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EGM 09-002, IMC 0612, Part 9900 Technical Guidance

2012 NEI MSO Workshop

Robert Daley

Region III, Fire Protection Branch Chief

Enforcement Guidance Memorandum (EGM) 09-002

- MSO non-compliances identified by May 2, 2010
  - Compensatory measures in place
  - Finding is not of high safety significance (Red)
    - Significance Determination Process (SDP) (Inspection Manual Chapter 0609, Appendix F) may not be needed to make this determination
- Identified MSO non-compliances corrected by November 2, 2012
- Non-compliances briefly described in the inspection report
- Not considered in Action Matrix

Inspection Manual Chapter (IMC) 0612

- Inspector Identified
- Licensee Identified
  - Low safety significance (Green), then minimally documented – no cross cutting aspect (CCA)
  - Greater than Green
    - documented as a finding just like licensee identified
    - Action Matrix is applicable

Inspection Manual Part 9900: Technical Guidance

"Operability Determinations & Functionality Assessments for Resolution of Degraded or Nonconforming Conditions Adverse to Quality or Safety"

Part 9900: Technical Guidance

- Corrective actions for nonconforming conditions.
  – "Reasonable efforts to complete corrective actions"
  – NRC considers:
    - Safety significance
    - What is necessary to implement the corrective actions

Part 9900: Technical Guidance

- NRC may also consider:
  - Time needed for design and modification
  - Other extenuating circumstances and/or factors

Nuances

- Only a “licensee identified violation” if we confirm that a violation exists
- MSO issues that are identified by the licensee today
  - No enforcement discretion
  - Treated as “licensee identified” per IMC 0612
    - (Green) Minimally documented
    - (> Green) Documented/Action Matrix

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Nuances

- Licensee identified finding
  - Minimally documented **IF** Green and "appropriate" corrective actions have been developed.
- EGM 09-002
  - < RED
    - "SDP may not be needed to make this determination"
    - Qualitative assessment may be applicable

Nuances

- Unresolved Issues (URIs)
  - NRC identified
  - Resolution dependent on issue being less than Red
  - SDP/Qualitative assessment dependent on licensee information on issue
  - No input – NRC makes the determination

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Any Questions?

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Stable Current Licensing Basis Framework for Fire Protection

2012 NEI MSO Workshop
Daniel M. Frumkin, Team Leader
Fire Protection Branch
Division of Risk Assessment, NRR

Topics

- Background
- NEI 00-01, Revision 3
- MSO Licensing Basis
- Fire Safe Shutdown Procedure Entry Conditions
- Application of “No Adverse Affect”
- Schedule

Background

- EGM 98-002, "Disposition of Violations of Appendix R, Sections III.G and III.L Regarding Circuit Failures"
- EGM 09-002, "Enforcement Discretion for Fire Induced Circuit Faults"
- SECY 11-0063, Closing Fire Protection Issues

NEI 00-01, Revision 3

- October 12, 2011, submittal to the NRC for endorsement
- NRC has concerns over some of the sections
- More communication is needed

- NRC's endgame is to document the stabilized regulatory framework for fire protection in Regulatory Guide 1.189

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NEI 00-01, Revision 3
Topic areas for NRC review

- Currently in NEI 00-01, Revision 3
  - Clarifications based on RG 1.189, Revision 2
  - Revised list of MSO configurations
- Additional information needed
  - White papers
  - NEI to inform NRC staff next steps for NRC review

MSO Licensing Basis (1)

- Licensees have reported having done considerable work to meet RG 1.189, Revision 2
- Licensee and inspector time is spent on discussing multiple spurious actuation licensing basis
- Ongoing discussion regarding current licensing basis for MSO's does not represent a stable regulatory framework

MSO Licensing Basis (2)

- January 31, 2012, meeting determined three primary tasks

1. NRC review of Chapter 3 of NEI 00-01, Revision 3, and industry stakeholders to determine path forward for white papers
2. A process to address future changes to MSO combination list
3. Incorporation of new circuit fault configuration
   - Specifically from the circuit failure research project (PIRT) which has not yet been released

Fire Safe Shutdown Procedure Entry Conditions – T=0

- Fire safe shutdown procedures have historically been prescriptive
- Some scenarios support prescriptive procedures
- Fire PRAs to support NFPA 805 have identified that in some circumstances there may be "higher risk by mandating actions . . ."
- Have licensees considered these insights?
- Are there technical and regulatory obstacles to considering these insights?
- NRC plans to hold a scoping meeting around May 2012 on this topic

“No Adverse Affect” (1)

- The fire protection standard licensing condition states:
  - The licensee may make changes to the approved fire protection program without prior approval of the Commission only if those changes would not adversely affect the ability to achieve and maintain safe shutdown in the event of a fire.
- 10 CFR 50.48(a) states:
  - Each holder of an operating license issued under this part . . . must have a fire protection plan that satisfies Criterion 3 of appendix A to this part.

“No Adverse Affect” (2)

- NEI 02-03, interprets this as evaluating changes only with respect to safe shutdown
- NRC staff has concerns that some fire protection commitments, specifically to Appendix A to Branch Technical Position (BTP) 9.5.1, are being incorrectly modified
- NRC plans to hold a scoping meeting around May 2012 on this topic

Schedule

- Series of public meetings planned to discuss these topics
- January scoping meeting (complete) followed by one in April 2012
  - NEI 00-01, Revision 3
  - MSO Licensing Basis
- May scoping meeting followed by one in August 2012
  - T=0
  - Adverse affect

Backup Slide – from September 2011 NEI Fire Protection Information forum – Fire PRA and Fire Risk Evaluation Insights

Evaluated Risk Based Plant Modifications
(Compiled from various plants)

- Procedure changes in support of existing or new operator actions
  - Opportunity to reduce or eliminate use of "fire emergency/ response procedures" for operator actions to shut down
    - Last vestige of event-based procedures
    - Can actually result in higher risk by mandating actions in case of fire instead of in case of actual fire-induced failure of equipment.
  - Move actions to symptom-based EOPs
    - Example: Opening a disconnect to disable a PORV. FEP might call for this to be done "just in case" a fire could cause spurious open. Instead of FEP, add to EOP in response to spurious opening of PORV as additional step if other responses fail.
    - Moving to EOP means it won't be done unless the PORV actually opens and cannot be closed or isolated. If fire does not cause this, then this component is available for use.
    - When no fire and valve stuck open, it can't hurt and might help.

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PIRT Panel Update

Gabriel Taylor

Fire Research Branch

On Behalf of:

Harry Barrett, David Crane, Bob Daley, Dan Funk, Tom Gorman, Steve Nowlen, Andy Ratchford

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What is a PIRT

- PIRT
  - Phenomena Identification and Ranking Table
  - Structured Expert Elicitation Process
    - Used for years in other technically complex areas that require expert judgement
      - Thermal hydraulics
      - Accident Analysis
      - Fire Modeling

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Why run one?

- Identify future research needs
- Primer for follow-on expert elicitation
- Assess current state-of-knowledge on fire-induced circuit failure issues

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PIRT Primary Objectives

- Identify phenomena and influencing parameters that would lead to fire-induced electrical circuit faults (spurious operations)
- Rank the influencing parameters on fire-induced spurious operation and subsequently duration
- Assess current level of knowledge for each identified parameter

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PIRT Secondary Objective

- Provide technical expert consensus on legacy fire protection circuit issues
  - Multiple high impedance faults
  - Current transformers
  - Smart shorts
    - Proper polarity dc, consequential ac
- Tom Gorman to present these issues and preliminary findings

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PIRT Meetings

- FIRST PIRT MEETING (November 16-18, 2010)
  - Developed PIRT process – Figures of Merit, cable fire related definitions, XCEL scoring sheets
  - Indentified influencing parameters for all circuit types
- SECOND PIRT MEETING (January 20-22, 2011)
  - Evaluated panel scores for all circuit types
  - Determined that because of lack of sufficient test data only control circuits will be considered for the PIRT
- THIRD PIRT MEETING (February 16-18, 2011)
  - Determined that for control circuits analysis of all test data is needed
  - Formulated the analysis procedures for addressing all influencing parameters
  - Developed preliminary ranking tables
- FOURTH PIRT MEETING (May 11-13, 2011)
  - Discussed both ac/dc test data analysis (preliminary)
  - Discussed power circuit and Instrument circuit Issues
  - Rescored (as a consensus) influence parameters based on ac/dc preliminary data evaluation
  - Discussed PIRT ranking tables and corresponding ac/dc circuit types to be addressed by the panel
- FIFTH PIRT MEETING (September 27-29, 2011)
  - Evaluated both ac/dc test data analysis - control circuit influencing parameters
  - Discussed power circuit and instrument circuit issues – developed scope and resolutions
  - Re-evaluated consensus scores for control circuits and PIRT ranking tables
- SIXTH PIRT MEETING (November 29 – December 1, 2011)
  - Re-evaluated both ac/dc test data analyses for control circuits
  - Re-evaluated both consensus scores on influencing parameters and PIRT ranking tables

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Results

- Output of PIRT project will be a joint NRC/EPRI Report
- Report will provide the conclusion and recommendations of the Panel.
- Recommendations are NOT regulatory positions (or guidance)

Project Structure

- Sponsors and Oversight
  - NRC & EPRI via Memorandum of Understanding
- Facilitator
  - Brookhaven National Laboratories
- Balanced Panel of Experts
  - 4 NRC
    - Harry Barrett, Bob Daley, Steve Nowlen, Gabe Taylor
  - 4 EPRI
    - Dave Crane, Dan Funk, Tom Gorman, Andy Ratchford

Approach

- Identify Scenarios (ac/dc & circuit types)
  - Instrumentation, Control, Power
- PIRT was conducted for Control only
- Instrumentation and Power
  - Consensus approach used
- Data Consolidation needed for Control
  - Discussed later

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Control Circuit Parameters

- Conductor Count
- Conductor Size
- Exposure Conditions
- Raceway Routing
  - Panel Wiring
- Raceway Fill
  - Bundles
- Wiring Configuration
- Insulation Type
- Aging
- Jacket
- Time-Current
- Grounded cable configuration
- Voltage Level
- Armor
- Suppression
- Latching

Ranking Table Structure

- Two Scenarios (ac, dc)
- Each Parameter
  - Parameter Applicability
  - Research Ease
- Parameter Effect (intra-cable, inter-cable, duration)
  - Parameter Importance
  - State of Knowledge

