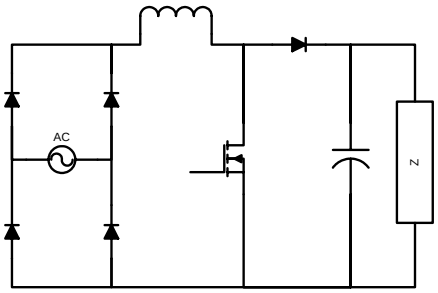

Kimball Power Electronics
503 Mustang Drive
Mahomet, IL 61853

Report

Analysis of Cablofil Cable Tray for Power Circuits

Reference: RP10002

Issue: 003

Status: Issued

Author: Jonathan Kimball

Created: 13 June, 2004

Contents

1. Introduction 4
1.1 Scope 4
1.2 Definitions 4
1.3 References 4
1.4 About the Author 5
2. Overview 6
3. General Occupancies 7
3.1 Uses Permitted 7
3.2 Uses Not Permitted 9
3.3 Grounding 10
3.3.1 Use as an Equipment Ground 10
3.4 Other Installation Requirements 10
3.5 Separation of Circuits 10
3.6 Additional Allowances per 392.3(B) 11
4. Special Occupancies 13
4.1 Class I Hazardous Locations 13
4.2 Class II Hazardous Locations 13
4.3 Class III Hazardous Locations 14
4.4 Intrinsically Safe Wiring 14
4.5 The Zone System of for Class I Hazardous Locations 14
4.6 Commercial Garages and Motor Fuel Dispensing Facilities 14
4.7 Aircraft Hangers 15
4.8 Bulk Storage Plants (Storage of Flammable Liquids) 15
4.9 Spray Booths 15
4.10 Health Care Facilities 15
4.11 Places of Assembly 15
4.12 Theaters, Audience Areas of Motion Picture and TV Studios, Performance Areas, and Similar Locations 15
4.13 Agricultural Buildings 16
4.14 Recreational Vehicles 16
4.15 Marinas 16
5. Ampacity and Geometric Concerns 17
5.1 Fill Factor 17
5.1.1 Cables Rated Less than 2000 V 17
5.1.2 Cables Rated More than 2000 V 18
5.2 Ampacity 18
5.2.1 Cables Rated Less than 2000 V 19

5.2.2 Cables Rated More Than 2000 V 19
6. A Brief Discussion of EMI/EMC 21
7. Summary 22

1. Introduction

This document is an analysis of Cablofil's wire mesh cable tray system in the context of power installations covered by the National Electrical Code. It covers issues generic to all types of cable tray, with consideration given to the particular requirements of Cablofil's products.

1.1 Scope

This work applies to any installation covered by the National Electrical Code. This explicitly excludes electrical installations in "ships, watercraft other than floating buildings, railway rolling stock, aircraft, or automotive vehicles other than mobile homes and recreational vehicles" [90.2(B)(1)]. There are several other exclusions in 90.2(B) as well.

The National Electrical Code (NEC) is published by NFPA (National Fire Protection Association) as NFPA 70. It is intended to protect personnel and property from the various hazards associated with electrical distribution, primarily fire and shock hazard. State and local organizations may make local variations from the code as they see fit, but otherwise, it applies to most fixed electrical installations in the United States. It is closely related to the CEC (Canadian Electrical Code), but distinct.

1.2 Definitions

A raceway is a fully-enclosed wiring system. Raceways include conduit and tubing of all types (basically, pipes). The requirement is that the wire be fully enclosed and protected. There are many types of conduit that can be used within a cable tray, as discussed in section 3.1.

Low voltage systems are systems rated less than 600 V (ac, line-to-line voltage).

Communications, control, and signal circuits are generally systems rated less than 50 V.

EGC is an abbreviation for "equipment ground conductor." Grounding is a complex subject covered by Article 250. In summary, an EGC or alternative path must be provided for ground fault current, that is, current that results from unintentionally connecting any live conductor to any metal.

Cable tray is defined as one or more units and fittings used to fasten and support cables and raceways. It is a type of mechanical support. It is not considered to be "raceway" as it does not fully enclose and protect the cables. Even solid bottom cable tray with covers is considered separate from raceway, as the construction requirements are different.

1.3 References

This work is primarily based on NFPA 70, The 2002 National Electrical Code. References in brackets refer to specific sections of the NEC.

Mark W. Earley, Joseph V. Sheehan, Jeffrey S. Sargent, John M. Caloggero, Timothy M. Croushore, *NEC 2002 Handbook*, National Fire Protection Association, Quincy, Massachusetts, 2002.

1.4 About the Author

After receiving a master's degree in electrical engineering from the University of Illinois at Urbana-Champaign (UIUC), Jonathan Kimball spent several years designing adjustable speed drives for industrial installations up to 600 Vac, 750 kVA. He recently returned to UIUC as a Research Engineer. In addition, he is the Vice President of Engineering for SmartSpark™ Energy Systems, Inc., a power electronics start-up company. He also provides consultation services for industrial power applications as the President of Kimball Power Electronics. He may be contacted at kimballpowerelectronics@att.net or jrkimball@ieee.org

2. Overview

Installation of cable tray is mainly dictated by Article 392. Section 392.3 gives broad permission to use cable tray in most types of installations. The restrictions primarily refer to cable types. It allows the use of any of a number of types of cable tray, plus "other similar structures" [392.1], clearly allowing the use of wire mesh cable tray for most installations. See also section 3.6 for a discussion of particular additional allowances. Mostly, this document will discuss limitations that apply to all types of cable tray, unless otherwise noted.

The primary restriction on the use of cable tray is "where subject to severe physical damage" [392.4]. This statement should be interpreted by qualified installers and engineers. Most other references in the Code place limits on certain cable types or raceways "where subject to physical damage." The implication is that the physical damage expected must be "severe" to restrict the use of cable tray. The author was unable to find any specific reference to a minimum height for indoor installations. In outdoor installations, there is a minimum height, but it applies equally to other wiring methods as well.

