Electrical Level 2

Conductor Terminations and Splices 26208-14

Objectives

When trainees have completed this lesson, they should be able to do the following:

1. Describe how to make a good conductor termination.
2. Prepare cable ends for terminations and splices and connect using lugs or connectors.
3. Train cable at termination points.
4. Understand the *National Electrical Code*® (*NEC*®) requirements for making cable terminations and splices.
5. Demonstrate crimping techniques.
6. Select the proper lug or connector for the job.

Performance Tasks

1. Terminate conductors using selected crimp-type and mechanical-type terminals and connectors.
2. Terminate conductors on a terminal strip.
3. Insulate selected types of wire splices and/or install a motor connection kit.

Introduction; Stripping and Cleaning Conductors

Size (A WG/kcmil)	Area (Circular Mils)	Overall Diameter in Inches	
		Solid	Stranded
18	1,620	0.040	0.046
16	2,580	0.051	0.058
14	4,130	0.064	0.073
12	6,530	0.081	0.092
10	10,380	0.102	0.116
8	16,510	0.128	0.146
6	26,240	—	0.184
4	41,740	—	0.232
3	52,620	—	0.260
2	66,360	—	0.292
1	83,690	—	0.332
1/0	105,600	—	0.373
2/0	133,100	—	0.419
3/0	167,800	—	0.470
4/0	211,600	—	0.528
250	—	—	0.575
300	—	—	0.630
350	—	—	0.681
400	—	—	0.728
500	—	—	0.813
600	—	—	0.893
700	—	—	0.964
750	—	—	0.998
800	—	—	1.03
900	—	—	1.09
1,000	—	—	1.15
1,250	—	—	1.29
1,500	—	—	1.41
1,750	—	—	1.52
2,000	—	—	1.63

- A properly made splice should last as long as the wire insulation itself.
- The first step in making a connection is to trim and strip the conductors. When selecting stripper blades, refer to the nominal wire sizes shown here.

Stripping Small Conductors

- The wire strippers shown here can be used to strip wires from No. 22 through No. 10 AWG.
- Match the conductor size to the correct knife groove, then insert the conductor and squeeze the tool handles. The length of the stripped conductor is determined by the amount extending beyond the blades.

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Wire Strippers

- Production-grade stripping tools can be used to strip larger wires and may have either front or side entry jaws.
- Strippers with front entry jaws can be used in tight spaces.

Stripping Power Cables and Large Conductors

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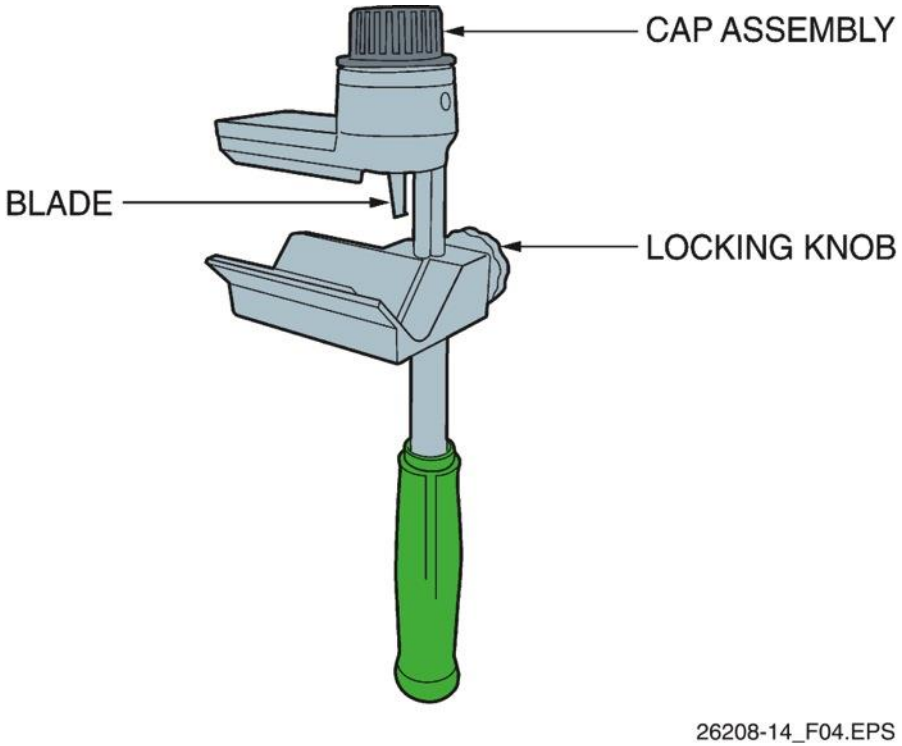
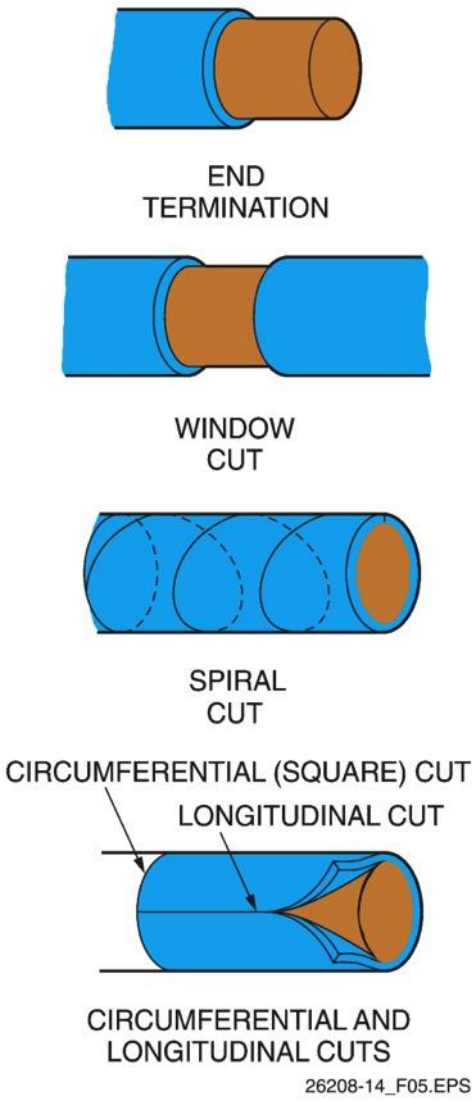
- Larger conductors can be cut using ratchet-type cable cutters.
- The cable cutters shown here can be used to strip wire up to 1,000 kcmil.

Heavy-Duty Cable Stripper



Heavy-duty cable strippers can be used to strip power cables from 1/0 through 1,000 kcmil.



Types of Cable Stripping

- Strippers can be used to strip the end insulation or to make window cuts.
- Follow the manufacturer's instructions to avoid personal injury or conductor damage.

Round Cable Slitting and Ringing Tool

- This tool can be used to strip single- or multi-conductor cable.
- It can make both square (circumferential) cuts or lengthwise (longitudinal) cuts.

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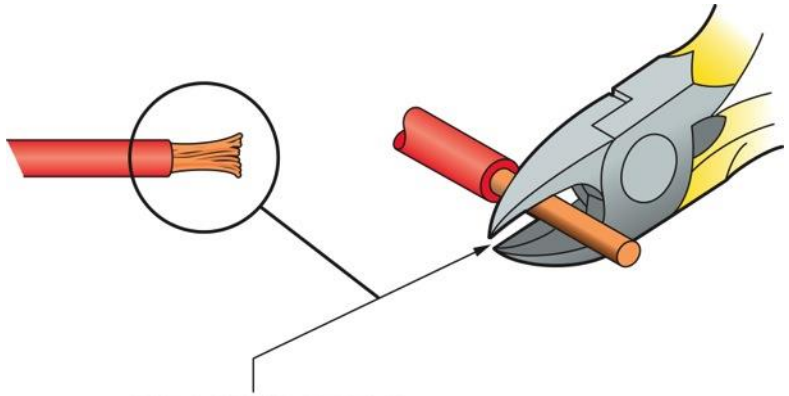
Stripping Control and Signal Cable/Conductors

- Scissors-type tools are preferred to those that leave a flattened chisel edge on the conductors. A chisel edge can make it difficult to insert the conductor into the connector.
- Keep all tools sharp for best performance.



