Industrial Ethernet – The Perfect Cable for an Imperfect Environment

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BACKGROUND

Industrial environments are not like normal premise environments. Cables in these environments can be exposed to dirt, grease and oil, extreme EMI noise sources, harsh chemicals, and even Ultraviolet (UV) radiation. This is a sharp contrast to premise installations, where Ethernet cable is tucked away behind ceiling tiles, protected in a conduit, or even installed in temperature and humidity controlled data centers and can remain undisturbed and well protected for years. In addition to the harsh conditions found in industrial settings, the applications in industrial settings can be more demanding than premise applications. Bit errors or latency may be hardly noticed when someone sends an email in the office. Meanwhile industrial protocols and applications like process control are highly deterministic and require data to be transmitted in real time with little to zero latency. Any bit errors or lost packets may cause a process to stop running and lead to costly downtime on machines and equipment. Unfortunately industrial settings like manufacturing plants, food processing facilities, and outdoor installations don't always allow for the cable to be installed in an ideal way where the cable is protected from hazardous conditions. And while the increasing availability of hardware, new applications like power-over-Ethernet (POE), and the ability to share information more easily has increased the popularity of Ethernet in industrial environments, the type of cables used in these settings is often overlooked.

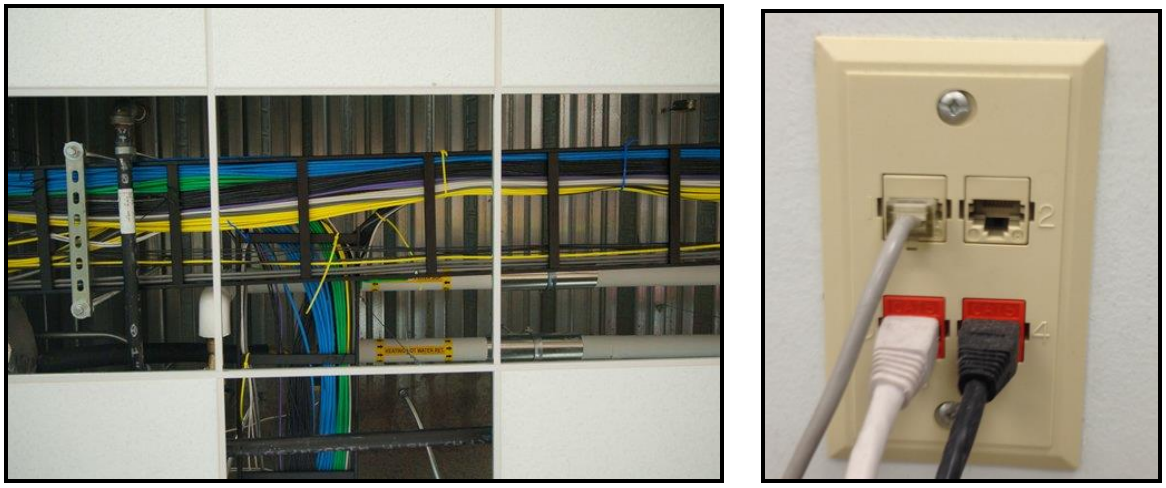

Figure 1: (Left) A typical premise installation with Ethernet cable behind a dropped ceiling and a work area outlet in an office setting (Right)

Figure 2: A workstation outlet on a plant floor

DEMANDING APPLICATIONS AND ENHANCED ELECTRICAL PERFORMANCE THROUGH PROCESS CONTROL

In typical premise applications like email and internet browsing, if bit errors or packet loss occurs the data is simply resent and the end user will likely never even know that anything happened. On the other hand, industrial applications like process, automation, and motion control send I/O signals and other deterministic data. When errors occur in these applications, machines can fail to operate properly or even shut off causing costly down time. These demanding applications and harsh environments may require Ethernet cables to have enhanced electrical performance compared to premise cables. Two performance parameters of particular importance for industrial Ethernet cables are Return Loss (RL) and Balance. Return loss performance can be dramatically impacted by the installation process and flexing while Balance is critical to the noise immunity of the cable, especially in unshielded (UTP) cables. These two parameters are so critical that the Open DeviceNet Vendors Association or ODVA standard for EtherNet/IP™ cables specifically requires enhanced return loss performance and balance requirements for Cat 5e cables. In the early days of twisted pair Ethernet cables, one way to improve the performance of these parameters was the use of bonded pairs. Over the years though, General Cable has introduced a number of technologies and processes to produce high quality Ethernet cable with excellent return loss and balance to meet the enhanced requirements for cables in industrial environments.

For twisted pair products like Ethernet cable, maintaining consistent conductor-to-conductor spacing is critical to producing cable with excellent return loss and balance performance. In 1996, General Cable filed United States Patent US5767441 that introduced the technology of pre-twisting individual conductors which significantly improved electrical and mechanical characteristics of communications cable. This process normalizes slight irregularities within the pair construction to produce consistent average conductor-to-conductor spacing. The end result of this process is improved electrical characteristics and specifically excellent return loss and balance performance meeting the ODVA EtherNet/IP™ standard without the need for bonding the pairs. In addition to processes like pre-twisting, improved measurement and control devices have been introduced into the manufacturing process, specifically at the insulating process. New and improved tooling for insulating lines has allowed for near perfect insulated conductor geometry. Additionally new real-time eccentricity monitors allow for the fine tuning of the insulating process. Together these technologies allow for consistent defect-free insulated conductors which produce exceptional electrical characteristics in the finished product. General Cable has made significant investment in these technologies to ensure our products meet the requirements for return loss and balance for Industrial Ethernet cables.

