Design Talk - Harsh Environments

An application does not have to be in the arctic or a desert waste to be considered operating in a harsh environment.

**Instrumentation and Tough Environments**
By Gordon Greathouse, Automation Products Group, www.apgsensors.com [1]

Dealing with tough environments is a normal part of nearly any instrumentation installation. Decisions must be made regarding protection from outside environmental elements such as water, dust, extreme heat or cold. Questions must be answered concerning installations in corrosive environments, as well as hazardous locations.

Though the list of “tough environments” is long and lengthy, what follows is a brief discussion on some of the more common considerations when installing instrumentation in such environments.

Wet/Damp Areas
Protection of electronics in wet/damp areas is vital to the life cycle of the instrumentation involved. Considerations include:

1. Determine whether the instrumentation and associated equipment (junction boxes etc...) is rated for use in a wet environment. What NEMA and IP ratings are needed?
2. Are the instruments sealed for protection? Make sure there will be no exposed electronics.
For example, to protect the electronics in a submersible pressure transmitter a desiccant cartridge would be attached to the vent tube in the cable which would draw out moisture that could cause a shift in the sensor output.
3. Determine that there are no static discharge issues that would damage electronics.

Dusty/Dirty Areas
Dusty and dirty environments can exist in any instrumentation application. Contamination of electronics can alter or ruin the functionality of instruments. Considerations include:

1. Determine whether the instrumentation and associated equipment (junction boxes etc…) is rated for use in a dusty/dirty environment. What NEMA and IP ratings are needed to protect the electronics and wiring from dust ingress? If the dust is combustible, hazardous location approvals are needed.
2. If installing photoelectric, laser or ultrasonic instrumentation, be aware excessive dust will alter their performance.
3. Extreme temperatures are often associated with dusty/dirty environments. Electronics and bonding materials used in components are affected by temperature. Be aware of the operating temperature limitations of your equipment.

Corrosive Environments
Instrumentation used in industry is often installed in corrosive environments. A corrosive environment may include gaseous contaminants like ammonia, hydrochloric and sulphuric acids to name a few. Dusty and humid areas can also be considered corrosive environments. Considerations include:

1. Corrosive chemicals usually attack instrumentation through plumbing leaks, fumes and vapors. Electronics and wiring may corrode and lead to instrument failure and loss of output information.
2. Exterior housing and any electronics must be protected from chemical exposure. Proper chemical compatibility with instrumentation materials is crucial.
3. There may be circumstances when a chemical attack on an instrument’s metal surface would cause contamination, such as in a clean room application. Instrumentation that is constructed from materials that are metal-free and resistant to the chemicals being used should be considered.

Hazardous Locations
The National Electrical Code (NEC) defines hazardous locations as those “where fire or explosion hazards may exist due to flammable gases or vapor, flammable liquids, combustible dust or ignitable flyings.”

The NEC has defined hazardous locations into three classifications:
Class I: Presence of flammable gases or vapors.
Typical Class I locations: gasoline refineries, spray finishing areas, natural gas plants.

Class II: Presence of combustible dust.
Typical Class II locations: Grain elevators, flour and feed mills, plants that manufacture metal powders from magnesium or aluminum.

Class III: Easily-ignitable fibers or flyings.
Typical Class III locations: textile mills, plants that cut wood and create sawdust or flyings.

Things to consider when installing instrumentation in hazardous locations:
1. Make sure the instrumentation has the proper approvals (CSA, FM etc…) and is approved for use in the proper hazardous location class.

2. Determine under what kind of conditions are hazards present. Normal or abnormal conditions. This will determine whether the instrumentation requires a Division 1 or Division 2 classification.
Division 1: Hazards present under normal conditions.
Division 2: Hazards present under abnormal conditions.
Note: If you are unsure, choose Division 1

3. Does the instrumentation need to be explosion proof and installed with rigid conduit, or will IS (intrinsically safe) approvals and installation with a barrier be acceptable? Installations with a barrier require incendive wiring and are acceptable in both Division 1 and 2. Non-incendive wiring is acceptable in Division 2, but a current limiting device is still required.

This discussion only covered a few basic areas of tough environments and the issues to consider when choosing and installing instrumentation equipment. Each area is worthy of its own discussion, and this article is intended to provide starting point when considering electronic installations in these tough environments.

