Getting Smart, Getting Rugged
Extending LANs into Harsher Environments

Virtually everything we do now on a daily basis touches the network—whether it's buying a snack, sending an email or taking a ride at an amusement park. The proliferation of digital information, wireless handheld devices and Ethernet into every facet of our lives means that connections to networks need to be in more places than ever before.

With manufacturing environments having rapidly migrated to Industrial Ethernet over the past decade as a means to deliver information for industrial automation and control systems and to integrate factory environments with the corporate LAN, it's no wonder that the industry is seeing a growing demand for network cables, patch cords and connectors capable of withstanding more severe conditions.

But what about environments that fall somewhere in between—not quite severe enough to be considered "industrial" but in need of something more ruggedized than what exists in everyday commercial office environments? Extending the network into these types of environments is becoming more common than one might think. As our world becomes more digital, these types of environments are popping up everywhere and demanding ruggedized network cables, patch cords and connectors that maintain long-term network reliability and prevent the need to replace components due to corrosion and damage from a variety of elements.

Knowing the Standards – From MICE to NEMA

While standards for industrial environments are certainly applicable to factory floors, manufacturing plants and processing facilities, the same standards can be used to determine the type of ruggedized cable and connectivity required for those in-between environments that are not as clearly identified as either commercial or industrial.

The international standard ISO/IEC 24702 provides application-independent requirements for both balanced copper and fiber optic cable systems that support Ethernet-based data communications in industrial environments. The standard provides implementation options and requirements for cable and connectivity that reflect the operating environments within industrial premises. ISO/IEC 24702, along with its comparable U.S. TIA-1005 and European EN 50173-3 standards, incorporate the MICE method of classifying parameters for the materials needed to build an industrial network.

MICE stands for Mechanical, Ingress, Climatic and Electromagnetic and includes three levels of environmental harshness—level 1 for everyday commercial office environments, level 2 for light industrial and level 3 for industrial. For example, M3I3C3E3 environments require network infrastructure components that are able to withstand the highest levels of vibration, shock, tensile force, impact and bending (see Table 1).

INCREASING SEVERITY			
Mechanical (shock, vibration, crush, impact)	M_1	M_2	M_3
Ingress (particulates and liquid)	I_1	I_2	I_3
Climatic (temperature, humidity, contaminants, radiation)	C_1	C_2	C_3
Electromagnetic (ESD, RFI, transients, magnetic fields)	E_1	E_2	E_3

Table 1: *MICE Parameters*

While the MICE method is used to determine the harshness level of commercial, light industrial and industrial, rarely is an environment exclusive to one MICE classification. Furthermore, one run of cabling from point A to point B can traverse through various MICE classifications along the route. Designers planning cabling systems in harsh environments therefore need to have a good understanding of the environment and what constitutes levels 1, 2 and 3 for each parameter. In some cases, measuring the environment can require specialized equipment, especially when it comes to measuring vibration and electromagnetic interference. The standards include MICE tables to help determine which levels exist within the targeted environment (see Table 2).

The trick to using MICE levels to determine components is to always consider the worst case scenario and worst case level parameter, regardless of the other parameters. For example, an environment exposed to liquid may be classified as M1I3C1E1. If only ruggedized components meeting M3I3C3E3 are available, they may need to be used regardless of whether that level of protection is required for all parameters.

