WITH STANDARDS TWO YEARS AWAY AND ABUNDANT COMMERCIAL-GRADE WIRING, SPECIFIERS SHOULD BE CAREFUL

# How Tough Is Your Ethernet Cable?

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**IT WILL BE TWO YEARS OR POSSIBLY MORE UNTIL U.S. AND** European standards for industrial Ethernet are fully in place. Until then, manufacturers who want to use this network are taking matters into their own hands to design, specify, and install the physical media needed to get their projects off the ground.

Projects currently under way range from the very large to the very small. General Motors Corp., Detroit, for example, is just finishing up an Ethernet-controlled system of 150 manufacturing cells at its Lordstown, Ohio, assembly plant, with each of the cells expected to use 500 ft. of industrial Ethernet cabling. At the other end of the spectrum, Triangle Package Machinery Co., Chicago., used about 20 ft. of Ethernet cable to serve an operator display in a recently introduced bag-in-box cartoning machine.

These and other projects are all wrestling with the same issues when it comes to selection and specification of the physical media: With so much commercial off-the-shelf (COTS) cable and other Ethernet products having proven themselves for so long in the office environment, can't those same products be used in the plant?

"Do not assume the cable acceptable at your office receptionist's desk will suffice in the harsh, real world of industrial process control and automation," warns Brian Shuman, senior product development engineer for cable manufacturer Belden Electronics (www.belden.com). "Commercial off-the-shelf Category 5e (Cat 5e) unshielded twisted-pair Ethernet cable is actually quite fragile by industrial standards. And beyond the obvious physical hazards to the cable are the more insidious, invisible hazards of electromagnetic interference (EMI) and radio frequency interference (RFI)."

"If somebody is looking to deploy a system, they definitely want to pay attention to the balance [of the cable] and the chemical and temperature aspects [of the environment]," says Bob Lounsbury, senior project engineer for Rockwell Automation (www.rockwellautomation.com) and co-chair of the Telecommunications Industry Assn.'s industrial telecommunications infrastructure subcommittee, which is drafting the U.S. standard.

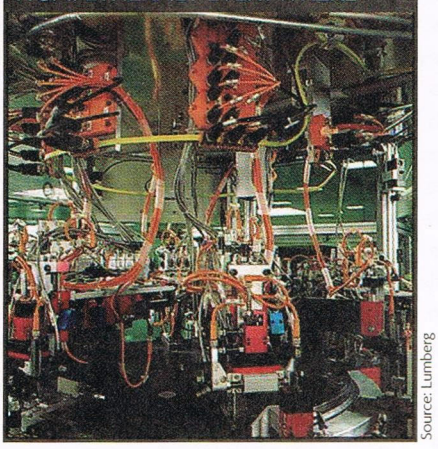
In signal transmission, a "balanced" line is one in which two conductors carry the signal and create a balanced circuit alternating, in unison, from positive to negative. The paired wires in the Ethernet cable balance out each other's signals and help to nullify the effect of any noise that may be introduced into the signal from adjacent wires or electromagnetic fields.

Both users and cable suppliers are pushing COTS cabling, which has long been used in office environments. But Lounsbury and others who are working on the development of industrial cabling standards claim COTS wiring is unsuitable for industrial environments.

"There is a large desire in the cabling industry to try to push the existing commercial technology into the industrial space, so they don't have to design yet another set of cables to bring to market," Lounsbury says. "And I don't mean just the cable manufacturers, but also component suppliers."

Other cabling manufacturers, however, have started to introduce cable products that provide protection from the environmental conditions common to industrial plants, which include electrical noise and interference, temperature and humidity extremes, and chemicals and other corrosive factors.

FIG. 1: ETHERNET EVERYWHERE



Source: Lumberg

**With Ethernet's tendrils snaking throughout the plant, companies should thoroughly study the factory conditions in which it will be working, with particular attention to noise, chemicals, and temperature.**

## QUIETING THE NOISE

Before selecting any kind of Ethernet cable, companies first should thoroughly study the factory conditions in which it

will be working (Figure 1). There are numerous factors, common in industrial sites but unknown in the office, that can adversely affect Ethernet wires and the signals they carry.

"Noise levels are probably very difficult for some users to quantify," Lounsbury continues. "But they can do that by taking a look at their machinery. If they have high-horsepower motors, high-horsepower drives, or if the density is relatively high, the chances are they have a very noisy environment."

