Cable Tray
26207-05

City of Phoenix Fire Station No. 50
Phoenix, Arizona
Commercial $2–5 Million Award Winner
FCI Constructors, Inc.

26207-05
Cable Tray

Topics to be presented in this module include:

Overview

Electricians who regularly work on commercial and industrial installations projects may not only be called upon to install conduit systems, but may also find themselves installing elevated or suspended cable trays to support cables or conductors, especially in industrial locations.

Cable tray systems can be accessorized with fittings that either snap or bolt into place to provide tees, wyes, crosses, reducers, barriers, covers, and even box connectors. Cable tray installations, like any raceway system, are regulated by the *National Electrical Code*®.

The support of cable tray is an important consideration and is determined by the number and size of conductors or cables to be installed in the tray. If the support is not adequate for the load at various stress points, overloading can cause rung and/or rail failure. To prevent these failures, load stress points must always be identified before making any splices in straight cable tray sections. Methods used to hang and support cable tray assembles include trapeze, direct rod, and wall mounting.

Objectives

When you have completed this module, you will be able to do the following:

1. Describe the components that make up a cable tray assembly.
2. Explain the methods used to hang and secure cable tray.
3. Describe how cable enters and exits cable tray.
4. Select the proper cable tray fitting for the situation.
5. Explain the NEMA standards for cable tray installations.
6. Explain the *NEC*® requirements for cable tray installations.
7. Select the required fittings to ensure equipment grounding continuity in cable tray systems.
8. Interpret electrical working drawings showing cable tray fittings.
9. Size cable tray for the number and type of conductors contained in the system.
10. Select rollers and sheaves for pulling cable in specific cable tray situations.
11. Designate the required locations of rollers and sheaves for a specific cable pull.

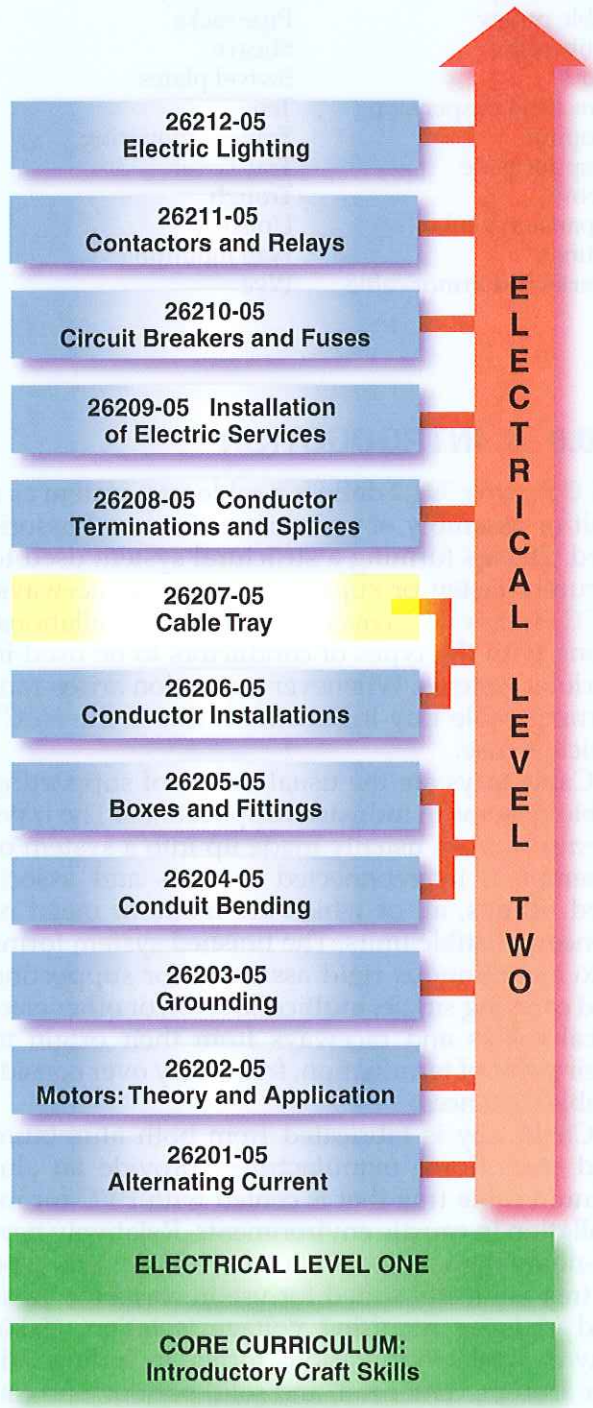
Required Trainee Materials

1. Paper and pencil
2. Appropriate personal protective equipment
3. Copy of the latest edition of the *National Electrical Code*®

Prerequisites

Before you begin this module, it is recommended that you successfully complete *Core Curriculum; Electrical Level One;* and *Electrical Level Two,* Modules 26201-05 through 26205-05.

This course map shows all of the modules in *Electrical Level Two.* The suggested training order begins at the bottom and proceeds up. Skill levels increase as you advance on the course map. The local Training Program Sponsor may adjust the training order.



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Trade Terms

Barrier strip	Ladder tray
Cable pulley	Pipe racks
Cable roller	Sheave
Cross	Swivel plates
Direct rod suspension	Tee
Dropout	Trapeze mounting
Dropout plate	Tray cover
Elbow	Trough
Expansion joints	Unistrut®
Fittings	Wall mounting
Interlocked armor cable	Wye

1.0.0 ◆ INTRODUCTION

NEC Section 392.2 defines a cable tray system as a unit or assembly of units or sections and associated **fittings** forming a structural system used to securely fasten or support cables and raceways. *NEC Article 392* covers cable tray installations, along with the types of conductors to be used in various systems. Whenever a question arises concerning cable tray installations, this is the *NEC®* article to use.

Cable trays are the usual means of supporting cable systems in industrial applications. The trays themselves are usually made up into a system of assembled, interconnected sections and associated fittings, all of which are made of metal or noncombustible units. The finished system forms into a continuous rigid assembly for supporting and carrying single, multiconductor, or other electrical cables and raceways from their origin to their point of termination, frequently over considerable distances.

Cable tray is fabricated from both aluminum and steel. Some manufacturers provide an aluminum cable tray that is coated with PVC for installation in caustic environments. Relatively new all-nonmetallic trays are also available; this type of tray is ideally suited for use in corrosive areas and in areas requiring voltage isolation. Cable tray is available in various forms, including ladder, **trough,** center rail, and solid bottom, and can be supported by either side mounts or center mounts.

Ladder tray, as the name implies, consists of two parallel channels connected by rungs, similar in appearance to a conventional straight or extension ladder. Trough types consist of two parallel channels (side rails) having a corrugated, ventilated bottom. The solid bottom cable tray is similar to the trough. All of these types are shown in *Figure 1*. Ladder, trough, and solid bottom trays are completely interchangeable; that is, all three types can be used in the same run when needed.

Cable tray is manufactured in 12' and 24' lengths. Common widths range from 6" to 36". All sizes are provided in either 3", 4", 5", or 6" depths.

Cable tray sections are interconnected with various types of fittings. Fittings are also used to provide a means of changing the direction or dimension of the cable tray system. Some of the more common fittings include:

- Horizontal and vertical **tees**
- **Wyes**
- Horizontal and vertical bends
- Horizontal **crosses**
- Reducers
- **Barrier strips**
- Covers
- Splice plates
- Box connectors

The area of a cable tray cross section that is usable for cables is defined by width (W) × depth (D), as shown in *Figure 2*. The overall dimensions of a cable tray, however, are greater than W times D because of the side flanges and seams. Therefore, overall dimensions vary according to the tray design. Cables rest on the bottom of the tray and are held within the tray area by two longitudinal side rails, as shown in *Figure 3*.

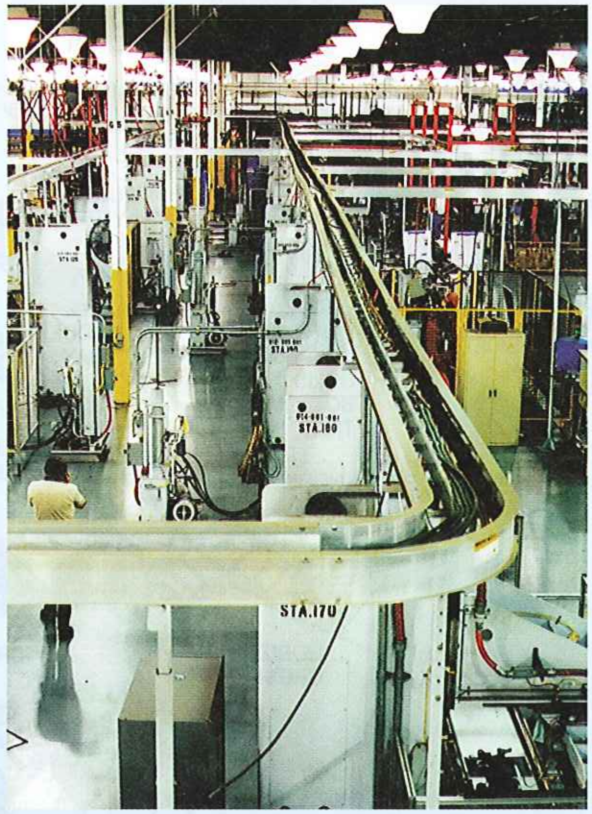
A channel is used to carry one or more cables from the main tray system to the vicinity of the cable termination (see *Figure 4*). Conduit is then used to finish the run from the channel to the actual termination.

Certain *NEC®* regulations and National Electrical Manufacturers Association (NEMA) standards should be followed when designing or installing cable tray. Consequently, practically all projects of any great size will have detailed drawings and specifications for the workers to follow. Shop drawings may also be provided.

INSIDE TRACK

Cable Tray Installation

Cable trays are widely used in many commercial and industrial installations.



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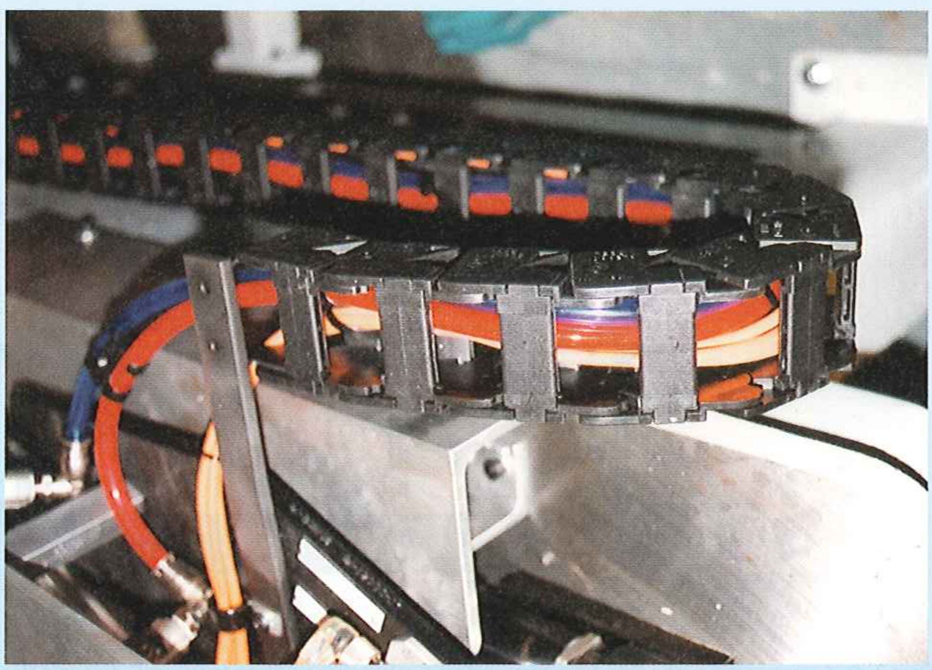
Special-Application Cable Tray

This lightweight, flexible nonmetallic cable tray is used to route wiring to the large motors in a manufacturing facility.



