
Cable Tray Technical Guide

A practical guide to product selection and installation



Table of contents

003	About this guide	046–047	Appendix I: Conductor size
005	What is a cable tray ?	048–049	Appendix II: Material properties
006–007	Types of cable tray	050–056	Appendix III: Corrosion resistance guides
008–021	Material and finishes	057–059	Appendix IV: Installation instructions
022–033	Cable tray installation	060	List of figures
034–044	National Electric Code and Canadian Electrical Code	061	List of tables
045	Reference		

Cable Tray Technical Guide

A practical guide to product selection and installation

This guide for engineers and installers has been developed by ABB as a practical reference regarding cable tray characteristics, installation, and requirements.

In addition to presenting our own product knowledge and engineering expertise, the content of this document draws from a range of other sources, including but not limited to the following:

- The National Electrical Code (U.S.), which publishes standards for all types of electrical applications. Articles 250, 318 and 800 cover various aspects of cable tray systems.
- The Canadian Electrical Code, which publishes standards for electrical applications. Articles 12-2200 to 12-2210 cover various aspects of cable tray systems.
- Documents from NEMA (National Electrical Manufacturers Association), an association representing the major electrical equipment manufacturers in the U.S. The Cable Tray Section committee has published three documents to date: NEMA VE 1, FG 1 and VE 2.

- NEMA VE 1 covers general cable tray definitions, manufacturing standards, performance standards, test standards and application information.
- NEMA FG 1 addresses the standards for fiberglass cable tray systems.
- NEMA VE 2 is a cable tray installation guideline that covers receiving and unloading material, storage of material and general installation practices

All alternate installation methods described in this document have been tested extensively by ABB using the specified products. Test reports are available upon request.

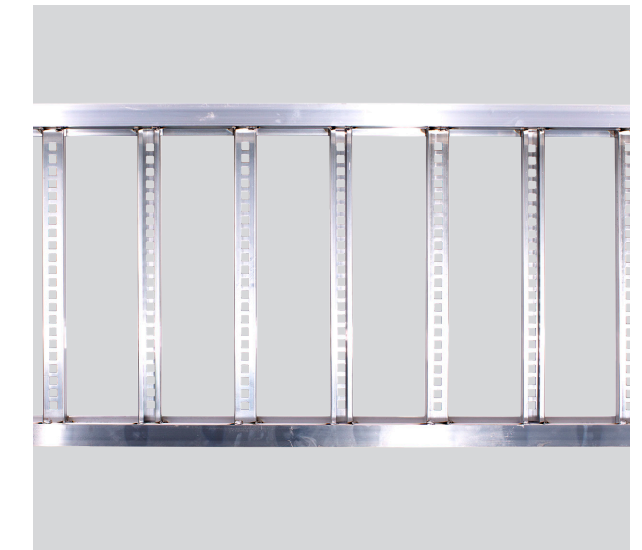
Users of this document should rely on their own independent judgment or, as appropriate, seek the advice of a competent professional in determining their specific application requirements.

What is a cable tray ?

Both the Canadian Electrical Code (CEC) and its American counterpart, the National Electrical Code (NEC), consider cable tray systems to be structural systems.

The CEC defines a cable tray as “a raceway consisting of troughing and fittings formed and constructed so that insulated conductors and cables may be readily installed or removed after the cable tray has been completely installed, without damage either to conductors or their covering.” Conductors are described in Appendix I of this technical guide.

The NEC 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.”



What is a cable tray ?

ABB offers a number of different types of cable tray for use in a range of different applications and environments.

LADDER CABLE TRAY

Ladder cable tray is a welded assembly composed of rungs and side rails. Cables are fastened to the rungs to maintain spacing or to keep cables in place when the tray is installed vertically. Cables can enter or exit from the top or bottom of the tray.

The open, ventilated design of ladder tray offers many advantages:

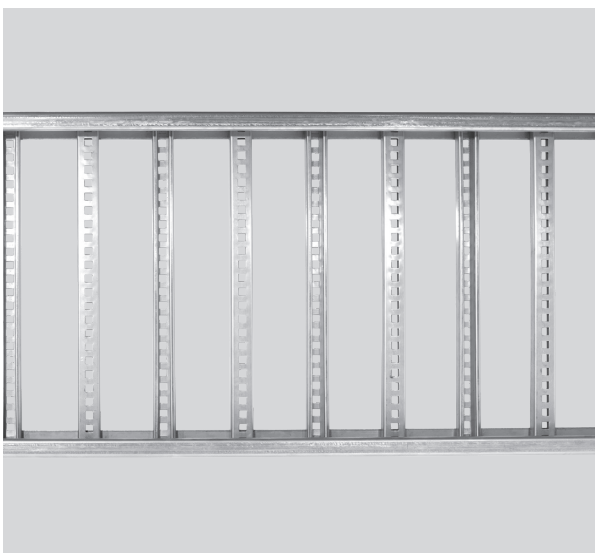
- Eliminates channeling of hazardous or explosive gases
- Prevents moisture formation that can compromise an electrical system or lead to premature corrosion
- Minimizes the buildup of debris and dust
- Offers excellent weight-to-span ratio and can be used for long spans

As per the NEC, the maximum allowable rung spacing is 9 inches (230 mm) when cable tray carries single-conductor cables of 1/0 to 4/0 AWG (American Wire Gauge) (Appendix I).

The rung spacing for cable tray that supports large power conductors should be between 9 and 12 inches (230 and 300 mm) to respect the minimum bend radius for cables as they exit the bottom of the cable tray. A rung spacing of 6 to 9 inches (150 to 230 mm) is preferable when the cable tray contains small multi-conductor cables used in instrumentation and control applications.

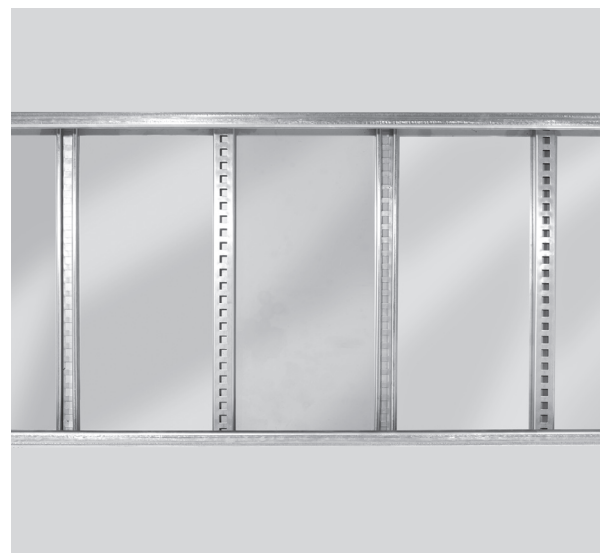
VENTILATED CABLE TRAY

Ventilated cable tray is an alternative for small multi-conductor cables used for instrumentation and control applications that require additional protection. The rung spacing for ventilated, ladder-type cable tray is 4 inches (100 mm).



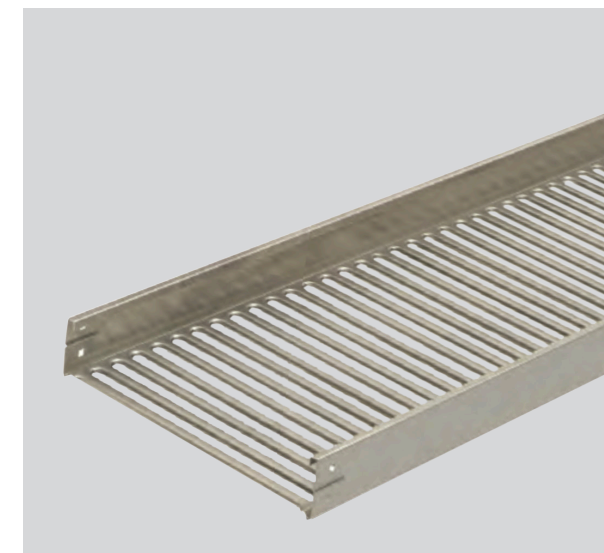
SOLID-BOTTOM CABLE TRAY

Providing additional cable protection, solid-bottom cable tray is sometimes preferred to support and protect numerous small instrumentation and control cables. Because of its closed design, this type of tray should be used in applications where there is minimal risk of heat generation and buildup. When equipped with a solid cover, this type of cable tray can be used to support non-plenum-rated cables in air-handling spaces (environmental air areas).



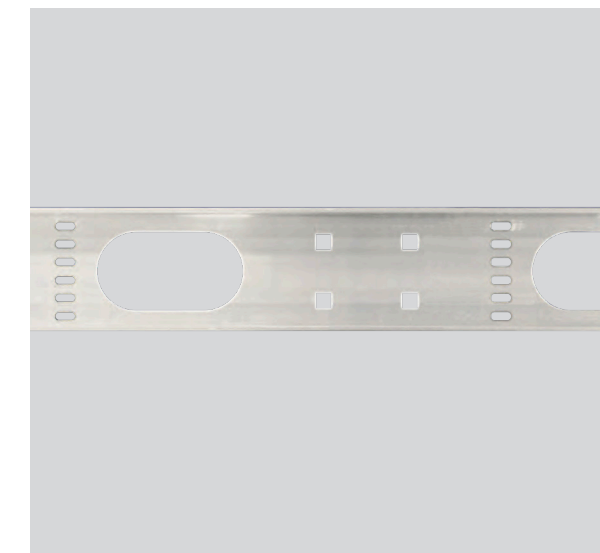
ONE-PIECE CABLE TRAY

Made of one continuous metal sheet, one-piece tray is typically used in applications where visual esthetics are important. It is used in a range of applications with spans of 10 feet (3.0 meters) or less, to support power cables and light-duty cables.



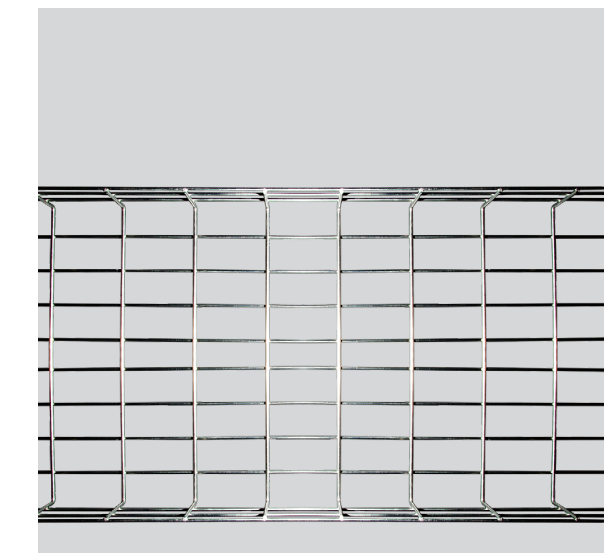
CHANNEL TRAY

Channel tray is typically used to support drop outs and smaller branch runs from the main cable tray system to electrical devices or other equipment. It is available with a ventilated or solid bottom. Channel tray can protect against electromagnetic interference when made of steel and equipped with a cover and wrap-around cover clamps.



WIRE MESH CABLE TRAY

Wire mesh cable tray, also referred to as basket tray, is a welded wire-mesh cable management system made of high-strength steel wire. It is used to manage cables for light power, telecommunications and fiber optics in commercial and industrial facilities.



Materials and finishes

ABB manufactures its cable tray in a range of materials with a variety of finishes. The selection of material and finish is a function of the environment in which the cable tray will be installed and the application for which it will be used.

ALUMINUM

Aluminum offers a number of advantages when used to fabricate cable tray. It is lightweight, naturally corrosion resistant in a wide range of environments, and easily formable (Appendices II and III). Aluminum's exceptional corrosion resistance, particularly its resistance to atmospheric agents, is due to a thin, continuous natural oxide film (alumina) that protects its surface.

Numerous aluminum alloys have been developed to meet different needs. Some of these are more mechanically resistant than structural steel.

ABB uses 5000 and 6000 series aluminum alloys (Aluminum Association designation) to manufacture cable tray. The alloys are selected for their mechanical properties, such as strength and hardness, as well as for their resistance to corrosion, particularly stress corrosion, cracking, and pitting corrosion.

Aluminum can be painted for esthetic reasons or for specific applications.

FIBERGLASS

Non-metallic fiberglass cable tray is manufactured using a pultrusion process that uses polyester resin or vinyl ester. This type of cable tray is designed to provide resistance comparable to steel but with a higher resistance-to-weight ratio (Appendix III). It provides good corrosion resistance in many corrosive environments. Non-metallic fiberglass cable tray is nonconductive, nonmagnetic and fire resistant.

STAINLESS STEEL

Stainless steel is a steel alloy with a high percentage of chromium (over 10.5%) and less than 1.2% carbon. The chromium content results in a fine protective layer on the surface, which makes the steel remarkably resistant to corrosion (Appendix III). This layer of chromium oxide, invisible and inert, is chemically bound to the surface and naturally reforms.

Stainless steel cable tray is manufactured using AISI 316L (U.S.) grade stainless steel. The various components are fabricated by temper rolling before being welded, which increases their mechanical resistance.

Alloy 316L is an austenitic stainless steel containing nickel, an element that improves many steel properties, including corrosion resistance and formability. The alloy also contains molybdenum. This component enhances the stainless steel's corrosion resistance (Appendix III), especially where chlorides are present, and its mechanical resistance at high temperatures (Appendix II).

This alloy's low carbon content reduces the risk of intergranular corrosion from chromium carbide precipitation during welding.

STEEL

In addition to stainless steel cable tray, ABB offers steel cable tray with pre-galvanized and hot-dip galvanized finishes. Hardware and some fittings are manufactured of electrogalvanized steel.

About galvanization

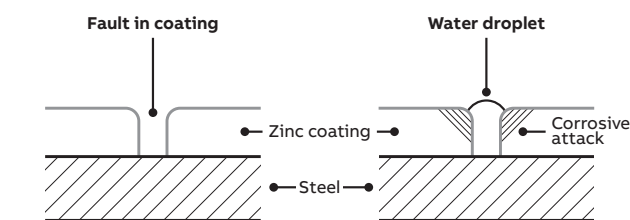
Galvanization is an economical and effective way to protect steel against corrosion. In this process, the steel is covered with a thin coating of zinc.

Zinc, like any metal, naturally oxidizes when exposed to air, but at a much slower rate than steel. Zinc provides sacrificial protection, which means that it corrodes while protecting the steel. As shown in Figure 1, small areas of exposed steel, such as cuts, scratches and weld margins, are protected by the by-products of zinc corrosion around these areas.

Zinc oxide is the product of a reaction between the galvanized coating and oxygen in the air. In wet environments, this oxide is converted over time to zinc carbonate, which forms a highly adherent, relatively insoluble layer. This protective layer or patina is primarily how galvanization protects against corrosion. In a given environment, the corrosion resistance of galvanized products is a linear function of the thickness of the zinc coating. The thickness varies according to the galvanization process used. ABB uses electrolytic (electrogalvanization) processes and hot-dip galvanization in the manufacture of its steel cable trays.

Table 1 shows the different galvanization processes, the associated ASTM International standard and the typical thickness of the zinc coating. As shown, hot-dip galvanization offers the most protection.

Figure 1.
The by-products of zinc corrosion provide sacrificial protection



Source : Anochrome Group

Table 1.
Thicknesses of galvanized coatings

Process	ASTM SPECIFICATION	Zinc coating (typical valuesw, one side)			
		oz/ft ²	mils	g/m ²	µm
Pre-galvanization	ASTM A653/M G90/Z275	0.45	0.8	137	19
Hot-dip galvanization (after fabrication)	ASTM A123 Gr. 65	1.50	2.6	460	65
Electrogalvanization	ASTM B633 SC2		0.3		8

Materials and finishes

ABB manufactures its cable tray in a range of materials with a variety of finishes. The selection of material and finish is a function of the environment in which the cable tray will be installed and the application for which it will be used.

Pre-galvanized steel

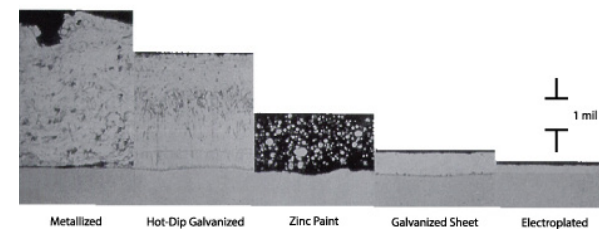
When galvanization takes place prior to the manufacture of finished goods, the steel is referred to as pre-galvanized steel or simply, galvanized sheet.

The zinc coating on pre-galvanized steel is applied in the rolling mill, where the steel coil is continuously passed through a molten zinc bath after various pre-treatment steps. The coil is then split again to make narrower coils or sheets that are used to make the finished product.

The continuous galvanization process creates a shiny, smooth gray surface of almost pure zinc with a minimum of zinc alloy sub-layers.

This coating is thin and not as hard as that achieved with hot-dip galvanization (Figure 2). As such, it is less resistant to abrasion damage.

Figure 2.
Micrograph of coating thickness showing the difference in coating thickness between hot-dip galvanization and pre-galvanization



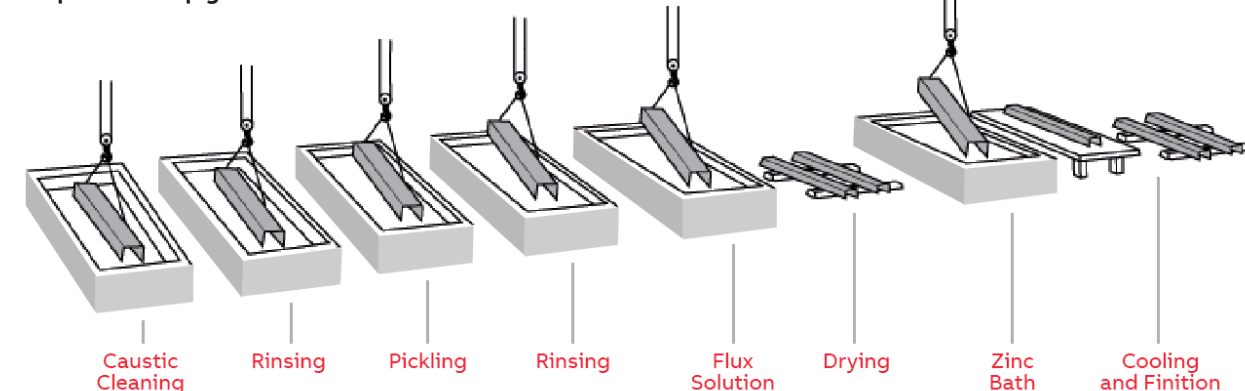
Source : American Galvanizers Association

Hot-dip galvanized steel

Hot-dip galvanization consists of binding zinc to steel by immersing the parts in a molten zinc bath after fabrication, coating all surfaces, including edges, holes and welds. Figure 3 illustrates the many steps involved in this process.