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Cable and Wire Stripping Tools

- When stripping conductors, remove the cable jacket using an adjustable blade or a die designed for the given wire size.
- The terminal manufacturer will recommend the correct stripping length.

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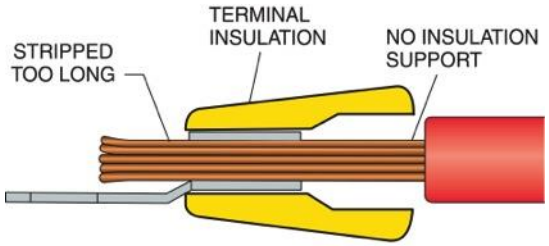
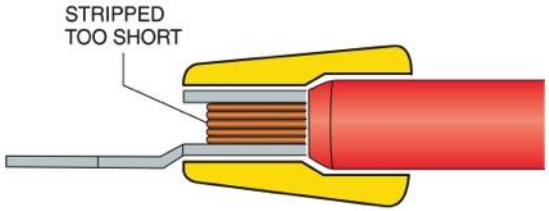
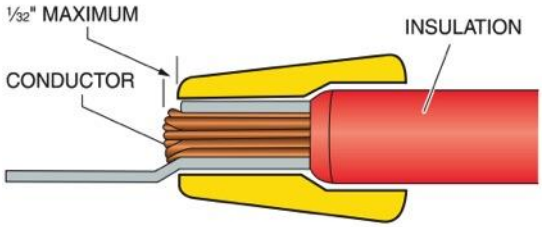
Proper Stripping Length



STRIPPING THAT IS TOO LONG WILL INTERFERE WITH THE TERMINAL SCREW



STRIPPING THAT IS TOO SHORT DOES NOT PROVIDE ENOUGH CONTACT SURFACE



PROPER STRIPPING LENGTH WITH INSULATION INSIDE THE TERMINAL

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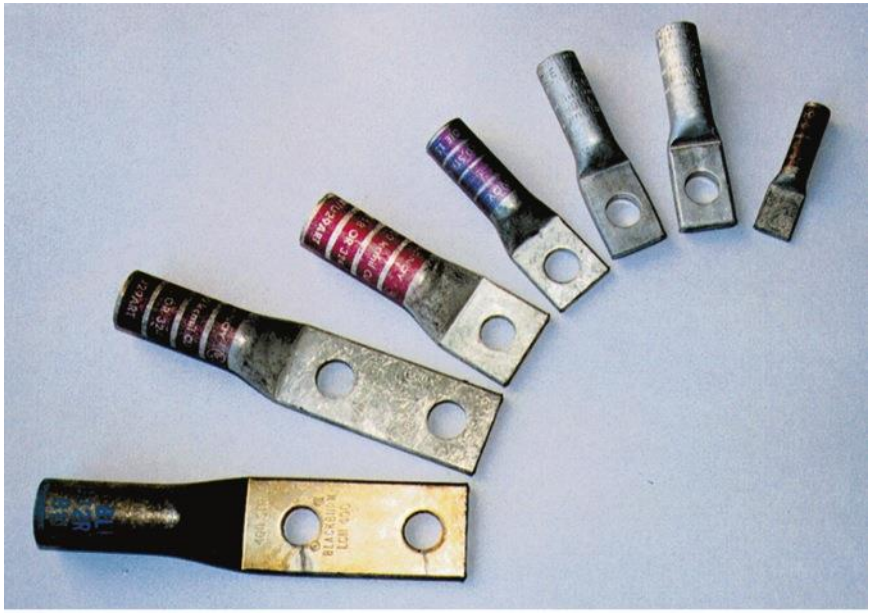
Wire Connections Under 600 Volts

- Crimp-on wire lugs are available in various sizes to accommodate wire sizes No. 22 AWG and larger. They are normally color coded for ease of identification.
- A variety of mechanical compression connectors are also available. These include various screw-on lugs and split-bolt connectors.



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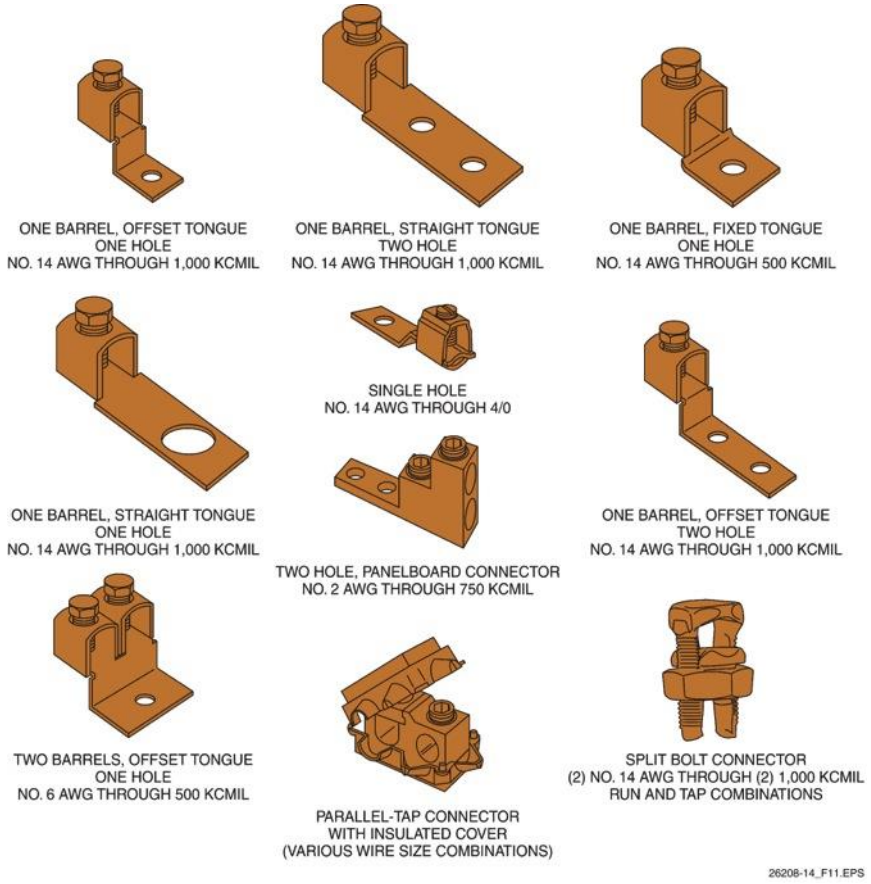
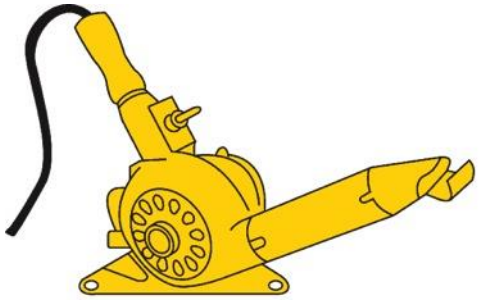
Various Mechanical Compression Connectors

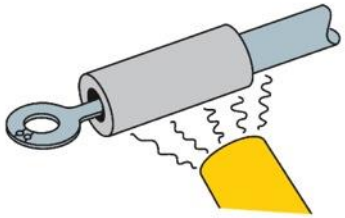


Heat-Shrink Insulators

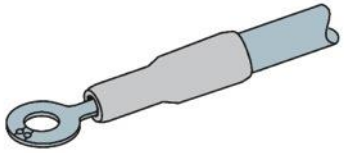
- Heat-shrink insulators slip over wires, terminals, and splices and are made skintight through the use of a heat gun.
- They are available in a wide variety of sizes and materials for different applications, and provide the advantage of quickly conforming to the contours of the insulated object.