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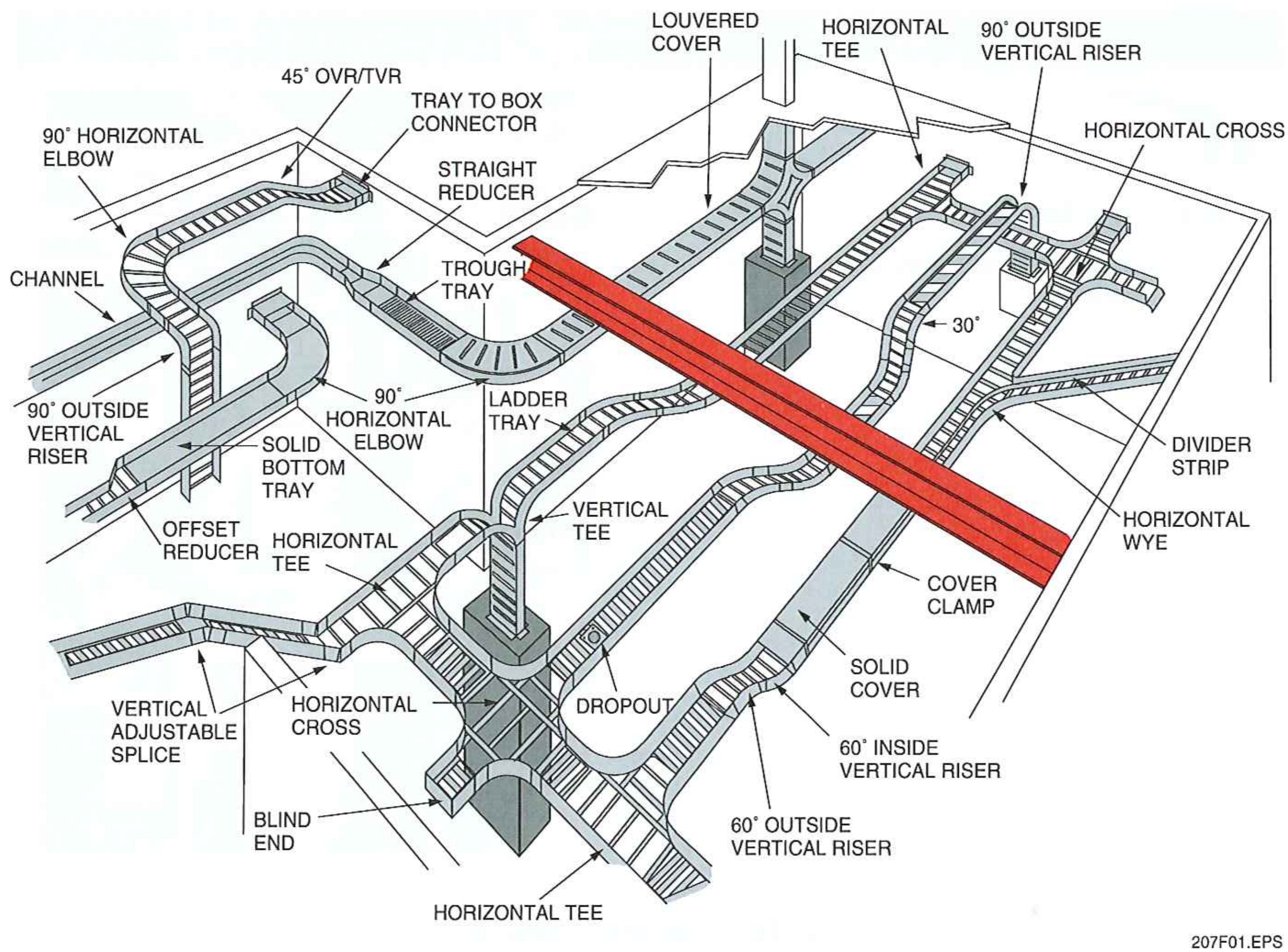


Figure 1 ◆ Typical cable tray system.

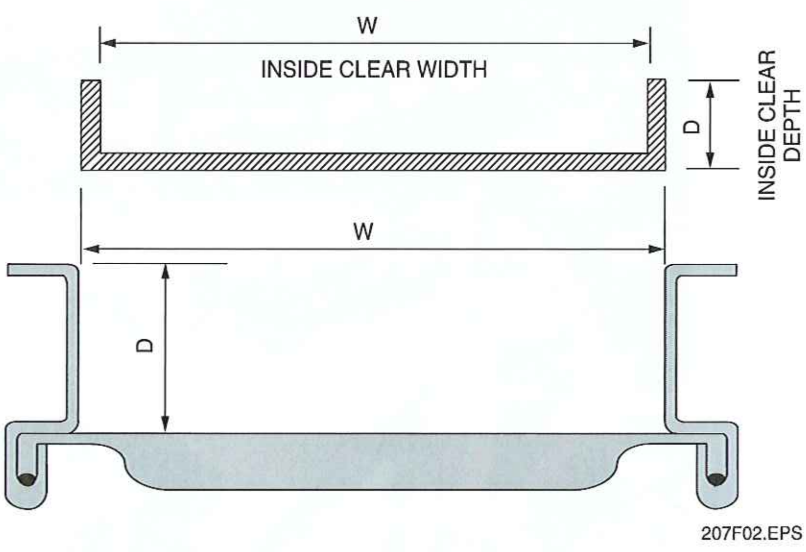


Figure 2 ◆ Cross section of cable tray comparing usable dimensions to overall dimensions.

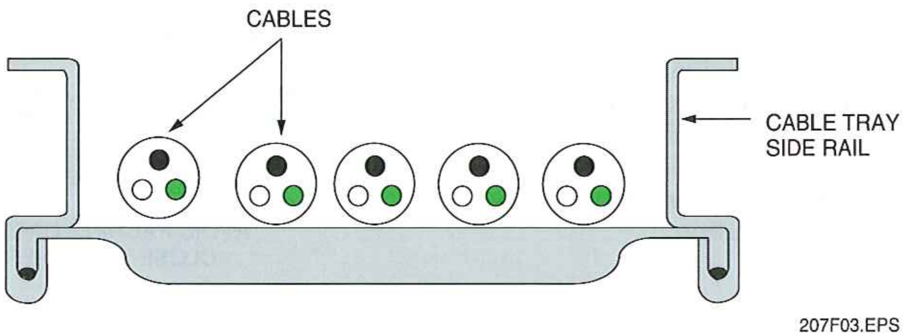


Figure 3 ◆ Cables rest on the bottom of the tray and are held in place by the longitudinal side rails.

INSIDE TRACK

Ladder Tray

Ladder tray is used for about three-fourths of today's installations. It offers numerous advantages:

- Ladder tray has greater air circulation than other trays, which helps to dissipate heat.
- The ladder rungs are convenient for tying down conductors.
- Ladder tray does not collect moisture.
- Conductors can be dropped through the bottom of the tray at any point.

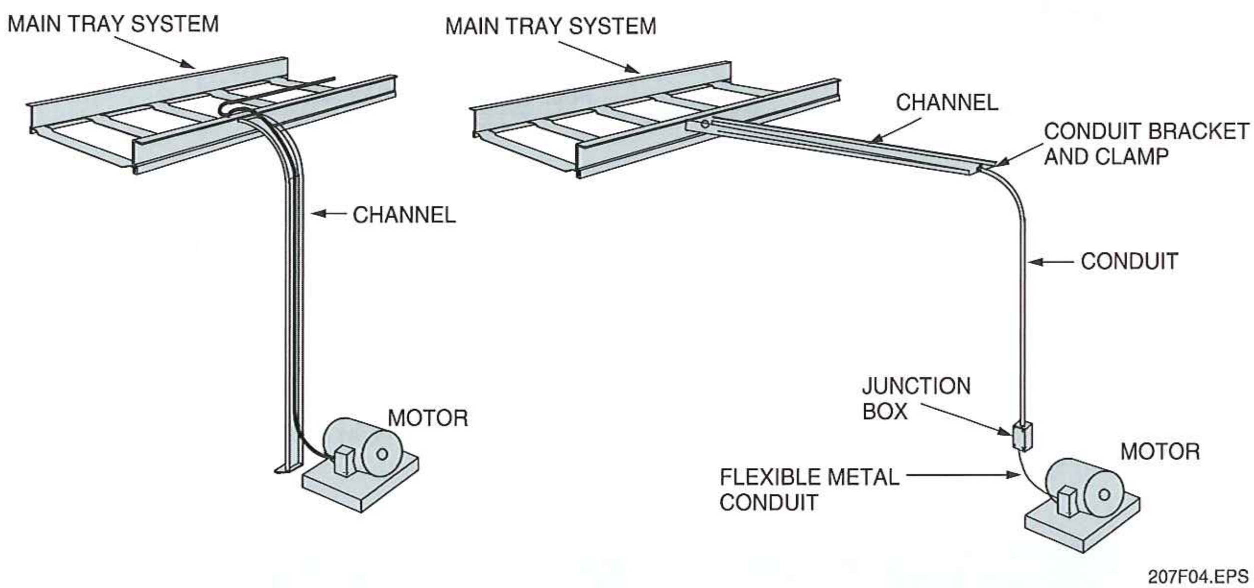


Figure 4 ◆ Two applications of cable tray channel.

2.0.0 ◆ NEMA STANDARDS

NEMA is a nonprofit organization supported by the manufacturers of electrical equipment and supplies. NEMA develops standards that are used when purchasing and installing electrical equipment. These standards help to ensure that the product will match the application.

2.1.0 Load Factors

The load capacity of cable tray varies with each manufacturer and depends on the shape and thickness of the side rails, the shape and thickness of the bottom members, spacing of rungs (if any), material used, safety factor used, method used to determine the allowable load, method of supporting the tray, and volume capacity. Consequently, each manufacturer publishes load data.

2.2.0 Determining Fill

The density of fill can only be determined by personnel laying out the system. In doing so, however, be aware that cables packed closely together can impair each other's efficiency (see *Figure 5*).

2.3.0 Determining the Load on Supports

Each support should be capable of safely supporting approximately 1.25 times the full weight of the cable and tray on a typical span, as shown in *Figure 6*.

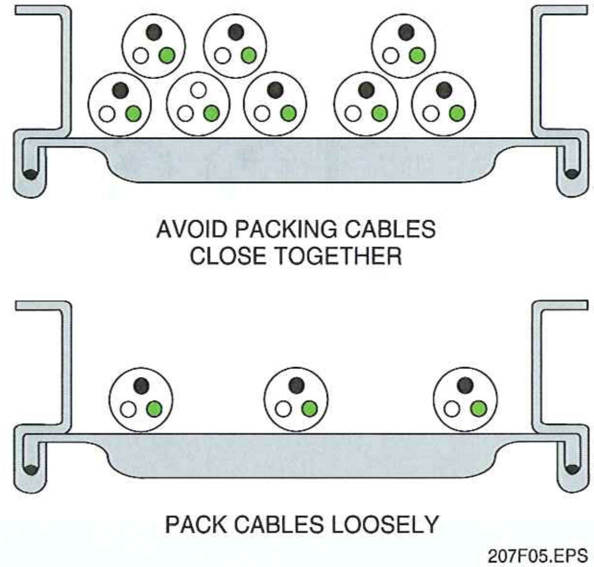


Figure 5 ◆ Cables packed closely together can impair efficiency.

2.4.0 Deflection Under Load

Consider the case of a cable tray spanning only two supports (simple span). As the tray is loaded, the side rails take the deflected form. Simultaneously, in cross section, the side rails rotate inward or outward and the tray bottom deflects. The amount of inward or outward movement of the side rails is a critical factor in the ability of the tray to carry a load.

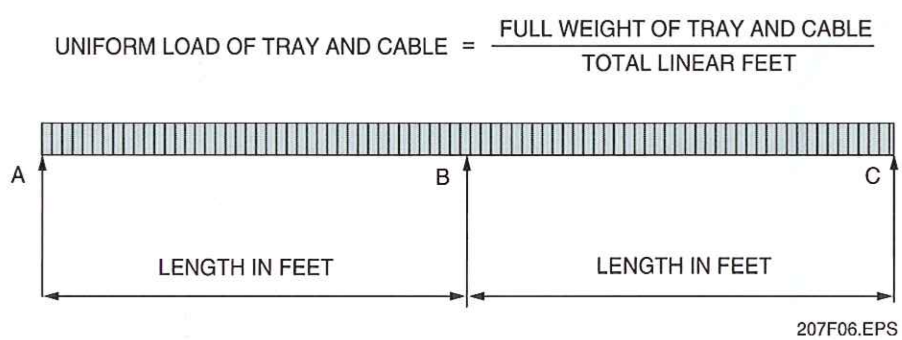


Figure 6 ◆ Each tray support should be capable of safely supporting 1.25 times the weight of the entire tray and cable assembly span.

