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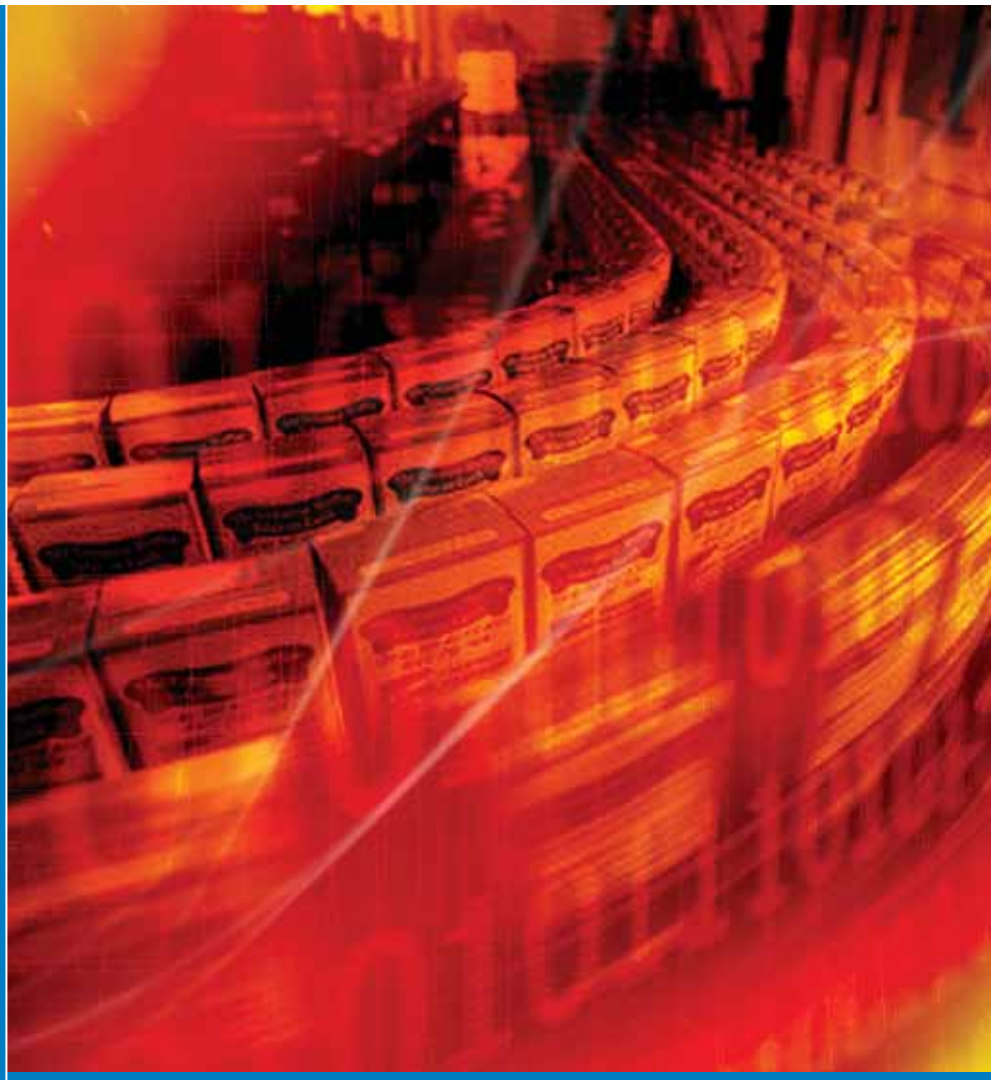
Industrial Ethernet User Guide



Tests Prove That Belden® DataTuff® Ethernet Cables are the Best Choice for an Industrial Setting

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Can a Commercial Ethernet Cable Really Meet the Needs of an Industrial Environment?

An office and an industrial environment are two very different settings — requiring a different approach to their Ethernet cabling.

