Motor Lead Wire Qualification Update

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Motor Lead Wire (EQ) Background

- ***Prior (EQ) qualified motor lead wire design :***

- ***SSRUG:*** ***S****emi-cured* ***S****ilicone* ***RU****bber-coated* ***G****lass-tape (i.e. orange cable)*
  - *Qualified in early 1980's*
  - *Manufactured by RSCC Wire and Cable LLC*
- ***SSRUG Material Obsolescence:*** *Silicone material became unavailable in late 2000's*
  - *RSCC began work to find an alternative material and perform a "like-for-like" analysis*
  - *The program was unsuccessful and halted in early 2012*
- ***EPRI:*** *Motor rewind re-qualification program*
  - *Program to address the issue of no other qualified motor lead wire cable*
  - *RSCC provided prototype motor lead wire cables in 2014*
  - *Project is currently on hold*
- ***Schulz Electric:*** *Limited stock of SSRUG motor lead wire*
  - *Searched the world for an alternative*
  - *Late 2014, committed to joint program with RSCC for a new design*

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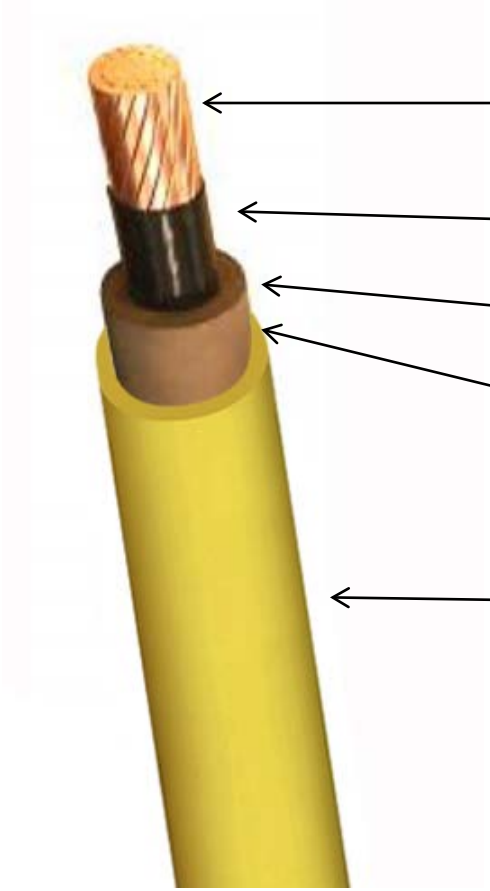
“New” Motor Lead Wire Design



Conductor

Permashield® Conductor Shield

Kerite® Discharge Resistant EPR Insulation

Woven Glass Braid

Flexible LSZH Jacket

Kerite Insulation System

- ***Five independent and successful qualifications to date:***

- ***QR-1305:*** *Kerite Shielded MV Power Cables for 60 Year Life at 90°C (LOCA)*
  - *Completed March 2013*
  - *Utilizes black CSPE jacket*
- ***QR-1403:*** *Kerite Shielded MV Power Cables for 60 Year Life at 90°C Normal Service Use and Raychem Splice and Termination Compatibility Testing*
  - *Completed March 2014*
  - *Utilizes colorable CSPE jacket*
- ***QR-1501:*** *Kerite Nonshielded MV Power Cables for 60 Year Life at 90°C (LOCA)*
  - *Completed February 2016*
  - *Utilizes electrical-grade CSPE jacket*
- ***QR-1601:*** *Kerite Shielded MV Power Cables for 60 Year Life at 90°C (LOCA)*
  - *Completed June 2016*
  - *Utilizes colorable, flexible LSZH jacket*
- ***QR-1602:*** ***Kerite Motor Lead Wire*** *for 40 Year Life at 90°C (LOCA)*
  - *Completed May 2016*
  - *Utilizes colorable, flexible LSZH jacket*

