WHITE PAPER

Extending the Network Into Nontraditional Spaces: An Enclosure Selection Guide for IT Systems Administrators That Support IoT

By David Knapp
Product Marketing Manager
Chatsworth Products
and
Sam Rodriguez
Sr. Product Manager, Enclosure
and Thermal Solutions
Chatsworth Products

Published: November 2017

US & Canada
+1-800-834-4969
Toronto, Ontario, Canada
+905-850-7770
chatsworth.com
techsupport@chatsworth.com

Latin America
+52-55-5203-7525
Toll Free within Mexico
01-800-01-7592
chatsworth.com.co

Europe
+44-1628-524-834
chatsworth.com

Middle East & Africa
Dubai, UAE
+971-4-2602125
chatsworth.ae

Asia Pacific
+86 21 6880-0266
chatsworth.com.cn

CHATSWORTH
PRODUCTS

Introduction

In January of 2017, the Boston Consulting Group published the market analysis *Winning In IoT, It's All About The Business Processes*[1] on the adoption of the Internet of Things (IoT). The article presents one very clear conclusion; that very specific use case scenarios will drive adoption of IoT by businesses. IoT deployments are expected to increase global technology spending €250 billion *($263 billion[2])* by 2020.

If your business is involved in discrete manufacturing, process industry, transportation and logistics, retail, health care, utilities or energy and natural resources, then you are–or will soon be–adopting IoT. In particular, the top 10 use cases over the next five years are expected to be: demand response (adjusting power use dynamically), fleet management, distributed generation and storage, smart meters, track and trace, connected cars, automated inventory management, predictive maintenance, self-optimizing production and remote patient monitoring.

As an IT systems administrator, you will need to extend the network to connect IoT and business systems. This means placing equipment in nontraditional spaces such as warehouses, manufacturing floors and outdoors. To specify equipment for nontraditional spaces, you will need to learn about special industrial enclosures, cooling systems and cable entry methods that protect equipment from exposure to dust and liquid.

This white paper, by Chatsworth Products (CPI), will help you understand the basics of specifying equipment enclosures for nontraditional spaces such as warehouses, manufacturing floors and outdoors.

Warehouses, Manufacturing Floors and Outdoors

More than 75 percent of enterprises that are currently adopting IoT are primarily focused on integrating IoT with legacy systems, according to the Telecommunications Industry Association's 2016 *Internet of Things Enterprise Survey*[3]. The survey responses indicate that the most important strategic reasons to adopt IoT are improving service and maintenance by continuously monitoring performance of devices and machines, and reducing operational expenses (i.e. improving operational efficiency).

In operations, IoT is improving predictive maintenance, service parts management, mean time to resolution, and truck roll schedules and routes. Although the majority of organizations will use a system integrator, IoT/Machine-to-machine (M2M) end-to-end provider or business software company to help implement IoT, your organization's IT staff (presumably you) will likely be responsible for expanding the enterprise network to connect things to the Internet.

If you are part of a manufacturing, utility or logistics organization, then you have counterparts in operational technologies (OT) that are very familiar with sensors and automation. For OT, automation and remote instrumentation has been the norm for decades. However, the current technology evolution, referred to in OT circles as Manufacturing 4.0 or Industrie 4.0, is a shift away from proprietary sensors and custom software toward low-cost sensors on an IP-based network with an application programming interface (API) to integrate with business management software.

FAST FACT:
Industrie 4.0 is a national program in Germany focused on the development and application of smart factory technology. Major manufacturers, software developers and telcos are participating in use cases across Germany. To browse the 160+ use cases across Germany click here.

As a result of this fourth industrial revolution, the networking of plant equipment is expected to soar over the next five years, according to the Frost & Sullivan report, *Manufacturing 4.0: A Playbook for Navigating the Journey to IT Modernization and Transformation*[5]. Companies are implementing end-to-end digitization of the manufacturing process to better trace quality issues, reduce the cost of poor quality, and enhance action on departmental feedback and customer-centric innovation.

