NX300 Main-Standby Transmitter System

All India Radio (AIR)

APPENDIX D

AC POWER

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Guidelines for installing transformers, part 1.

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Electrical Construction and Maintenance
Morgan, Robert R.

When your transformer arrives on site, various procedures should be carried out to assure successful operation.

The successful operation of a transformer is dependent on proper installation as well as on good design and manufacture. An article on how to choose a transformer based on the latter criteria appeared in the May '96 issue of EC&M. The article in this issue covers installation procedures you should consider to help assure your transformer will function properly and safely, and it's focused on installation practices that are common for both dry-type and liquid-filled transformers.

When viewing transformer product literature, you'll probably find that one manufacturer's units will have differences from that of a competing manufacturer. And, each manufacturer will have its own instructions for installing and testing its transformers. Regardless of manufacturer, you should carefully follow these instructions to ensure adequate safety to personnel and equipment. And its important that you follow current NEC practice and applicable local codes.

This material will provide additional general guidelines for installing and testing both dry-type and liquid-filled transformers for placement into service. A note of caution: The information presented here is not meant to supersede any manufacturer's instructions.

Acceptance testing requirements

Before your transformer is scheduled to be shipped to its designated site, it's important that you coordinate with the manufacturer what acceptance tests should be carried out. Each test has a particular objective that helps determine a transformer's suitability for use.

A number of these tests are done on the plant floor, while other tests are conducted usually after delivery is made. Two good references to dry-type transformer requirements are ANSI/IEEE C57.12.01-1989, IEEE Standard General Requirements for Dry-Type Distribution and Power Transformers Including Those With Solid Cast and/or Resin-Encapsulated Windings, which addresses general requirements, and C57.12.91-1995, IEEE Test Code for Dry-Type Distribution and Power Transformers, which addresses testing. (Most of the information in these standards also can be applied to liquid-filled transformers.)

Small transformers, arguable those below 400kVA, usually don't have extensive testing as they are often installed far downstream in a power system; as such, their importance is not as vital as compared with larger units. Also, it's a matter of cost. The expense associated with testing represents a larger portion of a small transformer's cost compared with the testing cost of a large kVA unit.

It's recommended that all conducted tests comply with applicable ANSI/IEEE and NEMA standards. Should a transformer be built to meet special requirements, however, then some additional testing is recommended to ensure that the unit operates as called for. Sometimes, when testing is carried out at the manufacturer's plant, the manufacturer will also allow a purchaser or a representative, such as a consulting engineer, to witness the tests.

Standard transformer tests performed for each unit include the following:

* Ratio, for voltage relationship;

* Polarity for single- and 3-phase units (because single-phase transformers are sometimes connected in parallel and sometimes in a 3-phase bank);

* Phase relationship for 3-phase units (important when two or more transformers are operated in parallel);

* Excitation current, which relates to efficiency and verifies that core design is correct;

* No-load core loss, which also relates to efficiency and correct core design;

* Resistance, for calculating winding temperature and [I.sup.2]R component of winding losses (usually not required on 600V class units);

* Impedance (via short circuit testing), which provides information needed for breaker and/or fuse sizing and interrupting rating and for coordinating relaying schemes;

* Load loss, which again directly relates to the transformer's efficiency;

* Regulation, which determines voltage drop when load is applied; and

* Applied and induced potentials, which verify dielectric strength.

There are additional tests that may be applicable, depending upon how and where the transformer will be used. Usually, additional testing means there will be an increase in transformer cost. Before specifying any additional tests, you should contact the manufacturer to find out what data it has accumulated from testing essentially duplicate units. If this data can be used, the extra cost to carry out tests can be avoided without sacrificing the quality of the transformer.

The additional tests that can be conducted include the following:

* Impulse (where lightning and switching surges are prevalent);

* Sound (important for applications in residential and office areas and that can be used as comparison with future sound tests to reveal any core problems);

* Temperature rise of the coils, which helps ensure that design limits will not be exceeded;

* Corona for medium voltage (MV) and high-voltage (HV) units, which helps determine if the insulation system is functioning properly;

* Insulation resistance (megohmmeter testing), which determines dryness of insulation and is often done after delivery to serve as a benchmark for comparison against future readings; and

* Insulation power factor, which is done at initial installation and every few years thereafter to help determine the aging process of the insulation.

Site considerations

When planning the installation, you should select a location that complies with all safety codes yet does not interfere with the normal movement of personnel, equipment, and material. The location should not expose the transformer to possible damage from cranes, trucks, or moving equipment. Other site considerations require closer analysis.

Foundations. Foundation preparation usually includes an evaluation of soil characteristics and concrete work. For transformers placed outside that are 2000kVA and above, you may wish to have the soil examined. Clay soils are compressible and can cause problems that may require stabilizing back-fill. Most soils are able to withstand a bearing pressure of 2500 lbs/sq ft.

The foundation should be constructed of reinforced, air entrained concrete having at least 3000 psi compressive strength at 28 days after pouring. For pad mount transformers with ratings 75kVA through 500kVA, a typical concrete base would be 5 1/2 by 6 1/2 ft and 10 in. thick with chamfered edges on top of the base and footings extending 20 in. down from each of the ends of the long sides. For units with ratings above 500kVA to 2500kVA, a typical concrete base would be 8 ft by 9 ft and 10 in. thick with chamfered edges on top of the base and footings extending 20 in. down from each of the ends of the long sides. [ILLUSTRATION FOR FIGURE 1 OMITTED]. In addition, to avoid problems, a civil engineer should be consulted for guidance on the above matters.

Structural support. When placed inside or on top of a building, you must consider structural capabilities because a transformer represents a highly concentrated load. For new buildings, you should work with the structural engineers so that the transformer's placement is included in the building plans.

Installing transformers in existing structures may require an analysis of the building for structural support capability since the original structural information may not be available. Structurally speaking, it's generally wiser to place a transformer as close as possible to a column. This may call for compromises regarding the length of the conductors going to and/or from the transformer.

In seismic areas, the stability of the unit with respect to turning over must be evaluated, whether placed outside or in a building, because a transformer usually has a relatively high center of gravity. Usually, lateral bracing and/or an extra solid anchorage will be required. Therefore, it's advisable that you seek guidance on this matter from an engineer knowledgeable in seismic supports and the associated code requirements.

To simplify installation, you should request from the manufacturer a simplified outline drawing of the transformer. By studying the overall mounting and terminal dimensions, it's possible to plan the installation with an orderly arrangement of connections. Also, with this information, it will be easier to plan site arrangements.

Preliminary inspection upon receipt of transformer

When received, a transformer should be inspected for damage during shipment. Examination should be made before removing it from the railroad car or truck, and, if any damage is evident or any indication of rough handling is visible, a claim should be filed with the carrier at once and the manufacturer notified. Subsequently, covers or panels should be removed and an internal inspection should be made for damage or displacement of parts, loose or broken connections, dirt or foreign material, and for the presence of water or moisture. If the transformer is moved or if it is stored before installation, this inspection should be repeated before placing the transformer in service.

Handle and lift with care

Transformers are designed with provisions for lifting, jacking, and/or rolling. These provisions will vary depending upon the weight, size, and mechanical configuration of the unit. The weight distribution should be studied by examining the inside of the transformer enclosure for dry-type units. If appropriate, supports should be used so that the transformer enclosure is not crushed when the unit is lifted.

You may lift transformers with enclosures having lifting lugs by using appropriate slings or chains. Larger units will have provisions for lifting from the base frame or from clamps at the top of the core. Make sure the rigging crew is experienced in lifting and moving heavy delicate equipment. Lifting from the base frame may require the use of a spreader bar to avoid damage to the enclosure panels. [ILLUSTRATION FOR FIGURE 2 OMITTED]. Units lifted from the top core clamps will sometimes require that the top cover or part of the cover be removed.

Transformers should be maintained in an upright position when being moved. There should be no attempt to handle a transformer in any other position. If this isn't possible, you first should contact the manufacturer to explore other options. Exercise care during handling to prevent equipment damage and/or personnel injury.

If the transformer can't be lifted by a crane, it can be skidded or moved on rollers, as shown in Fig. 3, on page 42. Take care not to damage the base or tip it over. When rollers are used on transformers without a structural base, you should use skids to distribute the stress over the base. Large enclosed units with base frame type enclosures may be jacked using the base frame angles. The transformer should be jacked evenly on all four corners to prevent warping or tipping over.

Plan for the prevention of contaminants

Develop a procedure for inventory of all tools, hardware, and any other objects used in the inspection, assembly, and testing of the transformer. A check sheet should be used to record all items, and verification should be made that these items have been properly accounted for upon completion of work.

Making connections that work

When you start making the connections between the transformer's terminals and the incoming and outgoing conductors, carefully follow the instructions given on the nameplate or on the connection diagram. Check all of the tap jumpers for proper location and for tightness. Re-tighten all cable retaining bolts after the first 30 days of service. Before working on the connections make sure all safety precautions have been taken. As appropriate, you should make arrangements to adequately support the incoming/outgoing connecting cables to ensure that there is no mechanical stress imposed on transformer bushings and connections. Such stress could cause a bushing to crack or a connection to fail.

Transformers are usually designed and built to provide good electrical connections using either copper or aluminum cable. A protective plating or compound that prevents surface oxidation on the aluminum terminals is usually applied at the factory. You should not remove this coating from tap and line terminals. Also, when aluminum conductors are used, give them a protective compound treatment at the terminal as specified by the cable manufacturer.

Representative torque requirements for making connections using steel nuts/bolts are shown in Table 1, on page 42.

Some equipment could have a different torque requirement than shown. This is especially true if bronze or other type material is used for the nuts/bolts. To avoid problems, you should follow the instructions provided by the transformer manufacturer. Torque specifications are sometimes listed on the hardware. After applying proper torque, you should wait a minute or so, and then re-tighten all bolts to the specified torque.

You should use commercially available, properly sized, UL-listed mechanical- or compression-type lugs. These terminations should be attached to the cables as specified by the termination or cable manufacturer. Such terminations are available from electrical distributors. Do not install washers between the terminal lugs and the termination bus bar as this will introduce an added impedance and will cause heating and possible connection failure.

Some transformer manufacturers recommend that the cable size be based on an ampacity level of 125% of nameplate rating. When speaking to consulting engineers on this topic, we've found that they recommend the cable be sized for the transformer's nameplate rating. You take your choice; extra safety and extra cost or regular-sized cables. Whatever the choice, the cable insulation rating must be adequate for the installation. The cables you install must be kept as far away as possible from coils and top blades. If in doubt about clearances, do not hesitate to call the transformer manufacturer. Information on minimum wire bending space clearances at terminals for conductors is found in NEC Sec. 373-6, Deflection of Conductors, and referenced in Sec. 450-12 on Terminal Wiring Space.

Controlling sound level

When testing a transformer for sound level, you should recognize that all transformers, when energized, produce an audible noise. Although there are no moving parts in a transformer, the core does generate sound. In the presence of a magnetic field, the core laminations elongate and contract. These periodic mechanical movements create sound vibrations with a fundamental frequency of 120 Hz and harmonics derivatives of this fundamental.

The location of a transformer relates directly to how noticeable its sound level appears. For example, if the transformer is installed in a quiet hallway, a definite hum will be noticed. If the unit is installed in a location it shares with other equipment such as motors, pumps, or compressors, the transformer hum will go unnoticed. Some applications require a reduced sound level, such as a large unit in a commercial building with people working close to it. Occasionally, the installation of some method of sound abatement will be called for. You should consider this when planning the unit's installation.

Often the location and the method in which a transformer is placed have much to do with the perceived sound as does the actual decibels generated. Locating a unit at the end of a long, narrow room, or in the corner of a room can cause a megaphone effect and amplify the transformer's sound. Mounting the unit on a platform that has less mass than the transformer will make the platform serve as a sounding board, just like the body of a violin. Even mounting the unit a distance that is an exact multiple of the 120 Hz wavelength from a solid reflective surface may reinforce the sound waves, causing the transformer to seem louder than it actually is. These considerations should be taken into account, as well as the use of sound absorbing materials on walls (for low frequency sound) and vibration isolation pads under the unit.

A transformer is designed to produce a minimum sound level when the connections to primary and secondary terminals are made with flexible connectors, when all transit bolts and shipping braces are loosened so the unit will float on rubber isolation pads, as shown in Fig. 4, on page 44, and when all enclosure hardware is tightened so panels do not vibrate.

Some manufacturers in the industry have extensive data on sounds produced by their transformers, and they usually can determine the sound level for a particular design quite accurately. You should note, though, that transformers serving large harmonic loads can produce a higher audible noise.

There are NEMA standards for transformer sound and depending upon the kVA rating of a unit, the sound it produces must be under a certain decibel level. The usual sound levels for liquid-filled transformers range from 40 dB to 60 dB for units below 500kVA, about 65 dB for units between 4000kVA to 5000kVA, 73 dB for transformers with ratings between 6000kVA to 7500kVA, and 76 dB for units between 8000kVA and 10,000kVA.

Dry-type transformers have sound levels that are somewhat higher. Sound levels associated with certain kVA ratings will vary depending upon the type of transformer and manufacturer.

Make sure the transformer is grounded

Grounding is necessary to remove static charges that may accumulate and also is needed as a protection should the transformer windings accidentally come in contact with the core or enclosure (or tank for wet types).

Before applying any voltage to the transformer, you should make sure that the tank for wet-types, or the enclosure and core assembly for dry-types, is permanently and adequately grounded. You should ground the transformer as per NEC Sec. 450-10 and check the grounding of the neutral as applicable per NEC.

Note that for MV transformers, the secondary neutral is sometimes grounded through an impedance.

Ensure that all grounding or bonding systems meet NEC and local codes.

Final inspection and testing

Once the transformer has been located on its permanent site, a thorough final inspection should be made before any assembly is accomplished and the unit is energized. Before energizing the unit, it's very important that you alert all personnel installing the transformer that lethal voltages will be present inside the transformer enclosure as well as at all connection points. The installation of conductors should be performed only by personnel qualified and experienced in high-voltage equipment. Personnel should be instructed that should any service work be required to the unit, the lines that power the transformer must be opened and appropriate safety locks and tags applied.

A careful examination should be made to ensure that all electrical connections have been properly carried out and that the correct ratio exists between the low and high-voltage windings. For this test, apply a low-voltage (240V or 480V) to the high-voltage winding and measure the output at the low-voltage winding. However, for low-voltage (600V and below) transformers, this is not practical. Here, a transformer turns ratio indicator should be used to measure the ratio.

Any control circuits, if any, should be checked to make sure they function correctly. These include the operation of fans, motors, thermal relays, and other auxiliary devices. Correct fan rotation should be visually verified as well as by checking indicator lights if they are installed. Also, you should arrange for a one-minute, 1200V insulation resistance test of the control circuits. (If the power transformer has CT circuits, they should be closed.) But be careful here: Before applying this voltage, check with the manufacturer's manuals. Some microprocessor-based electronic devices may not be able to withstand the voltage.

As prescribed by NEMA standards, transformers are shipped with both high and low-voltage windings connected to their highest rated voltage (except transformers that have taps above the rated voltage, in which case they will be shipped connected for rated voltage). You should check the internal connections with the diagram on the nameplate to make sure they are correct for the application. The tap setting should also be verified for the proper voltage.

All windings should be checked for continuity. You should arrange for an insulation resistance test to be carried out to make certain that no windings are grounded.

You will find it beneficial to carry out this testing for future comparative purposes, and also for determining the suitability of the transformer for energizing or application of a high potential test.

It's important that you have an understanding of the manufacturer's warranty. A number of manufacturers require that insulation resistance testing be successfully completed prior to the transformer being placed in service for the warranty to be valid. Some manufacturers require that the megohmmeter readings and date of energizing be sent to them within a specified time after the transformer is placed in service for the warranty to be valid. The insulation resistance test should be conducted immediately prior to energizing the transformer or the beginning of the dielectric test.

Caution is required when operating in parallel

When transformers are installed for parallel operation, their rated voltages, impedances, and turn ratios ideally should be the same and their phasor relationships identical. If these parameters are different, circulation current will exist in the circuit loop between these units. The difference in impedance should not exceed 7.5%. The greater the differences in these parameters, the greater the magnitude of the circulating current. When specifying a transformer to be operated in parallel with existing units, all these parameters should be discussed with the transformer manufacturer.

Applying the load

Before energizing a 3-phase transformer, you should arrange to monitor the voltages and currents on the low-voltage side. Then, without connecting the load, energize the transformer. The magnitude of the voltages shown (line-to-ground and line-to-line) should be very similar. If this is not the case, deenergize the transformer and contact the manufacturer before proceeding further.

Next, connect the load and energize the transformer. While monitoring the voltages and currents, gradually increase the load in a stepped or gradual application until full load is reached. If you cannot gradually increase the load, then full load may be applied. Both the voltages and currents should change in a similar fashion. If this does not happen, de-energize the transformer and contact the manufacturer.

The maximum continuous load a transformer can handle is indicated on its nameplate. However, a specially designed unit may have specific load capabilities not indicated on the nameplate. If you have some doubt as to the load capability of the unit, contact the manufacturer.

Adjustment for correct tap setting

After installation, you should check the output voltage of the transformer. This should be done at some safe access point near or at the load. Never attempt to check the output voltage at the transformer. Dangerous high voltage will be present within the transformer enclosure.

When changing taps, the same changes must be made for all phases. Consult the transformer diagrammatic nameplate for information on what tap must be used to correct for extra high or extra low incoming line voltage. The same adjustment should be made to compensate for voltage drop in the output due to long cable runs. When the load-side voltage is low, tap connections below 100% of line voltage must be used to raise the load voltage. If the load-side voltage is high, tap connections above 100% of line voltage must be used to lower the load voltage.

This article will continue in subsequent issues of EC&M. Part 2 will address installation procedures for dry- and wet-type transformers, the latter being fully assembled. Part 3 will cover installation procedures for liquid-filled transformers that are shipped unassembled.

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Guidelines for installing transformers - Part 2.

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Thu, 1999-07-01 12:00
Electrical Construction and Maintenance
Morgan, Robert B.

The successful operation of a transformer is pendent on proper installation as well as on proper design and manufacture. Part 1 of this article, which addressed installation procedures that are common to both dry- and wet-type units, appeared in the June '96 issue of EC&M. This article covers installation procedures peculiar to dry-type transformers as well as those relating to fully assembled liquid-filled units.

Each transformer manufacturer produces equipment having differences from competing manufacturers. And, each manufacturer has its own instructions for installing and testing their transformers. Such instructions should be carefully followed to assure adequate safety to personnel and equipment. And, it's important that you follow current NEC practice and applicable local codes.

The purpose of this article is to provide general installation guidelines for placing transformers in service. It is not meant to supersede manufacturer's instructions.

Dry-type transformers

Additional site considerations. The location where a transformer is to be placed should not expose the unit to possible damage from moving equipment. Remember, damage to the enclosure of a dry-type transformer may reduce insulation clearances to an unsafe level.

As an added safety precaution, you should keep in mind the possibility of children inserting rods, wire, etc. through an enclosure's ventilation openings of a dry-type transformer, thus coming into contact with live parts.

Transformer ventilation openings are designed in accordance with NEMA and ANSI standards, which require that a 1/2-in. diameter rod cannot be inserted through the openings.

The transformer enclosure is designed to prevent the entrance of most small animals and foreign objects. In some locations, however, you may have to consider additional protection. Transformers installed in public areas must be constructed to be impenetrable to foreign objects or the units must be protected by a fence in a manner that would prevent accessibility by the public and animals.

For dry-type transformers, the core/coil assembly (without enclosure) will usually have mounting and terminal dimensions to suit your enclosure requirements. The enclosure should give protection to the coils and have adequate clearance and sufficient ventilation openings. The manufacturer should always be consulted to determine these requirements.

Top covers may be designed for cable entry or exit with bolt-on cover plates. However, because heat rises, the insulation of cables placed above a transformer may age prematurely. Therefore, side and bottom cable entry and exit are recommended. Note that conduit, bus duct, etc. must be independently supported as the top cover is not designed for these loads.

Minimum electrical clearances regarding the installation of lugs and cables must be observed per NEC Sec. 373-11.

Ventilated dry-type transformers can be designed for installation indoors or outdoors. They will operate successfully where the humidity is high, but under this condition, it may be necessary to take precautions to keep them dry if they are shut down for appreciable periods.

When operating, you should take steps to arrange frequent inspection to ensure that there is no surface contamination on live parts of dry-type transformers. Caution: Make sure you deenergize the unit first. Excess contamination can cause problems and may even result in transformer failure. For locations where severe atmospheric conditions prevail, it may be better to use a liquid-filled transformer. However, if a dry-type is still preferred, you should consider using a totally enclosed, non-ventilated unit; sealed coil unit; or cast coil transformer.

Locations where there is dripping water should always be avoided. If this is not possible, suitable protection should be provided to prevent water from entering the transformer case. Precautions should be taken to guard against accidental entry of water, such as might be obtained from an open window, by a break in a water or steam line, or from use of nearby water.

Adequate ventilation is a must. Adequate ventilation is essential for the proper cooling of dry-type transformers. And the use of clean dry air is desirable for these types of units. It's highly advisable that you take steps to install ventilated dry-type transformers in locations free from unusual dust or chemical fumes. If such conditions exist, a wet-type unit, or another form of dry-type should be employed. Filtered air may reduce maintenance if the location has a contamination problem.

When transformers are installed in vaults or other restricted spaces, you should provide sufficient ventilation to hold the air temperature within established limits when measured near the transformer inlets. For dry-type transformers, this usually will require approximately 100 cu ft of air per minute per kW of transformer loss. The area of ventilation openings required depends on the height of the vault, location of openings, and maximum loads to be carried by the transformers. For self-cooled transformers, the required area of ventilation should be at least one sq ft each of inlet and outlet openings per 100 kVA of rated transformer capacity, after deduction of the area occupied by screens, gratings, or louvers. This is approximately equivalent to the requirements of NEC Sec. 450-45(c). High-efficiency, low-loss designed transformers may lead to reduced ventilation requirements.

Transformers should be located at least 12 in. to 18 in. away from walls and other obstructions that might prevent free circulation of air through and around each unit, unless the unit is designed for wall mounting and installed per the manufacturer.

Units rated for 600V operation and used for lighting are labeled for minimum distance, usually between 3 in. and 12 in. (6 in. for most units). This varies among manufacturers, and it's recommended that you follow such instructions. Also, accessibility for maintenance should be taken into account before locating the transformer. If it's to be located near combustible materials, the minimum separations established by the NEC, and local fire ordinances must be maintained.

Handling and lifting. Because of a dry-type transformer's high center of gravity, the unit is subject to tipping over during handling. It's wiser to apply force for moving such units at the bottom rather than near or at the top of the transformer.

When lifting the unit by the core/coil assembly, only use the lifting devices/holes provided on the core clamps. Make sure you take care to prevent damage to bus work, wiring, and termination assemblies during lifting. When lifting, you should increase tension gradually; do not jerk, jar, or move the transformer abruptly.

When moving transformers, avoid contamination by foreign objects. This is especially true for dry-type units as tools or other objects may be dropped into the air passages of the coils. It's important to instruct your work crews to take steps to prevent any foreign material from falling into or onto the coils, terminals, and insulators. Hardware, connecting parts, tools, or any foreign material should not be allowed on top of the core and coil assembly. Foreign material lodged in a coil duct can cause electrical failure or overheating.

Remove shipping supports. For dry-type transformers, after the transformer has been placed in its permanent location, you should arrange to have the bold-down bolts securing the core and coil assembly to the base or enclosure loosened but left in the holes to act as horizontal restraints. This loosening releases the sound isolation pads for maximum effectiveness. Also remove any shipping braces on the core and coil busses or the enclosure. For easy identification, these braces are usually painted a different color from the remaining assembly parts, made of wood, or left unpainted. Should it be necessary to move the transformer, replace the hold-down bolts and braces for the moving operation. Because each manufacturer uses different shipping procedures, you should carefully follow the specific instructions provided by the firm.

Extra grounding provisions. Make sure that the flexible grounding jumper between the core-and-coil assembly and the enclosure is intact, or that the core-and-coil assembly is directly grounded from the core clamp by a flexible means.

Insulation resistance testing. Variable factors affecting the construction and use of dry-type transformers make it difficult to set limits for this test. Experience indicates that for some transformers (manufacturers' guidelines may differ, and they should be followed), a minimum of 2 megohms (1 min reading at approximately 25 degrees C) per 1000V of nameplate voltage rating, but in no case, less than 2 megohms total, may be a satisfactory value of insulation resistance (IR) for the application of the high-potential test. If the IR is less than the above minimum values, do not energize the transformer. When this condition exists, the next step is to dry out the transformer and then do another IR test. Section 6.4.1 of the ANSI/IEEE Standard C57.94-1982, IEEE Recommended Practice for Installation, Application, Operation, and Maintenance of Dry-Type General-Purpose Distribution and Power Transformers, states that should the manufacturer's recommended values not be available, the readings as shown in the Table (above) may be used. If the IR is less than the minimum values stated in the above paragraph or in Table 1, do not energize the transformer. When the latter condition exists, the next step is to dry out the transformer and then do another IR test.

Other recommended on-site tests for dry-type units include the following:

* Winding resistance measurements,

* Polarity verification,

* Insulation power factor, and

* High potential (hi-pot) test to 75 % of factory test level, per ANSI C57.12.911995, IEEE Test Code for Dry-Type Distribution and Power Transformers, providing the transformer was not subjected to severe dielectric tests before this.

It's preferable that the dielectric tests (i.e., power factor and hi-pot) be done last. Note that the value of the power factor tests on dry-type transformers will be higher than on liquid units because the air is measured as a dielectric.

Drying varnish-insulated transformers. If the megohmmeter readings are low, it's an indication that the transformer needs to be dried. In fact, megohmmeter readings are of value in determining the status of drying. Measurements should be taken before starting the drying process and at 2-hr intervals during drying. The initial value, if taken at ordinary temperatures, may be high even though the insulation may not be dry. Because IR varies inversely with temperature, the transformer temperature should be kept approximately constant during the drying period to obtain comparative readings.

As a transformer is heated, the presence of moisture will be evident by the rapid drop in resistance measurement. Following this period, the IR will generally increase gradually until near the end of the drying period, when it will increase more rapidly. Sometimes, it will rise and fall through a short range before reaching a steady state because moisture in the interior of the insulation is working its way out through the initially dried coils. A curve, with time plotted on the X-axis (horizontal axis) and resistance on the Y-axis (vertical axis), should be plotted, and the run should be continued until the resistance levels off and remains relatively constant for a period extending 3 to 4 hrs.

Use caution when testing the insulation. The IR readings should be taken from each winding to ground, with all windings grounded except the one being tested. Before taking IR measurements, the winding should be grounded for at least 1 min to drain off any static charge. All readings should be for the same time of application of the test voltage, preferably 1 min.

Drying of the core/coil assembly. When it's necessary to dry out a transformer before installation (or after an extended shutdown under relatively high humidity conditions), one of the following methods may be used. (Before applying any of these methods, free moisture should be blown or wiped off of the windings to reduce the time of the drying period.)

When providing external heat, it's important that most of the heated air passes through the winding ducts, not around the sides. Three options are available here.

* Directing heated air into the bottom air inlets of the transformer enclosure.

* Placing the core and coil assembly in a nonflammable box with openings at the top and bottom through which heated air can be circulated. (By not using the transformer's enclosure, you avoid possible damage to gauges, gaskets, etc.)

* Placing the core and coil assembly in a suitable ventilated oven.

With either of the first two external heating methods, you can use resistance grids or space heaters. These may be located inside the case or box, or placed outside and the heat blown into the bottom of the case or box. A couple notes of caution here: The core and coil assembly should be carefully protected against direct radiation from the heaters, and the air temperature should not exceed 110 [degrees] C.

Drying by internal heat is relatively slow and should be used only when the other two methods are unavailable. The transformer should be located to allow free circulation of air through the coils from the bottom to the top of the enclosure. One winding should be short-circuited, and sufficient voltage at normal frequency should be applied to the other winding to circulate approximately 75 % of normal current. The winding temperature should not exceed 100 [degrees] C as measured by resistance or by thermometers placed in the ducts between the windings. The thermometers used should be of the alcohol type or thermocouples. Take care to protect the operator from dangerous voltage.

Drying by external and internal heat is a combination of the two methods previously described and is, by far, the quickest method. The transformer core and coil assembly should be placed in a nonflammable box, or kept in its own case when suitable, and external heat applied (as described in the first method) as current is circulated through the windings (as described in the second method). The current required will be considerably less than when no external heating is used, but should be sufficient to produce the desired temperature in the windings. However, the temperature attained should not exceed that stated in the foregoing paragraphs.

Applying load. Before applying load to a dry-type unit, you may wish to review ANSI/IEEE Standard C57.96-1989, Guide for Loading Dry-Type Distribution and Power Transformers.

You will observe vapor or smoke when initially applying a load to a varnish-insulated transformer. Do not be concerned. As the unit is brought up to full load, some temporary vapor or smoke may be given off from the unit's coil/core assembly. This is not an uncommon occurrence. It's due to the heating of residual varnish in the coils. This condition will disappear in a few hours after stabilizing at normal operating temperature.

Special procedures for tap selling. For dry-type transformers, after the correct tap connection has been determined from the nameplate, use the following procedure to change taps.

* Deenergize the transformer. Safety is of the utmost importance here. Make sure there is no back feed from a low-voltage tie breaker. Verify that the transformer is de-energized by testing.

* Remove front access panels from the transformer enclosure.

* When the output voltage requires adjustment, either up or down, you should change the percentage tap jumpers found on the front surface of the coils.

* Change the tap jumper on each phase to the correct tap connection. The tap jumper must be on the same tap position on all phases.

* The tap jumper must be installed on the upper side of the coil tap, with lugs on the ends of the cable tap jumpers positioned for maximum electrical clearances from the ground and other live parts. Be sure all bolts are tightened as described elsewhere.

* Replace the front access panel.

* Energize the transformer and recheck the output voltage.

Fully assembled liquid-filled transformers External inspection. This inspection calls for different criteria than for dry-type units. One of the first things you should check upon receipt and placement of the transformer is its fluid level. This is done by inspecting the liquid level gauge. If such a gauge is not used, check the level by opening the fill plug. Be careful when doing this. You should take steps to prevent the entrance of moisture or foreign objects. Moisture, dirt, and foreign objects can weaken the insulation level of the transformer fluid and greatly shorten the transformer's life.

Any unit that doesn't have the proper fluid level should be checked for leaks and topped off. When adding fluid to the transformer, use only quality oil, or if applicable, the appropriate fire-resistant fluid.

Transformers with liquid level gauges will have an indicator for the minimum allowed fluid level as well as a minimum 25[degrees]C level. Transformers without such a gauge must have the liquid level checked by removing the 25 [degrees] C level plug. If the liquid level is more than 1/2 in. below the 25 [degrees] C line, consult the manufacturer before energizing the transformer.

Presently, all transformers are filled or processed at the factory with dielectric fluid containing no detectable PCBs, in accordance with Federal Polychlorinated Bi-phenyl (PCB) Regulations. The presently accepted limit for PCBs in dielectric fluid is 1 ppm as based upon the latest detection capability. You should take precautions so that PCB contamination is not introduced during field filling or maintenance of a transformer. The use of old pumping equipment and old hoses that were at one time used for servicing transformers that contained PCB dielectric fluid is one of the main culprits for introducing PCBs into new transformers. And when storing dielectric fluid, you should make sure that the container being used is extremely clean and dry.

Testing the dielectric fluid. Upon receipt of the transformer, you should carry out certain tests using a sample of the dielectric fluid. These tests include dielectric withstand (per ASTM D1816 or D877), and dissipation (power) factor (per ASTM D924). The primary purpose of the tests is to confirm that the properties of the dielectric fluid meet the conditions established by the appropriate standards. But, the tests also set benchmark values for comparison with periodic testing done while the transformer is in use.

Standard dielectric fluid test procedures are found in ASTM D3487 for conventional mineral oil, ASTM D5222 for fire-resistant hydrocarbon fluids, and ASTM D4559 and D4652 for fire-resistant silicone liquids.

If analysis of dissolved gases in the dielectric fluid is to be performed as part of a preventive maintenance program, it's also advisable to set benchmark data for the new fluid. Fire-resistant (less-flammable) fluids also should be tested per ASTM D92 to confirm a minimum 300 [degrees] C fire point, which is required by the NEC for this class of fluid.

ANSI/IEEE is the best source for required acceptance tests for various fluid properties. Such applicable standards are C57.106-1991, IEEE Guide for Acceptance and Maintenance of Insulating Oil in Equipment, for conventional mineral oil; C57.121-1988, IEEE Guide for Acceptance and Maintenance of Less Flammable Hydrocarbon Fluid in Transformers, for fire-resistant hydrocarbon fluid; and C57.111-1989, IEEE Guide for Acceptance of Silicone Insulating Fluid and Its Maintenance in Transformers, for fire-resistant silicone fluids.

Internal tank inspection

Fully assembled liquid-filled transformers are usually shipped ready for installation and do not require internal inspection. However, if the transformer's tank must be opened, you should prevent the entrance of moisture, dirt, and foreign objects.

Mounting. It's important that you mount a liquid-filled transformer on a flat level pad strong enough to support the weight of the transformer (Part 1 of this article, in the June '96 issue, contained information on concrete bases for transformers). When supplied, hold-down cleats or brackets, as shown in the Figure (above), should be used to bolt the transformer securely to the pad. The unit should not be tilted in any direction greater than 1.5 degrees, as a greater tilt will cause deviations in the liquid level near fuses, pressure relief devices, and/or other accessories specifically located at or near the 25 [degrees] C liquid level. The result of a deviation in the liquid level can increase the possibility of a disruptive failure.

Locating the transformer. Since a conventional oil-filled transformer contains a combustible insulating fluid, transformer failure can cause fire and/or explosion. Alternatives, such as NEC compliant fire-resistant fluids (which have a reduced fire and/or explosion potential) should be considered when locating this type of transformer in buildings, or in close proximity to buildings or public thoroughfares. You should refer to the latest edition of the NEC for guidance in locating liquid-filled transformers and be guided by local codes. (Refer to the article "Knowing Liquid-Filled Transformer Installation Requirements" in the June '96 issue.)

Another consideration is that all indoor liquid-filled transformers require containment to control possible leaks of the fluid. Outdoor liquid-filled transformers containing more than 660 gal of fluid must meet the EPA's requirement for use of some type of containment to control possible leaks. Local codes may also have containment requirements.

Venting. Before accessing the inside of a transformer's tank, you must vent the unit by manually operating the pressure relief device normally provided, or by removing the vent plug. The transformer should be vented before it's energized if it has been pressurized for a leak test, since pressure will increase as the transformer reaches its operating temperature.

Treatment of bushings. Remove dirt and foreign material from all bushings. Carefully inspect the bushings for cracks or other damage before placing the transformer in service. If there are problems, contact the manufacturer and do not energize the transformer. Also, do not energize the transformer with the shipping caps on the bushings or inserts.

High-voltage porcelain bushings (when provided) are externally clamped gasketed bushings with eyebolt-type terminals. The primary cables enter the compartment from below and attach to the bushing terminals. The terminals will accommodate No. 8 through 250 kcmil cable.

Separable insulated connectors. Separable insulated connectors may be universal bushing wells, integral bushings, or bushing wells with inserts installed. They may be either loadbreak or nonload break. All connectors must be dry and clear of any contamination before installation. Unused terminals should be properly terminated to prevent possible contamination. Follow the manufacturer's instructions and warnings relating to the use of these terminations.

During installation, the recommended sequence of connections is to first make all ground connections, then the low-voltage (secondary) connections, and finally the high-voltage (primary) connections. Caution: Before making any connections, verify that all safety precautions have been taken in assuring that all conductors (both high-and low-voltage, the latter possible having back feed) not be energized. A transformer should be removed from service by reversing the above sequence of connections.

Carefully check the transformer nameplate for its rating and the connections that can be made to it. Avoid excessive strain on the bushing terminals or insulators; this could loosen the contact joints or damage the insulators. Remote energizing of a transformer, at a minimum using a hot stick, is recommended as a routine procedure.

Adjustments to the top changer. The tap changer provides a means of changing the voltage ratio of a transformer. These units serve a useful role to helping assure that the load receives the called-for voltage. Many transformers are supplied with an externally operated high-voltage tap changer, located near the high-voltage bushing. To change tap connections, use the instructions provided by the manufacturer.

Dual-voltage transformers, according to ANSI recommendations, should not have tap changes. For dual-voltage transformers that have tap changes, consult the name-plate to determine the proper tap changer setting for each voltage option.

Cabinet security. Before leaving the site of an energized transformer, you should make sure that all protective or insulating barriers are in place, the cabinet is completely closed, and all locking provisions are properly installed.

Accessories and their function. It's important that you're aware of the following accessories and their function.

Pressure relief device. A standard pressure relief device, located on the tank above the liquid level, relieves excessive internal tank pressure automatically and reseals at a lower positive pressure. It can be manually operated by grasping the end-cap (or ring, if provided) and slowly pulling it away from the tank until pressure is relieved.

Thermometer. When supplied, a thermometer indicates the liquid temperature near the top of the tank. The temperature-sensitive element is mounted in a leakproof well, permitting removal of the device without lowering the liquid level. These devices are usually furnished with an additional pointer, red in color, to show the highest temperature attained since last reset.

Liquid level gauge. When supplied, this gauge is located in the low-voltage compartment and indicates liquid level variation from the liquid level at a temperature of 25[degrees]C. This component is a readily available accessory and allows the fluid level to be easily checked without exposing the dielectric fluid to the atmosphere. You should make sure your transformer has one.

Pressure-vacuum gauge. When supplied, a pressure gauge is located in the low-voltage compartment above the bushings in the air space. The gauge indicates whether the gas space in the tank is under a positive or negative pressure.

Nameplate. A nameplate is supplied on each transformer according to Section 5.12 of ANSI Standard C57.12.00-1993, IEEE Standard General Requirements for Liquid-Immersed Distribution, Power, and Regulating Transformers. You should refer to the nameplate for transformer ratings and for proper connections of the transformer to the system. No internal connections should be made inside the transformer other than those shown.

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User's Manual

Assembly and Energizing For Power Transformers

ASSEMBLY AND ENERGIZING FOR POWER TRANSFORMERS

ABB

Table of contents

1 Objective

This instruction indicates the order of the activities to accomplish in the assembly and energizing of power transformers.

2 Description of the Manual

The recommendations, instructions and procedures here contained will give you a guide to accomplish labors of installation or assembly and implementation or energizing of a power transformer. This information is not the only one requirement to the transformer operates satisfactorily. It is required to count firstly on qualified personnel and tools and equipment designed for this purpose.

3 The assembly order of the transformer

It is important to remember that these instructions are general and for some transformers is possible that certain instructions and/or recommendations will not be applicable. After assembly of the transformer, make sure to check:

- Construction

Make sure that all the pieces are found in their respective places, and all bolts and nuts have been tightened.

- Connection

Check if all the electrical connections have been made correctly.

- Cooling System

Check if all the radiators' valves are opened, and that the cooling control device and cooling fans are operating normally.

- OLTC

Check if the OLTC operates smoothly, and the position of the Tap Changer corresponds to the desired tension. The control device for the OLTC (On-Load-Tap-Changer) must be in perfect conditions.

- Protection Relays

Check the correct operation of the contacts.

- Indicators

Check that the oil level indicators or the thermometers are displaying correctly the information on the scale.

- Air Breathers

Check their operation.

- Check if the valves are in the correct position.
- Grounding System

Make sure that the grounding system of the transformer is in perfect conditions. Since the adapters to ground have been painted to avoid any oxidation during transportation, remove all paint to obtain a good connection.

3.1 Transportation and arrival at installation site

When is necessary to transport the transformer to its installation site, please follow these steps in order to avoid any damages to its structure or accidents to the personnel responsible of such operation:

- Select preferably, as means of transportation a "trailer" of a low platform

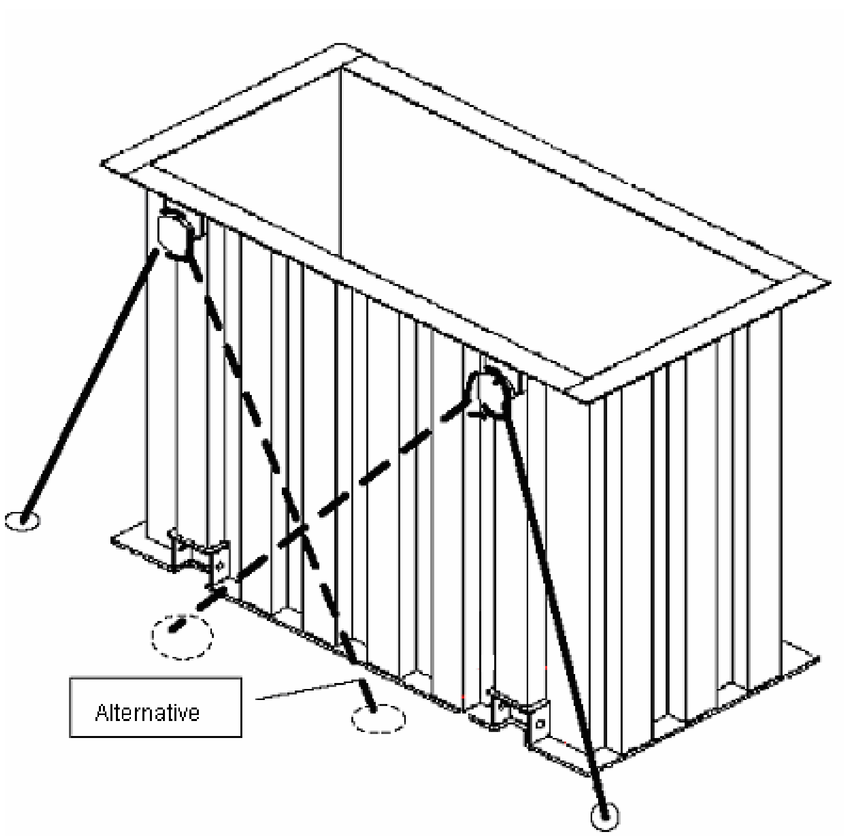

Figure 1. Tie-down hooks of the trailer

- Before the delivery of the transformer is strongly recommended to make a detailed revision of the route in order to anticipate to any possible obstacles (low clearance bridges), dangerous slopes, conditions of the highway, etc.

- As indicated in figure 2 the transformer must go as centered as possible in relation to the trailer.

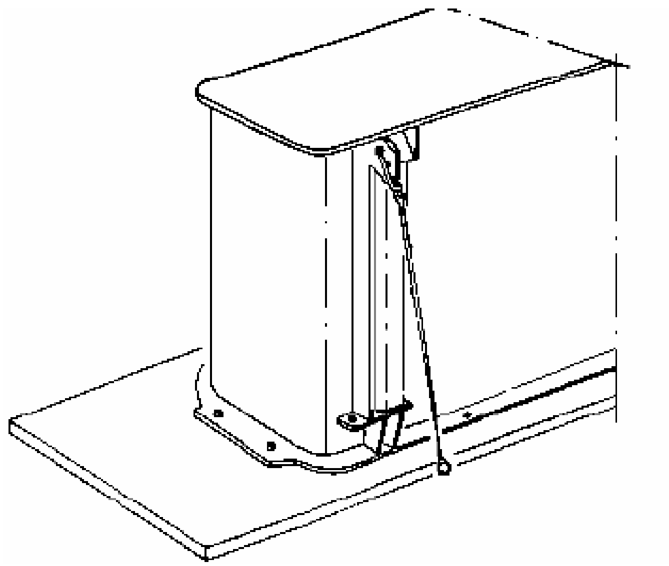

Figure 2. Position of the transformer on the trailer

- Check the condition of the tie-down hooks of the trailer and verify that they are in good condition.
- The expansion tank (if it is to be delivered with the transformer), must be placed behind the cabin of the truck.
- In each corner there should be at least two (2) tie-down hooks to secure the tank.
- Use when possible a steel chain or cable properly tensed. Never use either rope or any other material that may stretch. Each cable must offer a minimal resistance to traction of 15 tons.
- During transportation there should not be any slopes greater than 25° longitudinal and 30° transverse.
- Before transportation, dismantle all the radiators.

3.1.1 Handling

- Before unloading the transformer from the vehicle observe if there are any missing pieces or deformations. If so, inform the manufacturer of these irregularities before starting any repair.
- When lifting the transformer, the suspension cables have to be maintained almost parallel to avoid any bending of the hooking bolts or other parts of the structure.
- When a transformer can not be handled by means of a crane, it may be moved by sliding it on skates or on rollers, but being careful of not to damage the base or of not to tilt it.
- The transformer should never be lifted or moved by placing levers or hydraulic jacks under the purge valve, cooling oil drainage, connections of the radiators or any other devices.
- When large transformers are moved on rollers, beams must be supplied to distribute the forces on the base.

3.1.2 Recommendations during arrival at installation site

Some times the transformers are transported disassembled and in several sections such as the main tank, the insulators, the conservator tank, the radiators and other parts. The disassembled components are placed in crates or in boxes. These parts must be matched against the supplied packing list.

Immediately after arriving to the assembly site, a revision must be performed in order to find any damage that may have happened during transportation, and to verify if there are any missing pieces. If the damages are found, please issue a claim as soon as possible:

- **Checking for gas pressure**

In order to avoid any humidity from entering the main tank, it is filled with dried nitrogen gas (approximately 0.2 kg/cm² to 20°C). Remove the protective cover from the pressure gauge mounted on the tank, open the connection valve and check the pressure of the gas. After checking, close the valve tightly. A positive reading will means that no water or air has leaked to the interior of the tank. If the needle indicates zero, there may be water inside. In this case, measure the isolation resistance of the winding in order to establish the degree of humidity that has penetrated the transformer and to take the necessary corrective actions.

- **Outer Inspection**

Check if the transformer has suffered any accidental drops or if they are any twisted the reinforcements or pipes.

If the paint is damaged or if any metal pieces are rusted, used sandpaper and use an adequate anti-corrosive paint.

Check that all screws and nuts are not found loose.

Check the condition of the protecting instruments that are attached to the main tank.

If any damage is found relating to the previous points, the manufacturer must be immediately informed of this situation.

- **Inside Inspection**

Normally it is not required an inspection of the inside; in the case of being required, consult the following section in the instruction manual: “*Allowable time of exposure for the core and the winding and internal works*”.

3.2 Storage

After a transformer has been received at its final destination, it is advisable to put it (full of oil) on its permanent place, even if it is not going to be placed in operation immediately. If this is not possible, the transformer has to be placed in a dry place and the transformer must be filled with oil. If the unit is going to be located outdoors, the water vapor will condense inside the tank, due to the variations in temperature and humidity. This will be absorbed by the winding and it will be necessary to dry the unit before putting it on operation. Therefore, it is preferable to place the transformer in a place where the temperature is slightly high and stable, following the recommendations that are given below:

- The transformers for installation indoors have to be stored in a closed place. However, if it is going to be installed in open places, these places will have to be well covered to avoid the humidity and any foreign matters enter the tank.
- The transformers to be used outdoors must be stored whenever possible indoors.
- The base or the platform for the storage of the transformers must be sufficiently resistant as to withstand its weight and be perfectly flat.
- If the transformer is going to be stored outdoors, make sure that the area for storage has a good drainage system.
- Any incidental loss of oil will not harm the environment.
- To avoid any moisture from entering the tank, a periodic revision of the respirators of silica - gel and/or of the nitrogen pipes should be performed when the tank is partially filled with oil.
- Take the necessary steps to prevent that water condensation is formed in the accessories and parts that are delivered separately. Use the adequate protection against the weather elements. If it is necessary place Silica gel driers inside the bags and/or containers.
- Install all the necessary protection against corrosion and mechanical damages to the tank.
- Whenever possible, charge the control cabinets with their corresponding electrical tension to avoid any moisture from entering their interior.
- Storage for long periods of time

After a transformer has been received from the factory, it is recommended to put it on service on the shortest possible time. If the transformer is not going to be placed on operation immediately, it must be stored indoors and in a dry place by following these instructions:

3.2.1 Storage of transformers with sealed tank

- Transformers completely assembled

Check the internal pressure of the transformer: If the pressure gauge indicates a vacuum or pressure lower than 0.1 atm. (2 Psi), pressurize with 2 or 3 pounds of Nitrogen and check at least every month the internal pressure. In these conditions the transformer can be stored indefinitely.

If the pressure is higher than 0.3 atm (5 Psi), let escape the excess pressure.

- Transformers with detachable radiators

The transformer should be assembled totally, fill up with oil and pressurize it with Nitrogen to a pressure of 0.2 atm (3 Psi); following the recommendations from the numeral 1.1. In case of not being able to assemble it totally, the parts and pieces should be maintained sealed to avoid moisture from getting inside the parts.

WARNING

In the event of doubts or lack of knowledge of the qualities of the available oil and before filling the transformer, samples will be sent for tests to a competent laboratory. Oil that do not comply with our specifications, can not be used without our approval.

3.2.2 Transformers with expansion tank

- Fully Assembled

Place the silica gel breather following the instructions “Assembly of breathing silica gel".

WARNING

If during transportation the silica gel has absorbed any moisture (pink color), it will have to be dried in an oven to 150-180 °C, until it recovers its original blue color, or if it is possible to change it by a new silica gel.

In oil immersed transformers, the color of the silica gel will be controlled carefully every four (4) weeks, and in tropical climates every two (2) weeks. As it has been said previously, the silica gel will be replaced or will be dried in an oven, if more than half of the content of the present breather presents discoloration.

- Partially filled with oil

The expansion tank will be mounted and will proceed to fill it up with oil up to the corresponding level. Once the fill up is finished with oil, the silica gel breather will be mounted.

A transformer completely full of oil can be stored indefinitely. This storage is preferable than a transformer filled with gas.

- Fill up with Nitrogen gas

Verify the internal pressure of the transformer; this must be maintained in 0.2 atm (3 Psi). If the nitrogen bottle is empty, you must use for the fill up, nitrogen of a purity of 0.3% of its volume and a degree of maximum humidity of 250 ppm. Storing a transformer filled with nitrogen is possible, without other manipulations for a period of three (3) months.

For longer periods of storage, instructions to fill with oil will be requested. Each four (4) weeks the pressure of the main tank and of the bottle will be controlled

3.2.3 Storage of insulating oil

Insulating oil will be kept exclusively in clean containers and will be protected against humidity by placing the containers in a place where the temperature is maintained unchanged and on horizontal position. It will be avoided carefully any mixture with other liquids (oil for cables, lubricating and heating) or with solid particles. Small quantities of impurities can highly alter the qualities of the insulating oil. All the containers for storage are carefully checked and a detailed record will be kept of cleanliness and of perfect impermeability. It will be the responsibility of the selling company whenever possible to wash the dirty and/or used containers. In the event that becomes necessary a cleaning at the same installation site, these steps will be followed:

- The container will be sprayed with unleaded gasoline or with refined petroleum, until the cleaning liquid does not present some coloration.
- Once the container has been emptied thoroughly, will be placed to an oven or will be let to dry by means of a dried air flow for several hours. (Warning: There is explosion risk).
- After drying the container(s) will be closed hermetically, so no air would enter the container.

3.2.4 Problems and solutions presented during the reception and storage

- Oil leaks

Through the gaskets

Adjust the tie down devices (screws, flanges, etc.)

- Through strangulation valves

Adjust the hatches of the valves and flanges that protect them.

- Through pores or loose accessories or cracks

Make the necessary adjustments to avoid that any moisture continues penetrating the transformer.

When there are oil leaks of great consideration, adjustments to avoid this are done, and it is filled the interior of the transformer with nitrogen gas until a pressure of 2Psi is obtained and is communicated to the nearest distributor.

- Blows and dents

When the transformer or some of its elements presents signs of hits or impacts, inform the nearest distributor or the factory to indicate the impact place and receive relevant instructions.

- Deterioration of the paint

When deterioration of the painting is presented, clean the surface of any dirt (dust, oil, grease, etc) use degreasers or soapy water; then dry the surface, sand down the deteriorated spot, clean any new dust and apply a coat of epoxy paint. Let it dry this and during time intervals of drying, apply as many coats of paint as necessary, to return to the required thickness.

- Loose accessories

When there are loose accessories, tighten them again until they are returned to their correct position. Check that there are no cracks and no moisture is found in the interior of the transformer.

If any of these cases is presented, it is recommended after taking the indicated corrective measures, to perform the following tests:

- Test of the dielectric strength of the oil
- Test of the isolation resistance (Megger)
- Test of transformation ratio (+TTR)
- Tightness test by applying nitrogen gas to a pressure of 7 Psi.

If any of these tests does not give the expected results, contact the nearest distributor or with the factory directly.

3.3 Preliminary fill up with oil

In order to avoid during the assembly of the transformer direct contact of the winding and the insulation with the atmosphere, it is recommended to fill up the transformer previously with insulating oil up to a level that is 25 cm below the cover of the tank, In the case of a transformer equipped with expansion tank or 85°C labeled on the indicator level in the case of a sealed transformer.

Before filling up with oil, it is necessary to conduct the dielectric resistance test of the oil stored in drums.

Take a sample from each drum and make sure that the dielectric characteristic correspond or not to the specified. See standard ANSI/IEEE C57.106-1991, IEEE Guide for Acceptance and Maintenance of Oil in Equipment. In a negative case, that is to say, the oil does not possess the dielectric characteristics specified, filter totally the content of the oil. The Fill up with oil must be done only after the test values are found to be within the specified values.

There are two methods to conduct an oil fill up.

The first of them consists of filling the tank with oil through the drainage valve while gradually the nitrogen contained in the tank is released. The pressure of the nitrogen contained in the transformer tank must be kept between 0,05 and 0,2 kg/cm2 during the oil fill up.

The second method consists of filling with oil after reaching vacuum in the transformer.

See fill up with oil under vacuum. This method is recommended by ABB by being the safest method of the two.

3.4 Radiators assembly

When it is necessary to dismantle the radiators for transportation, They will be sent tightly closed with blind lids. The strangulation valves that are found welded or bolted to the main tank are dispatched in their close position and, are protected with blind lids. The general arrangement of the radiators is illustrated in the figure 3.

Upon receiving the radiators and removal from the crates, verify that they did not suffer any mechanical damages during transportation.

Remove the blind lids and check that the radiators are found clean and without moisture. In the event of moisture or impurities is found, it will be necessary to wash them with oil at 60 °C and to cover them to prevent than more moisture enters the radiators.

Before removing the protection lids from the strangulation valves, verify the type of insulation protection against moisture during the delivery. Normally, we find two types of preservation for shipment:

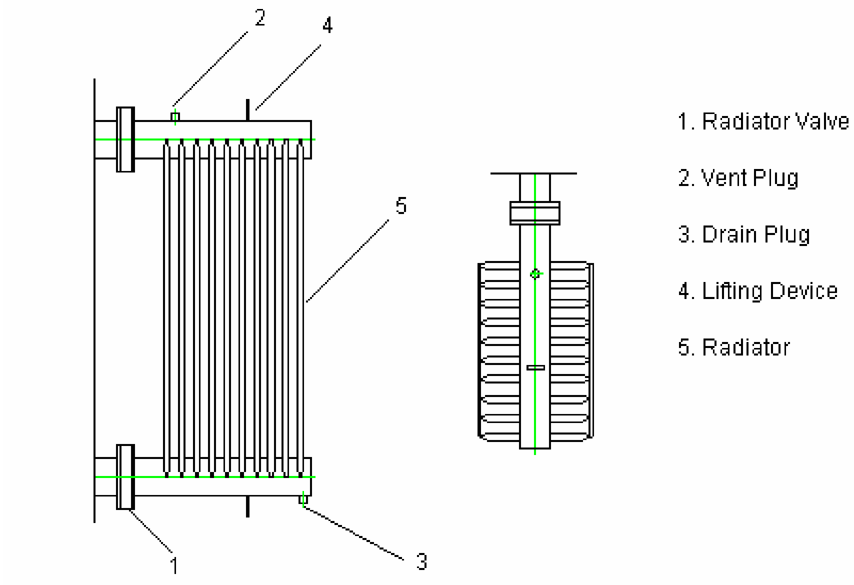

Figure 3 Radiator parts

1. Transformers totally filled with nitrogen
2. Transformers partially filled with oil and nitrogen gas

For the first, we recommend to follow the instruction PRELIMINARY FILL UP WITH OIL, before conducting any assembly on-site. However, if the only assembly to be done is for the radiators, it is possible to assemble the radiators with the tank full of nitrogen, but maintaining a positive internal pressure between 0,05 and 0,2 kg/cm2, during the assembly.

