



AUTHORIZED DISTRIBUTOR



**PROVEN IN THE HARSHTEST ENVIRONMENTS**







## TABLE OF CONTENTS

- 03** Proven in the Harshest Environments
- 04** Enabling Smarter, More Connected Applications
- 10** Data Connectivity in Harsh Environments
- 14** Switchgear Connectors for Offshore Wind Farm
- 20** Connectors That Outperform in Harsh Conditions
- 26** Sensors for Corrosive Environments Face Challenges
- 31** Heat-Shrink Cable Accessories are Proven Technology

### CONNECT WITH MOUSER



Terms Of Use: ©2021 Mouser Electronics, Inc., a TTI Berkshire-Hathaway company. Mouser and Mouser Electronics are registered trademarks of Mouser Electronics, Inc., TE Connectivity logo, product names, service marks, are trademarks, registered trademarks of TE Connectivity. All other trademarks are the property of their respective owners. Names, products, specifications, links, resources, and similar were verified at the time of publication. Article content, reference designs, datasheets, conceptual illustrations, and other images provided herein are for informational purposes only.



# Proven in the Harshest Environments

**Paul Golata**, Mouser Electronics

**L**ike humans, electronics systems and circuits are constantly under stress. Electronics are susceptible to being compromised or destroyed when introduced to harsh environmental conditions. Harsh environmental conditions can include exposure to extreme temperatures, temperature cycling, ingress of liquids or particulates, electrostatic discharge (ESD), electromagnetic interference (EMI), vibrations, and physical impact (shock).

TE Connectivity delivers reliable connectivity products designed to withstand harsh environmental conditions for on- and off-highway vehicles and recreational transportation, including heavy trucks, construction, agriculture, buses, and other vehicles. Likewise, TE Connectivity products and systems are designed and manufactured to operate effectively in harsh conditions ranging from the ocean's depths to the far reaches of space. The extreme operating conditions found within the commercial aerospace, defense, and marine industries are solved by employing our solutions.

TE Connectivity serves customers in over 140 countries worldwide, with its greater-than-15,000 patents providing the innovative technology needed to fend off and secure connections against external threats. With more than 80,000

employees focused on designing, manufacturing, and delivering connectivity and sensor solutions, TE Connectivity offers more than 100 global manufacturing and engineering centers focused on providing solutions for today's challenges. These solutions include powering electric vehicles (EV), aircraft, digital factories, and smart homes. It entails innovation that enables life-saving medical care, sustainable communities, efficient utility networks, and the global communications infrastructure.

For more than 75 years, TE Connectivity has collaborated with transportation, industrial, and communication customers to produce highly engineered connectivity and sensing products that make a connected world possible. Our focus on reliability and durability, our commitment to progress, and the unmatched range of our product portfolio enable companies large and small to turn ideas into technology that can transform how the world works and lives tomorrow.

In the following pages, we welcome you to come in and experience how TE Connectivity's broad range of connectivity and sensor solutions, proven in the harshest environments, enable advancements in transportation, industrial applications, medical technology, energy, data communications, and the home. ■



**PAUL GOLATA** joined Mouser Electronics in 2011. As a Senior Technology Specialist, Paul contributes to Mouser's success through driving strategic leadership, tactical execution, and the overall product-line and marketing directions for advanced technology-related products. He provides design engineers with the latest information and trends in electrical engineering by delivering unique and valuable technical content that facilitates and enhances Mouser Electronics as the preferred distributor of choice.

Before joining Mouser Electronics, Paul served in various manufacturing, marketing, and sales-related roles for Hughes Aircraft Company, Melles Griot, Piper Jaffray, Balzers Optics, JDSU, and Arrow Electronics. He holds a BSEET from the DeVry Institute of Technology (Chicago, IL); an MBA from Pepperdine University (Malibu, CA); an MDiv w/BL from Southwestern Baptist Theological Seminary (Fort Worth, TX); and a PhD from Southwestern Baptist Theological Seminary (Fort Worth, TX).





# Enabling Smarter, More Connected Applications



TE Connectivity's HTU31 Humidity & Temperature sensor provides:  
One of the smallest & most accurate humidity sensors on the market  
Fast response time & precision measurement  
Low hysteresis & sustained performance, even in the harshest environments

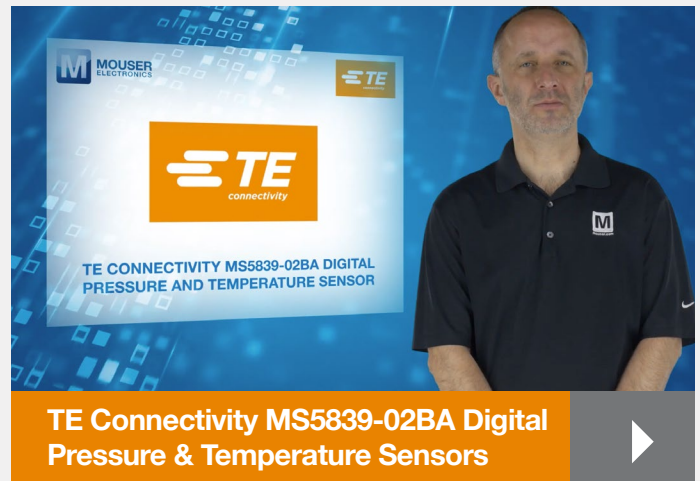
**TE Connectivity Humidity and Temperature Sensor - HTU31**



**N**ever before has technology been challenged to address the highest levels of safety, sustainability, productivity, and connectivity until now. From workplace modifications trying to mitigate a pandemic to heightened interest in environmental protection to creating safer and more sustainable production processes, these emerging trends are responsible for fundamental and transformative changes in how and where we produce and deliver goods and services.



From workplace modifications initiated by a pandemic to heightened interest in environmental protection to creating safer and more sustainable production processes, all these trends are responsible for fundamental and transformative changes in where and how we produce and deliver goods and services.



“Machinery manufacturers are pushing to evaluate and implement emerging technologies”

Evidence of these trends is witnessed each day on our manufacturing plant floors, visible in predictive maintenance capabilities, virtual reality (VR) and augmented reality (AR), and enhanced industrial communication speeds with Ethernet and 5G networks. Furthermore, the underlying technology adoption curves in the industrial space historically averaged seven years but are now on average just two to three years.

In recent years, an explosion of companies specializing in asset management software and hardware tools enable operators or site managers to optimize maintenance tasks in real-time, minimize disruption, and extend machinery life. Approximately one in three manufacturers already use or plans to use VR and AR for product design and development for safety and manufacturing training, maintenance, repair, operations, and remote collaboration of team members. The glue, tying the new technologies and equipment and industrial devices, integrates faster communication speeds on the plant floor via 10GB Ethernet and 5G wireless communications for smart manufacturing. 5G specifically offers wireless flexibility, high bandwidth capabilities, low latency,

and high reliability, enabling network machines and equipment to communicate wirelessly and with back-end systems in previously impossible ways.

Machinery manufacturers are pushing to evaluate and implement these emerging technologies for several reasons. For example, they are rapidly adapting to market realities shaped by customer demand. The rapid shift in digital trends, including overnight delivery of virtually everything, is now a new norm, the minimal threshold for companies planning on entering a new market or a new geographic region.

Recent repatriation of manufacturing and production to the United States, combined with the need to support regional and local customers, impacts the new production floor equipment. Regardless of where plants are located, this equipment must meet the rigors of production while also addressing employee safety, remote access to real-time production and equipment performance data, and do both with an eye toward earth-friendly processes. These global and regional trends drive companies to upgrade machinery and production equipment and change the way they do business.





## Design Considerations

Today's design considerations move well beyond building a better mousetrap to involve requirements for enhanced productivity, safety, and profitability through optimization of designs.

These considerations include:

- Durability for harsh environments
- Reliable functionalities
- Product and machine modularity
- Miniaturization
- Protection and safety
- Connectivity options
- Industry standards and certifications
- Ease of assembly
- Simplification of design
- Wireless technology

TE Connectivity's product portfolio addresses these design considerations. TE Connectivity offers various antennas for Wi-Fi communications, sensors for temperature, pressure, humidity, and electromechanical products, transformers, switches, heat-shrink tubing, and relays. Design simplification is achieved by our focus on one-step assembly and automated processes for high reliability. Features include pre-loaded housings, for example, that make for less labor-intensive and easier manufacturability, ultimately reducing cycle times. All application tooling supports product reliability and performance.

For designs that require high power and high operating temperatures, TE Connectivity's secondary-locking technology adds safety. When adding Internet of Things (IoT) features to existing circuit boards, TE Connectivity provides interconnects that saves board space to reduce cost or allow for more content on the board without increasing overall size.

Safety can be seen across the product spectrum. A low insertion force required for operators eliminate ergonomic issues for operators while still creating interconnects that are fully connected, avoiding failure. TE Connectivity features the most innovative applications for such product solutions involving connectors, terminals, and splices, heat shrink tubing, and relays.

## TE Connectivity Product Solutions

### CONNECTORS

TE Connectivity's vast connector selection addresses any type of configuration needed including wire-to-wire, wire-to-board, board-to-board, cable-to-cable, cable-to-panel, wire-to-panel, wire-to-component, single row, dual row, terminal position assurance (TPA), and shrouded and unshrouded headers. Additional connector features include American Wire Gauge (AWG) sizes from 30-8AWG and voltage ranges of 50V-600V and sometimes up to 1000V, depending on the connector.



