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Aged Cable Coating Project Plan

Presented by:
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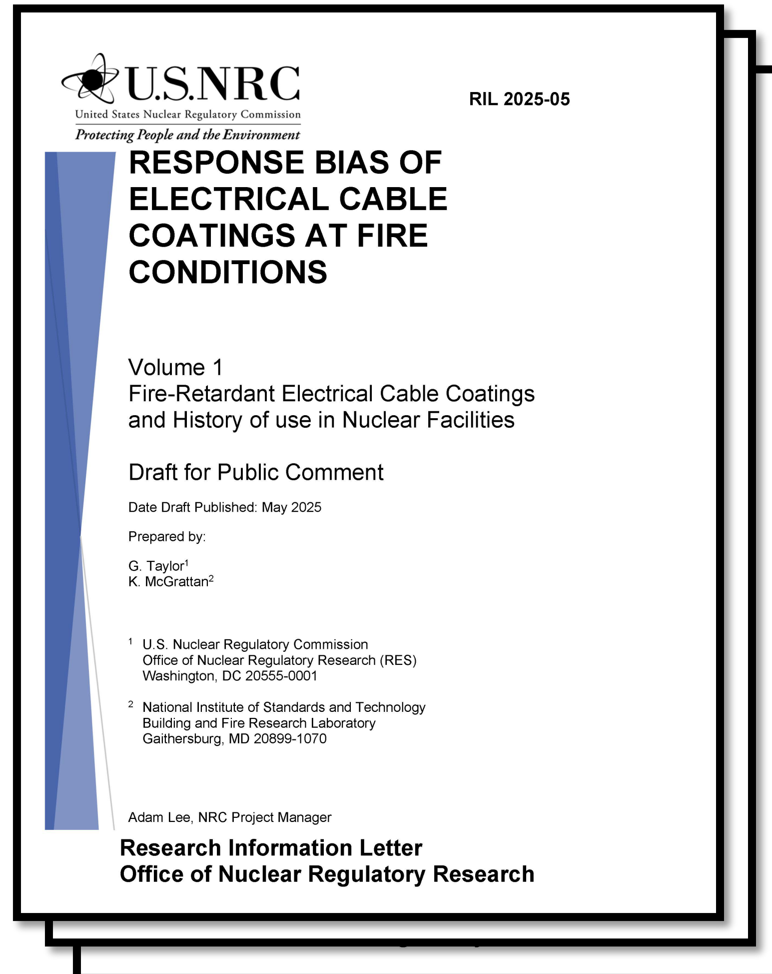
Project Overview

- Phase 1
  - Draft Research Information Letter (RIL) for stakeholder feedback
    - Volume 1 : Fire-Retardant Electrical Cable Coatings and History of use in Nuclear Facilities
    - Volume 2 : Fire Properties of Cables
    - Volume 3 : Cable Functionality
  - Final publication of RIL [1]
  - Draft Research Project Plan for Aged Cable Coatings
- Phase 2
  - Testing and Draft Aged Cable Coating RIL



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RIL 2025-05

RESPONSE BIAS OF ELECTRICAL CABLE COATINGS AT FIRE CONDITIONS

Volume 1
Fire-Retardant Electrical Cable Coatings and History of use in Nuclear Facilities

Draft for Public Comment

Date Draft Published: May 2025

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Research Information Letter
Office of Nuclear Regulatory Research

Project Overview

- Phase 3
  - Use unaged and aged data to develop/update fire PRA methodology with EPRI
  - NUREG/CR-6850 Appendix Q [2]
- Phase 4
  - Publish aged cable coating research in a RIL
  - Publish methodology update report to NUREG/CR-6850 Appendix Q

Purpose and Use of Results

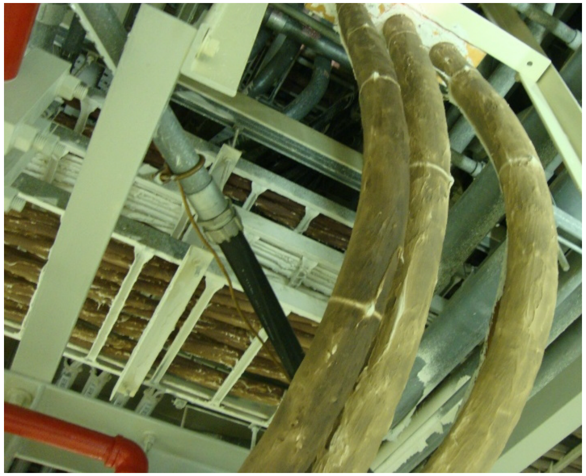
Understand the functional performance of aged cable coatings

- Electrical cables are critical for safety in nuclear facilities
- Fire-retardant coatings help prevent fire spread
- Limited research exists on aged coatings under fire conditions

Understand the fire protection aspects of aged cable coatings

- Inform how (aged) cable coatings may be credited in fire PRA
- Update NUREG/CR-6850 Appendix Q

Not environmental qualification (EQ) testing



Cable coatings showing change from their original white color.