Most other restrictions are not specific to cable tray. For example, flexible cords (such as SO cord) cannot be used in fixed wiring systems, whether in cable tray or conduit. When entering or leaving classified locations, seals are necessary whether using cable or conduit.

See section 1.2 of this document or 392.2 for a definition of "cable tray." Wire mesh cable tray of any dimension, including 1"x1", satisfies the definition. Cable tray has the most flexibility of application of any type of mechanical support. For example, "open wiring on insulators" [398] requires conductors in some type of tubing, is limited to industrial or agricultural installations, and is limited to 600 V. By contrast, cable tray is allowed in any occupancy at any voltage, if the proper type of cable is used, and requires no tubing.

There are at least two specific mentions of cable tray applications. Cable tray may be used for temporary wiring in theaters and can be used to carry welding cables. In both cases, the cable tray must be marked with signage indicating its use (e.g., "CABLE TRAY FOR WELDING CABLES ONLY" per 630.42(C)).

In general, wire mesh cable tray, as produced by Cablofil, is a safe, efficient wiring method that can be used in virtually any installation. It can replace conduit and other types of raceway for the majority of applications, including hazardous locations.

3. General Occupancies

3.1 Uses Permitted

Per 392.3, cable tray shall be "permitted…for services, feeders, [and] branch circuits." Additionally, it "shall not be limited to industrial establishments." There has never been a limit restricting use in commercial installations, but such installations have only recently recognized the benefits of cable tray. In essence, virtually all installations can benefit from the use of cable tray.

Table 392.3(A) lists a number of types of cable that are specifically approved for use in cable tray. Additionally, any factory-assembled, multi-conductor cable specifically approved for use in cable tray is allowed. In general, types whose names include "tray cable" are preferred if the application allows their use. Single-conductor cables for general wiring, covered under Article 310, cannot be used except under the additional provisions of 392.3(B), even if marked "CT" for cable tray use (see section 3.6).

Most types of cable cannot be used where subject to physical damage. There is some indication that there are degrees of protection. For example, 336.10(6) implies that cable tray provides suitable protection against physical damage to allow the use of type TC cable. That is, the restriction against physical damage applies to open wiring, not to cables in cable tray. The restrictions are mentioned below for reference, as one must always consider what happens to the cable when it leaves the tray.

Where exposed to sunlight, cables must be marked as sunlight resistant.

Types of cables listed are:

- Communications, control, and signal cables. For example, cable tray can be used for networking, etc.
- Raceways may be installed in cable tray if desired. The only type of conduit not specifically mentioned is type NUCC, which is not intended for use inside buildings. Types of raceway listed are:
    - Electrical metallic tubing, EMT
    - Electrical non-metallic tubing, ENT
    - Flexible metal conduit, FMC
    - Flexible metallic tubing, FMT
    - Intermediate metal conduit, IMC
    - Liquidtight flexible metal conduit, LFMC
    - Liquidtight flexible nonmetallic conduit, LFNC
    - Rigid metal conduit, RMC
    - Rigid nonmetallic conduit, RNC

- Type AC, Armored Cable. May be used in cable tray "where identified for such use" [320.10(2)]. This implies that type AC cable is not generally allowed, but is allowed if properly marked. Armored cable has an outer flexible metal jacket intended to offer modest protection to the inner conductors; the jacket may also be used as an equipment ground, since it includes an internal bonding strip. It is available in ratings up to 600 V and sizes to 1 AWG.
- Fire alarm cables. NPLFA (non-power-limited fire alarm) cables can only be mixed with power cables if they all go to the same equipment. PLFA (power-limited fire alarm) cables must be separated from all Class 1 circuits, NPLFA circuits, and medium-power network cables by a solid barrier, even if they go to the same equipment, but may be mixed with Class 2 and 3 cables or low-power network cables [760.56].
- Type ITC, Instrumentation Tray Cable. This type is used for circuits rated less than 5 A, less than 150 V. It is designed for use in cable tray.
- Type MC, Metal Clad. This is a highly versatile cable, as will be seen in the discussion of hazardous locations. However, it cannot be used where exposed to "physical damage" [330.10(A)] or certain corrosive conditions [330.12]. Metal clad cable is available with a copper, steel or aluminum sheath and is available in ratings to 2000 V. Copper sheathed cable would be considered impervious to most corrosive conditions listed; aluminum and steel sheathed cable must be protected with an outer nonmetallic jacket. If the outer sheath is of the smooth or corrugated types (NOT interlocking tape), it may be used as equipment ground.
- Type MI, Mineral-Insulated. This type of cable is even more versatile than type MC, but also cannot be used where exposed to physical damage or corrosive conditions unless protected by a suitable nonmetallic outer jacket. It is arguably the safest type of cable for use in hazardous locations, and so there are few limitations on its use. It is available in ratings to 600 V with either a copper or alloy steel sheath. Again, copper would be considered impervious to many corrosive conditions, as would stainless steel. A copper sheath may be used as equipment ground; all other cables must include an EGC.
- Type SE, USE, Service-Entrance. There are no limitations on the use of these types of cable that pertain to cable tray. There are no comments about physical damage, but 338.10(4)(a) implies that it is subject to many of the same limitations as type NM.
- Type UF, Underground Feeder. Must be of multiconductor type. May not be used "where subject to physical damage" [340.12(10)].
- Types NM, NMC, NMS, Nonmetallic-Sheathed Cable. Must be identified for cable tray use [334.10(4)] and only installed where not subject to physical damage.