For the second option, the transformer should be kept sealed and you should place a container (bucket, etc.) under the valve to collect oil that may spill out. Remember that this type of valve does not close completely to drip test. Therefore, you must not hit the valve to close hermetically.

For installing the radiator, follow these steps:

1. Raise the radiator from its storage position, and pay attention to avoid damages to the other radiators with the tools used for hoisting.

2. Remove the blind lid and the packing from the radiator.

3. Check visually the interior of the radiator.

4. Clean the surface of the assembly clamp of the radiator.

5. Remove the purge stopper (2) indicated in figure 2.

6. Remove the blind lid and the packing placed on the strangulation valve of the transformer.

7. Clean and if possible paint the surface of clamp of the valve from the radiator.

8. Clean the groove for gasket of the valve.Apply a small amount of adhesive in the groove and put the new specified gasket.

9. Lift the radiator with a crane.

Though the radiators are identical, each radiator comes labeled to be installed in the position that has been indicated on the main tank. You must follow this labeling in order to avoid delays in the placement of the same.

10. Move the radiator by hand, tilt it and drain any residual oil.

11. Align the radiator to the radiator valve.

12. Align the radiator valve and the surface of the clamp of the radiator and tight it with nuts.

13. Tight a pair of nuts located diagonally one after the other in order to tight them evenly.

14. Tight firmly until the radiator valve and the radiator clamp become one whole unit. Upon adjusting, the radiators should not be exposed in any case to mechanical tensions that may lead to breakings caused by vibrations.

15. Install the purge stopper (2) indicated in the figure 3. if the tank is filled with nitrogen, if the tank is partially full with oil. See Fill up of radiators.

16. Once finished with the assembly of the radiators, place the supports symmetrically and the clamps of the radiator.

3.4.1 Fill up of the radiators

- Tank totally filled with nitrogen.

Open all the strangulation valves and fill the tank following the instruction “Final fill up of oil under vacuum”. The radiators will be filled automatically at the same time. After minimum of a (12) hour resting time, purge the radiators.

- Tank partially filled with oil and nitrogen.

Open slowly the lower strangulation valve corresponding to the radiator that it is already installed. Oil will flow into the radiator from bottom to top, and the air will escape through the purge stopper. During this process, the oil level in the tank must be controlled and oil will be added in such a way that the oil will cover the windings.

To maintain oil level, follow the instruction “final fill up with oil under vacuum”

When oil comes out without bubbles through the stopper, this will be closed with the stopper nut provided for such effect. Next, open the upper strangulation valve. After a prudent rest time, purge again all the radiators.

3.5 Assembly of the expansion tank

There are three types of conservator depending on the degree on protection that is required and/or of the accessories included. These are:

3.5.1 Conventional conservator tank

The most common type found in transformers. Upon installing the conservator on the transformer, it is necessary to pay attention to the following items.

3.5.1.1 Assembly of the Buchholz relay (31)

If the transformer is provided with a Buchholz relay, install it in the conservator before proceeding with the assembly of the same in the transformer. The relay is found connected to the conservator through a clamp and four (4) screws. Normally in the connection pipe, there is a valve installed for future maintenance of the Buchholz relay. Remove a blind lid from the surface of the clamp, and replace the gasket with a new one. Install the relay in the conservator and tight it firmly and evenly the bolts. Make sure of putting the relay in the direction indicated on its characteristics plate or on the body of the relay.

Place the conservator tank on the bases destined for the attaching to the main tank of the transformer and place the eight screws, but do not tighten them completely at this stage. Align the clamp of the Buchholz relay with the connection clamp from the main tank and secure it with screws, making sure that no mechanical forces are placed on the relay. Once concluded this installation, make sure that the expansion tank is secured to the main tank and give final tightening to the screws. For more details on the relay check the relay manual.

3.5.1.2 Assembly of the Silica Gel Breather (33)

Once the transformer has been filled with oil, proceed to install the respirator following these steps:

- Verify that the silica is dry (purple color); if not, dry it by following the steps that are indicated in the maintenance handbook.

Thread the breather into the pipe given for such use. To obtain better tight seal, it is recommended to use Teflon tape in the screw thread.

-Fill up with dielectric oil the container located in the lower part of the breather up to the indicated level.

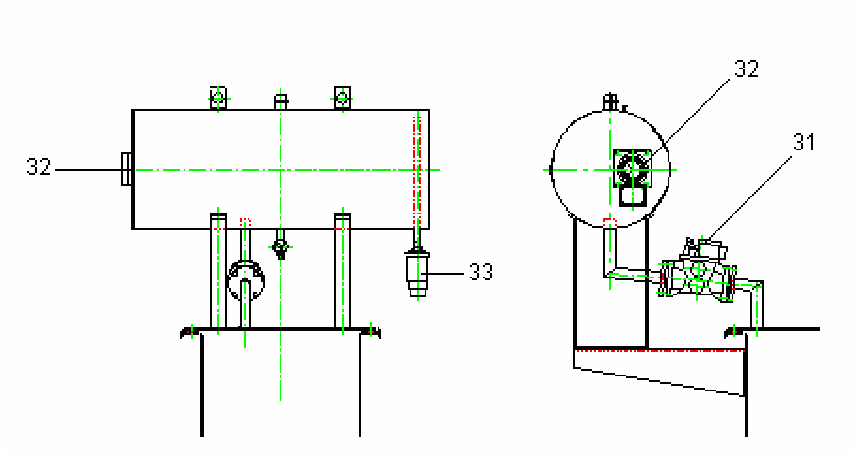

Figure 4. Conventional conservator tank

3.5.2 Conservator tank with OLTC.

This tank in reality are two conservators mounted in one same cylinder. The barrier has a job of separating the oil from the transformer and the OLTC. Therefore, during fill up, you must consider independently the two compartments.

For assembly, follow what is indicated in items 3.5.1.1 and 3.5.1.2, taking into account to the larger of the breathers is going to the main tank, while the small (38), corresponds to the OLTC. Do not forget to fill up with oil the container at the lower part of the breathers

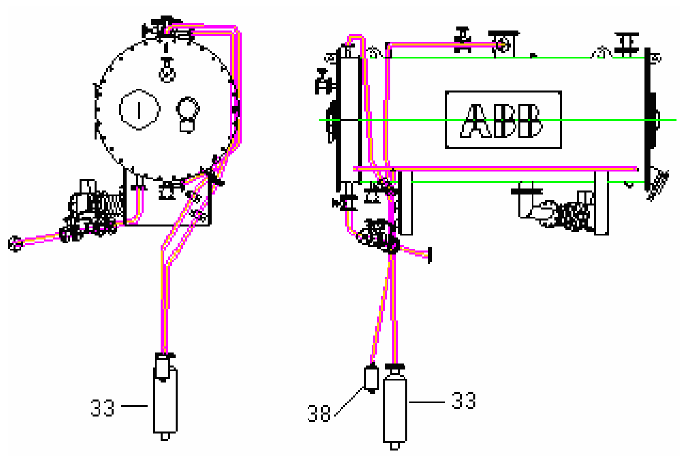

Figure 5. Conservator tank with OLTC

3.5.3 Expansion tank with bladder or flexible separator (21).

For assembly, follow the steps indicated in items 3.5.1.1 and 3.5.1.2.

As this device is not common for use in small power transformers, it is necessary to give the following indications

- **Description**

A flexible separator is placed in the interior of a cylindrical conservator or parallelepiped. The outer surface is in contact with the oil and the interior surface with the atmosphere

This type of assembly makes possible the compensation for the variations of the volume of oil due to temperature changes; guaranteeing:

- An efficient barrier between oil and the air
- A protection against moisture
- The suppression of any gas bubble formed in the oil
- The large volumes of compensation up to 15 m3.

- **Dimensions**

The dimensions of the separators are determined based on the conservator tank.

- **Procedure for fill up without vacuum in the conservator**

Proceed as follows:

- Verify the position of the separator inside the conservator, for such end is necessary to remove the lid that has been screwed into the conservator. This is done in order to guarantee that the oil float is found under the membrane, and the membrane is deployed.

- Inflate to 0.1 maximum bar, letting the escape orifice on the conservator open.

- Adjust the pressure six (6) hours after.

-Maintain the device at a constant temperature and verify if exist a loss of pressure for a period of 24 hours. If there is no loss of pressure, then you can considered that the separator and the conservator have been perfectly mounted.

- Inject oil at low pressure by the lower part of the conservator until it escapes through the venting orifices in the upper part.

- Close the venting orifices and fill the conservator through the lower part, while letting the separator deflated progressively.

- Conclude with the fill up when the oil reaches the level of operation temperature.

IMPORTANT: CAUTIONS

When the device is ready and working, never open an orifice in the upper part in order to verify the total empty. Such opening would create an air current in the upper part of the *device creating a drop in the oil level that is compensated by a drop in the volume of the separator.*

If you think that air has entered the conservator, first, you must inflate the separator below 0.1 bar and after to open the venting orifices.

- **Fill up under vacuum**

The conservator and the separator are mounted on the transformer and are connected to an oil source by means of a pipe in the lower part of the conservator tank.

Proceed as follows:

-Create vacuum inside the separator

-With the same source of vacuum, create vacuum in the conservator

-Open the valve at the lower part. Due to vacuum in the conservator, the oil level will rise automatically. Stop fill up with oil once the volume required in the conservator is reached.

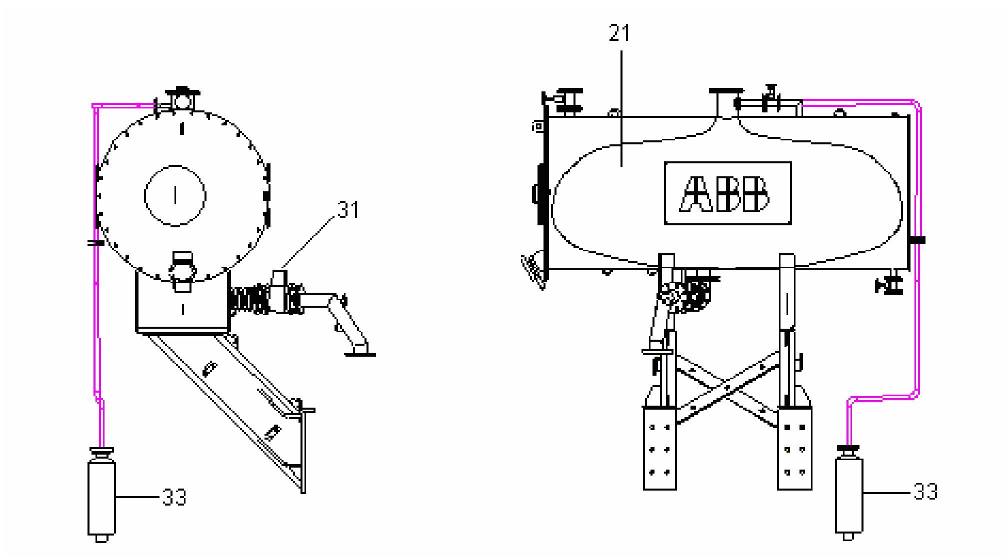

Figure 6. Expansion tank with bladder or flexible separator

-Maintain the conservator under vacuum, but let air or nitrogen enter the separator, then this will inflate by itself and will take all the free space because the conservator was not completely full.

Inflate the separator to a maximum pressure of 0.1 bar

-Check that in the venting orifices appear oil, guaranteeing that the conservator does not have anymore air.

-Close the venting orifices and if it is necessary adjust the level.

- **Insulating oil drainage and fill up with nitrogen**

The following instructions have two main applications:

1. For the delivery or movement from the operation site, of transformers completely filled with nitrogen.

2. To place on the better conditions the insulation, before final fill up.

For the first case, after removing all the removable accessories from the transformer, proceed to give a tight seal to the tank by using clamps and closing the valves. For the second case, after installing all the accessories, except the air breathers (this must be installed after fill up with oil); drain the total content of insulating oil from the transformer, in order to eliminate the impurities, dust, etc, that may be found in the oil, as well as any gas that could have been absorbed.

Inject nitrogen gas to the transformer to move any insulating oil, then drain the oil. Do not allow that the internal pressure of the transformer reach a negative level. The hermetic pressure of the nitrogen gas must be from 0,05 to 0, 2 kg/cm_

Once the transformer is thoroughly empty, seal all the orifices and maintain a positive pressure of 0,2 kg/cm2.

For the following step, follow the instruction "*Final fill up with oil under vacuum*".

3.6 Final fill up with oil under vacuum

Cautionary steps needed to create vacuum and fill up with oil.

1. Upon opening oil drums, pay attention in order to avoid that any humidity or moisture is condensed inside the drum. It is recommended to perform the fill up operation when the relative humidity in the air is low. The drums should be opened only when the oil is needed. Before fill up with oil, take samples of the oil contained in the barrels and test them for their dielectric characteristics. Refer to ANSI/IEEE C57.106-1991, IEEE Standard. Guide for Acceptance and Maintenance of Oil in Equipment.

2. The machine or equipment used for fill up with oil must be clean and free of humidity, pay close attention to avoid the insertion of moisture to the oil through the oil line.

3. Do not energize the transformer while performing vacuum or while it is being filled up with oil.

3.6.1 Vacuum treatment

1. Remove all the air from the transformer for more than 12 hours using a vacuum pump, and check if the vacuum level inside the transformer is less than 3mm Hg using a vacuum gauge.

2. After confirming the vacuum level, stop temporarily the vacuum pump and conduct the stop test.

The criterion for the stop test is by means of the level of vacuum, and its increase 15 minutes after the stop, as is specified below. If the result of the stop test is satisfactory, proceed to fill up with oil.

Rated Voltage of the transformer	Increase of the vacuum level
Less than 110 kV	less than 3,0 mmHg
More than 110 kV	less than 1,5 mmHg
More than 220 kV	less than 1,0 mmHg

Table 1. Rated Voltage and increase of the vacuum

3.6.2 Fill up with oil

- After performing the vacuum treatment previously described in the transformer, maintain vacuum for an hour. Then, open the oil drainage valve and pump degasified oil to the tank. Insulating oil must pass through oil press filter and the pre-conditioner of oil for vacuum.

In order to make more effective the fill up, it is recommended to place the contents from the barrels in a metallic tank or if possible in a collapsible tank.

The adequate capacity of the tank of oil is approximately 20% of total quantity of oil for the transformer, when the average voltage of the transformer that is to be installed is lower than 69 kV. When the average voltage of the transformer is 69 kV or higher, it is better to use an oil tank with an equivalent capacity to the total oil quantity, since it is preferable to drain the complete quantity of oil, once all the oil has been placed in the transformer. When the capacity of an oil tank is insufficient, use several tanks.

The internal surface of the oil tank must be cleaned and free of dust or any debris. It must be a sealed tank that will not allow the filtration of rain or air when is installed outdoors.

If air filters into the tank of oil, place a container with silica gel where the air is leaking into the tank, in order to prevent any moisture from getting in. It is convenient to put an indicator in the level of the oil or a transparent pipe.

- During fill up with oil, continue the operation with the vacuum pump. When the degree of vacuum is higher than 3mmHg, stop temporarily the fill up, and operate only the vacuum pump to reach the required degree from vacuum.
- When the indicator of oil level reaches a level scale at 85 °C, stop the fill up. Shut off the pipeline of the oil.
- After filling the transformer with insulating oil, a dehydrating breather will be installed if the transformer comes with a conservator tank or it will be sealed if it is of sealed tank type, and each valve will be placed in the work position.
- Release any air that may be inside by loosening the air purge stoppers. If necessary, change the packing or gaskets of the purge stoppers with new ones.
- Take an oil sample from the sampling stopper and conduct the dielectric tests of the insulating oil. Register the measured values.

- Wait for more than 8 hours to allow the oil to penetrate the various submerged parts, and then drain some oil until you obtain the normal oil level

3.7 Tests in field

The transformer has been tested in factory and is guaranteed that it will meet with the objectives for which it was built.

Of the size of the transformer, the importance of the supply, and the number of parts that had to be assembled on-site, depends the need of performing some or all of the following tests.

The tests that must be performed during and after the assembly are the following:

3.7.1 Measurement of the insulation resistance

3.7.1.1 Body of the transformer

Measure the isolation resistances between two coils and between each one of the coils and ground using a device of more than 1000V, to register the measured values. The values of the insulation resistances will change according to the temperature, therefore make sure to record the temperature of the transformer too. It is necessary an insulation resistance of more than 1000Mohms for a temperature of 30°C inside the transformer.

3.7.1.2 Control Panel

Measure the insulation resistances between two terminals from the terminal box and between each terminal and ground; from terminal to terminal, and register the value of the insulation resistance and the temperature. In the case of current transformer type BCT bushing in particular, make sure of measuring the resistance of the insulation between two BCT, as well as the insulation resistance of each BCT and ground, at a temperature of 30°C, it is required more than 100Mohms.

3.7.2 Polarity tests, phases rotation and transformation ratio

IPerform the polarity and rotation tests of phases with the tap changer in the nominal position. Turn Transformer Ratio or TTR

Yet, in the case of a transformer of three phases, it can be measured by using one source of energy of one phase, and will be very precise. Measure the transformation ratio in each one of the positions of the tap changer, considering each phase.

If you have available a transformer standard (TTR), it is recommended to use it for the tests of transformation ratio and polarity.

3.7.3 Insulation power-factor test and capacitance

The values revealed by this test must be kept and be used as reference to determine the humidity and/or the aging of the insulation with the course of the time. Also, it must be registered the temperature at which the measurement was accomplished.

It is recommended to perform an insulation power factor test of the insulating oil.

3.7.4 Dielectric breakdown test, and moisture in the insulating oil

The values shown in this test determine the degree of dryness of the insulating oil and serve to take the decision of energizing or to reprocess the insulating oil contained in the transformer. It is also recommended to accomplish a visual checkups, interfacial tension, color and number of neutralization or acidity.

3.7.5 Increase in temperature test

This test generally is not done even though there are numerous methods. Such as: method of the short circuit, where a coil is connected in short circuit and the impedance voltage is sent to other coil. The practical recommendation is to do a close follow-up at the temperatures of the transformer during the first operating days.

3.7.6 Test of the alarm systems and the control units

You can trigger each accessory, such as the pressure release device, the revealing Buchholz, etc., or you can create a short circuit in the terminal of the accessory; verify its operation with the terminals and with the alarm panel.

Regarding the box of the mechanism of the tap changer which is triggered by motor, if it is available, start it up and observe if there are any abnormalities or not. Verify the manufacturer´s manual.

3.7.7 Other

Put in the transformer a continuous pressure of 0.3 Kg/cm_ (obtained with nitrogen gas) for more than 24 hours and check if there is no oil leak. Furthermore, examines the appearance, dimension and other characteristic of the transformer, consulting the drawings. It is recommended to measure also the resistance of the coils.

4 General instructions

Practical and rigorous procedure must be followed during the inspection, assembly, energizing and transformers maintenance. These must be strictly followed for the protection and safety of the workers and the transformer.

4.1 Safety procedures

The tank of the transformer must be grounded at all times. All the windings and bushings must be connected to ground unless there are performing electrical tests. This reduces the possibility of static discharges that can be dangerous for the personnel, even to the point of starting a fire and/or an explosion. Electrical test should not be conducted when the transformer is found in vacuum conditions. An arch can occur at low tension due to the vacuum conditions, causing serious problems in the transformer.

The secondary windings from the current transformers can dangerously induce high tension through them unless they are shorted out or connected to an ammeter.

There are examples of electrical phenomena that can happen on or about transformers, therefore, it is necessary to work with qualified personnel under good supervision during any assembly operation, maintenance or maneuvers.

Before using an electrical source for motor tests or control, make sure that it all the sources of auxiliary power have been disconnected.

Fire extinguishers must be supplied in the event of emergency. One must be in the upper part of the transformer when working on upper part of the tank. No smoking next to the oil treatment machine or in the upper part of the transformer when some cover is removed or a hole is open.

If a fire extinguisher is used inside the transformer, there is serious danger of damaging its insulation.

Before removing any lid, it is necessary to make sure that no pressure exists in the tank, by opening slowly a valve in the upper part of the tank above the oil level.

The lights that are used inside the tank should have a protection against blows, and when possible to explosions test. Extreme caution should be taken by the persons that are working on the upper part of the transformer when it is opened, any object that falls within the unit will cause huge delays in putting it in service.

4.1.1 Cautions upon energizing the transformer

Once all the inspections and preliminary tests ended, the transformer is ready to be in service. Simply take into account the following recommendations:

- Place the position of the switch in relation with the tension line.
- Apply tension to the transformer without load.
- Maintain it under observation during for (24 hours) and make sure that it is in normal conditions.

- Also, it is necessary to observe the transformer during an hour after that it has been loaded.
- Once installed and energized, the transformer must be checked periodically.

4.2 Necessary tools for assembly

Below are listed the articles, specifications and warnings for all the tools required for the assembly of the transformer.

- Crane

It is convenient to use a crane to install the radiator, the conservator, etc. It is acceptable a crane with a load capacity of 10 tons and with a length of the extension arm of approximately 10 meters. A qualified conductor must handle the crane. Before lifting the part, lift a load of a similar weight to check that the crane works adequately.

- Oil Tank made of steel plates, or collapsible rubber.

The internal surface of the tank must be clean and free of dust and dirt. It must be guaranteed its total tight sealing and cleanliness.

- Oil Filtering Press.

Use an oil filtering press to transfer oil from the drum to the tub. Use a new paper filter and perfectly dry for the filtering press, since its function consist of removing the particles or the dust contained in the oil.

Generally, an oil filtering press with a capacity of 1,000 to 5,000 lt/hour is adequate.

- Oil Purifier.

Use an oil purifier to transfer oil from the steel tank or collapsible tank to the transformer. The principal task of the oil purifier is to eliminate the gas contained in the oil. Also, it eliminates the dust and debris. Therefore, this purifier must have the following parts: a vacuum pump, a heater, a filter, an injection pump, etc.

Generally, it is used a purifier with a capacity of 1000 to 5000 lts/hour.

Perform a flow test before filling with oil the transformer, in order to drain any residual oil from the purifier and to clean the inner parts of it.

- Vacuum pump.

When transferring oil from the tub of oil to the transformer, using the oil purifier, it is necessary to have vaccum in the interior of the transformer. For this, use a vacuum pump. To create vacuum, it is required approximately 12 hours, if the transformer is of less than 100 kV and 16 hours for transformers of 110 kV or more.

It is recommended that the degree of vacuum established be of 1 mm Hg or less. Once the waiting period mentioned above is over (12 or 16 hours depending on the transformer), you may start the fill up process. When the degree of vacuum is less, stop temporarily the fill up and wait until the vacuum conditions improve.

- Nitrogen gas cylinder

The cylinder of nitrogen gas must be equipped with a reducing valve, a gauge and a rubber hose.

- Tools needed

* Drum opener
* Scissors
* Stripping wire pliers
* Jack with lifting capacity of 10 tons.
* Monkey wrench
* Regulating wrench
* Small bar with tweezers.
* Set of wrenches of several dimensions

WARNING STEPS

- Keep to a minimum the number of persons that can get into the transformer.
- Before entering the transformer, all persons must check their pockets and make sure that they are empty. Also, check that all buttons are well attached to their garments and will not fall. These people must be wearing clean and dry shoes.
- Tie the wrenches or other tools to the waist or the wrist before using them inside the tank.
- Have a written record of the tools used inside the tank and check after ending any work to see if nothing was left in the tank.
- Use work lights that come with protective device for the bulbs. Do not replace any bulb inside the tank.
- Have an assistant near to the manhole for any assistance. The assistant always must care for the worker inside the tank, and never abandon the work area during any work in progress.
- Supply the parts or the required materials one at a time. Never, provide simultaneously many parts and/or many materials.
- No smoking is allowed in or near the transformer. Make sure to take the necessary steps to prevent a fire.

4.3 Internal inspection

Listed below the items to survey, if they are applicable. During the inspection, do not step nor rest on the coils and conducting threads. If you find any serious damage or anomaly, please notify the nearest office or agency of ABB.

- Tap lightly with a hammer the screwed portions of the metallic pieces such as yokes and clamps.
- Examine the insulation in the extreme of the windings and the clamping devices mounted between the cores and yokes such as the studs, supports and cradles.
- Examine the appearance of the coil.
- Examine the supports of the conducting thread, studs and insulating nuts. If loosened, tight it carefully. Do not apply too much torque to the studs and above-mentioned nuts.
- Examine the insulation in the conducting threads of the HV. Remove any damaged paper if there is some, and wind the crepe paper impregnated in oil with half lapped until the original diameter of the insulation.
- The length of the sharpened union will not be less than 10 times the thickness of the insulation.
- Examine the appearance of the bare conducting threads and their joints.
- Examine the appearance of the tap changers without tension and conducting threads. Confirm that the tap changer mobile contacts are found in a corresponding position to the indication No. 1 tap and in the center approximated between the contacts.
- Examine the appearance of the on load tap changer and the conducting threads. Confirm that the mobile contacts of the selector of tapping are found in the approximate center of the fixed tapping, when the design of the changer allows it.
- Examine that all CT´s are installed certainly in the normal position, and that their terminal and secondary conducting threads are in perfect conditions.

4.3.1 Internal connections

- **Preparation**

To accomplish the internal connections in the shortest possible time, prepare the following tools and insulating materials before beginning to work.

- **Tools**

- Set of torque wrenches

- Foresail keys (LLAVE DE TRINQUETE)

- Sharp blades

- Convex ruler

- Lamp(s)

- **Insulating materials**

- Crepe paper impregnated in oil

- Kraft Paper impregnated in oil

- Tapes

NOTE: Maintain in the interior of the tank the insulating materials. If they are stored outside, submerge them in insulating oil in order to prevent any moisture from being absorbed, and extract them immediately before being used.

4.3.2 Connections

- Due that the thread conductors consist of fine intertwined copper wires, do not cut these wires.
- Use the TORQUE WRENCH to tighten the bolt terminals or bare conductors. It is listed in following table, the torque required for the different size screws:

SIZE OF THE BOLT	TORSION PAR	
	kg - cm	Lbs - Inches.
M6	50 ± 10%	44 ± 10%
M8	120 ± 10%	104 ± 10%
M10	250 ± 10%	217 ± 10%
M12	600 ± 10%	522 ± 10%
M16	1000 ± 10%	870 ± 10%

Tabla 2. Size of the bolt and torsion par

- Any insulation work for the conductors must be followed according to the drawings kept in the instructions handbook for installation
- Upon winding the conductor with the creaping paper, unwrap 60% of the same and wrap it with half lapel. Do not unwrap it completely.

4.3.3 Inspection after connections

Below are the items to check.

- Examine that all the connections are according to the drawings or the reference markings.
- Examine that the screws and the nuts are tightened.
- Check that the required insulation distances are maintained between the conductors and the others parts.
- Make sure that no tool or material was forgotten inside.

4.4 Allowable time of exposure for core and windings

While some activities are performed such as the internal inspection, bushings installation, internal connections, etc., with the manhole of the transformer open, the core and the windings will absorb the moisture from the atmosphere.

Therefore, the exposure time of the core and the winding will have to be limited within the specifications that are mentioned below.

The transformer should not be opened when it is raining, there is the threat of rain or the relative humidity of the air is more than 80 %.

The manhole and other openings will have to be closed and be sealed immediately after any internal work is done or suspended. However, the time elapsed during a opening will let atmospheric air to enter the tank, and it must be considered as exposure time outdoors. Therefore, the core and the windings will absorb humidity during this period.

In the case of the tank is filled with atmospheric air and sealed in these conditions, the exposure time must be recorded as four (4) hours for one time during the installation of the transformer.

When the extraction of the dry nitrogen gas takes place, it is considered that the transformer will be filled with atmospheric air, situation that is recorded as two (2) additional hours of exposure.

The total allowable time of exposure is indicated in fig. 7.

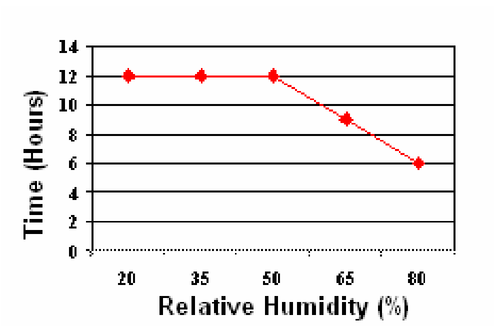

Figure 7. Relative Humidity average

4.5 Inspection of rubber gaskets

The disassembled gaskets in the field must be checked and examined to decide their use or not according to the following table:

REUSABLE	NOT USABLE
Without breaks or stretching Very small Stretching but without grooves or dents Only it stays the shape of the corresponding groove to the gasket Exists partial stretching but no grooves exist in the original width.	1. Very deep grooves and stretching 2. Deep grooves and dents are observed on the surface of the gasket.

Table 3. Inspection method of gaskets

4.5.1 Maintenance of the gaskets and sealed surfaces of the clamp during the installation

- Clean any dirt and oil from the reusable gaskets and from the sealed surface of the clamp, using a rag soaked in a dissolvent, that it can be alcohol or gasoline.

NOTES

- The gaskets should never be in contact with the dissolvent.
- The dissolvent should be used only for cleaning any dirt to avoid that the dissolvent or dust penetrates the interior of the transformer.
- The gaskets and the surfaces of the clamps will have to be mounted when the dissolvent used for cleaning have dried thoroughly.

4.6 Instruments for measurements and field test

Complete the inspection and the field test during and after the assembly of the transformer, using the following tools:

- **Oil Testers**

It is used to measure the dielectric characteristics of the oil. Though the Standard ANSI/IEEE C57.106-1991, specifies a good quantity of tests, is required at least to have a high dielectric breakdown tester and a measuring device of ppm of water (humidity) by the Karl Fisher method. The stages by which these measurements should be taken are:

* Select several drums and inspect them.

* After the oil is poured in the tank of the oil and before transferring it to the transformer.

* After the oil is in the transformer, take a sample from the bottom of the drum. Compare the results of the test with ASTM, BS or any other equivalent standard.

- **Voltmeter**

It is required an AC voltage meter for the following tests:

* Polarity test
* Monitoring of the vector graph
* Test of the sequence of the control circuit.

It is necessary a set of each one of the following voltmeters of double range precision for AC:

AC 150/300 V one set

AC 30/75 V one set

- **Ammeter**

A set of each of the following precision ammeters of double range is required to measure the excitation current. When it is applied in low voltage to the transformer, and to measure the current of the auxiliary devices of the transformer, such as the cooling fan, the oil pump, etc., in case it comes with the transformer.

AC 20/100 A one set

AC 10/50 A one set

For some applications, it is sufficient with a pair of ammetric tweezers.

- **Measuring Resistance Bridge**

This is necessary to test the resistance of the windings of the transformer. It must be capable of measuring between a range of 0.001 - 10 ohms

The Kelvin bridge is acceptable. You must have at hand some batteries.

- **Measuring device for the insulation resistances (megger)**

A hand-held device with a range of approximately 2000V and 2000 Megaohms is acceptable.

- **Universal tester or VOM**

This is a portable tester that can measure the AC voltage, the resistance and the DC current, changing the range. It is used to verify the controlling wiring or the electrical parts.

- **Turn Transformer Ratio (TTR)**

This device is very useful to check easily the relationship of transformation without requiring external feeding sources and/or to induce voltages in the winding dangerous for the workers. With this same equipment, you can check the polarity and depending on the model, the vector group.

- **Rotation phases meter**

Meter used to verify the direction of the rotation phases of a three-phase electrical motor, etc.

- **Vacuum Meter (Vacuometer)**

It is necessary to prepare the vacuum meter for measurement of the degree of vacuum during the use of the vacuum pump. It must be used a vacuum meter capable of measuring up to 10-2 mmHg

- **Pressure Indicator**

To check any oil leak under pressure after mounting the transformer, a pressure indicator is needed. A reading device Bourdon, pipe type (compound) with a measuring range of 0 to 1.0 Kg/m2.

- **Other**

Prepare to necessary instruments to perform the tests, such as tangent delta (insulating power factor or dielectric loss) and capacitances.

The values shown by this test should be kept and be taken as reference to determine the humidity and /or the aging of the insulation with the course of time.

1ZCL000002EG-EN– rev. 1

User's Manual

Operation and Maintenance for Power Transformers

OPERATION AND MAINTENANCE FOR POWER TRANSFORMERS

Table of contents

1 Introduction

The transformer requires less care compared with other electrical equipment. The degree of maintenance and necessary inspection for its operation depends on its capacity, on the importance within electrical system, the place of installation within the system, on the weather conditions, and the general operating conditions.

In this part of the manual the operating instructions and maintenance is supplied. Our intention is to provide the necessary assistance to the maintenance personnel to facilitate a periodic inspection of the transformer and to indicate the steps that they should follow to effect a more detailed examination of the active part in case that is required.

ATTENTION:

If this is going to be used as a spare transformer (in Stand-by), it will have to be preserved always in the best conditions. Therefore, its maintenance must be equal to the transformer in service; special care must be taken in monitoring the condition of the oil.The templates are intended to harmonize the visual impression of ABB Documentation throughout the organization, Common Look & Feel. To provide help for editors to adopt Visual Identity guidelines related to documentation presented to our customers.

2 Maintenance and lines and bus bar inspection

The maintenance and the inspection are a dangerous work; from there, beforehand a detailed program must be developed, placing special attention on the safety of the workers and of the equipment.

When working with bus bar, lines, terminal, etc., the work can only begin after confirming that these parts are not receiving any power, verifying for this that the switches are in the open position, something which can be checked with a detector for circuits. The omission of these revisions, thinking erroneously that the circuits do not have voltage can cause serious accidents.

3 Preventive maintenance program

Write down the readings from the meters or gauges that are generally installed. These readings will be very useful. If the readings are very different from the ones obtained in normal conditions, it is necessary to perform a careful revision.

In addition, pay close attention to any abnormal signs such as noise, color change or smells.

- **Transformer's temperature**

The temperature of the transformer is directly related to the life span of the insulating materials; therefore, it is necessary to pay close attention.

In the case of transformers built according to procedures ANSI, the maximum temperature permitted for oil is of 90°C and the maximum temperature of the hottest point is 110°C.

- **Inspection of oil volume**

The volume of the oil has to be verified from the point of view of the insulation and from the refrigeration.

If the oil level fluctuates notoriously in relationship to the temperature, the cause must be determined for proper repair.

- **Noise**

In some instances some abnormal noise can be perceived, when you or the operators are being familiarized with the noise that the transformer produces during its normal operation, which can help to discover some defects. The following are the possible causes of abnormal noise:

a) Resonance of the box and of the radiators due to abnormal changes in the frequency of the source of current,

b) Defect in the adjustment mechanism of the cores,

c) A defect in the central structure, (as loosening of the core) is possible that the tightening screws of the clamps have loosen up,

d) Loosening of the grounding plates, and

e) Abnormal noise by static discharge, due to lacking grounding plates or poor grounding.

These noises can be detected from outside the tank, even though they will not be very loud.

- **Loosening of the fixing pieces and the valves**

When grounding terminals are found to be loose, de-energize the transformer and tighten them immediately. The screws of the foundations that are subject to large loads must be tighten firmly to avoid the displacement of the transformer.

In some instances the valves are loosened due to vibrations, tight them again.

- **Oil leaks**

Oil leaks can be caused by the deterioration of some gaskets or they are in the wrong position; it takes some time to discover them, check carefully the valves and the gaskets. If there are any defects that could cause a leak, report it to ABB.

4 Periodicity of the inspections

The table 1 that appears below shows the frequency that the transformer must be checked.

No	Pieces to survey	Periodicity	Observations
1	Thermometers	once per year	
2	Accessory with alarm contacts and/or shut off	once per year	Verify the operation conditions of the contacts and measure the insulation resistance of the circuit
3	Cooling fans	once per year	If an anomaly is found
4	Conservator	once every five years	
5	Insulation resistance of the winding	once per year	When a sharp change after years of use is noted or when a change in comparison with data registered in previous tests.
6	Measurement of the tan Δ	Once in three years	just as the point 5.
7	Oil's breakdown value.	once per year	
8	Value of acidity of the oil.	once per year	
9	Test of the functioning of the oil.	Check if there is any abnormality noted in the tests of items 5 to the 8.	Take two liters of oil and check them according to ASTM D3487
10	Filtered insulating oil	Check if there is any abnormality noted in the tests of items 5 to the 8.	
11	Inside Components .	once every seven years	

Table 1. Periodicity of the inspections

5 Maintenance procedures for the insulating oil

To maintain the transformer in perfect operating conditions, keep in mind the previous items, also about the routine operation and not forgetting to give the proper treatment when some change in the service conditions is noted. It is necessary also to de-energize the transformer regularly and conduct a meticulous inspection.

With this routine and with regular inspection, the degree of deterioration will be minimized. Since a transformer is made of many parts, such as the insulating oil, the cooling equipment, etc. must be checked permanently. Oil in addition to serving as insulating means serves to transfer the heat generated in the windings and the core toward the walls of the tank and the radiators. Because of this, it is required that it complies with the following characteristics:

- High dielectric breakdown
- Low viscosity
- Well refined and free of materials that they may corrode the metallic parts
- Be free of moisture and polar ionic or colloidal contaminants
- To have a low pour point
- Low flash point.

The manufacturing techniques for transformers and their reliability have been improved to such degree that the internal inspection is almost unnecessary; currently the maintenance is limited almost exclusively to the maintenance of the oil to prevent its deterioration:

5.1 Deterioration of the insulating oil

The insulating oil deteriorates gradually with use. The causes are the absorption of the moisture from the air and foreign particles that get into the oil and start to cause oxidation. Oil is oxidized by the contact with the air and this process is accelerated by the increase in the temperature in the transformer and by the contact with metals such as copper, iron, etc.

In addition, the oil suffers a series of chemical reactions such as the decomposition and the polymerization that produces particles that are not dissolved in oil and that are collected in the coil and windings. These particles are called sediments. The sediments do not affect directly the dielectric breakdown, but the deposits that are formed on the winding hinder its normal refrigeration.

5.2 Preventing the deterioration of the oil

Due to the fact that the deterioration of the oil is caused generally by the oxidation, the method to prevent consists of reducing to a minimum possible its contact surface with the air. That is why a conservator tank is used. Moisture or humidity also accelerates the deterioration of the oil. To avoid this it must be used a dehydrating breather. The ideal method is the one that uses a nitrogen layer or a membrane on the surface of the oil to avoid that the oil be in direct contact with the air.

Dielectric oil is active under certain light conditions, heat and heavy metal ions, to produce free radicals that cause self-oxidation. To avoid this phenomenon, use additives that stop any oxidation.

5.3 Evaluation of the deterioration of dielectric oil

The methods to determine deterioration of dielectric oil are those that measure the degree of oxidation, the specific density, the superficial tension. In addition, it is common practice to measure the dielectric breakdown, it is recommended to make an objective analysis of all these methods.

6 Maintenance and inspection of the bushings

6.1 Routine inspection

- Excessive local heating:

Pay attention to the clamping section of the terminals. It is convenient to paint this section with heat indicating paint.

- Pollution:

When there is much dust and salt, a clean up must be performed and to do so, the transformer must be place out of service and use water, ammonia or carbon tetrachloride. If they are very dirty, use concentrated hydrochloric acid diluted 40 or more times in water.

The solution should not be in contact with any metallic part; after the cleaning the porcelain parts, these must be neutralized with water that contains sodium bicarbonate in a proportion of 30 grams by liter. As long as it uses a chemical solution, make sure of washing it after with fresh water, so that no strange elements are left.

In systems in which will be difficult to stop the operation of the transformer for cleaning, or in zones where there are many damages by the dust or the salt, it is being using recently a washing method designated "of hot line". It is a method to wash the equipment without stopping its operation, and there are 2 or 3 forms of doing it. In any case, it must be verified the degree of dust and salt, the quality of the water to wash and the method of waterproofing when the cleaning is done.

- Mechanical damages:

Check if there are any damages or oil leaks in the bushings.

6.2 Regular inspection (Once every two years).

- Evaluation of the deterioration of the insulation:

The methods to detect the deterioration of the insulation are the measurement of the insulation resistance and tan Δ

The measurement of the insulation resistance in the bushings is not simple, since the bushing and the winding of the transformer should be independent; nevertheless, the measurement must be made the best way possible.

The measurement of the tan Δ is also difficult, since the bushings should be separated from the transformer in most cases.

The evaluation of the result of the measurement should not depend solely on the absolute values obtained, but on the values obtained each year and from the variation among them. If there are large discrepancies in the values, special attention is necessary.

When the insulation resistance is superior to 1000 MΩ at normal temperatures, it can be considered as good condition, but the value of the tan□ also must be taken into consideration for the evaluation.

6.3 Inspection due to excessive partial heatings

The excessive heating of the terminals in most cases is due to loosening. If this condition is observed, eliminate the dust or dirt from the parts from contact and tighten firmly.

6.4 Local damages inspection (fissures) on the bushings

The cleaning of the bushings must be done according to what was mentioned. If the damages are very serious it must be replaced with new ones.

6.5 Inspection for oil leaks

Check the various pieces of the bushings to see if there is any oil leaks. If oil is leaking through the gasket, tighten it or replace it. If there are bushings of immersed in oil type and the oil leak is through other part of the bushing, report it to the manufacturer.

6.6 Storage

Keep the bushings in a vertical position and in a dry place. It is recommended to keep them in their original packaging.

7 Maintenance and inspection of the cooling equipment

The cooling equipment is the most important part in the normal daily operation of a transformer. It is necessary a special care for its maintenance and inspection, since any abnormality can reduce the useful life of the transformer or cause serious defects.

7.1 Self – cooling type radiator

Check oil leaks from the upper-ends of the radiator and the welded parts of the panel or from the pipe. If there are any sediments accumulated in the radiators´ elements or in the pipe, the flow of oil is hindered and the temperature drops. For this reason, check by hand if these parts have the adequate temperature. If the radiators are detachable, check that the valves are open correctly.

8 Maintenance and inspection of the thermometers

It is important to check the temperature of the transformer in service, since this indicates the conditions of operation. The internal conditions and the normality of the interior, therefore, the indicators that measure the temperature should be checked and be maintained in good conditions, so that they indicate correctly the temperature.

8.1 Dial type thermometer

This is a form of pressure measuring device with a bulb that contains a special liquid or sealed gas. It is connected with a very fine pipe to move the needle by expansion and contraction of the fluid; it must be verified comparing it with a normal thermometer once per year or more often.

Also, it must be checked carefully that it is free of rust in the inside, that water won't get in, that the needle moves adequately and that the alarm contacts operate correctly.

If the crystal is blurred by moisture that gets inside, remove the lid from the crystal and change the seal.

After many years of use, the pipe of Bourdon wears out, the same as the sprocket and the support, leading to wrong readings; also the movable indicating parts may fall because of blows or vibrations. The guiding pipeline generally is double and the connection with the measuring device is separated or is broken easily. Therefore, it is necessary a careful handling of the dial type thermometer, if it is to be removed during the inspection of the transformer.

Check that the alarm contacts have been made adequately.

9 Maintenance and inspection of oil level gauge

The gauge is placed outside the conservator and it is of simple construction; it shows the level of the oil directly, being able to see it from the outside. Pay attention to any oil leak that may be visible.

When the crystal is dirty, you can wipe it off with a rag.

The oil meter is resistant to damages and to inaccurate readings, compared with older models of oil level type L and type U.

9.1 Oil level gauge dial type

In this gauge, the revolving axle has on one end a floatation device that supports an arm connected to the gauge and on the other extreme a magnet to make to the rotor turn and to allow an upward and downward movement of the floatation device. When the level of the oil changes, this triggers the support arm that makes the magnet turn in the other extreme, and at the same time it triggers the rotor through the division wall that it is outside the gauge. The needle indicates the oil level.

The gauge needs the same maintenance that any ordinary instrument; furthermore, as it comes with a metallic floating device. It requires close attention when there is an inaccurate reading due to any leakage of oil into the flotation device, or by vibrations, and above all, when it has been in used for a long time.

10 Maintenance and inspection of the buchholz relay

This relay is made to protect the oil immersed transformer against internal defects. It is attached to the connection pipe between the tank of the transformer and the conservator.

The operation of the relay is divided into a first phase (minor defects) and a second phase (for severe defects); the first is used for the alarm, and the second for the shut down of the transformer.

Its structure presents two flotation devices, one in the upper part and other in the lower part of a steel box (oil chamber) and they are fixed in such a way that each floatation device can turn, being their rotation center the support beam or axle.

Each flotation device has a switch and the contacts are closed when the flotation device turns. If the organic structural materials of the transformer are burnt or produce a gas caused by a small flash over, this will remain in the internal upper part of the box. When the volume of the gas surpasses the fixed volume (approximately 150 to 250 cc) the flotation device of the first low phase and the contacts are closed, triggering off the alarm system.

The lower floatation device that is for the second phase closes the contacts and sets off the alarm system, or turns off the circuit switch when an arch is originated in the interior of the transformer and gas and oil vapors are produced quickly, forcing the movement of the oil. Also, if the oil level drops below the permissible minimum level of the conservator, the alarm system goes off.

On one side of the box of the Buchholz relay, there is an inspection window that allows to observe the volume and the color of the gas produced, and to extract samples to evaluate the cause and the degree of the failure.

The modern Buchholz relay comes with micro-interrupter magnetic contacts. Also, today there is a whole array of relays with mercury contacts.

The mercury contacts should be handled with extreme care, since they can be broken when there are vibrations. As a routine, examine for oil leaks and the gas production from the relay. If gas is found, take a sample and have it analyzed; also, verify the oil level in the conservator.

Clean the crystal from the inspection window, check the interior and verify if the flotation device is moving freely, with the support arm as its rotation center to regular intervals.

The relay can operate incorrectly when the float is submerged in oil, when the support shaft of the flotation device is left out from the joint or there is an oil leak.

11 Maintenance and inspection of the overpressure valves

The overpressure relief valve with contact alarm triggers the alarm when the needle of the switch moves. It is placed by making contact with the expansion plate; the adjustment spring and the contacts of the micro-switch are in relation with the elevator that is related at the same time with the interrupter's needle.

When there is an accident, the internal pressure increases and pushes the valve out, making the needle of the switch move, and then it pushes and bends the expansion plate. When the pressure reaches a certain limit, the expansion plate is broken and the pressure is released, closing (shutting off) the contacts of the micro-switch, that are in the step up that is related to the needle of the switch, and the alarm sounds.

Verify there is no oil leak or air coming out from the device.

12 Maintenance and inspection of the silica gel breathers

These devices are made to eliminate any moisture and dust that enters the transformers, with the air flow resulting from the fluctuation in temperature of the oil from the transformer; it is placed between the air duct of the transformer and the atmosphere.

It is formed by a deposit of a dehydrating agent and oil, as well as the attaching metal parts for its fixture. The gasket must be checked to see if it is secured, so it will not allow air from entering the transformer by any other space other than the vent hole. Also, check the oil level of the deposit is not below the pre-established level.

If the dehydrating agent becomes impregnated with oil, it is because there is too much oil in the deposit, or because there is an internal failure which cause must be detected. Silicon gelatin is used as the dehydrating agent.

Generally, it is dyed blue with cobalt chloride, and when the moisture absorption reaches a 30 or 40 %, the color changes from blue to pink. In this case, the silicon gelatin must be replaced or dried before reusing it. To regenerate the silicon gelatin, place the silicon gelatin in a bucket or in a clean pot and shake it while it is heated up at a temperature of 100 to 140 °C. Continue heating it until the color changes from rose to blue, or spread the wet silicon gelatin in a container, such as a filter box for 4 or 5 hours, maintaining the temperature between 100 and 140 °C.

13 Maintenance and inspection of gaskets

13.1 Installation of gaskets

When using a gasket follow the instructions supplied by the manufacturer, but in case that are not supplied, the following instructions can be followed for general cases. For the gaskets on the curbed surface of the common transformer, cork or nitrile is used, even though the cork no longer is employed. For some unions, special lead or asbestos gaskets or O rings are used; if the type of gasket is indicated, it must be used following the instructions.

13.2 Methods of joining or connecting gaskets

It is better to use the gasket without a joint, but this can not be avoided when the gasket is too large. There are round gaskets, square, rectangular and oval-shaped, but in any case try to join the gaskets by using a flat portion of the gasket. The part that overlaps must measure more than 50 mm and must apply an adhesive to the union.

When using an element or a component to seal, make sure of selecting the material adapted for the gasket; apply a thin layer and let it dry with air and then place the gasket.

13.3 Work instructions

To remove corrosion, nitrile, oil or the grease, use a wire brush, thinner and alcohol.

Apply the adhesive only to the side of the gasket and use only the necessary amount to attach it to its place.

If the gas or oil leak is not stopped after correct adjustment, the gasket will have to be replaced with a new one.

A gasket with low elasticity such as lead type must always be changed with a new. Do not use the old one again.

14 How to detect a leak?

When the leak is below the oil level, wash first with thinner or alcohol the affected part, and once the dust or the cement has been eliminated, the place where the leak is located, it will appear clearly as a black stain.

When the leak is above the oil level, load the nitrogen gas to an appropriate pressure (approximately 0.3 to 0.4 Kg/cm_), place a soapy solution on the suspected part of the gasket. If there is a leak, bubbles will be formed. Be careful not to permit the operation of the pressure exhaust pipe during this operation.

- Treatment of tank leaks.

If the leak is on the tank that contains oil, must be repaired by welding, make sure that the heat from the welding is not going to produce an explosive gas mixture. (There is no need to take any cautionary steps in the case of nonflammable oil).

If the leak is some 70-mm or more above the oil level and if the thickness of the wall of the tank is greater than 6 mm, there will not be danger of combustion, since the oil will cool the heat of the welding.

If the part of the leak is above the oil level, place nitrogen gas in the interior of the tank to prevent a fire.

If the thickness of the wall of the tank is less than 4.5 mm, place a metal piece on top of the part of the leak and weld it. It is better if there is no oil in the place of the repair.

The simplest way of repairing a small leak orifice is to caulk it carefully with a chisel.

Do not cover the small orifice of the leak with caulk or with painting, since it will not last for long.

Do not repair a leak orifice on the steel tank by welding or caulking it. The part of the steel box will have to be replaced. When it is not possible to puncture a hole in the place of the leak, tap and introduce a stopper impregnated in shellac or other component.

If a leak is found on an important piece of the equipment, consult with the manufacturer the adequate steps to take.

15 Failures and countermeasures

15.1 Causes of the failure

To track the cause of the failure is the first step to formulate its solution. The origin of the defects is not simple. Generally, it is the combination of many factors that can be classified in the following way:

- **Imperfection on the specifications**

- Mistake in the selection of the type of insulation.
- Not appropriate capacity.
- Lack of attention to the conditions in the place of installation (dampness, temperature, dangerous gases, etc)

- **Imperfection on the facilities**

- Wrong installation.
- Wrong capacity and protection range of lightning rods
- Switch and relay for protection is wrong.

- **Imperfections on the operation and maintenance of the equipment**

- External conducting parts loose and heating up of the same.
- Deterioration of the insulating oil
- Excessive load or mistakes in the connection of the cables.
- Mistake in the operation, and carelessness in the arrangement of the protection circuits.

- Insufficient inspection of the gaskets and valves.
- Poor maintenance of the accessories.

- Abnormal voltage
- Normal wear and tear
- Natural disasters

15.2 Types of failures

The failures produced by the causes mentioned above, create secondary failures and of a third type, hindering their tracking. However, the operating conditions in the moment of the failure, the inspection records of the relays of protection of the various parts, as well as the maintenance and the regular inspection, will help to detect the cause in many occasions.

The defects of a transformer can be classified in the following way:

- **Internal failures of the transformer: in core and coil**

- Dielectric interruption
- Rupture and twist of the winding
- Mistake on the grounding
- Open connection of tap changer
- Insulating oil

- **External defects of the transformer: In the tank**

- Due to oil leaks in the gasket, valve, or weld cord
- Due to the bushings of the breathers, over pressure valve, thermometers, oil level gauge, etc.
- Defects on the forced cooling fans, Buchholz Relay, exit of the current transformers of the bushings, etc.

15.3 Discovery of the failures

It is unnecessary to say that the sooner a failure is detected, the better for the transformer, and it requires a careful and detailed maintenance and inspection; there are procedures made for the regular inspection and of routine. By means of this inspection a failure can be detected before it becomes serious, and reduce any damage in whatever possible. Some defects are caused by reasons beyond human control. Such as:

- **Sudden failures**

Most of the dielectric interruptions occur suddenly, especially due to lightning or to an abnormal tension, causing a direct failure.

Excessive current by an external short circuit or by a mechanical hit also happen suddenly. Disturbances by earthquakes and fires can accidentally damage the transformer.

- **Defects that develop slowly**

Sudden defects are related generally to totally external or foreign factors to the transformer of such form that it is outside of our scope the power to foresee them and to prepare us to face these.

The objective of our maintenance and inspection is to discover the defects that occur and that may develop slowly. These defects are the following:

-Deformation of the insulation materials and of the windings, due to mechanical blows caused by an external short circuit. The transformer generally is designed and is manufactured to resist the heat and the mechanical blows. However, if it is exposed to frequent and intensive mechanical blows, even a small deformation can be converted into a serious internal defect.

- Insulation of the core. There can be poor insulation between the sheets of the core, between the tightening screw of the core and the insulation pipe, etc. The poor insulation cause a short circuit in the magnetic flow, producing a constant short circuit current flow in this place and generating excessive heating up which can lead to serious defects.

- Poor insulation due to a harsh operational condition such as excessive load. According to what was mentioned in the instruction manual, the insulation of the transformer deteriorates by the increase in the temperature and this deterioration over the years worsens and is converted into a serious failure when the transformer suffers an excessive load.

-Deterioration of the insulation materials such as oil, bushings, etc. due to moisture absorption, to oxidation and to formation of a partial discharge, etc.

-Deterioration of the external insulation of the transformer due to wind, snow, salt and dust. This can be prevented with the correct inspection and maintenance.

-Defects in the accessories, oil leak, gas leak, etc.

15.4 Internal defects of the transformer

a) Defects in the winding

-Short circuits

There are short circuits between the turns, between the phases and between the windings. Most short circuits failures are caused by abnormal tensions on the surge arresters and others because of the deterioration of the insulation oil and to the penetration of rain. Also, some short circuits are caused by the deterioration because of heat, caused by an electromagnetic mechanical force or by an abnormal excessive load. Generally, as secondary effect, internal short circuits cause serious deformations to the windings.

-Breakage of the terminals of the winding

The terminals of the spooled suffer damages by an excess of current (external short circuit, etc) or by a lighting strike. Also, the short circuit accidents of the system that accumulate, cause damages on the supports of the windings, by their repetitive mechanical destructive force, that finally break the terminals.

- Short circuit to ground.

The impulse voltage or the deterioration of the insulation can cause a short circuit to the grounding of the winding or of its terminal to the core or to the tank.

The mentioned defects can be detected easily through an external diagnosis or an electrical monitoring.

b) Defects in the core

There are defects due to poor insulation of the tightening screws of the core, or an oil-cooling duct obstructed, that cause excessive heating of the core. The defects on the core develop slowly. The insulation and the poor grounding contact already mentioned, cause a partial short circuit current, a deterioration of the oil of the insulation materials in their surroundings, which gradually are converted into serious failures.

A poor or loose tightening between the core and the clamps of the windings can cause damaging vibrations.

15.5 How to detect internal failures?

Use the different relays that the transformer has to detect and be protected of failures.

Next you can find which parts are used to protect the transformer from internal failures:

- Those devices that are attached directly to the transformer, and detect failures mechanically: Buchholz Relay, pressure rise relay, pressure relief device.