As shown in Figure 4, hot-dip galvanization creates a highly durable coating of an iron-zinc compound that consists of four sub-layers, three of which are stronger than the base steel.

Figure 3.
Steps in hot-dip galvanization

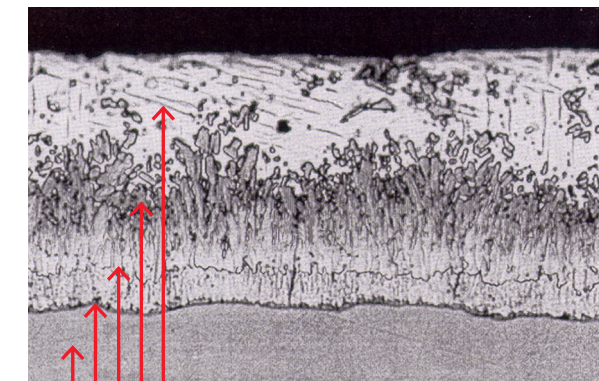


Source : American Galvanizers Association

Since galvanization occurs after the fabrication steps are completed, the entire product, including joints and welds, is coated with zinc. The resulting surface is a dull silvery-gray color.

When compared with pre-galvanized steel, hot-dip galvanized steel products more than triple the service life of products in a range of environments.

Figure 4.
Photomicrograph of the coating achieved with hot-dip galvanization



- **Eta**
(100% Zn) 70 DPN Hardness
- **Zeta**
(94% Zn, 6% Fe) 179 DPN Hardness
- **Delta**
(90% Zn, 10% Fe) 244 DPN Hardness
- **Gamma**
(75% Zn, 25% Fe) 250 DPN Hardness
- **Base Steel**
159 DPN Hardness

Source : American Galvanizers Association 2015

Electrogalvanized steel

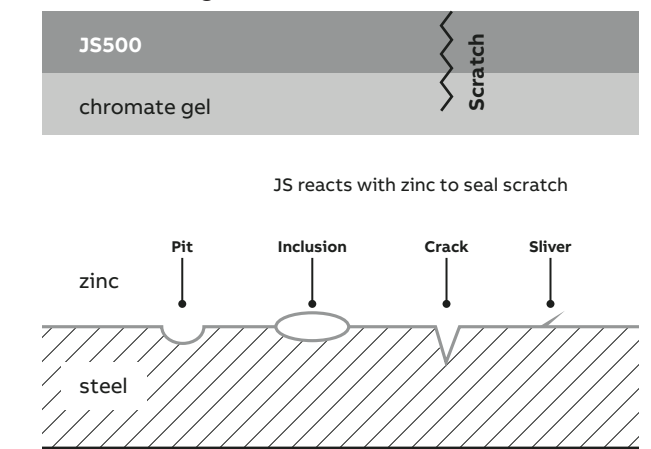
Electrogalvanization is primarily used to protect fittings and small steel parts. In this process, steel is galvanized through electrolysis in an alkaline solution.

After electrolysis, the parts are generally dipped in a passivation bath to form a layer of zinc chromate referred to as the conversion coating. Passivation considerably increases the zinc protection and gives the part its iridescent silvery-yellow color. The protective effect of these zinc chromate coatings depends on their thickness.

Dark coatings are generally more corrosion resistant than light coatings. However, because pigments can be added to the alkaline solution, color cannot be the basis for determining which process was used. In the past, passivation used hexavalent chromium, a controlled compound under the European Union's RoHS (Restriction of Hazardous Substances) directive, REACH (Registration, Evaluation, Authorisation, and Restriction of Chemicals) regulations and other initiatives intended to limit the use of hazardous substances. The industry is gradually replacing hexavalent chromium with trivalent chromium.

For certain hardware, ABB uses Leland Industries' JS500® coating. As illustrated in Figure 5, this treatment uses an outer layer as a sealant to delay zinc oxidation. JS500® coating is RoHS compliant.

Figure 5.
Leland Industries JS500® coating



Source: Leland Industries

Materials and finishes

ABB manufactures its cable tray in a range of materials with a variety of finishes. The selection of material and finish is a function of the environment in which the cable tray will be installed and the application for which it will be used.

Electrogalvanized steel

Table 2 lists important features and performance information for coatings commonly used for fittings and small metal parts.

Table 2.
Characteristics of coatings commonly used for fittings and small metal parts

Coating	Color	Corrosion resistance Salt spray (hours) ¹	Maximum temp. of use (°C)	Electrical conductivity	Mechanical resistance	Notes
Light trivalent zinc	Silvery	8w96r	120	Good	Good	—
Zinc chromate ²	Yellow	72w144r	60	Good	Good	—
JS500 ³	Silvery	96w500r	120	Average	Good	—
Light trivalent zinc-nickel	Matte silvery	360w600r	150	Good	Good	Can be used on aluminum
Tin-plated	Silvery	—	120	Very good	Average	Frequently used on aluminum
E-coat	Black	240r	180	Insulating	Average	

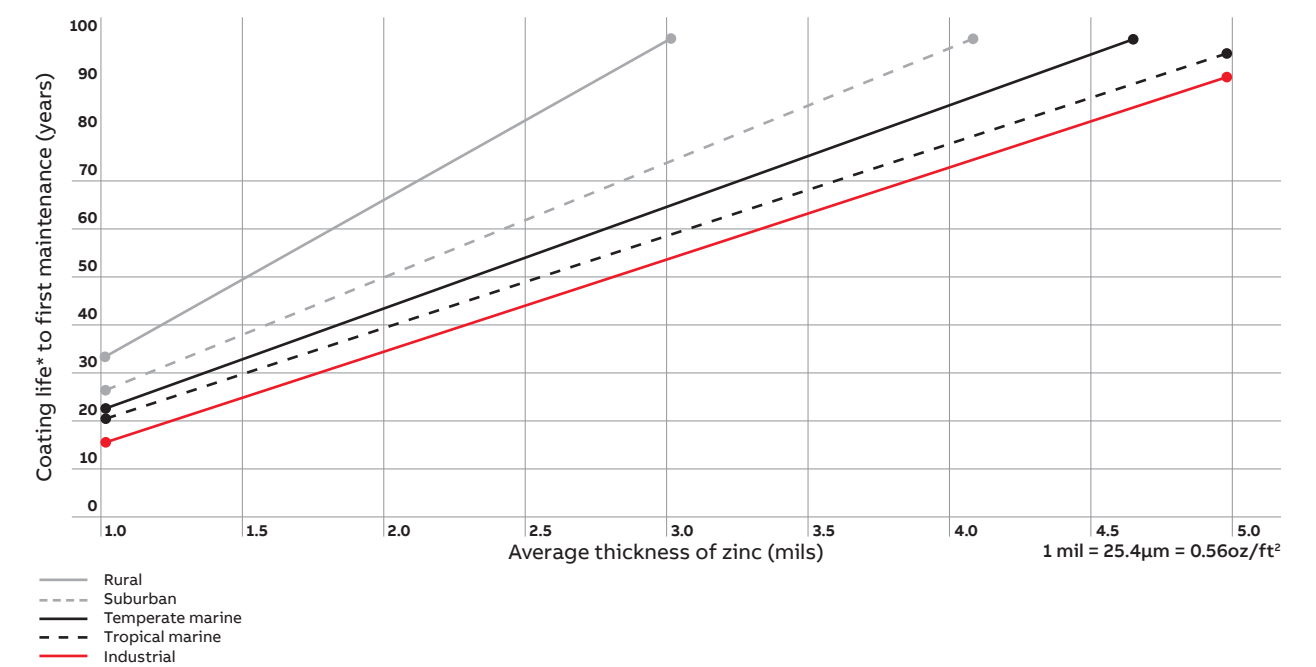
Source : Adapted from a document by Groupe Anachrome

¹w = White rust (zinc oxidation) ; r = Red rust (steel oxidation)
² = Contains 180 mg of hexavalent chromium per square meter

Longevity of galvanized coatings

The American Galvanizers Association publishes a chart showing the durability of galvanized surfaces by thickness of zinc coating in various environments (Figure 6). A similar chart (Figure 7) appears in ISO 14713 (Zinc Coatings – Guidelines and Recommendations for the Protection against Corrosion of Iron and Steel in Structures).

Figure 6.
Coating life to first maintenance for galvanized coatings in various environments



* Time to first maintenance is defined as the time to 5% rusting of the steel surface.

Source : American Galvanizers Association

Materials and finishes

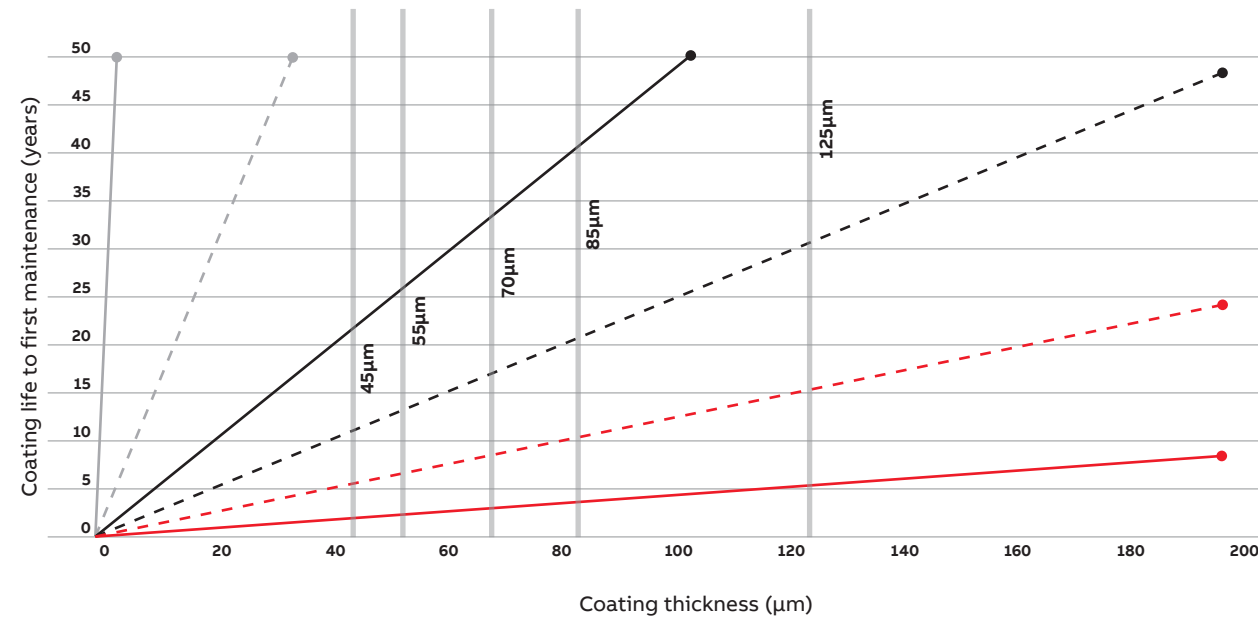
ABB manufactures its cable tray in a range of materials with a variety of finishes. The selection of material and finish is a function of the environment in which the cable tray will be installed and the application for which it will be used.

Longevity of galvanized coatings

The rate of zinc corrosion is influenced by the environmental conditions specific to the site, such as air salinity, humidity and the presence of airborne contaminants (especially sulfur dioxide) (Figure 6).

Figure 7 (reproduced from the ISO standard) relates coating life to coating thickness for a variety of corrosion environments. The various categories of corrosion environment represented in Figure 7 are explained in Table 3. The environments apply to steel exposed to ambient temperatures below 120°C (248°F).

Figure 7.
Coating life to first maintenance for hot-dip galvanized steel



Source : ISO 9223 and ISO 14713 standards

Table 3.
Corrosion categories from ISO 12944

Corrosion category	Interior	Exterior
C1 - Very low	Heated spaces with low relative humidity and low pollution levels (e.g., offices, schools, museums)	Dry or cold area, very little atmospheric pollution and very short periods of humidity (e.g., certain deserts, central Arctic/Antarctic areas)
C2 - Low	Unheated spaces with variable temperature and relative humidity. Infrequent condensation and low pollution levels (e.g., warehouses, sports facilities)	Temperate area, low level of atmospheric pollution (SO ₂ < 5 µg/m ³) (e.g., rural areas; small towns; dry or cold areas; atmospheric environment with short periods of humidity, such as deserts and subarctic regions)
C3 - Moderate	Spaces with a moderate frequency of condensation and moderate pollution from production processes (e.g., agri-food plants, laundries, breweries, dairies)	Temperate area, moderately polluted atmospheric environment (SO ₂ = 5 to 30 µg/m ³) or with certain chloride effects (e.g., urban areas, coastal areas with low chloride deposits). Tropical and subtropical areas, low levels of atmospheric pollution
C4 - High	Spaces with a high frequency of condensation and severe pollution from production processes (e.g., industrial processing plants, pools)	Temperate area, highly polluted atmospheric environment (SO ₂ = 30 to 90 µg/m ³) or substantial chloride effects (e.g., polluted urban areas, industrial areas, coastal areas without seawater projections, exposure to the powerful effects of de-icing salts). Tropical and subtropical areas, moderate levels of atmospheric pollution
C5 - Very high	Spaces with a very high frequency of condensation and/or very high levels of pollution from production processes (e.g., mining, unventilated hangars in tropical and subtropical areas)	Temperate and subtropical areas, highly polluted atmospheric environment (SO ₂ = 90 to 250 µg/m ³) and/or significant chloride effects (e.g., industrial areas, coastal areas, protected coastal locations)
CX - Extreme	Spaces with almost permanent condensation or extended periods of exposure to the extreme effects of humidity and/or high levels of pollution from production processes (e.g., unventilated hangars in humid tropical areas with extreme pollution penetration, including airborne chlorides and particulate matter that fosters corrosion)	Tropical and subtropical areas (very long periods of humidity on surfaces), highly polluted atmospheric environment (SO ₂ > 250 µg/m ³) including secondary or primary factors and/or significant chloride effects (e.g., extreme industrial areas, coastal and offshore areas, occasional contact with salt mists)

Note : These data are published for general information only. For more information, consult the ISO 9223 and ISO 14713 standards.

Source : ISO 9223 and ISO 14713 standards

Materials and finishes

ABB manufactures its cable tray in a range of materials with a variety of finishes. The selection of material and finish is a function of the environment in which the cable tray will be installed and the application for which it will be used.

Zinc whiskers

Zinc whiskers are tiny filaments that form, under certain conditions, on galvanized metal surfaces. Internal stresses in the coating, such as those induced by certain plating processes, appear to be the reason that these metal filaments form. Figure 8 illustrates zinc whiskers.

Figure 8. Zinc whiskers



Zinc whiskers can become airborne and create short circuits or trigger strong electrical arcing in electronic and electrical circuits.

Table 4 shows the different types of coatings and their associated relative risk of zinc whisker formation.

The potential for zinc whisker formation and associated risks should be carefully assessed when specifying cable tray materials, finishes and coatings. Data center environments, for example, are especially vulnerable to the short circuits that can potentially be caused by zinc whiskers.

Table 4. Relative risk of zinc whiskers from various coatings

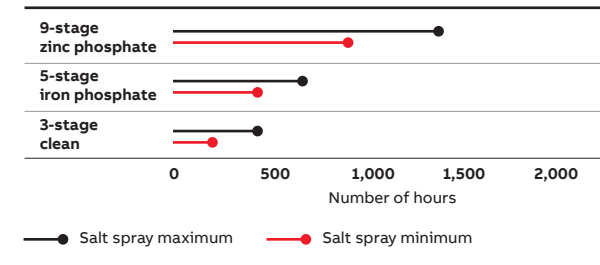
Coating	Relative risk of zinc whiskers
Electrogalvanization	++++
Pre-galvanization	++++
Hot-dip galvanization (after fabrication)	++
Paint coating	++
Nickel plating	Nil
Stainless steel	Nil

PAINT

Paint can be used on bare steel, galvanized steel, aluminum and stainless steel. However, it should be noted that paint may interfere with certain practices and electrical regulations or requirements, in particular the need to maintain electrical conductivity at cable tray junction points. In some instances, it may be necessary to remove paint from certain surfaces of factory-painted cable trays.

A powder-paint coating provides corrosion resistance, the longevity of which depends to a large degree on surface preparation. A nine-step process that includes zinc phosphate can provide over 1500 hours of resistance to salt spray when tested according to ASTM B117. Figure 9 illustrates the typical number of hours of corrosion resistance provided by a variety of powder-paint coatings.

Figure 9. Typical corrosion resistance provided by powder-paint coatings



Epoxy and polyester paint coatings

Epoxy and polyester paint coatings are used for esthetic purposes and to protect metal surfaces against corrosion. First, a paint coating is applied in a thermo-lacquering process. After several steps of surface preparation, a fine thermo-hardening resin powder is sprayed on the part, then polymerized with heat. The resulting surface is very hard and adhesive. This process does not use any solvents.

ABB offers epoxy and polyester paint coatings in a wide range of colors. Table 5 shows the primary characteristics of these products. Other types of paint coatings are also available.