- Type TC, Tray Cable. This type of cable is intended for use in cable trays, and so there are few limitations on its use. The limitations only pertain to hazardous environments; see Section 4. Additionally, type TC can be used for any length run between the cable tray and equipment if it includes a ground conductor and is UL Listed for "open wiring." Effective March 2004, types suitable for open wiring are designated TC-ER (meaning "exposed run"). Note that previously, there was a 50 ft. limitation that has been removed in the 2002 NEC, so that there is no limit on the length of the exposed run. An exposed run must be given continuous mechanical support and protection from physical damage, and the cable must be secured every 6 ft. [336.10(6)]. Given Cablofil's product offerings, an installer may choose to use the smallest available cable tray to offer this support and protection if there is no other convenient means.
- Power limited tray cable. As with types TC and ITC, this type of cable is intended for use in cable tray. Outdoors, only type PLTC can be used. Indoors, all types of power limited tray cable may be used, such as PLTC, CL3P, CL3R, CL3, CL2P, CL2R, CL2.
- Optical fiber. All regular types of optical fiber cable can be installed in cable tray.

3.2 Uses Not Permitted

The key limitations are in 392.4. "Cable tray systems shall not be used in hoistways or where subject to severe physical damage." The limitation on hoistways is clear, but the installer or engineer is left to interpret "severe physical damage." No specific reference to a minimum height has been found for indoor installations. The limitations for outdoor installations are identical to other wiring methods. The exception is for service-entrance cables, which must be in specific types of raceway (RMC, IMC, schedule 80 RNC, EMT) [service cables, 230.50(A)] or more than 10 ft. above grade [other than service cables, 230.50(B)]. Similarly, no specific reference restricting underfloor use can be found, as long as there is suitable protection. Covers can be used in areas where "physical damage" is expected to provide some degree of additional protection.

Also in 392.4, there are limitations on installation in environmental air spaces. These limitations are not really on the cable tray, but instead are on the cable: per 300.22, types MI and MC (without outer nonmetallic sheath) can be used in ducts; other environmental air spaces can also use type AC, types MI or MC with nonmetallic sheath, or cables marked for the use. Additionally, in other than ducts, types MPP, MPR, MPG, MP, CMP, CMR, CMG, and CM can be used for communications circuits.

Per 300.8, a cable tray that contains electrical conductors may only contain electrical conductors, and no other types of utility service (water, air, steam, etc.).

The following types of cables are not permitted for any occupancy since they are not included in Table 392.3(A):

- Types FC, FCC, Flat Cable Assemblies and Flat Conductor Cable. These types are specifically designed for other types of installation.
- Type IGS, Integrated Gas Spacer Cable.
- Type MV, Medium Voltage. However, this type of cable is allowed per 392.3(B) for industrial establishments with other limitations (see below).
- Type NUCC, Nonmetallic Underground Conduit with Conductors. This is not intended for use inside buildings or above ground.

- Flexible cords, such as SO cord, and fixture wires. These types of cable are not intended for fixed wiring in any system, including conduit.

3.3 Grounding

All cable trays must be grounded [392.7(A)]. Additionally, the whole system must be bonded [392.6(A)]. This holds true whether or not the tray is being used as an equipment ground. Where two sections meet, the connection should be solidly connected by an approved means, either a bolted connection or a bolt-free connection like Cablofil's EDRN. Where there are gaps in the cable tray, the gap must be bridged by a bonding jumper. Bonding jumpers must be connected via exothermic welding or Listed fittings (lugs, pressure connectors, clamps). A single ground lead must be connected to the cable tray system. Bonding jumpers and ground leads are sized according to 250.102.

3.3.1 Use as an Equipment Ground

In order to use cable tray as an equipment ground, several requirements must be met [392.7(B)]. First, the system must be bonded, as described above. Next, the cross-sectional area of the longitudinal members must be coordinated with the circuit protection per Table 392.7(B). Additionally, supervision must ensure that only qualified personnel service the cable tray system [392.3(C)]. As with conduit, only aluminum and steel cable tray can be used as the equipment ground; stainless steel cable tray must itself be grounded and bonded, but cannot be used as the equipment ground due to its lower conductivity.

Per 392.7(B)(3), "All cable tray sections and fittings shall be legibly and durably marked to show the cross-sectional area" of the longitudinal portion of the cable tray. This ensures that the installer can coordinate with the above mentioned table and only applies when the cable tray is used as an equipment ground. Also, per 392.7(B)(1), "The cable tray sections and fittings shall be identified for grounding purposes."

3.4 Other Installation Requirements

Cable tray may pass through walls. However, see section 300.21 on maintaining fire ratings.

Cable tray may be used to support conduit bodies, outlet boxes, etc. [392.6(J)] in qualified industrial establishments. Raceway must terminate at the cable tray with a UL Listed cable tray clamp or adapter. To be a qualified establishment, the installation and maintenance must ensure that only qualified personnel service the wiring system. Many or most industrial installations would qualify. The cable tray must also be rated to support the load. If all of these conditions are not met, then the conduit etc. must be supported within 3 ft. of the cable tray.

Cable trays must be supported at intervals in accordance with the installation instructions [392.6(C)]. Cables must also be supported to prevent stress where they enter or leave the cable tray. The cable tray system may be mechanically discontinuous, but the gaps may not exceed 6 ft. [392.6(A)].

3.5 Separation of Circuits

One must consider separation of cables. Per 392.6(E), there is no general requirement on separating cables that are all rated 600 V or less, but there are exceptions for certain types of circuits.

