Making the Connection

Listing Requirements and Manufacturer's Installation Instructions: Case Study

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Presentation will be available on www.iaeisnv.com

Topics

- UL Standards
- Listing Requirements
- Manufacturer’s Instructions

NEC

- 110.2 The conductors and equipment required or permitted by this Code shall be acceptable only if approved.
- 110.3 Examination, Identification, Installation, and Use of Equipment
  - 110.3(A) Examination
    - Suitability, strength and durability, connection space, insulation, heating effects, arcing effects
  - 110.3(B) Installation and Use
    - Listed or labeled equipment shall be installed and used in accordance with any instructions included in the listing or labeling.

UL Standards

- Wire and Cable
  - UL 44: Thermoset Insulations
  - UL 83: Thermoplastic Insulations
  - UL 719: Non-metallic sheathed cable
  - UL 854: Service-entrance cable
  - UL 1569: Metal-clad cable
- Pin Connectors
  - UL 486A/486B
- Compression Connectors
  - UL 486A/486B
- Mechanical Connectors
  - UL 486A/486B

UL 486A/486B Connection Procedure Requirement

- **10.15** A procedure that must be followed for proper assembly of a wire connector to a conductor shall be provided as follows:
  - a) **USE OF A SPECIFIC TOOL REQUIRED** – If a connector is intended to be assembled to a conductor(s) by a specific tool, the tool designation or the designation of a removable tool part, such as a pressing die, shall be marked on the connector, or on or within the unit container in which the connector is packed. The marking shall be by at least one of the following means:
    - 1) catalog or type designation;
    - 2) color coding;
    - 3) die index number; or
    - 4) other equivalent means.

UL 486A/486B Connection Procedure Requirement

- b) **MULTIPLE CRIMPING OPERATIONS** – Information shall appear either:
  - 1) on the unit container in which the connector is packed;
  - 2) on the tool or pressing die that must be used for its application;
  - 3) on the carrying case provided for permanent storage of the tool and dies; or
  - 4) on the connector.
- Location of the crimping points only, without additional instructions, may be marked on the connector if the additional required information is located as indicated in item 1), 2), or 3).

UL 486A/486B Connection Procedure Requirement

- c) **CONDUCTOR STRIP LENGTH** – Strip length marking as specified in Table 18 shall appear:
  - 1) on the connector;
  - 2) on the unit container or on an information sheet contained therein;
  - 3) on an insulating cover; or
  - 4) on the tool or on the carrying case provided for its permanent storage if:
    - i) the connector requires the use of a specific tool for its application; and
    - ii) the strip length applies to all insulated connectors with which the tool is used.

UL 486A/486B
Connection Procedure Requirement

- d) **PRELIMINARY PREPARATION OF CONDUCTOR REQUIRED** – Instructions for preparation of the conductors, such as use of compound or twisting conductors together before assembly, shall appear on the unit container or an information sheet packed in the unit container.

UL 486A-486B

- UL 486A-UL486B
  Wire Connectors
- UL 486C
  Splicing Wire Connectors
- UL486D
  Sealed Wire Connector Systems
- UL486E
  Equipment Wiring Terminals

UL 486A-486B

- **Table 21 – Tightening torque for screws**
- **Table 22 – Tightening torque for slotted head screws smaller than No. 10 intended for use with 8 AWG (8.4 mm2) or smaller conductors**
- **Table 23 – Tightening torque for screws with recessed allen or square drives**
- **Table 24 – Tightening torque for connecting hardware**

UL GuideInfo

- **www.ul.com**
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FEATURED LINKS

UL GuideInfo

- **ZMOW.GuideInfo**
  Wire Connector Adapters
- **DVYW.GuideInfo**
  Conductor Termination Compounds
- **ZMVV.GuideInfo**
  Wire Connectors and Soldering Lugs
- **ZMWQ.GuideInfo**
  Sealed Wire Connector Systems
- **ZMLS.GuideInfo**
  Crimp Tools Classified for Use with Specified Wire Connectors