Table 5. Characteristic of epoxy and polyester paint coatings

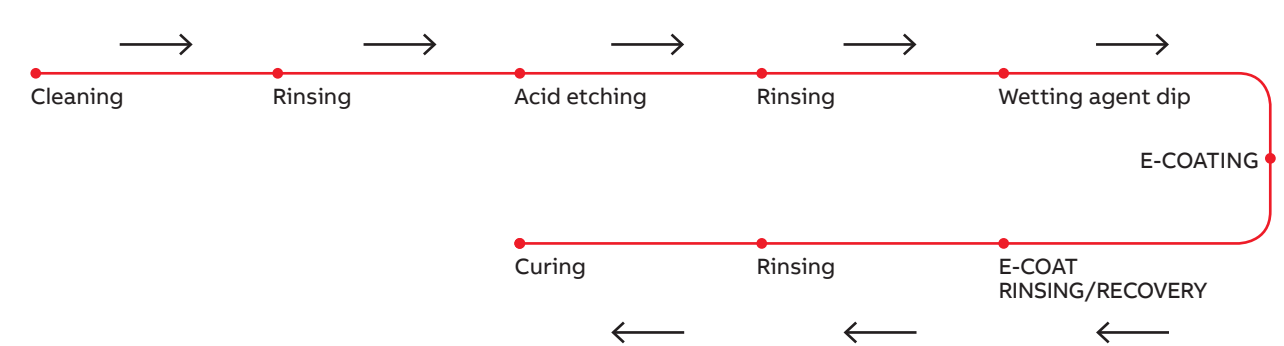
Characteristic	Type of paint	
	Epoxy	Polyester
Hardness	Excellent	Good
UV (ultraviolet) stability	Poor	Excellent
Protection against corrosion	Excellent	Very good
Chemical resistance	Excellent	Good

Paint on galvanized steel (duplex system)

Galvanized steel is mainly painted for esthetic reasons or to extend the life of products, particularly in harsh environments. Unlike bare steel, where there is a chemical bond between the steel and the phosphate treatment prior to painting, mechanical adherence is the mechanism at play when galvanized steel is painted. Sanding is required before painting.

Combining galvanization and painting extends the protection. Because the paint protects the galvanized surface and the galvanization protects the paint against corrosion by the underlying steel, this synergizing effect extends the duration of the protection longer than the sum of each coating separately.

Figure 10. Typical steps in an e-coating process



E-coating

Electrophoretic lacquering, or e-coating, is a paint process whereby a metal part is immersed in a water-based solution containing a paint emulsion. An electric voltage is applied to the part, causing the paint emulsion to condense onto the part. The process is illustrated in Figure 10.

This process covers the entire surface of the part, including sharp edges, with a thin coating of paint, such that threading can be painted.

Materials and finishes

ABB manufactures its cable tray in a range of materials with a variety of finishes. The selection of material and finish is a function of the environment in which the cable tray will be installed and the application for which it will be used.

CORROSION

Three types of corrosion are discussed below:

- Galvanic corrosion
- Atmospheric corrosion
- Chemical corrosion

In addition, corrosion resistance guides are provided in Appendix III.

Galvanic corrosion

Galvanic corrosion is the result of a chemical reaction arising from the contact of different metals in the presence of an electrolyte (a conducting liquid containing ions, such as water). Under these conditions, the least precious metal becomes anodic and more vulnerable to corrosion, while the more precious metal becomes cathodic and is protected.

The scope of the reaction depends on several factors, such as the electrical conductivity of the electrolyte, the relative size of the elements in contact and the potential difference between the metals.

Figure 11 shows the electropotential of metals with respect to a reference electrode, as determined under standardized experimental conditions.

The electropotential of metals can be measured in different water solutions and listed in galvanic series, as in Table 6. There is little risk of galvanic corrosion when the potential difference is less than 0.3 V in a damp, high-salinity environments or less than 0.5 V in a moderately damp inside environment.

Table 6 is used to assess the risk of corrosion. The deciding factor is the potential difference under actual operating conditions. Empirical tables of galvanic series have been created for typical environments such as salt water.

Figure 11.
The electropotential of metals can be measured in different water solutions and listed in galvanic series

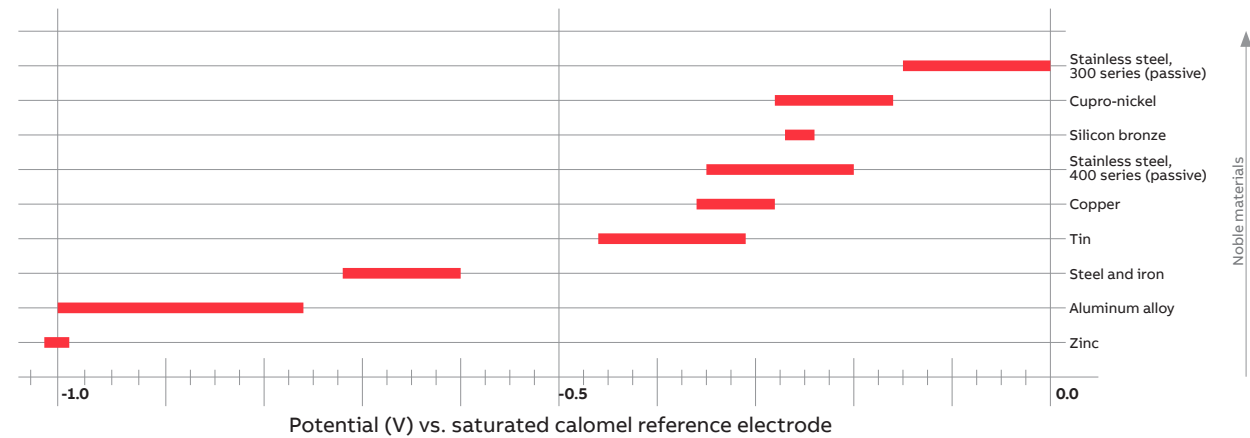


Table 6.
Galvanic series (selected materials)

Anodic	Potential (volts)
Stainless steel, 300 series (passive)	-0.00 to -0.15
Cupro-nickel	-0.16 to -0.28
Silicon bronze	-0.24 to -0.27
Stainless steel, 400 series (passive)	-0.20 to -0.35
Copper	-0.28 to -0.36
Tin	-0.31 to -0.46
Steel and iron	-0.60 to -0.72
Aluminum alloy	-0.76 to -1.00
Zinc	-0.98 to -1.03

Table 7 illustrates the compatibility of various hardware materials with base metals.

Table 7.
Compatibility of hardware materials with base metals

Base metal	Hardware material and plating				
	Zinc-coated steel	Aluminum alloy	Carbon steel	Copper alloy	Stainless steel (300 series)
Galvanized steel	1	2	2	3	3
Aluminum alloy	1	1	2	3	2
Carbonic steel and iron	1,4	1	1	3	2
Stainless steel (300 series)	1,4,5	1,5	1,5	1,5	1

- 1 Corrosion of the base metal is not increased by the fasteners.
- 2 Corrosion of the base metal is marginally increased by the fasteners.
- 3 Corrosion of the base metal may be markedly increased by the fasteners.
- 4 Coating of the fastener is rapidly consumed, leaving the bare metal exposed.
- 5 Corrosion of the fastener is increased by the base metal.

- Compatible metals
- Corrosion is accelerated by the combination of metals
- Corrosion is considerably accelerated by the combination of metals

Materials and finishes

ABB manufactures its cable tray in a range of materials with a variety of finishes. The selection of material and finish is a function of the environment in which the cable tray will be installed and the application for which it will be used.

Atmospheric corrosion

Atmospheric corrosion of metals is caused by air salinity, humidity and airborne chemical compounds. The Longevity of galvanized coatings section on page 13 of this document provides information on this type of corrosion.

Chemical corrosion

Chemical corrosion is caused by airborne chemical contaminants. The level of corrosion depends on the concentration of contaminants, the temperature and the duration of contact. Refer to the corrosion resistance guides in Appendix III of this document.

Wet storage stains

Wet storage stains are white or gray deposits formed by accelerated corrosion of aluminum or a zinc coating when items are tightly wrapped in damp and poorly ventilated conditions. In most cases, these stains are not a sign of serious deterioration of the surface or coating.

RECOMMENDED CABLE TRAY MATERIALS AND FINISHES

Table 8 summarizes the various materials and finishes available for ABB cable tray and recommendations for suitable environments.

Table 8.
Recommended cable tray materials and finishes

Markets	Recommended materials and finishes							
	EG1	PG2	HDG3	ALU4	SS316L5	FG6	EP7	PP8
Chemical processing	
Civil infrastructure
Commercial & institutional facilities	
Food & beverage			
Metals & mining			
Oil & gas				
Marine (offshore)		
Power generation			
Pulp & paper			
Renewable energy				
Wastewater treatment			

1 EG = Electrogalvanized steel
2 PG = Pre-galvanized steel
3 HDG = Hot-dip galvanized steel (after fabrication)

4 ALU = Aluminum alloy
5 SS316L = Stainless steel type 316L
6 FG = Fiberglass

7 EP = Epoxy paint
8 PP = Polyester paint

... Best
.. Can be used
. Avoid

Cable tray installation

This section brings together a range of information related to cable tray installation. It is designed to be a reference tool for general information related to installation, rather than a comprehensive installation guide. For detailed instructions, refer to the installation guide provided with the product.

COMMONLY USED TOOLS

The following tools are commonly used for the installation of cable tray systems: metal cutting saw, grinder, touch-up material (including sealant for fiberglass), screwdriver, drill and drill bits, files, adjustable wrench, leveling device, tape measure, square, clamps, torque wrench, socket wrench and sockets, offset bolt cutter (for cutting wire mesh tray), carbide- or diamond-tipped saw for cutting fiberglass, appropriate safety equipment (including dust mask for fiberglass).

DEFLECTION

Deflection is a measure of how much a cable tray bends under a load. The deflection of cable tray is proportional to the applied load. For example, if the applied load is doubled, the deflection will also be doubled. The position and type of load will also affect the amount of deflection. A point load will increase the deflection of a cable tray more than a uniformly distributed load of the same weight. If designing a system with a point load at mid-span, assume that the deflection will be twice that from the same load applied as a uniformly distributed load.

If deflection is an important factor, some ways to reduce it are to:

- Reduce the distance between supports
- Use a cable tray with a higher load rating
- Reduce the loading

SUPPORTS

When anchoring supports for cable tray, it is extremely important to avoid cutting or drilling into structural building components, such as I-beams, unless approval has been given by the general contractor or project leader on site.

In designing supports for a cable tray system, consideration should be given to the loads associated with future cable additions and any additional loading that may be applied to the cable tray system (e.g., point load, snow, ice, wind).

Additional supports may also be required for extreme-temperature applications or when seismic bracing is required.

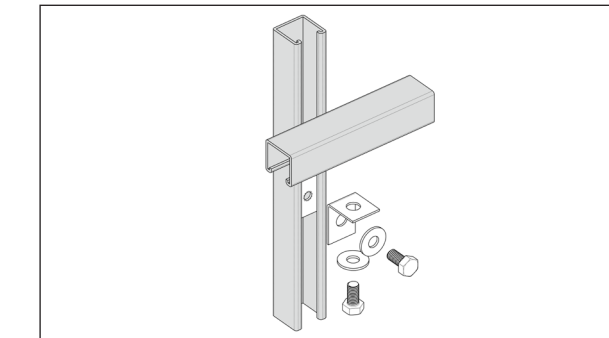
CHANNEL NUTS

Channel nuts are commonly used for cable tray support systems. There are two safe working load ratings for channel nuts: slip and pull-out. To achieve the designated slip and pull-out ratings, all connections should be made using clean, dry components, and the channel nuts should be tightened to the manufacturer's recommended torque value.

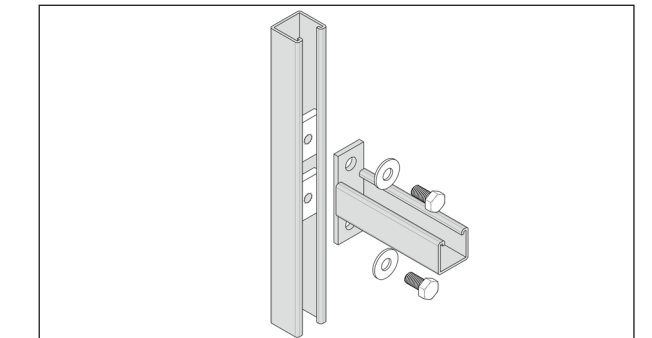
BRACKETS

Framework brackets are generally used to aid in the onsite fabrication of support structures. Some typical configurations are shown in Figure 12.

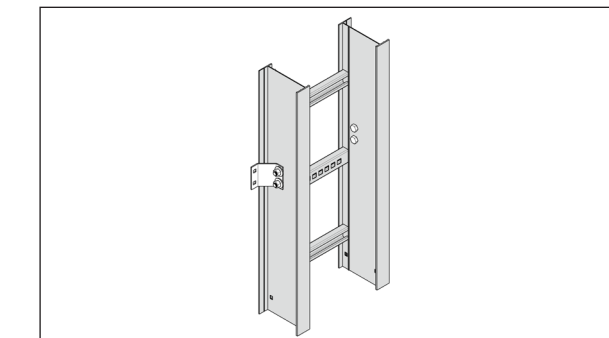
Figure 12.
Typical configurations of framework brackets



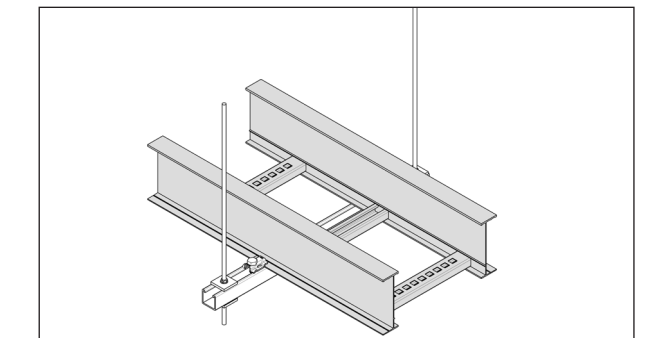
Use of brackets with channels



Cantilever arms



Vertical installation on a wall



Trapeze

Cable tray installation

This section brings together a range of information related to cable tray installation. It is designed to be a reference tool for general information related to installation, rather than a comprehensive installation guide. For detailed instructions, refer to the installation guide provided with the product.

FLOOR AND ROOFTOP APPLICATIONS

Cable tray should not be installed directly on the surface of a floor or roof. Instead, it should be mounted far enough off the floor or roof to allow the cables to exit through the bottom of the tray. If a channel support is used for this purpose, mount the channel directly to the floor or roof and attach the cable tray to the channel using the hardware recommended by the manufacturer.

CABLE TRAY LENGTH

Cable tray length is selected based on the load to be supported, the distance between the supports (also referred to as the span), and handling and installation constraints.

For a given load, the greater the distance between supports, the more robust the cable tray will need to be and the more expensive it will be. When supports are costly, it is generally more cost-effective to choose long-span cable tray to limit the number of supports required.

For cable tray, load is usually expressed as weight per unit length: pounds per foot (lb/ft) or kilograms per meter (kg/m).

It is strongly recommended not to use more than one splice plate between two supports (Figure 13). To comply with this recommendation, select cable tray that is at least as long as the distance between the supports.

Cable tray that is longer than the maximum authorized span may be used to reduce the number of junctions and installation time. For example, a NEMA 12B-designated cable tray, with a maximum allowable span of 12 feet (3.7 meters), could be ordered in 20-foot (6.1-meter) lengths. The product label would remain Class NEMA 12B.

ONSITE REPAIRS

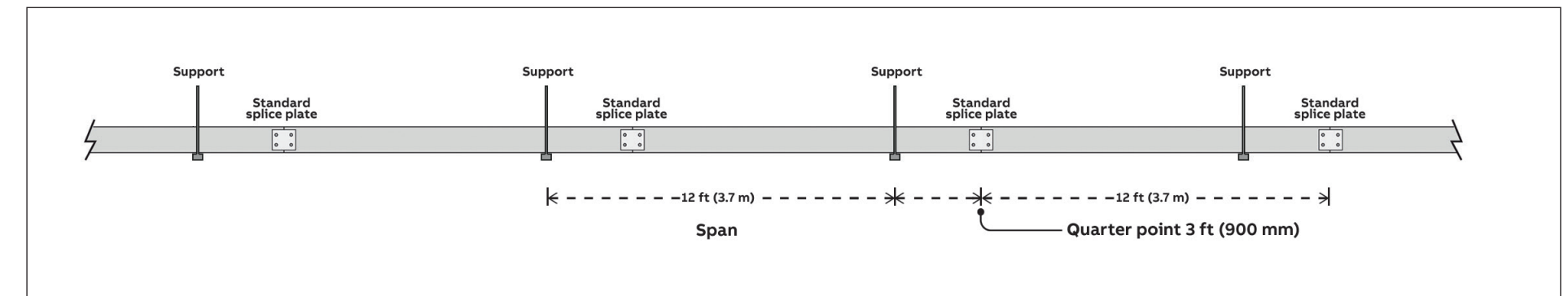
Cable tray that has been hot-dip galvanized after manufacturing needs to be repaired after cutting. Cable tray made from mill-galvanized steel does not need to be repaired.

Repairs to galvanized finishes must be done using a zinc-rich paint or an equivalent touch-up product. Other protective coatings, such as paint, that are cut or damaged on site must be repaired using compatible coatings.

POSITIONING OF SPLICE PLATES

Straight-section joints should be positioned at the quarter-point of the span to minimize stresses on splice plates and to minimize deflection. Figure 13 shows the ideal positioning of splice plates for a 12-foot (3.7 meters) cable tray length supported at 12-foot (3.7 meters) intervals (12-foot span).

Figure 13.
Ideal positioning of splice plates for a 12-foot (3.7 meters) cable tray length supported at 12-foot (3.7 meters) intervals



Cable tray installation

This section brings together a range of information related to cable tray installation. It is designed to be a reference tool for general information related to installation, rather than a comprehensive installation guide. For detailed instructions, refer to the installation guide provided with the product.

POSITIONING OF SPLICE PLATES

ABB offers a range of splice plates to provide many options for the positioning of joints (Table 9).