Cable Fables

By Tom Collen, Northwire, www.northwire.com [2]

Confusion and Misconceptions about NFPA-79

Confusion abounds about the “new” NFPA (National Fire Protection Association) regulations pertaining to UL-recognized (AWM style) cable. Long after the practice became widespread, inspectors became aware of the ubiquitous use of AWM (Appliance Wiring Material) style cables in machine interconnecting sensors, actuators, switches and other components—often as part of premolded connector assemblies.

The 2007 change to the NFPA-79 electrical code states that AWM-style single-conductor wire or multi-conductor cable is not permitted on machinery unless it is part of a UL-listed assembly. In other words, machine wiring requires UL-listed cable. Clearly, UL-listed cable has been available for many years. So the real question is, which UL listing is appropriate for particular applications?

Herein lies the confusion—speculating about the intent of the code change. Different interpretations of NFPA-79 have generated articles in trade publications and on Web sites, in white papers and in discussions and debates.

A Few of the Fables
Some integrators and other customers are being misled about what is the best cable for their application because of confusion, misinformation or lack of knowledge about the code changes among cable manufacturers. This is apparent from just looking at blogs and forums on the subject. However, the mystery about NFPA-79 isn't necessary. A careful reading of the code by a discerning cable expert reveals clear guidelines. Collen addresses specific misconceptions:

“AWM is strictly forbidden. If AWM is marked on the cable, I cannot use it.”
Not true. AWM is permitted in several cases. Table 12.2.7.3 of the NEC says: “... Exception: when part of a listed assembly suitable for the intended application, Type AWM shall be permissible.”

In another notable exception, it is permissible to use cable that has multiple listings and recognitions—listed type TC (Tray Cable) and AWM-recognized cable, for example. In this instance, the printed legend on AWM may be ignored in deference to the cable's listing type, TC. UL (or other agency) listed cables are required.

“The cable must be MTW.“
A fable. Although table 12.3.1 of the NEC specifically lists other types, such as UL-listed conductor types THHN, THW, THWN, RHH, and permitting MI (Mineral-Insulated wire), NFPA-79 allows any listed conductors and cables. Table 12.2.7.1 states: “Other listed conductors and listed cables shall be permitted.” This statement is not new. It has been part of previous NFPA-79 standard editions. The point of the NFPA-79 change was to disallow AWM-only types that were inappropriate to the installation. Other UL-listed types, such as UL type TC must be used under their own rules. In the example above, the use of TC is governed by NFPA-70, article 336.

“The cable must be 600V.”
A rumor. NFPA-79 does not specifically address 600V cable insulation rating. Table 12.3.2 specifies insulation thickness for 600V-rated conductors according to UL 1063—a specification for MTW (Machine Tool Wire). Some have interpreted that specification to infer a 600V rating requirement for the cable. UL 1063 does not define cable types such as low-voltage communication or instrumentation cables, nor does NFPA-79, section 12.3, “Insulations”—perhaps a carry-over from the standard originally released in 1943. The section needs to be revised (e.g., applies to power circuits only) to eliminate inference and differences of interpretation.

“The smallest conductor size allowed is 22 AWG.”
Fiction. This interpretation derives from NFPA-79, section 12.3. However, conductor sizing is subsequently discussed in section 12.6, which states: “Conductors shall not be smaller than 14 AWG for power circuits unless otherwise permitted in 12.6.1.1 or 12.6.1.2.” These sections define exceptions allowing 16 AWG and 18 AWG under certain conditions. Section 12.6.4 (1) allows 24 AWG for electronic PLC I/O or static control circuits in a raceway (30 AWG allowed in a multiconductor cable or cord). Section 12.6.4 (2) allows 26 AWG or larger if the

wires are inside an enclosure (30 AWG allowed in a multiconductor cable or cord). These are notable exceptions.

“Cords must be 600V.”

A falsehood. Section 12.8.1 states that cord types “… suitable for their intended use …” listed in table 12.8.2. This table includes numerous SJ types, which are 300V-rated cords.

More than MTW

One wire and cable manufacturer has suggested using MTW to ensure compliance with NFPA-79. MTW is a UL-listed 600V-rated single conductor cable with construction and properties that are governed by UL 1063—the UL standard for Machine Tool Wires and Cables. MTW is generally a larger cable suitable for use inside panels or pulled through conduit. It is constructed with larger copper conductors and contains more plastic than a 300V cable. Many sensor, switch and actuator designs use multi-conductor cables, often employing quick disconnects. One of the most common disconnects found in industrial automation is the M12 connector, which has voltage ratings ranging from 30 VDC to 250 VAC and 300 VDC. Lower voltage ratings and smaller cables generally translate to lower cost. A better choice for interconnection of low-voltage controls and instruments is UL-listed ITC/PLTC (Instrumentation Tray Cable/Power Limited Tray Cable).

