# PJM Emerging Technology Forum
# E3X Technology for overhead conductors

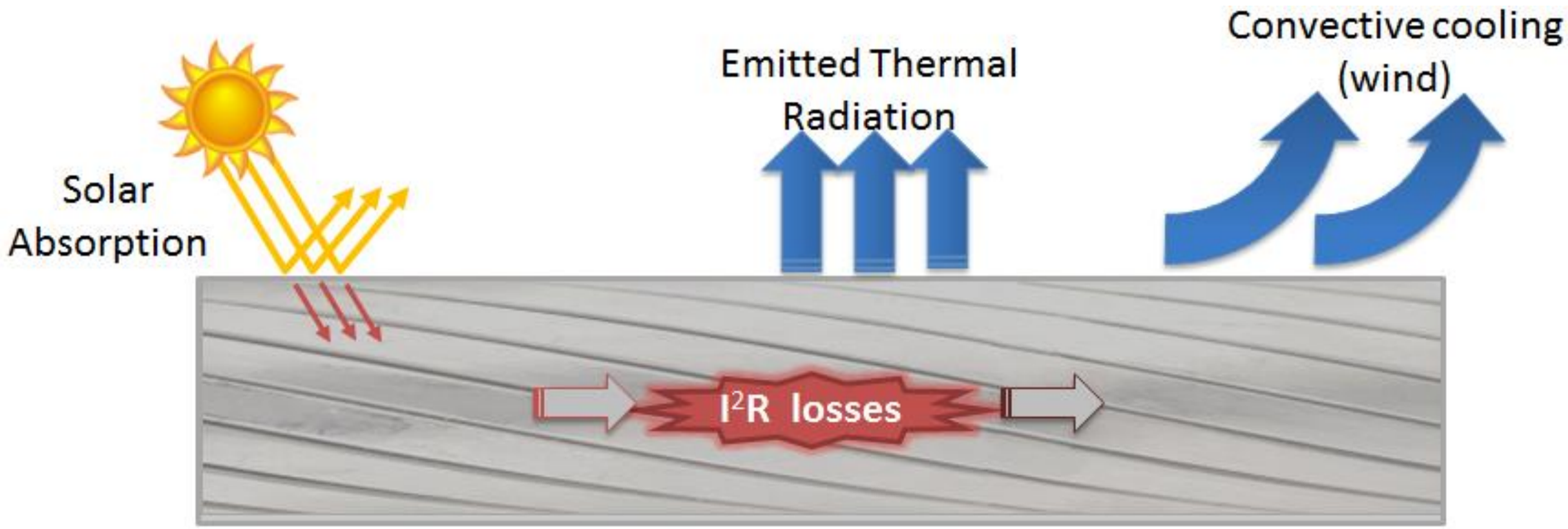
March 17, 2021

William Allen (Exelon)

Joe Coffey (Prysmian)

Prysmian Group

# Conductor Current/Temperature relationship




IEEE 738 methodology calculates ampacity based on conductor properties and environmental assumptions:

| | |
|---|---|
| Maximum conductor temp | Elevation |
| Ambient temperature | Radiated solar heat |
| Wind speed | Emissivity |
| Wind angle | Absorptivity |

# Atmospheric Pollutant Levels have fallen dramatically since 1960's

VI.A

BARE OVERHEAD TRANSMISSION CONDUCTOR RATINGS

GUIDE FOR DETERMINATION OF

BARE OVERHEAD TRANSMISSION CONDUCTORS

PJM INTERCONNECTION

January 2010

| Typical Normal Conditions-Summer | |
|---|---|
| **Ambient Temperature:** | **35°C** |
| **Wind Speed:** | 0 feet per second |
| **Wind Direction:** | 90° to conductor |
| **Solar/ Sky:** | Day -Industrial |
| **Elevation:** | 200 ft above sea level |
| ***Max. Allowable conductor temp.:*** | 100°-250°C(material dependent) |
| **Latitude:** | 40° North |
| **Sun Time:** | 14:00 |
| **Emissivity:** | 0.7 |
| **Absorptivity:** | 0.9 |

# “Determination of Bare Overhead Conductor Ratings.” Conductor Rating Task Force, PA, NJ, and MD Interconnection, May 1973

INVESTIGATION

The Task Force made arrangements with the scientists of the National Aeronautics and Space Administration (NASA), at its Goddard Thermophysics Branch, to conduct tests on four specimens of conductors. One of the samples was taken from unused stock, while the other three specimens had been in use at 230 kV for different periods in non-industrial areas adjacent to Washington, D.C.

Following careful preparation of the specimens, preliminary tests were performed in order to determine correction factors for the cylindrical shape of the specimens. This was necessary because the emissometer normally measures the emissivity of flat surfaces.

Figure 1 is a photograph of the test specimens.

“Determination of Bare Overhead Conductor Ratings.” Conductor Rating Task Force, PA, NJ, and MD Interconnection, May 1973.

# “Determination of Bare Overhead Conductor Ratings.” Conductor Rating Task Force, PA, NJ, and MD Interconnection, May 1973