Today, commercial Ethernet is the most widely installed local area network (LAN) standard. It was developed for the office and lab environment and has served there successfully, and safely, for over 30 years. Only in the past five years or so have engineers moved Ethernet into the industrial world, mainly for control and automation applications.

But the two environments couldn't differ more—especially when you consider the level of stress they place on an Ethernet cabling system. The office-type environment offers its cabling system a relatively safe harbor, but the industrial world can present very harsh and hazardous environmental conditions, meaning there's a real risk in bringing commercial off-the-shelf (COTS) cabling products into the industrial landscape.

The fact is, a commercial Cat 5e UTP Ethernet cable is quite fragile compared to an industrial-grade cable. With a commercial-grade cable, any number of stresses and challenges in the industrial environment could result in one of the classic failure models: catastrophic failure, intermittent operation, incremental failure and degradation of performance. The result could be a loss of data, process downtime or a drop in the safety level of your operation.

There's a better way—with cables designed specifically for the industrial environment: Belden® DataTuff® Industrial Ethernet cables.

Planning for an industrial environment should include Belden DataTuff Industrial Ethernet cables.

Why Commercial Cable Is Not Suitable

In an industrial environment, Ethernet cables are typically used to carry signals between devices to make events happen on schedule. Time is the key. There is no margin for error. By contrast, in an office setting signal transmission retries are usually acceptable when a fault occurs. The environment is more forgiving. Still another major difference between the two arenas is that unlike the office, industrial premises constantly experience harsh or extreme environments. For example:

- Extreme cold can make a cable stiff and brittle, while elevated temperatures can degrade the plastic used in the cable's construction. The signal attenuation in a typical COTS Category 5e cable will increase at a rate of 0.4% per degree Celsius above 20°C. At 60°C the attenuation may be increased by as much as 16%.
- Solvents and other strong chemicals, as well as lubricants, may be used on a manufacturing floor. Petroleum-based lubricants can soak into COTS Cat 5e cables, especially under heat, causing a cable's jacket to swell and lose mechanical strength.
- When COTS cables are exposed to the UV radiation in sunlight, the plastic outer jacket can decompose at an accelerated pace, losing mechanical strength. This can limit the useful life of the cable. Most commercial Cat 5e cables are not designed for outdoor use.
- Cables are more likely to experience pulling forces (i.e., beyond those of the initial installation process) in an industrial environment; it may be necessary to move cables around as equipment is rearranged. Pulling a commercial-grade unshielded twisted pair (UTP) cable with excessive force will stretch it. The elongation can increase attenuation, limiting the distance the cable can be run. And, unlike Belden® Bonded-pair technology which bonds the conductor insulation of the cable pairs along the complete length of the cable, traditional twisted pairs can open up, changing the conductor pair center-to-center spacing. The resulting imbalance can induce coupling between pairs (i.e., crosstalk), signal echoing (return loss), and increased susceptibility to ambient EMI/RFI.

Consider the *Real* Costs of Cable Failure

If an Ethernet cabling system fails in a harsh environment, the real cost to the manufacturer is typically much more than just the replacement cost of the cabling. In fact, the cost of the cabling itself is typically only a small fraction of the cost of the entire network.

The scope of the real cost may be much broader, including these factors:

- A loss of sales revenue due to unplanned downtime. The cost of downtime in an automotive facility has been estimated at $10,000 per hour. For a large paper mill facility, it's $3,000 per hour and for an oil pipeline, $25,000 per hour. What about your industry? Do you know what downtime would cost you?
- A greater need for repetitive repairs, if the cable performance is intermittent.
- A loss of worker safety. What costs would your company incur, in terms of liability, if a poorly-chosen cable fails in a safety-critical application?

