Cables in Wet Environments

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Abstract

Industrial environments and outdoor installations can also be wet or damp locations. Category communications cable products that are installed in these environments must be able to operate without issue when installed. The typical tests that are used to evaluate these products determine if water can enter the connectors or if water can propagate down the cable core. Unlike these typical tests, this investigation will focus on tests which evaluate electrical performance of cables that are in water. This will improve understanding of the full effect of wet or damp locations on structured cabling.

The high-frequency performance of an unshielded cable may be affected when the environment of the cable is water rather than air. This effect is mitigated by jacket design and shielding.

Stranded conductors in humid environments might wick moisture into the cable, which could cause failures. Some connectors for industrial environments are designed to avoid this.

By studying the effect of water and humidity on the cable, installation recommendations can be formed for twisted pair Ethernet cables in wet locations.

Keywords: Ethernet; damp location; wet location; outdoor cable; industrial cable; Insertion Loss

1. Introduction

Water can absorb electrical signals. Ethernet cables designed with water exposure in mind have different materials in their construction than indoor-rated cables. Products may have ANSI/ICEA water penetration ratings and sunlight resistance rather than fire and smoke safety ratings.

Indoor Ethernet products are not typically designed to tolerate wet locations. The cores of the cables are not water blocked and the jacket materials are chosen for electrical properties and fire safety.

Industrial Ethernet products are a wide range of cables that are designed to operate in environments that would cause normal cables to fail. These products may or may not be designed to handle the stresses of outdoor and wet locations.

When Ethernet cables are exposed to water, their performance can be affected several different ways. A water environment outside the cable will have higher loss than an air environment. The plastic of the jacket may be permeable enough to allow water to diffuse through. Water can get into the cable core. Barriers such as metal foils can keep water from diffusing into the cable core.

Water can pass through the jacket into the core of the cable by diffusing through the jacket material or by passing though holes caused by installation damage. If water enters the cable core, it can propagate to the electronics at the end of the cable run or cause shorts within the cable. Either of these effects would ruin the cable run.

The transmission lines of the pairs in the cable are designed to operate with an environment of the jacket and air around it. If the cable jacket absorbs water, this will change its electrical properties (loss, dielectric). The electrical performance of the cable will be degraded when these properties change. Even if the jacket does not absorb the water, an environment of water (rather than air) around the cable can change the high frequency electrical performance.

Of the electrical performance parameters, Insertion Loss and Impedance were expected to be most affected by water outside the cable core. Impedance has environmental components – the capacitance between the transmission pair and the surrounding materials has an impact. Insertion Loss increases when electrical fields are absorbed by a high loss medium.

2. Test Setup

2.1 Cables Submerged in Water

Samples of different designs of cables from different manufacturers were coiled and secured to maintain their shape. These samples were tested for electrical performance parameters using automated test equipment. These tests were treated as a baseline for the samples for the rest of the testing.

The cable samples tested included the following. All of the cables were four pair Ethernet cables rated to Category 5e. A sample of riser rated unshielded Ethernet cable with a PVC jacket was used to represent indoor cable products. A sample of outside plant cable with sunlight and water resistant polyethylene jacket and a gel-flooded core was used to represent outdoor cable products. An unshielded riser and outdoor rated industrial Ethernet cable with a PVC jacket that was designed for oil resistance and light duty environments was used to represent unshielded industrial Ethernet products. An industrial Ethernet cable with a metal foil shield with a braid over it (SF/UTP) that was riser and outdoor rated with a highly flexible TPE jacket was used to represent shielded industrial Ethernet products.

After the baseline tests, the samples were then placed into plastic barrels full of water. The coil portion of the sample was fully submerged in the water. The ends of the samples were kept out of the barrel for the distance needed to connect to test equipment. This was approximately two meters on each end. The samples were tested with the automated test equipment when first submerged in water and again periodically for several weeks.

The samples were removed from the water barrels and dried completely. The samples were tested using the automated test equipment again.

2.2 Cables in Humid Environment

Samples of stranded and solid conductor cables were tested at room temperature (~20°C) at low humidity. The samples were conditioned at 30°C and 90% relative humidity for one week. The samples were brought back to 20°C and tested again.

Additional samples of the same material were terminated using Ethernet and industrial cable plugs as appropriate to the cables. These samples were tested at room temperature (~20°C) at low humidity. The samples were conditioned at 30°C and 90% relative humidity for one week. The samples were brought back to 20°C and tested again.

3. Test Results

3.1 Cables Submerged in Water

The test results for the samples that were submerged in water were compared to the baseline results for the same cables. Changes in the electrical performance parameters were trivial except for the Insertion Loss parameter. The Impedance did not show the expected change. The Insertion Loss Parameter showed large changes for most of the samples that were tested.

The Category 5e Insertion Loss specification was applied and minimum margins for the products' Insertion Losses were calculated. These minimum margins were graphed and compared for each of the products to determine how much the submersion in water impacted the product's performance. For simplicity, the measurements when the samples were submerged were averaged together. See Figures 1 to 4 for the individual results presented graphically. Table 1 has the full results of the tests for cables submerged in water.