1 2 3 4

CONDUCTOR SPECIMENS FROM VICINITY OF WASHINGTON, D C

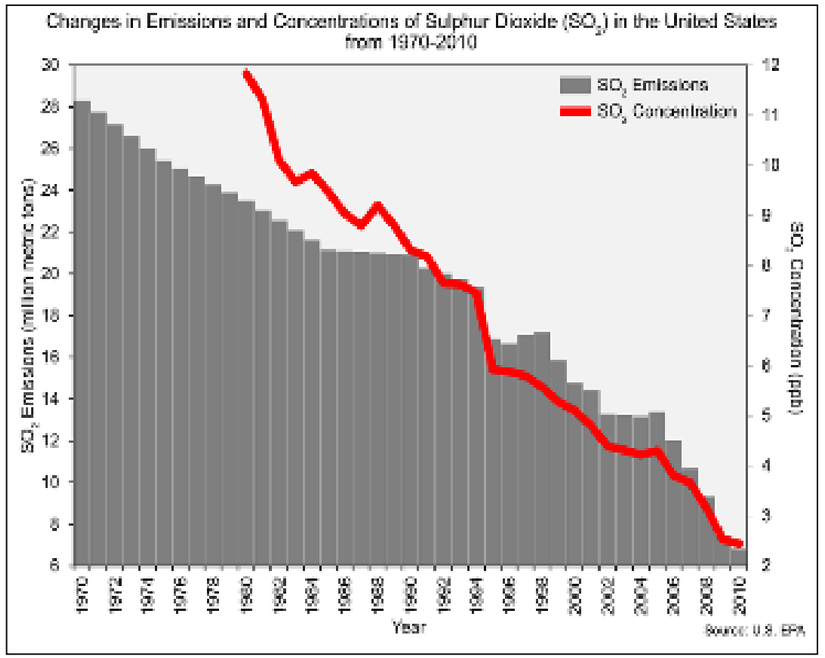
1. NEW CONDUCTOR FROM STOCK.
2. 10 MONTHS IN OPERATION AT 230 KV.
3. 8 YEARS IN OPERATION AT 230 KV.
4. 36 YEARS IN OPERATION AT 230 KV.

| Sample No. | Description ACSR | Years In Service | $\alpha$ | $\epsilon$ |
|---|---|---|---|---|
| 1 | 795 kCMIL 24/7 | NEW | 0.59 | 0.31 |
| 2 | 1033.5 kCMIL 45/7 | 0.83 | 0.78 | 0.46 |
| 3 | 795 kCMIL 24/7 | 8 | 0.93 | 0.74 |
| 4 | 795 kCMIL 30/19 | 36 | 0.92 | 0.85 |

“Determination of Bare Overhead Conductor Ratings.” Conductor Rating Task Force, PA, NJ, and MD Interconnection, May 1973.

# Atmospheric pollutant levels have fallen dramatically since 1960's

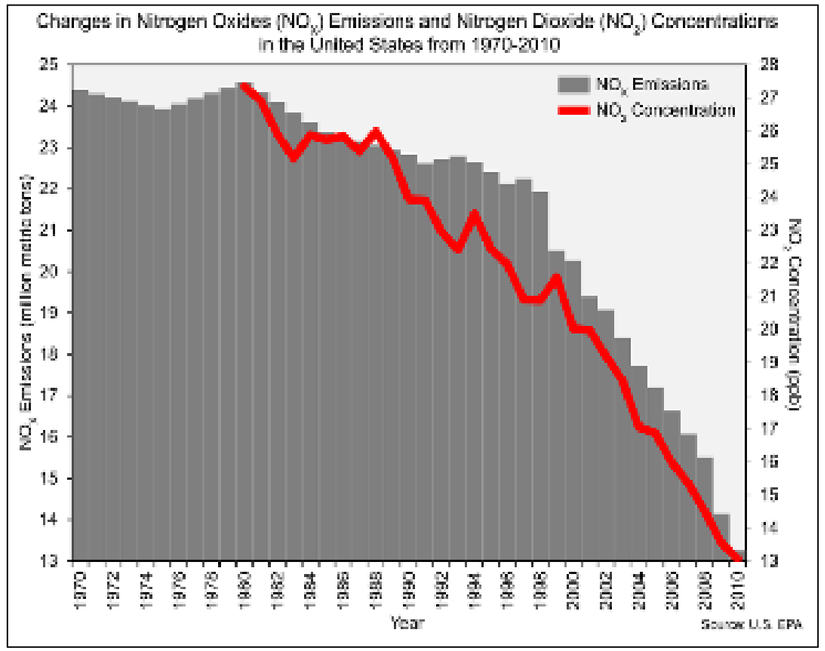
## Atmospheric $SO_2$ 1970-2010




Additional 71% decline 2010 to 2019

Sulfur Dioxide Trends | National Air Quality: Status and Trends of Key Air Pollutants | US EPA

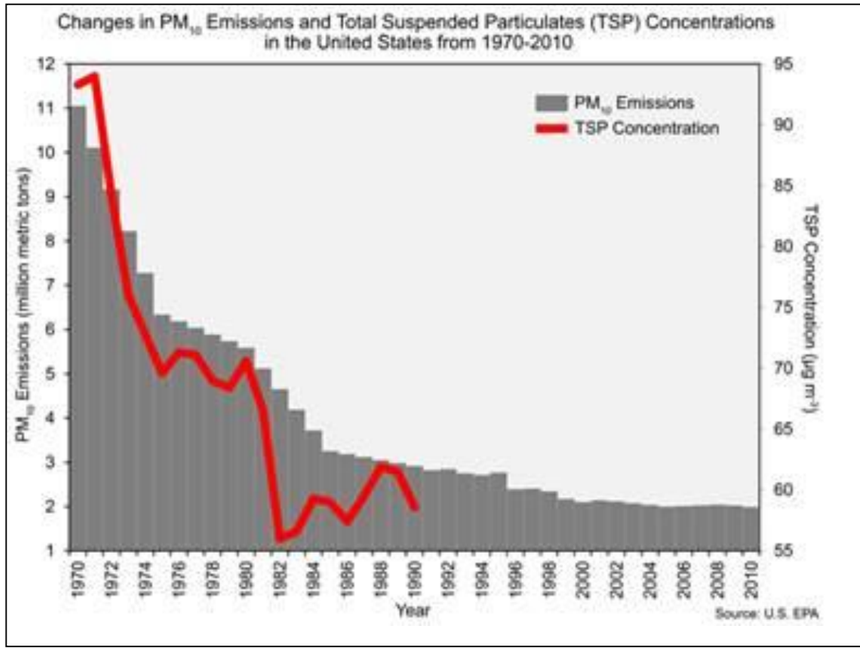
## Atmospheric $NO_X$ 1970-2010




Additional 17% decline 2010 to 2019

Nitrogen Dioxide Trends | National Air Quality: Status and Trends of Key Air Pollutants | US EPA