Ranking Table Example

AC CONTROL CIRCUITS
PANEL MEMBER: Panel Consensus

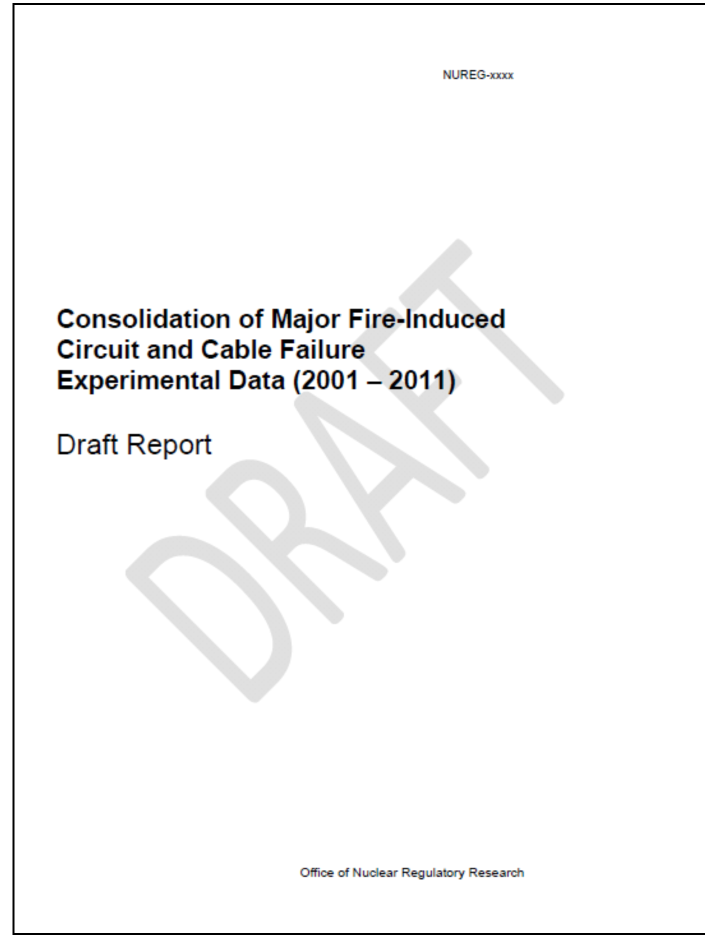
Row	Identification	INFLUENCING PARAMETERS	Parameter Applicability	Research Ease Ranking	Effect of Parameters on the Likelihood -- 1.1 SPURIOUS ACTUATION of AC control circuit - INTRA-CABLE short	Parameter Importance	State of Knowledge	Effect of Parameters on the Likelihood -- 1.2 SPURIOUS ACTUATION of AC control circuit - INTER-CABLE short	Parameter Importance	State of Knowledge	Effect of Parameters on the Plant Cable Configuration -- 1.5 DURATION of Spurious Actuations	Parameter Importance	State of Knowledge
5					1.1			1.2			1.3		
6													
7	1	Conductor Count			1.1.1	1.00		1.2.1	1.00		1.3.1	1.00	
8		a. 1	2	N/A		N/A	N/A		1	2		1	2
9		b. 2-6	3	3		1	2		1	2		1	2
10		c. 7-9	3	3		1	3		1	3		1	3
11		d. 10 - 15	3	3		1	2		1	2		1	2
12		e. >15	3	3		1	1		1	1		1	1
13													
14	2	Exposure Condition			1.1.2	2.00		1.2.2	2.00		1.3.2	3.00	
15		a. Flame	3	3		2	3		2	3		3	3
16		b. Plume	3	3		2	3		2	3		3	3
17		c. Hot Gas Layer	2	3		2	3		2	3		3	3
18		d. Time/temperature	1	3		2	1		2	1		3	1

Instrumentation Circuits

- More Research needed
  - Example circuits
    - Full pneumatic
    - Electro-hydraulic
    - Digital
    - Current loop
    - Combination of analog and digital

Data Consolidation Project

- Systematically evaluate PIRT panel identified parameters
- Primary Data set used in PIRT
  - EPRI/NEI tests (2001)
  - NRC CAROLFIRE (2008)
  - NRC DESIREE-Fire (2010)


NUREG-xxxx

Consolidation of Major Fire-Induced Circuit and Cable Failure Experimental Data (2001 – 2011)

Draft Report

DRAFT

Office of Nuclear Regulatory Research

Data Consolidation Report

- Evaluates intra-cable shorts, inter-cable shorts, ground faults, spurious actuation concurrence
- Factual data report without statistical treatment
- Multi-variable evaluations
  - were discussed but not pursued
  - may be done in follow-on expert elicitation

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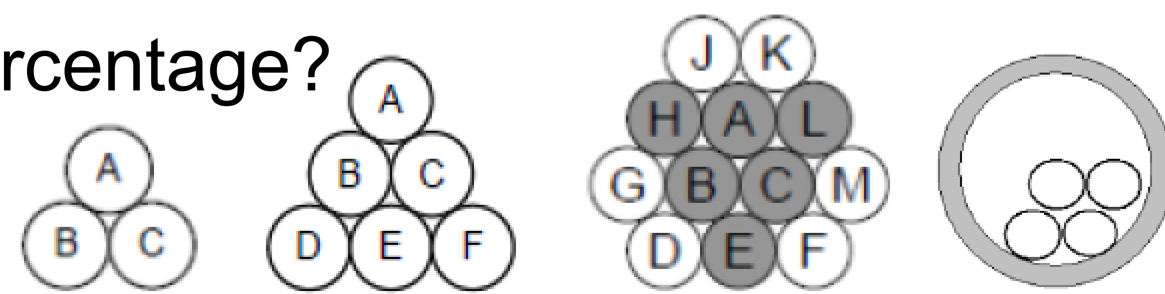
Data Report Identified

- Insulation Type
  - Thermoset or Thermoplastic
  - No discernible effect on spurious operation
- Thermal Exposure Conditions
  - Flame impingement has higher percentage of spurious operations then plume or hot gas layer
- Bundle arrangements
  - Higher percentage?



Control Power Transformers

- Initial EPRI/NEI results do not align with NRC confirmatory results
- Panel thoroughly discussed, but could not pin down technical cause
- Panel recommends combining data set

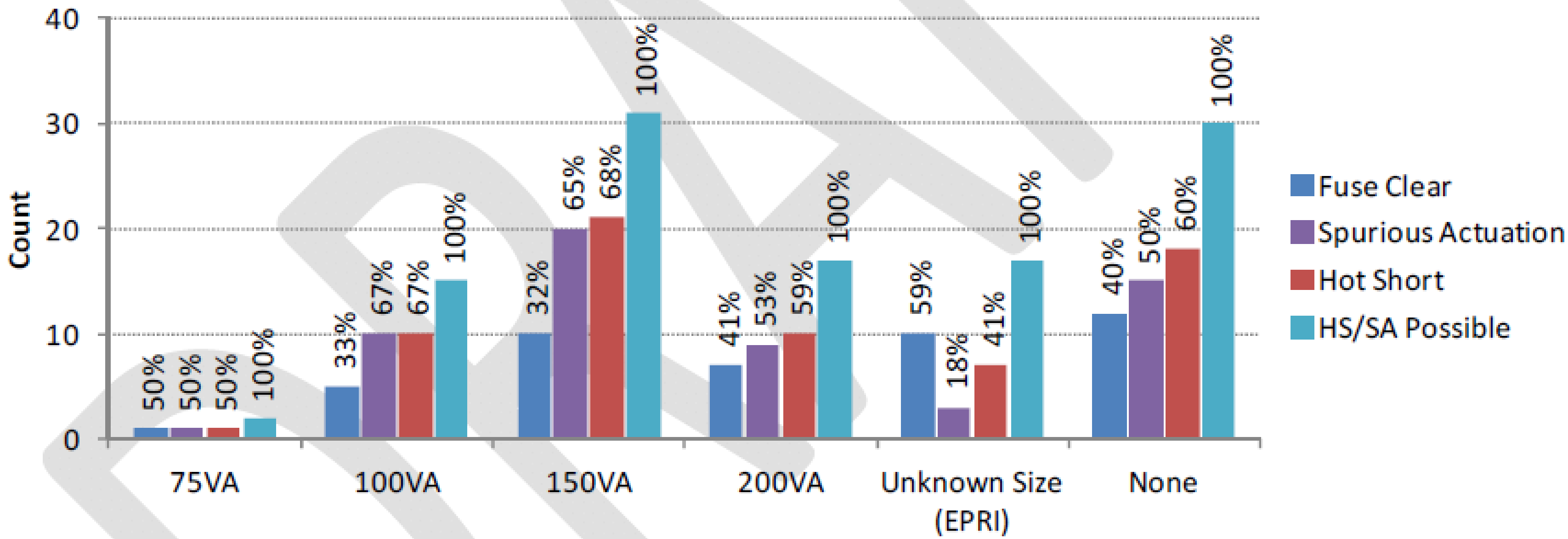


Figure 2-22. CPT size - global approach

Insulation Type Failure Modes

Table 2-14. Insulation type count data, global approach, ac tests

Global Approach	TP	TS	Total
Fuse Clear	17	28	45
Spurious Actuation	20	38	58
Hot Short	22	45	67
HS/SA Possible	39	73	112