THINK ABOUT IT

Cable Fill

In what way can cables installed too closely together impair each other's efficiency?

2.5.0 Failure Under Load

There are two types of failures that can occur with a loaded cable tray. These are longitudinal (side rail) failures and transverse (rung) failures. Transverse (rung) failures occur when the load applied causes the fibers on the tension side (bottom edge) of the rung to stretch and permanently deform. Simultaneously, fibers on the compression side (top edge) are permanently crushed. Longitudinal (side rail) failures occur either as bending failures when the tray is supported on a larger span, or, on longer spans, buckling failures may occur because the side rails of the tray have little resistance to inward or outward movement. As the tray deflects, the side rails rotate and the top (compression) flanges of the tray buckle. Bending failures occur on short spans because the side rails of the tray have greater resistance to rotation and remain reasonably upright. The tray does not fail until the load is such that it causes the fibers on the tension side (bottom edge) of the side rail to stretch and permanently deform. Simultaneously, fibers on the compression side (top edge) are permanently crushed. For any tray on an intermediate span, it is difficult to anticipate whether a bending or buckling failure would occur (see *Figure 7*).

2.6.0 Splicing Straight Sections

In *Figure 8*, the load on the cable tray creates bending moments along the spans. The stress in the

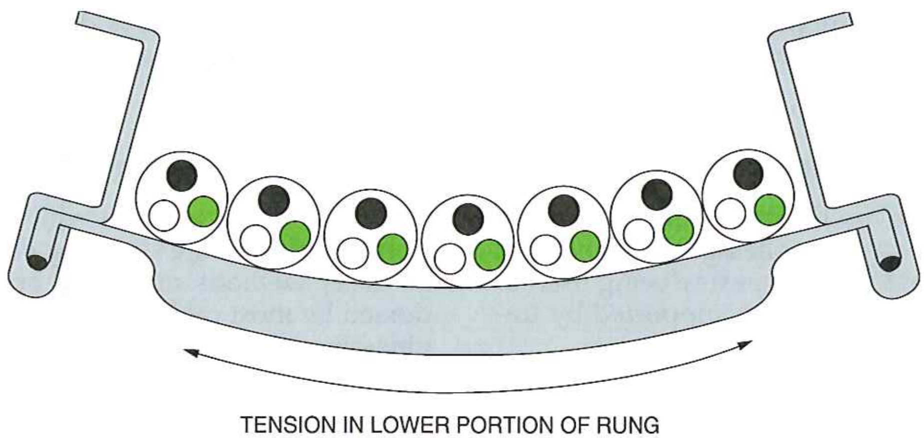


Figure 7 ◆ Bending of loaded tray.

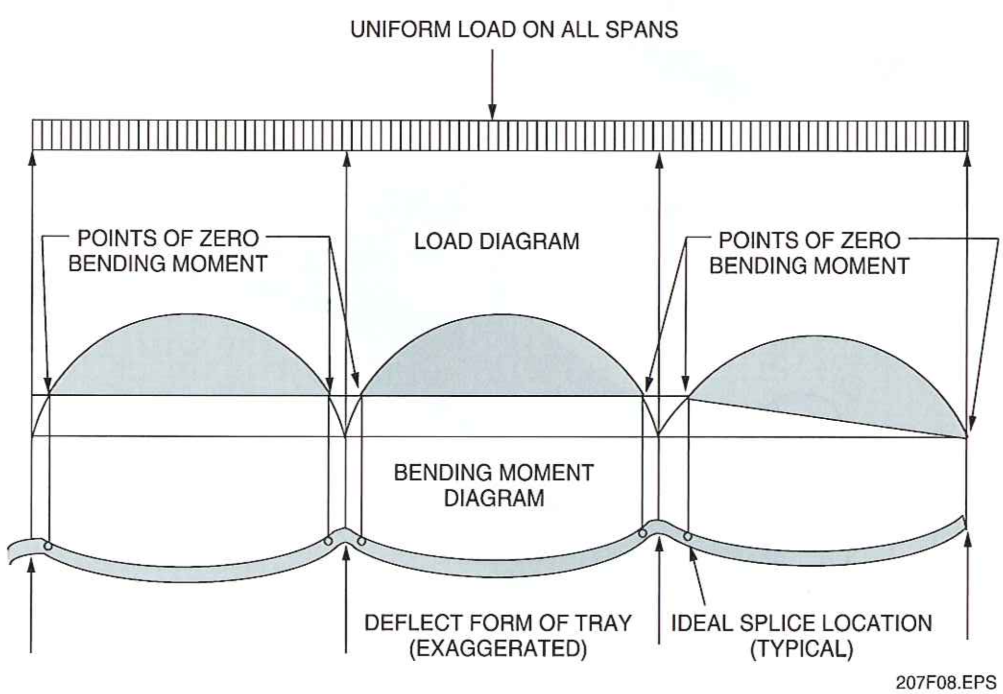


Figure 8 ◆ Load of cable creates bending moments along the span.

side rails of the tray is directly related to the bending moments at all points along the tray. The magnitude of the bending moment at any point is determined by measuring the vertical height of the shaded portion. In any cable tray system, a splice is a point of weakness. Consequently, splices should be located at the points of least stress. Ideally, splices would be located at the points of zero bending moment, and the strength of the tray system would be at a maximum. In actual practice, if the splice is located within one-fourth of the span's distance from the support, the result will be close to ideal.

Locating the splice within the one-fourth points of the span requires extra labor on the part of the installer. When a splice occurs within the central length of a span between the one-fourth points, the tray will support the load for which it was designed, but the safety factor will be greatly reduced.

2.7.0 Cable Placement in Tray

Cables are placed in the tray either by being pulled along the tray or by being laid in over the side. *Figure 9* shows a **cable pulley** being used to facilitate a cable pull in a tray supported by trapeze hangers.

2.8.0 Cable Tray Cover

A cable **tray cover** is used primarily for two reasons:

- To protect the insulation of the cables against damage that might be caused if an object were to fall into the tray. Prime hazards are tools, discarded cigarettes, and weld splatter.
- To protect certain types of cable insulation against the damaging effects of direct sunlight.

2.8.1 Cover Selection

When maximum protection is desired, solid covers should be used. However, if accumulation of heat from the cables is expected, caution should be used. Ventilated covers should be used if some protection of the cable is desired and provisions must be made to allow the escape of heat developed by the cables.

2.9.0 Cable Exit from Tray

Several different ways in which cables may exit from a cable tray are shown in *Figure 10*. While all of these methods are *NEC*®-approved and endorsed by most cable tray manufacturers, the engineering specifications on some projects may

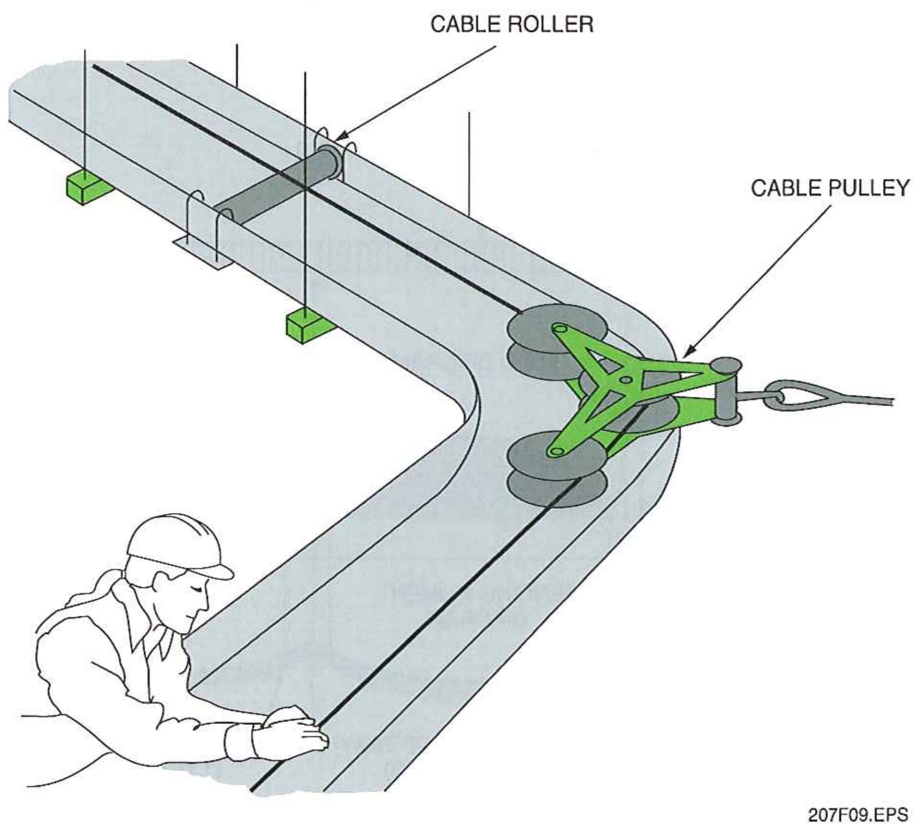


Figure 9 ◆ Cable pulley used to facilitate a cable pull in a tray.

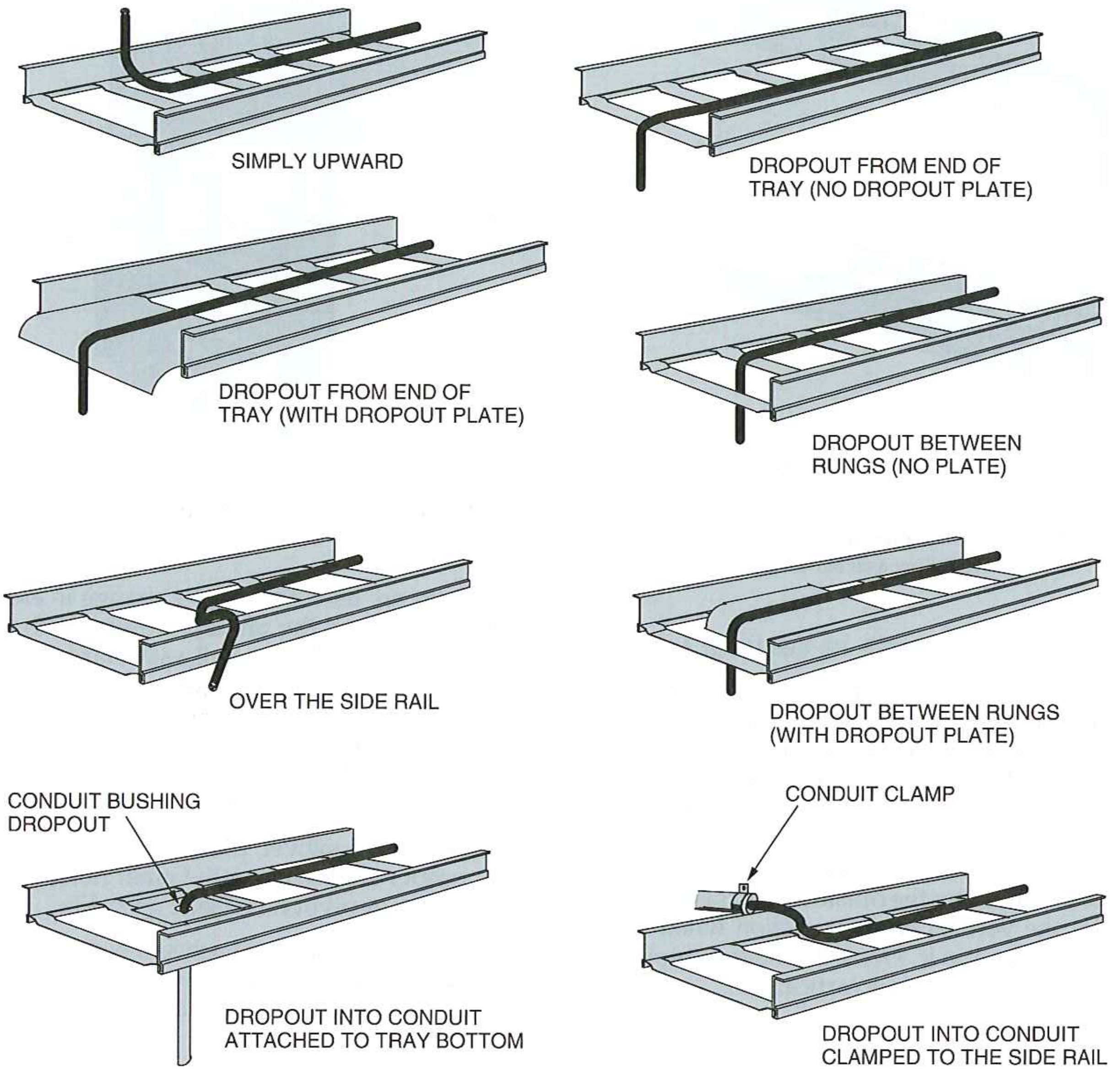


Figure 10 ◆ Several ways in which cables may exit from a cable tray.

prohibit the use of some of these methods. Most notable are the **dropout** between runs method and the dropout from the end of the tray method. The cable radius may be too short with either of these methods. Also, since no **dropout plates** are used, the cable or conductors are not protected. Although *NEC Section 392.5(B)* specifically requires that cable trays have smooth edges to ensure that cable will not be damaged, accidents do occur. For example, a tool might be dropped on a cable tray rung during the installation, which may cause a burr or other sharp edge on the rung. Then, after the cable is installed and the system is in use, vibrating machinery may cause this burr to cut into the cable insulation, resulting in a ground fault and possible power outage. Always review the project specifications carefully and/or check with the project supervisor before using either of these methods.