The ITC designation was added to the NEC in 1996 to meet contemporary demands for small-diameter, lower-cost cable for industrial environments and process control and instrumentation. The newer ITC specification is simpler to interpret than the older UL 13 specification. The NEC code change made it permissible to use a wiring method that had been used effectively for years on offshore oil rigs, an extremely rugged environment. By definition, ITC cable meets all the requirements for PLTC; hence the dual rating.

ITC is defined in NEC article 727, which classifies cable for remote instrumentation and controls in industrial environments under certain conditions. Most notably, article 727 specifies 300V insulation-rated cable, limited to applications of 150V or less with a 5-Amp maximum current. The conductor is limited to sizes not smaller than AWG 22 and not larger than AWG 12.

Careful, precise reading of NFPA-79 can affect a company's bottom line by helping to ensure you select the appropriate allowable cable that meets your need without unnecessarily exceeding it. ITC/PLTC cable is a more economical choice for industrial environments, process control and instrumentation applications. Other acceptable and lower cost cables worthy of consideration for these applications include CM (for communications cables) CL2, PLTC and SJTO (for power cords). This cable construction and testing are described in UL 2250.

A Bonus: Exposed Run

NEC 2008 article 725.154(D) hazardous (classified) locations (2) and article 727.4(5) allow ER (Exposed-Run) listed cables to be installed: “The cable shall be continuously supported and protected against physical damage using mechanical protection such as dedicated struts, angles or channels. The cable shall be secured at intervals not exceeding 1.8 m (6 ft.).” UL 13 PLTC and UL 2250 ITC-listed cables also may have an ER listing. These cables must pass the same crush and impact tests applied to metal-clad cables, (UL 1569 crush and impact tests). UL 13 PLTC-ER-listed cables meet the requirements of NEC article 725.154(D), and cables UL 2250 ITC-ER-listed cables meet the requirements of NEC article 727.4(5). These provisions can result in significant freedom for installers and system designers and significant cost savings compared to armored or conduit-installed cables. For 600V circuits, type TC-ER is also available.

Knowledge Is Power

NFPA-79 is ambiguous and potentially confusing to the casual reader or one who is tricked by others' interpretations of this important document. Copies of NFPA-79 are available for purchase from www.nfpa.org [3]. Cozy up with a copy—read and learn. At least closely examine the sections that apply to your application. True understanding of the code helps to ensure that you will not be influenced by hearsay and hyperbole. True understanding also helps to ensure that you will make well-informed decisions about what is required for your cable situations.

In Aesop's fable about the boy who cried wolf when no emergency was at hand, the villagers stopped believing him. The moral of the fable is to beware of those who cry wolf about NFPA-79.

Tough Environments Demand Tough Cables and Components

By Brian Shuman, Belden, www.belden.com [4]

Electronic cables and connectivity components used in Ethernet networks in manufacturing, processing and utility plants, face environmental challenges unheard of in commercial office settings. On the plant floor, mission-critical communications systems are routinely exposed to dust, moisture, oil and corrosive chemicals, as well as extreme temperatures, machine vibration and, often, high levels of EMI/RFI interference.

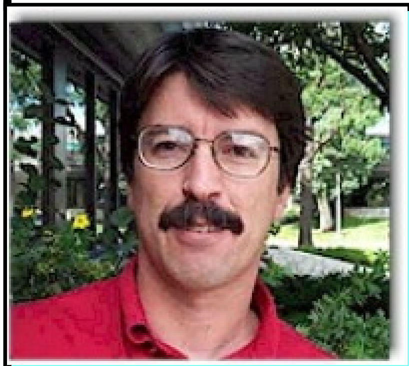
Commercial-grade components are not tough enough to withstand these harsh conditions on a sustained basis. In fact, using commercial off-the-shelf (COTS) Ethernet products in these harsh environments poses a risk of physical layer damage, which can result in incremental performance degradation, intermittent operation, and even catastrophic network failure.