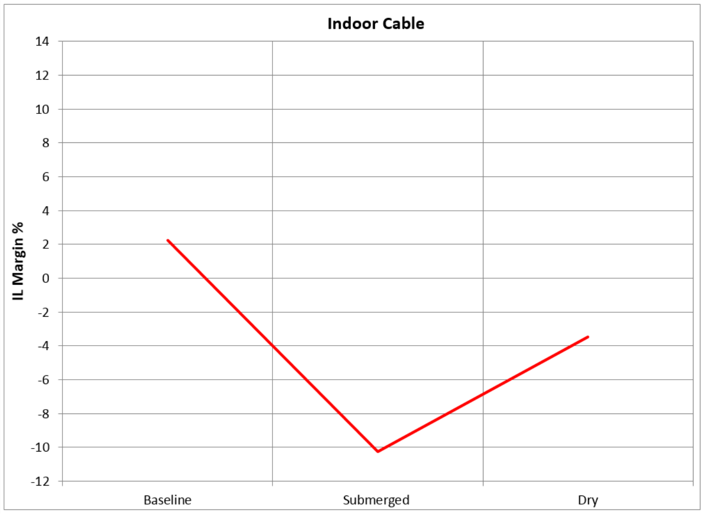

Figure 1 - Indoor Cable Test Result

In Figure 1, the impact of the water on the indoor rated product is clearly visible. The sample went from passing the specification with margin to thoroughly failing when it was submerged in water. When the sample was dried, the sample still failed to meet the Insertion Loss specification.

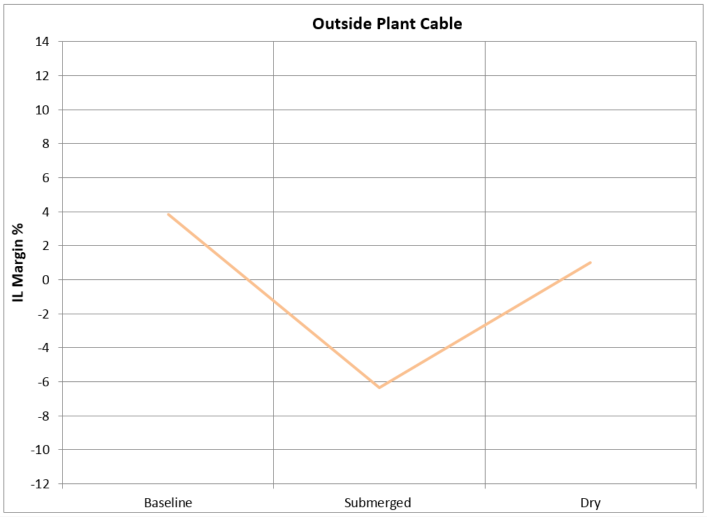

Figure 2 - Outside Plant Cable Test Result

The outside plant cable sample in Figure 2 lost Insertion Loss margin and failed to meet the specification when submerged in water. When the sample was dried, the test result returned to passing the specification, but it did not return to the original amount of margin to the specification.

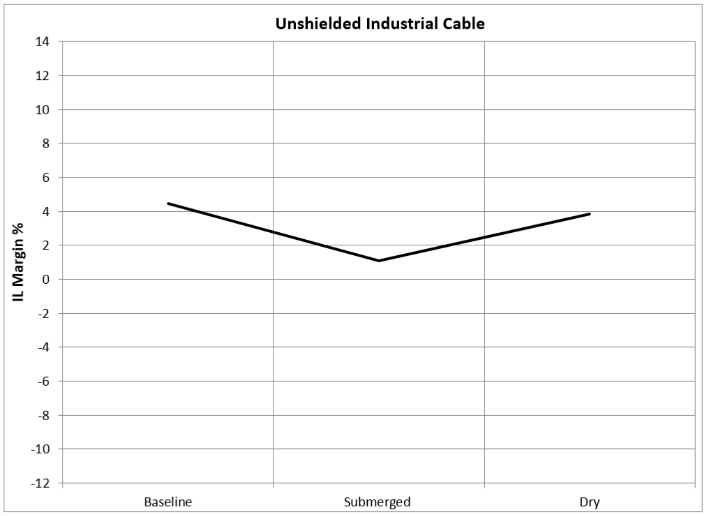

Figure 3 - Unshielded Industrial Cable Test Result

In Figure 3, water submersion's effect on an unshielded industrial cable sample can be observed. The sample lost performance margin when in water, but does not fail the specification. When the sample was dried, the performance margin was within the range allowed for measurement error from the baseline measurement.

