WHITE PAPER

MICE Environmental Classification

Recommendations for Industrial Ethernet Cables

April 2021

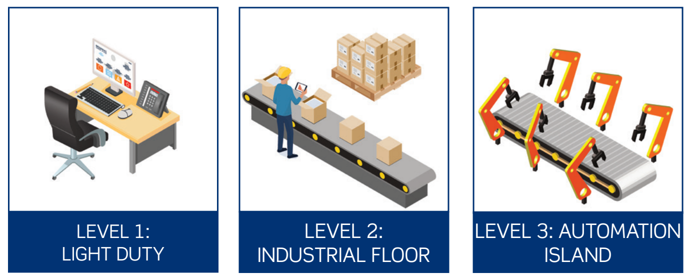
TABLE OF CONTENTS

LEVITON®

MICE EXPLAINED

In industrial Ethernet applications, components must be more durable and resistant to environmental effects than standard commercial components. The MICE environmental classifications are a set of parameters defined in various standards documents (ISO/IEC 11801 2017 6.2.2, TIA TSB 185, TIA 1005A, etc.) that attempt to define the conditions of various locations to ensure that components installed in those locations will function properly.

The letters in MICE each represent one type of environmental impact – Mechanical, Ingress, Climatic/Chemical and Electromagnetic. For each of these environmental impacts, there are three levels – 1, 2, and 3 – that represent levels of severity. Level 1 represents low impact, such as observed in a commercial installation. Levels 2 and 3 represent increasing severity locations. The higher severity levels attempt to describe the areas around the industrial floor and the automation island.



To accurately describe an environment, each of the impacts can be applied at a different level. For example, an assembly plant might have high amounts of Mechanical stress, M3, but have low Ingress, Climatic/Chemical and Electromagnetic stress (I1, C1, and E1).

Although the levels might describe the kinds of stressors that could occur, not every stressor will be in each environment. For example, an M3 environment at an automation island could have high flexing stress but very little crushing stress.

	MICE CLASSIFICATION TABLE		
	LEVEL 1	LEVEL 2	LEVEL 3
M MECHANICAL	M^1	M^2	M^3
I INGRESS	I^1	I^2	I^3
C CLIMATIC/ CHEMICAL	C^1	C^2	C^3
E ELECTRO-MAGNETIC	E^1	E^2	E^3

The wide diversity that exists among industrial environments has necessitated the development of products that are customized to ensure performance in very specific conditions. Rather than being designed for all possible stressors, the products are designed to perform very well against those expected to be present.

This paper will explore the stressors that make up the environmental levels in MICE and how they apply to copper Industrial Ethernet cables. It will also present test results and make recommendations for solutions in each of these environments.

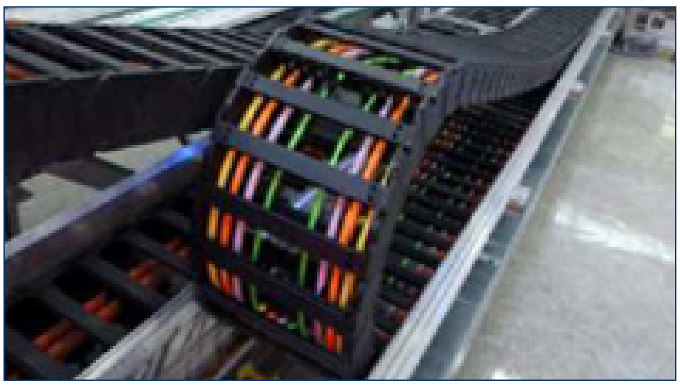
MECHANICAL

Mechanical stressors predominantly revolve around motion and durability. Stronger, tougher, and more durable cables are not necessarily best for motion and flexibility. Durability requirements encourage a rigid design, while flexibility requirements encourage a soft design. It is important to evaluate each mechanical stressor as it relates to your specific installation environment.