## Atmospheric $PM_{10}$ 1970-2010




Additional 17% decline 2010 to 2019

Particulate Matter (PM10) Trends | National Air Quality: Status and Trends of Key Air Pollutants | US EPA

http://sites.gsu.edu/geog1112/files/2012/12/PM10_Trends1.png

# What value of emissivity is appropriate for today's transmission lines?

Poland Utility (most polluted air in EU)
Bare aluminum conductor
Conductor deployed 2008-2015

Oncor Electric/ DFW Area
ACSR Conductor
Conductor deployed 1982-2015
Emissivity 0.32 (EPRI)

## EPRI report on emissivity

**Update on Conductor Emissivity Database Development: Summary of Test Results**

Type: Technical Update

Product #: 3002012666

Published: 12-18-2018

Size: 2.76 MB

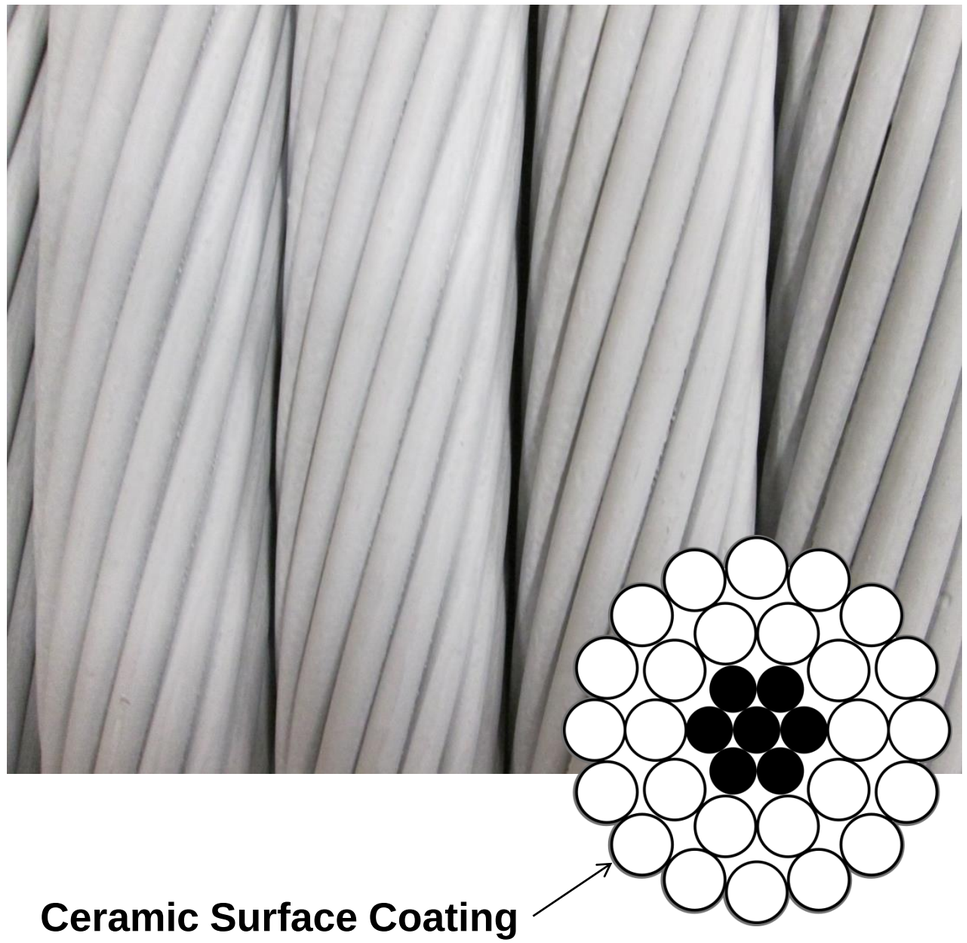
View Abstract | Download Full Report

**Non-Conservative errors in line rating are likely for newer nontreated conductors rated with emissivity >0.3. Risk increases with higher line temperatures (forth power dependency)**

# E3X® Technology

Prysmian Group

# Factory applied E3X®
# High Emissivity/Low Absorptivity coatings




**Engineered surface treatment turns variables into data sheet values**

**High Emissivity (0.9)**
**Low Absorptivity (0.2)**

**Results in cooler operating conductor for given load**

**Applied in the factory to the outside of the conductor**

**Environmentally stable**

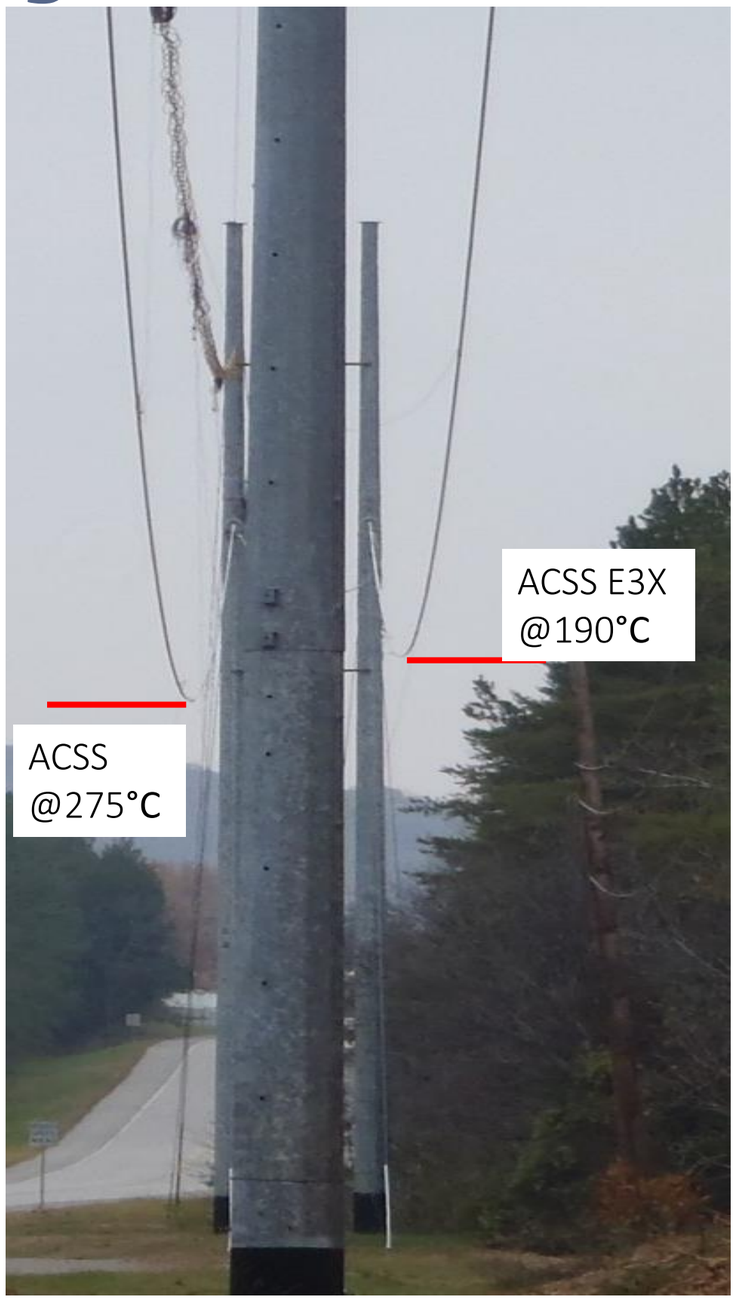
**Hard, Flexible, Durable, Abrasion and Heat Resistant**