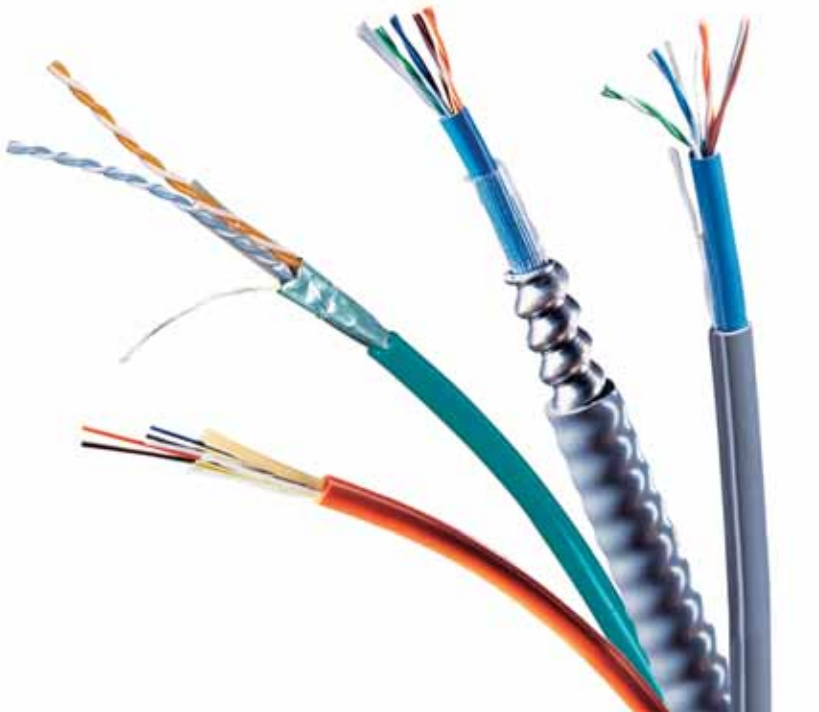
With a potentially large loss of revenue at stake, it's important to go with a cable designed from the beginning for a tough industrial environment.

Cable testing at Belden

Rigorous tests conducted at Belden on commercial cables has shown they do not stand up as well as industrial-grade cables in harsh industrial environments.

These tests include the following — all detailed on the following pages.

1. Abrasion
2. Cold Bend
3. Cold Impact
4. Crushing
5. Cut-through
6. High Temperature
7. Oil Resistance
8. UV Exposure
9. Water Immersion



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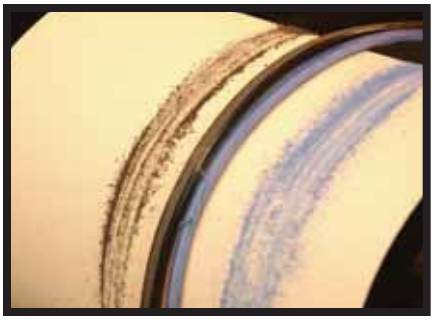
Comparing Commercial and Industrial Cabling

Belden® has done extensive testing to compare both the physical and electrical performance of commercial off-the-shelf (COTS) cables versus industrial cables. The results of each test (shown on the following pages) clearly indicate why a commercial-grade cable is never suitable for the wide variety of extreme conditions that can be at play in an industrial environment.

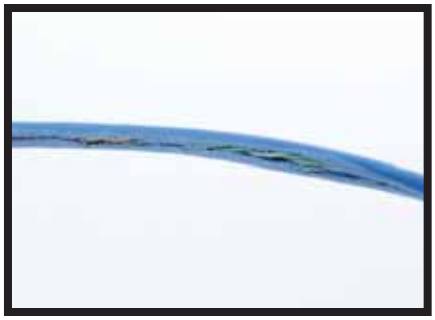
To conduct these tests, Belden used their state-of-the-art test equipment and proprietary test software. It's important to note that all the cables in this study initially tested as fully compliant to the TIA/EIA Category 5e standards—i.e., they were validated to be "good" when the test began.

Here, the cables are being connected to a switching mechanism that allows the interconnections to be made automatically. Above the switching mechanism, a network analyzer makes swept frequency measurements. Above that, a DC resistance and capacitance meter.