- Those devices that are indirectly joined to the control cabinet which detect failures electrically: Differential Relay, overcurrent relay, ground current relay.

ABB Inc.
Small Power Transformers
2135 Philpot Road
South Boston, VA 24592

Instruction Book
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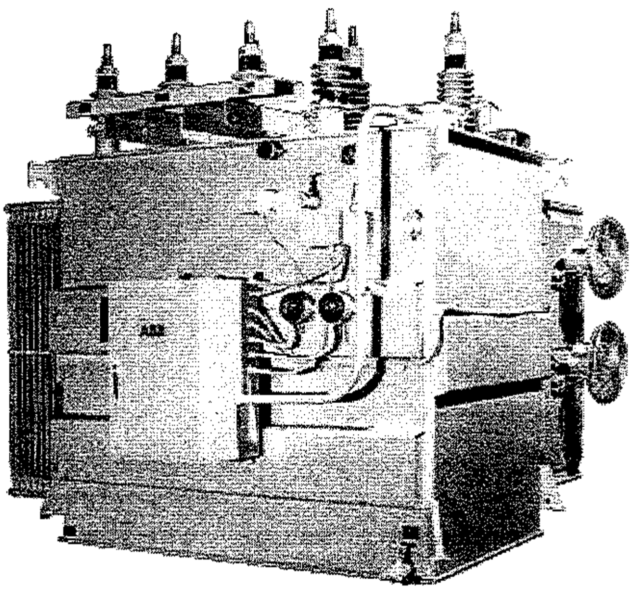
Liquid Insulated Primary and Secondary Unit Substation Transformers



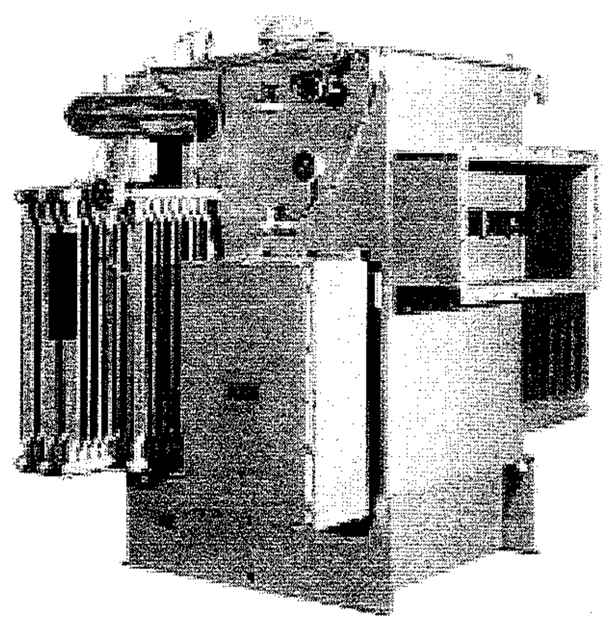


Table of Contents

READ THIS INSTRUCTION BOOK CAREFULLY BEFORE ATTEMPTING TO HANDLE, INSTALL, USE OR SERVICE THE TRANSFORMER. FAILURE TO FOLLOW INSTRUCTIONS COULD RESULT IN SEVERE INJURY, DEATH OR PROPERTY DAMAGE

SAFETY NOTES FOR INSTALLATION AND OPERATION

DO NOT LIFT OR MOVE A TRANSFORMER WITHOUT ADEQUATE EQUIPMENT AND PRECAUTIONS.

TERMINALS ARE FOR ELECTRICAL LOADING ONLY, USE FLEXIBLE CONNECTORS TO AVOID MECHANICAL STRAIN.

DO NOT MAKE ANY CONNECTIONS THAT ARE NOT AUTHORIZED BY THE NAMEPLATE OR CONNECTION DIAGRAM.

DO NOT ENERGIZE TRANSFORMER WITHOUT PROPER GROUND CONNECTIONS.

DO NOT ATTEMPT TO CHANGE THE TAP SETTING WHILE THE TRANSFORMER IS ENERGIZED FROM EITHER H.V. OR L.V. SIDE.

DO NOT TAMPER WITH INTERLOCKS, ALARM AND CONTROL CIRCUIT.

IMPORTANT NOTICE: FAILURE TO OBSERVE THE REQUIREMENTS OF OSHA STANDARD 1910.269 CAN CAUSE DEATH OR SEVERE BURNS AND DISFIGUREMENT. THAT STANDARD SPECIFICALLY PROHIBITS THE WEARING OF POLYESTER, ACETATE, NYLON, OR RAYON CLOTHING BY EMPLOYEES WORKING WITH EXPOSURE TO ELECTRIC ARCS OR FLAMES.

The unit(s) covered by these instructions have been inspected and tested to meet all applicable standards of ANSI, NEMA, and IEEE, to assure you of the highest quality product.

The instructions in this manual should familiarize qualified personnel with the proper procedures to keep all new unit(s) in proper operating condition.

These instructions do not propose to cover all details or variations in equipment, nor to provide for every contingency to be met in connection with installation, operation, or maintenance. Should further information be desired, or particular problems arise which are not covered, please contact ABB's South Boston factory.

1. INTRODUCTION

These instructions apply to liquid filled primary and secondary unit substation transformers manufactured by the ABB Small Power Transformer Facility at South Boston, Virginia.

The equipment covered by these instructions should be operated and serviced only by competent personnel familiar with good safety practices. These instructions are written for such personnel and are not intended as a substitute for adequate training and experience in the use of this equipment.

The transformer outline drawing shows the location of nameplates and warning signs. Read and follow all warning signs and nameplates installed on the transformer.

DO NOT REMOVE OR COVER THE WARNING SIGNS AND NAMEPLATES.

Electrical characteristics, winding connections and weights are on the nameplate. Physical details, such as weights and dimensions are shown on the transformer outline drawing. Control, fan and alarm wiring is shown on the wiring diagram.

Repair information for all parts is not included because replacement is recommended rather than repair. If information is desired in greater detail, copies of instruction leaflets referred to, but not included with this book can be obtained by contacting the ABB Small Power Transformer After Market Services representative.

2. RECEIVING

NOTE: **Inspection of transformer, packages and parts is required prior to unloading from carrier, in order to establish the condition of the equipment upon delivery.**

2.1 Drawing and Documents

Shipping papers, packing lists, outline drawings, this instruction book and other pertinent documents furnished with the transformer must be available for use during the inspection.

2.2 External Inspection

All transformers are carefully tested at the factory and are in good condition when shipment is made. If the inspection indicates a shortage, damage or evidence of hidden damage, it must be reported to the carrier's representative and to a representative of the ABB; Small Power Transformers before unloading the transformer. As a minimum the following inspections should be made.

External Inspection Transformer Tank and Fittings	
1.	Is there any indication of external damage?
2.	Is the paint finish damaged?
3.	Are the attached fittings loose or damaged?
4.	Is there evidence of fluid leakage on or around the tank coolers?
5.	Are any of the bushings broken or damaged?
6.	Is there any visible damage to the parts or packaging which shipped separately from the transformer?

2.3 Tank Pressure

The tank pressure may be positive or negative when received, depending on liquid temperature. In some cases, the vacuum pressure gauge may read zero, which could indicate a tank leak. In such cases, pressure test the tank according to the instructions in Section 6.5.1. Report tank leaks of new transformers to the ABB Small Power Transformer After Market Services representative.

2.4 Detail Parts

In making examinations of any parts of crates for shipping damage, check carefully for evidence of moisture and for damage to moisture barriers or waterproof wrappings when used.

The detail parts should be stored in a clean, dry area that will minimize exposure to weather and the possibility of damage or loss.

2.5 Internal Inspections

When a new transformer is delivered, an internal inspection is normally not required. Temporary shipping braces are not used inside the transformer. **No internal inspection should be performed unless authorized by ABB Small Power Transformer After Market representative.**

3. HANDLING PRIOR TO INSTALLATION

3.1 Tilting

Transformers should be handled in the normal upright position, but in no case tilted more than 15° from vertical, unless instructions have been given to the contrary. Refer to the outline for these instructions.

3.2 Lifting

Lifting hooks or eyes are provided on the transformer tank wall. Only these hooks can be used in lifting the complete transformer. Refer to the outline for the proper lifting hook locations. All four lifting hooks must be used for proper handling.

3.3 Jacking

Refer to the transformer outline drawing for jacking areas on the transformer tank. Only those areas may be used when the transformer is jacked.

4. STORAGE PRIOR TO ENERGIZING

4.1 Storage of Transformer

When storing the transformer, it should be completely assembled and pressure tested in accordance with Section 6.5.1. The gas space above the liquid should be pressurized with dry nitrogen between two to three PSIG. This will prevent moisture from being pulled into the tank by a negative pressure. Transformers designed for indoor use must be stored indoors.

4.2 Extended Storage Guidelines

If a unit is to be stored more than 60 days before being placed into service the following guidelines should be followed.

1. Store the transformer on a firm level foundation, preferably at its installation site. Perform external inspections listed in Para. 2.2 plus the below listed tests.

Tests
1. Record ambient temperature and barometric pressure for correction of test data. 2. Pressure test - to insure the tank and fittings do not have any leaks. After test is complete the pressure should be reduced to two (2) PSIG. 3. Test insulating liquid for dielectric strength and moisture content. 4. Test insulation with a 1000 or 2500 volt megger. 5. Check insulation power factor using Doble or similar test. 6. Test ratio in all tap positions to insure proper tap changer operation. 7. Verify liquid level by gauge reading. ***When busings are not on tank, tests #4, #5, and #6 can be omitted.***

2. These transformers should be completely assembled, including the terminal chambers, switches and removable radiators, if any, to provide additional protection.
   - If the transformer has wall-mounted bushings and the terminal chambers or switches have not been supplied, the bushings should be protected from the environment. A black polyvinyl material placed over the bushings will serve as protection. This material should be checked during routine inspections to insure that the material is not damaged.
   - Cover-mounted bushings which are shipped unmounted on the transformer do not have to be installed during storage. They should be stored in a clean dry location in their original shipping cartons. Condenser bushings should be stored upright. When the transformer is ready to be put into service, the bushings should be physically inspected for damage prior to installation in the transformer.
3. A Transformer designed for indoor use must be stored indoors.
4. Parts that are shipped separate from the transformer must be stored in a clean, dry area.
5. Space heaters, when supplied in switches, terminal chambers, control cabinets, or other cases, must be connected and energized at all times.
6. For control cabinets only, if space heaters are not supplied or it is not practical to energize the heaters, silica gel packets must be placed in cabinet.

The following inspection should be made while the transformer is in extended storage. Record the results for comparison with previous data to insure that there has been no deterioration in the condition of the transformer.

<u>Quarterly Inspection*</u>

1. Check the black polyvinyl material covering the bush ings to be sure it is not damaged. Replace if necessary.
2. Check the silica gel in the control cabinet and replace, if the silica gel container bag has a dark or wet appearence.
3. Record gauge readings, including the ambient temperature and barometric pressure.
   Note: a. Pressure should be maintained at two (2) psig, taking into account variances in barometric pressure.
   b. If pressure or liquid level readings indicate a possible leak in the transformer, make a pressure test according to the Instruction Book. Any leaks should be repaired immediately.

Perform the first inspection one month after the transformer has been put into storage,and quarterly thereafter.

Annual Inspection

1. Check paint finish and touch up as necessary.

2. Test insulating liquid for dielectric strength and moisture content.

3. Test insulation megger test.

4. Check insulation power factor.

Omit test #3 and #4 if the bushings have not been mounted on the transformer tank.

When the transformer is taken out of storage, the pre-energization tests and inspections identified in Section 6.5 must be performed. Review the storage records of the transformer to insure that there has been no deterioration in the condition of the transformer.

5. ACCESSORIES AND COMPONENTS

5.1 Alarm Switch Ratings

Accessories supplied are shown on the outline drawing. When accessories have control wiring or are equipped with alarm contacts, refer to the control wiring diagram referenced, or the outline drawing, for contact type and ratings and terminal points.

5.2 Transformer Nameplate

A nameplate is supplied on each transformer according to ANSI standard C57.12.00. The nameplate provides basic information for use of the transformer.

5.3 Control Cabinet

WARNING: THE CONTROL CABINET CONTAINS SOME EQUIPMENT OPERATING AT HIGH VOLTAGES. ALWAYS REMOVE THE CONTROL CABINET VOLTAGE SUPPLY PRIOR TO PERFORMING WORK INSIDE THE CONTROL CABINET EQUIPMENT OR CONNECTED ACCESSORIES. FAILURE TO DO SO COULD RESULT IN SEVERE PERSONAL INJURY, DEATH, OR PROPERTY DAMAGE.

Refer to the wiring diagram for electrical circuits inside the control cabinet. Use an indicating light type device when checking an alarm switch. Failure to do so could result in damage.

5.4 Current Transformers

WARNING: CURRENT TRANSFORMER SECONDARIES MUST BE CONNECTED TO A LOAD OR SHORT CIRCUITED TO AVOID DAMAGING VOLTAGES AT THE TERMINALS. FAILURE TO MAKE THESE CONNECTIONS COULD RESULT IN SEVERE PERSONAL INJURY, DEATH, OR PROPERTY DAMAGE.

Current Transformers are optional accessories. They are mounted inside the transformer tank around the transformer line leads. When the bushing is on the cover, the current transformer is mounted to the bottom of the cover around the bushing. When the bushing is on the tank wall, the current transformer may be mounted on top of the core and coil assembly. Current transformer secondary leads are always wired to a junction box. Refer to the transformer wiring diagram to identify the wire codes. The current transformer secondary leads are always shorted and grounded to the tank when the transformer is shipped.

5.5 Liquid Level Gauge

The liquid level indicator indicates the liquid level inside the tank. When indicators are installed at the factory, the tank is filled to the level which corresponds to a liquid temperature of 25°C which is considered the normal level. Should the tank be at some temperature other than 25°C, use Table 1 to determine the variation above or below the normal level before adjusting fluid level. The indicator is shipped mounted on the transformer tank and requires no maintenance other than the periodic inspection recommended in Section 7.5 of this Instruction Book.

Table 1 – Liquid Level Gauge

Average Liquid Temp. (°C)	Correct Level (Percent of Scale Above or Below 25°C Level)
85 (High)	100
70	75
55	50
40	25
25 (Normal)	0
10	-33
-5	-67
-20 (Low)	-100

Contact factory if liquid level gauge does not agree with Table 1.

5.6 Liquid Temperature Gauge

The temperature gauge is furnished to indicate the top liquid temperature in the tank. The temperature sensitive element is mounted in a dry, leakproof well, permitting removal of the thermometer without lowering the liquid level. The device is furnished with a red pointer to show the highest temperature attained since last reset. To reset the maximum indicator, rotate the magnet at the center of the dial or, on some models, push the reset button. During normal operations the liquid temperature gauge should read less than the sum on the ambient temperature and the rated temperature rise. For example, 30°C ambient + 55°C rated temperature rise = 85°C top oil temperature.

5.7 Pressure-Vacuum Gauge

WARNING: IF THE PRESSURE-VACUUM GAUGE READS ZERO AND DOES NOT CHANGE UNDER ANY TRANSFORMER LOAD, THE TRANSFORMER SHOULD BE CHECKED FOR A POSSIBLE LEAK. A LEAK WILL ALLOW MOISTURE AND AIR TO ENTER THE TRANSFORMER, WHICH COULD DEGRADE THE INSULATION AND FLUID. TRANSFORMER LIFE COULD BE REDUCED IF LEAKS ARE NOT REPAIRED.

The pressure-vacuum gauge indicates the tank gas space pressure relative to atmospheric pressure. Maintenance is not required except for the periodic inspection recommended in Section 7.5 of this instruction book.

5.8 Pressure Relief Device

WARNING: NEVER DISASSEMBLE A PRESSURE RELIEF DEVICE. DISASSEMBLY COULD RESULT IN SEVERE PERSONAL INJURY, DEATH, OR PROPERTY DAMAGE FROM HAZARDOUS FLYING OBJECTS.

Some transformers are furnished with a pressure relief device on the transformer cover. The pressure relief device will vent tank gases when excessive tank pressure exists. The device consists of a self-resetting, spring-loaded diaphragm and a mechanical operation indicator (Semaphore). The maximum tank pressure at which the pressure relief device will remain sealed is stamped on the relief device nameplate. Should the tank pressure increase above the pressure relief device nameplate rating, the gas pressure will lift the diaphragm, vent the excess pressure, and trip the Semaphore. Immediately after the pressure returns to normal, the diaphragm will reset and reseal the transformer. This event is not normal. If the semaphore indicator is lifted, the cause of the operation should be investigated. The mechanical operation indicator (semaphore) must be reset manually after each operation. The pressure relief device will withstand full vacuum and need not be removed from the transformer tank during any vacuum. A hood may be bolted over the relief device. When supplied, the hood must be vented to the outdoors.

5.9 Winding Temperature Gauge

This device is also known as a Dial Hot Spot Thermometer. It simulates the hottest spot temperature of the transformer windings by sensing both the surrounding liquid temperature and a current source that is proportional to the load current.

The sensing stem is mounted in a dry well, permitting its removal without lowering the fluid level. A red pointer is furnished to show the highest temperature attained since last reset. Rotating the magnet that is located on the dial face can reset this pointer.

Should a check on accuracy and calibration be desired, obtain additional information from ABB Small Power Transformer After Market Services representative.

Maintenance is not required except for the periodic inspection recommended in Section 7.5 of this instruction book.

5.10 TRO-2 Thermal Overload Relay

The Thermo Overload Relay (TRO-2) operates similar to the Winding Temperature Gauge described in section 5.9. The TRO-2 relay provides a simulated winding hot spot temperature in terms of "Percent Thermal Load." The TRO-2 is wall mounted in a well which permits removal of the instrument without lowering the liquid level. The dial face of the TRO-2 device has two colored zones, red and yellow. The yellow zone indicates a thermal load that exceeds 100%. When the indicator hand reaches this area, an alarm contact is actuated. The red zone indicates thermal loads that have reached the 110% region. In this zone, a tripout contact closes. In regions above 80%, a change in the ambient of 1°C is approximately equivalent to a 1% change in the thermal load. Maintenance is not required except for the periodic inspection recommended in Section 7.5 of this Instruction Book.

5.11 Sudden Pressure Relay and Rapid Pressure Rise Relay

The Sudden Pressure Relay (SPR) or a Rapid Pressure Rise Relay (RPRR) are optional items. Each relay's main pressure sensing element is in direct contact with the gas cushion of liquid-filled transformers. Positive operation of the bellows-actuated micro-switch occurs only in the event of an abnormal rate of rise of internal pressure and energizes a multi-contact seal-in relay fed from a separate voltage source. The relay's sensitivity is essentially unaffected by the existing static pressure in the gas space, making it sensitive to the high rates of rise that are associated with arc-producing faults in the transformer winding.

A seal-in relay reset switch, and the associated circuitry are mounted in a separate control cabinet. The seal-in relay is energized when the sudden pressure micro-switch operates and remains so until manually reset with the reset switch. Seal-in relay loads should be limited to the values given in the table listing given on the wiring diagram.

If field tests are required to check out the sudden pressure relay, consult the factory. If field tests are required to check out the rapid pressure rise relay, consult the factory.

If the SPR or the RPRR device has tripped the primary circuit breaker and disconnected the transformer, the following steps are suggested to assess the extent of damage to the transformer, if any.

1. Use a portable combustible gas detector to check for combustible gas products of decomposition in the gas space. Refer to the operating instructions for the Gas Detector.

2. Make the Field Tests of the Pressure Relay and its Panels to determine whether the Relay is in proper operating condition. Refer to instructions furnished with device or contact the factory.

3. Make insulation power factor and insulation resistance tests and check the transformer Turns Ratio.

4. Remove the manhole cover for observation. Sometimes the odor of burning is obvious.

5. Make any other tests which may be suggested by the results of the above checks.

After the condition of the transformer and Relay have been checked, and if no damage has been found, it is necessary to decide whether the breaker should be re-closed to put the transformer back into service. The risk of possible further internal damage must be balanced against the possibility that there is no serious internal damage.

5.12 Transformer Cooling Fan Motors

WARNING: ALWAYS DE-ENERGIZE THE FAN CIRCUIT WHEN INSTALLING FANS. IN ADDITION, DE-ENERGIZE THE TRANSFORMER WHEN IT IS POSSIBLE TO COME CLOSE TO LIVE PARTS. FAILURE TO DO SO COULD RESULT IN SEVERE PERSONAL INJURY OR DEATH.

The cooling fan motor electrical data can be found on the motor nameplate or the wiring diagram. The controls for the motor are contained in the control cabinet mounted on the transformer. The "Manual-Auto" switch determines the mode of operation for the fan motors. When the switch is in the "Manual" position, the fans will operate continuously. When the switch is in the "Auto" position, the fans will be automatically controlled from the thermal device mounted on the transformer.

The fan motors are provided with thermal overload protection. Usually, the overload protection is contained within the motor. However, if the motors are located in a hazardous location, the overload protection device may be located in the control box. Refer to the wiring diagram for specifics.

The fan motors have permanently sealed ball bearings and require no additional maintenance, other than that recommended in Section 7.5.

When fan packages are installed by the user, IT IS IMPORTANT TO PERMANENTLY REMOVE THE LOWER DRAIN PLUG FROM THE MOTOR HOUSING. This will prevent the build up of condensation inside of the motor housing. The motors will be shipped with the plugs installed.

5.13 De-energized Tap Changer

WARNING: DO NOT MOVE THE TAP CHANGER POSITION, UNLESS THE TRANSFORMER IS TOTALLY DE-ENERGIZED. FAILURE TO DO SO WILL RESULT IN THE FAILURE OF THE TRANSFORMER AND COULD RESULT IN SEVERE PERSONAL INJURY OR POSSIBLE DEATH.

The de-energized tap changer is provided as means to adjust the transformer voltage to closely match that of the user system voltage. It is not to be used as a means to regulate the secondary voltage. If the tap changer is used in this manner, it will result in high noise level and higher no-load losses and possible core saturation. Refer to the transformer nameplate for the tap voltages possible for the transformer.

The de-energized tap changer is provided with an operating handle, tap voltage position indicator and a position locking mechanism. Some de-energized tap changers may have provisions for a pad locking or a Kirk Key Interlock System.

Usually, the transformer is shipped in the rated voltage position. To change the tap voltage position, follow these steps:

1) DE-ENERGIZE THE TRANSFORMER

2) Disengage the position lock. This is done one of three ways, depending upon the tap changer used:

A. When a locking pin is provided, pull pin out and turn the operating handle;

B. When the locking provisions are in the operating handle, pull the handle straight out beyond the indicator plate, then turn the handle; or

C. When the model is locked in place by a small bolt, back the bolt out until it is passed the indicator plate, turn the handle to the new position.

3) Move the operating handle to the desired tap position. The tap voltage indicator plate identifies the tap position. On some models, the operating handle must be rotated 360° to engage the next position. Other models require only short movement to the next position indicator.

4) Re-engage the position lock. Only when the tap changer is in the correct position, can the position lock be engaged. DO NOT ENERGIZE THE TRANSFORMER UNLESS THE POSITION LOCK IS FIRMLY IN PLACE.

5.14 Bushings

WARNING: EXTERNAL CONNECTIONS MUST NOT EXCEED A CANTILEVER LOAD OF 100 POUNDS. GREATER LOADS MAY CAUSE BUSHING DAMAGE THAT COULD RESULT IN SEVERE PERSONAL INJURY, DEATH, OR PROPERTY DAMAGE.

5.14.1 Bulk Type Draw Lead Bushings

Bulk type draw lead bushings require no maintenance except as described in section 7.5 of this Instruction book. If Bulk-type draw lead bushings were removed for shipment, install them as follows:

1. Remove the blind flanges covering the bushing holes.

2. Locate and untie the draw lead and pull the free end out of the bushing hole. **NOTE:** When bushings are removed for shipment, the draw-through leads are coiled up and tied to the underside of the blind flange on the bushing boss, or to a loop on the underside of the transformer cover near the bushing hole.

3. Install the gasket supplied with the bushings to the bushing boss:

Cork-neoprene gaskets:
Apply a uniform coating of gasket cement part # 53351GH to the gasket area of the mounting boss, and to the bottom of the gasket. Allow cement to become tacky, then position gasket on boss. Apply a thin coating of petrolatum to the top surface of the gasket.

CAUTION: When applying gasket cement, keep all sparks and flames away from work area. Avoid breathing large quantities of vapor and avoid continuous or excessive contact with skin.

Nitrile or Viton gaskets:
Apply a thin coating of petrolatum to the bottom surface of the gasket and place the gasket in the center of the gasket area on the boss.

4. Fish a stout cord or wire through the bushing porcelain and attach the bottom end of it to the hole at the top of the terminal on the end of the lead.

5. Draw the lead taut so that it is straight and free of twists and kinks.

6. Slip the bushing down over the draw lead while holding lead by the cord or wire. Take care not to damage the insulation on the lead while doing this.

7. Install the bushing mounting hardware (use a flatwasher and lockwasher on the nut side, and a flatwasher on the bolt side if a bolt is used) and tighten it by alternately tightening opposite corners until the flange is properly tightened:

Bushings with porcelain flange and clamping flange: Torque hardware to 8 foot pounds.

Bushings with metal flanges: Tighten until the bushing flange has contacted the bushing boss and lock washers are flattened.

8. Rotate the terminal slightly until the steel pin pressed in the draw lead seats in the slot inside the porcelain top end. With the pin seated in the groove and the draw lead pulled up, approximately ½ inch of thread should protrude above the porcelain top.

9. If the lead appears to be too short it indicates a problem which should be investigated and corrected before proceeding.

10. Apply a thin coating of petrolatum to the top surface of the cap sealing gasket and press the coated surface into the gasket recess in the terminal cap.

11. Remove the cord or wire previously attached to the draw lead. A stiff draw lead will remain in position. However it may be necessary to hold some leads by pressing between threads of the terminal with a screwdriver until the terminal cap is partially threaded onto the draw lead terminal.

12. Install the terminal cap onto the draw lead terminal and hand tighten, being careful to keep the steel pin seated in the slot inside the porcelain top.

13. Verify that the gasket is properly seated and the terminal cap centered on the porcelain.

14. To obtain proper gasket compression, torque the terminal cap to 35 ft-lbs.

15. Apply 2-3 psi of dry air or nitrogen to the transformer and check the bushing mounting and the terminal cap gasket for leaks using soap bubble solution.

5.14.2 Condenser Bushings

Instruction literature for the condenser bushings will be shipped with the transformer. These instructions will cover installation of the bushings, maintenance, and use of the power factor test terminal.

5.14.3 Other Bushings

Unless specific bushing instruction literature is delivered with the transformer, other bushing types will be factory installed and require no maintenance except as described in section 8.1 of this instruction book. Contact the factory if additional information is required.

5.15 Surge Arresters

WARNING: TO PREVENT SURGE ARRESTER DAMAGE, FOLLOW THESE INSTRUCTIONS. FAILURE TO DO SO COULD RESULT IN SEVERE PERSONAL INJURY, DEATH, OR PROPERTY DAMAGE.

A) When installing the arrester, all mounting feet must be flush before tightening bolts. Shim if necessary.

B) The arrester must not be climbed or stood on.

C) Use only the lifting devices provided on the arrestor for lifting.

D) Arrester port exhaust, if supplied, must be directed away from protected equipment and other arrester poles.

E) Poles must be made of the serial numbered units identified on the master nameplate (located on the bottom of the arrester unit).

F) Maximum cantilever force is 100 pounds for intermediate and SMX Station Surge arresters. Distribution type arresters are not to be mounted in a cantilever mode.

Transformers may be furnished with Intermediate Class, Station Class, or distribution type surge arresters as optional items. These arresters are shipped separately in a protective carton or crate. On receipt, unpack the units and examine for breakage or other damage, especially to the porcelains. Check the parts with the packing list.

5.16 Radiators

When radiators are shipped detached, all openings will be closed with blind flanges and plugs. The radiator opening Flanges and Plugs should be examined for signs of damage.

Store radiators in such a manner that water cannot stand around the sealed openings.

Make a visual inspection of vent and drain plugs to see if the plugs are right. If they have been loosened, plugs must be removed, re-cemented and re-tightened (Teflon sealing tape may be used for sealing the threads). Store indoors or in a weatherproof shed. Radiators should be blocked off the floor if stored three months or more.

Lift individual radiators only by the lifting eye on the top end.

Radiators must be thoroughly inspected prior to assembly to be certain that no water or foreign material is in the liquid space. Avoid opening the ambient in order to prevent condensation.

If there is any evidence of moisture, the radiator must be thoroughly dried either by blowing hot air through or by flushing with hot liquid. In any case, it is desirable to flush out the cooling equipment thoroughly with hot liquid if at all possible. The radiators should be installed on the transformer the same day they are opened and not permitted to stand exposed after opening for inspection or flushing. All cooling equipment must be installed prior to final liquid filling. Radiator valves should be closed until immediately prior to final vacuum liquid filling. Lock open all radiator valves before final vacuum liquid filling.

6. INSTALLATION

6.1 Location and Mounting

Transformer must be placed on a foundation of sufficient strength to support the weight of the unit. The foundation must be level within one half inch per 100 inch base. If the unit is not level, the liquid may not circulate through all the cooling tubes and cause overheating that will shorten transformer life. When a transformer is designed to be energized while tilted, the degree of maximum tilt will be noted on the transformer nameplate. The location of the transformer should provide for adequate accessibility, ventilation and ease of inspection for the unit. To assure proper air circulation for cooling, the transformer coolers should be at least 24 inches from any obstruction. Location in areas of corrosive chemicals should be avoided.

6.2 Opening Transformer Tank

Transformers are generally shipped sealed and need not be opened. When transformers are shipped without bushings or internal field connections are required or core ground tests are required which require internal access the following precautions should be followed.

WARNING: RELEASE INTERNAL PRESSURE PRIOR TO REMOVING TANK ACCESSORIES WITH A PRESSURE SEAL (MANHOLES, RELIEF DEVICE, PLUGS). FAILURE TO DO SO COULD RESULT IN SEVERE PERSONAL INJURY, DEATH, OR PROPERTY DAMAGE.

Internal pressure may be relieved by use of gas sample valves; or by SLOWLY removing the filling cap a thread at a time until the pressure starts to relieve itself.

WARNING: TO AVOID DEATH FROM SUFFOCATION NEVER ALLOW ANYONE TO ENTER THE TRANSFORMER TANK UNLESS AN ANALYSIS OF THE AIR IN THE TANK SHOWS AT LEAST 19.5% OXYGEN. THE GAS SPACE ON AN OPERATING TRANSFORMER CONSISTS OF NITROGEN GAS. WHENEVER ANYONE IS IN THE TANK, A PERSON SHOULD BE STATIONED AT THE MANHOLE OUTSIDE THE TANK TO INSURE SAFETY OF THE PERSON INSIDE.

Safety Precautions For Opening A Tank

When it is necessary to open a transformer, the following procedure should be used.

Ventilate the gas space with dry air to purge it of the nitrogen gas that it contains.

Dry air should be used to ventilate the inside of the tank when it is opened for internal fitting. When dry air is used, the following restrictions should be observed:

a. Temperature of dry air entering the transformer shall be at least as high as that of the transformer and at least 10°C higher than the dew point of the outside air.

b. Dry air shall be blown into the transformer so as to create a flow of air through the cover opening. Air hoses may be taken into the transformer if they are clean and made from an oil-proof material.

c. The dew point in the transformer should never be higher than 20°F.

d. Dry Air and Nitrogen. When nitrogen is called for, the nitrogen used should have a dew point not higher than -50°C (-58°F), and total impurities not exceeding 0.1% by volume. Nitrogen can be obtained in high pressure steel cylinders, or in some locations in insulating low pressure containers in liquid form. In general, liquid nitrogen which will boil in the container to yield gaseous nitrogen, will have a lower dew point than gas in high pressure cylinders.

Dry air should also have a dew point of -50°C (-58°F) or lower. It is usually available in cylinders from the same source which supply nitrogen. Air drying equipment is also available which is capable of producing dry air by passing air through a desiccant bed to remove moisture.

When air or nitrogen is supplied from high pressure cylinders the proper regulating valve must be used for introducing the gas into the transformer tank. Cylinders should not be completely emptied, but should be returned to the supplier with at least 25 psi residual pressure.

Outside air may be used for ventilating the transformer if dry air is not available. If outside air is to be used for ventilation, open the transformer only if the outside relative humidity is less than 65% and if the temperature of the transformer is at least 10°C higher than the dew point of the outside air.

The maximum total time the transformer should be open is 24 hours. If this time must be exceeded, the tank should have a vacuum pulled for 24 hours prior to refilling the tank. If the work is interrupted, the tank should be closed, evacuated, and refilled with dry air or nitrogen.

Do not open the transformer in an area unprotected from weather during precipitation or in an area where the air may contain dirt or other particles. Either of the above could cause a transformer failure. If the transformer is opened, the openings should at all times be protected against entry of foreign matter into the transformer tank. It may be necessary to remove some liquid from liquid-filled units for adequate inspection. If this is done, refilling of the transformer must be done as specified in Section 6.3.1.

While the transformer is open, no one should be permitted on top or inside the transformer until he has emptied all pockets, checked for loose objects elsewhere on his person, such as in pants cuffs, and has removed watches and rings.

Never stand directly on any electrical insulation. Clean drop cloths should be used under working areas in the transformer to prevent objects from dropping into the structure.

All tools must be accounted for. If possible, tools should have lines attached so that they cannot be lost.

One person should be responsible for policing the people and materials into and out of the tank and for making certain that nothing is left in the tank accidentally. This person should also be responsible for limiting the length of time the tank is left open to 24 hours.

After the tank has been opened the following tests should be made

1. A ratio test should be made on all windings and tap positions. If any measurement is off ratio by more than 0.5%, resistance and temperature measurements should be made of the windings in question and compared with factory test values.

2. Insulation resistance of each winding to all other windings and ground and from all windings to ground should be made with the windings under liquid. Record the temperature of the liquid. These readings should be comparable with measurements made at the factory.

3. When accessible, disconnect the core ground connection on core form transformers and measure the resistance from the core to the tank or end frames, using a 1000 volt megger. The resistance should exceed 100 megohms if the core is not covered with liquid or 200 megohms if the core is under liquid. When the internal inspection is complete, reseal the tank and refill the gas space with dry air or dry nitrogen. Subsequent steps will be given by ABB Small Power Transformer After Market Services representative to whom the suspected damage was reported.

6.3 Filling in the Field (when required)

When transformers are to be filled or topped off in the field, they must be filled under vacuum according to specific instructions. Contact the factory for these specific instructions.

CAUTION: TRANSFORMER OIL SHOULD ALWAYS BE HANDLED AS A FLAMMABLE LIQUID. IT SHOULD ALSO BE REMEMBERED THAT CLOSED TRANSFORMER TANKS MAY UNDER SOME CONDITIONS ACCUMULATE EXPLOSIVE GASES, AND THAT HANDLING PROCEDURES MAY GENERATE STATIC ELECTRICITY. SAFETY PRECAUTIONS SHOULD INCLUDE PURGING ALL GAS SPACES WITH NITROGEN BEFORE OIL-FILLING OR FILTERING AND GROUNDING THE TRANSFORMER, ITS BUSHINGS, AND ALL OIL-HANDLING EQUIPMENT. OTHERWISE, STATIC ELECTRICITY COULD IGNITE THE OIL.

CAUTION: TRANSFORMERS SHOULD NOT BE LEFT UNDER VACUUM EXCEPT DURING THE VACUUM FILLING OPERATION. LEAKS IN THE TEMPORARY PIPING AND CONNECTIONS LEAD TO DANGER OF DRAWING MOISTURE INTO THE TANK IF IT IS UNDER VACUUM DURING PERIODS OF HIGH HUMIDITY OR DURING A RAIN. IT IS RECOMMENDED THAT THE TANK BE UNDER POSITIVE PRESSURE DURING RAIN TO PREVENT DRAWING MOISTURE INTO THE TANK.

6.4 Air Terminal Chamber and 15 KV and 5 KV Switchgear Adapter Installation

WARNING: POOR INSTALLATION OF CONNECTING CHAMBERS AND ADAPTERS MAY ALLOW WATER AND OTHER CONTAMINANTS TO CONTACT LIVE PARTS. FAILURE TO PROPERLY INSTALL CONNECTING EQUIPMENT COULD RESULT IN SEVERE PERSONAL INJURY, DEATH, OR PROPERTY DAMAGE.

Air terminal chambers are designed to provide adequate electrical insulation by maintaining a clean, dry environment around connections and to protect personnel from high voltages. Installed chamber must be installed as per instructions on drawing. Refer to the transformer outline, details and station plan drawings.

Bolt the flexible connectors to the switchgear bus bars. The number of flexible connectors supplied are determined by the transformer current and not by the current ratings of the bus bar. Check the length of flexible connectors. There should be approximately 0.375 inch (10 mm) slack to permit some movement of the bus bars to expansion and contraction and possible settling of the transformer. Next, make the ground bus connection between the transformer and switchgear. Before reinstalling the adapter housing, check electrical clearances as indicated on the outline drawing and the tightness of connections and supports. Complete the installation by assembling the housing. Install the adjustable plate so that the switchgear throat is sealed by the gasket.

6.5 Preparation for Energization

The following are instructions that must be followed when preparing the transformer for energization. These instructions provide minimum requirements to determine the transformer's readiness for service. Check off each section as it is completed.

6.5.1 (   ) Pressure Test

Prior to energization, check the integrity of the transformer tank by introducing dry air or dry nitrogen through the pressure test fitting (this may be identified as the air test valve or gas sampling valve on the transformer outline) until a positive internal pressure of 3 to 4 psig is established. Allow the tank to stand for one to two hours, then examine the tank and fittings for leaks. A leak above the liquid level can be located by applying a soap solution to all joints, pipe fittings and cable connections. When the pressure test is complete, reduce the internal pressure to 1 or 2 PSIG.

6.5.2 (   ) Insulating Liquid Test

Before energizing the transformer, the liquid must be tested in accordance with Section 7.6. The dielectric strength of new liquid must be 26 KV or higher.

6.5.3 (   ) Insulation Megger Test

To insure that no grounding of the windings exists, a 1000 volt Megger test and a power factor test should be made. Refer to Table 2 and 3 for allowed values of insulation resistance.

Table 2 – Minimum Insulation Resistance in Oil at 20°C

L-L Voltage Class KV	Megohms
1.2	32
2.5	68
5	135
8.66	230
15	410
25	670
34.5	930
46	1240
69	1860

Table 3 – Insulation Resistance Temperature Correction

Transformer Temperature °C	Correc-tion-Factor	Transformer Temperature °C	Correc-tion Factor
95	89.0	35	2.5
90	66.0	30	1.8
85	49.0	25	1.3
80	36.2	20	1.0
75	26.8	15	0.73
70	20.0	10	0.54
65	14.8	5	0.40
60	11.0	0	0.30
55	8.1	-5	0.22
50	6.0	-10	0.16
45	4.5	-15	0.12

6.5.4 (   ) Ratio Test

A ratio test should be made at all tap positions to insure proper transformer ratios and tap changer connection.

6.5.5 (   ) Continuity, Resistance Test

There should be a continuity check of all windings. If possible, measure the winding resistance and compare to the factory test values. An increase of more than 10% could indicate loose internal connections.

DANGER: DO NOT CHANGE CONNECTIONS ON A TRANSFORMER THAT IS ENERGIZED NOR MAKE ANY CONNECTIONS EXCEPT AS AUTHORIZED BY THE NAMEPLATE OR CONNECTION DIAGRAM. TO DO SO WILL RESULT IN SEVERE PERSONAL INJURY, DEATH, OR PROPERTY DAMAGE.

6.5.6 (   ) Connections

When electrical connections are made, all mating joints must be clean and connections must be tight. All electrical connections must be to the correct terminal and be mechanically secure. Check the following items:

(   ) a) Line connections must be made without placing undue stress on the bushings per Section 5.14.

(   ) b) Check that the tap changer operating mechanism is in the proper position for the required voltage.

(   ) c) If the transformer is equipped with an internal terminal board, read Section 6.2 for instructions and warnings prior to opening tank.

Delta-wye multiple connections are made using an internal terminal board or a de-energized switch. Make the connection according to the chart on the transformer nameplate. Terminal board connections must be mechanically tight to prevent overheating of the joint.

(   ) d) The transformer tank must be grounded permanently by connecting a ground cable per the National Electric Code to a ground pad located at the bottom of the tank.

6.5.7 (   ) Wiring

Make a physical examination of control circuit wiring and alarm devices, if provided. Look for damaged insulation, and loose connections.

6.5.8 (   ) Liquid Level

Liquid level should be at the correct level according to Table 1.

Liquid Level Gauge

WARNING: THE TRANSFORMER MUST HAVE THE CORRECT LIQUID LEVEL BEFORE ENERGIZING THE UNIT (REFER TO TABLE 1). FAILURE TO DO SO COULD RESULTING SEVERE PERSONAL INJURY, DEATH OR PROPERTY DAMAGE.

6.5.9 ( ) Tank Finish

All damaged paint surfaces should be cleaned, primed, and repainted.

6.5.10 ( ) Bolt Check

Tighten all external bolts.

6.5.11 ( ) Tools

All tools or other objects used in installation are accounted for and have been removed from the transformer.

6.5.12 ( ) Liquid Temperature

The liquid temperature must be no colder than -20°C when the unit is energized.

When inspections and tests in Sections 6.5.1 through 6.5.12 are completed and any required repairs have been made, the transformer may be energized.

7. REPAIR MAINTENANCE

WARNING: ALWAYS DE-ENERGIZE THE TRANSFORMER WHEN WORKING ON TRANSFORMER. FAILURE TO DO SO COULD RESULT IN SEVERE PERSONAL INJURY, DEATH, OR PROPERTY DAMAGE.

7.1 It is the responsibility of the owner to inspect, maintain, and keep the transformer in good repair.

7.2 Report all failures during the warranty period to the ABB Small Power Transformer After Market Service representative. All warranty repairs must be made or approved by the Small Power Transformer After Market Service representative.

7.3 The core and coil assembly can be repaired or replaced by authorized ABB personnel. Contact the ABB Small Power Transformer After Market Services representative.

7.4 Tank leaks must be repaired immediately to prevent serious damage to the transformer and danger to life. Request Instruction Leaflet 48-069-20 for detailed instructions on tank repair.

7.5 The following periodic test and inspections are recommended as routine maintenance. Refer to Table 4 for frequency of inspections.

7.5.1 The gauge readings should be recorded as well as the ambient temperature and the KVA load. Any abnormal reading as explained in Section 5 is justification to make other diagnostic test or inspections immediately.

7.5.2 If pressure or liquid level readings give cause to suspect a leak make a pressure test in accordance with the instructions and warnings of Sections 6.5.1
.

7.5.3 Check the cooling fans, if supplied, by setting the control switch to the "MANUAL" position. The fans should rotate at full speed within 5 seconds. The fans should rotate with very little vibration.

Table 4 – Recommended Minimum Maintenance Schedule

Check Period	One Month After Initial Energizing	Once A Year After Energization
7.5.1. Gauge Readings	x	x
7.5.2. Tank Leaks		x
7.5.3. Fan Operation		x
7.5.4. Control Wiring and Circuits		x
7.5.5. Paint Finish		x
7.5.6. Liquid Dielectric Test		x
7.5.7. Temperature Scan Bushing Terminal and Surface	x	x
7.5.8. Insulator Cleanliness Inspection		x

7.5.4 The control wiring should be checked for integrity of insulation: The conduit and control cabinet should be inspected to assure that weather resistant seals are intact. Control power supply voltage should be checked with respect to the wiring diagram.

7.5.5 Inspect the paint finish for scratches or wear that expose the prime coat or the tank steel itself.

7.5.6 Liquid Dielectric Test. It is recommended that a liquid sample be taken periodically and tested. The dielectric strength of the liquid should not drop below 26 KV.

7.5.7 Using an infrared scanner, check the bushings terminal temperatures. A loose or dirty connection would be indicated by an excessive bushing terminal temperature. (NOTE: Bushing temperature will be approximately 10°C hotter than liquid temperature when transformer is at rated kVA). If the transformer is not energized, the bushing terminal connections should be checked to ensure that they are tight. Loose connections will cause excessive conductor temperatures.

7.5.8 Bushing and surge arrester insulators should be clean. If the surfaces are excessively dirty, they should be cleaned while the transformer is not energized.

7.6 Sampling of Insulation Liquid

Care should be taken to procure a sample which fairly represents the liquid in the tank. A quart of liquid should therefore be drawn off before the sample is taken to insure that the sample will not be that which is stored in the sampling pipe. If the sample taken contains free water, it is not suitable for dielectric tests and the sample should be discarded. A second sample should then be taken after at least two quarts of liquid have been withdrawn. If free water still exists, the liquid should be run through a blotter filter press and tested for dielectric strength.

The sample of the liquid should be taken when the unit is warmer than the surroundings to avoid condensation and should also be taken only on clear days. When sampling oil from the transformer, the sample must come from the bottom of the tank.

When sampling SILICONE FLUID from the transformer, the sample may come from either the top liquid level or the bottom of the tank.

It is recommended that a 16-ounce amber glass container be used as a sampling receptacle so that any water present may readily be seen. Do not use rubber gaskets or stoppers on SILICONE FLUID sample bottles.

pers on SILICONE FLUID sample bottles.

Additional information concerning handling, sampling, filtering, testing and reconditioning can be obtained by ordering Instruction Book 45-063-100 for OIL, and Instruction Book 45-063-102 for SILICONE FLUID through the ABB Small Power Transformer After Market Services representative.

7.7 Gaskets

Before replacing a gasket, carefully and thoroughly clean the steel surfaces between which the gaskets are compressed to remove rust, oil grease, paint, and other foreign material. The cleaning may be done by scraping or wire-brushing the surface with de-natured alcohol. Use a recommended gasket cement when applying gaskets. Put the gasket in place and bolt the two surfaces together under uniform pressure. After the unit has been in service for a period of six months, retighten all the bolts.

7.8 Additional Maintenance Instructions

If additional instructions are needed contact the factory.

7.9 Renewal Parts

Order renewal parts from the ABB Small Power Transformer After Market Service representative, giving description of parts wanted, as well as the serial number on the transformer nameplate. A renewal parts list can be obtained in the same manner. In order to expedite maintenance, the parts listed on the Recommended Parts List should be stocked by the user.

Memorandum

Memorandum

Memorandum

TECK SERIES CABLE FITTINGS

Installation & Maintenance Information

Terminator™ CABLE FITTINGS

COOPER Crouse-Hinds

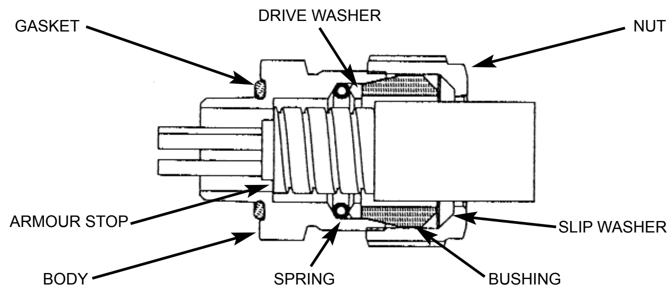
IF 1417

SAVE THESE INSTRUCTIONS FOR FUTURE REFERENCE

APPLICATION

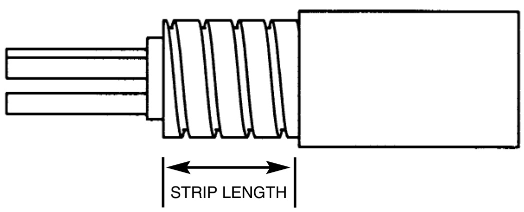
Crouse-Hinds Terminator™ TECK Series cable fittings are designed for use with jacketed Teck cable with aluminum or steel armour. TECK series cable fittings are installed to provide a means for passing Teck type cable into an enclosure, panel board or other equipment, to form a mechanical watertight and dust tight termination and to provide ground continuity between the cable armour and metal enclosures.

Terminator TECK Series cable fittings are CSA certified for ordinary wet locations (Type 4) as well as use in Class I, II, III (H.L.A.). They are suitable for use in Class I locations when used with a certified Class I hazardous location sealing fitting.



INSTALLATION

1. Measure the cable and select the appropriate fitting from actual cable diameter and Table 1.
2. Prepare the cable by first removing the jacket and armour from the cable to expose a sufficient length of conductors required for the job.
3. Next, refer to Table 1 to determine the amount of armour to be exposed for proper grounding of the cable (STRIP LENGTH). Remove jacket to expose armour to insure ground continuity between cable and fitting.



4. Examine the fitting to make sure that neither the spring nor the bushing is precompressed. If they are, loosen the body and the nut to allow the spring and the bushing to return to their maximum diameter. DO NOT DISASSEMBLE. It is not necessary to disassemble any of the components of the fitting during installation.
5. Install fitting in a threaded NPT opening or fasten in a slip hole with a locknut. An integral gasket is provided on the fitting for a watertight and dust tight seal. Use a wrench to securely tighten the body if installing in a threaded opening. If installing with a locknut, hand tighten the locknut and then further tighten 1/4" turn with a flat head screw driver and hammer.

   Note: When using the fitting with single conductor cable, an aluminum fitting and aluminum locknut must be used!
6. Insert prepared cable into fitting and push until cable armour rests on armour stop.
7. Completely tighten the gland nut to the torque value listed in Table 2.
8. Verify continuity between cable armour and enclosure.

NEW CAT. NO.	HUB SIZE NPT	STRIP LENGTH (INCH)	RANGE OVER JACKET (IN.)		RANGE OVER ARMOUR (IN.)	
			MIN.	MAX.	MIN.	MAX.
TECK050-1	1/2"	1 1/4"	0.525	0.650	0.415	0.570
TECK050-2	1/2"	1 1/4"	0.600	0.760	0.490	0.680
TECK050-3	1/2"	1 1/4"	0.725	0.885	0.615	0.805
TECK050-4	1/2"	1 1/4"	0.825	0.985	0.715	0.905
TECK075-5	3/4"	1 1/4"	0.880	1.065	0.770	0.985
TECK075-6	3/4"	1 1/4"	1.025	1.205	0.915	1.125
TECK100-7	1"	1 1/4"	1.187	1.375	1.077	1.295
TECK125-8	1 1/4"	13/4"	1.350	1.625	1.240	1.545
TECK125-9	1 1/4"	13/4"	1.500	1.625	1.390	1.545
TECK125-10	1 1/4"	13/4"	1.600	1.875	1.490	1.795
TECK150-11	1 1/2"	13/4"	1.700	1.965	1.590	1.885
TECK150-12	1 1/2"	13/4"	1.900	2.187	1.790	2.107
TECK200-13	2"	13/4"	1.900	2.187	1.790	2.107
TECK200-14	2"	13/4"	2.100	2.375	1.990	2.280
TECK200-15	2"	13/4"	2.300	2.565	2.190	2.485
TECK200-16	2"	13/4"	2.500	2.750	2.390	2.656
TECK250-17	2 1/2"	2 1/2"	2.380	2.640	2.240	2.560
TECK250-18	2 1/2"	2 1/2"	2.580	2.840	2.440	2.750
TECK300-19	3"	2 1/2"	2.790	3.060	2.640	2.970
TECK300-20	3"	2 1/2"	3.000	3.270	2.870	3.190
TECK300-21	3"	2 1/2"	3.210	3.480	3.042	3.390
TECK350-22	3 1/2"	2 1/2"	3.420	3.690	3.270	3.590
TECK350-23	3 1/2"	2 1/2"	3.610	3.870	3.440	3.770
TECK400-24	4"	2 1/2"	3.810	4.030	3.600	3.930
TECK400-25	4"	2 1/2"	3.965	4.185	3.755	4.065
TECK400-26	4"	2 1/2"	4.120	4.340	3.910	4.220

Table 1

Trade Size	Torque LB-Inch	Trade Size	Torque LB-Inch
1/2" & 3/4"	600	1 1/2"	1200
1"	700	2" to 4"	1600
1 1/4"	1000		

Table 2 - Tightening Torque

Cooper Industries Inc.
Crouse-Hinds Division
PO Box 4999, Syracuse, New York 13221 • U.S.A.

IF 1417
Revision 3
Revised 09/03
Supercedes 01/03

RACCORDS TERMINATOR^{MC} DE SÉRIE TECK POUR CÂBLES TECK

Renseignements sur l'installation et la maintenance

COOPER Crouse-Hinds

Terminator CABLE FITTINGS

IF 1417

SAVE THESE INSTRUCTIONS FOR FUTURE REFERENCE

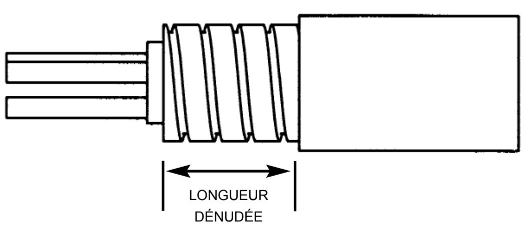
UTILISATION

Les raccords Terminator de série TECK de Crouse-Hinds sont conçus pour être utilisés avec les câbles Teck chemisés à blindage d'acier ou d'aluminium. Les raccords de câble de la série TECK permettent de faire passer des câbles de type Teck dans un boîtier, un panneau de commande ou tout autre équipement en assurant un branchement mécanique étanche à l'eau et à la poussière et la mise à la terre entre le blindage du câble et le boîtier de métal.

Les raccords Terminator de série TECK sont homologués CSA pour les emplacements mouillés ordinaires (type 4) ainsi que pour les utilisations dans les emplacements dangereux des classes I, II et III. Ils peuvent convenir aux emplacements de classe I à condition d'utiliser un raccord étanche homologué pour emplacements dangereux de classe I.

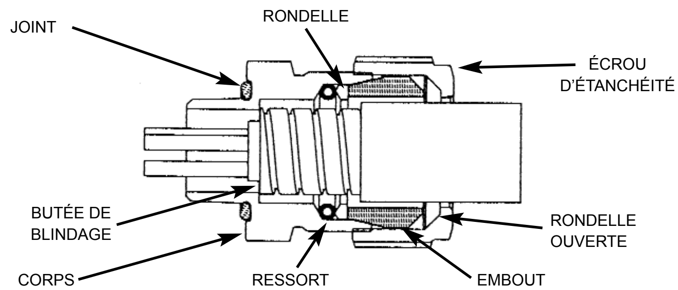
INSTALLATION

1. Mesurer le câble et choisir le raccord approprié compte tenu du diamètre réel du câble et du tableau 1.
2. Préparer le câble en retirant la gaine et le blindage, de manière à dégager les conducteurs sur une longueur suffisante.
3. Ensuite, se reporter au tableau 1 afin de déterminer la quantité de blindage à dénuder pour assurer une mise à la terre adéquate du câble (LONGUEUR DÉNUDÉE). Enlever la gaine pour exposer le blindage de manière à assurer la continuité de la mise à la terre entre le câble et le raccord.



4. Examiner le raccord pour s'assurer que ni le ressort ni la bague de raccordement ne sont comprimés. Si c'est le cas, desserrer le corps et l'écrou pour permettre au ressort et à la bague de raccordement de revenir à leur diamètre maximal. NE PAS DÉMONTER. Il n'est pas nécessaire de démonter les composants du raccord pendant l'installation.
5. Installer le raccord dans une ouverture filetée NPT ou le fixer dans un trou lisse avec un écrou de blocage. Le raccord comporte un joint intégré assurant l'étanchéité à l'eau et à la poussière. En cas d'installation dans une ouverture filetée, utiliser une clé pour fixer solidement le corps. Pour l'installation avec un écrou de blocage, serrer ce dernier à la main, puis serrer de 1/4 de tour supplémentaire avec un tournevis à lame plate et frapper avec un marteau.

   Nota: Si on utilise le raccord avec un câble à un conducteur, on doit choisir un raccord en aluminium et un écrou de blocage en aluminium.
6. Insérer le câble ainsi préparé dans le raccord et pousser jusqu'à ce que le blindage du câble repose sur la butée de blindage.



