Commissioning Cable System for Key Account Customer

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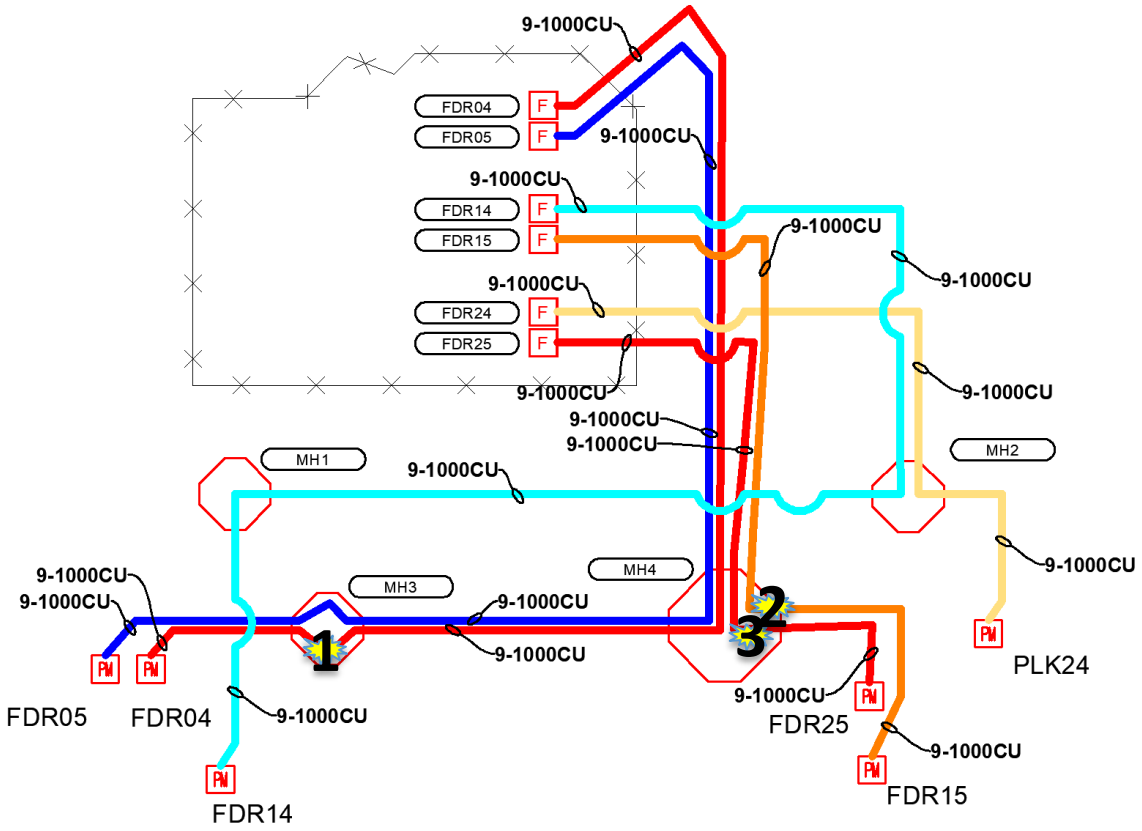
Introduction

- Arizona Public Service (APS) serves approximately 1.4 million customers

- Our service territory stretches across the state, from the southern border of Mexico all the way up to the Grand Canyon