HEAT GUN



SLIP INSULATOR OVER OBJECT TO BE INSULATED, THEN APPLY HEAT FOR A FEW SECONDS



WHEN FINISHED, IT PROVIDES PERMANENT INSULATION PROTECTION

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Next Session…

Tubing Selector Guide

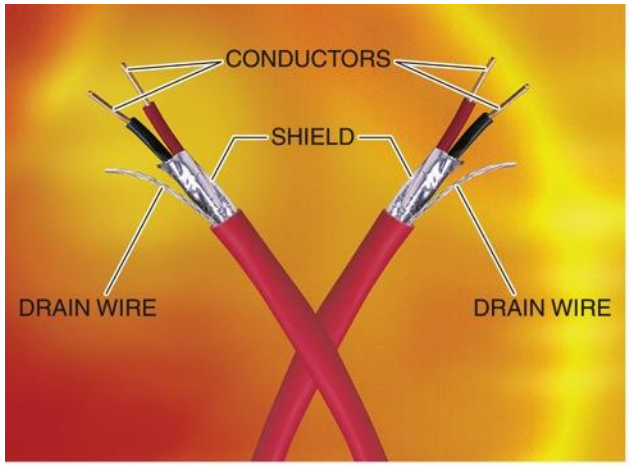
- Tubing is designed for specific temperature applications, as well as various tensile and dielectric strengths.
- It can be clear or color coded, depending on the material and its intended use.

Control and Signal Cable

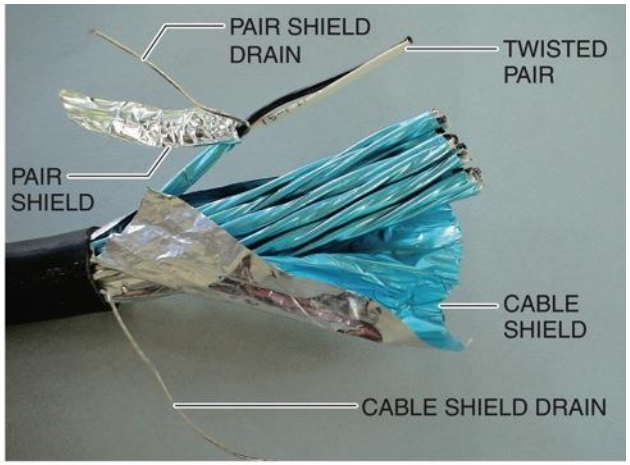
Type	Material	Temp. Range (°C)	Shrink Ratio	Max. Long. Shrinkage (%)	Tensile Strength (psi)	Colors	Dielectric Strength (V/mil)
Nonshrinkable	PVC	+ 105	—	—	2,700	White, red, clear, black	800
Shrinkable	PVC	– 35 to + 105	2:1	10	2,700	Clear, black	750
Nonshrinkable	Teflon®	– 65 to + 260	—	—	2,700	Clear	1,400
Shrinkable	Flexible polyolefin	– 55 to + 135	2:1	5	2,500	Black, white, red, yellow, blue, clear	1,300
Nonshrinkable	Teflon®	– 65 to + 260	—	—	7,500	Clear	1,400
Shrinkable	Polyolefin double wall	– 55 to + 110	6:1	5	2,500	Black	1,100
Shrinkable	Kynar®	– 55 to + 175	2:1	10	8,000	Clear	1,500
Shrinkable	Teflon®	+ 250	1.2:2	10	6,000	Clear	1,500
Shrinkable	Teflon®	+ 250	1½:1	10	6,000	Clear	1,500
Shrinkable	Neoprene	+ 120	2:1	10	1,500	Black	300

Control and Signal Cable

- Electricians are typically responsible for installing control and signal cables.
- Fire alarm and instrumentation cables typically contain a drain (ground) wire that must be effectively grounded. Refer to the drawings for the system to be installed.



(A) FIRE ALARM CABLE



(B) INSTRUMENTATION CABLE

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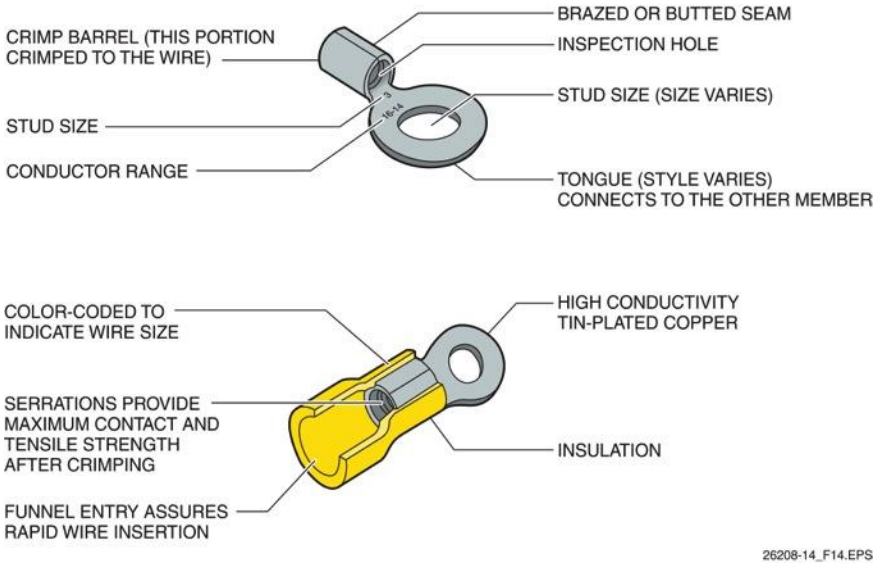
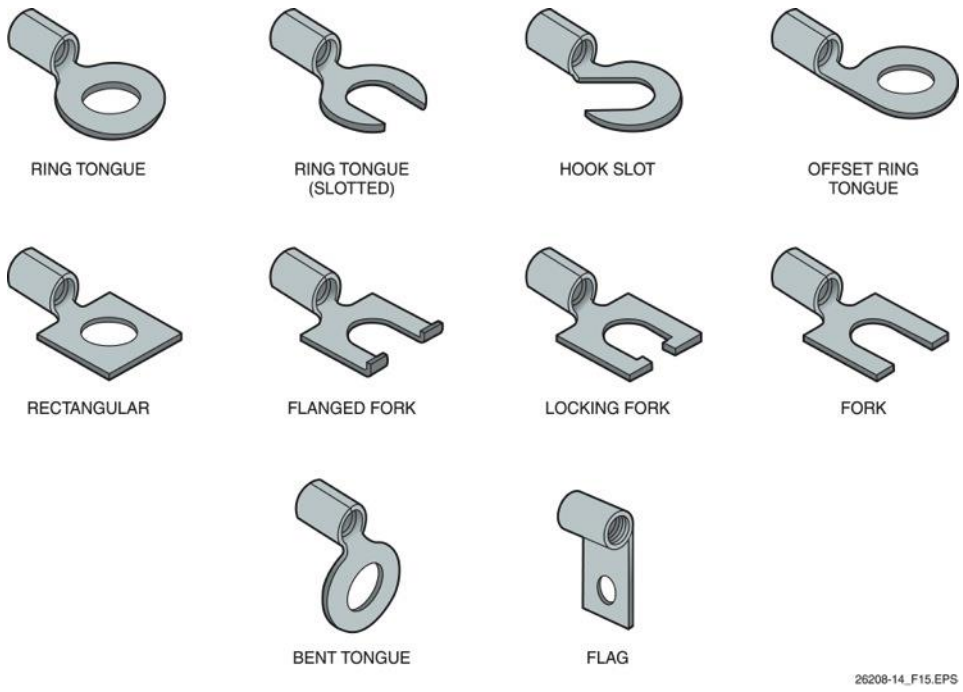
Low-Voltage Connectors and Terminals

- A basic crimp connector consists of a crimp barrel in which the conductor is inserted and a copper stud end with a bolt/screw opening.
- Most crimp connectors are color coded by size and insulated on the barrel end to prevent shorting to adjacent terminals.