7. Serrer à fond l'écrou d'étanchéité au couple indiqué dans le tableau 2.
8. Vérifier la continuité entre le blindage du câble et le boîtier.

Nouveau numero de catalogue	DIM. RACCORD NPT	LONGUEUR DENUDEE (PO)	GAMME DE GAINE (PO) MIN.	GAMME DE GAINE (PO) MAX.	GAMME DE BLINDAGE (PO) MIN.	GAMME DE BLINDAGE (PO) MAX.
TECK050-1	1/2 po	1 1/4 po	0,525	0,650	0,415	0,570
TECK050-2	1/2 po	1 1/4 po	0,600	0,760	0,490	0,680
TECK050-3	1/2 po	1 1/4 po	0,725	0,885	0,615	0,805
TECK050-4	1/2 po	1 1/4 po	0,825	0,985	0,715	0,905
TECK075-5	3/4 po	1 1/4 po	0,880	1,065	0,770	0,985
TECK075-6	3/4 po	1 1/4 po	1,025	1,205	0,915	1,125
TECK100-7	1po	1 1/4 po	1,187	1,375	1,077	1,295
TECK125-8	1 1/4 po	13/4 po	1,350	1,625	1,240	1,545
TECK125-9	1 1/4 po	13/4 po	1,500	1,625	1,390	1,545
TECK125-10	1 1/4 po	13/4 po	1,600	1,875	1,490	1,795
TECK150-11	1 1/2 po	13/4 po	1,700	1,965	1,590	1,885
TECK150-12	1 1/2 po	13/4 po	1,900	2,187	1,790	2,107
TECK200-13	2 po	13/4 po	1,900	2,187	1,790	2,107
TECK200-14	2 po	13/4 po	2,100	2,375	1,890	2,280
TECK200-15	2 po	13/4 po	2,300	2,585	2,190	2,485
TECK200-16	2 po	13/4 po	2,500	2,750	2,390	2,656
TECK250-17	2 1/2 po	2 1/2 po	2,380	2,640	2,240	2,560
TECK250-18	2 1/2 po	2 1/2 po	2,580	2,840	2,440	2,750
TECK300-19	3 po	2 1/2 po	2,790	3,060	2,640	2,970
TECK300-20	3 po	2 1/2 po	3,000	3,270	2,870	3,190
TECK300-21	3 po	2 1/2 po	3,210	3,480	3,042	3,390
TECK350-22	3 1/2 po	2 1/2 po	3,420	3,690	3,270	3,590
TECK350-23	3 1/2 po	2 1/2 po	3,610	3,870	3,440	3,770
TECK400-24	4 po	2 1/2 po	3,810	4,030	3,600	3,930
TECK400-25	4 po	2 1/2 po	3,965	4,185	3,755	4,065
TECK400-26	4 po	2 1/2 po	4,120	4,340	3,910	4,220

Tableau 1

Dimensions nominales	Couple en lb-po	Dimensions nominales	Couple en lb-po
1/2 po et 3/4 po	600	1 1/2 po	1200
1po	700	De 2 po à 4 po	1600
1 1/4 po	1000		

Tableau 2 - Couple de serrage

Cooper Industries Inc.
Crouse-Hinds Division
PO Box 4999, Syracuse, New York 13221 • U.S.A.

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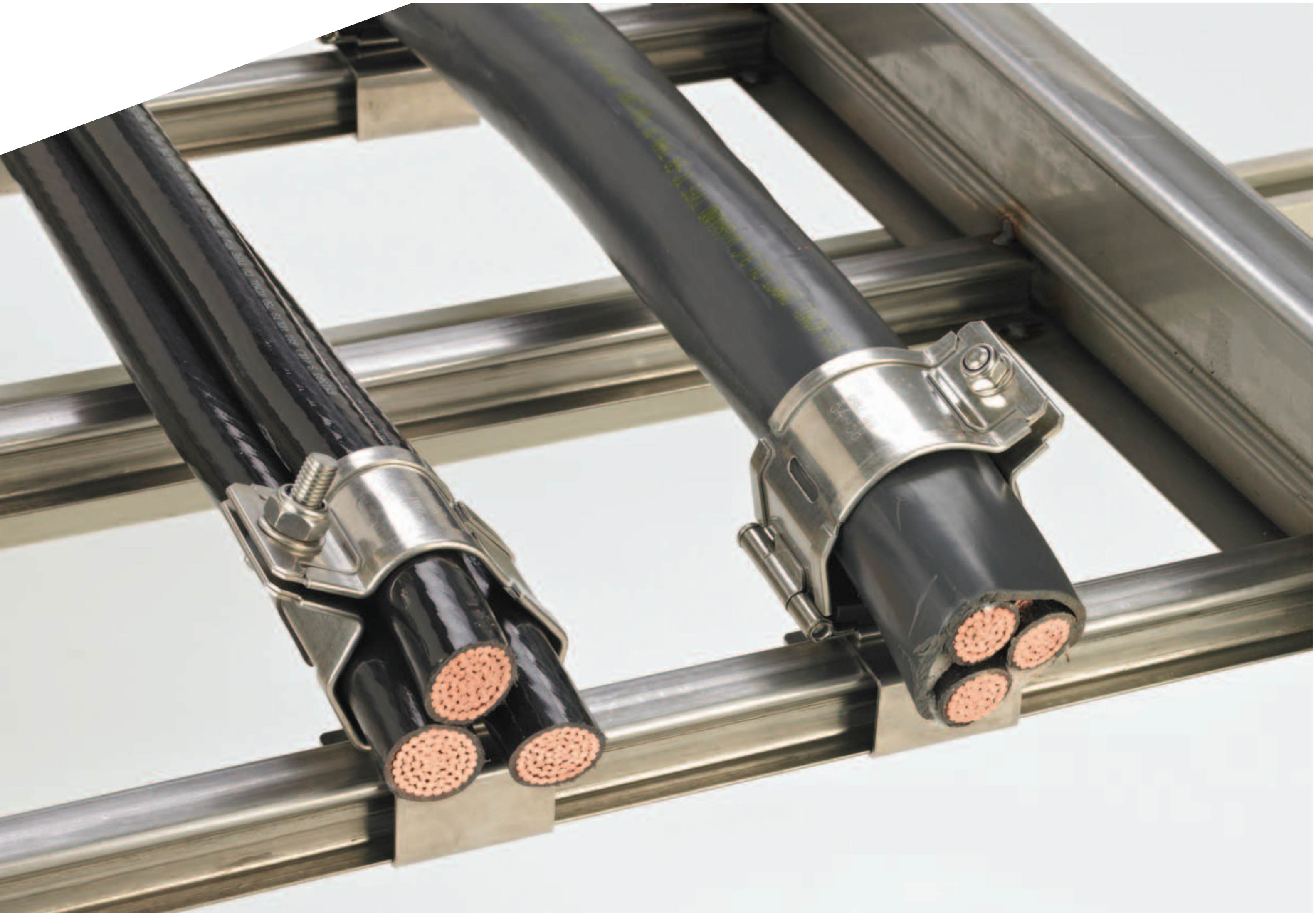
Revision 3
Revise 09/03
Supercedes 01/03



Cable Cleats

Protect Your Investments

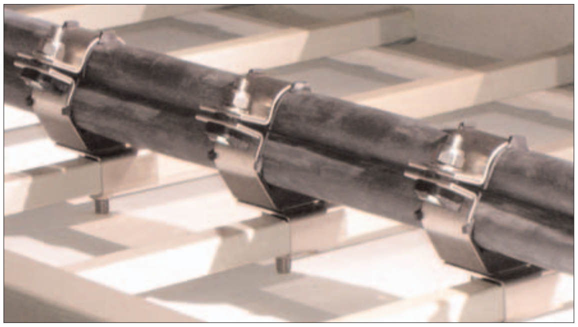
CTCC-10

COOPER B-Line

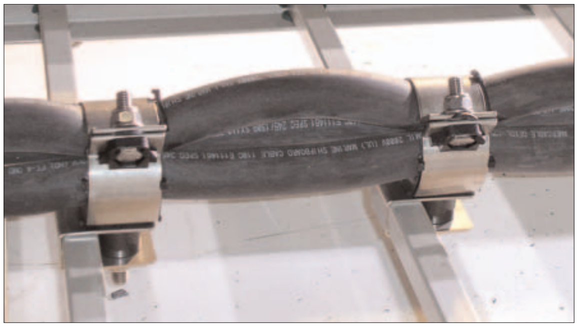
Protect your People | **Protect your Cables** | **Protect your Systems**



Cooper B-Line Cable Cleats are designed to support and retain your cables within your cable tray system in everyday conditions. More importantly, they help prevent damage in short circuit conditions. Unfortunately, short circuits do happen, and when they do, they are destructive and dangerous. Cable Cleats are one of the first lines of defense to help protect your personnel, your cables and your cable tray systems.



Properly restrained cables shown before a short circuit.



Properly restrained cables shown after a short circuit.

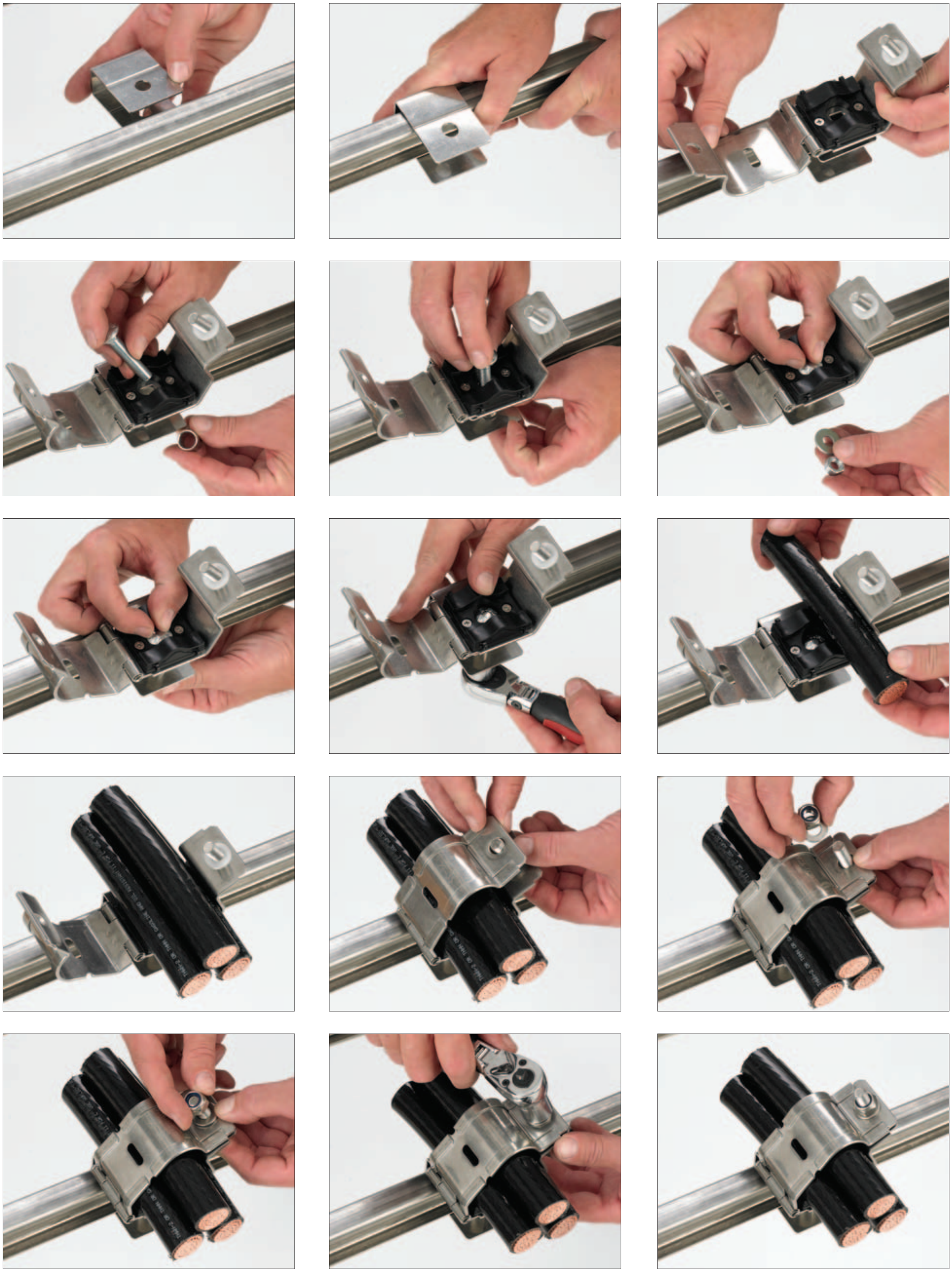
In the event of a short circuit, correctly installed cable cleats can restrain the cables within the tray, helping avoid cable breaks that can cause damage to the tray systems and injury to your personnel. Not only is this a prudent product to install, the National Electrical Code (NEC) requires adequate cable restraint in article 392.8 (D).

“Parallel connected single conductor cables shall be securely bound in circuit groups to prevent excessive movement due to fault current magnetic forces.”
NEC, Article 392.8 (D).

The cleats in this catalog are covered under IEC Standard 61914.

Cable cleats also help avoid downtime caused by short circuits. They help prevent the need for expensive repairs and downtime caused by short circuit damages.

Step by Step Installation



Step 1: Know Your Cables

- What type of cable is being used?
  - Single or Multi-conductor
- What is the outside diameter of the cable(s)?
- What is the cable arrangement (single conductor cables only)?
  - Flat or Trefoil
- If a ground wire will be installed within the cleat, you will need the ground wire outside diameter.

Step 2: Know Your System

- What is the available short circuit current (RMS or i_p (peak))?
- What type of Cooper B-Line cable tray is installed?

Step 3: Select Your Cable Cleats

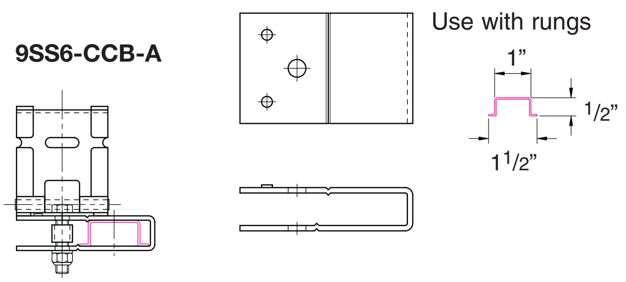
- See Pages 6 & 7

Step 4: Select Your Mounting Bracket

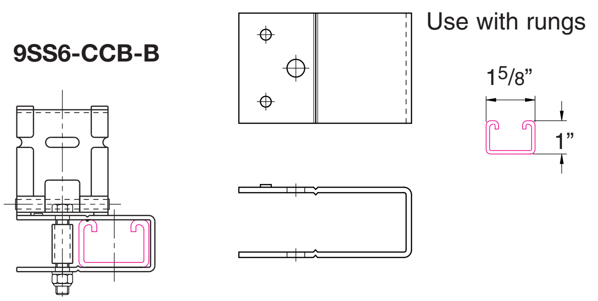
Mounting brackets are used to attach cable cleats to the rungs of the ladder type cable trays. Your tray type will determine the mounting bracket used.

Cooper B-Line Tray Types	Mounting Bracket
Aluminum welded rung trays with standard rungs. Steel Series 2, 3, 4 or 5, trays with standard rungs Fiberglass trays with standard rungs	9SS6-CCB-C
REDI-Rail™ Cable Tray	9SS6-CCB-D
Steel trays with strut rungs Aluminum trays with “Marine Rungs”	9SS6-CCB-B
Steel Series 1 trays with standard rungs	9SS6-CCB-A

9SS6-CCB-A



9SS6-CCB-B



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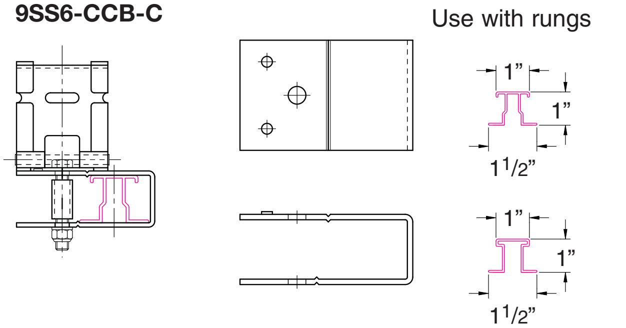

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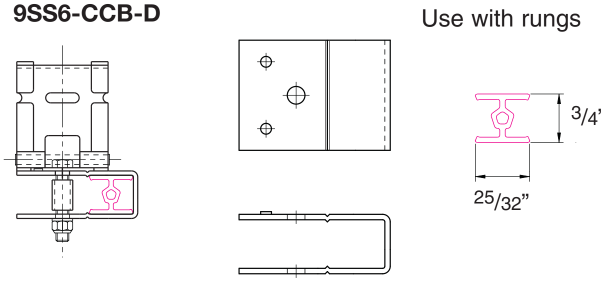
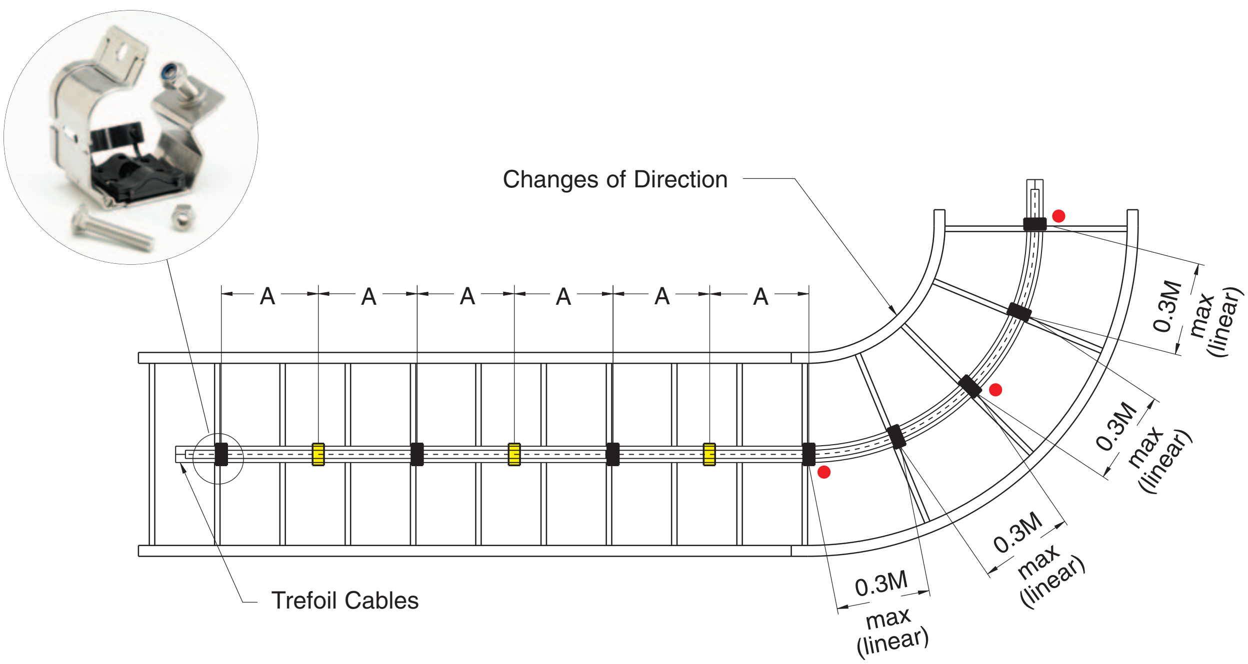


Step 5: Determine Cleat Spacing for Installation

Your cable diameter is equal to the spacing between conductor centers shown below. Find your cable diameter at the top of the table and look down at the column below it. Find the value equal to or greater than the available short circuit for your system.

Single Conductor Short Circuit Withstand Table													
Max. Cable Cleat Spacing (A)		Spacing Between Conductor Centers (mm)											
		23	25	27	29	31	33	35	37	39	41	43	45
mm	In.	i_p peak (kA)											
225	9	179	187	194	203	209	216	220	229	234	240	246	250
300	12	155	163	168	174	181	187	192	198	203	209	214	215
450	18	128	133	137	144	148	152	157	161	165	170	174	178
600	24	110	115	119	124	128	132	135	139	143	148	150	153
675	27	104	108	113	117	121	124	128	132	135	139	143	147
900	36	89	93	97	102	104	108	110	115	117	121	124	127



IMPORTANT: Recommended Installation Procedures

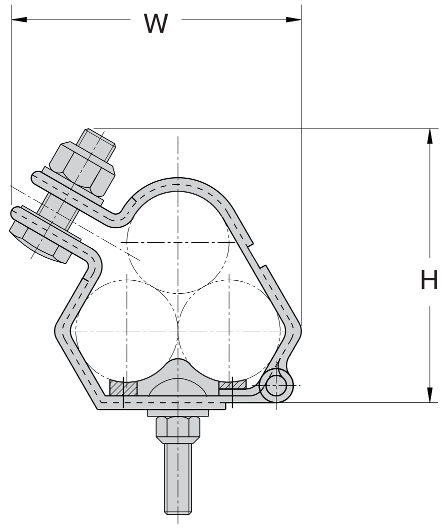
It is important that the cleats are installed properly to secure your cables:

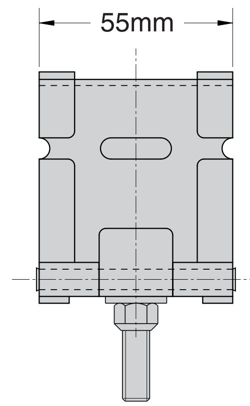
- It is not necessary for every cleat to be attached to the tray. Every other cleat (■) must be attached to the tray system to mount cable in tray. Unattached cleats (▯) provide additional restraint to keep cables bundled.
- The bend radius should be 8 to 12 times the cable diameter.
- Cleats should always be installed at the beginning, middle and end of a bend (●), and at no time should the distance between cleats on a bend be more than 0.3M center to center.

Cooper B-Line Sales Engineers are available to assist you in selecting your cable cleats.
Phone: (800) 851-7415 ext. 366

Trefoil Cable Cleat with LSF Pad

1. Cable Cleats are recommended for installations where the highest levels of short circuit withstand are required.
2. Cable Cleats have been short circuit current tested in accordance with BS EN 50368:2003 standard.
3. Cable Cleats are available for single and trefoil cable applications.
4. Cable Cleat LSF-pad incorporate an integral low smoke, low fume, zero halogen pad.
5. Hardware to attach cleat to rung attachment bracket is included with cleat. Bracket must be ordered separately.





BS EN 50368:2003 (Cable Cleats for Electric Installations) Classification	
Cleat Type	Composite
Resistance to Electromechanical Force	130 kA peak / 50 kA RMS 600 mm spacing
Lateral Load Test	3.439 kg average
Axial Load Test	Pass
Operating Temperature Range	-40°C to +60°C
Impact Resistance	Very Heavy
Needle Flame Test	30 seconds

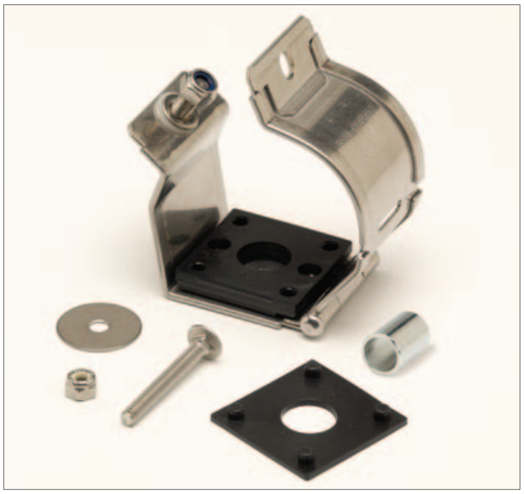
Technical Specifications	
Frame	50mm x 2mm Marine grade, Non-magnetic 316L
Closure Hardware	Captive 316 Stainless Steel M8 or M10 (M12 available) bolt and nylon-lock nut (Optional Hex Flange Lock Nut available)
Integral Pad	Low Smoke, Low Fume, Zero Halogen
Tools Required	Impact Wrench
Mounting Bolt	Provided with Cable Cleat

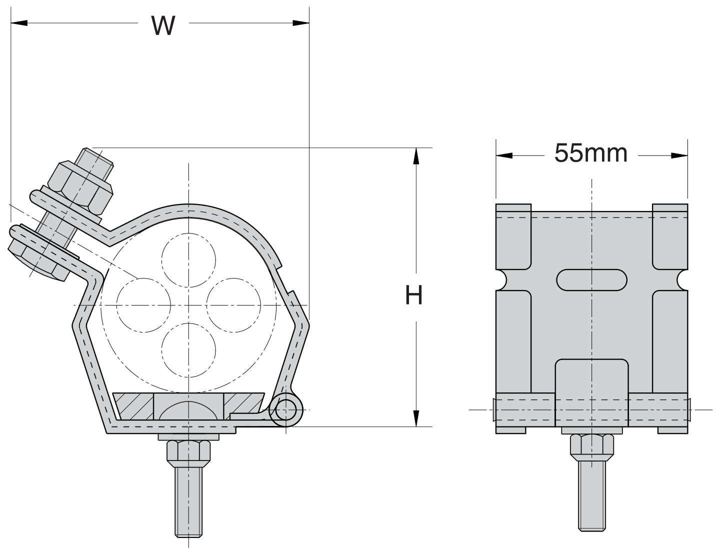
	Cable Range (mm)		Dimensions (mm)	
Part No.	Min. Dia.	Max. Dia.	H	W
9SS6-CCT1323	13	22	74	66
9SS6-CCT2125	21	25	77	70
9SS6-CCT2329	23	29	81	78
9SS6-CCT2531	25	31	84	81
9SS6-CCT2733	27	33	86	83
9SS6-CCT2935	29	35	90	89
9SS6-CCT3238	32	38	94	95
9SS6-CCT3541	35	41.5	98	100
9SS6-CCT3844	38	44.5	101	104
9SS6-CCT4248	42	48	105	111
9SS6-CCT4551	45	51	109	117
9SS6-CCT4753	47	53	111	120
9SS6-CCT4955	49	55	114	124
9SS6-CCT5157	51	57	116	127
9SS6-CCT5359	53	59	119	133
9SS6-CCT5561	55	61	127	137
9SS6-CCT5763	57	63	126	140
9SS6-CCT5965	59	65	128	144

	Cable Range (mm)		Dimensions (mm)	
Part No.	Min. Dia.	Max. Dia.	H	W
9SS6-CCT6167	61	67	132	147
9SS6-CCT6369	63	69	136	150
9SS6-CCT6571	65	71	140	153
9SS6-CCT6773	67	73	143	156
9SS6-CCT6975	69	75	147	160
9SS6-CCT7177	71	77	151	163
9SS6-CCT7379	73	79	154	166
9SS6-CCT7581	75	81	158	169
9SS6-CCT7783	77	83	161	173
9SS6-CCT7985	79	85	164	176
9SS6-CCT8187	81	87	169	179
9SS6-CCT8389	83	89	173	182
9SS6-CCT8896	88	96	181	192
9SS6-CCT96103	96	103	190	201
9SS6-CCT103111	103	111	199	204
9SS6-CCT111119	111	119	208	213
9SS6-CCT119128	119	128	217	221

Single Cable Cleat with LSF Pad

1. Cable Cleats are recommended for installations where the highest levels of short circuit withstand are required.
2. Cable Cleats have been short circuit current tested in accordance with BS EN 50368:2003 standard.
3. Cable Cleats are available for single and trefoil cable applications.
4. Cable Cleat LSF-pad incorporate an integral low smoke, low fume, zero halogen pad.
5. Hardware to attach cleat to rung attachment bracket is included with cleat. Bracket must be ordered separately.





BS EN 50368:2003 (Cable Cleats for Electric Installations) Classification	
Cleat Type	Composite
Resistance to Electromechanical Force	130 kA peak / 50 kA RMS 600 mm spacing
Lateral Load Test	3.439 kg average
Axial Load Test	Pass
Operating Temperature Range	-40°C to +60°C
Impact Resistance	Very Heavy
Needle Flame Test	30 seconds

Technical Specifications	
Frame	50mm x 2mm Marine grade, Non-magnetic 316L
Closure Hardware	Captive 316 Stainless Steel M8 or M10 (M12 available) bolt and nylon-lock nut (Optional Hex Flange Lock Nut available)
Integral Pad	Low Smoke, Low Fume, Zero Halogen
Tools Required	Impact Wrench
Mounting Bolt	Provided with Cable Cleat

	Cable Range (mm)		Dimensions (mm)	
Part No.	Min. Dia.	Max. Dia.	H	W
9SS6-CCS2832	28	32	61	55
9SS6-CCS3034	30	34	63	57
9SS6-CCS3236	32	36	65	59
9SS6-CCS3438	34	38	67	61
9SS6-CCS3640	36	40	17	63
9SS6-CCS3842	38	42	69	65
9SS6-CCS4044	40	44	71	67
9SS6-CCS4246	42	46	72	69
9SS6-CCS4448	44	48	74	71
9SS6-CCS4650	46	50	75	73
9SS6-CCS4852	48	52	77	75
9SS6-CCS5054	50	54	79	77
9SS6-CCS5256	52	56	80	79
9SS6-CCS5458	54	58	81	81
9SS6-CCS5660	56	60	83	83
9SS6-CCS5862	58	62	85	85
9SS6-CCS6064	60	64	86	87

	Cable Range (mm)		Dimensions (mm)	
Part No.	Min. Dia.	Max. Dia.	H	W
9SS6-CCS6266	62	66	88	89
9SS6-CCS6468	64	68	90	91
9SS6-CCS6670	66	70	91	93
9SS6-CCS6872	68	72	93	95
9SS6-CCS7074	70	74	95	97
9SS6-CCS7276	72	76	97	99
9SS6-CCS7478	74	78	99	101
9SS6-CCS7680	76	80	101	103
9SS6-CCS7682	76	82	103	105
9SS6-CCS8084	80	84	105	107
9SS6-CCS8286	82	86	107	109
9SS6-CCS8488	84	88	109	111
9SS6-CCS8690	86	90	110	113
9SS6-CCS9094	90	94	116	120
9SS6-CCS94118	94	118	135	137
9SS6-CCS118130	118	130	141	143
9SS6-CCS127150	127	150	162	165

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CTCC-10

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SYSTEMS THAT MAKE SENSE

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COOPER B-Line

CABLE TRAY MANUAL

Based on the 2011 National Electrical Code®

COOPER B-Line

Table of Contents

INTRODUCTION

The Cooper B-Line Cable Tray Manual was produced by Cooper B-Line's technical staff. Cooper B-Line has recognized the need for a complete cable tray reference source for electrical engineers and designers. The following pages address the 2011 ***National Electric Code***® requirements for cable tray systems as well as design solutions from practical experience. The information has been organized for use as a reference guide for both those unfamiliar and those experienced with cable tray.

Nearly every aspect of cable tray design and installation has been explored for the use of the reader. If a topic has not been covered sufficiently to answer a specific question or if additional information is desired, contact the engineering department at Cooper B-Line. We sincerely hope you will find the Cooper B-Line Cable Tray Manual a helpful and informative addition to your technical library.

The information contained herein has been carefully checked for accuracy and is believed to be correct and current. No warranty, either expressed or implied, is made as to either its applicability to, or its compatibility with, specific requirements, of this information, nor for damages consequent to its use. All design characteristics, specifications, tolerances and similar information are subject to change without notice.

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WHY CABLE TRAY?

BECAUSE A CABLE TRAY WIRING SYSTEM PROVIDES SAFE AND DEPENDABLE WAYS TO SAVE NOW AND LATER

Large numbers of electrical engineers have limited detail knowledge concerning wiring systems. There is the tendency by engineers to avoid becoming involved in the details of wiring systems, leaving the wiring system selection and design to designers or contractors. Certain decisions must be made for any wiring system installation, and these decisions should be made in the design and construction activities' chain where maximum impact is achieved at the lowest possible cost. Deferring design decisions to construction can result in increased costs and wiring systems incompatible with the owner's future requirements. Early in the project's design life, the costs and features of various applicable wiring systems should be objectively evaluated in detail. Unfortunately, such evaluations are often not made because of the time and money involved. It is important to realize that these initial evaluations are important and will save time and money in the long run. The evaluation should include the safety, dependability, space and cost requirements of the project. Many industrial and commercial electrical wiring systems have excessive initial capital costs, unnecessary power outages and require excessive maintenance. Moreover, the wiring system may not have the features to easily accommodate system changes and expansions, or provide the maximum degree of safety for the personnel and the facilities.

Cable tray wiring systems are the preferred wiring system when they are evaluated against equivalent conduit wiring systems in terms of safety, dependability, space and cost. To properly evaluate a cable tray wiring system vs. a conduit wiring system, an engineer must be knowledgeable of both their installation and the system features. The advantages of cable tray installations are listed below and explained in the following paragraphs.

- Safety Features
- Dependability
- Space Savings
- Cost Savings
- Design Cost Savings
- Material Cost Savings
- Installation Cost & Time Savings
- Maintenance Savings

CABLE TRAY SAFETY FEATURES

A properly engineered and installed cable tray wiring system provides some highly desirable safety features that are not obtainable with a conduit wiring system.

- Tray cables do not provide a significant path for the transmission of corrosive, explosive, or toxic gases while conduits do. There have been explosions in industrial facilities in which the conduit systems were a link in the chain of events that set up the conditions for the explosions. These explosions would not have occurred with a cable tray wiring system since the explosive gas would not have been piped into a critical area. This can occur even though there are seals in the conduits. There does have to be some type of an equipment failure or abnormal condition for the gas to get into the conduit, however this does occur. Conduit seals prevent explosions from traveling down the conduit (pressure piling) but they do not seat tight enough to prevent moisture or gas migration until an explosion or a sudden pressure increase seats them. The October 6, 1979 Electrical Substation Explosion at the Cove Point, Maryland Columbia Liquefied Natural Gas Facility is a very good example of where explosive gas traveled though a two hundred foot long conduit with a seal in it. The substation was demolished, the foreman was killed and an operator was badly burned. This explosion wouldn't have occurred if a cable tray wiring system had been installed instead of a conduit wiring system. A New Jersey chemical plant had the instrumentation and electrical equipment in one of its control rooms destroyed in a similar type incident.

- In addition to explosive gases, corrosive gases and toxic gases from chemical plant equipment failures can travel through the conduits to equipment or control rooms where the plant personnel and the sensitive equipment will be exposed to the gases.

- In facilities where cable tray may be used as the equipment grounding conductor in accordance with **NEC®** Sections 392.60(A) & 392.60(B), the grounding equipment system components lend themselves to visual inspection as well as electrical continuity checks.

CABLE TRAY DEPENDABILITY

A properly designed and installed cable tray system with the appropriate cable types will provide a wiring system of outstanding dependability for the control, communication, data handling, instrumentation, and power systems. The dependability of cable tray wiring systems has been proven by a 40 year track record of excellent performance.

- Cable tray wiring systems have an outstanding record for dependable service in industry. It is the most common industrial wiring system in Europe. In continuous process systems, an electrical system failure can cost millions of dollars and present serious process safety problems for the facility, its personnel and the people in the surrounding communities. A properly designed and installed cable tray system with the appropriate cable types will provide a wiring system of outstanding dependability for process plants.

• Television broadcast origination facilities and studios make use of cable tray to support and route the large volumes of cable needed for their operations with a high degree of dependability. It would be impossible to have the wiring system flexibility they need with a conduit wiring system.

• Large retail and warehouse installations use cable tray to support their data communication cable systems. Such systems must be dependable so that there are no outages of their continuous inventory control systems.

• Cable tray wiring systems have been widely used to support cabling in both commercial and industrial computer rooms overhead and beneath the floor to provide orderly paths to house and support the cabling. These types of installations need a high degree of dependability which can be obtained using cable tray wiring systems.

CABLE TRAY SPACE SAVINGS

When compared to a conduit wiring system, an equivalent cable tray wiring system installation requires substantially less space.

Increasing the size of a structure or a support system to handle a high space volume conduit wiring system is unnecessary when this problem can be avoided by the selection of a cable tray wiring system.

• Facilities with high density wiring systems devoted to control, instrumentation, data handling and branch circuit wiring have the choice of selecting cable tray or conduit wiring systems. A conduit wiring system is often a poor choice because large conduit banks require significant space, competing with other systems and equipment. Choosing a cable tray wiring system greatly reduces this problem.

• Financial institutions with large computer installations have high density wiring systems under floors or in overhead plenum areas that are best handled by cable tray wiring systems.

• Airport facilities have extensive cable tray wiring systems to handle the ever expanding needs of the airline industry.

• Cable tray is used in many facilities because of the ever present need of routing more and more cables in less space at lower costs.

• Large health care facilities have high density wiring systems that are ideal candidates for cable tray.

CABLE TRAY WIRING SYSTEM COST SAVINGS

Usually, the initial capital cost is the major factor in selecting a project's wiring system when an evaluation is made comparing cable tray wiring systems and conduit wiring systems. Such an evaluation often covers just the conductors, material, and installation labor costs. The results of these initial cost evaluations usually show that the installed cable tray wiring system will cost 10 to 60 percent less than an equivalent conduit wiring system. The amount of cost savings depends on the complexity and size of the installation.

There are other savings in addition to the initial installation cost savings for cable tray wiring systems over conduit wiring systems. They include reduced engineering costs, reduced maintenance costs, reduced expansion costs, reduced production losses due to power outages, reduced environmental problems due to continuity of power and reduced data handling system costs due to the continuity of power. The magnitudes of many of these costs savings are difficult to determine until the condition exists which makes them real instead of potential cost savings.

DESIGN COST SAVINGS

• Most projects are roughly defined at the start of design. For projects that are not 100 percent defined before design start, the cost of and time used in coping with continuous changes during the engineering and drafting design phases will be substantially less for cable tray wiring systems than for conduit wiring systems. A small amount of engineering is required to change the width of a cable tray to gain additional wiring space capacity. Change is a complex problem when conduit banks are involved.

• The final drawings for a cable tray wiring system may be completed and sent out for bid or construction more quickly than for a conduit wiring system. Cable tray simplifies the wiring system design process and reduces the number of details.

• Cable tray wiring systems are well suited for computer aided design drawings. A spread sheet based wiring management program may be used to control the cable fills in the cable tray. While such a system may also be used for controlling conduit fill, large numbers of individual conduits must be monitored. For an equal capacity wiring system, only a few cable tray runs would have to be monitored.

• Dedicated cable tray installation zones alert other engineering disciplines to avoid designs that will produce equipment and material installation conflicts in these areas. As more circuits are added, the cable tray installation zone will increase only a few inches; the space required for the additional conduits needed would be much greater.

• **The fact that a cable can easily enter and exit cable tray anywhere along its route**, allows for some unique opportunities that provide highly flexible designs.

• Fewer supports have to be designed and less coordination is required between the design disciplines for the cable tray supports compared to conduit supports.

• Excluding conductors, the cost of the cable trays, supports, and miscellaneous materials will provide a savings of up to 80% as compared to the cost of the conduits, supports, pull boxes, and miscellaneous materials. An 18 inch wide cable tray has an allowable fill area of 21 square inches. It would take 7 - 3 inch conduits to obtain this allowable fill area (7 x 2.95 square inches = 20.65 square inches).

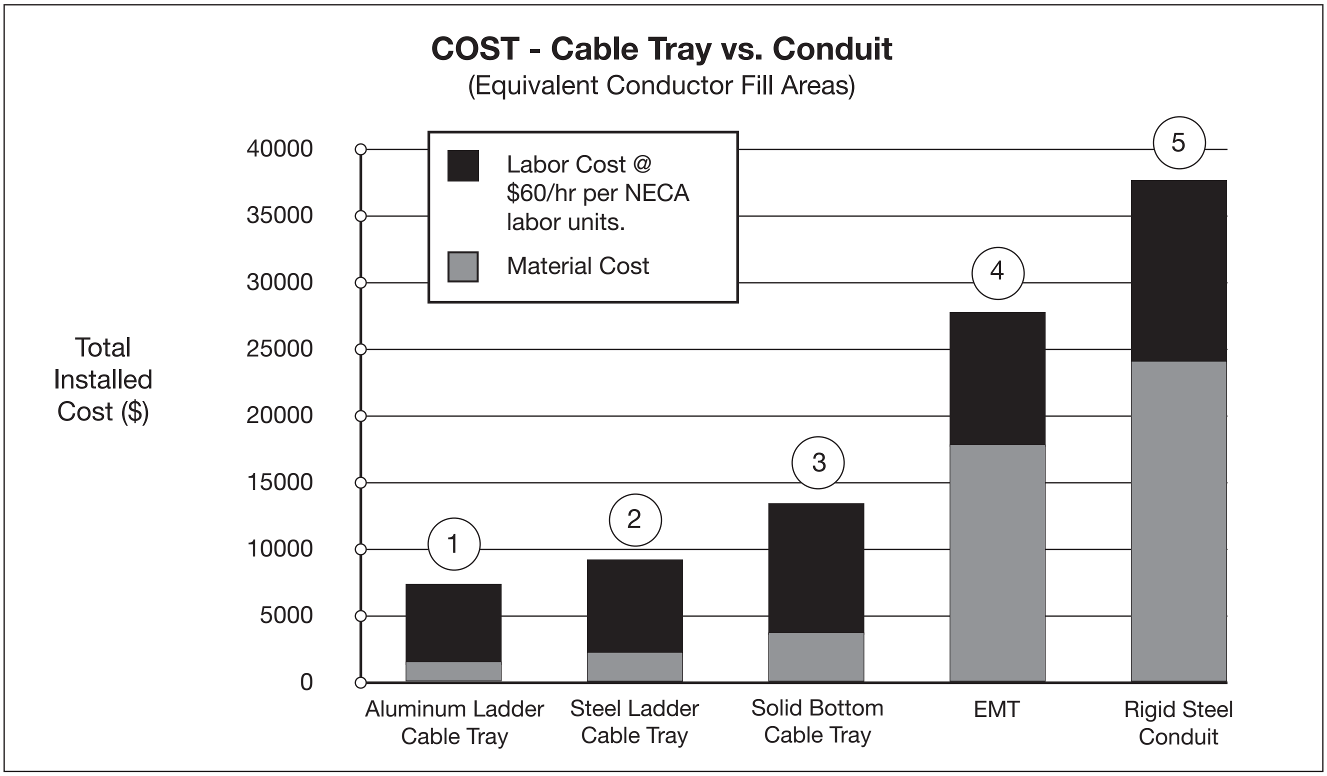
• The cost of 600 volt insulated multiconductor cables listed for use in cable tray is greater than the cost of 600 volt insulated individual conductors used in conduit. The cost differential depends on the insulation systems, jacket materials and cable construction.

• For some electrical loads, parallel conductors are installed in conduit and the conductors must be derated, requiring larger conductors to make up for the deration. If these circuits were installed in cable tray, the conductor sizes would not need to be increased since the parallel conductor derating factors do not apply to three conductor or single conductor cables in cable tray.

• Typical 300 volt insulated multiconductor instrumentation tray cables (ITC) and power limited tray cables (PLTC) cost the same for both cable tray and conduit wiring systems. This applies for instrumentation circuits, low level analog and digital signal circuits, logic input/output (I/O) circuits, etc. There are other cable tray installations which require a higher cost cable than the equivalent conduit installation. Such installations are limited to areas where low smoke emission and/or low flame spread ITC or PLTC cables must be used.

• Conduit banks often require more frequent and higher strength supports than cable trays. 3 inch and larger rigid metal conduits are the only sizes allowed to be supported on 20 foot spans.

• When a cable tray width is increased 6 inches, the cable tray cost increase is less than 10 percent. This substantially increases the cable tray's wiring capacity for a minimal additional cost. To obtain such an increase in capacity for a conduit wiring system would be very costly.



Installation: 200 linear feet of cable supported with four 90° direction changes and all trapeze supports on 8 ft. spans.

1. Aluminum, 18" wide, ladder cable tray (9" rung spacing) with all hardware.
2. Hot dip galvanized steel, 18" wide, ladder cable tray (9" rung spacing) with all hardware.
3. Hot dip galvanized steel, 18" wide, solid bottom cable tray and all hardware.
4. 7 parallel runs of 3" diameter EMT with concentric bends.
5. 7 parallel runs of 3" diameter galvanized conduit with concentric bends.

Note: Above costs do not include cable and cable pulling costs. Cable costs differ per installation and cable/conductor pulling costs have been shown to be considerably less for cable tray than for conduit.

INSTALLATION COST AND TIME SAVINGS

• Depending on the complexity and magnitude of the wiring system, the total cost savings for the initial installation (labor, equipment and material) may be up to 75 percent for a cable tray wiring system over a conduit wiring system. When there are banks of conduit to be installed that are more than 100 feet long and consist of four or more 2 inch conduits or 12 or more smaller conduits, the labor cost savings obtained using cable tray wiring systems are very significant.

• Many more individual components are involved in the installation of a conduit system and its conductors compared to the installation of a cable tray system and its cables. This results in the handling and installing of large amounts of conduit items vs. small amounts of cable tray items for the same wiring capacity.

• The higher the elevation of the wiring system, the more important the number of components required to complete the installation. Many additional man-hours will be required just moving the components needed for the conduit system up to the work location.

• Conduit wiring systems require pull boxes or splice boxes when there is the equivalent of more than 360 degrees of bends in a run. For large conductors, pull or junction boxes may be required more often to facilitate the conductor's installation. Cable tray wiring systems do not require pull boxes or splice boxes.

• Penetrating a masonry wall with cable tray requires a smaller hole and limited repair work.

• More supports are normally required for rigid steel conduit due to the requirements of **NEC**® Table 344.30(B)(2).

• Concentric conduit bends for direction changes in conduit banks are very labor intensive and difficult to make. However if they are not used, the installation will be unattractive. The time required to make a concentric bend is increased by a factor of 3-6 over that of a single shot bend. This time consuming practice is eliminated when cable tray wiring systems are used.

• Conductor pulling is more complicated and time consuming for conduit wiring systems than for cable tray wiring systems. Normally, single conductor wire pulls for conduit wiring systems require multiple reel setups. For conduit wiring systems, it is necessary to pull from termination equipment enclosure to termination equipment enclosure. Tray cables being installed in cable trays do not have to be pulled into the termination equipment enclosures. Tray cable may be pulled from near the first termination enclosure along the cable tray route to near the second termination enclosure. Then, the tray cable is inserted into the equipment enclosures for termination. For projects with significant numbers of large conductors terminating in switchgear, this may be a very desirable feature that can save hours of an electrician's time. Unnecessary power outages can be eliminated since tray cable pulls may be made without de-energizing the equipment. For conduit installations, the equipment will have to be de-energized for rubber safety blanketing to be installed, otherwise the conductor pulls might have to be made on a weekend or on a holiday at premium labor costs to avoid shutting down production or data processing operations during normal working hours.

• Conductor insulation damage is common in conduits since jamming can occur when pulling the conductors. Jamming is the wedging of conductors in a conduit when three conductors lay side by side in a flat plane. This may occur when pulling around bends or when the conductors twist. Ninety-two percent of all conductor failures are the result of the conductor's insulation being damaged during the conductor's installation. Many common combinations of conductors and conduits fall into critical jam ratio values. Critical jam ratio (J.R.= Conduit ID/Conductor OD) values range from 2.8 to 3.2. The J. R. for 3 single conductor THHN/THWN insulated 350 kcmil conductors in a 2$^1/_2$ inch conduit would be 3.0 (2.469 inches/ 0.816 inches). If conductor insulation damage occurs, additional costs and time are required for replacing the conductors. This cannot occur in a cable tray wiring system.

• Smaller electrician crews may be used to install the equivalent wiring capacity in cable tray. This allows for manpower leveling, the peak and average crew would be almost the same number, and the electrician experience level required is lower for cable tray installations.

• Since the work is completed faster there is less work space conflict with the other construction disciplines. This is especially true if installations are elevated and if significant amounts of piping are being installed on the project.

MAINTENANCE SAVINGS

• One of the most important features of cable tray is that tray cable can easily be installed in existing trays if there is space available. Cable tray wiring systems allow wiring additions or modifications to be made quickly with minimum disruption to operations. Any conceivable change that is required in a wiring system can be done at lower cost and in less time for a cable tray wiring system than for a conduit wiring system.

• Moisture is a major cause of electrical equipment and material failures. Breathing due to temperature cycling results in the conduits accumulating relatively large amounts of moisture. The conduits then pipe this moisture into the electrical equipment enclosures which over a period of time results in the deterioration of the equipment insulation systems and their eventual failure. Also, moisture may become a factor in the corrosion failure of some of the critical electrical equipment's metallic components. Conduit seals are not effective in blocking the movement of moisture. The conduit systems may be designed to reduce the moisture problems but not to completely eliminate it. Few designers go into the design detail necessary to reduce the effects of moisture in the conduit systems. Tray cables do not provide internal moisture paths as do conduits.

• In the event of external fires in industrial installations, the damage to the tray cable and cable tray is most often limited to the area of the flame contact plus a few feet on either side of the flame contact area. For such a fire enveloping a steel conduit bank, the steel conduit is a heat sink and the conductor insulation will be damaged for a considerable distance inside the conduit. Thermoplastic insulation may be fused to the steel conduit and the conduit will need to be replaced for many feet. This occurred in an Ohio chemical plant and the rigid steel conduits had to be replaced for 90 feet. Under such conditions, the repair cost for fire damage would normally be greater for a conduit wiring system than for cable tray and tray cable. In the Ohio chemical plant fire, there were banks of conduits and runs of cable tray involved. The cable tray wiring systems were repaired in two days. The conduit wiring systems were repaired in six days and required a great deal more manpower.

• In the event of an external fire, the conduit becomes a heat sink and an oven which decreases the time required for the conductor insulation systems to fail. The heat decomposes the cable jackets and the conductor insulation material. If these materials contain PVC as do most cables, hydrogen chloride vapors will come out the ends of the conduits in the control rooms. These fumes are very corrosive to the electronic equipment. They are also hazardous to personnel. A flame impingement on a cable tray system will not result in the fumes going into the control room as there is no containment path for them. They will be dispersed into the atmosphere.

IN MOST CASES AN OBJECTIVE EVALUATION OF THE REQUIREMENTS FOR MOST HIGH DENSITY WIRING SYSTEMS WILL SHOW THAT A CABLE TRAY WIRING SYSTEM PROVIDES A WIRING SYSTEM SUPERIOR TO A CONDUIT WIRING SYSTEM.

Abandoned Cables

Easily identified, marked, or removed - all possible from an open Cable Tray System

For the 2002 *National Electrical Code*, several proposals were submitted to the NFPA to revise the 1999 **NEC**® for Articles 300, 640, 645, 725, 760, 770, 800, 820, and 830 to require all abandoned cables to be removed from plenum spaces.

The purpose of the proposals is to remove the cables as a source of excess combustibles from plenums and other confined spaces such as raised floors and drop ceilings. All of the Code Making Panels agreed that this should be acceptable practice except Code Making Panel 3, which oversees Article 300.

Because Article 300 is exempt from this requirement only low-voltage and communication cables are affected.

Each Article adopted a definition of abandoned cables and the rule for removal. The general consensus is that abandoned cable is cable that is not terminated at equipment or connectors and is not identified for future use with a tag. Please refer to each individual **NEC**® Article for specifics.

Having to tag, remove, or rearrange cables within an enclosed raceway can be a time consuming and difficult job. Without being able to clearly see the cables and follow their exact routing throughout a facility, identifying abandoned cables would be very difficult and expensive.

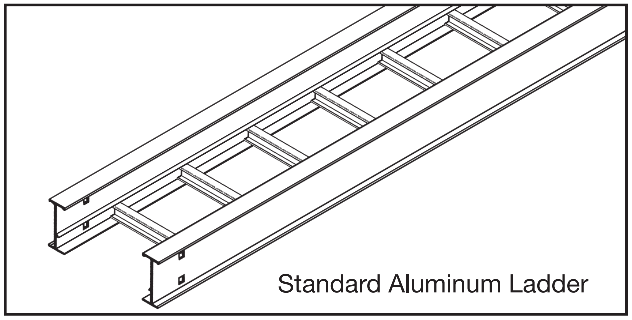
With the open accessibility of cable tray, these changes can be implemented with ease. Abandoned cables can be identified, marked, rearranged, or removed with little or no difficulty.

AN IN-DEPTH LOOK AT 2011 *NEC*®
ARTICLE 392 - CABLE TRAY

(The following code explanations are to be used with a copy of the 2011 NEC®.)

To obtain a copy of the **NEC**® contact:
National Fire Protection Association®
1 Batterymarch Park • P.O. Box 9101
Quincy, Massachusetts 02269-9101
1-800-344-3555

392.1. Scope.



Standard Aluminum Ladder

Of the types of cable trays listed in this section, ladder cable tray is the most widely used type of cable tray due to several very desirable features.

- The rungs provide a convenient anchor for tying down cables in vertical runs or where the positions of the cables must be maintained in horizontal runs.
- Cables may exit or enter through the top or the bottom of the tray.
- A ladder cable tray without covers provides for the maximum free flow of air, dissipating heat produced in current carrying conductors.
- Moisture cannot accumulate in ladder cable trays and be piped into electrical equipment as happens in conduit systems.
- Ladder cable tray cannot pipe hazardous or explosive gasses from one area to another as happens with conduit systems.
- In areas where there is the potential for dust to accumulate, ladder cable trays should be installed. The dust buildup in ladder cable trays will be less than the dust buildup in ventilated trough or solid bottom cable trays.

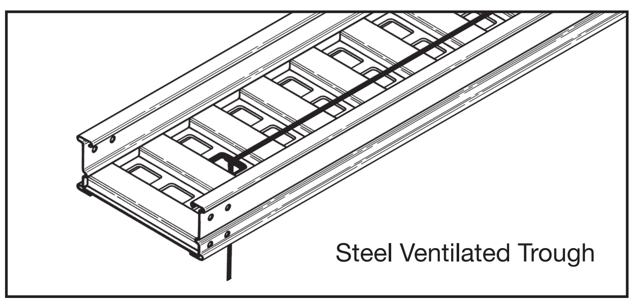
Ladder cable trays are available in widths of 6, 9, 12, 18, 24, 30, 36, and 42 inches with rung spacings of 6, 9, 12, or 18 inches. Wider rung spacings and wider cable tray widths decrease the overall strength of the cable tray. Specifiers should be aware that some cable tray manufacturers do not account for this load reduction in their published cable tray load charts. Cooper B-Line uses stronger rungs in wider cable trays to safely bear the loads published.

With one exception, the specifier selects the rung spacing that he or she feels is the most desirable for the installation. The exception is that 9 inches is the maximum allowable rung spacing for a ladder cable tray supporting any 1/0 through 4/0 single conductor cables [See Section 392.10(B)(1)(a)].

Where the ladder cable tray supports small diameter multiconductor control and instrumentation cables; 6, 9, or 12 inch rung spacings should be specified. Quality Type TC, Type PLTC, or Type ITC small diameter multiconductor control and instrumentation cables will not be damaged due to the cable tray rung spacing selected, but the installation may not appear neat if there is significant drooping of the cables between the rungs.

For ladder cable trays supporting large power cables, 9 inch or wider rung spacings should be selected. For many installations, the cable trays are routed over the top of a motor control center (MCC) or switchgear enclosure. Cables exit out the bottom of the cable trays and into the top of the MCC or switchgear enclosure. For these installations, the cable manufacturer's recommended minimum bending radii for the specific cables must not be violated. If the rung spacing is too close, it may be necessary to remove some rungs in order to maintain the proper cable bending radii. This construction site modification can usually be avoided by selecting a cable tray with 12 or 18 inch rung spacing.

If you are still uncertain as to which rung spacing to specify, 9 inch rung spacing is the most common and is used on 80% of the ladder cable tray sold.