Kerite Insulation System Differences

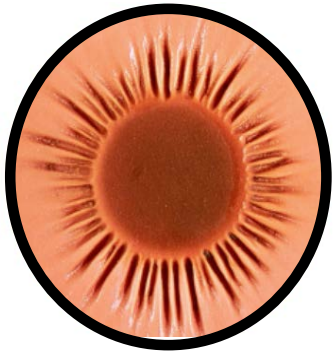
- ***Consists of the Permashield conductor shield and Kerite Discharge Resistant (DR) insulation:***

- ***Permashiled:*** *Nonconducting stress control layer*
  - *The only type of shield that is 100% production tested*
  - *66% improvement in average AC breakdown strength over semicon material*
- ***Kerite DR insulation:*** *Point Probe Test for Discharge Resistance per ASTM D2275*
  - *Formulated to prevent the degradation that occurs as a result of partial discharge.*
- ***Field Proven Performance History:*** *NEI 06-05, Medium Voltage Underground Cable White Paper, April 2006, Details a Study Performed Across a Variety of Medium Voltage Cables Installed in US Nuclear Power Plants*
  - *81/104 US Nuclear Units Reported and the 20 Units Having Brown EPR (Kerite) Reported Zero Failures*
    - *Still Only Cable With Zero Failures of the Insulation System*
  - *Concluded that "at a minimum, a proven, modern cable design should be used for replacements. Based upon successful performance … brown EPR (Kerite) is the current material of industry preference."*

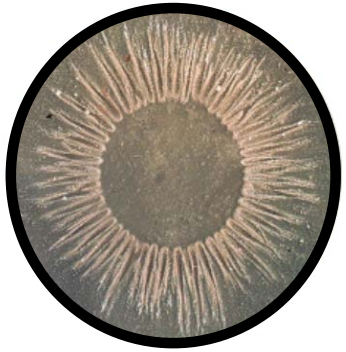
Discharge Resistance

TIME TO INCEPTION OF EROSION (HOURS)			
>250	48	Immediate	Immediate
TIME TO DIELECTRIC FAILURE (HOURS)			
>250	120	80	45
AVERAGE EROSION RATE (MIL/HOURS)			
0	.15	.10	.5

Discharge Resistant EPR



Discharge Free EPR

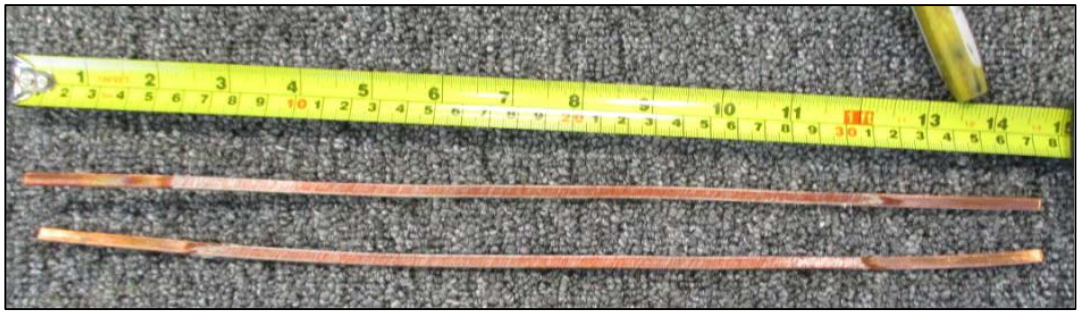


TR-XLPE

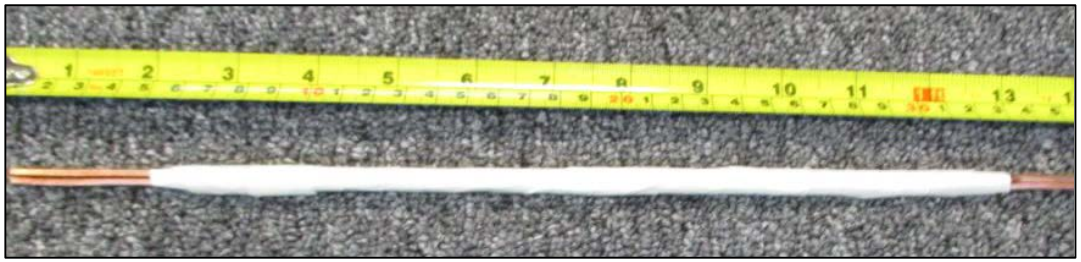
XLPE

(EQ) Test Sample Preparation

- ***Compatibility between motor lead wire materials and motor winding materials was demonstrated by the qualification:***