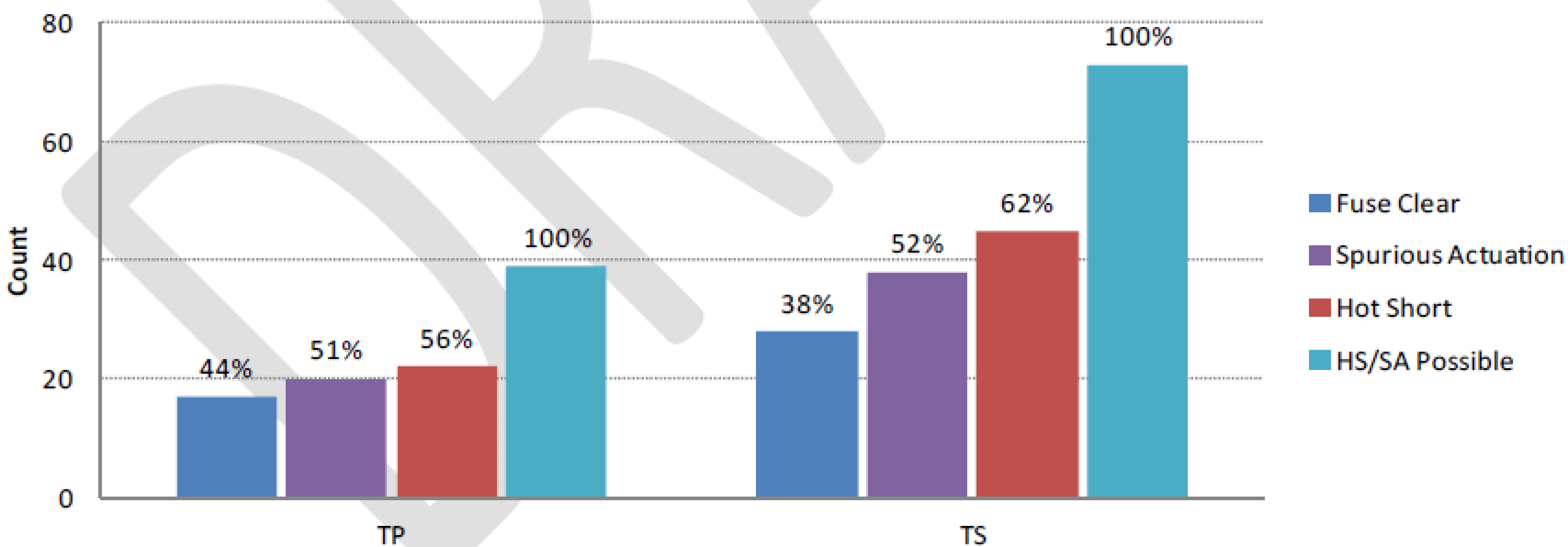


Figure 2-16. Insulation type column plot, global approach, ac tests

Insulation Type Duration

Table 2-15. Insulation type, duration data table, ac tests

	Hot Short		Spurious Actuation	
	TP	TS	TP	TS
q1	5	11	6	15
min	1	1	1	1
median	23	28	24	39
max	456	1345	456	231
q3	100	72	64	81
mean	80	61	73	53

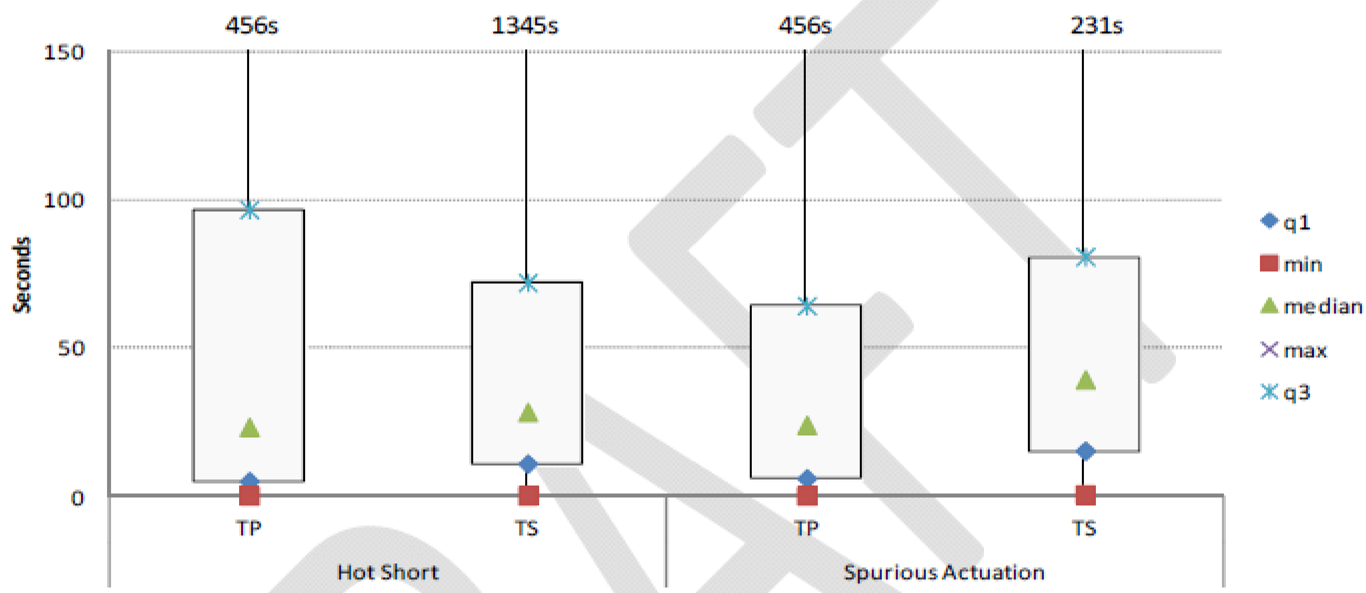


Figure 2-17. Insulation type box plot, duration, ac tests

Next Steps

- PRA expert elicitation panel to use base data to support effort
- Public comment period is envisioned
  - 45-days
  - Comment period start date is to be determined

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Summary

- PIRT
  - Evaluates state of knowledge
  - Identifies and Prioritize Future research needs
  - Builds consensus on long standing FP circuit issues
  - It is NOT a regulatory position
- Data Report
  - Consolidates 3 major testing projects performed to date
  - Provides factual information on failure modes and hot short duration

ELECTRIC POWER RESEARCH INSTITUTE

Industry PIRT Perspective

Tom Gorman, PPL Susquehanna, LLC

PIRT Composition

NRC

- Gabe Taylor - RES
- Harry Barrett - NRR
- Bob Daley - RIII
- Steve Nowlen - SNL

EPRI

- Dan Funk – EDAN
- Tom Gorman – PPL
- Andy Ratchford – RDS
- Dave Crane - Pyrolico

Industry Perspectives

- A Significant Body of Cable Fire Testing existed
- The testing used circuit configurations and components representative of those used throughout the US Nuclear Power Industry
- A detailed analysis of the test data had not been performed
- The PIRT Panel did a thorough analysis of the test data

Industry Perspectives

- The results of the data analysis provide a very reasonable and very representative depiction of how circuits used in the US Nuclear Power Industry will respond **if subjected to fire damage**
- The results provide a very good basis for the judgments provided by the PIRT members
- The judgments provided by the PIRT Members represent a consensus position

Industry Perspectives

- The PIRT judgments do **not** represent a regulatory requirement or even a regulatory position
- The PIRT judgments will be incorporated into a NUREG and, if any of the positions do become part of the regulations or guidance, this will occur only if the NRC Staff chooses to act upon them and the appropriate process is followed

Industry Perspectives

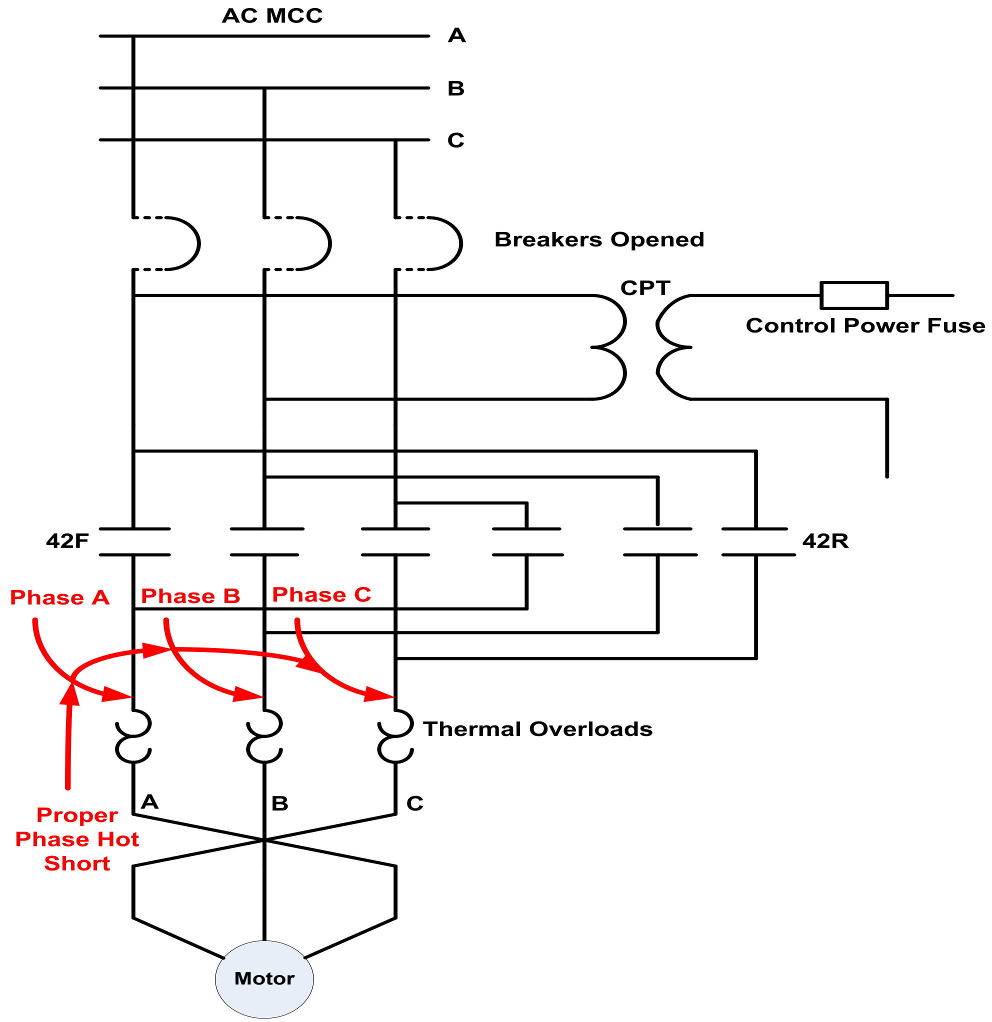
- A primary focus of the PIRT was to provide information to be used by the follow-on Expert Elicitation PRA Panel for revising the probability numbers currently used in the Fire PRA
- A secondary focus was to provide information useful in performing a deterministic post-fire safe shutdown circuit analysis

