White Paper

February 2015

Environmental: Outdoor

Protecting Control Panels in Outdoor Environments

www.pentairprotect.com

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Introduction

Outdoor environments create multiple sources of risk for equipment failure within control panel enclosures. For example, enclosures located outdoors must withstand potential ultra-violet (UV), solar heat, rain, hurricanes, earthquakes, and tornadoes. These harsh elements create unique reliability and protection needs for applications such as solar combiner boxes, mobile telecommunications, outdoor industrial controls, traffic toll systems, railway signals, and outdoor electrical junctions.

Along with the environmental risks created by adverse climates, it is important to consider the relevant technical factors, such as ingress requirements, chemical presence, Electromagnetic Interference (EMI) and standards, when selecting a control panel for outdoor use. Determining whether the enclosure needs a cooling system, corrosion resistance, and a water or dust-tight seal will allow design/controls engineers to select the proper enclosure and material to provide the appropriate level of equipment protection against the elements.

Although it is sealed off from intense weather conditions, the internal assembly of the control panel must also be designed for harsh conditions, such as extreme temperature variations. This and other dynamic factors (e.g., moisture, condensation, chemicals, and corrosive gases) can affect internal component and material selection, panel layout and design, and the need for environmental conditioning (cooling and/or heating).

This white paper is one of three papers that collectively address the environmental protection of control panels. The intent is to review and provide guidance on the risks and solutions available for outdoor environmental applications. For additional information on this topic, including copies of the white papers as they become available and more information on Panduit or Pentair Equipment Protection (Manufacturers of the Hoffman brand of enclosure), please visit www.Hoffman-Panduit.com.

The Toll of Mother Nature on Control Panels

Environmental elements that have a harmful effect on control panel reliability and performance include precipitation, dust, and seismic activity.

Precipitation

Water damage is one of the more common issues that plague electrical equipment. Differences in ambient air temperature can cause condensation to form, increasing the risk of equipment failure and short circuits. Condensation can also form as the temperature cools at night or when the equipment is shut down. In especially wet or humid applications, moisture can enter when a door is opened for maintenance or service purposes.

For the internal components and wiring connections within the control panel, moisture and corrosion can affect continuity and the lifespan of the connections. It is essential to select corrosion-resistant materials to maintain continuity where moisture is likely to be present. It is also important to inspect critical electrical connections to the panel, such as power and grounding and bonding connections, for signs of corrosion.

For help when evaluating the environment for climatic conditions, refer to:

- TIA TSB-185, Environmental Classification (M.I.C.E.) Tutorial
- IEC 60721-1 - 3, Classification of groups of environmental parameters and their severities

Dust

Dust or accumulation of other combustible particles (such as coal dust) within an enclosure drastically increases the chance of equipment overheating, fire, or catastrophic failure. Non-combustible dust, dirt, and other particles also reduce the integrity of the equipment. Solar heat accelerates these issues. However, selecting a proper location, material/rating, cooling system, and color may alleviate ignition concerns.

Regarding ingress, failure can occur where accessory devices or cable connections are made through the panel. These components should match or exceed the enclosure rating to properly seal out dirt, dust, and particles, and maintain the control panel's ingress rating.

Seismic Activity

Seismic-rated enclosures are needed in areas where earthquakes or other vibrations occur, such as power plants, airports, and railroads. For these environments, it is important to select an enclosure with the proper frame strength and rigidity to ensure the equipment does not become over stressed or damaged.

Choosing the Right Enclosure for the Right Outdoor Environment

Enclosure ratings define the types of environment where an electrical enclosure can be used and specify how well an enclosure can tolerate certain environmental conditions. Refer to the *Environmental Protection of Control Panels: Overview and Standards Compliance* white paper on Hoffman-Panduit.com for more information on enclosure ratings.

NEMA Type 3R

NEMA Type 3R enclosures are primarily used outdoors for protection against rain and sleet, and can withstand damage from ice formation. When substance infiltration is a concern but other requirements do not allow an enclosure to be completely watertight, a 3R rated enclosure offers an adequate level of protection. However, openings for vents, louvers, fans, air conditioners and other accessories can create an avenue for water or dust to enter the enclosure. While the 3R enclosure is rated for protection against rain, sleet, ice or other infiltration, without additional safeguards, abnormal conditions or events could damage the equipment.