Standard Tongue Styles of Crimped Connectors

- Crimp connectors are available in a variety of tongue styles.
- The most common styles are the ring tongue and the flanged or locking fork.



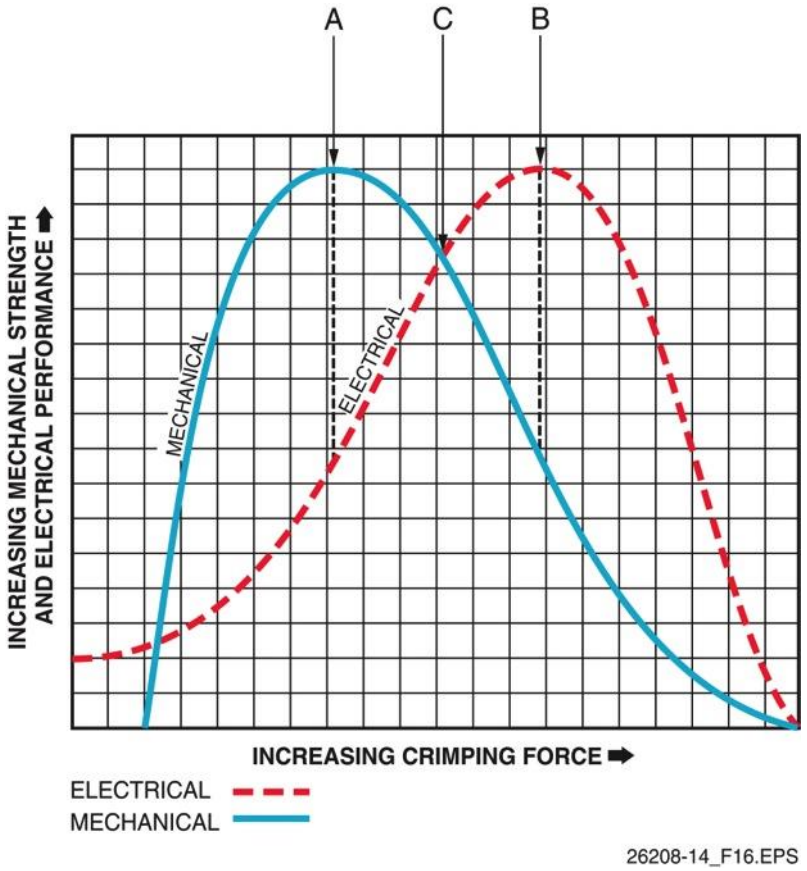
Color Codes

- Color codes may vary by manufacturer, but certain color standards have become common.
- Typical crimp connector color codes are shown here.

AWG Wire Size	Color Code
22–16	Red
16–14	Blue
12–10	Yellow

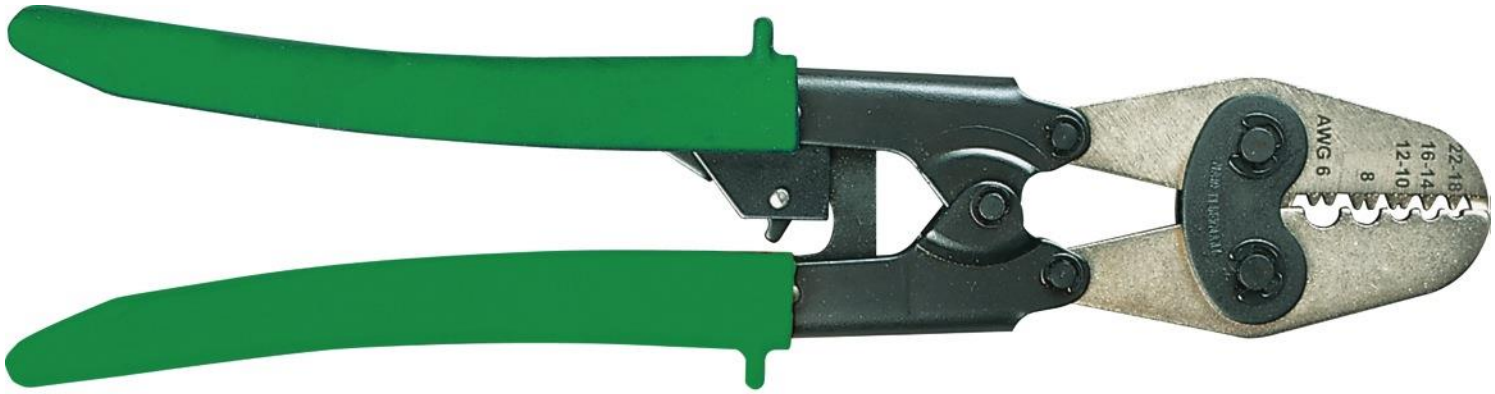
Guidelines for Installing Connectors

- Review the project drawings and specifications before making any line connections.
- Always use the correct tool for the connector and the wire size. Failure to do so can result in damaged conductors and poorly made connections.



Hand Crimpers

Pliers-type hand crimpers are used with smaller wires or when only a few connections are required.



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Leveraged Crimping Tool

- A leveraged tool provides a mechanical advantage through the use of a ratchet control.
- This type of tool multiplies the crimping force for a better connection and has interchangeable dies for use with various terminal sizes.

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DIE SET

HAND-OPERATED

HYDRAULIC

26208-14_F19.EPS

Crimping Tools Used to Crimp Large Connectors

- The tools used to crimp large connectors supply crimping forces of about 12 tons of compression at 10,000 pounds per square inch (psi).
- These tools are available in hand-operated, hydraulic, battery-operated, and corded types.

Battery-Operated Crimping Tool

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Corded Crimping Tool

26208-14_F21.EPS

Universal Crimping Tool

Universal crimping tools offer an advantage in that they can fit a variety of terminations without the need for separate dies.

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Multiple Crimps

- Multiple crimps may be required to ensure a tight and solid connection.
- If multiple crimps are specified, crimp from the lug back to the barrel base, rotating the crimper as necessary to avoid deforming the barrel.

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Recommended Tightening Torques for Various Bolt Sizes

- After the conductor has been crimped in the connector, the connector must be bolted to the required torque to ensure a good electrical connection at the termination.
- Common torque values are shown here.

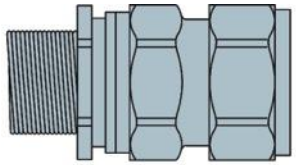
Steel Hardware		Aluminum Hardware	
Bolt Size	Recommended Torque (Inch-Pounds)	Bolt Size	Recommended Torque (Inch-Pounds)
¼–20	80	½–13	300
5⁄16–18	180	⅝–11	480
⅜–16	240	¾–10	650
½–13	480	—	—
⅝–11	660	—	—
¾–10	1,900	—	—

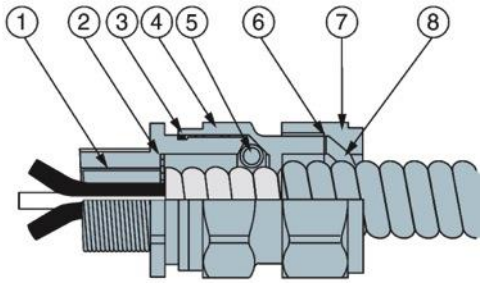
Performance Task

Trainees practice terminating conductors using selected crimp-type and mechanical-type terminals and connectors.

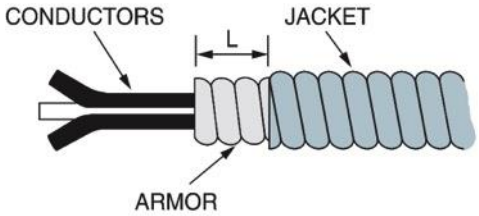
Installing Specialized Cable Connectors

- A variety of specialized connectors are used with specific applications and cable types.
- This weatherproof connector is used with metal-clad (Type MC) cable.
- The specific connector is determined by the type and size of cable and the application.