TE Connectivity connectors are rated to IP standards, Military Specifications (MIL-SPEC), and automotive certifications. They reliably transmit data, signals and power in the harshest and most extreme environment conditions. Key portfolio benefits in this product segment include:

- IP56-IP69K rated sealing protection
- High-power options
- High-temperature range spanning -25°C to 110°C and even 150°C and higher, based on applications
- A broad portfolio
- Glow-wire tested solutions for harsh environments
- Wire-to-wire, wire-to-board, and wire-to-panel options
- Insulation offerings
- Miniaturized solutions
- Polarized housings and latching mechanisms

Power Versa-Lock Connectors (**Figure 1**) are tiny in size and IP rated. Also, latching polarized housings (right photo) avoid housings either upside down or in the wrong position.

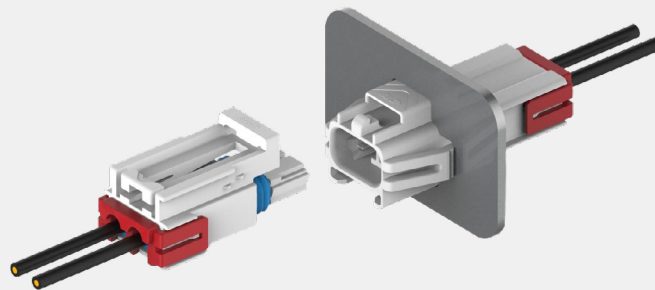
Today's connectors go into smaller, more confined areas that are extremely hot. TE Connectivity offers the correct wires and the proper insulation on connectors used in temperature ranges of -25°C to 110°C and even 150°C and higher.

## Terminals and Splices

The TE Connectivity family of terminals and splices (**Figure 2**) offers pre-insulated or non-insulated, closed barrel, and open barrel terminals. These ergonomic-friendly wiring solutions are designed for high retention and low insertion force. They ensure enough insertion force to lock into position without causing pain or strain on the installer.

Key portfolio benefits:

- Pre-insulation and uninsulated options
- High-temperature solutions
- Application tooling
- Variety of plating options
- Straight and flag configurations
- Vibration resistance
- Low insertion force—ergonomic
- High retention
- MIL-SPEC certified offerings



**FIGURE 1:** TE Connectivity's featured connectors are tiny in size (Source: TE Connectivity)

This portfolio features a wide range of options. Wire gauges available are 26AWG to 10AWG, voltage ratings are 250V to 600V, and maximum operating temperatures between 105°C to 250°C. Considering application tooling on the front end ensures that the correct interconnects are available and on hand going into production.

Material types include brass, copper, steel, copper alloy, phosphor bronze, stainless steel, and nylon, while plating options include nickel, tin, silver, and unplated, pre-tin.

Extra locking mechanisms ensure that during vibration, the parts themselves do not vibrate off of their mated parts.



**FIGURE 2:** TE Connectivity offers various TE Connectivity terminals and splicers. (Source: TE Connectivity)



**FIGURE 3. TE** Connectivity features relays up to 16A, panel, plug-in relays, single relays, high-frequency and so on, solid-state circuit breakers, and transformers. (Source: TE Connectivity)



Terminal shapes include flag receptacle, straight receptacle, housing, ring and spade tongue, wire crimp tabs, PCB tabs, and board-mount tabs. Careful consideration should be given to the width and even thickness of tabs. TE Connectivity designs its models specifically to ensure they are not affected by vibration and latch and permanently lock. Approvals include UO, CSA, and IEC 60335-1. Packaging in this category includes real loose piece, small pack, or tape mounted, all based on the production environment.

## Relays

The TE Connectivity relays portfolio provides high-inrush capabilities and powerful switching needs.

Key portfolio benefits:

- High-temperature options
- Various models to support a range of loads
- Insulation systems—UL Class F approved
- Designed to withstand extreme shock/vibration
- ROHS compliant and IEC60335-1 approved offerings
- Sensitive and standard coil options to accommodate a variety of drive circuits
- Current ratings include 3A, 5A, 8A, and 10A and, in some cases, up to 50A, while contact voltage ratings are 277VAC/30VDC, 250VAC/28VDC, and 250VAC.

TE Connectivity relays (**Figure 3**) also include power printed circuit board (PCB) relays up to 16A, panel, plug-in relays, single relays, high-frequency and so on, solid-state circuit breakers, and transformers.

## Heat-Shrink Tubing

TE Connectivity offers a wide range of single wall, dual wall, and specialty products that seal, protect, insulate, organize and offer strain relief (**Figure 4**). TE Connectivity features one of the largest portfolios when it comes to heat shrink tubing products. TE Connectivity offers single-wall adhesive-lined products that seal, protect, insulate, organize, and offer strain relief.

Key tubing benefits include:

- Electrical insulation to protect components
- Strain relief
- Protection against mechanical damage and abrasion
- Offered in single wall, dual wall, or specialty
- Mechanical protection
- Wide range of operating temperatures
- High-quality solutions for harsh environments
- MIL-SPEC offerings





**FIGURE 4:** TE Connectivity offers a wide range of single wall, dual wall, and specialty products that seal, protect, insulate, organize and offer strain relief. (Source: TE Connectivity).

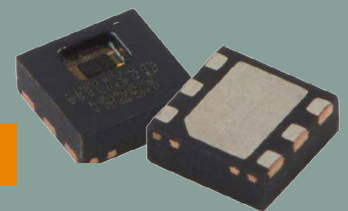
TE Connectivity's heat shrink tubing, offer mechanical protection or features double fabric and superior abrasion resistance. TE Connectivity offers high-quality heat shrink tubing for harsh and MIL-SPEC environments, such as chemical fluid flame resistance. Shrink ratios include 2:1, 3:1, 4:1 up to 5.6:1, and specialty products can be an 8:1 ratio. Fifteen color options are available. Flammability ratings include UL, CSA, ASTM, Proc. B & C and FMVSS302. Size ranges include 0.8mm to 101mm on a standard basis and parts that are 127mm and a diameter up to 432mm for application in more rugged environments.

### Why Partner with TE Connectivity?

TE Connectivity has an extensive product portfolio and has been a long-term industry partner for many, many years. Since its inception, the company continues to invest heavily into research and development, spending an impressive budget annually, even in downturns, to design new products to meet and exceed industry needs. TE Connectivity addresses the highest levels of safety, sustainability, productivity, and connectivity in a rapidly changing industry, creating safer and more sustainable production processes to meet the fundamental and transformative changes in where and how goods are produced and goods and services delivered. ■

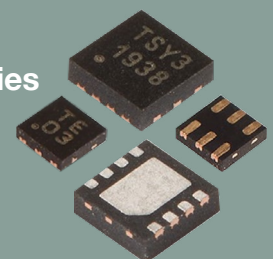
### TE Connectivity / Measurement Specialties HTU31 Relative Humidity Sensors

[LEARN MORE](#)



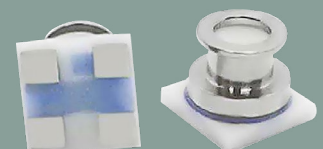
### TE Connectivity / Measurement Specialties TSYS03 Digital Temperature Sensors

[LEARN MORE](#)



### TE Connectivity MS5839-02BA Digital Pressure & Temperature Sensors

[LEARN MORE](#)





# Data Connectivity in Harsh Environments

**Christian Manko**, Data Connectivity Product Manager, TE Connectivity



Customers are demanding functionality that automates or enhances operational tasks to increase driver productivity and safety and, in many cases, reduce total cost of ownership. Basic customer requirements for vehicles now include automatic adaptive braking and steering, onboard diagnostics, vehicle-to-vehicle (V2V) and vehicle-to-infrastructure (V2I) communication, and cameras that give drivers a 360-degree view of their environment.

These features require large amounts of data to be transmitted at high speeds. As engineers design new models to meet these customer demands, the challenge is to ensure signal integrity and data transmission in the trucking and off-highway industries' harsh environment.

## Applying Ethernet in a Mixed Architecture

To handle increased data demands and high-speed connectivity, sophisticated network infrastructure is needed. Controller Area Network (CAN) bus architectures, which typically manage speeds up to 500kbps, have been the stalwart backbone for most heavy-duty vehicles' communication networks for a few decades. However, the data bandwidth required for advanced vehicle functionality and automated features for safety and productivity is too great to be served by CAN alone.



Single-pair Ethernet protocol (100BASE-T1 at 100Mbps or 1000BASE-T1 at 1Gbps) provides the ability to transmit data at high speeds. Ethernet networks and connectors allow original equipment manufacturer (OEM) designers to seamlessly integrate more devices into the network and accelerate data connectivity in their vehicles. As a point-to-point topology, Ethernet changes the vehicle's electrical and electronic (E/E) architecture. As OEMs decide to add more features and devices, designers will also need to factor in Ethernet switches to direct the signal and gateways to communicate between Ethernet and CAN.

To optimize space, weight, and performance under harsh conditions, designers must consider in the first stages of design how they will integrate Ethernet where it is needed for advanced functionalities.

Decisions such as how many cables to place inside the vehicle and where to place them, where to place Ethernet switches and whether the switch should be in an existing electronic control unit (ECU) or a new dedicated ECU must be made for every feature that requires Ethernet. This decision is crucial to avoid or mitigate electromagnetic interference (EMI) or other mechanical disturbances.

For example, 360-degree cameras on a heavy-duty vehicle transmit high-speed data from the outside of the vehicle to the in-cabin display for the driver to view. Four cameras (one on each side of the vehicle) send signals to an ECU. Designers need to plan where to place a switch to combine the data from the four cameras and send that data in one signal to the ECU. The switch can be in the vehicle or in one of the cameras, which would have four ports to input data from the three other cameras and then send out data. Another option is to integrate the switch into the video display monitor.

Active automated functions such as automatic adaptive braking and other advanced driver-assistance systems (ADAS) that include a multi-sensor array, require even more thought in early design stages. Each sensor will have a dedicated communication link to an ECU. The more sensors the vehicle has, the more cables and communication connections are needed. An autonomous heavy-duty vehicle of the future would require a wide sensor array for about 16 radars, 10 lidars, and 10 cameras around the vehicle.





