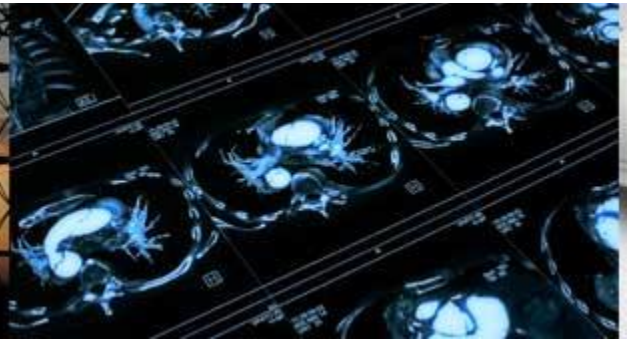
Field Rep Training Modules

Electrical Insulated Conductors

Dec 10, 2019

The Association of Electrical Equipment and Medical Imaging Manufacturers


The Basics

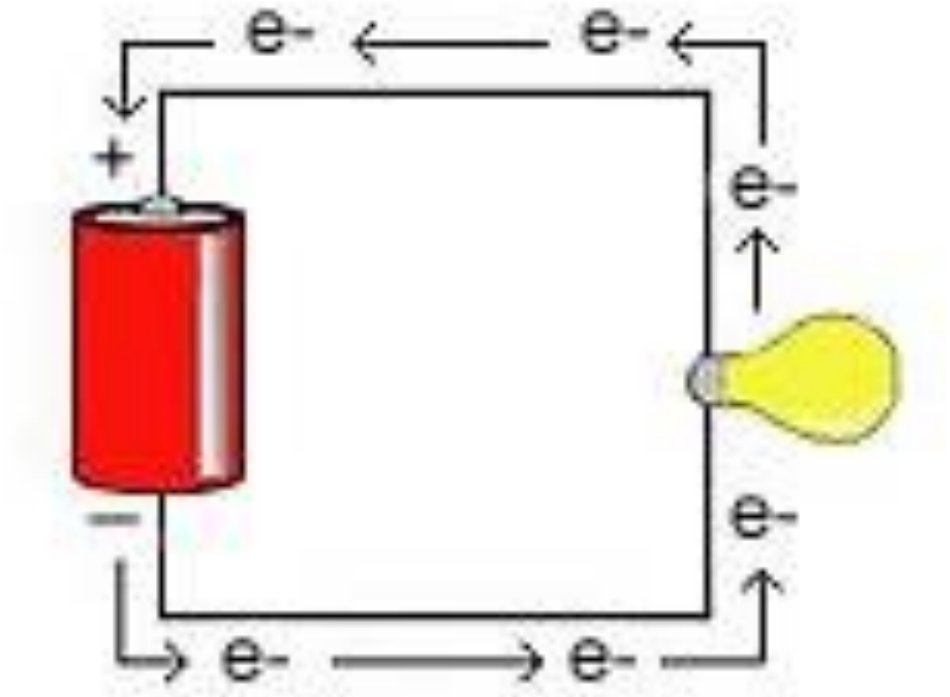
What is Electrical Current?

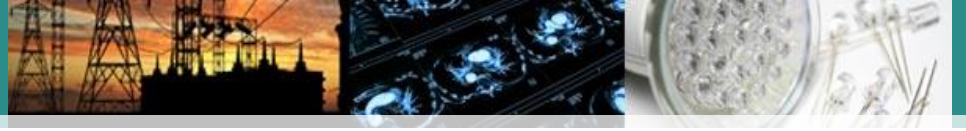
Answer: Electron Flow

Electrical current is the flow of electrons in a conductor.

Current is produced when an excited electron from one atom collides with an electron from another atom. This action displaces the electron from its orbit around the nucleus.

This electron flow is known as **electricity**.





The Basics

How is Electricity Produced?

Answer: 6 ways

1: **Magnetism**

2: Chemical

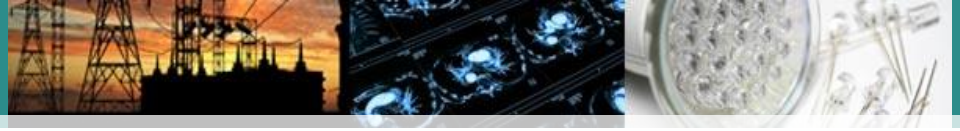
3: Pressure

4: Heat

5: Friction

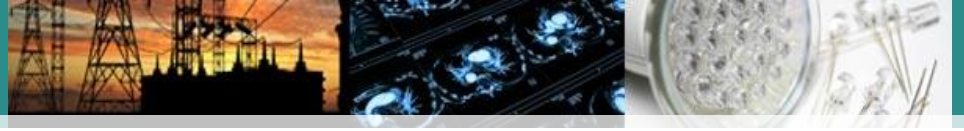
6: Light

- Magnetism is the most common way to generate electricity. The movement of a wire in a magnetic field generates electricity in the wire.



DC Resistance

- Electron flow through a conductor connected to a direct current source is subject to some amount of ohmic resistance, depending on the conductor material, length, and diameter.

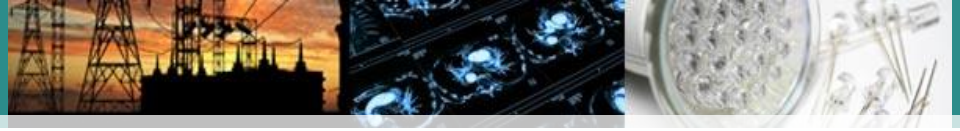


AC Resistance

- In a conductor connected to an alternating current source, the resistance of the conductor to the flow of current is slightly higher because AC causes the electrons to be repelled toward the outer surface of the conductor.

- This phenomenon is called the “skin effect”

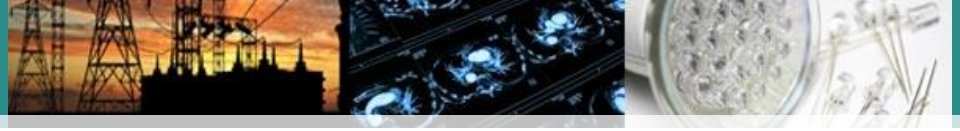
- The “skin effect” is proportional to frequency. At 60 Hz, skin effect is not a factor in determining wire size for 600 V applications.