Mechanical	M_1	M_2	M_3
Shock			
Peak acceleration	40 ms^{-2}	100 ms^{-2}	250 ms^{-2}
Vibration			
Displacement amplitude (2-9Hz)	1.5 mm	7.0 mm	15,0 mm
Acceleration amplitude (9 -5000Hz	5 ms^{-2}	20 ms^{-2}	50 ms^{-2}
Tensile Force		Installation specific	
Crush	45 N	1100 N	2200 N
Impact	1 J	10 J	30 J
Bending, Flexing and Torsion		Installation specific	
Ingress	**I_1**	**I_2**	**I_3**
Particulate maximum diameter	12.5 microns	50 microns	50 microns
Immersion	None	Intermittent jet ≤12.5 l/min ≥6.3 mm jet >2.5 m distance	Intermittent jet ≤12.5 l/min ≥6.3 mm jet >2.5 m distance Immersion ≤ 1 for ≤30 min
Climatic Chemicals	**C_1**	**C_2**	**C_3**
Ambient temperature	-10 ˚C to 60 ˚C	-25 ˚C to 70 ˚C	-40 ˚C to 70 ˚C
Rate of temperature change	.1 ˚C per minute	1.0 ˚C per minute	3.0 ˚C per minute
Humidity	5% to 85% (non-condensing)	5% to 95% (condensing)	5% to 95% (condensing)
Solar radiation	700 Wm^{-2}	1120 Wm^{-2}	1120 Wm^{-2}
Liquid Pollutants			
Sodium chloride (sea water)	0 ppm	<0.3 ppm	<0.3 ppm
Oil (dry-air concentration)	0 ppm	5.0 ppm	<500 ppm
Sodium Stearate (soap)	None	5% aqueous non-gelling	>5% aqueous gelling
Detergent	None	ffs	ffs
Conductive materials in solution	None	Temporary	Present
Gaseous Pollution Contaminants	Mean/Peak (concentration X 10^{-6})	Mean/Peak (concentration X 10^{-6})	Mean/Peak (concentration X 10^{-6})
Hydrogen sulphide	<0.003/<0.01	<0.05/<0.5	<10/<50
Sulphur dioxide	<0.01/<0.03	<0.1/<0.3	<5/<15
Sulphur trioxide (ffs)	<0.01/<0.03	<0.1/<0.3	<5/<15
Chlorine wet (>50% humidity)	<0.0005/<0.001	<0.005/<0.03	<0.0051/<0.03
Chlorine dry (>50% humidity)	<0.002/<0.01	<0.02/<0.1	<0.2/<1.0
Hydrogen chloride	-/0.06	<0.06/<0.3	<0.06/<0.3
Hydrogen Fluoride	<0.001/<0.005	<0.01/<0.05	<0. 1/<1.0
Ammonia	<1/<5	<10/<50	<50/<250
Oxides of Nitrogen	<0.05/<0.1	<0.5/<1	<5/<10
Ozone	<0.002/<0.005	<0.025/<0.05	<0.1/<1
Electromagnetic	**E_1**	**E_2**	**E_3**
Electrostatic discharge – contact (.667 µC)	4 kV		
Electrostatic discharge – Air (.132 µC)	8kV		
Radiated RF – AM	3 V/m @ 80-1000 MHz 3 V/m # 1400-2000 MHz 1 V/m@2000-2700 MHz		
Conducted RF	3 V @150 KHz-80 MHz		10 V@150 kHz-80 MHz
EFT/B	500 V		1000 V
Surge (transient ground potential difference)	500 V		1000 V
Magnetic Field (50/60 Hz	1 AM^{-1}	3 AM^{-1}	30 AM^{-1}
Magnetic Field 60-200000 Hz	ffs		

Table 2: *MICE Classifications*

Another standards-based rating to consider for harsh environments is the ingress protection (IP) ratings developed by the European Committee for Electro Technical Standardization (CENELEC). Sometimes referred to as an IP code, the IP rating consists of the letters IP followed by two digits—the first digit classifying protection against solids (i.e., dust) and the second classifying protection against liquids (i.e., water). For example, as shown in Table 3, an IP rating of IP22 would indicate protection against finger-size objects and vertically dripping water

Table 3: *IP Code Ratings*

Protection Against Solids		
0	No special protection	
1	>50 mm	Protected against objects greater than 50 mm (e.g., accidental touch by surface of human hands)
2	>12.5 mm	Protected against solid objects greater than 12 mm (i.e., human finger size)
3	>2.5 mm	Protected against solid objects greater than 2.5 mm (e.g., tools, thick wires)
4	>1 mm	Protected against solid objects greater than 1 mm (e.g., most wires, screws, paperclips)
5	Dust Protected	Protected against limited dust ingress (e.g., protection against contact but no harmful deposit of dust)
6	Dust Tight	Totally protected against dust
	Protection Against Liquids	
0	No special protection	
1	Dripping water	Vertically falling drops have no harmful effect
2	Dripping water with 15-degree tilt	Vertically falling drops have no harmful effect if enclosure tilted up 15 degrees
3	Spraying water	Water falling as spray at any angle up to 60 degrees from the vertical has no harmful effect
4	Splashing water	Water splashing from any direction has no harmful effect
5	Water jetting	Water projected (12.5 mm nozzle) from any direction has no harmful effect
6	Immersion up to 1 m	Immersion in water under defined conditions of pressure and time (up to 1 m) has no harmful effect
7	Immersion above 1 m	Continuous immersion as specified by manufacturer has no harmful effect. Typically hermetically sealed.

NEMA 4X Enclosures provide protection against dust, water and corrosion in rugged environments.

One of the common IP ratings seen for ruggedized connectivity in our industry is IP66/IP67, which offers total protection against dust ingress and water ingress. While the IP rating is especially useful for determining the level of protection needed when dealing with wet, dusty environments, it's important to remember the remaining MICE parameters such as ability to withstand higher temperature and humidity ranges or to maintain performance amidst higher levels of electrostatic discharge (ESD) or radio frequency interference (RFI).