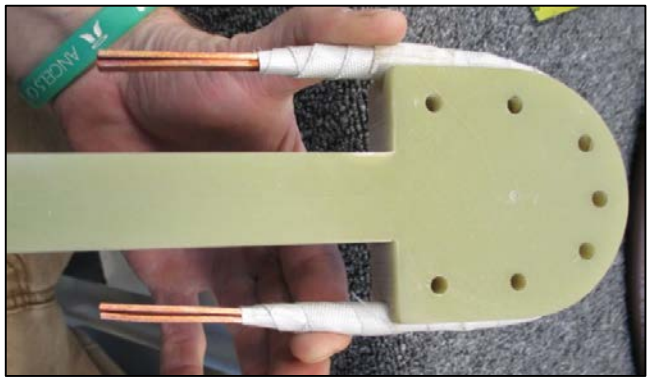
- ***Motor Winding Splice:*** *Two motor lead wire samples were spliced*
  - *Magnet wire was wrapped in (2) half-lapped layers of mica tape. The untreated fiberglass armor tape was then wrapped around the mica tape.*



(EQ) Test Sample Preparation

- ***Compatibility between motor lead wire materials and motor winding materials was demonstrated by the qualification:***

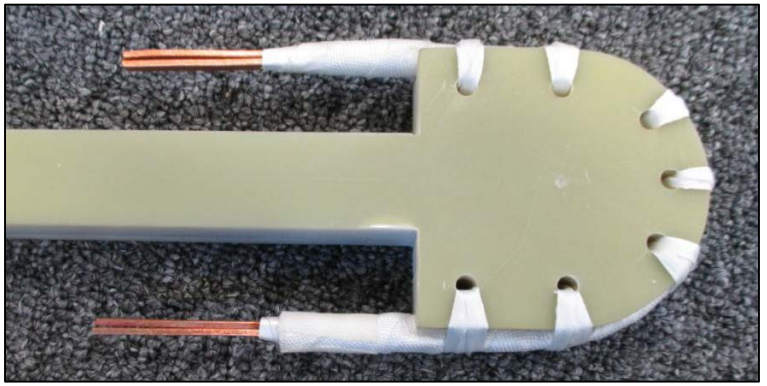
- ***Motor Winding Splice:*** *Two motor lead wire samples were spliced*
  - *A G-10 form was used to mount the magnet wire to the test fixture securely.*



(EQ) Test Sample Preparation

- ***Compatibility between motor lead wire materials and motor winding materials was demonstrated by the qualification:***

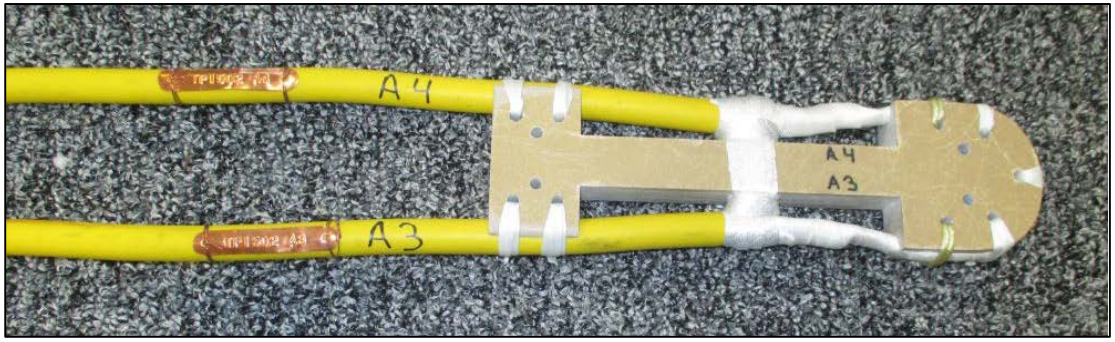
- ***Motor Winding Splice:*** *Two motor lead wire samples were spliced*
  - *Tie cord was used to attach the magnet wire to the test fixture in order to hold it in place.*



