Engineering Test Report

Rolling Bend Flex Test

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Flex Test for Industrial Ethernet cables

Introduction:

Cable flexibility can mean one of two things. A cable can be flexible to a degree so that it can be manipulated (bent) enough to facilitate installation. For example a stranded patch cable being installed in a rack to connect a signal between two patch panels can be bent in a U shape during installation. However, once the cable is installed, it's left alone. This type of flexibility is often referred to as static flex or a static bend and is *not* the focus of this test report. The focus of this test report is concentrated on the destructive flex forces involved in a continuous motion application. For continuous motion flex testing there are a few different tests available. Many people will be familiar with a "Tick Tock" test since they've been around for quite some time. The test is named "Tick Tock" because the test fixture's swing arm moves back and forth through a 180 degree arc similar to the movement of a clock pendulum. Quabbin performed the original flex testing on their industrial Ethernet cables using a "Tick Tock" fixture and received positive results. However, after field observations and experimentation Quabbin concluded the "Tick Tock" method is a special case because it is a supported bend, that is the cable bend radius is fixed by a mandrel. This is not the typical installation of a cable on a robot arm. Quabbin believes that a more realistic test is an unsupported rolling bend. In an unsupported bend the cable construction has to prevent the bend from becoming concentrated in a small area and kinking the cable without the help of a mandrel. Flexing at a kink will cause conductor and shield failure. A robotic arm has reach and exhibits variety in the flex motion that inevitably spreads force over a sizable section of the cable. Simulating these parameters requires a more comprehensive type of flex testing equipment, specifically a device that can simulate a rolling bend. Loosely making the comparison of a human arm to a robotic arm, a rolling bend test is going to simulate not only the bending of an elbow (like the Tick Tock) but additionally the reach of the arm which in fact turns out to be critical. As a side note, there is also a third test commonly referred to as a torsion test. If we can again use the analogy of the human arm to the robotic arm, the torsion test represents the turning of a wrist. Although still called a flex test, it might have been more properly coined a "twist test". For more information on torsional force testing, please refer to the Quabbin Industrial Ethernet, Torsion Test Report.

Test Description:

This test is a rolling bend test. The goal of the testing is to simulate an application that subjects the cable to continuous motion/movement in an unsupported bend. Testing was performed without the benefit of a protective C-Track mechanism. The basis for this was twofold. First, the primary goal was to determine the true reliability and life expectancy of the cable, not to determine the effectiveness of the C-Track in protecting the cable. Secondly, many applications such as robotic arms do not provide a method to implement a C-Track and consequently must rely on the robustness of the cable and the cable alone in providing system reliability.

In order to set up this rolling bend style flex test the cable assembly is clamped near the start and end of the unsupported bend. See figure 1

All assemblies were terminated with AMP® Cat 6 modular plugs. All assemblies were tested using a Fluke DTX -1800® CableAnalyzer™ hand held tester with patch cord adapters. Cat 6 limit lines were used so that performance changes would be more visible.

As would be expected, the "tightness" of the bend has an impact on the cable's life expectancy. Consequently, two tests were run on each cable tested. One test was conducted on what will commonly be considered a small bend radius and the second test represents a moderate bend radius. (exact specifications follow below) The first test was the small bend and was run for 1 million cycles and the second, moderate bend was a 10 million cycle test.

All testing was done in a heated warehouse space. Temperatures ranged from 15C to 35 C. Humidity was uncontrolled and not measured.

Cables were clamped using 4 bolts through a plate at each end of the flex stroke. Foam polyurethane was used to prevent damage to the cable and to provide strain relief at the clamp point.

1 million cycle test:
The cables were tested with a radius of 10X the cable OD (4.5") and a 9" stroke for 1 million cycles at a rate of 120k cycles per 24 hours. Using the Fluke® tester the cables were tested for transmission and continuity daily while moving slowly. Testing the cable while it slowly moved through the flex test stroke cycle helps eliminate any hidden intermittent failures that may not present themselves if the cable were tested in a motionless state.

10 million cycle test
For the second test, two new assemblies were tested with a radius of 20X the cable OD (8") and a 9" stroke for 10 million cycles at a rate of 120k per 24 hours for the first 6 million cycles. Ironically, the test fixture's motor failed at 6 million cycles. The motor was replaced with a heavy duty unit and the cycle rate was increased to 170k cycles per 24 hours for the remainder of the test. Using the Fluke DTX -1800 Cable Analyzer™ tester the cables were tested moving slowly at approximately 1 million cycle intervals.