Only ruggedly constructed industrial-grade cabling, switches and connectivity components can provide the protection needed to ensure the reliable performance of the communications infrastructure over time, averting signal transmission problems that can lead to excessive downtime, costly repairs, lost productivity and reduced safety.

For Industrial Ethernet systems, designers should select:

• Heavy-duty, all dielectric, indoor/outdoor-rated optical fiber cabling in single-mode and multimode constructions.
• Industrial grade Cat 5e or Cat 6 cables with heavy-duty oil- and UV-resistant jackets. Some cables feature a bonded-pair construction in which the conductor insulation of the pairs is affixed along their longitudinal axis to ensure consistent conductor concentricity to prevent any performance-robbing gaps between the conductor pairs during installation and use.
• Upjacketed and armored cables for more extreme environments. Continuous flex cables for use in continuous motion machine systems. Low smoke zero halogen cables, waterblocked cables and burial cables.
• Cables designed specifically for use with leading industrial automation networking and communications protocols, such as EtherNet/IP (ODVA), Modbus TCP/IP, ProfiNet and Fieldbus HSE.
• Industrial grade connectivity components and active networking devices, including: IP 67- or IP 20-rated UTP or FTP cord sets, modular jacks and plug kits, connectors, adaptors and ruggedized switches of every type.

In industrial plants, maximum productivity with minimal downtime is always a key goal, and 24/7 network performance and reliability are critical to achieving that goal. If a switch or cable fails, the cost of its replacement and repair represents only a tiny fraction of the overall costs associated with production outages and downtime. So if you are responsible for designing and specifying a plant floor control system, remember to ask: Are my Ethernet cables and connectivity hardware built tough enough?



Challenge: Data recording in Harsh Environments
by Ken Owens, Conduant, www.conduant.com [5]

In high speed, long duration data recording applications, traditional hard disk drives always become problematic when the project calls for ruggedization of the solution. Truck mounted, airborne and field implementations bring vibration, shock and dust contamination into play. These harsh conditions, at some point, rule out traditional hard drives as a viable storage option. So, the solid state drive (SSD) enters the picture. With no moving parts, the SSD is impervious to vibration, if properly mounted, highly shock resistant and immune to dust. Performance can also improve dramatically. The major barrier to greater use of SSDs has been cost. However the landscape is changing and at some point, in the future, the price of equivalent capacity drives will equalize.

SSDs are based on DRAM volatile memory or NAND flash non-volatile memory. Many SSD manufacturers use non-volatile flash memory to create more rugged and compact devices for the consumer market. These flash memory-based SSDs, also known as flash drives, do not need batteries. They are available in standard disk drive form factors (1.8-inch, 2.5-inch, and 3.5-inch). In addition, the non-volatility of flash SSDs means content retention even during sudden power outages, ensuring data persistence. Flash SSDs are slower than DRAM and some designs can be slower than traditional HDDs on large files. But flash SSDs have no moving parts and thus long seek times and other delays inherent in conventional electro-mechanical disks are not a consideration. SSDs based on volatile memory, such as DRAM, are characterized by ultra fast data access, typically less than 0.01 milliseconds. They are used primarily to accelerate applications that are held back by the latency of Flash SSDs or traditional HDDs. DRAM-based SSDs usually incorporate internal battery and backup storage systems to ensure data preservation during power failure.

Flash based systems are leading the way in market share and price performance. There are two types of memory: SLC and MLC. MLC stores twice the bits per cell and is used more commonly due to its inherent cost savings. However, for the applications that utilize “circular buffer recording” (highly repetitive recording), SLC is recommended due to superior read/write cycle reliability.

SSDs are here to stay and their use in a myriad of applications is growing each quarter. At Conduant Corporation, more of the custom high performance recording systems supplied to scientific and defense related clients require the stability and ruggedness SSDs provide. Try SSDs on your next project. You won’t be sorry.

MEMS Accelerometer for Shock Measurements

By ANthony Chu, Measurement Specialties, www.meas-spec.com [6]

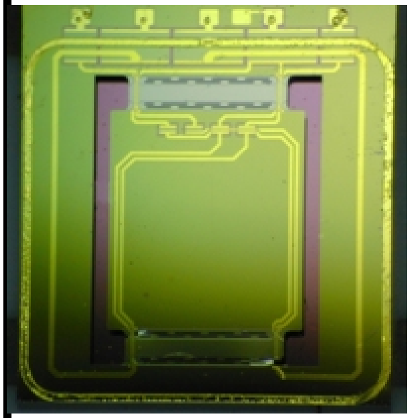
MEMS accelerometers have been used in diverse applications for shock and vibration measurement for more than two decades. It has become increasingly apparent to many engineers that wide dynamic range and built-in damping in the MEMS element design can play a critical role in the fidelity of the measurements. In practice, it is very common to encounter over 1,000 g of acceleration during routine measurements, such as car collision or product drop testing.