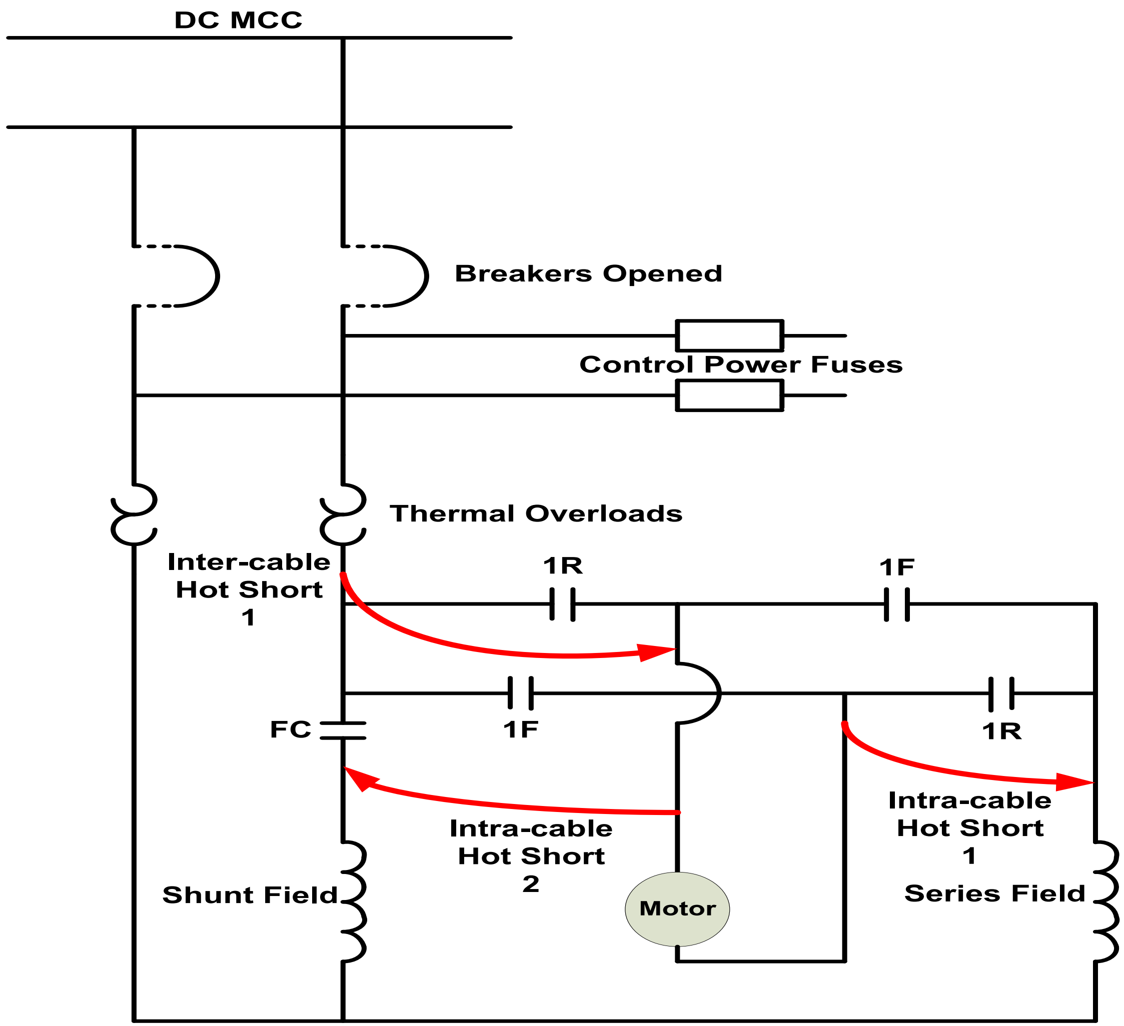
Industry Perspectives

- The insights for a deterministic analysis will be discussed further today, since this workshop is geared primarily towards Licensees addressing MSO under a deterministic analysis
- All of the information provided herein should be considered **preliminary** and **not** useable under your current licensing basis

Industry Perspectives

- **Power Cable**
  - The current position in the Industry relative to circuit failures on hi/lo pressure interface valves, both ac and dc, is conservative.
  - The practice of opening the breaker on ac or dc power feeds to hi/lo pressure interface motor-operated valves is acceptable in mitigating the effects of a spurious operation of the valve.

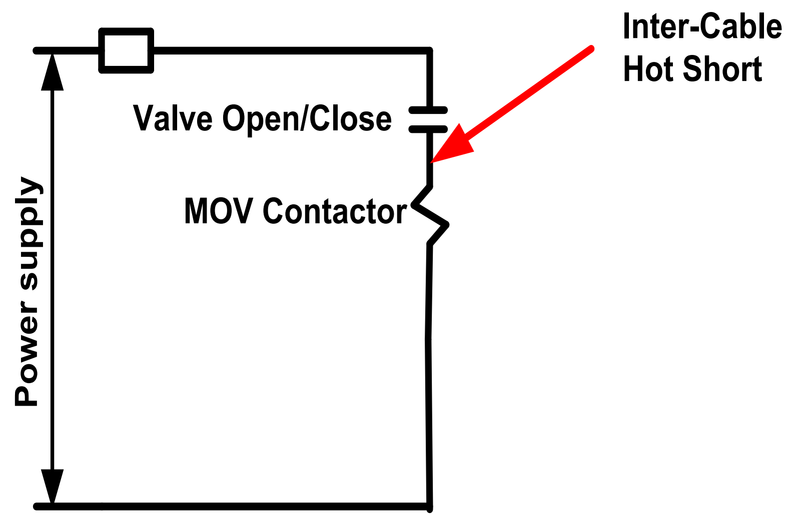

AC MCC
A
B
C
Breakers Opened
CPT
Control Power Fuse
42F
42R
Phase A
Phase B
Phase C
Thermal Overloads
A
B
C
Proper
Phase Hot
Short
Motor


DC MCC
Breakers Opened
Control Power Fuses
Thermal Overloads
Inter-cable Hot Short 1
1R
1F
FC
1F
1R
Intra-cable Hot Short 2
Intra-cable Hot Short 1
Shunt Field
Motor
Series Field

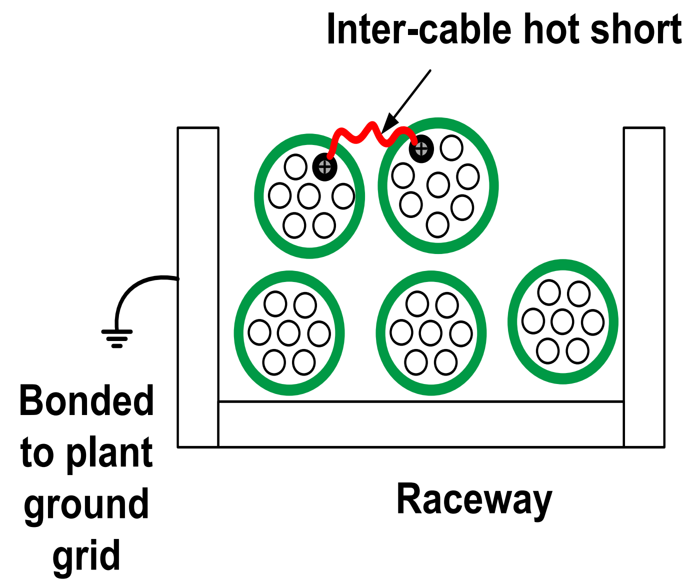
Industry Perspectives

- **Control Circuits**
  - Grounded ac or Ungrounded ac or dc circuits using **thermoset** cabling
    - Inter-cable hot shorts are very unlikely and probably should only be considered **for high consequence conditions, e.g., hi/lo pressure interfaces**

Industry Perspectives

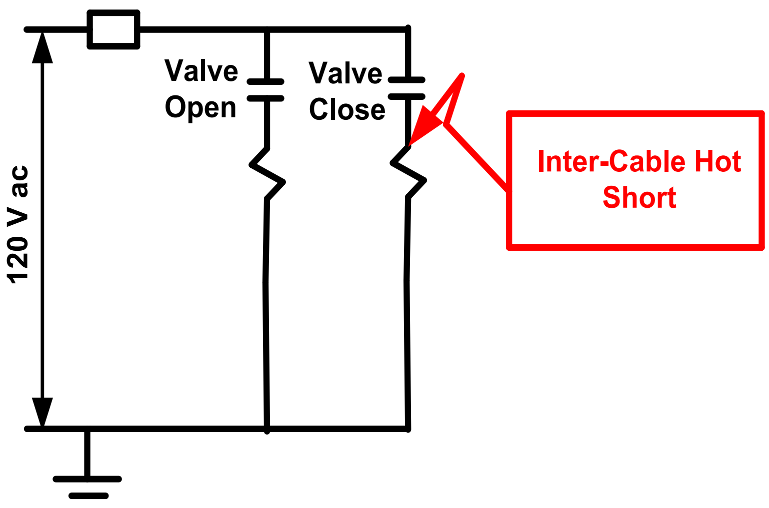


Schematic Configuration

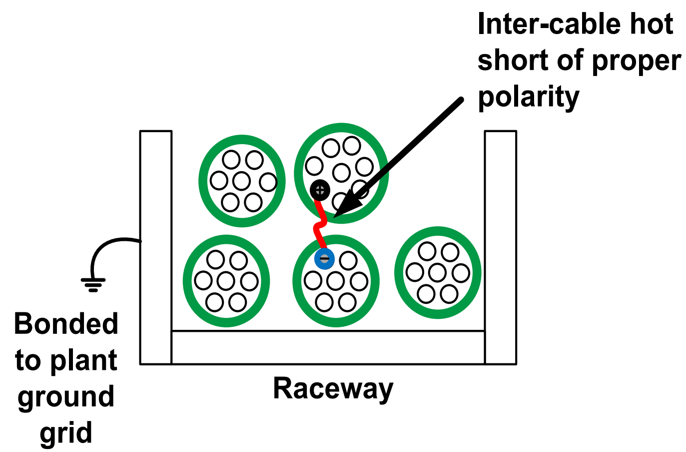


Physical Configuration

Industry Perspectives



<u>Simplified Schematic</u>

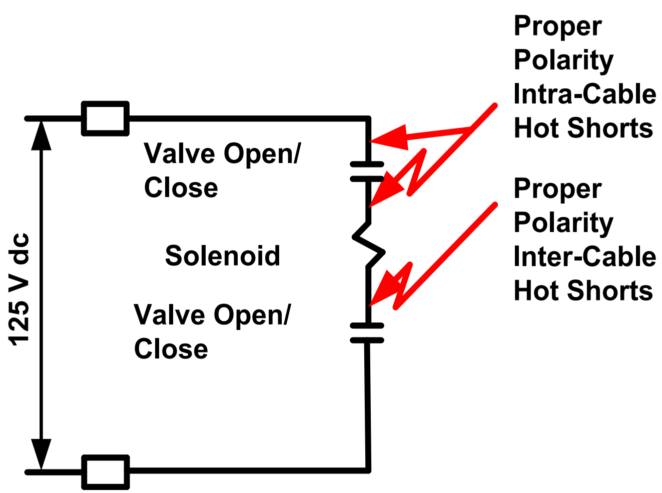


<u>Physical Configuration</u>

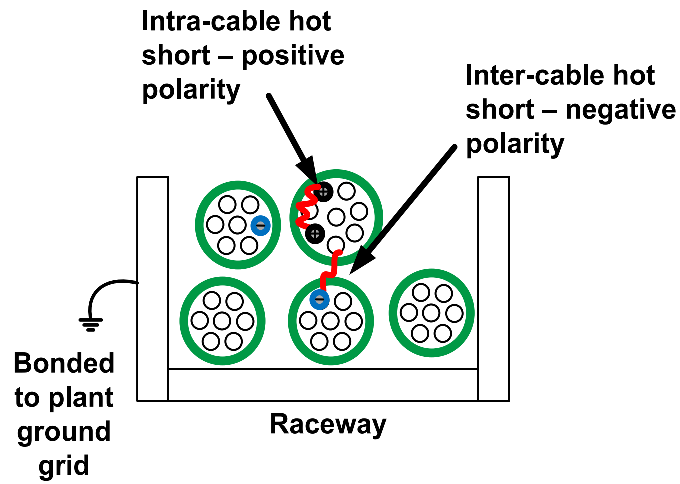
Industry Perspectives

- **Control Circuits**
  - Grounded ac or ungrounded ac or dc circuits using **thermoset** cabling with a double-break design
    - An Intra-cable + an Inter-cable hot short are very unlikely and probably should only be considered for **high consequence conditions, e.g., hi/lo pressure interfaces**