Products Tested

Part number 5752 - 4 pair, unshielded DataMax® Extreme patch cable with TPE jacket

Part number 5772 - 2 pair, unshielded DataMax® Extreme patch cable with TPE jacket

Quabbin part number 5077 - 4 pair, double shielded (foil & braid), DataMax® Extreme with Non Halogen TPU jacket

Test Results

Initial test were done on the 2 and 4 pair unshielded TPE cables. Testing on the 5077 double shielded, non-halogenated TPU cable was performed at a later date and results are included at the end of this report.

1 million cycle test

The 5752, 4 pair and the 5772, 2 pair cable passed the cat 6 assembly test after 1 million cycles (see table 1). The performance of the cables does appear to change slightly, but the variation is within the limits of tester accuracy. The cable was tested while it was moving slowly to rule out conductor failure. Some of the variation seen in table 1 may be due to the cable moving. Following the flex testing, the cables were dissected and inspected for damage. The polyester tape had damage visible to the unaided eye in both cables.   Inspection under a microscope revealed no damage to the 2 pair cable (Fig. 2) and some slight abrasions to the insulation in the 4 pair cable (Fig. 3). The insulation damage in the four pair cable is not significant as the remaining wall is well above the UL minimum required for the CM approval and to meet high potential tests for a 300V rating. The damage is also on the outside of the pair, therefore it has no impact on electrical performance.

10 Million Cycles

Both the 4 pair and the 2 pair cables passed the Cat 6 assembly test after 10 million cycles (see table 2). As in the 1 million cycle test the performance of the cables does appear to change, but much of the variation is within the limits of tester accuracy. The cable was tested while it was moving slowly to rule out conductor failure. Some of the variation seen in table 2 may be due to the cable moving. After the flex testing, the cables were dissected and inspected for damage. As in the 1 million cycle test the polyester tape had damage visible to the unaided eye in both cables.   Inspection under a microscope revealed no damage to the 2 pair cable (Fig. 4 and 5). The 4 pair cable had some visible powder and slight abrasions to the insulation in the 4 pair cable (Fig. 6 and 7). The insulation damage in the four pair cable is not significant as the remaining wall is well above the UL minimum required for the CM approval and to meet high potential tests for a 300V rating. The damage is also on the outside of the pair, therefore it has no impact on electrical performance