Nine Important Tests



1. The test set-up — with the cables on a fixed drum covered with sandpaper.



2. Commercial cable after 25 cycles.

3. Industrial cable after 25 cycles.

Abrasion

Description of test:

In this ambient temperature test, the surface of a fixed drum was covered with rough sandpaper and the cables stretched across a portion of its circumference then moved back and forth cyclically, with the cable driven on one end by a reciprocating arm, while a suspended weight on the other end applied tension. A counter logged the cycle count.

Commercial cable:

After 25 cycles, the conductors of commercial Cat 5e cable could be seen through breaks in the jacket. In other words, due to abrasion damage from 25 cycles on the drum, this cable began to lose mechanical and electrical integrity.

Industrial cable:

Belden's DataTuff® Industrial Ethernet cable 121700A — an armored cable — was tested. The mechanical and electrical integrity of the cable was never compromised.

What the test results say:

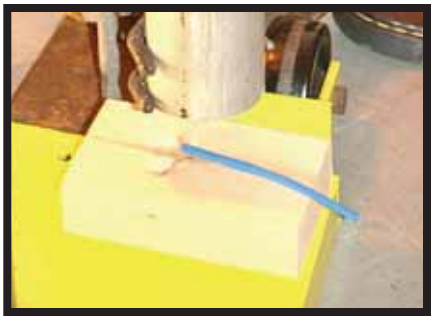
If a COTS cable's jacket is compromised by abrasion — the cable might still be capable of communication, but it certainly won't be stable on a long-term basis. Eventually, a catastrophic short circuit becomes likely; arcing could occur — which would be a safety issue.

Belden's DataTuff cables last much longer than COTS cable in an environment where cable jacket abrasion is a risk.

DataTuff®

In the cold bend test, the cables were first placed into a cold box.

Then they were partially wound around a mandrel and subjected to the tension experienced through the use of an aluminum weight.



In the cold impact test, after the cable is cooled an aluminum weight smashes against it.

Cold Bend

Description of test:

In this test, carried out per UL 444, samples of cables were left in a controlled temperature and humidity environment chamber called a cold box. They remained that way for one hour to get them acclimatized to the temperature of the test (three temperatures were looked at: -80°C, -60°C and -40°C). The cables were then partially wound, around a 3-inch diameter horizontal mandrel, with one end of the cables under tension from an aluminum weight (a cold bend test). They were then immediately unrolled and visually inspected to look for cracks in the jacket.

Commercial cable:

The commercial-grade cables became brittle and cracked by the exposure to these cold temperatures.

Industrial cable:

The 7928A DataTuff® Industrial Ethernet cable was taken down to -80°C, and bent without cracking the jacket.

What the test results say:

Commercial-grade Ethernet cables are fine for the climate-controlled environment of the office but will fail as they become embrittled by exposure to cold temperatures. In the test described here, Belden's engineers couldn't get this industrial cable cold enough to crack its jacket!

Cold Impact

Description of test:

In this test, conducted per UL 444, an aluminum weight was dropped down a hollow guide-tube to smash against a segment of cable under test; the cable had been previously cooled. The impact force delivered 24 in-lbs or 2.7 joules of impact energy. Ten samples were inspected at a series of increasingly lower temperatures.

The failure mechanism here was similar to that experienced in the abrasion test, or the cold bend test, wherein jacket integrity is lost, allowing the ingress of chemicals or moisture. This could lead to a short, plus the cable could short to any other metallic object it makes contact with. There could also be catastrophic failure in electrical performance.

Commercial cable:

The commercial cable failed at -20°C.

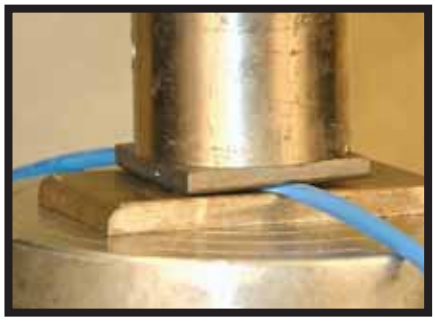
Industrial cable:

The 7928A high/low temp DataTuff cable jacket did not crack until impacted at -70°c.