Selecting an Enclosure to Protect Equipment from Dust and Liquid

How do you extend the network into nontraditional spaces? Simply stated, the network is fundamentally the same, but the components and equipment must be rated for use in areas that are dusty or dirty, possibly wet, and may experience wide temperature variations. Obviously, this includes the cable and network switches, but you should start with the enclosure.

In nontraditional spaces, the enclosure provides the primary protection for equipment. The main difference between industrial enclosures and standard IT enclosures is that industrial enclosures are completely sealed when closed *(see Figure 1)*. Fortunately, there are already standards that define degrees of environmental protection by enclosures to simplify selection.

Figure 1: Openings in industrial enclosures include seals to prevent ingress of dust and liquid. Note the seal around the perimeter of the door, the channel around the door opening and the multi-point latch, which help prevent dust and liquid penetration into the enclosure. For the best protection, look for a seal that is created using formed-in-place foam gasket technology. A robotic process applies this type of seal, and it is much more durable than adhesive-backed foam tape.

IP Codes

The international standard for ingress protection (IP) ratings is International Electrotechnical Commission (IEC) standard 60529, *Degrees of Protection Provided by Enclosures (IP Code)* [6]. The IP code is stated as two numbers, ex. IP55. The first number identifies the degree of protection against hazardous parts and against solid foreign objects (dust penetration). The second number identifies the degree of protection against ingress of water (liquid penetration). A higher number indicates better protection. IP codes do not address corrosion protection. *See (Table 1)* below for the definitions of IP codes.

Table 1: IP Codes (IPXX). The numbers (i.e. IP00 to IP69k) indicate the level of protection against dust and liquid penetration. A larger number indicates a higher level of protection.

First number = Solid object protection	Second number = Liquid protection
0 = No protection	0 = No protection
1 = Objects over 50 mm (2")	1 = Vertical falling drops of water
2 = Objects over 12.5 mm (0.5")	2 = Spray of up to 15-degrees vertical
3 = Objects over 2.5 mm (0.1")	3 = Spray of up to 60-degrees vertical
4 = Objects over 1 mm (0.04")	4 = Light spray from all directions
5 = Dust protected with limited ingress	5 = Light jets from all directions
6 = Totally protected from dust	6 = Powerful jets from all directions
	7 = Immersion to 1 meter (3.28')
	8 = Immersion > 1 meter (3.28')
	9k = Powerful jets, high temperature

Note: With IP codes, a larger number indicates a higher level of protection. When specifying enclosures based on an IP number, any enclosure rated for that IP level or a higher IP level will meet the specification.

NEMA/UL Types

In the United States, the National Electrical Manufacturers Association (NEMA) publishes NEMA Standard 250 *Enclosures for Electrical Equipment (1,000 V Maximum)* [7], which identifies 16 types of enclosures for nonhazardous locations, each providing a different level of protection against dust and liquid penetration. Underwriters Laboratory (UL) has a similar system in UL 50 *Enclosures for Electrical Equipment, Non-Environmental Considerations*; UL 50E *Enclosures for Electrical Equipment, Environmental Considerations*; and UL 508A *Standard for Industrial Control Panels*. The difference between NEMA Type and UL Type is that manufacturers can self-certify NEMA Type enclosures, but UL Type enclosures are verified by UL through a series of design review and performance testing. *See (Table 2) and (Table 3) below* for the NEMA types of enclosures used in indoor and outdoor non-hazardous locations.

Table 2: NEMA Type ratings for enclosures used in indoor nonhazardous application

Specific Applications, Indoor Nonhazardous Locations	**Type of Enclosure**					
Provides a degree of protection against:	**1**	**2**	**5**	**11**	**12**	**13**
Incidental contact with enclosed equipment	X	X	X	X	X	X
Falling dust	X	X	X	X	X	X
Airborne dust, particles			X		X	X
Dripping noncorrosive liquid, light splash		X		X	X	X
Oil/coolant seepage					X	X
Oil/coolant spray/splash						X
Corrosive agents				X		

Note: With NEMA Types, each number has a specific range of protection, and a larger number does not always mean more protection. However, as you can see from these tables, some NEMA Types include the protections of other NEMA Types. For example, any of the enclosure types listed in the table above will protect against falling dust, but only Type 12 and 13 will protect against oil/coolant seepage.

