Perspective on Connector Tests to ANSI C119.4 & IEEE 404

Presented by:

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Introduction

- Results previously reported at ICC have indicated there may be a problem with connectors installed on filled strand conductors.
- The NEETRAC membership is sponsoring work to investigate the effect(s) that filled strand conductor has on connector performance.
- Test methods applied:
  - IEEE 404 in-air heat rise and cyclic aging of medium voltage joints at different temperatures
  - ANSI C119.4 current cycle submersion tests of connectors
- Test samples included:
  - Conductor with non-filled and different types of filled strand materials
  - Different connectors and joints
  - Wire-brushed and not wire-brushed connections

Project Advisors

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Exelon	Jim Crane, John Hans, Dan Zoladz
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Oncor Electric Delivery	Richie Harp
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Southwire	Kim Knuckles, Joe McAuliffe, Nick Ware
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ANSI C119.4 Test Samples

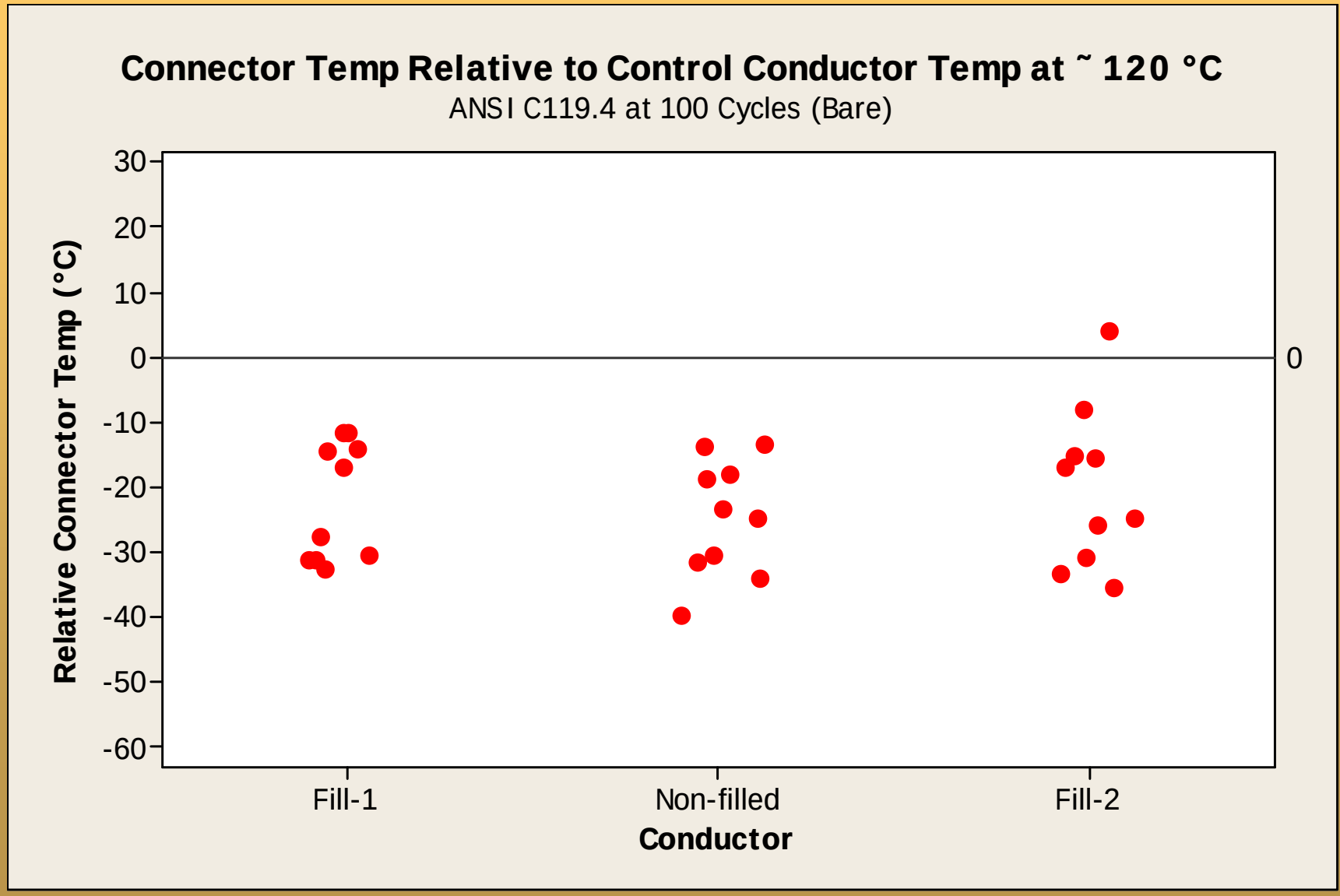
- Conductor : 1/0 AWG Class B Compressed 1350 Al 3/4 HD
  - Without Filled Strand Material, Non-filled
  - Filled Strand Material, Fill-1
  - Filled Strand Material, Fill-2

- Connectors : Two different 1/0 AWG Compression Sleeve Connectors (**crimped using recommended die with three crimps per side according to manufacturer instructions)**
  - Small : ≈ 2.15 inches long and 0.65 inch diameter
  - Large : ≈ 3 inches long and 0.90 inch diameter