- Per 725.55(H), Class 2 and Class 3 circuits must be separated from lighting, power, Class 1, non-power-limited fire alarm, and medium power network-powered communications circuits by a solid barrier, of a material compatible with the cable tray.
- When mixing Class 1 circuits and power circuits, one or the other must be some metal clad type (MI, MC, AC), or else there must be a solid barrier between them [725.26(B)(4)].
- There are other limitations on fire alarm cables and in some health care facilities; see sections 3.1 and 4.9, respectively, for more details.
- If some of the cables are rated greater than 600 V (medium voltage), then the medium voltage cables must be of type MC and must be separated from low voltage cables [392.6(F)].
- Intrinsically safe systems must not occupy the same cable tray as other circuits, or else must be separated by 2 in. or a solid metal barrier. Otherwise, either the intrinsically safe system or all of the other cables in the tray must be of a metal-clad type capable of being an EGC (such as Armored Cable, Type AC) [504.30(A)(2)]. The cable tray must then be marked, "Intrinsic Safety Wiring," by signage spaced not more than 25 ft. and visible and traceable along the length of the tray.

Unrelated to voltage separation, cables of certain types must be spaced in order to maintain ampacity. See section 5.2 for details.

3.6 Additional Allowances per 392.3(B)

There are additional installations allowable under 392.3(B) for qualified industrial establishments and in "ladder, ventilated trough, solid bottom, or ventilated channel cable trays." A note in the *NEC 2002 Handbook* is contradictory, and actually applies to the 1999 NEC, which excluded solid bottom cable tray. One may argue that wire mesh cable tray is equivalent, or superior, to ladder cable tray from both structural support and cable protection perspectives. There is some indication, when reading all of the notes in the *Handbook*, that the list of cable tray types is intended to be inclusive, not exclusive.

These additional allowances apply to "industrial establishments only, where conditions of maintenance and supervision ensure that only qualified persons service the installed cable tray system." This specifically excludes commercial and residential installations, but would include many or most industrial installations. Note that commercial and residential installations are only excluded from these allowances, but may instead use any of the cable types listed in Section 3.1. For allowed industrial installations, one may use:

- Single conductors, 1/0 AWG or larger. They must be marked for use in cable trays, but otherwise all commonly used conductors for general wiring (Article 310) are appropriate. Most cables of this size are approved for cable tray use (usually abbreviated "CT"), but certifications vary from manufacturer to manufacturer. Single conductors used as an EGC may be insulated or bare and "shall be 4 AWG or larger" [392.3(B)(1)(c)]. Three-phase circuits should be installed as bunched three-phase groups, with one wire per phase in paralleled systems [392.8(D)]. Such an installation is good engineering practice and ensures equal reactance on each phase, minimizing line imbalance.
- Medium voltage cable, type MV, whether single- or multiconductor. As above, when mixed with low voltage cable (anything less than 600 V), only type MC is allowed for voltages above 600 V.

- Single conductors, welding cable. Per 630.42(C), the cable tray must be marked with signs reading, “CABLE TRAY FOR WELDING CABLES ONLY,” spaced not more than 20 ft. Cables must be supported every 6 in.

4. Special Occupancies

The most important special occupancies to consider are hazardous locations. However, there are also limitations for other types of occupancies as well, such as health care facilities. For hazardous locations, the two considerations are types of cable to use and types of seals required. Refer to the appropriate sections of the NEC for more details on how to seal the cable.

There are two systems for classifying hazardous locations. The older system uses Class I through Class III, each separated into Division 1 and Division 2. The newer system uses Zones 0 through 2 for Class I locations rather than Divisions. Cable tray of any type can be used in any classified location, so long as the proper type of cable is used. Class I refers to the presence of flammable gases or vapors. Class II refers to the presence of combustible dust. Class III refers to the presence of combustible fibers or flyings.

Certain types of facilities place special limits on areas physically located above classified areas. This allows for the fact that vapors may escape and rise.

4.1 Class I Hazardous Locations

Class I Division 1 locations must use MI (Mineral Insulated), MC-HL (a type of Metal Clad), or ITC-HL (a type of Instrumentation Tray Cable) cable with appropriate fittings [501.4(A)(1)(b-d)]. MC-HL and ITC-HL cable must be marked for use in Class I locations and are only allowed if the installation is only serviced by qualified personnel. Class I Div 1 is an area where flammable gases exist under normal conditions, may exist frequently because of repair or maintenance operations or because of leakage, or faulty operation of equipment may simultaneously result in ignitable concentrations of flammable gases and electrical equipment malfunction that would ignite the gases [500.5(B)(1)].

Class I Division 2 locations may use any of the above wiring methods, as well as PLTC (Power Limited Tray Cable), ITC (Instrumentation Tray Cable), MC (Metal Clad), MV (MediumVoltage), and TC (Tray Cable) cable types [501.4(B)(1)(4-6)]. Additionally, nonincendive field wiring of any wiring method allowed in unclassified locations is also allowed in Class 1 Div 2. Nonincendive field wiring is affiliated with a circuit that is incapable of igniting the vapor that may be present; see Article 100 for a full definition and test conditions. Class I Div 2 is an area where flammable vapors are normally contained but may be released due to breakdown of containers or ventilation failures (including areas adjacent to Class I Div 1 areas) [500.5(B)(2)].

Flexible cords are also allowed [501.11]. They must be listed for extra-hard usage, must contain a ground conductor, must be supported to remove tension from any terminals, and protected from damage. Seals are also necessary where they enter explosion-proof enclosures.

Everywhere seals are necessary for conduit, seals are also necessary for cable. The above listed cables are gas-tight, but may transmit vapors to unclassified locations if not properly sealed.

4.2 Class II Hazardous Locations

Class II Division 1 locations must use MI (Mineral Insulated) or MC (Metal Clad, must be marked for the use) cable types with appropriate fittings [502.4(A)(1)(b-d)]. Class II Div 1 is defined as a location where combustible dusts are in the air normally, or where mechanical failure may cause the simultaneous presence of combustible dust and an electrical spark source, or where combustible dusts of an electrically conductive nature are present [500.5(C)(1)].