ZMVV: Wire Connectors and Soldering Lugs

- **INSTALLATION INSTRUCTIONS**
- **Use of specific tools** — A specific tool and die used to assemble a wire connector to a conductor is identified on the connector, or on or within the unit container of the connector. The identification consists of a catalog or type designation, color coding, die index number, or equivalent means. Color coding of the crimp barrel is common.
- **Multiple crimping operations** — The number of crimps necessary to make a connection using the specific tool is identified on the connector, or on or within the unit container of the connector. Location and number of crimping points is commonly located on the crimp barrel of the connector.
- **Conductor strip length** — Wire connectors requiring a specific strip length have this information identified on the connector, on or within the unit container of the connector, on an insulating cover, or on the tool or tool carrying case. Strip length marking is optional for some constructions.
- **Preliminary preparation of conductor** — Some wire connectors supply instructions for the preliminary preparation of conductors, such as use of conductor termination compound (antioxidant compound) or pre-twisting of conductors, on or within the unit container.
- **Pre-twisting** — Some connectors may specify that conductors are to be pre-twisted before assembly onto the connector.
- **Conductor Termination Compound** — Some connectors are shipped pre-filled with conductor termination compound (antioxidant compound). For non-prefilled connectors, conductor termination compound may be used if recommended by the connector manufacturer as preliminary preparation of the conductor. Wire brushing of the conductor may also be performed if recommended. Also see Conductor Termination Compounds (DVYW).

ZMOW: Wire Connector Adapters

- **INSTALLATION INSTRUCTIONS**
- **Use of specific tools** — A specific tool and die used to assemble a wire connector adapter to a conductor is identified on the wire connector adapter, or on or within the unit container of the wire connector adapter. The identification consists of a catalog or type designation, color coding, die index number, or equivalent means. Color coding of the crimp barrel is common.
- **Multiple crimping operations** — The number of crimps necessary to make a connection using the specific tool is identified on the wire connector adapter, or on or within the unit container of the wire connector adapter. Location and number of crimping points is commonly located on the crimp barrel of the wire connector adapter.
- **Conductor strip length** — Wire connector adapters requiring a specific strip length have this information identified on the wire connector adapter, on or within the unit container of the wire connector adapter, on an insulating cover, or on the tool or tool carrying case. Strip length marking is optional for some constructions.
- **Preliminary preparation of conductor** — Some wire connector adapters supply instructions for the preliminary preparation of conductors, such as use of conductor termination compound (antioxidant compound), on or within the unit container.
- **Conductor termination compound** — Some wire connector adapters are shipped pre-filled with conductor termination compound (antioxidant compound). For non-prefilled wire connector adapters, conductor termination compound may be used if recommended by the wire connector adapter manufacturer as preliminary preparation of the conductor. Wire brushing of the conductor may also be performed if recommended. Also see Conductor Termination Compounds (DVYW).

ZMLS: Crimp Tools Classified for Use with Specified Wire Connectors

- The inside cover of the tool storage case or a permanently attached label to the tool itself contains a compatibility list that tabulates the company name and catalog number of the crimp tool and the company name, catalog number, wire size and number of crimps of the applicable Listed grounding and bonding connectors, quick-connect terminals, wire connectors and wire connector adapters for which the crimp tool has been investigated.

Burndy K2A: Mechanical

NOTES:

1. MATERIAL–BODY: ALUMINUM
   SCREW: ALUMINUM

2. FINISH–BODY: TIN PLATED
   SCREW: TIN PLATED

3. CONNECTORS ARE UL LISTED TO UL486B FOR INDICATED CONDUCTOR RANGE.

4. CONNECTORS ARE CSA CERTIFIED TO C22.2, NO. 65 FOR INDICATED CONDUCTOR RANGE.

5. "N" INDICATES NEMA STANDARD STUD HOLES.

6. LISTED TORQUE VALUES ARE FOR MAXIMUM CONDUCTOR SIZES ACCOMMODATED. CONSULT UL486 TABLES 7–4, 7–5, & 7–6 FOR SMALLER CONDUCTOR SIZES.

7. DIMENSIONS IN BRACKETS [ ] ARE IN MILLIMETERS ROUNDED OFF TO THE NEAREST MILLIMETER, UNLESS OTHERWISE NOTED, AND ARE FOR REFERENCE ONLY.

