Design and Testing of Commercial vs Nuclear Qualified Cable

Jim Fitzgerald
The Okonite Company
COLLEAGUES

John Cancelosi

Carl Zuidema

ICC Fall 2006
Subcommittee D
Jacket
Integrally color coded insulation
Jacket
CHARACTERISTICS

COMMERCIAL

• WET ELECTRICALS
• MECHANICALS
• PRODUCTION TESTING

NUCLEAR

40 YEAR LIFE ANALYSIS
• THERMAL AGING
• RADIATION AGING
• WET ELECTRICALS
• MECHANICALS
• PRODUCTION TESTING
COMMERCIAL LOW VOLTAGE POWER and CONTROL CABLES

INDUSTRY STANDARDS

• NATIONAL ELECTRICAL CODE
• UNDERWRITERS LABORATORY
• ICEA
• AEIC
NATIONAL ELECTRICAL CODE

- THHN/THWN________PVC/NYLON
- XHHW________XLPE
- RHH/RHW________EPR
|                | RHH        | 90°C  | Dry and damp locations | 14-10 | 1.14 | 45  | Moisture-resistant, flame-retardant, nonmetallic covering
|                |            | 194°F |                          | 8-2   | 1.52 | 60  |  
|                |            |       |                          | 1-4/0 | 2.03 | 80  |  
|                |            |       |                          | 213-500 | 2.41 | 95  |  
|                |            |       |                          | 501-1000 | 2.79 | 110 |  
|                |            |       |                          | 1001-2000 | 3.18 | 125 |  
| Moisture-      | RHW        | 75°C  | Dry and wet locations   | Flame-retardant, moisture-resistant thermoset | 14-10 | 1.14 | 45  | Moisture-resistant, flame-retardant, nonmetallic covering
| resistant       | RHW-2      | 167°F |                          | 8-2   | 1.52 | 60  |  
| thermoset       |            |       |                          | 1-4/0 | 2.03 | 80  |  
|                |            |       |                          | 213-500 | 2.41 | 95  |  
|                |            |       |                          | 501-1000 | 2.79 | 110 |  
|                |            |       |                          | 1001-2000 | 3.18 | 125 |  
| Silicone        | SA         | 90°C  | Dry and damp locations  | Silicone rubber | 14-10 | 1.14 | 45  | Glass or other suitable braid material
|                |            | 194°F |                          | 8-2   | 1.52 | 60  |  
|                |            |       |                          | 1-4/0 | 2.03 | 80  |  
|                |            |       |                          | 213-500 | 2.41 | 95  |  
|                |            |       |                          | 501-1000 | 2.79 | 110 |  
|                |            |       |                          | 1001-2000 | 3.18 | 125 |  
|                |            | 200°C | For special application  | Silicone rubber | 14-10 | 1.14 | 45  | Glass or other suitable braid material
|                |            | 392°F |                          | 8-2   | 1.52 | 60  |  
|                |            |       |                          | 1-4/0 | 2.03 | 80  |  
|                |            |       |                          | 213-500 | 2.41 | 95  |  
|                |            |       |                          | 501-1000 | 2.79 | 110 |  
|                |            |       |                          | 1001-2000 | 3.18 | 125 |  

1. moisture-resistant thermoset
2. For special application
3. nonmetallic covering
<table>
<thead>
<tr>
<th>Moisture-resistant thermostat</th>
<th>XHHW²</th>
<th>90°C</th>
<th>194°F</th>
<th>Dry and damp locations</th>
<th>Flame-retardant, moisture-resistant thermostat</th>
<th>1001–2000</th>
<th>2.41</th>
<th>95</th>
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<tr>
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<td>75°C</td>
<td>167°F</td>
<td>Wet locations</td>
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<td>XHHW-2</td>
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<tr>
<td>XHHW-2</td>
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<td></td>
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</table>

None
(C) Type NMS. The overall covering shall be flame retardant and moisture resistant. The sheath shall be applied so as to separate the power conductors from the communication conductors.