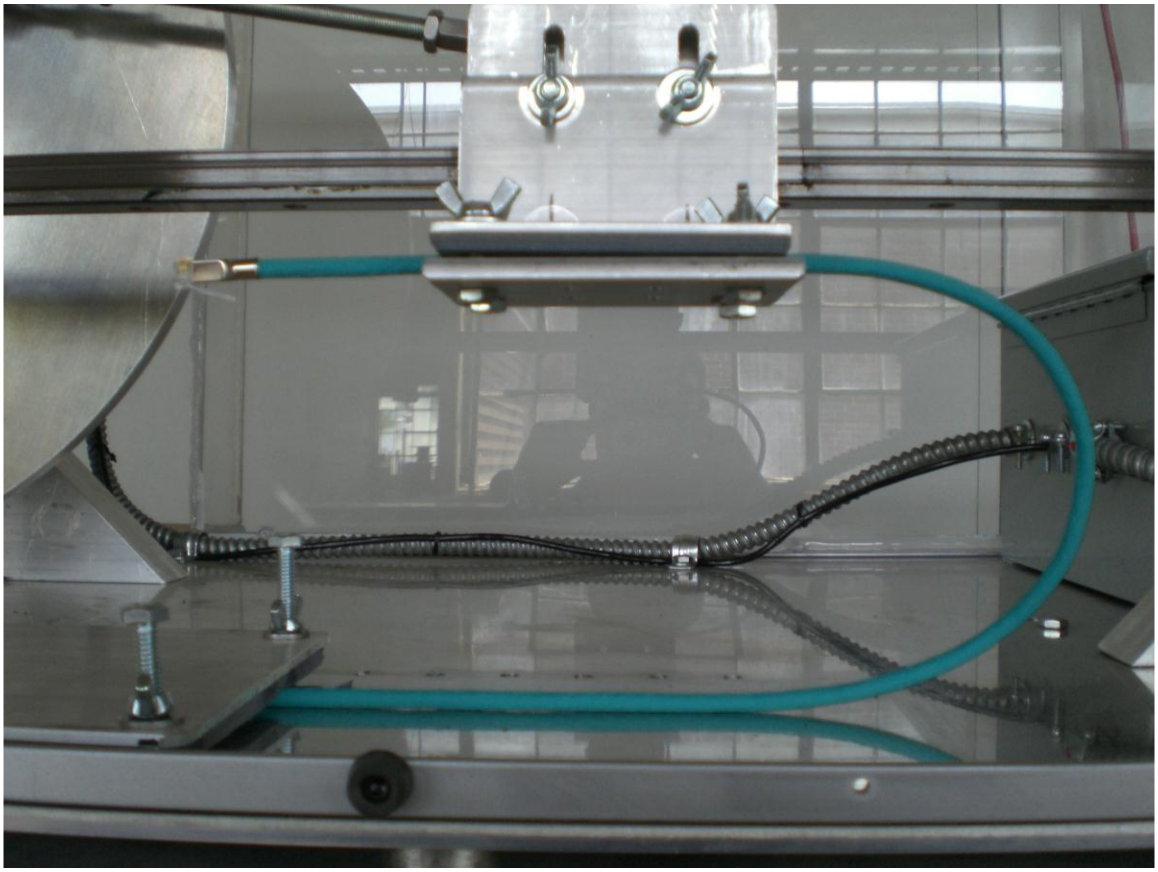


Figure 1.
Flex test fixture

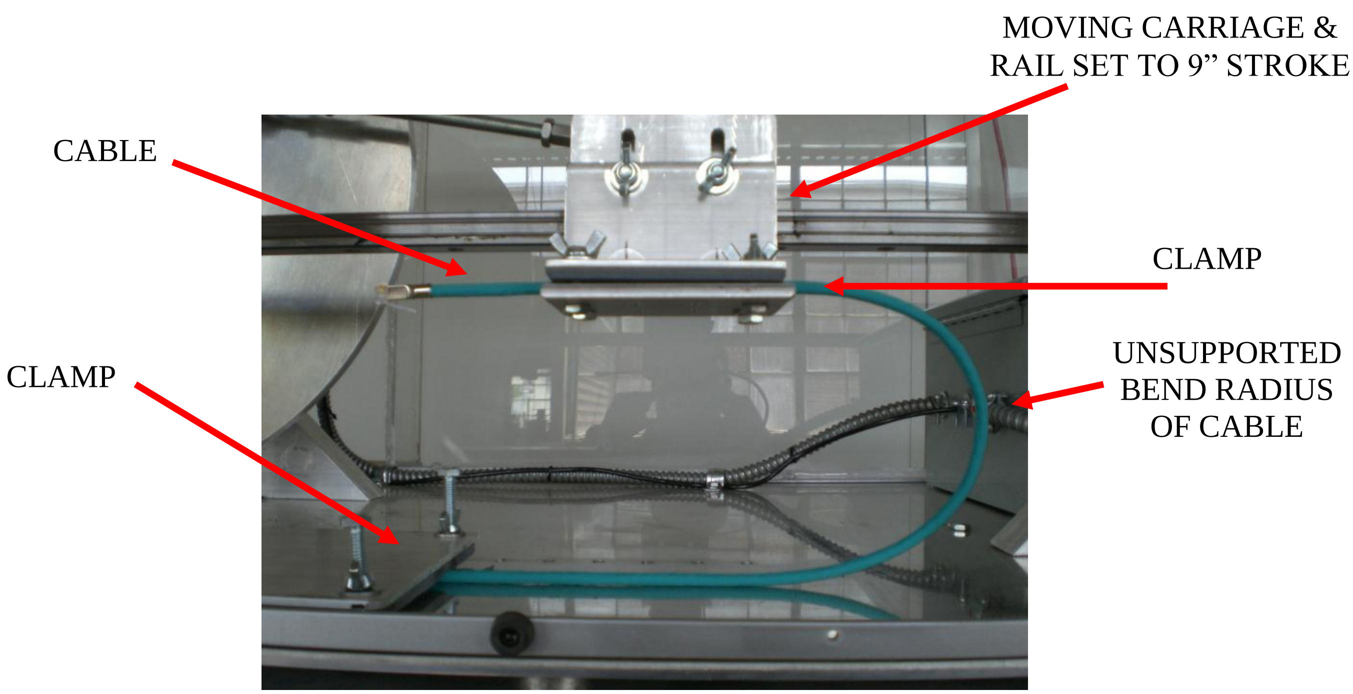


Table 1
Electrical Performance Testing
1 MILLION CYLCLES

Part number	**RETURN LOSS (Cat 6 Limits)**					**NEXT (Cat 6 Limits)**				
	Pair	Return Loss Margin Before	Frequency (MHz)	Return Loss Margin After	Frequency (MHz)	Pairs	NEXT Margin Before	Frequency (MHz)	NEXT Margin After	Frequency (MHz)
5770	Org (1-2)	1.3	229.0	3.9	90.8	Org x Grn	.4	222.0	1.4	220.0
	Grn (3-6)	1.1	127.0	3.6	94.0					
5750	Blue (4-5)	2.2	21.7	3.0	24.0	Blue x Org	3.2	165.0	2.9	167.0
						Blue x Grn	6.6	240.0	5.0	235.0
	Org (1-2)	3.0	21.0	3.4	23.8	Blue x Brn	5.2	249.0	7.3	40.2
						Org x Grn	4.6	215.0	2.4	250.0
	Grn (3-6)	1.4	23.9	1.7	22.7	Org x Brn	9.3	231.5	6.2	217.5
	Brn (7-8)	3.9	23.8	4.7	24.0	Grn x Brn	3.8	50.8	2.3	153.0

