U.S. Department of Labor
Occupational Safety and Health Administration
Directorate of Technical Support & Emergency Management
Office of Technical Programs and Coordination Activities

Safely Installing, Maintaining and Inspecting Cable Trays

Safety and Health Information Bulletin

SHIB 01-16-2008

Purpose

The purpose of this Safety and Health Information Bulletin is to:

- Review the proper methods for safely installing, maintaining and inspecting electrical cable trays;
- Provide information regarding the hazards of overloaded cable trays;
- Identify specific Occupational Safety and Health Administration (OSHA) regulatory requirements and National Electrical Code® (NEC) guidance that address the proper installation and maintenance of cable trays;
- Recognize electrical cable tray misuse that can lead to electric shock and arc-flash/blast events and fires caused by overheating.

OSHA Regulations and Industry Consensus Standards that Apply to Cable Trays

The use and installation of cable trays is covered by legally enforceable OSHA regulations in 29 CFR 1910.305(a)(3), or comparable standards promulgated by States operating OSHA-approved State plans. In addition, this document contains several references to provisions of the National Electric Code (NEC), which is published by the National Fire Protection Association (NFPA). The 2005 edition of NEC is listed as a reference in Appendix A – "Reference Documents" of OSHA Subpart S, Electrical (1910.301 through 1910.399). While these references provide nonmandatory information that can be helpful in understanding and complying with Subpart S, compliance with the referenced provisions of the NEC is not required and is not a substitute for compliance with any applicable OSHA standards.

Although the recently promulgated electrical standards for general industry at 29 CFR 1910 Subpart S (72 FR 7136—7221, February 14, 2007) are based on the 2002 edition of the NEC, OSHA has not conducted rulemaking to adopt all of the requirements of the NEC (or subsequent revisions) and, therefore, cannot enforce those requirements. However, industry consensus standards such as the NEC and others referenced throughout this Bulletin can be used by employers as guidance for conducting hazard analyses and selecting effective control measures.

The National Electrical Manufacturers Association (NEMA) also publishes three consensus standards that apply to the proper manufacture and installation of cable trays: ANSI/NEMA-VE 1-1998, Metal

Cable Tray Systems; NEMA-VE 2-1996, Metal Cable Tray Installation Guidelines; and NEMA-FG-1998, Nonmetallic Cable Tray Systems.

Cable Trays

According to OSHA 1910.399, a cable tray system is "[a] unit or assembly of units or sections and associated fittings forming a rigid structural system used to securely fasten or support cables and raceways. Cable tray systems include ladders, troughs, channels, solid bottom trays, and other similar structures." Cable trays are not raceways, but they are treated as a structural component of a facility's electrical system. Cable trays are a part of a planned cable management system to support, route, protect and provide a pathway for cable systems. Cable trays support cables across open spans in the same way that roadway bridges support traffic.

Cable trays can provide a safe component of a power, low voltage control, data or telecommunications wiring distribution system. Cables in trays can be easy to mark, find, and remove. Their flexibility makes cable trays a good choice for installation situations that require upgrading, reconfiguring, or relocation.

Cable trays are available in a number of different configurations, including ladder, ventilated trough, ventilated channel, solid bottom, wire mesh, single rail and other configurations. They come in a wide variety of shapes and sizes, with a host of hanging options that are able to meet almost any installation need. Cable trays are manufactured of steel, stainless steel, aluminum and fiber reinforced plastic (FRP). They also are available with special finishes including polyvinylchloride (PVC) coated and galvanized finish. A significant portion of cable trays used in industry today are aluminum. Aluminum, steel and coated-steel cable trays, all being metallic, may be used as equipment grounding conductors in accordance with OSHA 1910.305(a)(3)(iii). This requirement is mirrored by the guidance provided by NEC Section 392.3(C). Depending on the need, covers and ventilated louvers or slats are available for all trays. Covers physically protect the cables as well as shielding the cable jackets from the sun's ultraviolet radiation when used outdoors. Suitable guards or covers must be installed to a minimum height of 2.5m (8 ft.) above grade such as where cable trays are exposed to physical damage from vehicular traffic. Ventilated louvers also protect the cables and facilitate cooling by allowing natural convection (heat dissipation) to occur.

Figure 1. Ladder cable tray, ventilated cable tray, solid-trough cable tray.

