PEG PROTECTION ENGINEERS GROUP

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Connector Theory and Installation

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Session 3: *Electrical Protection/ Surge Protection*
March 23, 2022

- We would LOVE to be outside in Raleigh after a brief theory of connector technology and doing hands on certification training.
- Our goal is the same – we hope to train an audience to be Proper Connection Trainers!
- We have attempted to be non-Commerical but there are differences in Connectors and Methods, FOLLOW the Connector Manufacturer's Instructions!

Theory of Connector Technology

Electrical Connector

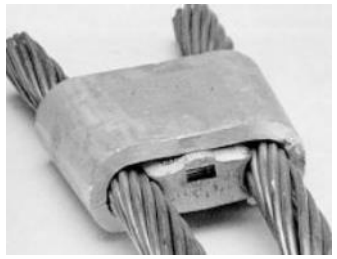
- In their simplest form, join two or more conductors in a continuous, electrically conductive path

In Addition

- Satisfy the electrical current requirements
- Satisfy all the mechanical requirements
- Satisfy the electrical and mechanical requirements for the **life of the connection**

Connector Technologies Overview

- **Mechanical**
  - Bolted
  - Wedge
- **Fusion**
  - Welded
  - Exothermic
  - Solder
  - Braze
- **Compression**
- **Implosive**



Connector Technology - Mechanical

Advantages

- Install with basic tools – but must be torque indicating
  - Socket or open end wrenches
  - Screwdrivers
  - Etc…
- Require minimal training to install a connector
- Physical exertion is typically not excessive
- Removable connections
- Depending on the condition of the connector, a mechanical connector may be reused (check with the manufacturer for their recommendation on reuse)
- When conditions warrant, mechanical connectors disassemble without damage to the connection components
- Electrical performance meets or exceeds the industry requirements for which they are designed

Connector Technology - Mechanical

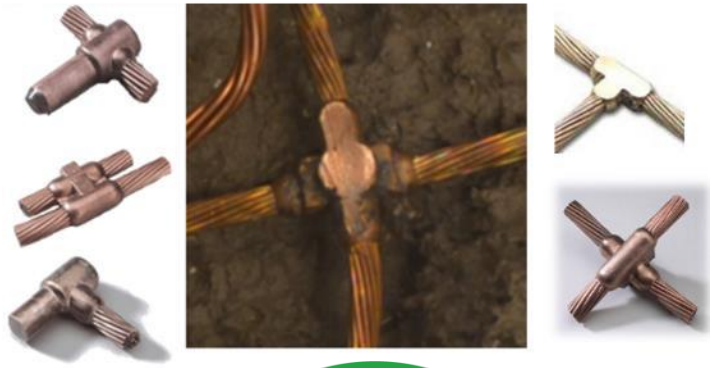
Disadvantages

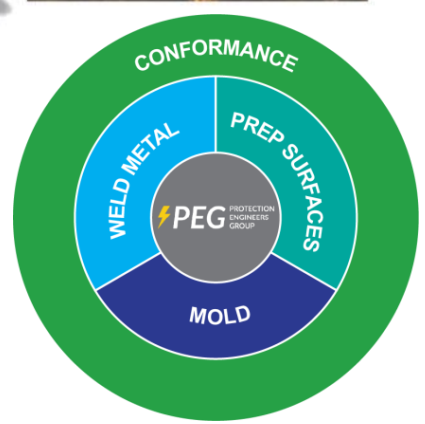
- Specific torque requirements must be followed to provide the proper clamping force needed for a sound electrical connection
- Installers are required to calibrated torque wrenches to tighten the nuts and bolts on mechanical connectors. Without this, the consistency of forces applied over identical mechanical installations is not generally repeatable.
- General nature of a mechanical connection does not allow for high mechanical holding strength. Hence, mechanical connectors are not sued as full tension connections.
- Mechanical connectors in high vibration, like seismic locations, will typically require more maintenance

Connector Technology – Exothermic Advantages

Advantages

- When properly installed, current carrying capacity is typically greater than the conductor
- When properly installed, connections can withstand repeated high current surges without deteriorating
- When properly installed, connections will not deteriorate with age since they are bonded at the molecular level
- Installation process is repeatable and reliable by a trained installer
- No external power or heat is required to make connections. Therefore, this is a light and portable means of making a permanent connection
- IEEE Standard 837-89 stipulates exothermic connections, when properly installed, are equal to the conductor itself. Today IEEE 837 requires qualification of Exothermic connections to be tested for compliance to the various performance criteria.
- When properly installed, the connections are solid molecular bonds that do not loosen or corrode over the lifetime of the connection





Connector Technology – Exothermic Disadvantages

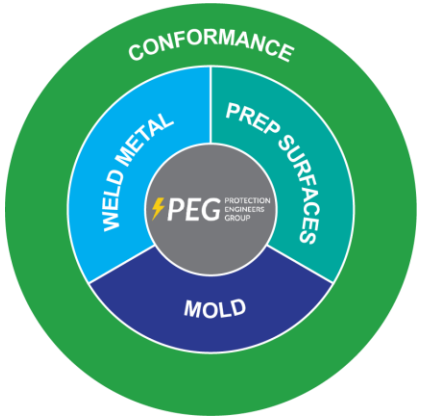
Disadvantages

- Cost advantages may not apply when installing numerous exothermic connections. In many cases, the installed cost of exothermic connections is lost in prep time and weather delays.
- The repeatability of the process cannot be easily determined, as the inspection of completed connections is visual for the most part
- Extreme heat generated during the reaction presents several problems:
  - Inherent risks to personnel and equipment
  - Wet molds can produce can serious safety concern from the rapid vaporization of the moisture
  - Hot molds and the process are a fire hazard that must be addressed
- Due to the annealing of the conductor, exothermic connections cannot not be used in tension applications
- Range taking capabilities of a mold is limited. One mold per application
- Powder is sensitive to improper storage and mishandling

Basic Connection Requirements:

- Torch
- Proper Mold
- Weld Metal
- Steel Disc
- Handle Clamps
- Wire Brush & Accessories

Connection Inspection Go/No Go



Theory of Connector Technology (contd.)

Electrical Connection Objective

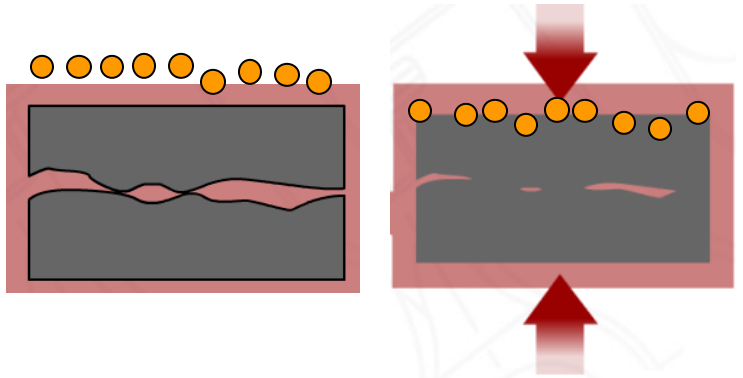
- Provide a path of electrical conduction between the conductors joined

Connection + Inherent Resistance

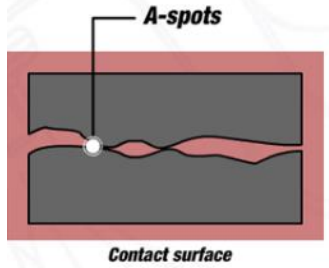
- An inherent result of this objective, is that the connection must exhibit low contact resistance
- Two conductor surfaces in contact can never be perfectly matched as each surface on a microscopic level is like a rough terrain
- When the surfaces come together random asperities (A-Spots) of contact are established and at those points the resistance is theoretically zero

