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Underwriters Laboratories Inc. (UL) and the National Electrical Code (NEC) Requirements for Corrosion Protection of Galvanized Steel Conduit and Electrical Metallic Tubing

When selecting a wiring method, life expectancy is one of the key issues typically considered. Depending upon the installation, part of that consideration is the resistance of the wiring method to corrosive environments. Most materials will eventually experience some corrosion, since corrosion is a natural and inevitable process; however, corrosion is also a controllable process.

Steel conduit systems provide long-lasting protection to the conductors and cables within. Due to the range of the environments in which conduit is installed and the fact the environment may change over time, it is impossible to provide life expectancy data. An understanding of the corrosion protection requirements of steel conduit product standards and of the National Electrical Code® (NEC) together with guidelines on the use of supplementary corrosion protection will help in the selection of the best system for the installed environment.

(Chart A)
CORRODED END
(Anodic or less noble)
Magnesium
Zinc
Aluminum
Steel
Lead
Tin
Nickel
Brass
Bronzes
Copper
Stainless Steel (passive)
Silver
Gold
Platinum
PROTECTED END
(Cathodic or more noble)
Source: American Galvanizers Association

Corrosion Prevention

The performance of a material in different environments is governed by a number of factors, including the potential and resistance between anodic and cathodic areas (Chart A), dust, harsh chemicals, the pH of the environment, temperature and humidity. Appropriate product selection, good maintenance procedures, and/or control of environmental factors can slow the rate of corrosion. In addition to corrosive environments such as concrete and soil discussed above, dust can also be very corrosive to certain materials. Harsh chemicals can affect both metal and nonmetallic conduits.

Manufacturers of these products can be contacted for information on the reaction of their products in certain chemical environments. Due to the endless variety of conditions and possible uses the best determination of suitability for use remains local experience and the Authority having Jurisdiction (AHJ). Corrosion in liquid chemical environments is affected by the pH of the solution. According to the American Galvanizers Association, galvanizing performs well in solutions of pH above 4.0 and below 12.5. Aluminum performs well in a range of 4-9. (See chart D).

Underwriters Laboratories Inc. (UL) Standards

U.S. manufacturers of steel conduit are members of the National Electrical Manufacturers Association (NEMA) Section BI-RN and also of the U.S. Conduit Committee of the Steel Tube Institute (STI). The U.S. manufacturers of steel conduit produce rigid steel conduit (RMC), intermediate metal conduit (IMC), electrical metallic tubing (EMT), and elbows, couplings and nipples. In order to have an installation that is in compliance with the NEC, raceways are required to be Listed. NEMA/STI member products are Listed to Underwriters Laboratories Inc. (UL) standards. RMC and associated elbows, couplings, and nipples are Listed to UL 6, IMC to UL 1242 and EMT to UL 797.

While life expectancy tests are not a requirement within the UL standards, there are tests and performance requirements for the coatings used to protect steel conduit, EMT, elbows, couplings, and nipples. The typical outside diameter coating for steel conduit and EMT is zinc. The interior diameter is usually coated with zinc or an organic coating. The UL standards include a copper sulfate test (often referred to as a Preece test) that is used to evaluate the zinc coatings to ensure the required protection from corrosion. The products pass if they do not show a bright, adherent deposit of copper after four 60-second immersions in the copper sulfate solution.

The process of applying Zinc over steel is called “galvanizing” and has been used to protect iron and steel from rusting for over two hundred years. Zinc has a number of characteristics that make it well-suited to provide corrosion protection to steel products. It protects steel from rusting by forming a protective barrier between the steel and the environment. In addition, it provides sacrificial (galvanic) protection. Since steel is more cathodic than zinc - that is, steel will attract electrons from the Zinc (see Chart A) – the current flow from zinc to steel will reduce the corrosion rate of the steel. The zinc coating is thus “sacrificed” to prevent corrosion of the steel. Galvanizing protects the steel even when the coating is attacked. The appearance of white powder on steel conduit or EMT is evidence that the zinc coating is doing its job. When steel or iron rusts, the oxide is red. The UL standards allow the use of a surface coating over the primary corrosion protection coating and most manufacturers do use a surface coating to provide additional corrosion protection.

For galvanized steel conduit, the UL standards require that threads that are cut after the protective coatings are applied shall be treated to keep corrosion from taking place before the conduit is installed. Threads cut at the factory for listed products are protected during manufacturing. These products are typically shipped with a coupling on one end and thread protector on the other end. UL standards require that threads cut after protective coatings are

applied be treated to keep corrosion from taking place before the conduit is installed.