Cable Tray Use

Cable trays can be used in a variety of settings. Cable trays can be rated for outdoors, indoors, corrosive and classified hazardous locations, and areas with high electrical noise and vibration. As with any electrical equipment, cable trays and the wiring contained in the trays must be listed, labeled or otherwise approved, pursuant to the requirements of 29 CFR § 1910.303(a). The National Electrical Manufacturers Association (NEMA) Standard VE 1-2002 provides guidance for metal cable trays and associated fittings designed for use in accordance with the rules of the NEC. NEMA Standard VE 2-2006 addresses shipping, handling, storing, and installing cable tray systems; it also provides information on cable tray maintenance and system modification. Compliance with these standards helps to ensure safe loading and the electrical continuity of cable tray systems.

Cable trays may be designed to cross through partitions and walls, as well as go vertically through platforms and floors.

However, where cable trays (and the conductors and cables they contain) pass through fire-rated partitions, walls and floors, appropriate fire-stops should be provided in accordance with NEC Section 300.21 to prevent the spread of a fire or the by-products of combustion. Typically, specific building codes should be consulted and the design and oversight should be done by a qualified engineer.

Use of cable trays is popular in hazardous locations where concentrations of flammable or combustible gases, vapors and dusts exist. However, the improper use of cable trays in these environments could result in an explosion. 29 CFR § 1910.305(a)(3)(iv) requires that cable trays in hazardous (classified) locations contain only the cable types permitted in such locations (see 1910.307 for details on hazardous (classified) locations). In addition, the NEC also contains specific requirements for wiring in hazardous or classified environments. For example, NEC Section 392.3(D) states that cable trays in hazardous locations should contain only the wiring permitted in specific sections of Chapter 500 (Sections 501.10, 502.10, 503.10, 504.20 and 505.15).

Proper Loading of Cable Trays

Since cable trays come in a wide variety of sizes, they can be designed to accommodate a wide range of loading configurations. Because of their flexibility, cable trays are especially subject to overloading. Safe and permissible loading of cable trays is governed by three criteria: manufacturer-specified weight restrictions; limitations of cable fill because of cross-sectional area limitations; and conductor spacing

Figure 2. Outdoor metal clad cable in cable tray.

Figure 3. Electrical wires in multiple cable trays.

requirements. The appropriate size and number of cable trays for an installation depends on the number and size of conductors included and the allowable fill area specified in the guidance provided by the NEC. Because cable trays offer flexibility for expansion and changes, engineers and designers should design and size cable tray systems to anticipate both current and future needs.

Load and Support Requirements

29 CFR § 1910.303(b)(8) requires the appropriate mounting and cooling of electrical equipment. Additionally, guidance provided in NEC Section 392.6(C) states, in part, that cable trays shoul be supported at intervals in accordance with the installation instructions. This straightforward approach is corroborated in 29 CFR § 1910.303(b)(2), which states that "listed or labeled equipment shall be used or installed in accordance with any instructions included in the listing or labeling," and guidance provided by NEC Section 110.3(B). The type and number of cable trays, and the support required to handle loads must take into account several factors, including, but not limited to, environmental or weather factors; the weight of the cable tray; current and future cable needs; electromagnetic forces; and any accessories installed. Manufacturers of cable tray systems provide a wide range of parts and typical support methods, as well as detailed installation guides and tables for appropriate supports and support

spacing for cable trays. However, engineering calculations are often required to determine where to place supports so that the designed cable tray system provides the proper strength.

Concurrently, NEC 392.6(J) permits cable tray systems to externally support raceways, cables and boxes, and conduit bodies as covered by Section 314.1, provided that the cable tray is listed and designed for the application. Support for the equipment also must be in accord with the appropriate NEC article. This permission does not extend to other non-electrical equipment, such as water pipes, sprinklers, and gas pipes. In addition, cable tray supports should also take into account dynamic loads (e.g., loads caused by the motion of the cable tray system and its contents) and lateral stressors. Cable tray systems need not be absolutely rigid; most systems are designed with about a 1/200 span-deflection ratio (i.e., 1.2 inches in a 20-foot span) when fully loaded.