Figure 2
2 pair cable

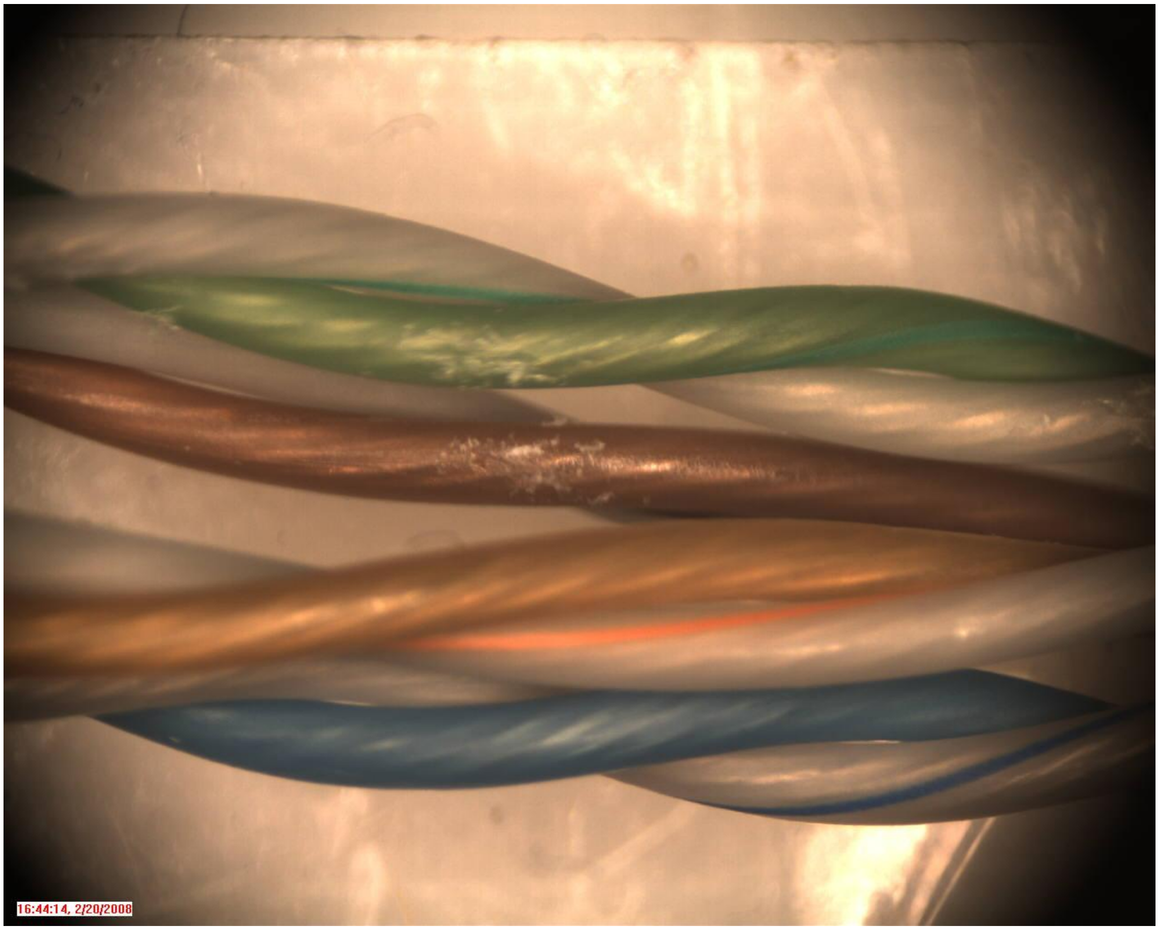


Figure 3
4 pair cable

Table 2
Electrical Performance Testing
10 MILLION CYCLES

Part number	RETURN LOSS (Cat 6 Limits)					NEXT (Cat 6 Limits)				
	Pair	Return Loss Margin Before	Frequency (MHz)	Return Loss Margin After	Frequency (MHz)	Pairs	NEXT Margin Before	Frequency (MHz)	NEXT Margin After	Frequency (MHz)
5770	Org (1-2)	7.3	250.0	1.4	213.5	Org x Grn	4.3	250	2.8	210.0
	Grn (3-6)	5.4	224.5	2.3	224.5					
5750	Blue (4-5)	3.0	21.7	3.2	22.7	Blue x Org	2.4	197.5	.5	195.0
						Blue x Grn	4.8	46.4	4.7	40.4
	Org (1-2)	9.1	241.0	8.5	17.0	Blue x Brn	7.8	120.5	8.9	124.5
						Org x Grn	3.8	249.0	4.8	248.5
	Grn (3-6)	5.8	98.0	6.3	22.7	Org x Brn	10.4	239.0	7.8	47.6
	Brn (7-8)	4.9	239.5	7.6	67.8	Grn x Brn	2.1	239.5	2.4	241.5

