Class 1E Cable Qualification to the Latest IEEE Standards

IEEE NPEC SC-2 Meeting

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Knoxville, TN

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The Okonite Company
Ramsey, NJ

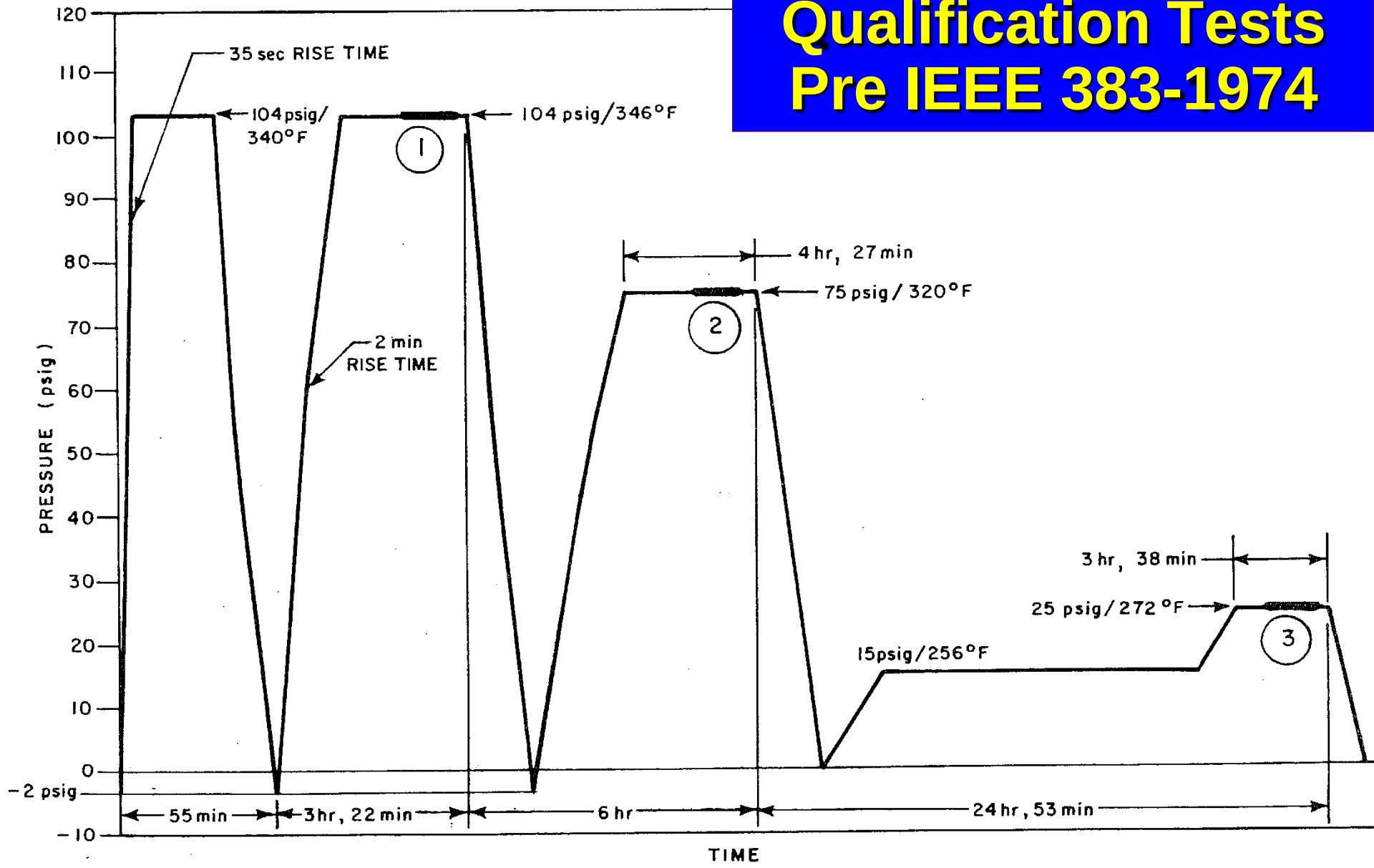
Overview

- History of Class 1E Testing
- IEEE 383-1974 vs. IEEE 383-2003
  - 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



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

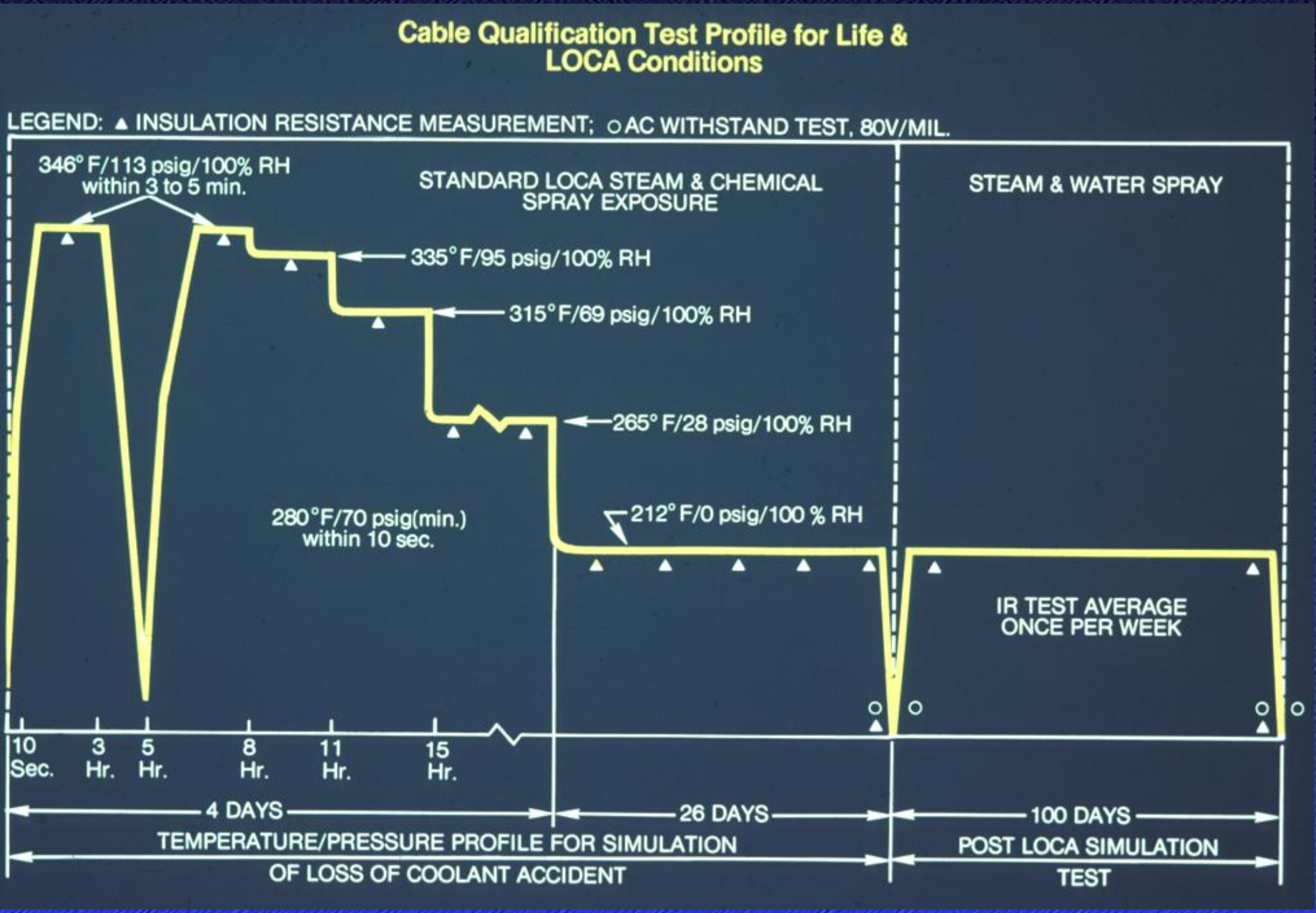
1) Aging to "End of Life" condition
2) Radiation Exposure (50 MRads)
3) Mechanical & Electrical Withstand