Wiring Fill and Spacing Requirements

In industrial establishments, where the conditions of maintenance and supervision assure that only qualified persons will service the installation, OSHA 1910.305(a)(3)(ii) defines the wiring methods that may be installed in cable trays. Cable tray fill is addressed in NEC Sections 392.8, 392.9, 392.10, and 392.12. The type of cable tray (e.g., solid, ventilated), ampacity (current-carrying limit) requirements, and the type and voltage rating of cable used determines the allowable fill for each cable tray. Ventilated cable trays provide for the greatest allowable fill due to increased airflow. A generic guideline developed by the Cable Tray Institute indicates that cable trays should not be filled in excess of 40-50% of the inside area of the tray or of the tray's maximum weight based on the cable tray specifications. However, the NEC provides more detailed requirements for cable tray fill (e.g., single conductors sized 1/0 through 4/0 used in ladder or ventilated cable trays must be installed in a single layer and where multi-conductor cable is used 4/0 and larger conductors must be installed in a single layer and the sum of the diameters of the cables must not exceed the width of the cable tray). In making cable tray fill determinations, the best strategy is to review and follow the requirements of the NEC and the manufacturer's installation guides to determine the appropriate fill when installing cable in cable trays. The ampacity (current-carrying rating) for conductors and cables in cable trays provided in NEC Sections 392.11 and 392.13 is based on compliance with the NEC cable tray fill requirements.

Importance of Supports and Allowable Fill

Overfilling cable trays can lead to a number of serious hazards. The weight of the cables inside the cable tray may pose a hazard. All cable trays and their associated supports are rated for a specific maximum weight, based partly on the allowable fill area and the spacing of the cable tray supports. Overloading cable trays can lead to a breakdown of the tray, its connecting points, and/or supports, causing hazards to persons underneath the cable tray and even leading to possible electric shock and arc-flash/blast events from component failure that occurs when the cables are suddenly no longer supported. Paragraph (b)(1) of 29 CFR 1910.303 requires that equipment shall be free from recognized hazards that are likely to cause death or serious physical harm to employees. Some of the tests for suitability and use are mechanical strength and durability (1910.303(b)(1)(ii)), heating effects under all conditions of use (1910.303(b)(1)(v)), and arcing effects (1910.303(b)(1)(vi)).

Paragraphs (b)(8)(ii) and (b)(8)(iii) of 29 CFR 1910.303 contain requirements for the cooling of electrical equipment. Avoiding heat buildup is another important issue. The NEC requirements for cable tray fill address heat build-up in conductors while current is flowing. When cable trays are overloaded, excessive heat builds up in and around live conductors, which can cause the insulation to break down and create potential shock hazards or fires. Fires can occur either in cable trays (which may provide a fire path) or in combustible materials near cable trays. Furthermore, the improper use of flexible cord within cable trays could lead to the spread of toxic vapors if a fire were to occur.

Types of Conductors to Use

Any wiring method used in cable trays must be "acceptable" as defined in OSHA 1910.399. In other words, the wiring method used must be listed by a nationally recognized testing laboratory (NRTL) as suitable for use in cable trays and in the environment in which it is installed. 29 CFR § 1910.305(a)(3)(i) and NEC Table 392.3(A) provide corresponding lists of wiring methods permitted in cable tray systems. Additionally, 29 CFR § 1910.305(a)(3)(i)(b) and NEC Section 392.3(B) allow other specific conductors in industrial establishments where maintenance and supervision assure that only qualified persons will service the cable tray systems.

Mixing of cable types and voltages is permitted in cable trays provided that some specific requirements are met. For example, NEC Section 392.6(F) permits cables rated to carry over 600V to be installed with cables rated 600V or less, provided that the cable rated over 600V is Type MC, or if a solid fixed barrier of material compatible with the cable tray is installed to separate the voltage levels. Installing barriers between power and control cables is a recommended practice, regardless of the ratings and voltages of the cables in question.

It is important to note that although NEC Table 392.3(A) states that "other factory-assembled, multi-conductor control, signal, or power cables that are specifically approved for installation in cable trays" may be used in cable trays, flexible cords and cables are not approved for use in cable trays (29 CFR § 1910.305(g) - Flexible cords and cables, and NEC Article 400). There are several reasons for this. First, both OSHA and the NEC prohibit the use of flexible cord as a replacement for the fixed wiring of a building. Since wiring in cable trays is considered a fixed or permanent wiring method by both OSHA and the NEC, flexible cords are prohibited from being used in cable trays (see NEC Article 400.4 for a list of prohibited flexible cords). Secondly, flexible cord insulation can break down and become brittle over time which can result in electrical shorts, shock hazards, and fires releasing toxic smoke. Additionally, flexible cords and cables might not be rigid enough to span the openings in ladder and ventilated-type cable trays. Furthermore, the conductor insulation might not withstand the load of stacked cables.