Cables and Coatings

	Cable I	Cable II
Type	Thermoset (TS)*	Thermoplastic (TP)
Manufacturer	Marmon Industrial Energy & Infrastructure (formerly Rockbestos-Suprenant)	Global Cable and Wire
Part Name	Firewall® III Nuclear M1K1 Blk CSPE 600V 7C 12 AWG	#12-7C THHN-PVC Tray Cable
Insulation Material	XLPE	PVC
Jacket Material	CSPE	PVC
Number of Conductors	7	7
AWG	12	12
RIL-2025-05 Cable Reference Number	#803	-

*IEEE 1202 [3] and 383 [4] qualified

Cables and Coatings

	Cable Coating A	Cable Coating B	Cable Coating C	Cable Coating D
RIL-2025-05	Carboline Intumastic 285	Flamemastic 77	Viamsco 3i	FS15
Aged Cable Coating Experiments	TBD	Flamemastic 77	Charcoat	TBD
Comments	Carboline Intumastic 285 is no longer available. Currently looking for replacements or substitutes.		Charcoat was recommended as an adequate substitute for Viamsco 3i by the vendor.	FS15 is no longer in production. Currently looking for replacements or substitutes.

Thermally Aging Cables and Coatings

Accelerated Thermal Aging Using Arrhenius Model

$$\frac{t_\mathrm{s}}{t_\mathrm{a}} = e^{\left(\frac{\Phi}{k}\right)\left(\frac{1}{T_s} - \frac{1}{T_a}\right)} \qquad [5]$$

where:

- Φ activation energy (eV) (1 eV = 23.06 kcal/mole)
- k Boltzmann's constant (8.617×10^{-5} eV/K)
- t_a accelerated aging time
- t_S service time being simulated
- T_a aging temperature (K)
- T_S service temperature (K)

Assumptions

- Utilize an aging temperature (T_a) of 90 °C (363 K)
- Assume cables will predominantly experience a service temperature (T_S) of 36 °C (309 K) for most of their life [6]
- Target ages for thermoset cables: 0, 40, 80, 120 years
- Activation energy is provided by the manufacturer for thermoset cable set

Expected Aging Timeline for TS Cables

Recommended accelerated aging time in oven in days	0	6.5	13	20
Simulated Age for Thermoset Insulation Cable in years	0.0	40.0	80.0	120.0

*All samples will be loaded into the oven and incrementally taken out and tested after the appropriate amount of time is spent in the oven.
**Elongation at Break (EAB) testing will be performed at each incremental age to determine if aging is occurring.
***Additionally, performing tests as we age the overall batch of samples will allow us to tailor our testing as the project moves forward.

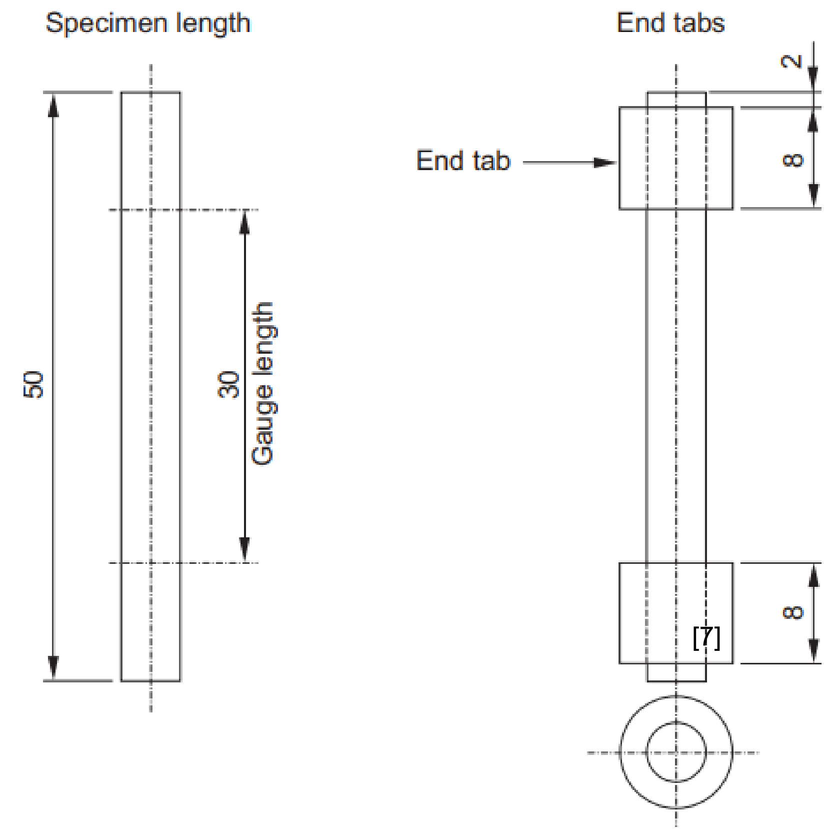
Elongation at Break (EAB)