1. ENTRY COMPONENT
2. END STOP
3. O-RING
4. CONNECTOR BODY
5. RETAINING SPRING
6. WASHER
7. JACKET SEAL
8. COMPRESSION NUT



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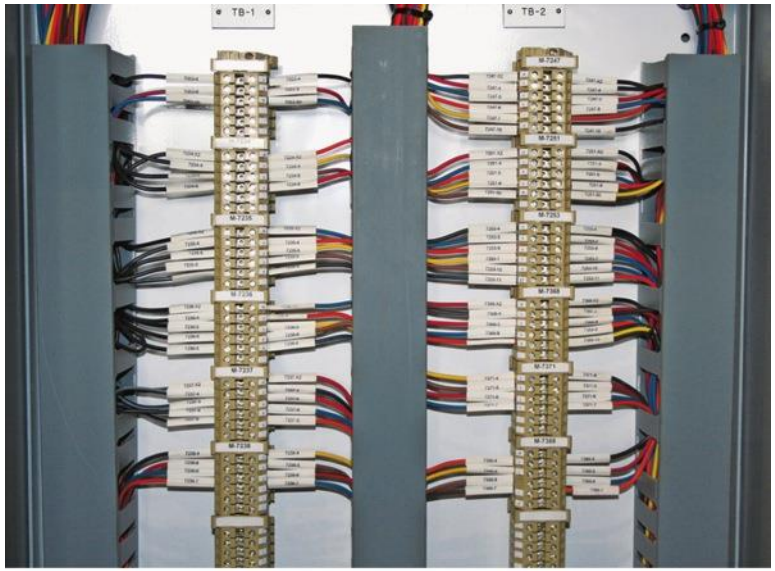
Installing Control and Signal Cables/Conductors

- Before making a crimped connection, organize, dress, and label the conductors/cables.
- Check the size and type of wire, and make sure the conductor and connector materials are compatible.
- Select the correct tool and die for the terminal and conductor, and make sure they are in good operating condition.



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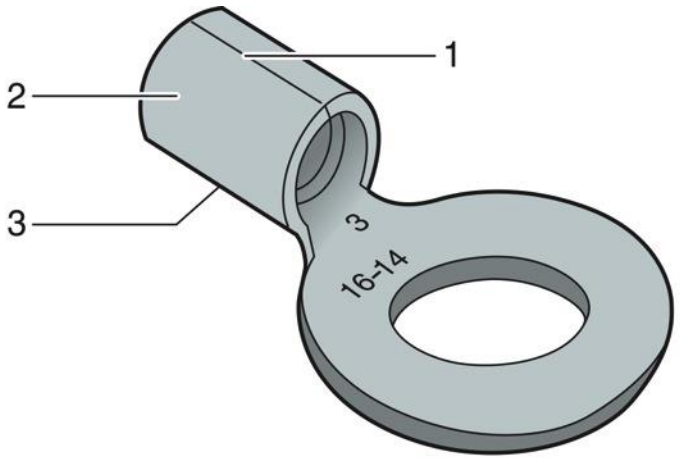
Indent Position

- The correct indent position is essential to ensuring a good electrical connection. Inspect all terminations prior to making any connections.
- An indent on the side can split the terminal seam, while an indent on the bottom may produce a loose connection.



1 – ACCEPTABLE – INDENT ON SEAM (TOP)
2 – UNACCEPTABLE – INDENT ON SIDE
3 – UNACCEPTABLE – INDENT ON BOTTOM
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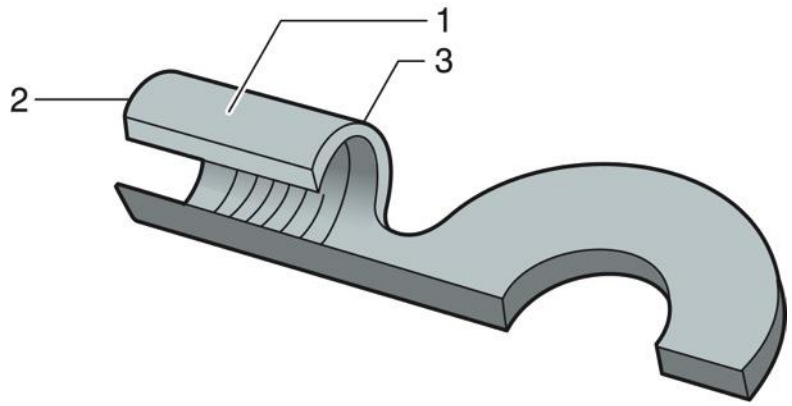
Crimp Centering

- The conductor must be properly centered in the crimp indent.
- A crimp over the belled mouth will compress the insulation and result in poor or no continuity.
- A crimp over the inspection hole reduces both continuity and holding capacity.



1 – ACCEPTABLE – CENTERED OVER SERRATIONS
2 – UNACCEPTABLE – OVER BELLED MOUTH
3 – UNACCEPTABLE – OVER INSPECTION HOLE

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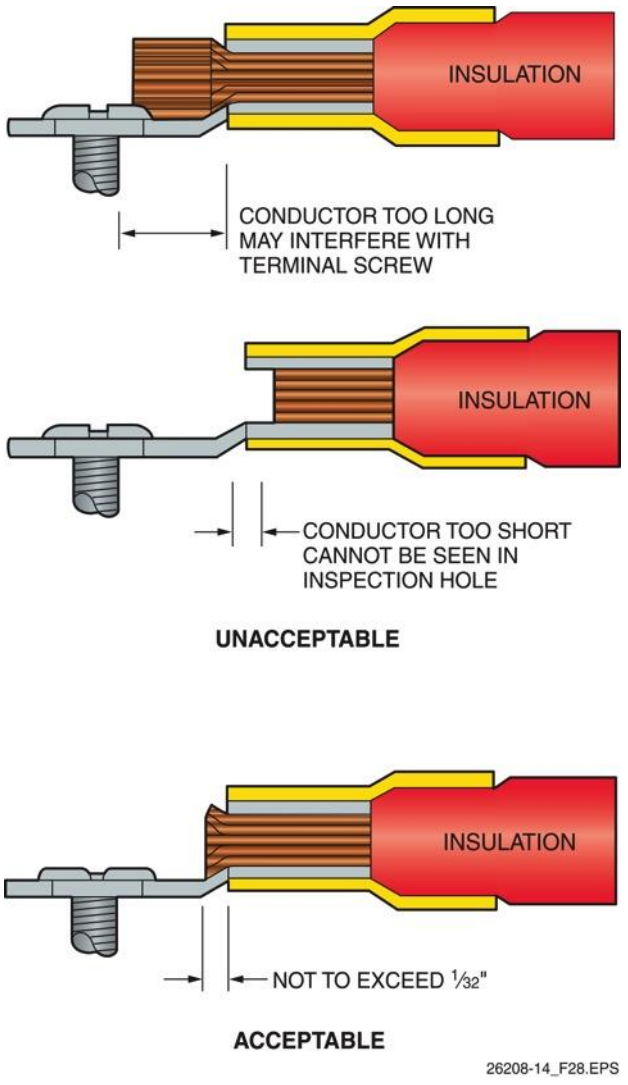
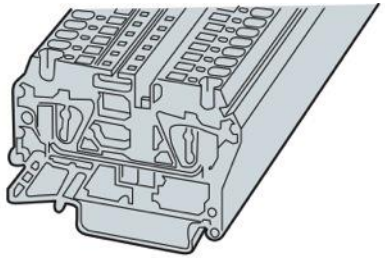
Conductor Positioning

- If the stripped end of the conductor is too short, it cannot be checked in the inspection hole and may represent a loose connection.
- Conductors that extend too far may interfere with the terminal screw.