Table 9.
ABB Application products options for splice plates

Type of splice plate	ABB catalogue number	Application
Regular aluminum splice plate	ABW7SSP, ABW6SSP ABW5SSP, ABW4SSP	For aluminum cable tray with a span of up to 20 feet (6 m). Positioned at the quarter-point of the span.
Regular steel splice plate	S*W7SSP, S*W6SSP S*W5SSP, S*W4SSP S*W3SSP	For steel cable tray with a span of up to 20 feet (6 m). Positioned at the quarter-point of the span.
Heavy-duty aluminum splice plate	AL-7-SSPHD AL-6-SSPHD	For aluminum cable tray with a span of up to 30 feet (9 m). Positioned at the quarter-point of the span.
Aluminum expansion splice plate	ABW7ESP, ABW6ESP ABW5ESP, ABW4ESP	For aluminum cable tray. Allows for 1 inch expansion or contraction of the cable tray.
Steel expansion splice plate	S*W7ESP, S*W6ESP S*W5ESP, S*W4ESP	For steel cable tray. Allows for 1 inch expansion or contraction of the cable tray.
Super-Duty Splice Plate™ – aluminum	ABW6SDP	For expansion joints at the quarter-point of the span (without additional support) or for joints at mid-span. For aluminum cable tray.
Super-Duty Splice Plate™ – steel	S*W7SDP, S*W6SDP S*W5SDP, S*W4SDP	For expansion joints at the quarter-point of the span (without additional support) or for joints at mid-span. For steel cable tray.
Over-support splice adaptor	ABW46-OSS-B ABW46-OSS-S	For expansion joints located over a support. For aluminum cable tray.

THERMAL EXPANSION JOINTS

Thermal expansion and contraction should be considered when designing and installing a cable tray system. Seasonal and other temperature variations can put stress on the cable tray installation and its supporting structure. The length of the straight cable tray run and the temperature differential between seasonal highs and seasonal lows determine the maximum spacing between expansion splices (Table 10). Splice positioning at the quarter-point of the span also applies to thermal expansion joints. An expansion splice requires more supports than a static splice unless special splice plates are used.

Effect of thermal expansion on cables

Thermal expansion and contraction also affects cables and should be taken into consideration. It is advisable to allow some extra cable length, such as a loop or partial bend, at expansion joint positions.

Procedure to calculate the gap setting for an expansion splice plate

This procedure refers to Figure 14.

- On the vertical axis on the right, locate the lowest metal temperature on low temperature line.
- On the vertical axis on the left, locate the highest metal temperature on high temperature line.

- Draw a diagonal line connecting these two points.
- On the vertical axis on the left, locate installation temperature and draw a horizontal line from that point that connects to A-B.
- From the diagonal line, draw a vertical to the horizontal axis.
- The final point will give you the required gap setting at the time of installation. In this situation the gap is 9.5mm.

Figure 14.
Recommended gap setting of expansion splice plate

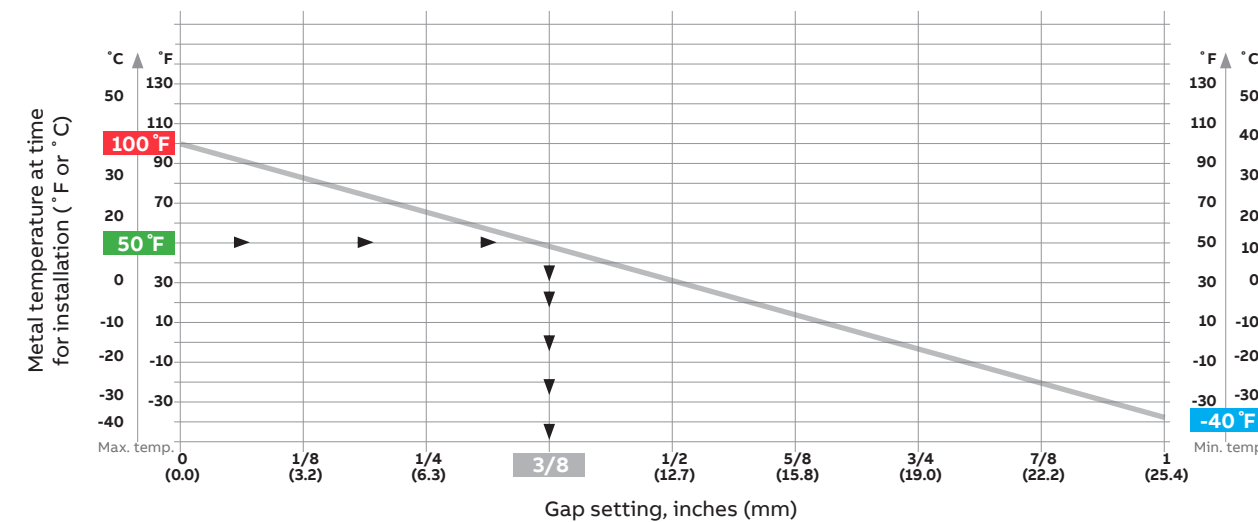


Table 10.
Maximum spacing between expansion joints*

Temperature differential	316 Stainless steel		Steel		Aluminum		
	°C	°F	m	feet	m	feet	
14	25	115	379	156	512	79	260
28	50	58	189	78	256	40	130
42	75	38	126	52	171	27	87
56	100	29	95	39	128	20	65
70	125	23	76	31	102	16	52
83	150	19	63	26	85	13	43
97	175	16	54	22	73	11	37

* That provide for 1 inch (25.4 mm) of movement.

Cable tray installation

This section brings together a range of information related to cable tray installation. It is designed to be a reference tool for general information related to installation, rather than a comprehensive installation guide. For detailed instructions, refer to the installation guide provided with the product.

NEMA recommendation and ABB alternatives

NEMA's recommended positioning for expansion joints and supports is illustrated in Figure 15. Note that NEMA recommends the installation of an extra support on either side of the expansion splice plate in addition to the supports located at quarter span.

ABB offers two alternatives to reduce the number of supports normally required for a thermal expansion joint.

Alternative #1 - Over-support splice adaptor

This alternative uses an expansion joint above the support, and uses an over-support splice adaptor (Figure 16). The over-support splice adaptor was originally designed for modular aluminum assemblies. It allows supports to be placed right under the joints with no additional supports required.

Alternative #2 - Super-Duty Splice Plate™

This alternative uses an expansion joint at the quarter-span with a Super-Duty Splice Plate (Figure 17). The Super-Duty Splice Plate eliminates the need for additional supports on either side of expansion joints.

For installation instructions, refer to Appendix IV of this document.

Figure 15.
NEMA recommendation for positioning of expansion joints and supports

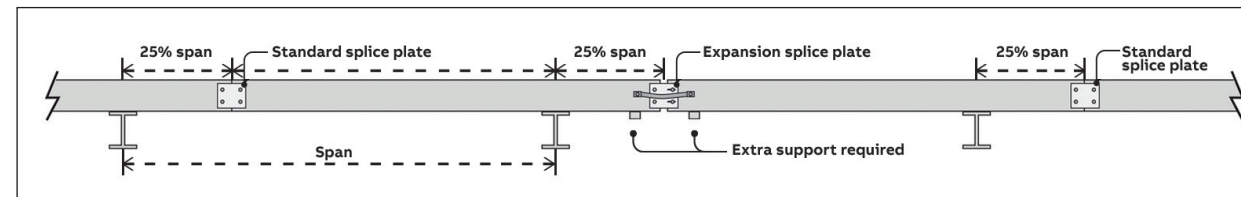


Figure 16.
ABB alternative #1: Expansion joint above the support, with an over-support splice adaptor

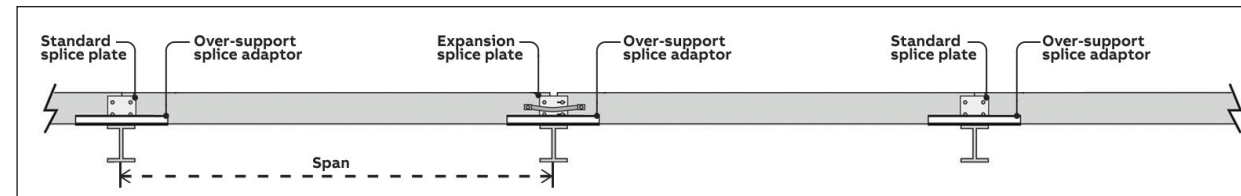
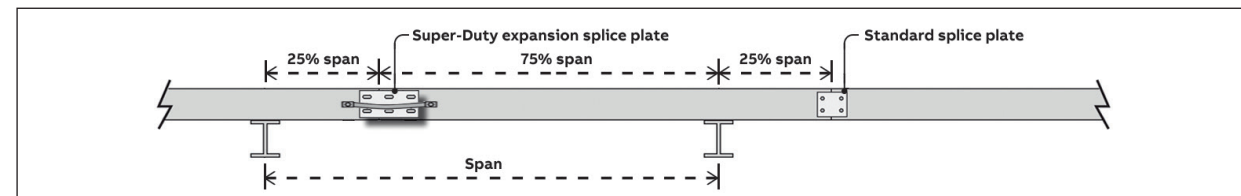


Figure 17.
ABB alternative #2: Expansion joint at the quarter-span with a Super-Duty Splice Plate™



FITTINGS

General recommendations for fitting supports can be found in NEMA VE 2 – Cable Tray Installation Guidelines.

A number of ABB cable tray fittings are robust enough to permit alternatives to the position and number of supports recommended in NEMA VE 2 without compromising safety. These alternatives can significantly reduce material and labor costs.

Horizontal fittings

Horizontal fittings may comprise elbows, tees or crosses. For each of these three types of horizontal fitting, Figure 18 shows three installation methods:

- NEMA VE 2 recommendation: Dedicated fitting support and supports at 24 inches (600 mm) from the splice
- ABB alternative #1: Maintain dedicated fitting support and extend support distance to a maximum of 10 feet (3.0 meters) from the splice

- ABB alternative #2: Eliminate the dedicated fitting support and maintain supports at 24 inches (600 mm) from the splic

These alternatives use the regular splice plates supplied with the cable tray and have been extensively tested. The alternatives apply to the following fittings only:

- Fittings with a 6-inch (150 mm) side rail
- Fittings with a maximum bend radius of 36 inches (900 mm)

Table 11.
Maximum allowable load rating for 6 in. side rail horizontal fittings

		ABB Alternative #1	ABB Alternative #2
		Radius 36 in max. (900 mm)	Radius 36 in max. (900 mm)
Horizontal elbows	AHF	165 lb/ft (245 kg/m) (a)	121 lb/ft (180 kg/m) (b)
	AUF	90 lb/ft (134 kg/m) (c)	90 lb/ft (134 kg/m) (c)
	SPF, SHF, SSF	145 lb/ft (216 kg/m) (d)	135 lb/ft (201 kg/m) (d)
Horizontal tees	AHF	165 lb/ft* (245 kg/m) (a)	150 lb/ft* (223 kg/m) (b)
	AUF	121 lb/ft (180 kg/m) (c)	80 lb/ft (119 kg/m) (c)
	SPF, SHF, SSF	152 lb/ft (226 kg/m) (d)	116 lb/ft (173 kg/m) (d)
Horizontal crosses	AHF	200 lb/ft* (297 kg/m) (a)	140 lb/ft* (208 kg/m) (b)
	AUF	175 lb/ft (260 kg/m) (c)	84 lb/ft (125 kg/m) (c)
	SPF, SHF, SSF	180 lb/ft (268 kg/m) (d)	133 lb/ft (198 kg/m) (d)

(a) Applicable for use with straight section series up to AH66
 (b) Applicable for use with straight section series up to AH56
 (c) Applicable for use with straight section series up to AH36
 (d) Applicable for use with straight section series up to 46

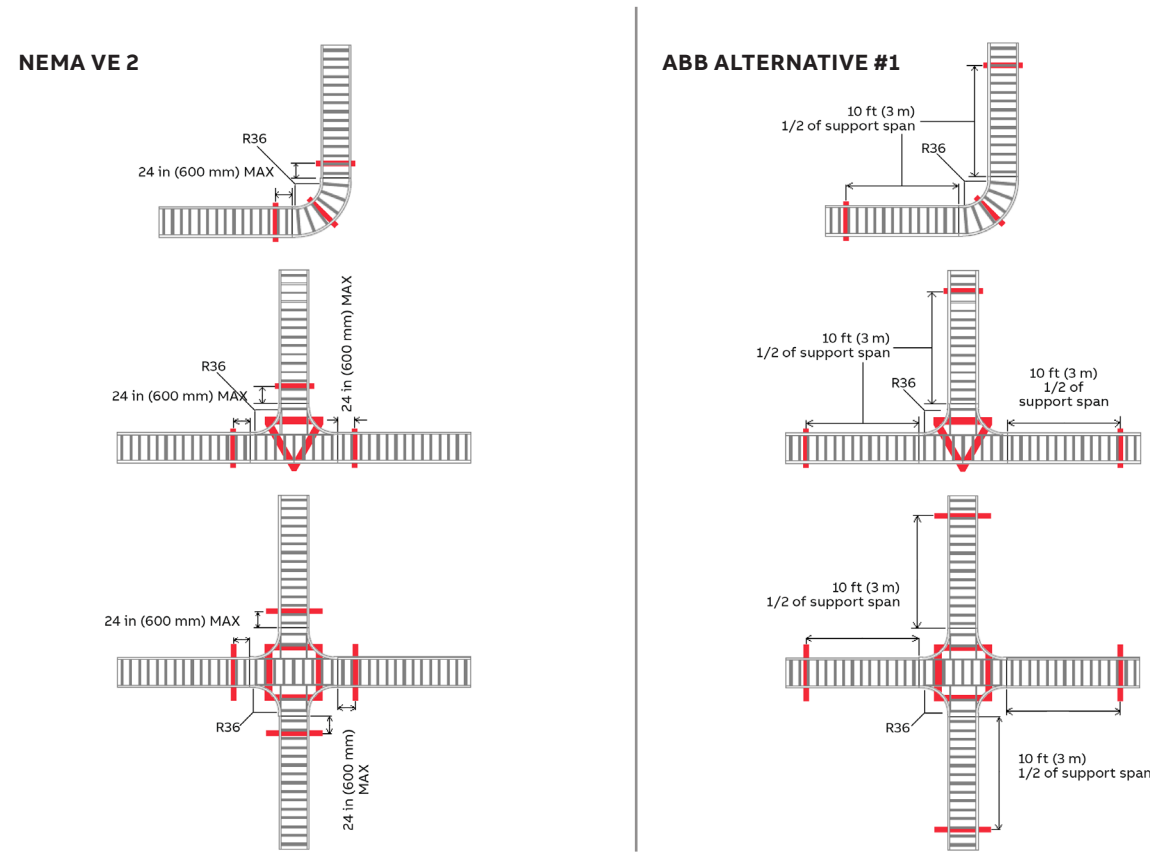
*This load rating applies to fittings manufactured on or after April 20, 2020. Please check the date code stamped on the fitting label. For a fitting manufactured before that date, please get in touch with an ABB sales representative to validate the load rating.

Cable tray installation

This section brings together a range of information related to cable tray installation. It is designed to be a reference tool for general information related to installation, rather than a comprehensive installation guide. For detailed instructions, refer to the installation guide provided with the product.

Horizontal fittings

Figure 18.
ABB alternatives to NEMA recommendations for horizontal fittings



* Refer to Table 11

Vertical fittings

Vertical fittings comprise inside and outside elbows. For each of these two types of vertical fitting, Figure 19 shows two installation methods:

NEMA VE 2 recommendation
Elbows at the top of runs are supported at both ends. At the bottom of a run, an elbow is supported at the top and within 24 inches (600 mm) of the lower end.

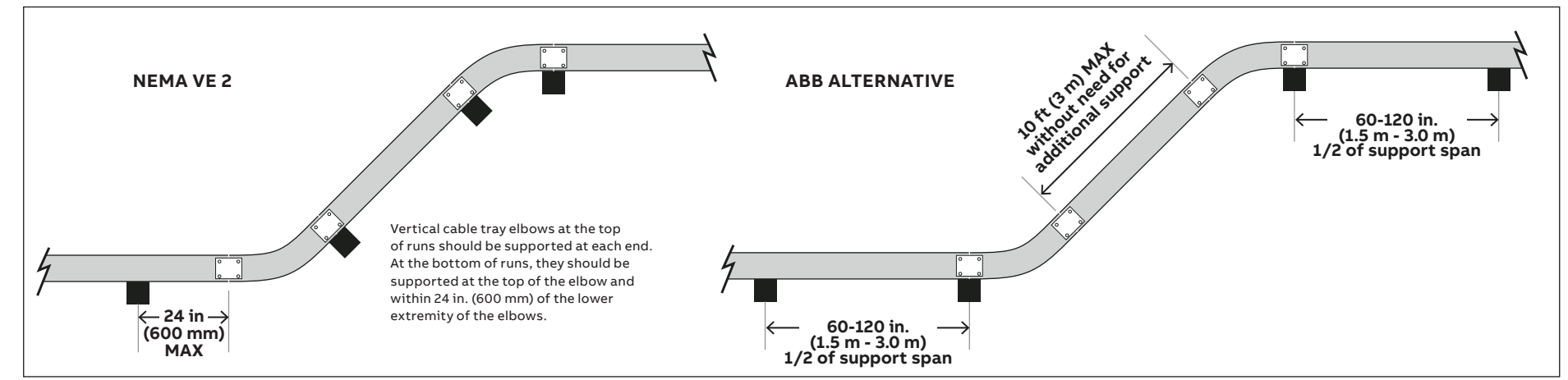
ABB alternative
Extend support distance to a maximum of 10 feet (3.0 meters) from the splice. Install a dedicated fitting support at the mid-point of fittings.

Radius of cable tray fittings

The radius for cable tray fittings is normally determined by the bend radius and rigidity of the cables installed in the tray. The cable manufacturer will typically recommend a minimum bend allowance for each type of cable.

The radius of the cable tray fitting should be equal to or greater than the minimum bend radius of the largest cable installed.

Figure 19.
ABB alternatives to NEMA recommendations for vertical elbows



Cable tray installation

This section brings together a range of information related to cable tray installation. It is designed to be a reference tool for general information related to installation, rather than a comprehensive installation guide. For detailed instructions, refer to the installation guide provided with the product.