**Chemically Bonded to the aluminum**

**Dozens of deployments since 2013**

# E3X temperature reduction at Oak Ridge National Laboratory

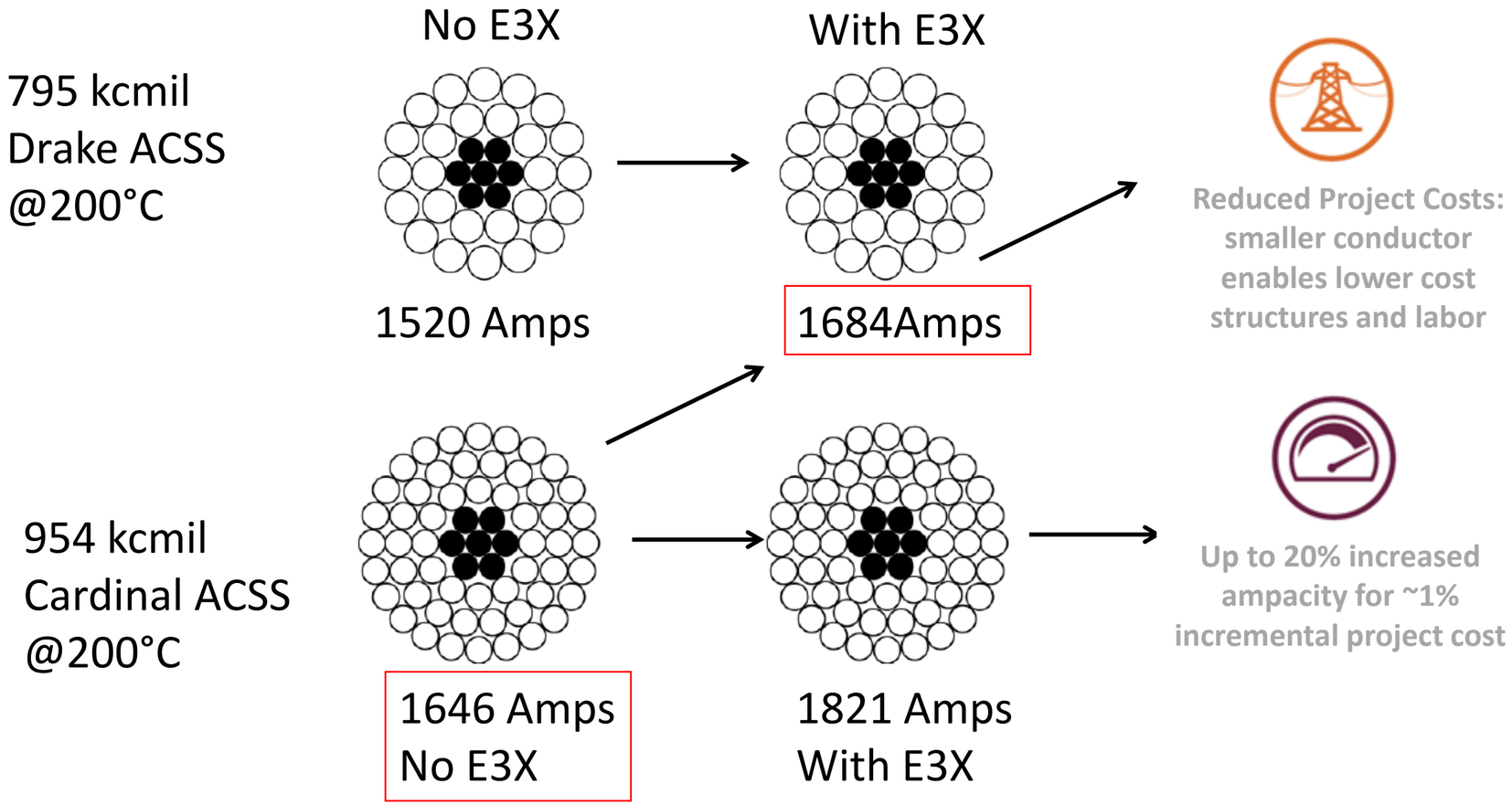
| Constant Current test | | |
|---|---|---|
| Temperature (°C) | | |
| Drake ACSS | Drake ACSS E3X | Reduction (°C) |
| 30 | 27 | 3 |
| 90 | 72 | 18 |
| 125 | 94 | 31 |
| 200 | 150 | 50 |
| 275 | 190 | 85 |




Pub59272.pdf (ornl.gov)

Pub138393.pdf (ornl.gov)

# Conductor Ampacities-PJM summer Normal rating



# Example Application: More capacity on difficult projects

GRID OPTIMIZATION > TRANSMISSION

## Designs for Capacity

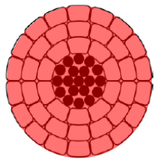
Avista Utilities uses ACSS to deliver 15% more capacity without any compromise.