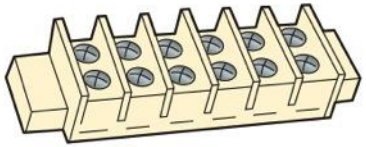


Terminal Blocks

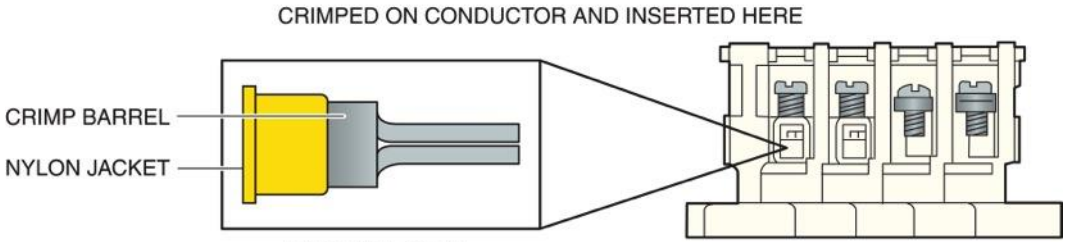
- Terminal blocks are available with a variety of connection types.
- Clamp-type, spring-loaded, and screw-type terminal blocks are common.



SPRING-LOADED TERMINAL BLOCK

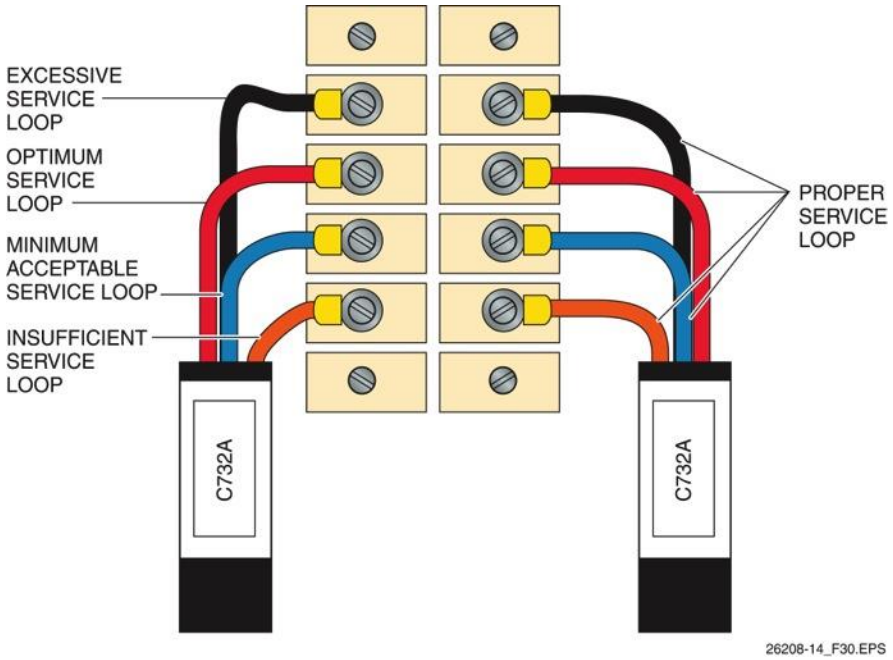


SCREW-TYPE TERMINAL BLOCK



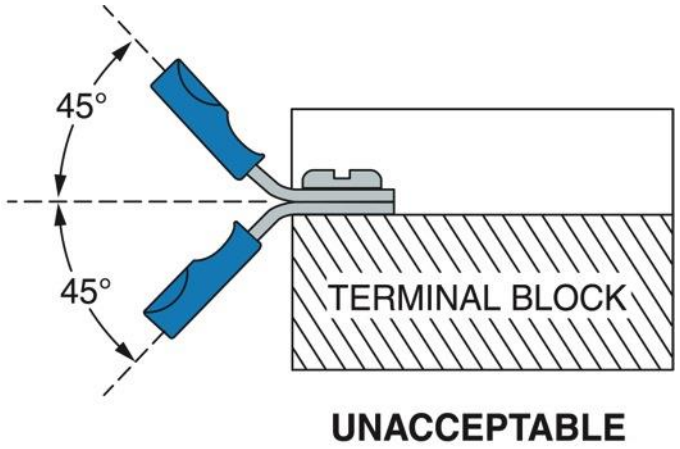
Routing Cabling

- When multiple cables are installed, tie them neatly to a support without blocking access to other terminal blocks.
- Take care to avoid routing cable over sharp edges or at tight angles.
- To minimize interference, avoid wire crossovers whenever possible.

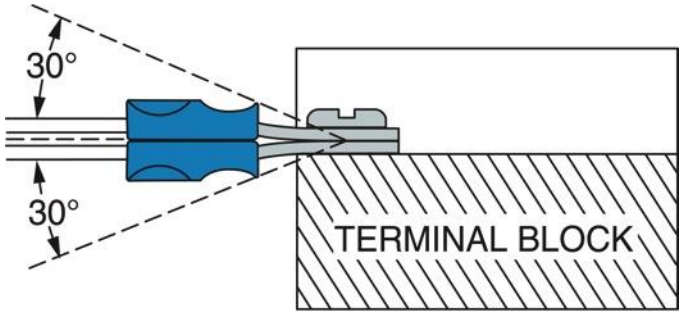


Terminal Bend Radius

Do not bend terminals more than 30 degrees above or below the termination point.



UNACCEPTABLE



ACCEPTABLE

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Performance Task

Trainees practice terminating conductors on a terminal strip.

Bending Cable and Training Conductors

- Training is the positioning of cable so that it is not under tension.
- Proper bending and training is essential to ensure that the conductor maintains its electrical characteristics over the expected service life. Ratchet and hydraulic benders are commonly used to bend large cable to the desired radius for installation.

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Hydraulic Bender

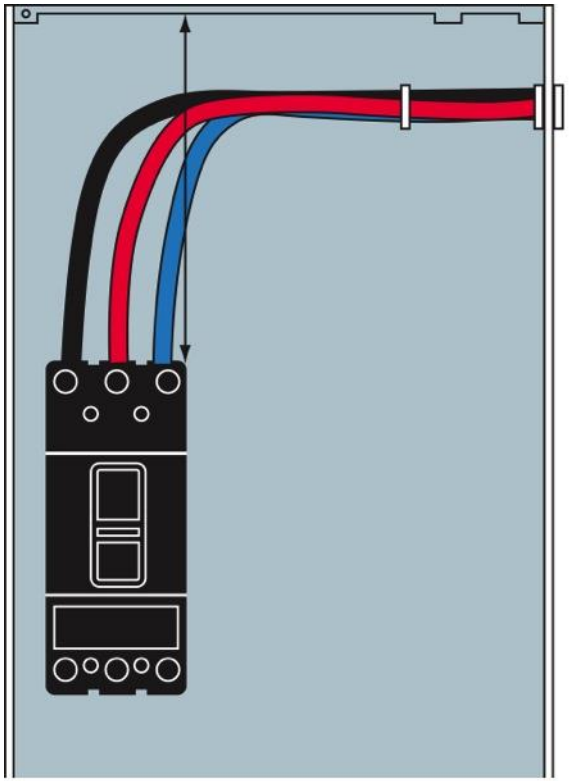
26208-14_F33.EPS

Minimum Wire Bending Space for Conductors Not Entering or Leaving Opposite Wall

AWG or Circular-Mil Size of Wire	Wires per Terminal				
	1	2	3	4	5
14–10	Not Specified	—	—	—	—
8–6	1½	—	—	—	—
4–3	2	—	—	—	—
2	2½	—	—	—	—
1	3	—	—	—	—
1/0–2/0	3½	5	7	—	—
3/0–4/0	4	6	8	—	—
250 kcmil	4½	6	8	10	—
300–350 kcmil	5	8	10	12	—
400–500 kcmil	6	8	10	12	14
600–700 kcmil	8	10	12	14	16
750–900 kcmil	8	12	14	16	18
1,000–1,250 kcmil	10	—	—	—	—
1,500–2,000 kcmil	12	—	—	—	—

NEC Table 312.6(A) provides the minimum wire bending space required for conductors not entering or leaving the opposite wall of an enclosure.