(EQ) Test Sample Preparation

- ***Compatibility between motor lead wire materials and motor winding materials was demonstrated by the qualification:***

- ***Motor Winding Splice:*** *Two motor lead wire samples were spliced*
  - *Lead wire was brazed onto the magnet wire, then insulated and taped using the same process used for winding EQ form wound insulation systems.*



(EQ) Test Sample Preparation

- ***Compatibility between motor lead wire materials and motor winding materials was demonstrated by the qualification:***

- ***Motor Winding Splice:*** *Two motor lead wire samples were spliced*
  - *The test samples put through the vacuum pressure impregnation (VPI) process.*

IEEE 383 (EQ) Qualification

- ***Aging properties (section 6.4.1):***

- *"Aging data shall be used to establish the activation energy of the critical materials, including insulation, jacket (when cable jacketing may impact cable qualification), mastics (when used and credited as part of field splice qualification), and semiconducting material if used."*
  - *Kerite utilizes a nonconducting conductor shield and whereas typical medium voltage designs utilize semicon shields, it is considered as a critical material.*

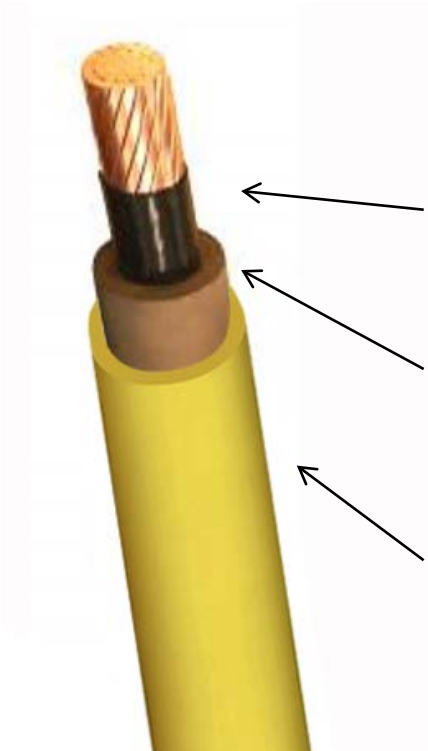
IEEE 383 (EQ) Qualification

- ***Sample selection criteria (section 6.1.1):***

- *"medium voltage cables shall only be tested as a completed cable, including jackets, shields, and stress control layers where applicable."*
- *"Qualification of a type test sample cable shall qualify cable with the same insulation thickness and with heavier thickness without regard to voltage rating, within the same voltage class if and only if the applied peak voltage stress in V/mil during the test is equal to or greater than the peak voltage stress that a test sample or the higher voltage rating would require."*

IEEE 383 (EQ) Qualification

- ***Thermal Aging and Activation Energies:***
- *Samples were thermally aging at 165°C for 460 hours*



Polymeric Layer	Activation Energy	Qualified Life
Permashield Conductor Shield	1.232 eV	44 years at 90°C
Kerite DR-EPR Insulation	1.238 eV	44 years at 90°C
Flexible LSZH Jacket	1.342 eV	81 years at 90°C