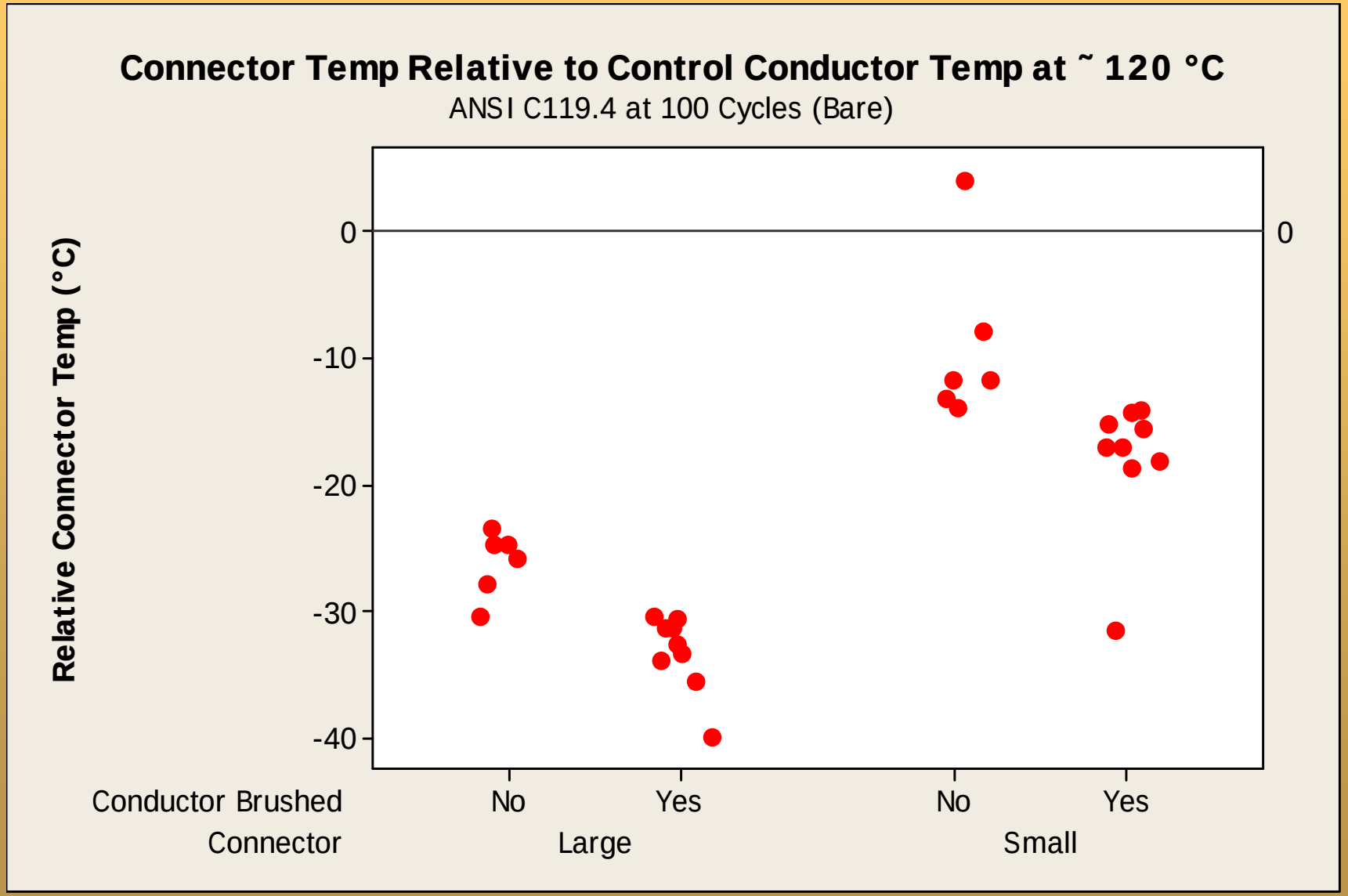
ANSI C119.4 CCST
(Current Cycle Submersion Test)

- 18 Samples in Test Loop A
  - Three replicates per condition – conductor wire brushed
- 12 Samples in Test Loop B
  - Two replicates per condition – conductor **not** wire brushed
- Samples all properly installed
- 100 cycles – 1 hour current ON, ½ hour current OFF