Table 3: NEMA Type ratings for enclosures used in outdoor nonhazardous applications

Specific Applications, Outdoor Nonhazardous Locations	**Type of Enclosure**									
Provides a degree of protection against:	**3**	**3X**	**3R***	**3RX***	**3S**	**3SX**	**4**	**4x**	**6**	**6P**
Incidental contact with enclosed equipment	X	X	X	X	X	X	X	X	X	X
Rain, snow, and sleet**	X	X	X	X	X	X	X	X	X	X
Sleet***					X	X				
Windblown dust, lint, fiber, and flying	X	X			X	X	X	X	X	X
Hose down							X	X	X	X
Corrosive agents		X		X		X		X		X
Occasional temporary immersion									X	X
Occasional prolonged immersion										X

*Notes: *3R enclosures may be ventilated. **External mechanisms are not required to be operable when the enclosure is ice covered. ***For 3S enclosures, external mechanisms are required to be operable when the enclosure is ice covered.*

Comparing IP Code and NEMA Type

There is no direct comparison between IP code and NEMA types, because NEMA standards include additional product features and tests. However, the following comparison table *(Table 4)*, based on a NEMA conversion table[8], is generally accepted as the minimum NEMA equivalence. This means the listed NEMA Type enclosure exceeds the listed IP Code requirements. Individual enclosures should list IP Code and NEMA/UL Type ratings, and in some instances may test to a higher level of protection. For example, some NEMA Type 12 enclosures may have an IP55 rating.

IP Code	Closest NEMA Type Equivalent	Acceptable NEMA Types
IP20	1	1, 2, 3, 3X, 3S, 3SX, 3R, 3RX, 4, 4X, 5, 6, 6P, 12, 12K, 13
IP22	2	2, 3, 3X, 3S, 3SX, 3R, 3RX, 4, 4X, 5, 6, 6P, 12, 12K, 13
IP24	3R, 3RX	3R, 3RX, 4, 4X, 6, 6P, 12, 12K, 13
IP53	5	3, 3X, 3S, 3SX, 4, 4X, 5, 6, 6P, 12, 12K, 13
IP54	12, 12K, 13	3, 3X, 3S, 3SX, 4, 4X, 6, 6P, 12, 12K, 13
IP55	3, 3X, 3S, 3SX	3, 3X, 3S, 3SX, 4, 4X, 6, 6P
IP66	4, 4X	4, 4X, 6, 6P
IP67	6	6, 6P
IP68	6P	6P

The Three Enclosures You Need

With the above in mind, when you extend your network into warehouses, manufacturing floors and outdoors, you can satisfy most nonhazardous location requirements by focusing on three enclosure ratings: IP54/NEMA Type 12, IP 66/NEMA Type 4 and NEMA Type 4X. See *(Table 5)* below for a comparison and typical applications.

Table 5: Comparison of three most common enclosure ratings for nonhazardous locations used in IIoT digitization

Typical Application	Indoor or Outdoor Use	Protection Against Solids	Protection Against Liquids	Corrosion Protection	Minimum Enclosure Rating
Manufacturing floor, warehouse	Indoor	Dust Tight	Dripping liquid or Light Spray	No	IP54 NEMA Type 12
Utility distribution, network distribution	Indoor and Outdoor	Dust Tight	Heavy Spray, Rain, Snow, Sleet*	No	IP66 NEMA Type 4
Food** and chemical processing, salt water	Indoor and Outdoor	Dust Tight	Heavy Spray, Rain, Snow, Sleet*	Yes***	NEMA Type 4X

