

UL and NEC requirements for corrosion protection of 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 concerns the resistance of the product to corrosive environments. All materials will eventually experience some corrosion, since corrosion is a natural and inevitable process. But corrosion is also a controllable process.

Steel conduit systems provide long-lasting protection to the conductors and cables within. Due to the changing environments in which conduit is installed, it is impossible to provide firm life expectancy data. However, 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.

UL Standards

U.S. manufacturers of steel conduit are members of the National Electrical Manufacturers Association (NEMA) Section 5RN and also of the U.S. Conduit Committee of the Steel Tube Institute of North America (STINA). The products we produce include rigid steel conduit; 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 must be listed. NEMA/STI member products are listed to Underwriters Laboratories standards. Rigid steel conduit and associated elbows, couplings and nipples are listed to UL 6, IMC to UL 1242 and EMT to UL 797.

While there are no life expectancy tests in the UL standards, there are tests and performance requirements for the coatings used to protect steel conduit, EMT, elbows, couplings and nipples. The typical OD (outside diameter) coating for steel conduit and EMT is zinc. The ID (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 200 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 zinc corrodes, the oxide is white. When steel or iron rusts, the oxide is red. The UL standards allow the use of a surface coating on top of the primary corrosion protection coating (e.g., zinc) and most U.S. manufacturers do use a surface coating to provide additional corrosion protection.

For rigid steel conduit and IMC, the UL standards require that a protective coating be applied to protect the conduit threads until installation. These products are shipped

with a coupling on one end and thread protector on the other end. Manufacturers typically color-code these thread protectors to aid in trade size identification. For rigid, even trade sizes are color-coded blue, 1/2 trade sizes are black and 1/4 trade sizes are red. For IMC, even trade sizes are orange, 1/2 are yellow and 1/4 are green.

(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)

From: American Galvanizers Association

UL White Book Guidance

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. This data became the basis for the guidelines for supplementary corrosion protection that appears in the UL White Book General Information for Electrical Equipment and the UL Green Book Electrical Construction Equipment Directory.

In concrete: Two of the environments that have a high potential for corrosive conditions are concrete and soil. The UL guidelines state that when galvanized rigid steel conduit (GRC) or IMC are installed in concrete, supplementary corrosion protection is not required.

UL states that when EMT is installed in a concrete slab on grade or above, supplementary corrosion protection is generally not required. However, if EMT is installed in a concrete slab below grade, supplementary protection may be required.

In soil: UL further states that when GRC 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 2,000 ohmcentimeters, supplementary corrosion protection may be required. Local utilities commonly measure the resistivity of soils.

The authority having jurisdiction (AHJ) has the authority to determine the necessity for additional protection.

EMT in contact with soil generally requires supplementary corrosion protection.

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, we recommend the same method of protection for EMT emerging from concrete into salt air to lengthen the service life.

These UL guidelines are summarized in Chart B and are also included in the National Electrical Code (NEC).

National Electrical Code Requirements

To determine additional requirements for corrosion protection, it is crucial to understand the rules of the NEC, which govern electrical installations. Rigid metal conduit is covered by Article 344 in the NEC, 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. Note that Article 344 is entitled “Rigid Metal Conduit.” 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, steel conduit with the UL label is protected by corrosion protection, through the use of the zinc (typical) primary corrosion protection coating. The use of the words “judged suitable for the condition” means that the authority having jurisdiction (AHJ) must approve the installation. If the AHJ determines that supplementary corrosion protection is required, that is his/her call.

(Chart B)

UL GUIDELINES Corrosion Protection SUMMARY

In Concrete:	Required	Optional
- Steel Rigid Conduit		X
- Intermediate Metal Conduit		X
- Aluminum Rigid Conduit	X	
- Steel EMT	Below grade may need	On or above grade
- Aluminum EMT	X	
In Soil:		
- Steel Rigid Conduit		X
- Intermediate Metal Conduit		X
- Rigid Aluminum Conduit	X	
- Steel EMT	Generally Required	
- Aluminum EMT	X	

From: Soares Book on Grounding

Red brass conduit is only available in trade size 1/2 and 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.” That means that additional corrosion protection must be applied (see “Supplementary Corrosion Protection” below) and it must meet the approval of the AHJ.

Article 342. Intermediate Metal Conduit (IMC) is only available in steel. The NEC requirements for IMC are exactly the same as for rigid steel conduit.

Article 358. 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.” As with rigid and IMC, UL listed EMT is protected by corrosion protection by its zinc (typical) 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. Article 300 covers general requirements for wiring methods. 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 by the UL standards. The NEC makes sure that “where corrosion protection is necessary”, field-cut threads are 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. A UL-listed compound is also available.

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 paints, tape wraps, or shrink wraps which are subject to the approval of the Authority Having Jurisdiction. Conduit with factory-applied PVC coating, which is additional to the primary coating, is also available.

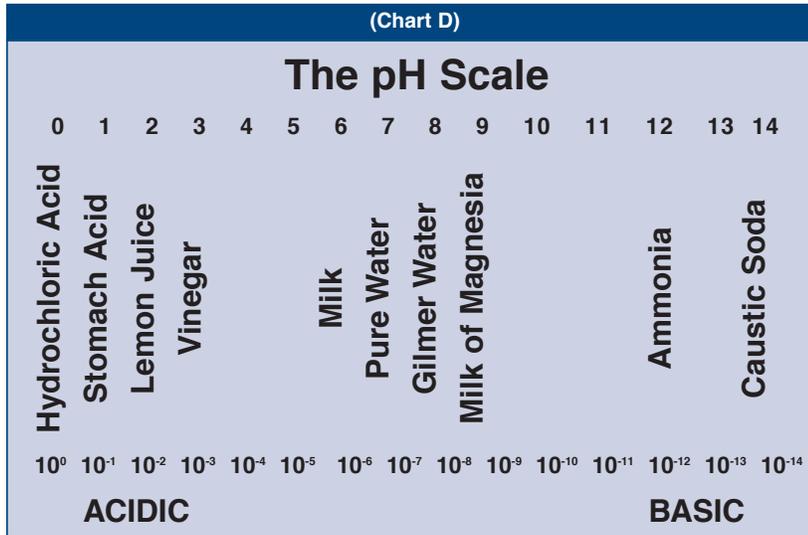
Paints. A bitumastic coating, zinc-rich paints or acrylic, urethane or weather stable epoxy-based resins are frequently used. Oil-based or alkyd paints should not be used. Surface preparation is important for proper adherence. The tube should be washed, rinsed and dried. It should not be abraded, scratched or blasted since these processes could compromise the protective zinc layer. A compatible paint primer or two coats of paint adds protection.

(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	3
Copper	1	2	2		2	1	2	1	1
Galvanized steel (zinc)	3	2	2	2	3	3		2	3
Lead	2	2	2	2	3	3		2	3
Stainless steel*	3	1	1	1	2	2	2		1
Zinc	3	1	1	1	3	1	3	1	

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

Tape wraps and shrink wraps. Several companies sell 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 supplementary coatings. The 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. A UL listed product is also available.

Corrosion Prevention

Corrosion is a very complex subject. 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; for example,

PVC-coated conduit is not intended for use in a Class 2 classified location due to the possibility of a static charge on the PVC coating.

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 methods of use, however, the best determination of suitability for use remains local experience.

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).

In Summary

Galvanized steel conduit and EMT have excellent corrosion protection coatings and can be depended upon for a long service life. For severely corrosive environments, supplementary corrosion protection can be applied to further extend the life expectancy of the installation.