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



IEEE 383-1974

Tests to Qualify for DBE - Flame

- Vertical wire flame test
- Vertical tray flame test

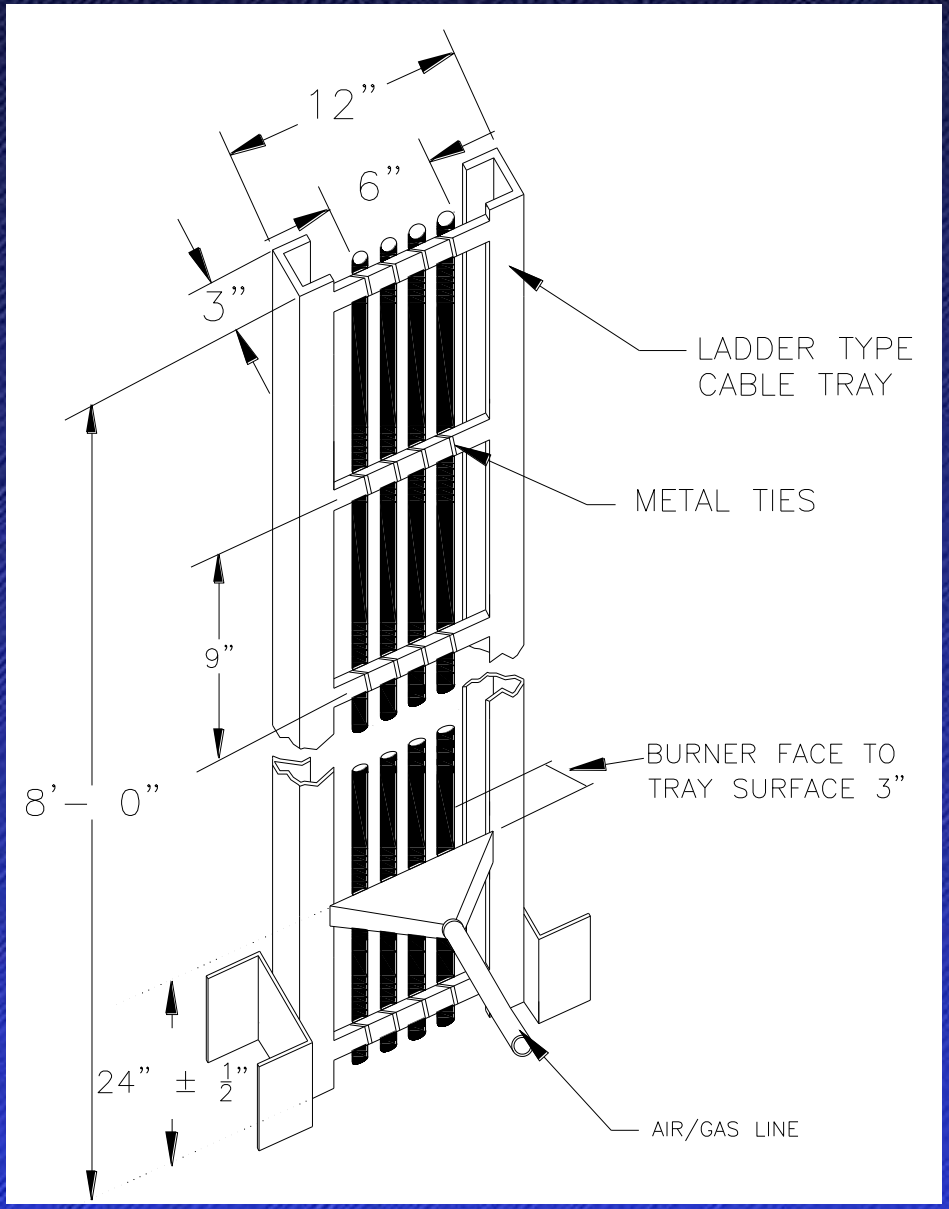
Vertical Wire Flame

Test Procedure

- 22” specimen
- Flame impingement 10” below paper flag
- Flame temp ~ 1530F
- 15 sec flame application
- 15 sec off period
- 5 cycles
- Pass: < 25% flag damage

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 damage cannot reach the top of the specimens.