Bryan Hyde | Nov 13, 2017

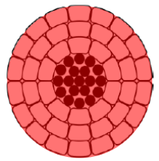
A transmission line connecting Ninth & Central and Sunset stations crosses a mix of residential and public land.

# Example application:
# Achieve 250°C Ampacity with 200 °C Conductor

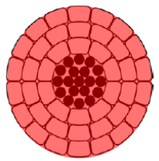
- **Increase temperature of 1926.9 kcmil Cumberland ACSS**



Utility standard
180°C
**2569 Amps**
**Sag OK**

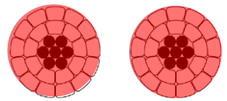


200°C
**2664 Amps**
**Sag OK**



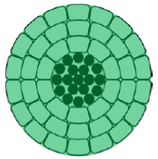
250°C
**3022 Amps**
**Excessive Sag**

- **Use bundle of 2-959kcmil Suwanee ACSS per phase**



**Oncor standard @ 180°C**
**3302 Amps for bundle**
**Structures not able to support added tension**

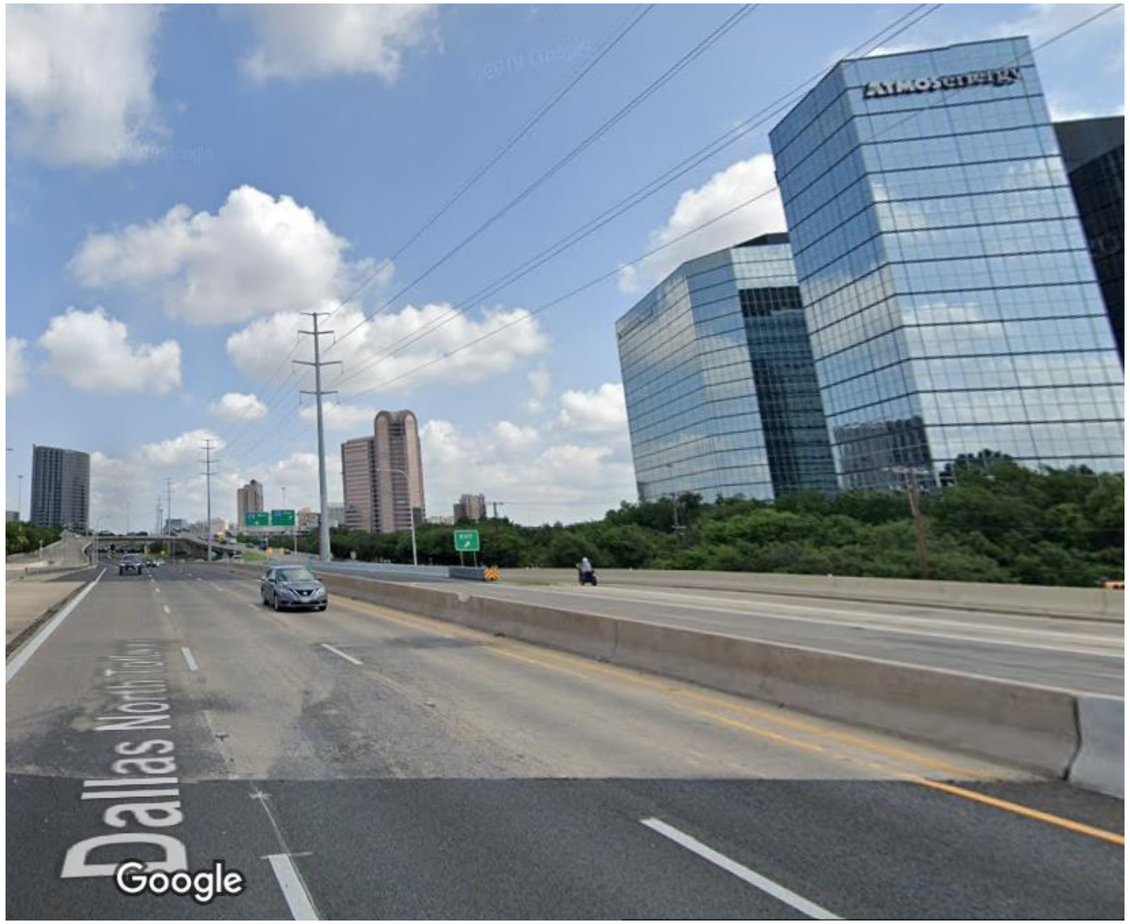
- **Option Selected: heat dissipating E3X®ceramic coating added to Cumberland ACSS**



200°C
**3065 Amps**
**Sag OK**
**Structure Loading OK**

# Example application:
# Toll Road Project

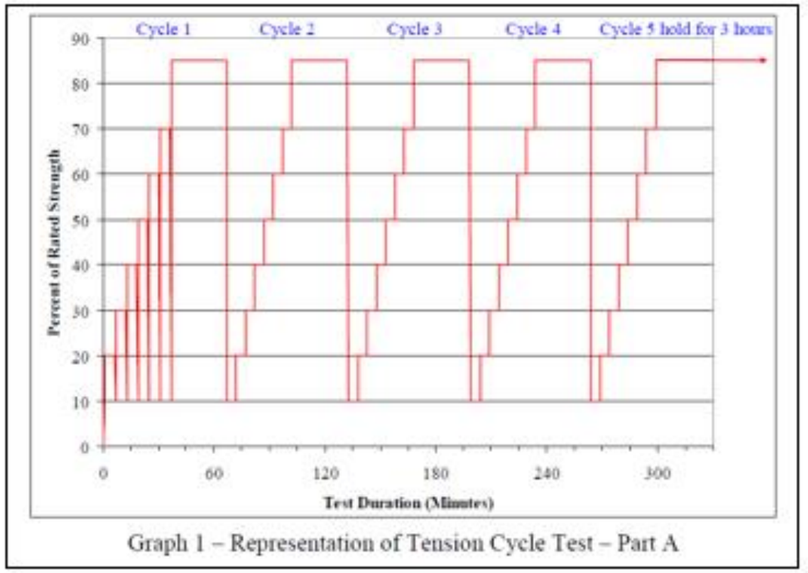
- Project required toll road closure
  utility had to pay to “rent” lanes
- E3X added 15% incremental capacity for <1% project cost
- Added capacity during difficult rebuild
- “capacity insurance”