Conductor Materials

According to Clause 110.5 of the NEC, allowable conductor materials for applications up to 2000 V are:

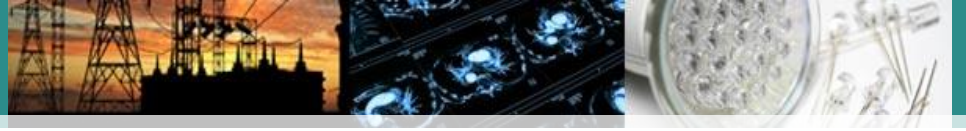
- Copper
- Aluminum
- Copper-clad aluminum



Alloy

A metal formed by the combination of two or more metals

- Copper is not typically alloyed.
- Aluminum may be alloyed to produce specific electrical, mechanical and physical properties.
  - 1350
  - AA 8000 series



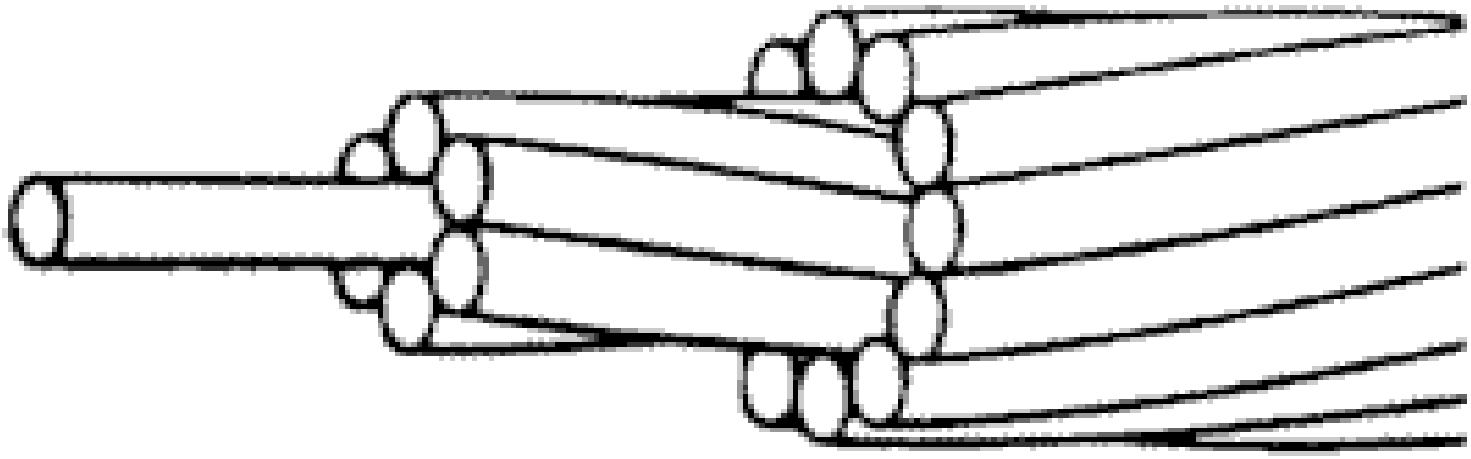
Solid Conductors

- Smaller wire sizes (14, 12 and 10 AWG) are typically solid conductors, but may be stranded.

Stranded Conductors

What are they?

- Conductors composed of a group of wires or of any combination of groups of wires.

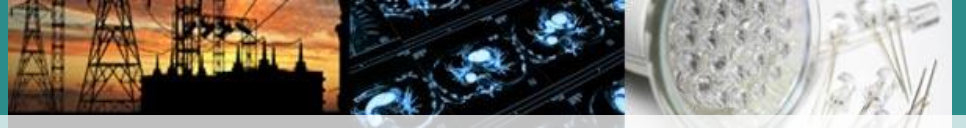


- Stranded conductors can be unilay or reverse-lay stranded (or other geometric configuration), and can be concentric, compressed, rope-lay, bunch or compact stranded.

Stranded Conductors

Why Use Them?

- Practicality in Handling
- Flexibility during installation
- Connectability/Terminations



Stranded Conductors

Designations

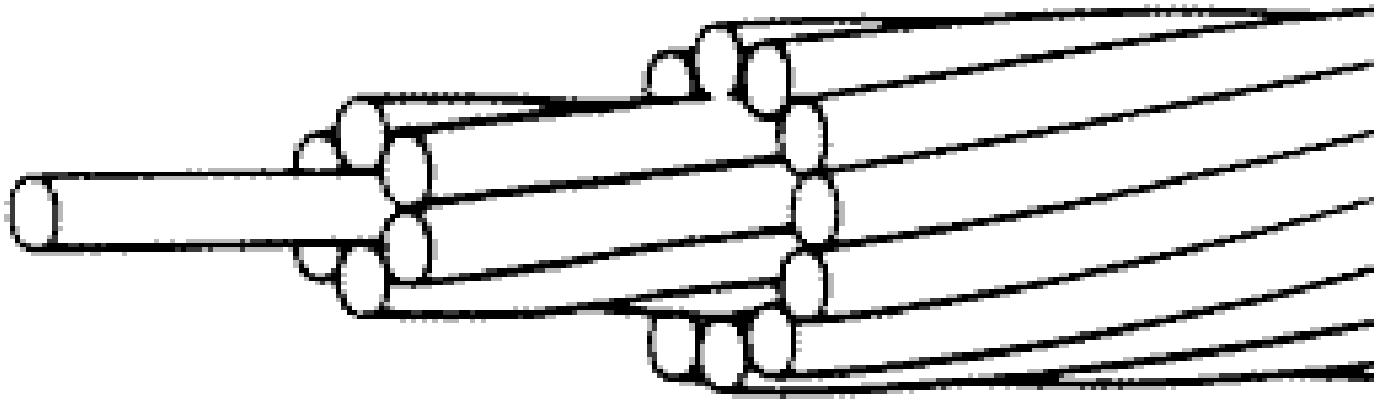
- ASTM International* categorizes conductor stranding in classes: B, C, D, etc.
- Increased flexibility of stranded conductors is signified by progression in letter designations. (e.g. Class M is more flexible than Class B)
- Table 8 of NEC® Chapter 9 includes conductor properties for solid and Class B stranded conductors.
- Some stranded conductors conform to ASTM standards for single-input wire, which may have a different number of strands than classical stranding methods.

**Formerly known as American Society for Testing and Materials*

Stranding Types

Concentric Stranding

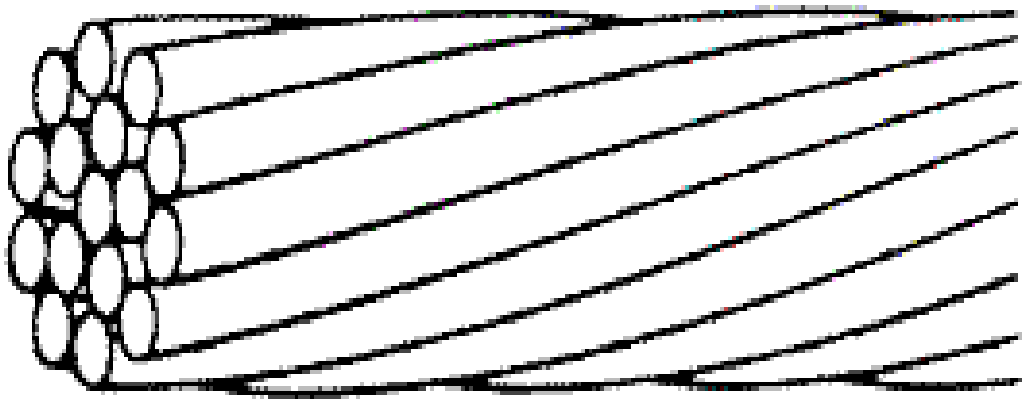
- Constructed with a central wire surrounded by one or more layers of helically wound strands in a fixed round geometric arrangement.