“When trying to meet mechanical resilience needs, some engineers may instinctively think to add a larger, more robust housing, but thicker walls may negatively impact electrical performance.”

— **Mark Brubaker**, Data Connectivity Product Manager, TE Connectivity



That's more than 30 cables and links that need to be EMI-resistant and smartly routed while considering space, weight, and EMI to maintain signal integrity inside and outside of the chassis and as the links come into one ECU. More data means more bandwidth needs, which means connectors and cables that can handle more speed.

The immense size of industrial and commercial vehicles presents a challenge to maintaining signal integrity and transmitting data reliably. For sending an Ethernet signal in cars, the Ethernet standard specifies technical requirements up to 15m. But in trucks, buses, and off-highway vehicles, signal integrity must be maintained for longer lengths, up to 40m, while withstanding heavy vibration, extreme temperatures, and shock, severe dust conditions, and more.

The Ethernet standard currently specifies for up to four in-line connections along that 40 meters. Designers need to assess how long each segment can maintain optimal signal integrity. Factors affecting this could be exposure to outside elements or high temperatures, placement near an antenna, or other components that could cause EMI. Routing is a critical element of design, and the entire physical layer must be scaled for the performance expected.

### Choosing the Right Components

“When designing a mixed architecture with CAN and Ethernet, engineers need to think about the entire connectivity infrastructure upfront in terms of what advanced, data-heavy functions they will be incorporating,” says Abbas Alwishah, TE Connectivity data connectivity engineering manager. “The more advanced technology gets, the more collaboration between OEMs and suppliers is important.

“Suppose a customer tells me they need a high-definition camera or proximity detection system that works with very low latency. In that case, I can explain all the individual components needed for that function or system—sensors, connectors, cable assemblies, antennas, processors, display, etc.—and make recommendations on the topology to optimize performance, space, weight, and costs.”

Choosing Ethernet-compatible components that can withstand harsh conditions is key to reliable data transmission in long-lifetime, heavy-duty vehicles. Automotive Ethernet connectors (those designed originally for passenger vehicles) can be used in the cabin or other areas of the vehicle not exposed to extreme shock, temperature, or other elements, where more ruggedized connectors and longer-length cables are not needed.



A high-quality unshielded twisted-pair cable is suitable for Ethernet in most areas of the vehicle, with shielded twisted-pair cables used only where necessary. The designer's choices also will help control costs and save space and weight.

Modular and scalable MATEnet connectors developed by TE Connectivity for automotive Ethernet, for example, can also be used in heavy-duty vehicles for applications requiring mid- to large-size data volumes and low latencies, such as onboard diagnostics (V2X technologies), telematics, dashboard infotainment, ADAS, and more. The connectors can transmit data at 100Mbps to 1Gbps (per IEEE 100BASE-T1/1000BASE-T1) and can be used with unshielded or shielded twisted-pair cables.

On-chassis components require more than just ruggedness. They must demonstrate mechanical reliability, be serviceable, withstand extreme

to opt for cables and connectors specifically designed for high-speed data transmission in harsh environments.

"When trying to meet mechanical resilience needs, some engineers may instinctively think to add a larger, more robust housing, but thicker walls may negatively impact electrical performance," says Mark Brubaker, Data Connectivity Product



temperatures and operate efficiently with longer channel lengths. When dealing with higher frequencies, cable/connector quality and design can significantly impact channel performance, which affects application performance. Especially for on-chassis components, engineers need

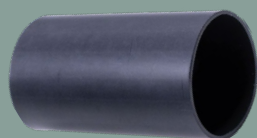
Manager, TE Connectivity. "It's important to look at what historically has worked, but also to take a further step to understand this new generation of electrical needs for transmitting high-speed data and test how connections will perform given the higher frequencies involved."

## Conclusion

Product choice and placement cannot be an afterthought when designing advanced and automated functionality that requires high-speed data transmission. When adding Ethernet to heavy-duty vehicle architectures, designers must think about and plan for the complexities involved much earlier and deeper than before to successfully balance reliability and mechanical resilience with electrical requirements for high-speed data and longer channel lengths, as well as serviceability needs. ■

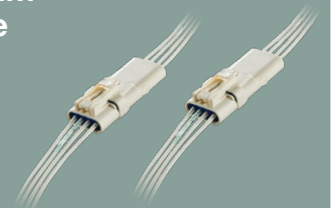
### TE Connectivity BATTU Dual Wall Heat Shrink Tubing

LEARN MORE



### TE Connectivity 2.5mm Sealed Signal Double Lock Connectors

LEARN MORE





# Switchgear Connectors For Offshore Wind Farm



**DEUTSCH DT Series  
Connector Instructions**



**T**HE Connectivity was able to offer a complete switchgear connect solution to empower one of the world's largest offshore wind farms because of its broad-screened separable connectors portfolio, making the project less challenging and more efficient.

## **THE CHALLENGE**

A consortium of three world-leading renewable energy companies initiated the construction of one of the world's largest offshore wind farms. With an area of approximately 100km<sup>2</sup>, the wind farm would supply power for nearly half a million homes a year and significantly decrease the CO<sub>2</sub> emissions in the region.



For this project, the engineers in charge of the energy supply structure requested screened separable connectors that would enable them to connect large cross-section cables in their unique and very compact switchgears. Because of the challenging environmental conditions of the offshore wind farm, they were looking for connectors that could withstand extreme temperatures in an environment characterized by its high humidity and salinity.

A customized approach was needed to address this technical challenge and ensure the reliable electrical performance of the offshore wind farm.

1500	170	460k
Screened separable connectors delivered	Switchgears provided with Raychem screened separable connectors RSTI	Homes supplied in electricity by the wind farm each year

THE SOLUTION

Based on more than 60 years of experience, TE Connectivity’s experts offered a complete package of customized switchgear connect solutions that meet the unique technical requirements of the wind farm:

- RSTI Screened Separable base and coupling connectors
- RSTI Screened Separable connectors with surge arrestors
- RSTI Dead End Plugs designed to face environmental challenges during turbine installation

TE Connectivity’s Raychem RSTI Screened Separable Connectors adapted easily to the customer’s cable type and size. Their compact design and the flexibility of their silicone components facilitated the installation of the connectors, reducing installation time and errors.

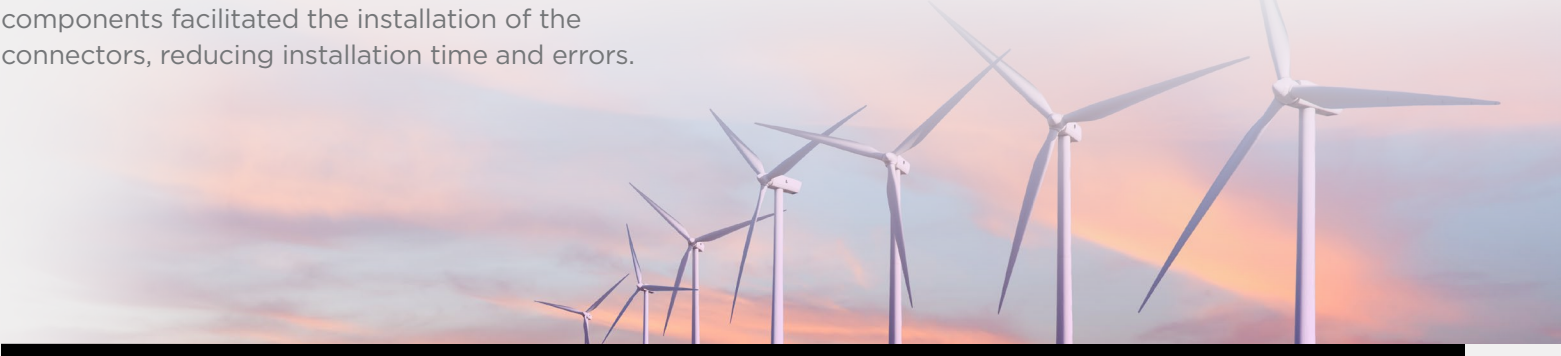
THE OUTCOME

TE Connectivity’s experts identified the right solution and reduced project management time with end-to-end customer service, including local language support, on-site training, and installation supervision.

By completing another project in offshore environments, TE Connectivity reinforced its role as a key provider of switchgear connect solutions for the renewable energy market.



“TE Connectivity’s customized switchgear connectors, along with TE’s high-level technical support and training, provide the ideal solution for customer requirements.”





## Improving Power Density and Efficiency in South Korea

### THE CHALLENGE

The country's marine designers and engineers face tough operating environments. Depleting oil reserves make it necessary to drill even deeper and wider. This has led to a dramatic increase in demand for power. More pertinently for TE Connectivity, it's led to an increase in demand for higher-density installations to answer the calls for improved cost-effectiveness and efficiency.

- Tough operating environments
- Higher density installations

### THE SOLUTION

TE Connectivity's solution was to introduce a low-profile, short- and high-performance medium voltage (MV) termination to ensure ease and simplicity of installation and resistance to humid environments.

To deliver increased power density, TE Connectivity developed new designs of cable accessories that facilitate simpler, faster, and more reliable installations. One good example of this is the low-profile MV termination that allows several cables to be successfully terminated into a small space.

To ensure an even smaller, more compact, and robust solution that outperforms the competition, TE Connectivity incorporated a radical new stress control system (employing a metal oxide varistor material) and a total seal to the cable insulation, sheath, and lug barrel.