*Note: *NEMA Type 4 and NEMA Type 4X enclosures are rated for use in sleet, but if external mechanisms need to be operable when the enclosure is ice covered, a NEMA Type 3S or 3SX design or a special hinge design may be required. **Food processing generally requires a stainless steel enclosure with a removable seal for sanitizing. There are different enclosure Types (ratings) used in hazardous locations around flammable dust and chemicals, such as mines, refineries, mills and aboard ship. ***IP66 provides similar protection to NEMA Type 4X, but IP Codes do not address corrosion protection.*

FAST FACT:

If the enclosure is not watertight and will be exposed to rain or spray, then you should consider adding a drain plug on the bottom of the enclosure. If the enclosure is placed in a location with rapid temperature or humidity change and is not equipped with a cooling unit or fan, you should consider adding a vent to the enclosure. Drain plugs allow liquid to escape and vents allow pressure to equalize quickly, but block access to equipment from people or pests.

The three enclosures listed in *(Table 5)* cover the majority of nonhazardous environmental requirements and can be field-adapted with drains, vents, fans or air conditioners as required. See *(Table 6)* below for a list of other ratings covered by the three types listed. Note that there are different enclosures (ratings) used in hazardous locations around flammable dust and chemicals, such as mines, refineries, mills and aboard ship.

Table 6: Other ratings covered by the three most common enclosure types

Enclosure Rating	Other IP Codes Covered	Other NEMA Types Covered
IP54 NEMA Type12 (Indoor use)	Anything less than IP54 (IP53, IP44, etc.)	NEMA Type 1 NEMA Type 2* NEMA Type 5
IP66 NEMA Type 4 (Outdoor use)	Anything less than IP66 (IP65, IP56, etc.)	NEMA Type 3 NEMA Type 3R*
NEMA Type 4X (Corrosion protection)	IP Code does not address corrosion protection	NEMA Type 11 NEMA Type 3X NEMA Type 3RX
Exceptions**		
Enclsoure Rating	**Other IP Codes Covered**	**Other NEMA Types Covered**
IP67 NEMA Type 6 (Temporary immersion)	Anything less than IP67 (IP66, IP57, etc.)	NEMA Type 4
IP68 NEMA Type 6P (Extended immersion)	Anything less than IP68 (IP 67, IP58, etc.)	NEMA Type 4X
NEMA Type 3S NEMA Type 3SX (Operable when ice covered)	Requires external mechanisms that are operable when enclosure is ice covered	Requires external mechanisms that are operable when enclosure is ice covered

*Note: *NEMA Type 2 and NEMA Type 3R enclosures require a drain hole. Drill a 1/8" to 1/4" diameter drain hole for liquids at the bottom of these enclosures per manufacturer instructions. Recommend sealing the hole with a Threaded Drain Plug or Protective Vent Kit accessory.*
***There are different enclosure Types (ratings) used in hazardous locations around flammable dust and chemicals, such as mines, refineries, mills and aboard ship.*

Enclosure Styles

Once you have determined the enclosure rating you need, then you can select the enclosure style and size that best fits your application. There are four basic styles of industrial enclosures: modular enclosures, free-standing enclosures, floor-mount enclosures and wall-mount enclosures *(see Figure 2)*.

Figure 2: (Left to right, clockwise) Modular Enclosure, Free-Standing Enclosure, Floor-Mount Enclosure, Standard Wall-Mount Enclosure, and Swing Wall-Mount Enclosure.

Modular enclosures

Modular enclosures are most similar to IT equipment cabinets. The frame includes hinged doors and bolt-on side panels, top panel and bottom panel. Leveling feet support the frame or a plinth attaches the frame to the floor. The removable panels allow you to create bays of multiple enclosures to hold larger arrays of equipment, and the frames have a multitude of mounting locations for rails, panels and accessories. They can be fitted with an assortment of 19" EIA mounting rails for IT equipment or panels for automation electronics. They typically have very high load ratings and a wide range of accessories for both IT and automation applications.

Free-standing enclosures

Free-standing enclosures are simpler designs, formed as single monolithic enclosures in specific sizes used as stand-alone enclosures. They have a single door or front and rear doors, and support panels for mounting automation, controls or instrumentation electronics. Specific size enclosures may include 19" EIA mounting rails for IT equipment.