Class II Division 2 locations may also use PLTC (Power Limited Tray Cable) or ITC (Instrumentation Tray Cable) cable types. There must be spaces between the cables equal to the cable diameter [502.4(B)(1)(6)]. Nonincendive field wiring of any wiring method acceptable in unclassified areas is also allowed. Class II Div 2 is an area where combustible dust is not normally present but may be present infrequently, or where combustible dust accumulation may interfere with the normal cooling of electrical equipment [500.5(C)(2)].

Flexible cords may be used under conditions similar to Class I locations [502.12]. Flexible cord must be approved for extra-hard usage, except for pendant luminaries (fixtures), which only require cord for hard usage. The cord shall not be used to support the fixture.

As with conduit, seals are necessary when entering or leaving Class II locations.

4.3 Class III Hazardous Locations

Class III refers to the presence of easily ignitable fibers or flyings; Division 1 is where they are manufactured or handled, Division 2 is where they are stored [500.5(D)]. Class III Div 1 and Div 2 locations may use MC (Metal Clad) or MI (Mineral Insulated) cable types. No seals are required.

Flexible cords may be used under conditions similar to Class I locations [503.10]. Seals are not required, but there must be means to prevent the entrance of fibers or flyings into equipment.

4.4 Intrinsically Safe Wiring

Intrinsically safe wiring is a system. Cable tray is not excluded, nor are any particular cable types. The emphasis is on the complete system, including adequate bonding of the cable tray and appropriate apparatus to ensure energy limitation. It depends underneath on intrinsically safe apparatus. Then the wiring methods may be of any type suitable for general occupancies. Intrinsically safe wiring must be in its own cable tray, or separated from other circuits by at least 2 in. or a grounded metal partition, or the intrinsically safe wiring must be in a metal sheathed cable where the sheath is capable of carrying ground fault currents (such as Type AC, Armored Cable). The cable tray must be marked, “Intrinsic Safety Wiring,” at intervals not greater than 25’ [504.80(B)].

4.5 The Zone System of for Class I Hazardous Locations

Zone 0 requires intrinsically safe wiring methods. See above. Seals are required entering or leaving Zone 0. Zone 0 is an area where flammable vapors are present normally or for long periods of time [505.5(B)(1)].

Zone 1 may use MI cable, or where serviced by qualified personnel, types MC-HL or ITC-HL. The latter types must be marked for the use. Seals are required entering or leaving Zone 1. Zone 1 approximates Division 1, and includes areas adjacent to Zone 0 areas unless proper ventilation and positive pressure prevent communication of flammable gases [505.5(B)(2)].

Zone 2 may use MI, MC, MV, TC, ITC, or PLTC cable. Seals are required entering or leaving Zone 2. Zone 2 approximates Division 2, and includes areas where flammable gases may occur under normal conditions but only for short periods of time [505.5(B)(3)].

Flexible cords are allowed under conditions similar to the Division classifications [505.17].

4.6 Commercial Garages and Motor Fuel Dispensing Facilities

Class I areas follow standard rules, and are pre-defined by 511.3(B). Areas physically above Class I locations are also restricted: only types MC, MI, PLTC, TC, and ITC cable are allowed.

4.7 Aircraft Hangers

Parts of aircraft hangers are Class I, as determined in the standard way or according to 513.3. Other areas, even if not Class I, may only use types MI, TC, and MC cable unless the area is cut-off and ventilated from the remainder of the hanger.

4.8 Bulk Storage Plants (Storage of Flammable Liquids)

Above Class I locations, only types MI, TC, and MC can be used. Table 515.3 defines certain Class I locations and specifies their Division or Zone.

4.9 Spray Booths

In the actual spray area, only type MI cable may be used. Other areas follow hazardous location classifications. Above Class I and II locations, only types MI, TC, and MC may be used. In 516.3, certain locations are classified.

4.10 Health Care Facilities

There are a number of special requirements for health care facilities, but most apply to life safety and critical branch circuits. There is a blanket acceptability of cable tray, with exceptions. Also, if circuits cannot share a raceway, they cannot share a cable tray.

Per 517.13(A), in patient care areas, each cable must have an outer ground sheath in addition to an inner copper ground conductor. This limits cables to types AC (Armored Cable), MC (Metal Clad), and MI (Mineral Insulated). Even where otherwise acceptable, the outer sheath cannot be used as an equipment ground.

Per 517.30(C), life safety and critical branch circuits must be run separate from normal circuits. These circuits must use type MI cable if not in raceway.

Per 517.61, special requirements apply to areas around anesthetizing areas. Above anesthetizing areas considered hazardous locations, types MI or MC must be used, and must include a gas-tight sheath. Above non-hazardous anesthetizing locations, type MI or MC must be used, and its outer sheath must be identified as usable for an EGC.

4.11 Places of Assembly

In general, fixed wiring requires types MI, MC, or AC (with a ground conductor). Type NM (Nonmetallic Sheathed) may be used in areas where building codes do not require fire ratings.

Per 518.3(B), flexible cords may be used in temporary cable tray with appropriate signage. There must be a sign reading, “CABLE TRAY FOR TEMPORARY WIRING ONLY,” spaced not more than 25 ft.

4.12 Theaters, Audience Areas of Motion Picture and TV Studios, Performance Areas, and Similar Locations

As with places of assembly, fixed wiring must be of type MI, MC, or AC (with a ground conductor), or type NM as building codes allow. Footlights must be wired with type MC.

4.13 Agricultural Buildings

Agricultural installations require types UF (Underground Feeder), NMC (a type of Nonmetallic Sheathed), SE (Service Entrance), or MC cable. Many agricultural locations are corrosive, and so type MC cable must be marked for such use.

4.14 Recreational Vehicles

RVs cannot use cable tray.

4.15 Marinas

In general, there are no restrictions on cable tray use in marinas. However, above piers and landing decks, rigid conduit (types RMC and RNC only) must be used for protection. This a case of a location pre-defined to be subject to physical damage. It is allowable to place RMC and RNC into cable tray, if so desired.