Other factors contributing to "noisy" environments include processes such as welding or relay-type equipment. The easiest and probably best solution is to find cable that overcomes those problems. Just as simple and effective is routing the cable as far away as possible from EMI/RFI noise sources. Yet another alternative is through isolation or separation, although that can be expensive to accomplish.

"We even took commercial-grade cabling and wrapped it around a weld gun and fired the gun to test it. We didn't find any real problems."

"One option is to use fiberoptic cable, which is absolutely immune to the effects of EMI/RFI," says Shuman. "However, if you are concerned about the cost, complexity, or robustness of fiber, consider a shielded Cat 5e copper cable solution. Even a simple aluminum foil shield, when properly grounded, provides significant immunity to EMI/RFI."

Shuman also notes a balanced and stable unshielded twisted pair (UTP) Ethernet cable will provide significant noise immunity. "Each half-twist of a pair may be thought of as a loop antenna. Each consecutive half-twist is opposite in orientation of the conductor on top. In a perfectly balanced cable, the alternating polarity of the loop antennas cancels out any noise coupled on the pair. Bonded-pair cables, however, provide the closest approximation of perfect balance, especially after the rigors of installation and everyday abuse."

John Keinath is a senior manufacturing engineer for GM who is leading the cable selection activity for the Lordstown project, as well as efforts to standardize on industrial Ethernet in future cabling projects. He says the automotive manufacturer found no significant problems from factory noise in tests conducted over the past two years to determine the response of Ethernet cabling in factory environments.

"We even took commercial-grade cabling and wrapped it around a weld gun and fired the gun to test it." Keinath says the tests involved twisted pair cable from different manufacturers, none of which stood out in superiority or inferiority in the end. "We didn't find any real problems."

Nevertheless, to minimize the potential of noise-induced problems, Keinath says GM is planning the cabling in Lordstown to provide the shortest possible leads in high-noise areas. "We don't route it near a bunch of relays that might cause interruptions," he admits.

Keinath says GM has tried to avoid the use of shielded cabling following problems in DeviceNet installations at plants in Europe, which resulted from improper grounding of cables in multiple spots. "Unshielded cables may not have enough noise immunity, but so far we haven't had a problem with them and we haven't had any need to use grounded Ethernet," he says.

Routing of cables through conduit for protection is another way to set up a type of shield. For that new cartoning machine, Triangle Package is running Ethernet cabling inside a sealed conduit from a controller and drives to an operator interface, says Steve Bergholt, chief engineer. There also are Ethernet ports on the machine that allow it to be connected to plant-wide and enterprise networks. Sealing also protects the cable from fluids and chemicals that might be found in industrial settings.

But Lounsbury warns that placing cable in conduit can cause its own problems. Placing unshielded cable in conduit effectively puts a shield around the cable and can affect electrical performance of the cable. He notes that standards for qualifying the electrical performance of cable

calls for it to be done in mid-air with no metal present.

"That tells you that you will get some degraded performance if you are near metal with unshielded cables," he says. "We tell our customers that if you need conduit, which would be primarily for protection, then you should use a shielded cable. If you are using conduit as a means of getting isolation, you could probably do just as well just using a shielded cable."

Noise immunity virtually is guaranteed through use of fiberoptic cabling, although use of this cable is still limited on the factory floor. The main issues for fiberoptic cable are that it is not as flexible as copper and it requires special, often expensive, efforts to terminate and maintain it.

In many industrial installations, copper now works in concert with both fiberoptic and wireless systems, notes Tom Boucino, product engineer and head of the copper research and development laboratory for cable maker CommScope Inc. (www.commscope.com). "Fiber might be the perfect application for one area, and the signals can be transitioned from fiber to copper in another," he says.

**RESISTING CHEMICALS**

Among the critical considerations in specifying cabling for industrial enviroments are the chemicals, oils, and other liquids in the factory environment that may be encountered by the cable over time.

"Users need to pick components that are able to handle the nasty stuff they have on the plant floor," says Jim Westerman, industrial Ethernet marketing manager for Siemon Co. (www.siemon.com). Oil, for example, can cause cable jackets to swell and lose mechanical strength, contributing to contamination and deterioration of their inner cores.

