Title: **Industrial Ethernet Media Selection and Installation**

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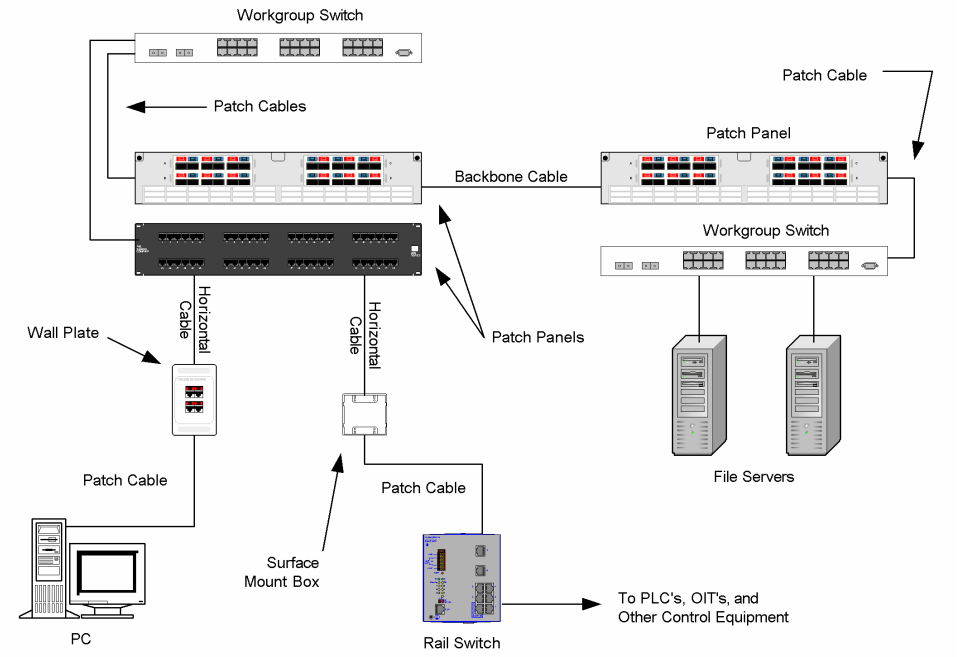
In the past the majority of Ethernet networks were to be found in commercial office and academic environments! However today, due to the power and robustness of Ethernet, it is expanding to process areas, manufacturing facilities, and many other industrial venues. So the question which must be asked is; what factors should be considered when selecting media and components for the industrial environment? Before discussing the factors pertaining to media selection, let's first describe some characteristics common to many industrial environments:

- Industrial environments are noisy! There are many more sources of radiated noise to be found. These include things like inverters, solenoids, starters, etc.

- Industrial environments are often dirty! This could be anything from every day dust to solvents and other corrosive substances.

- Industrial environments are often subject to extreme environmental conditions! It might be very hot, or very cold, or both depending upon the time of year!

So, how do these factors affect the choice of Ethernet cabling or media? In order to pursue the answer to this important question, consider the following typical network infrastructure:



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The infrastructure diagram illustrates the three different cable applications found within every network. The applications are as follows:

- Patch cables – Provides connectivity between end devices / network hardware (PC's, PLC's, hubs, switches, etc.) and cable termination hardware (patch panels, wall plates, surface mount boxes, etc.).

- Horizontal cabling – Provides connectivity between data communication rack termination hardware (patch panels) and work area termination hardware (wall plates, surface mount boxes, etc.).

- Backbone cabling – Provides connectivity between data communication racks.

Each one of these cabling/media applications has its unique requirements and characteristics, and thus will be explored.

Horizontal and Backbone Cabling:

In a typical local area network (LAN) there are two possible types of media that can be used for the horizontal and/or backbone cabling. The specific type chosen, copper twisted pair (TP) or multi-mode fiber (MMF), is determined by the required data rate and the distance requirements. The following table summarizes the characteristics of each type of media:

LAN Media	Standard	Maximum Data Rate (M bits/sec)	Distance (meter)
Twisted Pair (TP), 4 pair, Category 5 or better	10Base-T 100Base-TX 1000Base-T	10 100 1000	100 100 100
62.5/125 um Graded Index Multimode Fiber (MMF)	10Base-FL 100Base-FX 1000Base-SX	10 100 1000	2000 2000 275

When dealing with any of the above media it is important to remember that the distance limit is defined as being from network interface to network interface. This means that the COMBINED length of the horizontal cabling plus the patch cables must not exceed the specified limit. It should also be noted that some hardware will have distance limits that are greater than those specified above. However all quality hardware should meet or exceed the numbers given here.