What the test results say:

In an industrial arena, cold temperatures can sometimes combine with mechanical shock or collision to damage a cable's jacket. Commercial Ethernet cable, designed for relatively light stresses in benign environments, is simply not built to withstand cold impact as it becomes susceptible to cracking.

The Instron crushing device.



The COTS cable is smashed flat and fails at 400 lbs.

The DataTuff cable fails only after a ton of crush pressure.

Crushing

Description of test:

In this test, an Instron machine head brings a 2"x2" plate down on a segment of cable to crush it—with failure defined as the point at which the cable would no longer support Cat 5e applications reliably. To perform the test, the cables were electrically connected to test equipment to measure their electrical characteristics, i.e., return loss and impedance, as the crush pressures were increasingly applied. The test failure criteria for this test, performed at ambient temperature, were in accordance with TIA/EIA Category 5e standard.

Commercial cable:

The blue COTS cable with a PVC jacket is smashed flat; it will not spring back to its original shape. It failed at 400 lbs applied force.

Industrial cable:

By contrast, the failure value for the Belden® DataTuff® 121700A black-jacketed, armored industrial cable was over a ton (2,250 lbs).

What the test results say:

Sometimes workers will step on a cable, run over it with a vehicle, or accidentally apply a crushing force in some way. If the cable is a COTS, its performance will likely be degraded or fail. By contrast, an industrial cable, especially an armored product, can sustain significantly more crushing force and keep working.

A battery of rigorous tests conducted at Belden show commercial cables will not perform as well as their industrial grade counterparts in factories or other harsh environments.

Cut-through

Description of test:

In this test, based on CSA standard # 22.2, a chisel-point mandrel on an Instron machine was lowered onto a segment of cable. This test reveals the susceptibility of a cable to having its conductor exposed after being cut; which directly relates to a cable's vulnerability to short circuits, and therefore safety. In practice, the cable was cut through by the chisel to the point where a short circuit was sensed across the conductors (by means of a lead attached from the cable to the fixture)—i.e., a simple continuity test was carried out.

Commercial cable:

Cables examined in this test included the COTS product which shorted out at 92 lbs applied force.

Industrial cable:

Unarmored DataTuff® cables showed the following results: 7923A took 205 lbs applied force to short; 11700A took 346 lbs to short. And, Belden's 121700A armored industrial cable took 346 lbs applied to pierce the armor; however, the conductors themselves did not short until a force of 1,048 lbs was applied.

What the test results say:

It takes considerably more applied force to puncture an armored industrial cable than a commercial off-the-shelf product. If a commercial-grade Ethernet cable is looped in tension around a sharp cutting edge, or is run into by, say, the sharp corner of the blade on a forklift truck, it only takes a force on the order of 90 lbs or less to functionally damage the cable. Once it's out of commission, the entire network goes with it.

A chisel-point mandrel on an Instron machine performs the cut-through procedure.

High Temperature

Description of test:

In this test, three spools of cable were suspended from a mandrel in a high temperature oven; the blue cable in the middle is a COTS cable with a standard Cat 5e PVC jacket and the other black-jacketed cables are industrial-grade Belden® DataTuff 7928A cable with an FEP jacket and 7922A cable with a PVC jacket. These cables were first tested for signal attenuation at an ambient temperature (20°C) and were then tested again after being exposed to a high temperature over time (60°C).

In Chart A, the solid black line represents a performance specification for an ideal Cat 5e cable. Signal attenuation curves must lie on or above this target line for the cables to be considered to be working properly.

Commercial cable:

The COTS cable functioned acceptably at 20°C, but—over time—at 60°C attenuation increased to where the cable would not support a run distance of 100 meters.

Industrial cable:

Even after exposure to 60°C over time, the industrial-grade cable continued to support the maximum run distance.