NEMA Rating	NEMA Definition	IP Equivalent
1	Enclosures constructed for indoor use to provide a degree of protection to personnel against incidental contact with the enclosed equipment and to provide a degree of protection against falling dirt	IP10
3R	Enclosures constructed for either indoor or outdoor used to provide a degree of protection to personnel against incidental contact with the enclosed equipment; to provide a degree of protection against falling dirt, rain, sleet, and snow; and that will be undamaged by external formation of ice on the enclosure	IP14
4	Enclosures constructed for either indoor or outdoor use to provide a degree of protection to personnel against incidental contact with the enclosed equipment; to provide a degree of protection against falling dirt, rain, sleet, snow, windblown dust, splashing water, and hose-directed water; and that will be undamaged by the external formation of ice on the enclosure	IP66
4X	All of the same capabilities of NEMA 4 but with the added benefit of resistance to corrosion	IP66
12	Enclosures constructed (without knockouts) for indoor use to provide a degree of protection to personnel against incidental contact with the enclosed equipment; to provide a degree of protection against falling dirt; against circulating dust, lint, fibers, and flying; and against dripping and light splashing of liquids	IP52

Table 4: *NEMA Enclosure Ratings and IP Equivalents*

There is yet another standard to consider related to enclosures, which can include cabinets, surface mount boxes, floor and ceiling boxes, junction boxes and even network equipment housing. The National Electric Manufacturer Association (NEMA) uses a standard rating system for enclosures that defines the types of environments where they can be used. NEMA ratings for enclosures also have IP code equivalents, as shown in Table 4 that highlights the most common NEMA enclosures.

Identifying the Key Components – From Cables to Connectors

When it comes to selecting ruggedized cable and connectivity, both copper and fiber solutions may need to be considered—especially as more fiber is extending out of the commercial data center and telecommunications room environment to bring higher bandwidth closer to the work area outlet or to deal with longer distance requirements.

While not all MICE parameters will relate to both copper and fiber, especially with fiber being immune to electromagnetic interference, the IP66/IP67 rating on connectivity can easily apply to both as can other mechanical, climatic and chemical parameters. In general, ruggedized cable and connectivity solutions for harsher environments should feature components and characteristics such as the following:

- **Chemical-resistant thermoplastic housing on connectivity** — Plugs and outlets should use materials that provide the widest range of protection from most solvents and common industrial chemicals.
- **Dust caps for outlets** — Ruggedized dust caps can protect unused outlets and seal outlets during wash downs.
- **IP67-rated copper and fiber connectivity** — Ruggedized outlets and modular patch cords with an IP66/IP67-rated seal protect plugs and outlet contacts from dust and moisture.
- **Shielded twisted-pair cabling for copper** — Shielded copper cabling such as F/UTP cables and S/FTP cables will provide much higher resistance to EMI/RFI.
- **More durable cable jacket materials** — Jacket materials such as polyurethane and thermoplastic elastomers can provide better tensile strength and lower temperature flexibility and brittle points, as well as better tear, abrasion, chemical and moisture resistance.
- **IP44-rated faceplates** — Stainless steel faceplates with rear sealing gaskets provide a protective seal from moisture and debris.
- **NEMA 4X enclosures** — Enclosures and surface mount boxes with a NEMA rating will protect the termination points of ruggedized outlets.

The need for ruggedized connectivity can also relate to fiber outlets in a variety of environments.

Stainless steel faceplates with rear sealing gaskets and dustcaps for unused connections are ideal for protecting critical network connections in harsh environments.

Making the Best Choice – From Home Plates to Seafood Platters

With the proliferation of digital information, handheld devices and Ethernet, consumers and employees everywhere demand network and Internet access at all times and digital applications that make their lives and jobs easier. Consequently, enterprise businesses are required to expand their networks into places that in the past would have gone without network connections and wireless service. With many of the environments that now need access being outside of the realm of standard commercial environments, enterprise businesses are partnering with manufacturers that offer ruggedized cable and connectivity in addition to commercial-grade components.

In a $150 million upgrade at Dodger Stadium, the 52-year old home of the Los Angeles Dodgers and the third oldest park in Major League Baseball, plenty of enhancements were made to deliver a state-of-the-art experience to fans, including a new high-performance copper and optical fiber cable system to support stadium-wide WiFi, digital displays, IP-based security, box offices, kiosks and point-of-sale locations.

Dodger Stadium

Siemon Ruggedized Z-MAX Category 6A shielded IP66/IP67-rated outlets and cords were deployed at Dodger Stadium's outdoor concession stands and kiosks

As part of the upgrade, two new plazas were added at the left field and right field stadium entrances. While concession stands are located throughout the stadium, the new Bullpen Overlook Bars, the Think Blue Bar-B-Que and Tommy Lasorda's Italian Trattoria concession stands in the new plazas have drawn the most pre- and post-game attention.