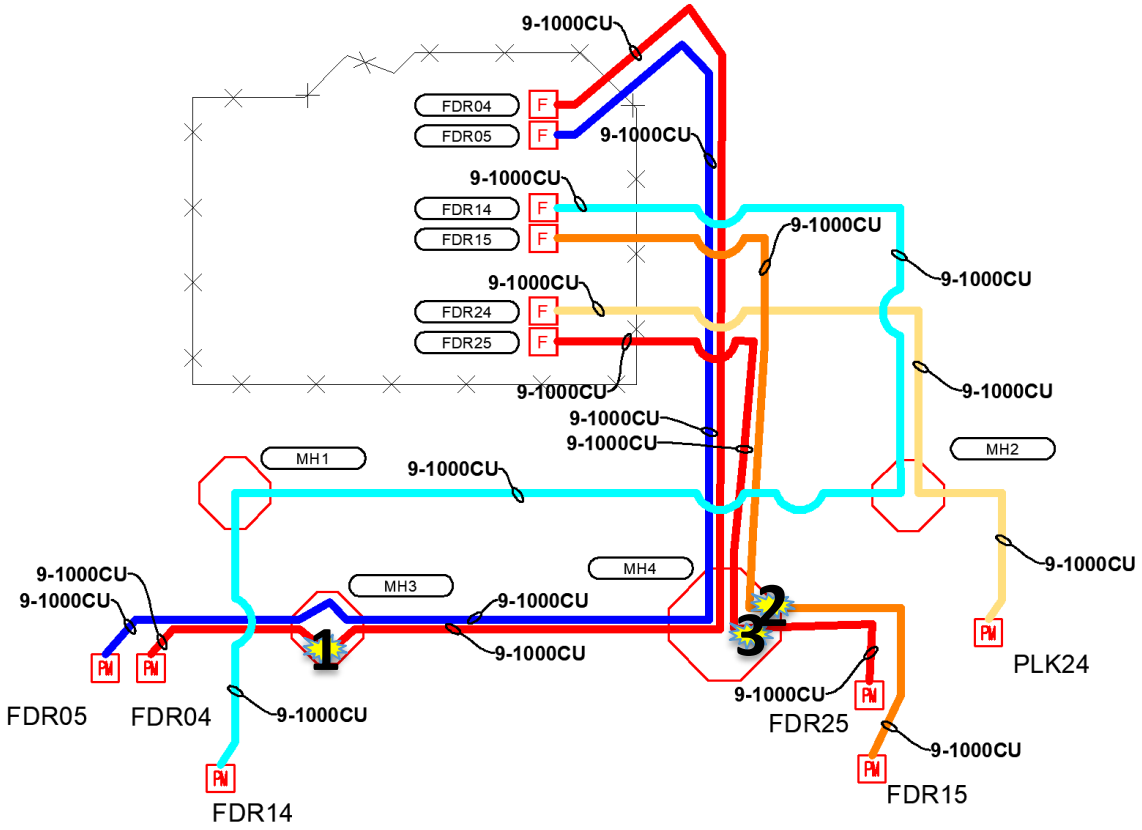
The Challenge

- Had three (3) splice failures within the span of 6 months on feeders that serve key account customer with sensitive loads
- Lost customer's confidence in our ability to provide reliable power



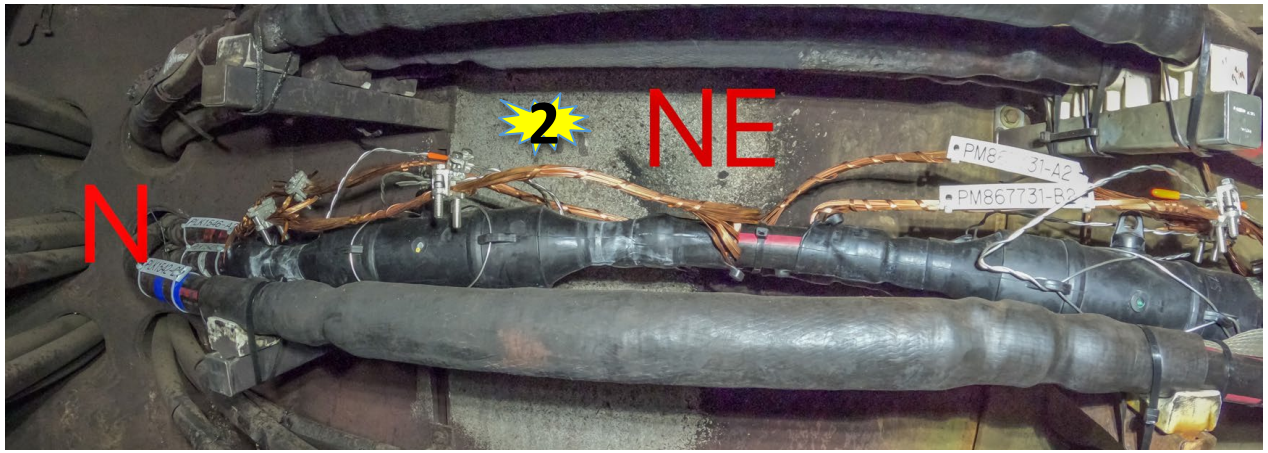
The Challenge

- **1st Splice Failure - 12/9/2022**
  - Original install year 2021
  - Feeder loading 1.5MW
- **2nd Splice Failure – 5/2/2023**
  - Original install year 2022
  - Feeder loading 0.9MW
- **3rd Splice Failure – 5/22/2023**
  - Original install year 2022
  - Feeder loading 0MW