Due to the physical restrictions needed to maintain protection against the ingress of water, an enclosure can be vulnerable to extreme temperatures and heat load produced by the equipment. Inside a cabinet, uncooled components can generate trapped heat comparable to heat generated by a home furnace. AC power supplies, controllers, drives and servos, transformers and rectifiers, along with radio equipment and processors or servers are sources for this heat load. To help release heat produced, vents or louvers are allowed on a 3R enclosure but limitations may prevent full air movement, exhaust, or the exchange of heat. See Figure 1.

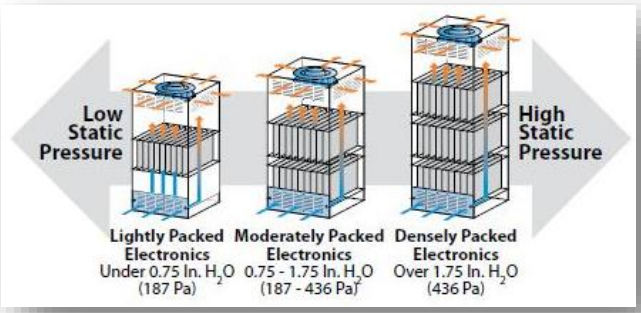


Figure 1: Depending on the configuration of the components inside, airflow can be restricted by static pressure, increasing the temperature.

Through the Arrhenius Equation, research has shown that for every 18ºF above normal room temperature, the reliability of electronic components is reduced by half. A more densely packed enclosure will require a larger, more powerful solution to resolve airflow problems. Without additional mechanisms for air movement, heat stratification within an enclosure increases greatly, causing hot spots and raising the potential of overheating or malfunction.

Ball parks and theme parks constantly face thermal challenges. With enclosures exposed to the sunlight and precipitation, and the heat generated by the electronic equipment, controls have to consistently perform in hot and humid conditions. Whether it is the lighting, scoreboards, roller coasters or the computer for pyrotechnic shows, reliability is crucial.

NEMA Type 4 and 4X

NEMA Type 4 enclosures resist corrosion, protect against rain, sleet and ice formation, but also safeguard equipment from splashing, hose directed water, and windblown dust. In addition to the typical rain, sleet, or ice hazards, NEMA Type 4 and 4X enclosures must exclude at least 65 GPM of water from a one-inch nozzle at a distance within ten feet for five minutes. These rigorous standards are typical in outdoor locations such as ships, docks, and piers. Improperly installed or modified enclosures increase the risk of interior equipment damage. A single exposed opening can lead to the failure of the equipment, causing an increase in costs, resources, and time.

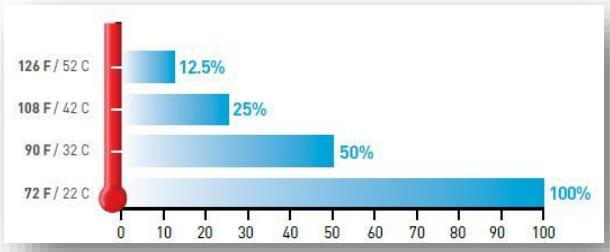


Figure 2: Electronics Life Expectancy percentage (Source: Digital Equipment Corporation).

Enclosures in extreme environments without proper heating and cooling elements have seen catastrophic failures in their equipment, de-rated drive performance, and changes in silicone material properties. See Figure 2. Integrated circuit devices can intermittently fluctuate in output, voltage migration, and decrease exponentially in mean time between failure. These problems increase missed shipping dates, labor costs, scrap, and component costs, while productivity and customer satisfaction decrease.

Drilling, pipeline, and refining operations are located in some of the most extreme conditions, such as searing heat, torrential rains, or bitter cold. These on and offshore applications require enclosure solutions that preserve watertight seals while maintaining a proper temperature within to deter any fires, sparks, or combustion, which could be deadly in these situations.

Applications requiring NEMA 4/4X, (e.g., completely watertight enclosures and corrosive environments), create an even greater concern regarding heat load. The watertight necessity of the enclosure does not allow louvered venting and further limits the options to reduce heat load.

Additionally, 4X stainless steel enclosures absorb and conduct heat better than non-metallic enclosures. While stainless steel enclosures improve heat dissipation issues better than non-metallic enclosures, they are inferior insulators. This causes additional challenges with UV or solar heat penetrating an enclosure. Non-metallic enclosures are also more susceptible to damage from heavy machinery or frequent access.

Wind farms are a specific application where an enclosure requires rain, sleet, and ice protection, but also needs some airflow for its components to provide their best performance. Excess heat is generated by electrical inverters at these farms, and dust accumulation can decrease the inverter's performance or cause equipment failure, if not properly addressed. Even if the wind allows the turbine to operate at ideal speed, this lost efficiency at the inverter will reduce its power potential and revenue.