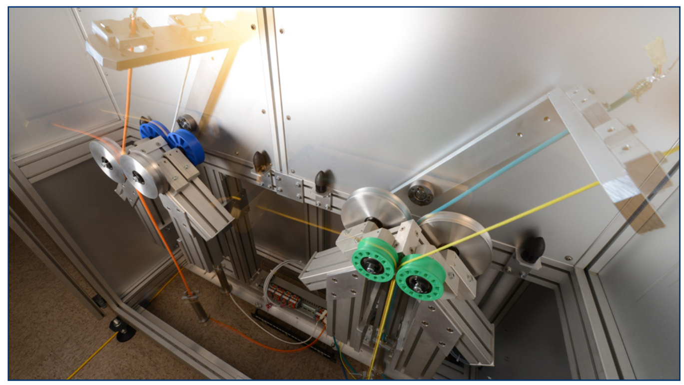
Bending, Flexing, and Torsion

In comparison to commercial cables, which are rarely moved after installation, industrial cables may be attached to equipment that must move frequently. High-flex-life cables are designed with key features for survival. Conductors are formed from stranding together smaller, more flexible wires. The stranding allows for bending and turning without putting stress and strain on the copper. The insulation and jacket materials are specifically chosen for flexibility. More rigid materials would wear out, crack, and crumble under repeated stress. High-flex-life materials maintain their consistency throughout millions of flex cycles.

There are several tests designed for flexibility and flexing lifetime of products. Drag chain, tick tock, and similar tests can determine the expected survival time of a product put under motion stress.



Drag Chain Test



Tick Tock Test

To prove a product is capable of high-flex-life, the motion stress tests must run for a long duration. Months of constant bending and twisting in the flex lab are needed to prove that the cable can survive the strain. After the flexing, the product is also tested for electrical performance parameters to verify that the design has remained intact and the product will function while installed in a high-flex location.

Tables 1 and 2 show a sampling of test results for several products that were tested extensively for flex life. These products are recommended for use in M3 flexibility environments because they are designed and proven to function under this type of stress.

TABLE 1: DRAG CHAIN FLEX TEST RESULTS		
Test Setting	Product	Cycles
16x cable OD	LANmark-C538	35,000,000
10x cable OD	LANmark-C538	1,000,000
16x cable OD	LANmark-C539	35,000,000
10x cable OD	LANmark-C539	1,000,000
15x cable OD	LANmark-C541	35,000,000
9x cable OD	LANmark-C541	1,000,000
13x cable OD	LANmark-C542	35,000,000
10x cable OD	LANmark-C542	1,000,000
12x cable OD	LANmark-C545	35,000,000
9x cable OD	LANmark-C545	1,000,000
6x cable OD	LANmark-C547	35,000,000
10x cable OD	LANmark-C547	1,000,000
17x cable OD	LANmark-C637	35,000,000
10x cable OD	LANmark-C637	1,000,000
7x cable OD	LANmark-C726	1,000,000
5x cable OD	LANmark-C811	1,000,000
6x cable OD	LANmark-C826	35,000,000

TABLE 2: TORSION FLEX TEST RESULTS		
Test Setting	Product	Cycles
270°	LANmark-C538	3,000,000
270°	LANmark-C539	3,000,000
270°	LANmark-C541	3,000,000
270°	LANmark-C542	3,000,000
270°	LANmark-C545	3,000,000
270°	LANmark-C547	3,000,000
270°	LANmark-C637	3,000,000
180°	LANmark-C726	3,000,000
180°	LANmark-C811	5,000,000
180°	LANmark-C826	20,000,000

Shock/Bump and Vibration

Ethernet cables are made of simple, continuous components like conductors and plastic sheaths. These cables do not exhibit structural weaknesses that are vulnerable to vibration or bumps. In most situations, the cable itself has low risk from vibration and bump effects. However, when the cables are connectorized, there is a difference in materials and a potential discontinuity at the connection point. The connectors must be designed with enough support to ensure that vibration and bumps do not break connections. A single break in continuity could cause a system failure.

Tensile Strength

Tensile strength is the measure of a product's durability when pulled along its length. For cable products, this kind of stress can damage the outer jacket, stretch the pairs, or otherwise pull the cable core out of shape. Ethernet cables are typically installed by pulling the cable into position over long distances. Industrial Ethernet cables, being more durable than commercial Ethernet cables, will demonstrate higher tensile strength.

Copper category cable products do not typically have longitudinal strength members. Any tension on the product is placed on the jacket material and transferred to the pairs that are transmitting signals. The strength of the jacket material and the design of the transmitting pairs provide the resistance to tension.

Resistance to tensile forces is also affected by the method used to apply connectors to the cable A high tensile pull could strip the connector off the end of the cable. Industrial Ethernet connectors are typically applied to cables in ways that try to provide a strong connection so that the combination is not weak against such forces.

One way to test a category cable's resistance to tension is to pull a reel of material through an elevated-tension line. The pulled cable is then measured for electrical performance and inspected for physical damage. This is compared to samples that have not been pulled through the elevated-tension setup.