Resistance has a negative impact on the connectors long-term performance

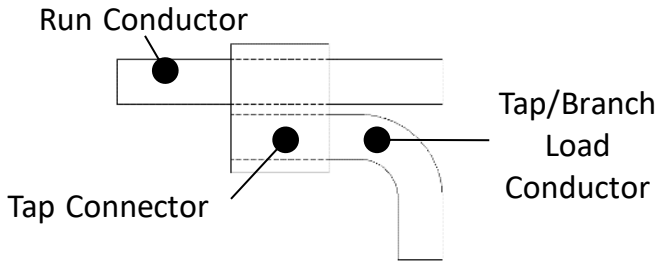
- Connector must maximize the contact points during installation and for the life of the connections. Less contact points = increased resistance



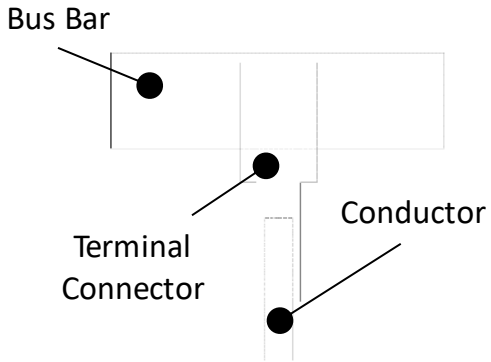
These 2 animated diagrams illustrate the value of optimizing contact points.
Illustration 1 – Minimal A-spots preventing current transfer thus increasing resistance. Only 2 of the 9 current circles transfer.
Illustration 2 – Maximum A-spots allowing more current transfer thus less resistance. 5 of 9 are transferring current



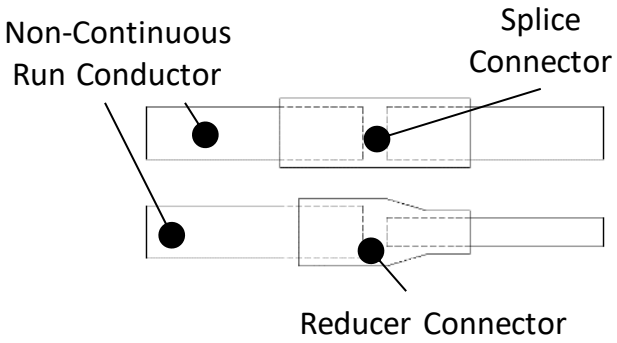
Types of Connections



Electrical Tap Connection
Electrical connection to a main or run conductor, for supplying electrical energy to a branch application(s) from the main runs principal load



Electrical Terminal Connection
A connection used to join two different forms of conductor, often incorporating more than one means of connection methodology

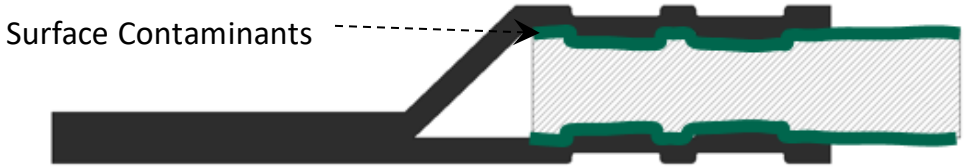


Electrical Splice Connection
Connection that joins two (or more) similar but non-continuous run conductors

Theory of Connector Technology (contd.)

Threats to a good connection

- Surface contaminants or corrosion will interfere with establishing initial contact



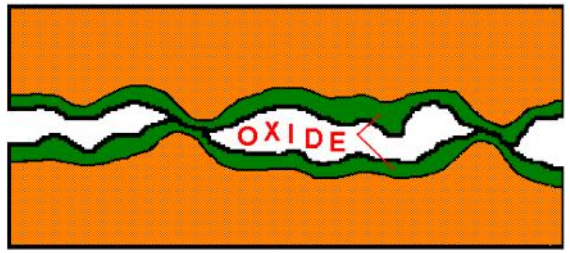
- Over time, thermal fatigue can loosen the connector and reduce the number of contact points. Increased voids due to heat cycling = less contact surface = increased resistance = long-term connection failure

- Improper installation = increased resistance due to:
  - Inadequate number of crimps
  - Insufficient torque

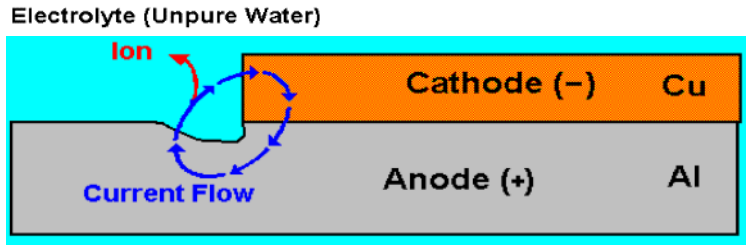
Theory of Connector Technology (contd.)

- Corrosion reduces the life of all connections and site location may include chemical corrosion.

- Two types of corrosion we will highlight are
  - Oxidation
    - Prevents metal-to-metal contact between the connector and conductor minimizing A-Spots = increased resistance



  - Galvanic Corrosion
    - Corrosion of a metal due to an electrical contact with a more noble metal (higher electrical potential) in the presence of a corrosive electrolyte

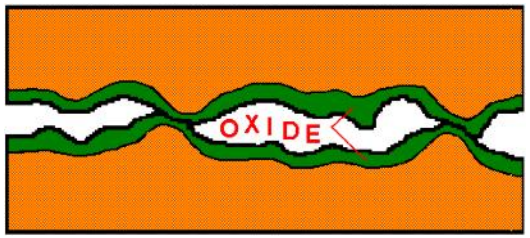


Theory of Connector Technology (contd.)

Copper Oxidation

- Evidence of copper oxide can be seen as a black or green surface discoloration

- Copper oxide layer will reduce the number of contacting points in a connection, thus increasing the contact resistance

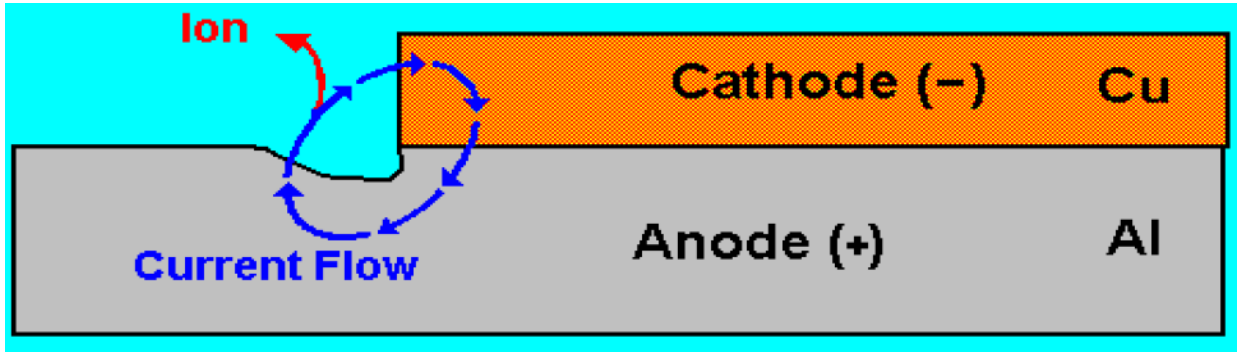


- Copper Oxides are generally weak and will break under the pressure of the installation

Theory of Connector Technology (contd.)