In outdoor applications where enclosures are exposed to direct sunlight, unpainted metallic enclosures can experience significant increases in temperature. In addition to the heat buildup from the internal components, the amount of solar exposure, enclosure color, material type, and sustained atmospheric temperature must be considered when selecting an enclosure. Choosing the right color, features, and material is crucial to maintain the maximum life expectancy of the equipment.

Enclosures subjected to 200 hours of salt spray with no evidence of corrosion are given a NEMA 4X rating. These watertight enclosures prevent salt from damaging the electrical components, and guard against rust and decay. A general environmental matrix as seen in Table 1 can help in the selection of an enclosure when faced with the potential sources of infiltration. Appendix III provides a guideline for Hoffman's thermal management solutions.

Table 1: Comparison of Specific Non-hazardous Applications in Outdoor Locations.

Enclosure Type Rating Provides a Degree of Protection Against the Following Environmental Conditions	3	3R	3RX*	4*	4X	6
Incidental contact with the enclosed equipment	●	●	●	●	●	●
Rain, snow, and sleet [b]	●	●	●	●	●	●
Windblown dust	●			●	●	●
Hose-down				●	●	●
Corrosive agents			●		●	
Occasional temporary submersion						●

Reproduced with permission of the National Electrical Association from NEMA Standards Publication 250 Enclosures for Electrical Equipment (1000 Volts Maximum).
**These enclosures may be ventilated.*
[b]External operating mechanisms are not required to be operable when the enclosure is ice covered.

3R Outdoor Solution Considerations

Enclosures needing protection from outdoor hazards maintain a 3R rating and have many design features that accommodate the specific application. 3R enclosures can utilize both natural and forced convection as a means for air movement. They can also apply several forms of functional ingress and egress for wires and cables, or service and repair. Gaskets and channels help deter the ingress of liquids, while the enclosure material can help eliminate thermal issues or corrosion. Painted enclosures and solar shields relieve issues caused by solar radiation, and thermal solutions help maintain proper equipment protection.

Sealing

Gaskets are mechanical devices that provide a leak-tight seal between two irregular mating surfaces, for example, between a 3R enclosure and its door or accessories. Gaskets, latches, and other fastening elements provide a secure seal to prevent substances from entering the enclosure through the door or cover. While primarily used to prevent the ingress of water, dust, or additional sources of infiltration, they can also be used to contain noise or other interference. Latching systems provide a secure, tight connection from the door to the enclosure, preventing the door from opening or coming loose, which allows the seal or gasket to keep the necessary bond that protects the equipment. See Appendix I, #1.

Material

Selecting the proper 3R enclosure material optimizes equipment performance and reduce costs. Painted mild steel for 3R enclosures provides adequate protection and can withstand damage from direct sunlight.

Stainless steel 3R enclosures are more robust than mild steel, maintain their appearance well and are more durable than mild steel for applications in extreme temperatures. These enclosures can be used in a wider range of applications but the added value has higher upfront costs. However, stainless steel 3R enclosures need less maintenance and repair than mild steel, which increases cost savings over time.

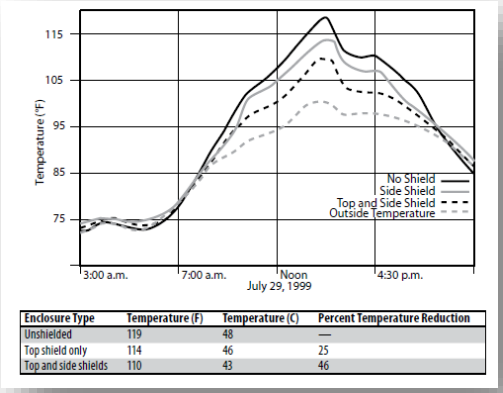
Non-metallic enclosure materials such as fiberglass, polyester, or polycarbonates have corrosion resistance along with UV stabilizers, and reduced flammability for better performance. Non-metallic enclosures are also significantly lighter than steel. Polyester enclosures are 50% lighter than fiberglass and 6.5 times lighter than steel. However, strength and impact resistance for non-metallic enclosures are greatly reduced compared to their steel counterparts. See Appendix I, #1 and #2.

Finish

To protect the enclosure and equipment from corrosion and solar heat, coatings or finishes can be applied. Painted metallic enclosures have a significant decrease in the rate of temperature rise above the ambient level vs. unfinished aluminum and stainless steel enclosures. The color of the painted enclosure also makes a large difference in the solar load. For example, white and polished metallic finishes produce the least solar load and keep the internal components the coolest. Black finishes perform the worst in solar load comparisons. See Appendix I for Hoffman 3R enclosures.