(< 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

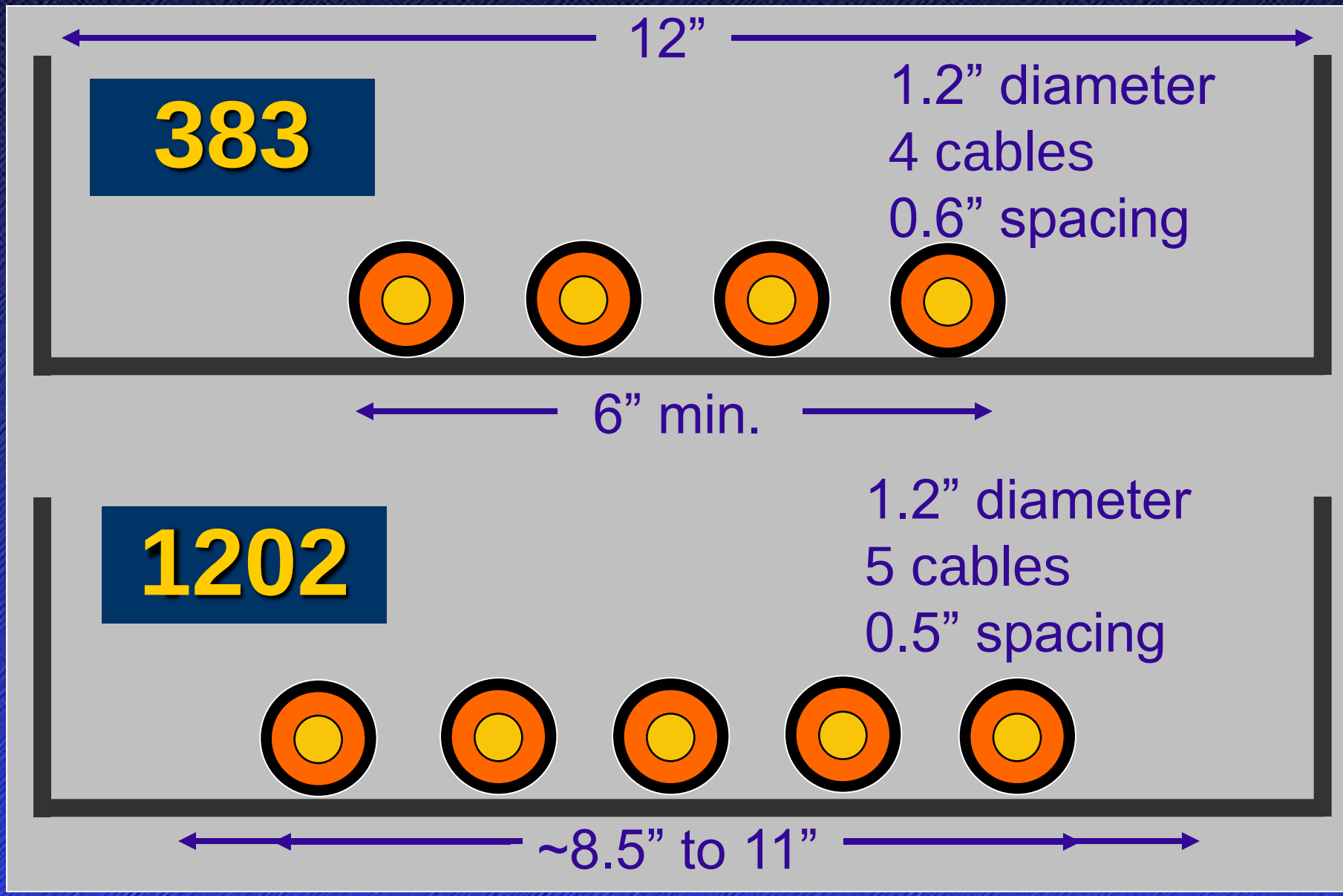
IEEE 383-2003 - Changes

- 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

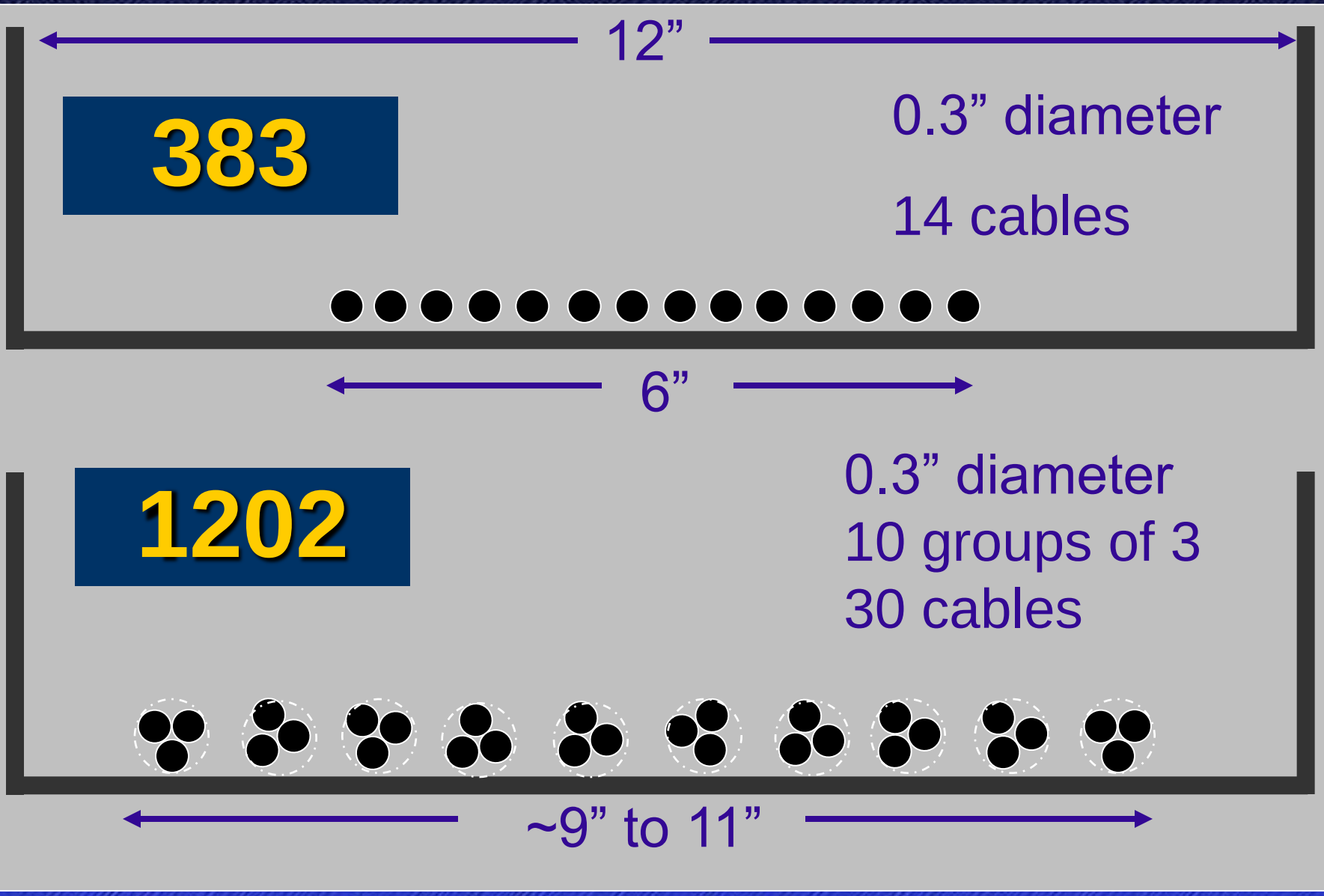
1202 vs. 383-1974 VTFT Comparison

- 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



Tray Loading and Spacing



Tray Loading
OD = 0.97”