2.9.1 Dropout Plates

A dropout plate provides a curved surface for the cable to follow as it passes from the tray, as shown in *Figure 11(A)*. Without a dropout plate, cables can be bent sharply, causing damage to the insulation. See *Figure 11(B)*.

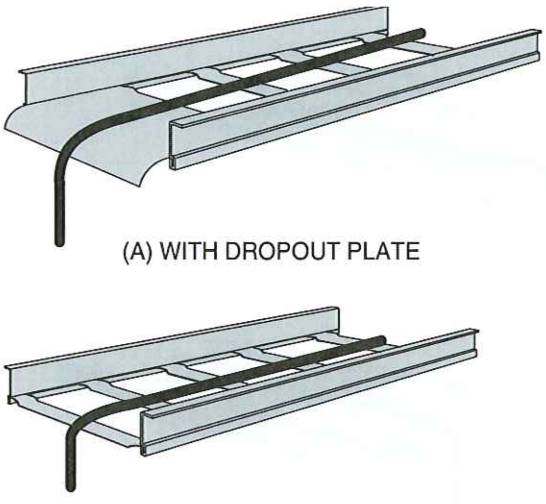


Figure 11 ◆ A dropout plate provides a curved surface for the cable to follow as it leaves the tray.

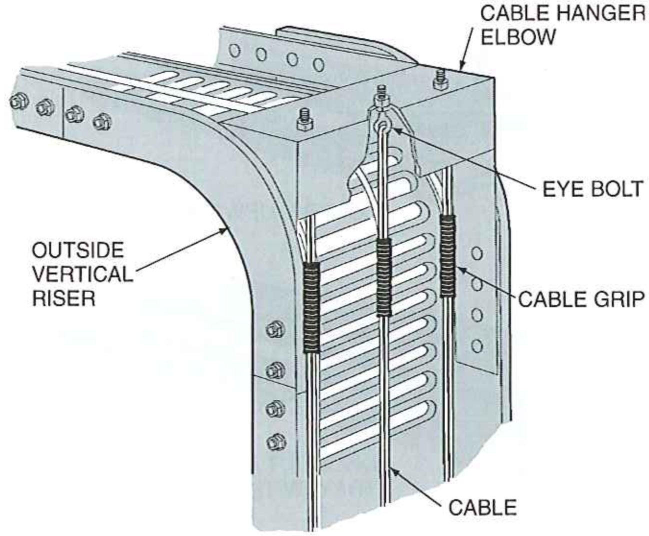


Figure 12 ◆ Typical application of supports in a vertical run.

2.10.0 Cable Supports in Vertical Trays

A cable hanger **elbow** is used to suspend cables in long vertical runs. Care should be taken to ensure that the weight of the suspended length of cable does not exceed the cable manufacturer's recommendation for the maximum allowable tension in the cable.

In short vertical runs, the weight of cables can be supported either by the outside vertical riser elbow or by the vertical straight section when the cables are clamped to it. *Figure 12* shows a typical application of supports in a vertical run.

2.11.0 Cable Edge Protection

The bottom of the solid bottom tray might be convex, concave, or flat. When two pieces of tray are butted together, the bottoms may be out of alignment. An alignment strip, also known as an H bar, is placed between the tray bottoms.

2.12.0 Splice Plates

There are several types of splice plates available, including vertical, horizontal, and expansion plates.

2.12.1 Vertical Adjustment Splice Plates

Vertical adjustment splice plates are used to change the elevation in a run of cable tray. They should not be used when it is important to maintain a cable bending radius. Vertical adjustment splice plates are useful when the change in elevation is so slight or the angle so unusual that it would not be possible to install a standard outside vertical riser elbow and an inside vertical riser elbow in the space available.

In general, four **swivel plates** are used to build an offset in a cable tray system. Once the proper angles have been calculated, proceed as follows:

Step 1 Bolt four swivel plates together at the proper angles, using the inner holes as the center or pivot hole (see *Figure 13*).

Step 2 Using a flat surface such as a bench or concrete deck, space two swivel plates at the proper center-to-center distance apart (refer to *Figure 13*).

Step 3 Measure and cut the amount of tray needed to complete the offset.

2.12.2 Horizontal Adjustment Splice Plates

These plates are sometimes used in place of horizontal elbows to change the direction in a run of cable tray. They are used primarily where there is insufficient space or an unusual angle that prevents the use of a standard elbow.

2.12.3 Expansion Splice Plates

These plates are used at intervals along a straight run of cable tray to allow space for thermal expansion or contraction of the tray to occur, or where offsets or **expansion joints** occur in the supporting structure.

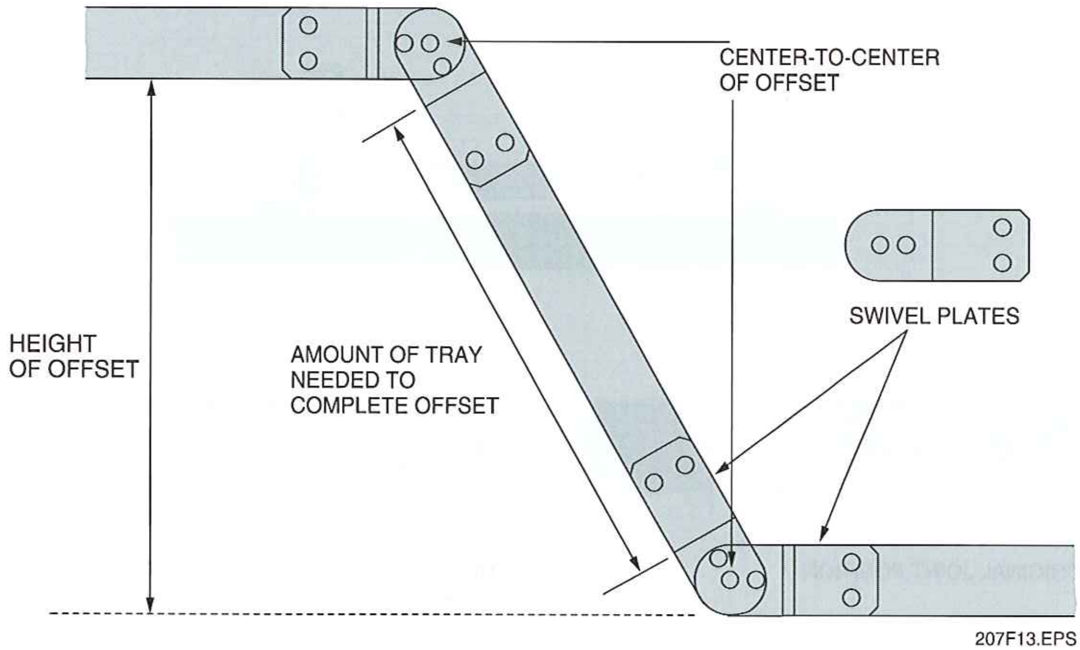


Figure 13 ◆ Fabricating a cable tray offset with swivel plates.

To enable the expansion joint to function properly, the cable tray must be allowed to slide freely on its supports. Any cable tray hold-down device used in an installation subject to expansion or contraction must give clearance to the tray. An expansion joint and splice plates are shown in *Figure 14*.

2.13.0 Barrier Strips

Barrier (divider) strips are used to separate certain types of cable as a result of the nature of the installation, types of circuits used, type of equipment used, local codes, or the *NEC*®. Some reasons for using divider strips are to:

- Separate or isolate electrical circuits
- Separate or isolate cables of different voltages
- Separate cable or wire runs from each other to prevent fire or ground fault damage from spreading to other cables or wires in the same tray
- Aid neatness in the arrangement of the cables
- Warn electricians of the difference between cables on each side of the divider strip

2.13.1 Barrier Strip Cable Protectors

Barrier strip cable protectors are used to bind any raw metallic edge over which a cable is to pass. Their purpose is to protect the cable insulation against damage.

INSIDE TRACK

Contraction and Expansion of Cable Tray

Structural expansion joints do not normally provide a solution to the thermal contraction and expansion of cable trays, because the materials of the structures and trays are different. For example, for a 100°F variance in temperature, a steel tray will require an expansion joint every 128' and an aluminum tray will require a joint every 65'. You must determine the gap setting for the joint according to the temperature at the time of installation. Tables for setting up the gap distances are available from cable tray manufacturers.

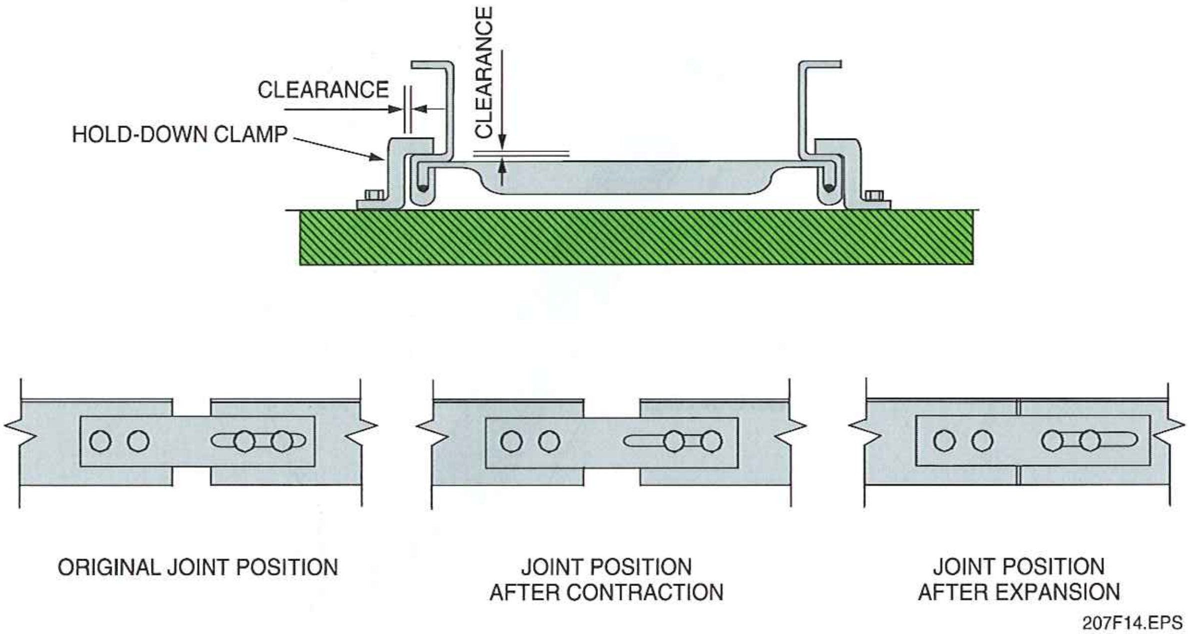


Figure 14 ◆ Expansion joint and splice plates.