5. Ampacity and Geometric Concerns

There are two things to consider when detailing a wiring system: the fill factor of the cable tray or raceway and the size of the conductor. The following attempts to cover all situations. Fill factor is complicated for cable tray, depending on the size and type of cable used. Ampacity mostly depends on finding the right table and any derate factor necessary.

5.1 Fill Factor

See Figure 1 for easy reference.

5.1.1 Cables Rated Less than 2000 V

Multiconductor cables 4/0 AWG or larger must be installed in a single layer. Single conductor cables rated 1/0 AWG or larger must also be installed in a single layer or in circuit bunches (e.g. triplexed in a triangular fashion for three-phase circuits).

Where all cables are multiconductor of 4/0 AWG or larger or single conductor 1/0 AWG through 4/0 AWG, the cable tray must be at least as wide as the sum of the diameters of all cables.

If all cables are multiconductor smaller than 4/0 AWG, the available fill area is found in Column 1 of Table 392.9. If there is a mix of multiconductor smaller and larger than 4/0, those larger must be installed in a single layer, and the remaining fill area is found in Column 2 of Table 392.9.

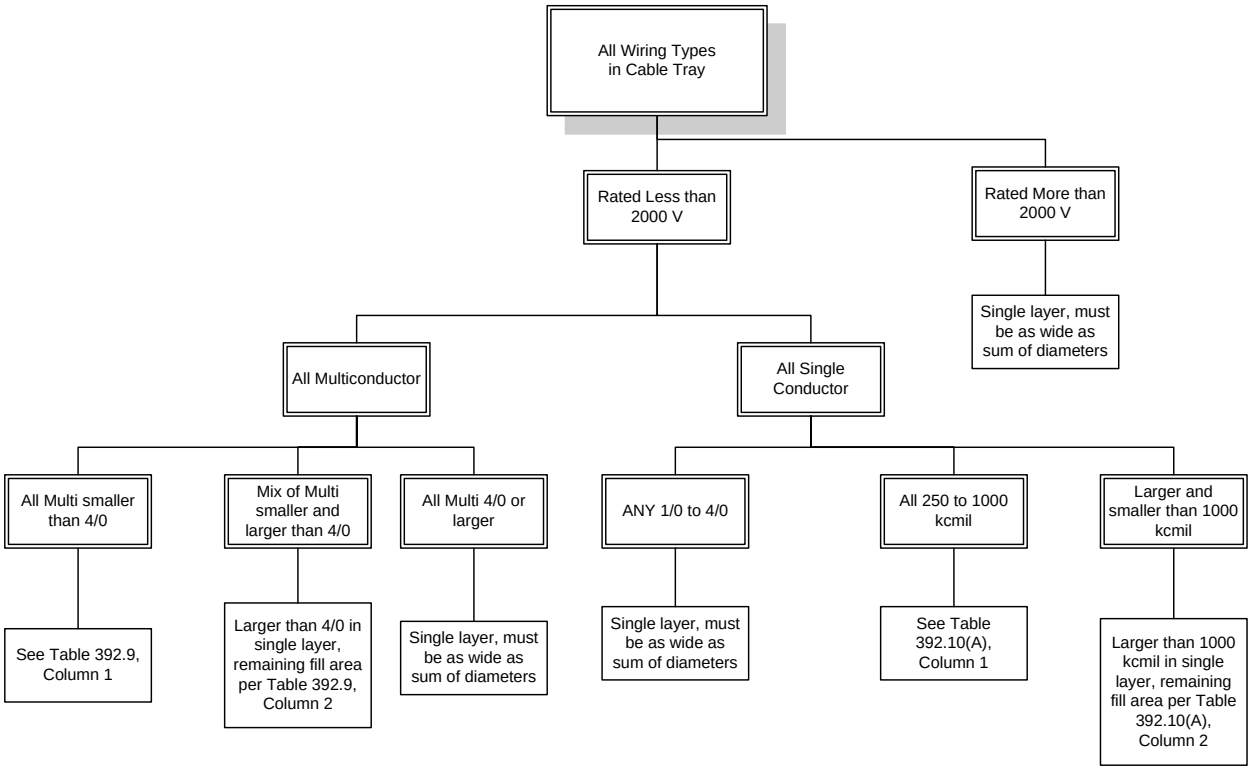

Figure 1: Fill Area Determination

If all cables are single conductor 250 kcmil to 1000 kcmil, the available fill area is found in Column 1 of Table 392.10(A). If single conductors larger and smaller than 1000 kcmil are mixed, those larger must be installed in a single layer or circuit bunches, and the remaining fill area is found in Column 2 of Table 392.10(A).

5.1.2 Cables Rated More than 2000 V

All cables rated more than 2000 V must be installed in a single layer or in bunches per circuit. The cable tray must be as wide as the sum of all cable diameters, even if installed in circuit bunches.

5.2 Ampacity

Figures are provided for easy reference. The derate of 310.15(B)(2) (more than three conductors in a raceway or cable) applies only to multiconductor cables of more than three conductors. It does not apply to single conductor cables in cable tray, nor does it refer to the total number of cables in the cable tray. Therefore, the ampacity of multiple three-conductor cables in a single cable tray (with no derate) will be significantly higher than 6, 9, 12, or more single-conductor cables or multiple three-conductor cables in a single raceway (with significant derate).