During the design stages of the network, Ralph Esquibel, the Dodgers' vice president of IT, worked with Siemon to determine which products would best ensure reliability for LAN connectivity at the outside food and beverage locations. Due to the potential for harmful environmental factors that could adversely impact commercial-grade components, Siemon Ruggedized Z-MAX category 6A shielded IP66/IP67-rated outlets and modular cords were selected for use at these locations.

The Ruggedized Z-MAX connectors offer total protection against dust ingress and short-term protection against water ingress, as well as the ability to withstand higher temperature and humidity ranges. They feature a durable, chemical resistant, industrial-grade thermoplastic and patented bayonet style quarter-turn mating design for superior protection. Siemon shielded F/UTP cabling was also selected to provide the performance and noise immunity required throughout the stadium.

"We don't know when we'll be able to make this type of investment again," says Esquibel. "We have a lot of technology here, and we need to make sure we are protecting it."

Trident Seafoods

The largest seafood company in the U.S., Seattle-based Trident Seafoods is a vertically integrated seafood company of fishing vessels and processing plants that produce fresh, frozen, canned, smoked and ready-to-eat seafood products under a variety of brand names, including Trident, Louis Kemp and Rubenstein's. When the company wanted to extend network access throughout its three factory trawlers, they turned to Siemon's ruggedized connectivity.

Starting with the 276-foot Kodiak Enterprise, Trident sought to upgrade the entire on-board network to not only improve existing wheel house communications, but also to provide whole-ship Wi-Fi for the more than 125-person crew that lives on the ship for extended periods of time during peak fishing season. During the short month of dry-dock time, Cabling & Technology Services (CTS), a full service integrator of network infrastructure systems, removed and replaced the ship's entire cabling infrastructure.

"It's very challenging to deploy cabling on a ship due to tight spaces, corrosive sea water and other environmental elements," says James Gannon, service project manager for CTS. "We needed to deploy connections throughout for Wi-Fi access and to connect to computerized packaging systems in the fish processing area, which is often wet from floor to ceiling and undergoes wash downs as part of the company's sanitation process."

Throughout the ship, Siemon Ruggedized MAX IP66/IP67-rated category 6 outlets and modular cords were once again deployed to offer protection against water ingress, as well as the ability to withstand the corrosive nature of sea water that can typically cause non-ruggedized components to fail.

Trident Seafoods' 276-foot Kodiak Enterprise is just one of the company's trawlers that uses Siemon Ruggedized MAX IP66/IP67-rated outlets.

"Trident wanted something that could handle the wet, and Siemon had the product," says Gannon. "While I've used Siemon products for many projects in the past, I had not used their ruggedized connectivity before. We're also using it in the two other factory trawlers—the Island Enterprise and the Seattle Enterprise—both of which will be completed this year."

Choosing the Right Partner – From Experience to Breadth of Product

With an increase in the number of harsh environments that are an extension of the corporate LAN, designers and installers who are experienced in commercial environments may not necessarily understand industrial standards, how to use MICE parameters or which product features to look for. Furthermore, standards-based methods and parameters for determining the level of harshness and the components required are not always cut and dry.

While industry standards can be used for determining components based on environment, they often refer to in-between environments as "light industrial." This term can be confusing when the environment is clearly not one that is industrial but is simply an extension of the commercial LAN into a harsher environment. Consequently, "industrial" standards are not always followed during the planning stages of these environments, often resulting in the use of inadequate components and network failures.

Experience goes a long way in designing for these environments. For example, designers experienced with deploying networks in industrial and harsh environments will likely know that induction heating within about 10 feet of a component can require an E3 classification while fluorescent lighting located a few feet away will have little impact and require only an E1 classification.

Another consideration when selecting ruggedized cable and connectivity is a breadth of copper and fiber types in a variety of performance levels. Most manufacturers of industrial/ruggedized components provide category 6 at best for copper, with many offering only category 5e. Furthermore, few offer the latest fiber cable and connectivity in ruggedized versions. This could very well be due to the fact that many industrial systems don't require the higher bandwidth associated with category 6A and fiber. However, as more LANs extend into harsher environments, designers are looking to maintain the same performance level as the rest of the corporate LAN. Selecting a manufacturer with ruggedized copper and fiber cable connectivity available in the same copper and fiber performance as the rest of the LAN will prevent connections in more demanding environments from having to compromise on bandwidth and performance.

Commercial designers with limited experience in planning for cable and connectivity that extends into harsh environments would be wise to work closely with cable and connectivity manufacturers who understand the standards and specifications, offer the latest copper and fiber ruggedized components and have experience in determining the type of cable and connectivity required based on a variety of environmental factors.

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