### THE RESULTS

The MV termination has multiple advantages, including material and space savings, easy installation and operation, and a long operating life:

- Short length
- Small profile (no need for sheds on the cores)
- Easily installed on cables that are not straight and in confined spaces
- Total sealing of termination to cable and lug substrate
- Heat-shrink installation technology ensures no moisture is captured or retained under the termination, even when installed in very wet/humid environments
- Extremely robust, tough materials
- Exceptional electrical performance
- No shelf life limitations



## Harsh Environmental Resistant Cable Joints for Shipbuilding and Offshore

### BACKGROUND

The North Sea presents some of the harshest operating conditions for marine installations and products. The average temperature in the North Sea during the summer months is 17°C while in winter, a season of frequent gales and storms, the average temperature is 6°C while salinity averages 34g to 35g of salt per liter of water.

### THE CHALLENGE

The average temperature in the North Sea during the summer months is 17°C while in winter—a season of frequent gales and storms—the normal temperature is 6°C while salinity averages 34g to 35g of salt per liter of water. The North Sea is also prone to storm surges, an offshore rise of water associated with a low-pressure weather system caused primarily by high winds pushing the ocean's surface.

The early days of exploration and recovery of North Sea offshore oil in the 1970s called for exceptionally enduring products that would meet the exacting requirements of the companies operating in this harsh environment. A well-known British oil and gas company, an early leader in the industry, was looking for high-performance low-voltage (LV) and MV joints and terminations for their innovatively constructed platforms.

The challenge for TE Connectivity was to design, test, and manufacture several fire-resistant cable joints in a limited time that could be quickly and easily installed.

**40+**

Years of operation

**35g**

Salt per liter of water

### THE SOLUTION

With many years of expertise and experience in designing and supplying products for demanding environments, TE Connectivity rose to the challenge. It implemented an accelerated development program to design, test, and manufacture a range of rugged, high-performance, and long-lasting products.

The program resulted in the development of a wide range of fire-resistant LV and MV joints for control, communications, and power cables that satisfied the customer's stringent specifications.

### THE RESULT

The resilience and reliability of these specially engineered TE Connectivity solutions are born because they are still in operation more than 40 years after they were installed. ■

#### TE Connectivity / DEUTSCH DT Family Connectors

LEARN MORE



#### TE Connectivity / DEUTSCH HD Harsh Environment Connectors

LEARN MORE







# Connectivity and sensor solutions proven in the harshest environments



## Radiation

- Cosmic rays
- Electromagnetics



## Mechanical-Stress

- Shock
- Vibration
- Pressure
- Thermal expansion



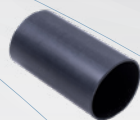
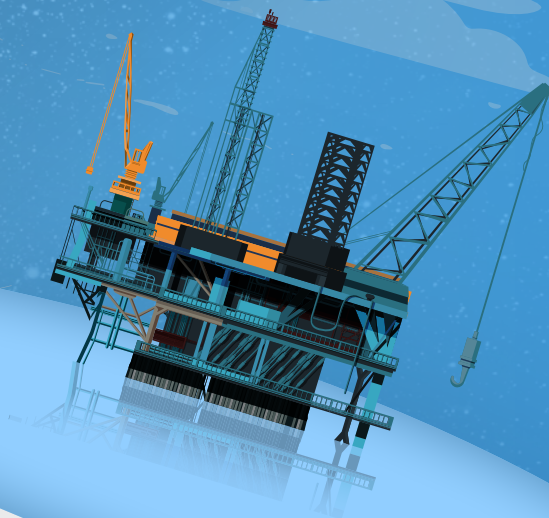
## Chemical-Resistance

- Moisture
- Saltwater
- Fuel
- Noxious gases



## Extreme Temperatures

- Hot:  $>125^{\circ}\text{C}$
- Cold:  $<-40^{\circ}\text{C}$



**MOUSER**  
ELECTRONICS



AUTHORIZED DISTRIBUTOR



# Connectors That Outperform in Harsh Conditions



**T**he industrial and commercial transportation market is extremely demanding. Heavy-duty vehicles and equipment perform some of the world's toughest jobs daily. Electric system failures are difficult to diagnose and repair quickly, and unplanned equipment downtime in the field is extremely expensive.

For decades, agricultural tractors, construction equipment, heavy-duty trucks, buses, and recreational marine vessels featured relatively basic electrical systems. In comparison, today's highly productive machines leverage complex closed-loop electronics that feature multiple joystick controls, load sensing, fuel-efficient engines with elaborate after-treatment systems, multifunction interactive displays, adaptive LED lighting, predictive automated transmissions, and real-time telematics asset tracking—and it's all standard equipment.

All this equipment represents a substantial cost to purchase, use, maintain, diagnose, and repair. Used in various harsh environments and punishing conditions, unexpected downtime typically requires mobile field service that is difficult to coordinate and schedule at best. Moving equipment from remote locations to a shop for service is often not a viable option. Therefore, prevention is key to maximizing operational uptime, equipment productivity, and safety over long service life using advanced components.

Original equipment manufacturers (OEM), tier one, specialty vehicle outfitters, and maintenance repair overhaul suppliers that serve the commercial industrial vehicle markets know that specifying and using the best electrical components for optimal 24/7/365 performance is a must. That is why so many customers around the world rely on DEUTSCH connection products from TE Connectivity.

## Why DEUTSCH Connectors?

DEUTSCH is the preferred connector product for harsh-condition use for these reasons:

- The DEUTSCH common contact system provides pin and socket contacts in five sizes, including solid and stamped and formed contact versions, along with a wide variety of plating finishes.
- An unprecedented breadth and scope of connection solutions with an extensive portfolio that includes more than 8,300 finished part numbers and applicator tooling used in most electrical systems globally.
- DEUTSCH tools and connector product knowledge. Whether it's harness-making shop or a maintenance, repair, and overhaul (MRO) facility, professionals know and count on DEUTSCH. These connectors have earned strong reliability and use with nearly all customers in commercial and industrial vehicle markets worldwide.

Common Contact System

At the center, DEUTSCH connectors are the common contact system. These contacts are available in five sizes, spanning a wide range of signal and power options from 7.5A to 100A, with matching wire sizes. DEUTSCH contacts are available in solid and stamped, and same-size contacts are interchangeable in connector cavities. Stamped and formed contacts come on a reel, while solid contacts are loose. All options provide the same high level of performance.

Common contacts provide design flexibility for TE Connectivity customers, allowing them to go through prototype build, production, and service with an equal level of performance regardless of the contact and crimp tools used.



TE Connectivity offers several applicators for crimped and formed contacts, a bench crimper for solid contacts, and crimp and repair tools for prototype and field repairs. A limited number of tools support the entire DEUTSCH connector portfolio. This provides OEMs a simpler and faster deployment of service technicians to the field, limiting machine downtime and guaranteeing production-level quality repairs.

DEUTSCH Common Contact System

- DEUTSCH Common Contacts is a series of round pins and sockets.
- Used in all ICT DEUTSCH connector series.
- Contacts of the same size are interchangeable in connector cavities.



S&F Contacts  
Size 12, 16, 20



Solid Contacts  
Size 4, 8, 12, 16, 20

Key Features	
Contact Sizes:	4 (100 amps), 8 (60 amps), 12 (25 amps), 16 (13 amps), 20 (7.5 amps)
Wire Gauge:	4-22 AWG (25.00-0.35 mm²)
Options:	Solid and Stamped & Formed
Plating:	Nickel, Gold, Tin
Use in all:	DEUTSCH ICT Products

FIGURE 1: DEUTCH Common Contact System Overview. (Source: TE Connectivity)



## Typical applications HD10/HDP20/HD30



**FIGURE 2:** Typical applications for HD10/HDP20/HD30 (Source: TE Connectivity)

These connectors are also available with multiple wire grommet options from thin-wall to thick-wall wire insulation commonly found in the heavy-duty con-ag industry. HDs are available with various backshells that provide additional protection at the back of the connector with various options for wire routing. Straight and right-angled backshells are available, with caps to protect unmated connectors.

HD10 is a smaller plastic circular connector series that offers five connector arrangements, typically used for diagnostics. The drain connector that you see to the left is a standard Controller Area Network (CAN bus) diagnostic connector used under a dashboard, where one would plug in a diagnostic tool. Dust caps are also available to protect diagnostic ports or unmated connectors.

## HD/HDP Circular Connector Series

The HD/HDP heavy-duty circular connector series delivers quick connect and bayonet connectors used on panel and bulkhead applications. HDP and HD offer identical features, with HDP being a plastic connector and HD being the metal alternative. HD connectors in five common contact sizes are available with 19 cavity arrangements offering a wide array of options for signal and power mixes.



**FIGURE 4:** HD10. (Source: TE Connectivity)

## HDP20/HD30 Series Accessories

### HDP20 Backshell and Adapters

- L015 - Threaded adapter for backshells
- L017 - Ring adapter for backshells (clamshells)
- L024 = Wide threaded adapter for "end bell" style backshell



### HD30 Backshell, Adapters and Cable Clamps

- 072 - Threaded adapter only
- 059 - Threaded adapter and cable clamp



**FIGURE 3:** HDP20/HD30 Series Accessories. (Image Source: TE Connectivity)

## DT / DTM / DTP Series Connectors



Hydraulic  
Pumps,  
Clutches,  
PTO



ABS/ESC  
Controllers



Motors &  
Gearboxes



Sensors &  
Instrumentation



Wire-2-Wire  
Coupling for  
Modular Assembly



Switches



Actuators



Solenoids &  
Remote Valves

FIGURE 5: DT/DTM/DTP Series Connectors. (Source: TE Connectivity)

### DT Connector Series

In the above image, the first photo (from left) demonstrates typical wire-to-wire and pass-through wired-to-board controller interfaces and J1939 CAN connections using DT series connectors. Next are electro-hydraulic power solenoid valve actuators on a construction machine using a two-position DT plug. The middle photo shows multiple bulkhead pass-through flange DT connectors on an agricultural machine. The next photo is a series of DT connectors on a series of marine-gauge instruments used to network them together. A DT wire-to-board connector on a truck auxiliary power control unit is shown on the far right.

