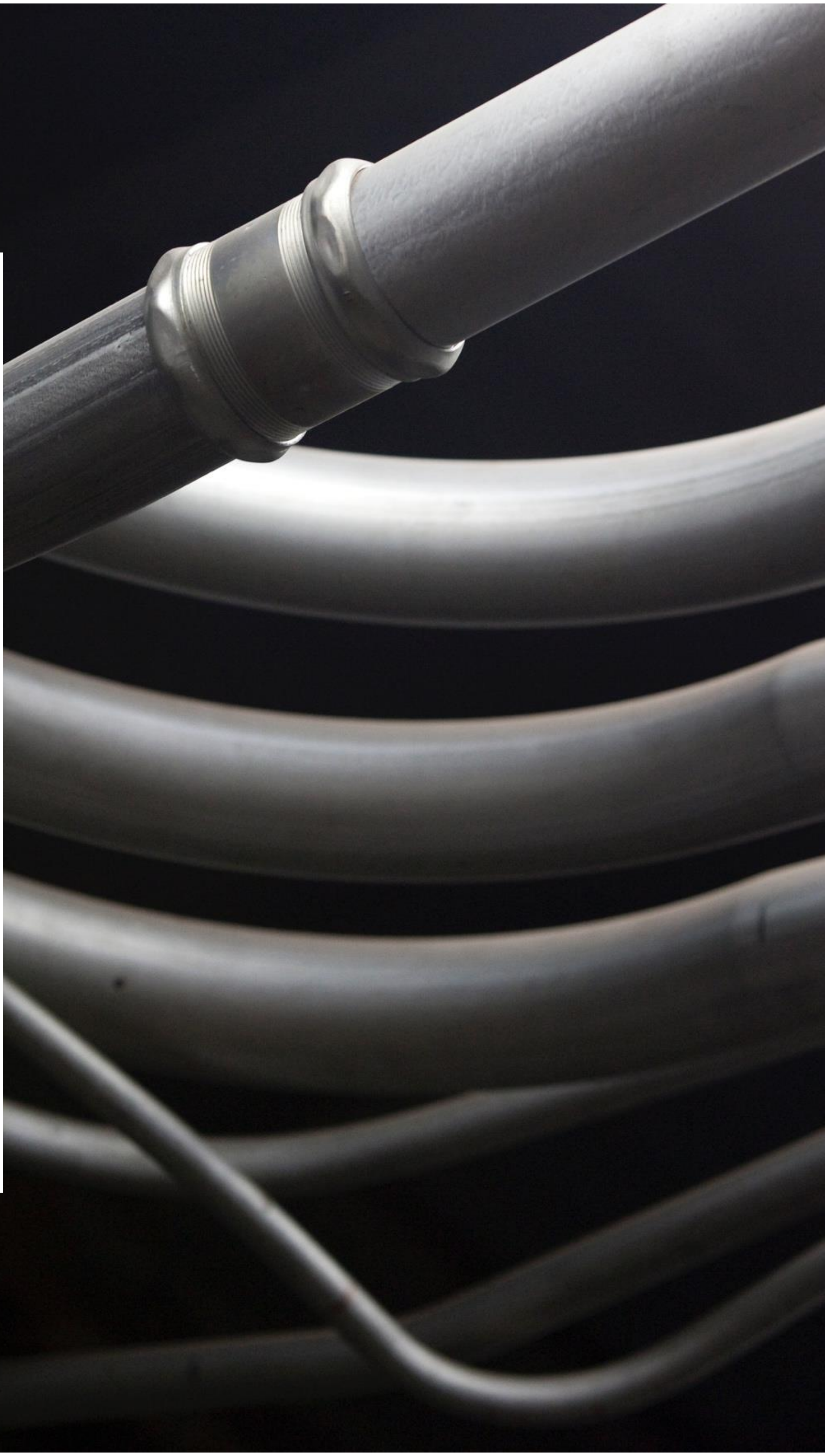
Steel Conduit

TECH TALK

PHYSICAL PROTECTION OF CIRCUITS

Technical Information About Steel Conduit and Electrical Metallic Tubing



When deciding which type of wiring method to use in your project, one of the main considerations that comes into play is the physical protection the electrical installation will need. Will it be completely within a wall during and after installation and have little or no exposure to physical damage? Will it be in an area where some physical damage can occur, but it won't be exposed to repeated damage or major damage — such as higher up on a wall, across a ceiling, or dropping down into a piece of equipment on a factory floor? Maybe the installation is taking place in an industrial establishment where physical damage is likely to occur and can be severe, such as being run over or hit by a forklift. No matter where the electrical wiring is located, there is a wiring method to use, but making the proper choice may be difficult.