ANSI C119.4 CCST Results



ANSI C119.4 CCST Results



ANSI C119.4 CCST Results

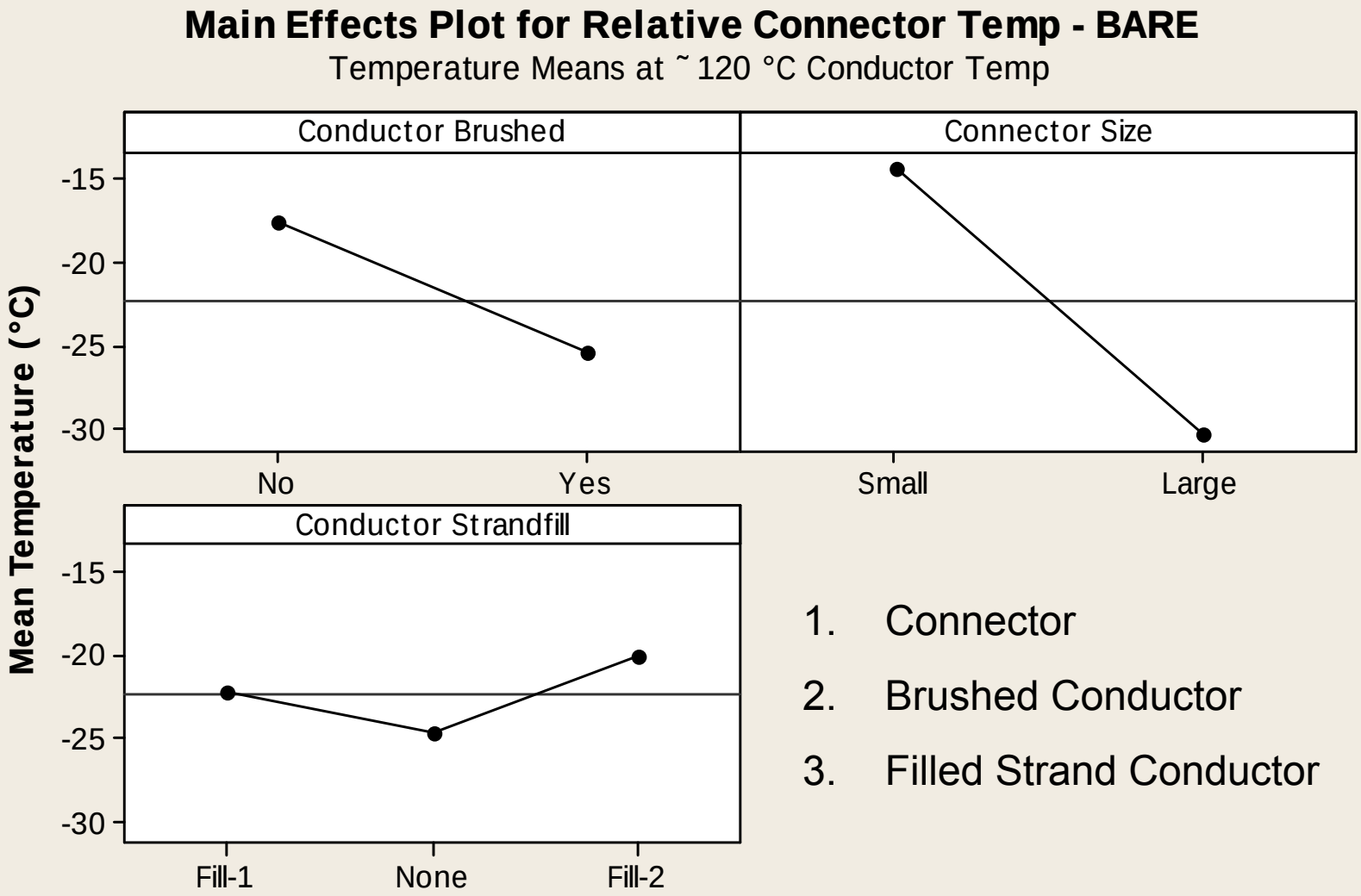
Analysis of Variance (ANOVA)

Relative Connector Temperature

Factor	***Levels***	***Values***
Connector	2	Small, Large
Brushed Conductor	2	No, Yes
Stand Filled Conductor	3	Non-filled, Fill-1, Fill-2

Source	***P***	***Significance***
Connector	0.000	**>99.9%**
Brushed Conductor	0.000	**>99.9%**
Strand Filled Conductor	0.072	**92.8%**