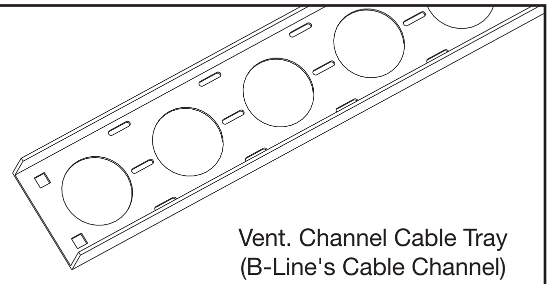


Steel Ventilated Trough

The 1999 **NEC**® added the word 'ventilated' in front of trough to clear up some confusion that solid trough is treated the same as ventilated trough. It is not. Solid trough is recognized as solid bottom cable tray.

Ventilated trough cable tray is often used when the specifier does not want to use ladder cable tray to support small diameter multiconductor control and instrumentation cables. As no drooping of the small diameter cables is visible, ventilated trough cable trays provide neat appearing installations. Small diameter cables may exit the ventilated trough cable tray through the bottom ventilation holes as well as out the top of the cable tray. For installations where the cables exit the bottom of the cable tray and the system is subject to some degree of vibration, it is advisable to use Cooper B-Line Trough Drop-Out Bushings (Cat. No. 99-1124). These snap-in bushings provide additional abrasion protection for the cable jackets. Just as for ladder cable tray, ventilated trough cable tray will not pipe moisture into electrical equipment.

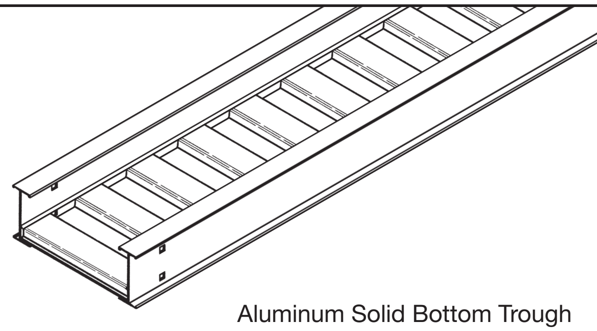
Standard widths for ventilated trough cable tray systems are 6, 9, 12, 18, 24, 30, and 36 inches. The standard bottom configuration for ventilated trough cable tray is a corrugated bottom with 2 7/8 inch bearing surfaces - 6 inches on centers and 2 1/4 inch x 4 inch ventilation openings. Since a corrugated bottom cannot be bent horizontally, the standard bottom configuration for horizontal bend fittings consists of rungs spaced on 4 inch centers. This difference in bottom construction may be objectionable to some owners, so be sure you are aware of the owner's sensitivity to aesthetics for the cable tray installation.



Vent. Channel Cable Tray
(B-Line's Cable Channel)

Channel cable tray systems (Cooper B-Line's cable channel) are available in 3, 4, and 6 inch widths with ventilated or solid bottoms. **The NEC® now recognizes solid bottom cable channel**. Prior to the 2002 Code, the **NEC®** did not have any specific provisions for the use of solid cable channel.

Instead of large conduits, cable channel may be used very effectively to support cable drops from the cable tray run to the equipment or device being serviced and is ideal for cable tray runs involving a small number of cables. Cable channel may also be used to support push buttons, field mounted instrumentation devices, etc. Small diameter cables may exit ventilated cable channel through the bottom ventilation holes, out the top or through the end. For installations where the cables exit through the ventilation openings and the cable channel or the cables are subject to some degree of vibration, it is advisable to use Cooper B-Line Cable Channel Bushings (Cat. No. 99-1125). These snap-in plastic bushings provide additional abrasion protection for the cable jackets.

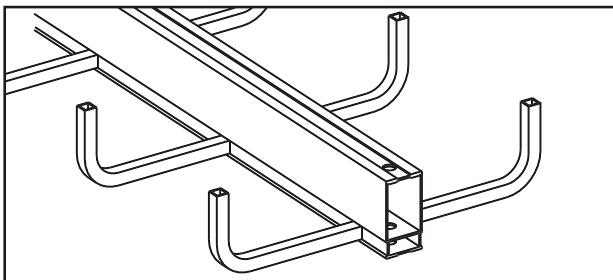


Aluminum Solid Bottom Trough

Some specifiers prefer solid bottom cable tray to support large numbers of small diameter control and multiconductor instrumentation cables. Solid bottom steel cable trays with solid covers and wrap around cover clamps can be used to provide EMI/RFI shielding protection for sensitive circuits.

Unlike ladder and ventilated trough cable trays, solid bottom cable trays can collect and retain moisture. Where they are installed outdoors or indoors in humid locations and EMI/RFI shielding protection is not required, it is recommended that 1/4 inch weep holes be drilled in their bottoms at the sides and in the middle every 3 feet to limit water accumulation.

The words "and other similar structures." were incorporated in Section 392.1 for future types of cable tray that might be developed, such as center supported type cable tray. All the technical information developed by the 1973 **NEC®** Technical Subcommittee on Cable Tray for Article 318 - Cable Trays was based on cable trays with side rails and this technical information is still the basis for the 2011 **NEC®** Article 392 - Cable Trays.



Center Supported Cable Tray
(B-Line's Cent-R-Rail System)

The standard lengths for cable trays are 10, 12, 20 and 24 feet (consult Cooper B-Line for the availability of nonstandard cable tray lengths). Selecting a cable tray length is based on several criteria. Some of these criteria include the required load that the cable tray must support, the distance between the cable tray supports, and ease of handling and installation. **One industry standard that is strongly recommended is that only one cable tray splice be placed between support spans** and, for long span trays, that they ideally be place at 1/4-span. This automatically limits the length of tray you choose, as the tray must be longer than or equal to the support span you have selected. Matching the tray length to your support span can help ensure that your splice locations are controlled.

Cable trays can be organized into 4 categories: Short Span, Intermediate Span, Long Span, and Extra-Long Span.

Short Span trays, typically used for non-industrial indoor installations, are usually supported every 6 to 8 feet, while Intermediate Span trays are typically supported every 10 to 12 feet. A 10 or 12 foot cable tray is usually used for both of these types of installations. To keep from allowing two splices to occur between supports, a 12 foot tray should be used for any support span greater than 10 feet, up to 12 feet. Placing the cable tray splices at 1/4-span is not critical in a short or intermediate span application given that most trays have sufficiently strong splice plates.

In an indoor industrial installation 10 or 12 foot tray sections may be easier to handle and install as you may have piping or ducting to maneuver around. However, using 20 foot instead of 12 foot straight sections may provide labor savings during installation by reducing the number of splice joints. If this is done, the selected tray system should meet the loading requirements for the support span you are using. If you are interested in supporting 100 lbs/ft and you are buying 20 foot tray sections while supporting it every 12 feet, it isn't necessary to specify a NEMA 20C tray (100 lbs/ft on a 20 foot span). A NEMA 20A tray (50 lbs/ft on a 20 foot span) will support over 130 lbs/ft when supported on a 12 ft span with a safety factor of 1.5. Specifying a 20C tray is not an economical use of product. If you desire to use 20 foot sections of cable tray, it makes more sense to increase your support span up to 20 feet. This not only saves labor by decreasing the number of splices, but also by decreasing the number of supports that must be installed.

Long Span trays are typically supported anywhere from 14 to 20 foot intervals with 20 feet being the most popular. In long span situations, the placement of the splice locations at 1/4-span becomes much more important. Matching the tray length to your support span can help control your splice locations.

Extra-Long Span trays are supported on spans exceeding 20 feet. Some outdoor cable tray installations may have to span anywhere from 20 to 30 feet to cross roads or to reduce the number of expensive outdoor supports. The distance between supports affects the tray strength exponentially; therefore the strength of the cable tray system selected should be designed around the specific support span chosen for that run.

[See Section 392.100(A) on page 431 for additional information on cable tray strength and rigidity.]

Cooper B-Line has many cataloged fittings and accessory items for ladder, ventilated trough, ventilated channel, and solid bottom cable trays which eliminate the need for the costly field fabrication of such items. When properly selected and installed, these factory fabricated fittings and accessories improve the appearance of the cable tray system in addition to reducing labor costs.

Cable Tray Materials

Metallic cable trays are readily available in aluminum, pregalvanized steel, hot-dip galvanized after fabrication, and stainless steel. Aluminum cable tray should be used for most installations unless specific corrosion problems prohibit its use. Aluminum's light weight significantly reduces the cost of installation when compared to steel.

A fine print note is included in the 2005 **NEC**® that references the National Electrical Manufacturers Association (NEMA) documents for further information on cable tray. These documents: ANSI/NEMA VE-1, Metal Cable Tray Systems; NEMA VE-2, Cable Tray Installation Guidelines; and NEMA FG-1, Non Metallic Cable Tray Systems, are an excellent industry resource in the application, selection, and installation of cable trays both metallic and non metallic. Contact Cooper B-Line for more information concerning these helpful documents.

392.2. Definition. Cable Tray System.

This section states that cable tray is a rigid structural support system used to securely fasten or support cables and raceways. Cable trays are not raceways. Cable trays are mechanical supports just as strut systems are mechanical supports. **NEC**® Article 392 - Cable Trays is an article dedicated to a type of mechanical support. <u>It is very important that the personnel involved with engineering and installing cable tray utilize it as a mechanical support system and not attempt to utilize it as a raceway system</u>. There are items in the **NEC**® that apply to raceways and not to cable tray. There are also items in the **NEC**® that apply to cable tray and not to raceways. These differences will be covered at the appropriate locations in this manual.

392.10. Uses Permitted. Cable tray installations shall not be limited to industrial establishments.

The text in Section 392.10 clearly states that cable tray may be used in non-industrial establishments. The use of cable tray should be based on sound engineering and economic decisions.

For clarity, the **NEC**® now lists all types of circuits to explicitly permit their use in cable trays. These circuit types include: services, feeders, branch circuits, communication circuits, control circuits, and signaling circuits.

The 2002 **NEC**® also added a new requirement that where cables in tray are exposed to the direct rays of the sun, they shall be identified as sunlight resistant for all occupancies, not just industrial.

392.10. Uses Permitted. (A) Wiring Methods.

This section identifies the 300 & 600 volt multi-conductor cables that may be supported by cable tray. The "Uses Permitted" or "Uses Not Permitted" sections in the appropriate **NEC**® cable articles provide the details as to where that cable type may be used. Where the cable type may be used, cable tray may be installed to support it except as per Section 392.12 which states that cable trays shall not be installed in hoistways or where subject to severe physical damage. Where not subject to severe physical damage, <u>cable tray may be used in any hazardous (classified) area to support the appropriate cable types in accordance with the installation requirements of the various Articles that make up **NEC**® Chapter 5 or in any non-hazardous (unclassified) area.</u>

It should be noted that Section 300.8 of the NEC® states that cable trays containing electric conductors cannot contain any other service that is not electrical. This includes any pipe or tube containing steam, water, air, gas or drainage.

For commercial and industrial cable tray wiring systems: Type ITC, Type MC, Type TC, and Type PLTC multiconductor cables are the most commonly used cables. Type MI and Optical-Fiber cables are special application cables that are desirable cables for use in some cable tray wiring systems. The following paragraphs provide information and comments about these cable types.

Type MI Cable: *Mineral-Insulated, Metal Sheathed Cable (Article 332)*. This cable has a liquid and gas tight continuous copper sheath over its copper conductors and magnesium oxide insulation. Developed in the late 1920's by the French Navy for submarine electrical wiring systems, properly installed MI cable is the safest electrical wiring system available. In Europe, Type MI cable has had a long, successful history of being installed (with PVC jackets for corrosion protection) in cable trays as industrial wiring systems. This cable may be installed in hazardous (classified) areas or in non-hazardous (unclassified) areas. The single limitation on the use of Type MI cable is that it may not be used where it is exposed to destructive corrosive conditions unless protected by materials suitable for the conditions. Type MI cable without overall nonmetallic coverings may be installed in ducts or plenums used for environmental air and in other space used for environmental air in accordance with Sections 300.22(B) and (C). Cable tray may be installed as a support for Type MI cable in any location except where the cable is installed in a hoistway. Section 332-30 states that MI cable shall be securely supported at intervals not exceeding 6 feet (1.83 m). Type MI cable has a UL two hour fire resistive rating when properly installed. An installation requirement for this rating is that the cable be securely supported every 3 feet. Steel or stainless steel cable trays should be used to support Type MI cable being used for critical circuit service. During severe fire conditions, steel or stainless steel cable tray will remain intact and provide support longer than aluminum or fiberglass reinforced plastic cable trays.

Type MC Cable: *Metal-clad cable (Article 330)*. There are large amounts of Type MC cable installed in industrial plant cable tray systems. This cable is often used for feeder and branch circuit service and provides excellent service when it is properly installed. The metallic sheath may be interlocking metal tape or it may be a smooth or corrugated metal tube. A nonmetallic jacket is often extruded over the aluminum or steel sheath as a corrosion protection measure. Regular MC cable, without nonmetallic sheath, may be supported by cable tray in any hazardous (classified) area except Class I and Class II, Division 1 areas. For Type MC cables to qualify for installation in Class I and Class II Division I areas (Section 501-4(A) (1) (c & d), they must have a gas/vapor tight continuous corrugated aluminum sheath with a suitable plastic jacket over the sheath. They must also contain equipment grounding conductors and listed termination fittings must be used where the cables enter equipment. Type MC Cable employing an impervious metal sheath without overall nonmetallic coverings may be installed in ducts or plenums used for environmental air in accordance with Section 300.22(B) and may be installed in other space used for environmental air in accordance with Section 300.22(C). The maximum support spacing is 6 feet (1.83 m).

Type TC Cable: *Power and control tray cable (Article 336)*. This cable type was added to the 1975 **NEC**® (as an item associated with the revision of Article 318-Cable Trays). Type TC cable is a multiconductor cable with a flame retardant nonmetallic sheath that is used for power, lighting, control, and signal circuits. It is the most common cable type installed in cable tray for 480 volt feeders, 480 volt branch circuits, and control circuits. Where Type TC cables comply with the crush and impact requirements of Type MC cable and is identified for such use, they are permitted as open wiring between a cable tray and the utilization equipment or device. In these instances where the cable exits the tray, the cable must be supported and secured at intervals not exceeding 6 feet (See Section 336.10(6)). The service record of UL listed Type TC cable where properly applied and installed has been excellent.

For those installations where the **NEC**® allows its use, a cost savings is realized by using Type TC cables instead of Type MC cables. Type TC cable may be installed in cable tray in hazardous (classified) industrial plant areas as permitted in Articles 392, 501, 502, 504 and 505 provided the conditions of maintenance and supervision assure that only qualified persons will service the installation [See Section 336.10(3)].

Where a cable tray wiring system containing Type TC cables will be exposed to any significant amount of hot metal splatter from welding or the torch cutting of metal during construction or maintenance activities, temporary metal or plywood covers should be installed on the cable tray in the exposure areas to prevent cable jacket and conductor insulation damage. It is desirable to use only quality Type TC cables that will pass the IEEE 383 and UL Vertical Flame Tests (70,000 BTU/hr). Type TC cable assemblies may contain optical fiber members as per the UL 1277 standard.

Type ITC Cable: Instrumentation Tray Cable (Article 727). Although this was a new cable article in the 1996 **NEC®**, it is not a new type of cable. Thousands of miles of ITC cable have been installed in industrial situations since the early 1960's. This is a multiconductor cable that most often has a nonmetallic jacket. The No. 22 through No. 12 insulated conductors in the cables are 300 volt rated. A metallic shield or a metallized foil shield with a drain wire usually encloses the cable's conductors. These cables are used to transmit the low energy level signals associated with the industrial instrumentation and data handling systems. These are very critical circuits that impact on facility safety and on product quality. Type ITC cable must be supported and secured at intervals not exceeding 6 feet [See Section 727.4].

Type ITC Cable may be installed in cable trays in hazardous (classified) areas as permitted in Articles 392, 501, 502, 504 and 505. It states in Article 727 that Type ITC cables that comply with the crush and impact requirements of Type MC cable and are identified for such use, are permitted as open wiring in lengths not to exceed 50 ft. between a cable tray and the utilization equipment or device. Where a cable tray wiring system containing Type ITC cables will be exposed to any significant amount of hot metal splatter from welding or the torch cutting of metal during construction or maintenance activities, temporary metal or plywood covers should be installed on the cable tray to prevent cable jacket or conductor insulation damage. It is desirable to use only quality Type ITC cables that will pass the IEEE 383 and UL Vertical Flame Tests (70,000BTU/hr).

Type PLTC Cable: *Power-Limited Tray Cable (Sections 725-154(C), and 725-154(E))*. This is a multiconductor cable with a flame retardant nonmetallic sheath. The No. 22 through No. 12 insulated conductors in the cables are 300 volt rated. A metallic shield or a metallized foil shield with drain wire usually encloses the cable's conductors. This cable type has high usage in communication, data processing, fire protection, signaling, and industrial instrumentation wiring systems.

There are versions of this cable with insulation and jacket systems made of materials with low smoke emission and low flame spread properties which make them desirable for use in plenums. In Industrial Establishments where the conditions of maintenance and supervision ensure that only qualified persons service the installation and where the cable is not subject to physical damage Type PLTC cable may be installed in cable trays hazardous (classified) areas as permitted in Section 501.10(B)(1), 501.10(B)(4) and 504.20. Type PLTC cables that comply with the crush and impact requirements of Type MC cable and are identified for such use, are permitted as open wiring in lengths not to exceed a total of 50 ft. between a cable tray and the utilization equipment or device. In this situation, the cable needs to be supported and secured at intervals not exceeding 6 ft. Where a cable tray wiring system containing Type PLTC cables will be exposed to any significant amount of hot metal splatter from welding or the torch cutting of metal during construction or maintenance activities, temporary metal or plywood covers should be installed on the cable tray to prevent cable jacket and conductor insulation damage. It is desirable to use only quality Type PLTC cables that will pass the IEEE 383 and UL Vertical Flame Tests (70,000 BTU/hr). Type PLTC cable assemblies may contain optical fiber members as per the UL 1277 standard.

Optical Fiber Cables (Article 770). The addition of optical fiber cables in the Section 392.10(A) cable list for the 1996 NEC was not a technical change. Optical fiber cables have been allowed to be supported in cable trays as per Section 770.6. Optical fibers may also be present in Type TC cables as per UL Standard 1277.

For the 1999 **NEC®** code, Article 760 - Fire Alarm Cables and Articles 800 - Multipurpose and Communications Cables were added to the list of cables permitted to be installed in cable tray systems.

For the 1993 **NEC®**, the general statement in the 1990 **NEC®** which allowed all types of raceways to be supported by cable trays was replaced by individual statements for each of the ten specific raceway types that may now be supported by cable tray. The chances of any such installations being made are very low, since strut is a more convenient and economic choice than cable tray to support raceway systems.

392.10. Uses Permitted. (B) In Industrial Establishments.

This section limits the installation of single conductor cables and Type MV multiconductor cables in cable trays to qualifying industrial establishments as defined in this section.

Per the 2002 **NEC®** solid bottom cable trays are now permitted to support single conductor cables only in industrial establishments where conditions of maintenance and supervision ensure that only qualified persons will service the installed cable tray system. However, at this time, no fill rules for single conductor cables in solid bottom cable tray have been established. [see Section 392.10(B)]

392.10. Uses Permitted. (B) In Industrial Establishments. (1) Single Conductor.

Section 392.10(B)(1) covers 600 volt and Type MV single conductor cables.

There are several sections which cover the requirements for the use of single conductor cables in cable tray even though they only comprise a small percentage of cable tray wiring systems. Such installations are limited to qualifying industrial facilities [See Section 392.10(B)]. Many of the facility engineers prefer to use three conductor power cables. Normally, three conductor power cables provide more desirable electrical wiring systems than single conductor power cables in cable tray (See Section 392.20. Cable and conductor installation - three conductor vs. single conductor cables).

392.10(B)(1)(a)

Single conductor cable shall be No. 1/0 or larger and shall be of a type listed and marked on the surface for use in cable trays. Where Nos. 1/0 through 4/0 single conductor cables are used, the maximum allowable rung spacing for ladder cable tray is 9 inches.

392.10(B)(1)(b)

Welding cables shall comply with Article 630, Part IV which states that the cable tray must provide support at intervals not to exceed 6 inches. A permanent sign must be attached to the cable tray at intervals not to exceed 20 feet. The sign must read "CABLE TRAY FOR WELDING CABLES ONLY".

392.10(B)(1)(c)

This section states that single conductors used as equipment grounding conductors (EGCs) in cable trays shall be No. 4 or larger insulated, covered or bare.

The use of a single conductor in a cable tray as the EGC is an engineering design option. Section 300.3(B) states that all conductors of the same circuit and the EGC, if used, must be contained within the same cable tray.

The other options are to use multiconductor cables that each contain their own EGC or to use the cable tray itself as the EGC in qualifying installations [see Section 392.60(A)]

If an aluminum cable tray is installed in a moist environment where the moisture may contain materials that can serve as an electrolyte, a bare copper EGC should not be used. Under such conditions, electrolytic corrosion of the aluminum may occur. For such installations, it is desirable to use a low cost 600 volt insulated conductor and remove the insulation where connections to equipment or to equipment grounding conductors are made. (See Section 392.60. Grounding and Bonding, for additional information on single conductors used as the EGC for cable tray systems).

392.10. Uses Permitted. (B) In Industrial Establishment (2) Medium Voltage.

Single and multiconductor type MV cables must be sunlight resistant if exposed to direct sunlight. Single conductors shall be installed in accordance with 392.10(B)(1)

392.10. Uses Permitted. (C) Hazardous (Classified) Locations.

This section states that if cable tray wiring systems are installed in hazardous (classified) areas, the cables that they support must be suitable for installation in those hazardous (classified) areas. The cable carries the installation restriction. The installation restriction is not on the cable tray except that the cable tray installations must comply with Section 392.12. The following is an explanation of the parts of the code which affect the use of cable tray in hazardous locations.

501.10. *Wiring Methods - Listed Termination Fittings. (A) Class I, Division 1 (Gases or Vapors). 501.10(A)(1)(b)* Type MI cable may be installed in cable tray in this type of hazardous (classified) area.

501.10(A)(1)(c) allows Type MC-HL cables to be installed in Class I, Division I areas if they have a gas/vapor tight continuous corrugated aluminum sheath with a suitable plastic jacket over the sheath. They must also contain equipment grounding conductors sized as per Section 250.122 and listed termination fittings must be used where the cables enter equipment.

501.10(A)(1)(d) allows Type ITC-HL cable to be installed in Class I, Division I areas if they have a gas/vapor tight continuous corrugated aluminum sheath with a suitable plastic jacket over the sheath and provided with termination fittings listed for the application.

501.10. *Wiring Methods. (B) Class I, Division 2 (Gases or Vapors).* Types ITC, PLTC, MI, MC, MV, or TC cables may be installed in cable tray in this type of hazardous (classified) area. Under the conditions specified in Section 501.15(E), Cable seals are required in Class 1, Division 2 areas. Cable seals should be used only when absolutely necessary.

501.15. *Sealing and Drainage. (E) Cable Seals, Class 1, Division 2. (1)* Cables will be required to be sealed only where they enter certain types of enclosures used in Class 1, Division 2 areas. Factory sealed push buttons are an example of enclosures that do not require a cable seal at the entrance of the cable into the enclosure.

501.15. *Sealing and Drainage. (E) Cable Seals, Class 1, Division 2. (2)* Gas blocked cables are available from some cable manufacturers but they have not been widely used. For gas to pass through the jacketed multi-conductor cable's core, a pressure differential must be maintained from one end of the cable to the other end or to the point where there is a break in the cable's jacket. The existence of such a condition is extremely rare and would require that one end of the cable be in a pressure vessel or a pressurized enclosure and the other end be exposed to the atmosphere. The migration of any significant volume of gas or vapor though the core of a multiconductor cable is very remote. This is one of the safety advantages that cable tray wiring systems have over conduit wiring systems. There are documented cases of industrial explosions caused by the migration of gases and vapors through conduits when they came in contact with an ignition source. There are no known cases of cables in cable tray wiring systems providing a path for gases or vapors to an ignition source which produced an industrial explosion.

501.15. *Sealing and Drainage. (E) Cable Seals, Class 1, Division 2. (3)*

Exception: Cables with an unbroken gas/vapor-tight continuous sheath shall be permitted to pass through a Class 1, Division 2 location without seals.

This is an extremely important exception stating that cable seals are not required when a cable goes from an unclassified area through a classified area then back to an unclassified area.

501.15. *Sealing and Drainage. (E) Cable Seals, Class 1, Division 2. (4)*

If you do not have a gas/vapor-tight continuous sheath, cable seals are required at the boundary of the Division 2 and unclassified location.

The sheaths mentioned above may be fabricated of metal or a nonmetallic material.

502.10. *Wiring Methods. (A) Class II, Division 1 (Combustible Dusts).*

Type MI cable may be installed in cable tray in this type of hazardous (classified) area.

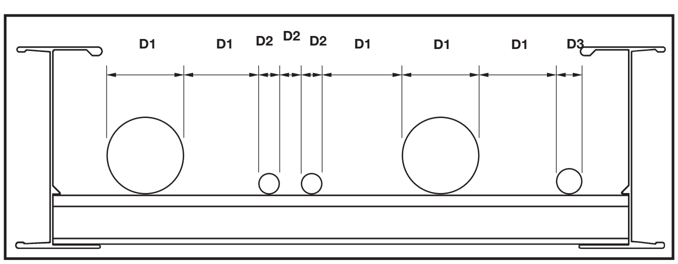
The Exception allows Type MC cables to be installed in Class II, Division 1 areas if they have a gas/vapor tight continuous corrugated aluminum sheath with a suitable plastic jacket over the sheath. They must also contain equipment grounding conductors sized as per Section 250.122 and listed termination fittings must be used where the cables enter equipment.

502.10. *Wiring Methods. (B) Class II, Division 2 (Combustible Dusts).*

This section states:

Type ITC and PLTC cables may be installed in ladder or ventilated cable trays following the same practices as used in non-hazardous (unclassified) areas. No spacing is required between the ITC or PLTC cables. This is logical as the ITC and PLTC cable circuits are all low energy circuits which do not produce any significant heat or heat dissipation problems.

Type MC, MI and TC [See Section 336.4(3)] cables may be installed in ladder, ventilated trough, or ventilated cable channel, but they are not allowed to be installed in solid bottom cable trays.



Required Spacing in Cable Trays for Type MC, MI & TC Cables in Class II, Division 2 Hazardous (Classified) Areas

Note 1. The cables are limited to a single layer with spacing between cables equal to the diameter of the largest adjacent cable. This means that the cables must be tied down at frequent intervals in horizontal as well as vertical cable trays to maintain the cable spacing. A reasonable distance between ties in the horizontal cable tray would be approximately 6 feet (See Section 392.30(B).

Note 2. Spacing the cables a minimum of 1 inch from the side rails to prevent dust buildup is recommended. This is not an NEC requirement but a recommended practice.

Where cable tray wiring systems with current carrying conductors are installed in a dust environment, ladder type cable trays should be used since there is less surface area for dust buildup than in ventilated trough cable trays. The spacing of the cables in dust areas will prevent the cables from being totally covered with a solid dust layer. In dusty areas, the top surfaces of all equipment, raceways, supports, or cable jacket surfaces where dust layers can accumulate will require cleanup housekeeping at certain time intervals. Good housekeeping is required for personnel health, personnel safety and facility safety. Excessive amounts of dust on raceways or cables will act as a thermal barrier which may not allow the power and lighting insulated conductors in a raceway or cable to safely dissipate internal heat. This condition may result in the accelerated aging of the conductor insulation. A cable tray system that is properly installed and maintained will provide a safe dependable wiring system in dust environments.

Exception: Type MC cable listed for use in Class II, Division I locations shall be permitted to be installed without the above spacing limitations. This was a new exception for the 1999 **NEC**® code.

For this type of wiring there is no danger of the cables being overheated when covered with dust. The current flow in these circuits is so low that the internally generated heat is insufficient to heat the cables and cable spacing is not a necessity. Even under such conditions, layers of dust should not be allowed to accumulate to critical depths as they may be ignited or explode as the result of problems caused by other than the electrical system.

502.10(B)(3). *Nonincendive Field Wiring*
Wiring in nonincendive circuits shall be permitted using any of the wiring methods suitable for wiring in ordinary locations.

503.10. *Wiring Methods. (A) Class III, Division 1 and (B) Class III, Division 2 (Ignitable Fibers or Flyings).* Type MI or MC cables may be installed in cable tray in these types of hazardous (classified) areas. The installations should be made using practices that minimize the build-up of materials in the trays. This can be done by using ladder cable tray with a minimum spacing between the cables equal to the diameter of the largest adjacent cable. In some cases, a greater spacing between cables than that based on the cable diameters might be desirable depending on the characteristics of the material that requires the area to be classified. Here again, it must be emphasized that good housekeeping practices are required for all types of wiring systems to insure the safety of the personnel and the facility.

504.20. *Wiring Methods.* This section allows intrinsically safe wiring systems to be installed in cable trays in hazardous (classified) areas. Section 504.30 specifies the installation requirements for intrinsically safe wiring systems that are installed in cable trays. Section 504.70 specifies the sealing requirements for cables that may be part of a cable tray wiring system. Section 504.80(B) states that cable trays containing intrinsically safe wiring must be identified with permanently affixed labels.

Cable trays are ideal for supporting both intrinsically safe and nonintrinsically safe cable systems as the cables may be easily spaced and tied in position or a standard metallic barrier strip may be installed between the intrinsically and nonintrinsically safe circuits.

505.15. *Wiring Methods.* This section was added to the 2002 **NEC**® to explicitly permit cable trays in hazardous areas classified by the international zone system, if the cables comply with the cable requirements for zone locations.

392.10. Uses Permitted. (D) Nonmetallic Cable Tray.

There are limited numbers of applications where nonmetallic cable trays might be preferred over metallic cable trays for electrical safety reasons and/or for some corrosive conditions. An example of an electrical safety application would be in an electrolytic cell room. Here, the amperages are very high and significant stray current paths are present. Under such conditions, there is the possibility for a high amperage short circuit if a low resistance metallic path (metallic cable tray or metallic raceway) is present [See information under Section 392.5(F) Nonmetallic Cable Trays].

392.12. Uses Not Permitted.

This is the only place in the **NEC**® where all the various types of cable tray have limitations on their place of use. No cable trays can be used in hoistways or where subject to severe physical damage. The designer must identify the zones of installation where a cable tray might be subjected to severe physical damage. Usually such areas are limited and provisions can be made to protect the cable tray by relocating it to a more desirable location or as a last resort to provide protection using the appropriate structural members.

Metallic cable trays may support cable types approved for installation in ducts, plenums, and other air-handling spaces as per Section 300.22(B) and the cable types approved for installation in Other Space Used for Environmental Air as per Section 300.22(C).

The second sentence of Section 300.22(C)(1) is as follows:

<u>Other types of cables and conductors shall be installed in</u> electrical metallic tubing, flexible metallic tubing, intermediate metal conduit, rigid metal conduit without an overall nonmetallic covering, flexible metal conduit, or, where accessible, surface metal raceway or metal wireway with metal covers or <u>solid bottom metal cable tray with solid metal covers</u>.

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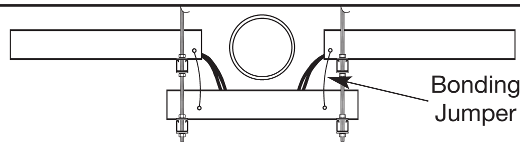
This part of Section 300.22(C) is confusing. The statement as underlined in the above paragraph leads some to assume, for installations in Other Spaces Used for Environmental Air, that the types of insulated single conductors which are installed in raceway installations may also be installed in solid bottom metal cable trays with metal covers. This is not so. Only the appropriate multiconductor cable types as per Section 392.10(A) may be installed in solid bottom cable trays.

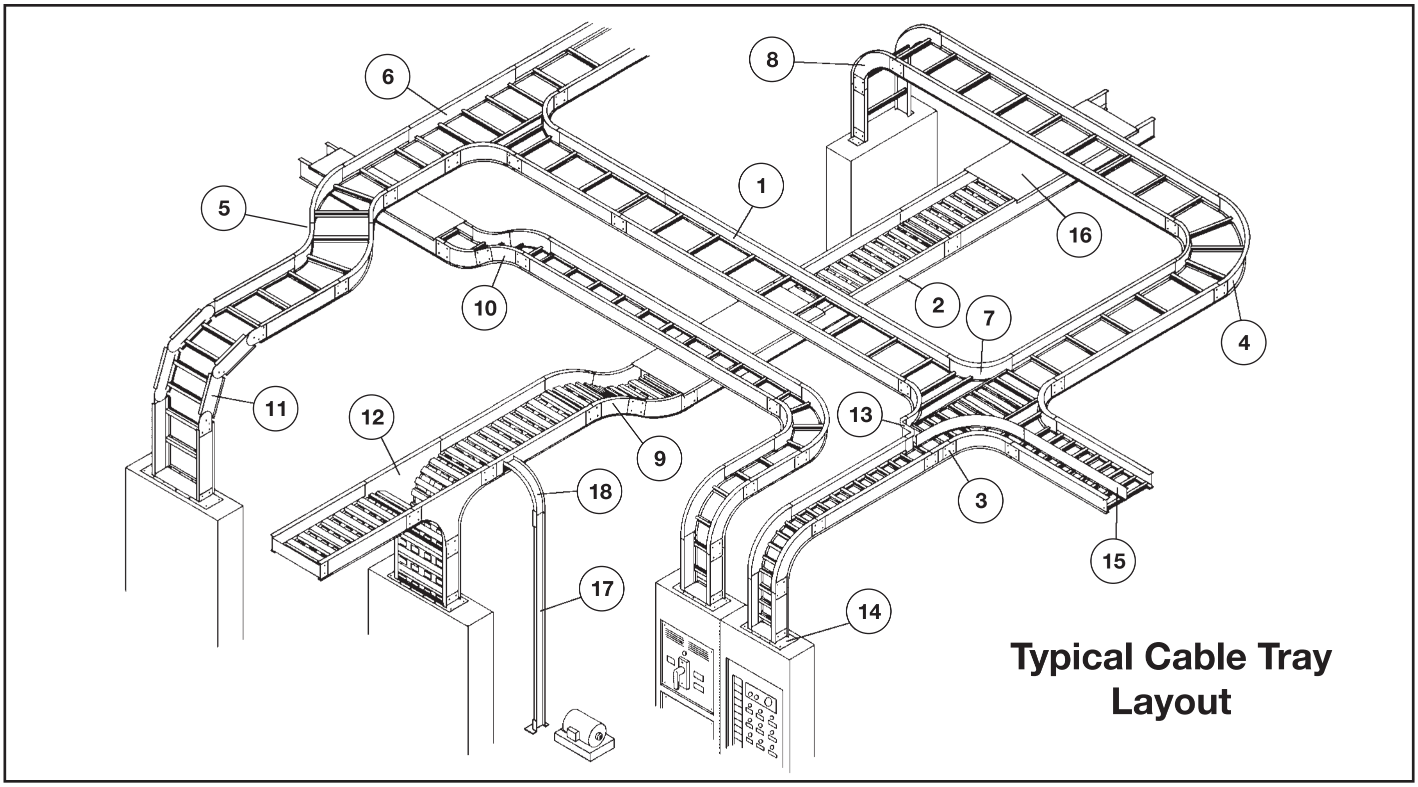
Cable tray may be used to support data process wiring systems in air handling areas below raised floors as per Sections 300.22(D) and 800.52(D).

392.18. Cable Tray Installation. (A) Complete System.

This section states that cable tray systems can have mechanically discontinuous segments, and that the mechanically discontinuous segment cannot be greater than 6 feet. A bonding jumper sized per Section 250.102 is necessary to connect across any discontinuous segment. The bonding of the system should be in compliance with Section 250.96.



Cable Tray Elevation Change Without Fittings

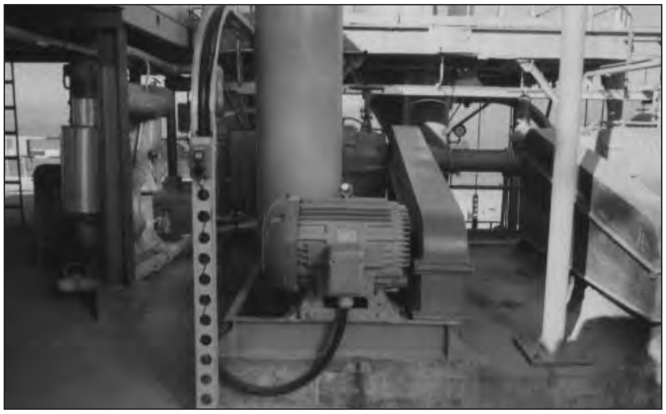


Nomenclature

1. Ladder Type Cable Tray
2. Ventilated Trough Type Cable Tray
3. Splice Plate
4. 90° Horizontal Bend, Ladder Type Tray
5. 45° Horizontal Bend, Ladder Type Tray
6. Horizontal Tee, Ladder Type Tray
7. Horizontal Cross, Ladder Type Tray
8. 90° Vertical Outside Bend, Ladder Type Tray
9. 45° Vertical Outside Bend, Ventilated Type Tray
10. 30° Vertical Inside Bend, Ladder Type Tray
11. Vertical Bend Segment (VBS)
12. Vertical Tee Down, Ventilated Trough Type Tray
13. Left Hand Reducer, Ladder Type Tray
14. Frame Type Box Connector
15. Barrier Strip Straight Section
16. Solid Flanged Tray Cover
17. Cable Channel Straight Section, Ventilated
18. Cable Channel, 90° Vertical Outside Bend

There are some designers, engineers, and inspectors that do not think that cable tray is a mechanical support system just as strut is a mechanical support system. Cable tray is not a raceway in the **NEC**® but some designers, engineers, and inspectors attempt to apply the requirements for raceway wiring systems to cable tray wiring systems even when they are not applicable. Cable tray wiring systems have been used by American industry for over 35 years with outstanding safety and continuity of service records. The safety service record of cable tray wiring systems in industrial facilities has been significantly better than those of conduit wiring systems. There have been industrial fires and explosions that have occurred as a direct result of the wiring system being a conduit wiring system. In these cases, cable tray wiring systems would not have provided the fires and explosions that the conduit systems did by providing as explosion gas flow path to the ignition source even though the conduit systems contained seals.

The most significant part of this section is that the metallic cable tray system must have electrical continuity over its entire length and that the support for the cables must be maintained. These requirements can be adequately met even though there will be installation conditions where the cable tray is mechanically discontinuous, such as at a firewall penetration, at an expansion gap in a long straight cable tray run, where there is a change in elevation of a few feet between two horizontal cable tray sections of the same run, or where the cables drop from an overhead cable tray to enter equipment. In all these cases, adequate bonding jumpers must be used to bridge the mechanical discontinuity.



Cable Entering Motor Terminal Box from 6 Inch Channel Cable Tray System (Bottom entries provide drip loops to prevent moisture flow into enclosures.)

Cables Exiting 480 Volt Outdoor Switchgear and Entering Cable Tray System (Cable fittings with clamping glands are required to prevent moisture flow into equipment due to the cable's overhead entry into the switchgear enclosure).

Cables Entering and Exiting Motor Control Centers from Cable Tray Systems.

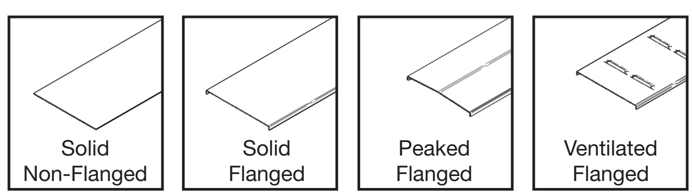
392.18. Cable Tray Installation. (B) Completed Before Installation.

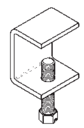
This means that the final cable tray system must be in place before the cables are installed. It does not mean that the cable tray must be 100% mechanically continuous. The electrical bonding of the metallic cable tray system must be complete before any of the circuits in the cable tray system are energized whether the cable tray system is being utilized as the equipment grounding conductor in qualifying installations or if the bonding is being done to satisfy the requirements of Section 250.96.

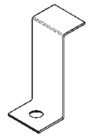
392.18. Cable Tray Installation. (C) Covers.

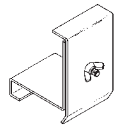
Cable tray covers provide protection for cables where cable trays are subject to mechanical damage. The most serious hazard to cable in cable trays is when the cables are exposed to significant amounts of hot metal spatter during construction or maintenance from torch cutting of metal and welding activities. For these exposure areas, the cable tray should be temporarily covered with plywood sheets. If such exposure is to be a frequent occurrence, cable tray covers should be installed in the potential exposure areas. Where cable trays contain power and lighting conductors, raised or ventilated covers are preferable to solid covers since the raised or ventilated covers allow the cable heat to be vented from the cable tray.

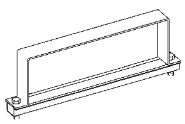
When covers are installed outdoors, they should be attached to the cable trays with heavy duty wrap around clamps instead of standard duty clips. During high winds, the light duty clips are not capable of restraining the covers. Outdoor cover installations should be overlapped at expansion joint locations to eliminate cover buckling. Covers which fly off the cable tray create a serious hazard to personnel, as was the case at a Texas gulf coast chemical plant where operators would not leave their control room because hurricane force winds had stripped many light gauge stainless steel covers off a large cable tray system. These sharp edged metal covers were flying though the air all during the high wind period, posing a serious threat to the worker's safety.

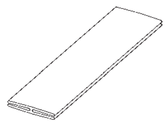



Standard Cover Clamp


Combination Cover & Hold Down Clamp


Raised Cover Clamp


Heavy Duty Cover Clamp

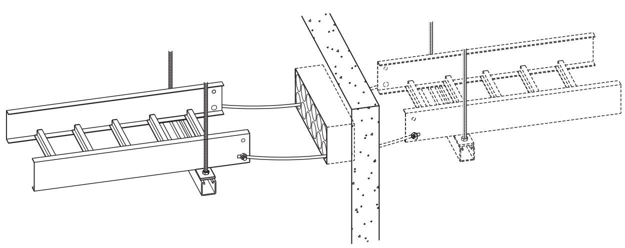

Cover Joint Strip

Aluminum Cable Tray Cover Accessories
Equivalent items are available for Steel Cable Trays.

392.18. Cable Tray Installation. (D) Through Partitions and Walls.

Whether penetrating fire rated walls with tray cable only or cable tray and tray cable, the designer should review with the local building inspector the method he proposes to use to maintain the fire rating integrity of the wall at the penetration. Many methods for sealing fire wall penetrations are available, including bag or pillow, caulk, cementitious, foam, putty and mechanical barrier systems.

Many designers prefer to run only the tray cable through fire rated walls. Sealing around the cables is easier than sealing around the cables and the cable tray. Also, should the cable tray or its supports become damaged, the tray will not exert forces which could damage the wall or the penetration.



392.18. Cable Tray Installation. (E) Exposed and Accessible.

Article 100 - Definitions.

Exposed: (as applied to wiring methods) on or attached to the surface or behind panels designed to allow access.

Accessible: (As applied to wiring methods) Capable of being removed or exposed without damaging the building structure or finish, or not permanently closed in by the structure or finish of the building.

392.18. Cable Tray Installation. (F) Adequate Access.

Cable tray wiring systems should be designed and installed with adequate room around the cable tray to allow for the set up of cable pulling equipment. Also, space around the cable tray provides easy access for installation of additional cables or the removal of surplus cables. Where cable trays are mounted one above the other, a good rule to follow is to allow 12 to 18 inches between the underside and the top of adjacent cable trays or between the structure's ceiling and the top of the cable tray.

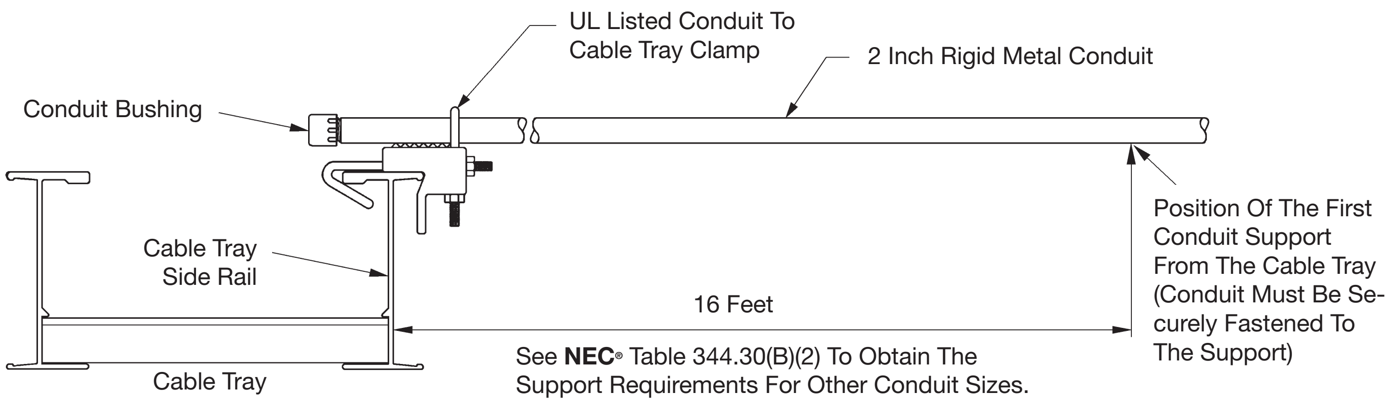
392.18. Cable Tray Installation. (G) Raceways, Cables, Boxes, and Conduit Bodies Supported from Cable Tray Systems.

For the 1996 **NEC®**, a significant change was made in this section. The installations covered in this section may now only be made in qualifying industrial facilities.
In Section 392.6(J) of the 1993 **NEC®**, cable tray installations that supplied support for conduits were not restricted to qualifying industrial facilities. The 1996 **NEC®**, Section 392.6(J) text restricts the use of such installations even though there is no documented history of problems in non-industrial installations.

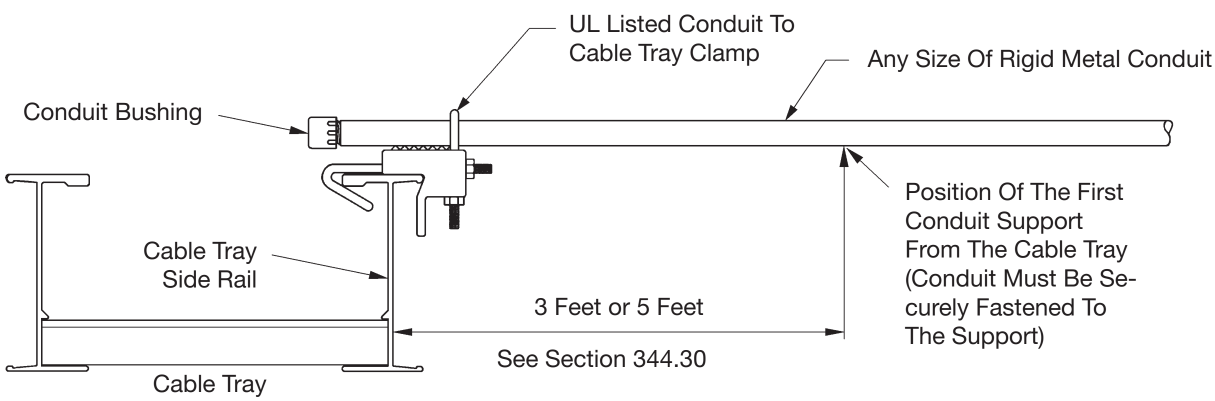
As a result of the change in this section, identical functional installations in non-qualifying installations (commercial and industrial) and qualifying industrial installations have different physical requirements. In a qualifying industrial installation, a conduit terminated on a cable tray may be supported from the cable tray. In a commercial or non-qualifying industrial installation, the conduit that is terminated on the cable tray must be securely fastened to a support that is within 3 feet of the cable tray or securely fastened to a support that is within 5 feet of the cable tray where structural members don't readily permit a secure fastening within 3 feet. The conduit of the non-qualifying installation still needs to be bonded to the cable tray. A fitting may be used for this bonding even though it will not count as a mechanical support.

Over 99 percent of the conduits supported on cable trays are the result of conduits being terminated on the cable tray side rails [See Section 392.46]. For over 40 years, it has been common practice to house the cables exiting the cable tray in conduits or cable channel where the distance from the cable tray system to the cable terminations requires the cable be supported. Several manufacturers supply UL approved cable tray to conduit clamps such as the Cooper B-Line 9ZN-1158.

In addition to conduit and cables being supported from cable tray; industrial companies have been mounting instrumentation devices, push buttons, etc. on cable tray and cable channel for over 40 years. This section once lead some to believe that only conduit or cables may be supported from cable trays which is not correct as cable tray is a mechanical support just as strut is a mechanical support. Because of this, the wording in Section 392.6(J) of the 2002 **NEC**® was changed. Instead of allowing only cable and conduit to be supported from cable tray, the code now states that **raceways, cables, boxes and conduit bodies** are now permitted to be supported from the cable tray. Where boxes or conduit bodies are attached to the bottom or side of the cable tray, they must be fastened and supported in accordance with Section 314.23.



Conduit Terminated On And Supported By The Cable Tray Side Rail.
Installation For Qualifying Industrial Facilities As Per 392.18(G).



Conduit Terminated On The Cable Tray Side Rail.
Installation For Commercial And Non-Qualifying Industrial Facilities As Per 392.18(G).

392.20. Cables and Conductor Installation. (A) Multiconductor Cables Rated 600 Volts or Less.

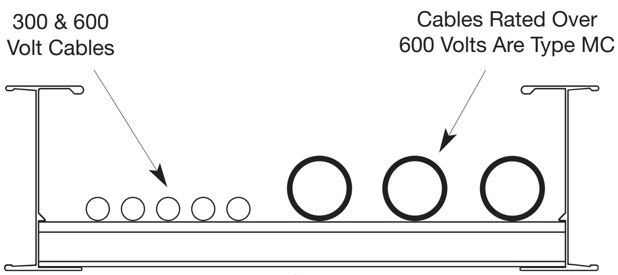
Cables containing 300 or 600 volt insulated conductors may be installed intermingled in the same cable tray which is different from the requirements for raceways. This is a reasonable arrangement because a person may safely touch a 300 or 600 volt cable which is in good condition, so having the cables come into contact with each other is not a problem either. Many cable tray users separate the instrumentation cables from the power and control cables by installing them in separate cable trays or by installing barriers in the cable trays. Often, because of the volume of the instrumentation cable, using separate cable trays is the most desirable installation practice.

Numerous cable tray systems have been installed where the instrumentation cables and branch circuit cables are installed in the same cable trays with and without barriers with excellent performance and reliability. Most problems that occur involving nstrumentation circuits are due to improper grounding practices. For analog and digital instrumentation circuits, good quality twisted pair Type ITC and Type PLTC cables with a cable shield and a shield drain wire should be used. Do not purchase this type of cable on price alone, it should be purchased because of it's high quality. Engineers specifying cables should be knowledgeable of the cable's technical details in order to design systems which will provide trouble free operation.

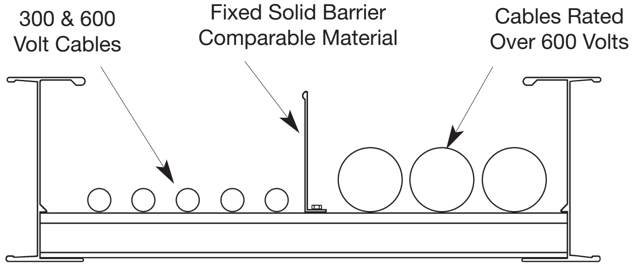
392.20. Cable and Conductor Installation. (B) Cables Rated Over 600 Volts.

Cables with insulation rated 600 volts or less may be installed with cables rated over 600 volts if either of the following provisions are met.

No. 1: *Where the cables over 600 volts are Type MC.*



NO. 1



NO. 2

No. 2: *Where separated with a fixed solid barrier of a material compatible with the cable tray.*

392.20. Cable and Conductor Installation. (C) Connected in Parallel.

Section 310.10(H)(2). Conductors in Parallel.
States the following:

The paralleled conductors in each phase, neutral or grounded conductor shall:

(1) Be the same length.
(2) Have the same conductor material.
(3) Be the same size in circular mil area.
(4) Have the same insulation type.
(5) Be terminated in the same manner.

Where run in separate raceways or cables, the raceways or cables shall have the same physical characteristics. Conductors of one phase, neutral, or grounded circuit shall not be required to have the same physical characteristics as those of another phase, neutral, or grounded circuit conductor to achieve balance.

A difference between parallel conductors in raceways and those in cable trays is that the conductors in the cable tray are not derated unless there are more than three current carrying conductors in a cable assembly **[as per Exception No.2 of Section 310.15(B)(3)(a) and Section 392.80(A)(1)(a)].** Where the single conductor cables are bundled together as per Section 392.20(C) and if there are neutrals that are carrying currents due to the type of load involved (harmonic currents) it may be prudent to derate the bundled single conductor cables.

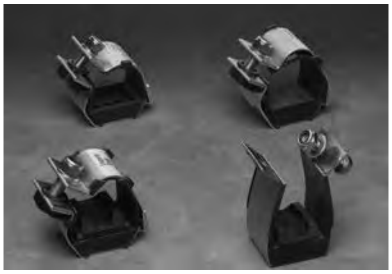
The high amperages flowing under fault conditions in 1/0 and larger cables produce strong magnetic fields which result in the conductors repelling each other until the circuit protective device either de-energizes the circuit or the circuit explodes. Under such fault conditions, the cables thrash violently and might even be forced out of the cable tray. This happened at a northern Florida textile plant where several hundred feet of Type MV single conductor cable was forced out of a cable tray run by an electrical fault because the cables were not restrained properly. This potential safety threat is precisely why Article 392.20(C) requires single conductor cables be securely bound in circuit groups to prevent excessive movement due to fault-current magnetic forces. For a three-phase trefoil or triangular arrangement (the most common single conductor application), these forces can be calculated according to the formula:

$$F_t = (0.17 \times i_p^2) / S.$$

F_t=Maximum Force on Conductor (Newtons/meter)

i_p=Peak Short Circuit Current (kilo-Amperes)

S=Spacing between Conductors (meters) = Cable Outside Diameter for Triplex (trefoil) Installations.



One technique to prevent excessive movement of cables is to employ fault-rated cable cleats.

To maintain the minimum distance between conductors, the single conductor cables should be securely bound in circuit groups using fault rated cable cleats. If the cleat spacing is properly chosen according to the available fault-current, the resulting cable grouping will inherently maintain a minimum distance between conductors. These circuit groups provide the lowest possible circuit reactance which is a factor in determining the current balance amoung various circuit groups.

For installations that involve phase conductors of three conductor or single conductor cables installed in parallel, cable tray installations have conductor cost savings advantages over conduit wiring systems. This is because the conductors required for a cable tray wiring system are often a smaller size than those required for a conduit wiring system for the same circuit. No paralleled conductor ampacity adjustment is required for single conductor or three conductor cables in cable trays [See **NEC**® Section 392.80(A)(1)].

There were changes in the 1993 **NEC**® and 1996 **NEC**® for installations where an equipment grounding conductor is included in a multiconductor cable: the equipment grounding conductor must be fully rated per Section 250.122. If multiconductor cables with internal equipment grounding conductors are paralleled, each multiconductor cable must have a fully rated equipment grounding conductor.

Section 250.122 now prohibits the use of standard three conductor cables with standard size EGCs when they are installed in parallel and the EGCs are paralleled. There have been no safety or technical problems due to operating standard three conductor cables with standard sized EGCs in parallel. This has been a standard industrial practice for over 40 years with large numbers of such installations in service. This change was made without any safety or technical facts to justify this change.

To comply with Section 250.122, Three options are available: 1. Order special cables with increased sized EGCs which increases the cost and the delivery time. 2. Use three conductor cables without EGCs and install a single conductor EGC in the cable tray or use the cable tray as the EGC in qualifying installations. 3. Use standard cables but don't utilize their EGCs, use a single conductor EGC or the cable tray as the EGC in qualifying installations.