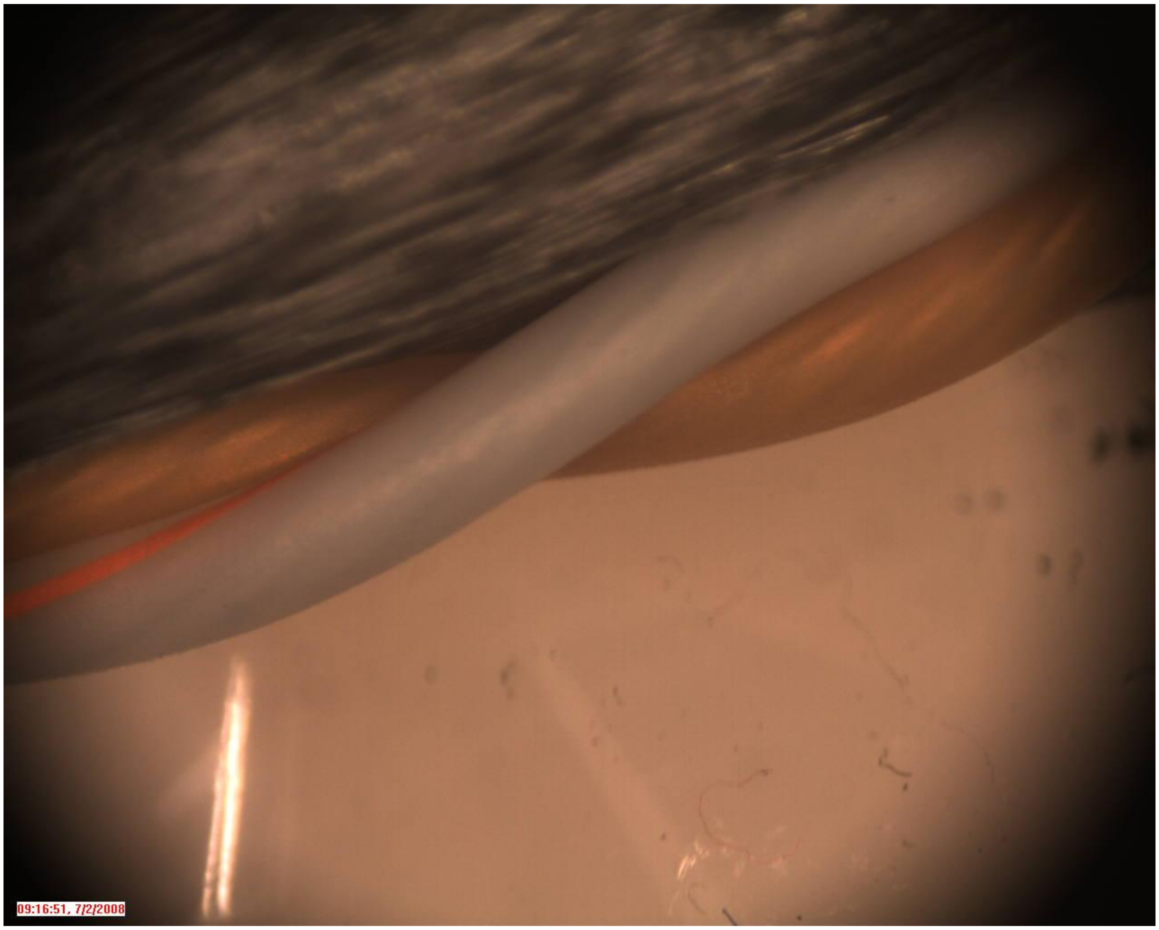


Figure 4
Orange pair of 2