For a light-duty Ethernet cable, a 25-pound maximum pull tension is typical (M1 tension). For industrial Ethernet products with stronger jackets and more rigid designs, a 40-pound or 50-pound tension is possible (M2 tension). If the industrial Ethernet products were specifically designed for tension, even higher capabilities are possible (M3 tension).

TABLE 3: EXAMPLE MAXIMUM TENSIONS	
Product	Max Tension
Light Duty Category Cables	25 lbs
Industrial Ethernet Cable	50 lbs

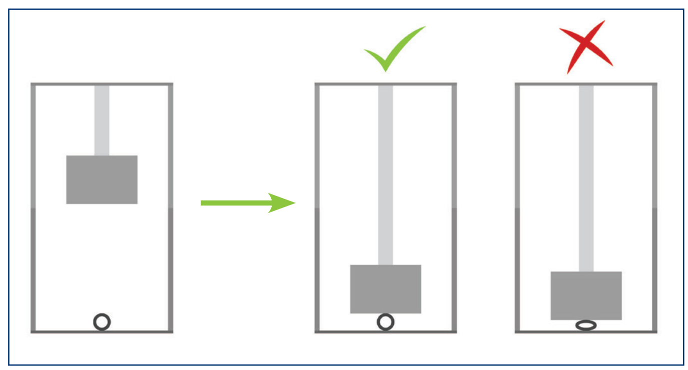
The following Berk-Tek cables were pulled at 40 pounds of tension and demonstrated to maintain performance: LANmark-C538, LANmark-C539, LANmark-C541, LANmark-C542, LANmark-C545, LANmark-C547, LANmark-C637, LANmark-C826, LANmark-C851

The following Berk-Tek cables were pulled at 50 pounds of tension and demonstrated to maintain performance: LANmark-C538, LANmark-C539, LANmark-C541, LANmark-C542, LANmark-C545, LANmark-C547, LANmark-C637.

Crush and Impact

With moving equipment in a factory space, it is possible for products to be hit with sudden forces. For cable products, a strong impact could distort the pair structure or otherwise affect the cable core, compromising the transmission capabilities of the cable.

The test for impact resistance is a dropped hammer with a known force. By impacting a cable with a known weight dropped from a set distance, incidental damages from the environment can be simulated. The weight, drop height, and shape of the impact hammer can be adjusted to varying levels of severity to represent the environmental stressors.

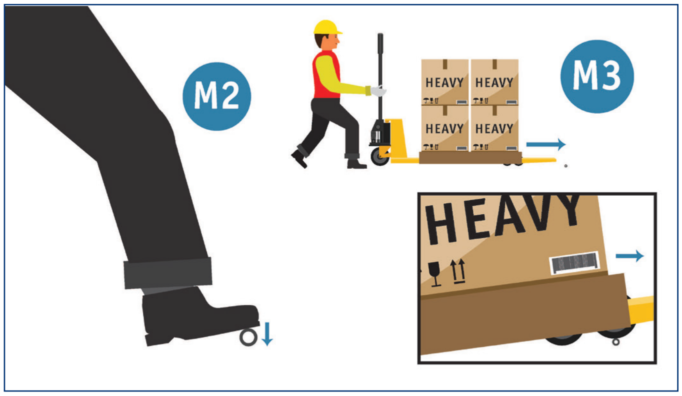


Impact Test

Industrial cables can also be rated for crush resistance. More rigid and durable cables will be capable of handling strong crushing forces that can occur in their environment. If the product is not durable enough, it will flatten in the location where the crushing force is applied. Flattening the cable will degrade its performance, and the damage will be physically obvious.

Durability and resistance to transverse stresses are critical for products to survive crushing forces and impacts. Products that are not designed for these stressors will crush, the performance will degrade, and the products could potentially fail from damage to the transmission lines. Rigid jackets, armor layers, and strength members that support the outer layers will improve the resistance to these environmental factors

The M3 level of crush is 2200N applied over a linear 150mm. The M3 level of impact is 30J. The industrial Ethernet cables that were previously tested for flexibility were tested to the M3 levels of crush and impact. These flexible products were damaged to a failing condition by the M3 crush and the M3 impact tests.These environmental conditions are too severe for products that are not designed to handle the stress.