ANSI C119.4 CCST Results



1. Connector
2. Brushed Conductor
3. Filled Strand Conductor

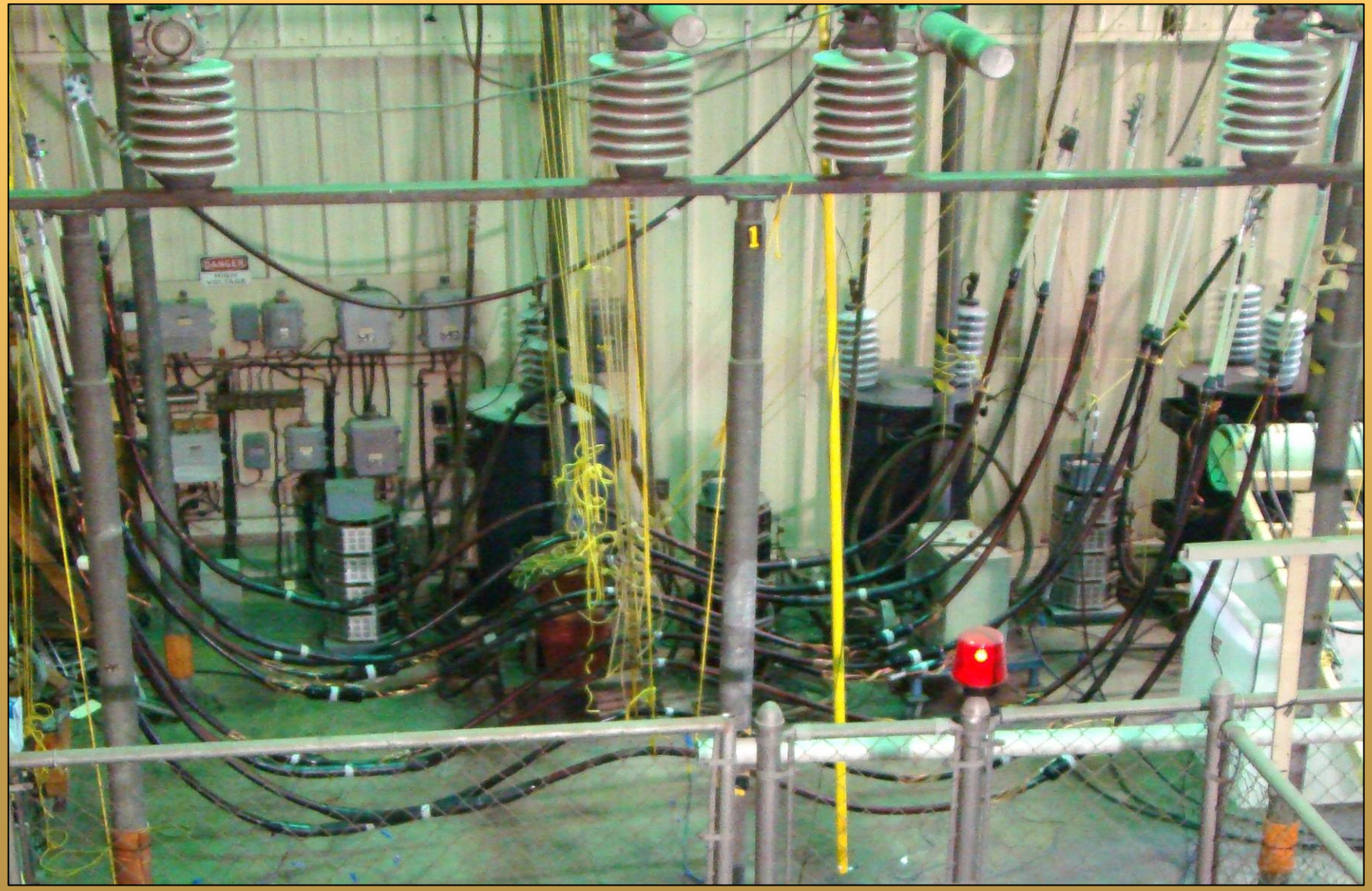
IEEE 404 Test Samples

- Cable : 25 kV, 260 mil TRXLPE, 16 - #14 AWG Concentric Neutrals, Encapsulating LLDPE Jacket
  - Without Filled Strand Material, Non-filled
  - Filled Strand Material, Fill-1
  - Filled Strand Material, Fill-2
- Joints : Two different 1/0 AWG, 25 kV rated joints (joint kits came with the same connectors previously described)
  - Joint A : Cold-shrink, small connector
  - Joint B : Molded, large connector

IEEE 404 In-Air Cyclic Aging

- 18 samples in one loop
  - Conductor WAS wire brushed before connector installation on two replicates per condition
  - Conductor WAS NOT wire brushed before connector installation on one replicate per condition
- 37 cycles have been completed – 8 hours current on / 16 hours current off