DIVIDERS

Dividers are used to physically separate different types or groups of cable within one cable tray.

FASTENING CABLES TO CABLE TRAYS

To prevent movement of the cables under normal use and during fault conditions, cables may be fastened to the cable tray using cable clamps, cable cleats or cable ties. Where fastening is desired or required, details should be obtained from the electrical installation designer and/or the supplier of the fastenings. Cable cleats and cable ties should be correctly sized and should be tightened enough to secure the cable without indenting the insulation sheath.

On vertical runs, the fastenings must be able to withstand the force exerted by the weight of the cable. The cable weight should be supported in such a manner as to prevent damage to the cable tray and cable.

COVERS

Covers provide mechanical and environmental protection for cables being carried by cable tray. They can be ventilated or solid and should be installed in accordance with the manufacturer's instructions.

DATA CABLES

Because data cables are delicate, cable ties used to attach cables to tray must not be over-tightened. Any cable within a tied bundle must be movable through the tie with minimal resistance. To prevent the tie from cutting into the cable sheathing, the cable tie must not be too narrow.

Where power and data cables are installed within the same containment system or within close proximity to each other, a barrier strip or other appropriate divider should be used.



National Electric Code and Canadian Electrical Code

The following section contains excerpts from and interpretations of various National Electrical Code (NEC) and Canadian Electrical Code (CEC) rules related to cable tray installation. Section references (shown in square brackets) are to the NEC except for material shown in **gray**, which is from the CEC.

PERMITTED USES [392.10]

The use of cable tray is not limited to industrial establishments.

Cable tray can be used to support service conductors, feeders, branch circuits, communications circuits, control circuits and signaling circuits.

Cables that are exposed to direct sunlight must be identified as being UV resistant.

Cable tray installed under a floor can be used to support communication cables in air-handling areas. [300.22(D)], [800.52(D)]

Wiring methods [392.10(A)]

This section refers to NEC sections that set out the rules for using various types of 300 and 600 V cables (medium voltage). In all cases where the NEC permits the use of a specific cable type, a cable tray can be used to support that cable, even in hazardous locations (covered in Chapter 5 of the NEC).

Conductors used in cable tray must be specified in Table 19 of the CEC and, except where permitted under paragraphs [12-2202(2)] and [(3)], covered by a continuous metal sheath or an interlocking armor.

Industrial establishments [392.10(B)]

Single-conductor cables can be installed in cable tray only at qualified establishments.

Any of the cables specified in sections [392.10(B)(1)] and [(B)(2)] can be installed in ladder, ventilated and solid tray as well as channel tray.

[392.10(B)(1)(a)] Single-conductor cables must be 1/0 AWG or larger and identified with a marking indicating suitability for use in cable tray. When 1/0 through 4/0 AWG single-conductor cables are installed in ladder tray, the maximum allowable rung spacing must not exceed 9 inches (230 mm).

[392.10(B)(1)(b)] Welding cables must be supported at a maximum interval of 6 inches (150 mm). The cable tray must be permanently marked "CABLE TRAY FOR WELDING ONLY."

[392.10(B)(1)(c)] Single-conductor cables used as grounding conductors for equipment can be insulated, covered or bare. They must be a minimum of 4 AWG.

[392.10(B)(2)] Single- and multi-conductor medium-voltage cables must be Type MV and meet the requirements of section [392.10(B)(1)].

Hazardous locations [392.10(C)]

Cable tray installed in a hazardous location must contain only those cables that are appropriate for this type of environment as defined in Chapter 5 of the NEC.

Nonmetallic cable tray [392.10(D)]

Section [392.10(D)] authorizes the use of non-metallic cable tray in corrosive environments or when there is a risk associated with electrical conductivity of the cable tray.

This is not intended as a complete overview of code related to cable tray. For complete details, please refer to the NEC or CEC standards.

USES NOT PERMITTED [392.12]

Cable tray containing electrical conductors must not contain any other non-electrical services, such as pipes containing air or steam, for example. [300.8]

Cable tray must not be used in hoistways (e.g., elevator shafts) or in areas where there is a risk of significant damage.

CABLE TRAY INSTALLATION [392.18]

Continuous system [392.18(A)]

Cable tray is considered to be a system. It must provide continuous support for cables, and the electrical continuity of the cable tray system must be maintained.

Mechanical discontinuity is allowed between cable tray runs or between cable tray runs and equipment. A bonding jumper must provide electrical continuity in all cases.

Completed before installation [392.18(B)]

Each cable tray run must be completed before cables are installed.

Covers [392.18(C)]

The material for both cover and cable tray must be compatible.

Through partitions and walls [392.18(D)]

Cable tray can pass through partitions, walls, ceilings and floors, as long as provisions to prevent the spread of smoke and fire have been made, as specified in section [300.21]. There are many ways to seal penetration areas in walls and ceilings.

The choice of method should be discussed with a local inspector. The best decision may be to extend only the cables, creating a discontinuity in the cable tray.

The CEC does not allow cable tray to pass through walls unless they are built with non-combustible materials [12-2200(3)]. Cable tray may extend vertically through floors in dry areas, if the areas are equipped with firewalls and if the cable tray is completely closed where it passes through the floor. Cable tray must also be protected, between the floor and a height of at least 6.6 feet (2.0 meters) against any mechanical damage [12-2200(4)].

National Electric Code and Canadian Electrical Code

The following section contains excerpts from and interpretations of various National Electrical Code (NEC) and Canadian Electrical Code (CEC) rules related to cable tray installation. Section references (shown in square brackets) are to the NEC except for material shown in **gray**, which is from the CEC.

CABLE TRAY INSTALLATION [392.18]

Visible and accessible [392.18(E)]

Cable tray must be installed in such a way that it can be removed or exposed without damaging the building structure or finishes. It should not be permanently enclosed in the building's structure or finishes. Cable tray must be installed on the surface, mounted on a surface or installed behind panels designed to allow cable tray access.

Exceptions are set out in section [392.10(D)].

Adequate access [392.18(F)]

Sufficient space must be maintained around cable tray to allow adequate access for cable installation and maintenance.

Minimum clearance [12-2200(6)]

- **Stacked cable tray:**
6 inches (150 mm) vertically, but 12 inches (300 mm) clearance if cables 2 inches (50 mm) in diameter or larger may be installed in the trays
- **Ceiling, conduit or heating apparatus:**
12 inches (300 mm), or 6 inches (150 mm) for compact-length obstacles
- **Sides:**
24 inches (600 mm) on one side, or 24 inches (600 mm) on both sides if the width of the cable tray is greater than 39 inches (1.0 meters)

Raceway, cables, boxes and conduit bodies supported by cable tray systems [392.18(G)]

In industrial facilities where maintenance and supervision conditions ensure that only qualified persons service the installation, cable tray can be used to support raceway, cables and conduit covered in section [314.1].

Channel tray that ends at cable tray must be securely fastened to the tray using a certified clamp or adaptor to ensure a proper connection. Refer to the appropriate sections of the NEC for details on how to mount and support a raceway or cable below or beside a cable tray.

Refer to section [314.23] for details on how to mount and support a box or conduit below or beside a cable tray.

Markings [392.18(H)]

Cable tray containing conductors over 600 V must have a permanent warning notice saying "DANGER—HIGH VOLTAGE—KEEP AWAY" placed in a highly visible position. This warning must appear on all cable tray sections at intervals of no more than 10 feet (3.0 meters). Marking requirements are covered in section [110.21(B)]. The installer is responsible for obtaining and applying these markings.

CABLE AND CONDUCTOR INSTALLATION [392.20]

Multi-conductor cables operating at 600 V or less can be installed in the same cable tray. [392.20(A)] Cables over 600 V must be separated from lower-voltage cables by a separator made of a material compatible with the cable tray. This separator is not required if the cables over 600 V are Type MC. [392.20(B)]

Parallel connections [392.20(C)]

Where single-conductor cables comprising each phase, neutral or grounded conductor of an alternating-current circuit are connected in parallel, the conductors shall be installed in groups consisting of not more than one conductor per phase, neutral or grounded conductor to prevent current imbalance in the paralleled conductors due to inductive reactance.

Single conductors must be securely bound in circuit groups to prevent excessive movement due to fault-current magnetic forces, unless single conductors are cabled together, as in triplexed assemblies.

Single conductors [392.20(D)]

When 1/0 to 4/0 AWG single conductors are installed in ladder or ventilated cable tray, these conductors must be installed in a single layer. Conductors that are grouped in a triplex assembly do not need to be installed in a single layer.

Refer to Table 11 to match conductor type and size with filling rules and NEC references.

National Electric Code and Canadian Electrical Code

The following section contains excerpts from and interpretations of various National Electrical Code (NEC) and Canadian Electrical Code (CEC) rules related to cable tray installation. Section references (shown in square brackets) are to the NEC except for material shown in **gray**, which is from the CEC.

CABLE AND CONDUCTOR INSTALLATION [392.20]

Table 12.
Number of allowances conductors or cables [392.22]

Multi-conductor cables, rated 2000V or lower			
Conductors	Bottom type	Rule	NEC Section
4/0 AWG or larger	Ladder or ventilated	$W \geq S_d$; 1 layer	392.22(A)(1)a
	Solid	$W \geq 0.9S_d$; 1 layer	392.22(A)(3)a
Less than 4/0 AWG	Ladder or ventilated	$W \geq 0.855 S_A$	392.22(A)(1)b
	Solid	$W \geq 1.091 S_A$ $W \geq 1.125 S_A$	392.22(A)(3)b
Mixed: 4/0 AWG or larger with less than 4/0 AWG	Ladder or ventilated	$W \geq 6/7 (S_A + 1.2 S_d)$; 1 layer for 4/0 AWG or larger cables	392.22(A)(1)c
	Solid	$W \geq 12/11 (S_A + S_d)$; 1 layer for 4/0 AWG or larger cables	392.22(A)(3)c
Control and/or signaling cables	Ladder or ventilated	$W \geq 2 S_A / H$	392.22(A)(2)
	Solid	$W \geq 2.5 S_A / H$	392.22(A)(4)
Multi-conductor cable	Ventilated raceway	$W = 3 A_2 \leq 2.3 \text{ in}^2$ $W = 4 A_2 \leq 4.5 \text{ in}^2$ $W = 6 A_2 \leq 7.0 \text{ in}^2$	392.22(A)(5)a
	Solid raceway	$W = 2 A_2 \leq 1.3 \text{ in}^2$ $W = 3 A_2 \leq 2.0 \text{ in}^2$ $W = 4 A_2 \leq 3.7 \text{ in}^2$ $W = 6 A_2 \leq 5.5 \text{ in}^2$	392.22(A)(6)a
Several multi-conductor cables	Ventilated raceway	$W = 3 S_{A2} \leq 1.3 \text{ in}^2$ $W = 4 S_{A2} \leq 2.5 \text{ in}^2$ $W = 6 S_{A2} \leq 3.8 \text{ in}^2$	392.22(A)(5)b
	Solid raceway	$W = 2 S_{A2} \leq 0.8 \text{ in}^2$ $W = 3 S_{A2} \leq 1.1 \text{ in}^2$ $W = 4 S_{A2} \leq 2.1 \text{ in}^2$ $W = 6 S_{A2} \leq 3.2 \text{ in}^2$	392.22(A)(6)b

Single-conductor cables, rated 2000V or lower			
Conductors	Bottom type	Rule1	NEC Section
1000 kcmil or larger	Ladder or ventilated	$W \geq S_{d1}$; 1 layer unless bound together (in which case more than one layer is permitted)	392.22(B)(1)a
250 kcmil to 900 kcmil	Ladder or ventilated	$W \geq 12/13 S_{A1}$ $W \geq 18/19 S_{A1}$ for $W = 9$ inches	392.22(B)(1)b
Mixed: 1000 kcmil or larger with less than 1000 kcmil	Ladder or ventilated	$W \geq 12/13 (S_{A1} + 1.1 S_{d1})$ $W \geq 18/19 (S_{A1} + 1.1 S_{d1})$	392.22(B)(1)c
1/0 to 4/0 AWG	Ladder or ventilated	$W \geq S_{d2}$	392.22(B)(1)d

MV- and MC-type cables, rated 2001 V or higher			
Conductors	Rule1	NEC Section	
Multi-conductor cables and single-conductor cables	$W \geq S_{d3}$; 1 layer $W \geq S_{d4}$; 1 layer (bound) Where the single conductors have 3 or 4 twisted or bound conductors	392.22(C)	

Note:

W = inner width of cable tray (6, 9, 12, 18, 24, 30 or 36 inches) (150, 230, 300, 450, 600, 750 or 900 mm).

S_A = sum of the cross-sectional areas for multi-conductors smaller than 4/0 AWG.

S_{A1} = sum of the cross-sectional areas for single conductors smaller than 1000 kcmil.

S_{A2} = sum of the cross-sectional areas for single conductors in a raceway.

A_2 = cross-sectional area of a single conductor in a raceway.

S_d = sum of the diameters for 4/0 AWG or larger multi-conductors.

S_{d1} = sum of the diameters for 1000 kcmil or larger single conductors.

S_{d2} = sum of the diameters for 1/0 to 4/0 AWG single conductors.

S_{d3} = sum of the diameters for Type MV and MC cables.

S_{d4} = sum of the diameters for Type MV and MC single conductors.

H = usable height for cables. When greater than 6 inches (150 mm), use 6 inches (150 mm). Single conductors of 2000 V or less must be distributed evenly over the width of the cable tray.

National Electric Code and Canadian Electrical Code

The following section contains excerpts from and interpretations of various National Electrical Code (NEC) and Canadian Electrical Code (CEC) rules related to cable tray installation. Section references (shown in square brackets) are to the NEC except for material shown in **gray**, which is from the CEC.

SECURING AND SUPPORTING [392.30]

Cable tray [392.30(A)]

Cable tray must be supported in accordance with installation instructions (refer to NEMA VE 2).

In a horizontal run, there is no need to secure the multi-conductor cables to the cable tray. Cable clamp should be used to maintain spacing between cables when required or to prevent movement in seismic- or vibration-prone locations. [392.30(A)]

Cable trays must be supported with fire-resistant supports [12-2200(5)].

Horizontal runs [392.30(B)]

There is no need to fasten multi-conductors to the cable tray unless (1) there is a risk of wear due to rubbing of cable sheaths, (2) a space between the cables must be maintained or (3) the cables must be positioned in a specific location in the cable tray.

Non-horizontal runs [392.30(B)(1)]

Multi-conductors measuring less than 1 inch (25 mm) in diameter should be fastened to the rungs at intervals no greater than 4 inches (100 mm). Type MC or TC multi-conductors measuring 1 inch (25 mm) or more in diameter should be fastened to the rungs every 6 feet (1.8 meters). Metal cable clamps are recommended. The use of nylon cable ties should be avoided for power cables.

Supports shall be provided to prevent stress on cables where they enter raceways from cable tray systems. [392.30(B)(2)]

Where individual cables connect one cable tray to another cable tray, to raceway or to equipment, the distance between the cable trays, between the cable tray and raceway, or between the cable tray and equipment must not exceed 6 feet (1.8 meters). The cables must be secured to the cable tray at the point of transition and must be protected from damage. [392.22(B)(3)]

Single conductors must be fastened to prevent excessive movement due to fault-current magnetic forces [12-2202(4)]. Where single conductors are fastened to cable tray, precautions must be taken to prevent overheating of the fasteners due to induction. [12-2202(5)]

BUSHED CONDUIT AND TUBING [392.46]

The use of a conduit-cable clamp is recommended to connect a cable or conductor to cable tray from a conduit. A junction box is not required.

CABLE SPLICES [392.56] [12-2204]

Cable splices are allowed within a cable tray provided they are insulated and accessible.

Connections to other wiring must be completed in such a way as to prevent mechanical damage to the conductors and to ensure effective bonding. [12-2206]

GROUNDING AND BONDING [392.60]

Metal cable tray [392.60(A)]

All metal cable tray supporting electrical cables must be grounded as described in section [250.96] of the NEC.

Where metal supports for cable tray are bolted to the tray and are in good electrical contact with the grounded structural metal frame of a building, the tray is deemed to be bonded to ground [12-2208(1)].

If paragraph [12-2208(1)] above does not apply, the cable tray must be grounded at intervals not to exceed 50 feet (15 meters) (Figure 20), and the size of the bonding conductors must be established based on the permitted current of the largest non-grounded conductor in the cable tray, in accordance with section 10-814. [12-2208(2)]

Cable tray sections must be connected using approved bolted splice plates, a grounding conductor or a bonding jumper. Bonding jumpers or grounding conductors are required at specific locations such as expansion joints, certain adjustable plates and mechanical discontinuities. Refer to Table 250.122 of the NEC to determine the size of the bonding jumper or grounding conductor required. The minimum size is 10 AWG for cable tray sections that do not contain power cables. The maximum length for mechanical discontinuities between cable trays is 6 feet (1.8 meters).