Industry Perspectives



Schematic Configuration

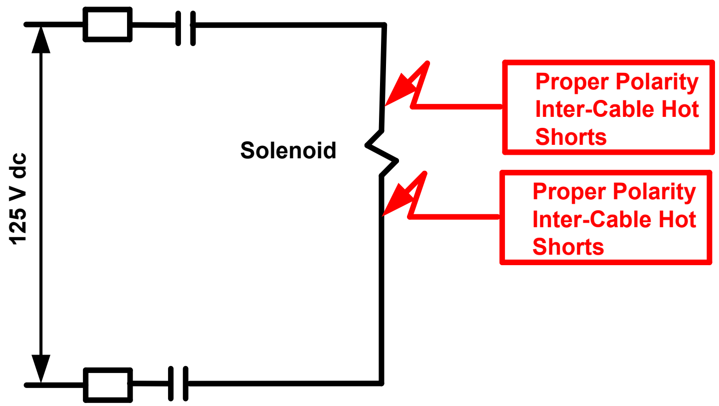


Physical Configuration

Industry Perspectives

- **Control Circuits**
  - Ungrounded ac or dc circuits using thermoset cabling with a double-break design
    - An Inter-cable + an Inter-cable hot short are very, very unlikely to the point of being **incredible**

Industry Perspectives



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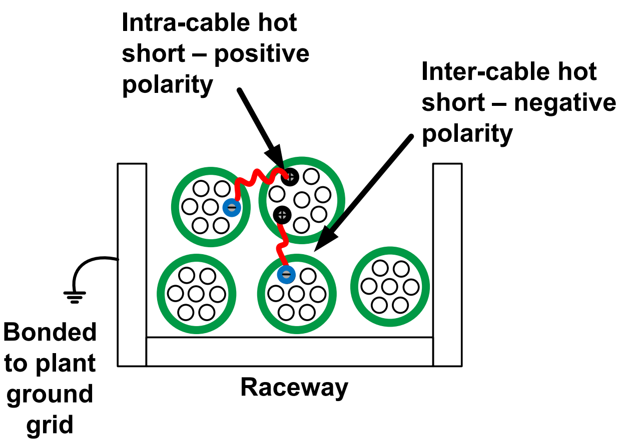
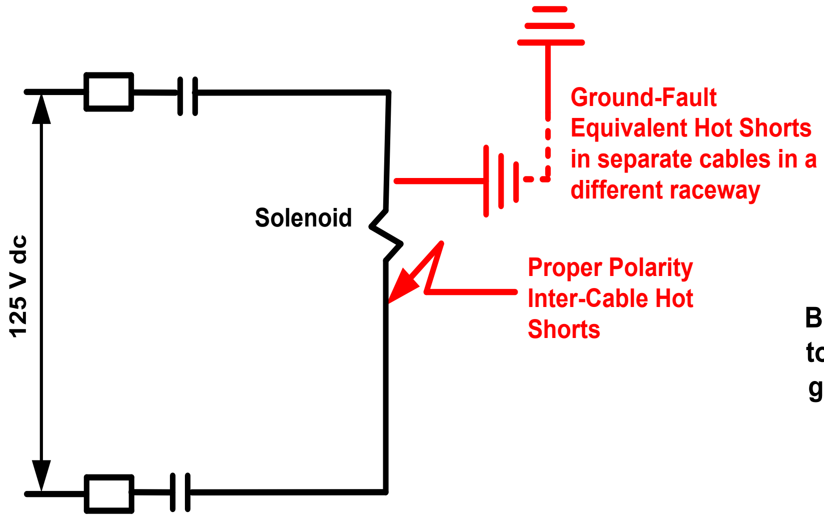


Physical Configuration

Industry Perspectives

- **Control Circuits**
  - Ungrounded ac or dc circuits using thermoset cabling with a double-break design
    - A ground equivalent hot short + an Inter-cable hot short are very unlikely and probably should only be considered for **high consequence conditions, e.g., hi/lo pressure interfaces**
  - **Additional data review to be performed of this failure mode for thermoplastic cable.**

Industry Perspectives



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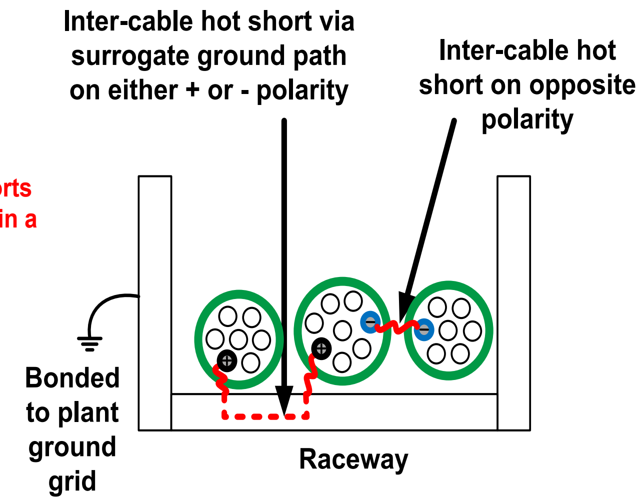
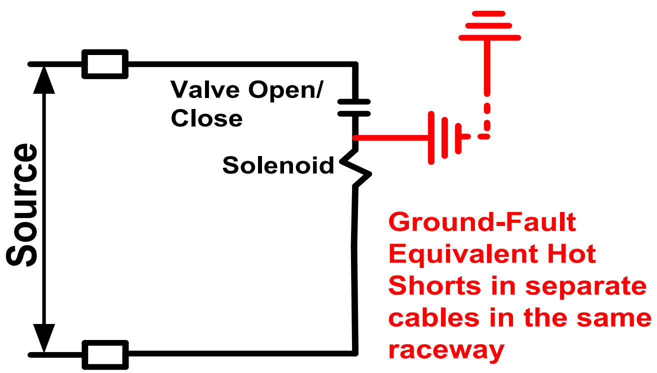


Physical Configuration

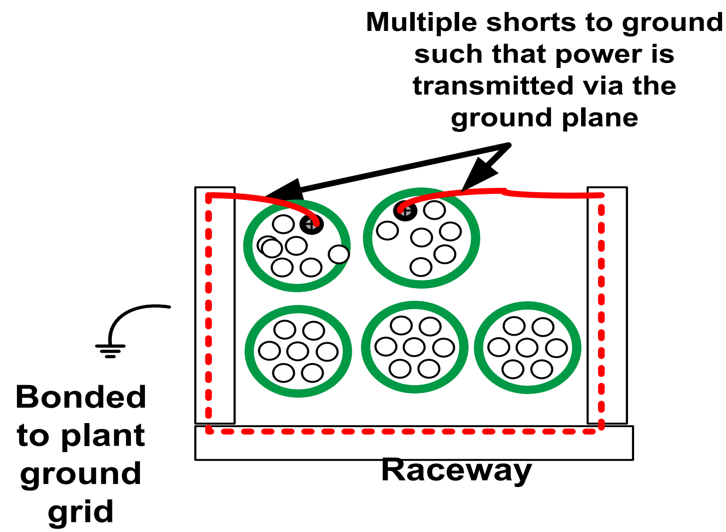
Industry Perspectives

- **Control Circuits**
  - Other circuit types, however, are judged to be credible for all safe shutdown circuits
  - Some examples are shown on the next few slides