Solar Shields

In applications where white or light colored paint cannot minimize the heat load, or where aesthetic requirements prevent those options, solar shields may be an alternative solution. Solar shielding creates an added surface that shades the enclosure from the solar radiation and reduces the solar load. Solar shields have at least a one-inch space for airflow between the shield and the enclosure, where venting can be placed to allow internal heat to escape the enclosure. Testing has proven that solar shielding can reduce solar loads by as much as 50% if shields are placed on all sides. See Figure 3 and Appendix I, #3.



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

Figure 3: Shielding effectiveness.

Channels, Slopes, Vent Drains, Dehumidifiers

Channels and slopes funnel water away from entry points and eliminate flat surfaces for liquid to pool. Enclosures subject to wet, humid conditions or environmental applications that typically generate condensation may need vent drains and dehumidifiers. Vent drains use gravity to allow accumulated water to drain out the bottom of an enclosure. In addition to draining liquids, pressure differences could pull water or moisture into the enclosure through the vent drain. See Appendix I, #4, #5, and #10.

Dehumidifiers remove internal moisture from the enclosure to help reduce corrosion, or the chance of equipment failure. While highly effective, dehumidifiers can inexpensively protect the enclosure and components from the effects of condensation. See Appendix I, #4.

Thermal Solutions

Many 3R enclosures use cooling systems to maintain a proper temperature for the equipment inside. Convection systems work through differences in ambient air temperature and pressures, where heated air inside an enclosure rises, leaves through a vent or opening near the top, and cooler air replaces it through an opening near the bottom. These systems may be open or closed loop, where open loop or “fresh air” systems replace the air completely, and a closed loop system recycles the heated air through a method where the air cools down and descends before it enters the enclosure again to restart the process.

Natural convection systems are considered passive cooling and do not use any mechanisms to increase the airflow. These systems use only ventilation or louvers to allow the heated air to escape the enclosure and are generally applied in relatively cool environments. These systems do not maintain a seal from the outside environment and they should only be used when infiltration is not considered a significant risk.

Forced convection cools similarly to natural convection, but uses additional methods to increase airflow through the enclosure. Options available for forced convection include filter fans, fan trays, motorized impellers, and packaged blowers. See Appendix I, #2.

Enclosures rated for 3R applications accommodate means of ingress for wires, cable service, and repair more easily than their 4X counterparts. Although 3R enclosures prevent the ingress of precipitation, they are not required to protect against backflow or in washdown environments. Therefore, open bottoms, knockouts and other openings that allow access without creating a viable way for falling or dripping water to enter are acceptable. This allows the 3R enclosure to expel heat more effectively than a fully sealed enclosure. For instance, the Weatherpro outdoor pad mount enclosure comes standard with an open bottom that allows for both airflow and an ingress/egress for power distribution and control applications. See Appendix I, #1.

For applications where an open bottom is not viable, a knockout may be a better choice. A knockout allows the user to install conduits, wires, or thread cables that run to and from the enclosure while maintaining a 3R rating and limiting access to the interior. Many Hoffman products come standard with knockout provisions.

4 / 4X Outdoor Solution Considerations

Several outdoor applications are located in areas that need full protection against ingress of water, wind, and dust. Enclosures for these applications require a NEMA 4 or 4X rating. While many features are also used in 3R enclosures, 4 and 4X enclosure features provide additional protection for applications in more harsh environments.

Sealing

NEMA Type 4X enclosures may employ a seamless foam-in-place gasket to eliminate points of entry for water, oil, or dust. These enclosures may have various cover options to hold the watertight seal in place, whether it is screw down, clamp down, quarter turn latch, or a three-point latching system. Depending on the size of the enclosure and its need for accessibility, any of these options is optimal. Specific applications may also require sloped covers and channels to provide drainage away from the enclosure opening. See Appendix I, #5.

Material

Stainless steel, (Type 304 and Type 316L), is used in many harsh natural environment applications due to its superior corrosion resistance. Table 2 can help with determining which material is best if the application exposes the enclosure to sprays other than salt water. Mild steel can be used in situations where a watertight seal is needed, but corrosion resistance is not a concern. Other materials such as polyester, fiberglass, ABS, or polycarbonates may also be suitable, depending on the environmental need. However, NEMA 4X ratings are only certified for corrosion from salt water. See Appendix I, #6, #7.