Enclosure Styles (continued)

Floor-mount enclosures

Floor-mount enclosures are similar to free-standing enclosures formed as single monolithic enclosures in specific sizes used as standalone enclosures, but they are elevated above the finished floor adding clearance and easier cable access. They are typically wider with double doors and have a large panel for mounting automation electronics, controls and instrumentation.
They do not include 19"EIA mounting rails for IT equipment.

Wall-mount enclosures

Wall-mount enclosures attach to the wall and support smaller amounts of equipment. There are two basic styles. The swing-out style is hinged at the rear so you can access the back of equipment. This style can be fitted with 19" EIA mounting rails for IT equipment or panels for automation electronics. The fixed style has front-only access, and may also feature both 19" EIA mounting rails and panels or just panels.

Enclosure Selection

Enclosures are typically selected to match equipment mounting requirements according to useable space and size. If the enclosure has 19" EIA mounting rails, then the usable space is according to the rack-mount space and depth of the enclosure. If the enclosure has a panel, then the usable space is based on the panel size and depth of the enclosure. The overall size of the enclosure should provide sufficient clearance to ensure the equipment and connections will fit in the location and provide sufficient air circulation.

Select cooling and cable access accessories to match your equipment and cabling requirements. Remote monitoring for power, environmental and access control should be considered to provide real-time monitoring and alerts if an issue is detected. Unlike IT cabinets, mounting rails and panels are typically ordered separately; however, some suppliers provide kitting or configuration services that groups the enclosure, panels and accessories to simplify ordering and ensure compatibility *(See Figure 3)*.

Because of the complexity of enclosure selection, enclosure vendors offer online sizing tools to help select a complete solution. As an example, explore Chatsworth Products' CPI Product Designer[9] at: http://www.chatsworth.com/product-designer/.

Figure 3: Modular Enclosure with rack-mount PDUs and filter fan installed. Some manufacturers offer online tools for configuration and will kit or preinstall components with enclosures.

Cooling Electronics within an Industrial Enclosure

The sealed design of industrial enclosures does not allow for needed ventilation to cool internal electronics, so a filter fan or cooling unit is typically required to exhaust or reject heat from the enclosure. Like the enclosures, the filter fan or cooling unit need to be IP- or NEMA-rated to match (or exceed) the enclosure rating.

Filter Fans

Filter fans *(see Figure 4)* with matching exhausts are a good choice where the amount of dust is minimal and when equipment within the enclosure can operate at higher temperatures than the temperature of the ambient air.

Figure 4: Filter Fans and matching exhaust vents draw filtered air through the enclosure to exhaust heat and have replacable filters to block dust penetration.

Photo provided by Pfannenberg USA (www.pfannenbergusa.com).

Filter fans draw filtered air into the enclosure and exhaust air through a matched filtered exhaust or a second filter fan. Filter fans are available in different sizes to provide different amounts of airflow based on equipment needs. Both fan and exhaust grills have replaceable filters that help maintain the rated protection for the enclosure. If the enclosure is outdoors or exposed to dripping water, a rain shield (hood) can be placed over the fan and exhaust to offer additional protection. Placing the intake near the base of the enclosure and the exhaust near the top of the enclosure improves heat removal. Placing the fan on the intake, instead of the exhaust, pressurizes the enclosure, reducing the amount of dust drawn through the enclosure *(see Figure 5)*.

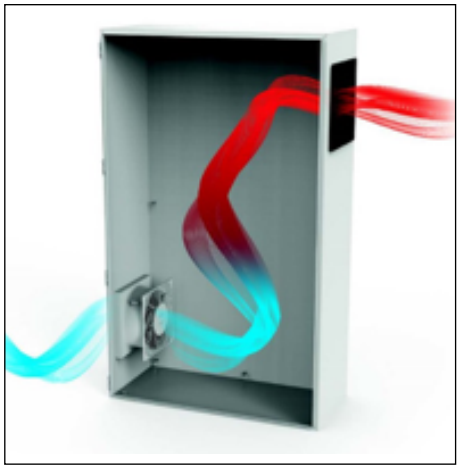


Figure 5: Recommended airflow through an industrial enclosure. Place the intake near the base and exhaust near the top. Place the filter fan on the intake to pressurize the enclosure and reduce dust penetration.