Industry Perspectives

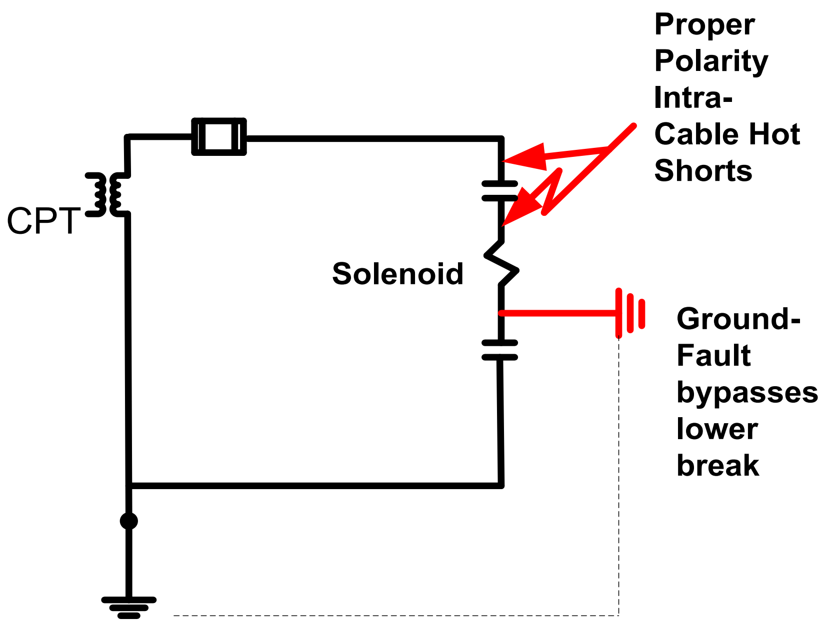


Schematic Configuration

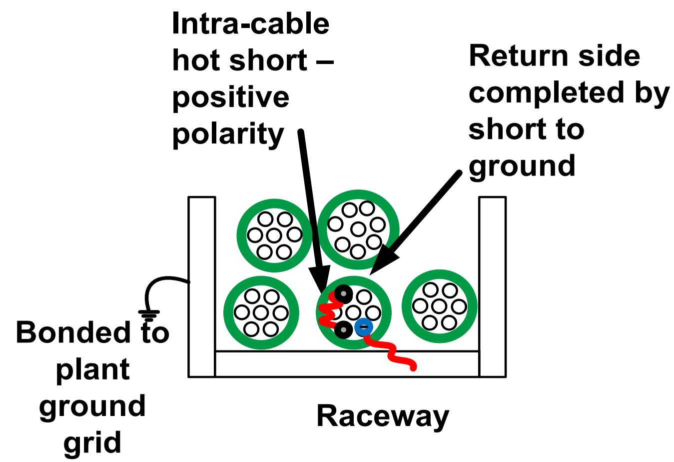


Physical Configuration

Industry Perspectives

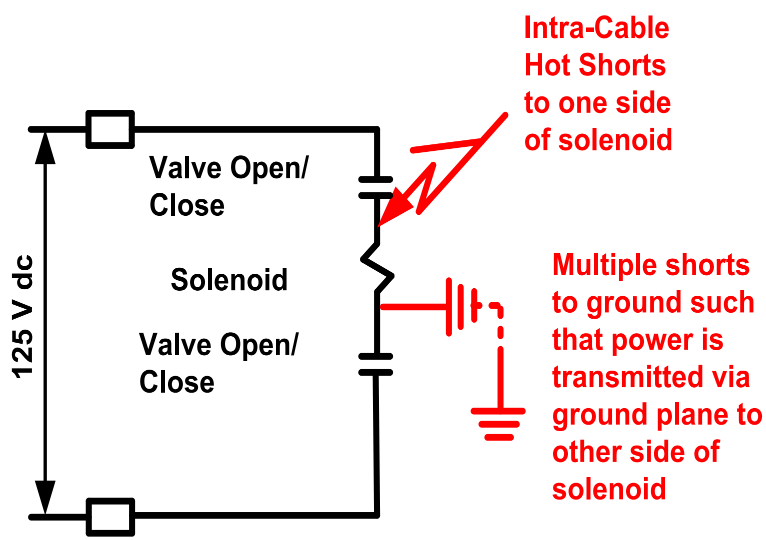


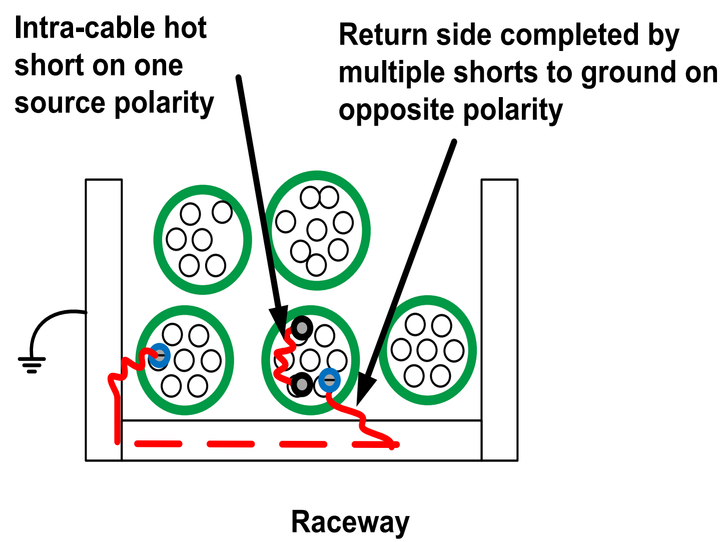
Schematic Configuration



Physical Configuration

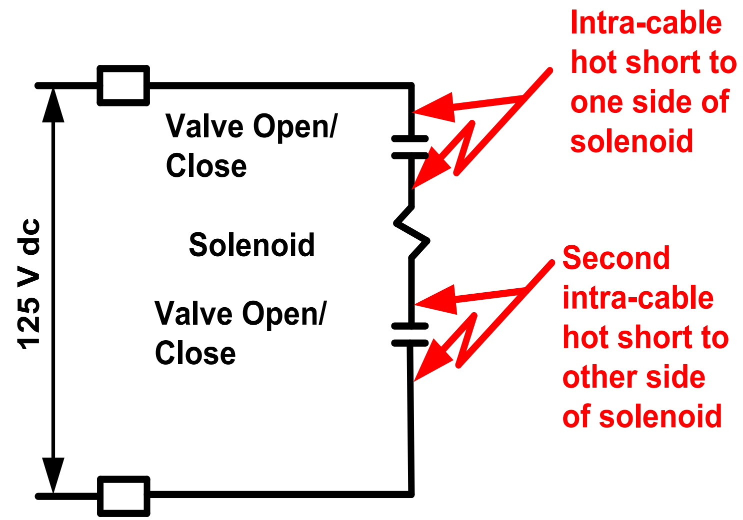
Industry Perspectives



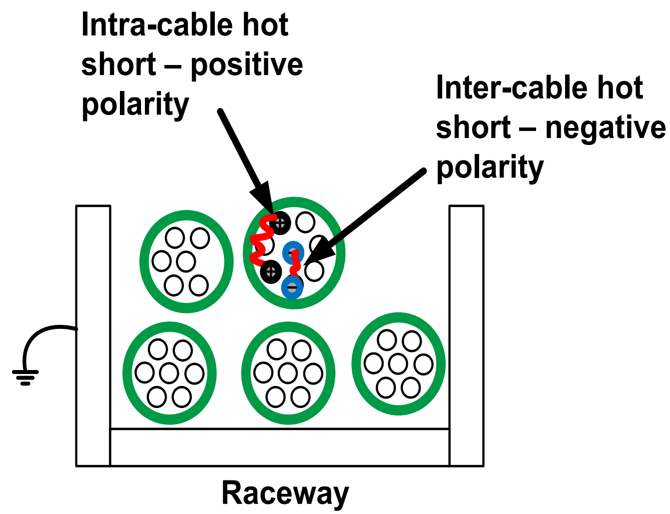


<u>Schematic Configuration</u> **<u>Physical Configuration</u>**

Industry Perspectives



Schematic Configuration



Physical Configuration

Industry Perspectives

- **Instrumentation**
  - Leakage current
  - High or Low outputs will eventually be seen
  - Control Room indications may not be easy to diagnose
  - Conclusion: More Research needed

Industry Perspectives

- **Current Transformers**
  - Exhaustive search for information
    - Nuclear & non-nuclear
    - Minimal data available
  - Ratio 800:5 and lower
    - Data and theory indicate secondary fires are not credible risk
  - Ratio > 800:5
    - Risk judged to be very low but no test data to support position
    - Additional testing recommended
  - Threshold Value of 1200:5 is being considered

Industry Perspectives

- **Multiple High Impedance Faults (MHIF)**
  - Not credible concern if…
    - Proper coordination exists
    - General ANSI/IEEE criteria applied
    - Suitable periodic testing implemented

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Conceptual Test Plan for High Energy Arcing Faults (HEAF) Fire Experiments

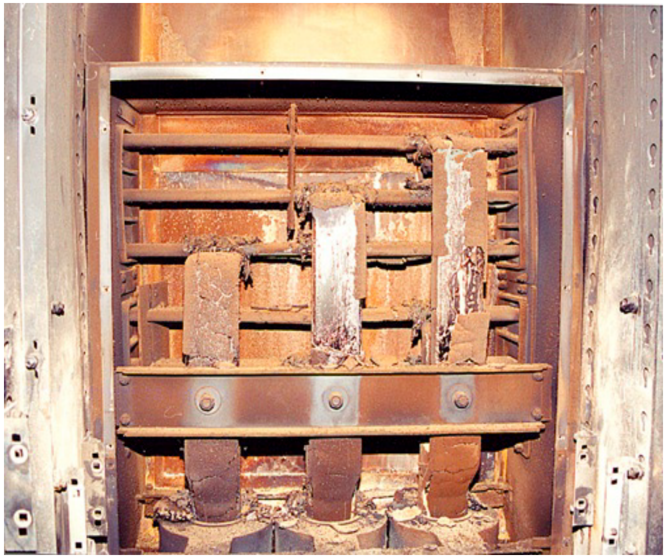
Gabriel Taylor
Office of Nuclear Regulatory Research
Fire Research Branch

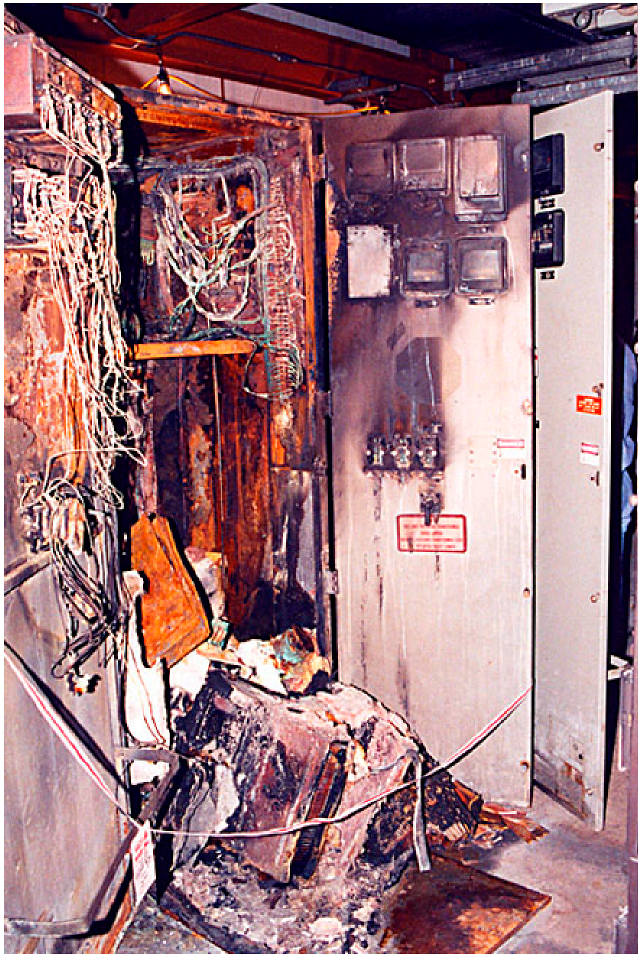
Background

- Massive electrical discharges, referred to as High Energy Arcing Faults (HEAF), have occurred in nuclear power plant switching components throughout the world
  - Rapid release of electrical energy in a very short time duration
  - Difficult to model extent of damage in fire PRA and mathematical fire models
- HEAF in electrical equipment are generally initiated in one of three ways:
  - poor physical connection between the switchgear and the holding rack
  - environmental conditions, or
  - the introduction of a conductive foreign object
- A HEAF typically would cause large pressure and temperature increases in the component cabinet, which could lead to serious equipment failure
- After the energetic arcing, secondary fires have been observed to impact cables and other equipment in the vicinity of the event