Example Crush Ratings

Evaluating a cable for use in a M2 environment requires a crush pressure of 1100N and an impact level of 10J. The industrial Ethernet products that were previously tested for flexibility were exposed to the M2 crush and impact levels. The designs were durable enough to withstand the crush and impact, but physical change was observed in the products. With this observation, it is recommended to only use products that are designed for durability in environments with elevated crushing and impact.

INGRESS

The ingress parameter defines a product's ability to prevent both particulate and liquid material from entering and causing issues with their function. In an industrial environment, it is not uncommon to encounter high levels of particulate matter and liquids, so cables for industrial locations need to be rated to their ability to survive this.

The levels of ingress (I1, I2, I3) are defined as follows: The I1 level indicates the presence of relatively larger particles (up to 12.5 mm) but no liquids. The I2 level indicates the presence of smaller particles (like dust) and liquid sprays. The I3 level indicates small particles and potential immersion in liquids. The increasing levels of ingress in the environment apply requirements on equipment placed in that environment. The openings, connection points, and surfaces must have better seals as the ingress level increases.

Ethernet cables are specified to have a continuous outer jacket to protect the insulated conductors within. As long as the outer jacket is not punctured, Ethernet cables will resist ingress. Industrial Ethernet cables are designed with special jacket materials to prevent ingress and resist the damages that could enable Ingress.

Cable assemblies have connectors at the ends that also need to be tested for ingress. Typically, industrial assemblies are exposed to specific tests (e.g. IP67 test in a meter of water) to verify that the assemblies do not allow the passage of unwanted substances into the connection. The IP67 rated products would be suitable for an I3 environment (one with the potential for liquid immersion) as well.

Leviton's Berk-Tek Industrial cables have been tested in an IP67 rated tank with fully immersed cables in one meter of water. Cable construction with multiple layers of tape, braid and shield have been proven to perform the best in full water immersion. The recommendation table on page 14 lists lists I3 ratings for SF/UTP industrial construction.

WANT TO LEARN MORE?
For more information on the ingress parameter, please refer to Cables in Wet Environments (IWCS International Cable & Connectivity Symposium).
Click here to read the paper.

CLIMATIC/CHEMICAL

Climatic/Chemical parameters include humidity, sun exposure, temperature and chemical Compatibility. These are significant concerns in an industrial environment because chemical contact, UV lights and other elements such as weld spatter, moisture and temperature changes are present. A cable must resist these elements in order to function properly and protect the critical network data in the factory.

Humidity

Exposure to high humidity can impact products in several ways: 1) materials could absorb the water, changing their properties, 2) condensation could lead to moisture accumulating in parts of devices, and 3) fine wires or tubes could wick the moisture out of the air. Moisture and condensation can have negative impacts on the performance of electronics. In the case of industrial Ethernet cables, the performance could degrade, as moisture either inside or on the surface of the cable will absorb signal. Insertion loss (the measure of signal received compared to signal sent) is a transmission parameter which is most affected by humidity and water contact.

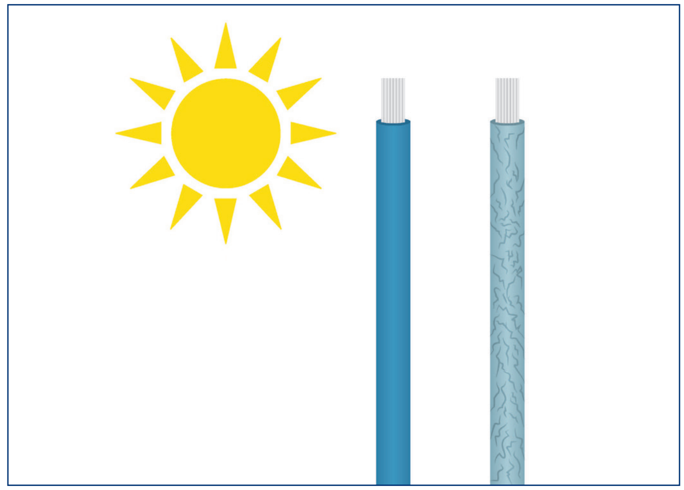
Thorough humidity tests require either extended exposure times (months or years) or stressed conditions (constant high humidity at varying temperatures). The conditions used to stress the products in our testing were as follows: constant 95% humidity, temperature ranging from 30°C to 60°C in several hour steps, duration of 10 days minimum, no special precautions taken to avoid condensation during temperature changes.