Table 2. Recommended Materials for Corrosive Environments

	SOLVENTS	ALKALIS	ACIDS
RECOMMENDED	• Type 304 stainless steel • Type 316 stainless steel • Fiberglass (compression molded) • Aluminum • Polyester	• ABS • Polyester • Type 304 stainless steel	• ABS • Polyester • Polycarbonate • Fiberglass (spray-up) • Type 304 stainless steel • Type 316 stainless steel
SATISFACTORY	• Steel (polyester powder coat) • Fiberglass (spray-up) • Polycarbonate • ABS	• Type 316 stainless steel • Polycarbonate • Fiberglass (compression molded) • Fiberglass (spray-up)	• Fiberglass (compression molded)
LIMITED USE		• Aluminum • Steel (polyester powder coat)	• Aluminum • Steel (polyester powder coat)

Finish

Type 4 and 4X enclosures, being composed of a wider variety of materials, can also have finishes that vary extensively. Most 4X stainless steel or aluminum enclosures are unpainted, to minimize heat absorption, while 4X non-metallic enclosures are manufactured or painted in light colors to reduce solar heat effects. Type 4 mild steel enclosures utilize a polyester powder paint to reduce the solar load. These finishes also play a role in the corrosion resistance. Using an example from Table 2, a Type 4 mild steel enclosure with a polyester powder coat may be satisfactory for solvents, but it would not be recommended for applications involving acids or alkalis. See Figure 4.

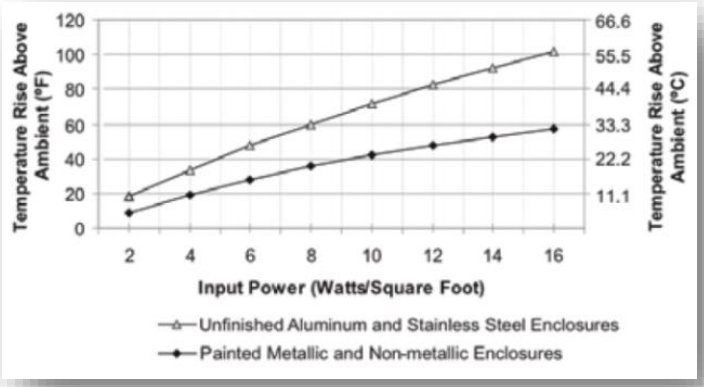


Figure 4: Sealed enclosure temperature rise.

Drip Shield

The watertight component of a NEMA Type 4 or 4X enclosure is necessary in washdown or wet environments. A drip shield helps protect the integrity of the seal where the door meets the enclosure. By creating a barrier that prevents direct liquid contact from reaching the seam, a drip shield adds an additional layer of equipment protection.

4X Thermal Solutions – Natural Convection

Since Type 4 and 4X enclosures need a watertight seal, the inability to use open cooling systems makes natural convection extremely difficult for these enclosures. Simple conduction, where cooling occurs by the transfer of heat through the surfaces of the enclosure, is possible with 4X. However, conduction provides a very low amount of heat removal and needs an environment with low heat loads or a cool location. Closed loop systems that use convection, such as air-to-air and air-to-water heat exchanges, are more common with Type 4X because no seal is broken. However, most of these systems use forced convection to run more efficiently than air movers. Using internal circulating fans alone can improve heat dissipation within an enclosure by as much as 10%.

Forced Convection

Air movers allow more avenues for cooling in a 4X enclosure. Heat exchangers, vortex coolers, thermoelectric coolers, and air conditioners are all potential methods of air movement in 4 or 4X applications. A heat exchanger can be used to transfer heat from inside the enclosure to outside when the electronic components can operate safely at a higher temperature than the ambient air outside. It also can be used when humidity is not an issue and when a low to moderate heat load is generated by the internal components. Thermoelectric coolers operate using the Peltier effect and are an ideal solution for small enclosures. Since condensers, compressors and filters are not necessary, thermoelectric coolers are reliable and require little maintenance, making them suitable for hard to reach or demanding applications. Vortex coolers generate chilled air by powering compressed air through a tube. Vortex coolers also operate without refrigerants or moving parts, therefore, their reliability is suitable for demanding and harsh environments. See Appendix I, #8.