The Challenge

- Multiple feeders in manhole
- For safety reasons, all feeders in manholes were de-energized to make splice repairs causing major impacts to our customer

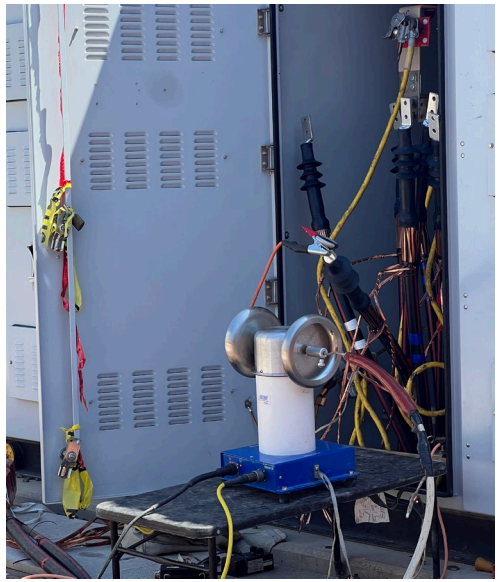


Action Taken

- Laid out temporary cable to bypass permanent feeders to eliminate risk of another splice failing unexpectedly
- Committed to our customer that we would remove and re-install all their permanent feeders
- Committed to our customer that we would eliminate as many splices as possible during re-install

Action Taken

- Sent faulted splices and a select few non-faulted splices out for evaluation
- Performed Partial Discharge (PD) commissioning testing on all newly installed feeders
- PD testing distribution feeders has not been an APS practice
- Performing this additional test showed our commitment to ensure the reliability of all newly installed feeders



PD Testing Results

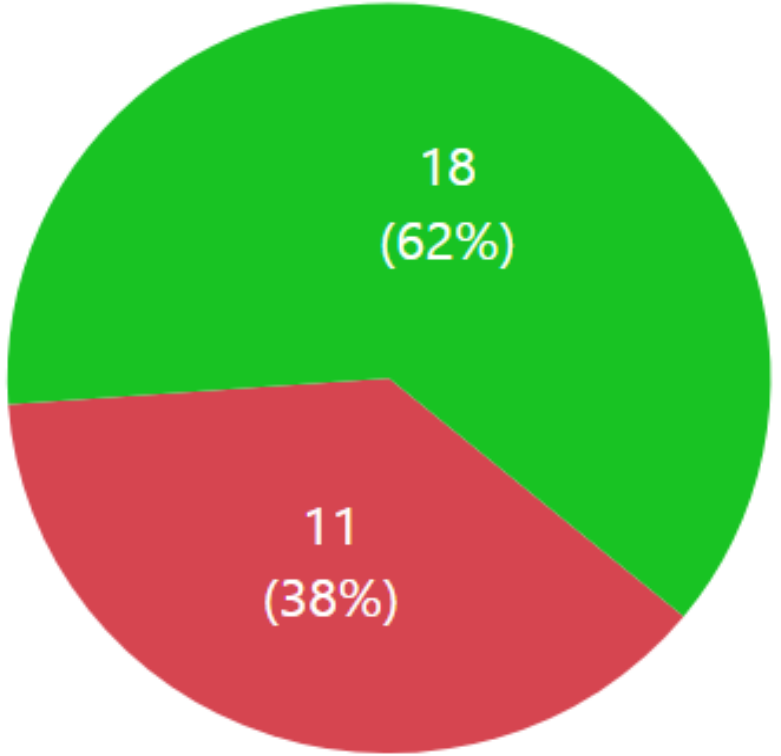
- Installation crews were required to rebuild multiple terminations due to PD detection found at 1.0 U_o and 1.5 U_o
- PD Testing found some subpar termination installs
- PD Testing forced installation crews to slow down and be super meticulous at critical steps during installs