Stranding Types

Bunch Stranding

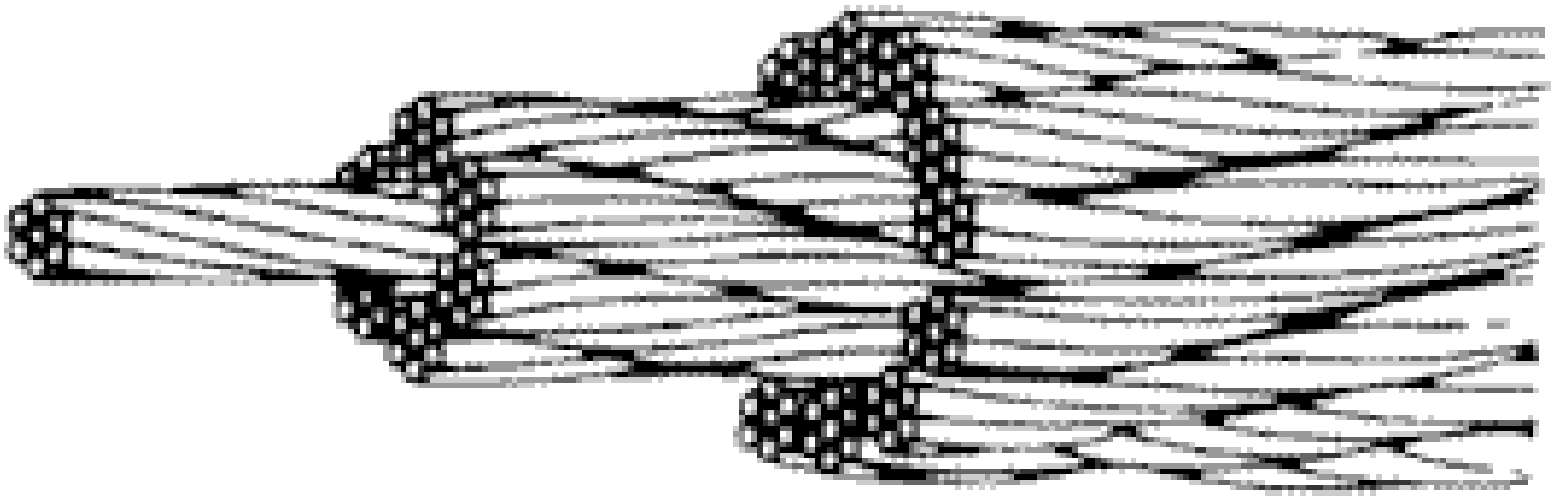
- A group of wires twisted together in the same direction with no pre-determined pattern



Stranding Types

Rope Stranding

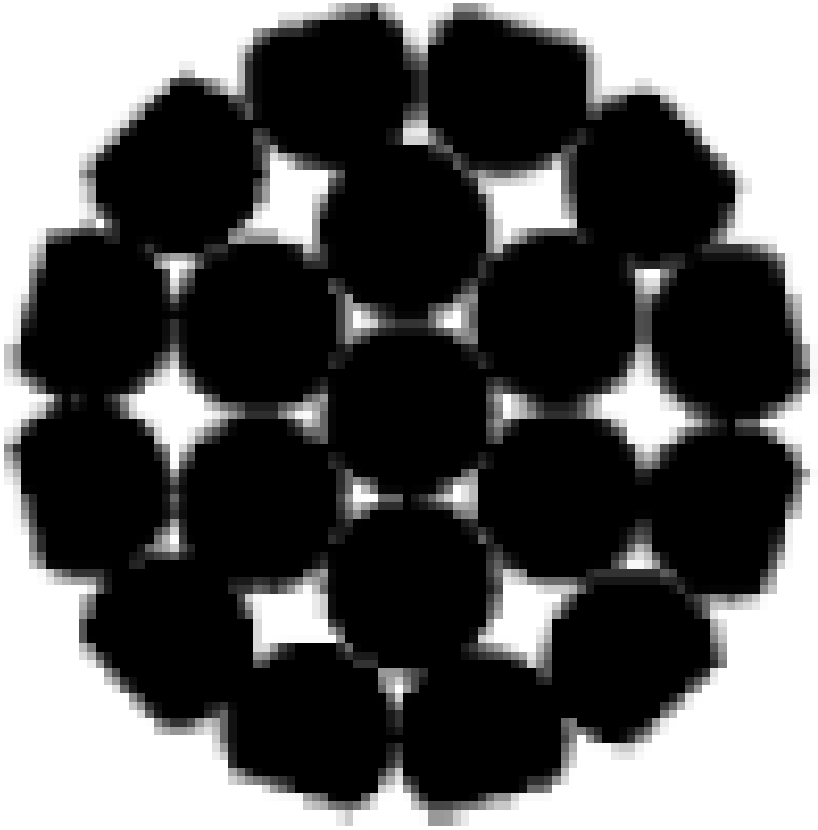
- Shown as concentric rope stranded construction with concentric-stranded component wires



Stranding Types

Compressed Stranding

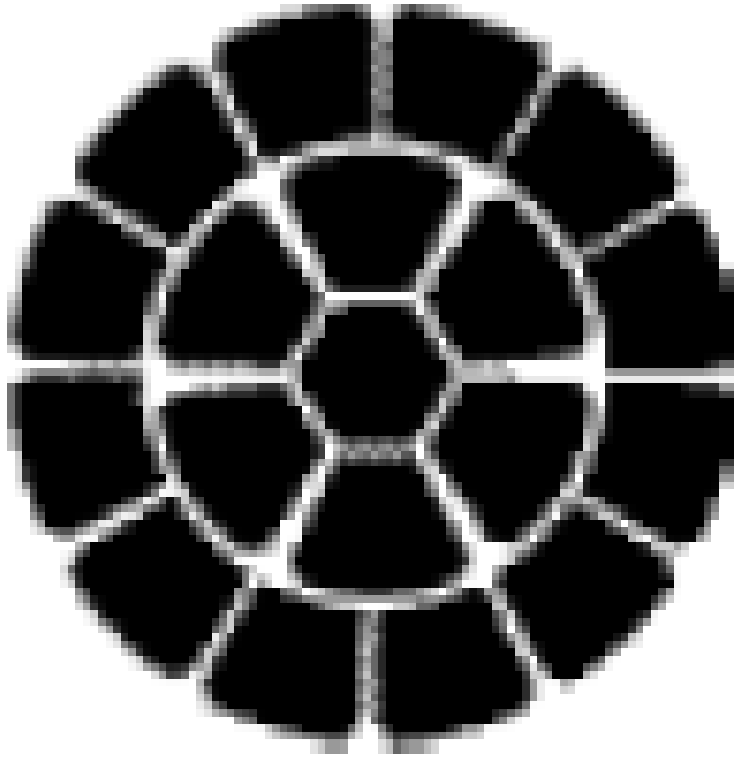
- A concentric stranded conductor drawn through a forming die (to about 97% of its original diameter, but with the same volume of metal).

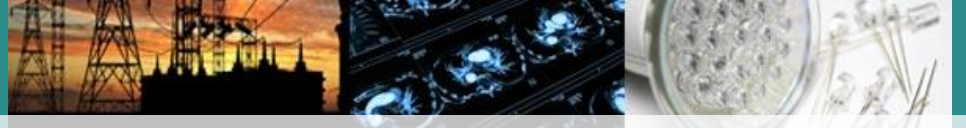


Stranding Types

Compact Stranding

- A concentric stranded conductor drawn through a series of forming dies (to about 90% of its original diameter, but with the same volume of metal).