# E3X® Technology Testing

Prysmian Group

# E3X Durability: Kinectrics Sequential Mechanical Test

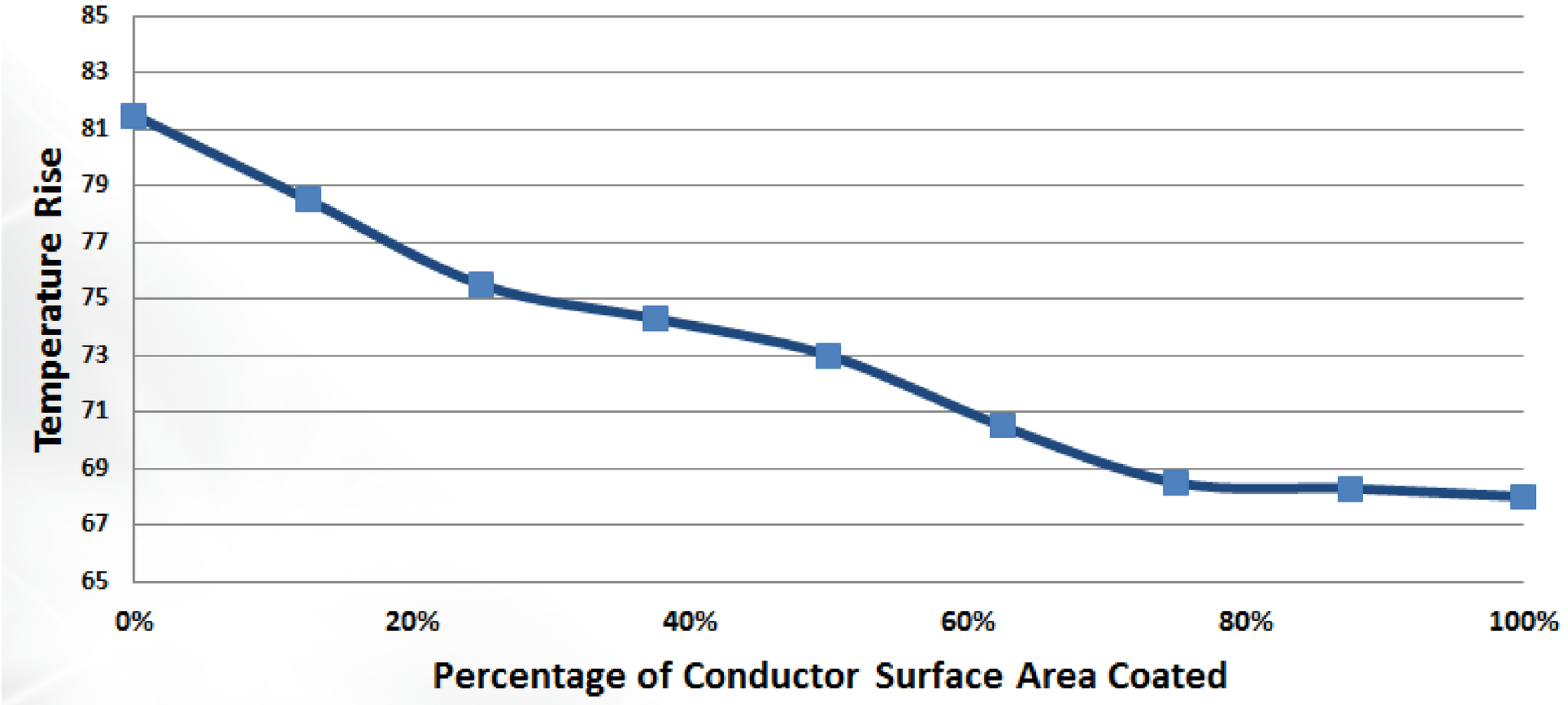


Graph 1 – Representation of Tension Cycle Test – Part A

- Conductor pulled under tension over sheave 30 cycles
- Conductor galloped for 24 hrs
- Aeolian Vibration 40 days 100,000,000 cycles
- Conductor pulled to tensions 20, 30, 40, 50, 60, 70, 85% of rated strength for 5 cycles
- “No visible signs of breaks, cracks, failure or discoloration of any components of the test conductor after completing the sequential mechanical tests”