Real Events

Switchgear, load centers, and bus bars/duct are subject to this unique failure mode





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International Collaboration on HEAF Under OECD

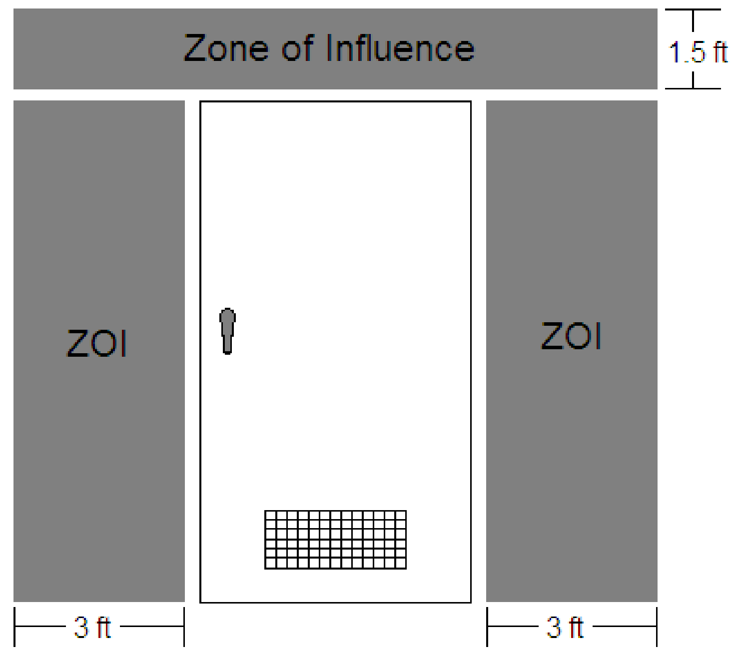
- HEAF events have occurred throughout the world in NPPs
  - Germany, France, Belgium, Japan, and Canada
- Discussions at international meetings generated a world interest in this research
- NRC is proposing to lead the international research program through the OECD

US NPP Participation in the International HEAF Testing Project

- NRC-RES will work through EPRI under Memorandum of Understanding
- EPRI's role will be to facilitate equipment donation from US utilities that wish to participate and provide technical support
- US utilities participating will support experiments by providing in-kind contributions
  - Switchgear, cabinets, bus bars, etc.

Current State-of-the-Art

- NUREG/CR-6850, Appendix M (2005)
- Method based on **one** well documented fire event at San Onofre in 2001 to define zone of influence (ZOI)
- Components within ZOI are assumed to fail or ignite
- This becomes the input to fire PRA model
- How does the recent Robinson event fit this model?



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Objective

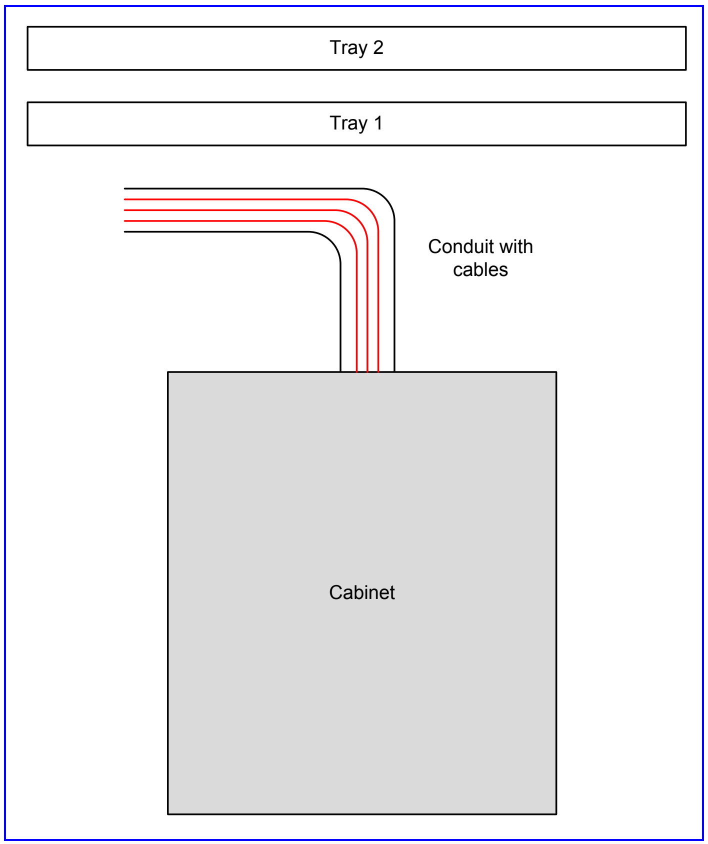
- Perform experiments to obtain scientific fire data on the HEAF phenomenon known to occur in nuclear power plants through carefully designed experiments
- Use data from these experiments and past events to develop a more realistic model to account for the failure modes and consequence portions of HEAFs
- Improve the state of knowledge and provide better characterization of HEAF in the fire probabilistic risk assessment (PRA) and NFPA 805 license amendment request applications

Arc Blast

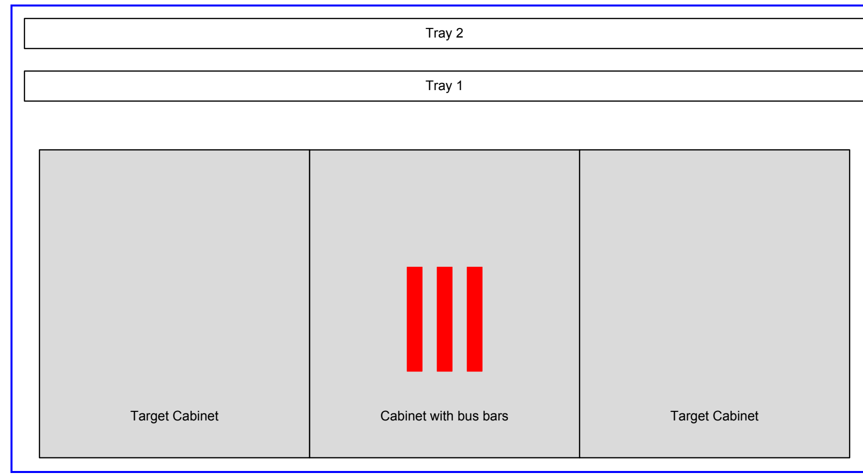
- We desire to reproduce an arc blast and not an arc flash
  - During an arc flash the voltage can drop to about 10% of the original while current is maintained
  - An arc blast is obtained when both voltage and current are maintained for a relatively prolonged period of time (2+ seconds)
  - The intensity of an arc flash is therefore less than that of an arc blast
- The power load of an arc blast is much larger and is very difficult to maintain under a testing environment without causing power problems
- If arc blasts are not feasible in the testing environment, the possibility exists that an equivalent heat-releasing surrogate be used to expose the components to a transient heating that will also help improve current fire PRA methods

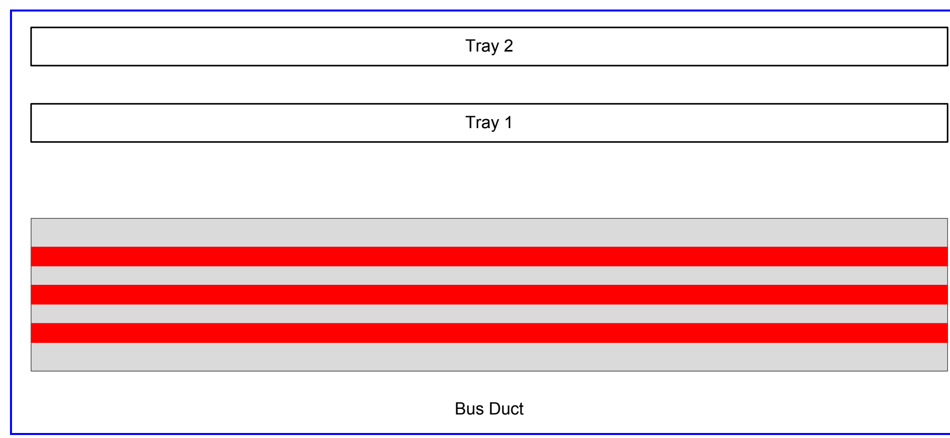
Tests will include:

Switchgears & Conduits



Bus Bars





Tests at different voltages: 480V, 4160V, and 6900V

Equipment Needs

Component	Low Voltage (208V-1000V)	Medium Voltage (1kV – 22kV)
Switch Gear		
Breaker		Korea 6.9kV Germany 6.9kV
Cabinet		Korea 6.9kV
Motor Control Center		
Breaker		
Cabinet		
Load Center	Westinghouse DB-25, DB-50 GE AK breakers	
Distribution Connections		
Cabinet		
Bus bars & bus ducts		
Iso-phase		
Non-segregated		
Transformer Bushings		
Test support and safety protection equipment	NRC	NRC

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Data Acquisition

- Proper instrumentation will be used to collect data about:
  - Arc intensity and duration
  - Target damage as a result of the arc
  - Post-HEAF fire damage
- Pressure, temperature, and heat flux will be measured
- Electrical data will also be collected

Instrumentation

- Thermocouples
- Directional flame thermometers (DFTs) / Heat flux gages
- Plate thermometers
- Calorimeters
- Pressure gages
- High-speed cameras

Fast recovery DC amplifiers and inverse filter functions are being considered to minimize the effects of electrical noise in the data.