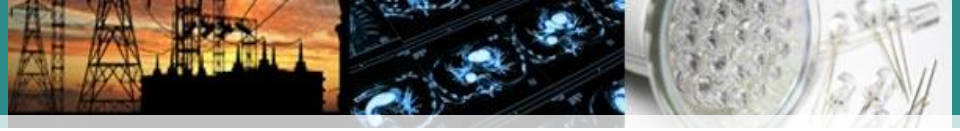




Stranding Types

Compressed and Compact Stranding Benefits

- Smoother conductor interface for stripping
- Normally used for larger sizes
- Helps reduce the overall cable diameter
- Helpful in increasing the number of conductors in conduit



Marking of Stranding

NEC Clause 110.14

- Connectors and terminal for conductors more finely stranded than class B and Class C shall be identified for the specific conductor class
- These specific conductor classes (other than Class B and Class C) would be part of the conductor marking

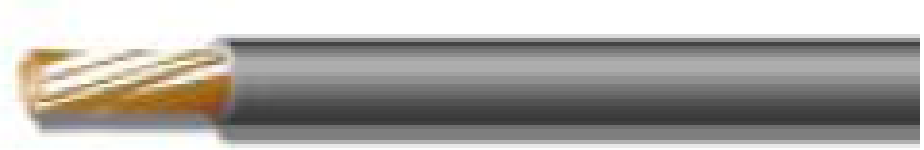
Insulation Materials

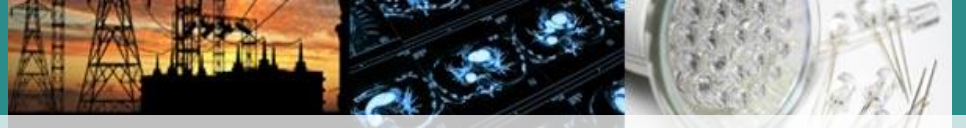
Materials include:

- Thermoplastic compounds
- Thermoset compounds

See NEC© Table 310.104(A)

Commercial/Industrial Conductors



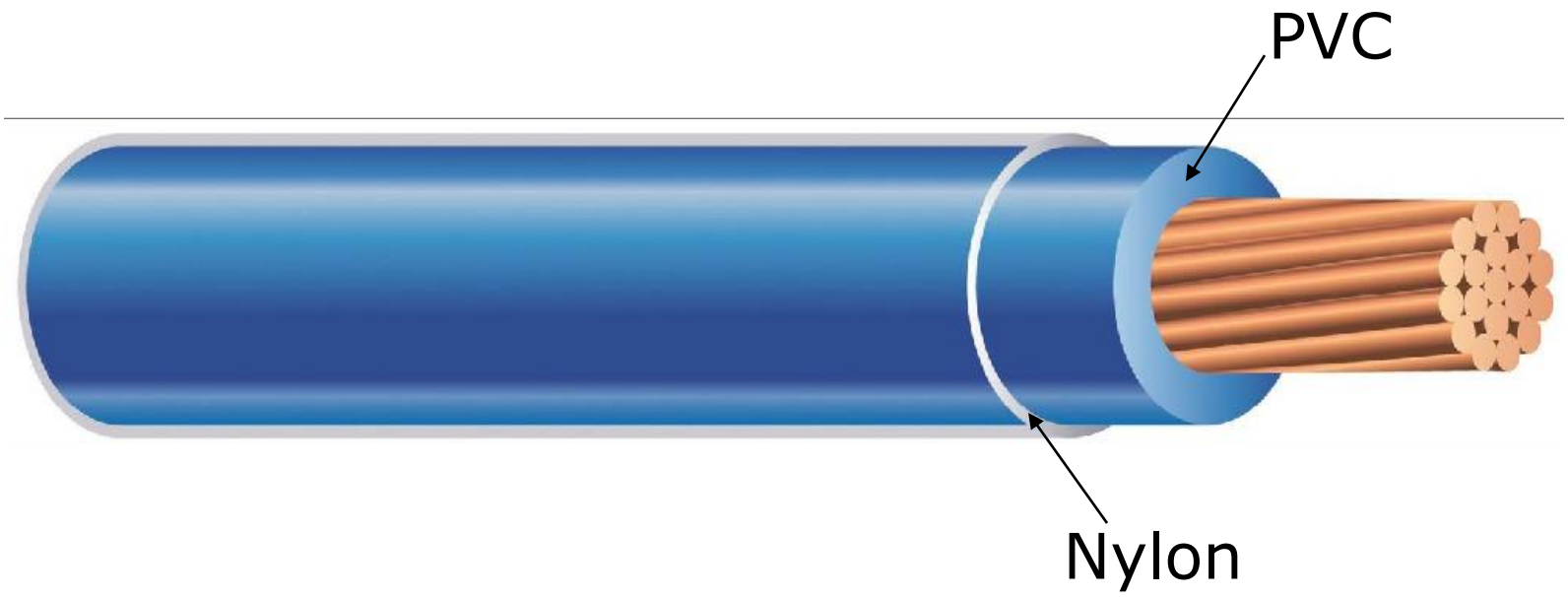


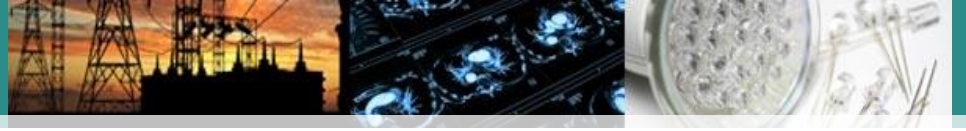
RHW vs. XHHW

- RHW requires a thicker insulation
- RHW and XHHW are both normally manufactured with a “-2” rating, allowing use in 90 degrees C, wet or dry
- RHW is often multi-rated to include insulation types RHH and USE (e.g. USE-2/RHH/RHW-2)

Commercial/Industrial Conductors

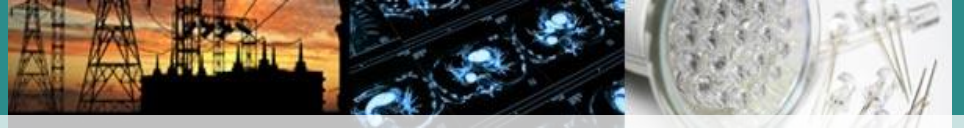
THHN / THWN-2





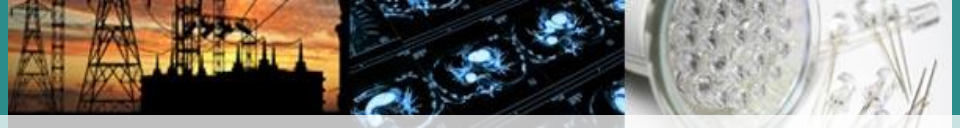
Applications for XHHW or THWN

- Service entrance – either in cable or conduit
- Feeders – either in cable or conduit
- Branch circuits – either in cable or conduit
- Wet or dry locations
- Aboveground or underground in cable or conduit



Sunlight Resistance

- Per NEC® 310.10(D), insulated conductors or cables used where exposed to direct rays of the sun must be listed, or listed and marked, as being sunlight resistant.



“W” (Wet) Rated Conductors

- “W” as part of the insulated conductor Type designation indicates that it may be used in a wet location.
- Insulated conductors with a “-2” in their Type designation are 90°C rated wet or dry.
- Refer to NEC Table 310.104(A) for conductor Type designations and temperature ratings.