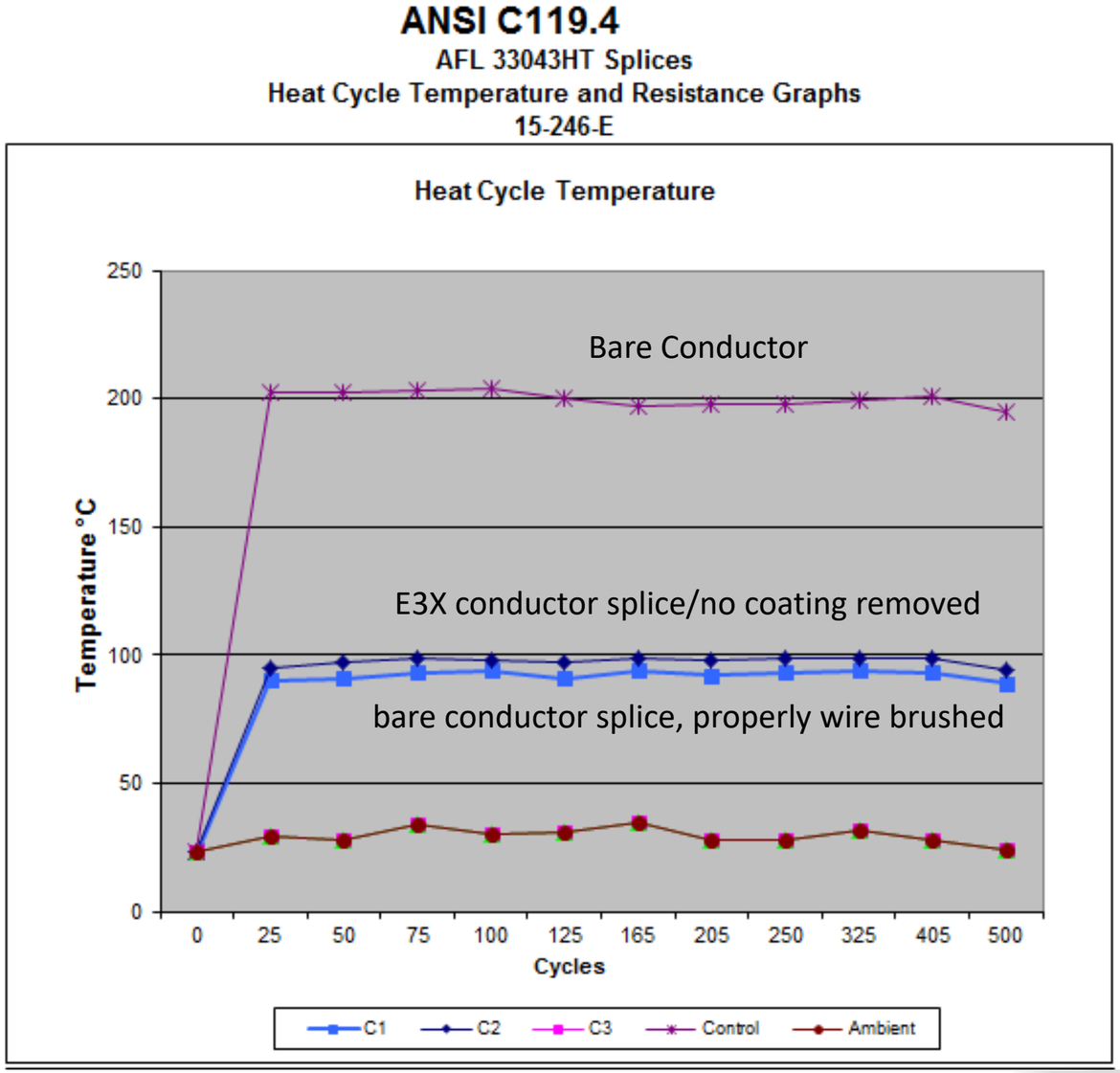
# E3X Durability: Temperature Reduction vs. % Coating Coverage

Performance loss is minimal if 75% coating is maintained



# Wire brushing is important with or without E3X coating

- Installation of E3X conductor is no different from standard conductor
- Wire brushing electrical connections is important with or without E3X
- Removal of coating gives visual feedback
- Tests show stable temp even with no coating removal



# E3X Durability: Salt Spray test (ASTM B117) E3X compared to steel

## E3X conductor @ 2000hr

**Coated Conductor:**
After 1000+ hours test
No corrosion observed. No flaking, chipping or discoloration of the sample seen.
After 1500+ hours test
No corrosion observed. No flaking, chipping or discoloration of the sample seen.
After 2000 hours test
No corrosion observed. No flaking, chipping or discoloration of the sample seen.

----------END----------OF----------REPORT----------

Tested By: Harshala Mawale

For ELCA LABORATORIES
Authorised Signatory
Kartik Iyer
C.E.O.

## Galvanized steel @ 500 hr

## Mischmetal steel @1500 hr


Salt spray test (ASTM B 117, DIN SS 50021)

***photos courtesy of Bekaert***

- Also tested for:
  - Heat
  - Humidity
  - UV Exposure
  - Sand Abrasion
  - Acid
  - Base
  - Corona
  - Soot
  - Texas clay

- **E3X will last the life of the conductor**

# E3X Icephobic Properties

Laboratoire international des matériaux antigivre LIMA AMIL Anti-icing Materials International Laboratory

**January 2016**

Coating performance to reduce ice adhesion is evaluated using the following criteria:

ARF ≥ 1 Ice adhesion reduction, icephobic effect, the higher the value the more icephobic the coating

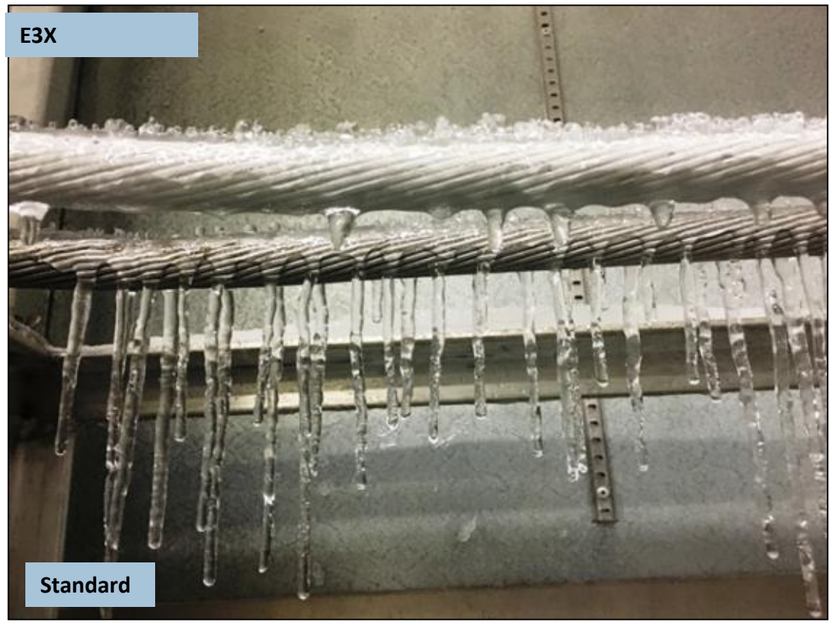
ARF ≤ 1 An increase in adhesion on the candidate coating with respect to the bare beam (icephilic)