Photo provided by Pfannenberg USA (www.pfannenbergusa.com).

Cooling Units

Use cooling units *(see Figure 6)*, enclosure-mounted air conditioners, to keep the enclosure completely sealed in areas with a lot of dust or where internal temperature must be tightly controlled.

Figure 6: Cooling units maintain a fixed temperature within the enclosure and provide closed-loop cooling so the enclosure remains completely sealed.

Photo provided by Pfannenberg USA (www.pfannenbergusa.com).

Cooling units mount through the door or side of the enclosure and provide closed-loop cooling. The cooling unit has independent internal and external air paths *(see Figure 7)*, so air does not enter or exit the enclosure. The cooling unit circulates air within the enclosure, rejecting heat to the outside of the enclosure through an air conditioning circuit.

Figure 7: Cooling units provide a closed-loop system. Air is circulated within the enclosure and conditioned to a fixed set point. Heat is rejected through an air conditioning circuit to outside air.

Photo provided by Pfannenberg USA (www.pfannenbergusa.com).

Industrial cooling units are different from computer room air conditioners (CRACs). They typically have a fixed set point and circulate air continuously. The compressor will cycle off if the temperature within the enclosure is under the threshold, but fans run continuously at a constant rate. Industrial cooling units are sized for a specific heat load to match the sum of the heat produced by the equipment in the enclosure. If the enclosure supports mission critical equipment, a redundant cooling unit should be added, but the conditioners are typically cycled, not operated together at partial load.

Filter Fan and Cooling Unit Selection

Sizing of fans or cooling units includes consideration of many factors including: the size of the enclosure, desired temperature within the enclosure, material type and insulation of the enclosure, supply voltage for the fan or cooling unit, type of enclosure, location of enclosure, whether the enclosure is bayed or stand alone, ambient air temperature, and anticipated heat load. Because of the complexity of the calculation, filter fan and cooling unit vendors offer online sizing tools *(see Figure 8)* to help select a correctly sized model. As an example, explore Pfannenburg's Sizing Software (PSS)[10] at: https://www.pfannenbergusa.com/pss.

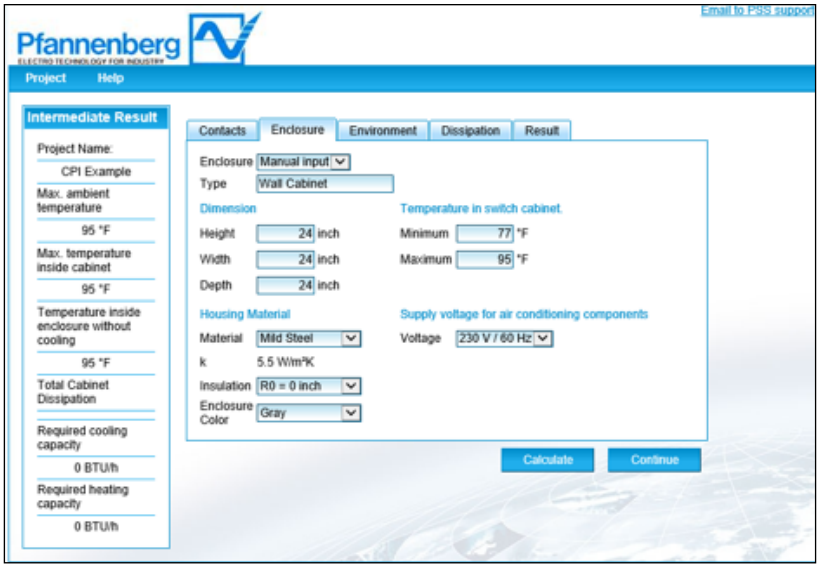


Figure 8: Screenshot from Pfannenberg's Sizing Software for selecting filter fans and cooling units.