Bending Space at Terminals is Measured in a Straight Line



When using *NEC Table 312.6(A)*, bending space at terminals must be measured in a straight line from the end of the lug or wire connector (in the direction that the wire leaves the terminals) to the wall, barrier, or obstruction.

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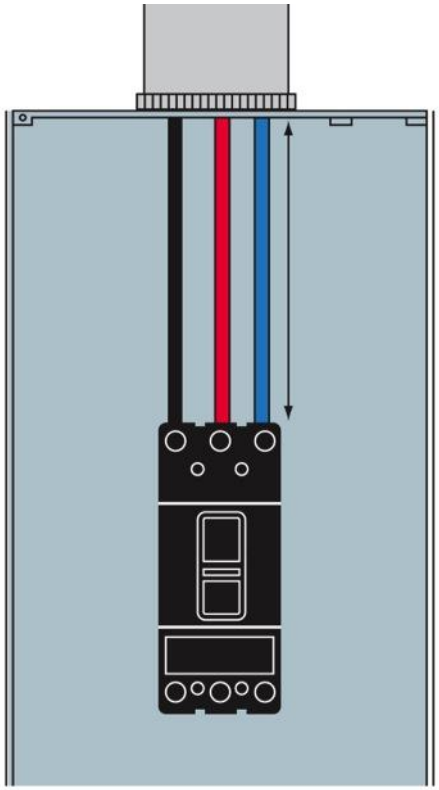
Conductors Entering an Enclosure Opposite the Conductor Terminals



Bending space at terminals must be measured in a straight line from the end of the lug or wire connector in a direction perpendicular to the enclosure wall. Use the values in *NEC Table 312.6(B)*.

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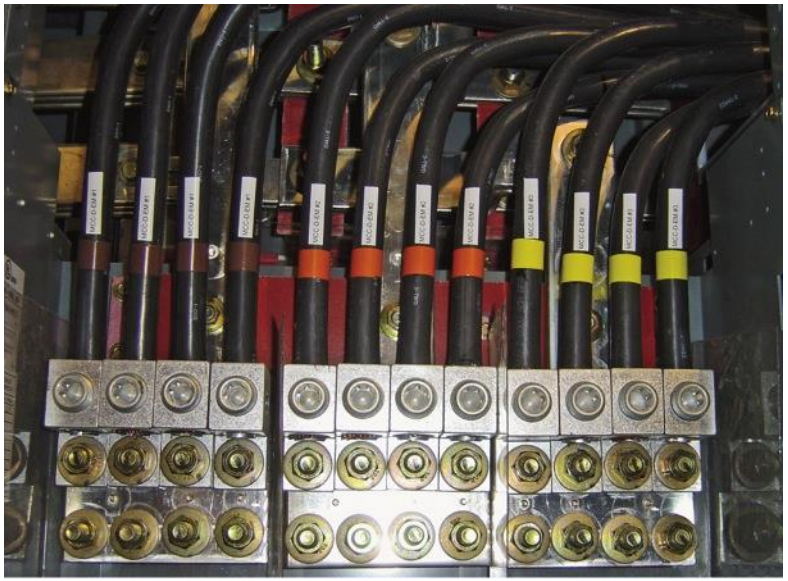
Minimum Wire Bending Space for Conductors Entering or Leaving Opposite Wall

NEC Table 312.6(B) provides the minimum wire bending space required for conductors entering or leaving the opposite wall of an enclosure.

AWG or Circular-Mil Size of Wire	Wires per Terminal			
	1	2	3	4 or More
14–10	Not Specified	—	—	—
8	1½	—	—	—
6	2	—	—	—
4	3	—	—	—
3	3	—	—	—
2	3½	—	—	—
1	4½	—	—	—
1/0	5½	5½	7	—
2/0	6	6	7½	—
3/0	6½ (½)	6½ (½)	8	—
4/0	7 (1)	7½ (1½)	8½ (½)	—
250	8½ (2)	8½ (2)	9 (1)	10
300	10 (3)	10 (2)	11 (1)	12
350	12 (3)	12 (3)	13 (3)	14 (2)
400	13 (3)	13 (3)	14 (3)	15 (3)
500	14 (3)	14 (3)	15 (3)	16 (3)
600	15 (3)	16 (3)	18 (3)	19 (3)
700	16 (3)	18 (3)	20 (3)	22 (3)
750	17 (3)	19 (3)	22 (3)	24 (3)
800	18	20	22	24
900	19	22	24	24
1,000	20	—	—	—
1,250	22	—	—	—
1,500–2,000	24	—	—	—

NEC® Termination Requirements

- ***NEC Sections 110.14 and 312.6*** provide the minimum requirements for the safe termination of conductors and enclosures.
- Overcurrent requirements can be found in ***NEC Section 240.21***.



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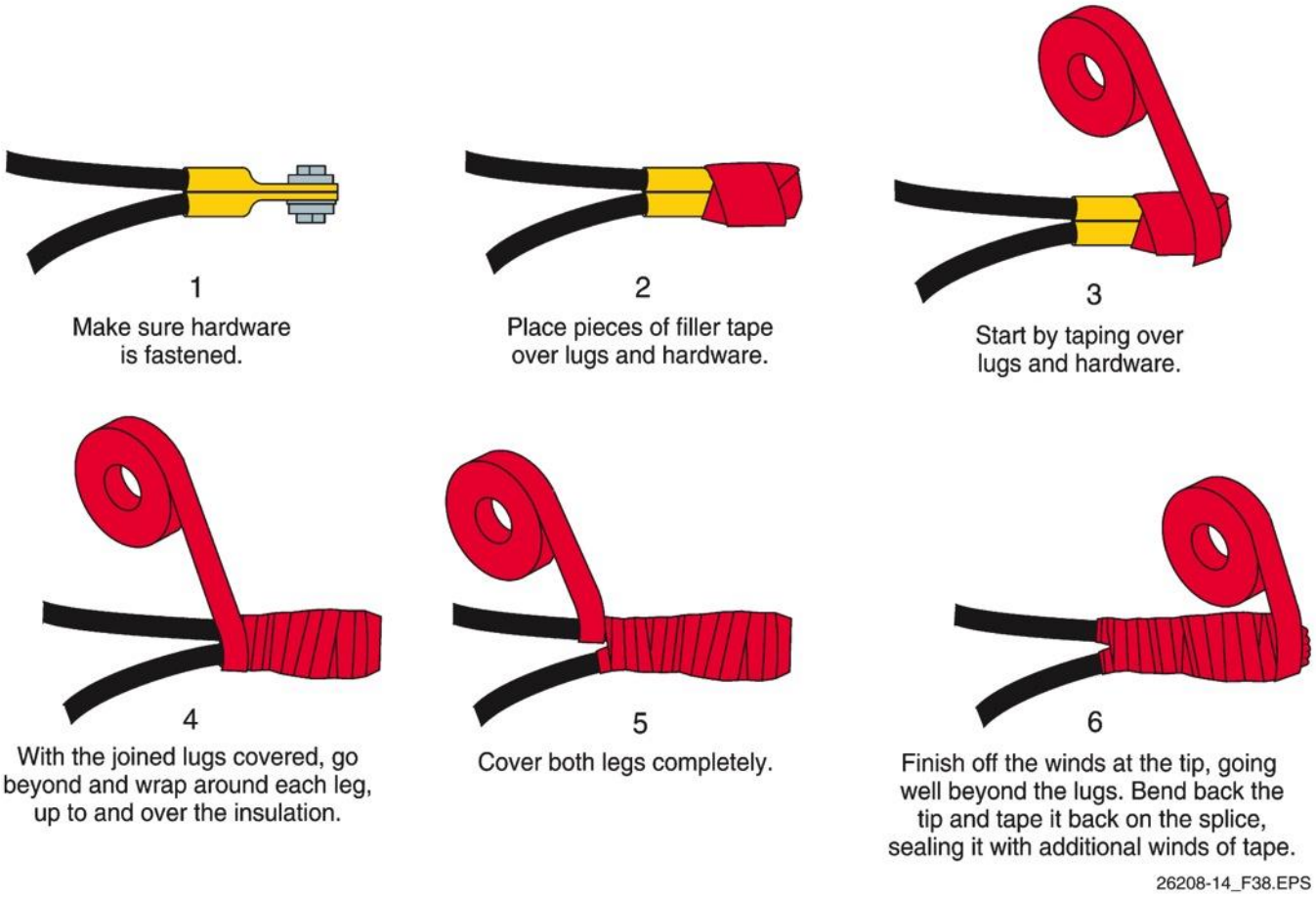
8.0.0 – 8.1.3

