



**National Electrical Manufacturers
Association**
1300 North 17th Street, Suite 1847
Rosslyn, VA 22209
703-841-3200
Fax: 703-841-3300

WHITE PAPER ON HEXAVALENT CHROME ON STEEL CONDUIT

What is Conduit?

Steel Electrical Conduit products (Rigid Steel Conduit, Intermediate Metal Conduit-Steel and Electrical Metallic Tubing - Steel) are used in the electrical wiring systems in the United States. They are raceways of circular cross section (i.e. piping) designed for the physical protection and routing of electricity conductors and cables. They are also used as an equipment-grounding conductor, when installed using appropriate fittings or the associated coupling, based on the type of product. Grounding is necessary to prevent fires or shock hazards from ungrounded equipment. This combined definition is from the 2002 National Electrical Code.

Major Components of Conduit

These products are principally made from a carbon steel tubular hollow with a zinc exterior coating and either zinc or an organic interior coating designed for corrosion protection. Zinc provides a superior corrosion protection for the base steel tube since it acts in a sacrificial manner with oxygen attacking the zinc rather than the steel

Underwriter's Lab (UL), using the American National Standards Institute (ANSI) consensus method, develops material standards for these products designed around the use and performance requirements for the product. Additionally, an ANSI committee managed by the National Electrical Manufacturers Association (NEMA) develops similar material standards.

Galvanized steel electrical conduits are typically rinsed in a complex chromate conversion solution to provide the zinc galvanizing corrosion protection against white rusting (bulky deposits of porous zinc oxide or hydroxide). Hexavalent chrome bearing conversion coatings are chosen for conduits because of their beneficial film properties such as: inflammability, corrosion protection, mechanical flexibility, long shelf life, electrical conductivity, ease of soldering, low toxicity since the majority of the hexavalent chromium is converted to water-insoluble trivalent chromium, pretreatment for painting, and self-healing. The additional process benefits are ease of application and handling.

The safety of these wiring systems has a long history and is covered by the National Electrical Code (NEC) published by the National Fire Protection Association (NFPA), an ANSI consensus organization. Local jurisdictions, such as states and cities typically adopt the NEC as their local electric code requirement. The NEC recognizes as acceptable the use of products listed by Underwriters Laboratory (UL) as having been approved for use after rigorous testing and follow-up inspections at the manufacturers' facilities. Steel conduit products have long been recognized as being extremely beneficial to the safe operation of our country's electrical systems.

Why is zinc used?

Underwriter's Lab (UL) develops material standards for these products designed around the use and performance requirements for the product. The three standards covering steel conduit products, UL 6, UL 797 and UL 1242 have historically specified zinc as a primary coating for corrosion protection. ANSI steel conduit standards C80.1, C80.3, and C80.6 have similar material standards for these products that also require a coating of zinc. Zinc protection of many steel products enables the use of steel, one of the most recyclable materials, to be used in applications where it might not otherwise be acceptable. Hampering the use of zinc to protect steel would be counterproductive to the environment.

The principle reasons that zinc is used as a protective coating for these steel products are that zinc corrodes much more slowly than steel in natural environments and the sacrificial galvanic nature of zinc at small discontinuities in the zinc coating. This means that oxygen will attack the zinc rather than the steel and the zinc still protects the steel in those small bare spots because it's effect "spreads out."

What happens to zinc under normal use?

The behavior of the zinc coating during atmospheric exposures has been examined in tests throughout the world. Fresh zinc surfaces are more prone to attack (oxidation) unless the zinc surfaces have been passivated (chemical treatment to form a protective passive film) by a topcoat. A fresh zinc surface, which has not been passivated, will form bulky deposits of porous zinc oxide or hydroxide, which are commonly called "wet storage stain" or "white rust". Without the zinc passivation, the zinc will corrode uninhibited thus destroying its intended purpose.

What is the effect of zinc corrosion?

Zinc provides a superior corrosion protection for the base steel tube since it acts in a sacrificial manner in the presence of oxygen. However, without zinc passivation, the zinc will corrode uninhibited and it will be consumed in a non-galvanic protection mode, thus destroying its intended purpose. With the zinc eventually consumed, the bare steel becomes exposed. Since steel is electrochemically more reactive than zinc, it will corrode at an even greater rate than the zinc. Unprotected, the steel conduit will be

consumed such that the enclosed wires are exposed, creating the possibility of an electrical fire or electrocution.

Why is hexavalent chromium used?

Galvanized steel electrical conduits are typically rinsed in a complex chromate conversion solution to provide the zinc galvanizing corrosion protection against white rusting that occurs on unprotected zinc surfaces.

Conversion coatings bearing hexavalent chromium are chosen for conduits because of their beneficial film properties such as:

- 1). Chromate films are inorganic and will not flame or catch fire. The inorganic feature makes for long shelf life as bacteria or ultraviolet rays have no effect as with organic films.
- 2) The chromate film has excellent corrosion protection, and the film is self-healing. Scratches or gouges in the chromate film will reseal themselves upon contact with water or humidity.
- 3) The films will bend and flex with the conduit without peeling or degrading and continue protecting afterwards.
- 4) The chromate film is electrically conductive/ low resistance. This permits easy and reliable grounding or electrical continuity in the conduit.
- 5) Chromate films are a pretreatment for paints and may be easily painted for color identification with assurance of good adhesion and long service life.

Additional process benefits are ease of application and handling.

How much hexavalent chromium is used?

Conversion coatings are applied by liquid contact of the galvanized tube with a chromating solution.

Application during the hot dip galvanizing process is typically accomplished by using a diluted chromate solution as a quench medium, when exiting the zinc bath at approximately 850°F. This sequence uses the inherent temperature of the coated product to quickly dry the film. Other methods include spraying the diluted chromate solution onto the galvanized tube prior to a drying oven. Both methods include convenient-to-handle water-based chemistry at non-hazardous temperatures. A typical chromate film weight of 5-10 micrograms/ square inch of total chromium is created during these processes.

A chemical reaction occurs during the application process, which reduces the majority of the hexavalent chromium to *water-insoluble* trivalent chromium, as a film. The self-healing nature of the chromate conversion coating is the result of trapped hexavalent chromium in the water-insoluble trivalent chromate film. Only a small portion of this coating remains as hexavalent chromium. *The dried chromate conversion is water insoluble from which only a trace amount of hexavalent chromium can leach out.*

What are the alternatives?

Much research has been carried out to develop alternatives to using a chromate solution for conversion coating. To date, no direct substitute has been identified that has equal benefits and can provide the required properties such as longevity in the protection of white rust formation, electrical conductivity, etc.