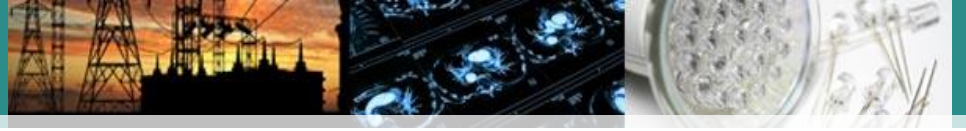
Ampacities of insulated conductors or cables

- Ampacities can be found in tables in NEC Article 310 or under engineering supervision, derived from the Neher-McGrath formula in NEC 310.15(C)
- Under engineering supervision, conductor ampacities shall be permitted to be calculated by the following equation:

$$I = \sqrt{\frac{T_c - T_a}{R_{dc}(1 + Y_c)R_{ca}}} \times 10^3 \text{ amperes}$$

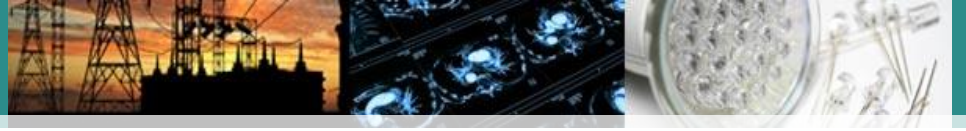
where:

- → *Tc* = conductor temperature in degrees Celsius (°C)
- → *Ta* = ambient temperature in degrees Celsius (°C)
- → *Rdc* = dc resistance of 305 mm (1 ft) of conductor in micro-ohms at temperature, *Tc*
- → *Yc* = component ac resistance resulting from skin effect and proximity effect
- → *Rca* = effective thermal resistance between conductor and surrounding ambient



Correction Factors from Table 310.15(B)(2)(a)

- Conductor ampacity from the NEC Tables are based on an ambient of 30ºC. Ambient temperature correction factors are important because exposing conductors to ambient temperatures ~~are~~ higher than 30ºC may cause insulation failure.



Cable Design

- Selection of power cable for a particular circuit or feeder should be based on the following considerations, as applicable:
  - Electrical
  - Thermal
  - Mechanical
  - Chemical
  - Flame Resistance
  - Limited Smoke
  - Acid Gas Emission

Proper Connection Methods

The following slides will describe the proper method to terminate conductors on compression and mechanical connectors

Thanks to the NEMA Electrical Connector Section for providing slides on proper connection methods.

Connector Installation Guide For Compression Connectors

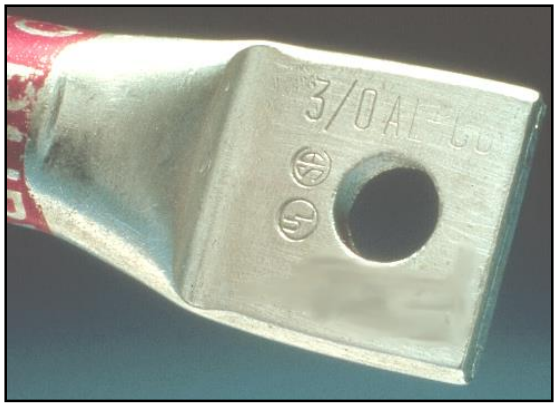
1. Determine Proper Connector For Cable
   - Conductor size and CU = Copper conductors only
   - Conductor size and “AL9” = Aluminum conductors only
   - Conductor size and “AL9CU” = Aluminum or Copper conductors
   - Match size and type of conductor to proper lug

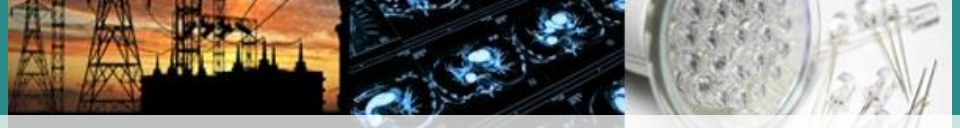
Note: Consult manufacturers instructions on whether fine stranded conductors or welding cable conductor types may be used.

Connector Installation Guide For Compression Connectors

Marking Information on Connectors:

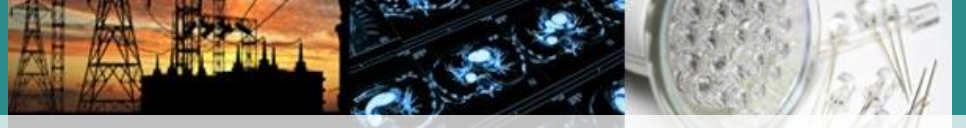
- Manufacturer
- Wire Size
- Wire material- CU, AL, or
- AL9CU (indicates Dual Rating and 90° C)
- Optional Crimp Indicator Bands
- Listing Information





Connector Installation Guide For Compression Connectors

2. Strip and Properly Prepare Cable
   - Strip insulation carefully to avoid nicking strands.
   - Strip to proper length so conductor can be fully inserted.
   - Refer to manufacturers instructions for strip length.
   - Most connectors are suitable for one conductor. Never install more than one conductor unless specifically allowed by the manufacturer's instructions.