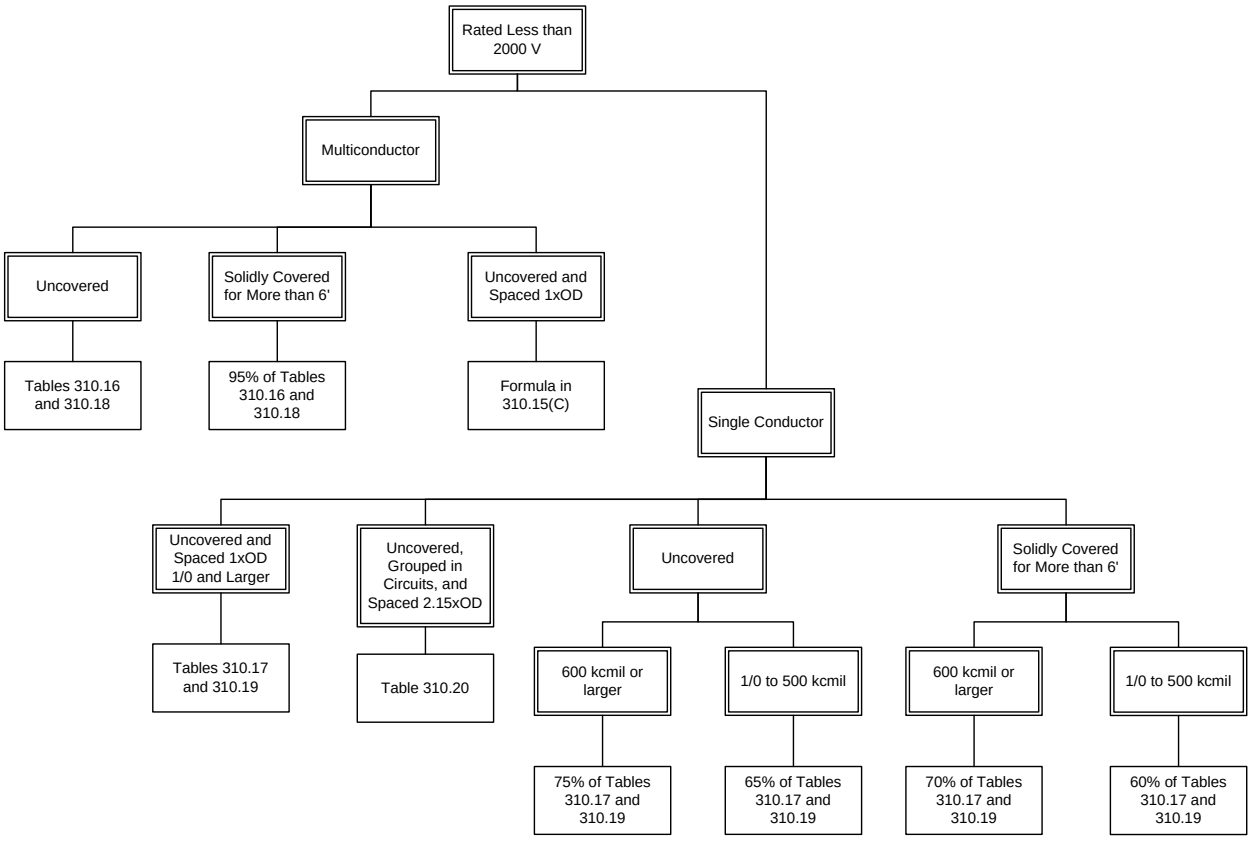

Figure 2: Ampacity, Cables Rated Less than 2000 V

5.2.1 Cables Rated Less than 2000 V

See Figure 2. Multiconductor cable ratings are found in Tables 310.16 and 310.18, the same tables that are used for raceway (conduit). If the cable tray is covered with a solid, unventilated cover for more than 6 ft., ampacity is 95% of that found in Tables 310.16 and 310.18. If the cables are spaced so that there is one cable diameter between each cable, then ampacities are calculated as if the cables were in free air, according to the formula in 310.15(C) (with engineering supervision).

Single conductors 600 kcmil or larger uncovered are rated to 75% of Tables 310.17 and 310.19; when covered by 6 ft. of solid covers, ampacity is only 70% of Tables 310.17 and 310.19. Conductors from 1/0 AWG to 500 kcmil are rated to 65% of Tables 310.17 and 310.19 if uncovered, 60% if covered for 6 ft. or more. Conductors 1/0 AWG or larger with one cable diameter space between are rated to 100% of Tables 310.17 and 310.19. Conductors grouped into circuits with 2.15 times the cable diameter space between bunches are rated according to Table 310.20.

5.2.2 Cables Rated More Than 2000 V

See Figure 3. Multiconductor cable is normally rated to Tables 310.75 and 310.76. When covered for more than 6 ft. with solid covers, ampacity is reduced to 95% of Tables 310.75 and 310.76. With one cable diameter space between cables, Tables 310.71 and 310.72 apply.