There are three ways to carry out a grounding connection for equipment in a cable tray installation:

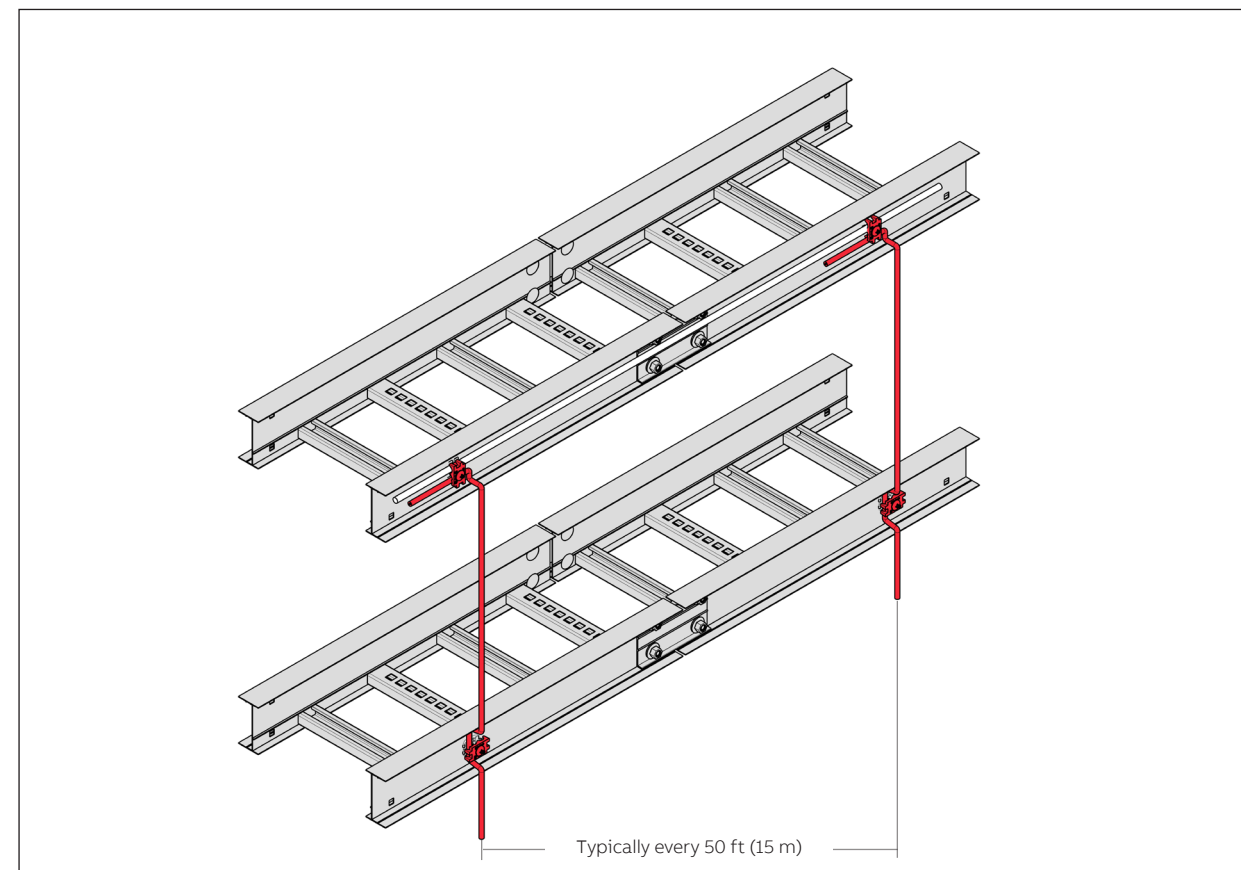
- A grounding conductor for equipment is installed on the cable tray
- The cable tray is used as grounding for the equipment
- Each multi-conductor has a grounding conductor

National Electric Code and Canadian Electrical Code

The following section contains excerpts from and interpretations of various National Electrical Code (NEC) and Canadian Electrical Code (CEC) rules related to cable tray installation. Section references (shown in square brackets) are to the NEC except for material shown in **gray**, which is from the CEC.

GROUNDING AND BONDING [392.60]

Figure 20.
Example of grounding every 50 feet (15 meters) pursuant to [12-2208(2)]



Use of a grounding conductor on cable tray

When a grounding conductor is installed on a cable tray, it is recommended that it be electrically connected to each section of the cable tray using a certified connector.

The use of a bare copper conductor on an aluminum cable tray is prohibited because of the potential for galvanic corrosion. A good practice is to use a tin-plated or galvanized connector and to remove the conductor sheath at the splices.

Use of steel or aluminum cable tray as grounding conductors for equipment [392.22(B)]

Steel or aluminum cable tray can be used as equipment-grounding conductors at qualified establishments. The minimum area required is listed in Table [392.60(A)] of the NEC. This is the combined total area of both side rails for ladder cable tray or the minimum cross-sectional area for one-piece tray or channel tray.

When the cable tray is used as an equipment-grounding conductor, there is no need for a grounding cable in the cable tray or a grounding conductor in the cables.

AMPACITY OF CONDUCTORS [392.80]

Cables rated 2000 V or less, in cable trays

[392.80(A)] – Multi-conductor cables [392.80(A)(1)]
The adjustment factors of Table [310.15(B)(3)(a)] apply only to multi-conductor cables with more than three current-carrying conductors and not to the number of conductors in the cable tray. [392.80(A)(1)(a)]

Where multi-conductor cables are installed in a single layer in uncovered trays, with a maintained spacing of not less than one cable diameter between cables, the ampacity must not exceed the allowable ambient temperature-corrected ampacities of multi-conductor cables, with not more than three insulated conductors rated 0 through 2000 V in free air, in accordance with [310.15(C)].

Combinations of multi-conductor and single-conductor cables [392.80(A)(3)]

Where a cable tray contains a combination of multi-conductor and single-conductor cables, the allowable ampacities must be as given in [392.80(A)(1)] for multi-conductor cables and [392.80(A)(2)] for single-conductor cables, provided that the following conditions apply:

- The sum of the following two amounts totals not more than 100%
 - Multi-conductor cable fill area as a percentage of the allowable fill area for the tray, calculated in accordance with [392.22(A)]
 - Single-conductor cable fill area as a percentage of the allowable fill area for the tray, calculated in accordance with [392.22(B)]
- Multi-conductor cables are installed according to [392.22(A)], and single-conductor cables are installed according to [392.22(B), (C) and (D)]

Table 12 provides information about the allowable ampacity of conductors in various types of cable tray.

National Electric Code and Canadian Electrical Code

The following section contains excerpts from and interpretations of various National Electrical Code (NEC) and Canadian Electrical Code (CEC) rules related to cable tray installation. Section references (shown in square brackets) are to the NEC except for material shown in **gray**, which is from the CEC.

AMPACITY OF CONDUCTORS [392.80]

Table 13.
Ampacity of conductors

Cables	Cable trays	NEC ampacity table	Maximum allowance percentage of the value from ampacity tables (%)
Multi-conductor cables rated 2000 V or lower [392.80](A)(1)			
	Continuous solid cover over more than 6 feet (1.8 meters)	310.15(B)(16) 310.15(B)(18)	95
Single-conductor cables rated 2000 V or lower [392.80](A)(1)			
	No cover	310.15(B)(17)	75
600 kcmil or higher	Continuous solid cover over more than 6 feet (1.8 meters)	310.15(B)(19)	70
	No cover	310.15(B)(17)	65
1/0 AWG to 500 kcmil	Continuous solid cover over more than 6 feet (1.8 meters)	310.15(B)(19)	60
1/0 AWG or larger, in a single layer and spaced at least 1 x external diameter	No cover	Solid bottom 310.15(C)	100
1/0 AWG or larger. Clover-shaped or square layout, spaced at least 2.15 x external diameter of the largest conductor in the group	No cover	310.15(B)(20)	100
Type MV and MC multi-conductor cables, rated 2001 V or higher [392.80](B)			
	Continuous solid cover over more than 6 feet (1.8 meters)	310.60(C)(75) 310.60(C)(76)	95
Installed in a single layer and spaced at least 1 x external diameter	No cover	310.60(C)(71) 310.60(C)(72)	100
Single-conductor cables rated 2001 V or higher [392.80](B)(2)			
	No cover	310.60(C)(69) 310.60(C)(70)	75
1/0 AWG or larger	Continuous solid cover over more than 6 feet (1.8 meters)	310.60(C)(69) 310.60(C)(70)	70
1/0 AWG or larger, in a single layer and spaced at least 1 x external diameter	No cover	310.60(C)(69) 310.60(C)(70)	100
1/0 AWG or larger. Clover-shaped or square layout, spaced at least 2.15 x external diameter of the largest conductor in the group	No cover	310.60(C)(67) 310.60(C)(68)	100

REFERENCES

- Canadian Standards Association. (2015).
 - Canadian Electrical Code, part I: Safety standard for electrical installations (23rd ed.). Standard C22.1-15 (2015). Toronto, ON: CSA Group.
- National Electrical Manufacturers Association. (2004).
 - NEMA FG 1-1993: Fiberglass Cable Tray Systems. NEMA standards publication FG 1-1993. Rosslyn, VA: NEMA.
- National Electrical Manufacturers Association. (2006).
 - NEMA VE 2-2006: Cable Tray Installation Guidelines. NEMA standards publication VE 2-2006. Rosslyn, VA: NEMA.
- National Electrical Manufacturers Association. (2009).
 - NEMA VE 1-2009: Metal Cable Tray Systems. NEMA standards publication VE 1-2009. Canadian Standards Association Publication CSA C22.2 No. 126.1-09. (Joint publication of NEMA and CSA.) Rosslyn, VA: NEMA.
- National Fire Protection Association. (2017). National Electrical Code. ANSI/NFPA 70. Quincy, MA: NFPA.

Appendix I: Conductor sizes

SOLID AND STRANDED CONDUCTORS

A conductor refers to one or more wires encased in an insulated coating. The units used to measure conductor size are AWG (American Wire Gauge) units for small-diameter conductors and kcmil (thousands of circular mils) for large-diameter conductors.

AWG and kcmil both refer to the cross-sectional area of the bare (uninsulated) conductors, which is an important measure of how much current the conductor can safely carry. Conductors can be made from one solid wire or from a number of stranded wires.

Small-diameter conductors may exist in both solid and stranded versions. A solid conductor and a stranded conductor of the same AWG size will have the same current-carrying capacity. However, the stranded conductor will be thicker because of the voids between strands.

Large-diameter conductors are all stranded, because solid wire would be too rigid to bend and therefore difficult to work with. The minimum conductor size used for power and lighting is 14 AWG for copper conductors and 12 AWG for aluminum conductors.

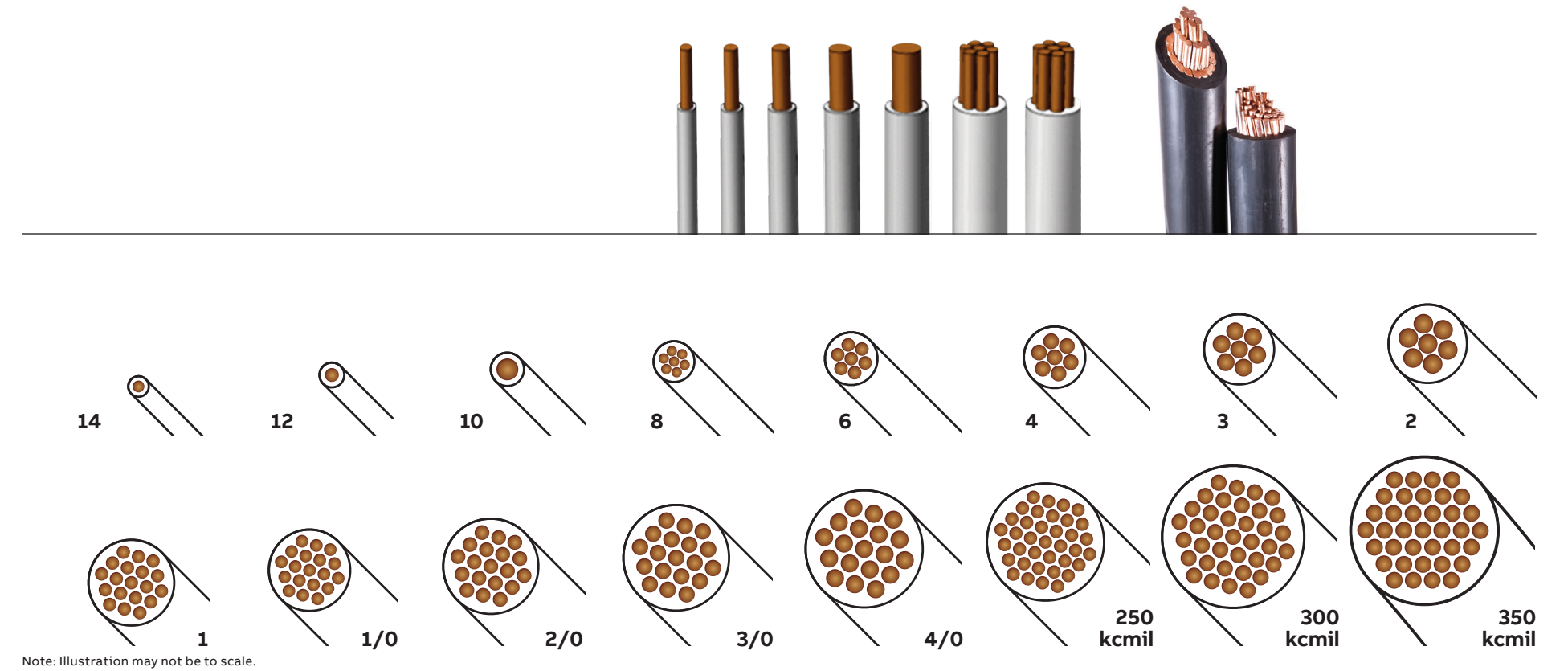
Note that aluminum conductors are slightly larger in diameter, for the same wire gauge. They are generally about two sizes larger. For example, an aluminum conductor of 10 AWG is about the same diameter as a 6 AWG in copper, but they both can carry the same current.

A NOTE ABOUT CONDUCTOR SIZES

American Wire Gauge units are based on measurements of bare (uninsulated) single-strand wire using a wire gauge. For historical reasons, larger AWG numbers denote smaller diameters (Figure AI-1).

One circular mil refers to the area of a circle whose diameter is 1 one-thousandth of one inch (0.001 inch) (0.025 mm). Because a single circular mil is narrow and some wires are thick, it is more practical to measure in thousands of circular mils, or kcmil. Larger kcmil numbers indicate larger diameters (Figure AI-1).

Figure AI-1.
Example of AWG and kcmil wire sizes



Appendix II: Material properties

STAINLESS STEEL

Table AII-1.
Relative mechanical resistance
for AISI 316L stainless steel at elevated temperatures

Temperature		
(°F)	(°C)	Relative ¹ mechanical resistance (%)
68	20	100
400	204	83
600	316	74
800	427	67
1000	538	57
1200	649	50
1400	760	43
1600	871	38

¹ Data are based on the yield strength at 20°C.

ALUMINUM

Table AII-2.
Physical and mechanical properties
of aluminum

Property	Aluminum Association standard			
	6063-T6	6063-T54	6063-T4	5052-H32
Mass density (g/cm ³ at 20°C)	2.68	2.68	2.68	2.68
Young's modulus (GPa at 20°C)	68.9	68.9	68.9	70.3
Yield strength (MPa at 20°C)	214 (min.)	207 (min.)	69 (min.)	193
Thermal expansion coefficient (µm/m/°C)	23.4	23.4	23.4	23.8
Electrical resistivity (MΩ-cm at 20°C)	2.8	2.8	2.8	2.8
Magnetic permeability (at 200 H)	Slightly greater than 1 (very slightly paramagnetic)			
Hardness (Brinell hardness number with 500 kg mass and 10 mm bead)	73	Not available	Unstable	60

Table AII-3.
Relative mechanical resistance
of AA6063-T6 aluminum by temperature

Temperature		
(°F)	(°C)	Relative ¹ mechanical resistance (%)
-112	-80	106
-18	-28	103
75	24	100
212	100	90
300	149	65
400	204	6.5

¹ This data is provided for general information only. It must not be specified as engineering requirements or used for design purposes.

Appendix III: Corrosion resistance guide

ALUMINUM, STEEL AND STAINLESS STEEL

The following table has been compiled as a guide for selecting appropriate cable trays for various industrial environments. The information can only be used as a guide because corrosion processes are dictated by the unique circumstances of any particular assembly.

Corrosion is significantly affected by trace impurities which, at times, can become concentrated through wet/dry cycles in locations that are prone to condensation and evaporation. It is not uncommon to find aggressive mists created from contaminant species, notably from sulfur or halogen sources.

Temperature greatly influences corrosion, sometimes increasing the rate of metal loss, (a rule of thumb guide is that a 30°C change in temperature results in a 10X change in corrosion rate). Sometimes corrosion attack slows down at higher temperatures because oxygen levels in aqueous solutions are lowered as temperatures increase. If an environment completely dries out then there can be no corrosion.

Stress-associated corrosion might occur when assemblies are poorly installed and/or fabricated, e.g., on-site welding or mechanical fastening. Premature failure can result from: corrosion fatigue, which can occur in any environment; stress corrosion cracking, which occurs in the presence of a specific chemical when the metal is under a tensile stress, which may

be residual or applied, (e.g., from poor fabrication or welding); fretting, where two adjacent surfaces (under load) are subjected to an oscillatory motion across the mating surfaces.

Design should minimize the risk of stress concentrations within a structure. Examples include sharp profiles, abrupt section changes, and threaded screws. These measures are particularly important for metals that are prone to stress corrosion cracking in specific media. Design plays a significant role in exacerbating corrosion. Non-draining locations create liquid traps; local metal-to-metal (or metal-to- non-metal) contact points (e.g., mechanical assembly bolts with washers or spacers), permit crevice corrosion and/or galvanic corrosion to occur. Areas that are poorly maintained, (e.g., surfaces are not regularly or properly washed and stubborn deposits remain on the metal surface), are particularly prone to localized corrosion damage due to different levels of oxygen under and adjacent to the location in question (differential aeration). Resulting damage from these situations is in the form of small holes (pits). In each of the examples just quoted there is a restricted supply of oxygen. Thus, metals (e.g., aluminum, stainless steels, zinc) that rely on oxygen to form protective corrosion films (oxides, hydroxides, carbonates, etc.,) may be prone to localized pitting and/or crevice corrosion.

A further example of localized corrosion occurs when dissimilar metals contact each other in the presence of a corrosive, i.e., galvanic corrosion. Each metal will corrode but the one that is most active [anode] can be more corroded especially when there is a large surrounding area of the less active [cathodic] metal. It is wise to avoid small anodic areas. Some examples include: steel bolts [small area of anodic metal] in stainless steel plate, [large area of cathodic metal]; steel bolts in copper plate - the steel corrodes. There can be environmental influences, for example a fluid that contains active metallic species, like copper ion contact with aluminum (copper picked up from aqueous solutions conveyed in copper pipe) - the aluminum corrodes. A further dramatic example is provided when trace quantities of mercury contact aluminum - the aluminum corrodes very rapidly. These are examples of deposit corrosion.

This guide provides an indication of the suitability of a potential candidate material for a specific chemical environment. These tables should be regarded only as a GUIDE to anticipated performance because of possible contributions from temperature, pollutant (contaminant) species, etc.