Galvanic Corrosion Key Concepts

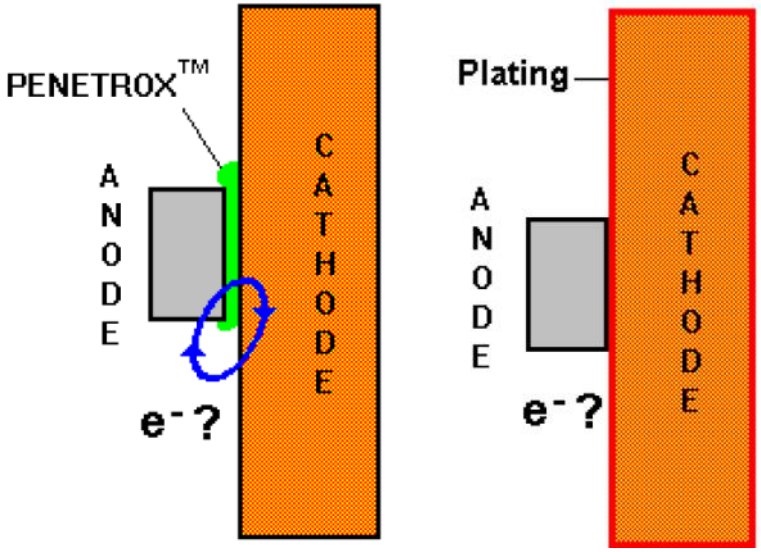
- Anodic material is attacked
  - In a Copper/Aluminum situation, the AL will be attacked and deteriorated by the CU
- The anodic material loses its integrity as it breaks down or deteriorates when in the presence of a cathodic material
- This deterioration of the Anodic material ultimately erodes the number of A-Spots
- Loss of contact surface or A-Spots causes a high contact resistance = eventual connection failure



Theory of Connector Technology (contd.)

Reducing Galvanic Corrosion

- Oxide Inhibitors
  - Creates a barrier between the Anode (AL) and Cathode (CU), thus reducing the effects of galvanic corrosion
- Plating
  - By plating the Cathode (CU), a barrier is created between the Anode and Cathode, thus reducing the effects of galvanic corrosion
  - As a precautionary measure to reduce galvanic corrosion, tin plate copper connectors

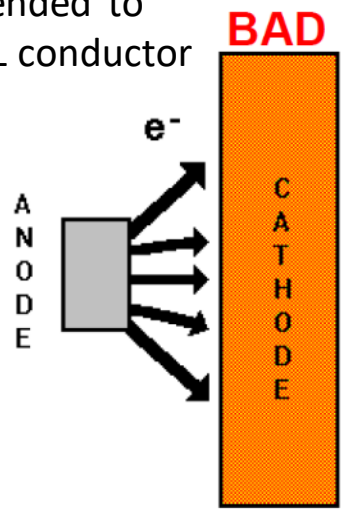


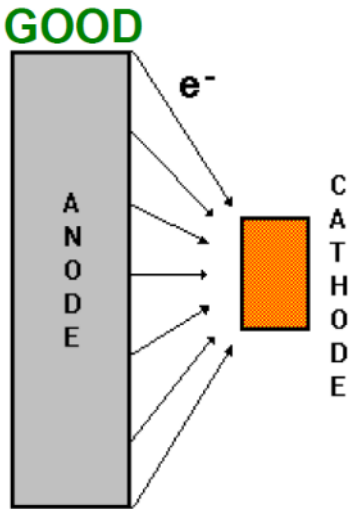
Theory of Connector Technology (contd.)

Reducing Galvanic Corrosion (contd.)

- Mass Anode Principle
  - Increase the size of the Anode (AL) mass in comparison the Cathode (CU)
  - The electrolytic current density over the exposed face of the Anode (AL) is greatly reduced
  - Since the rate of corrosion is directly related to the current density of the surface of the Anodic (AL) material, the relatively large face of the AL connector will suffer only a minor attack

This is why CU connectors are not recommended to accommodate AL conductor





This is why AL connectors can be dual rated for CU and AL

Theory of Connector Technology (contd.)

Galvanic Protection Summary

- Oxide inhibitors as a barrier
- Plating of the Cathode (CU) as a barrier
- Insulating the Anode (AL) as a barrier
- Similar Metals
- Mass Anode Principle
- ABC (Aluminum 'Bove Copper) Outdoors

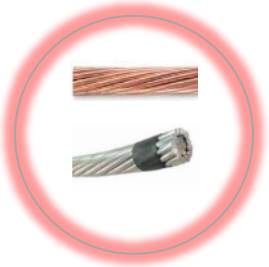
What makes a good connection – compression focused

Controlled Variables

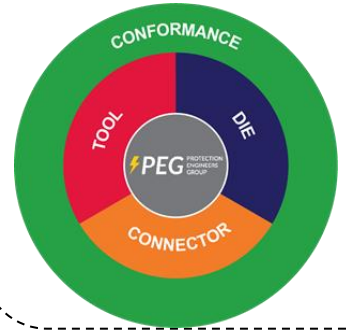
Connector Design

Connector Manufacturing Processes & QA

Customer Controlled Variables



Connector-to-Conductor Material Selection



Connector Installation

Connection Theory (Material Selection)

Recommendations

Copper to **Copper**


TO


→ **Copper** Connector

Aluminum to **Aluminum**


TO


→ **Aluminum** Connector

Aluminum to **Copper**

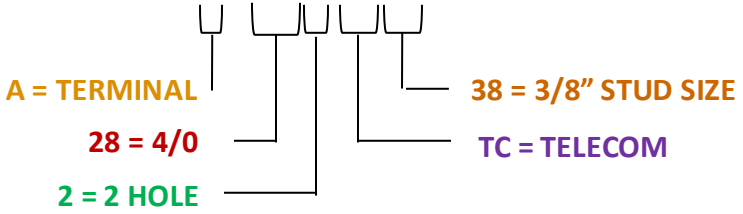

TO


→ **Aluminum** Connector

Engineered System

Example:

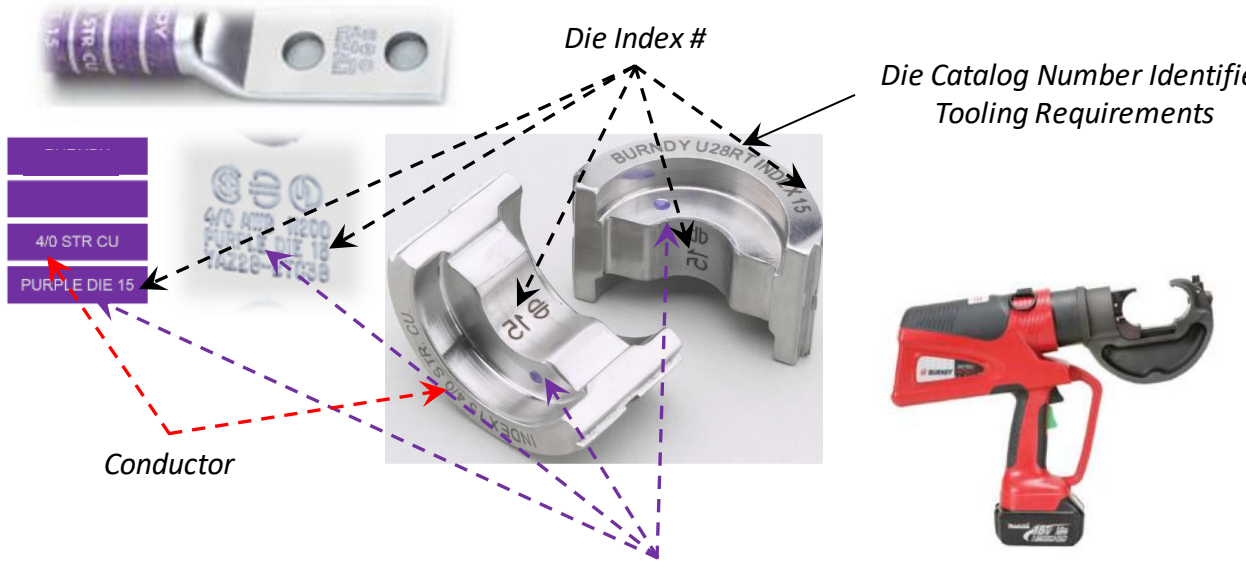
- Conductor: Code / Copper / 4/0
- Connection: Termination / 2 Stud Holes / 3/8” Studs / Telecom
- Connector: YAZ282TC38 – Confirms you have the proper connector or refer to literature



Barrel Ink Stamping Lettering on Copper Connectors

Tang / Pad Stamp Lettering

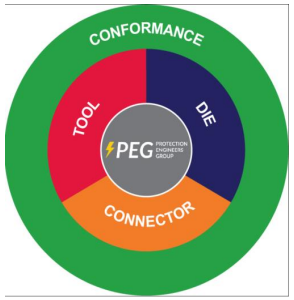
Engineered System



CONNECTOR → **DIE** → **TOOL**

Engineered System:

- CONNECTOR: YAZ282TC38
- DIE: U28RT
- TOOL: PAT750 or others recommended by the Connector Manufacturer



CU "Code" Conductor Connectors

Accommodates

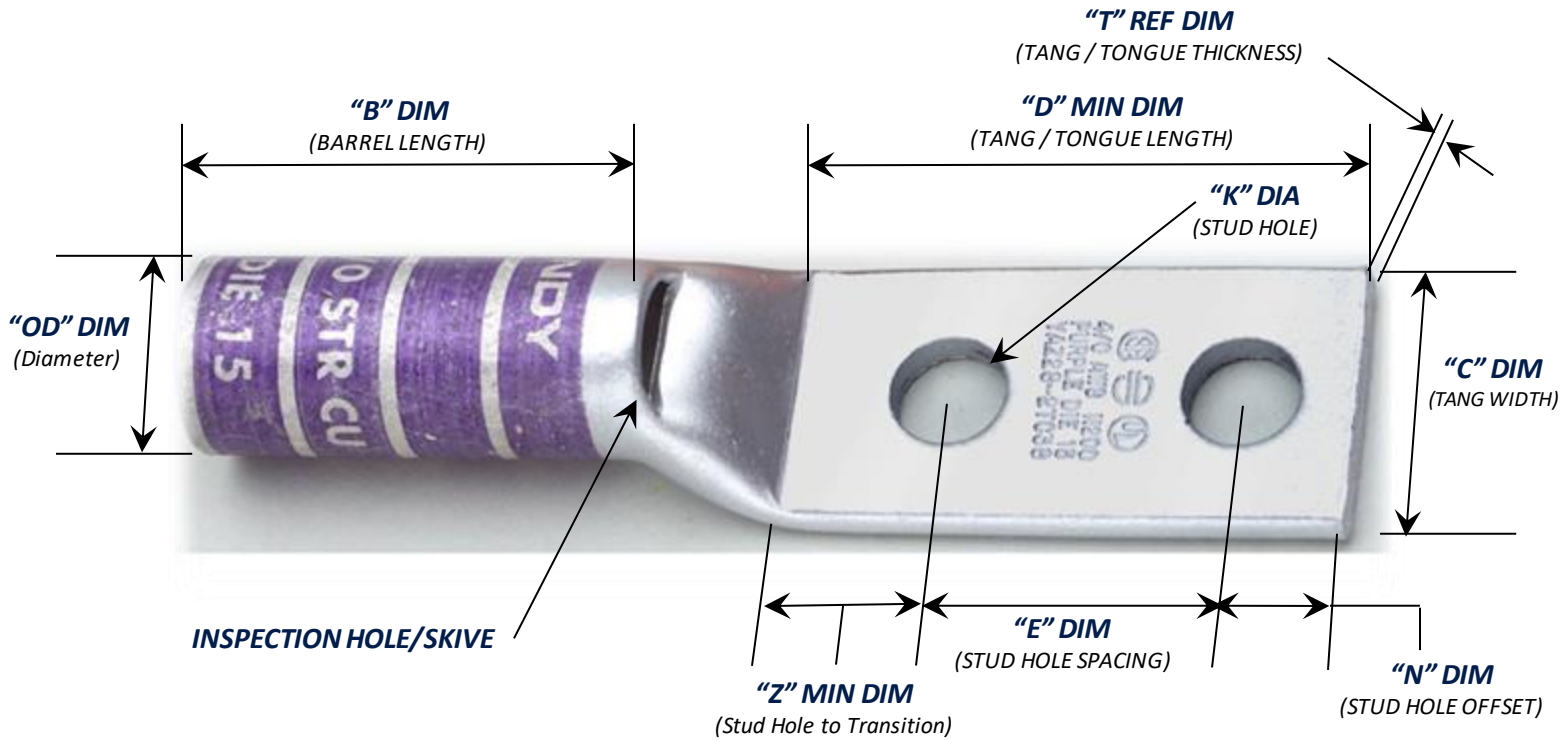
- Bare Solid Copper Conductor (ASTM B1, B2, B3)
  - ASTM B1 – Standard Spec for Hard-Drawn Copper Wire
  - ASTM B2 – Standard Spec for Medium-Hard-Drawn Copper Wire
  - ASTM B3 – Soft or Annealed Copper Wire
- Compact Stranded Copper Cable (ASTM B496)
  - ASTM B496 – Standard Spec for Compact Round Concentric-Lay-Stranded Copper Conductor
- Stranded Copper Wire (ASTM B8)
  - ASTM B8 – Standard Spec for Concentric-Lay-Stranded Copper Conductors, Hard, Medium-Hard, or Soft

CU Flex Conductor Connectors

Accommodates

- Flexible Copper Stranded Cable
- Conductor Class:
  - Class I – Apparatus cable and motor leads
  - Class G – All cables for portable use
  - Class H – All cables where extreme flexibility is required
  - Class K – Stationary Service use. Cords and cables composed of No. 30 AWG coper wires
  - Class M – Constant Service use. Cords and cables composed of No. 34 AWG copper wires

CU Compression Terminal Anatomy



UL 486A/B Listed 90°C 600 Volts to 35kV may also be UL 467 listed for bonding and grounding.

Standard Barrel, Long, Bent….do not field modify unless product includes Listing for that.

Standard / Short Barrel

- Ideal for confined spaces as the connectors overall length is reduced

Long Barrel

- Additional crimps give the connector greater mechanical strength
- Longer contact surface will help reduce heating of the connection

45°, 90° and any other variation required

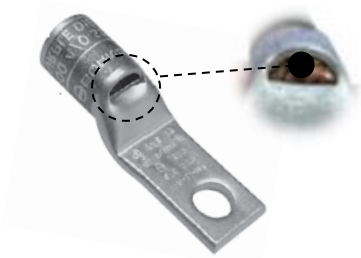
CU Narrow Tongue

Space requirements are becoming more limited everyday with molded case circuit breakers, motor controllers, safety switches, etc…

CU Skive vs. No Skive

Skive/Inspection Hole

- Inspection hole that allows an installer to verify that the conductor is fully inserted in the connector barrel
- Skives are not recommended for highly corrosive environmental conditions that can accelerate corrosion to exposed conductor