<u>Tensile Test Machine:</u>

- Provides continuous tension and capable of measuring the load exerted on the specimen during continuous stretching at a constant rate

<u>Specimen Configuration Machine:</u>

- Tubular specimens are recommended for testing cable insulation
- Specimens are prepared by removing the conductor from lengths of the insulation material



Elongation at Break (EAB)

EAB Tests:

- Utilize EAB measurements as indication signs of cable aging
- Expect EAB percentage to decrease as cables increase in age

$$\varepsilon(\%) = 100 \times \frac{E_b - E_0}{E_0}$$

Where ε is the elongation at break, E_0 is the initial distance between the specimen grips, and E_b is the distance between the grips at break.

Test Standard: IEC/IEEE 62582-3:2011, Nuclear Power Plants - Instrumentation and control important to safety - Electrical equipment condition monitoring methods - Part 3: Elongation at break [7]

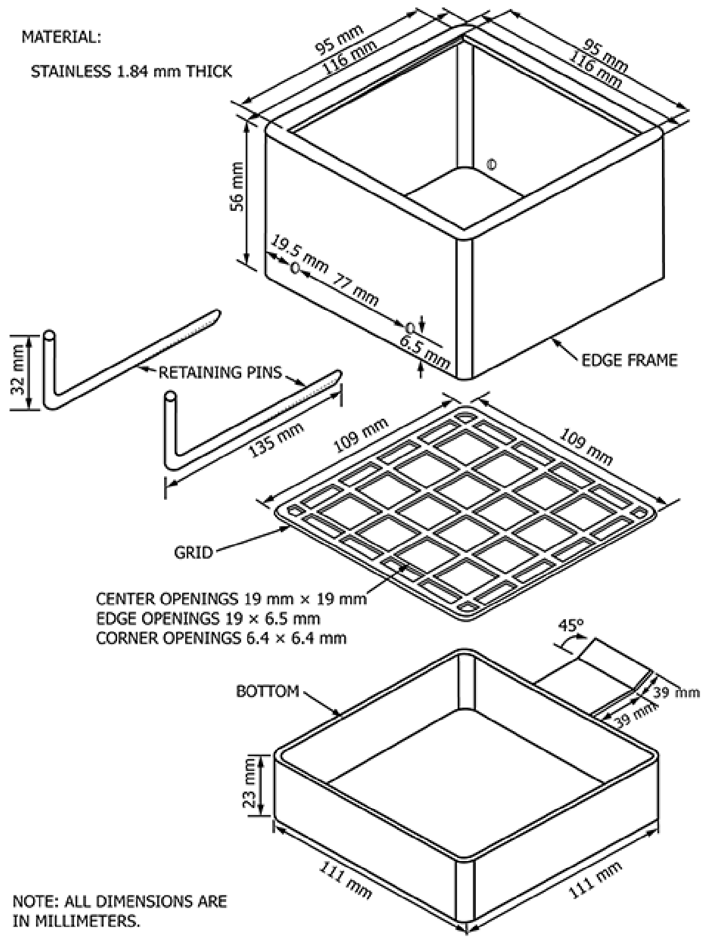
Measuring Fire Properties

Cone Calorimeter Equipment

- Sample holder: frame bottom, several layers of mineral wool (ensures tight fit), wire grid, and a frame top