Securing Cables within Cable Trays

There are many reasons for securing cables within cable trays. Securing cables will maintain proper spacing between cables, keep cables in the trays, and confine the cables to specific locations within trays. Those designing and installing the system must determine the distances between fastenings in cable trays. While the weight of the cable itself keeps it in the tray in horizontal runs, the recommended practice is to tie all cables down so that the cables are not knocked out or "whipped" during abnormal or fault current conditions. When cables are not installed in horizontal runs, guidance presented by NEC 392.8(B) indicates that said cables should be securely fastened to transverse (crosswise) members. Smaller diameter cables might need to be lashed or tied to the cable tray more frequently than the stiff large diameter cables to prevent them from hanging away from the cable tray. Support is also required where cables are routed from one cable tray to another or where cables enter raceways or other enclosures (see OSHA 1910.305(a)).

Certain cable installations, such as in higher ambient temperatures, might require the spacing between adjacent cables to be increased to not less than one cable diameter between cables pursuant to NEC Section 392.11. Generally, multiconductor cables do not need to be spaced.

Cable ties should be appropriate for the conditions in which they are used. Factors such as moisture resistance, ultraviolet resistance, extremely high or low temperatures, chemical resistance, flammability, low-smoke characteristics, tensile strength, and length are important to consider. In all cases, persons installing or inspecting cable tray installations should refer to the manufacturer's instructions and specific NEC articles for the proper wiring support method to be used.

Figure 4. Cable ties.

Proper Grounding and Bonding

Grounding and bonding help to prevent electrocutions and arcing by facilitating the operation of over current devices and preventing exposed non-current-carrying metal parts and enclosures from being energized. Proper grounding and bonding is done before the cable is installed and must be tested before the cables are energized.

Grounding and bonding are often associated together, although, in reality, they represent two different concepts. Bonding is the permanent joining of metallic parts to form an electrically conductive path. Equipment grounding is the connection of non-current-carrying metal parts of equipment, raceways, and other enclosures to the system's grounded conductor, the grounding electrode conductor, or both, at the service equipment or at the source of a separately derived system. Both grounding and bonding are done to ensure electrical continuity and also to assure the capacity to safely conduct any current likely to be imposed upon those non-current-carrying metal parts, like cable trays.

Metallic cable tray systems used to support electrical conductors must be grounded and electrically continuous, and effectively bonded as required for conductor enclosures (specified by 29 CFR §§ 1910.304(g)(5), 1910.304(g)(6) and mirrored by the guidance provided by NEC Section 250.96). If the employer is following NEC guidelines, cable trays may be used as equipment grounding conductors provided that continuous maintenance and supervision ensure that qualified persons will service the installed cable tray system and that the provisions of NEC Section 392.7 are met (i.e., cable trays are marked for use as equipment grounding conductors and minimum cross-sectional areas meet, and are marked as meeting, the requirements of Table 392.7(B)). If the cable tray system does not meet the marking requirements of NEC Section 392.7, it also would not meet OSHA's suitablilty requirement in 1910.303(b)(1). Therefore it cannot be used as the equipment grounding conductor for branch or feeder circuits unless a single equipment grounding conductor is installed in the tray and listed bonding connectors or jumpers are used to effectively bond the cable tray sections together to ensure electrical continuity. Grounding of cable trays is so important that it has become the industry practice to use grounding conductors in cable trays for added reliability, regardless of how the tray is listed and marked. It is also recommended that cable trays be bonded to building steel or earth every 60 feet in order to reduce noise in the system. Where a cable tray includes only multiconductor cables, there is generally no need to use the tray as an equipment grounding conductor because each multiconductor cable should have integral equipment grounding conductor. Cable trays, however, should be bonded in accordance with NEC Section 250.96(A). Bonding jumpers on cable trays are important to maintain the electrical continuity and the ability to safely carry any fault current likely to be imposed (in accordance with NEC Section 250.96). As cable trays are typically fastened using direct bolted connections, which provide bonding, bonding jumpers are only required at adjustable splice plates, expansion plates and non-continuous sections of trays. However, as with the use of equipment grounding conductors, industry practice is to use bonding jumpers at all splice points to ensure continuity.

Figure 5. Grounding and bonding hardware.

Required continuity applies to all enclosures and utilization equipment and to cable dropouts from the tray system to enclosures. If channel dropouts or conduit-to-cable tray adapters listed for grounding are not used, grounding and bonding must be provided by grounding conductors in the cable or by bonding jumpers.