Vents and Drains

If the enclosure is placed in a location with the potential for rapid temperature or humidity changes and is not equipped with a cooling unit or filter fan, then you should consider adding venting to equalize pressure and reduce condensation. If the enclosure is not watertight, but will be exposed to rain or spray, you should consider adding a drain on the bottom of the enclosure. Vents and drains are designed to maintain the seal against accidental contact and pests.

Delivering Network and Power Connections

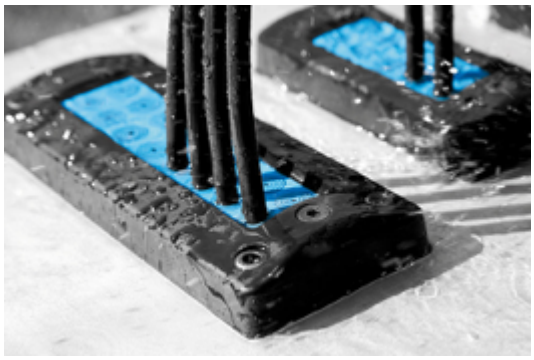
To maintain the enclosure protection rating, any openings added to the enclosure for network and power cables need to be sealed. In most instances, electrical conduit is used to protect and deliver cables. However, when electrical conduit is not used, the cable openings need to be sealed with special grommets that match the enclosure's protection level and maintain the seal around the cable.

The best solution is a single service seal with an adaptable inner and outer diameter, which allows multiple cables to enter a single enclosure opening *(see Figure 9)*. This system uses a single grommet housing with an internal multi-piece assembly that creates a tight seal around each cable. Sealing around individual cables provides the best result for maintaining protection category, but this approach is very different from the brush-sealed grommets typically used on IT cabinets. As an alternative, if you only have one cable to pass into the enclosure, a basic gasket seal (i.e. one cable, one opening) will work.

Cable Entry Grommet Selection

Sizing cable entry grommets includes consideration of the number and size of the cables that need to enter the enclosure and the degree of protection required. Grommet vendors offer online sizing tools to help select a correctly sized model. As an example, explore Roxtec's Transit Designer[11] tool at: https://www.roxtec.com/us/service-support/design/roxtec-transit-designer/.

Figure 9: Single service seal grommet by Roxtec. Note that each cable is individually sealed using a multi-diameter insert.



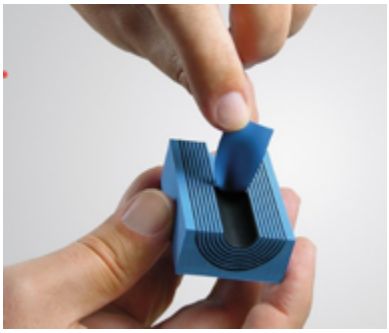


Image provided by Roxtec (www.roxtec.com/us/).

Remote Monitoring and Control

To ensure environmental conditions remain optimal for equipment and to detect changes in the environment or signs of tampering, consider adding remote monitoring and control.

Environmental monitoring appliances *(see Figure 10)* can measure temperature, humidity, airflow, power and detect entry of water. Rack-mount power distribution units (PDUs) distribute power to switches, provide remote outlet control so you can remotely cycle power to equipment, and monitor power use by equipment. Some PDUs also monitor environmental conditions. Both devices automate monitoring, keep logs of measured data and let you set thresholds and receive alarm notifications when conditions approach limits, so you can prevent network outages.

Figure 10: Remote monitoring through a rack-mount PDU or an environmental monitoring appliance provides automated measurement and monitoring of power use, temperature, humidity and other factors from within the sealed enclosure.

Image provided by Chatsworth Products. (www.chatsworth.com)

Modified Standard Enclosures (i.e. Customization)

As a final consideration, no digitalization project is the same. Your enclosure requirements will change with each project, and you may not be able to find the optimal solution from standard product. Some enclosure manufacturers offer modified standard enclosures with openings added to the enclosure. Additional services may include kitting and preassembly of factory installed accessories. Finally, some manufacturers may offer customized solutions for enclosure designs that meet a specific application. These services can be of great value as they ensure high-quality seals between components and any openings, and that accessory components are fully compatible. Preassembly and kitting keeps components together for easier logistics on the job site and reduces time to deploy simplifying logistics, reducing overall labor costs and minimizing packaging disposal.