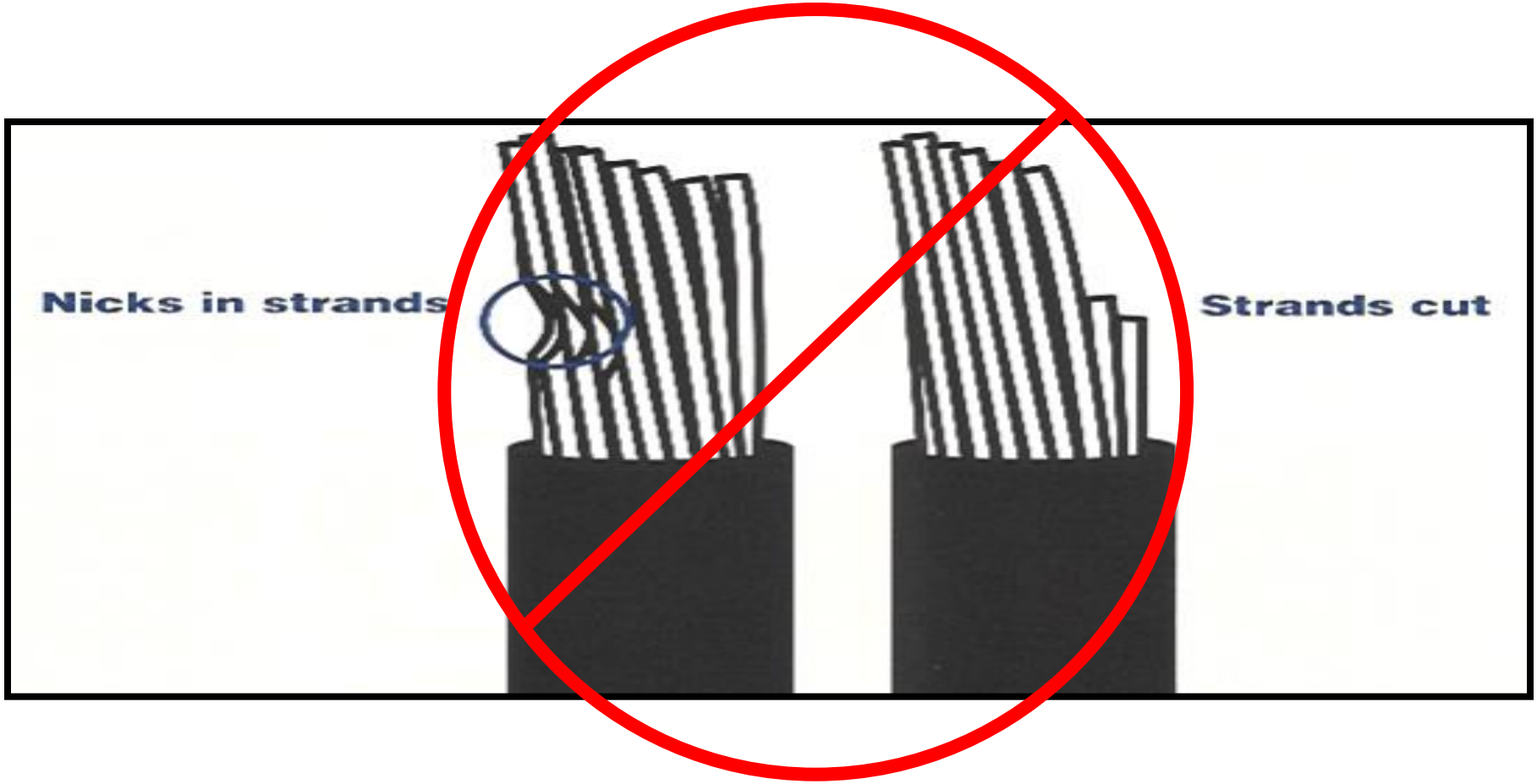


Connector Installation Guide For Compression Connectors

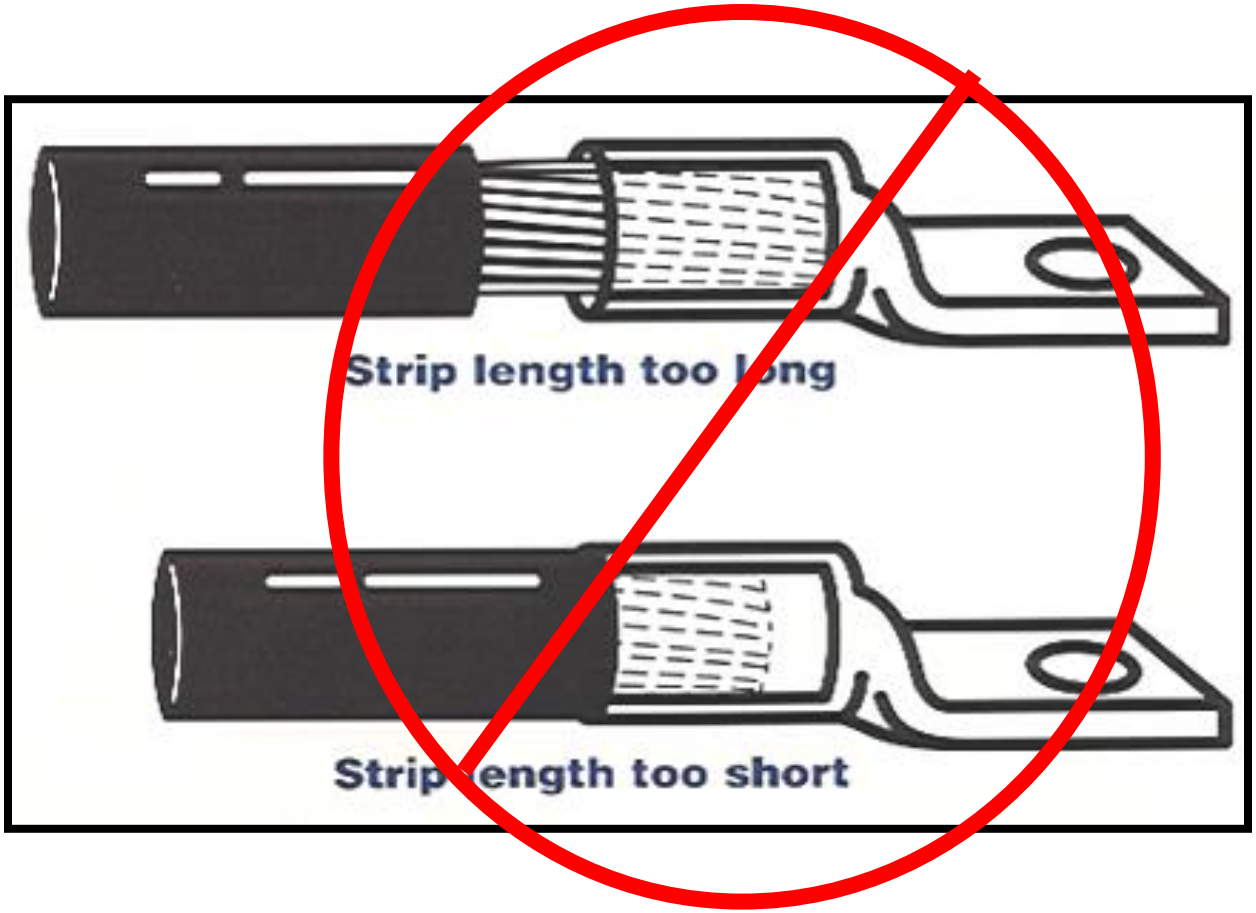
2. Strip and Properly Prepare Cable (Continued)

- Brush the stripped portion of the conductor to remove oxide film using a stainless steel wire brush.
- Apply oxide inhibitor compound if recommended by the connector manufacturer. Do not remove pre-filled inhibitor from the barrel.

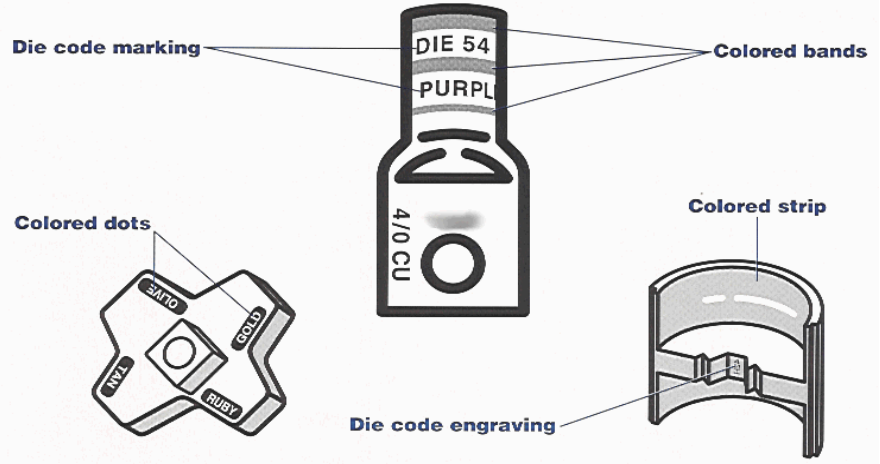
Connector Installation Guide For Compression Connectors