ARTICLE 336
Power and Control Tray Cable: Type TC

I. General

336.1 Scope. This article covers the use, installation, and construction specifications for power and control tray cable, Type TC.

336.2 Definition.

Power and Control Tray Cable, Type TC. A factory assembly of two or more insulated conductors, with or without associated bare or covered grounding conductors, under a nonmetallic jacket.

II. Installation

336.10 Uses Permitted. Type TC cable shall be permitted to be used as follows:

1. For power, lighting, control, and signal circuits.
2. In cable trays.
3. In raceways.
4. In outdoor locations supported by a messenger wire.
5. For Class 1 circuits as permitted in Parts II and III of Article 725.
6. For non-power-limited fire alarm circuits if conductors comply with the requirements of 760-49.
7. In industrial establishments where the conditions of maintenance and supervision ensure that only qualified persons service the installation, and where the cable is continuously supported and protected against physical damage using mechanical protection, such as struts, angles, or channels, Type TC tray cable that complies with the harsh and impact requirements of Type MC cable and is identified for such use with the marking Type TC-ER shall be permitted between a cable tray and the utilization equipment or device. The cable shall be secured at intervals not exceeding 1.8 m (6 ft). Equipment grounding for the utilization equipment shall be provided by an equipment grounding conductor within the cable. In cables containing conductors sized 6 AWG or smaller, the equipment grounding conductor shall be provided within the cable or, at the time of installation, one or more insulated conductors shall be permanently identified as an equipment grounding conductor in accordance with 250.110(B).

Exception: Where not subject to physical damage, Type TC-ER shall be permitted to transition between cable trays and between cable trays and utilization equipment or devices for a distance not to exceed 1.8 m (6 ft) without continuous support. The cable shall be mechanically supported at exit points of the cable tray, and in a space 0.6 m (2 ft) without support. The cable shall be supported by the manufacturer's recommended method until it is mechanically supported where exiting the cable tray to ensure that the minimum bending radius is not exceeded.

8. Where installed in wet locations, Type TC cable shall also be resistant to moisture and corrosive agents.

FPN: See 310.10 for temperature limitation of conductors.

336.12 Uses Not Permitted. Type TC tray cable shall not be installed or used as follows:

1. Installed where it will be exposed to physical damage
2. Installed outside a raceway or cable tray system, except as permitted in 336.10(7)
3. Used where exposed to direct rays of the sun, unless identified as sunlight resistant
4. Direct buried, unless identified for such use

336.24 Bending Radius. Bends in Type TC cable shall be made so as not to damage the cable. For Type TC cable without metal shielding, the minimum bending radius shall be as follows:

1. Four times the overall diameter for cables 25 mm (1 in.) or less in diameter
2. Five times the overall diameter for cables larger than 25 mm (1 in.) but not more than 50 mm (2 in.) in diameter
3. Six times the overall diameter for cables larger than 50 mm (2 in.) in diameter

Type TC cables with metallic shielding shall have a minimum bending radius of not less than 12 times the cable overall diameter.

336.80 Amperage. The ampacity of Type TC tray cable shall be determined in accordance with 392.11 for 14 AWG and larger conductors, in accordance with 402.5 for 18 AWG through 16 AWG conductors where installed in cable tray, and in accordance with 310.15 where installed in a raceway or as messenger-supported wiring.

III. Construction Specifications

336.100 Construction. A metallic sheath or armor as defined in 330.116 shall not be permitted either under or over the nonmetallic jacket. Metallic shield(s) shall be permitted over groups of conductors, under the outer jacket, or both.

336.104 Conductors. The insulated conductors of Type TC cables shall be in sizes 18 AWG in 1000 kcmil copper.
nicker, or nickel-coated copper, and sizes 12 AWG through
1000 kcmil aluminum or copper-clad aluminum. Insulated
conductors of sizes 14 AWG, and larger copper, nickel, or
nickel-coated copper, and sizes 12 AWG through 1000 kcmil
aluminum or copper-clad aluminum shall be one of the
types listed in Table 310.13(A) or Table 310.13(B) that is
suitable for branch circuit and feeder circuits or one that is
identified for such use.