Should industry be required to have special cables fabricated for such installations when there have been absolutely no safety problems for over 40 years? Each designer and engineer must make his own decision on this subject. If the installations are properly designed, quality materials are used, and quality workmanship is obtained, there is no safety reason for not following the past proven practice of paralleling the EGCs of standard three conductor cable.

392.20. Cable and Conductor Installation. (D) Single Conductors.

This section states that single conductors in ladder or ventilated trough cable tray that are Nos. 1/0 through 4/0, must be installed in a single layer.

In addition to the fill information that is in Section 392.20(D), an exception was added which allows the cables in a circuit group to be bound together rather than have the cables installed in a flat layer. The installation practice in the exception is desirable to help balance the reactance's in the circuit group. This reduces the magnitudes of voltage unbalance in three phase circuits.

Where ladder or ventilated trough cable trays contain multiconductor power or lighting cables, or any mixture of multiconductor power, lighting, control, or signal cables, the maximum number of cables that can be installed in a cable tray are limited to the Table 392.22(A) allowable fill areas. The cable tray fill areas are related to the cable ampacities. Overfill of the cable tray with the conductors operating at their maximum ampacities will result in cable heat dissipation problems with the possibility of conductor insulation and jacket damage.

Compatibility Of Cable Tray Types And Cable Trays Based On The *NEC*®

	Ladder Cable Tray	Ventilated Trough Cable Tray	Solid Bottom Cable Tray	3", 4", & 6" Wide Solid or Ventilated Channel Cable Tray
Multiconductor Cables 300 & 600 Volt *	X	X	X	X
Single Conductor Cables - 600 Volt *	*** X	X	X	X
Type MV Multiconductor Cables **	X	X		X
Type MV Single Conductor Cables **	X	X		X

X - Indicates the Installations Allowed by Article 392

* - For cables rated up to 2000 volts.

** - For cables rated above 2000 volts.

*** - For 1/0 - 4/0 AWG single conductor cables installed in ladder cable tray, maximum rung spacing is 9 inches.

392.22. Number of Conductor of Cables. (A) Number of Multiconductor Cables, Rated 2000 Volts or Less, in Cable Trays. (1) Ladder or Ventilated Trough Cable Trays Containing Any Mixture of Cables. (a) 4/0 or Larger Cables

The ladder or ventilated trough cable tray must have an inside usable width equal to or greater than the sum of the diameters (Sd) of the cables to be installed in it. For an example of the procedure to use in selecting a cable tray width for the type of cable covered in this section see page 441 (Appendix Sheet 3), [Example 392.22(A)(1)(a)].

Increasing the cable tray side rail depth increases the strength of the cable tray but the greater side rail depth does not permit an increase in cable fill area for power or lighting cables or combinations of power, lighting, control and signal cables. The maximum allowable fill area for all cable tray with a 3 inch or greater loading depth side rail is limited to the 38.9 percent fill area for a 3 inch loading depth side rail (Example: 3 inches x 6 inches inside cable tray width x 0.389 = 7.0 square inch fill area. This is the first value in Column 1 of Table 392.22(A). All succeeding values for larger cable tray widths are identically calculated).

392.22. Number of Conductor of Cables. (A) Number of Multiconductor Cables, Rated 2000 Volts or Less, in Cable Trays. (1) Ladder or Ventilated Trough Cable Trays Containing Any Mixture of Cables. (b) Cables Smaller Than 4/0

The allowable fill areas for the different ladder or ventilated trough cable tray widths are indicated in square inches in Column 1 of Table 392.22(A). The total sum of the cross-sectional areas of all the cables to be installed in the cable tray must be equal to or less than the cable tray allowable fill area. For an example of the procedure to use in selecting a cable tray width for the type of cable covered in this section see page 442 (Appendix Sheet 4), [Example 392.22(A)(1)(b)].

392.22. Number of Conductor of Cables. (A) Number of Multiconductor Cables, Rated 2000 Volts or Less, in Cable Trays. (1) Ladder or Ventilated Trough Cable Trays Containing Any Mixture of Cables. (c) 4/0 of Larger Cables Installed With Cables Smaller Than 4/0

The ladder or ventilated trough cable tray needs to be divided into two zones (a barrier or divider is not required but one can be used if desired) so that the No. 4/0 and larger cables have a dedicated zone as they are to be placed in a single layer.

The formula for this type of installation is shown in Column 2 of Table 392.22(A). This formula is a trial and error method of selecting a cable tray of the proper width. A direct method for determining the cable tray width is available by figuring the cable tray widths that are required for each of the cable combinations and then adding these widths together to select the proper cable tray width. [Sd (sum of the diameters of the No. 4/0 and larger cables)] + [Sum of Total Cross Sectional Area of all Cables No. 3/0 and Smaller) x (6 inches/7 square inches)] = The Minimum Width of Cable Tray Required. For an example of the procedure to use in selecting a cable tray width for the type of cable covered in this section, see page 443, (Appendix Sheet 5), [EXAMPLE 392.22(A)(1)(c)].

392.22. Number of Conductor of Cables. (A) Number of Multiconductor Cables, Rated 2000 Volts or Less, in Cable Trays. (2) Ladder or Ventilated Trough Cable Trays Containing Multiconductor or Control and/or Signal Cables Only.

A ladder or ventilated trough cable tray, having a loading depth of 6 inches or less containing only control and/or signal cables, may have 50 percent of its cross-sectional area filled with cable. If the cable tray has a loading depth in excess of 6 inches, that figure cannot be used in calculating the allowable fill area as a 6 inch depth is the maximum value that can be used for the cross-sectional area calculation. For an example of the procedure to use in selecting a cable tray width for the type of cable covered in this section, see page 444 (Appendix Sheet 6),[Example 392.22(A)(2)].

392.22. Number of Conductor of Cables.
(A) Number of Multiconductor Cables, Rated 2000 Volts or Less, in Cable Trays. (3) Solid Bottom Cable Trays Containing Any Mixture of Cables.

For solid bottom cable tray, the allowable cable fill area is reduced to approximately 30 percent as indicated by the values in Columns 3 and 4 of Table 392.22(A). The first value in Column 3 was obtained as follows: 3 in. loading depth x 6 in. inside width x 0.305 = 5.5 square inches. The other values in Column 3 were obtained in a like manner. The Sd term in Column 4 has a multiplier of 1 vs. the multiplier of 1.2 for Column 2.

392.22. Number of Conductor of Cables.
(A) Number of Multiconductor Cables, Rated 2000 Volts or Less, in Cable Trays. (3) Solid Bottom Cable Trays Containing Any Mixture of Cables. (a) 4/0 or Larger Cables.

The procedure used in selecting a cable tray width for the type of cable covered in this section is similar to that shown on Appendix Sheet 3 page 441, but only 90 percent of the cable tray width can be used.

392.22. Number of Conductor of Cables.
(A) Number of Multiconductor Cables, Rated 2000 Volts or Less, in Cable Trays. (3) Solid Bottom Cable Trays Containing Any Mixture of Cables. (b) Cables Smaller Than 4/0.

The procedure used in selecting a cable tray width for the type of cable covered in this section is similar to that shown on Appendix Sheet 4 page 442. The maximum allowable cable fill area is in Column 3 of Table 392.22(A).

392.22. Number of Conductor of Cables.
(A) Number of Multiconductor Cables, Rated 2000 Volts or Less, in Cable Trays. (3) Solid Bottom Cable Trays Containing Any Mixture of Cables. (c) 4/0 or Larger Cables With Cables Smaller Than 4/0.

No. 4/0 and larger cables must have a dedicated zone in the tray in order to be installed in one layer. Therefore the cable tray needs to be divided into two zones (a barrier or divider is not required but one can be used if desired).

The formula for this type of installation is shown in Column 4 of Table 392.22(A). This formula is a trial and error method of selecting a cable tray of the proper width. A direct method for determining the cable tray width is available by figuring the cable tray widths that are required for each of the cable combinations and then adding these widths together to select the proper cable tray width. [Sd (sum of the diameters of the No. 4/0 and larger cables) x (1.11)] + [(Sum of Total Cross-Sectional Area of all Cables No. 3/0 and Smaller) x (6 inches/5.5 square inches) = The Minimum Width of Cable Tray Required. The procedure used in selecting a cable tray width for the type of cables covered in this section is similar to that shown on Appendix Sheet 5 page 443.

392.22. Number of Conductor of Cables.
(A) Number of Multiconductor Cables, Rated 2000 Volts or Less, in Cable Trays. (4) Solid Bottom Cable Trays Containing Multiconductor Control and/or Signal Cables Only.

This is the same procedure as for ladder and ventilated trough cable trays except that the allowable fill has been reduced from 50 percent to 40 percent. The procedure used in selecting a cable tray width for the type of cable covered in this section is similar to that shown on Appendix Sheet 6 page 444. [Example 392.22(A)(2)]

392.22. Number of Conductor of Cables.
(A) Number of Multiconductor Cables, Rated 2000 Volts or Less, in Cable Trays. (5) Ventilated Channel Cable Trays Containing Multiconductor Cables of Any Type.

392.22(A)(5)(a)
Where only one multiconductor cable is installed in a ventilated channel cable tray.

Ventilated Channel Cable Tray Size	Maximum Cross-Sectional Area of the Cable
3 Inch Wide	2.3 Square Inches
4 Inch Wide	4.5 Square Inches
6 Inch Wide	7.0 Square Inches

392.22(A)(5)(b)
The fill areas for combinations of multiconductor cables of any type installed in ventilated channel cable tray.

Ventilated Channel Cable Tray Size	Maximum Allowable Fill Area
3 Inch Wide	1.3 Square Inches
4 Inch Wide	2.5 Square Inches
6 Inch Wide	3.8 Square Inches

392.22. Number of Conductor of Cables.
(A) Number of Multiconductor Cables, Rated 2000 Volts or Less, in Cable Trays. (6) Solid Channel Cable Trays Containing Multiconductor Cables of Any Type.

392.22(A)(6)(a)
Where only one multiconductor cable is installed in a solid channel cable tray.

Solid Channel Cable Tray Size	Maximum Cross-Sectional Area of the Cable
2 Inch Wide	1.3 Square Inches
3 Inch Wide	2.0 Square Inches
4 Inch Wide	3.7 Square Inches
6 Inch Wide	5.5 Square Inches

392.22(A)(6)(b)
The fill areas for combinations of multiconductor cables of any type installed in solid channel cable tray.

Solid Channel Cable Tray Size	Maximum Allowable Fill Area
2 Inch Wide	0.8 Square Inches
3 Inch Wide	1.1 Square Inches
4 Inch Wide	2.1 Square Inches
6 Inch Wide	3.2 Square Inches

392.22. Number of Conductor or Cables, (B) Number of Single Conductor Cables, Rated 2000 Volts or Less, in Cable Trays.

Installation of single conductors in cable tray is restricted to industrial establishments where conditions of maintenance and supervision assure that only qualified persons will service the installed cable tray systems. Single conductor cables for these installations must be 1/0 or larger, and they may not be installed in solid bottom cable trays.

392.22. Number of Conductor of Cables.
(B) Number of Single Conductor Cables, Rated 2000 Volts or Less, in Cable Trays. (1) Ladder or Ventilated Trough Cable Trays. (a) 1000 KCMIL Through 900 KCMIL Cables.

The sum of the diameters (Sd) of all single conductor cables shall not exceed the cable tray width, and the cables shall be installed in a single layer.

392.22. Number of Conductor of Cables.
(B) Number of Single Conductor Cables, Rated 2000 Volts or Less, in Cable Trays. (1) Ladder or Ventilated Trough Cable Trays. (b) 250 KCMIL Through 900 KCMIL Cables.

Number Of 600 Volt Single Conductor Cables That May Be Installed In Ladder Or Ventilated Trough Cable Tray - Section 392.10(A) (2)

			Cable Tray Width							
Single Conductor Size	Dia. In. (Note) #1	Area Sq. In.	6 In.	9 In.	12 In.	18 In.	24 In.	30 In.	36 In.	(Note #2) 42 In.
1/0	0.58	--	10	15	20	31	41	51	62	72
2/0	0.62	--	9	14	19	29	38	48	58	67
3/0	0.68	--	8	13	17	26	35	44	52	61
4/0	0.73	--	8	12	16	24	32	41	49	57
250 Kcmil	0.84	0.55	11	18	24	35	47	59	71	82
350 Kcmil	0.94	0.69	9	14	19	28	38	47	57	65
500 Kcmil	1.07	0.90	7	11	14	22	29	36	43	50
750 Kcmil	1.28	1.29	5	8	10	15	20	25	30	35

Notes:

#1. Cable diameter's used are those for Okonite-Okolon 600 volt single conductor power cables.

#2. 42 inch wide is ladder cable tray only.

#3. Such installations are to be made only in qualifying industrial facilities as per Sections 392.10(B) & (B)(1).

#4. To avoid problems with unbalanced voltages, the cables should be bundled with ties every three feet or four feet. The bundle must contain the circuit's three phase conductors plus the neutral if one is used.

#5. The single conductor cables should be firmly tied to the cable trays at six foot or less intervals.

392.22. Number of Conductor of Cables.
(B) Number of Single Conductor Cables, Rated 2000 Volts or Less, in Cable Trays. (1) Ladder or Ventilated Trough Cable Trays. (c) 1000 KCMIL or Larger Cables Installed With Cables Smaller Than 1000 KCMIL.

Such installations are very rare.

392.22. Number of Conductor of Cables.
(B) Number of Single Conductor Cables, Rated 2000 Volts or Less, in Cable Trays. (1) Ladder or Ventilated Trough Cable Trays. (d) Cables 1/0 Through 4/0.

The sum of the diameters (Sd) of all 1/0 through 4/0 cables shall not exceed the inside width of the cable tray.

392.22. Number of Conductor of Cables. (B) Number of Single Conductor Cables, Rated 2000 Volts or Less, in Cable Trays. (2) Ventilated Channel Cable Trays.

The sum of the diameters (Sd) of all single conductors shall not exceed the inside width of the ventilated cable channel.

Number Of 600 Volt Single Conductor Cables
That May Be Installed In A Ventilated Channel
Cable Tray - Section 392.22(B)(2)

Single Conductor Size	Diameter Inches (Note #1)	3 Inch V. Channel C.T.	4 Inch V. Channel C.T.	6 Inch V. Channel C.T.
1/0 AWG	0.58	5	6	10
2/0 AWG	0.62	4	6	9
3/0 AWG	0.68	4	5	8
4/0 AWG	0.73	4	5	8
250 Kcmil	0.84	3	4	7
350 Kcmil	0.94	3	4	6
500 Kcmil	1.07	2	3	5
750 Kcmil	1.28	2	3	4
1000 Kcmil	1.45	2	2	4

Notes:

#1. Cable diameter's used are those for Okonite-Okolon 600 volt single conductor power cables.

#2. Such installations are to be made only in qualifying industrial facilities as per Sections 392.10(B) & (B)(1).

#3. The phase, neutral, and EGCs cables are all counted in the allowable cable fill for the ventilated channel cable tray.

#4. To avoid problems with unbalanced voltages, the cables should be bundled with ties every three feet or four feet. The bundle must contain the circuit's three phase conductors plus the neutral if one is used. If a cable is used as the EGC, it should also be in the cable bundle. If the designer desires, the ventilated channel cable tray may be used as the EGC as per Table 392.60(A).

#5. The single conductor cables should be firmly tied to the ventilated channel cable tray at six foot or less intervals.

392.22. Number of Conductors of Cables. (C) Number of Type MV and Type MC Cables (2001 Volts or Over) in Cable Trays.

Sum the diameters of all the cables (Sd) to determine the minimum required cable tray width. Triplexing or quadruplexing the cables does not change the required cable tray width. Whether the cables are grouped or ungrouped, all installations must be in a single layer.

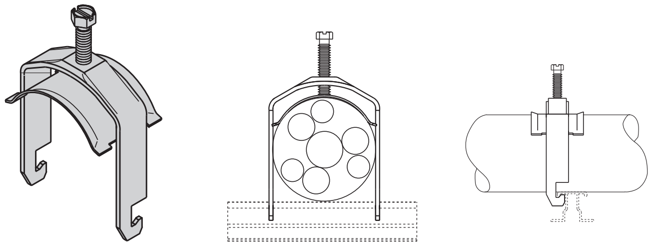
392.30. Securing and Supporting. (B) Cables and Conductors.

The intent of this section is to ensure that the conductor insulation and cable jackets will not be damaged due to stress caused by improper support. Multiconductor 600 volt Type TC cables and 300 volt Type PLTC cables exhibit a high degree of damage resistance when exposed to mechanical abuse at normal temperatures.

During an inspection of industrial installations by the 1973 **NEC**® Technical Subcommittee on Cable Tray, a test setup was constructed of an 18 inch wide Class 20C aluminum cable tray supported three feet above ground level containing several sizes of multiconductor cables. This installation was continuously struck in the same area with eight pound sledge hammers until the cable tray was severely distorted, the cables however, exhibited only cosmetic damage. When these cables were tested electrically, they checked out as new tray cable. Since that time, significant improvements have been made in cable jacket and conductor insulation materials so that the cables available today are of better quality than the 1973 test cables. Although tray cables are capable of taking a great deal of abuse without any problems, cable tray installations must be designed by taking appropriate measures to ensure that the tray cables will not be subjected to mechanical damage.

392.30. Securing and Supporting. (B) Cables and Conductors. (1) Other Than Horizontal Runs.

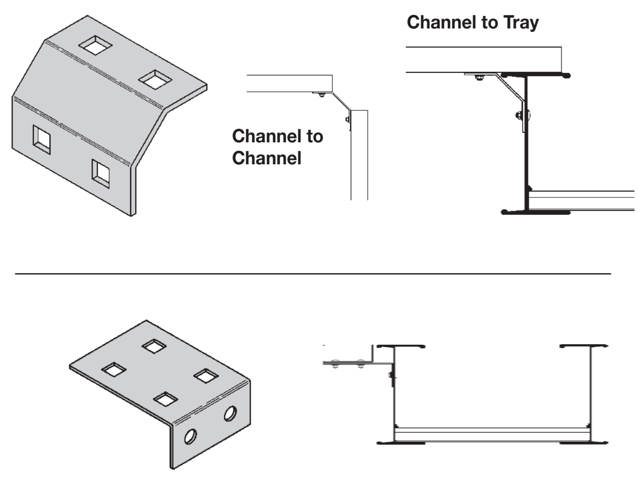
In seismic, high-shock and vibration prone areas, cables (especially unarmored cables) should be secured to the cable tray at 1 to 2 foot intervals to prevent the occurrence of sheath chafing. Otherwise, there is no safety or technical reason to tie down multiconductor cables in horizontal cable tray runs unless the cable spacing needs to be maintained or the cables need to be confined to a specific location in the cable tray. In non-horizontal cable tray runs, small multiconductor cables should be tied down at 3 or 4 foot intervals and larger (1 inch diameter and above) Type MC and Type TC multiconductor cable should be tied down at 6 foot intervals. If used outdoors, plastic ties should be sunlight, ultraviolet (UV), resistant and be made of a material that is compatible with the industrial environment. Installed outdoors, white nylon plastic ties without a UV resistant additive will last 8 to 14 months before breaking. Also available for these applications are cable cleats, stainless steel ties and P-clamps.



(P-Clamp shown installed on industrial aluminum rung)

392.46. Bushed Conduit and Tubing.

For most installations, using a conduit to cable tray clamp for terminating conduit on cable tray is the best method. Where a cable enters a conduit from the cable tray, the conduit must have a bushing to protect the cable jacket from mechanical damage; a box is not required **[See Section 300.15(C). Boxes, Conduit Bodies, or Fittings - Where Required. Where cables enter or exit from conduit or tubing that is used to provide cable support or protection against physical damage. A fitting shall be provided on the end(s) of the conduit or tubing to protect the wires or cables from abrasion.].** There are some special installations where the use of conduit knockouts in the cable tray side rail for terminating conduit is appropriate. This would not be a good standard practice because it is costly and labor intensive, and if randomly used may result in damaging and lowering the strength of the cable tray.



Cable Channel Branch Circuit

392.56. Cable Splices.

There is no safety problem due to cable splices being made in cable trays if quality splicing kits are used, provided that the splice kits do not project above the siderails and that they are accessible. A box or fitting is not required for a cable splice in a cable tray.

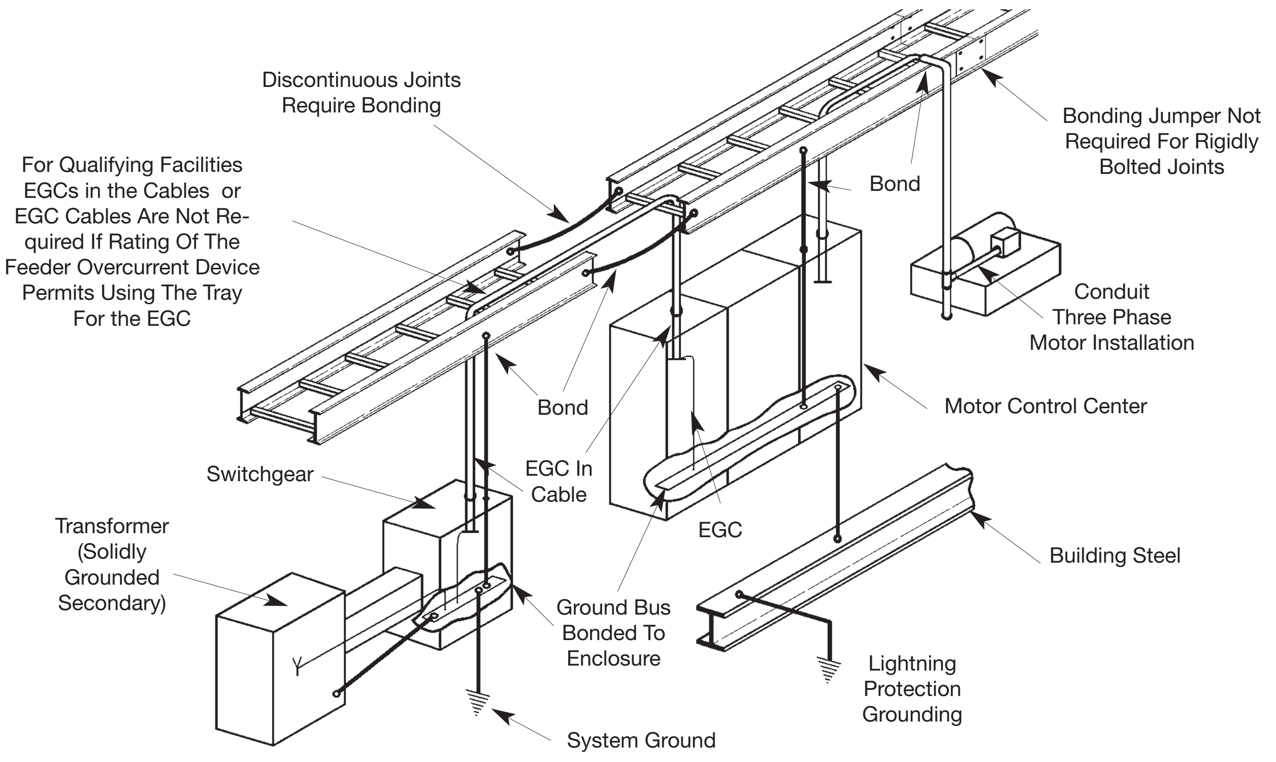
92.60. Grounding and Bonding, (A) Metallic Cable Trays.

Cable tray may be used as the EGC in any installation where qualified persons will service the installed cable tray system. There is no restriction as to where the cable tray system is installed. The metal in cable trays may be used as the EGC as per the limitations of table 392.60(A).

All metallic cable trays shall be grounded as required in Article 250.96 regardless of whether or not the cable tray is being used as an equipment grounding conductor (EGC).

The EGC is the most important conductor in an electrical system as its function is electrical safety.

There are three wiring options for providing an EGC in a cable tray wiring system: (1) An EGC conductor in or on the cable tray. (2) Each multiconductor cable with its individual EGC conductor. (3) The cable tray itself is used as the EGC in qualifying facilities.



Correct Bonding Practices To Assure That The Cable Tray System Is Properly Grounded

If an EGC cable is installed in or on a cable tray, it should be bonded to each or alternate cable tray sections via grounding clamps (this is not required by the **NEC**® but it is a desirable practice). In addition to providing an electrical connection between the cable tray sections and the EGC, the grounding clamp mechanically anchors the EGC to the cable tray so that under fault current conditions the magnetic forces do not throw the EGC out of the cable tray.

A bare copper equipment grounding conductor should not be placed in an aluminum cable tray due to the potential for electrolytic corrosion of the aluminum cable tray in a moist environment. For such installations, it is best to use an insulated conductor and to remove the insulation where bonding connections are made to the cable tray, raceways, equipment enclosures, etc. with tin or zinc plated connectors.

See Table 250.122 on page 445 for the minimum size EGC for grounding raceway and equipment.

Aluminum Cable Tray Systems. (1) & (2)

Table 392.60(A). Metal Area Requirements for Cable Trays Used as Equipment Grounding Conductors

Maximum Fuse Ampere Rating, Circuit Breaker Ampere Trip Setting, or Circuit Breaker Protective Relay Ampere Trip Setting for Ground-Fault Protection of Any Cable Circuit In the Cable Tray System	Minimum Cross-Sectional Area of Metal* In Square Inches	
	Steel Cable Trays	Aluminum Cable Trays
60	0.20	0.20
100	0.40	0.20
200	0.70	0.20
400	1.00	0.40
600	1.50**	0.40
1000	---	0.60
1200	---	1.00
1600	---	1.50
2000	---	2.00**

For SI units: one square inch = 645 square millimeters.

***Total cross-sectional area of both side rails for ladder or trough cable trays; or the minimum cross-sectional area of metal in channel cable trays or cable trays of one-piece construction.**

****Steel cable trays shall not be used as equipment grounding conductors for circuits with ground-fault protection above 600 amperes. Aluminum cable trays shall not be used as equipment grounding conductors for circuits with ground-fault protection above 2000 amperes.**

Table 392.60(A) "Metal Area Requirements for Cable Trays used as Equipment Grounding Conductors" shows the minimum cross-sectional area of cable tray side rails (total of both side rails) required for the cable tray to be used as the Equipment Grounding Conductor (EGC) for a specific Fuse Rating, Circuit Breaker Ampere Trip Rating or Circuit Breaker Ground Fault Protective Relay Trip Setting. These are the actual trip settings for the circuit breakers and not the maximum permissible trip settings which in many cases are the same as the circuit breaker frame size. If the maximum ampere rating of the cable tray is not sufficient for the protective device to be used, the cable tray cannot be used as the EGC and a separate EGC must be included within each cable assembly or a separate EGC has to be installed in or attached to the cable tray. [See also Section 250-120 for additional information]

The subject of using cable tray for equipment grounding conductors was thoroughly investigated by the 1973 **NEC**® Technical Subcommittee on Cable Tray. Many calculations were made and a number of tests were performed by Monsanto Company Engineers at the Bussman High Current Laboratory. The test setup to verify the capability of cable tray to be used as the EGC is shown in Figure 1 on page 428. The test amperes available were forced through one cable tray side rail which had three splice connections in series. No conductive joint compound was used at the connections and the bolts were wrench tight. Copper jumper cables were used from the current source to the cable tray. The cable tray was NEMA Class 12B. The test results are shown on page 439 (Appendix Sheet 1), Table I for aluminum and Table II for steel cable tray.

One of the most interesting results of the tests was for an aluminum cable tray with a corroded joint and only two nylon bolts. 34,600 amperes for 14 cycles produced only a 34° C temperature rise at the splice plate area. If the protective devices work properly, the temperature rises recorded at the cable tray splices during these tests would not be sufficient to damage the cables in the cable tray. Also note that in these tests only one side rail was used, but in a regular installation, both side rails would conduct fault current and the temperature rise at the splice plate areas would be even lower.

When the cable tray is used as the EGC, consideration has to be given to the conduit or ventilated channel cable tray connections to the cable tray so that the electrical grounding continuity is maintained from the cable tray to the equipment utilizing the electricity. Conduit connections to the cable tray were also tested. At that time, no commercial fittings for connecting conduit to cable tray were available, so right angle beam clamps were used with very good results. There are now UL Listed fittings for connecting and bonding conduit to cable tray. This test setup and results are shown on page 440 (Appendix Sheet 2).

Temperature Rise Test

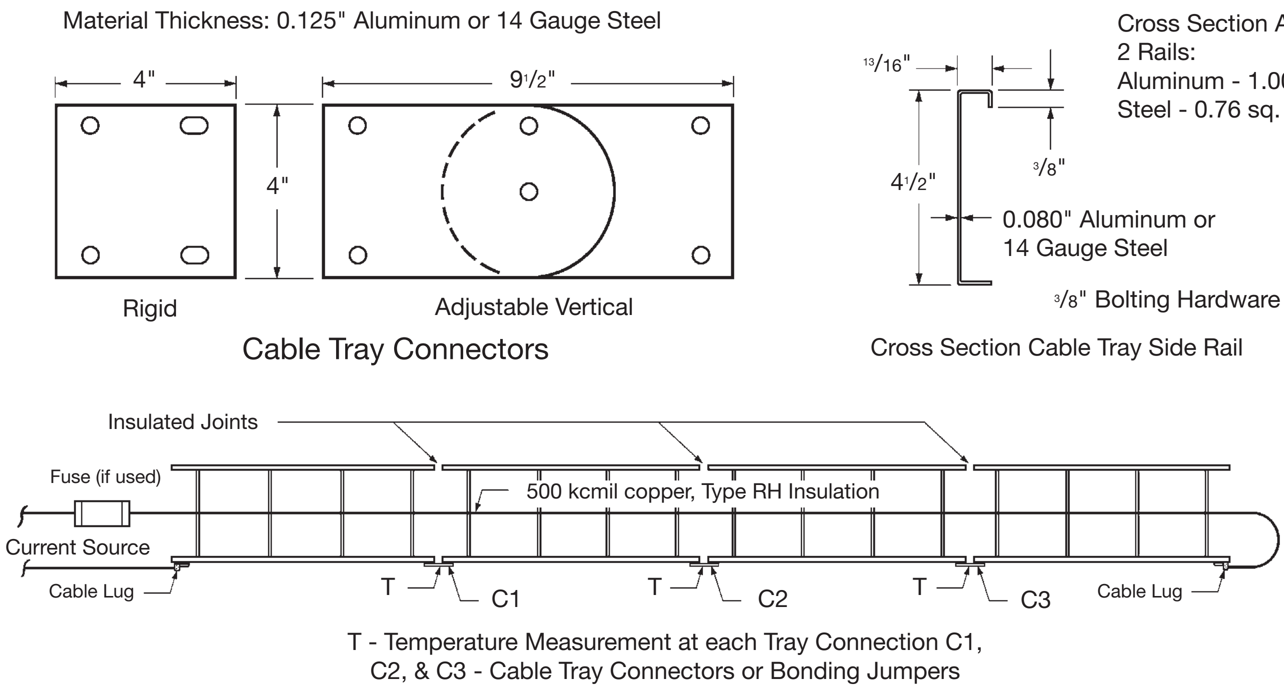
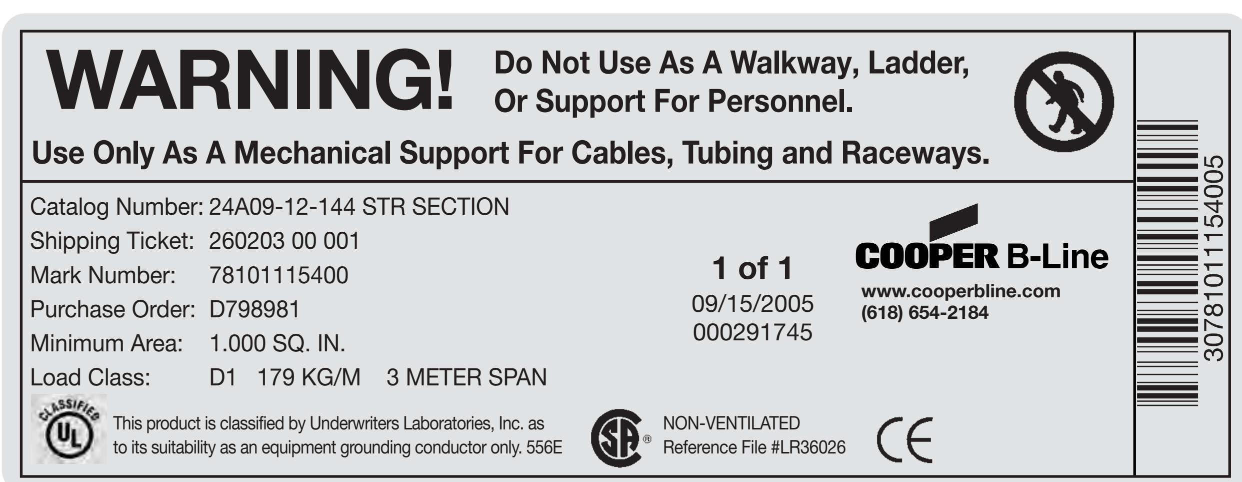


Figure 1
(See Page 419 Appendix Sheet 1)

Cable Tray Label

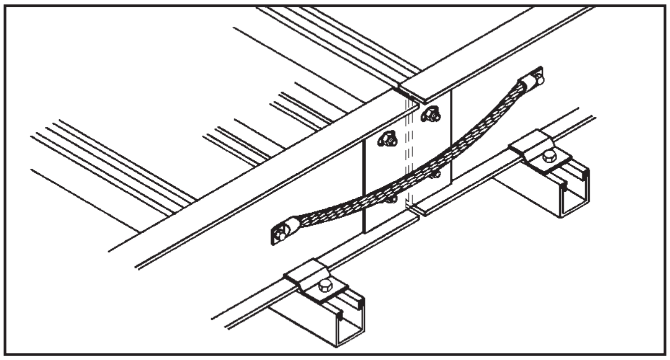


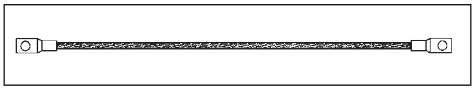
392.60. Grounding and Bonding. (B) Steel or Aluminum Cable Tray Systems. (3) & (4)

For a cable tray to be used as an EGC the manufacturer must provide a label showing the cross-sectional area available. This also holds true for some mechanically constructed cable tray systems such as Redi-Rail®. Redi-Rail has been tested and UL Classified as an EGC. Cooper B-Line's label is shown at the bottom of page 428.

The cable tray system must be electrically continuous whether or not it is going to serve as the EGC. At certain locations (expansion joints, discontinuities, most horizontal adjustable splice plates, etc.), bonding jumpers will be required. Section 250.96. Bonding Other Enclosures states that cable tray shall be effectively bonded where necessary to assure electrical continuity and to provide the capacity to conduct safely any fault current likely to be imposed on them (also see Sections 250.92(A)(1) & 250.118(12)).

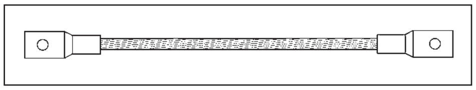
It is not necessary to install bonding jumpers at standard splice plate connections. The splice connection is UL classified as an EGC component of the cable tray system.

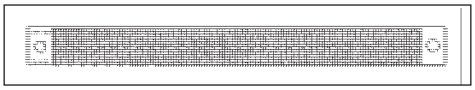




99-N1
600 amps max.

99-40
1600 amps max.





99-1620
2000 amps max.

NOTE: The **NEC**® only recognizes aluminum and steel cable trays as EGC's. As with all metallic cable trays, stainless steel cable trays must be bonded according to **NEC**® guidelines. Fiberglass cable trays do not require bonding jumpers since fiberglass is non-conductive.

392.80. Ampacity of Conductors. (A) Ampacity of Cables. Rated 2000 Volts or Less in Cable Trays.

Ampacity Tables 310.15(B)(16) and 310.15(B)(18) are to be used for multiconductor cables which are installed in cable tray using the allowable fill areas as per Section 392.22(A). The ampacities in Table 310.15(B)(16) are based on an ambient temperature of 30° Celsius. Conduit and cable tray wiring systems are often installed in areas where they will be exposed to high ambient temperatures. For such installations, some designers and engineers neglect using the Ampacity Correction Factors listed below the Wire Ampacity Tables which results in the conductor insulation being operated in excess of its maximum safe temperature. These correction factors must be used to derate a cable for the maximum temperature it will be subjected to anywhere along its length.

392.80(A)(1)(a)

Section 310.15(B)(3)(a) refers to Section 392.80 which states that the derating information of Table 310.15(B)(3)(a) applies to multiconductor cables with more than three current carrying conductors but not to the number of conductors in the cable tray.

392.80(A)(1)(b)

Where cable trays are continuously covered for more than 6 feet (1.83m) with solid unventilated covers, not over 95 percent of the allowable ampacities of Tables 310.15(B)(16) and 310.15(B)(18) shall be permitted for multiconductor cables.

This is for multiconductor cables installed using Table 310.15(B)(16) or 310.15(B)(18). If these cables are installed in cable trays with solid unventilated covers for more than 6 feet the cables must be derated. Where cable tray covers are to be used, it is best to use raised or ventilated covers so that the cables can operate in a lower ambient temperature.

392.80(A)(1)(c)

Where multiconductor 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 shall not exceed the allowable ambient temperature corrected ampacities of multiconductor cables, with not more than three insulated conductors rated 0-2000 volts in free air, in accordance with Section 310.15(C).

By spacing the cables one diameter apart, the engineer may increase the allowable ampacities of the cables to the free air rating as per Section 310.15(C) and Table B-310.3 in Appendix B. Notice that the allowable fill of the cable tray has been decreased in this design due to the cable spacing.

392.80. Ampacity of Conductors. (A) Ampacity of Cables. Rated 2000 Volts or Less in Cable Trays. (2) Single Conductor Cables.

Single conductor cables can be installed in a cable tray cabled together (triplexed, quadruplexed, etc.) if desired. Where the cables are installed according to the requirements of Section 392.22(B), the ampacity requirements are shown in the following chart as per Section 392.80(A)(2), (a), (b), (c), and (d):

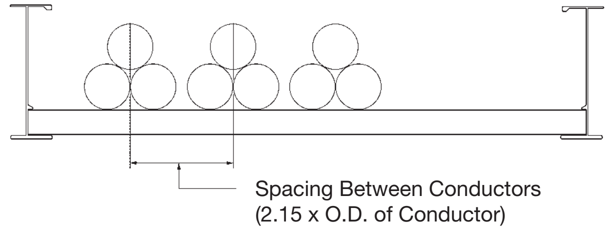
An exception is listed under 392.80(A)(2)(c). Stating that the capacity for single conductor cables be placed in solid bottom shall be determined by 310.15(C).

Sec. No.	Cable Sizes	Solid Unventilated Cable Tray Cover	Applicable Ampacity Tables (*)	Mult. Amp. Table Values By	Special Conditions
(1)	600 kcmil and Larger	No Cover Allowed (**)	310.15(B)(17) and 310.15(B)(19)	0.75	
(1)	600 kcmil and Larger	Yes	310.15(B)(17) and 310.15(B)(19)	0.70	
(2)	1/0 AWG through 500 kcmil	No Cover Allowed (**)	310.15(B)(17) and 310.15(B)(19)	0.65	
(2)	1/0 AWG through 500 kcmil	Yes	310.15(B)(17) and 310.15(B)(19)	0.60	
(3)	1/0 AWG & Larger In Single Layer	No Cover Allowed (**)	310.15(B)(17) and 310.15(B)(19)	1.00	Maintained Spacing Of One Cable Diameter
(4)	Single Conductors In Triangle Config. 1/0 AWG and Larger	No Cover Allowed (**)	310.15(B)(20) [See NEC Section 310.15(B)]	1.00	Spacing Of 2.15 x One Conductor O.D. Between Cables(***)

(*) The ambient ampacity correction factors must be used.

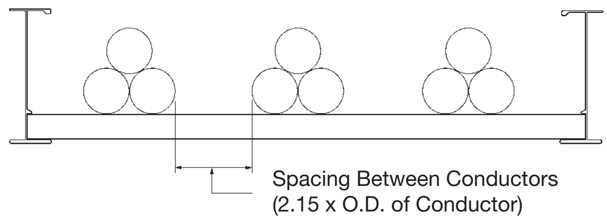
(**) At a specific position, where it is determined that the tray cables require mechanical protection, a single cable tray cover of six feet or less in length can be installed.

The wording of Section 392.80(A)(2)(d) states that a spacing of 2.15 times one conductor diameter is to be maintained between circuits. Two interpretations of this statement are possible. Interpretation #1. - The 2.15 times one conductor diameter is the distance between the centerlines of the circuits (the center lines of the conductor bundles). Interpretation #2. - The 2.15 times one conductor diameter is the free air distance between the adjacent cable bundles. The use of the word “circuit” is unfortunate as its presence promotes Interpretation #1. An installation based on Interpretation #1 is not desirable as a free air space equal to 2.15 times one conductor diameter between the cable bundles should be maintained to promote cable heat dissipation.



Technically Undesirable Installation

Interpretation #1



Technically Desirable Installation

Interpretation #2

392.80. Ampacity of Conductors. (B) Ampacity of Type MV and Type MC Cables (2001 Volts or Over) in Cable Trays. (1) Multiconductor Cables (2001 Volts or Over)

Provision No. 1: Where cable trays are continuously covered for more than six feet (1.83 m) with solid unventilated covers, not more than 95% of the allowable ampacities of Tables 310.60(C)(75) and 310.60(C)(76) shall be permitted for multiconductor cables.

Cables installed in cable trays with solid unventilated covers must be derated. Where cable tray covers are to be used, it is best to use raised or ventilated covers so that the cables can operate in a lower ambient temperature.

Provision No. 2: Where multiconductor cables are installed in a single layer in uncovered cable trays with a maintained spacing of not less than one cable diameter between cables, the ampacity shall not exceed the allowable ampacities of Table 310.60(C)(71) and 310.60(C)(72).

If the cable tray does not have covers and the conductors are installed in a single layer spaced not less than one cable diameter apart, the cable conductor ampacities can be 100 percent of the ambient temperature corrected capacities in Tables 310.60(C)(71) or 310.60(C)(72).

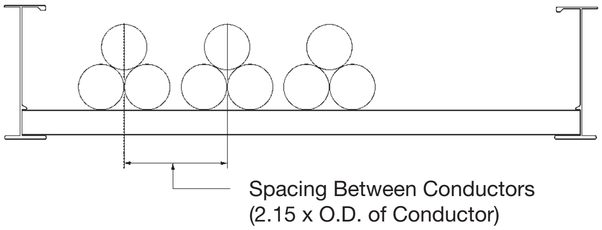
392.80. Ampacity of Conductors. (B) Ampacity of Type MV and Type MC Cables (2001 Volts or Over) in Cable Trays. (2) Single-Conductor Cables (2001 Volts or Over)

Sec. No.	Cable Sizes	Solid Unventilated Cable Tray Cover	Applicable Ampacity Tables (*)	Mult. Amp. Table Values By	Special Conditions
(1)	1/0 AWG and Larger	No Cover Allowed (**)	310.60(C)(69) and 310.60(C)(70)	0.75	
(1)	1/0 AWG and Larger	Yes	310.60(C)(69) and 310.60(C)(70)	0.70	
(2)	1/0 AWG & Larger In Single Layer	No Cover Allowed (**)	310.60(C)(69) and 310.60(C)(70)	1.00	Maintained Spacing Of One Cable Diameter
(3)	Single Conductors In Triangle Config. 1/0 AWG and Larger	No Cover Allowed (**)	310.60(C)(67) and 310.60(C)(68)	1.00	Spacing Of 2.15 x One Conductor O.D. Between Cables(***)

(*) The ambient ampacity correction factors must be used.

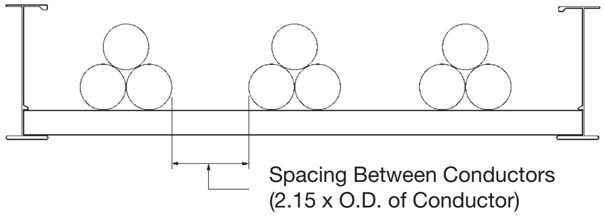
(**) At a specific position, where it is determined that the tray cables require mechanical protection, a single cable tray cover of six feet or less in length can be installed.

The wording of Section 392.80(B)(2)(c) states that a spacing of 2.15 times one conductor diameter is to be maintained between circuits. Two interpretations of this statement are possible. Interpretation #1. - The 2.15 times one conductor diameter is the distance between the centerlines of the circuits (the center lines of the conductor bundles). Interpretation #2. - The 2.15 times one conductor diameter is the free air distance between the adjacent cable bundles. The use of the word “circuit” is unfortunate as its presence promotes Interpretation #1. An installation based on Interpretation #1 is not desirable as a free air space equal to 2.15 times one conductor diameter between the cable bundles should be maintained to promote cable heat dissipation.



Technically Undesirable Installation

Interpretation #1



Technically Desirable Installation

Interpretation #2

392.100. Construction Specifications. (A) Strength and Rigidity.

The designer must properly select a structurally satisfactory cable tray for their installation. This selection is based on the cable tray's strength, the cable tray loading and the spacing of the supports. The ANSI/NEMA Metallic Cable Tray Systems Standard Publication VE-1 contains the cable tray selection information and it is duplicated in Cooper B-Line's Cable Tray Systems Catalog.

The NEMA Standard provides for a static load safety factor of 1.5. A number (Span in Feet - the distance between supports) and letter (Load in lbs/ft) designation is used to properly identify the cable tray class on drawings, in specifications, in quotation requisitions, and in purchase requisitions to guarantee that the cable tray with the proper characteristics will be received and installed. The designer must specify the cable tray type, the material of construction, section lengths, minimum bend radius, width, rung spacing (for a ladder type cable tray), and the total loading per foot for the cables on a maximum support spacing (See pages 448 & 449 for cable tray specifications checklist). For many installations, the cable trays must be selected so that they are capable of supporting specific concentrated loads, the weight of any equipment or materials attached to the cable tray, ice and snow loading, and for some installations the impact of wind loading and/or earthquakes must be considered.

Most cable trays are utilized as continuous beams with distributed and concentrated loads. Cable trays can be subjected to static loads like cable loads and dynamic loads such as wind, snow, ice, and even earthquakes. The total normal and abnormal loading for the cable tray is determined by adding all the applicable component loads. The cable load + the concentrated static loads + ice load (if applicable) + snow load (if applicable) + wind load (if applicable) + any other logical special condition loads that might exist. This total load is used in the selection of the cable tray.

The following is an explanation of the 'historical' NEMA cable tray load classifications found in ANSI/NEMA VE-1.

There used to be four cable tray support span categories, 8, 12, 16, and 20 feet, which are coupled with one of three load designations, "A" for 50 lbs/ft, "B" for 75 lbs/ft, and "C" for 100 lbs/ft. For example, a NEMA class designation of 20B identifies a cable tray that is to be supported at a maximum of every 20 feet and can support a static load of up to 75 lbs/linear foot.

The cable load per foot is easy to calculate using the cable manufacturer's literature. If the cable tray has space available for future cable additions, a cable tray has to be specified that is capable of supporting the final future load. Although these historical load designations are still useful in narrowing down the choices of cable trays, NEMA has recently changed the VE-1 document. ANSI/NEMA VE-1 now requires the marking on the cable trays to indicate the exact rated load on a particular span. Trays are no longer limited to the four spans and three loads listed above. Now, for example, a tray may be rated for 150 lbs/ft on a 30 ft. span. It is recommended when specifying cable tray, to specify the required load, support span and straight section length to best match the installation.

Example of Cable Loading per foot:

10 - 3/C No. 4/0 (2.62 lbs/ft)
Total = 26.20 lbs/ft
3 - 3/C No. 250 kcmil (3.18 lbs/ft)
Total = 9.54 lbs/ft
4 - 3/C No. 500 kcmil (5.87 lbs/ft)
Total = 23.48 lbs/ft

Total Weight of the Cables = **59.22 lbs/ft**

These cables would fill a 30 inch wide cable tray and if a 36 inch wide cable tray were used there would be space available for future cables (See pages 439 thru 445 for information on calculating tray width.). To calculate the proper cable tray design load for the 36" wide cable tray multiply 59.22 lbs/ft x 36 inches/30 inches = 71.06 lbs/ft. If this cable tray is installed indoors, a load symbol "B" cable tray would be adequate. If there were additional loads on the cable tray or the cable tray were installed outdoors, it would be necessary to calculate all the additional potential loads. The potential load most often ignored is installation loads. The stresses of pulling large cables through cable trays can produce 3 times the stress of the cables' static load. If the installation load is not evaluated the cable tray may be damaged during installation. A 16C or 20C NEMA Class should be specified if large cables are to be pulled.

Even though walking on cable tray is not recommended by cable tray manufacturers and OSHA regulations, many designers will want to specify a cable tray which can support a 200 lb. concentrated load "just in case". A concentrated static load applied at the midspan of a cable tray is one of the most stressful conditions a cable tray will experience. To convert a static concentrated load at midspan to an equivalent distributed load take twice the concentrated load and divide it by the support span [(2 x 200 lbs.)/Span]. The strength of the rung is also a very important consideration when specifying a concentrated load. The rung must be able to withstand the load for any tray width, as well as additional stresses from cable installation. Excessive rung deflection can weaken the entire cable tray system. Cooper B-Line uses heavier rungs on their wider industrial trays as a standard. Most cable tray manufacturer's rungs are not heavy enough to withstand concentrated loads at 36" tray widths.

For outdoor installations a cable tray might be subject to ice, snow, and wind loading. Section 25 of the National Electrical Safety Code (published by the Institute of Electrical and Electronic Engineers) contains a weather loading map of the United States to determine whether the installation is in a light, medium, or heavy weather load district. NESC Table 250-1 indicates potential ice thicknesses in each loading district as follows: 0.50 inches for a heavy loading district, 0.25 inches for a medium loading district, and no ice for a light loading district. To calculate the ice load use 57 pounds per cubic foot for the density of glaze ice. Since tray cables are circular and the cable tray has an irregular surface the resulting ice load on a cable tray can be 1.5 to 2.0 times greater than the glaze ice load on a flat surface.

Snow load is significant for a cable tray that is completely full of cables or a cable tray that has covers. The density of snow varies greatly due to its moisture content, however the minimum density that should be used for snow is 5 pounds per cubic foot. The engineer will have to contact the weather service to determine the potential snow falls for the installation area or consult the local building code for a recommended design load.

Usually cable trays are installed within structures such that the structure and equipment shelter the cable trays from the direct impact of high winds. If wind loading is a potential problem, a structural engineer and/or the potential cable tray manufacturer should review the installation for adequacy. To determine the wind speed for proper design consult the Basic Wind Speed Map of the United States in the NESC (Figure 250-2).

For those installations located in earthquake areas, design engineers can obtain behavioral data for Cooper B-Line cable trays under horizontal, vertical and longitudinal loading conditions. Testing done for nuclear power plants in the 1970's indicates that cable trays act like large trusses when loaded laterally and are actually stronger than when loaded vertically. Cable tray supports may still need to be seismically braced and designers should consult the Cooper B-Line Seismic Restraints Catalog for detailed design information.

The midspan deflection multipliers for all B-Line cable trays are listed in the Cable Tray Systems catalog. Simply pick your support span and multiply your actual load by the deflection multiplier shown for that span. The calculated deflections are for simple beam installations at your specified load capacity. If a deflection requirement will be specified, extra care needs to be taken to ensure that it does not conflict with the load requirement and provides the aesthetics necessary. Keep in mind that continuous beam applications are more common and will decrease the deflection values shown by up to 50%. Also, aluminum cable trays will deflect 3 times more than steel cable trays of the same NEMA class.

To complete the design, the standard straight section length and minimum bend radius must be chosen. When selecting the recommended length of straight sections, be sure that the standard length is greater than or equal to the maximum support span. Choose a fitting radius which will not only meet or exceed the minimum bend radius of the cables but will facilitate cable installation.

[See pages 407 - 409 for more information on selecting the appropriate cable tray length]

392.100. Construction Specifications. (B) Smooth Edges.

This is a quality statement for cable tray systems and their construction. Cooper B-Line cable tray is designed and manufactured to the highest standards to provide easy, safe installation of both the cable tray and cables.

392.100. Construction Specifications. (C) Corrosion Protection.

Cable tray shall be protected from corrosion per Section 300.6, which lists some minimum criteria for different corrosive environments. The Cooper B-Line Cable Tray Catalog contains a corrosion chart for cable tray materials. Cable trays may be obtained in a wide range of materials including aluminum, pregalvanized steel, hot dipped galvanized steel (after fabrication), Type 304 or 316 stainless steel, polyvinyl chloride (PVC) or epoxy coated aluminum or steel and also nonmetallic (fiber reinforced plastic). Check with a metallurgist to determine which metals and coatings are compatible with a particular corrosive environment. B-Line has corrosion information available and may be able to recommend a suitable material. Remember that no material is totally impervious to corrosion. Stainless steel can deteriorate when attacked by certain chemicals and nonmetallic cable trays can deteriorate when attacked by certain solvents.

392.100. Construction Specifications. (D) Side Rails.

The technical information in Article 392 was originally developed for cable trays with rigid side rails by the 1973 **NEC**® Technical Subcommittee on Cable Tray. “Equivalent Structural Members” was added later to incorporate new styles of cable tray such as center rail type tray and ‘mesh’ or wire basket tray.

392.100. Construction Specifications. (E) Fittings.

This section has been misinterpreted to mean that cable tray fittings must be used for all changes in direction and elevation [See Section 392.18(A) Complete system for further explanation). When two cable tray runs cross at different elevations, lacing a cable between the rungs of one tray and dropping into the other is a common practice which changes the direction of the cable while providing adequate cable support. Although the use of cable tray fittings is not mandatory, it is often desirable to use them when possible to improve the appearance of the installation.

392.100. Construction Specifications. (F) Nonmetallic Cable Tray.

This type of cable tray is usually made of Fiberglass Reinforced Plastic (FRP). Applications for FRP cable tray systems include some corrosive atmospheres and where non-conductive material is required. Cooper B-Line fiberglass cable tray systems are manufactured from glass fiber reinforced plastic shapes that meet ASTM flammability and self-extinguishing requirements. A surface veil is applied during pultrusion to ensure a resin rich surface and increase ultraviolet resistance, however, for extended exposure to direct sunlight, additional measures, such as painting the tray, are sometimes employed to insure the longevity of the product. Ambient temperature is also a design consideration when FRP cable tray is used. An ambient temperature of 100°F will decrease the loading capacity of polyester resin fiberglass cable tray by 10%.

CABLE TRAY WIRING SYSTEM DESIGN AND INSTALLATION HINTS.

Cable tray wiring systems should have a standardized cabling strategy. Standard cable types should be used for each circuit type. Most of the following circuits should be included; feeder circuits, branch circuits, control circuits, instrumentation circuits, programmable logic controller input and output (I/O) circuits, low level analog or digital signals, communication circuits and alarm circuits. Some cables may satisfy the requirements for several circuit types. Minimizing the number of different cables used on a project reduces installed costs. Some companies have cable standards based on volume usage to minimize the numbers of different cables used on a project. For example: if a 6 conductor No. 14 control cable is needed but 7 conductor No. 14 control cable is stocked, a 7 conductor control cable would be specified and the extra conductor would not be used. Following such a practice can reduce the number of different cables handled on a large project without increasing the cost since high volume cable purchases result in cost savings. Orderly record keeping also helps provide quality systems with lower installation costs. The following items should be included in the project's cable records:

• Cable Tray Tag Numbers - The tagging system should be developed by the design personnel with identification numbers assigned to cable tray runs on the layout drawings. Cable tray tag numbers are used for controlling the installation of the proper cable tray in the correct location, routing cables through the tray system and controlling the cable fill area requirements.

• Cable Schedules - A wire management system is required for any size project. Cable schedules must be developed to keep track of the cables. This is especially true for projects involving more than just a few feeder cables. A typical cable schedule would contain most or all of the following:

• The Cable Number, the Cable Manufacturer & Catalog Number, Number of conductors, the conductor sizes, and the approximate cable length.