Modified Setup

- Cables cut into nominal 10 cm (4 in) segments and arranged in a single row approximately 20 cm wide (8 in)
- Cables are coated on all sides uniformly

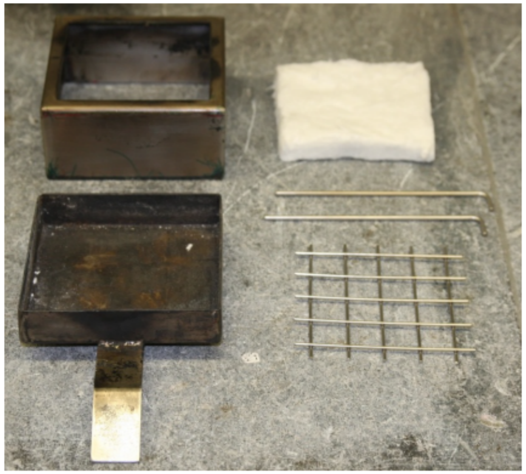


[5]

Measuring Fire Properties

Cone Calorimeter:

- Measures the heat release rate (HRR) of a material sample under a constant imposed heat flux.
- Utilize various radiant heat fluxes [1]
  - 50 kW/m^2
  - 75 kW/m^2
- Calculate the **heat release rate per unit area (HRRPUA) as a function of time** and **time to ignition** for subsequent radiant heat fluxes in ambient air conditions



[1]

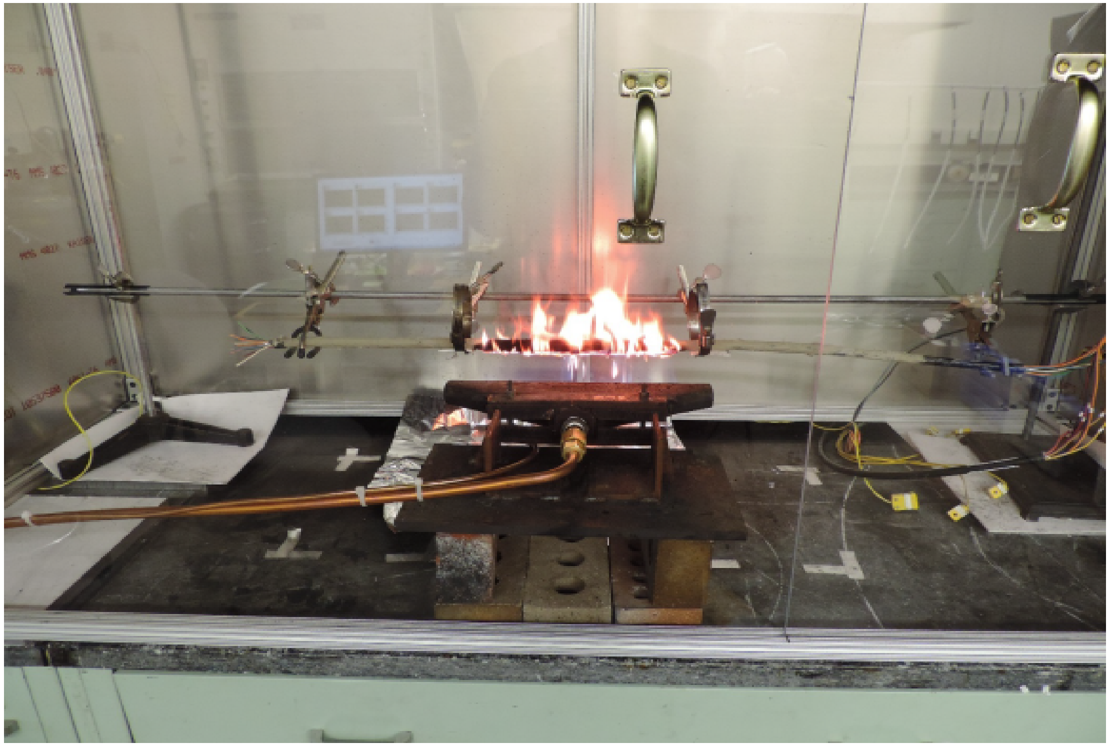
[1]

Test Standard Reference: ASTM D6113-03 Standard Test Method for Using a Cone Calorimeter to Determine Fire-Test-Response Characteristics of Insulating Materials Contained in Electrical or Optical Fiber Cables [8]