(A) Fire Alarm Systems. Where used for fire alarm sys-
tems, conductors shall also be in accordance with 760.49.

(B) Thermocouple Circuits. Conductors in Type TC cable
used for thermocouple circuits in accordance with Part III
of Article 725 shall also be permitted to be any of the
materials used for thermocouple extension wire.

(C) Class 1 Circuit Conductors. Insulated conductors of
18 AWG and 16 AWG copper shall also be in accordance
with 725.49.

336.116 Jacket. The outer jacket shall be a flame-
retardant, nonmetallic material.

336.120 Marking. There shall be no voltage marking on a
Type TC cable employing thermocouple extension wire.

#ARTICLE 338
Service-Entrance Cable: Types SE and USE

I. General

338.1 Scope. This article covers the use, installation, and
construction specifications of service-entrance cable.

338.2 Definitions.

Service-Entrance Cable. A single conductor or multicon-
ductor assembly provided with or without an overall cov-
ering, primarily used for services, and of the following
types:

Type SE. Service-entrance cable having a flame-retardant,
moisture-resistant covering.

Type USE. Service-entrance cable, identified for under-
ground use, having a moisture-resistant covering, but not
required to have a flame-retardant covering.

II. Installation

338.10 Uses Permitted.

(A) Service-Entrance Conductors. Service-entrance
cable shall be permitted to be used as service-entrance
conductors and shall be installed in accordance with 230.6,
230.7, and Parts II, III, and IV of Article 230.

(B) Branch Circuits or Feeders.

(1) Grounded Conductor Insulated. Type SE service-
entrance cables shall be permitted in wiring systems where
all of the circuit conductors of the cable are of the thermost
set or thermoplastic type.

(2) Grounded Conductor Not Insulated. Type SE
service-entrance cable shall be permitted for use where the
insulated conductors are used for circuit wiring and the
 uninsulated conductor is used only for equipment ground-
ing purposes.

Exception: Uninsulated conductors shall be permitted as a
grounded conductor in accordance with 250.37 and
250.140 where the ungrounded conductor of the cable orinsulates in service equipment, and 225.30 through
225.40.

(3) Temperature Limitations. Type SE service-entrance
cable used to supply appliances shall not be subject to con-
ductor temperatures in excess of the temperature specified
for the type of insulation involved.

(4) Installation Methods for Branch Circuits and
Feeders.

(a) Interior Installations. In addition to the provisions
of this article, Type SE service-entrance cable used for in-
terior wiring shall comply with the installation require-
ments of Part II of Article 334.

FPN: See 310.10 for temperature limitation of conductors.

(b) Exterior Installations. In addition to the provisions
of this article, service-entrance cable used for feeders or
branch circuits, where installed as exterior wiring, shall be
installed in accordance with Part I of Article 225. The cable
shall be supported in accordance with 334.30. Type USE
cable installed as underground feeder and branch circuit
cable shall comply with Part II of Article 340.

* 338.12 Uses Not Permitted.

(A) Service-Entrance Cable. Service-entrance cable (SE)
shall not be used under the following conditions or in the
following locations:

(1) Where subject to physical damage unless protected in
accordance with 230.50(A)

(2) Underground with or without a raceway

(3) For exterior branch circuits and feeder wiring unless
the installation complies with the provisions of Part I of
Article 225 and is supported in accordance with 334.30
or is used as messenger-supported wiring as permitted
in Part II of Article 396
Jacket

Integrally color coded insulation
COMMERCIAL
XHHW-2 or RHH/RHW-2

• Dimensions
  Physics
  – 7d at 121°C
  – 4d in oil at 100°C
  – 720hr weatherometer

• Conductor Corrosion

• Cold Bend

• Deformation Resistance

• Crush Test

• Long Term IR at 90°C and 600v
  – Capacitance
  – SIC
  – Pf Stability

• Horizontal Flame test

• VW-1 Flame Test

• Dielectric Withstand
  – ACBD after Glancing Impact
  – ACBD after Limited Scoring
SINGLE PASS INSULATION
OR INSULATION + JACKET