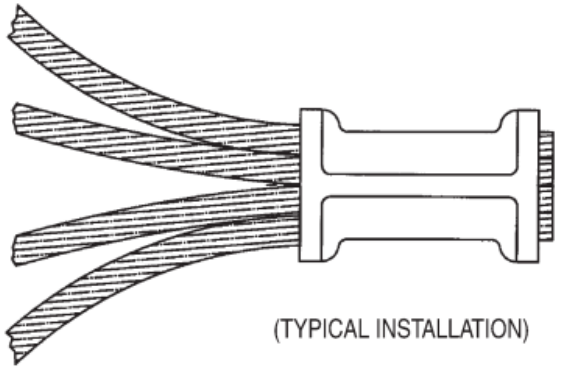


No Skive

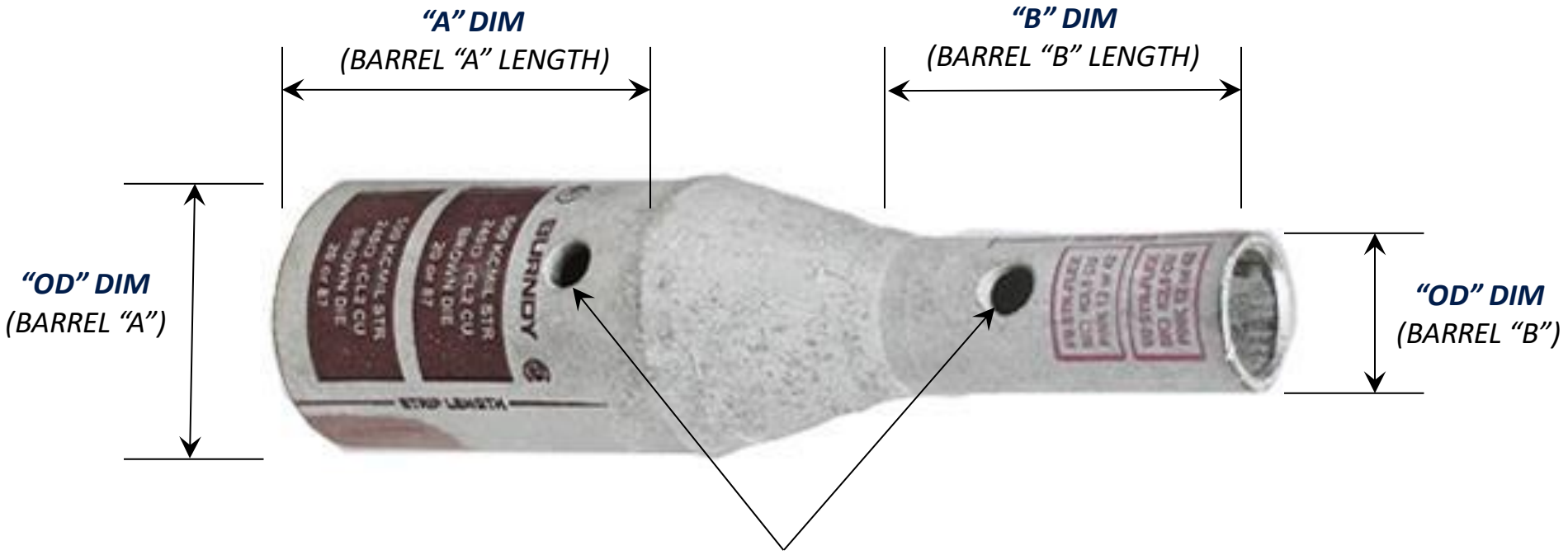
- Recommended for highly corrosive environmental conditions as the conductor is not exposed at the transition
- There is an option to add an oil tight seal in the barrel transition, making the connector water resistant and help mitigate corrosion further

CU Parallel Splice

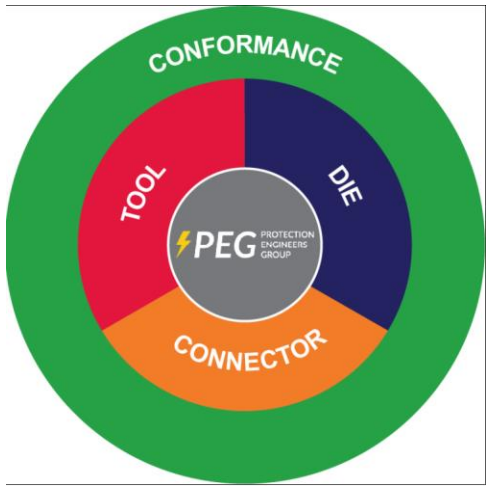
- Uninsulated Parallel Splice
- Parallel splice permits stranded wires to be laid parallel inside the connector
- Connectors are c UL us LISTED per UL 486A/B for GROUNDING and BONDING, and UL 467 and rated for **Direct Burial** Earth and Concrete
- Seamless tubing with beveled entry
- Stranded conductor only, but listed for multiple conductors in one barrel.

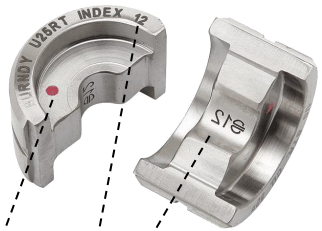


CU REDUCER Anatomy



REDUCER Conformance





Barrel "A" Stamping

1/0 STR-FLEX 50 fCL5 CU PINK 12 or 42

1/0 STR-FLEX 50 fCL5 CU PINK 12 or 42

1/0 STR-FLEX 50 fCL5 CU PINK 12 or 42

1/0 STR-FLEX 50 fCL5 CU PINK 12 or 42

YSR25FX6CFXLTC

DIE COLOR CODE: PINK
DIE INDEX 12

DIE COLOR CODE: BLUE
DIE INDEX 7

#6 STR FLEX CU

BLUE DIE 7 or 24

Barrel "B" Stamping

C-Tap Copper – Range Taking Compression Utilizes Tool Pressure vs. Die Dimension for Compliance

PAT750

DIE COLOR CODE:
ORANGE

DIE INDEX: 997

250-2 STR. CU.
4/0-2 FLEX
ORANGE DIE 997

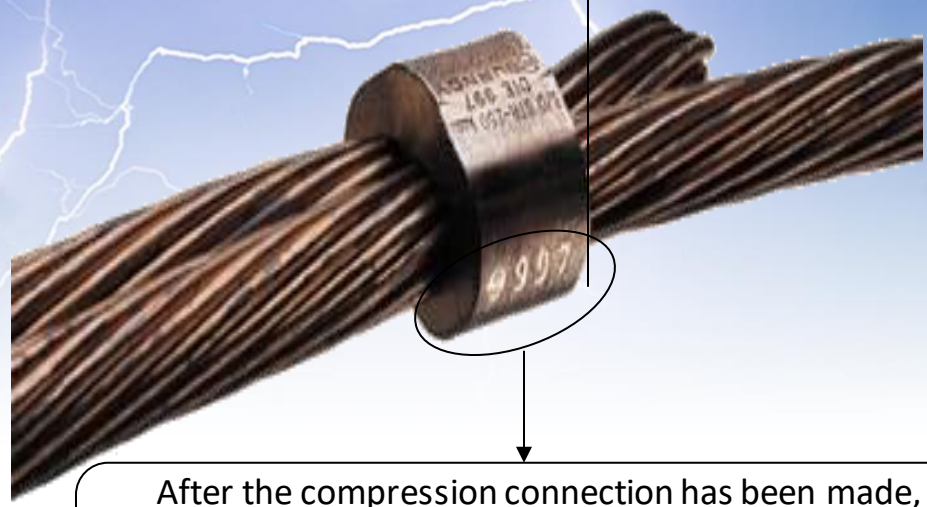
YCHC29TC29
250-2 STR. CU.
4/0-2 FLEX

INK STAMPING

Direct Burial Grounding Utilizes Range Taking design for most components. No color coding is used to avoid confusion.

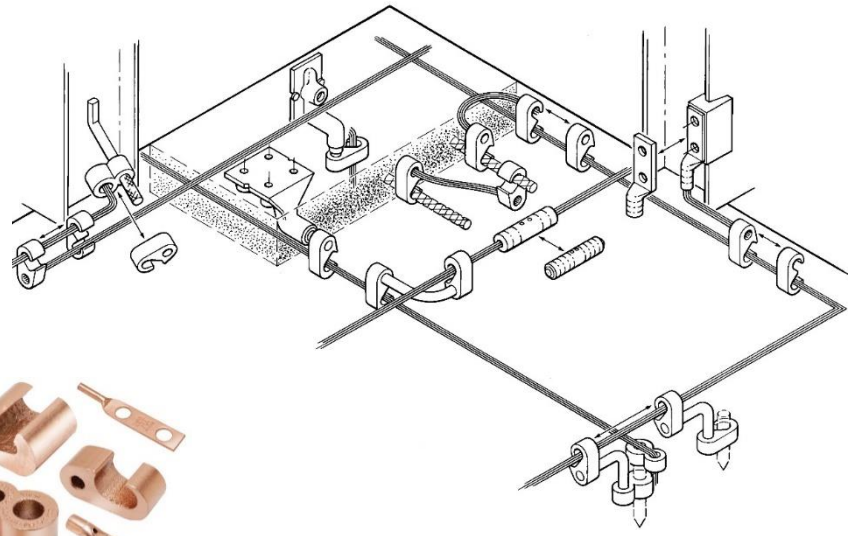
The connector identification markings including Item Catalog #, Conductor ranges and Installation die

Embossed Number shows that output force used to make compression connection was correct.



After the compression connection has been made, embossed die set number should match exactly as noted on the connector. This confirms that correct die set has been used for making the connection.