Air Conditioner

An air conditioner should be used when the environment places a heat load on the enclosure, but temperatures within the enclosure need to be maintained at or below the ambient air temperature. Additional situations where an air conditioner should be specified are when humidity needs to be removed, or when a high or moderate heat load is produced by the equipment and cannot be adequately removed by other means. Air conditioners use refrigerants and forced air, therefore regular maintenance

and access may be necessary to keep equipment running at the optimal temperature. However, air conditioners provide the most relief from generated heat loads. See Appendix I, #9.

Functional Ingress

The 4 and 4X enclosure requires a watertight seal, which makes it more difficult to create access to data cables, wires, or to view gauges. Fortunately, design engineers have created solutions that allow access to the equipment inside the enclosure without voiding the enclosure's integrity. Hoffman offers Intersafe data ports that eliminate the need to open the enclosure to gain data access. Windows and window kits also provide a safe environment that allows visual access to the gauges and equipment inside. In addition, integrated wire and cable support systems create access to the enclosure without losing its functionality. Hoffman offers a full line of wireway options that meet 4 and 4X requirements.

Outdoor Environmental Considerations of the Control Panel Infrastructure

To ensure performance, reliability, and a long life span of the controls system, the design and selection of the internal control panel components must also consider several outdoor environmental factors. These factors include variations in the internal operating temperature with temperature extremes, water, and dust ingress at cabling connections. Other dynamic factors include moisture, condensation, chemicals, and corrosive gases that can affect internal component and material selection, panel layout and design, and the need for environmental conditioning (cooling and/or heating).

Evaluating the Outdoor Plant Environment

Conducting a thorough examination of the plant environment is an important aspect to selecting products that meet the most severe conditions for the controls system. There are many standards and guidelines available to aid in conducting such an examination. A convenient approach is outlined by the Telecommunications Industry Association, TIA TSB-185, and the Environmental Classification (M.I.C.E.) Tutorial. The M.I.C.E. methodology references many existing standards that classify environmental parameters, including standard IEC 60721-1 thru 3, "Classification of groups of environmental parameters and their severities."

Note: Although not discussed in detail in this paper, it is important to note there are significant additional design criteria and rating requirements for control panels and equipment used in hazardous environments. (Refer to hoffmanonline.com for more information).

Ingress of Enclosure for Cabling and Access Ports

A potential point of failure regarding ingress is where accessory devices or cable connections are made through the panel. These components must be selected to match or exceed the enclosure rating to properly seal out dirt, dust, and particles, and maintain the control panel's ingress rating.

Techniques that could potentially be intended for light industrial environments include use of cable transits or cabling routed through openings lined with grommet edging, but these methods are inconceivable for enclosures deployed in outdoor environments. Durable metal conduit is often used, but particular consideration needs to be given to the metal type, and the compatibility of metals used with those to which the conduit is attached. Failure to give due attention can cause galvanic corrosion problems that can result in water ingress and consequent damage and downtime further down the road. The seals used at joints made in the conduit run as well as those used where the conduit enters the enclosure, and require attention during design and installation.

Similar consideration must be taken to maintain proper seals when installing user interface and data ports through the enclosure wall. Specifying by the component IP rating will help to ensure a sealing method adequate to maintain the enclosure NEMA rating. See Appendix II for examples of data access ports from Panduit.

Humidity and Moisture

Moisture and corrosion can affect continuity and the lifespan of the internal components and wiring connections. It is not always possible to strictly control the humidity level, therefore it is essential to select corrosion-resistant products to maintain continuity where moisture is likely be present. It is also important to inspect critical electrical connections to the panel, such as power, and grounding and bonding connections, for signs of corrosive effects.

Chemical and Corrosive Elements

In the harshest applications where the environment has concentrations of sprays, or potential fog of chemicals, and salt solutions, it is important to examine the possibility for exposure of the internal control panel components and the effects to components over time. Many component suppliers provide chemical resistance charts and materials to aid this examination and material selection process, and mitigate the potential effects. Refer to the Panduit chemical resistance chart for more information. Considering these factors when selecting components can help ensure the longest possible life for the controls systems operating in harsh environments.

Extreme Temperatures

When deployed in an outdoor environment, the data, control, and power cabling need to be rated for temperature extremes. For example, typical off-the-shelf copper data cabling has an operating temperature range from -10ºC to + 60ºC (14ºF to 140ºF), which is suitable for many applications, but its use is limited if operating in extreme cold. There are more durable twisted pair copper cables used for Ethernet communications, and other cable types, which are specifically designed for industrial and harsh environments and can withstand greater extremes than seen in these installations. See Appendix III.