CABLE SYSTEM COMMISSIONING SUMMARY		
	Circuit Segments	Mitigations
SUBSTATION A	**21**	**33**
Feeder 04	5	22
Feeder 05	4	5
Feeder 14	3	0
Feeder 15	3	2
Feeder 24	3	0
Feeder 25	3	4
SUBSTATION B	**8**	**1**
Feeder 03	4	0
Feeder 13	4	1(Splice)
TOTAL	**29**	**34**

34 Mitigations
33-Terminations
1-Splice

PD Testing Results

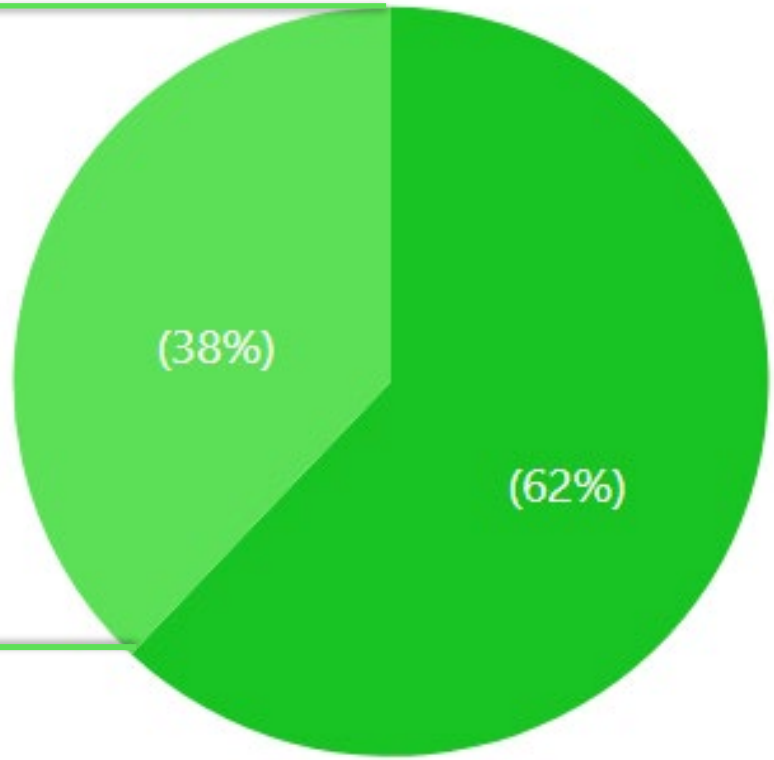
11 of 29 [38%] of New Segments Did Not Meet Standard



PD Testing Results

MITIGATION METHODS

- Decontamination
- Corrected Cutback
- Corrected Stress Control Position
- Mechanical Void Compression
- Reapplied Void Filler (Mastic)
- Replaced Termination



Splice Root Cause Analysis - Summary

- 4 samples received of 15kV Class [redacted] Cold Shrink Shear Bolt Joints installed on [redacted] Cu 1000kcmil EPR 220 mil Flat Strap Concentric Wire cable.
- 1 sample had faulted in service. The other 3 samples had not been PD tested in the field.
- The observations listed below would most likely exhibit substandard performance and shorten the design life of the joint.

Sample ID	Observations
Joint Sample 1	• Root cause of faulted joint was determined to be a dimensional error. The dimensions used to make the semi-con cutbacks were too long, causing the overall cable dimension within the splice body to be too long. This caused the stress control within the splice body to be misaligned over the cable.
Joint Sample 2	• Both semi-con cutbacks were not radial. Discharge control compound (Blue Grease) was scarce along cable insulation. • Splice body was not centered over entire joint.
Joint Sample 3	• Right side semi-con cutback was not radial.
Joint Sample 4	• Both semi-con cutbacks were not radial. The dimensions used to make the semi-con cutbacks were too long, causing the overall cable dimension within the splice body to be too long. • Splice body was not centered over entire joint. This, combined with dimensional error, caused the stress control within the splice body to be misaligned over the cable.