Once the type of media has been chosen it will be necessary to specify if a plenum or non-plenum cabling must be used. Plenum cabling is cabling designed to be used with in a return air path for the buildings heating, ventilation, and air conditioning system. This type of cabling is special because the materials used in the cabling construction have been

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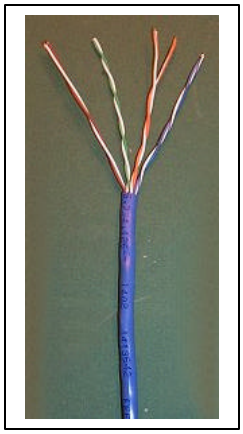
selected based on their low flammability, high heat resistance, and low smoke producing characteristics. Plenum cabling is generally more expensive than the non-plenum cabling equivalent.

Twisted Pair Media, Termination, and Certification:



All twisted pair cabling serving as horizontal or backbone cabling and the corresponding termination hardware should be rated at no less than Category 5e. Horizontal twisted pair cabling always contains solid core conductors due to the superior electrical characteristics of this type of cable. In an industrial environment, where the cabling must be pulled through conduit and/or may be subjected to a greater degree of radiated noise, a higher grade of Category 5e cabling is recommended like Belden's DataTwist 350 (Belden No. 1700A). This cabling has a higher Maximum Pulling Tension (40 lbs.) and a tighter Minimum Bend Radius (0.25") due to the cables bonded pairs and other design details making it the best choice for installation and use in the industrial environment.

When terminating CAT 5e it is essential that the terminating hardware be rated in the same category as that of the cabling. The overall rating of the cabling infrastructure is determined by the lowest rated component used. This means that using Category 5e cabling with Category 3 modular RJ-45 jacks results in the entire system being rated at the lower rating of Category 3. Thus for optimum performance all of the solid conductor horizontal cabling should be permanently terminated in either a Category 5e patch panel, or within some type of modular work area component suitable for wall or surface mounting. Terminating the cabling in this fashion will maximize performance and minimize the possibility of the terminations becoming damaged at some point in the future.

Some lines of modular work area products have additional features which make them better suited for industrial installations. For instance you might consider using modular RJ-45 jacks that are angled downward to prevent dust and dirt from collecting within an unused jack. An additional level of protection is realized by using jacks that are not only angled downward but also have rubbers flaps that completely seal off a jack that is not in use! These types of features vary form manufacturer to manufacturer, but the point is you want to select termination hardware that will provide you with a quality termination and protect that termination from the environment in which it is used.

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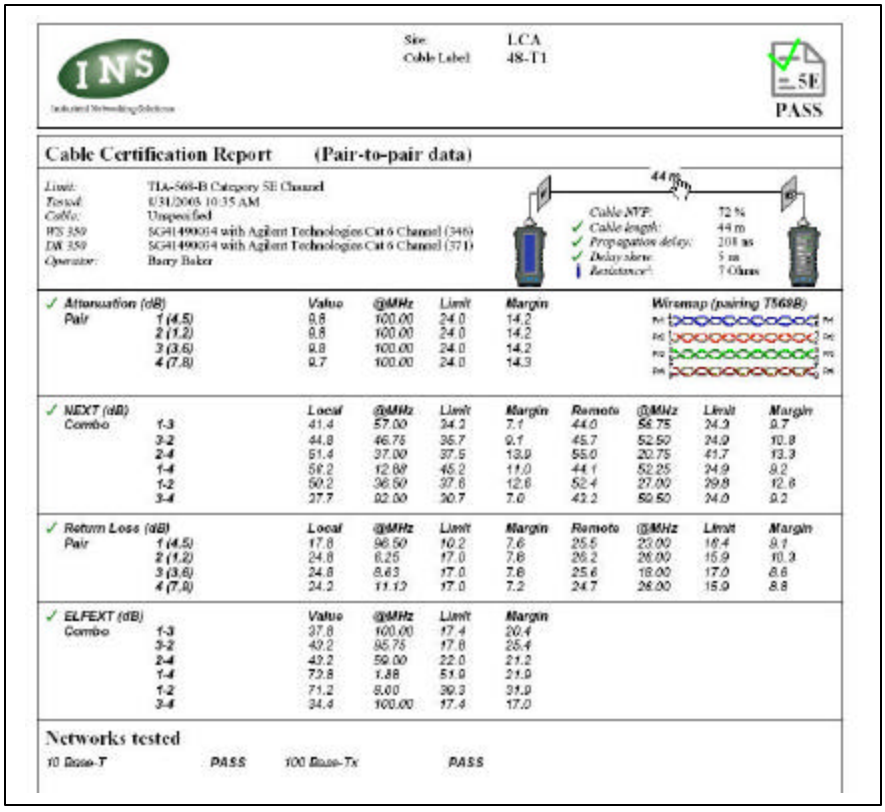
In extreme industrial environments that need to be protected from not only dust and dirt, but also water, solvents, or any liquid. There are connectors, like the one shown here, that carry an IP 67 rating making them ideal for really harsh environments where network connectivity must be provided.