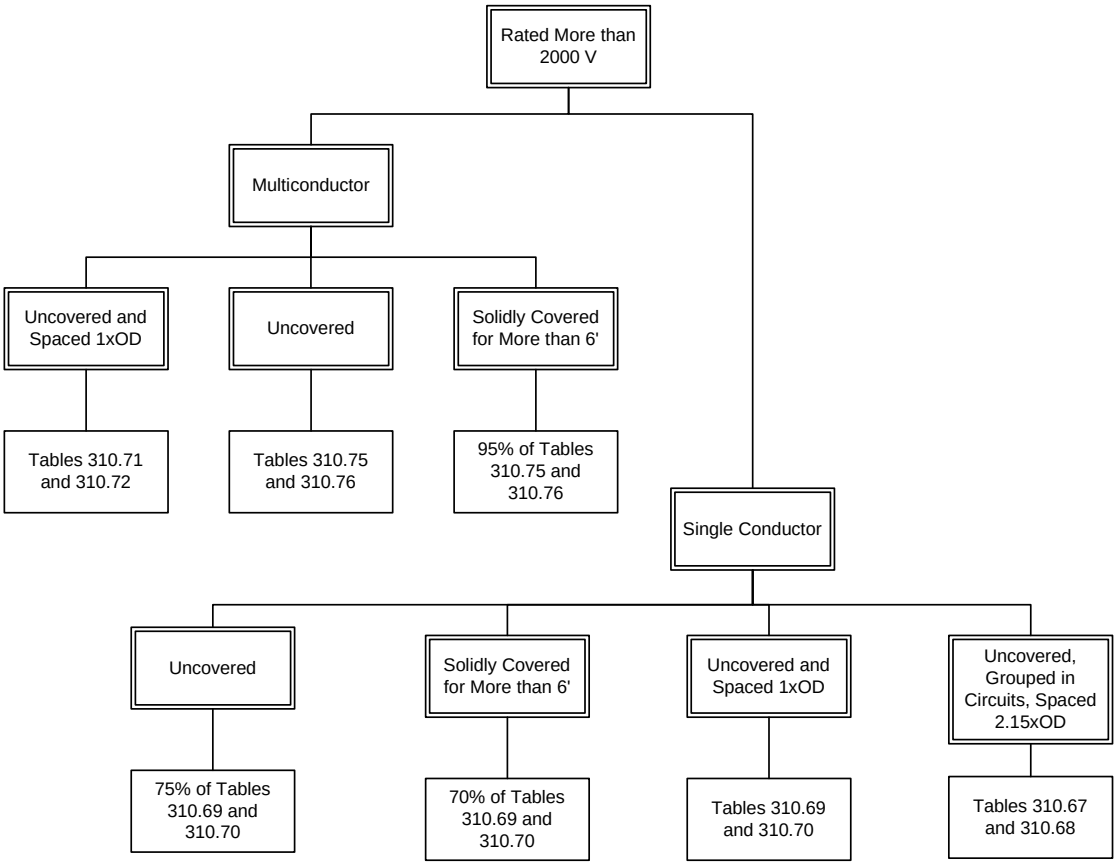

Figure 3: Ampacity, Cables Rated More than 2000 V

Single conductor cable is rated to 75% of Tables 310.69 and 310.70. When covered for more than 6 ft. with solid covers, ampacity is reduced to 70% of Tables 310.69 and 310.70. With spaces equal to cable diameter, ampacity is increased to 100% of Tables 310.69 and 310.70. When grouped into circuits and spaced 2.15 times the cable diameter, ampacity is 100% of Tables 310.67 and 310.68.

6. A Brief Discussion of EMI/EMC

When comparing raceway (conduit) installations to cable tray installations, one must consider EMI, electromagnetic interference (the negative consequences of noise), or EMC, electromagnetic compatibility (a positive aspect of wiring and equipment that minimizes EMI). This is not covered in the National Electric Code, and must instead be based on engineering judgment and experience. The subject has already been investigated thoroughly for communications, control, and signal cables in close proximity to each other. Essentially, so long as all of the cables are quality shielded types, there are no significant concerns.

Power cables are a different story. The energy available is much greater in some cases, and shielding is the exception rather than the norm. Several options are available to the engineer/installer to protect communications, control, and signal cables from interference.

1. Separate power cables from communications, control, and signal cables. Install covers and/or separators to maximize the amount of metal between the transmitter (power) and receiver (signal) cables. This is necessary per Code (see Section 3.4), but extending beyond the minimum requirements may be necessary for EMI/EMC reasons.
2. Use raceway within the cable tray. In some installations, this may only be necessary over short runs, making it an attractive alternative. EMI mostly affects cables that run parallel, not perpendicular.
3. Use shielded power cables. Shielding must be a solid (or substantially solid, including fine woven mesh) metal layer surrounding all of the conductors of a given cable. Types MC, MI, and AC would qualify, particularly type MC with a copper sheath (CS). There are also other types of cable specifically designed for e.g. motor drive applications. These cables include several ground paths and an outer grounded shield. They are generally considered superior to single conductors in conduit due to the extra ground paths inside a shield and close conductor spacing.

The author's experience with EMC testing indicates that the best solution for strong radiators is a copper sheath. Copper was found to offer 10 dB greater shielding than steel in a particular application (the connection between an adjustable speed drive and the load motor). That study would indicate that even RMC does not offer the best solution for some situations.

A cable tray system that is grounded as required offers a good deal of EMI protection. However, best practice to minimize EMI is to include a separate EGC in each cable. This provides a path for the ground current inherent to high-frequency devices (adjustable speed drives, some types of lighting, welders and other similar devices). In these situations, it is undesirable to have parallel ground paths. Instead, only the EGC should be tied to the chassis of the equipment, and the cable tray should be separately grounded. Then, the EGC serves as the main ground current conductor and the cable tray acts as a modest shield.

7. Summary

Wire mesh cable tray is a highly versatile wiring support system. A review of section 4 will show that it can be used in virtually any occupancy (except RVs), including hazardous locations. Any voltage from communications cabling up to medium voltage (greater than 2000 V) is allowable.

The installer or engineer is simply left to determine what type of cable to use. Many options are available, as summarized in section 3.1. In certain installations, such as hazardous locations or environmental air spaces, there are limitations on what type may be used. In many cases, the advantages of cable tray will outweigh the added cost of special cable.

Grounding remains a confusing issue to many installers, engineers, and inspectors when confronting cable tray. The requirement is to ground and bond the entire system.

Cable ampacity can be greater in cable tray, particularly when compared to conduit containing many (more than three) conductors. In certain installations, material cost will be reduced for a cable tray system due to greater fill factor and greater ampacity.

Some designers will have concerns about EMI when considering a switch from conduit. These concerns are valid, but there are many options available to achieve equal or greater noise immunity. A little creativity in system design can mitigate the cost impact of these decisions—for example, moving the cable tray to a different location to achieve greater separation.

Taken as a whole, Cablofil's wire mesh cable tray is an attractive option to consider for both new and retrofit electrical installations of any type.