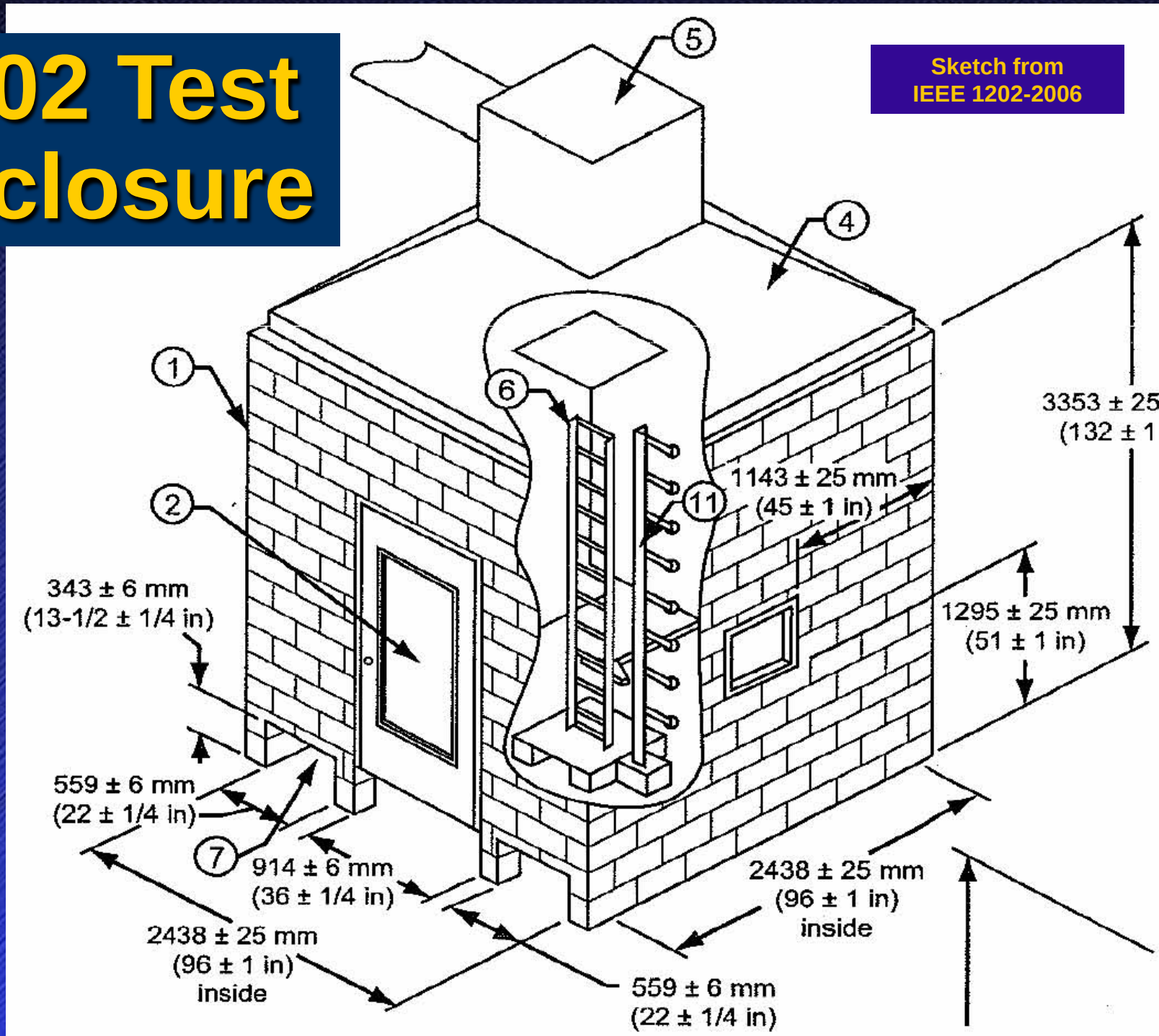
383-74
5 cables

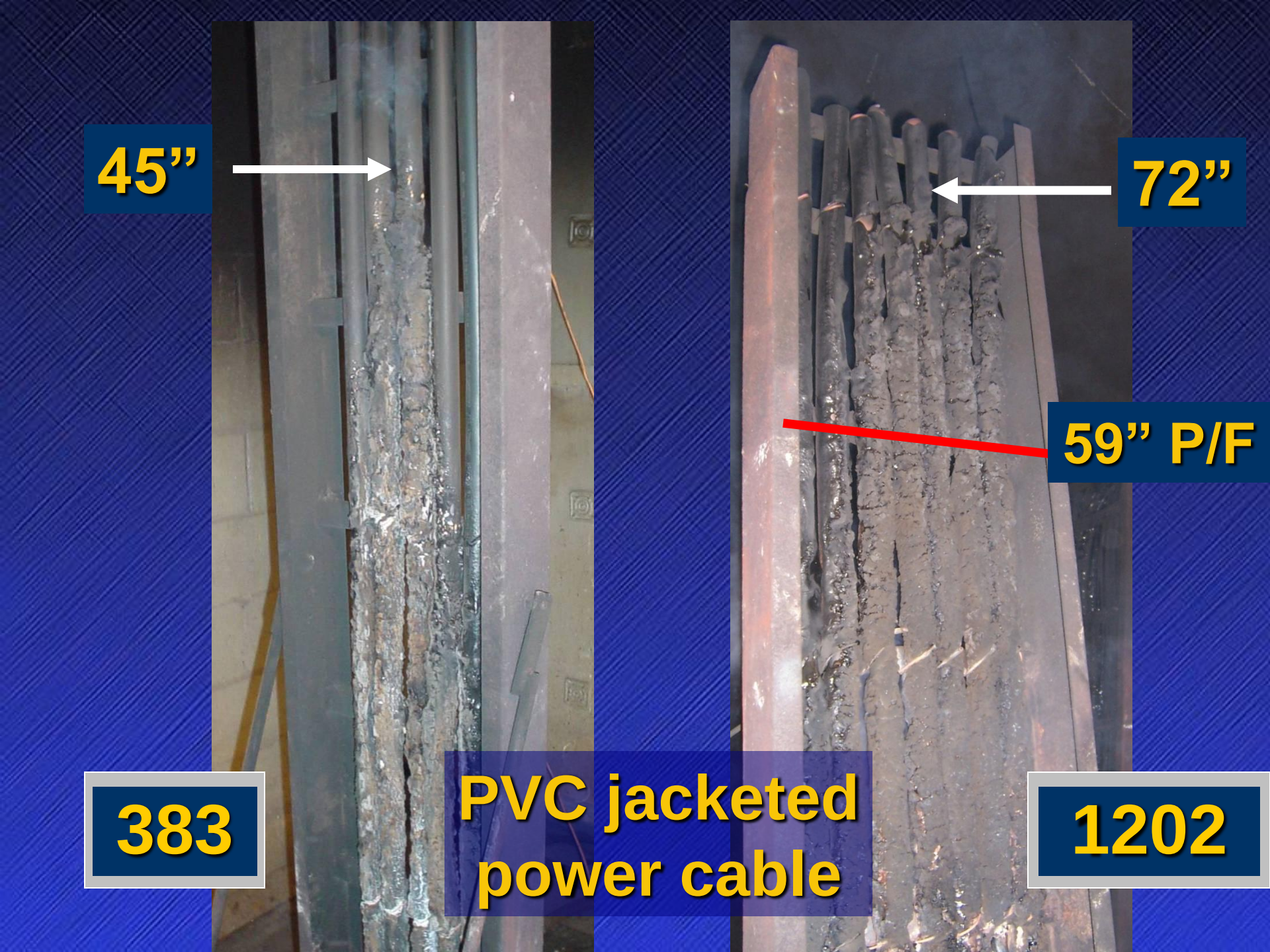
1202
7 cables

Cable OD
0.31”

1202
30 cables
fill = 9.7”

1202 Test Enclosure




45”
72”
59” P/F
383
PVC jacketed
power cable
1202

Class 1E Qualification Program

for a Instrumentation, Control, LV Power & Medium Voltage EPR Insulations

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

Class 1E Qualification Program EPR-N

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

Class 1E Qualification Program MV EPR

1. Industry Standard tests

ICEA S-93-639 & S-94-649

UL 1072

Class 1E Qualification Program EPR-N Insulation

2. LOCA Test Sample selection:

Single Conductors:

#14 AWG (7x) Cu, 0.030” EPR-N

#16 AWG (7x) Cu, 0.025” EPR-N

Six colors

Class 1E Qualification Program

EPR-N Insulation

2. LOCA Test Sample selection: M/C

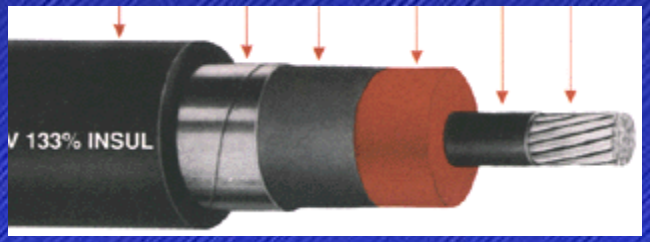
3/C #14 AWG Cu, 0.030” EPR-N, cabled, binder tape, TS-CPE jacket
3/C #14 AWG Cu, 0.030” EPR-N, cabled, binder tape, CSPE jacket
1 Pr #16 AWG Cu, 0.025” EPR-N, #18AWG drain wire, Cu laminate tape, XLPO jacket

Class 1E Qualification Program

MV EPR Insulation

2. LOCA Test Sample selection: 1/C

#6 AWG Cu, SC-EPR, 0.115” MV EPR, SC-EPR, 0.005” Cu tape, cable tapes, TS-CPE jacket



Class 1E Qualification Program

2. LOCA Test

Non aged specimens

Aged specimens

Radiation – 50 Mrads (gamma)