Compression Direct Burial Systems



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March 23, 2022

When is the compression tool Critical? When is it Not?

Copper Medium and Large Compression (HYDENT™) UL 486A-486B Matrix										
UL Listed Categories	ZMVV	ZMVV	ZMVV	ZMVV	ZMVV	ZMVV	ZMOW	ZMVV	ZMVV	ZMVV
UL LISTED										
	CU Code Lugs (YA-)	CU Flex Lugs (YA-FX)	CU- E-Line Lugs (YA-E)	CU Break-Away Lugs (YBA-)	CU Code Splices (YS-)	CU Flex Splices (YS-FX)	CU Pin Terminals (YE-)	CU YSCM-Splices	CU H-Taps & C-Taps (YC-)	CU Splice Reducers (YSR)
Burndy UL Listed	●	●	●	●	●	●	●	●	●	●

Aluminum Medium and Large Compression (HYDENT™) Comparison Matrix - UL 486A-486B						
UL Listed Categories	ZMVV	ZMVV	ZMVV	ZMVV	ZMVV	ZMOW
UL LISTED						
	AL Code Lugs (YA-A)	AL CCA Lugs (YA-A)	AL- E-Line Lugs (YA-A-E)	AL Code Splices (YS-A)	AL Code Slice Reducer (YRB-)	AL Pin Terminals (AYP/AYPO)
Burndy UL Listed	●	●	●	●	●	●

Copper Medium and Large Compression (HYGROUND® / HYDENT™) Comparison Matrix - UL 467						
UL Listed Categories	KDER	KDER	KDER	KDER	KDER	KDER
UL LISTED						
	HYGROUND®	CU Code Lugs (YA-)	CU Code Splices (YS-)	CU YSCM-Splices	CU H-Taps & C-Taps	CU Splice Reducers (YSR)
Burndy UL Listed	●	●	●	●	●	●

UL Classified tools can't be used for PEG applications….

Competitor Crimp Tools

SAFETY, RELIABILITY, CONFORMANCE WORTH THE RISK?

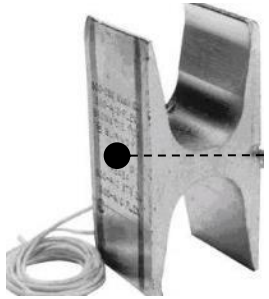
UL486A-486B ZMVV	UL486A-486B ZMOW	UL467 KDER	WARRANTY	TECHNICAL SUPPORT
Code Terminals ✓	Code Pin Adaptors ✗	HYGROUND ✗	Connectors ✗	Connectors ✗
Code Splices ✓	Flex Pin Adaptors ✗	Terminals ✗	Crimp Tool ✓	Crimp Tool ✓
Flex Terminals ✗		Splices ✗	Crimp Dies ✓	Crimp Dies ✓
Flex Splices ✗		Splice Reducers ✗	Connection ✗	Connection ✗
Code Splice Reducers ✗		H-Taps ✗		
Flex Splice Reducers ✗				
Code E-Line Terminals ✗				
Code Breakaway Terminals ✗				
Code Parallel Splices ✗				
Code H-Taps ✗				
Flex H-Taps ✗				

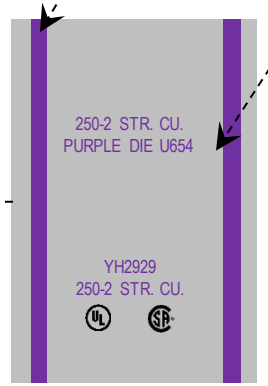
No 467….No Grounding or Bonding
No Flex cable stranding for Power 486 or 467
No connection warranty……

H-Tap Copper Conformance – Also Range Taking Compliance

DIE COLOR CODE:
PURPLE

DIE INDEX: 654

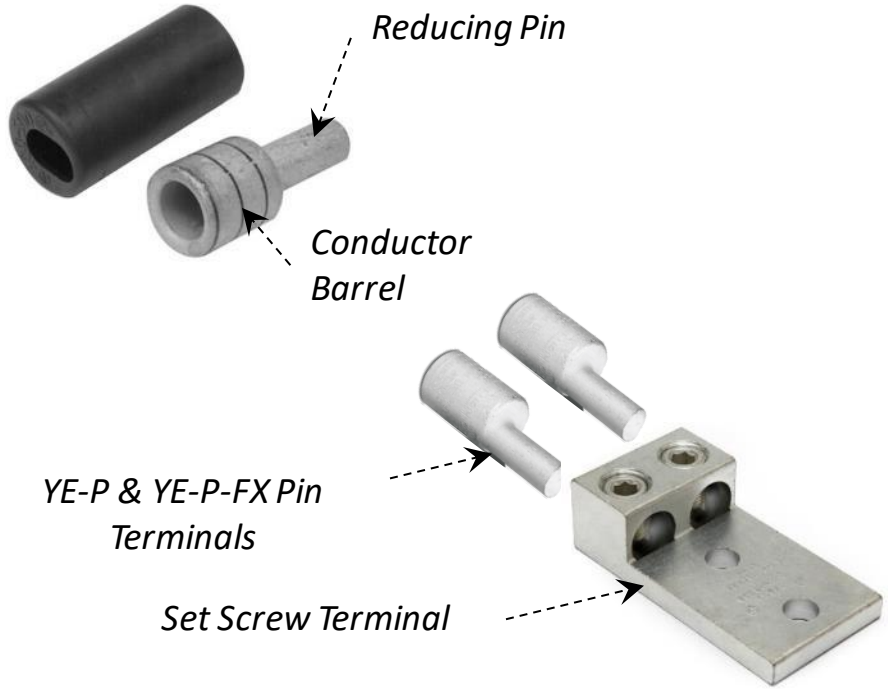




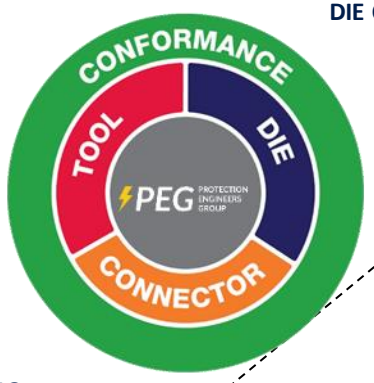
INK STAMPING

Adapters For Copper Features & Benefits

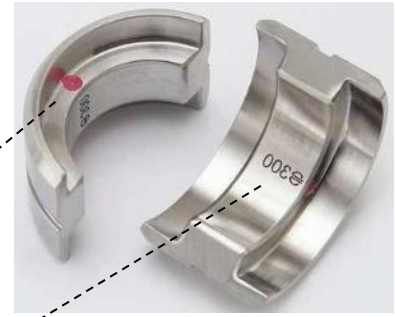
- Compression adapters are designed for voltage drop protection when oversized conductor is used for Code and Flex conductors
- Facilitate the termination into existing mechanical set screw connectors
- Solid pin design
  - Current carrying will perform the same or better than stranded conductor pin terminals
  - No risk of breaking stranded conductor strands during installation



AL Compression Terminals Conformance

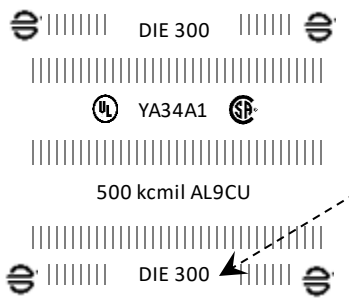


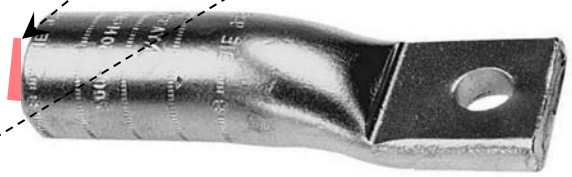
DIE COLOR CODE: PINK



DIE INDEX: 300

METAL BARREL STAMPING





- Note, no color ink marking on barrels of Aluminum connections to help identify the difference.