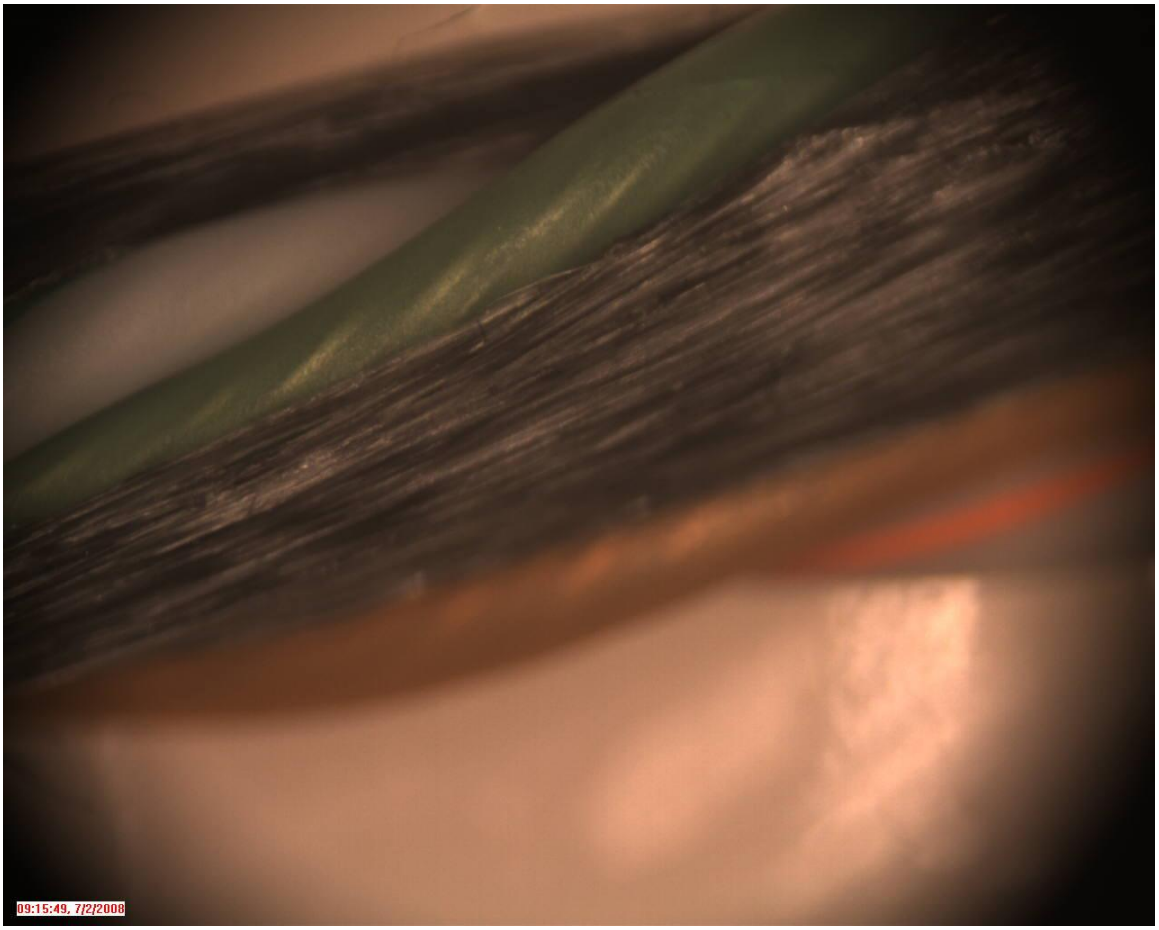


Figure 5
Green pair of 2
pair cable