At the five-day mark and again at the end of the testing, electrical performance was measured. Some of the products suffered a decrease in insertion loss margin. This was caused by the jacket material of the cables absorbing the moisture, which changes the dielectric properties of the jacket and causes a decrease in signal strength over the length of the cable. The products that degraded would be more suitable for C1 humidity environments. The products that maintained performance would be suitable for C3 humidity environments.

In this test set, the following Berk-Tek cables did not have their performance degraded by the humidity: LANmark-C541, LANmark-C542, LANmark-C545, LANmark-C547

Solar Radiation

Sunlight, specifically UV radiation, can cause deterioration of organic compounds such as plastics. Over time, this can cause loss of flexibility, brittleness and cracking in the outer jacket of a cable. Cable products that are designed for sunlight resistance will have jackets made from compounds specifically formulated to survive such exposure.



Cable on right shows effects of solar radiation.

Tests to evaluate a product's resistance to solar radiation can focus on two things: 1) Heating caused by energy absorption, and 2) Materials degradation from the UV portion of the light. As long as the products are kept within their specified operating temperature range, heating due to sunlight is not a concern for industrial Ethernet cables.

Regarding UV degradation (examining the test methods for solar radiation that are available in MIL-STD-810H), the magnitude of UV radiation is less than or equal to the level used in sunlight resistance tests for cabling. That means if products are tested and verified for the UL sunlight-resistant mark, then they will withstand the UV portion of solar radiation portion in the C3 environment.

Rate of Change of Temperature

Industrial environments experience much more rapid changes in temperature than commercial office environments. For example, the area next to a motor or near a cooling bath might experience rapid heating and/or cooling.

To test a product's ability to withstand rapid changes in temperature without degradation, an environmental chamber can be set to drive a product across its operation temperature with rapid change. If different materials expand or contract at different enough rates, cracks could form in materials and seals could open.

The following Berk-Tek industrial Ethernet cables were tested by cycling their temperature from their highest rated temperature to their lowest rated temperature and back several times at the maximum rate possible using an environmental chamber: LANmark-538, LANmark-541, LANmark-542, LANmark-545, LANmark-547, LANmark-637.

This rate exceeded the C3 rate of change of temperature. After cycling the temperature, the products were examined for cracks, damage, and any other changes in the materials,. The products were then wrapped around a mandrill to check for brittleness. None of the industrial Ethernet products tested suffered any detectable impact from rate of change of temperature.

Ambient Temperature

The functional temperature range of Ethernet cable products and Industrial Ethernet cable products is factored into climatic ratings, but since it is already well documented, further research into this topic is unnecessary.

Chemicals Resistance

The chemicals present in an industrial environment will vary greatly depending on the industry and the site. For maximum confidence in a product's resistance to chemicals it is important to carefully evaluate a cable's specific performance parameters in relation to those chemicals. Table 4 shows a representative listing of some of the chemicals that could be present in an industrial environment, as well as the corresponding classification for each chemical. For example, if salt water is present, we recommend a cable that is C3 Resistant. Please note that this is not an exhaustive list. Contact Leviton to inquire about a specific chemical(s) present in your installation environment.

TABLE 4: RECOMMENDATIONS FOR CHEMICAL ENVIRONMENTAL FACTORS

Chemical in Environment	Recommended "C" Classification for that Chemical
Salt/Sea Water	C3 Resistant
Oil	C3 Resistant
Soap	C2 Resistant
Detergent	C2 Resistant
Conductive Materials	C2 Resistant
Hydrogen Sulphide	C3 Resistant
Sulphur Dioxide	C3 Resistant
Sulphur Trioxide	C3 Resistant
Chlorine (wet or dry)	Avoid. Do not expose product to chlorine.
Hydrogen Chloride	C3 Resistant
Hydrogen Fluoride	C3 Resistant
Ammonia	C3 Resistant
Oxides of Nitrogen	Avoid. Do not expose product to oxides of nitrogen.
Ozone	C2 Resistant

ELECTROMAGNETIC

For sensitive electronics and controls, electromagnetic stresses can be the most concerning. Damage or failure in any one part of an electrical system can cause unwanted malfunction in other areas as well. For passive components such as cables, it is critical that they not deliver environmental power to the connected electronics, so interference and device failure can be avoided.

To resist unwanted external fields and signals, industrial Ethernet cables can have shielding layers and well-balanced pairs. The pair balance provides resistance to unbalanced signals coupling into the cable. The shielding layers prevent the signals from reaching the transmission line.