Thermal - 3 weeks @ 150 C

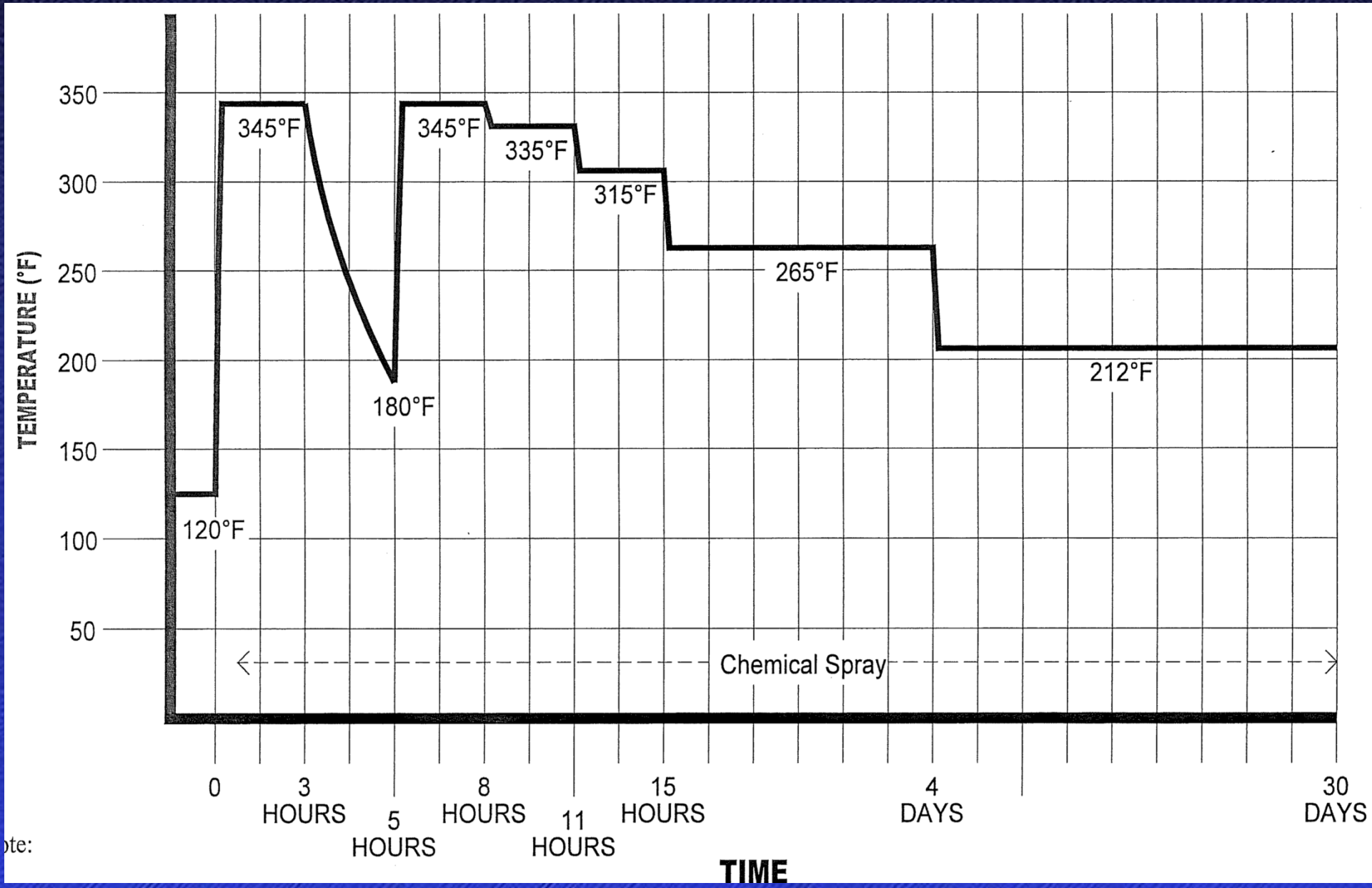
- 2 weeks @ 165 C

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

LOCA Profile



ote:

Margins

- Double peak
- Voltage: ø-ø Rated voltage applied ø-grd
- Radiation
  - Normal aging: 50 Mrads - gamma
  - Accident: 150 Mrads - gamma
- Thermal Aging: 60 years

Class 1E Qualification Program

LOCA Test EPR-N Specimens

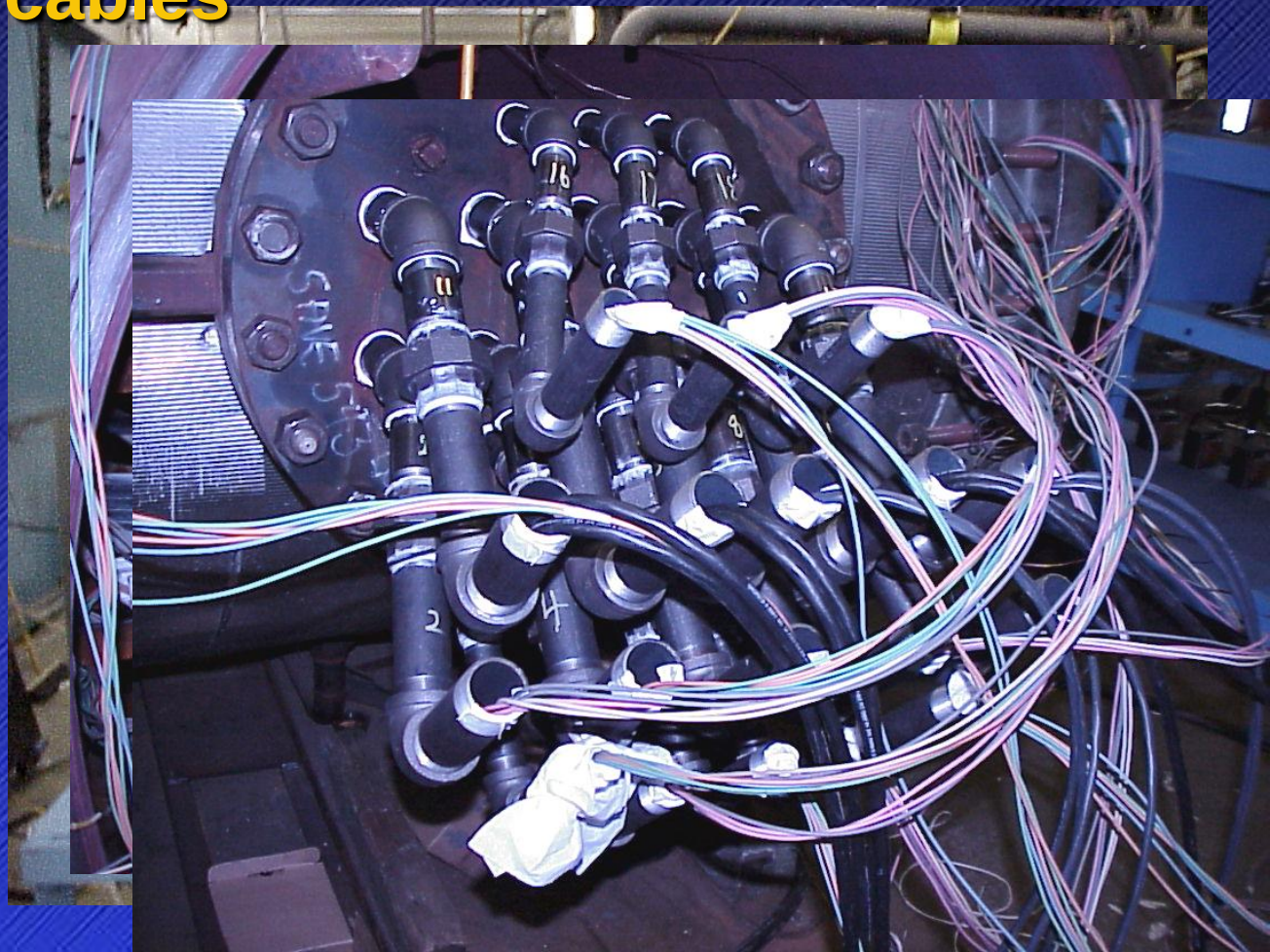
- 42 1/C wires
- Six 3/C cables
- Three 1 Pr cables