3.0.0 ◆ CABLE TRAY SUPPORT

Proper supports for cable tray installations are very important in obtaining a good overall layout. Cable is usually supported in one or more of the following ways:

- **Trapeze mounting**
- **Direct rod suspension**
- **Wall mounting**
- Center hung support
- Pipe rack mounting

3.1.0 Trapeze Mounting

When trapeze mounting is used, a structural member—usually a steel channel or **Unistrut®**—is connected to the vertical supports to provide an appearance similar to a swing or trapeze. The cable tray is mounted to the structural member using anchor clips or J-clamps. Often, the underside of the channel or Unistrut® is used to support conduit (see *Figure 15*).

3.2.0 Direct Rod Suspension

The direct rod suspension method of supporting cable tray uses threaded rods and hanger clamps. The threaded rod is connected to the ceiling or other overhead structure and is connected to the hanger clamps that are attached to the cable tray side rails, as shown in *Figure 16(A)*.

3.3.0 Wall Mounting

Wall mounting is accomplished by supporting the tray with structural members attached to the wall, as shown in *Figure 16(B)*. This method of support is often used in tunnels (mining operations) and other underground or sheltered installations where large numbers of conductors interconnect equipment that is separated by long distances. When using this or any other method of supporting cable tray, always examine the structure to which the hangers are attached, and make absolutely certain that the structure is of adequate strength to support the tray system.

3.4.0 Trapeze Mounting and Center Hung Support

Trapeze mounting of cable tray is similar to direct rod suspension mounting. The difference is in the method of attaching the cable tray to the threaded rods. A structural member, usually a steel channel or strut, is connected to the vertical supports to provide an appearance similar to a swing or tra-

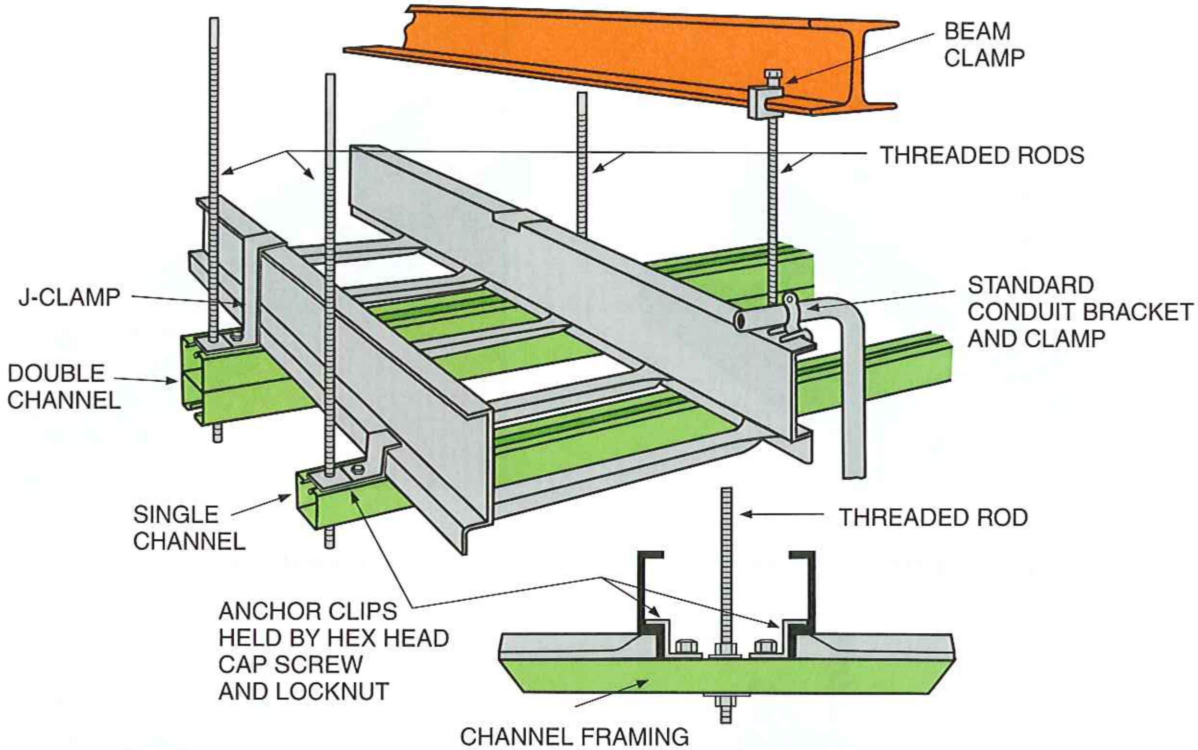


Figure 15 ◆ Channel support details.

INSIDE TRACK

Center Hung Trays

With center hung trays, care must be taken to balance the weight of the cable on either side of the tray to prevent tipping.

peze. The cable tray is mounted to the structural member. Often, the underside of the channel or strut is used to support conduit. A trapeze mounting assembly is shown in *Figure 16(C)*.

A method that is similar to trapeze mounting is a center hung tray support, as shown in *Figure 16(D)*. In this case, only one rod is used and it is centered between the cable tray side rails. A bushing sleeve, such as a short piece of small-diameter PVC, may be used over the center rod to protect the conductors.

3.5.0 Pipe Rack Mounting

Pipe racks are structural frames used to support the piping that interconnects equipment in outdoor industrial facilities. Usually, some space on the rack is reserved for conduit and cable tray. Pipe rack mounting of cable tray is often seen in petrochemical plants where power distribution and instrumentation wiring is routed over a large area and for long distances.

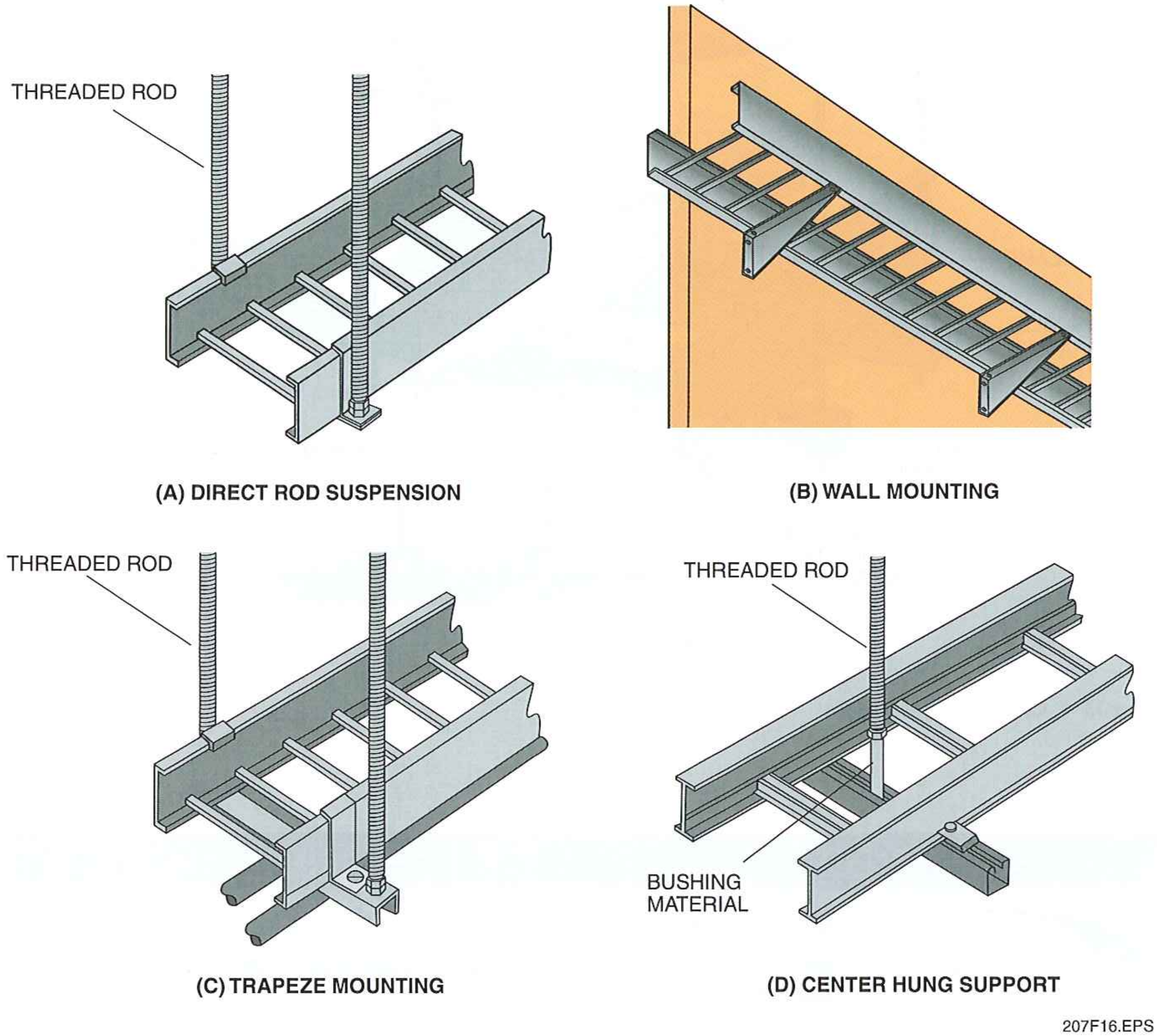


Figure 16 ◆ Alternate ways to hang cable tray.

4.0.0 ◆ CENTER RAIL CABLE TRAY SYSTEMS

Center rail or monorail cable tray systems (*Figure 17*) are light, easy to install, and provide open sides for ready access when changing or adding cables. Center rail cable tray is used in light-duty applications such as sound, telephone, and other communications systems. In addition to its weight limitations, it cannot be used with dividers so its use is restricted to systems where dividers are not necessary.

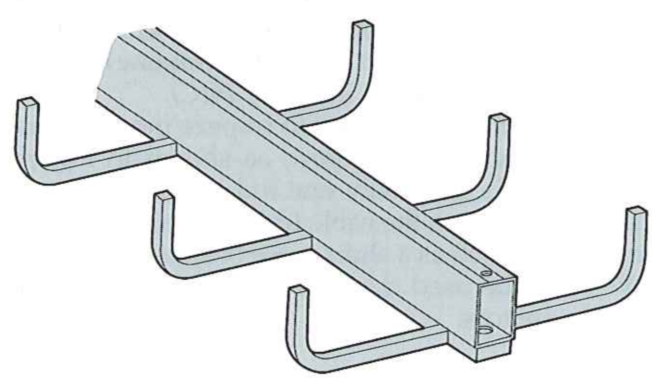


Figure 17 ◆ Center rail cable tray.

5.0.0 ◆ *NEC*® REQUIREMENTS

NEC Article 392 deals with cable tray systems along with related wire, cable, and raceway installations.

Figures 18, 19, and *20* summarize the *NEC*® requirements for cable tray installations. For in-depth coverage, always refer to the *NEC*®. Cable tray manufacturers also have some excellent reference material available that details the installation of their products. Consult your local dealer for more information.