Electrostatic Discharge and Surge

Electrostatic Discharge (ESD) can destroy electronic circuits with ease. Equipment in industrial environments does not have the luxury of being installed with anti-static precautions and humidity-controlled spaces to prevent ESD.

To address this limitation, as part of product inspection for Ethernet cables, the products are tested with high voltage to check for insulation gaps and spark potential. Unless there is damage to the insulating materials of the cable, they have high resistance to ESD.

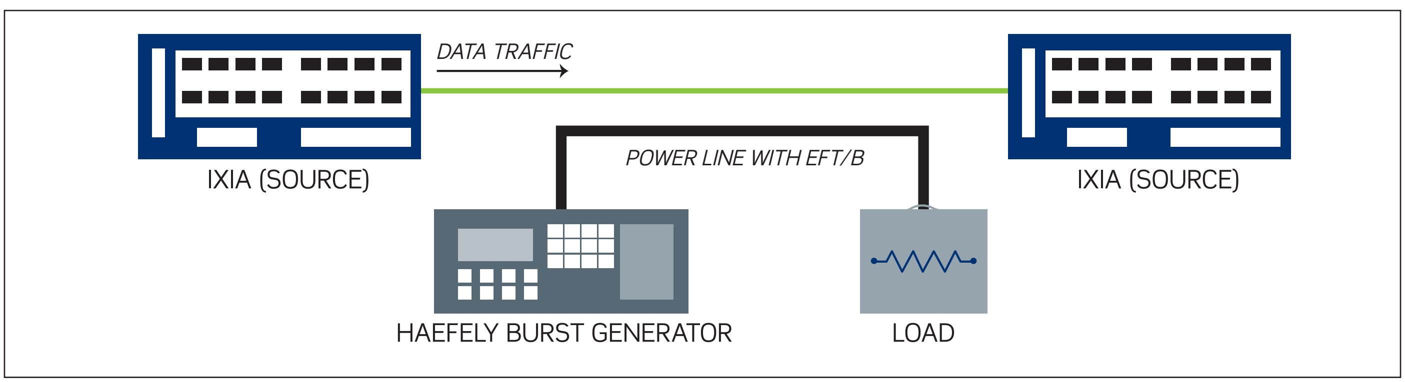
Similar to ESD, surge is a sudden and unexpected voltage in an electric circuit. Where ESD involves a charged body with different potential, a surge could occur within the voltage source or ground plane of the circuit. With many different pieces of equipment switching on and off, industrial environments will experience more surges and variations from the targeted nominal voltages.

The impact of surge is manifested more in the equipment than in the cable. Under most circumstances, the highly conductive nature of the copper conductors in cabling will transfer the surge to the equipment to which it is attached. The cables themselves won't be damaged, but the equipment will be unless it is designed to handle the surge.

Electric Fast Transient/Burst (EFT/B)