CONDUCTOR
USUALLY COPPER
COMPRESSED OR COMPACT
SMALL WIRE TESTING
WATER TANK TESTING
Is There a Short Term Test That can Predict Long Term Performance
Compounding Objectives

- New Base Polymer
- 1 - Compound with XHHW Properties
- 2 - Flexible-Low Set Compound
- 3 – New Flame Test IEEE 1202
- 4 – Plant Life Extension to 60 years
Compound Development

• Survey Experiments
  – Broad Evaluation of Numerous Variables and Levels

• Mixture Designs
  – Valuable for Predicting Response within Design Space

• Factorial Designs
  – High Reliability Requires Numerous Trials

• Optimizations
  – For Fine Tuning – Can be of Various Designs
EPR-N Physical Properties

Tensile Properties

Stress @ 100%, psi

EPR-N

ICEA

Type II EPR

Tensile Strength, psi

EPR-N

ICEA

Type II EPR

Elongation, %

EPR-N

ICEA
Fluid Resistance, 100 Hour Immersions

- EPR-N
- EPR Type II
- XLPE XHHW

Bar chart showing % Swell for different materials and fluids at various temperatures.
EPR-N Accelerated Aging

- Acceleration methods:
  - 21 Days @ 150°
  - 14 Days @ 165°

- Graph showing:
  - Hardness
  - % Tensile Strength Ret.
  - % Elongation Ret.

- Comparison between Original and treated samples.
VW-1 Flame Test Performance

![Graph showing burn time after flame application for different applications and flags.]
EPR-N Electrical Properties

- SIR $\Omega$ – 1000ft  
  6910000
- Dielectric Const. 40V/mil  
  2.77
- Dielectric Const. 80 V/mil  
  2.77
- DF 40 V/mil  
  0.0020
- DF 80 V/mil  
  0.0020
EPR-N
Dissipation Factor after Water Immersion

Days Immersion

DF x 100
Unique IEEE 383 Requirements

- **Type Testing**
  - Simulate Significant Aging Mechanisms
  - Simulate Specific Service Conditions

- **Characterize Aging Performance**

- **Test After Characteristic Aging**
  - Thermal Aging
  - Radiation Aging
  - Aging Sequence?
EPR-N Oven Aging Performance
Arrhenius Treatment

![Graph showing the Arrhenius behavior of different materials at various temperatures.](attachment:image.png)
Analysis of Arrhenius Data

![Graph showing Arrhenius plots for different materials and temperatures.]
Accelerated Aging Conclusions

• From Past Experience
  – EPR II Aged 21 Days @ 150°C Simulates 40 Year Service

• Arrhenius Chart
  – EPR-N ~3 x Improvement over EPR II
  – EPR-N Aged 14 Days @ 165°C, (~3x EPRII) to Simulate 60 Years Service is Conservative
Unique IEEE 383 Requirements

- **Type Testing**
  - Simulate Significant Aging Mechanisms
  - Simulate Specific Service Conditions

- **Characterize Aging Performance**

- **Test After Characteristic Aging**
  - Thermal Aging ✔
  - Radiation Aging
  - Aging Sequence?
# Sequential Aging, Design Matrix

## Step 1, Thermal Aging

<table>
<thead>
<tr>
<th>Thermal Aging Test</th>
<th>None</th>
<th>21 days @ 150°C</th>
<th>14 days @ 150°C</th>
<th>14 days @ 150°C</th>
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</table>

## Step 2, Aging sequence

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<th>Thermal Aging</th>
<th>None</th>
<th>21 days @ 150°C</th>
<th>14 days @ 150°C</th>
<th>21 days @ 150°C</th>
<th>14 days @ 150°C</th>
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</thead>
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<td>Radiation Aging</td>
<td>50 M Rads</td>
<td>50 M Rads</td>
<td>50 M Rads</td>
<td>50 M Rads</td>
<td>50 M Rads</td>
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<tr>
<td>Aging Sequence</td>
<td>N/A</td>
<td>Thermal-1 Radiation</td>
<td>Radiation-1 Thermal</td>
<td>Radiation-1 Thermal</td>
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<tr>
<td>Test</td>
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<td>X</td>
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</table>