DT connectors are available in pressure, humidity, and temperature sensors, along with core position and speed-sensing technology. They are sometimes available on enhanced flow and fluid quality-type sensors. Wire-to-wire is a key enabler of efficient modular assembly methods that allows for future upgrades and technology advances.

Recently, the DEUTSCH team worked with a recreational OEM that had packaging and sealing issues and tried to protect the OEM's control unit. DEUTSCH engineering provided an integrated voltage protection diode solution. A DTM product fit into its machine better than the old part being replaced. The solution provided a net-cost savings.

The DEUTSCH DT, DTP, and DTM series connectors feature rugged snap-latch IP68 sealed housings for power and signal needs throughout the machine or vehicle. In this case, DT stands for DEUTSCH transportation, while DTM is the mentor version with size 20 contacts. DTP is the power version with size 12 contacts. Rated operating temperature for the series is -55°C to +125°C. Options include mounting flanges, accessory clips, brackets, and PCB header and electronics enclosure integration.





## DT Family Modifications

- DEUTSCH modifications are used when a configuration change is desired.



Next Generation DEUTSCH DT Connectors with Snap Cap



**FIGURE 6:** DT Family Modifications. (Source: TE Connectivity)

The DT family relies on an extensive series of modifications used when part configuration changes are made to a basic connector version. They include flange adapters, styles, types, keys, colors, caps, and integrated electronic components as resistors and diodes. Approximately 300 choices are available. Many features can be aggregated into a combination modification, such as the popular CE10 modification, including the CO15 E-seal grommet plus EO4 black color housing in a PO12 enhanced seal-retention attribute.

The splitter product is the PO7 CAN splitter, a three-way, three-position part shown above in **Figure 6**, and DT detector parts with a status indicating on and off LEDs for both 12- and 24-volt applications used on several solenoid valve applications in vehicles.

The DT family requires wedge lock-in seals for both plugs and receptacles and the wedge locks used to retain the terminals in place securely. They also ensure contact alignment, secondary retention, and are sold separately.

DEUTSCH launched its DT snap-cap product line in

2019 and continues to build upon this global platform with product enhancements and variations. For example, new plating options will offer price savings over gold while maintaining performance. Next-generation designs will also continue to improve ergonomics and handling. TE Connectivity provides customization for its customers. Often this customization has broad market use, and in those instances, that can lead to further parts for the complete customer base. That's why more than 8,300 products

are in the TE Connectivity portfolio—proof that TE Connectivity has listened to customers for decades and is successful in bringing innovative solutions to market.

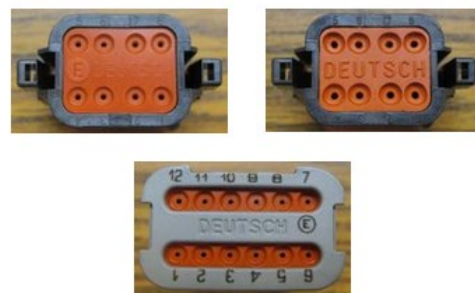
The DT 06-2 S series plugs shown on the left contain PO12 enhanced seal retention, along with an associated wedgelock, the W2 SPO12. DT series connectors are available with a reduced diameter rear grommet, referred to as an E-seal for small wire insulation found typically on ISO-grade wires and available as a modification of most DT family of products. These seals are readily identified with the E and a circle marking on the grommet or laser welded on the seal cap when outfitted with a cap.

## DT Family Wedgelocks and Seals

- DT family plugs and receptacles require a wedgelock.



- DT and DTP series connectors are available with a reduced diameter rear grommet (E-seal).



**FIGURE 7:** DT Family Wedgelocks and Seals. (Source: TE Connectivity)

## The Future

High-speed data conductivity will require greater use of unshielded twisted pair cabling, and DEUTSCH connectors are under development to address these requirements for Ethernet applications and beyond. As electric commercial vehicles come to market, DEUTSCH connectors will provide vital modular assembly and low-voltage controls and related connections for EV hardware, from inverters to battery thermal management controllers. DEUTSCH products are 48-volt capable, so they are ready for emerging applications.

“TE Connectivity has listened to customers for decades and is successful in bringing innovative solutions to market.”

The DEUTSCH connection system family of products is used for some of the toughest connection jobs in harsh environments. Trusted by OEMs, maintenance, repair, and overhaul organizations for more than 40 years, TE Connectivity is continuing the DEUTSCH tradition and is adding capacity in North America, China, and Europe. This greater localization and global availability support customers through all economic fluctuations ■



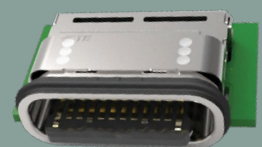
### TE Connectivity MATEnet Automotive Ethernet Cable Assemblies

LEARN MORE



### TE Connectivity IPX8 Waterproof USB Type C Onboard Receptacle

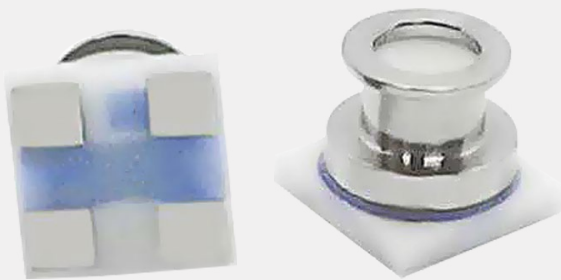
LEARN MORE



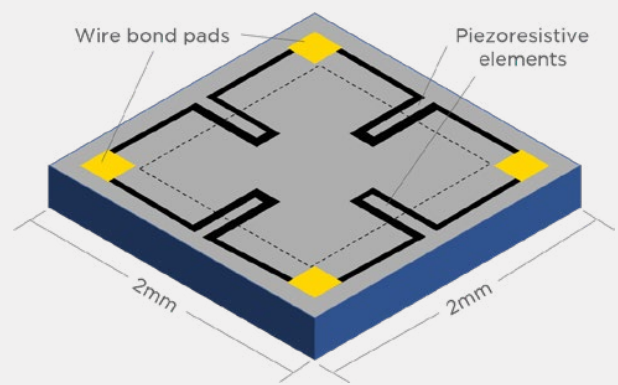


# Sensors for Corrosive Environments Face Challenges

**F**rom factory floors to fitness trackers, sensors play a crucial role in the ever-evolving demands to meet tomorrow's expectations. Consumer and industrial devices contain a growing number of sensors driven by wireless and Internet of Things (IoT) technology's widespread use. Advances within sensors are vital to these markets—ultra-compact, low power, high accuracy, digital, and harsh media-resistant sensors must be designed to meet and surpass these performance challenges.



**FIGURE 1:** The MS5839-02BA is an ultra-compact pressure and temperature sensor optimized for applications where chlorine and saline are present. (TE Connectivity)



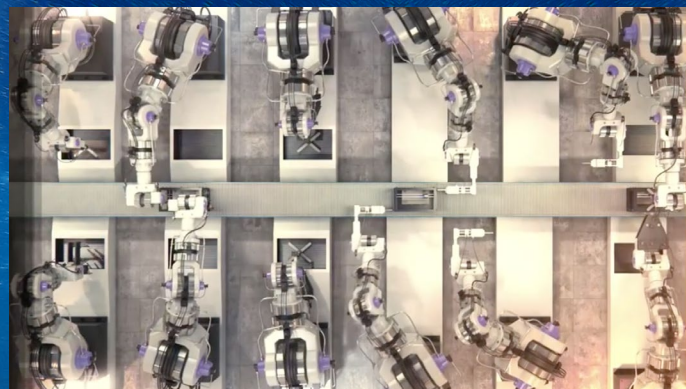
**FIGURE 2:** MEMS pressure die. (TE Connectivity)



Pressure sensors are in various markets such as automotive, industrial, medical, and consumer products. Our world is becoming more connected and smarter. Sensors are also in applications and environments that are not so friendly. Many of these applications require sensors designed to withstand exposure to corrosive and hostile chemicals. Often these chemicals exist in the medium that the sensor is trying to measure. The chemicals will have direct contact with the sensor itself. Modern sensors must withstand and resist attacks by these chemicals to provide reliability and long service life. One example is the use of a pressure sensor in a swimming watch. These watches are regularly exposed to water containing chlorine as either a dissolved gas (swimming pool) or in ionic form (ocean water). Chlorine is a strong oxidizer that quickly corrodes most metals and does irreversible damage to the product.