Measuring Cable Functionality

Bench-Scale Flame Test Equipment:

- Two thermocouples (TCs) inserted towards the center of the cable. TCs will be placed 5 cm (2 in.) to the left and right of the midpoint of the burner
- Premixed propane-air flame burner with a nominal face length of 25 cm (10 in)
- Two shielded TCs to ensure the average flame temperature over 10 minutes is within the requirement of 750°C (1,292°F) ± 50°C (122°F)
- Insulation Resistance Measurement System (IRMS) to monitor resistance



[1]

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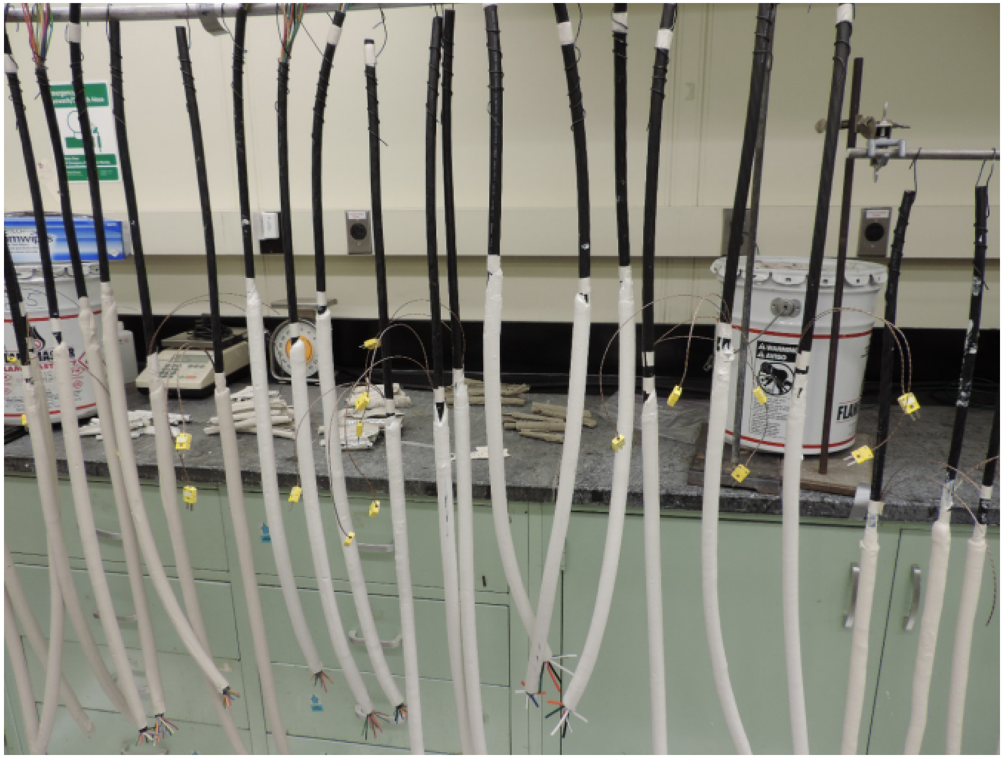
Measuring Cable Functionality

<u>Bench-Scale Circuit Integrity Tests</u>

- **Failure time** (i.e., resistance monitoring using IRMS)
- **Temperature at time of failure**
- Temperature and electrical integrity measurements cannot be done within the same cable
- Separate experiments will be conducted—one for circuit integrity and one for temperature measurement
- Experiments will be repeated three times (i.e., three times for failure time and three times for temperature measurements)



[1]

Test Standard: IEC Standard 60331-11 Tests for electric cables under fire conditions—Circuit integrity—Part 11: Apparatus—Fire alone at a flame temperature of at least 750°C [9]

Project Steps

1. Prepare all specimen samples
2. Perform EAB, cone calorimetry, and electrical functional testing on unaged cables
3. Place remaining specimen in the oven to thermally age the TS cables for 6.5, 13, and 20 days, which is expected to represent 40, 80, and 120 years, respectively
    a. At each expected simulated age, perform EAB, cone calorimetry, electrical functional testing
    b. Document results
4. Repeat steps 3a and 3b until all samples have been tested
5. Draft Research Information Letter (RIL)

References

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[9] IEC. (2009). IEC Standard 60331-11 Tests for electric cables under fire conditions—Circuit integrity—Part 11: Apparatus—Fire alone at a flame temperature of at least 750°C. Geneva: International Electrotechnical Commission.

Questions