In other applications with elevated interior operating temperatures (typically exceeding 50ºC, [122ºF]), alternative internal component materials should be considered to ensure performance, reliability, and long life. For example, wiring duct/wire channel materials are available and warranted for use in such applications. Panduit PPO material is an example with a rating up to 105ºC (221ºF). Note that operating at elevated temperatures requires a review of ratings of all wiring and components used within the panel.

Heat build-up due to direct sunlight is another factor often overlooked when shipping finished control panels. To avoid this occurrence, steps should be taken to either insulate a finished panel or provide an environmentally controlled shipment method.

UV Resistant Labeling

Warning and identification labeling can be very critical to maintain over the lifespan of the outdoor control panel, especially in hazardous applications. Many outdoor applications, such as Solar, are exposed (necessarily) to excessive direct sunlight and high UV. These applications require external labeling designed to meet any applicable codes, such as NEC and IFC standards for Solar. These labels should be made using high-performance UV stable materials and adhesives to withstand the harsh environment.

Conclusion

With the number of hazards and applications that outdoor enclosures encounter, design/controls engineers have a tremendous amount of complexity to manage when applying control panels in today's industrial environments. As a result, it is imperative to consider all the risks, both present and potential, when selecting an enclosure and control panel infrastructure. This includes weighing the alternatives for internal components to address and mitigate the environmental conditions in outdoor applications. It is also important to understand the environment and level of protection required from customers. Together, Panduit and Pentair leverage their solutions to provide premium control panel protection and optimization best practices that add value to our customers' organizational needs.

Appendix I – Outdoor Enclosure Solutions

#1		**Weatherpro 3R** Hoffman outdoor enclosure models feature three-point latching systems with a heavy-duty handle. Padlock provisions are available, while bolted hinges and bonding provisions on each door securely protect electrical equipment.
#2		**Weatherflo HD Enclosure** The vented enclosure from Hoffman is finished with RAL 99003 white polyester powder paint that minimizes the heat load on equipment.
#3		**Comline Wall Mount Enclosure** This enclosure from Hoffman offers a solar shield that provides a vented area at the top to absorb solar heat and keep the enclosure cool. The Comline products are ideal for applications on rooftops or towers.
#4		**H2OMIT™ Thermoelectric Dehumidifier** This thermoelectric dehumidifier removes moisture from the air within an enclosure, providing an inexpensive yet highly effective way to protect electronic and electrical components from condensation.
#5		**Type 4X Watershed Enclosure** The Hoffman Type 4X Watershed enclosure features provisions to allow direct flushing of the hinge area. It also allows 20 degree sloped tops and door edges, slanted flanged trough collars that prevent the pooling of liquids, gaskets, and a self-grounding latch system with a double seal.
#6		**Polypro Enclosure** From Hoffman, Polypro polyester enclosures perform exceptionally well in applications where harsh chemicals, weather extremes, and corrosive environments demand toughness from a lightweight enclosure. Providing excellent ultraviolet protection and a tight environmental seal, these versatile, feature-rich enclosures are also recyclable.
#7		**Ultrx, Type 4X** Providing outstanding protection against corrosion and the elements, the clean lines and molded, embossed design of Ultrx fiberglass enclosures make them the most stylish and aesthetically pleasing of their class. These enclosures feature hidden hinges, a padlocking capability for security, and flexible internal mounting options.
#8		**Climaguard Air-to-Air Heat Exchanger** This exchanger from Hoffman is designed for outdoor use, and includes a unique counterflow aluminum core for high efficiency and high performance heat transfer. Applications include outdoor cabinets, telecom shelters, equipment buildings, and instrument enclosures.

#9		**Spectracool Air Conditioner** This air conditioner from Hoffman features an energy efficient compressor and earth friendly refrigerants that help minimize the impact on the environment and energy costs.
#10		**H2OMIT™ Vent Drain** This Hoffman vent drain allows accumulated water to drain out the bottom of an enclosure. The UL-approved vent drain also functions as an air pressure equalizer, reducing the harmful effects of temperature-induced vacuums that could pull water and moisture into the enclosure.