Splice Root Cause Analysis Findings | Defects

DIMENSIONS

DIMENSION CUTBACK TO CUTBACK = 20 ½"
SPECIFICATION - NOT BE GREATER THAN 19 ¾"

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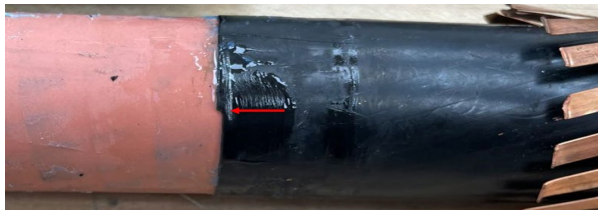
CUT-BACKS



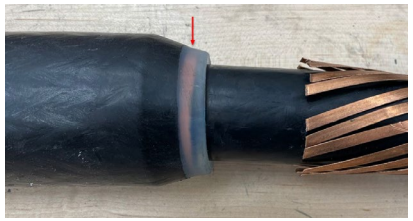
SEMI-CON CUTBACK IS NON-RADIAL

IMPROPER CUTBACKS

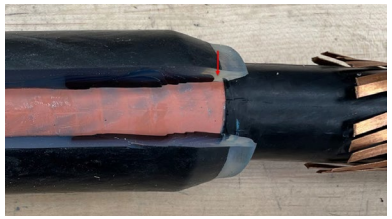
VOID FILLER | DCC

BLUE DISCHARGE CONTROL COMPOUND (DCC)
SCARCE ALONG INSULATION

INTERFACE | ALIGNMENT



SPLICE BODY NOT OVERLAPPING SEMI-CON; INSULATION IS VISIBLE



SPLICE BODY MISALIGNED –STRESS CONTROL MUST OVERLAP SEMI-CON

SPLICE BODY NOT OVERLAPPING SEMI-CON

Splice Root Cause Analysis Findings | DIMENSIONS

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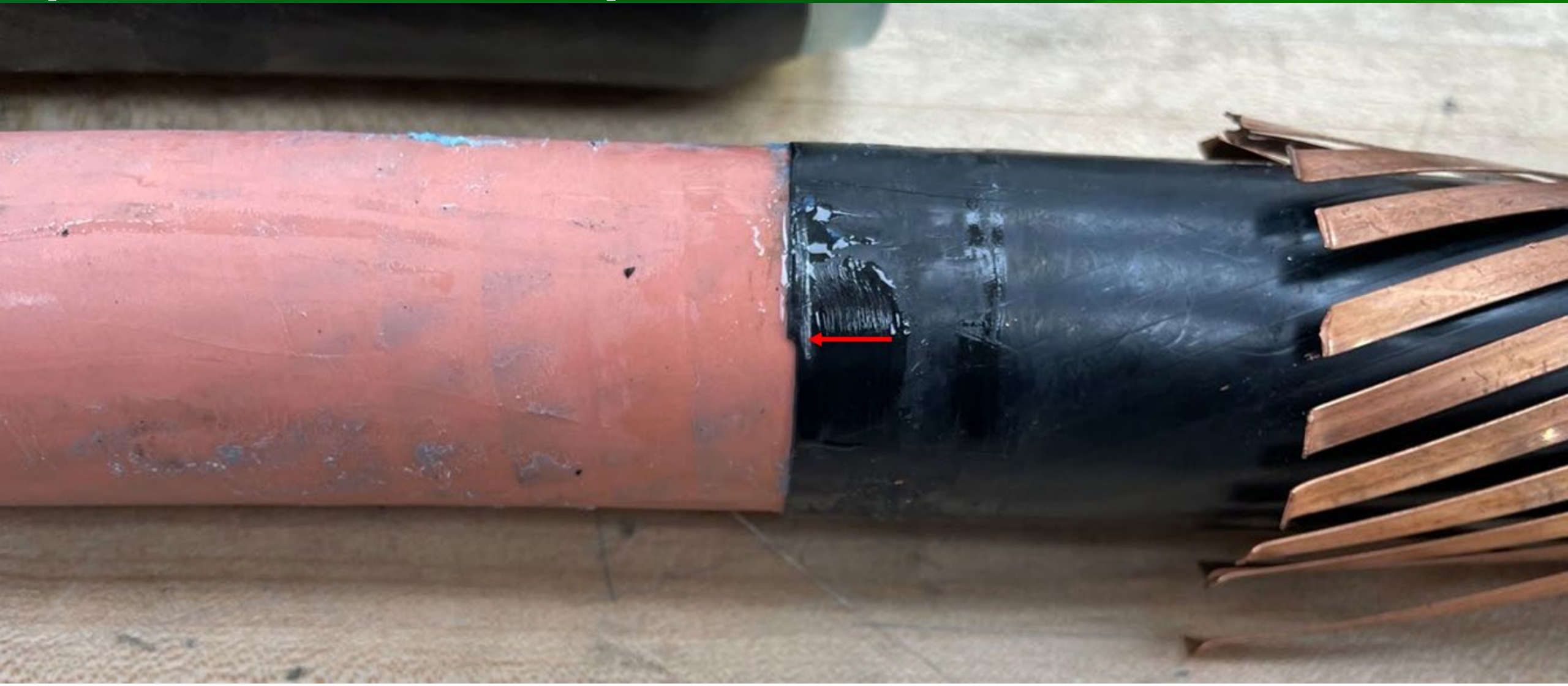
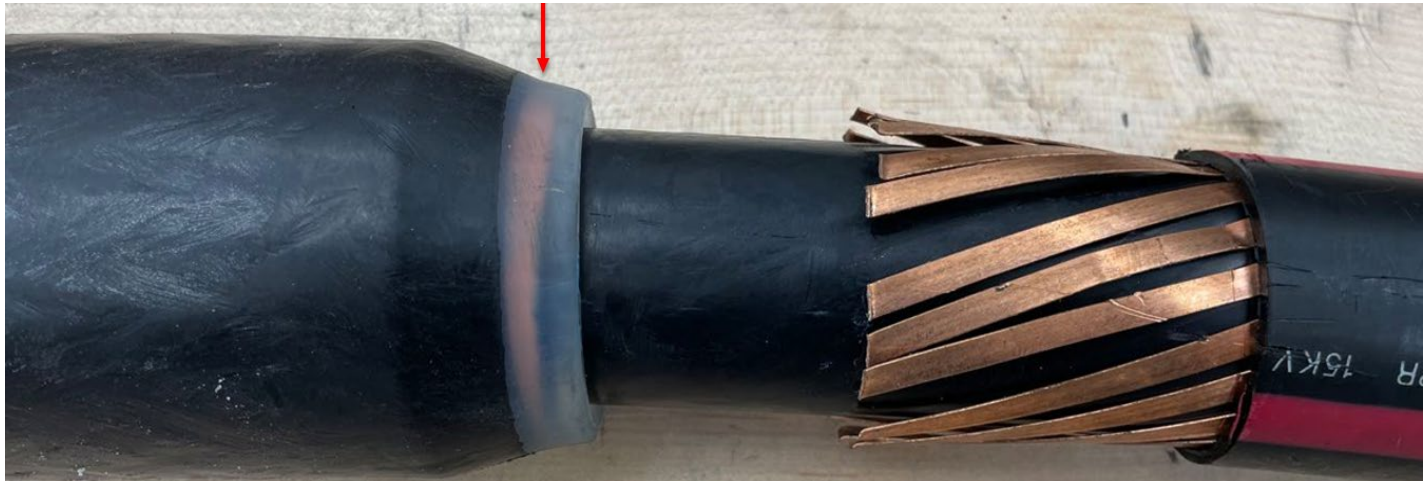
Splice Root Cause Analysis – CUT-BACKS 1



Right side semi-con cutback is non-radial and would likely exhibit substandard performance.

Splice Root Cause Analysis Findings | ALIGNMENT

SPLICE BODY NOT OVERLAPPING SEMI-CON



SPLICE BODY NOT OVERLAPPING SEMI-CON; INSULATION IS VISIBLE

Splice Root Cause Analysis Findings | DDC – VOID FILLER

BLUE DISCHARGE CONTROL COMPOUND (DCC) SCARCE ALONG INSULATION

SPECIFICATION: APPLY DCC ABUNDANTLY ALONG INSULATION AND SEMI-CON CUTBACK

Splice Root Cause Analysis Findings | CUT-BACKS 2

IMPROPER CUTBACKS

Splice Root Cause Analysis Findings | ALIGNMENT

SPLICE BODY NOT OVERLAPPING SEMI-CON

Lessons Learned

- Importance of understanding the ultimate build out of customer sites
- Found value in spending money upfront to perform extensive commissioning testing especially on key account customers who have sensitive loads.
- This whole ordeal showed the APS team (engineering, maintenance crews, contractors) the importance of challenging each other respectfully and embracing different perspectives.
- Precise workmanship is essential to ensure the safety, reliability and longevity of feeders.