• Cable Origin Location - The origin equipment ID with the compartment or circuit number and terminals on which the cable conductors are to be terminated. It should also include the origin equipment layout drawing number, and the origin equipment connection diagram number.

• Cable Routing - Identifies the cable tray sections or runs that a cable will occupy. Cable tray ID tag numbers are used to track the routing.

• Cable Termination Location - The device or terminal equipment on which the cable conductors are to be terminated. It should also include the termination equipment layout drawing number, and the termination equipment connection diagram number.

Some design consultants and corporate engineering departments use spread sheets to monitor the cable tray runs for cable fill. With such a program, the cable tray fill area values for each cable tray run or section can be continuously upgraded. If a specified cable tray run or section becomes overfilled, it will be flagged for corrective action by the designer.

• Cable Installation Provisions - The cable tray system must be designed and installed, to allow access for cable installation. For many installations, the cables may be hand laid into the cable trays and no cable pulling equipment is required. There are other installations where sufficient room must be allotted for all the cable pulling activities and equipment.

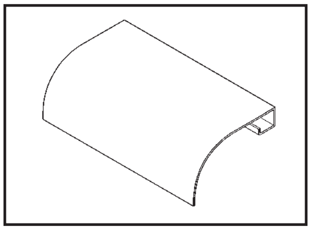
The cable manufacturers will provide installation information for their cables such as maximum pulling tension, allowable sidewall pressures, minimum bending radii, maximum permissible pulling length etc.. Lubricants are not normally used on cables being installed in cable trays.

The engineer and designers should discuss in detail the installation of the cables with the appropriate construction personnel. This will help to avoid installation problems and additional installation costs. It is important that the cable pull is in the direction that will result in the lowest tension on the cables. Keep in mind there also needs to be room at the ends of the pulls for the reel setups and for the power pulling equipment. Cable pulleys should be installed at each direction change. Triple pulleys should be used for 90 degree horizontal bends and all vertical bends. Single pulleys are adequate for horizontal bends less than 90 degrees. Use rollers in-between pulleys and every 10 to 20 feet depending on the cable weight. Plastic jacketed cables are easier to pull than are the metallic jacketed cables and there is less chance of cable damage. The pulling eye should always be attached to the conductor material to avoid tensioning the insulation. For interlocked armor cables, the conductors and the armor both have to be attached to the pulling eye.

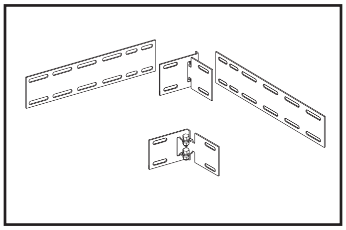
Normally, the cables installed in cable trays are not subjected to the damage suffered by insulated conductors pulled into conduit. Depending on the size of the insulated conductors and the conduit, jamming can take place which places destructive stresses on the cable insulation. In the October, 1991 issue of EC&M magazine, the article on cable pulling stated that 92 percent of the insulated conductors that fail do so because they were damaged in installation.

CABLE TRAY ACCESSORIES.

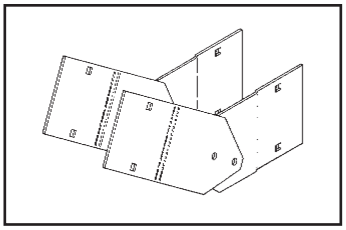
B-Line manufactures a full line of prefabricated accessories for all types of B-Line cable trays. The use of the appropriate accessories will provide installation cost and time savings. In addition to providing desirable electrical and mechanical features for the cable tray system, the use of the appropriate accessories improves the physical appearance of the cable tray system. Some of the most common accessories are shown below and on the following page.



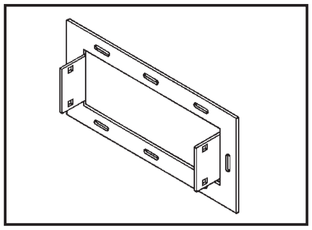
Ladder Dropout



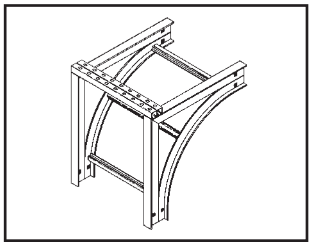
Horizontal Adjustable Splice
Requires supports within 24" on both sides, per NEMA VE 2.



Vertical Adjustable Splice
Requires supports within 24" on both sides, per NEMA VE 2.



Frame Box Connector



Cable Support Fitting

FIREPROOFING CABLE TRAY

Cable trays should not be encapsulated for fire protection purposes other than for the short lengths at fire rated walls unless the cables are adequately derated. Encapsulation to keep fire heat out will also keep conductor heat in. If conductors cannot dissipate their heat, their insulation systems will deteriorate. If the cable tray will be encapsulated, the cable manufacturer should be consulted for derating information.

CABLE TRAY MAINTENANCE AND REPAIR

If the cable tray finish and load capacity is properly specified and the tray is properly installed, virtually no maintenance is required.

Pre-Galvanized - This finish is for dry indoor locations. No maintenance is required.

Hot Dip Galvanized - This finish is maintenance free for many years in all but the most severe environments. If components have been cut or drilled in the field, the exposed steel area should be repaired with a cold galvanizing compound. Cooper B-Line has a spray on zinc coating available which meets the requirements of ASTM A780, *Repair of Hot Dip Finishes*.

Aluminum - Our cable tray products are manufactured from type 6063-T6 aluminum alloy with a natural finish. The natural oxide finish is self healing and requires no repair if it is field modified.

Non-metallic - Fabrication with fiberglass is relatively easy and comparable to working with wood. Any surface that has been drilled, cut, sanded, or otherwise broken, **must be sealed** with a comparable resin. Polyester or vinyl ester sealing kits are available.

Cable tray should be visually inspected each year for structural damage i.e., broken welds, bent rungs or severely deformed side rails. If damage is evident, from abuse or installation, it is recommended that the damaged section of cable tray be replaced rather than repaired. It is much easier to drop a damaged section of tray out from under the cables than it is to shield the cables from weld spatter.

CABLE TRAY. THERMAL CONTRACTION AND EXPANSION

All materials expand and contract due to temperature changes. Cable tray installations should incorporate features which provide adequate compensation for thermal contraction and expansion. Installing expansion joints in the cable tray runs only at the structure expansion joints does not normally compensate adequately for the cable tray's thermal contraction and expansion. The supporting structure material and the cable tray material will have different thermal expansion values. They each require unique solutions to control thermal expansion.

NEC® Section 300.7(B) states that **'Raceways shall be provided with expansion joints where necessary to compensate for thermal expansion or contraction.'** **NEC®** Section 392 does not address thermal contraction and expansion of cable tray. One document which addresses expansion is the NEMA Standards Publication No. VE 2, Section 4.3.2. NEMA VE-2 Table 4-2 shows the allowable lengths of steel and aluminum cable tray between expansion joints for the temperature differential values.

Table 4-2
Maximum Spacing Between Expansion Joints That Provide For One Inch (25.4 mm) Movement

Temp. Differential		Steel		Aluminum		Stainless Steel 304		Stainless Steel 316		FRP	
°F	(°C)	Feet	(m)	Feet	(m)	Feet	(m)	Feet	(m)	Feet	(m)
25	(-4)	512	(156.0)	260	(79.2)	347	(105.7)	379	(115.5)	667	(203.3)
50	(10)	256	(78.0)	130	(39.6)	174	(53.0)	189	(57.6)	333	(101.5)
75	(24)	171	(52.1)	87	(26.5)	116	(35.4)	126	(38.4)	222	(67.6)
100	(38)	128	(39.0)	65	(19.8)	87	(26.5)	95	(29.0)	167	(50.9)
125	(51)	102	(31.1)	52	(15.8)	69	(21.0)	76	(23.2)	133	(40.5)
150	(65)	85	(25.9)	43	(13.1)	58	(17.7)	63	(19.2)	111	(33.8)
175	(79)	73	(22.2)	37	(11.3)	50	(15.2)	54	(16.4)	95	(28.9)

For a 100°F differential (winter to summer), a steel cable tray will require an expansion joint every 128 feet and an aluminum cable tray every 65 feet. The temperature at the time of installation will dictate the gap setting.

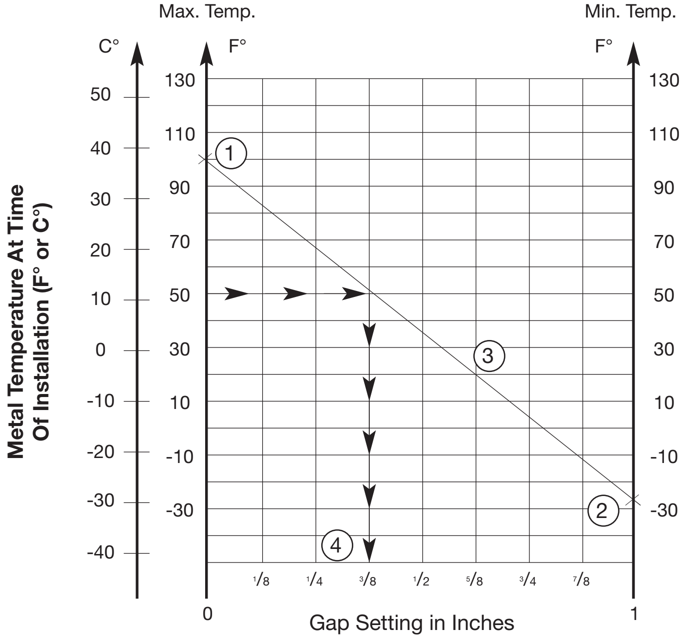


Figure 4.13B
Gap Setting Of Expansion Splice Plate
1" (25.4 mm) Gap Maximum

The Gap

Setting of the Expansion Joint Splice Plate is used as follows per the example indicated in VE-2 Figure 4.13B.

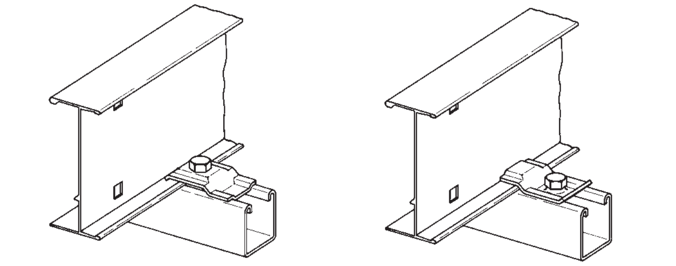
Step 1. Plot the highest expected cable tray metal temperature during the year on the maximum temperature vertical axis. Example's Value: 100 Degrees F.

Step 2. Plot the lowest expected cable tray metal temperature during the year on the minimum temperature vertical axes. Example's Value: - 28 Degrees F.

Step 3. Draw a line between these maximum and minimum temperature points on the two vertical axis.

Step 4. To determine the required expansion joint gap setting at the time of the cable tray's installation: Plot the cable tray metal temperature at the time of the cable tray installation on the maximum temperature vertical axis (Example's Value: 50 Degrees F). Project over from the 50 Degrees F point on the maximum temperature vertical axis to an intersection with the line between the maximum and minimum cable tray metal temperatures. From this intersection point, project down to the gap setting horizontal axis to find the correct gap setting value (Example's Value: 3/8 inch gap setting). This is the length of the gap to be set between the cable tray sections at the expansion joint.

The plotted High - Low Temperature Range in Figure 4-13B is 128° F. The 125° F line in Table 4-1 shows that installations in these temperature ranges would require 3/8" expansion joints approximately every 102 feet for Steel and every 52 feet for Aluminum cable tray.



As a clamp. As a guide.

Another item essential to the operation of the cable tray expansion splices is the type of hold down clamps used. The cable tray must not be clamped to each support so firmly that the cable tray cannot contract and expand without distortion. The cable tray needs to be anchored at the support closest to the midpoint between the expansion joints with **hold down clamps** and secured by **expansion guides** at all other support locations.The expansion guides allow the cable tray to slide back and forth as it contracts and expands. Supports must also be located on both sides of an expansion splice. The supports should be located within two feet of the expansion splice to ensure that the splice will operate properly. If these guidelines for cable tray thermal contraction and expansion are not followed, there is the potential for the cable trays to tear loose from their supports, and for the cable trays to bend and collapse.

Appendix Pages

TABLE I
TEMPERATURE RISE TESTS, CABLE TRAY CONNECTORS, CLASS II ALUMINUM LADDER CABLE TRAY

Test Current Amps And Fuse Size*	Test Time Cycles	I^2T mult. by 10^6	Connector Data								
			C1			C2			C3		
			Type Of Connector	No. & Type Bolts	Temp. Rise °C	Type Of Connector	No. & Type Bolts	Temp. Rise °C	Type Of Connector	No. & Type Bolts	Temp. Rise °C
7,900 1,200A Fuse	66	69	Adj. Vert. 1 Bolt**	4 Steel	6	3/0 CU Bond	AL-CU Lugs	18	Rigid Clean	2 Steel	8
7,900 1,200A Fuse	82	85	Rigid Corroded	4 Steel	10	3/0 CU Bond	AL-CU Lugs	22	Rigid Clean	2 Steel	9
12,000	120	288	Rigid Corroded	2 Nylon	50	3/0 CU Bond	AL-CU Lugs	104	Rigid Clean	2 Steel	32
12,000	124	297	Rigid Corroded	4 Steel	40	Rigid Corroded	4 Lugs	46	Rigid Clean	4 Steel	21
34,600	14	280	Rigid Corroded	2 Nylon	34	3/0 CU Bond	AL-CU Lugs	75	Rigid Clean	2 Steel	29
34,400	14	276	Rigid Corroded	4 Nylon	28	Rigid Corroded	4 Steel	35	Rigid Clean	4 Steel	20

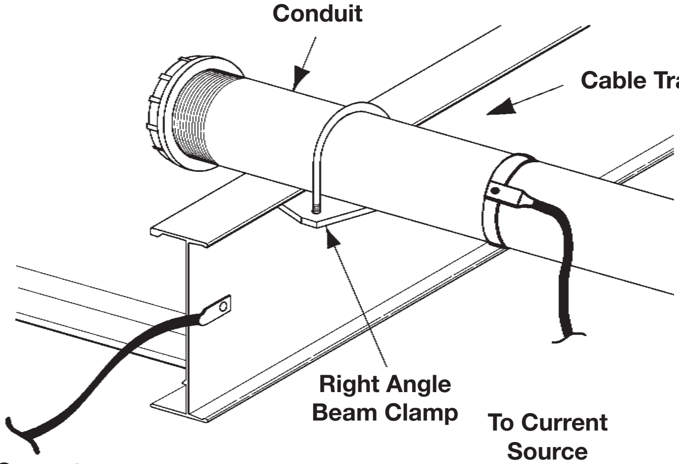
TABLE II
TEMPERATURE RISE TESTS, CABLE TRAY CONNECTORS, CLASS II STEEL LADDER CABLE TRAY

Test Current Amps And Fuse Size*	Test Time Cycles	I^2T mult. by 10^6	Connector Data								
			C1			C2			C3		
			Type Of Connector	No. & Type Bolts	Temp. Rise °C	Type Of Connector	No. & Type Bolts	Temp. Rise °C	Type Of Connector	No. & Type Bolts	Temp. Rise °C
1,980 200A, FU	52	3.4	Adj. Vert. 1 Bolt**	4	2	No. 6 CU Bond	AL-CU Lugs	10	Rigid	2	3
1,970 400A, FU	394	25.5	Adj. Vert. 1 Bolt**	4	9	No. 6 CU Bond	AL-CU Lugs	***	Rigid	2	15
1,960 400A, FU	8100	51.8	Adj. Vert. 1 Bolt**	4	18	Rigid	4	23	Rigid	2	32
12,000	120	288	Adj. Vert. 2 Bolts**	4	94	Adj. Vert. 2 Bolts**	4	89	Rigid	4	81
12,000	123	295	Rigid	4	70	Rigid	4	87	Rigid	4	85
34,000	13	250	Rigid	4	71	Rigid	4	57	Rigid	4	69

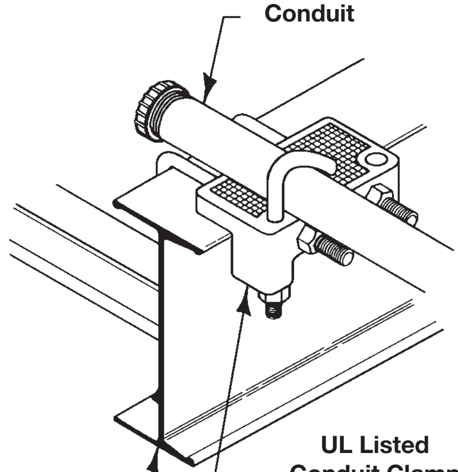
* Test current was interrupted in a predetermined time when a fuse was not used.
** 1 or 2 Bolts - Number of bolts installed on the adjustable vertical connector hinge.
*** The No. 6 bonding jumper melted and opened the circuit when protected by 400A fuse.

(See Page 428 - Figure 1 for Temperature Rise Test illustration)

Appendix Sheet 1



Test Set-Up



Conduit Clamp Detail

CIRCUIT ARRANGEMENT FOR RIGID CONDUIT TEMPERATURE RISE TESTS

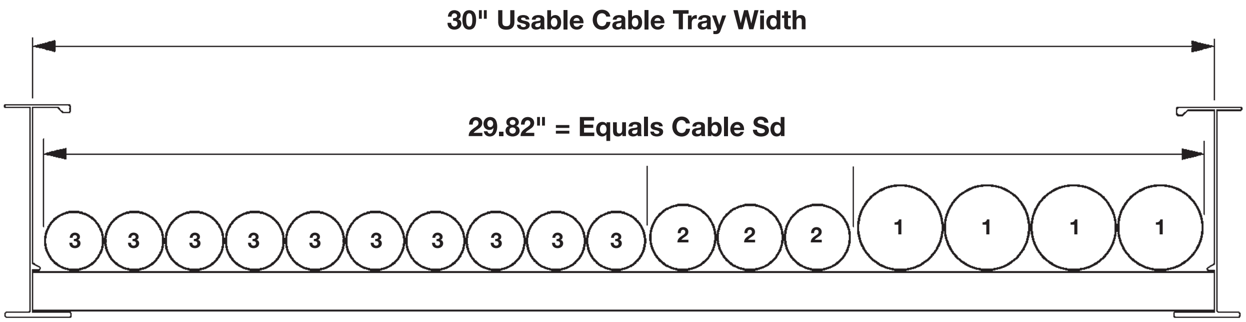
TABLE III
TEMPERATURE RISE TESTS, CONDUIT CLAMPS FOR BONDING RIGID CONDUIT TO CABLE TRAY

Test Current Amperes	Test Time Cycles	I^2T mult. 10^6	Rigid Conduit		Cable Tray		Temp. Rise °C	Condition After Test
			Size	Material	Class	Material		
36,000	16	344.7	4"	Aluminum	II	Aluminum	19	No arcing or damage
20,900	60.5	441.2	4"	Aluminum	II	Aluminum	70	No arcing or damage
12,100	178	433.3	4"	Aluminum	II	Aluminum	74	No arcing or damage
21,000	20	146.8	4"	Steel	II	Steel	(?)	Zinc melted at point where conduit contacted with tray
3,260	900	159.5	4"	Steel	II	Steel	63	No arcing or damage
21,000	30	220	2"	Aluminum	II	Aluminum	21	No arcing or damage
12,100	120.5	294.2	2"	Aluminum	II	Aluminum	59	No arcing or damage
8,000	245	261.1	2"	Aluminum	II	Aluminum	44	No arcing or damage
21,000	14	103.8	2"	Steel	II	Steel	62	Zinc melted at point where conduit contacted with tray
12,000	60.5	145.4	2"	Steel	II	Steel	22	Slight arc between clamp and tray
3,240	600	104.9	2"	Steel	II	Steel	49	No arcing or damage
21,000	20	146.8	1"	Aluminum	II	Aluminum	20	No arcing or damage
12,200	60.5	150.3	1"	Aluminum	II	Aluminum	24	No arcing or damage
12,100	14.5	35.3	1"	Steel	II	Steel	6	No arcing or damage
8,000	63.5	67.84	1"	Steel	II	Steel	59	No arcing or damage
1,980 200A FU	44.5	2.9	1"	Steel	II	Steel	1	No arcing or damage

Appendix Sheet 2

Example - *NEC*® Section 392.22(A)(1)(a)

Width selection for cable tray containing 600 volt multiconductor cables, sizes #4/0 AWG and larger only. Cable installation is limited to a single layer. The sum of the cable diameters (Sd) must be equal to or less than the usable cable tray width.



Cross Section Of The Cables And The Cable Tray

Cable tray width is obtained as follows:

Item Number	List Cable Sizes	(D) List Cable Outside Diameter	(N) List Number of Cables	Multiply (D) x (N) Subtotal of the Sum of the Cables Diameters (Sd)
1.	3/C - #500 kcmil	2.26 inches	4	9.04 inches
2.	3/C - #250 kcmil	1.76 inches	3	5.28 inches
3.	3/C - #4/0 AWG	1.55 inches	10	15.50 inches

The sum of the diameters (Sd) of all cables (Add Sds for items 1, 2, & 3.)
9.04 inches + 5.28 inches + 15.50 inches = 29.82 inches (Sd)
A cable tray with a usable width of 30 inches is required. For a 10% increase in cost a 36 inch wide cable tray could be purchased which would provide for some future cable additions.

Notes:

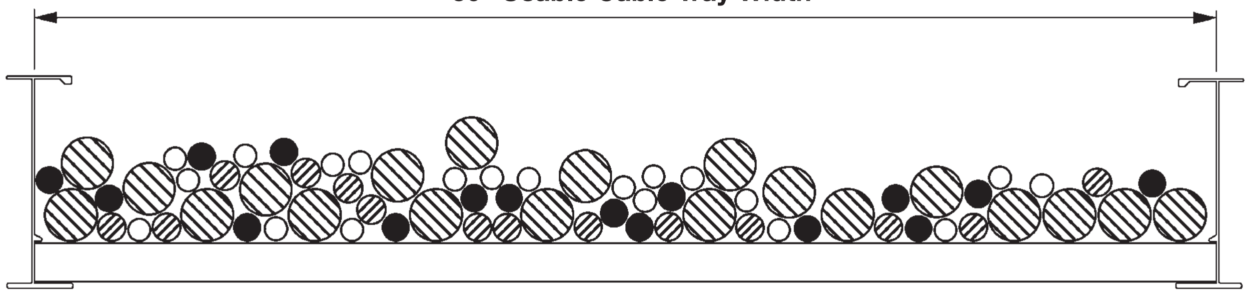
1. The cable sizes used in this example are a random selection.
2. Cables - copper conductors with cross linked polyethylene insulation and a PVC jacket. (These cables could be ordered with or without an equipment grounding conductor.)
3. Total cable weight per foot for this installation.
   61.4 lbs./ft. (without equipment grounding conductors)
   69.9 lbs./ft. (with equipment grounding conductors)
   This load can be supported by a load symbol "B" cable tray - 75 lbs./ft.

Appendix Sheet 3

Cable Tray Manual

Example - *NEC*® Section 392.22(A)(1)(b)

Width selection for cable tray containing 600 volt multiconductor cables, sizes #3/0 AWG and smaller. Cable tray allowable fill areas are listed in Column 1 of Table 392.22(A).



Cross Section Of The Cables And The Cable Tray

Cable tray width is obtained as follows:

Item Number	List Cable Sizes	(A) List Cable Cross Sectional Areas	(N) List Number of Cables	Multiply (A) x (N) Total of the Cross Sectional Area for Each Item
1.	3/C #12 AWG	0.17 sq. in.	20	3.40 sq. in.
2.	4/C #12 AWG	0.19 sq. in.	16	3.04 sq. in.
3.	3/C #6 AWG	0.43 sq. in.	14	6.02 sq. in.
4.	3/C #2 AWG	0.80 sq. in.	20	16.00 sq. in.

Method 1.
The sum of the total areas for items 1, 2, 3, & 4:
3.40 sq. in. + 3.04 sq. in. + 6.02 sq. in. + 16.00 sq. in. = 28.46 sq. inches
From Table 392.9 Column 1 a 30 inch wide tray with an allowable fill area of 35 sq. in. must be used. The 30 inch cable tray has the capacity for additional future cables (6.54 sq. in. additional allowable fill area can be used.)

Method 2.
The sum of the total areas for items 1, 2, 3, & 4 multiplied by

$$\left(\frac{6\text{ in.}}{7\text{ sq. in.}}\right) = \text{cable tray width required}$$

3.40 sq. in. + 3.04 sq. in. + 6.02 sq. in. + 16.00 sq. in. = 28 46 sq. in.

$$\left(\frac{28.46\text{ sq. in. x }6\text{ in.}}{7\text{ sq. in.}}\right) = 24.39\text{ inch cable tray width required}$$

Use a 30 inch wide cable tray.

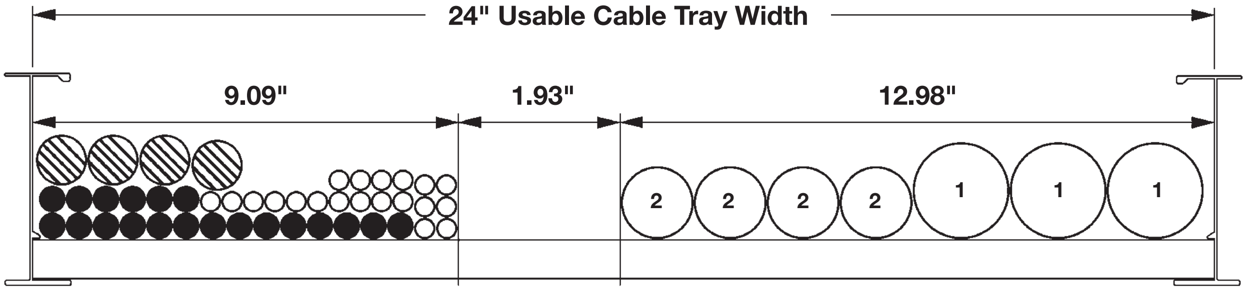
Notes:

1. The cable sizes used in this example are a random selection.
2. Cables - copper conductors with cross linked polyethylene insulation and a PVC jacket. (These cables could be ordered with or without an equipment grounding conductor.)
3. Total cable weight per foot for this installation.
31.9 lbs./ft. (Cables in this example do not contain equipment grounding conductors.)
This load can be supported by a load symbol "A" cable tray - 50 lbs./ft.

Appendix Sheet 4

Example - *NEC*® Section 392.22(A)(1)(c)

Width selection for cable tray containing 600 volt multiconductor cables, sizes #4/0 AWG and larger (single layer required) and #3/0 AWG and smaller. These two groups of cables must have dedicated areas in the cable tray.



<u>Cross Section Of The Cables And The Cable Tray</u>

<u>Cable tray width is obtained as follows:</u>

A - Width required for #4/0 AWG and larger multiconductor cables -

Item Number	List Cable Sizes	(D) List Cable Outside Diameter	(N) List Number of Cables	Multiply (D) x (N) Subtotal of the Sum of the Cables Diameters (Sd)
1.	3/C - #500 kcmil	2.26 inches	3	6.78 inches
2.	3/C - #4/0 AWG	1.55 inches	4	6.20 inches

Total cable tray width required for items 1 & 2 = 6.78 inches + 6.20 inches = 12.98 inches

B - Width required for #3/0 AWG and smaller multiconductor cables -

Item Number	List Cable Sizes	(A) List Cable Cross Sectional Area	(N) List Number of Cables	Multiply (A) x (N) Total of the Cross Sectional Area For Each Item
3.	3/C #12 AWG	0.17 sq. in.	20	3.40 sq. in.
4.	3/C #10 AWG	0.20 sq. in.	20	4.00 sq. in.
5.	3/C #2 AWG	0.80 sq. in.	4	3.20 sq. in.

Total cable tray width required for items 3, 4, & 5

$$(3.40 \text{ sq. in.} + 4.00 \text{ sq. in.} + 3.20 \text{ sq. in.}) \left(\frac{6 \text{ in.}}{7 \text{ sq. in.}}\right)^{1} = (10.6 \text{ sq. in.}) \left(\frac{6 \text{ in.}}{7 \text{ sq. in.}}\right)^{1} = 9.09 \text{ inches}$$

Actual cable tray width is A - Width (12.98 in.) + B - Width (9.09 in.) = 22.07 inches
A 24 inch wide cable tray is required. The 24 inch cable tray has the capacity for additional future cables (1.93 inches or 2.25 sq. inches allowable fill can be used).

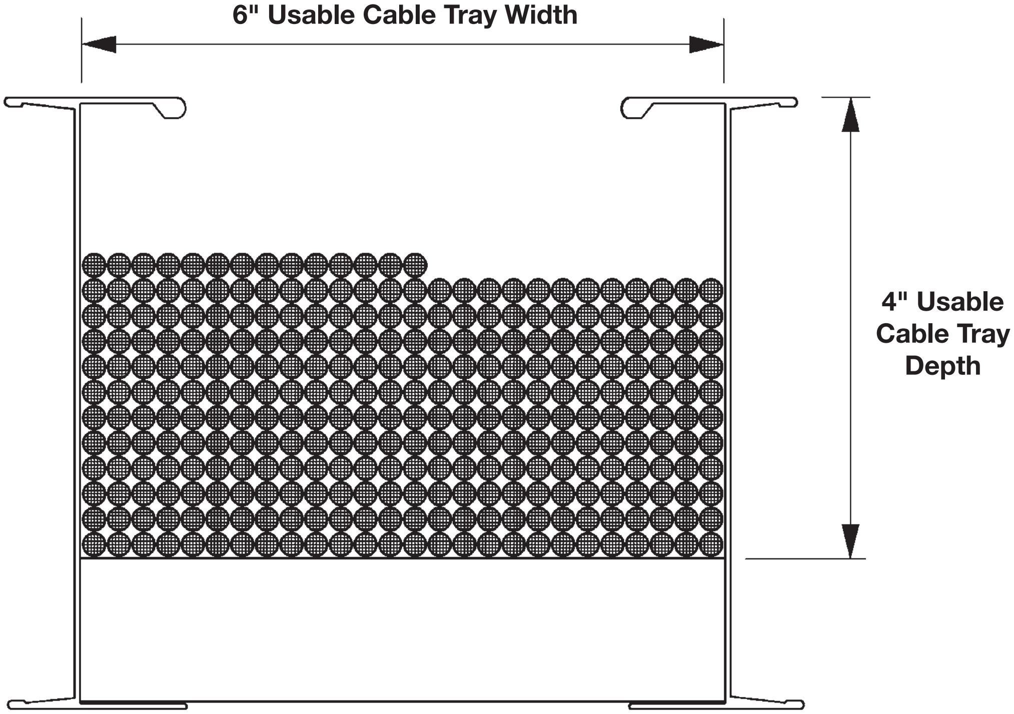
Notes:

1. This ratio is the inside width of the cable tray in inches divided by its maximum fill area in sq. inches from Column 2 Table 392.22(A).
2. The cable sizes used in this example are a random selection.
3. Cables - copper conductors with cross linked polyethylene insulation and a PVC jacket.
4. Total cable weight per foot for this installation.
   40.2 lbs./ft. (Cables in this example do not contain equipment grounding conductors.)
   This load can be supported by a load symbol "A" cable tray - 50 lbs./ft.

Appendix Sheet 5

Example - *NEC*® Section 392.22(A)(2)

Cable Tray containing Type ITC or Type PLTC Cables



Cross Section Of The Cables And The Cable Tray

50% of the cable tray useable cross sectional area can contain type PLTC cables

4 inches x 6 inches x .050 = 12 square inches allowable fill area.

2/C - #16 AWG 300 volt shielded instrumentation cable O.D. = 0.224 inches.

Cross Sectional Area = 0.04 square inches.

$$\frac{\text{12 sq. in.}}{\text{0.04 sq. in./cable}} = \text{300 cables can be installed in this cable tray.}$$

$$\frac{\text{300 cables}}{\text{26 cables/rows}} = \text{11.54 rows can be installed in this cable tray.}$$

Notes:

1. The cable sizes used in this example are a random selection.
2. Cables - copper conductors with PVC insulation, aluminum/mylar shielding, and PVC jacket.

Appendix Sheet 6

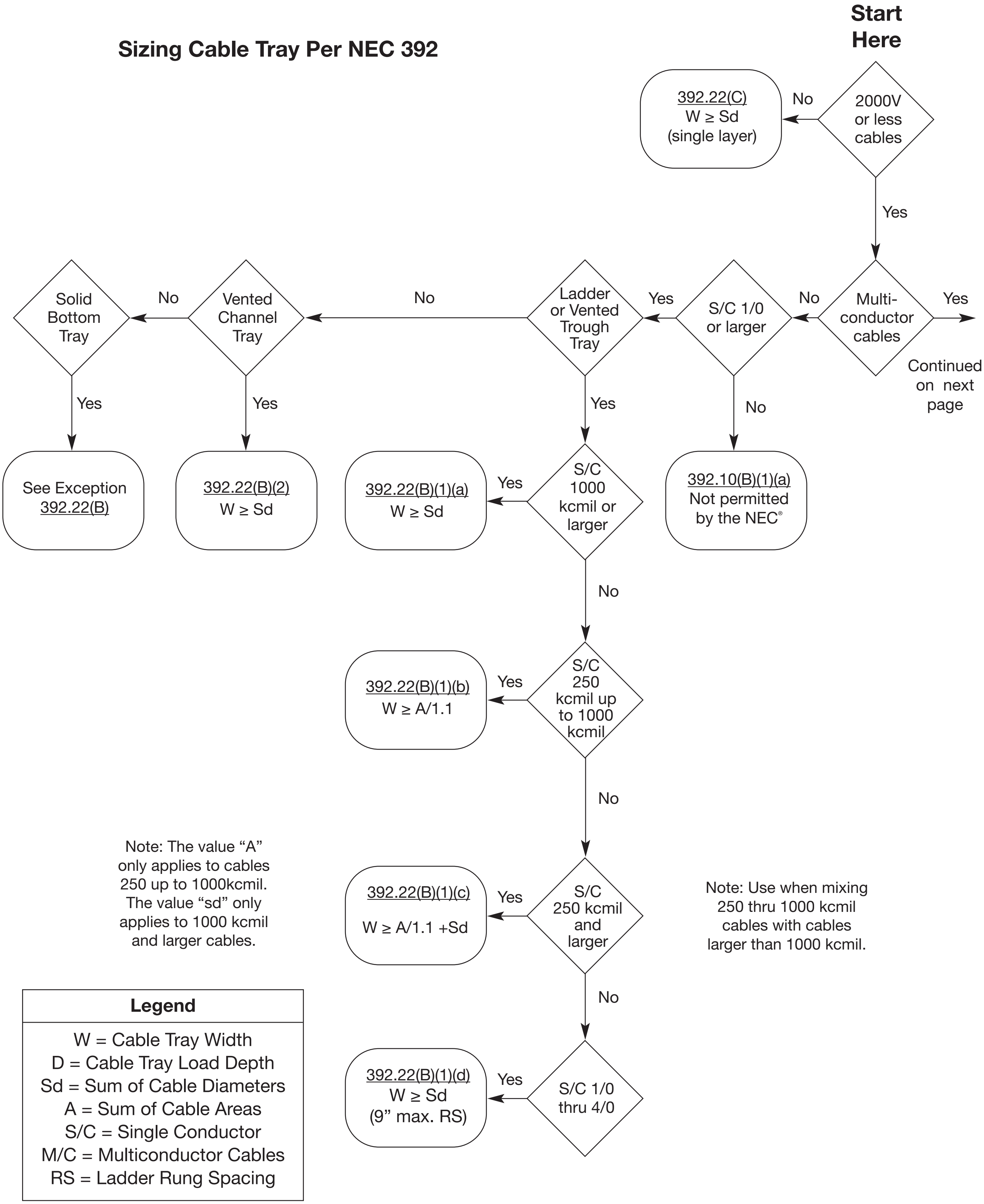
Table 250.122. Minimum Size Equipment Grounding Conductors for Grounding Raceways and Equipment

Rating or Setting of Automatic Overcurrent Device in Circuit Ahead of Equipment, Conduit, etc., Not Exceeding (Amperes)	Size (AWG or kcmil)	
	Copper	Aluminum or Copper-Clad Aluminum*
15	14	12
20	12	10
60	10	8
100	8	6
200	6	4
300	4	2
400	3	1
500	2	1/0
600	1	2/0
800	1/0	3/0
1000	2/0	4/0
1200	3/0	250
1600	4/0	350
2000	250	400
2500	350	600
3000	400	600
4000	500	750
5000	700	1200
6000	800	1200

Appendix Sheet 7

CABLE TRAY SIZING FLOWCHART

Sizing Cable Tray Per NEC 392

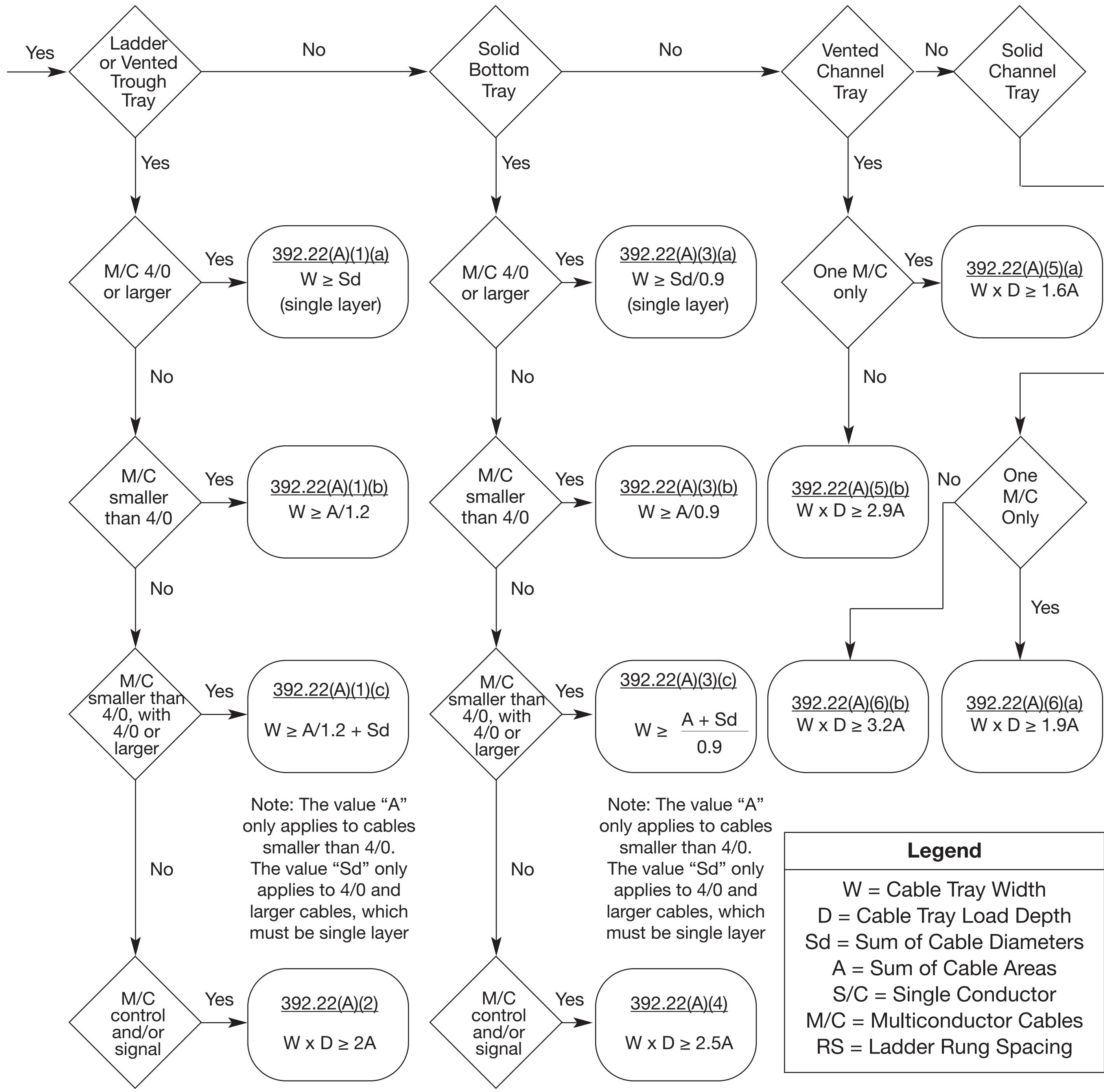


Appendix Sheet 8

CABLE TRAY SIZING FLOWCHART

Ampacity: See pages 430 - 432 for information on cable ampacity that might affect the cable tray sizing flowchart.

See pages 411 - 414 for information on hazardous (classified) areas that might affect the cable tray sizing flowchart.



Appendix Sheet 8

CABLE TRAY INSTALLATION & SPECIFICATION CHECKLIST

Project Information

Project Name: ______________________ # __________
Location: ______________________
Contractor/Engineer: ______________________
Phone: ______________________

Project Information

Distributor Name: ______________________
Location: ______________________
Contact: ______________________
Phone: ______________ Fax: ______________

Cable Tray

Material

Aluminum	❏
Pre-Galvanized Steel	❏
Hot-Dip Galvanized Steel	❏
304 Stainless Steel	❏
316 Stainless Steel	❏
Fiberglass-Polyester Resin	❏
Fiberglass-Vinyl Ester Resin	❏
Fiberglass-Zero Halogen	❏
Fiberglass-Dis Stat	❏

NEMA Load Depth*

2” **	❏
3”	❏
4”	❏
5”	❏
6”	❏

** Load depth is 1” less than siderail height.*

*** Fiberglass and wire mesh.*

Width

6”	❏
9”	❏
12”	❏
18”	❏
24”	❏
30”	❏
36”	❏
42”	❏

Bottom Styles

6”	❏
9”	❏
12”	❏
18”	❏
Ventilated Trough	❏
Non-Ventilated Trough	❏
Non-Ventilated Bottom	❏

Length

Metallic

120”	❏
144”	❏
240”	❏
288”	❏
	❏

Non-Metallic

120”	❏
240”	❏

Fitting Radius

12”	❏
24”	❏
36”	❏
48”	❏

Tray Series

B-Line Series __________ OR

System Loading

(50 lbs./ft.)	❏
(75 lbs./ft.)	❏
(100 lbs./ft.)	❏
__________	❏

Support Span ________ ft.
Load Rating ________ lbs./ft.
Safety Factor ________

Appendix Sheet 9

CABLE TRAY INSTALLATION & SPECIFICATION CHECKLIST

Cable Channel

Material

Aluminum ❑
Pre-Galvanized Steel ❑
Hot-Dip Galvanized Steel ❑
304 Stainless Steel ❑
316 Stainless Steel ❑
Fiberglass-Polyester Resin ❑
Fiberglass-Vinyl Ester Resin ❑
Fiberglass-Zero Halogen ❑
Fiberglass-Dis Stat ❑

Type

Ventilated ❑
Non-Ventilated ❑

Width

3” ❑
4” ❑
6” ❑
8” * ❑

** Fiberglass only.*

Fitting Radius

0” ❑
6” ❑
12” ❑
24” ❑
36” ❑

Cent-R-Rail

System

Data-Track ❑
Verti-Rack ❑
Half-Rack ❑
Multi-Tier Half Rack ❑

Depth*

Straight Rung ❑
2” ❑
3” ❑
4” ❑
6” ❑

Width*

3” ❑
6” ❑
9” ❑
12” ❑
18” ❑
24” ❑

Rung Spacing*

6” ❑
9” ❑
12” ❑
18” ❑
24” ❑

Tiers*

2 ❑
3 ❑
4 ❑
5 ❑
6 ❑

Length

120” ❑
144” ❑

* Options shown are not available for all systems. Please check B-Line Cent-R-Rail Catalog for availability.

Flextray

Width*

2” ❑
4” ❑
6” ❑
8” ❑
12” ❑
16” ❑
18” ❑
20” ❑
24” ❑
30” ❑
32” ❑

Depth*

1.5” ❑
2” ❑
4” ❑
6” ❑

* Widths shown are not available for all depths.

Wire Mesh Size

2 x 4

Length

118” (3 meters)

Appendix Sheet 9

Footnotes:

[1] NEMA Standard VE-2, Section 4, Installation 4.3 Straight Section Installation - 4.3.1. Horizontal Cable Tray Straight Sections states that straight section lengths should be equal to or greater than the span length to ensure not more than one splice between supports.

Additional Cable Tray Resources

Cable Tray Institute 1300 N. 17th Street Rosslyn, VA 22209 www.cabletrays.com	National Electrical Manufacturers Association 1300 N. 17th Street Rosslyn, VA 22209 www.nema.org

B-Line Engineering Software

TrayCAD™

TrayCAD is a Cable Tray layout design program that works within the AutoCAD® environment. TrayCAD is a windows based program and installs as an add-on to your AutoCAD system. Use the TrayCAD toolbar to add cable tray to your existing plans by drawing a single centerline representation of the tray run. Then, with the click of a button, the program will build a full-scale 3-D wire-frame model of the cable tray and all the appropriate fittings. The program also automatically creates a Bill of Material and contains a library of modifiable details.

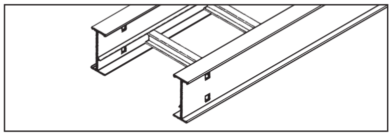
Runway Router™

Runway Router is a cable ladder runway (ladder rack) layout design program that works within your AutoCAD environment. Use the commands from the Runway Router toolbar to layout runway, relay racks and electronic cabinets. Add cable tray or Cent-R-Rail™ to your existing plans by drawing a single centerline representation of the cable run. Then, with the click of a button, the program will build a full-scale 3-D wire-frame model of the cable runway and all the appropriate connectors and fittings. The program also automatically creates a Bill of Material and contains a library of modifiable details.

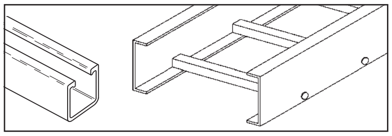
Cooper B-Line Wire Management Resources

Cooper B-Line Product Catalogs

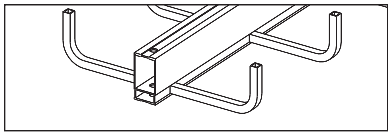
- Cable Tray Systems ....
  Metallic, Two Siderail System
  Commercial and Industrial Applications



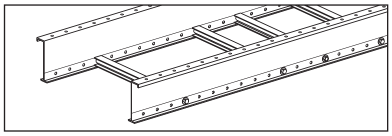
- Fiberglass Cable Tray ....
  Non-Metallic, Two Siderail Trays
  Non-Metallic Strut Systems



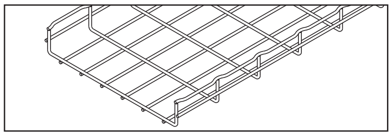
- Cent-R-Rail™ ....
  Center Supported Cable Tray
  "Lay-In" Cable Design for Easy Installation
  of Low Voltage Cables



- Redi-Rail™ ....
  Pre-Punched Aluminum Side Rail Design
  Unmatched Job Site Adaptability for a Two
  Side Rail System - Load Depths 2" to 6"

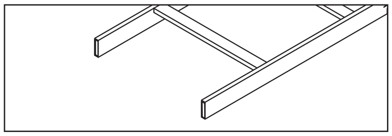


- Flextray™ ....
  Unmatched Adaptability to Site Conditions
  Pre-Packaged Installation Kits and Accessories
  Fast - Adaptable - Economical

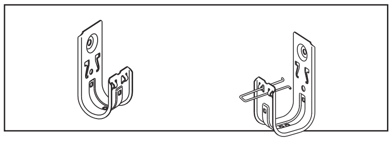


Other Cooper B-Line Wire Management Systems

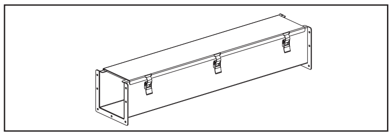
- Telecom ....
  Saunders' Cable Runway and Relay Racks
  Unequal Flange Racks



- Cable Hooks ....
  Supports all Cat 5, Fiber Optic, Innerduct
  and Low Voltage Cabling Requirements

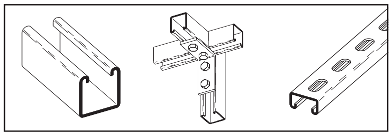


- Wireway ....
  Houses Runs of Control and Power Cable
  Available in NEMA 12, Type 1 & Type 3R

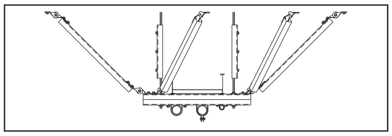


Cooper B-Line Mechanical Support Systems

- Strut Systems ....
  Metal Framing Support System. Fully Adjustable
  and Reusable, with a Complete Line of Channel,
  Fittings and Accessories for Multi-Purpose Applications



- Seismic Restraints ....
  Multi-Directional Bracing for Electrical Conduit,
  Cable Tray and Mechanical Piping Systems.
  OSHPD Pre-Approved Details



EATON | Cutler-Hammer

Pow-R-Line® Switchboards

Instruction Manual

New Information

Safety Measures

This publication contains instructions on the installation of Cutler-Hammer® brand Pow-R-Line low voltage distribution switchboards from Eaton's Electrical business. Any person or persons that design, purchase, install, operate or maintain new systems utilizing these products must understand the equipment, its markings and limitations.

Hazardous voltages in distribution switchboards and all other electrical equipment pose a potential hazard to life and property. Please follow instructions, labeling and applicable codes and standards for installation, maintenance and operation of this equipment and its components. Only "Qualified Persons" should install and/or service this equipment. C22.1 Canadian Electrical Code® Part 1 defines a "Qualified Person" as "One who has skills and knowledge related to the construction and operation of electrical equipment and installations and has received safety training on the hazards involved."

Standard symbols have been established for recognition of potentially hazardous situations and conditions. Please review and understand the critical warning symbols shown below. These symbols will appear on safety labels affixed to the product. Installer should always read and understand these labels before working on equipment.

Symbol	Meaning
	The addition of either symbol to a "Danger" or "Warning" safety label indicates that an electrical hazard exists which will result in personal injury if the instructions are not followed.
	This is the safety alert symbol. It is used to alert you to potential personal hazards. Obey all safety messages that follow this symbol to avoid possible injury and death.

DANGER

"DANGER" INDICATES AN IMMINENTLY HAZARDOUS SITUATION WHICH, IF NOT AVOIDED, *WILL RESULT* IN DEATH OR SERIOUS INJURY.

WARNING

"WARNING" INDICATES A POTENTIALLY HAZARDOUS SITUATION WHICH, IF NOT AVOIDED, *CAN RESULT* IN DEATH OR SERIOUS INJURY.

CAUTION

"CAUTION" INDICATES A POTENTIALLY HAZARDOUS SITUATION WHICH, IF NOT AVOIDED, *CAN RESULT* IN MINOR OR MODERATE INJURY.

CAUTION

"CAUTION", USED WITHOUT THE SAFETY ALERT SYMBOL, INDICATES A POTENTIALLY HAZARDOUS SITUATION WHICH, IF NOT AVOIDED, *CAN RESULT* IN PROPERTY DAMAGE.

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Introduction

This instruction manual is designed to supplement other industry standards including all local, provincial and federal codes and safety regulations, such as OSHA. (C22.1 Canadian Electrical Code). *Operation and Maintenance of Deadfront Distribution Switchboards Rated 600 Volts and Less*, other workplace, electrical installation requirements and all safety rules.

Safety

Due to the weight and size of switchboards and dangers from electrical hazards, every precaution should be taken to maintain safe working conditions when handling this equipment. Due to the custom nature of switchboards and the site variables, every potential situation cannot be anticipated. Safety must always be the overriding factor.

Pre-Installation: Receiving, Handling and Storage

Receiving

Upon delivery, use the packing list to confirm the number of items against what was received to ensure that the shipment is complete. Any discrepancies should be noted on the freight bill before signing. Report any shortages or damage to the freight carrier immediately.

Immediately upon receipt of the switchboard, the plastic covering should be carefully removed and a thorough inspection of each section should be made to detect any damage incurred during shipment. Any damage should be noted on the bill of lading (freight bill) and the consignee receiving the equipment should notify the freight carrier. **FAILURE TO NOTIFY THE FREIGHT CARRIER OF DAMAGE IN A TIMELY MANNER MAY RESULT IN THE CONSIGNEE ASSUMING THE COSTS ASSOCIATED WITH REPAIR OR REPLACEMENT OF DAMAGED EQUIPMENT.**

After inspection, it is recommended that a plastic covering be used to protect the equipment from dust, dirt, moisture and damage until ready for installation.

The switchboard should remain attached to its shipping skid until it has been moved into its final installation position.

Handling

WARNING

SWITCHBOARD IS TOP HEAVY. USE CARE IN HANDLING.

Switchboards are top heavy. Switchboard sections may weigh over 2000 pounds. Before moving or lifting, verify that the equipment used to handle the switchboard is within safe limits of its lifting capacity.

Switchboard shipping lengths will vary. Each shipping section is bolted with lag bolts to heavy wooden skids that extend beyond all sides of the switchboard.

Utilizing Lifting Means

Lifting means are bolted to each switchboard shipping length. Lifting a switchboard by crane is the recommended method for moving this equipment.

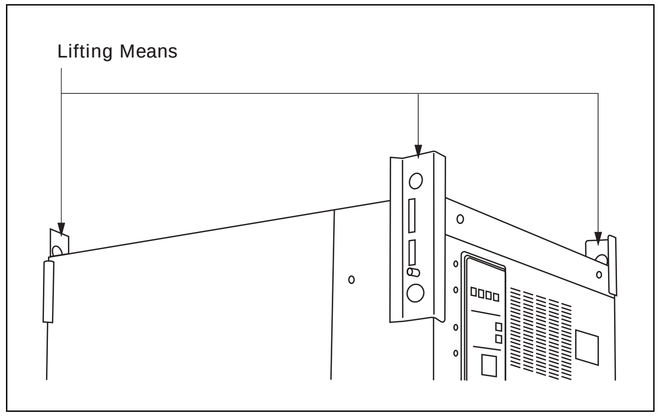


Figure 1. Typical Indoor Lifting Means

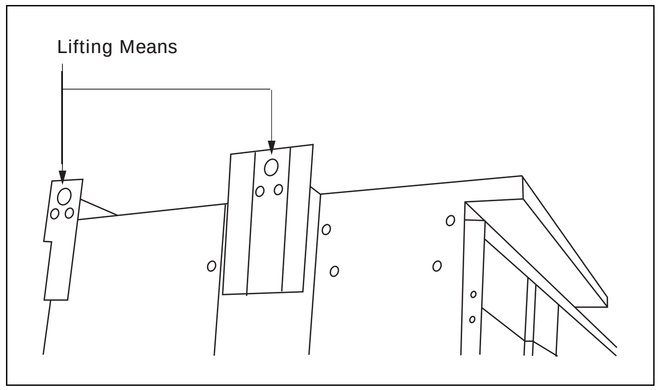


Figure 2. Typical Outdoor Lifting Means

DO NOT pass cables or chains through the holes in the lifting means. Utilize cables or chain with hooks or shackles rated for the load and weight of the switchboard shipping length to be lifted.

Prepare a sling and a spanner or spreader. (See **Figures 3** and **4**.) Eaton does not provide chain, cables, shackles, hooks, spanner or spreader.