Appendix II – Control Panel Solutions

#1		**Grounding and Bonding Solutions** Panduit offers end-to-end grounding and bonding solutions to meet customer needs and today's critical application requirements for control panel solutions. These solutions provide a high quality, visually verifiable and dedicated grounding path to maintain system performance, improve network reliability, and protect network equipment and personnel.
#2		**IndustrialNet™ Data Access Port** Provides data port and electrical outlet access to control panels without the safety hazards of opening the panel in the presence of electrical voltages. The data access port is rated to NEMA 4X and incorporates a weatherproof clear polymer-based cover for ease of port identification. The data access port incorporates a locking hasp that accepts Panduit lockout / tagout products or a padlock to prevent unauthorized access for improved security.
#3		**Panduct® Type NNC Wiring Duct** This wiring duct from Panduit is made from halogen-free material* that will not emit corrosive or harmful toxic gases when burned, and withstands higher continuous-use temperatures than PVC. *Per IEC 60754-2 determination of the amount of halogen acid gas evolved during the combustion of material.
#4		**Identification Solutions for Harsh Environments** These Panduit solutions are designed for extreme UV resistance and have strong holding power for rough, textured, and powder-coated surfaces.

Appendix III -Thermal Solutions Chart – Pentair Hoffman Cooling Systems Characteristics

COOLING SYSTEM TYPE	TECHNOLOGY DESCRIPTION	HEAT REMOVAL RANGE	INDICATIONS FOR USE	TYPICAL APPLICATIONS	Cools Below Ambient	Cools Above Ambient	Closed Loop
Air Conditioners	Forced air Refrigerant-based	High	Hot Environments (typically over 35 (/ 95F) High Heat Load (300W – 17,300W) Dirty or Corrosive Air Harsh/Humid Environments	Indoor or Outdoor Industrial enclosures Telecommunications Wastewater treatment Metal working Oil rig/refinery Foundry	✓		✓
Thermoelectric Coolers	Peltier effect No moving parts or liquids	Law	Small Enclosures Low Heat Load (60-200W) Remote/DC-powered applications	Indoor or Outdoor Telecommunications Battery cabinets Industrial enclosures Security systems	✓		✓
Air-to-Air Heat Exchangers	Closed loop No liquids	Moderate	Cool Air Environment Moderate Heat Load (7-150W/F) Dirty or Corrosive Air	Indoor or Outdoor Telecommunications Light-duty manufacturing		✓	✓
Air-to-Water Heat Exchangers	Close-coupled water cooling No moving parts exposed to environment	Highest	Very Hot Environments High Heat Load (370W to 6700W) Extremely Dirty/Dusty Air	Extreme conditions where air conditioners would be subject to failure Automotive manufacturing Machine tool Packaging Paper mill	✓		✓
Filter Fans, Blowers, Impellers or Direct Air Cooling Systems (DACS)	Forced, fresh air Open loop	Low to Moderate	Cool, Clean Air Environment	Industrial manufacturing Outdoor telecom Data networking		✓	
Vortex Coolers	Requires compressed air source Forced air No liquids or moving parts	Moderate	Hot Environments (typically over 35 (/95 F) Heat Load (up to 1,465W) Dirty or Corrosive Air Harsh/Humid Environments	Heavy manufacturing Metal working Oil rig/refinery Paper mill Foundry Hazardous location models available	✓		✓
Conductive (no cooling unit)	Passive Heat radiates through enclosure walls	Very Low	Cool Air Environment (<78 F/25C) Low Heat Load (50W)	Where enclosed components operate within recommended temperature range		✓	Pre-enclosure rating

Referenced Resources

- 518-1982 - IEEE Guide for the Installation of Electrical Equipment to Minimize Electrical Noise Inputs to Controllers from External Sources
- 1100-2005 - IEEE Recommended Practice for Powering and Grounding Electronic Equipment
- TIA TSB-185, Environmental Classification (M.I.C.E.) Tutorial
- IEC 60721-1 thru 3, Classification of groups of environmental parameters and their severities

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About Pentair Equipment Protection

Pentair Equipment Protection, a Pentair global business unit, is the leading provider of worldwide product and service solutions for enclosing, protecting and cooling electrical and electronic systems. Its industry-leading brand—Hoffman—

provides a broad variety of standard, modified and engineered solutions to the commercial, communications, energy, general electronics, industrial and infrastructure markets.

About Panduit

Panduit is a world-class developer and provider of leading-edge solutions that help customers optimize the physical infrastructure through simplification, increased agility and operational efficiency. Panduit solutions give enterprises the capabilities to connect, manage and automate communications, computing, power, control and security systems for a smarter, unified business foundation. Panduit provides flexible, end-to-end solutions tailored by application and industry to drive performance, operational and financial advantages. Panduit global manufacturing, logistics, and e-commerce capabilities along with a global network of distribution partners help customers reduce supply chain risk. Strong technology relationships with industry leading systems vendors and an engaged partner ecosystem of consultants, integrators and contractors together with its global staff and unmatched service and support make Panduit a valuable and trusted partner.