Connector Installation Guide For Compression Connectors



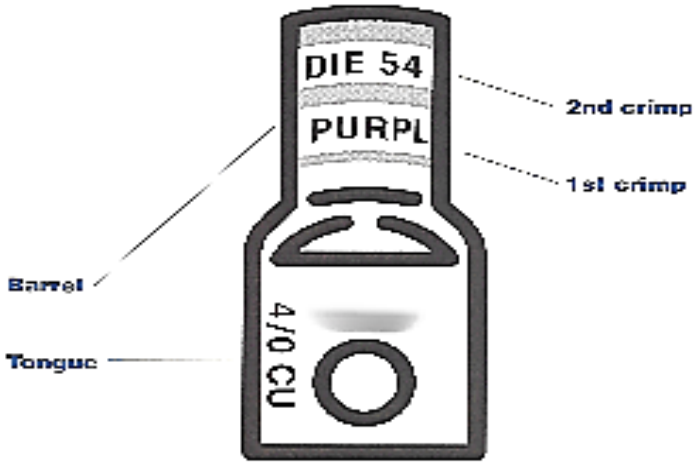
Connector Installation Guide For Compression Connectors



3. Select proper installing die tool

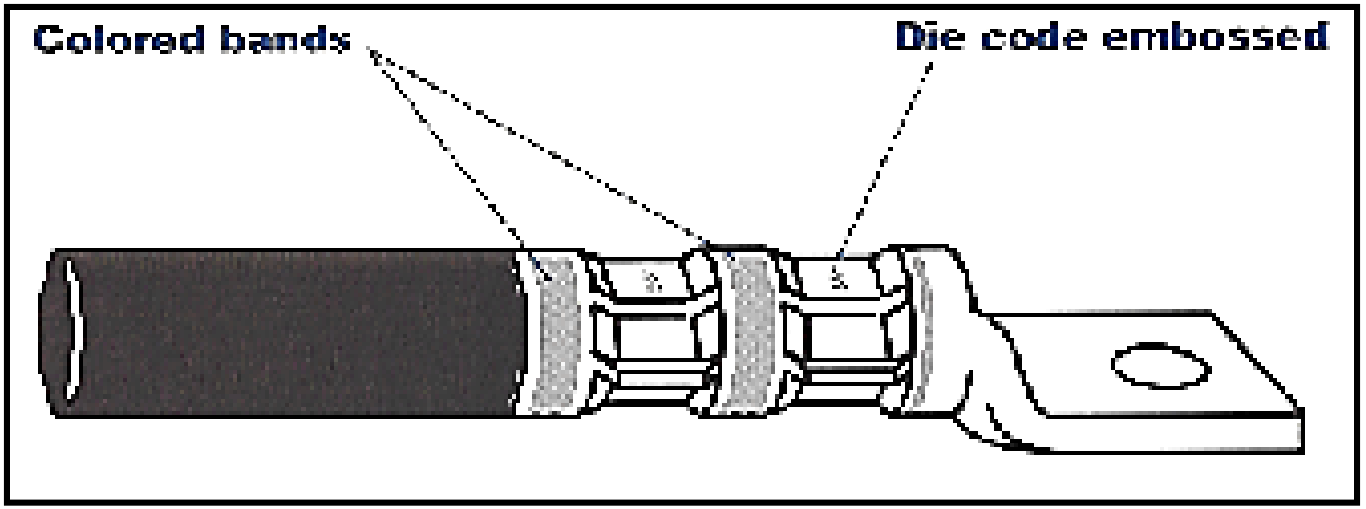
- Always refer to the connector manufacturer's instructions for the proper compression die that is intended for the connector.
- Manufacturers may use colored bands or dots that correspond to color markings on dies.
- Manufacturers may use die code number marked or stamped on the connector.
- Knurls may be used in place of colored bands.

Connector Installation Guide For Compression Connectors



4. Locate tool with correct die in proper position on connector and activate tool
    - Connectors that are banded with colored stripes to indicate number and location of each crimp.
    - Connectors may also be marked with the die code number at each compression location.
    - Follow manufacturers instructions whether to crimp on the colored bands or between the colored bands.

Connector Installation Guide For Compression Connectors



4. Continued….

When crimped, the die code number or other marking will be embossed on connector for easy inspection to determine if correct die and connector combination were used.

Connector Installation Guide For Compression Connectors

4a. Die-less Tools




Select proper installing die-less tool

*** Crimp as directed by the manufacturer's instructions.**

*** Advanced tools are now available with RF sensing technology allowing terminals to provide compression requirements directly to the tools.**

Connector Installation Guide For Compression Connectors

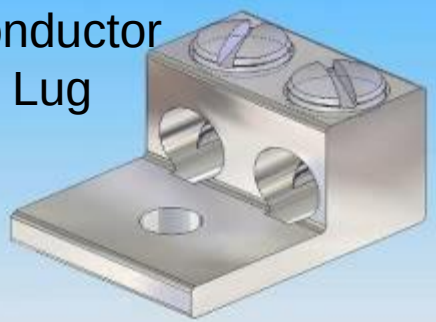
5. Connector Securement

Use a 2-hole connector if there is a concern for twisting the connection.

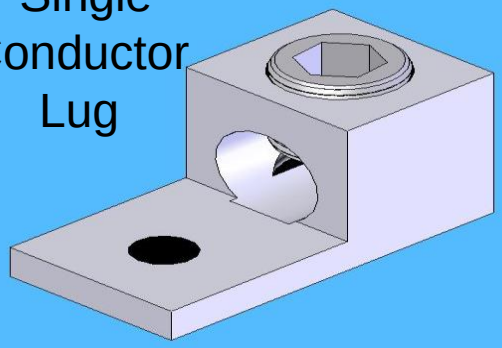
Connector Installation Guide For Mechanical Connectors

Connector Types

Double Conductor Lug

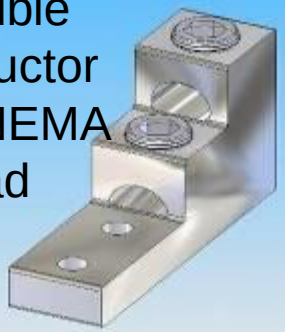


Single Conductor Lug

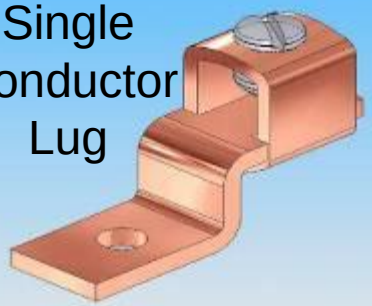


Overhead Transformer

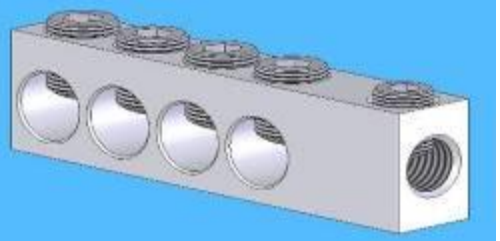
Double Conductor Lug, NEMA Pad



Copper Single Conductor Lug



Stud Type Transformer



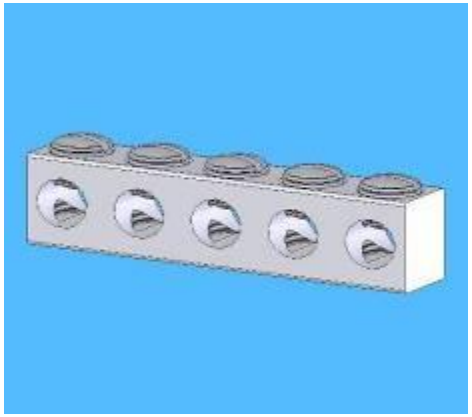
Connector Installation Guide For Mechanical Connectors