"We wanted to make sure that it could stand up to the chemicals in our environment and specifically water," says Keinath. He says thicker jackets and resistance to a catalog of the chemicals in GM plants are among the company's Ethernet cabling specifications.

Both high and low temperatures are factors in some industrial environments. High temperatures can cause degradation of plastic jackets, while low temperatures can make cable brittle or stiff. As a result, "Industrial cable needs to be a higher-grade thermal product," says Bob Svacina, marketing manager for Interlink BT (www.interlinkbt.com).

Lounsbury notes some industrial users say temperatures below 0° C can cause jackets to crack, and at -20° C most cables cannot be struck or even moved without damaging them.

Insulation degradation isn't the only concern with elevated temperatures. "Typical COTS Cat 5e cable attenuation increases at a rate of 0.4% per degree Celsius above 20° C. At 60° C, the attenuation may be increased by 16%," says

TABLE I: TYPES OF INDUSTRIAL NOISE

| SOURCE | NOISE | COUPLING MECHANISM |
|---|---|---|
| Electric motors | Surge and EFT[1] | Local ground, conducted |
| Drive controllers | Conducted and surge | Local ground, conducted |
| Relays and contactors | EFT | Radiated, conducted |
| Welding | EFT, induction | Radiated magnetic |
| RF induction welding | Radio frequency | Radiated, conducted |
| Material handling, paper/textile | ESD[2] | Radiated |
| Heating | EFT | Local ground, conducted, radiated |
| Induction heating | EFT | Local ground, conducted, radiated |
| Radio communications | Radio frequency | Radiated |

1. Electrical fast transient
2. Electrostatic discharge

Source: Rockwell Automation/Anixter Inc.

Shuman. "For these reasons, it's also critical to select a ruggedized cabling system that offers industrial-strength, high-temperature attenuation performance."

Because they were designed for indoor use, most COTS cables are affected by exposure to ultraviolet radiation. So exposure to simple sunlight can cause cabling jackets to deteriorate.

Mechanical strength is a major issue for GM, says Keinath. Because equipment is built at supplier locations and then torn down for delivery to and installation at GM plants, strength of cabling is critical, he notes. Bendability and jacket thickness that resist tie-downs also are important, he says. Other potential mechanical hazards for industrial Ethernet cables include cutting, abrasion, and crushing—workers walk all over industrial cables.

Both GM and standards organizations are seeking products with higher pulling tensions, ones that can withstand more force during installation than the 25-lb. maximum that is specified for COTS products. Svacina notes the goal in most industrial installations in the future is likely to be pulling tensions of at least 40 lbs.

"Pulling a commercial-grade UTP with excessive force will stretch the cable," says Shuman. "You may start with 100 ft. of cable and end up with 100 ft. and two inches. This elongation causes excessive signal loss (attenuation) and signal delay, effects which will limit the distance the cable can be run."

He also notes that rough handling of cable during installation can lead to changes in center-to-center spacing of pair conductors, which may result in pair-to-pair coupling or crosstalk, signal echoing or return loss, and susceptibility to EMI and RFI.

New thermoplastics have been developed for cable that increase strength but often lessen flexibility and ease of installation. The same is true for higher bandwidth cables beyond the 10 and 100 megabit versions that are covered by Ethernet's standard Category 5e specification. Few uses have yet developed for Category 6 cable, although some industrial users are considering or installing this higher bandwidth product.

Vibration also could be a problem for Ethernet cabling in areas such as those around automotive transfer presses, but the bigger issues are with the connectors involved.

**STANDARDS TO THE RESCUE?**

Open standardization is an obvious strength of Ethernet. But "Any product can be designed to meet the minimum requirements as specified by the Institute of Electrical and Electronic Engineers (IEEE)," adds Shuman. "However, the physical layer of the Ethernet must be adapted to the unique challenges of the industrial environment. While COTS cable may work in some industrial applications, in most instances its lack of robustness will be unacceptable."

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The TR-42.9 subcommittee, a joint committee of the Telecommunications Industry Assn. and the Electronics Industry Assn., is studying industrial telecommunications infrastructure and hoped to publish a standard for industrial Ethernet late this year. But that draft now is not expected until early next year, and committee members expect revisions and balloting will take the process well into 2005.

Until standards are set, users are going to have to sort through issues and even specifications on their own. Or, like GM, rely on trusted vendors for advice. ●

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