The National Electrical Code® (NEC®) breaks these areas into three different categories:

- Products allowed to be used in areas of severe physical damage
- Products allowed to be used in areas of physical damage
- Products not allowed to be used in areas of physical damage

The first bullet is the most restrictive, and the only products that are always allowed to be used are rigid metal conduit (RMC, GRC) and intermediate metal conduit (IMC). The other two areas are interesting — the NEC doesn't define physical damage, but it does discuss which methods should be allowed where subject to physical damage and which methods should not be allowed where subject to physical damage.

The range of products not allowed to be subjected to physical damage varies greatly, from non-metallic cable to armored cable. Two such wiring methods that are always in this conversation are Electrical Metallic Tubing (EMT) and Metal Clad Cable (Type MC Cable).

Currently the NEC makes it clear that EMT or electrical metallic tubing provides greater physical protection from damage than MC Cable. This is apparent by uses permitted and not permitted: NEC Section 330.12 states that MC Cable is not allowed to be used where subject to physical damage, and Section 358.12 states that EMT is not allowed to be used in areas of severe physical damage. Section 358.10(E) allows EMT to be installed in areas of physical damage.

Many public inputs have been submitted over the years claiming that MC Cable offers similar protection to EMT, and thus either both should be allowed to be used in areas subject to physical or neither of them should be. Due to these claims, the Steel Tube Institute decided to test the differences in physical protection provided by both these products. The Steel Tube Institute Conduit Technical Committee reached out to independent testing laboratories to have testing done on the physical protection properties of EMT and MC Cable. Intertek Testing Laboratory (ETL) in Coquitlam, British Columbia, agreed to do the testing. Intertek performed crush and impact tests on ½ and ¾ trade size EMT in August and September of 2014 according to UL® Safety Standard 1569 with slight modifications to take the testing to failure.

DEVIATIONS FROM STANDARD TEST METHODS

Impact tests were conducted on 3-ft. sections of EMT and MC cable instead of the required 10 impacts over a single continuous length of at least 11 ft. Additionally, instead of the 1.5-ft. drop height as specified in the standard, the maximum failure height of each sample was determined and reported.

Crush tests were conducted on 3-ft. sections of EMT or MC cable instead of the required ten crush tests over a single continuous length of at least 100 in.

CRUSH TEST

The crush test shows the raceway's ability to endure field hazards such as construction variable's structure shifts, as well as abuse, such as being run over / into by a forklift or being stepped on by construction workers.

The crush test was performed in accordance with Section 25, "Crushing Test — All Cable" of UL 1569 with slight deviations. For each product type, three samples, each measuring three feet long, were used for testing. Each test sample was placed into an Instron universal testing machine and laid over a ¾ inch diameter steel rod. The top compression plate was a flat plate that measured two inches wide. Each of the insulated circuit conductors in the length of EMT or MC Cable being tested was connected in a series with a buzzer and its supply circuit, one leg of which was grounded (earth). All equipment grounding conductors in the test length were connected to the conduit body or metal jacket, to all metal parts of the compression apparatus, to ground (earth), and to the grounded supply wire. Each sample was tested at a compression rate of 0.50 ± 0.05 inches per minute until one or more of the indicators signaled that contact occurred between the circuit conductors or between one or more of the circuit conductors and any equipment grounding conductor, the conduit body, or both. The maximum load obtained at the moment of contact was recorded. The three test results were averaged and reported. Below are the results of the crush test:

Sample:

1. ½ EMT with 2 conductors of 14 AWG THHN had an average load of 1,809 lbf before failure.
2. ½ EMT with 3 conductors of 14 AWG THHN had an average load of 1,845 lbf before failure.
3. ¾ EMT with 2 conductors of 12 AWG THHN had an average load of 2,155 lbf before failure.
4. ¾ EMT with 3 conductors of 12 AWG THHN had an average load of 2,016 lbf before failure.
5. 14/2 aluminum MC cable with a green equipment grounding conductor had an average load of 1,011 lbf before failure.
6. 14/3 steel MC cable with a green equipment grounding conductor had an average load of 808 lbf before failure.
7. 14/3 aluminum MC cable with a green equipment grounding conductor had an average load of 834 lbf before failure.
8. 12/2 steel MC cable with a green equipment grounding conductor had an average load of 848 lbf before failure.
9. 12/2 aluminum MC cable with a green equipment grounding conductor had an average load of 792 lbf before failure.
10. 12/3 steel MC cable with a green equipment grounding conductor had an average load of 720 lbf before failure.
11. 12/3 aluminum MC cable with a green equipment grounding conductor had an average load of 895 lbf before failure.

IMPACT TEST

The impact strength test is an important indicator of the raceway being able to handle mechanical abuse. One example of such mechanical abuse would be an item being dropped on it during the construction process.

The impact test was conducted in accordance with Section 24, "Impact Test" of UL 1569 with minor deviations. For each product type, three samples, each measuring three feet long, were used for testing. Test samples were placed into an impact test apparatus and laid over a ¾ inch diameter steel rod. Each of the insulated circuit conductors in the length of EMT or MC Cable being tested was connected in series with a 3W, 120V neon lamp to one of the ungrounded conductors of a 208V, 48–62 Hz, 4-wire grounded AC supply circuit. The insulated equipment grounding conductor in the test length of the tubing / cable was connected to the conduit body / metal jacket, to all parts of the impact apparatus, to ground (earth), and to the grounded supply conductor. Each test sample was impacted at the center of each three-foot section using an impact weight of 10 pounds. The impact weight was a solid rectangular block of steel with the impact face measuring two inches by six inches. The impact weight was raised to the required drop height. A release mechanism allowed the impact weight to fall freely in the guides of the impact apparatus and strike the sample. Upon impact, the neon lamps were observed to see if they lit, indicating momentary or other contact between the circuit conductors or between one or both of the circuit conductors and the equipment grounding conductor, conduit body, or both. The maximum impact height was reported for three consecutive failures. Below are the results of the impact test:

Sample:

1. ½ EMT with 2 conductors of 14 AWG THHN. The sample reached the limits of the testing apparatus (96") without a failure. No short and the wires were able to move freely.
2. ½ EMT with 3 conductors of 14 AWG THHN. The sample reached the limits of the testing apparatus (96") without a failure. No short and the wires were able to move freely.
3. ¾ EMT with 2 conductors of 12 AWG THHN. The sample reached the limits of the testing apparatus (96") without a failure. No short and the wires were able to move freely.
4. ¾ EMT with 3 conductors of 12 AWG THHN. The sample reached the limits of the testing apparatus (96") without a failure. No short and the wires were able to move freely.
5. 14/2 aluminum MC cable with a green equipment grounding conductor had a failure at 24"; wires were pinched.

6. 14/3 steel MC cable with a green equipment grounding conductor had a failure at 30"; wires were pinched.
7. 14/3 aluminum MC cable with a green equipment grounding conductor had a failure at 24"; wires were pinched.
8. 12/2 steel MC cable with a green equipment grounding conductor had a failure at 30"; wires were pinched.
9. 12/2 aluminum MC cable with a green equipment grounding conductor had a failure at 24"; wires were pinched.
10. 12/3 steel MC cable with a green equipment grounding conductor had a failure at 26"; wires were pinched.
11. 12/3 aluminum MC cable with a green equipment grounding conductor had a failure at 24"; wires were pinched.

RESULTS

Crush Test:

- MC Cable's best result was an average load of 1,011 lbf while EMT's worst result was 1,809 lbf before recording a short or open circuit. That means EMT's worst result is almost double the protection of MC cable's best result in the crush test. In the rest of the results, EMT could handle double and sometimes almost triple the crushing force before affecting the integrity of the circuit compared to what MC Cable could take.