UL Certification Database

In 1965 a new requirement was added to the National Electrical Code®. The requirement was that "raceway be suitable for the corrosive environment to which it is exposed." Since there was no conclusive way to prove the suitability of raceways for their environments, UL conducted surveys as well as field and laboratory tests. The guidelines for supplementary corrosion protection that appears in the UL Certification Database were based on this data.

Two of the environments that have a high potential for corrosive conditions are concrete and soil.

In concrete: The UL guidelines state that when RMC or IMC are installed in concrete, supplementary corrosion protection is not required. When steel EMT is installed in a concrete slab on grade or above, supplementary corrosion protection is generally not required. However, if steel EMT is installed in a concrete slab below grade, supplementary protection may be required.

***In Soil*:** The UL guidelines further states that when RMC or IMC is in contact with soil, supplementary protection is *generally not* required. However, if the soil is particularly corrosive characterized by a resistivity of less than 2000 ohm-centimeters, supplementary corrosion protection may be required. Local utilities commonly measure the resistivity of soils. The Authority Having Jurisdiction (AHJ) determines the necessity for additional protection. EMT in contact with soil *generally* requires supplementary corrosion protection. These UL guidelines are summarized in Chart B and are also included in the NEC.

***From concrete to soil*:** The UL guidelines also state that severe corrosive effects may occur when steel conduit or EMT emerge from concrete into soil. NEMA/STI conduit manufacturers recommend that supplementary corrosion protection be provided a minimum of 4 inches on each side of the point where the raceway emerges. In areas such as coastal regions, NEMA/STI conduit manufacturers also recommend the same method of protection for EMT emerging from concrete into salt air.

(Chart B) UL Guidelines Corrosion Protection Summary			
		Required	Optional
In Concrete	Steel RMC		X
	IMC		X
	Aluminum RMC	X	
	Steel EMT	Below grade may need	On or above grade
	Aluminum EMT	X	
In Soil	Steel RMC		X
	IMC		X
	Aluminum RMC	X	
	Steel EMT	Generally Required	
	Aluminum EMT	X	
Source: Soares Book on Grounding			

Note: RMC is now available in the following materials: steel, stainless steel, aluminum, and red brass. IMC is available in steel and stainless steel. EMT is available in steel, stainless steel and aluminum. This Bulletin only covers corrosion protection for steel RMC, IMC and EMT.

National Electrical Code Requirements

To determine additional requirements for corrosion protection, it is crucial to understand the rules of the NEC. RMC is covered by Article 344; IMC is covered by Article 342 and EMT is covered by Article 358. In addition to these Articles, Section 300.6 Protection against Corrosion and Deterioration also contains important information.

Article 344 Rigid Metal Conduit (Type RMC). This article covers not only rigid steel conduit, but rigid aluminum, red brass, and stainless steel conduit. Both rigid steel and rigid stainless steel conduit are allowed to be used in "all atmospheric conditions and occupancies". They are allowed in concrete, direct burial and "*areas subject to severe corrosive influences where protected by corrosion protection and judged suitable for the condition*." Since the NEC mandates the use of listed conduit, listed steel conduit is protected by corrosion protection, through the use of the zinc (most commonly used) or an alternative corrosion protection coating such as PVC. The use of the words *"judged suitable for the condition*" means that the Authority Having Jurisdiction (AHJ) must approve the installation. The AHJ may require supplementary corrosion protection.

Red brass conduit is most commonly used in swimming pool applications. The rules governing its use are similar to those for rigid steel and stainless steel conduit.

The NEC allows the use of rigid aluminum conduit in concrete or direct buried *"where provided with approved supplementary corrosion protection."* This means that additional corrosion protection meeting the requirements of the AHJ is required (see "Supplementary Corrosion Protection" below).

Article 342 Intermediate Metal Conduit (IMC). The NEC requirements for IMC are exactly the same as for RMC.

Article 358 Electrical Metallic Tubing (Type EMT). This Article covers steel (ferrous) or aluminum (nonferrous) EMT. EMT is allowed to be used in concrete, in soil or "in areas subject to severe corrosive influences where protected by corrosion protection and judged suitable for the condition." listed steel EMT is protected by corrosion protection through the use of a zinc coating (most commonly used) or an alternative corrosion protection coating.

Dissimilar Metals. Each of the NEC Articles listed above has a section on dissimilar metals. The NEC advises that where practicable, dissimilar metals shall be avoided.

However, aluminum fittings and enclosures are allowed to be used with steel conduit and EMT and vice versa *where not subject to severe corrosive influences*. Chart C shows galvanic corrosion potential between common construction metals. Note that galvanic action is insignificant between aluminum and steel.