LOCA Test MV EPR Specimens

- Three 1/C cables

LOCA Test Specimens

- 42 1/C wires
- Six 3/C cables
- Three 1 Pr cables
- Three 1/C cables



Class 1E Qualification Program

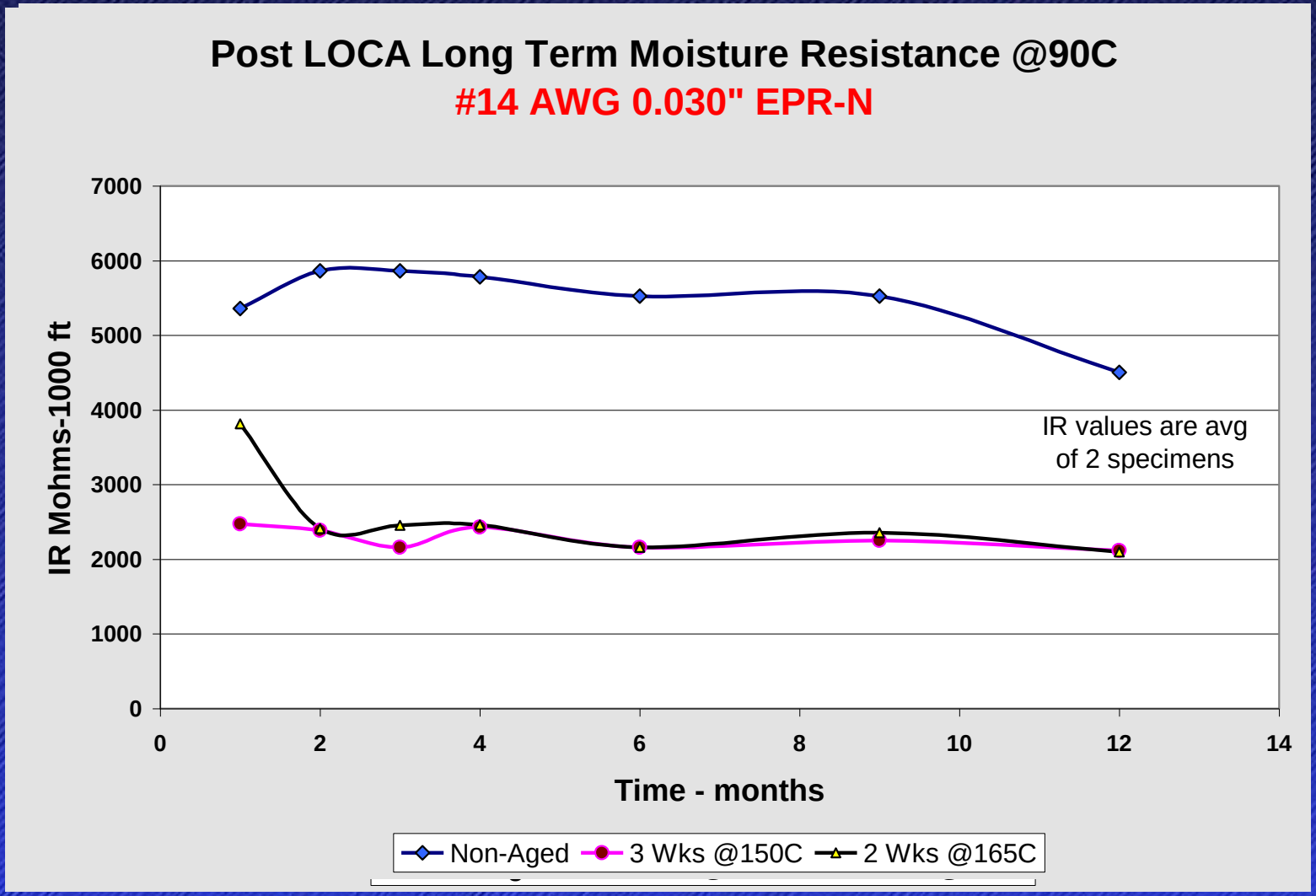
3. LOCA Test Results

All samples:

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

Class 1E - Qualification Program

3. Post LOCA Test Results



Class 1E - Qualification Program

3. Post LOCA Test Results

Instrumentation jacket integrity

Specimen	Jacket Resistance - Megohms @500 Vdc after 1 minute	Charging Current mA @ 600Vac after 1 minute
Unaged	**3.5 E3**	**< 1 mA**
3 weeks @ 150C	**1.5 E6**	**< 1 mA**
2 weeks @ 165C	**4.3 E1**	**< 1 mA**

Class 1E Qualification Program

3. Normal Operation Test

Sample selection: **Single Conductors**

#16 AWG (7x) 0.025” EPR-N
six specimens

#6 AWG Cu, SC-EPR, 0.115” MV EPR, SC-EPR, 0.005” Cu tape, cable tapes, TS-CPE jacket
three 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

Class 1E Qualification Program

4. HELB Test

Specimens –

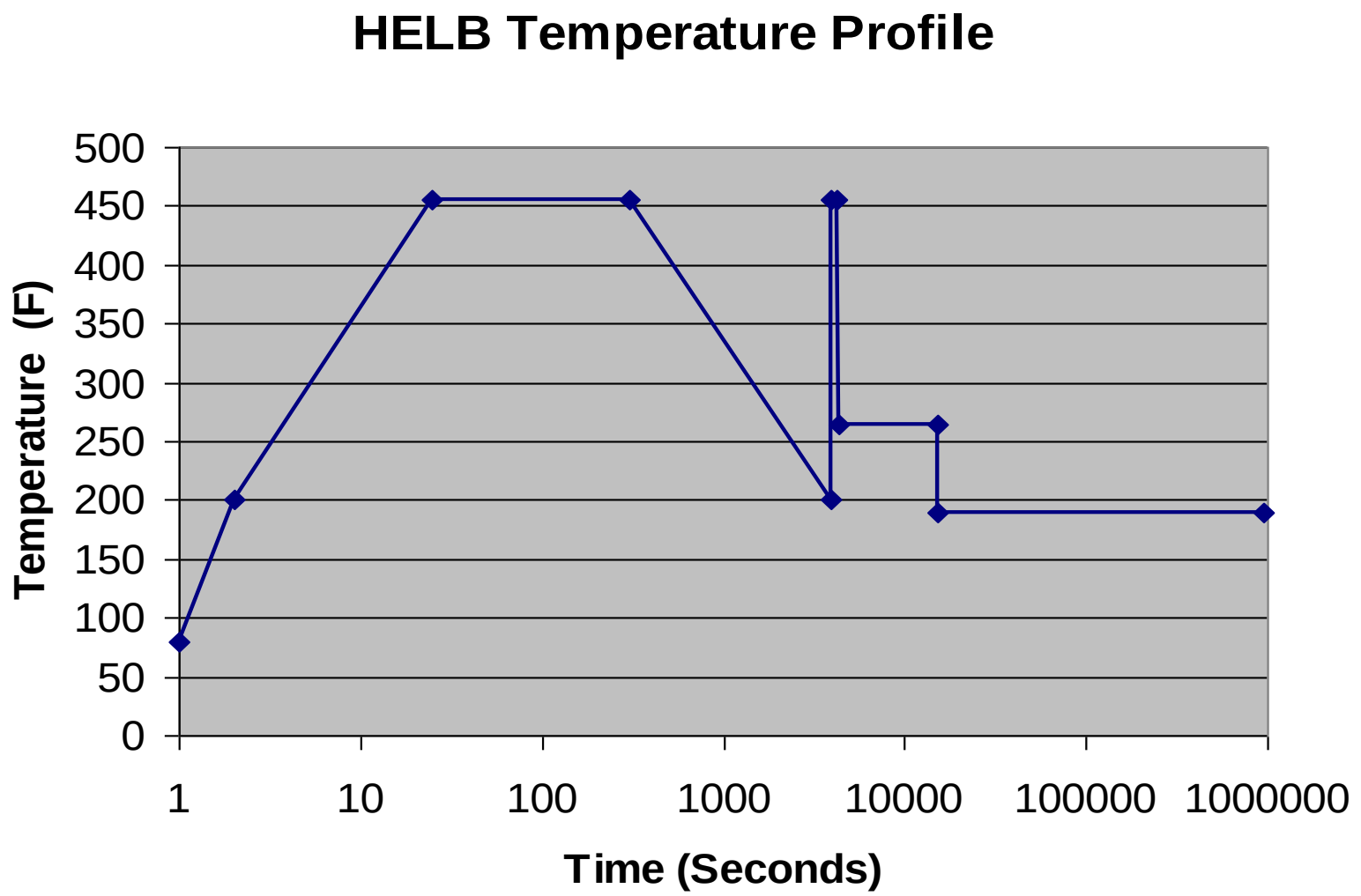
- #16 AWG Cu, 0.025” EPR-N
- #6 AWG Cu, SC-EPR, 0.115” MV EPR, SC-EPR, 0.005” Cu tape, cable tapes, TS-CPE jacket