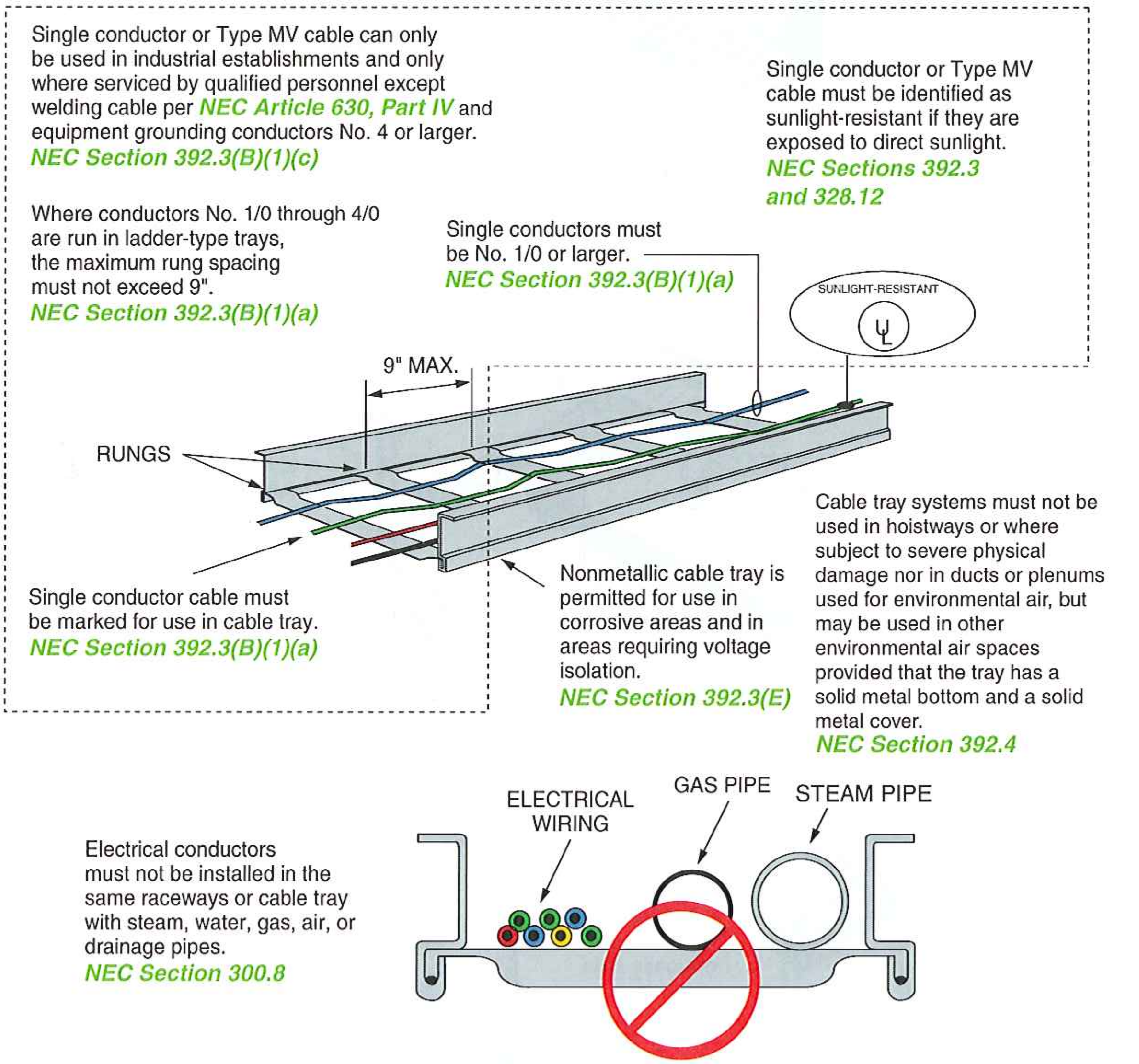


Figure 18 ◆ *NEC*® regulations governing the use of cable tray.

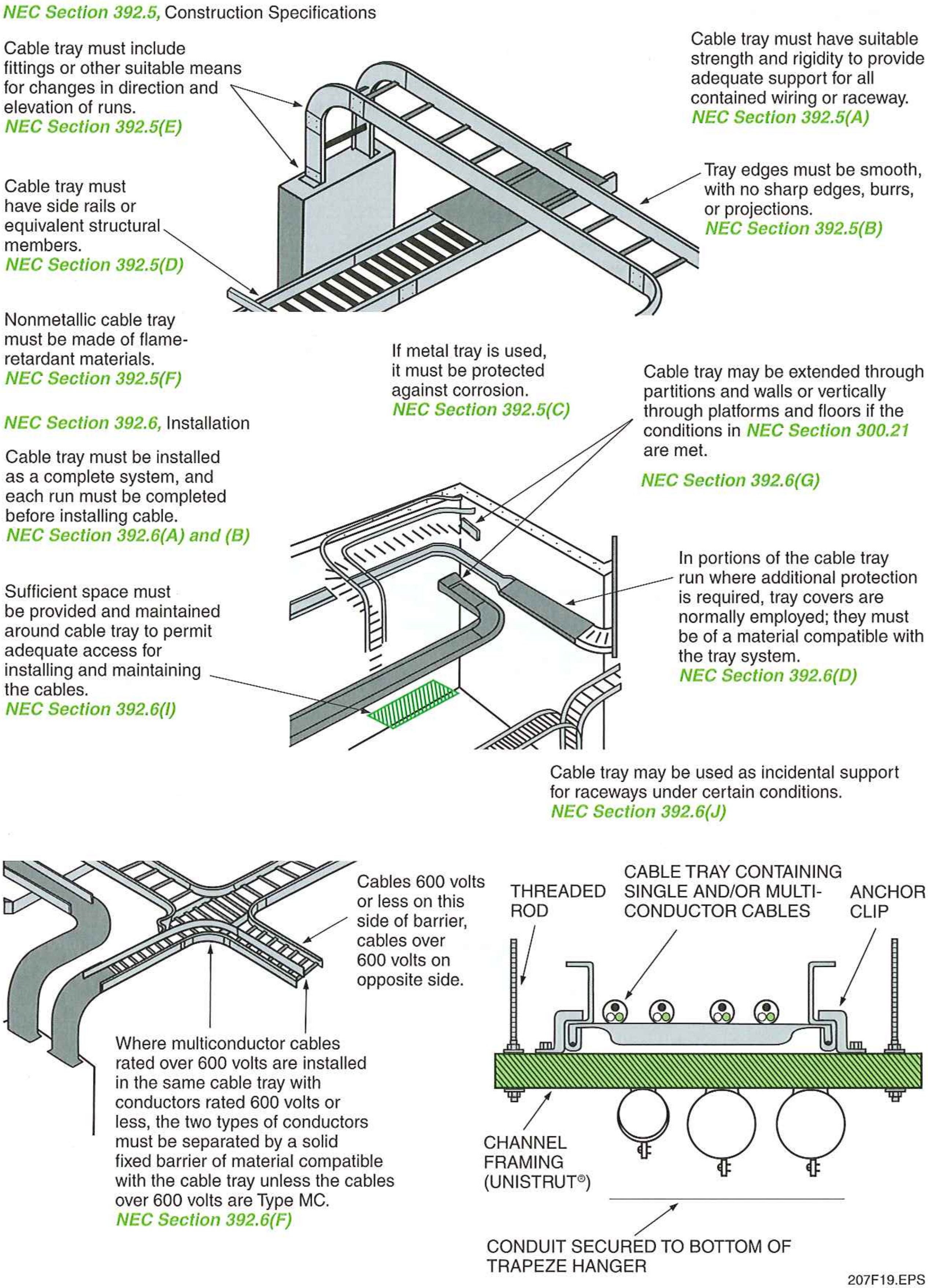


Figure 19 ◆ *NEC*® regulations governing cable tray construction and installation.

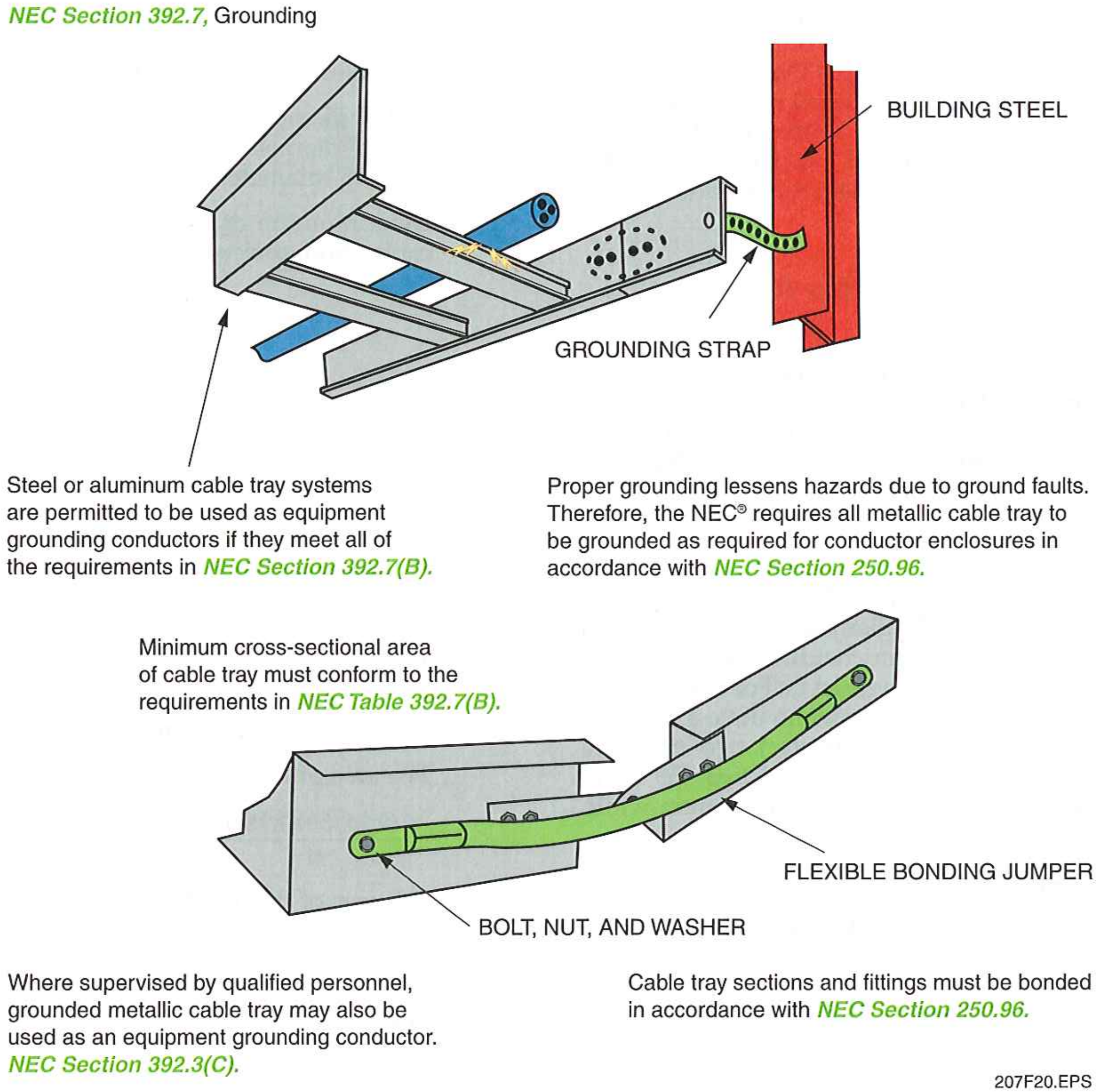


Figure 20 ◆ *NEC*® regulations governing cable tray grounding.

6.0.0 ◆ CABLE INSTALLATION

NEC Section 392.8 covers the general installation requirements for all conductors used in cable tray systems; that is, splicing, securing, and running conductors in parallel. For example, cable splices are permitted in cable trays provided they are made and insulated by *NEC*®-approved methods. Furthermore, any splices must be readily accessible and must not project above the side rails of the tray.

In most horizontal runs, the cables may be laid in the tray without securing them in place. However, on vertical runs or any runs other than horizontal, the cables must be secured to transverse members of the cable tray.

Cables may enter and leave a cable tray system in a number of different ways, as discussed previously. In general, no junction box is required where such cables are installed in bushed conduit or tubing. Where conduit or tubing is used, it must be secured to the tray with the proper fittings. Further precautions must be taken to ensure that the cable is not bent sharply as it enters or leaves the conduit or tubing.

6.1.0 Conductors Connected in Parallel

Where single-conductor cables comprising each phase, neutral, or grounded conductor of a circuit are connected in parallel as permitted in *NEC Section 310.4,* the conductors must be installed in groups consisting of not more than one conductor per phase, neutral, or grounded conductor to prevent a current imbalance in the paralleled conductors due to inductive reactance. This also prevents excessive movement due to fault current magnetic forces.

6.2.0 Number of Cables Allowed in Cable Tray

The number of multiconductor cables rated at 2,000V or less that are permitted in a single cable tray must not exceed the requirements of *NEC Section 392.9.* This section applies to both copper and aluminum conductors.