Impact Test:

- MC Cable's best result on the impact test was a 10-pound weight falling from a height of 30 inches. EMT reached the testing apparatus's limit of 96 inches without a failure. EMT did not have a failure when a 10-pound weight was dropped from eight feet high, yet the cable failed before reaching a height of three feet on its best test and most cable failed around two feet high.

IN SUMMARY

After reviewing the testing, EMT outperformed MC Cable by four times in the impact test and did not have a failure where MC cable did. EMT also outperformed MC Cable by almost double in the crush test. There is nothing equal about the protection that EMT provides when compared with that of MC Cable. After seeing the results of the crush and impact tests, it is clear that EMT offers superior protection against physical damage.

You may be asking yourself: What do the impact or crush test results mean in the real world? Let's look at a couple of examples that could happen, taking into consideration the results of these tests.

Example #1 (Crush Test Example):

- There is an electric cart driving through the warehouse. This cart weighs 4,000 pounds and has a maximum speed of five miles per hour. So, let's say the cart was traveling at three miles per hour (speed limit near pedestrians in most plants) when it turned the corner and ran into a wall, hitting the EMT or MC Cable running up the wall. We will estimate it took the cart 0.5 seconds to come to a complete stop.
  - Newton's second law is Force = Mass times acceleration
    - For mass, we convert pounds to kilograms: 4,000 lbs. / 2.2 = 1,818.18 kg
    - For acceleration we have the change in speed divided by the time it took to change the speed.
      - 3 mph is equal to 1.34 m/s
      - (0 m/s - 1.34 m/s) / 0.5 s = 2.68 m/s
    - 1,818.18 kg x 2.68 m/s^2 = 4,872.72 N
    - 4,872.72 N / 4.448 = 1,095 lbf
      - Note: This testing was measured in lbf rather than Newtons (N). The conversation is provided above.
  - **When the cart impacts the raceway, it is with 1,095 pounds of force. With this amount of force MC Cable would have a failure and need to be replaced. The EMT may be dented, but the integrity of the conductors inside should not be compromised.**

Example #2 (Impact Test Example):

- The electrical system has been installed for a wall before the drywall or finishing of the walls, and the contractor needs the plumber to do some work. The plumber is up on a six-foot ladder working overhead when he drops his 24-inch pipe wrench. The average weight of a 24-inch inch pipe wrench is 9.5 pounds. So, we have a 9.5-pound weight falling from six feet hitting the MC Cable or EMT. Will it cause damage to the conductors?

- The first step is to convert pounds to kilograms and feet to meters.
- The second step to answer this question is to determine the force created by the falling object and compare to the force created in our impact test.
- The force of a falling object is determined by taking Mass x Height x Acceleration (in this case, free-falling acceleration is gravity, which is 9.8 m/s2)
    - (9.5 lbs. / 2.2) x 9.8 m/s2 x (6 ft. x 0.3048) = 77.44 N
        - **So, the force the wrench will impact the raceway with is 77.44 N.**
    - In the Intertek test, MC Cables best result was an impact from a 10-lb. weight at 30 inches. We will need to figure out that force to see if it would fail under the force of the fallen wrench.
    - (10 lbs. / 2.2) x 9.8 m/s2 x (2.5 ft. x 0.3048) = 33.94 N
        - **MC Cable's best result only allowed for an impact force of 33.94 N before failure. Therefore, with an impact force of 77.44 N, the cable would be compromised in this scenario.**
    - In the Intertek test, EMT did not have a failure from 8 ft. with a 10-lb. weight.
        - (10 lbs. / 2.2) x 9.8 m/s2 x (8 ft. x 0.3048) = 135.77 N
        - **EMT never had a failure or compromised the integrity of conductors when being impacted by a force of 135.77 N. Therefore, the force of 77.44 N in this scenario should not compromise the integrity of the conductors.**

This testing validates the NEC's allowable uses for both products and shows that EMT offers superior protection to conductors when compared to MC Cable. If you would like to review the entire test study performed by Intertek please visit our website at: steeltubeinstitute.org/resources/emt-crush-impact-testing-results/