## Step 3, Final Radiation

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<tr>
<th>Test</th>
<th>150 M Rads</th>
<th>150 M Rads</th>
<th>150 M Rads</th>
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<tbody>
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<td>X</td>
<td>X</td>
<td>X</td>
<td>X</td>
<td>X</td>
</tr>
</tbody>
</table>
EPR-N, Effect of Aging Sequence

- No Oven Aging
- 21 Day 150° Oven First
- 14 Day 165° Oven First
- 21 Day 150° Rad First
- 14 Day 165° Rad First

% Retention

- No radiation
- 50 MRads
- + 150 MRads
Summary

• New Compound, Very Superior Properties:
  – Dielectric
  – Flame Resistance
  – Aging
  – Physicals
  – Lab & Prototype Tests Gives High Confidence
  – UL Ratings: XHHW-2, RHW-2
Overview

• History of Class 1E Testing
  – DBE LOCA Test
  – Vertical Tray Flame Test
• Qualification Test Program
  – Specimen Selection
  – Aging
  – LOCA & HELB
  – Flame Tests
Early Cable Qualification Tests (Pre IEEE 383-1974)

- Early 1960’s - Effects of radiation
- ’60s – early ’70s
  - Thermal aging to ICEA requirements
    - 1 week @ 121 C
  - Radiation: 100 Mrads gamma
  - Mild LOCA profile
Early Cable Qualification Tests
Pre IEEE 383-1974

1. 35 sec RISE TIME
   - 104 psig/340°F

2. 2 min RISE TIME
   - 75 psig/320°F
   - 4 hr, 27 min

3. 3 hr, 38 min
   - 25 psig/272°F

4. 15 psig/256°F
   - 24 hr, 53 min

5. -2 psig
   - 55 min
   - -3 hr, 22 min
   - 6 hr
IEEE Standards

• IEEE 323-1974 – Std for Qualifying Class 1E Equipment for Nuclear Power Generating Stations

• IEEE 383-1974 – Std for Type Test of Class 1E Electric Cables, Field Splices and Connections for Nuclear Power Generating Stations
IEEE 383-1974

Qualification (Type) Tests

• Tests to Qualify for Normal Operation
• Tests to Qualify for Design Basis Event
  • LOCA
  • HELB / MSLB
• Tests to Qualify for Design Basis Event – Fire
IEEE 383-1974

Tests to Qualify for Normal Operation

- Made, tested and qualified to Industry Standards ICEA - AEIC - NEMA
- Long Term Physical Aging Properties
- Thermal & Radiation Exposure
  1) Aging to “End of Life” condition
  2) Radiation Exposure (50 MRads)
  3) Mechanical & Electrical Withstand
IEEE 383-1974
Tests to Qualify for DBE - LOCA

- Thermal & Radiation Exposure
  - Aging to “End of Life” condition
  - Radiation Exposure
    - Normal Life Dosage (50 MRads)
    - One accident dose (150 MRads)
- Loss of Coolant Accident simulation
  - Temperature, Pressure & Chem spray
- Post LOCA Simulation test
  - Mechanical & Electrical Withstand
Cable Qualification Test Profile for Life & LOCA Conditions

**LEGEND:** ▲ INSULATION RESISTANCE MEASUREMENT; ○ AC WITHSTAND TEST, 80V/MIL.

346°F/113 psig/100% RH within 3 to 5 min.

335°F/95 psig/100% RH

315°F/69 psig/100% RH

265°F/28 psig/100% RH

280°F/70 psig(min.) within 10 sec.