AL H Tap connectors – Range Taking Conformance

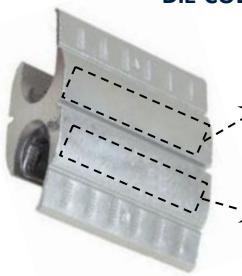
DIE ENGRAVING

U-YFO

INDEX
O

DIE INDEX: O

DIE COLOR CODE: GREEN



6-1/0 STR GREEN DIE 0
HYD. TOOL ONLY MADE IN MEXICO
YFO-140

6-10 STR UL AL9CU

8 Steps to Compression Connector Installation Instructions – Virtual Hands On

Sponsored by:

Session 3: *Electrical Protection/ Surge Protection*
March 23, 2022

Copper Connectors

STEP ONE

Select the appropriate connector for the conductor to be crimped and verify the conductor and connector markings are the same.

For better visual identification, the connector which accommodates Class A, B & AA (code conductor) will have solid color band(s) on the connector barrel. Flexible Conductors Class G, H, I K & M will have the lettering and narrow bands color coded

STEP TWO

Measure appropriate strip length. Line up the connector barrel to the wire and mark cable.

Strip the cable to the needed length with a wire stripper or similar tool to strip the insulation.

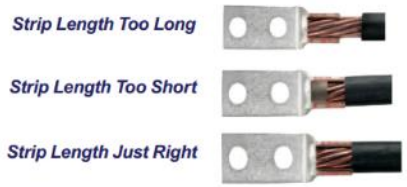
Note: for recommended strip length please refer to catalog page of connector of sales drawing

Copper Connectors (contd.)

STEP TWO (CONTD.)

Strip the insulation carefully to avoid nicking or cutting conductors (wire brush as required).

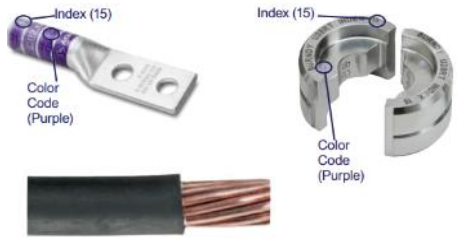
Strip the insulation to the proper length so the conductor can be fully inserted into the connector barrel.



STEP THREE

Select the appropriate die style to match the installation tool.

The die index number and color code indicated on the connector should match when the correct die is



Copper Connectors (contd.)

STEP FOUR

Insert the dies into the tool

STEP FIVE

Insert the conductor fully into the connector barrel. If an inspection window is provided, the conductor end can be easily seen.

Copper Connectors (contd.)

STEP SIX

Place the connector between the installed dies. Use the color stripes as a guide for crimp placement. Refer to Master catalog pages for required amount of crimps depending on tool and die selected.

NOTE: It is easier to place the connector on the non-moving top die, allowing the ram die to move up to crimp the connector.

For terminals: Be sure to always crimp from the tongue end to the conductor end.

For splices: Standard practice is to start crimping from the middle. Crimping is performed on alternating sides moving out towards the end of the connector.

Using this process of crimping allows the material to extrude outwards, thereby reducing electrical and mechanical stress points.

STEP SEVEN

Begin the tool's crimping cycle and continue until the full cycle is complete. Release ram. Repeat process until all crimp locations on the barrel have been completed. Refer to Master Catalog pages for required amount of crimps depending on tool and die selected.

Copper Connectors (contd.)

STEP EIGHT

Once all crimps have been completed, the connection is ready and can be inspected for proper installation. The embossment made by the die should match that on the connector. .

STEP NINE: INSPECTION

- Ensure the correct number of crimps were made (see catalog, sales drawing or cut sheet)
- Ensure the die index embossment matches the die index on the connector markings.
- The crimps should be reasonably within the color bands/knurling areas.
- The orientation of the crimp is not critical on a seamless barrel.
- Standard practice for Medium and Large HYDENT terminals is not to alternate the crimp direction but doing so would not negatively affect the integrity of the connector or resulting connection.

Installation Summary

- Choosing the correct conductor, connector, die and tool, connection system is imperative to mechanical and electrical performance of a compression connection
- Incorrect tooling and die selection can lead to over and under crimped connections - "A few thousandths does matter"
  - Over crimped connections can damage the conductor strands or leave excess flash that can heat a connection causing for a shortened connection life expectancy
  - Under crimped connections will minimize the number of contact points between the conductor and connector causing for a low mechanical hold and high resistance causing for a shortened connection life expectancy and increase resistance during that time
  - Mechanical connections must be properly torqued and marked for vibration effects.
  - Exothermic welds require proper and consistent preparation and strict process compliance.

PEG PROTECTION ENGINEERS GROUP

atis

Annex material for reference- not presented

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March 23, 2022

Detailed training/installation videos are available at:

- (165) Burndy LLC – YouTube
- https://www.youtube.com/c/burndy/videos

Copper Connectors – How Many Crimps? Read the details for your connector supplier. Example of two types of tools and dies and the instructions.

Crimping a Code Lug (YA282N)

W28RT (4 crimps)

- Due to the crimp die plow width

U28RT (2 crimps)

- Due to the crimp die plow width

Copper Connectors (contd.)

Crimping a Flex Lug (YAZV282TC38FX)

W28RT (4 crimps)

- Due to the crimp die plow width

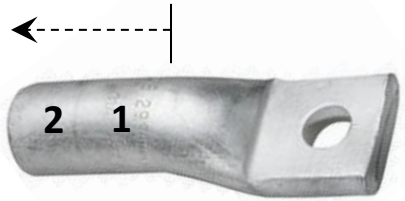
U28RT (2 crimps)

- Due to the crimp die plow width

Connector Crimp Direction

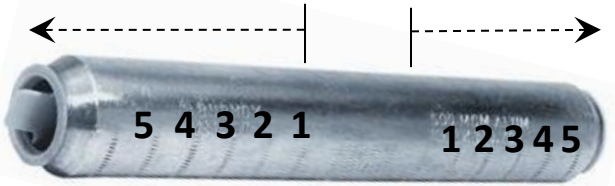
Terminal Crimps

- Crimping is done starting with crimp zone 1, which is closest to the tongue transition. Each consecutive crimp will take place toward the cable insertion end away from the tongue transition. This method reduces high stress points in the connection



Splice Crimps

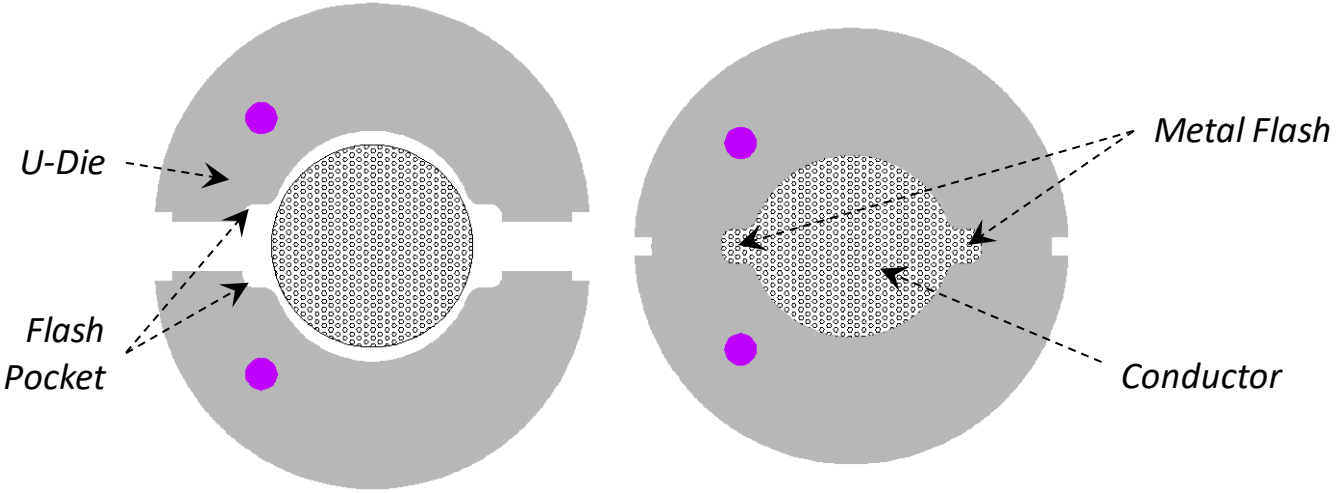
- Crimping is done starting with crimp zone 1, which is closest to center of the splice. Each consecutive crimp will take place toward the cable insertion end away from the splice center.
- Working from the center out to the conductor reduces electrical and mechanical stress points