IEEE 404 In-Air Cyclic Aging

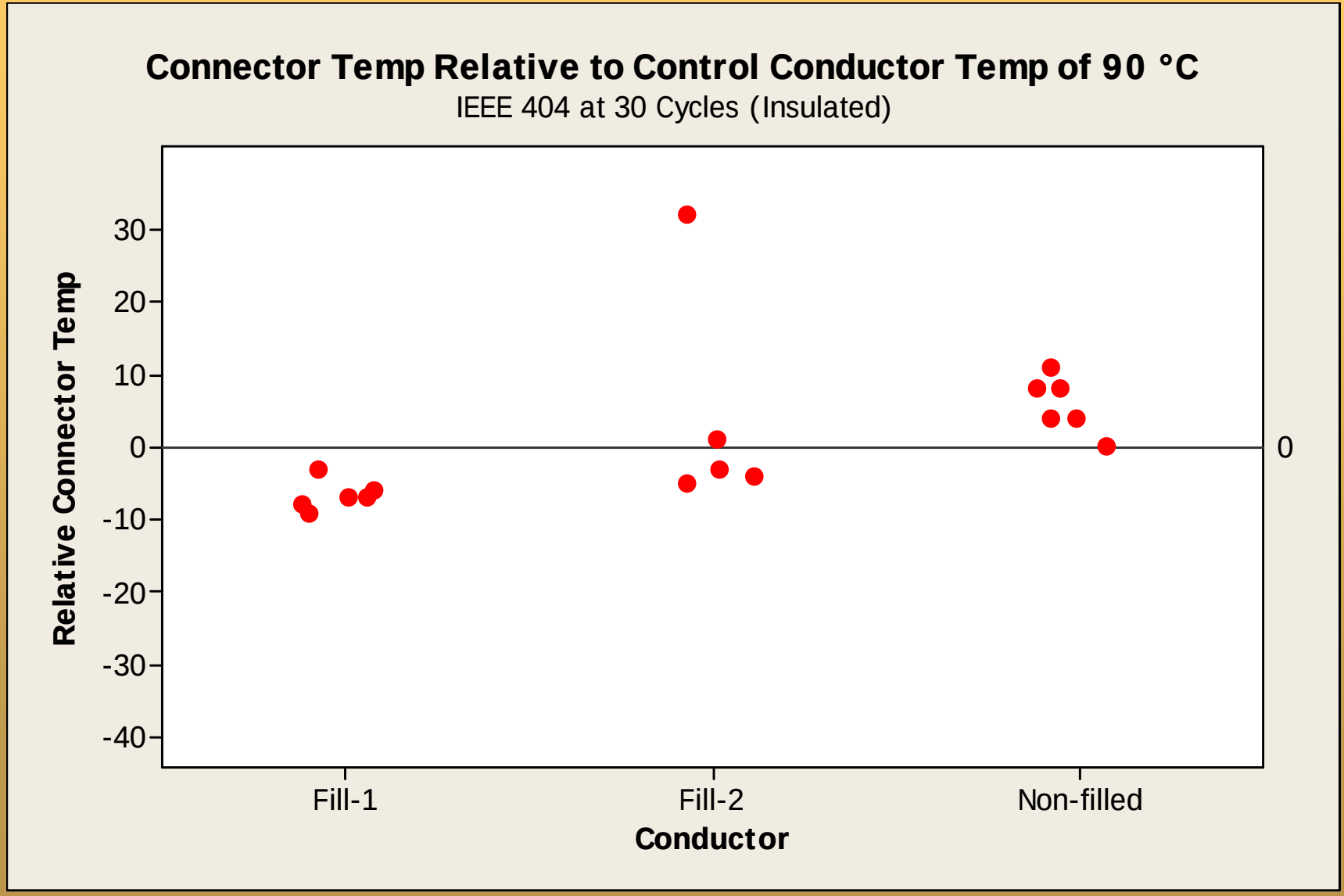


IEEE 404 In-Air Cyclic Aging

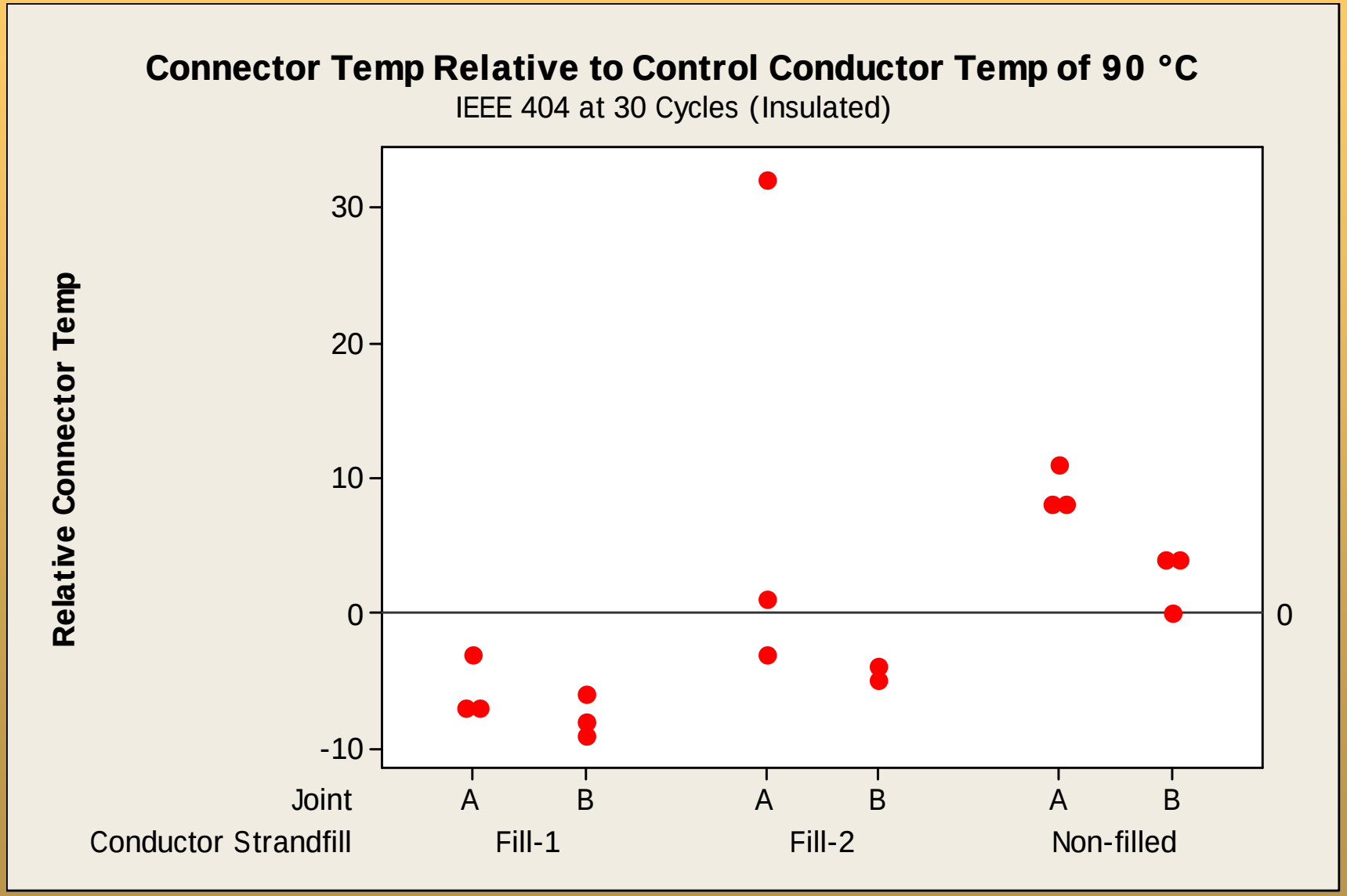
Load Cycle History

Cycles	Target Conductor Temperature (°C)	Comments
1-24	90	IEEE Std. 404 load cycles (in air) with voltage applied
-	-	Thermocouples installed on joint connector through hole drilled in joint housing. No test voltage applied for remainder of testing.
25-30	90	Seven samples found to be exceeding the control conductor temperature at cycle 25. One was removed after 29 cycles because it was exceeding 130 °C.
31-37	105	Ten samples now found to be exceeding the control conductor temperature at cycle 31 after increasing control conductor temperature to 105 °C.