212°F/0 psig/100% RH

IR TEST AVERAGE ONCE PER WEEK

TEMPERATURE/PRESSURE PROFILE FOR SIMULATION OF LOSS OF COOLANT ACCIDENT

4 DAYS

26 DAYS

100 DAYS POST LOCA SIMULATION TEST
IEEE 383-1974

Tests to Qualify for DBE - Flame

- Vertical wire flame test
- Vertical tray flame test
IEEE 383 VTFT Procedure

• 8 ft ladder type tray
• 12” wide
• Gas burner placed 3” behind tray and 2 ft off the floor
• Theoretical Heat Input 70,000 BTU/hr
• Specimens fill at least center 6” of tray width
• Specimens spaced ½ OD apart
• Flame Exposure 20 minutes
• Allow cable to burn until self-extinguished
IEEE 383 VTFT Requirement

Cable cannot propagate to the top of the tray. (<6 feet damage)
1974 to 2003

• Additional issues, such as
  • Synergistic effects
  • Factory Splices
  • Fire Resistance
  • Multiconductor qualification
IEEE 383-2003

- Not intended to require re-qualification
- Type Testing still preferred
- Emphasizes other methods of qualification
  - Past operating experience
  - Ongoing qualification
  - Qualification by analysis
IEEE 383-2003 - Changes

- Vertical Tray Flame Test procedure removed and refers to IEEE 1202-1991
- Synergistic effects
- Factory splice qualification
- Multiconductor qualification
- Class 1E qualification for normal service must be demonstrated separately from DBE qualification
1202 vs. 383-1974 VTFT
Comparison

• Both 70k BTU/hr
• IEEE 1202
  ▪ Increased Tray loading
  ▪ Decreased spacing (> 1” cables)
  ▪ Bundled small diameter cables (< 0.5”)
  ▪ Less damage allowed (4.9 ft vs 6 ft)
  ▪ Burner angle (20°)
  ▪ Test Enclosure
  ▪ Forced Ventilation
Tray Loading and Spacing

- 383: 1.2” diameter, 4 cables, 0.6” spacing
- 1202: 1.2” diameter, 5 cables, 0.5” spacing

- ~8.5” to 11”
Tray Loading and Spacing

383

12"

0.3” diameter
14 cables

~9” to 11”

1202

6"

0.3” diameter
10 groups of 3
30 cables
Tray Loading
OD = 0.97"

383-74
5 cables

1202
7 cables
Cable OD
0.31”

1202
30 cables
fill = 9.7”
1202 Test Enclosure

Sketch from IEEE 1202-2006

Dimensions:
- 3353 ± 25 mm (132 ± 1 in)
- 1295 ± 25 mm (51 ± 1 in)
- 914 ± 6 mm (36 ± 1/4 in)
- 559 ± 6 mm (22 ± 1/4 in)
- 2438 ± 25 mm (96 ± 1 in)
- 2438 ± 25 mm (96 ± 1 in) inside
- 1143 ± 25 mm (45 ± 1 in)
Class 1E Qualification Program for a Instrumentation, Control & LV Power EPR Insulation

1. Industry Standard Tests
2. LOCA Test
3. Normal Operation Test
4. HELB Test
5. Vertical Tray Flame Test
Class 1E
Qualification Program

1. Industry Standard tests

ICEA & UL requirements

1/C: Listed as RHW-2, XHHW-2, X110

VW-1 & Oil Resistant

M/C: Listed as Type TC
2. LOCA Test Sample selection:

**Single Conductors:**

- #14 AWG (7x) 0.030” EPR-N
- #16 AWG (7x) 0.025” EPR-N

Six colors
Class 1E
Qualification Program

2. LOCA Test Sample selection: M/C

- 3/C #14 AWG 0.030” EPR-N, cabled, binder tape, TS-CPE jacket
- 3/C #14 AWG 0.030” EPR-N, cabled, binder tape, CSPE jacket
- 1 Pr #16 AWG 0.025” EPR-N, #18 AWG drain wire, Cu laminate tape, XLPO jacket.
Class 1E
Qualification Program

2. LOCA Test

Non aged specimens

Aged specimens

Radiation – 50 Mrads (gamma)

Thermal - 3 weeks @ 150 C

- 2 weeks @ 165 C
Class 1E
Qualification Program

2. LOCA Test

Accident radiation dose - 150 Mrads
Current & voltage loaded
Temp-Pressure-Chem Spray profile
Charging current monitored
Periodic IR measurements
Margins