### Operation of a MEMS Pressure Sensor

A typical structure of a piezoresistive pressure sensor is a planar silicon diaphragm formed by chemical or dry etching. Piezoresistors are placed near the edge of the membrane and within the sensor's linear operating range (**Figure 1**). When applying pressure to the micro-electromechanical system (MEMS) element, it deflects much like a trampoline (**Figure 2**). The deflection causes a strain in the piezoresistive elements, and they change their resistance value in proportion to the deflection (**Figure 3**). In practice, four piezoresistors are used, arranged in a Wheatstone bridge configuration, to maximize signal levels and

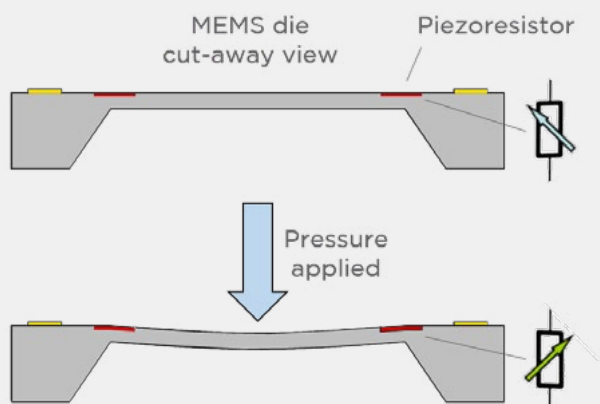


**TE Connectivity M12 X-Code Field-Installable Connectors**

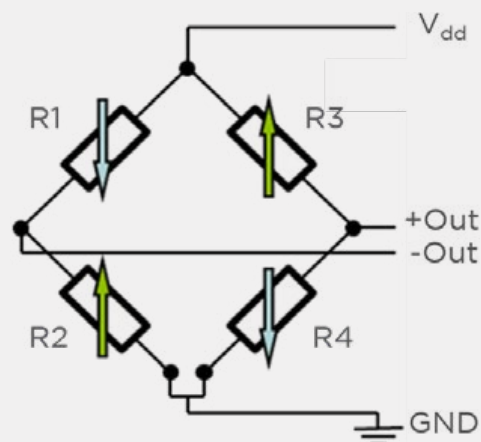


provide a degree of common-mode rejection to undesirable noise (**Figure 4**). One way to detect problems with the sensor is to look at the output signal offsets with no pressure applied. If operating correctly, the differential output should be 0V. If the output is not 0V, it's an indication of a problem with the sensing element. Corrosion from aggressive chemicals can affect how the piezoresistive components, interconnects, and wire bond pads function. The corrosion can introduce offsets in the output signal and erroneous data from the sensor.

The MEMS sensor element signal is connected to a complementary metal-oxide-semiconductor (CMOS) application-specific integrated circuit (ASIC) where it is compensated for temperature linearity and other errors, then amplified and digitized. This digital data is then formatted for accessible communication to a master microprocessor via I<sup>2</sup>C or SPI protocol.

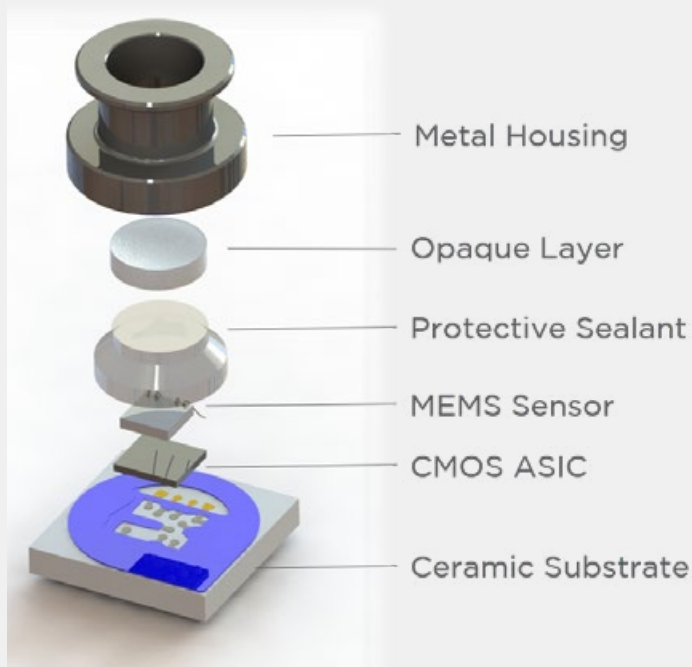


**FIGURE 3:** Die reaction to pressure. (TE Connectivity)



**FIGURE 4:** Wheatstone bridge. (TE Connectivity)





**FIGURE 5:** Packaging and environmental isolation of the MEMS sensing element and the CMOS ASIC is essential for the pressure sensor's reliable functionality. (TE Connectivity)

### Packaging for Protection

Packaging and environmental isolation of the MEMS sensing element and the CMOS ASIC is essential for the pressure sensor's reliable functionality. They protect the chip and, at the same time, allow connectivity to the outside world. All sensors must be physically in contact with the medium or phenomenon they are measuring. Also, they must be connected to the electronic system that is using the data provided by the sensor (**Figure 5**).

### Unique Technology for Harsh Environments

TE Connectivity has developed miniaturized pressure sensors suitable for exposure to harsh and corrosive environments, including strong oxidizers such as halogens—fluorine (F), chlorine (Cl), bromine (Br), iodine (I). These types of harsh environments exist in automotive, medical, and personal wearables markets.

Chlorinated water in swimming pools presents a similar and related problem for wearables applications. TE Connectivity's pressure sensors are used as altimeters for sports watches used by triathletes or depth sensors in dive computers. Without appropriate device packaging and protection, the sensors can corrode and fail when used in swimming pools or seawater, both rich in dissolved or ionic chlorine (**Figure 6**).



**FIGURE 6:** Sports watch. (TE Connectivity)

#### TE Connectivity 369 Shielded Rectangular Connectors

[LEARN MORE](#)



#### TE Connectivity / Polamco Swept Elbow Backshells

[LEARN MORE](#)

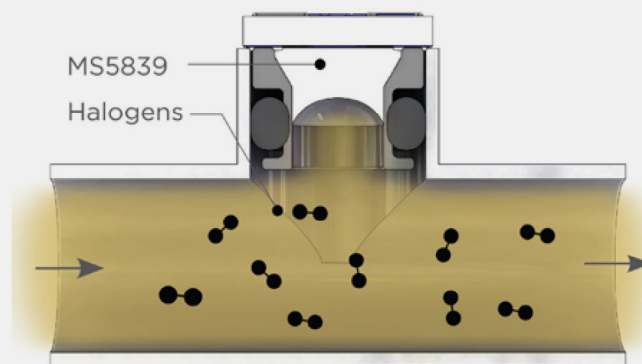






## Testing and Validation

Technology and design developed by TE Connectivity have been tested with the sensor package exposed to saltwater, chlorine water, and diiodomethane (methylene iodide, MI) gas. Diiodomethane exposure has been shown as the harshest test. The figures below illustrate the drift in signal output of the sensing element concerning the diiodomethane and chlorine water exposure. The drifts are considered very limited. Additionally, the drift in offset can mainly be explained through the presence of the humid environment rather than the diiodomethane in it. Another accelerated life test, at 85°C and in 85 percent relative humidity (RH), showed the same drifts in offset and span, as plotted alongside the diiodomethane results.



**FIGURE 7:** Chlorine test results. (TE Connectivity)

### CHLORINE TESTING (FIGURE 7)

#### Test Conditions and Procedure:

- Samples fully submerged in a chlorine solution at 60°C for 6 hours
- Dried in a temperature/humidity chamber at 60°C and 60% RH for 18 hours
- Test and record data
- Repeat steps 1-3 until 40 cycles are completed
- Repeat steps 1-4 at increasing levels of chlorine concentration (from 20ppm to 100ppm)
- Samples were compared with standard packaged sensors (not enhanced for harsh media).

### TE Connectivity M12 Industrial Ethernet Cable Assemblies

LEARN MORE





## Chlorine exposure test

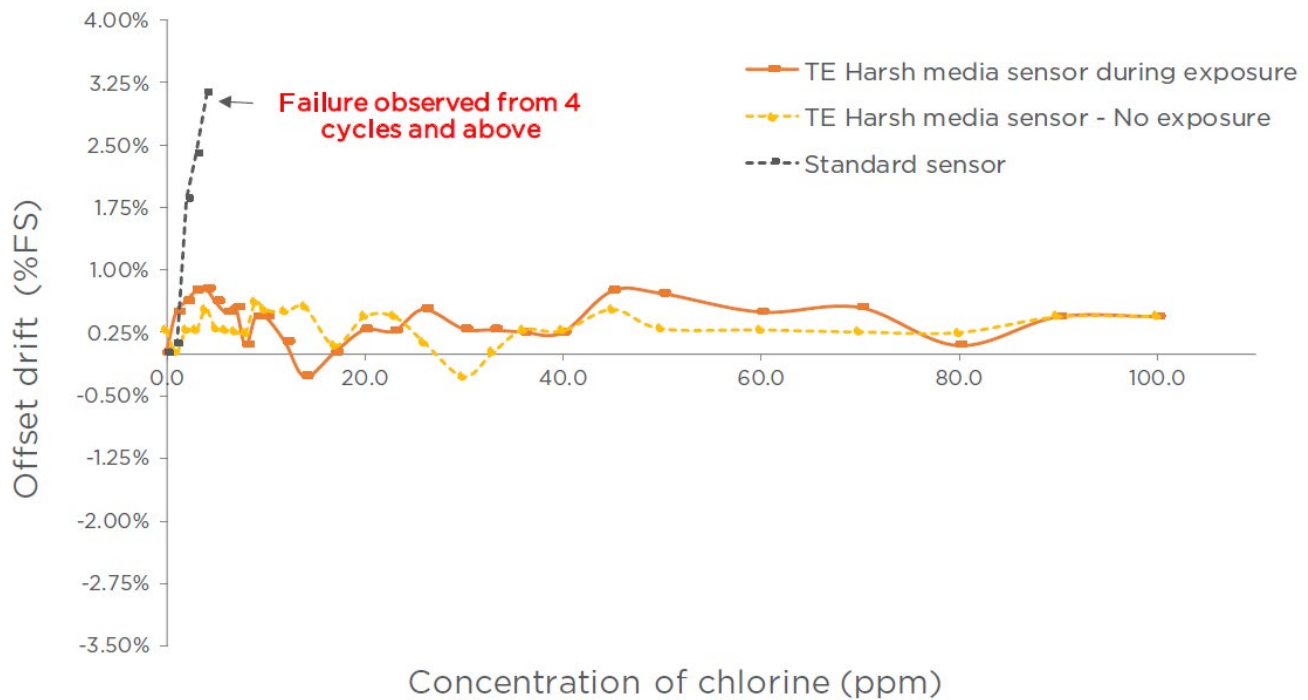


FIGURE 8: Diiodomethane test results. (TE Connectivity)

### DIIDOMETHANE TESTING (FIGURE 8)

#### Test Conditions and Procedure:

- Samples placed in a chamber:
- 95 percent relative humidity
- 85°C constant temperature
- Total exposure time-500 hours
- Samples tested at 48, 170, 300, and 500 hours
- Samples were compared with standard packaged sensors (not enhanced for harsh media).



