heat exchanger. Heat exchangers are available with cooling capacities ranging from 11 to 71.6 Watts/°C.

Filtered Fan Selection

Filtered fans are a viable solution for enclosures rated NEMA Type 1 or 3R because they do not keep particles or liquids out of electrical enclosures. Filtered fans can also only be effectively used when the ambient temperature is lower than the temperature inside the enclosure.

Calculating Cooling Capacity

The cooling capacity of a filtered fan is expressed in cubic feet per minute (CFM). The equation used to calculate the required CFM of a filtered fan includes both the internal heat load and Delta T.

- **Internal heat load** – Just as with an air conditioner or heat exchanger, the internal heat load of an enclosure that uses a filtered fan is calculated by adding the maximum heat output specifications for all of the components in the enclosure.

- **Delta T** – This is the difference between the maximum ambient temperature and the maximum internal temperature.

Calculate the required CFM by multiplying the industry standard constant 3.17 by the internal heat load (in Watts), and then dividing the result by Delta T. Filtered fans are available with cooling capacities ranging from 80 to 750 CFM. However, the air resistance of the filters needs to be accounted for. A general rule of thumb is to reduce the effective fan CFM by 33 percent for each filter in the air flow path. For example, the effective air flow rate for a 750 CFM fan with one inlet filter and one exhaust filter is 248 CFM.

Conclusion

Selecting the right cooling system for an electrical enclosure is important for keeping operating costs low, protecting valuable equipment, and getting the most from your investments. Choosing the wrong system could result in equipment damage, higher operating costs, or even equipment failure.

The steps for selecting the right cooling system include:

- Determining the NEMA rating of the enclosure
- Calculating the heat load of the enclosure
- Deciding which type of cooling system is appropriate
- Calculating the required cooling capacity
- Selecting a system that meets all of the above requirements and physically fits on the enclosure

Although each step in the process is clearly defined, the actual process of selecting a cooling system can be quite intimidating, especially if you have never done it before. When you consider the potential consequences of installing a cooling system that does not function as expected, it is clear that making the right choice from the beginning is extremely important.

The Enclosure BTUH Calculator on the Thermal Edge website has been designed to simplify the selection process. We offer air conditioners, heat exchangers, and filtered fans for a broad range of applications, including enclosures with all of the NEMA ratings discussed in this white paper.

If you need help selecting the right cooling system for your application, talk to the professionals at Thermal Edge. Our experts will work with you from beginning to end to ensure that you have the most cost-effective solution for your application. We also work with engineers who design electrical enclosures to help determine the right temperature control solution early in the design process.

Get in touch with us today to review case studies that are similar to your application, review product literature, or schedule a consultation.