- Double peak
- Voltage: $\varnothing - \varnothing$ Rated voltage applied $\varnothing - \text{grd}$
- Radiation
  - Normal aging: 50 Mrads - gamma
  - Accident: 150 Mrads - gamma
- Thermal Aging: 60 years
Class 1E Qualification Program for a Instrumentation, Control & LV Power EPR Insulation

**LOCA Test EPR-N Specimens**
- 42 1/C wires
- Six 3/C cables
- Three 1 Pr cables
LOCA EPR-N Test Specimens

- 42 1/C wires
- Six 3/C cables
- Three 1 Pair cables
Class 1E
Qualification Program

3. LOCA Test Results

All samples:

• Maintained voltage & current
• Withstood Post-LOCA Simulation Test
  • Straighten & Recoil (40 x OD)
  • 80 v/mil ac withstand
3. Post LOCA Test Results

Post LOCA Long Term Moisture Resistance @90C

#14 AWG 0.030" EPR-N

IR values are avg of 2 specimens
Class 1E Qualification Program

3. Normal Operation Test

Sample selection: Single Conductors

#16 AWG (7x) 0.025” EPR-N
six specimens
Class 1E
Qualification Program

3. Normal Operation Test

Aging

Radiation – 50 Mrads (gamma)

Thermal – 3 weeks @ 150 C
- 2 weeks @ 165 C
Class 1E
Qualification Program

3. Normal Operation Test

Mechanical & Voltage Withstand

Straighten

20 x OD bend

80 volt/mil ac withstand test
4. HELB Test

Specimens - #16 AWG 0.025” EPR-N
Non-aged & aged specimens
Temp – Press – Chem spray profile
Current & voltage loaded
Charging current monitored
Periodic IR measurements
High Energy Line Break Test Temperature / Time Profile

[Graph showing the HELB Temperature Profile with temperature on the vertical axis (F) and time on the horizontal axis (Seconds)]
HELB EPR-N Test Specimens
Class 1E
Qualification Program

4. HELB Test Test Results

All samples:

- Maintained rated voltage & current
- Withstood Post-LOCA Simulation Test
  - Straighten & Recoil (40 x OD)
  - 80 v/mil ac withstand
Class 1E
Qualification Program

5. IEEE 1202 VTFT Test Results

600 V Constructions:

- 3/C #14 AWG 0.030” EPR-N, cabled, binder tape, TS-CPE jacket - Passed
- 3/C #14 AWG 0.030” EPR-N, cabled, binder tape, CSPE jacket - Passed
- 1 Pr #16 AWG 0.025” EPR-N, #18 AWG drain wire, Cu laminate tape, XLPO jacket - Passed
5. IEEE 1202 VTFT Test Results

2 kV Constructions:

- 3/C #14 AWG 0.045” EPR-N, cabled, binder tape, TS-CPE jacket - Passed
- 3/C #14 AWG 0.045” EPR-N, cabled, binder tape, CSPE jacket - Passed
- 1/C #6 AWG 0.060” EPR-N - Passed
Summary

• IEEE 383-2003
  – Doesn’t require re-qualification
  – Allows other types of qualification
  – Addressed ’74 to ’03 issues

• Qualification Test Program
  – EPR-N qualified to 383-74 & 383-03
    Normal, LOCA, HELB & 1202
  – Qualification Report documents results
Previously Qualified Materials

- Type I EPR/CSM – LV
- Type II EPR – LV
- Type II FR EPR – LV
- Type II EPR – MV
- FR XLPE – LV
- PVMQ – Silicone Rubber
- ETFE – Ethylene Tetrafluoroethylene
Why Requalify

• Obsolete Materials
  – Base Polymers – Several EPRs
  – Compounds – Silicone Rubber

• New Standard – IEEE 383-2003
  – Only Applies to New Construction

• Offer Materials with Enhanced Properties
  – Improve Flame Resistance
  – Improve Physical Properties
  – Improve Aging