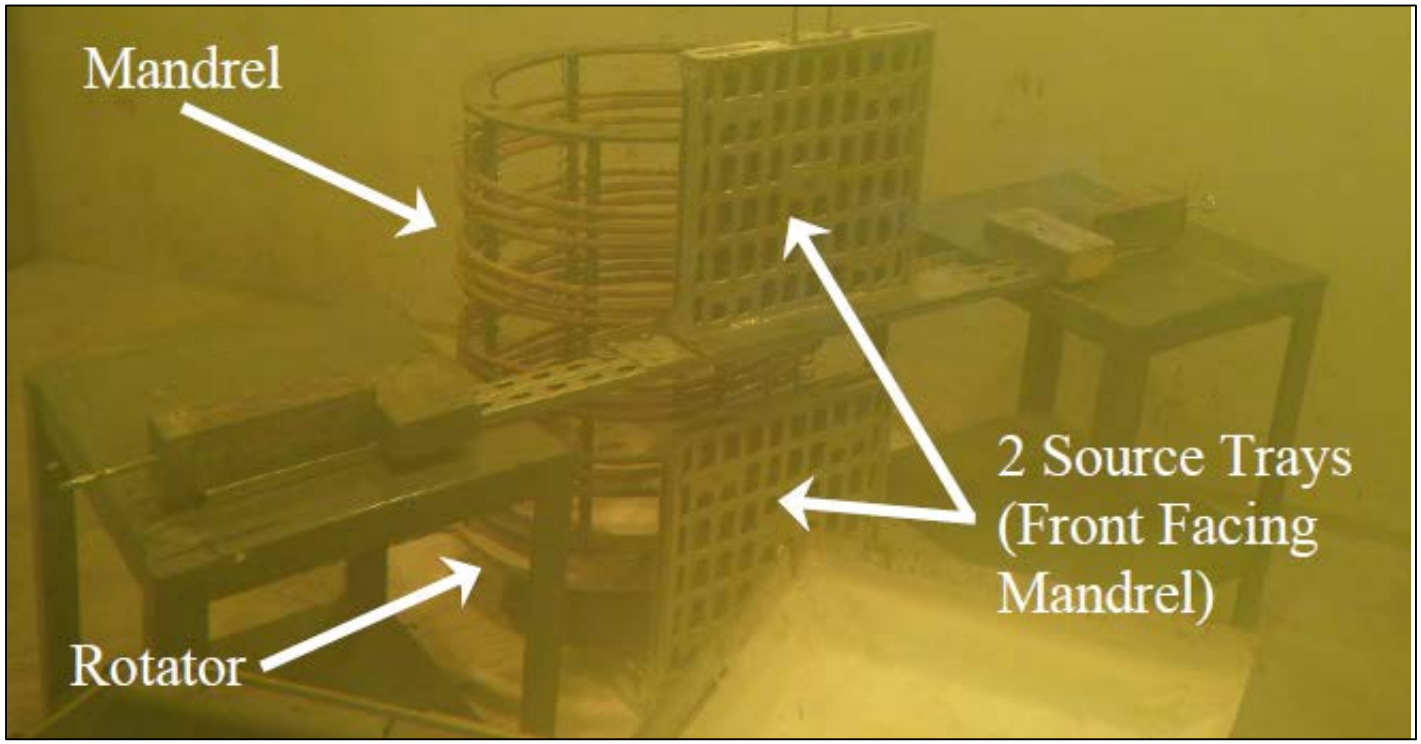
IEEE 383 (EQ) Qualification

- ***Test samples:***

- ***Sample Set #1:*** *Unaged and 220 Mrads*
- ***Sample Set #2:*** *40 years aged and 220 Mrads*
  - *Since thermal aging was based on the conductor shield, then the flexible LSZH jacket was over aged ~81 years*

IEEE 383 (EQ) Qualification

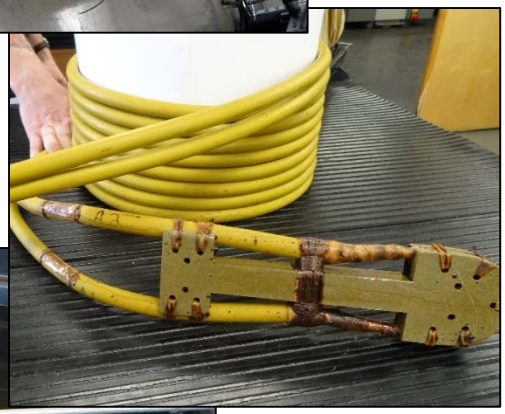
- ***Gamma radiation exposure:***
- *220 Megarads total integrated dosage (TID) was based on 2σ confidence level*