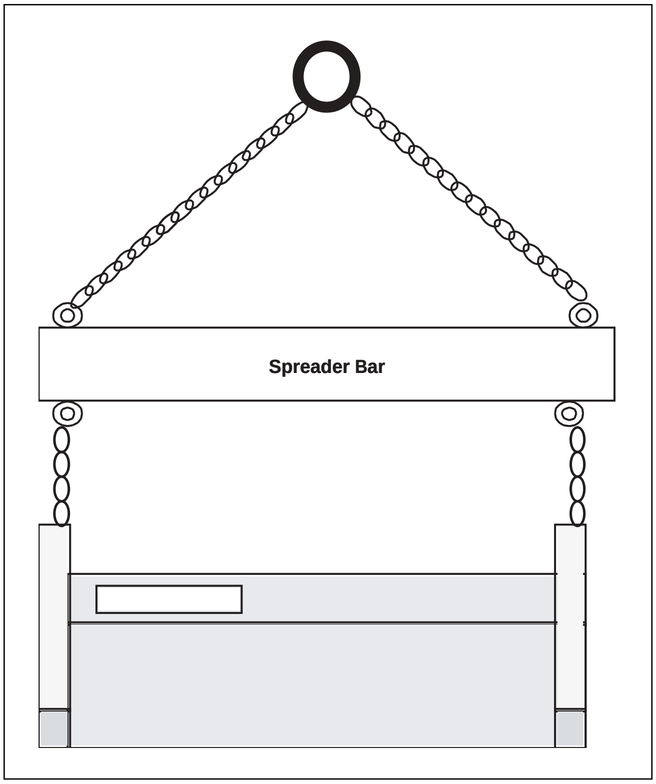


Figure 3. Front View

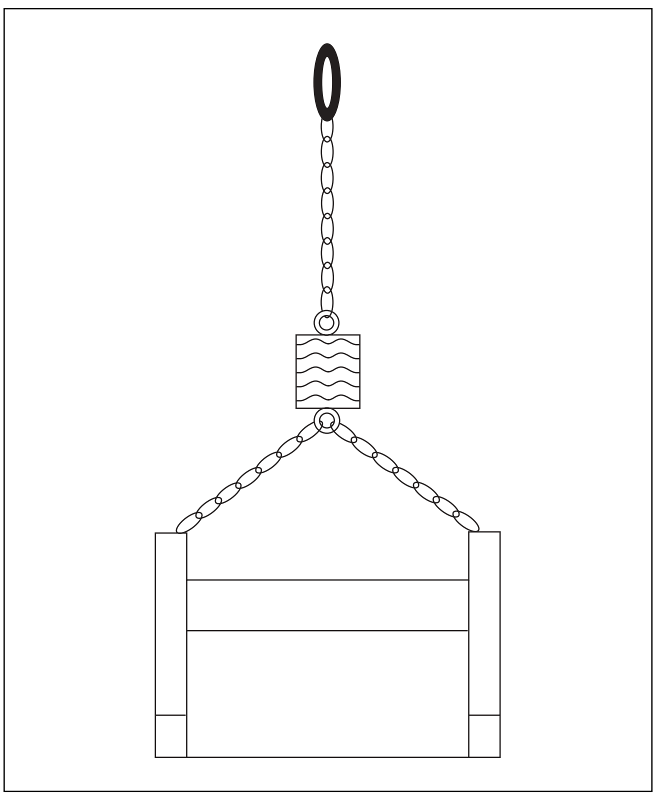


Figure 4. Side View

Chains/cables must be securely attached to hooks, eyes and shackles and the spanner/spreader. Prior to lifting, check the security of the rigging assembly. Use the crane to bring the assembly taut without raising the switchboard from the floor.

Check the security of the rigging, again. Make any adjustments necessary before moving the equipment.

Slowly lift equipment to the minimum height from the floor required to safely relocate it. Move the equipment to approximately 2 inches above its resting place. Safely make a visual inspection of the rigging. If necessary, return the switchboard to its original resting place to make any modifications necessary to the rigging.

Forklifts

A forklift may be utilized for handling switchboards. Only personnel trained for that equipment should operate forklifts.

Be sure that the ground surface is solid and follow all safety recommendations for operating the forklift. Be aware of wet or slick floors and surfaces, which can affect stopping and turning. Check labeling on the switchboard packaging material for additional information.

Verify that the forklift load and lifting ratings are within safe limits for the weight of the switchboard being lifted.

Do not lift switchboard from the front. Damage to components, such as breakers, fusible switches and metering, can result.

CAUTION

SWITCHBOARD IS TOP HEAVY. USE CARE IN HANDLING.

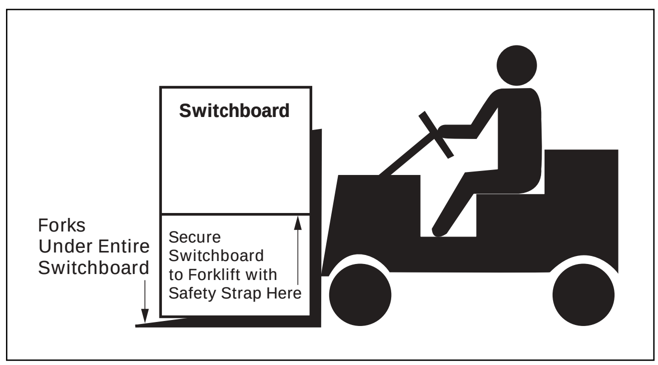


Figure 5. Forklift

Note: Always use caution when moving switchboards, which are top-heavy equipment.

The forks or blades of the forklift must run through the entire switchboard shipping length and shall be extended to the outermost sides of the wooden shipping skids. (See **Figure 5**.)

Secure the switchboard with a safety strap, belt or leash approved for this purpose. Take care in positioning of the strap to ensure stability of the equipment and confirm that it is not in an area that will damage components.

Slowly lift equipment to the minimum height from the floor required to safely relocate it.

Rollers

Rollers should only be used on solid and flat surfaces, such as a finished floor. Only use rollers suitable for this purpose.

Storage

Switchboards, which cannot be immediately installed and energized, should be stored in an indoor dry, clean and heated environment.

Do not store in areas where conditions such as dampness, changes in temperature, cement dust or a corrosive atmosphere is present.

Should the storage area be prone to moisture condensation, take precaution by making sure that the switchboard is covered and install temporary heating equipment. Approximately 250 watts per vertical section are required for average conditions.

Switchboards should be placed on solid, level surfaces for storage. Switchboard sections must remain in an upright position at all times. Laying switchboard sections on their back or side can result in permanent damage to components and the switchboard structure.

Outdoor switchboards are not weather resistant until completely and properly installed and energized. Additionally, utilizing temporary heating as described above should keep an un-energized outdoor switchboard dry internally.

Pre-Installation Preparation

The permanent location of switchboards must be on a smooth, solid and level foundation. Alignment is verified in the factory prior to shipment.

An uneven foundation can cause misalignment of sections, units, doors and other parts.

If a housekeeping pad is utilized, check factory drawings and verify handle height rules relative to the Canadian Electrical Code (CEC) and utility meter heights where applicable.

When embedded anchors or channel sills are used, materials and attachments must be adequate to support the structure(s). Switchboard sections must be aligned and level over the length of the installation.

From manufacturer's drawings, determine the layout of the electrical distribution equipment for each location. Verify and confirm that the available equipment space and equipment location(s) is in compliance with the minimum working space clearances per the CEC.

Refer to the manufacturer's switchboard drawings for available conduit area in each section before installing the finished grade flooring. (See **Figure 6**.) Conduits must be installed in conduit area shown to ensure compliance with CEC wire bending space requirements.

Note: Conduit areas may vary in each section of a multi-section switchboard lineup.

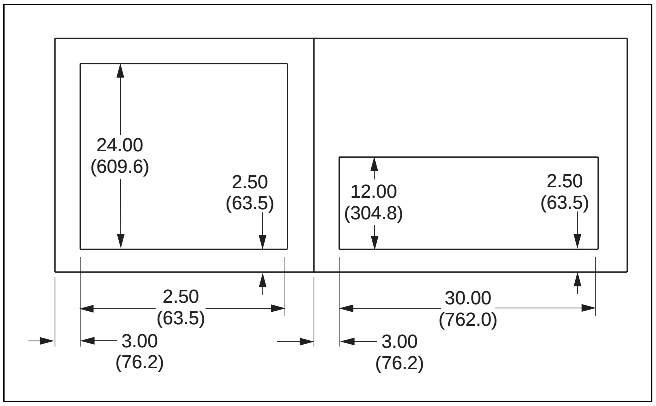


Figure 6. Typical Conduit Space Drawing — Floor Plan

Note: Used for reference only. See drawings for actual space.

The preferred method of anchoring the switchboard is by fastening the switchboard to steel channels that are properly and permanently embedded in a concrete floor or by using anchors designed for this purpose.

Conduits, floor and/or wall openings, such as busway or other penetrations, should be located relative to the space shown on the manufacturer's drawings.

Refer to the Canadian Electrical Code for installations in damp locations for additional requirements.

Final preparation of the entire area and around the switchboard should be thoroughly cleaned of all debris.

Considerations for Seismic Qualified Installations

Switchboards that are “Seismically Qualified” require additional considerations. Since electrical equipment is installed as part of a system, pre-engineering layouts are critical in seismic applications.

When seismic qualified and marked Cutler-Hammer brand switchboards are used, anchoring the switchboard recommended by the design engineer is critical. Experienced engineers in seismic requirements should select methods and techniques of attachment and tested anchoring systems. Embedded concrete anchors or steel attachments must be adequate to resist the forces established by the local building code. Bolts of the proper grade of steel must be correctly sized and torqued. The embedded anchors must be correctly installed in accordance with the method specified by the anchor manufacturer.

Conduit layout in concrete for loads entering and/or exiting the bottom must be designed and installed to prevent damage from an earthquake. If top entry is necessary, seismic fittings or flexible conduit is needed.

Consult applicable local building codes and regulatory agencies for other specific requirements for seismic installations.

Additionally, six (6) inches of space should be added to the length of the switchboard assembly to accommodate seismic anchor plates. Contact Eaton for additional information.

Installation

Use caution and appropriate equipment and practices when moving switchboard into its final position.

CAUTION

SWITCHBOARD IS TOP HEAVY. USE CARE IN HANDLING.

Determine the switchboard orientation with the use of manufacturer’s drawings and markings on the switchboard sections. Switchboards may be shipped either in individual sections or in two or more sections joined by the manufacturer. The individual sections are marked “SS” to show shipping splits.

Alignment of multi-section switchboards is designed to be front and rear aligned or rear (only) aligned. Drawings provided by the manufacturer and located in the switchboard will show footprint details. Orientation, as shown on the drawings, must be maintained. (See **Figures 7** and **8**.)

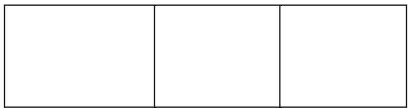


Figure 7. Example of Front and Rear Aligned Switchboard

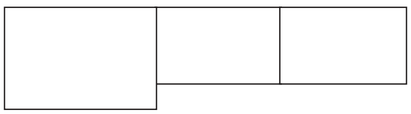


Figure 8. Example of Rear Aligned Switchboard

Sections may contain factory cross bus and/or cable to connect power between switchboard structures and other components. Installers should note the location and orientation of all splice plates and/or cables as reference for installation once sections are joined.

If supplied, remove splice plates and associated hardware, again noting the orientation for re-installation once switchboard is in place. If additional hardware is needed to complete these connections, extra hardware will be provided. For shipping purposes, it will typically be secured inside one of the structures. Keep bus and hardware in a clean and protected environment to guard against damage until re-installation. Protect any factory-installed cables (wire) used to connect components between sections from damage when moving switchboard sections into place.

An outdoor multi-section switchboard will ship with un-installed intermediate roof cap(s) for each joint between sections. Remove roof cap(s) prior to moving sections into their permanent position. Retain roof cap(s) and associated hardware for re-installation. Keep roof caps and associated hardware in a clean and protected environment to guard against damage awaiting re-installation.

There are two roof designs for outdoor switchboards. These are the flat roof design and the sloped roof design.

The standard outdoor switchboard utilizes a flat roof design. This design does not require any sealant when the intermediate roof cap is correctly installed in the field.

The optional sloped roof outdoor design also uses an intermediate roof cap design. When a break occurs between sections for shipping purposes, the intermediate roof cap on the optional outdoor sloped roof design shall have a 3/16” minimum bead of silicone sealant (RTV 732) applied to the underneath side of the roof cap. Each roof cap should have two (2) continuous beads of sealant from end to end. Each bead must be located between the row of mounting holes and the outer edge of the roof cap. A tube of sealant is provided with every outdoor switchboard for customer’s use.

Use caution and appropriate equipment and practices when moving switchboard into its final position.

WARNING

SWITCHBOARD IS TOP HEAVY. USE CARE IN HANDLING.

Exercise caution while maneuvering top-heavy switchboard sections into place. Switchboard sections must always remain in the upright position during installation. Use care when moving the switchboard so not to damage the section, including the structural base and frame. Some switchboards house sensitive components, which can be damaged by rough handling.

Prior to moving the switchboard sections into its permanent position, make note of all obstacles including conduit stubs. Implement a plan for safe transition and appropriate means to accommodate these obstructions. Take note of conduits entering through the bottom of the switchboard, rear of the switchboard, and at the top of the switchboard to ensure appropriate clearances from chassis, structure, cross bus, ground, neutral and components.

Provide space for a minimum 1/2” clearance from back of switchboard and any wall for front accessible switchboards installed indoors.

Front accessible switchboards, which are built and marked for outdoor installation, must maintain a 6-inch minimum clearance from any wall or building structure. For other required clearances, including rear-connected switchboard, refer to the Canadian Electrical Code (CEC) clearances.

When unpacking the switchboard, exercise care not to scratch or mar the finish. Repair all scratches with touch-up paint, which is available from Eaton. Remove shipping skids and all packaging material. Remove any temporary shipping braces or spacers. Remove lifting angles and associated hardware. Plug lifting angle holes with hole plugs supplied by the manufacturer. (See **Figure 9**.)

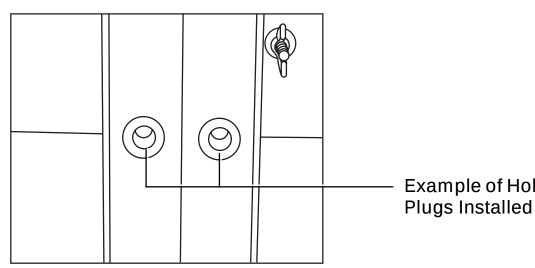


Figure 9. Hole Plugs Installed

Where two or more switchboard sections are to be joined together, they should first be aligned and all sections leveled.

Once aligned and level, attach switchboard sections together.

Attaching Switchboard Sections

The manufacturer has provided hardware with the equipment to join switchboard sections. The hardware includes 3/8" x 1 1/8" carriage bolts and 3/8" hex nuts with captive Belleville-type washer. (See **Figure 10**.)

Holes are provided on the side of each switchboard section for this purpose. Three holes are located on the side of each section towards the front and back. Switchboards with deep designs, including rear-connected switchboards, may have an additional three holes for attachment on the center vertical section support. (See **Figure 11**.)

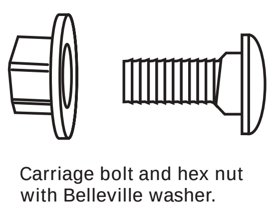


Figure 10. Hardware

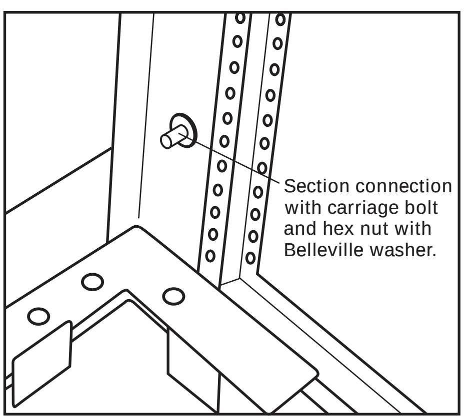


Figure 11. Switchboard Section Connection

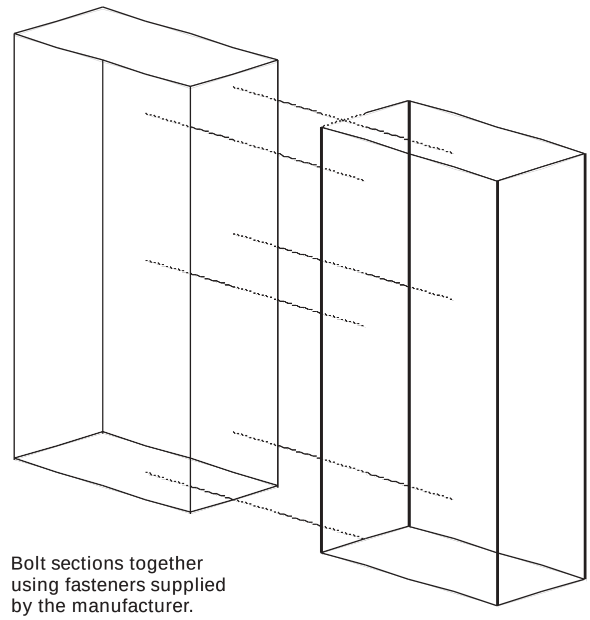


Figure 12. Joining Switchboard Sections

Join sections utilizing the carriage bolts and hex nuts with captive Belleville-type washer through the holes provided. (See **Figure 12**.) While maintaining level and alignment of the structures, torque each connection to the values shown in Appendix **Table 2**.

If switchboard sections are outdoor type, re-install roof cap(s). Visually inspect the roof cap to ensure a reliable, permanent watertight fit prior to energizing the switchboard.

Once the switchboard structures are attached, visually inspect the board for foreign objects and visually inspect the structure for proper clearances of live parts.

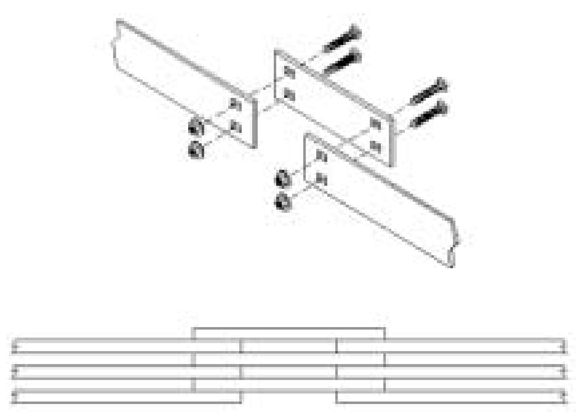
Electrical Connection of Switchboard Sections

Several methods may be used to make electrical connections within switchboards. More than one of these methods may be used in a section and/or switchboard lineup. These include bus splice plates, factory installed cable and busway connections. Consult the manufacturer's drawings for details for each switchboard section.

Remove structure deadfront covers and side sheets as needed to access switchboard chassis and components. Retain all cover mounting hardware and covers for re-assembly. Protect hardware and parts from moisture, debris and damage.

Splice Plates

Splice plates are short pieces of bus bar that join the main bus running horizontally through multiple section switchboards. Depending on the configuration and alignment of the switchboard, the splice plates used for the main cross bus may vary. These plates may either be flat or "Z" shaped. (See **Figures 13**.)



View "A"
Typical View When More
Than 1 Bar Per Phase

Figure 13. Splice Plates

For larger amperage switchboards, multiple splice plates are to be used on the same phase. Maintain the orientation, by phase and sequence of the splice plates. The orientation of the splice plates must remain identical as they were shipped from the manufacturer. Clearances must be maintained. If unsure about the correct orientation or questions about the installation, contact Eaton before installing the splice plates.

Splice plates are used to attach the main horizontal bus between switchboard sections or shipping splits. While maintaining the correct phase orientation and sequence, install splice plates with the carriage bolts and hex nuts with captive Bellville washers supplied by the manufacturer. Refer to Appendix **Table 2** for torque values.

Carriage bolts must align with the corresponding rectangular holes in the fixed horizontal bus and the splice plates. If multiple splice plates are used, install in the same sequence as shipped from the manufacturer. The neutral (when furnished) and ground bus should be connected in the same manner.

Inspect splices plates and main fixed horizontal bus prior to installation. If there is any suspected damage, contact the manufacturer immediately for replacements. NEVER ENERGIZE ANY SWITCHBOARD WITH DAMAGED BUS OR COMPONENTS.

To accommodate future serviceability, the manufacturer recommends that the head of the carriage bolt should be mounted from the rear of the switchboard for FRONT ACCESSIBLE switchboards with the hex nut with Belleville washer positioned to the front.

For REAR ACCESSIBLE switchboards, the manufacturer recommends that the head of the carriage bolt should be mounted from the front of the switchboard with the hex nut and Belleville washer positioned to the rear.

Repeat the process until all holes in the horizontal bus are connected with bolts and nuts for each shipping split. Inspect connections to ensure that there is no foreign material at the connection point and that all connections are properly aligned and bolts are seated.

Torque all connections to torque requirements on labels affixed to each switchboard and as shown in Appendix **Table 2**.

IFS Switchboard Factory Cabling

Some switchboards utilize cable/wire for some connections in lieu of bus. Cabling is typical in Integrated Facility System™ (IFS™) type switchboards that incorporate lighting and appliance branch circuit panelboards and dry-type distribution transformers within a switchboard lineup.

Eaton's selection of wire and cable follows CSA 22.2 NO.31 switchboard procedures, and the Canadian Electrical Code standards for IFS switchboards.

The manufacturer identifies each phase conductor by means of color-coded tape if required. Markings are affixed to both the line and load ends of the conductors. Markings follow the industry accepted phase colors. (See **Figure 14** and **Table 1**.)

Factory Installed

Figure 14. Typical Phase "A" 240 Vac Wire Label

Table 1. Wire Label Color Codes

240 Vac Systems and Below Nominal			
Phase A	Red		
Phase B	Black		
Phase C	Blue		
Neutral	White		
Ground	Green		

Conductors installed by the manufacturer have been cut and stripped to pre-determined lengths for connection between components. When conductors are intended to run between components in two different sections that are joined by the manufacturer, the manufacturer will connect both the line and load ends of the conductors.

Note: The Canadian Electrical Code restricts the field installation of conductors that run horizontally through switchboard vertical sections. Refer to the CEC for specifics.

When there is a shipping split between sections that are cabled, the factory connects one end of the conductors. The remainder of the conductors are coiled and secured in the section with the connection.

Factory drawings included in the switchboard clearly indicate the required field connections for the coiled conductors.

Inspect conductors/cables for damage. Any damaged conductors must be replaced. Contact manufacturer for replacement.

Factory color-coded markings indicate phasing/neutral and are marked on both the line and load ends of the conductors.

Using the factory drawings, the installer connects conductors to the component(s) indicated on the drawings keeping phases correctly oriented. Care should be taken in forming insulated cables to ensure that no insulation is forced permanently against edges of any metal parts.

Torque both line and load connections to values indicated on the labeling on the switchboard. Refer to Appendix **Table 2** for torque values.

Installation of Incoming Switchboard Connections

DANGER

DE-ENERGIZE SWITCHBOARD — HAZARDOUS VOLTAGE. WILL CAUSE SEVERE INJURY OR DEATH.

DO NOT work on electrical equipment while energized. Verify power entering the equipment is de-energized at the source.

Power is normally brought into a switchboard either by cable or by busway (busduct).

Remove structure covers as needed to access switchboard chassis and components. Retain all cover mounting hardware and covers for re-assembly. Protect hardware and parts from moisture, debris and damage.

Note: As a minimum, all switchboard connections are rated for use with 75°C or higher rated conductors. When wire is used with temperature ratings above 75°C, it shall be sized based on the ampacity of wire rated 75°C.

Wire/Cabling

When cable connections are used, either mechanical set screw or compression lugs are typically supplied. (See **Figure 15**.) See factory drawing for specific lug terminations and wire ranges. Some utilities make their own service entrance connections. In these cases, the manufacturer typically supplies lug landing provisions or a landing pad in lieu of lugs. These are designed to the specific utility's requirements. Refer to the manufacturer's drawings for specifics covering this connection.

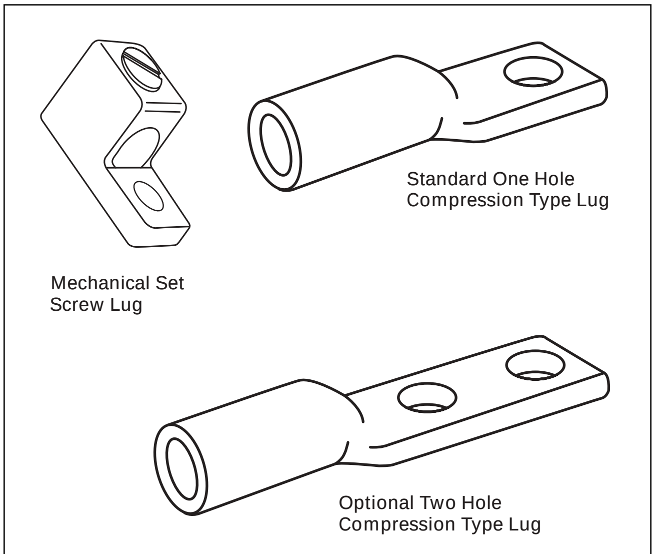


Figure 15. Screw and Compression Lugs

Unless a switchboard specifically restricts entry to a single means or area, cables may enter through the top, bottom, side or back of the main incoming section. These restrictions are typically required to conform to wire bending space requirements of the CEC. Consult the manufacturer's drawings for conduit entry data.

Once the conductors are pulled inside the main section, the cables should be formed in the space provided. Clearly identify and segregate conductors by phase and neutral. Care should be taken in forming insulated cables to ensure that no insulation is forced permanently against the edges of any metal parts.

Using appropriate tools, the installer must strip the conductor insulation sufficiently to fill the entire barrel of the connector with bare, un-insulated conductor. Conductor must be stripped without damage to the conductor strands. Bare strands should be of equal length (flush) on the end cut.

Do not strip off more insulation than needed. Exposure of bare conductor outside lug can compromise clearances.

The connector and conductor should be free of all foreign debris.

Never clip cable/wire strands in order to fit within connectors. If cable/wire does not match the rating of the connector, contact the manufacturer.

Mechanical set screw lugs are the most common. Use an antioxidant compound, if required. Insert bare conductor into lug so the bare conductor fills the full length of the lug body. Tighten lug, then torque to levels indicated on the switchboard label.

If compression lugs are utilized and supplied with the switchboard, the lugs will be mounted on the incoming lug pad. Remove lugs from the pad. Use an antioxidant compound, if required. Use a crimping tool approved for that specific lug manufacturer and lug size. Follow instructions provided by the manufacturer of the crimp tool.

Once the lug is affixed to the conductor, re-install the lug on the lug pad utilizing the existing hardware. Torque hardware using information provided on switchboard labeling. Refer to Appendix **Table 2** for torque values.

Other Requirements for Rear Connected Switchboards

On systems that require short circuit current ratings above 10,000 amperes rms, Cable Bracing may be required to restrict cable movement. Lashing and lacing cables accomplish this.

Busway

A switchboard may include one or more provisions for connection to Cutler-Hammer brand busway. Busway can feed the switchboard, be fed from the load side of an overcurrent device within the switchboard, or both.

Switchboards with busway connection(s) may contain flange connection 'tie-bar(s)' assembled in the appropriate section. The tie-bars will accept the corresponding busway flange extension. Consult switchboard and busway drawings for specifics. The tie-bars are a transition between the switchboard conductors and the busway flange extension, and are assembled as part of the switchboard section.

The bus assembly is completely formed and drilled for connections, including phase bussing and neutral, if needed.

Busway typically enters a switchboard section through the top. However, busway may attach from the bottom, back or side of the switchboard in special configurations.

Temporary bracing may be provided to support the busway assembly in the switchboard during shipment. All temporary bracing must be removed after connections are completed.

The switchboard structure should NOT be used to support any busway run or flange and extension.

When a busway connection is supplied on an outdoor switchboard, sealing the busway connection is very critical. Upon completing the necessary bus connection, the installer is responsible for sealing the connection point where the busway flange connects to the top cover or side/rear cover.

Pre-Energizing Procedures and Inspection

Before energizing any switchboard, perform a comprehensive inspection to make certain that the switchboard is ready to be energized. This includes the following steps:

1. Verify that the switchboard is not energized.
2. Visually inspect the switchboard and remove all foreign materials, such as, tools, scraps of wire and other debris from all switchboard sections.
3. Remove and discard all packing materials and temporary shipping braces from the switchboard.
4. Any accumulation of dust and dirt should be removed with a vacuum cleaner. Use a lint-free cloth to remove dust and dirt on other surfaces. Never use compressed air as this may blow contaminants into electrical and/or electronic components. Never use solvents or other chemicals to clean surfaces or components.
5. Visually inspect all ventilation points to ensure that there is no blockage or debris. Remove all debris, if present.
6. Verify all field bus and wire connections have the proper torque per instructions on the switchboard and on components.
7. All factory connections are made utilizing calibrated power tools. However, vibrations do occur in transit and handling. Verify factory connections by checking at least 10% of the total factory connections for tightness. If this spot check reveals loose connections, proceed to check all factory connections. These connections include bus hardware connections, circuit breaker and switch terminals, contactors, metering and other connections, including the incoming terminals.
8. Visually inspect switchboard insulators, bus bar and conductors for damage. DO NOT ENERGIZE IF DAMAGE IS FOUND. Contact Eaton.
9. If fusible switch type overcurrent devices are used, verify proper fusing has been selected and installed. Eaton does not typically supply switchboards with these fuses.

Overcurrent Devices

Overcurrent devices are typically shipped in either the open (OFF) or "tripped" position. Manually close, and then open these devices to ensure they are functioning properly. At the completion of this process, be sure that the overcurrent device is in the "OFF" or "tripped" position.

Inspect overcurrent devices for any visible damage.
If damage is found, DO NOT ENERGIZE the switchboard.
Contact Eaton.

Circuit Breakers

Some circuit breaker types include the ability to adjust trip settings. When shipped, settings are typically at the minimum rating. There are two types of trip units included in this group. These types are adjustable thermal magnetic and electronic trip units.

Thermal magnetic trip units may have an adjustable magnetic setting. Use the engineering study recommendations, if available, to adjust to the proper setting. Low magnetic settings feeding high inrush loads, such as motors, could nuisance trip on startup. For specifics on breaker types, consult the circuit breaker instruction leaflets shipped with the switchboard.

Electronic trip units have several settings depending on the breaker ordered. Electronic trip units may include long-time (L), short-time (S), instantaneous (I) and ground fault (G) settings. These trip units are available in combinations LS, LSI, LSG and LSIG. Check the electrical drawings, engineering study or the engineer's recommendations for these trip unit settings. For details on each type, refer to the Eaton circuit breaker and electronic trip unit instruction leaflets shipped with the switchboard.

For certain breakers with electronic trip units, a portable test kit is available from Eaton. An auxiliary power module is included in the test kit. This auxiliary power module powers the electronic trip unit when the board is de-energized and allows testing. The kit includes complete instructions and test times for testing long-time, short-time/instantaneous operations and optional ground fault operation of the circuit breakers.

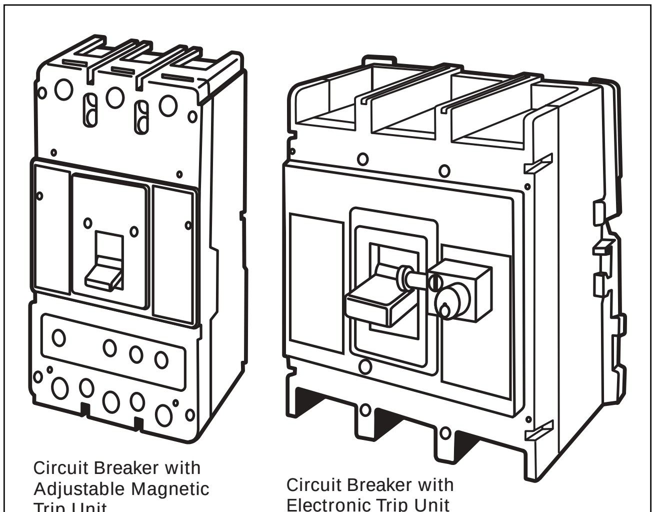


Figure 16. Circuit Breakers

Overcurrent Devices with Ground Fault Protection

This switchboard may contain overcurrent devices with Ground Fault Protection (GFP). The Canadian Electrical Code may require ground fault protection for this installation. Other GFP applications may be used including multi-level ground fault protection. Refer to the switchboard drawings and electrical construction drawings for usage and placement within the switchboard.

Ground fault protection may be installed integral to overcurrent device(s) or as a separate system. Separate systems typically are connected to a shunt tripping mechanism on an overcurrent device.

Visibly inspect connections on GFP systems, neutral sensors and ground connections. Refer to manufacturer's instructions for details.

Prior to shipment, the manufacturer has pre-set the ground fault protection at minimum set points. Adjust settings per engineered electrical plan drawings. If this information is not readily available, contact the design engineer or other qualified persons responsible for the specifics of the installation and system design.

Prior to testing the GFP system, remove the neutral disconnect link(s) on the switchboard to isolate the neutral of the system from the supply and ground.

Confirm that the neutral connection has been run from the supply to the service equipment per the Canadian Electrical Code.

GFP systems should be performance tested when first installed. Conduct tests in accordance with the approved instructions provided with the equipment. A written test report should be available for the Authority Having Jurisdiction. Refer to the Canadian Electrical Code for specific requirement or contact Eaton.

For certain breakers with electronic trip units, a portable test kit is available from Eaton, at additional cost. The kit includes complete instructions and test times for testing long-time, short-time/instantaneous operations and ground fault operation of the circuit breakers. Use of testing equipment other than that supplied by Eaton can cause permanent damage to the circuit breaker trip unit and will void the warranty.

CAUTION

DO NOT TEST A CIRCUIT BREAKER WHILE IT'S IN-SERVICE AND ENERGIZED.

CAUTION

TESTING OF A CIRCUIT BREAKER THAT RESULTS IN THE TRIPPING OF THE CIRCUIT BREAKER SHOULD BE DONE ONLY WHEN THE SWITCHBOARD IS DE-ENERGIZED.

Field-testing of ground fault protection must follow instructions provided with each GFP device. Due to the varied types of GFP systems, testing instructions can vary from device to device. Refer to the specific testing instructions for each device. Refer to instruction leaflets that are shipped with each switchboard containing GFP or contact Eaton.

Current Transformers

Switchboards containing metering and monitoring equipment may contain current transformers (CTs) integral to the switchboard. Ensure that the load side of the CTs are connected or are shorted together with terminal block shorting means. Remove shorting means for normal CT operation with metering equipment. For additional information and instructions, refer to instruction leaflet shipped with the switchboard.

Preparing Switchboard for Insulation/Megger Testing

CAUTION

FAILURE TO SHORT OR DISCONNECT DURING SWITCHBOARD TESTING WILL RESULT IN FAILURE OF ELECTRONIC COMPONENTS.

Devices Installed with Control Power Fusing

Devices, which require control power fusing, can be easily damaged beyond repair if not disconnected during the testing phase. These devices include, but are not limited to, customer metering equipment, electronic breaker trip units, motor operators and communication equipment.

WARNING

DISCONNECT POWER AT SOURCE BEFORE REMOVING OR INSTALLING FUSES. HAZARDOUS VOLTAGE WILL CAUSE SEVERE INJURY OR DEATH.

Prior to testing the switchboard, turn off all control power devices in the switchboard to prevent damage to components. The control power may be turned off by utilizing the control power switch or by removing the fuses. Components that use power supplies include customer metering and certain breaker accessories and these must be isolated before testing.

CAUTION

FAILURE TO DISCONNECT CONTROL POWER DURING SWITCHBOARD TESTING WILL RESULT IN FAILURE OF ELECTRONIC COMPONENTS.

Failure to disconnect control power during switchboard testing will result in failure of electronic components and void manufacturer's warranty.

Transient Voltage Surge Suppression (TVSS) and Surge Protective Devices (SPD)

Prior to testing the switchboard, disconnect line and neutral connections to all TVSS and/or SPD units in the switchboard. Keep hardware in a clean and protected environment to guard against damage until re-installation.

CAUTION

FAILURE TO DISCONNECT LINE AND NEUTRAL DURING TESTING WILL CAUSE THE TVSS AND SPD SURGE PROTECTION SYSTEM TO FAIL AND WILL VOID THE WARRANTY ON THE DEVICE.

Failure to disconnect line and neutral during testing will cause the TVSS and SPD surge protection system to fail and will void the warranty on the device. After testing, re-install all connections.

Pre-Energizing Switchboard Insulation Testing

Exercise extreme care to prevent the equipment from being connected to the power source while tests are being conducted.

Prior to energizing the switchboard, perform a Megger or DC test of the switchboard's insulation. With the neutral isolated from the ground and the switches and/or circuit breakers open, conduct electrical insulation resistance tests from phase to phase, phase to ground, phase to neutral, and neutral to ground. Retain results for use to compare to results produced in the future. A form for recording test results is provided in the Appendix of this document. Prior to testing, remove all control power fusing and connections to products, which will be damaged in this test. See above.

WARNING

TO PREVENT DAMAGE TO GROUND FAULT CONTROL CIRCUITS, METERING CIRCUITS, OR OTHER CONTROL CIRCUITS WHEN MEGGERING SWITCHBOARD, ISOLATE CIRCUITS FROM SWITCHBOARD SYSTEM BEFORE BEGINNING THE MEGGER OPERATION. BE SURE TO RECONNECT THOSE CIRCUITS AFTER MEGGER TESTS ARE COMPLETED.

NOTE: SOME GROUND FAULT CIRCUITS MAY NOT BE FUSED, THEREFORE ISOLATION OF THOSE CIRCUITS REQUIRES DISCONNECTING WIRING FROM BUS BARS.

DO NOT USE AC dielectric testing.

WARNING

DO NOT USE AC DIELECTRIC/MEGGER TESTING.

Test resulting in readings at or above 1 megaohm is satisfactory.

Post-Testing

After testing, and with the switchboard de-energized, reconnect all devices, control fusing and disconnects removed prior to testing. Re-attach Transient Voltage Surge Suppressors (TVSS) and Surge Protective Devices (SPD).

Securing the Switchboard

Re-install all side covers, deadfront plates, doors and trim parts on the switchboard using hardware supplied by the manufacturer. Take caution that conductors are not pinched between parts when installing the deadfront, cover plates, side sheets and filler plates. All parts should be aligned and secured when installed. Do not leave holes or gaps in the deadfront construction. Clean up any debris in and around the switchboard.

Energizing Switchboard

WARNING

HAZARDOUS VOLTAGE WILL CAUSE SEVERE INJURY OR DEATH.

WARNING

ONLY THOSE PROFESSIONALS TRAINED AND QUALIFIED ON ELECTRICAL DISTRIBUTION SWITCHBOARDS SHOULD INSTALL AND/OR SERVICE THIS EQUIPMENT.

Extreme hazards can exist when energizing electrical distribution equipment and switchboards. Take all precautions necessary to protect people and property when energizing the equipment. Short circuits and ground faults may exist as a result from inadequate installation. Short circuits and ground faults within the switchboard can cause catastrophic damage, injury and death.

1. Prior to energizing the switchboard, turn OFF all overcurrent devices and loads internal to the switchboard plus mains in downstream equipment.
2. Verify and follow the sequence of energizing circuits and loads. Verify phase sequencing on loads, such as motors, which can be damaged or destroyed by incorrect phase connections.
3. If provided, use remote operators to close and energize switchboard, overcurrent devices and loads.
4. Beginning with the main(s), turn ON each overcurrent device.

Maintenance

It is essential to maintain the equipment in satisfactory condition.

To ensure continued quality service, a systematic maintenance schedule is vital. Facility operation and local conditions vary to such an extent that the schedule must be prepared to suit the conditions. The maintenance schedule for individual devices, such as circuit breakers, meters, fusible switches, etc., should be based upon recommendations contained in the individual instruction leaflet for each device. Inspection and test operations should be coordinated with an overall testing program to result in the least operating inconvenience and system shutdowns.

DANGER

HAZARDOUS VOLTAGE WILL CAUSE SEVERE INJURY OR DEATH. DE-ENERGIZE SWITCHBOARD PRIOR TO SERVICING.

WARNING

ONLY THOSE PROFESSIONALS TRAINED AND QUALIFIED ON ELECTRICAL DISTRIBUTION SWITCHBOARDS SHOULD INSTALL AND/OR SERVICE THIS EQUIPMENT.

Prior to performing any maintenance on the switchboard, first de-energize the switchboard at the source. Use lock-out/tag-out precautions as prescribed in CEC and other safety manuals.

The switchboard should be given a thorough maintenance check annually.

Exercise extreme care to prevent the equipment from being connected to the power source while tests are being conducted.

Switchboard Insulation Resistance Testing

Maintenance Before Cleaning

Prior to cleaning, perform an initial Megger or DC test of the switchboard insulation, between phases and ground. Inspect for symptoms which may indicate overheating or weakened insulation. Record test readings.

Prior to testing, remove all control power fusing and connections to products, which will be damaged in this test. This includes all components with control wire fusing, Transient Voltage Surge Suppression, Surge Protective Devices, metering equipment, etc.

WARNING

TO PREVENT DAMAGE TO GROUND FAULT CONTROL CIRCUITS, METERING CIRCUITS, TRANSIENT VOLTAGE SURGE PROTECTION (TVSS) OR OTHER CONTROL CIRCUITS, WHEN MEGGERING SWITCHBOARD, ISOLATE CIRCUITS FROM SWITCHBOARD SYSTEM BEFORE BEGINNING THE MEGGER OPERATION. BE SURE TO RECONNECT THOSE CIRCUITS AFTER MEGGER TESTS ARE COMPLETED.

NOTE: SOME GROUND FAULT CIRCUITS MAY NOT BE FUSED, THEREFORE ISOLATION OF THOSE CIRCUITS REQUIRES DISCONNECTING WIRING FROM BUS BARS.

DO NOT USE AC dielectric testing.

WARNING

DO NOT USE ALTERNATING CURRENT (AC) DIELECTRIC/ MEGGER TESTING. DAMAGE TO COMPONENTS WILL OCCUR.

Cleaning

While the switchboard is de-energized, remove dust and debris from bus bars, connections, supports and enclosure surfaces. A vacuum cleaner with a long nozzle will be of assistance. Wipe clean with a lint-free cloth. Do not use solvents to clean equipment as damage to surfaces can occur.

Should the switchboard be exposed to adverse conditions, such as, airborne contaminants, more frequent inspections and cleaning may be required.

WARNING

DO NOT USE COMPRESSED AIR TO CLEAN OR BLOW OUT DEBRIS OR DUST IN SWITCHBOARDS.

Use of compressed air to clean or blow out debris in switchboards may imbed the contaminants within overcurrent devices, metering equipment and other components. Damage to insulation and other surface materials can occur. Do Not Use Compressed Air in cleaning.

Switchboard Insulation Resistance Testing

Maintenance After Cleaning

After cleaning, perform a second Megger or DC test of the switchboard insulation between phases and ground.

Prior to testing, remove all control power fusing and connections to products, which will be damaged in this test. This includes all components with control wire fusing, Transient Voltage Surge Suppression, Surge Protective Devices, metering equipment, etc.

WARNING

TO PREVENT DAMAGE TO GROUND FAULT CONTROL CIRCUITS, METERING CIRCUITS, TRANSIENT VOLTAGE SURGE PROTECTION (TVSS) OR OTHER CONTROL CIRCUITS, WHEN MEGGERING SWITCHBOARD, ISOLATE CIRCUITS FROM SWITCHBOARD SYSTEM BEFORE BEGINNING THE MEGGER OPERATION. BE SURE TO RECONNECT THOSE CIRCUITS AFTER MEGGER TESTS ARE COMPLETED.

NOTE: SOME GROUND FAULT CIRCUITS MAY NOT BE FUSED, THEREFORE ISOLATION OF THOSE CIRCUITS REQUIRES DISCONNECTING WIRING FROM BUS BARS.

DO NOT USE AC dielectric testing.

WARNING

DO NOT USE ALTERNATING CURRENT (AC) DIELECTRIC/ MEGGER TESTING. DAMAGE TO COMPONENTS WILL OCCUR.

Test resulting in readings at or above 1 megaohm is satisfactory.

Compare these test readings with prior readings and retain with previous testing for future comparisons. Trends of lowered insulation resistance are signs of potential problems. A form is provided in the Appendix to record readings.

Bus and Cable Connections

1. Inspect bus bar and cables for visible damage.
2. Visually inspect connections for overheating and damage.
3. All bus bar and cable connections should be checked and torqued in accordance with labeling on the switchboard. Refer to Appendix **Table 2** for torque values.
4. Inspect for broken wire strands and pinched or damaged insulation on cable connections.

Insulation

All bus bar and structure insulation in the switchboard including bus supports, bus shields, bus bracing, insulating barriers, etc., should be visually checked for damage. Replace damaged parts. The life of insulation material is dependent on keeping the material dry and clean.

Overcurrent Devices

Maintenance instructions and field-testing for overcurrent devices are included with the instruction leaflet for each device within a family. Refer to the leaflet on each device. If leaflets are missing, contact Eaton for replacement.

Circuit Breakers

Visually inspect circuit breakers for signs of discoloration, cracking, scorching, overheating or broken parts. Exercise the breaker operating mechanism making sure it is opening and closing. A breaker showing signs of any one of these issues should be replaced.

Fusible Overcurrent Devices

Visually inspect the switching mechanism and fuse connections. Visually inspect the fusible devices for signs of discoloration, cracking, scorching, overheating or broken parts. Replace any worn parts or the entire switch.

Fuse Replacement

DANGER

HAZARDOUS VOLTAGE WILL CAUSE SEVERE INJURY OR DEATH. DE-ENERGIZE BOARD PRIOR TO SERVICING FUSIBLE DEVICES.

Be sure the switch mechanism is turned to the OFF position before attempting to remove fuses. Visually inspect the switch contacts, blades and mechanism to ensure that the mechanism is in the open/off position.

Check fuses to ensure that they are of the proper class, ampere, voltage and interrupting rating. Ensure that non-current limiting fuses are not used as replacements for current limiting fuses. Never attempt to defeat rejection mechanisms which are provided to prevent the installation of the incorrect class of fuse.

Meters, Controllers, Surge Equipment and Other Devices

Individual devices should be maintained according to the specific instructions supplied for each device. Remove dust and dirt from exterior with a dry lint-free cloth. Unless specifically instructed in the individual device instruction leaflet, do not attempt to open sealed cases or containers.

WARNING

NEVER USE COMPRESSED AIR TO CLEAN OR BLOW OUT DEBRIS OR DUST IN SWITCHBOARDS.

Secondary Wiring

Check all wiring connections for tightness, including those at the current and potential transformers, if present, and at all terminal blocks. Check all secondary wiring connections to ensure they are properly connected to the switchboard ground bus, where indicated. Look for broken wire strands and pinched or damaged insulation.

Ventilation

Check all grills and ventilation ports for obstructions and accumulations of dirt. Clean ventilation ports, if necessary. For switchboards installed outdoors, inspect the air space under the switchboard to be sure that it is clean and clear of debris, leaves and obstructions.

Records

It is essential to maintain the equipment in satisfactory condition.

Maintain a permanent record of all maintenance activities and testing for future reference. (See **Appendix B**.)

The condition of each switchboard should be recorded as a guide for anticipating the need for any replacement parts or components or special attention at the next regular maintenance period. It is recommended that a series of inspections be made at quarterly intervals until the progressive effects of local conditions can be analyzed to determine a regular schedule.

Switchboard Events and Service Interruptions

Short Circuits, Ground Faults and Overloads

WARNING

DO NOT ATTEMPT TO RE-ENERGIZE SWITCHBOARD OVERCURRENT DEVICES AFTER ELECTRICAL EVENTS, SUCH AS SHORT CIRCUITS, GROUND FAULTS AND OVERLOADS, UNTIL THE CAUSE OF THE EVENT HAS BEEN IDENTIFIED AND CORRECTED.

A thorough assessment, identification and correction of the event origin must be completed. An additional assessment of the conductor insulation and other insulating materials should be made. Replace all damaged insulation materials, conductors and overcurrent devices. Original switchboard parts, insulators, insulation material and overcurrent devices must be replaced with renewal parts from Eaton. (See Renewal Parts **Page 19**.)

Do not attempt to re-energize switchboard overcurrent components after electrical events, such as short circuits, ground faults and overloads, until the cause of the event has been identified and corrected.

After the event has been rectified, test equipment per the maintenance process described in this publication.

Physical Damage

Any physical damage to the switchboard that occurs after the switchboard is installed must be corrected. A thorough inspection, which includes the exterior enclosure and dead-front, plus interior components in the damaged portion of the switchboard, should be conducted. Replace all damaged parts and components. Ensure that there are no gaps in the switchboard enclosure that could cause exposure to live parts. Contact Eaton for renewal parts and assistance.

After the physical damage has been corrected, test equipment per the maintenance process described in this publication.

Water Damage

DANGER

WET SWITCHBOARDS PRESENT A HAZARDOUS CONDITION AND MAY CAUSE INJURY OR DEATH. DE-ENERGIZE POWER TO ALL EQUIPMENT BEFORE SERVICING.

DO NOT WORK ON SURFACES OR FLOORS WHERE THERE IS STANDING WATER.

DANGER

DO NOT WORK ON SWITCHBOARDS OR ENTER AREAS THAT HAVE STANDING WATER. DE-ENERGIZE ALL EQUIPMENT IN AREAS WITH STANDING WATER.

DO NOT WORK ON WET ENERGIZED ELECTRICAL EQUIPMENT.

Major accumulation of water or moisture on any part of the switchboard can cause catastrophic damage to the switchboard. If a switchboard has been submerged by more than 2 inches or where running or standing water has had contact with current carrying parts, it has sustained significant damage.

WARNING

SWITCHBOARD COMPONENTS, INCLUDING CIRCUIT BREAKERS, FUSIBLE SWITCHES, METERING, ETC., SUBJECTED TO WATER OR MOISTURE MAY BE RENDERED UNSAFE. REPLACEMENT IS REQUIRED.

The switchboard and its components may be damaged beyond repair and may need replacement.

1. **Do not attempt to clean or repair water damaged equipment or components.**
2. **De-energize the switchboard at its source.**
3. **Do not energize.**
4. **Contact Eaton for replacement.**

Minor accumulations of moisture, such as condensation, over a short period of time may be corrected using heat.

De-energize switchboard.

Apply approximately 250 watts per vertical section for a sufficient period of time until the moisture disappears, then remove all heat sources and materials used for drying.

Inspect for damage to components and any corrosion.
If any damage or corrosion is present, contact Eaton.
DO NOT RE-ENERGIZE SWITCHBOARD.

After the switchboard has completely dried, remove all materials and tools from the equipment. Inspect all connections for damage and torque. Re-install all covers, fillers, deadfront assemblies and side sheets. Conduct switchboard insulation resistance testing described in this publication.

Renewal Parts

Switchboards can be complex assemblies with unique parts to fit the specific application and need. The manufacturer offers expertise with renewal part identification. To ensure safety and to maintain CSA certification, it is essential that only new parts and components from Eaton be utilized.

When ordering renewal parts or when requesting information on the switchboard, it is essential to include as much information as possible.

Each switchboard will have a nameplate and other identification marks with details that will help expedite information requests and orders. The following may be required to help identify parts and information requests.

- GO or General Order Number
- Item number
- Description of the equipment
- Supply voltage
- Equipment ratings
- Catalog number or style number of part, if available

Electrical distribution equipment has a limited life span. As such, the manufacturer cannot guarantee the availability of obsolete equipment or parts. Equipment replacement may be recommended.

Appendix

Appendix A

Table 2. Torque Values for Copper or Aluminum Bus Bar Connections

Bolt Size	Torque Inch Lbs	Torque Foot Lbs
#10	30 Inch Lbs.	2.5 Foot Lbs.
1/4”	65 Inch Lbs.	5.4 Foot Lbs.
5/16”	130 Inch Lbs.	10.8 Foot Lbs.
3/8”	240 Inch Lbs.	20.0 Foot Lbs.
1/2”*	600 Inch Lbs.	50.0 Foot Lbs.

Note: For other torque values, refer to instruction leaflet for the specific component.

Note: *Some applications use (2) Belleville wahsers per bolt. Convex side up. In these cases bolts should be torqued to 70 foot/ pounds.

Appendix B

Switchboard Maintenance, Testing and Inspection Logs

Refer to Maintenance section of this document on **Page 16** for detailed information.

DANGER

**HAZARDOUS VOLTAGE WILL CAUSE SEVERE INJURY OR DEATH.
DE-ENERGIZE BOARD PRIOR TO SERVICING FUSIBLE DEVICES
ONLY “QUALIFIED PERSONS” SHOULD INSTALL AND OR SERVICE THIS EQUIPMENT.**

WARNING

TO PREVENT DAMAGE TO GROUND FAULT CONTROL CIRCUITS, METERING CIRCUITS, TRANSIENT VOLTAGE SURGE PROTECTION (TVSS) OR OTHER CONTROL CIRCUITS, WHEN MEGGERING SWITCHBOARD, ISOLATE CIRCUITS FROM SWITCHBOARD SYSTEM BEFORE BEGINNING THE MEGGER OPERATION. BE SURE TO RECONNECT THOSE CIRCUITS AFTER MEGGER TESTS ARE COMPLETED.

NOTE: SOME GROUND FAULT CIRCUITS MAY NOT BE FUSED, THEREFORE ISOLATION OF THOSE CIRCUITS REQUIRES DISCONNECTING WIRING FROM BUS BARS.

WARNING

DO NOT USE ALTERNATING CURRENT (AC) DIELECTRIC/ MEGGER TESTING. DAMAGE TO COMPONENTS WILL OCCUR.

Table 3. Initial Insulation Resistance Test Record

Date	**ALL OVERCURRENT DEVICES OPEN**						
	Phase to Phase Connections			Phase to Ground Connections			Neutral-Ground Connection
	A-B	A-C	B-C	A – Ground	B – Ground	C – Ground	
Date	**ALL OVERCURRENT DEVICES CLOSED**						
	Phase to Phase Connections			Phase to Ground Connections			Neutral-Ground Connection
	A-B	A-C	B-C	A – Ground	B – Ground	C – Ground	
Notes:							

Date	**ALL OVERCURRENT DEVICES OPEN**						
	Phase to Phase Connections			Phase to Ground Connections			Neutral-Ground Connection
	A-B	A-C	B-C	A – Ground	B – Ground	C – Ground	
Date	**ALL OVERCURRENT DEVICES CLOSED**						
	Phase to Phase Connections			Phase to Ground Connections			Neutral-Ground Connection
	A-B	A-C	B-C	A – Ground	B – Ground	C – Ground	
Notes:							

Date	**ALL OVERCURRENT DEVICES OPEN**						
	Phase to Phase Connections			Phase to Ground Connections			Neutral-Ground Connection
	A-B	A-C	B-C	A – Ground	B – Ground	C – Ground	
Date	**ALL OVERCURRENT DEVICES CLOSED**						
	Phase to Phase Connections			Phase to Ground Connections			Neutral-Ground Connection
	A-B	A-C	B-C	A – Ground	B – Ground	C – Ground	
Notes:							

Date	**ALL OVERCURRENT DEVICES OPEN**						
	Phase to Phase Connections			Phase to Ground Connections			Neutral-Ground Connection
	A-B	A-C	B-C	A – Ground	B – Ground	C – Ground	
Date	**ALL OVERCURRENT DEVICES CLOSED**						
	Phase to Phase Connections			Phase to Ground Connections			Neutral-Ground Connection
	A-B	A-C	B-C	A – Ground	B – Ground	C – Ground	
Notes:							

Table 4. Switchboard Inspection Log

Date	Check List	✓	Notes and Actions Taken
	Cleaning		
	Bus and Cable Connections		
	Insulation Inspection		
	Overcurrent Device Inspection		
	Meters		
	Controllers		
	Surge Protective Devices		
	Other Protective Devices		
	Secondary/Control Wiring		
	Clean Ventilation		

Date	Check List	✓	Notes and Actions Taken
	Cleaning		
	Bus and Cable Connections		
	Insulation Inspection		
	Overcurrent Device Inspection		
	Meters		
	Controllers		
	Surge Protective Devices		
	Other Protective Devices		
	Secondary/Control Wiring		
	Clean Ventilation		

Date	Check List	✓	Notes and Actions Taken
	Cleaning		
	Bus and Cable Connections		
	Insulation Inspection		
	Overcurrent Device Inspection		
	Meters		
	Controllers		
	Surge Protective Devices		
	Other Protective Devices		
	Secondary/Control Wiring		
	Clean Ventilation		

Note: Refer to Maintenance section on **Page 16**.

Notes