Once properly terminated it is imperative that the cabling be certified relative to the Category 5e Standard. Cabling certification not only tests the cabling installation for the proper wire mapping (possible problems include open pairs, split pairs, reversed pairs, shorted pairs, etc.), but also determines cable length, and measures the actual performance characteristics (attenuation, near-end cross talk, far-end cross talk, etc.) of the installed cable. Once certified a report is generated like the one shown that documents the proper installation and performance for each of the tested cables. This means that the tested cabling WILL NOT be the source of any future network problems!



INS

Site: LCA
Cable Label: 48-T1

5E
PASS

Cable Certification Report (Pair-to-pair data)

Limit: TIA-568-B Category 5E Channel
Tested: 1/31/2008 10:35 AM
CabNo: Unspecified
WS 350: SG41490004 with Agilent Technologies Cat 6 Channel (346)
DA 350: SG41490004 with Agilent Technologies Cat 6 Channel (371)
Operator: Barry Baker

44 m

Cable NVP:	72 %
Cable length:	44 m
Propagation delay:	208 ns
Delay skew:	5 ns
Resistance:	7 Ohms

Attenuation (dB) Pair		Value	@MHz	Limit	Margin
	1 (4,5)	9.8	100.00	24.0	14.2
	2 (1,2)	9.8	100.00	24.0	14.2
	3 (3,6)	9.8	100.00	24.0	14.2
	4 (7,8)	9.7	100.00	24.0	14.3

Wiremap (pairing T568B)

NEXT (dB) Combo		Local	@MHz	Limit	Margin	Remote	@MHz	Limit	Margin
	1-3	41.4	57.00	34.2	7.1	44.0	56.75	34.9	9.7
	3-2	44.8	46.75	35.7	9.1	45.7	52.50	34.9	10.8
	2-4	51.4	37.00	37.5	13.9	55.0	20.75	41.7	13.3
	1-4	58.2	12.88	45.2	11.0	44.1	52.25	34.9	9.2
	1-2	60.2	36.50	37.6	12.6	52.4	27.00	29.8	12.6
	3-4	37.7	92.00	30.7	7.0	43.2	50.50	34.0	9.2

Return Loss (dB) Pair		Local	@MHz	Limit	Margin	Remote	@MHz	Limit	Margin
	1 (4,5)	17.8	96.50	10.2	7.6	25.5	23.00	18.4	9.1
	2 (1,2)	24.8	6.25	17.0	7.8	26.2	26.00	15.9	10.3
	3 (3,6)	24.8	8.63	17.0	7.8	25.6	18.00	17.0	8.6
	4 (7,8)	24.2	11.13	17.0	7.2	24.7	26.00	15.9	8.8

ELFEXT (dB) Combo		Value	@MHz	Limit	Margin
	1-3	37.8	100.00	17.4	20.4
	3-2	43.2	95.75	17.8	25.4
	2-4	43.2	59.00	22.0	21.2
	1-4	72.8	1.88	51.0	21.9
	1-2	71.2	8.00	39.3	31.9
	3-4	34.4	100.00	17.4	17.0

Networks tested

10 Base-T PASS 100 Base-Tx PASS

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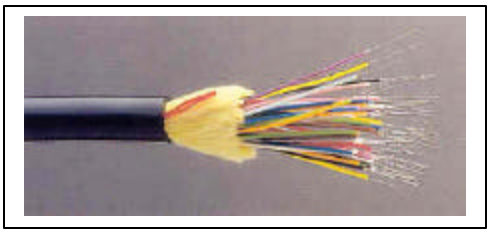
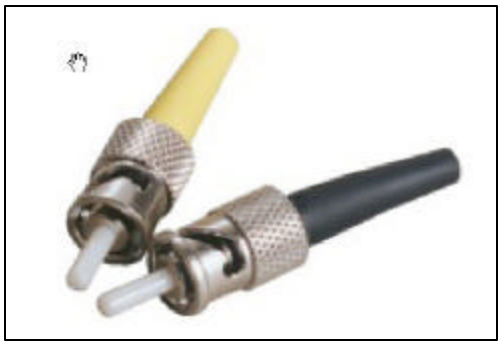
Multimode Fiber Media, Termination, and Certification:

Using multimode fiber (MMF) instead of twisted pair media as horizontal or backbone cabling is a great way to minimize the impact of radiated noise that is common in industrial environments. There are many ways to use MMF in your industrial network. One approach that yields terrific results is to design a distributed network, instead of using a hub and spoke approach to the overall topology. This is done by identifying locations with in the process areas for Network Communication Centers (NCC) where the network equipment can be located. Each of the NCC's are interconnected with multimode fiber (MMF) optic cabling. This approach minimizes the effects of radiated electrical noise on network communications since MMF is inherently immune to radiated noise. Also by carefully selecting the locations for each NCC the length of the copper cabling can also be minimized thus further isolating the communications from radiated noise.