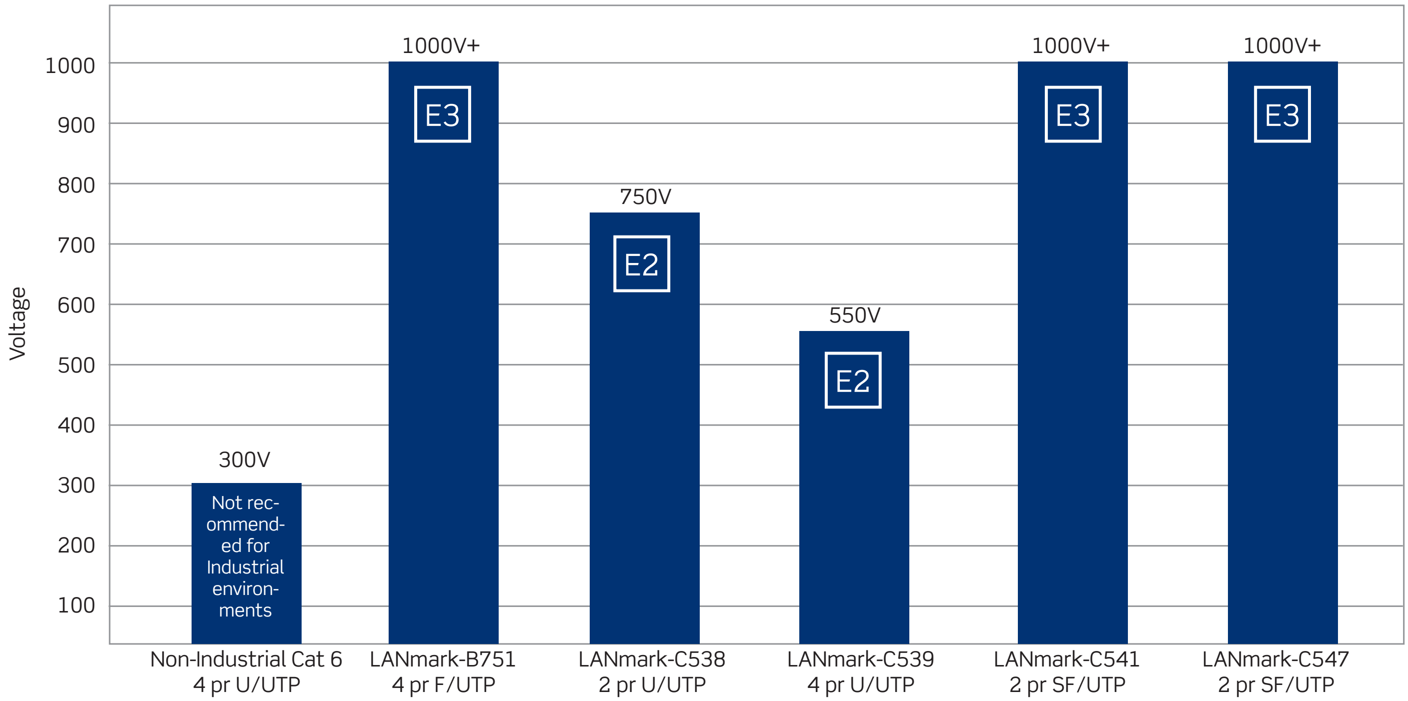
Electrical Fast Transient/Burst are short, repeated pulses of high voltage that typically occur when motors start or equipment changes state. The pulses can interfere in the frequency range used by Ethernet, which is 1 MHz to 500 Mhz. Ethernet cables can have high levels of shielding or well-balanced twisted pairs to protect from this sort of interference.

To determine the impact of EFT/B on cabling, a data traffic test can be used. Data is sent on Industrial Ethernet cables that are run alongside power cables. The power cables are attached to a EFT/B generator that supplies line voltage and the transient peaks. The data transmission will experience errors and dropped packets if the cabling is susceptible to EFT/B. This test is illustrated below.



Data Traffic Test

The graph below shows maximum voltage of neighboring EFT/B that each cable could withstand before experiencing errors in data transmission, as well as the corresponding E Level of the MICE classification. Three of the cables tested experienced zero errors at the maximum voltage tested (1000 volts).



Magnetic Field, Radiated RF, and Conducted RF

Electric and magnetic fields of the right frequencies can couple into cabling and cause issues with the data being transmitted. This is a well-studied phenomenon. In the "Correlation Between Radiated Immunity and Coupling Attenuation" study by Michiel Pelt (Alcatel), EMC at 3V/m was studied with coupling attenuation to show how shielded products can resist EMC. By design, industrial Ethernet products can resist coupling from electromagnetic fields. For the best performing industrial Ethernet products, look for Shield Foil and Braid Screen (SF/UTP) to provide shielding against high- and low- frequency noise. For best performance, we recommend specifying the following: 1) For Coupling Attenuation, IEC 61156-5, Type I and 2) For Transfer Impedance, IEC 61156-5, Grade 2.

COMPREHENSIVE MICE LEVEL TABLE

Based on the existing definition of MICE and the findings presented in this paper, Leviton's recommendation on MICE characterization per product is summarized in the table below. It is important to note that MICE is a high level definition of the environment and it leaves an open interpretation to the manufacturer regarding test methods, pass/fail criteria and specific applications that may apply to the product. This white paper serves as an educational review about MICE and Leviton's Berk-Tek Industrial Ethernet product performance in that environment. For more information about product performance in specific environments and conditions, please contact Leviton support at appeng@leviton.com. Details on Leviton's Berk-Tek Industrial Ethernet product specifications and a selector guide can be found on our website at www.leviton.com/berktek.