What the test results say:

In environments where your Ethernet cable will be located in an area with a very high ambient temperature, or located near a high temperature source, a commercial off-the-shelf cable will simply not be able to maintain an acceptable level of performance.

The cables were tested, as suspended, in a high temp oven.

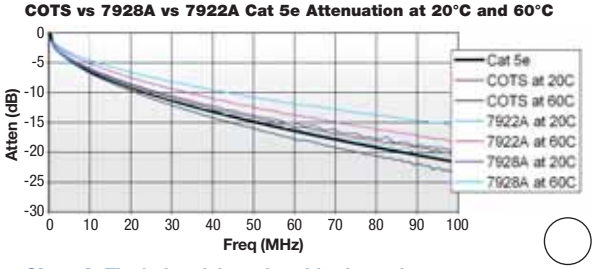


Chart A. The industrial-grade cable showed little attenuation – even at 60°C.

Oil Resistance

Description of test:

In this test, conducted per UL 1277, lengths of cable were immersed in containers of oil, which in turn were immersed in a water bath that was put into a chamber held at 125°C for 60 days. The blue cable in the photo is a commercial-grade product, and the black one is an industrial-grade DataTuff® cable. After the 60-day test period, the cable segments were removed and their jackets evaluated for tensile and elongation properties.

Commercial cable:

Exposure to oil can make the jacket of a commercial-grade cable brittle and fragile, even at room temperature, with a resulting loss in mechanical properties like tensile strength and elongation. In other words, the service life of a COTS cable can be diminished by oil exposure—even in "normal" heat conditions. Things get worse from there. If a commercial cable is exposed to oil long enough and at high enough temperatures, its jacket can swell and blister and, eventually, fall apart. In the process, the geometry of the cable is changed, and along with it the dielectric constant and related electrical properties.

Industrial cable:

The jacket materials and jacket thicknesses on Belden® DataTuff cables are appropriate for exposure to oil at elevated temperatures, such as lubricants or cutting fluids.

What the test results say:

With a COTS cable, short circuits and catastrophic failure are possible, with a resulting loss in communication. When the weakness in a cable jacket induced by oil exposure is combined with a crushing force or an impact—events that are not at all unlikely in an industrial environment—a brittle cable will offer essentially no resistance to damage.

The oil bath test, conducted as specified in UL 1277.

UV Exposure

Description of test:

In this ASTM procedure-based test (ASTM G 154: Standard Practices for Operating Fluorescent Light Apparatus for UV Exposure of Non-Metallic Materials), segments of various cables were affixed to panels that were mounted so that the cable segments faced inward toward a fluorescent UV light source (whose output range was adjusted to match that of solar radiation levels). The circular artifacts shown are retaining springs. The samples were exposed to the light for 720 hours—30 days. When the cable segments were removed they were visually checked for discoloration and then the jacket was checked for tensile strength and elongation.

Commercial cable:

Like most commercial-grade cables, this cable's jacket was not sunlight-resistant. Therefore, the light-colored COTS cable in the photo (at right), shows the first symptom of excessive exposure to UV: discoloration. Color degradation is also a precursor of the degradation of the plastic material of the jacket. When the jacket begins to decompose, its mechanical properties are likely being compromised too, including elongation and tensile strength. As the jacket falls apart, the cable becomes susceptible to water or moisture permeation and the situation is only worsened when the UV-weakened jacket is simultaneously stressed by effects like abrasion, cut-through, etc.

Industrial cable:

Belden's DataTuff cables have a broad range of UV-resistant jackets.

What the test results say:

In an industrial environment with UV present, it's important to use a cable with a jacket that resists damage to radiation. This is especially critical when the cable will see application outdoors, or be located near a window or other UV sources.

The UV exposure test is based upon ASTM procedures.

Water Immersion

Description of test:

Here, the electrical properties of the cables (primarily signal strength) were measured as the cables were received, then they were coiled up into a dry container and water was added to submerge them. To determine electrical performance, the cables were tested over time (up to six months immersed in water).