Chemical species	Aluminum	HDG/ Steel	316SS
Acetaldehyde	++	+	++
Acetic acid - aerated	(+)T,C	X	(++)T
Acetone	++	++	++
Acetylene	++	nd	++
Allyl alcohol	+	nd	++
Aluminum chloride - dry	+	nd	(+)T,P
Aluminum chloride - wet	X	X	(-)P
Aluminum sulfate - satd.	X	nd	+
Ammonia - anhydrous	++	++	++
Ammonia - gas	-	+	(+)T
Ammonium acetate	+	nd	+
Ammonium bicarbonate	-	nd	(+)T
Ammonium carbonate - satd.	+	X	+
Ammonium chloride - 28%	X	X	(+)P,S
Ammonium chloride - 50%	X	X	X
Ammonium hydroxide	+	+	(++)C
Ammonium chloride - 28%	X	X	(+)P,S
Ammonium chloride - 50%	X	X	X
Ammonium hydroxide	+	+	(++)C
Ammonium nitrate	+	X	(++)S
Ammonium phosphate - 40%	X	nd	+
Ammonium sulfate - to 30%	X	-	+
Amyl acetate	++	++	++
Asphalt	++	+	+
Beer	++	X	++

SYMBOLS:

- ++ First choice; very low corrosion rate, typically <5 mpy, or <0.005 inch/year (1 mil = 1/1000 inch)
- + Good choice; low corrosion rate, typically <20 mpy, or <0.02 ipy
- Can use; corrosion rate up to 50 mpy (0.05 ipy); some limitations may apply
- X Not recommended

- (-) Brackets indicate probable limitations, e.g., at higher temperatures [symbol "T"]; at higher concentrations [symbol "C"]; due to pitting [symbol "P"]; due to local grain boundary attack in the metal - intergranular corrosion [symbol "I"]; or due to stress corrosion cracking [symbol "S"]
- nd No available data

Appendix III: Corrosion resistance guide

ALUMINUM, STEEL AND STAINLESS STEEL

Chemical species	Aluminum	HDG/ Steel	316SS
Copper nitrate	X	nd	++
Copper sulfate	X	-	+
Cresol	+	+	+
Crude oil	++	++	++
Diethylamine	+	++	++
Dimethyl ketone	See acetone		
Ethyl acetate	(++)dry	++	+
Ethyl alcohol (ethanol)	++	++	++
Ethylene dichloride	(-)dry	++	(+)P,S
Ethylene glycol (glycol)	++	++	++
Ferric chloride	X	X	X
Ferric nitrate - 10%	X	nd	+
Ferrous sulfate	+	nd	(+)P
Formaldehyde (methanal)	(+)P	++	(++)T,C
Fluorine gas - moist	X	X	X
Formalin - see formaldehyde	+	+	(++)C
Formic acid (methanoic acid) - 10%	(+)T	X	(+)P,C
Furfural (furfuraldehyde)	+	nd	+
Furol - see furfural	+	+	(++)C
Gelatin	++	+	++
Glycerine (glycerol)	++	++	++
Hexamine - 80%	++	nd	++
Hydrobromic acid	X	X	X
Hydrochloric acid (muriatic acid)	X	X	X
Hydrocyanic acid - dilute	+	nd	+

SYMBOLS:

- ++ First choice; very low corrosion rate, typically <5 mpy, or <0.005 inch/year (1 mil = 1/1000 inch)
- + Good choice; low corrosion rate, typically <20 mpy, or <0.02 ipy
- Can use; corrosion rate up to 50 mpy (0.05 ipy); some limitations may apply
- X Not recommended

Chemical species	Aluminum	HDG/ Steel	316SS
Hydrocyanic acid - conc	X	nd	+
Hydrofluoric acid	X	X	X
Hydrogen chloride gas - dry	X	X	(++)S
Hydrogen chloride gas - wet	X	X	+
Hydrogen fluoride	(-)T	nd	+
Hydrogen peroxide - to 40%	++	nd	+
Hydrogen sulfide - wet	(+)P	nd	(+)P,S
Hypo	See sodium thiosulfate		
Hypochlorous acid	X	X	X
Iodine solution - satd.	X	X	X
Lactic acid	(+)T	nd	(+)P,I
Latex	++	-	++
Lithium chloride - to 30%	X	nd	++
Linseed oil	+	nd	++
Magnesium chloride - 50%	X	X	(+)P,S
Magnesium hydroxide	+	nd	++
Magnesium sulfate	+	X	+
Maleic acid (maleinic acid) - 20%	+	nd	+
Methyl alcohol (methanol)	++	++	++
Methyl ethyl ketone	+	++	+
Milk	++	X	++
Molasses	+	nd	++
Naptha	+	+	+
Natural fats	++	++	++
Nickel chloride	X	nd	(+)P,S

- (-) Brackets indicate probable limitations, e.g., at higher temperatures [symbol "T"]; at higher concentrations [symbol "C"]; due to pitting [symbol "P"]; due to local grain boundary attack in the metal - intergranular corrosion [symbol "I"]; or due to stress corrosion cracking [symbol "S"]
- nd No available data

Chemical species	Aluminum	HDG/ Steel	316SS
Nickel sulfate	X	nd	+
Nitric acid	X	X	(++)I
Oleic acid	(++)T	nd	++
Oxalic acid - dilute	-	nd	+
Oxalic acid - saturated	(+)T	X	X
Paraformaldehyde - to 30%	+	nd	++
Perchloroethylene	+	X	(++)P
Phenol (carbolic acid)	+	+	++
Phosphoric acid - dilute	X	X	++
Phosphoric acid - 50%	X	X	(++)I
Picric acid	++	nd	+
Potassium bicarbonate - 30%	X	nd	++
Potassium carbonate	X	nd	++
Potassium chloride - to 25%	X	X	(++)P
Potassium dichromate - 30%	(++)T	X	++
Potassium hydroxide	X	nd	(+)S
Potassium nitrate	++	++	+
Potassium sulfate	++	++	++
Propionic acid (propanoic acid)	(+)T	X	(+)T
Propyl alcohol (propane)	++	++	++
Prussic acid	See hydrocyanic acid		
Pyridine	+	nd	++
Soaps	+	-	+
Sodium bicarbonate - 20%	+	nd	++
Sodium bisulfate	X	X	(+)T

SYMBOLS:

- ++ First choice; very low corrosion rate, typically <5 mpy, or <0.005 inch/year (1 mil = 1/1000 inch)
- + Good choice; low corrosion rate, typically <20 mpy, or <0.02 ipy
- Can use; corrosion rate up to 50 mpy (0.05 ipy); some limitations may apply
- X Not recommended

Chemical species	Aluminum	HDG/ Steel	316SS
Sodium bisulfite	X	X	+
Sodium chloride - to 30%	X	X	(+)P,S
Sodium cyanide	X	nd	(+)T
Sodium hydroxide - 10-30%	X	X	(+)S
Sodium hydroxide - 50%	X	X	(++)S
Sodium hypochlorite - conc	X	X	++
Sodium hypochlorite - conc	X	+	(-)P,S
Sodium nitrate	++	X	++
Sodium peroxide - 10%	+	nd	+
Sodium silicate	++	nd	++
Sodium sulfate	(++)30%	X	++
Sodium sulfide - to 50%	X	nd	(+)T
Sodium thiosulfate	+	nd	+
Steam	(+)P	++	++
Stearic acid	+	nd	++
Sorbital (hexahydric alcohol)	++	+	++
Sulfur dioxide - dry	+	+	++
Sulfur dioxide - wet	X	X	(+)T
Sulfuric acid - to 80%	X	X	X
Sulfuric acid - 80-90%	X	X	(-)I
Sulfuric acid - 98%	X	X	(+)I
Tannic acid (tannin)	X	X	+
Tartaric acid - to 50%	(+)T	nd	++
Toluene (toluol; methyl benzene)	++	++	++
Trichloroethylene	(++)T	+	(+)P

Chemical species	Aluminum	HDG/ Steel	316SS
Turpentine	+	++	++
Water - acid, mine	X	-	(++)P
Water - potable	+	+	++
Water - sea	+	+	++
Zinc chloride - dilute	++	nd	(++)P,S

- (-) Brackets indicate probable limitations, e.g., at higher temperatures [symbol "T"]; at higher concentrations [symbol "C"]; due to pitting [symbol "P"]; due to local grain boundary attack in the metal - intergranular corrosion [symbol "I"]; or due to stress corrosion cracking [symbol "S"]
- nd No available data

Appendix III: Corrosion resistance guide

FIBERGLASS NONMETALLIC CABLE TRAY

The information shown in this corrosion guide is based on full immersion laboratory tests and data generated from resin manufacturers. It should be noted that in some of the environments listed, splashes and spills may result in a more corrosive situation than indicated due to the evaporation of water. Regular wash down is recommended in these situations.

All data represents the best available information and is believed to be correct. The data should not be construed as a warranty of performance for that product as presented in these tables. User tests should be performed to determine suitability of service if there is any doubt or concern.

Such variables as concentration, temperature, time of exposure and combined chemical effects of mixtures of chemicals make it impossible to specify the exact suitability of fiber-reinforced plastics in all environments. ABB will be happy to supply material samples for testing. These recommendations should only be used as a guide and ABB does not take responsibility for design or suitability of materials for service intended. In no event will ABB be liable for any consequential or special damages for any defective material or workmanship including, without limitation, labor charges or other expenses or damage to property resulting from loss of materials or profits or increased expenses of operations.

Chemical environment	Polyester		Vinyl ester	
	Max wt. %	Max operation temp °F (°C)	Max wt. %	Max operation temp °F (°C)
Acetic acid	10	190 (88)	10	210 (99)
Acetic acid	50	125 (52)	50	180 (82)
Acetone	N/R	N/R	100	75 (24)
Aluminum chloride	SAT	170 (77)	SAT	200 (93)
Aluminum hydroxide	SAT	160 (71)	SAT	170 (77)
Aluminum nitrate	SAT	150 (65)	SAT	170 (77)
Aluminum sulfate	SAT	180 (82)	SAT	200 (93)
Ammonium chloride	SAT	170 (77)	SAT	190 (88)
Ammonium hydroxide	1	100 (38)	10	150 (65)
Ammonium hydroxide	28	N/R	28	100 (38)
Ammonium carbonate	N/R	N/R	SAT	150 (65)
Ammonium bicarbonate	15	125 (52)	SAT	130 (54)
Ammonium nitrate	SAT	160 (71)	SAT	190 (88)
Ammonium persulfate	SAT	N/R	SAT	150 (65)
Ammonium sulfate	SAT	170 (77)	SAT	200 (93)
Amyl alcohol	ALL	N/R	ALL	90 (32)
Amyl alcohol vapor	-	140 (60)	-	120 (49)
Benzene	N/R	N/R	100	140 (60)
Benzene sulfonic acid	25	110 (43)	SAT	200 (93)
Benzoic acid	SAT	150 (65)	SAT	200 (93)
Benzoyl alcohol	100	N/R	100	N/R
Borax	SAT	170 (77)	SAT	200 (93)
Calcium carbonate	SAT	170 (77)	SAT	200 (93)
Calcium chloride	SAT	170 (77)	SAT	200 (93)

NOTES:
 — No information available **SAT** Saturated solution
 N/R Not recommended **FUM** Fumes

Chemical environment	Polyester		Vinyl ester	
	Max wt. %	Max operation temp °F (°C)	Max wt. %	Max operation temp °F (°C)
Calcium hydroxide	25	70 (21)	25	165 (74)
Calcium nitrate	SAT	180 (82)	SAT	200 (93)
Calcium sulfate	SAT	180 (82)	SAT	200 (93)
Carbon disulfide	N/R	N/R	N/R	N/R
Carbonic acid	SAT	130 (54)	SAT	180 (82)
Carbon dioxide gas	-	200 (93)	-	200 (93)
Carbon monoxide gas	-	200 (93)	-	200 (93)
Carbon tetrachloride	N/R	N/R	100	75 (24)
Chlorine, dry gas	-	140 (60)	-	170 (77)
Chlorine, wet gas	-	N/R	-	180 (82)
Chlorine water	SAT	80 (27)	SAT	180 (82)
Chromic acid	5	70 (21)	10	120 (49)
Citric acid	SAT	170 (77)	SAT	200 (93)
Copper chloride	SAT	170 (77)	SAT	200 (93)
Copper cyanide	SAT	170 (77)	SAT	200 (93)
Copper nitrate	SAT	170 (77)	SAT	200 (93)
Crude oil, sour	100	170 (77)	100	200 (93)
Cyclohexane	N/R	N/R	N/R	N/R
Cyclohexane, vapor	ALL	100 (38)	ALL	130 (54)
Diesel fuel	100	160 (71)	100	180 (82)
Diethyl ether	N/R	N/R	N/R	N/R
Dimethyl phthalate	N/R	N/R	N/R	N/R
Ethanol	50	75 (24)	50	90 (32)
Ethyl acetate	N/R	N/R	N/R	N/R

NOTES:
 — No information available **SAT** Saturated solution
 N/R Not recommended **FUM** Fumes

Chemical environment	Polyester		Vinyl ester	
	Max wt. %	Max operation temp °F (°C)	Max wt. %	Max operation temp °F (°C)
Ethylene chloride	N/R	N/R	N/R	N/R
Ethylene glycol	100	90 (32)	100	200 (93)
Fatty acids	SAT	180 (82)	SAT	200 (93)
Ferric chloride	SAT	170 (77)	SAT	200 (93)
Ferric nitrate	SAT	170 (77)	SAT	200 (93)
Ferric sulfate	SAT	170 (77)	SAT	200 (93)
Ferrous chloride	SAT	170 (77)	SAT	200 (93)
Fluoboric acid	N/R	N/R	SAT	165 (74)
Fluosilicic acid	N/R	N/R	SAT	70 (21)
Formaldehyde	50	75 (24)	50	100 (38)
Formic acid	N/R	N/R	50	100 (38)
Gasoline	100	80 (27)	100	150 (66)
Glucose	100	170 (77)	100	200 (93)
Glycerine	100	150 (66)	100	200 (93)
Heptane	100	110 (43)	100	200 (93)
Hexane	100	90 (32)	100	130 (54)
Hydrobromic acid	50	120 (49)	50	120 (49)
Hydrochloric acid	10	150 (66)	10	200 (93)
Hydrochloric acid	20	140 (60)	20	190 (88)
Hydrochloric acid	37	75 (24)	37	95 (35)
Hydrochloric acid	N/R	N/R	15	80 (27)
Hydrogen bromide, dry	100	190 (88)	100	200 (93)
Hydrogen bromide, wet	100	75 (24)	100	130 (54)
Hydrogen chloride	-	120 (49)	-	200 (93)

Chemical environment	Polyester		Vinyl ester	
	Max wt. %	Max operation temp °F (°C)	Max wt. %	Max operation temp °F (°C)
Hydrogen peroxide	5	100 (38)	30	100 (38)
Hydrogen sulfide, dry	100	170 (77)	100	210 (99)
Hydrogen sulfide, wet	100	170 (77)	100	210 (99)
Hypochlorous acid	20	80 (27)	20	150 (66)
Isopropyl alcohol	N/R	N/R	15	80 (27)
Kerosene	100	140 (60)	100	80 (27)
Lactic acid	SAT	170 (77)	SAT	200 (93)
Lead acetate	SAT	170 (77)	SAT	200 (93)
Lead chloride	SAT	140 (60)	SAT	200 (93)
Lead nitrate	SAT	-	SAT	200 (93)
Linseed oil	100	150 (66)	100	190 (88)
Lithium chloride	SAT	150 (66)	SAT	190 (88)
Magnesium carbonate	SAT	140 (60)	SAT	170 (77)
Magnesium chloride	SAT	170 (77)	SAT	200 (93)
Magnesium hydroxide	SAT	150 (66)	SAT	190 (88)
Magnesium nitrate	SAT	140 (60)	SAT	180 (82)
Magnesium sulfate	SAT	170 (77)	SAT	190 (88)
Mercuric chloride	SAT	150 (66)	SAT	190 (88)
Mercurous chloride	SAT	140 (60)	SAT	190 (88)
Methyl ethyl ketone	N/R	N/R	N/R	N/R
Mineral oils	100	170 (77)	100	200 (93)
Monochlorobenzene	N/R	N/R	N/R	N/R
Naphtha	100	140 (60)	100	170 (77)
Nickel chloride	SAT	170 (77)	SAT	200 (93)

Appendix III: Corrosion resistance guide

FIBERGLASS NONMETALLIC CABLE TRAY

Chemical environment	Polyester		Vinyl ester	
	Max wt. %	Max operation temp °F (°C)	Max wt. %	Max operation temp °F (°C)
Nickel nitrate	SAT	170 (77)	SAT	200 (93)
Nickel sulfate	SAT	170 (77)	SAT	200 (93)
Nitric acid	5	140 (60)	5	150 (66)
Nitric acid	20	70 (21)	20	100 (38)
Oleic acid	100	170 (77)	100	90 (32)
Oxalic acid	ALL	75 (24)	ALL	120 (49)
Paper mill liquors	-	100 (38)	-	120 (49)
Perchloroethylene	100	N/R	100	N/R
Perchloric acid	N/R	N/R	10	150 (66)
Perchloric acid	N/R	N/R	30	80 (27)
Phosphoric acid	10	160 (71)	10	200 (93)
Phosphoric acid	100	120 (49)	100	200 (93)
Potassium alum. sulfate	SAT	170 (77)	SAT	200 (93)
Potassium bicarbonate	50	80 (27)	50	140 (60)
Potassium bichromate	SAT	170 (77)	SAT	200 (93)
Potassium carbonate	10	N/R	10	120 (49)
Potassium chloride	SAT	170 (77)	SAT	200 (93)
Potassium hydroxide	N/R	N/R	25	150 (66)
Potassium nitrate	SAT	170 (77)	SAT	200 (93)
Potassium permanganate	100	80 (27)	100	210 (99)
Potassium sulfate	SAT	170 (77)	SAT	200 (93)
Propylene glycol	ALL	170 (77)	ALL	200 (93)
Phthalic acid	-	-	SAT	200 (93)
Sodium acetate	SAT	160 (71)	SAT	200 (93)