Next Session…

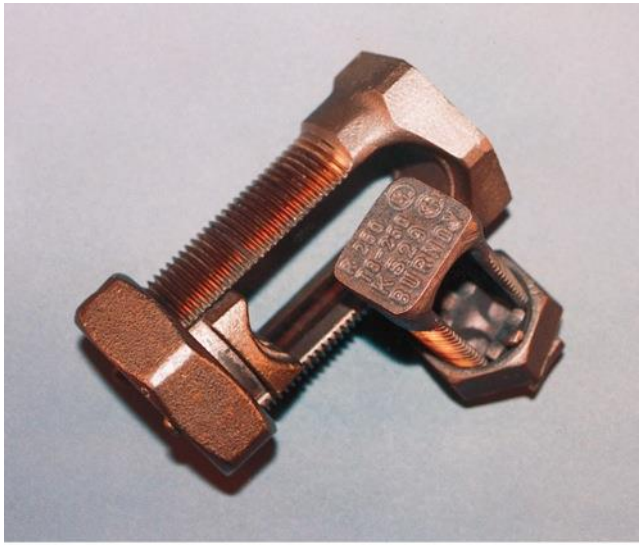
MCC Fed Directly from a Transformer Secondary

Taping Electrical Joints

Taping Electrical Joints



Typical Method of Taping a Split-Bolt Connector



(A) SPLIT-BOLT CONNECTOR

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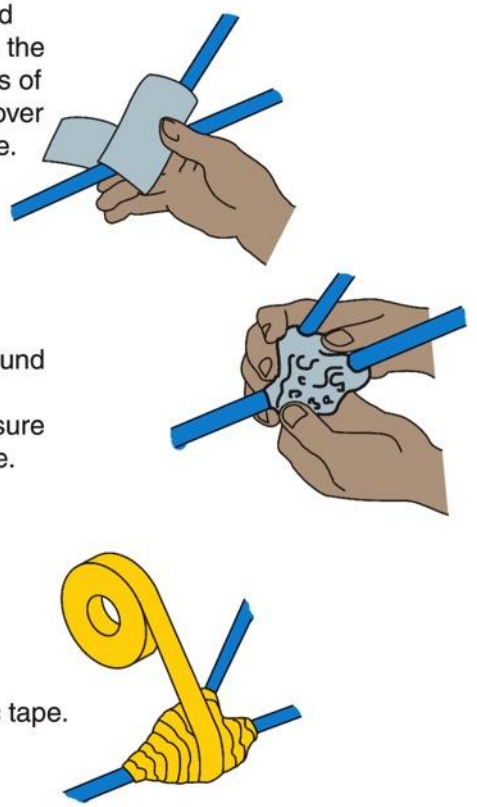
Once the split-bolt connector has been installed and tightened securely on the conductors, cut pieces of filler tape, and place over each side of the splice.

Wrap both pieces around the connector, using moderate finger pressure to shape the filler tape.

Wrap the covered connector with plastic tape.



(B) TAPING PROCEDURE

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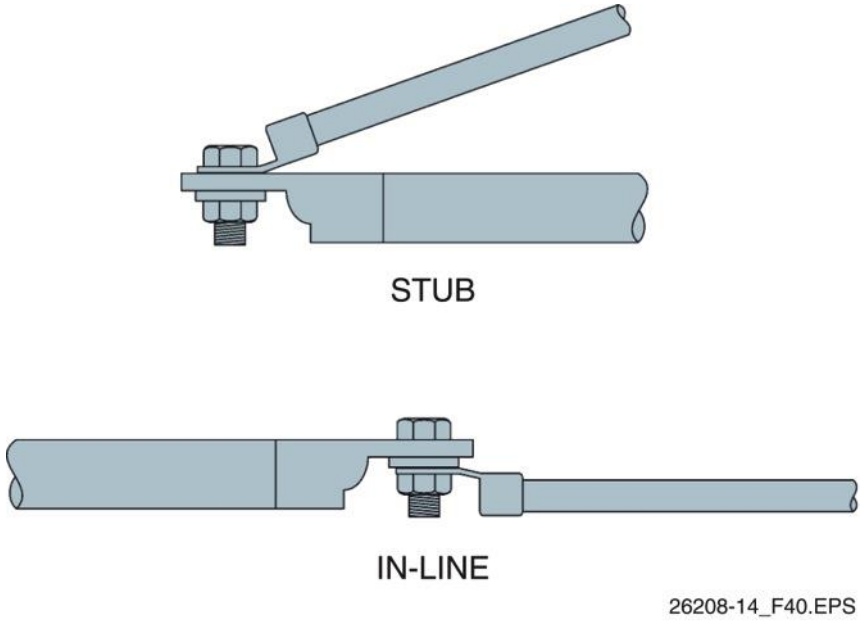
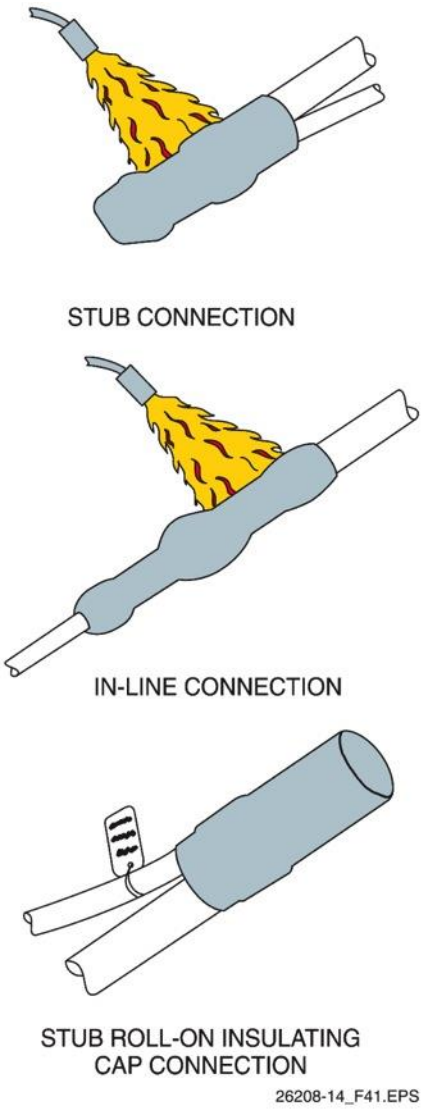
Motor Connection Kits

- Motor connection kits are available to insulate bolted splice connections.
- These kits eliminate the need for taping and the use of filler tape or putty.



Motor Connection Kits Installed on Splices

- One common type of motor connection kit is a simple heat-shrink insulator.
- It is slid over the bolted connection and then heat is applied to insulate the splice.



Performance Task

Trainees practice insulating selected types of wire splices and/or installing a motor connection kit.

Wrap Up

3-2-1

3 – Write 3 important things learned during class

2 – Write 2 questions you have about the material

1 – Write 1 thought you had about the material

Next Session…

MODULE EXAM

Review the complete module to prepare for the module exam. Complete the Module Review as a study aid.