To accurately characterize the physical behavior of the object under high acceleration impact, an accelerometer should have sufficient headroom (dynamic range) in its measurement range. Although many of the piezoelectric (ceramic) accelerometers on the market offer ample of dynamic range for the task, piezoelectric-based sensors cannot provide DC response which is necessary for deriving velocity and displacement information accurately from the acceleration data. MEMS accelerometers, on the other hand, offer DC response needed for these critical measurements. Unfortunately, most common capacitive MEMS accelerometers one can buy off the internet today are limited to 200g full scale range - too low to be useful under most shock testing conditions.

Piezoresistive MEMS accelerometers have been used for auto safety testing for many years. In auto safety testing, crashing of automobiles generate impacts that are both high in g level and rich in frequency content (think of the dummy head hitting the windshield), making it one of the most difficult measurement environments for any accelerometer. It is in these kinds of environments that a capacitive MEMS design, with its limited dynamic range and bandwidth, has been proven inadequate in capturing the total event without compromising signal fidelity. When engineers turned to piezoresistive MEMS accelerometer in the late '90 for its higher dynamic range and bandwidth capabilities, however, they soon discovered that the undamped nature of nearly all piezoresistive design has created a different set of problems in their measurements and analyses.

An accelerometer with insufficient internal damping may set itself into resonance (ringing) when exposed to the high acceleration impacts during the course of the measurement. The primary (direct) and secondary (indirect) effects of the resonance eventually manifest themselves in the acceleration output signals. The primary effect of the ringing may result in sensor output non-linearity at frequencies below the resonance, which is sometime difficult to characterize. The secondary effect of ringing may result in non-linearity behaviors in the subsequent electronic stages due to high (unexpected) input signal amplitude. Even when the signal conditioning electronics is set to accommodate the high input signal level, it robs the measurement chain of its useful dynamic range. Modern capacitive type MEMS accelerometers with built-in gas damping seem to offer the perfect solution. But these capacitive MEMS products are unfortunately available only in very low measurement range (<200g) and provide limited linear frequency response (< 100 Hz).

The current third generation of piezoresisitive MEMS accelerometer elements have gone through many iterations in FEA modeling and structural refinements to fine tune their dynamic behaviors. The latest generation of die design offers up to 6000 g in measurement range. To avoid overrange in the MEMS structure, special mechanical features have been incorporated in the caps to act as over-travel stops. These stops limit stress at the hinges where the piezoresistors are located to prevent premature structural failure. Damping has been dialed in to provide the maximum effect at its resonance. This new generation of accelerometers is now available in SMD package, with full scale G range at 50g, 100g, 200g, 500g, 2000g, and 6000g. Housed in a hermetically sealed LCC package, these SMD accelerometers seem ideal for a variety of applications including on-board shock and vibration monitoring in heavy equipments, off-road vehicles, and light/heavy weapons where metal-to-metal impacts are common occurrences.



Another performance advance in high-G MEMS accelerometer relates to its temperature response improvement. In applications such as engine testing and weapons development where the external temperature can change drastically from moment to moment. The accelerometer can be exposed to unexpected thermal transients that have an effect on the acceleration output performance. To compensate for the thermal non-linearity of the MEMS sensor, a custom digital ASIC has been integrated in a similar LTCC package design. This accelerometer (Figure 3) is capable of operating in temperature environment from -55°C to +125°C with very low thermal sensitivity shift and thermal zero shift. The improvement in output accuracy over a wide temperature range allows the sensor to be used in hostile environment where typical MEMS accelerometer may have problem dealing with the temperature gradient of the application, such as firing of rocket engine or gun fire. This accelerometer also features a patented design allowing the sensor to be mounted in vertical (in plane) or in the transverse (parallel) direction. This feature offers the user the flexibility of arranging multiple sensors on the same PCB to measure shock impact in all three orthogonal directions. This is particularly useful in applications where space for mounting the MEMS accelerometer is at a premium.

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