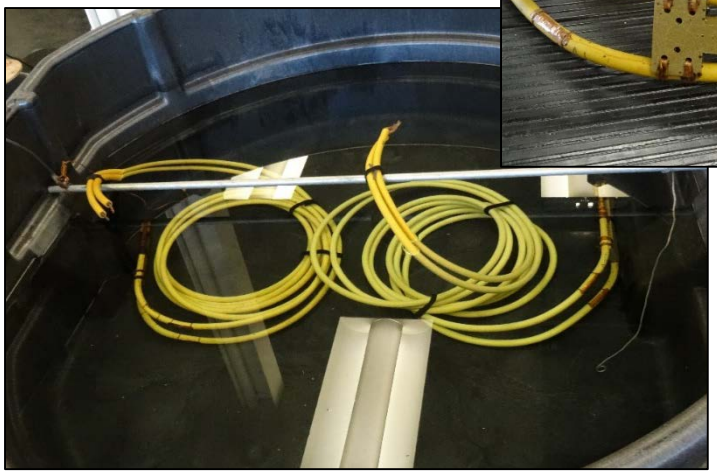


IEEE 383 (EQ) Qualification

- ***Normal service use testing:***

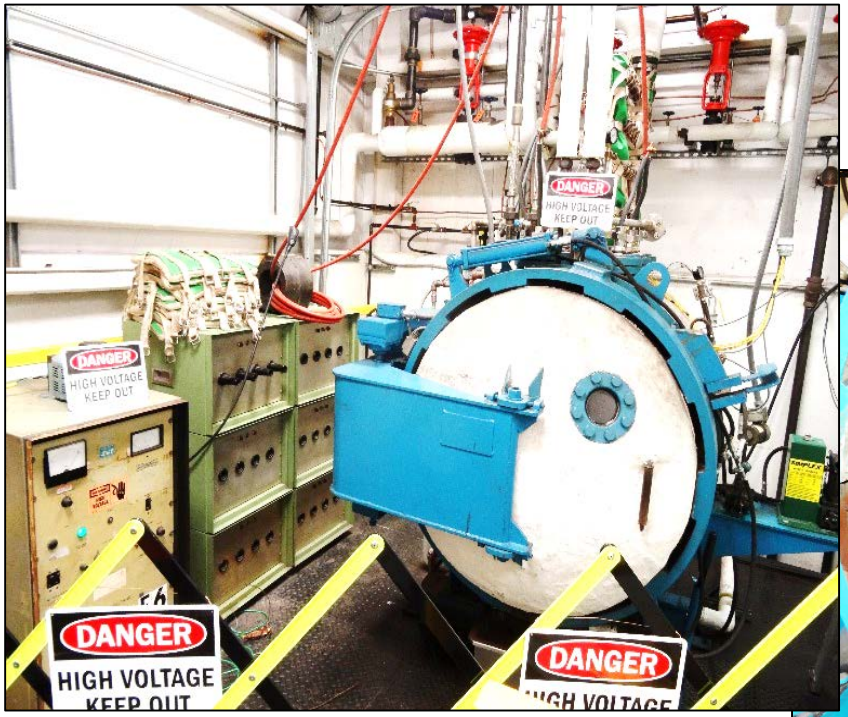
- *Following thermal and radiation aging:*
  - *samples were straightened*
  - *… bent around 20x mandrel*
  - *… submerged for 1 hour*
  - *… voltage withstand tested submerged at 80 VAC/mil*