Conclusion

Digitalization is affecting every workplace, and many businesses are extending the network into nontraditional spaces.

When placing equipment into spaces such as warehouses, manufacturing floors and outdoors, select an industrial enclosure with appropriate environmental protection ratings; address thermal requirements by adding a fan or a cooling unit that matches the enclosure protection rating and equipment cooling requirements; and use a cable entry system that will maintain the enclosure rating by completely sealing around cables. Finally, consider remote monitoring and control to ensure the environmental conditions match equipment requirements and to monitor and cycle power to equipment without opening the enclosure.

References

[1] *Boston Consulting Group, BCG Perspectives newsletter. January 2017. Winning in IoT: It's All About the Business Processes.* https://www.bcgperspectives.com/content/articles/hardware-software-energy-environment-winning-in-iot-all-about-winning-processes/

[2] *Exchange Rate. January 1, 2017.* www.exchangerates.org.uk

[3] *Telecommunications Industry Association (TIA). December 2016. Internet of Things Enterprise Survey.* https://machinaresearch.com/report/enterprise-iot-survey-2016-1/. http://www.tiaonline.org/documents/diy2lgsjapoi5n6l2e/IoT%20Enterprise%20Survey%20White%20Paper.pdf

[4] *Federal Ministry for Economic Affairs and Energy. Germany Trade and Invest. Federal Ministry for Economic Affairs and Energy. April 2014. Industrie 4.0 Smart Manufacturing for the Future.* https://industrie4.0.gtai.de/INDUSTRIE40/Navigation/EN/industrie-4-0. http://www.gtai.de/GTAI/Content/EN/Invest/_SharedDocs/Downloads/GTAI/Brochures/Industries/industrie4.0-smart-manufacturing-for-the-future-en.pdf

[5] *Frost & Sullivan. Digital Industrial Group. 2017. Manufacturing 4.0: A Playbook for Navigating the Journey to IT Modernization and Transformation. White paper.* www.frost.com; http://nala.frost.com/forms/itmodernization

[6] *International Electrotechnical Commission (IEC). August 2013. IEC 60529, Degrees of Protection Provided by Enclosures (IP Code), Edition 2.2.*

[7] *National Electrical Manufacturers Association (NEMA). January 2014. NEMA 250, Enclosures for Electrical Equipment (1000 Volts Maximum).*

[8] *National Electrical Manufacturers Association (NEMA). January 2012. A Brief Comparison of NEMA 250 and IEC 60529.* https://www.nema.org/ Standards/Pages/A-Brief-Comparison-of-NEMA-250-and-IEC-60529.aspx

[9] *Chatsworth Products. CPI Product Designer:* http://www.chatsworth.com/product-designer/

[10] *Pfannenberg USA. Pfannenberg Sizing Sofware (PSS).* https://www.pfannenbergusa.com/pss

[11] *Roxtec. Roxtec Transit Designer™.* https://www.roxtec.com/us/service-support/design/roxtec-transit-designer/

Contributors

David Knapp | Product Marketing Manager

David Knapp has more than 20 years of experience in the telecommunications industry with CPI as a product-application expert and technical communicator in the roles of Technical Support, Technical Writer and Product Marketing Manager. He is currently focusing on data center, enterprise networking, including industrial networks, and power management solutions.

Sam Rodriguez | Sr. Product Manager, Enclosure & Thermal Solutions

Sam Rodriguez has more than 23 years of experience in the telecommunications industry. He has been employed at CPI since 1997 and has held various technical roles including Technical Support, Technical Services Supervisor and now Sr. Product Manager of Cabinet & Thermal Solutions. Sam is a BICSI member and is RCDD certified. He is also a member of CPI's product development organization and contributes to the design and development of new product solutions.

CHATSWORTH PRODUCTS