When choosing a method of termination for MMF it is important to take into account the environment that connector will be subjected to. The traditional method of termination is one in which the connector is attached with epoxy and then crimped to the prepared fiber. Once the epoxy has cured, the excess fiber is cleaved and then the end is polished. The other approach is to use a pre-polished connector. For this method the fiber is cleaved to a prescribed length and then the connector is locked and crimped to the cleaved fiber. In the case of the pre-polished connector the boundary formed by the pre-polished fiber and the field fiber is filled with a substance known as index matching gel. This gel minimizes the reflection and loss caused by the mechanical joining of the two pieces of fiber. Both of these connection methods, when properly performed, result in low lose high quality connections. However both of these connection methods are not appropriate for all locations within an industrial environment.

In locations that are subject to things like thermal cycling, vibration, or a corrosive atmosphere, the preferred method of termination is the traditional method using a high quality connector like the Johanson ST connector pictured here. This connector is a precision machined nickel plated brass connector with a zirconia ferrule. The high quality materials hold up well to corrosive environments, while the epoxy will not be affected in any way when subjected to thermal cycling and/or vibration.



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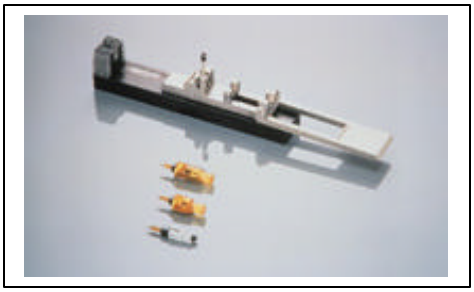

In locations where the above factors are not an issue, a pre-polished connector, like Corning's UniCam Connector is a good choice. The advantage of this type of connector is that they are much faster to install because the time consuming task of polishing the fiber end is eliminated. It is for this reason that they are often preferred by many installers.

When selecting the type of connector and the installation method it is important to keep in mind that most of the cost of fiber installation is the actual termination of the fiber. This means that you should chose what ever type of connector and termination method that delivers the highest quality and most durable installation.

Once the fiber is installed and terminated it is important to test that fiber for continuity and end to end loss. Should the end to end loss be greater than expected, the problem must be identified and corrected. For MMF the expected loss is calculated using the following formulas for 850nm (10Mbit/sec) and 1300nm (100Mbit/sec) are:

Loss = 0.5db * (no_of_connectors / 2) + 3.0db/km * km_of_fiber

Loss = 0.5db * (no_of_connectors / 2) + 1.0db/km * km_of_fiber

The physical network infrastructure plays a very important part in determining the overall performance of the network. No less than 70 % of network problems arise from poor installation and termination practices. Choosing the right media/connectors, and having it properly installed and tested will go a long way towards minimizing network problems and maximizing network performance.

Patch Cables:

More often than not, patch cables are the weakest link in the whole cabling infrastructure due to the fact that they are often unprotected, moved around, and generally abused. Copper patch cables are made from stranded Category 5e cabling and Category 5e RJ-45 connectors. Stranded cabling is used because of its increased flexibility however it also has lower performance characteristics due in part to the higher amount of attenuation per length of cable. Patch should be kept relatively short to minimize the effects of the lower performance characteristics. People will often try to make there own patch cables. On the surface, this may seem to be a good idea, however producing consistently good results is difficult even under controlled conditions. The best practice is to buy copper patch cables that have been certified by the manufacturer, thus minimizing the possibility of poor performance due simply a bad patch cable.

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Summary:

Industrial networks are growing in size and complexity! There are many exciting hardware developments leading to all kinds of performance advantages. However it is important to realize that you can buy the best hardware and still have bad performance due to an inferior cabling infrastructure. The performance of the network depends upon quality cabling! As stated earlier 70% of network performance problems are due to bad cabling! Industrial Networking Solutions exists to assist you in designing, installing, and maintaining a quality industrial network. We look forward to helping you as you utilize Ethernet to its fullest potential in your industrial environment.

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