The graphs plot signal attenuation over a range of frequencies—with data taken when the cables were first placed in water, and six months later. The solid black line shows the Category 5e performance requirement—a kind of ideal reference standard.

Commercial cable:

After half a year it's evident the commercial-grade Cat 5e cable is failing to meet its expected performance level. In fact, remarkably, as soon as the cable was placed in water it showed increased attenuation; after six months the attenuation continued to degrade.

Industrial cable:

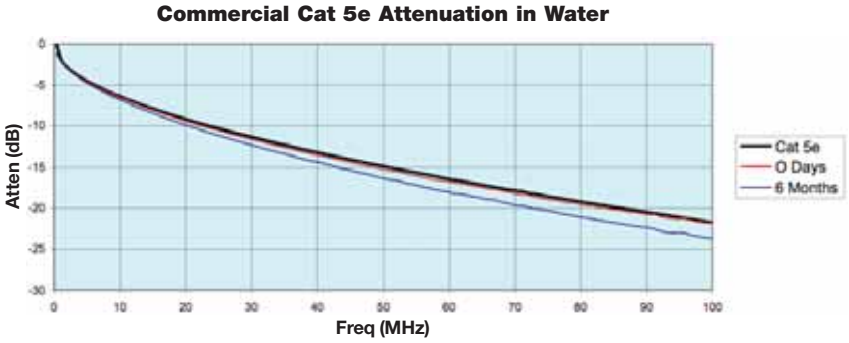
The DataTuff® 7934A chart shows that the performance requirement (solid black line) was not only met but initially exceeded. After six months, there was only slight attenuation increase, and the cable still exceeded the Cat 5e requirements.

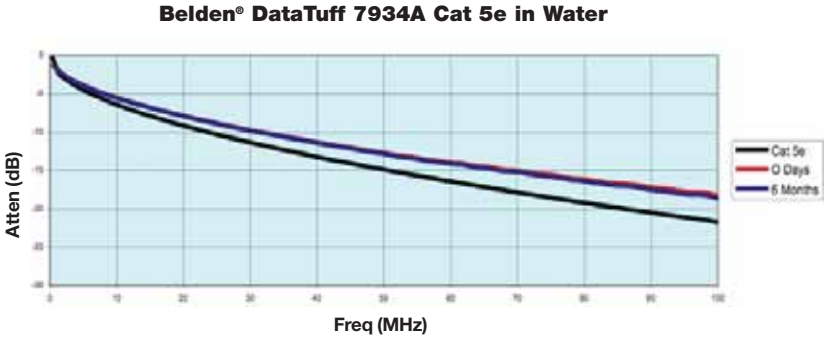
What the test results say:

Water can breech the jacket of a commercial-grade cable by permeating areas of the jacket material or by seeping through pinholes. Once that happens, the dielectric constant can change enough to degrade the attenuation performance. In some cases, the cable's conductors can short out—though before that occurs you'd likely have a loss of communication. The effect is insidious in that it can build up over time, even though the cable worked fine initially.

In the controlled environment of an office, moisture exposure is not a concern. That's not true in many industrial applications however, like those where the cable is submerged in a tank, placed in troughs or below-grade trays, or exposed to rain or water on a continual basis. There, an industrial-grade cable is essential. In addition, industrial-grade—not commercial-grade—cables are called for in applications where a cable is to be buried underground. There might be a situation where remote outdoor consoles send signals back to a master location via a buried cable. Ethernet cables are common in many transportation scenarios, as well, such as in railways and subways. Moisture is a concern in all of these situations and only an industrial-grade burial flooded cable is acceptable.

The water bath test is a six-month long test, with the cables fully submerged in water.





A six-month long test, fully submerged in water: top chart depicts the extensive attenuation degradation of the COTS cable; the bottom chart shows the superior performance of Belden DataTuff 7934A.

DataTuff® Industrial Ethernet Cable Selection Guide

This chart is meant to help the user in proper cable selection.