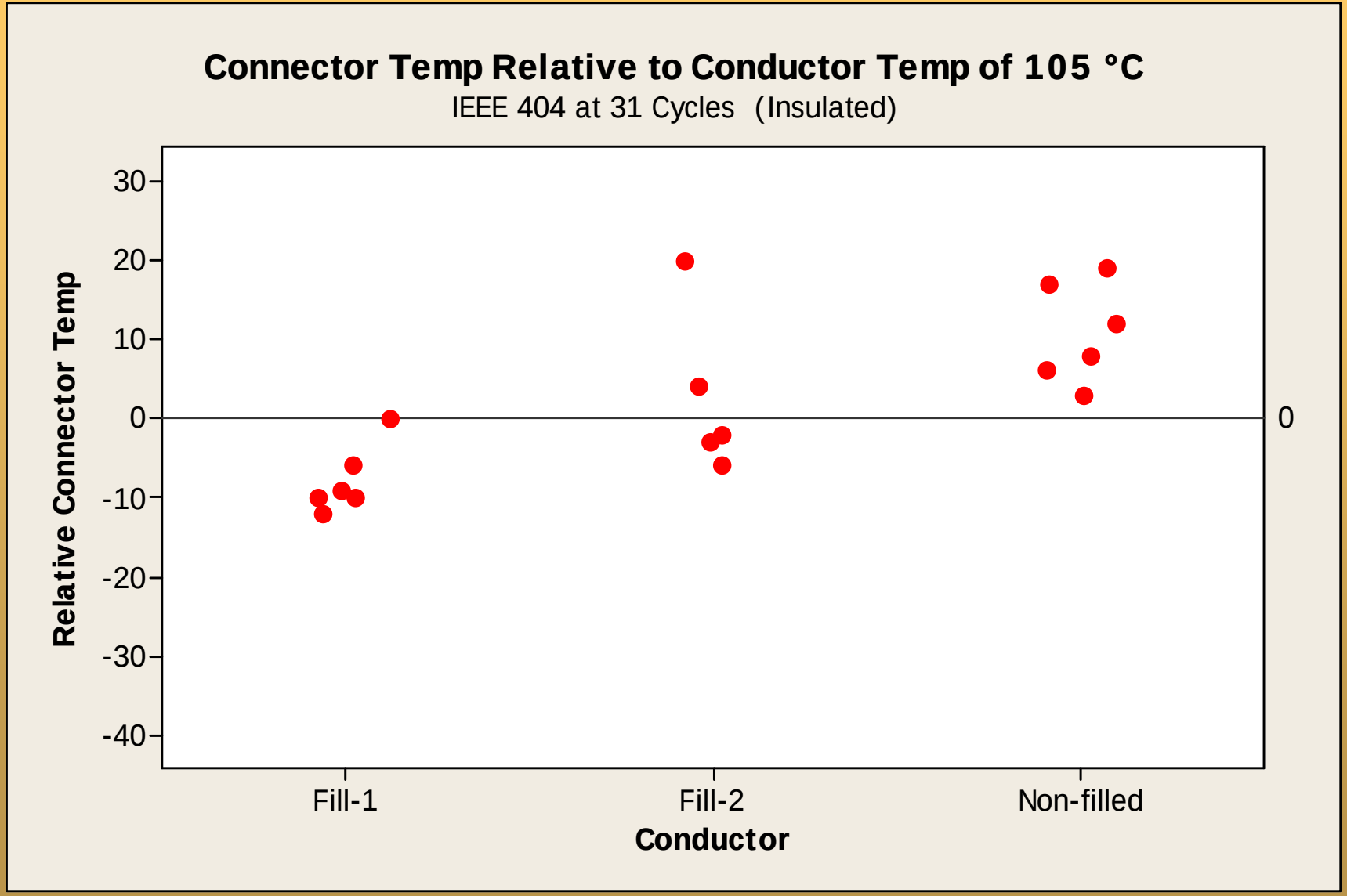
IEEE 404 In-Air Cyclic Aging Results



IEEE 404 In-Air Cyclic Aging Results



IEEE 404 In-Air Cyclic Aging Results



IEEE 404 In-Air Cyclic Aging Results

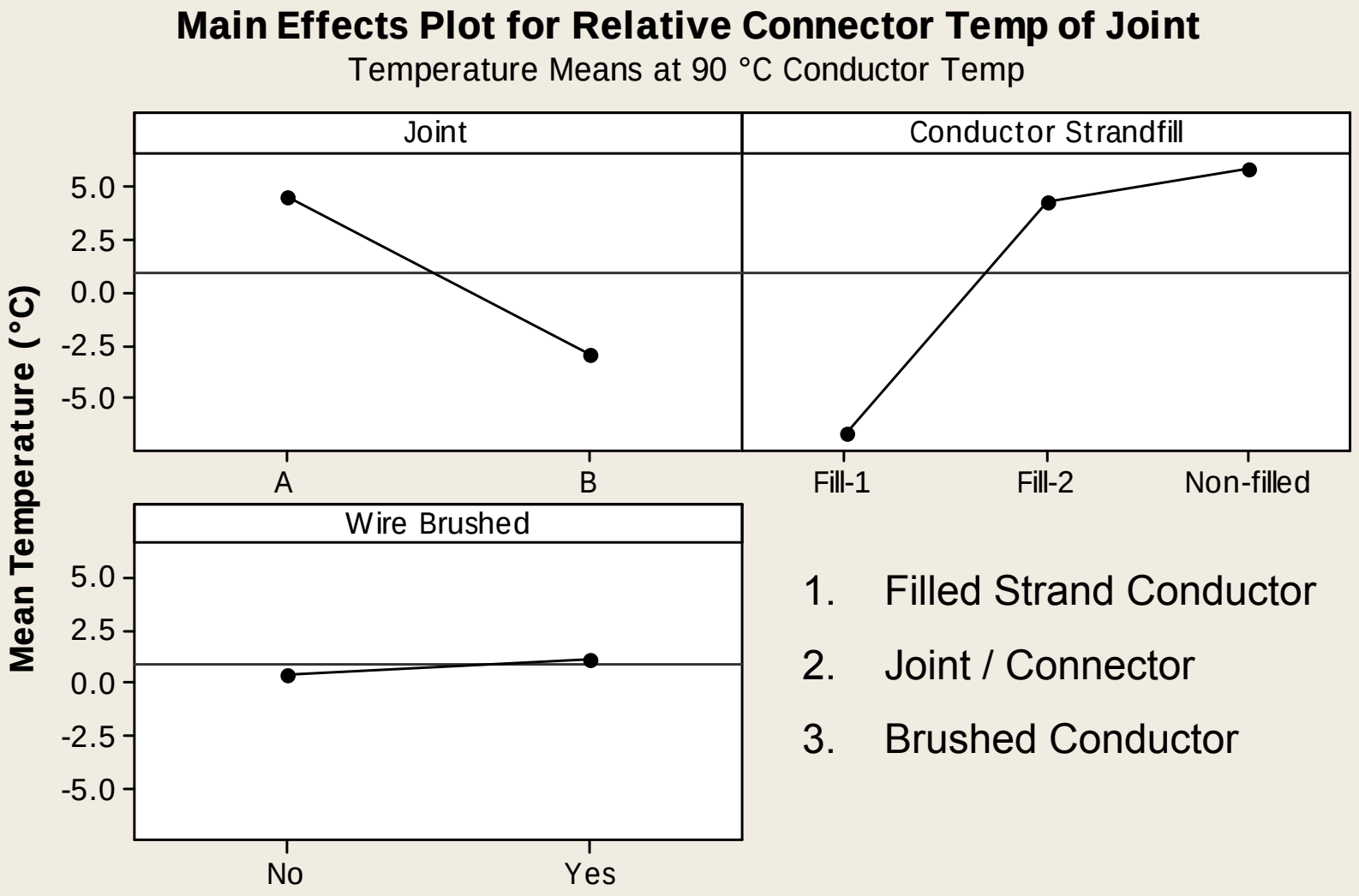
Analysis of Variance (ANOVA)

for 90 °C Control Conductor Temperature

Factor	***Levels***	***Values***
Joint / Connector	2	A, B
Brushed Conductor	2	No, Yes
Filled Strand Conductor	3	Non-filled, Fill-1, Fill-2

Source	***P***	***Significance***
Joint / Connector	0.110	**89%**
Brushed Conductor	0.834	**16.6%**
Filled Strand Conductor	0.061	**93.9%**

IEEE 404 In-Air Cyclic Aging Results



1. Filled Strand Conductor
2. Joint / Connector
3. Brushed Conductor

Main Effects for Connector Temperature

Significance of Effect	ANSI C119.4 CCS Bare Conductor and Connectors	IEEE 404 In-Air Cyclic Aging of Medium Voltage Insulated Cable and Joints
1(Most)	Connector	Filled Stand Conductor
2	Brushed Conductor	Joint / Connector
3 (Least)	Filled Strand Conductor	Brushed Conductor

Temperature Results

- ANSI C119.4 CCST — **1 out of 30** exceeded conductor temperature (3.3%)*
- IEEE 404 at 90 °C — **7 out of 18** exceeded conductor temperature (38.9%)
- IEEE 404 at 105 °C — **10 out of 18** exceeded conductor temperature (55.6%)

NOTE: * Two failures based on resistance criteria.