LANmark Product	MICE Levels	Tensile Strength	Crush	Impact	Bend, Flex, Torsion	Ambient Temp	Rate of Change Temp	Humidity	Solar Radiation	Oil Res	Chem Res*	RF	EFT/B	Magnetic	Immersion
A753	M1I1C2E1	M2	M1	M1	M1	C3	C3	C1	C3	C2	C2	NO	NO	NO	NO
A774	M1I1C2E1	M2	M1	M1	M1	C3	C3	C1	C3	C3	C3	NO	NO	NO	NO
A921	M1I1C2E1	M2	M1	M1	M1	C3	C3	C1	C3	C2	C2	NO	NO	NO	NO
A689	M1I1C2E1	M2	M1	M1	M1	C3	C3	C1	C3	C2	C2	NO	NO	NO	NO
A922	M1I1C2E1	M2	M1	M1	M1	C3	C3	C1	C3	C2	C2	NO	NO	NO	NO
A750	M1I1C2E1	M2	M1	M1	M1	C3	C3	C1	C3	C2	C2	E1	E1	E1	NO
A920	M1I1C2E1	M2	M1	M1	M1	C3	C3	C1	C3	C2	C2	E1	E1	E1	NO
B535	M1I1C2E1	M2	M1	M1	M1	C3	C3	C1	C3	C3	C3	NO	NO	NO	NO
B536	M1I3C3E2	M2	M1	M1	M1	C3	C3	C3	C3	C3	C3	E2	E3	E2	I3
B537	M1I3C3E2	M2	M1	M1	M1	C3	C3	C3	C3	C3	C3	E2	E3	E2	I3
B789	M1I3C3E2	M2	M1	M1	M1	C3	C3	C3	C3	C3	C3	E2	E3	E2	I3
B587	M2I3C2E2	M2	M1	M1	M2	C3	C3	C3	C1	C2	C2	E2	E3	E2	I3
B585	M2I1C1E1	M2	M1	M1	M2	C3	C3	C1	C1	C2	C2	NO	NO	NO	NO
B540	M2I1C1E1	M2	M1	M1	M2	C3	C3	C1	C1	C2	C2	NO	NO	NO	NO
B907	M2I3C1E2	M2	M1	M1	M2	C3	C3	C3	C1	C2	C2	E2	E3	E2	I3
B752	M1I2C2E2	M2	M1	M1	M1	C3	C3	C1	C3	C2	C2	E2	E3	E2	NO
B840	M1I2C2E2	M2	M1	M1	M1	C3	C3	C1	C3	C2	C2	E2	E3	E2	NO
B917	M1I2C2E2	M2	M1	M1	M1	C3	C3	C1	C3	C2	C2	E2	E2	E2	NO
B751	M1I2C2E2	M2	M1	M1	M1	C3	C3	C1	C3	C2	C2	E2	E3	E2	NO
B919	M1I2C2E2	M2	M1	M1	M1	C3	C3	C1	C3	C2	C2	E2	E2	E2	NO
C541	M3I3C3E2	M2	M2	M2	M3	C3	C3	C3	C3	C3	C3	E2	E3	E2	I3
C542	M3I3C3E2	M2	M2	M2	M3	C3	C3	C3	C3	C3	C3	E2	E3	E2	I3
C538	M3I2C2E1	M2	M2	M2	M3	C3	C3	C1	C3	C3	C3	NO	E2	NO	NO
C539	M3I2C2E1	M2	M2	M2	M3	C3	C3	C1	C3	C3	C3	NO	E2	NO	NO
C547	M3I3C3E2	M2	M2	M2	M3	C3	C3	C3	C3	C3	C3	E2	E3	E2	I3
C826	M3I3C3E2	M2	M2	M2	M3	C3	C3	C3	C3	C3	C3	E2	E3	E2	I3
C851	M3I3C3E2	M2	M2	M2	M3	C3	C3	C3	C3	C3	C3	E2	E3	E2	I3
C545	M3I3C3E2	M2	M2	M2	M3	C3	C3	C3	C3	C3	C3	E2	E3	E2	I3
C637	M3I3C3E2	M2	M2	M2	M3	C3	C3	C3	C3	C3	C3	E2	E3	E2	I3

*These are general classifications. Contact Leviton to inquire about a specific chemical(s) present in your installation environment.

Today's networks must be fast and reliable, with the flexibility to handle ever-increasing data demands. Leviton can help expand your network possibilities and prepare you for the future. Our end-to-end cabling systems feature robust construction that reduces downtime, and performance that exceeds standards. We offer quick-ship make-to-order solutions from our US and UK factories. We even invent new products for customers when the product they need is not available. All of this adds up to the **highest return** on **infrastructure investment**.

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