Marking Information on Connectors:

- Manufacturer's name or Symbol
- Wire Size or range
- Wire material- CU, AL, or Both
- Temperature Rating if applicable
- AL9CU Shows Dual Rating (Al & Cu) and 90°C
- UL and/or CSA if it is a listed connector

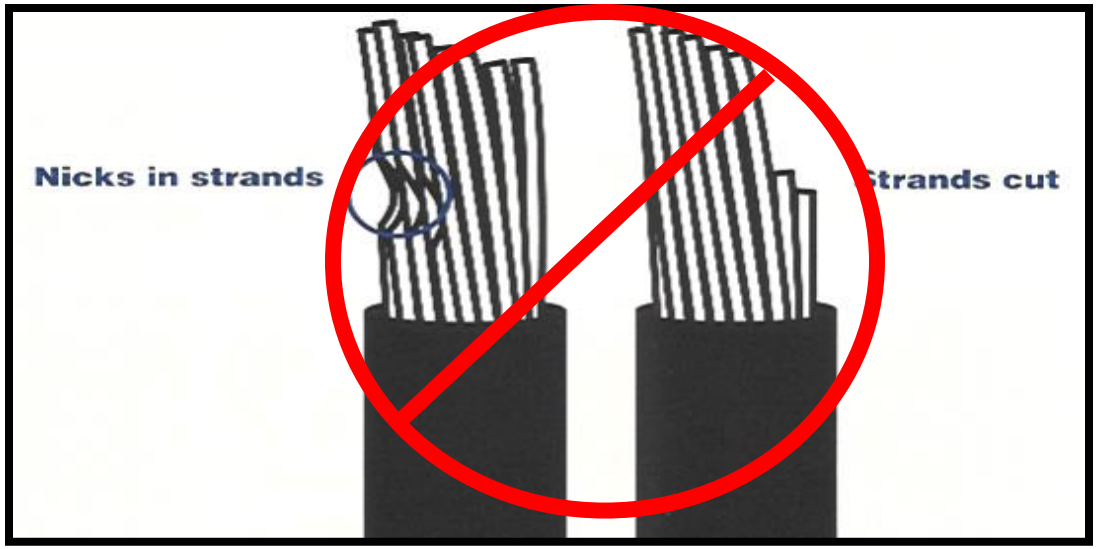
Caution: Fine-stranded wires may only be used with connectors that are specifically listed and marked for use with fine-stranded wires. This applies to both set-screw and crimp-on connectors.

Connector Installation Guide For Mechanical Connectors



- Unlike Compression connectors, mechanical connectors typically take a range of conductors. It is important to check that the cable falls within the cable range listed on the connector.
- If the connector is intended to be used on a bus, pad or equipment, mount the connector and tighten the mounting hardware per the manufacturer's specifications.

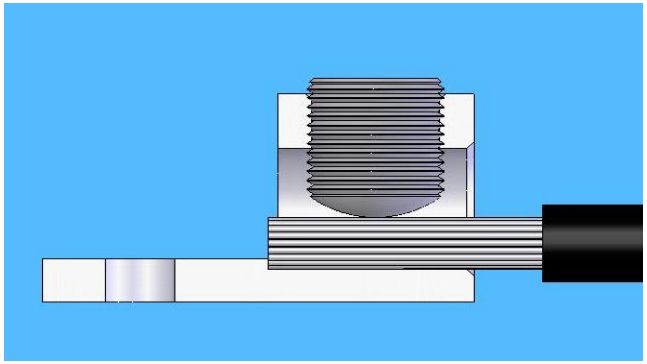
Connector Installation Guide For Mechanical Connectors



6.Strip and Properly Prepare Cable

- Strip insulation carefully to avoid nicking strands
- Strip to proper length so conductors can be fully inserted
- Refer to manufacturers instructions for strip length
- Brush the stripped portion of the conductor to remove oxide film with a stainless steel wire brush. Apply oxide inhibitor compound if recommended by the connector manufacturer.

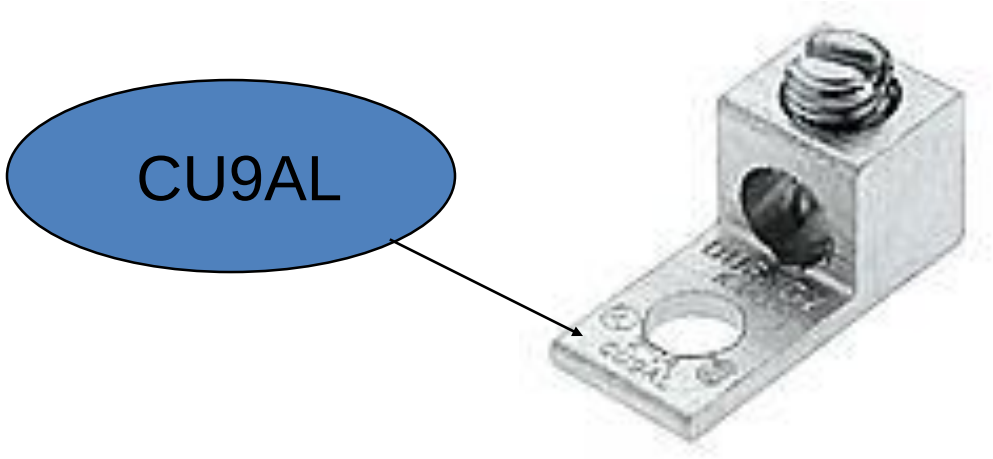
Connector Installation Guide For Mechanical Connectors

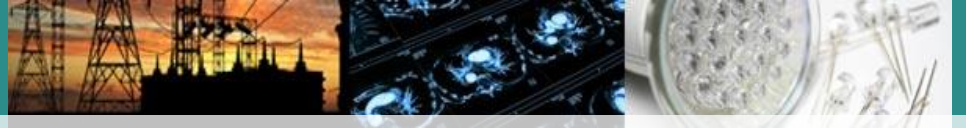


7. Insert the conductor(s) and tighten all set screws per the manufacturer's recommendations.
   - Do not retighten after properly torqued.
   - Most connectors are suitable for one conductor. Never install more than one conductor unless specifically allowed by the manufacturers instructions.
   - Use the mounting bolt size as recommended by the manufacturer.

Connector Installation Guide
Connector Rating Marking

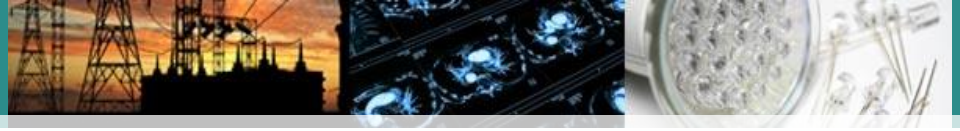
Marking	Material	Temp Rating
AL 9	Aluminum	90°C
AL9CU CU9AL	Aluminum/Copper	90°C
AL7	Aluminum	75°C
AL7CU CU7AL	Aluminum/Copper	75°C





Good Connections

- Follow manufacturers instructions
  - Torque requirement
  - Cleaning/wire brushing contact surfaces
  - Use of hardware (nuts, bolts, washers)
  - Oxide inhibitors
  - Strip length



Questions?