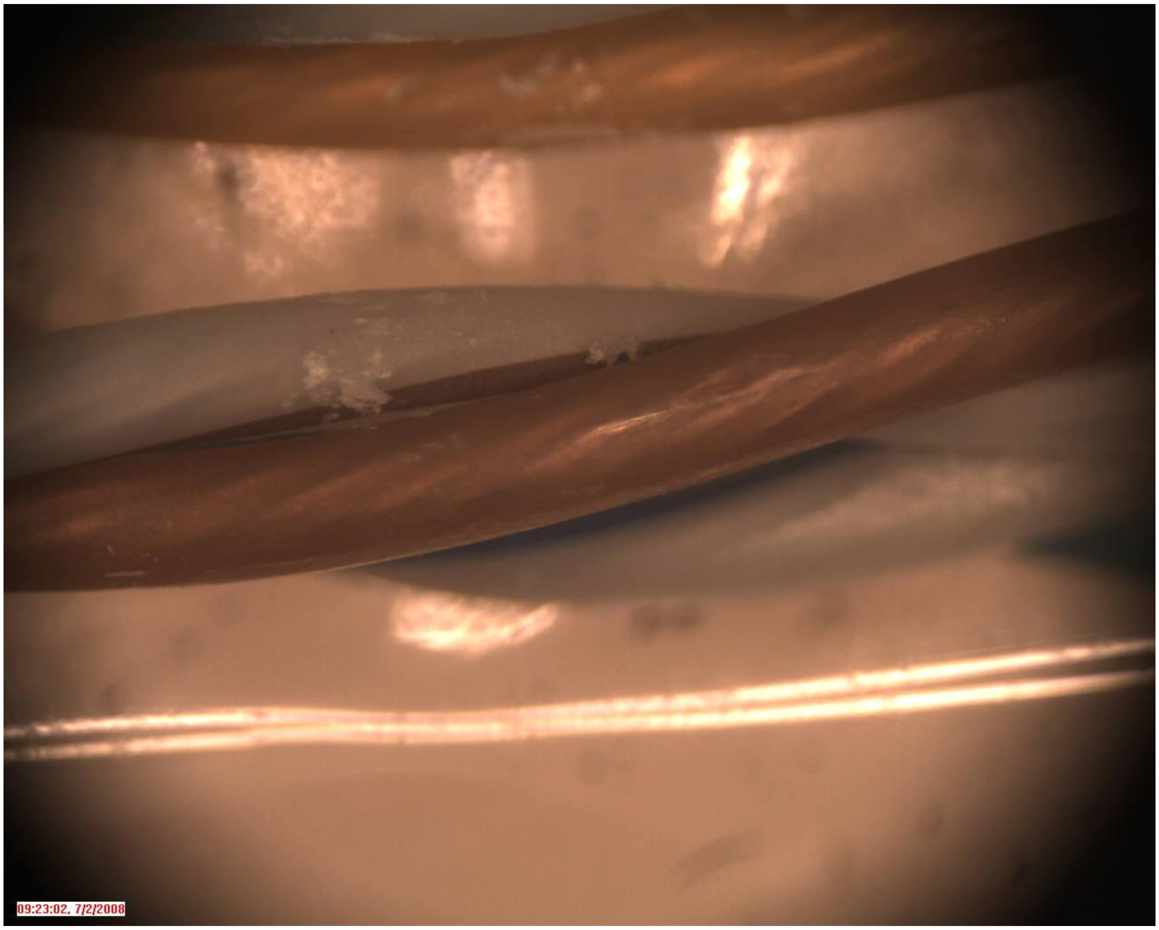
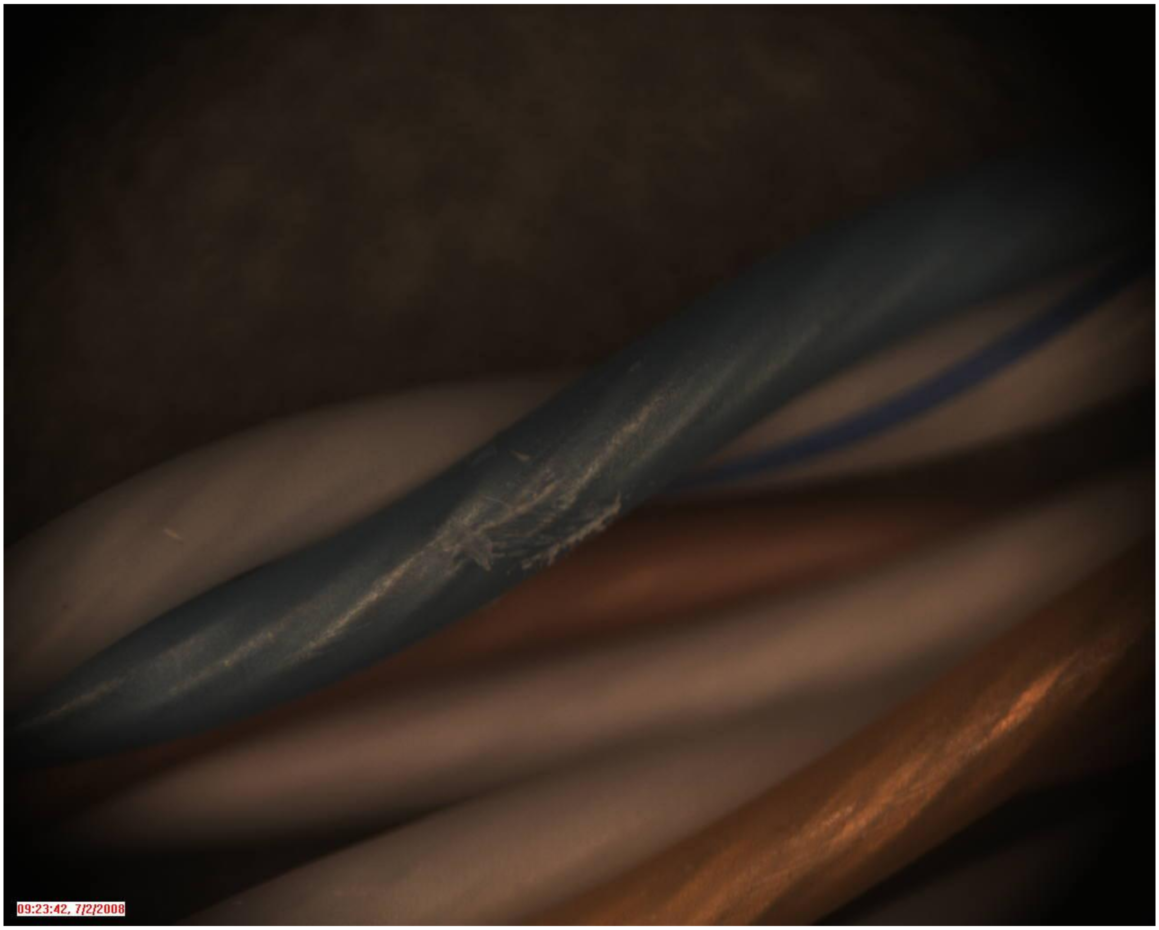