#### TE Connectivity M12 X-Code Field-Installable Connectors

LEARN MORE




### Conclusion

TE Connectivity's package design and assembly procedures provide a sensor with enhanced resistance to corrosive chemicals and atmospheres. These design and assembly procedures provide customers with added confidence that TE Connectivity sensors will better resist failure or malfunction in applications in corrosive environments. ■

# Heat-Shrink Cable Accessories are Proven Technology

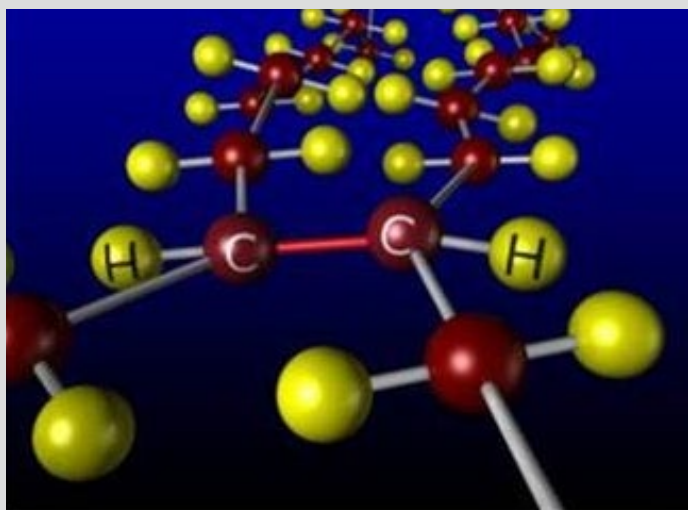
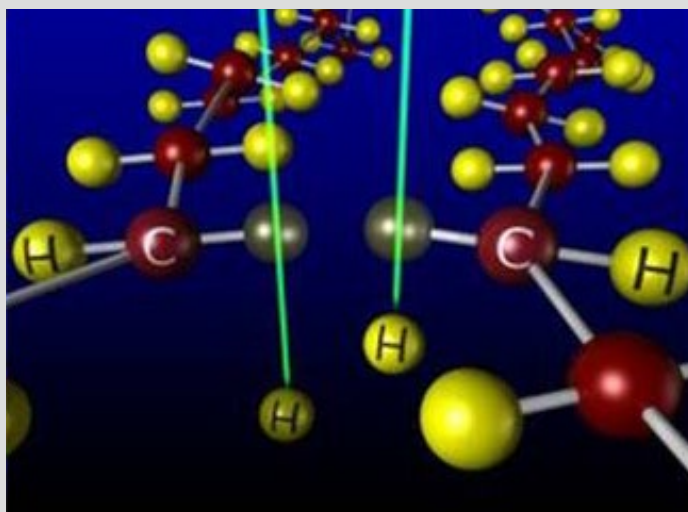
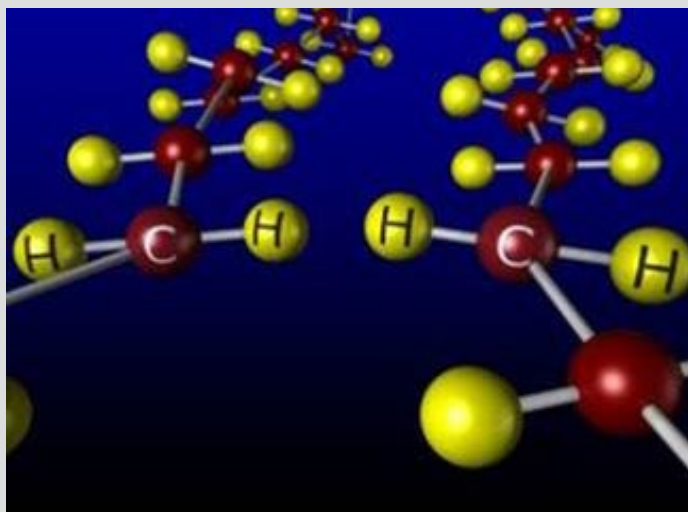
**Dr. Frank Drumm**, Global Product Director, Senior Director Product Management



Heat-shrink cable accessories have been successfully used for more than 40 years in low and medium voltage applications and the lower range of high-voltage applications. The continuous development of polymers and elastomers has led to steady improvements.

**M**ore than 40 years ago, cross-linked polyethylene (XLPE) cables started to replace step-by-step oil-impregnated paper cables in low voltage (LV) and medium voltage (MV) distribution networks. In parallel to this change in the cable network, heat shrink cable accessories have been introduced to the market and were an ideal solution for both joining and terminating paper and polymeric cable technologies.





**FIGURE 1:** Cross-linking process. (TE Connectivity)

Although the majority of applications were for typical settings—such as the connection of standard cables and terminations—utility and industrial applications developing needs went beyond everyday environments, such as:

- High UV requirements
- Heavy pollution areas
- Salt fog environments
- Oil barrier properties
- Flame retardant properties
- Fire resistance and system integrity
- Gamma radiation resistance
- Functionality under a loss of coolant accident (LOCA) conditions

### Heat-Shrink Technology

The base material for the heat-shrink technology is polyethylene-based molecule chains. These are subjected to cross-linking processes such as chemical or radiation cross-linking. In a radiation cross-linking process, multi MeV electron accelerators are used, where electrons are accelerated to gain such high energy that they can initiate the cross-linking process (**Figure 1**). In this case, hydrogen atoms are separated from the polyethylene chains, and the carbon elements between adjacent polymer chains can establish a connection between the two polymer chains. The higher the number of connections along the chain will be established, the higher the cross-linking rate will be. With an increased cross-linking rate, the material usually gets more rigid.

One key benefit for heat-shrink products is this cross-linking effect in the material that causes these products to lose their melting properties. Products can now be heated to temperatures beyond the crystalline melting point without melting. Above this temperature, heat-shrink products such as extruded tubes or molded parts (breakouts and end caps) can be expanded and formed in shape and remain in this position. In contrast, the temperature will decrease below the crystalline melting point again.

Suppose the products are heated up again beyond the crystalline melting point, which typically happens during the installation by a gas torch or hot air gun. In that case, the products will shrink again to their original shape. This kind of memory effect remains valid for the entire lifetime of the product. It allows an almost unlimited shelf life for the products under specific storage and warehouse conditions.

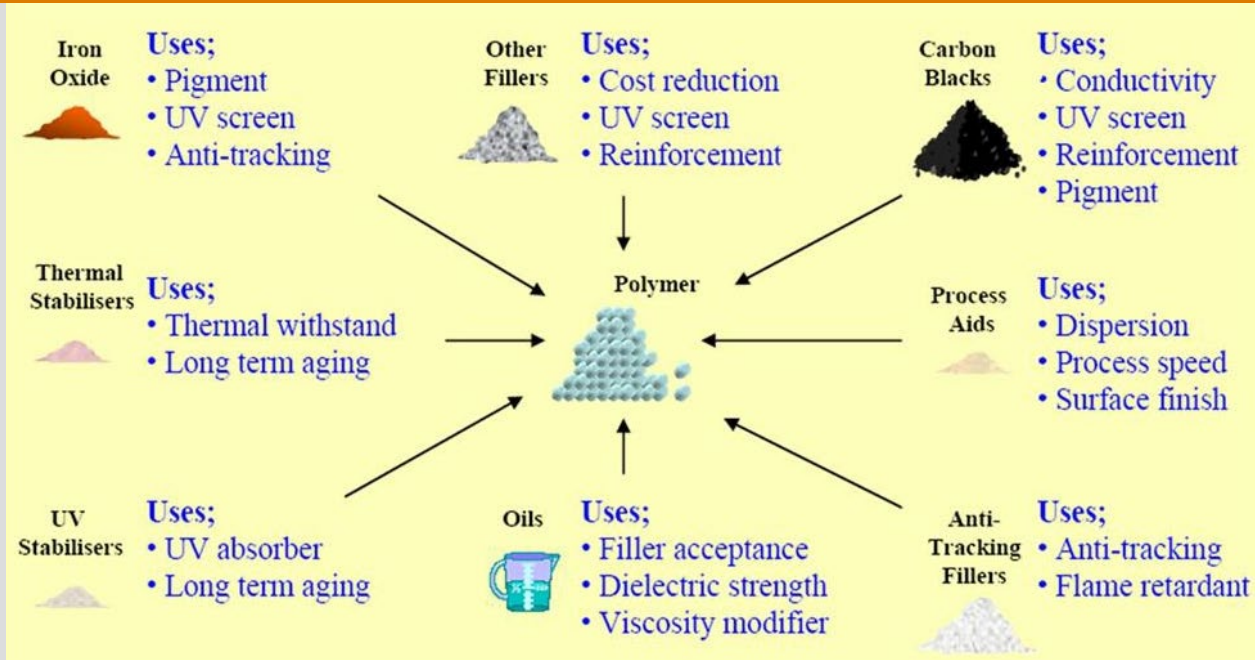
## Material Modification

By using additives to the formulation, characteristics of the tubes or molded parts can be modified. The chemical formulation is the key element to achieve features required for various industrial applications and ensure that it can be processed in a cost-efficient manufacturing process.

**Figure 2** displays a general overview of the different ingredients used to formulate heat shrink materials to gain the desired properties, depending on the final product.