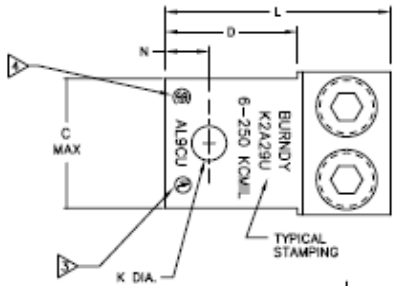

Table 21 – Tightening torque for screws

(Clauses 9.1.9.4 and 9.1.9.6)

Test conductor size installed in connector		Tightening torque, N·m (lbf-in)							
		Slotted head No. 10 and larger[a]				Hexagonal head – external drive socket wrench			
		Slot width – 1.2 mm (0.047 in) or less and slot length – 6.4 mm (1/4 in) or less		Slot width – over 1.2 mm (0.047 in) or slot length – over 6.4 mm (1/4 in)		Split-bolt connectors		Other connectors	
AWG or kcmil	(mm^2)	A	B	A	B	A	B	A	B
30 – 10	(0.05 – 5.3)	1.7 (15)	2.3 (20)	2.8 (25)	4.0 (35)	7.3 (65)	9.0 (80)	6.8 (60)	8.5 (75)
8	(8.4)	2.3 (20)	2.8 (25)	3.4 (30)	4.5 (40)	7.3 (65)	9.0 (80)	6.8 (60)	8.5 (75)
6 – 4	(13.2 – 21.2)	2.8 (25)	4.0 (35)	4.0 (35)	5.1 (45)	15.3 (135)	18.6 (165)	10.2 (90)	12.4 (110)
3	(26.7)	2.8 (25)	4.0 (35)	4.5 (40)	5.6 (50)	25.4 (225)	31.1 (275)	14.1 (125)	16.9 (150)
2	(33.6)	3.4 (30)	4.5 (40)	4.5 (40)	5.6 (50)	25.4 (225)	31.1 (275)	14.1 (125)	16.9 (150)
1	(42.4)	–	–	4.5 (40)	5.6 (50)	25.4 (225)	31.1 (275)	14.1 (125)	16.9 (150)
1/0 – 2/0	(53.5 – 67.4)	–	–	4.5 (40)	5.6 (50)	35.6 (315)	43.5 (385)	16.9 (150)	20.3 (180)
3/0 – 4/0	(85.0 – 107.2)	–	–	4.5 (40)	5.6 (50)	45.2 (400)	56.5 (500)	22.6 (200)	28.2 (250)
250 – 350	(127 – 177)	–	–	4.5 (40)	5.6 (50)	62.1 (550)	73.4 (650)	28.2 (250)	36.7 (325)
400	(203)	–	–	4.5 (40)	5.6 (50)	76.3 (675)	93.2 (825)	28.2 (250)	36.7 (325)
500	(253)	–	–	4.5 (40)	5.6 (50)	76.3 (675)	93.2 (825)	33.9 (300)	42.4 (375)
600 – 750	(304 – 380)	–	–	4.5 (40)	5.6 (50)	90.4 (800)	113.0(1000)	33.9 (300)	42.4 (375)

Torque Tables

- Connector Manufacturer
- NEC Handbook commentary after 110.3
- NECA/AA 104-2006
- Future Editions of the NEC?

Connection Rules

- No such thing as a “general rule”
- Oxide inhibitor
- Wire brushing
- Crimp methods
- Follow the manufacturer’s instructions!

Wire Brushing - Copper Oxide

- **Conductor Coatings** Bare copper conductor will oxidize from exposure to the atmosphere forming copper oxide on the surface. Oxidation and other types of corrosion are accelerated by the presence of heat, moisture, and some insulating materials such as rubber. The oxide film is a poor conducting material and must be removed to assure a good, reliable terminal connection.
- Source: http://madisoncable.tycoelectronics.com/CableDesign.asp, January 2009

Wire Brushing - Aluminum Oxide

- Aluminum oxide must be removed from a conductor's surface prior to making a connection. Wire brushing and the immediate application of an oxide inhibitor are recommended to prevent the reformation of the nonconductive coating prior to connector installation. An alternate method that is used to achieve low contact resistance is for the connection methodology to physically break through the aluminum oxide layer as the connection is being made.
- Source: http://cs.pennnet.com/display_article/194291/42/ARTCL/none/none/1/Electrical-connections:-What-you-can-do-to-prevent-corrosion/; January 2009

Where are the instructions?

- Connector
- Packaging (Box, Wrap or Insert)
- Equipment Labeling
- Catalog
- Online
- Letter from manufacturer

Case Study: Pin Connectors

- UL: Wire Connector Adapters
- Common usage: MacAdapts
- A.K.A.: Reducer

- Solid or Stranded Pin

- Why do we need pin connectors?
  - Used to transition between incompatible conductor and connector

Pin Connectors

- What do you need to know to make a reliable connection?
  - Size of conductor allowed in barrel
  - Size of pin to be inserted
  - What tool can be used?
  - What die must be used?
  - How many crimps?
  - If more than one, where do you start?

Pin Connectors

- Demonstration