Figure 6
Powder in 4 pair cable



Part II: High flex shielding

The two tests outlined above cover both 2 and 4 pair unshielded cable constructions. In most cases these unshielded products are suitable for most industrial environments even when high levels of Electromagnetic Interference (EMI) are prevalent. The reason for this is the exceptional balance properties of the unshielded designs. In theory a cable with perfect balance would reject all interference. Perfect balance would be a rare find. However, the balance of Quabbin data cables is extremely good and has demonstrated a profound resistance to EMI; enough so, that it is recommended that they be tried in an application before immediately assuming that a shielded construction is required. With that said, there will be applications that will require shielding. This is quite a tall order in a continuous movement application. The downfall of shielding is that it cracks when repeatedly flexed which leads to failures. It isn't a problem of degrading the shielding properties as many people might think. Instead the problem becomes conductor failures that rapidly set in once the shield has cracked. If you can visualize the shield as a piece of aluminum wrapped around the cable core, it's easy to see how it would wear and fracture under the stress of repeated movement. Once the shield is fractured, the newly exposed edges around the break point are very sharp. As the cable continues to flex the exposed sharp edges of the fractured shielding begin to "saw" into the insulation of the conductors in the cable. It is also possible that the braided shield will abrade the insulation on the wire leading to a short. At this point, failure of the cable assembly isn't far off. Fortunately, after the expenditure of more R&D hours than either the Quabbin Engineering or Accounting department would care to count, we've conquered this issue.

Currently patent pending, the unique double shield (foil & braid) design implemented in the Quabbin DataMax® Extreme, shielded flex cables is not only unique, but more importantly, solves the problem. Since the inner core of the double shielded cables is the same design (pair and cable lay) to the proven core of the unshielded cables scaled to 26 AWG, this round of flex testing was not concerned with verifying electrical performance following the test. The focus was pure and simple…the cable must not destroy itself from the inside out. Consequently, the test results were determined by physical inspection, including inspection after dissection.

Product Tested

Quabbin part number 5077 - 4 pair, double shielded (foil & braid), DataMax® Extreme with Non Halogen TPU jacket

Set up & Duration

The same flex test apparatus, stroke, bend radii speed and cycle counts were used for this round of testing as outlined previously for the unshielded cables.

Test Results

Failure Mode	1 million cycles	10 million cycles
Jacket cracks	None	None
Tape cracks	None	None
Braid strands broken	None	None
Abrasion of insulation	None	None (slight abrasion of foam tape)
Conductor Failure	None	None

Given that there is no physical damage to the cable and the cable passed bulk tests we expect that this construction would pass all required electrical parameters after 1 million cycles at 10x the OD and 10 million cycles at 20x the OD.

For more information or to discuss any part of this report, please contact Quabbin Wire and Cable Co., Inc. at (800)-368-3311.