As a consequence, the formulation of a material can be pretty complex. Without adversely impacting each other, it needs to be assured that the combination of all the different materials will combine functions including:

- Mechanical properties
- UV resistance for outdoor applications
- Electrical properties
- Oil blocking characteristics
- Tracking and erosion
- Radiation resistance
- Flame retardant /fire resistant properties
- Electrical stress control
- High UV requirements



**FIGURE 2:** Potential Ingredients to formulate heat-shrink materials with the desired properties. (TE Connectivity)





**FIGURE 3:** Long-term UV Materials testing in a desert area and termination in service in a high UV environment. (TE Connectivity)

Outdoor heat-shrink materials are used in different areas of the world with different UV radiation levels. The most challenging UV requirements might be found in desert environments where insulation materials are consistently subjected to high UV radiation.

With increased elevation, UV radiation also increases. A typical value is that for every 500m of altitude, the UV radiation increases by about 3.5 percent.

Test sites in desert areas were used to analyze different formulations to prove their long-term UV requirements (**Figure 3**). For accelerated UV aging tests, UV lamb (Xenon) testing for lab simulation has become standard. EMMAQUA® or Weather-Ometer® testing has been used as an alternative to verify materials properties.

## Environments Demanding Oil Blocking Characteristics

Environments where oil-blocking characteristics are required can be seen as another harsh environment. A typical application would be using a cable accessory in a joint or termination for oil-impregnated paper cables, either in a paper-to-paper cable connection or today's more common paper-to-polymeric cable joint, a so-called transition joint.

Without oil-blocking characteristics, the oil-impregnated paper cables would face a migration of the oil and dry out over time. As the oil with its good insulation characteristics plays a vital insulation role, its loss would constantly lead to the loss of the cable's electrical insulation property, which finally could end up in a breakdown of the insulation and a failure of the cable accessory.

“ The most challenging UV requirements might be found in desert environments where insulation materials are consistently subjected to high UV radiation. ”





This function usually needs to be maintained for a service life of 40 years under maximum operating temperatures of the cable conductor in the range of 70°C. Heat-shrink materials with oil-blocking characteristics can also be used in the oil and gas or petrochemical industry applications, where oil-blocking features are required.

### Flame-Retardant Heat-Shrink Cable Accessories

Specific environments such as railway, offshore applications, government buildings, or power-plant applications have requested flame-retardant cables and cable accessories requirements. Typical standards need to be met by cables. The standards are IEC-60332 and IEEE-1202 and usually only refer to cables. However, it

has become common practice and industry-understanding to qualify cables with cable accessories to prove their suitability.

During the IEEE-1202 test, the flame is applied to the cable or cable with accessory for 20 minutes. After this time, the flame will be removed, and the product characteristics need to assure that the flame will self-extinguish. The damaged area or flame propagation caused by this test shall be less than 1.5m (such as in a vertical tray application).

The right material choice, which is usually combined with a particular wall thickness in the heat-shrink tube, will result in a flame-retardant heat-shrink tube. Shown is a typical arrangement where cables with flame-retardant heat-shrink tubes are subjected (**Figure 5**).



**FIGURE 4:** Oil barrier tube used in a 3-core paper cable joint. (TE Connectivity)



**FIGURE 5:** Flame-retardant heat-shrink cable accessories in a vertical tray arrangement. (TE Connectivity)



## Fire-Resistant Heat-Shrink Cable Accessories

Despite flame-retardant requirements, specific industry requirements require fire resistance properties, where cable and accessories need to maintain system integrity up to 180 minutes. This request is usually combined with low-smoke zero-halogen (LSZH) materials. However, low smoke zero-halogen properties on their own will not give the properties needed for heat-shrink cable accessories to achieve the system integrity requirements.

As a solution, the heat-shrink cable accessories are combined with additional protective layers acting as a barrier against the fire application and preventing the flame from penetrating the inner insulation. A typical standard where test procedures for fire-resistant cable and cable accessories (**Figure 6**) are defined as IEC-60331.



**FIGURE 6:** Fire-resistant joint before, during, and after a fire-resistant test. (TE connectivity)

## Heat-Shrink Cable Accessories for Nuclear Power-Plant Environments

One of the most severe environments for cable accessories is applications in the containment area of nuclear power plants, which would include function under accident conditions. One of the most severe accident conditions is a loss of coolant accident (LOCA).

For more than 40 years, Raychem class 1E safety-related cable accessories are in use, which in case of an accident can support, such as the emergency shutdown of the reactor, containment isolation, and prevent the release of radioactive material.

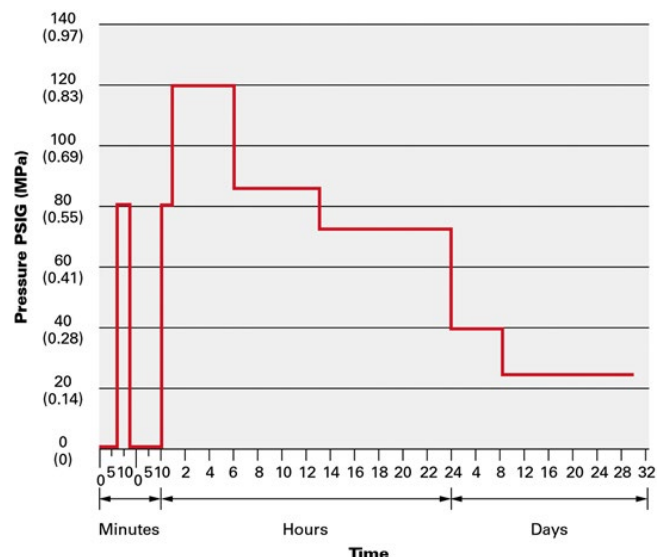
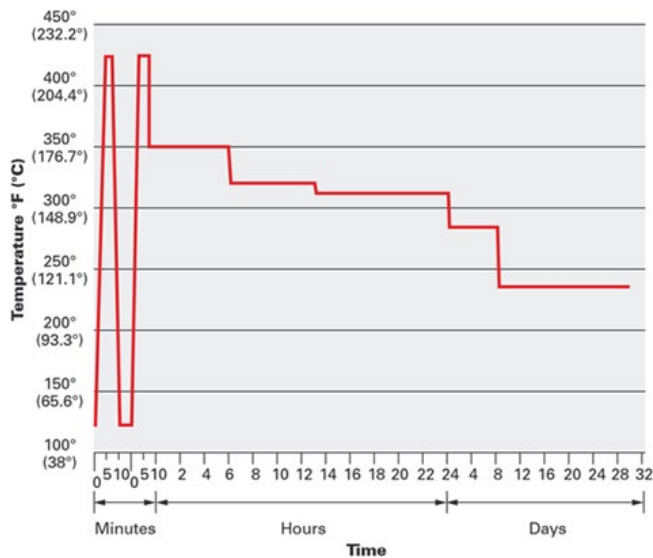
A full LOCA qualification simulates the severe accident conditions and therefore has to cover the following elements:

- Simulation of aging (thermal and gamma-radiation)
- Radiation exposure during the lifetime
- LOCA—accident simulation with high radiation, temperature and pressure profile during saturated steam conditions, and chemical spray testing

The newest generation of nuclear power plants, such as AP1000 or the European Pressurized Water Reactor (EPR), is built for a 60-year service life. Therefore, the qualification process's thermal aging was already chosen to simulate a 60-year lifetime at a constant temperature of 90°C, which typically represents the maximum conductor temperature in power cables.

Although the products installed in the containment area are subjected to nuclear radiation, a 40/60 years gamma radiation needs to be simulated. Also, high gamma radiation can occur during the accident, which needs to be taken into account and tested during the qualification process. Typical values can exceed 200Mrad of Gamma radiation.

During the accident simulation, the heat-shrink cable accessories installed on cables will be taken into a vessel, where the temperature and pressure occurring during an accident will be simulated. A typical profile for a 30 days test on cable accessories is shown below, with maximum temperatures beyond 200°C and a maximum pressure beyond 0.8Mpa over normal environmental pressure.



## Conclusion

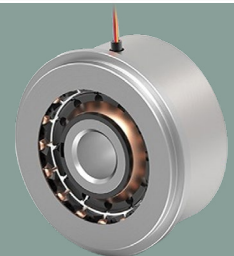
Heat-shrink cable accessories have been successfully used for more than 40 years in low-, medium-, and high-voltage networks. One of the challenging areas they are in use is harsh environments with, high UV requirements, heavy pollution, salt fog environments, and areas where oil barrier, flame retardant, or even fire-resistant properties are needed. Nuclear environments are one of the most severe environments where heat shrink cable accessories are in use today and have to fulfill safety-related functions in accident conditions.

The investigation in heat shrink material formulation started more than 50 years ago has been the foundation to establish optimum formulations in heat shrink cable accessories to service properly in these harsh environments. Zero halogen heat shrink products can be combined with additional fire protection materials to achieve system integrity for up to 180 minutes to achieve fire-resistant properties. ■

**FIGURE 7:** Temperature and pressure profile used to qualify heat-shrink cable accessories for use in nuclear power plant environments. (TE Connectivity)

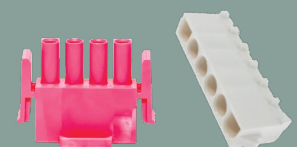
### TE Connectivity Industrial Resolvers

[LEARN MORE](#)



### TE Connectivity / AMP Connectors Universal MATE-N-LOK Pin & Socket Connectors

[LEARN MORE](#)





# How DO YOU Define Harsh Environment?

Harsh environments are found everywhere. Sensors, connectors, and relays must be able to withstand dirt, moisture, salt, and vibration endemic to all harsh environments. TE Connectivity delivers reliable products capable of withstanding a variety of harsh environments.

[mouser.com/te-connectivity-harsh-environments](https://mouser.com/te-connectivity-harsh-environments)



AUTHORIZED DISTRIBUTOR