Article 300 General Requirements for Wiring Methods and Materials. Section 300.6 is entitled "*Protection Against Corrosion and Deterioration"* and contains requirements for ferrous metal equipment, aluminum equipment and nonmetallic equipment. This section includes many of the same requirements that are found in the individual conduit and EMT Articles. It also includes a rule for field-cut threads. As noted above, the threads on conduit shipped from the factory are required to be coated per the UL standards. The NEC requires that *"where corrosion protection is necessary",* field-cut threads be coated with an *approved electrically conductive, corrosion-resistant compound*. This means that the coating used must have the approval of the AHJ. Zinc-rich paints or similar compounds are commonly used. Listed compounds are also available.

(Chart C) Dissimilar Metals
Galvanic corrosion potential between common construction metals

	Aluminum	Brass	Bronze	Copper	Galvanized Steel	Iron/Steel	Lead	Stainless Steel	Zinc
Aluminum		1	1	1	3	2	2		3
Copper	1	2	2		2	1	2		1
Galvanized Steel (Zinc)	3	2	2	2	3	3			3
Lead	2	2	2	2	3	3			3
Stainless Steel*									
Zinc	3	1	1	1	3	1	3		

1. Galvanic action will occur with direct contact
2. Galvanic action may occur.
3. Galvanic action is insignificant between these metals.

*Stainless steel conduit and EMT shall only be used with stainless steel fittings and approved accessories, outlet boxes and enclosures. If stainless steel is used with galvanized steel or aluminum, galvanic corrosion can occur. In galvanic corrosion, the more noble metal is protected and becomes the cathode, and the weaker alloy will become the anode and corrode at an accelerated rate. Since stainless teel is more noble than either aluminum or galvanized steel it would become the cathode and will cause the other metals to corrode at an accelerated rate.

Supplementary Corrosion Protection

While the coatings on steel conduit and EMT provide excellent corrosion protection, supplementary corrosion protection may be necessary in very corrosive environments.

Types of supplementary corrosion protection include compounds, tape wraps, or shrink wraps which are subject to the approval of the AHJ. Conduit with factory-applied supplemental PVC coatings is also available.

Compounds. Bitumastic coating, zinc-rich paints or acrylic, urethane or weather stable epoxy-based resins are frequently used. Oil-based or alkyd paints should not be used. Surface preparation is important for proper adherence. The raceway should be washed, rinsed and dried.

It should not be abraded, scratched or blasted since these processes could compromise the protective zinc layer. A compatible paint primer or two coats of paint adds additional protection.

Tape Wraps And Shrink Wraps. Several companies offer tapes with special high tack adhesives. These tapes must overlap and cover the entire surface of the conduit and fittings. Shrink wraps are available that will protect the conduit and fittings without requiring a heat source. Manufacturers of these types of tapes and wrap will provide installation recommendations.

PVC-Coated Conduit. Each of the UL standards for steel conduit and EMT (UL 6, UL 1242, and UL 797) includes information on factory applied supplementary coatings. The factory applied supplementary coating(s) are not required to meet the requirements for primary corrosion-resistant coatings. Supplementary nonmetallic coatings -typically PVC - are evaluated with respect to flame propagation, detrimental effects on the corrosion resistance provided by the primary protective coatings, the fit of the couplings, and electrical continuity with couplings. If a manufacturer chooses to list both the Zinc galvanizing and the PVC as primary corrosion protection methods, the PVC coating must also comply with the salt-spray (fog), moist carbon dioxide-sulfur dioxide-air, and ultraviolet light and water tests.

In addition to the UL standards, the NEMA RN-1 standard *PVC Externally-Coated Galvanized Rigid Steel Conduit and Intermediate Metal Conduit* provides the properties and dimensions of the coating and is intended as an aid for selecting and obtaining proper coating for added corrosion protection.

The same NEC requirement for *field-cut* threads applies to PVC-coated conduit: where corrosion protection is necessary, the threads must be coated with an approved electrical conductive, corrosion-resistant compound. Manufacturers of PVC-coated conduit supply a coating for this purpose. Listed products are also available.

(Chart D) The pH Scale

0	1	2	3	4	5	6	7	8	9	10	11	12	13	14
Hydrochloric Acid	Stomach Acid	Lemon Juice	Vinegar			Milk	Pure Water		Milk of Magnesia			Ammonia		Caustic Soda
10^{0}	10^{-1}	10^{-2}	10^{-3}	10^{-4}	10^{-5}	10^{-6}	10^{-7}	10^{-8}	10^{-9}	10^{-10}	10^{-11}	10^{-12}	10^{-13}	10^{-14}
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