What did we learn?

- Filled Strand **always** affects connector temperatures to some extent, but the impact is different depending on the circumstances.
- The impact of filled strand is
  - Third in significance for the ANSI C119.4 CCS test (bare connectors), but
  - Most significant for IEEE 404 Cyclic Aging style tests (insulated connectors).
- Filled Strand appears to hurt performance with bare connectors, but may sometimes help performance with insulated connectors.

What did we learn?

- Connectors run hotter in insulated tests than in bare tests for the combinations tested
- Other factors affect connector performance, such as:
  - The choice of connector used
  - Wire brushing the conductor before installing connectors
- Tests on bare connectors and conductor may not necessarily be sufficient to qualify connectors for use in medium voltage (insulated) systems.

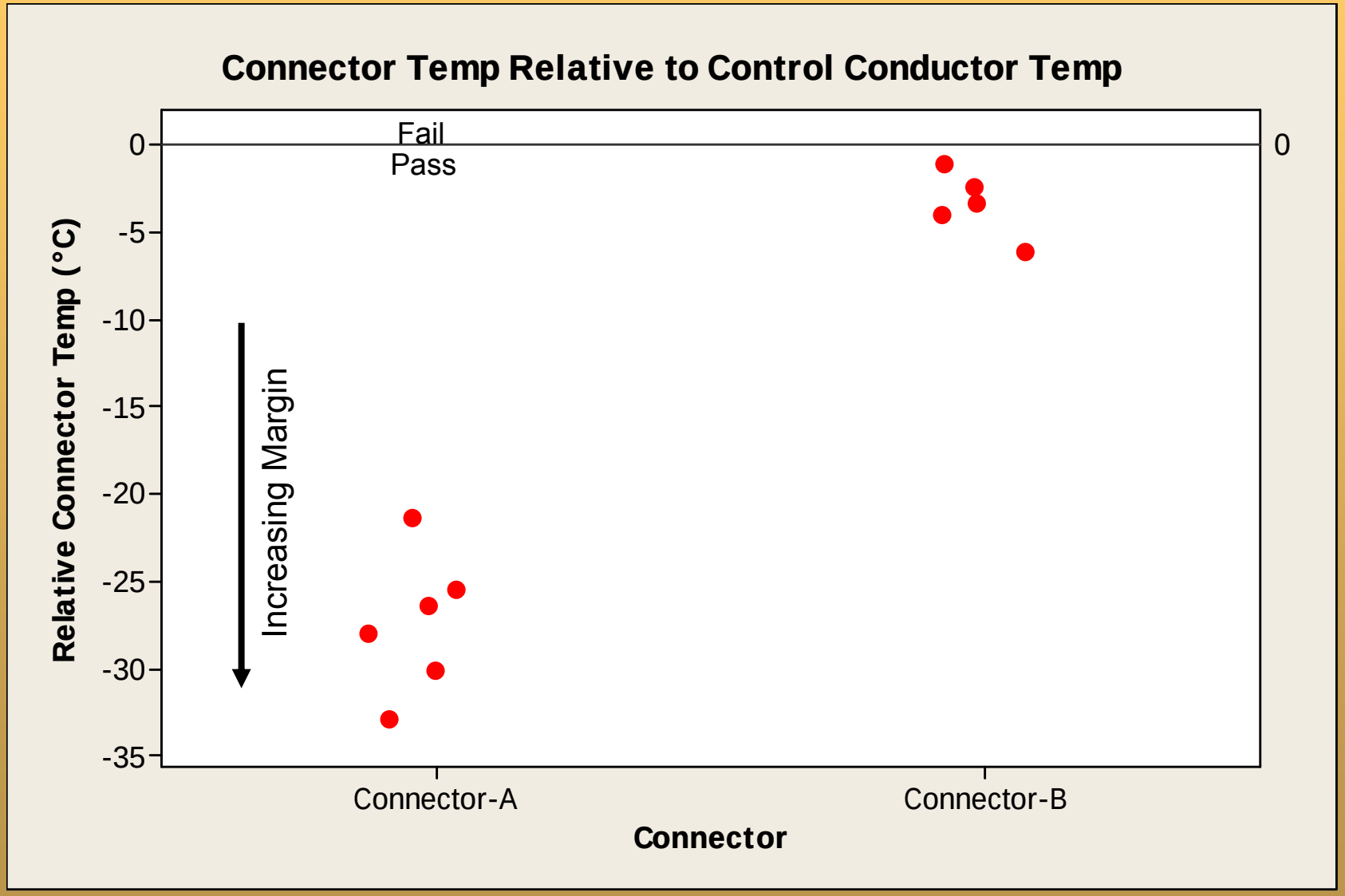
What do we not know?

- We do not know about other:
  - Connectors or joints
  - Filled Strand compounds
  - Long Term vs. Short Term Performance
- We have not looked at the effect of:
  - Different connectors with the same joint
  - Incorrect installation of connectors

Additional Food for Thought

- Tests in existing Standards may not be sufficient to make an informed choice of the best connector for a given application (existing requirements are pass / fail only)

ANSI C119 Pass / Fail vs. Margin



Questions ?