**Results:**

**Adhesion Reduction Factor Results**

| Centrifuge Adhesion Test | | | | |
|---|---|---|---|---|
| **Coating** | **Test Serie #** | **Ice Adhesive Stress on Coating (MPa)** | **Ice Adhesive Stress on Aluminum Control General Cable (MPa)** | **ARF** |
| **E3X** | CATZL660 | 0.08 ± 0.01 | 0.48 ± 0.11 | 6.4 |

Prysmian ice chamber results:




- Lab testing shows lower ice growth and ice adhesion

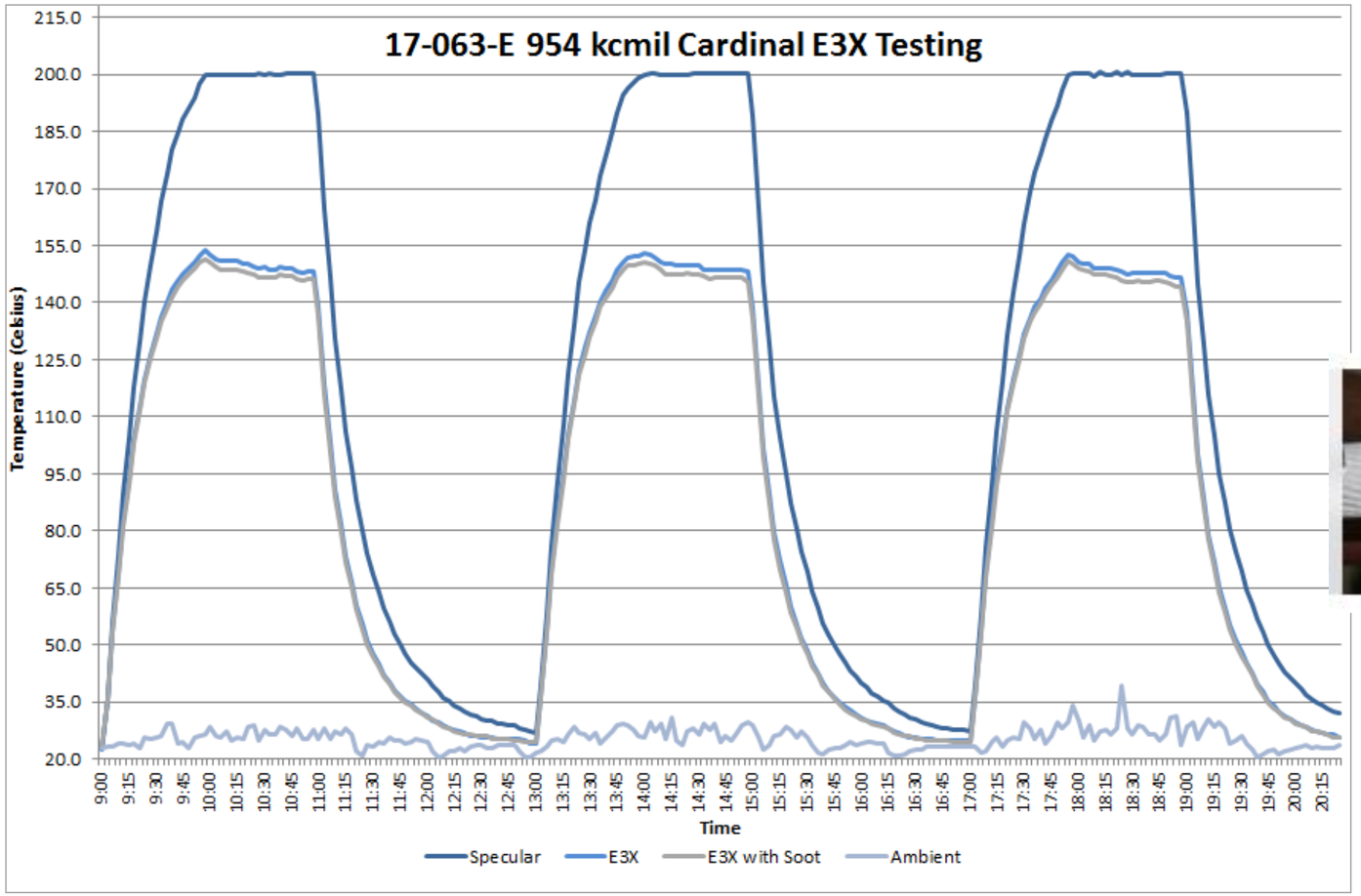
- 2 Field trials were inconclusive due to lack of frozen precipitation during monitoring period
- EPRI developing concurrent ice/wind testing chamber

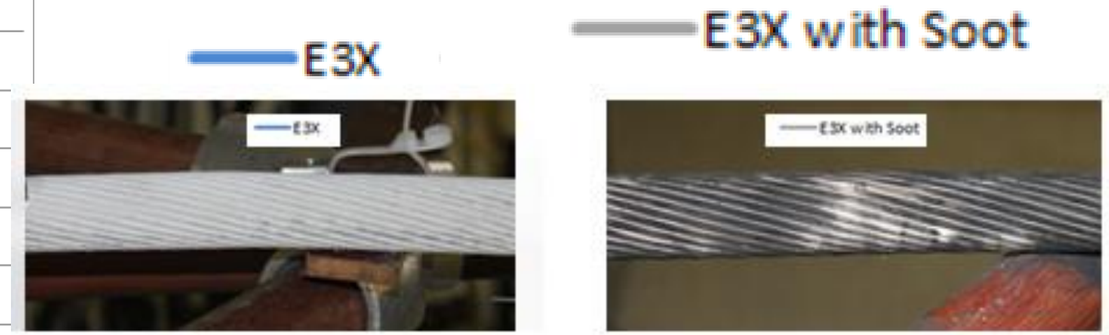
# E3X testing with soot and clay: “dirty” E3X performance improved

E3X conductor intentionally contaminated with acetylene soot and Texas clay

Cooling performance compared to clean E3X.

Cooling performance improved



# Questions?

# Thank you!