In addition to these improvements, other new and innovative controls help to predict and improve the return loss performance of cables. One of these technologies is on-line Structural Return Loss monitoring. This equipment uses on-line monitoring devices to detect imperfections in the construction of the insulated conductor in real time. The analysis software utilizes Fast Fourier Transform Algorithms to predict electrical performance of the insulated conductor. The use of this technology permits General Cable to immediately monitor and control electrical performance of the cable in real-time and receive warnings indicating when the performance is being impacted. Based on these methods of control, there is little need to bond the conductors because the eccentricity of the conductor is nearly perfect. Bonding conductors can also induce deformation during the fusing process that may negate the positive effect of locking in the conductor spacing. The simpler approach is to make a perfect insulated conductor that does not require bonding.

While these techniques provide excellent return loss, they also help to significantly improve the balance performance of products. Balance performance, which is critical to noise rejection in UTP cables and is represented by mode conversion parameters TCL, LCL, TCTL and LCTL, is only a requirement for Cat 6 and 6A premise products. However because of the many noise sources present in industrial settings, there are also balance performance requirements for industrial UTP Category 5e cables in standards like ODVA EtherNet/IP™ and ANSI/TIA-1005. These parameters measure the amount of conversion of the source signal from differential to common mode or common mode to differential mode due to physical or structural imbalances within the pair construction. These imbalances are determined by the quality of the insulated conductor and the quality of the pair. Any imperfections like copper or insulation diameter variation, pair lay variation, or eccentricity variation can significantly impact the balance of the finished cable. General Cable has made significant investments and

improvements in our manufacturing facilities to produce high quality Category 6 and 6A products. These process improvements have also translated into improved balance performance in our industrial Category 5e products allowing us to meet the requirements of industrial Ethernet standards without the use of bonded pairs.

DESIGN FEATURES FOR INDUSTRIAL ENVIRONMENTS

In addition to the added electrical performance requirements for Ethernet cables in industrial settings, there are also many other conditions that cables are subjected to in these settings that impact the design and construction. Industrial settings can expose cables to a number of chemicals and other potentially harmful conditions like impact, varying temperatures, and higher voltage cabling and equipment. To combat these issues, these cables use specialized PVC jackets that are able to perform in a wide range of temperatures and handle exposure to chemicals like oil and UV radiation. These UV and sunlight resistant jackets allow the cables to obtain safety ratings like the UL 444 CMX Outdoor – CMR rating and the UL 444 SUN RES rating. With these ratings, many of these cables are suitable for use both indoors in traditional CMR applications as well as in outdoor applications where UV and sunlight exposure are issues. These jackets are also much thicker than traditional Premise cable jackets, which allow them to have UL AWM 600V ratings making them suitable for use in applications where normal Premise cables cannot be used.

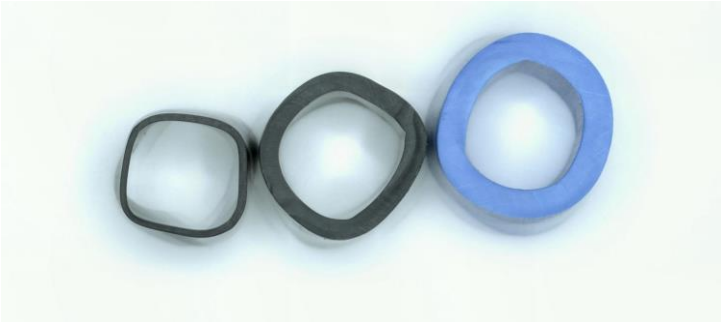

Figure 3: (Left to Right) Cross-sections of a standard premise cable jacket, an AWM 600V jacket, and an AWM 600V PLTC jacket.

While specialized jacket materials allow industrial Ethernet cables to be used in a variety of environments, other design features are also used to increase the capabilities and possible applications for Ethernet. Traditionally premise Ethernet cables use 24 AWG or 23 AWG conductors. For some industrial Ethernet products, 22 AWG conductors are used along with thick insulation and jacket walls to meet UL 13 requirements for PLTC cables. This combination of design features allows the cable to obtain a UL 444 CMX Outdoor – CMR rating, a UL 13 PLTC rating, and a UL AWM 600V rating. The combination of these ratings dramatically increases the number of locations and applications where the cable can be used in an industrial environment.

In industrial environments, there are also many noise sources present like drives, transformers, power sources, and higher voltage cables. The presence of these noise sources can have a very detrimental impact of the performance of the cable. Disturbances like Electrical Fast Transients (EFTs), Radiated RF, Electrostatic Discharge (ESD), and power surges can all cause issues with the cable and the connected equipment. These disturbances could cause bit errors, data packets, and lead to machine downtime or even directly damage the cable itself. To help provide protection from these noise sources, shields are often employed in cables that will be used in extremely noisy environments. Based on the particular application either a foil shield or a combination of a foil and braid shield may be used. With proper termination and grounding, these shields allow the cable to perform in a variety of noisy environments.

CONCLUSION

The presence of harsh conditions and demanding applications in industrial environments makes choosing a high quality industrial Ethernet cable with the appropriate features critical. Installing the right cable for the environment can be the difference between meeting the requirements of industrial applications and having a loss in productivity due to equipment down time. While in the past, technologies like bonded pairs were required for these applications, today process controls and design features like pre-twisting, online structural return loss monitoring, and eccentricity gauges allow General Cable products to have excellent return loss and balance performance required for cables in industrial environments without the use of bonded pairs. By combining improved manufacturing processes with enhanced design features, General Cable Industrial Ethernet products can be the perfect cable for an imperfect environment.