6.2.1 All Conductors Size 4/0 or Larger

Where all of the cables installed in the tray are 4/0 or larger, the sum of the diameters of all cables shall not exceed the cable tray width, and the cables must be installed in a single layer. For example, if a cable tray installation is to contain three 4/0 multiconductor cables (1.5" in diameter), two 250 kcmil multiconductor cables (1.85"), and two 350 kcmil multiconductor cables (2.5"), the minimum width of the cable tray is determined as follows:

$$3(1.5) + 2(1.85) + 2(2.5) = 13.2''$$

The closest standard cable tray size that meets or exceeds 13.2" is 18". Therefore, this is the size to use.

6.2.2 All Conductors Smaller Than 4/0

Where all of the cables are smaller than 4/0, the sum of the cross-sectional area of all cables smaller than 4/0 must not exceed the maximum allowable cable fill area as specified in Column 1 of *NEC Table 392.9;* this gives the appropriate cable tray width. To use this table, however, you must have the manufacturer's data for the cables being used. This will give the cross-sectional area of the cables.

The steps involved in determining the size of cable tray for multiconductors smaller than 4/0 AWG are as follows:

Step 1 Calculate the total cross-sectional area of all cables used in the tray. Obtain the area of each from the manufacturer's data.

Step 2 Look in Column 1 of *NEC Table 392.9* and find the smallest number that is at least as large as the calculated number.

Step 3 Look at the number to the left of the row selected in Step 2. This is the minimum width of cable tray that may be used.

For example, determine the minimum cable tray width required for the following multiple conductor cables—all less than 4/0 AWG:

- Four at 1.5" diameter
- Five at 1.75" diameter
- Three at 2.15" diameter

Step 1 Determine the cross-sectional area of the cables from the equation:

$$A = \frac{\pi \times D^2}{4}$$

Where:

A = area

D = diameter

The area of a 1.5" diameter cable is:

$$\frac{(3.14159)(1.5^2)}{4} = 1.7671 \text{ square inches}$$

The area of the four 1.5" cables is:

$$4 \times 1.7671 \text{ square inches} = 7.0684 \text{ square inches}$$

The area of 1.75" diameter cable is:

$$\frac{(3.14159)(1.75^2)}{4} = 2.4053 \text{ square inches}$$

The area of the five 1.75" cables is:

$$5 \times 2.4053 \text{ square inches} = 12.0265 \text{ square inches}$$

The area of the three 2.15" cables is:

$$\frac{(3.14159)(2.15^2)}{4} = 3.6305 \text{ square inches}$$

Therefore, the total area of the three cables is:

$$3 \times 3.6305 \text{ square inches} = 10.8915 \text{ square inches}$$

The total cross-sectional area is found by adding the above three totals to obtain:

$$7.0684 + 12.0265 + 10.8915 = 29.9864 \text{ square inches}$$

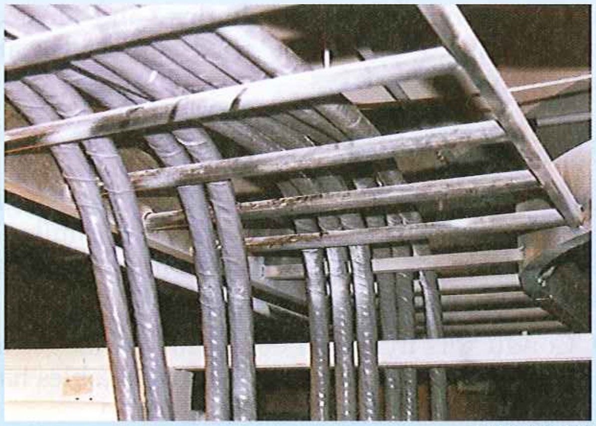
Step 2 Look in Column 1 of *NEC Table 392.9* and find the smallest number that is at least as large as 29.9864 square inches. The number is 35.

Step 3 Look to the left of 35 and you will see the inside tray width of 30". Therefore, the minimum tray width that can be used for the given group of conductors is 30".

Low-Voltage Cable

INSIDE TRACK

Increasingly, cable trays are being used to carry many low-voltage conductors in communication centers. In a large commercial building, thousands of telecommunications cables are distributed in bundles from the equipment room to the telecommunications closets on each floor. Cable trays offer a convenient means of running these cables through the building as well as a much easier method of allowing for system expansion. Instead of having to access conduit buried within the building walls, a new communication cable can simply be added to the cable tray system, which is normally accessible through a dropped ceiling.



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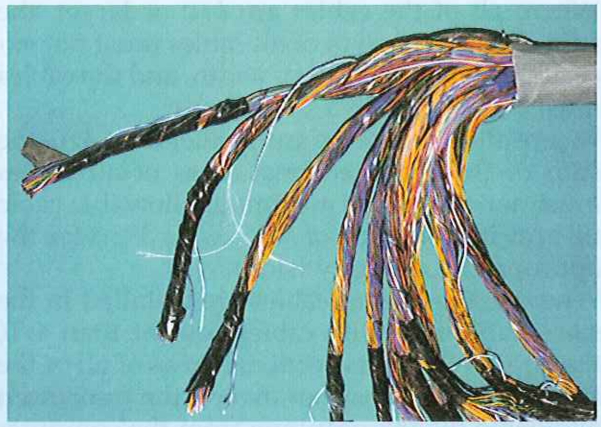

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6.2.3 Combination Cables

Where 4/0 or larger cables are installed in the same cable tray with cables smaller than 4/0, the sum of the cross-sectional area of all cables smaller than 4/0 must not exceed the maximum allowable fill area from Column 2 of *NEC Table 392.9* for the appropriate cable tray width. The 4/0 and larger cables must be installed in a single layer, and no other cables can be placed on them.

To determine the tray size for a combination of cables as discussed in the above paragraph, proceed as follows:

Step 1 Repeat the steps from the procedure used previously to determine the minimum tray width required for the multiconductor cables having conductors sized 4/0 and larger.

Step 2 Repeat the steps from the procedure used previously to determine the cross-sectional area of all multiconductor cables having conductors smaller than 4/0 AWG.

Step 3 Multiply the result of Step 1 by the constant 1.2 and add this product to the result of Step 2. Call this sum A. Search Column 2 of *NEC Table 392.9* for the smallest number that is at least as large as A. Look to the left in that row to determine the minimum size cable tray required.

To illustrate these steps, we will assume that we need to find the minimum cable tray width of two multiconductor cables, each with a diameter of 2.54" (conductors size 4/0 or larger); three cables with a diameter of 3.30" (conductors size 4/0 or larger), plus eight cables with a diameter of 1.92" (conductors less than 4/0).

Step 1 The sum of all the diameters of cable having conductors 4/0 or larger is:

$$2(2.54) + 3(3.30) = 14.98"$$

Step 2 The sum of the cross-sectional areas of all cables having conductors smaller than 4/0 is:

$$\frac{(8)(3.14159)(1.92^2)}{4} = 23.1623 \text{ square inches}$$

Step 3 Multiply the result of Step 1 by 1.2 and add this product to the result of Step 2:

$$(1.2 \times 14.98) + 23.1623$$
$$= 41.1383 \text{ square inches}$$

The smallest number in Column 2 of *NEC Table 392.9* that is not larger than 41.1383 is 42. The tray width that corresponds to 42 is 36". Therefore, select a cable tray width of 36".

6.2.4 Solid Bottom Tray

Where solid bottom cable trays contain multiconductor power or lighting cables, or any mixture of multiconductor power, lighting, control, and signal cables, the maximum number of cables must conform to the following:

- Where all of the cables are 4/0 or larger, the sum of the diameters of all cables must not exceed 90% of the cable tray width, and the cables must be installed in a single layer.
- Where all of the cables are smaller than 4/0, the sum of the cross-sectional areas of all cables must not exceed the maximum allowable cable fill area in Column 3 of *NEC Table 392.9* for the appropriate cable tray width.
- Where 4/0 or larger cables are installed in the same cable tray with cables smaller than 4/0, the sum of the cross-sectional areas of all of the smaller cables must not exceed the maximum allowable fill area resulting from the computation in Column 4, *NEC Table 392.9* for the appropriate cable tray width. The 4/0 and larger cables must be installed in a single layer, and no other cables can be placed on them.

Where a solid bottom cable tray with a usable inside depth of 6" or less contains multiconductor control and/or signal cables only, the sum of the cross-sectional areas of all cables at any cross section must not exceed 40% of the interior cross-sectional area of the cable tray. A depth of 6" must be used to compute the allowable interior cross-sectional area of any cable tray that has a usable inside depth of more than 6".

In a previous example, we determined that the minimum tray size for multiconductor cables with all conductors size 4/0 or larger was 18". The sum of all cable diameters for this example was 13.2". To see if an 18" solid bottom tray can be used, multiply the tray width by 0.90 (90%):

$$18 \times 0.9 = 16.2"$$

Therefore, 16.2" is the minimum width allowed for solid bottom tray. Since we are using 18" tray, this meets the requirements of *NEC Section 392.9(C)(1).*

When dealing with solid bottom trays and using *NEC Table 392.9,* use Columns 3 and 4 instead of Columns 1 and 2, as used for ladder and trough-type cable trays.

6.2.5 Single-Conductor Cables

Calculating cable tray widths for single-conductor cables (2,000V or under) is similar to the calculations used for multiconductor cables, with the following exceptions:

- Conductors that are 1,000 kcmil and larger are treated the same as multiconductor cables having conductors size 4/0 or larger.
- Conductors that are smaller than 1,000 kcmil are treated the same as multiconductor cables having conductors smaller than size 4/0.

NEC Section 392.10 covers the details of installing single-conductor cables in cable tray systems.

6.3.0 Ampacity of Cable Tray Conductors

NEC Section 392.11 gives the requirements for cables used in tray systems with rated voltages of 2,000 volts or less. *NEC Section 392.13* covers cables with voltages of 2,001 and over.

THINK ABOUT IT

Ampacity in Cable Trays

Examine **NEC Sections 392.11 and 392.13.** What are the factors that affect the permitted ampacity?

7.0.0 ◆ CABLE TRAY DRAWINGS

For an economical and satisfactory installation, working out the details of supports and hangers for a cable tray system is usually done beforehand by the engineering department or project engineer and is seldom left to the judgment of a field force that is not acquainted with the loads and forces to be encountered. As a result, drawings and specifications will usually be furnished to the work crew to provide details about the cable tray system. All workers involved with the installation should know how to interpret these drawings.

The exact method of showing cable tray systems on working drawings will vary, so always consult the symbol list or legend before beginning the installation. Also, study any shop or detail drawings that might accompany the construction documents.

If space permits, many engineers prefer to draw the cable tray system as close to scale as possible, using various symbols to show the different types of cable tray to be installed.

Look at the floor plan drawing in *Figure 21*. The cable tray system in this project originates at several power panels and motor control centers to feed and control motors in other parts of the building. The trays run from the motor control centers, are offset to miss beams and other runs of cable tray, and then branch off to various parts of the building.