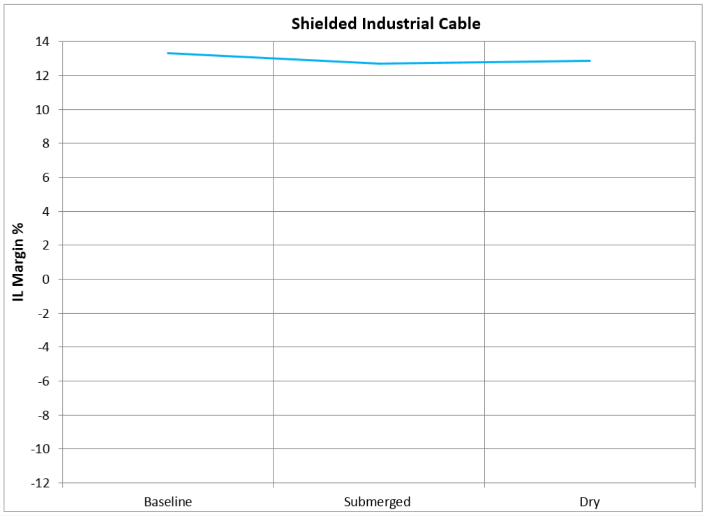

Figure 4 - Shielded Industrial Cable Test Result

Figure 4 shows the impact of the water test on a shielded industrial cable sample. The Insertion Loss margin varied by less than the range allowed for measurement error from the baseline measurement for the entire test.

Sample	Base	Subm in Water	1 Week Subm	2 Week Subm	3 Week Subm	Dry
Indoor Cable	2.3	-8.6	-9.3	-10.7	-11.4	-3.5
Outside Plant Cable	3.8	-2.1	-5.7	-7.6	-8.2	1.0
Unshielded Industrial	4.4	1.6	1.3	0.7	0.9	3.9
Shielded Industrial	13.3	12.0	13.0	12.6	13.3	12.8

Table 1 - Insertion Loss Margin (%) of Samples Submerged in Water for Several Weeks

In Table 1, the change over time in Insertion Loss of the samples in the water can be observed. The Industrial Ethernet cables had stable Insertion Loss margin over time once submerged. The other two products showed degrading performance as the duration of submersion continued.

3.2 Cables in Humid Environment

Samples of stranded and solid conductor cables were tested at room temperature and low humidity and then again at room temperature after conditioning at elevated temperature and humidity for one week. The solid conductor sample showed no change in high electrical parameters. The stranded conductor sample lost 2.5%

Insertion Loss Margin when compared to the Category 5e specification.

The same baseline and humidity conditioning testing was performed on stranded and solid conductor cables with connectors (plugs) attached. The results after the conditioning showed no change from the baseline measurements.

4. Analysis and Conclusions

None of the products in this survey are intended for long term submersion in water. In practical installations, the entire length of the cable would not be soaked in water and the cable would be able to dry out after getting wet. This test set magnifies the effect of the environmental water to attempt to determine trends with a small test population.

After a review of the designs of the cable samples tested, the revised expectations matched the results. Design features that are used for higher frequency performance, such as tight twist lay lengths and thick cable jackets, affect the cable's interaction with its environment. Shielded products, which typically boast high protection from environmental electric effects, demonstrate high resistance to being affected by a wet environment. These shielded products protect the cable core not only by electrical isolation, but also by presenting a barrier that water won't diffuse through.

The outside plant cable sample and the indoor cable sample that had poor performance had very long pair lay lengths and a thin cable jacket. These traits would make the cable more sensitive to environmental electric effects. Higher frequency products (such as a Category 6 outside plant cable with tight lay lengths) or cables with thicker jackets (for more rugged environments) would also resist effects from a wet environment.

Jacket material also matters, as observed in the indoor cable test result, which degraded and did not recover when dried. This cable sample most likely absorbed water into its jacket. This water affected the material's properties even after the cable was dried off.

The unshielded industrial product experienced a degradation of performance while submerged, but recovered all but 0.5% of its performance margin when dried back out. This loss of margin is within the expected measurement error in the test.

Comparing this product to the indoor cable, the pair lay lengths are slightly different and the plastic compounds are different. The jacket material properties are the most likely reason that this product did not remain degraded when it was dried off. If the jacket didn't absorb water, the performance returning when the cable was dried off is the expected result.

The humidity test results matched expectations. Stranded conductor products like patch cable or flexible industrial cable can absorb water if left exposed. Terminated products won't suffer from this performance loss as the humidity won't wick into the conductor.

This survey of cables showed some results that are worth investigating further. Some of the cable types showed degrading results over time while the samples were submerged. Longer submersion experiments could investigate how far this degradation could progress. It would also be worthwhile to investigate the jacket compounds used in wet and damp location products to determine how these materials interact with water over time. Future studies can evaluate jacket material permeability, water retention, the impact of pair lay length, construction factors such as shielding, different levels of wet or damp environment and different durations.

For installations in environments where cables will be exposed to water, the following recommendations can be made. Extra margin should be built into an install that is expecting to have wet cable.

This can be achieved by cable choice or by installation design for Insertion Loss (usually controlling run lengths). Shielded products and products that are designed to resist electric environment effects will be least affected by water exposure. It is recommended that flexible stranded cables be terminated before installing them to humid environments or as soon as possible after installation.

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