Recognizing Overloaded Trays

Recognizing overloaded cable trays is not difficult. If visual observation of the cable tray reveals that the cable tray is nearly full or overflowing with cables, then the installation does not meet the guidance provided by the NEC. Cable tray fill is addressed in the 2005 edition of NEC Sections 392.8, 392.9, 392.10, and 392.12. The number of single conductors or multiconductor cables that are permitted in a cable tray as indicated by the NEC range from a single layer to a fill value that might represent 50% of the cross-sectional area of the interior space within the cable tray. This is an extreme limit and the cable tray will appear to be over half full due to voids between the cables or conductors. Another consideration for cable tray fill is not to overload the cable tray or its support system beyond their ratings.

In any case, the best strategy is to review and follow the rules set out in the NEC and the manufacturer's installation guides when installing cables in cable trays.

Solutions for Overloaded Cable Trays

If cable trays are overloaded because of poor design and/or installation, the solution is to add additional able trays in accordance with guidance provided by the NEC. Another effective strategy for preventing overfill is to review and follow the manufacturer's installation guides when installing cables in cable trays. However, one of the major causes of overloaded cable trays is abandoned conductors and cables for circuits no longer in use, which often are not removed from the cable tray when replacement or additional cables are added. The solution in this instance is to remove abandoned cable when they are no longer necessary.

In fact, Section 590.3(D) and various sections in Chapter 8 of the NEC specifically indicate that abandoned communication cable and temporary wiring installed within cable trays should be removed upon the completion of projects.

Figure 6. Overloaded Cable Tray.

Preventing Damage to Cables and Conductors

The cables and conductors approved for use in cable trays are required to be insulated. However, while the insulation of the conductors does provide some protection, it is important to use measures to prevent damage to the insulation when working around energized conductors or cables so as not to damage the insulation. If the work the employee is performing, such as adding boxes or other approved electrical equipment using screws or bolts, drilling into the cable tray, and pulling or dragging cables or conductors across each other, could damage the insulation, then the wiring must be de-energized when attaching boxes or other approved electrical equipment to cable trays. In general, 29 CFR 1910.333(a)(1) requires that live parts to which an employee may be exposed shall be deenergized before an employee works on or near them.

Conclusion

Cable trays can provide a safe component of a wiring distribution system. However, if not designed and installed properly, wiring inside cable trays may pose hazards such as fire, electric shock and arc-flash blast events. During the maintenance, installation and inspection of cable trays, the following concerns should be taken into consideration.

- Cable trays, and the conductors and cable they contain, must be listed or labeled by a NRTL as suitable in the environment in which they are installed.
- Where cable trays pass through fire-rated partitions, walls and floors, appropriate fire stops should be provided in accordance with guidance provided by NEC Section 300.21 to prevent the spread of a fire or the by-products of combustion.
- Cable trays in hazardous locations must only contain the wiring permitted in such locations.
- Cable trays must be properly supported in accordance with the installation instructions. Overloading cable trays can lead to a breakdown of the tray, its connecting points and/or supports, causing hazards to persons underneath the cable tray and even leading to possible electric shock and arc-flash/blast events from component failure when the cables are suddenly no longer supported.
- When cable trays are overfilled, excessive heat build-up in and around live conductors can cause the insulation to break down, leading to potential shock hazards or fires.
- The fill values for cable trays specified in the 2005 NEC range from a single layer to roughly a 50% fill of the cross-sectional area of the cable tray.
- When cable trays are overfilled beyond the fill criteria established by the NEC, add another cable tray system above, below, or next to the overfilled tray. Allow enough working space around the added cable tray.
- Grounding of cable tray systems is essential for personal safety and protection against arcing that can occur anywhere in the wiring system. Proper grounding must be done before cables are installed and tested before cables are energized.
- Abandoned cables within cable trays should be removed.
- Work on cable tray installations may expose employees to live parts. According to 29 CFR 1910.333(a)(1) deenergization of live parts to which an employee may be exposed is required before employees begin work on or near them.

For more information

National Electrical Code® (2005) Article 392 (See also NEC® Handbook).
OSHA Electrical Standard on Cable Trays, 29 CFR 1910.305(a)(3).

OSHA Fact Sheet - Electrical Safety Hazards of Overloading Standard Cable Trays (http://www.osha.gov/Publications/cable_trays_fs.pdf)

Cable Tray Institute (http://www.cabletrays.com)

Cable Tray Manufacturers:

Cabofil (http://www.cablofil.com)

Chalfant (http://www.chalfantcabletray.com)

Cooper (http://www.b-line.com)

Enduro Systems, Inc. (http://www.endurocomposites.com)

GS Metals (http://www.gsmetals.com)

MPHusky (http://www.mphusky.com)