Part No.	No. of Pairs	Shielding		Conductor		Installation		Environmental Issues							Industrial Grade Jacket		
		Unshielded	Shielded ▲	Solid	Stranded ▲▲	Installation Stress Resistance††	Pull Tension	Oil Resistance	UV Sunlight Resistance	CMX/ Outdoor	Underground (burial)	Gasoline Resistance	LSZH	MSHA	Hi/Lo Temp	Heavy	Upjacket	Armored
Category 5e Cable																		
7932A EtherNet/IP	2	●		●		●	20	●	●							●		
7933A EtherNet/IP	2		●	●		●	20	●	●							●		
7923A EtherNet/IP	4	●		●		●	40	●	●	●				●		●		
7918A	4	●		●			35	●	●	●				●		●		
7924A	4	●			●	●	40	●	●	●						●		
7930A	4	●			●		25	●	●	●						●		
7922A PLTC	4	●		●		●	40	●	●	●						●		
7934A EtherNet/IP	4	●		●		●	40		●		●					●		
new **7937A**	4		●	●		●	40		●		●						●	
7928A EtherNet/IP	4	●		●		●	40	●	●			●			●	●		
11700A EtherNet/IP	4	●		●		●	40	●	●	●				●			●	
11700A2 Oil Res I&II	4	●		●		●	40	●	●								●	
121700A	4	●		●		●	40	●	●									●
new **121700R**	4	●		●		●	40	●	●									●
7929A	4		●	●		●	35	●	●	●				●		●		
7919A	4		●	●			25	●	●	●				●		●		
7921A EtherNet/IP	4		●	●		●	75	●	●	●						●		
new **7935A** EtherNet/IP	4	●		●		●	40		●				●			●		
new **7936A** EtherNet/IP	4		●	●		●	40		●				●			●		
Category 6 Cable																		
7927A	4	●		●		●	45	●	●							●		
7931A	4	●		●		●	40	●	●			●			●	●		
11872A	4	●		●		●	45										●	
121872A	4	●		●		●	45	●	●									●

▲ Shielded products are recommended for high-noise environments.
▲▲ Stranded products are recommended where more flexibility is needed.
†† Products with Bonded-Pair technology provide Installable Performance® advantages — refer to Belden's Bonded-Pair Cable Bulletin #BP02

Belden DataTuff Cables Mean Greater Reliability

To ensure optimum industrial plant performance, be sure to specify Belden DataTuff cables. As we have shown on the preceding pages, commercial-grade cables, or COTS cables, are really quite fragile compared to Belden DataTuff cables. And because of their fragility, COTS cables could lead to data transmission problems and/or catastrophic failures—with untold costs.

Only Belden DataTuff cables provide the reliability you are looking for, the reliability you need. We've been at the forefront of the industrial marketplace for decades and we thoroughly understand the industrial environment. Our product range is also outstanding, providing:

- Tray Optic® Indoor/Outdoor optical fiber cables
- Copper Category 5e and Enhanced Category 5e twisted pair cables (unshielded and shielded with heavy-duty oil- and UV-resistant jackets)
- Copper Category 6 twisted pair cables (unshielded with heavy-duty oil- and UV-resistant jackets)
- Upjacketed and armored cables for the more extreme environments

Many unshielded twisted pair cables also feature Belden's patented Bonded-pair technology. This construction feature affixes the conductor insulation of the unshielded twisted cable pairs along with their longitudinal axes to ensure that no performance-robbing gaps can develop between the conductor pairs. Since no gaps can occur, and the conductor-to-conductor spacing, or centricity, is always uniform, so the cable offers excellent and consistently reliable electrical performance—even after the cable has been subjected to the bending, pulling and twisting that is inherent in the installation process, the stresses of the plant floor. Belden calls this unique performance capability Installable Performance®.

Whatever your need, Belden provides the solution. And all of our Industrial Ethernet cables are RoHS compliant. Call **1.800.BELDEN.1** or visit our web site at **www.belden.com** for more product information or to find a Belden sales associate or a distributor near you.

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