Although experienced workers in the industrial electrical trade will have little trouble reading the information in this drawing, new electricians may have some difficulty in visualizing the system. However, if a supplemental drawing were provided with the floor plan drawing in *Figure 21*, it would provide a clearer picture of the system

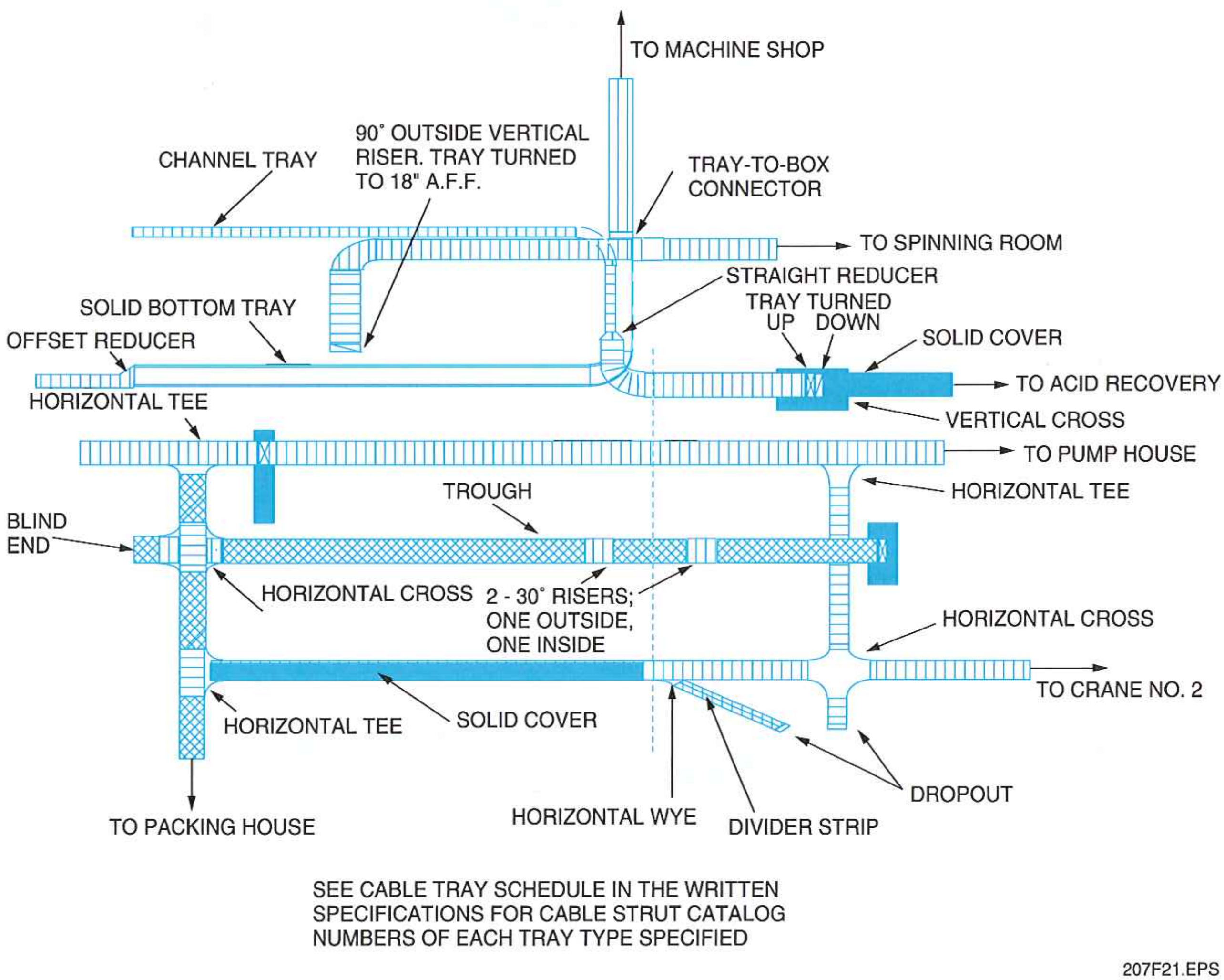

Figure 21 ◆ Sample floor plan of a cable tray system.

and leave little doubt as to how the cable tray system is to be installed. Even new workers in the trade would be able to see how the system should be installed, and this would take some of the load off experienced workers and give them more time to accomplish other tasks.

In actual practice, however, consulting engineering firms seldom furnish the isometric drawing; they merely show the layout in plan view. Consequently, plan views involving the construction details of cable tray systems must be studied carefully during the planning stage—before the work is begun.

8.0.0 ◆ PULLING CABLE IN TRAY SYSTEMS

When installing cables in tray systems, proper precautions must be taken to avoid damaging the cables. A complete line of installation tools is available for pulling long lengths of cable up to 1,000' or longer. These tools save considerable installation time.

Short lengths of cable can be laid in place without power pulling tools, or the cable can be pulled manually using a basket grip and pulling rope. Long lengths of small cable, 2" or less in diameter, can also be pulled with a basket grip and pulling rope. Larger cables, however, should be pulled by the conductor and the braid, sheath, or armor. This is usually done with a pulling eye applied to the cable at the factory, or by tying the conductor to the eye of a basket grip and taping the tail end of the grip to the outside of the cable.

In general, the pull exerted on the cables pulled with a basket grip that is not attached to the conductor should not exceed 1,000 pounds. For heavier pulls, care should be taken not to stretch the insulation, jacket, or armor beyond the end of the conductor nor bend the ladder, trough, or channel out of shape.

The bending radius of the cable should not be less than the values recommended by the cable manufacturer, which range from four times the diameter for a rubber-insulated cable that has a 1" maximum outside diameter without lead, shield, or armor, to eight times the diameter for **interlocked armor cable.** Cables of special construction such as wire armor and high-voltage cables require a larger radius bend.

When installing long lengths of cable up to 1,000' with as many as a dozen bends, best results are obtained by pulling the cable in one continuous operation at a speed of 20' to 25' per minute. The pulling line diameter and length will depend on the pull to be made and construction equipment available. The winch and power unit must be of an adequate size for the job and capable of developing the high pulling speed required for the best and most economical results.

A complete description of a **cable roller, sheave,** and other pulling equipment, along with their setup, was covered in *Conductor Installations.* You will also find information on parallel tuggers

CASE HISTORY: Pulling Cable in a Tray

At a clothing manufacturing plant in New York, an electrician attempted to pull cable in a tray already partly filled with energized cables. He used plenty of cable-pulling lubricant, but did not use sheaves and rollers to isolate the new cables from the existing ones. During the pull, the new cables wedged against the live ones, yanking one hot wire apart at a splice. The wire grounded itself on the tray and arced for 30' down the tray, fatally shocking the electrician.

The Bottom Line: Use sheaves and rollers when pulling cables, especially when pulling them between existing live cables.

INSIDE TRACK: *Big Pulls*

For very long pulls, some contractors use an auxiliary winch. Power winches may exceed their preset tension limits and abort the pull, so a second winch is installed in a high-tension area of the pull in a straight section of tray. The second winch is used to pull a loop of slack cable and reduce the tension on the main winch, which now pulls only the length of slack cable between itself and the auxiliary winch.

and dynamometers (tension meters). Please refer to this module for additional information concerning cable pulls.

9.0.0 ◆ SAFETY

Installing cable tray means working at heights above the floor. Consequently, workers must take the necessary precautions. In general, workers installing cable tray will use ladders, scaffolds, lifts, work from the tray assembly itself, or a combination of all these.

Keep the tray assembly uncluttered during installation. Tools, tray fittings, and the like are ideal obstacles for tripping workers. They may also fall off the tray and injure workers below. To help prevent the latter, set up work barriers beneath the section of tray assembly being worked on. If you are working on the ground, never penetrate or move these barriers until the work above is complete.

Learn to secure your life line properly, and also make sure your full body harness is a proper fit. A harness that is too large may slip, resulting in a serious injury or even death.

THINK ABOUT IT

Putting It All Together

If possible, examine the conduit system at your workplace or school. Did the installers make use of cable tray? If not, is the system large enough to warrant the use of it?

Review Questions

1. A barrier strip is a _____.
   a. division strip installed in a raceway to separate certain types of cables
   b. strip used to provide the tray with added support
   c. glass strip used as a cable tray insulator
   d. metal strip used solely for grounding purposes

2. Which of the following best describes how closely packed cables will be affected when energized?
   a. Their efficiency will be increased.
   b. Their efficiency will be decreased.
   c. No change will be encountered.
   d. The operating temperature of each cable will be lower.

3. When cable exits downward from a tray without a dropout plate, _____ could occur.
   a. current surges
   b. reduced amperage
   c. voltage surges
   d. insulation damage

4. The main purpose of vertical adjustment splice plates is to _____.
   a. increase the strength of a cable tray section
   b. support the cable tray system
   c. change the elevation in a run of cable tray
   d. secure the cable within the tray

5. Which of the following is a violation of *NEC Section 300.8?*
   a. Placing an instrumentation air line in the same tray with electrical conductors
   b. Spacing tray rungs 9" or less apart
   c. Running single conductors in trays that are larger than size 1/0
   d. Using nonmetallic tray systems in corrosive areas

6. When a cable tray section branches off from a main section in two 90° turns, the section is called a(n) _____.
   a. wye
   b. tee
   c. divider strip
   d. ell

7. A section of cable tray that makes a horizontal 90° turn is known as a _____.
   a. vertical tee
   b. vertical ell
   c. horizontal elbow
   d. straight reducer

8. When a cable tray system must be protected from dropping objects that may damage the cable, a _____ is used.
   a. solid bottom tray
   b. trough-type tray
   c. tray cover
   d. blind end

9. Which of the following best describes the type of fitting that will be used with a solid cover cable tray?
   a. An Ericson coupling
   b. Vertical splices
   c. A horizontal cross
   d. A cover clamp

10. A(n) _____ branches in four different directions.
    a. horizontal wye
    b. horizontal cross
    c. inside vertical riser
    d. dropout

Summary

A cable tray system includes the assembly of units or sections and associated fittings that form a rigid structural system used to support cables and raceways. Cable tray systems are commonly used in industrial applications and are normally constructed of either aluminum or steel, although PVC-coated and all-nonmetallic trays are also available.

Cable tray is available in various forms, including ladder, trough, center rail, and solid bottom, and can be supported by either side mounts or center mounts. *NEC Article 392* covers cable tray installations, along with the types of conductors to be used in various cable tray systems.

Notes

Trade Terms Introduced in This Module

Barrier strip: A metal strip constructed to divide a section of cable tray so that certain kinds of cable may be separated from each other.

Cable pulley: A device used to facilitate pulling conductor in cable tray where the tray changes direction. Several types are available (single, triple, etc.) to accommodate almost all pulling situations.

Cable roller: A device used to facilitate cable pulls (lower the pulling resistance) in cable trays. Several types are available, including straight rollers, radius rollers, etc.

Cross: A four-way section of cable tray used when the tray assembly must branch off in four different directions.

Direct rod suspension: A method used to support cable tray by means of threaded rods and hanger clamps. One end of the threaded rod is secured to an overhead structure, while the other end is connected to hanger clamps that are attached to the cable tray side rails.

Dropout: Cable leaving the tray assembly and travelling directly downward; that is, the cable is not routed into a conduit or channel.

Dropout plate: A metal plate used at the end of a cable tray section to ensure a greater cable bending radius as the cable leaves the tray assembly.

Elbow: A section of cable tray used to change the direction of the tray assembly a full quarter turn (90°). Both vertical and horizontal elbows are common.

Expansion joints: Plates used at intervals along a straight run of cable tray to allow space for thermal expansion or contraction of the tray.

Fittings: Devices used to assemble and/or change the direction of cable tray systems.

Interlocked armor cable: Mechanically protected cable; usually a helical winding of metal tape formed so that each convolution locks mechanically upon the previous one (armor interlock).

Ladder tray: A type of cable tray that consists of two parallel channels connected by rungs, similar in appearance to the common straight ladder.

Pipe racks: Structural frames used to support the piping that interconnects equipment in outdoor industrial facilities.

Sheave: A pulley used to facilitate cable pulls in cable tray.

Swivel plates: Devices used to make vertical offsets in cable tray.

Tee: A section of cable tray that branches off the main section in two other directions.

Trapeze mounting: A method of supporting cable tray using metal channel, such as Unistrut®, Kindorf, etc., supported by two threaded rods, and giving the appearance of a swing or trapeze.

Tray cover: A flat piece of metal, fiberglass, or plastic designed to provide a solid covering that is needed in some locations where conductors in the tray system may be damaged.

Trough: A type of cable tray consisting of two parallel channels (side rails) having a corrugated, ventilated bottom or a corrugated, solid bottom.

Unistrut®: A brand of metal channel used as the bottom bracket for hanging cable trays. Double Unistrut® adds strength and stability to the trays and also provides a means of securing future runs of conduit.

Wall mounting: A method of supporting cable tray systems using supports secured directly to the wall.

Wye: A section of cable tray that branches off the main section in one direction.

Additional Resources

This module is intended to present thorough resources for task training. The following reference works are suggested for further study. These are optional materials for continued education rather than for task training.

American Electrician's Handbook, Latest Edition. New York: Croft and Summers, McGraw-Hill.

National Electrical Code® Handbook, Latest Edition. Quincy, MA: National Fire Protection Association.