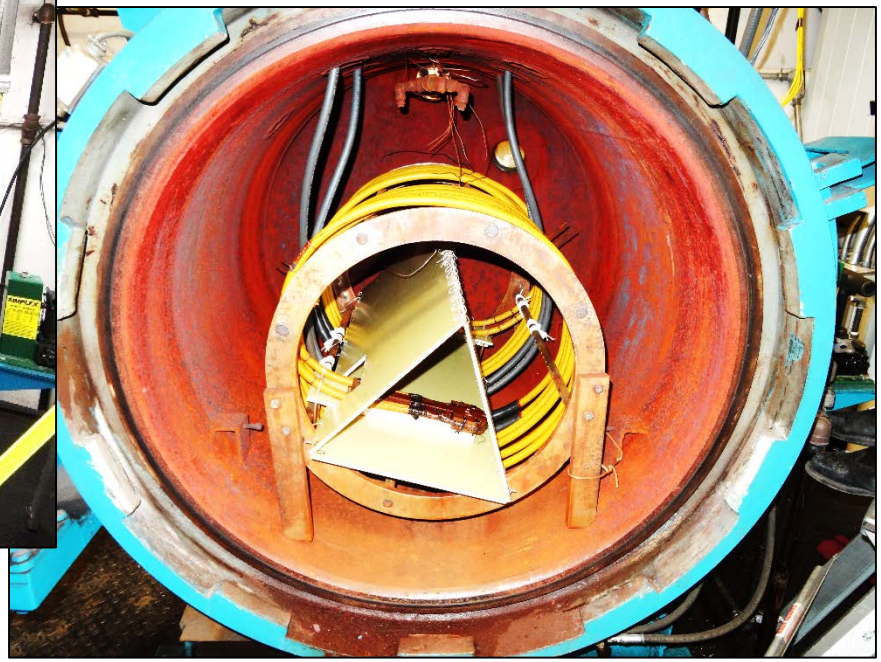




IEEE 383 (EQ) Qualification

- ***DBE simulation performed at RSCC test laboratory:***





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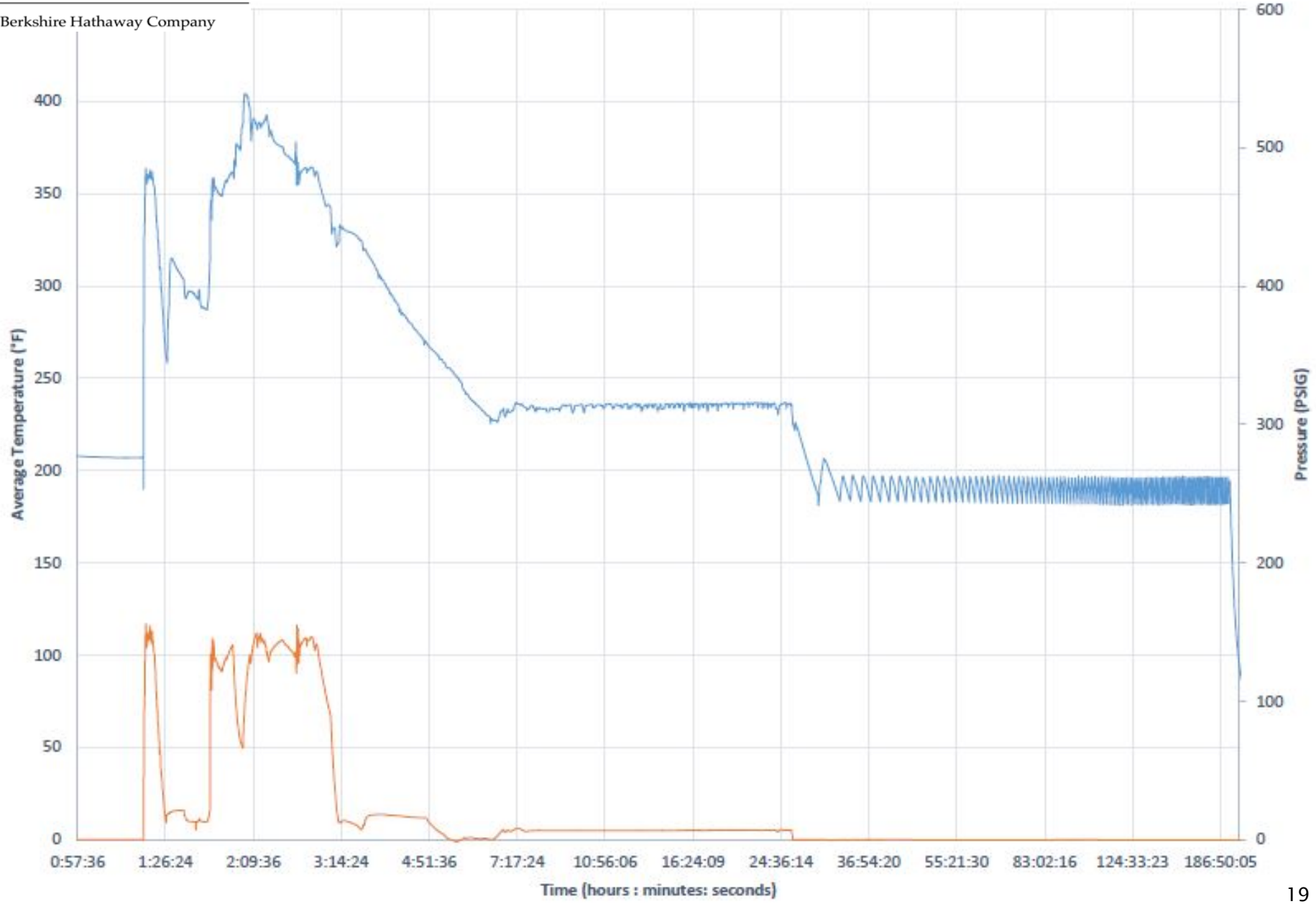
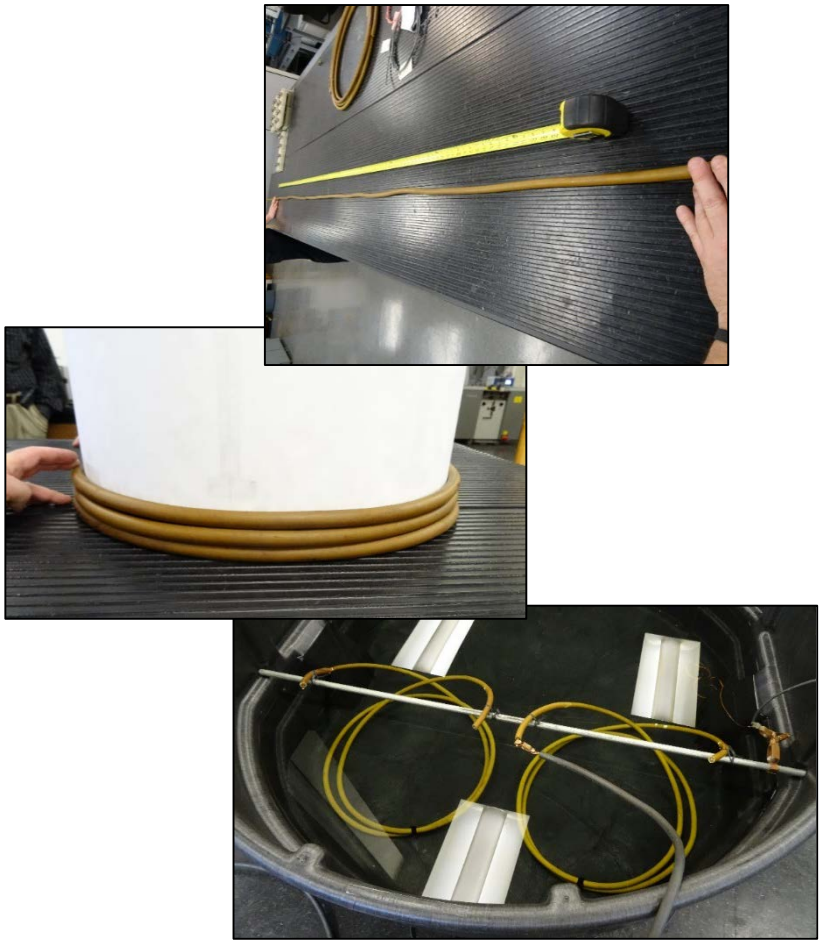


IEEE 383 (EQ) Qualification

- ***Post DBE final acceptance testing:***

- *Samples maintained voltage and current through-out the simulation*
- *IR measurements were performed*
- *Following DBE simulation:*
  - *samples were straightened*
  - *… bent around 40x mandrel*
  - *… submerged for 1 hour*
  - *… voltage withstand tested submerged at 80 VAC/mil*



IEEE 383 (EQ) Qualification

- ***Anomalies:***

- *3 due to DBE test chamber falling below the required profile*
- *1 due to a test sample connection not maintaining voltage during post DBE final acceptance test.*
- *1 due to typographical error in qualification test plan*

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Thank You!

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