Class 1E Qualification Program

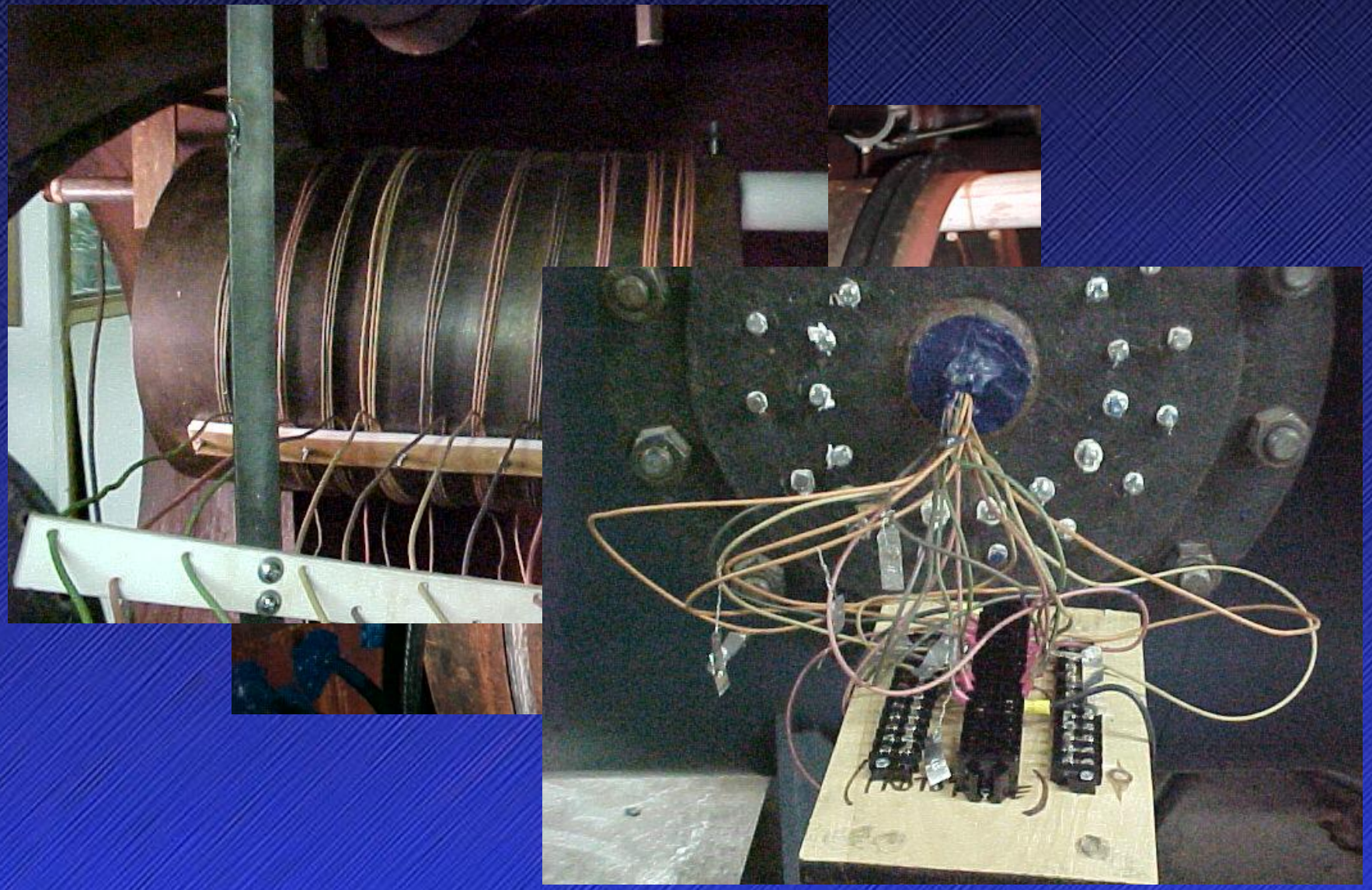
4. HELB Test

- 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



HELB EPR-N Test Specimens



Class 1E Qualification Program

4. HELB 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
- 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

5. IEEE 1202 VTFT Test Results

2 kV Constructions:

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

Class 1E Qualification Program

5. IEEE 1202 VTFT Test Results

5 kV Construction:

#2/0 AWG Cu, SC-EPR, 0.115” MV EPR, SC-EPR, 0.005” Cu tape, cable tapes, TS-CPE jacket

Qualification Reports

- **EPR-N**
  - Engineering Report # 526

  "Class 1E Qualification of Okonite FMR-N Insulated Cables For Nuclear Power Generation Stations"
- **MV EPR**
  - Engineering Report # 527

  "Class 1E Qualification of Okoguard Insulated Cables For Nuclear Power Generation Stations"

Summary

- IEEE 383-2003
  - Re-qualification not required
  - Allows other types of qualification
  - Addressed ’74 to ’03 issues
  - VTFT (1202) more severe
- Qualification Test Program
  - EPR-N & MV EPR insulations qualified to 383-74 & 383-03 for Normal, LOCA, HELB & IEEE 1202
  - 40 and 60 year accelerated aging

Any Questions?