NOTES:
 - No information available
 N/R Not recommended
 SAT Saturated solution
 FUM Fumes

Chemical environment	Polyester		Vinyl ester	
	Max wt. %	Max operation temp °F (°C)	Max wt. %	Max operation temp °F (°C)
Sodium benzoate	SAT	170 (77)	SAT	200 (93)
Sodium bicarbonate	SAT	160 (71)	SAT	175 (79)
Sodium bisulfate	ALL	170 (77)	ALL	200 (93)
Sodium bromide	ALL	170 (77)	ALL	200 (93)
Sodium carbonate	10	80 (27)	35	160 (71)
Sodium chloride	SAT	170 (77)	SAT	200 (93)
Sodium cyanide	SAT	170 (77)	SAT	200 (93)
Sodium hydroxide	N/R	N/R	50	150 (66)
Sodium hydroxide	N/R	N/R	25	80 (27)
Sodium hypochloride	N/R	N/R	10	150 (66)
Sodium monophosphate	SAT	170 (77)	SAT	200 (93)
Sodium nitrate	SAT	170 (77)	SAT	200 (93)
Sodium sulfate	SAT	170 (77)	SAT	200 (93)
Sodium thiosulfate	ALL	100 (38)	ALL	120 (49)
Stannic chloride	SAT	160 (71)	SAT	190 (88)
Styrene	N/R	N/R	N/R	N/R
Sulfated detergent	0/50	170 (77)	0/50	200 (93)
Sulfur dioxide	100	80 (27)	100	200 (93)
Sulfur trioxide	100	80 (27)	100	200 (93)
Sulfuric acid	93	N/R	93	N/R
Sulfuric acid	50	N/R	50	180 (82)
Sulfuric acid	25	75 (24)	25	190 (88)
Sulfurous acid	SAT	80 (27)	N/R	N/R
Tartaric acid	SAT	170 (77)	SAT	200 (93)

Chemical environment	Polyester		Vinyl ester	
	Max wt. %	Max operation temp °F (°C)	Max wt. %	Max operation temp °F (°C)
Tetrachloroethylene	N/R	N/R	FUM	75 (24)
Toluene	N/R	N/R	N/R	N/R
Trisodium phosphate	N/R	N/R	SAT	175 (79)
Urea	SAT	130 (54)	SAT	140 (60)
Vinegar	100	170 (77)	100	200 (93)
Water, distilled	100	170 (77)	100	190 (88)
Water, tap	100	170 (77)	100	190 (88)
Water, sea	SAT	170 (77)	SAT	190 (88)
Xylene	N/R	N/R	N/R	N/R
Zinc chloride	SAT	170 (77)	SAT	200 (93)
Zinc nitrate	SAT	170 (77)	SAT	200 (93)
Zinc sulfate	SAT	170 (77)	SAT	200 (93)

Appendix IV: Installation instructions

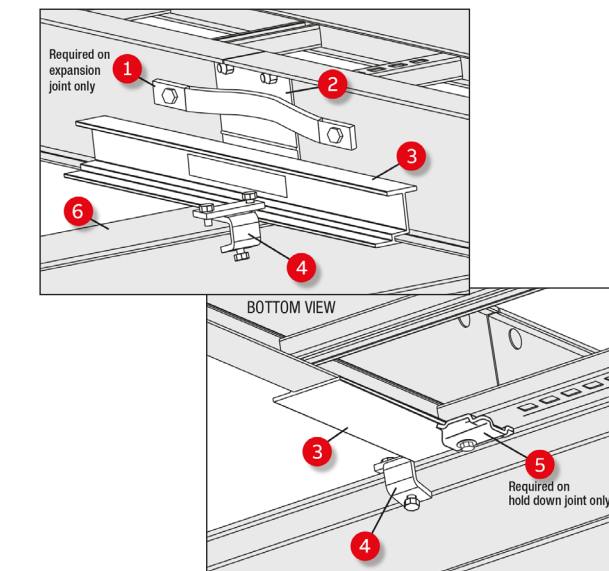
OVER-SUPPORT SPLICE ADAPTOR

The over-support splice adaptor allows proper functionality of the cable tray system when splices are placed directly above the supports.

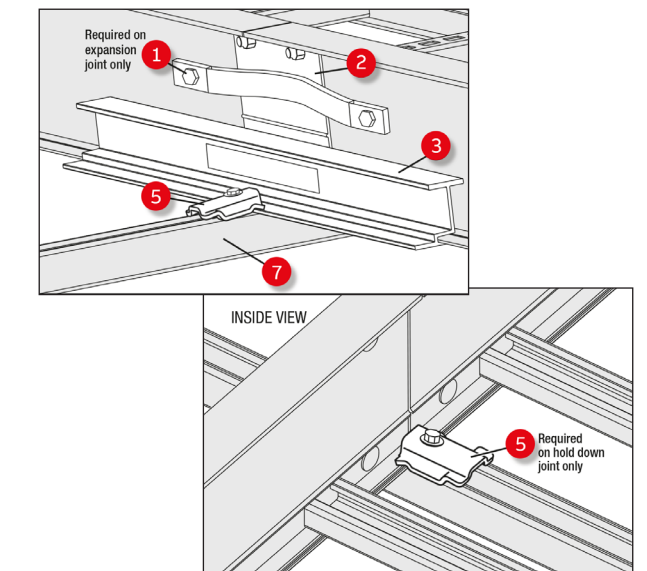
Installation components:

- 1 Bonding jumper
- 2 Splice plate
- 3 Over-support splice adaptor
- 4 Beam clamp
- 5 Hold down clamp
- 6 Structural beam
- 7 Strut

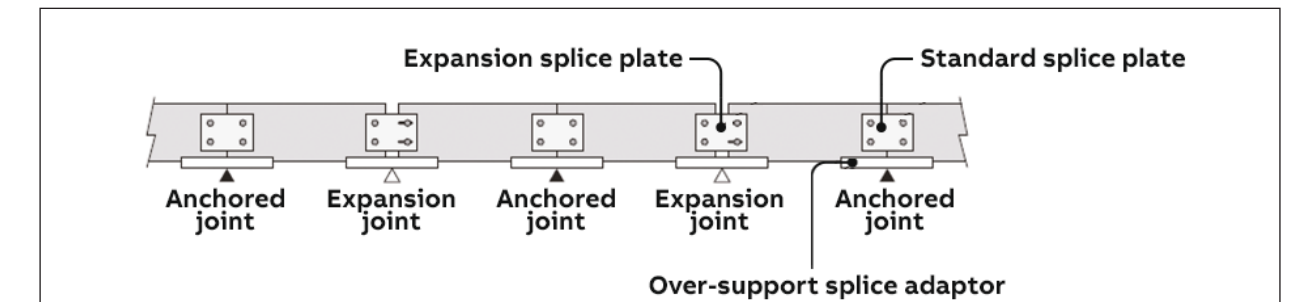
Beam installation CAT. NO. ABW46-OSS-B



Strut installation CAT. NO. ABW46-OSS-S



Cable tray series	Safe load rating when used with ABW46-OSS at 20-ft (6m) span
AH36	80 lb/ft — 119 kg/m
AH46	100 lb/ft — 149 kg/m
AH56	120 lb/ft — 178 kg/m
AH66	165 lb/ft — 245 kg/m



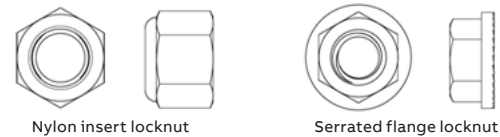
Appendix IV: Installation instructions

ALUMINUM SUPER-DUTY SPLICE PLATE™

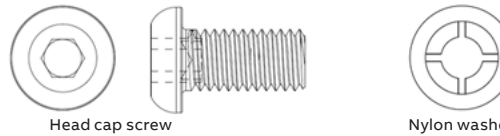
Cat. No. ABW6SDP

Material included:

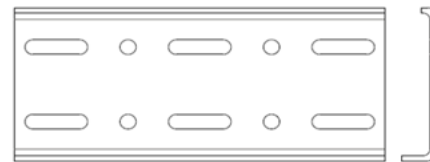
- 2 Super-Duty Splice Plates™
- 8 Nylon insert locknuts
- 12 Nylon washers
- 12 Hexagon socket button head cap screws
- 8 Serrated flanged locknuts
- 1 Instruction sheet



Nylon insert locknut Serrated flange locknut



Head cap screw Nylon washer



Super-Duty Splice Plates™

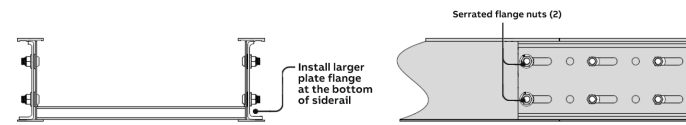
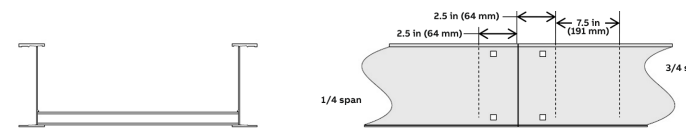
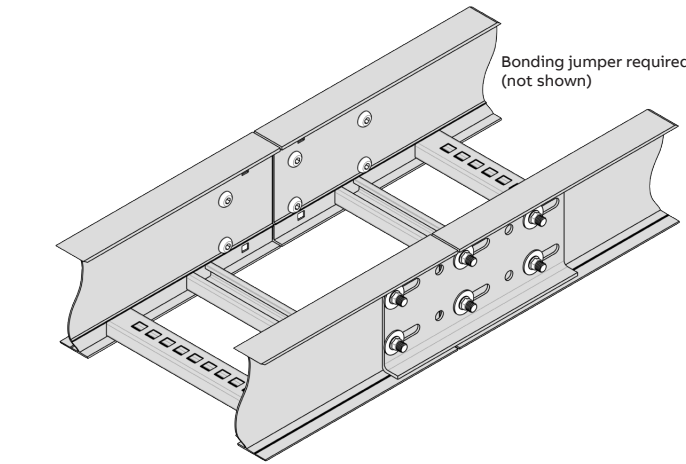
Quarter-span expansion splice installation
(For T&B cable tray up to Series AH66
maximum span 20 ft (6 m))

Step 1
Mark side rail as shown (3 places).

Step 2
Using the Super-Duty Splice Plate as a template,
drill six 9/16 in (14 mm) diameter holes on the
side rail markings.

Step 3
Insert the bolts into the holes and use nylon
retaining washers to keep the bolts in place.
The washers must be placed between the
plate and siderails.

Step 4
Install the serrated flange nuts and the nylon
locknuts. Torque serrated nut to 45 lb-ft (60 Nm).
Tighten nylon locknuts until snug, then loosen
to allow plate movement. Set gap according to
NEMA VE 2. Bonding jumpers required.

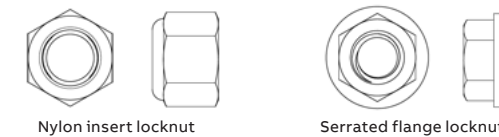


STEEL SUPER-DUTY SPLICE PLATE™

Cat. No. SHW(4,5,6 or 7) SDP
Cat. No. SPW(4,5,6 or 7) SDP
Cat. No. SSW(4,5,6 or 7) SDP

Material included:

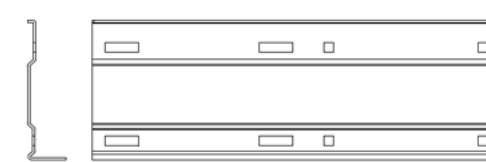
- 2 Super-Duty Splice Plates™
- 8 Nylon insert locknuts
- 16 Nylon washers (spacers)
- 16 Carriage bolts
- 8 Serrated flanged locknuts
- 1 Instruction sheet



Nylon insert locknut Serrated flange locknut



Carriage bolt Nylon washer



Super-Duty Splice Plates™

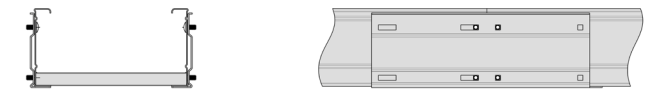
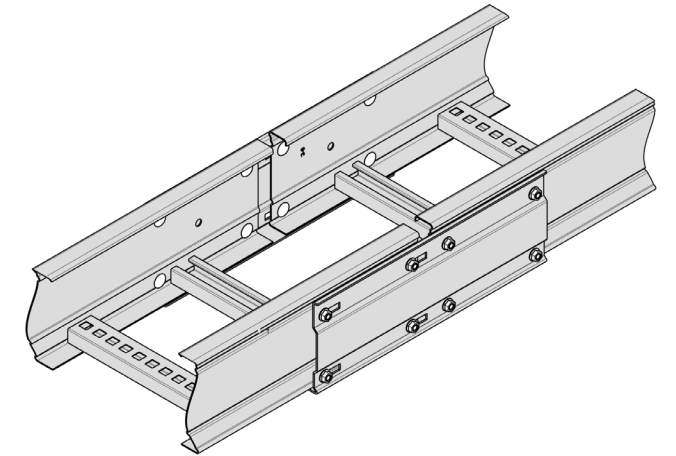
Quarter-span expansion splice installation:

Step 1
Insert bolts into existing holes (bolt heads inside the
cable tray). Use nylon retaining washers to keep the
bolts in place.

Step 2
Install the plate, positioning the widest flange at the
bottom and aligning the existing holes. Using the
Super-Duty Splice Plate as a template, mark the
position of the two holes at each end of the plate.
The holes must be marked on the right extremity of
the rectangular slots.

Step 3
Remove the plate and drill four 11 mm (7/16 in) holes.
Insert the remaining bolts and nylon retaining washers.
The washers must be placed between the plate and
the siderails.

Step 4
Put the plate back into position and tighten the four
bolts of the cable tray at 1/4 span using the serrated
flange nuts. Tighten to 19 lb-ft (25 Nm). Use locknuts
with nylon insert for the rectangular bolts holes.
Tighten each nut until it is tight, then loosen slightly
to allow movement of the plate. Adjust spacing
according to NEMA VE 2. Bonding jumpers are required.



List of figures

Figure 1	The by-products of zinc corrosion provide sacrificial protection	9
Figure 2	Micrograph of coating thickness showing the difference in coating thickness between hot-dip galvanization and pre-galvanization	10
Figure 3	Steps in hot-dip galvanization	10
Figure 4	Photomicrograph of the coating achieved with hot-dip galvanization.....	11
Figure 5	Leland Industries JS500® coating	11
Figure 6	Coating life to first maintenance for galvanized coatings in various environments	13
Figure 7	Coating life to first maintenance for hot-dip galvanized steel.....	14
Figure 8	Zinc whiskers.....	16
Figure 9	Typical corrosion resistance provided by powder-paint coatings	16
Figure 10	Typical steps in an e-coating process	17
Figure 11	The electropotential of metals can be measured in different water solutions and listed in galvanic series	18
Figure 12	Typical configurations of framework brackets	23
Figure 13	Ideal positioning of splice plates for a 12-foot (3.7 meters) cable tray length supported at 12-foot (3.7 meters) intervals.....	25
Figure 14	Recommended gap setting of expansion splice plate.....	27
Figure 15	NEMA recommendation for positioning of expansion joints and supports.....	28
Figure 16	ABB alternative #1: Expansion joint above the support, and use of over-support splice adaptor.....	28
Figure 17	ABB alternative #2: Expansion joint at the quarter-point of the span, and use of Super-Duty Splice Plate	28
Figure 18	ABB alternatives to NEMA recommendations for horizontal fittings	30
Figure 19	ABB alternatives to NEMA recommendations for vertical elbows.....	31
Figure 20	Example of grounding every 50 feet (15 meters) pursuant to [12-2208(2)].....	42
Figure AI-1	Examples of AWG and kcmil wire sizes.....	47

List of tables

Table 1	Thicknesses of galvanized coatings	9
Table 2	Characteristics of coatings generally used for fittings and small metal parts	12
Table 3	Corrosion categories from ISO 12944	15
Table 4	Relative risk of zinc whiskers from various coatings.....	16
Table 5	Characteristics of epoxy and polyester paint coatings.....	17
Table 6	Galvanic series (selected materials).....	18
Table 7	Compatibility of hardware materials with base metals	19
Table 8	Recommended cable tray materials and finishes	21
Table 9	ABB options for splice plates	26
Table 10	Maximum spacing between expansion joints	27
Table 11	Maximum allowable load rating for 6 in. side rail horizontal fittings	29
Table 12	Number of allowable conductors or cables [392.22]	38
Table 13	Ampacity of conductors.....	44
Table AII-1	Relative mechanical resistance for AISI 316L stainless steel at elevated temperatures.....	48
Table AII-2	Physical and mechanical properties of aluminum	48
Table AII-3	Relative mechanical resistance of AA6063-T6 aluminum by temperature.....	49



ABB Electrification Canada ULC

Installation Products

700 Thomas Avenue
Saint-Jean-sur-Richelieu, Quebec J2X 2M9
Tel.: +1 (450) 347 5318
Toll Free: +1 (800) 362 2952
Fax: +1 (450) 347 1976

Regional Sales Offices

Atlantic Provinces

Tel.: +1 (902) 450 1307
Toll Free: +1 (877) 862 4357
Fax: +1 (902) 450 1309

Quebec

Tel.: +1 (450) 466 1102
Toll Free: +1 (800) 465 1399
Fax: +1 (450) 466 1163

Ontario

Tel.: +1 (905) 635 7888
Toll Free: +1 (877) 291 7771
Fax: +1 (905) 635 7889

Manitoba / Saskatchewan

Tel.: +1 (604) 598 9811
Toll Free: +1 (866) 540 8220
Fax: +1 (604) 598 9840

Alberta

Tel.: +1 (780) 424 7092
Toll Free: +1 (888) 664 5666
Fax: +1 (780) 424 7093

British Columbia

Tel.: +1 (604) 598 9811
Toll Free: +1 (866) 540 8220
Fax: +1 (604) 598 9840

tnb.ca.abb.com

20CTTG-ABBIP-E-???