Crimp Profiles - Circumferential

Crimp Profiles - Circumferential

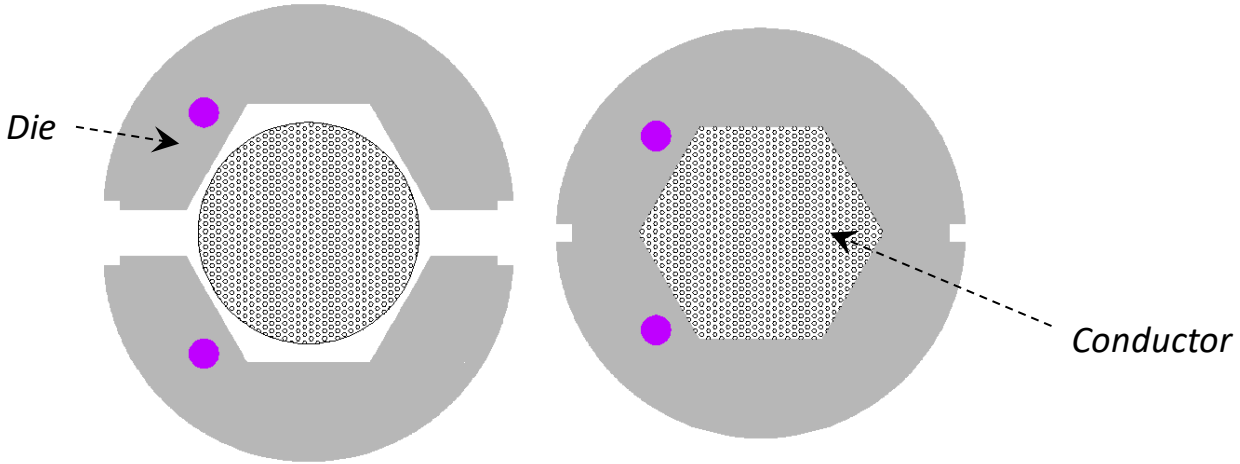
- Produce a circular uniform indent on opposite sides of the compression barrel
- There will be a thick region of flash material, which is a redistribution of material, and must NOT be removed
- When a circumferential crimp is to be insulated for a higher voltage applications, the gaps around the flash areas must be filled with a suitable insert material to remove air pockets and ensure dielectric integrity



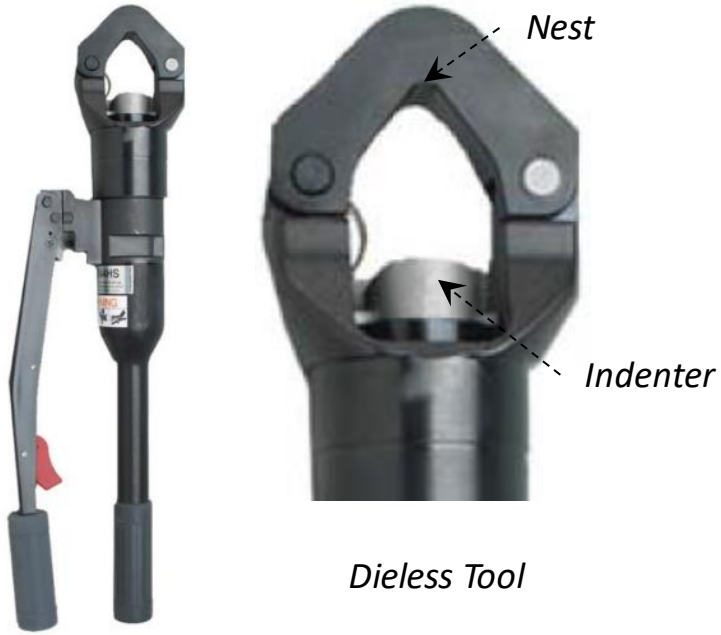
Crimp Profiles - Hexagonal

Crimp Profiles - "Hex"

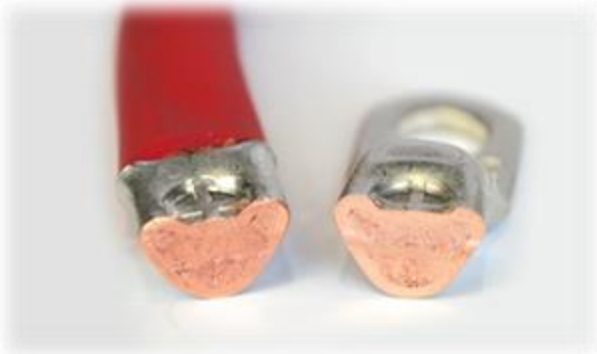
- Produce a uniform compression crimp
- In the process of crimping, a thin, sharp flash may result on the completed crimp. The flash must be removed to prepare the connector for insulated use at higher voltages due to the need of a smooth finish (prevent corona)
- Care must be taken to remove the flash from the connector as plating will be removed, possibly requiring a secondary means of corrosion protection



Crimp Profiles – Nest & Indenter & "Dieless"



Dieless Tool



Nest & Indenter Die Set

Crimp Profiles – Nest & Indenter & Dieless

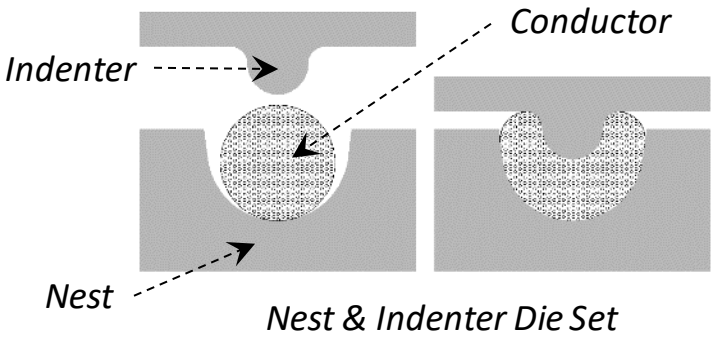
Nest & Indenter dies and Dieless work very similar

- Nest die or nest in the dieless crimp head cradles the tubular barrel being crimped
- Indenter die or dieless indenter crimp head, compresses and cold-works the conductor and connector into a sound crimp

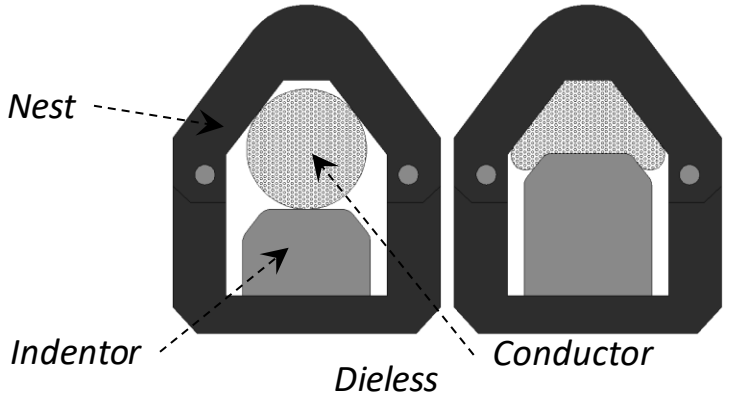
These methods of crimping are:

- Uniform
- Resist pullout
- Provide a secure connection to flexible and extra-flexible stranded conductor

Like circumferential, nest and indenter crimps may require a filler in the finished crimp indentation for high-voltage installation



Nest & Indenter Die Set



Dieless