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Current Status

- The preliminary test plan is currently being revised to include more details
- Some equipment has already been identified and shipped to U.S. for testing
- Seeking additional equipment and expert support from U.S. utilities through EPRI Memorandum of Understanding

Summary

- HEAF events are expected to occur in the nuclear and non-nuclear fields
- Data from experimental testing will assist in developing more realistic tools to model the risk in fire PRAs
- Motive for experimental program is supported internationally by CSNI/IAGE HEAF TG work

DC Testing

Gabriel Taylor
Fire Research Branch

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DESIREE-FIRE

- Direct Current Electrical Shorting in Exposure Fire
- Experimental testing program to evaluate direct current (dc) circuit response to fire exposure.
- Cooperative research project with EPRI via Memorandum of Understanding
- Sandia National Laboratories conducted the testing

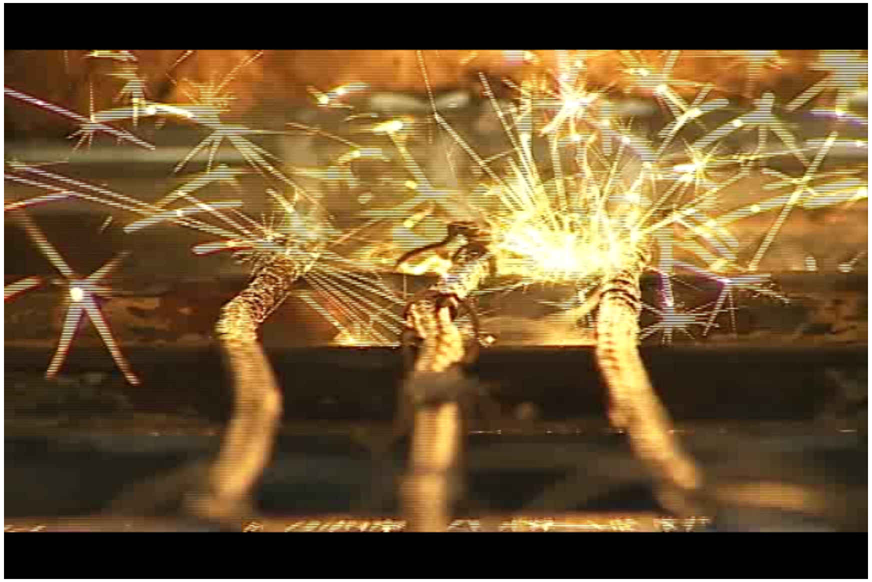
Need for Testing

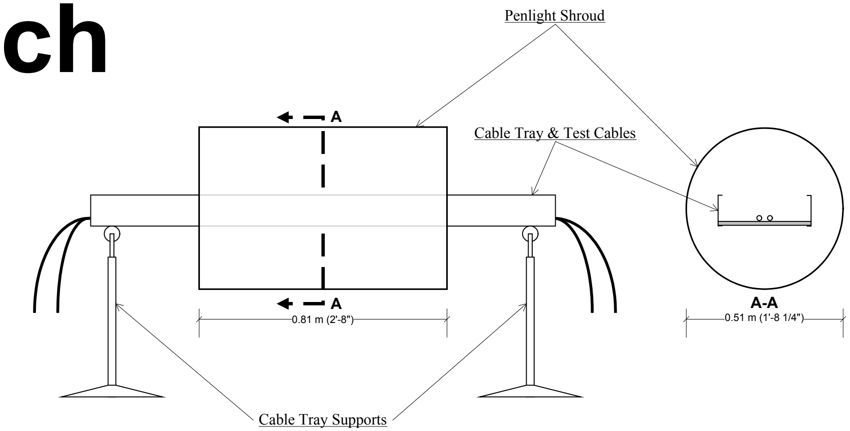
- Lack of data and uncertainties extrapolating alternating current (ac) results to dc circuits
- Numerous safety related systems commonly powered with dc
- Duke testing in 2006 indicated that dc circuits may react differently than ac circuits to fire-induced failures

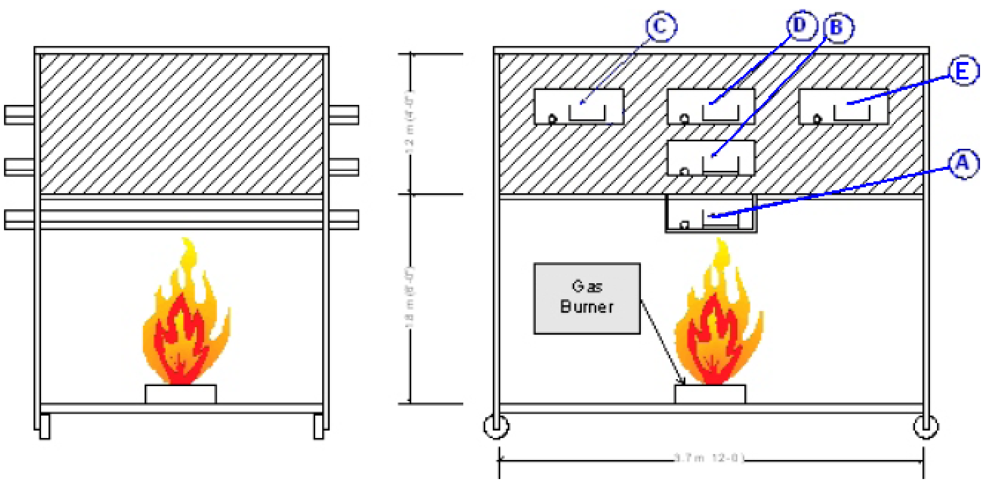
Objectives

- Realistic circuits and configurations
- Inter-cable shorting
- Ground plane interactions
  - stay tuned
- Proper polarity, coincident hot shorting
- PLUS
  - Role of CPTs
  - Kerite cable characterization
- Minus
  - Instrumentation circuits

Approach




Penlight Shroud
A
Cable Tray & Test Cables
A
0.81 m (2'-8")
A-A
0.51 m (1'-8 1/4")
Cable Tray Supports


C
D
B
E
A
Gas
Burner

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Testing Outline

- 59 small scale
- Radiant Thermal Exposure
- 3.7-87.5 kW/m^2 (260-900°C)
- 17 intermediate-scale
- Multiple exposures
  - Flame, plume, HGL
- 200kW
- 7 CAROLFIRE cables, 10 EPRI cables
- 8 surrogate circuits + inter-cable rig + ac MOV

Timeline

- Project Plan developed: 2008
  - Public comment & peer-review
- Testing
  - Small scale: July – November 2009
  - Intermediate: December – March 2010
  - Draft Report: November 2010
    - ADAMS Accession No(ML103230105)
- Final issuance on hold until PIRT review
  - Completed

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Was the delay worth it?

- Several errors were identified regarding the circuit faulting sequence
  - Times reported were not correct
    - Some off by 100 seconds
- Documentation of medium voltage circuit breaker was corrected.
  - Actual internal wiring was reverse of manual specifications
- Final Report issuance expected March 2012
  - NUREG/CR-7100

Circuits tested

- Two dc motor contactor sets
- Two small-pilot solenoid operated valves
- 1-inch solenoid-valve assembly
- Large coil (representative of PORV)
- Medium voltage circuit breaker w/ dc control circuit

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Results

- Energetic Faulting
  - – Open circuits
  - – Pilot to ignition
  - – Aid in flame spread

Results (2)

- Fuse size has influence on failure
  - Larger fuses take longer to clear and can influence hot short duration
  - In some tests 35A fuse did not clear, conductors open circuited

Grounding

- DC battery bank is ungrounded
- Only one battery bank – common power supply
- Consolidation report evaluated concept of multiple shorts to ground causing spurious actuations
  - "Ground equivalent hot short"

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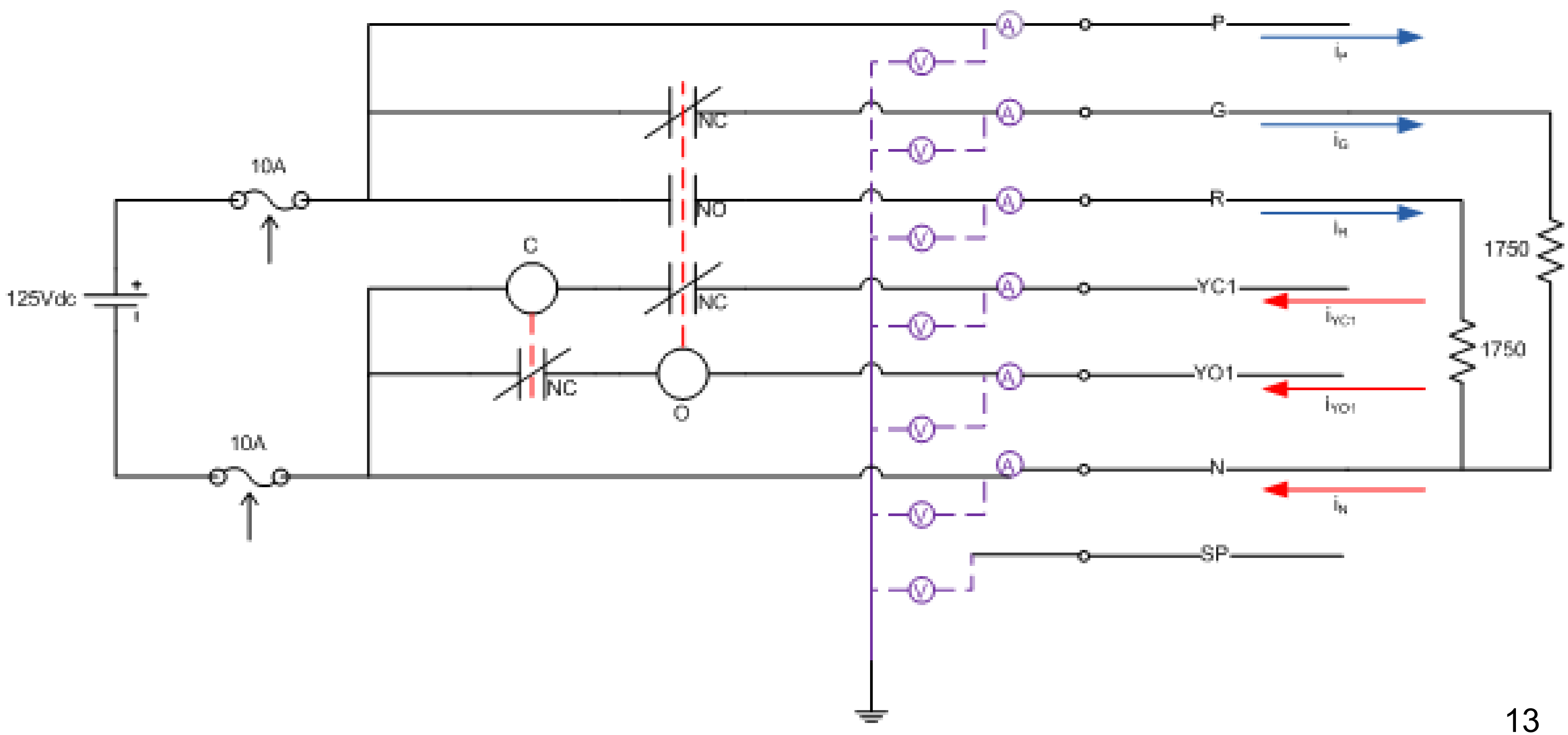
Method to Identify Multiple Hot Shorts

- Kirchhoff's Current Law



Example

Location D: 1-inch vlv
Location B: SwGr-T

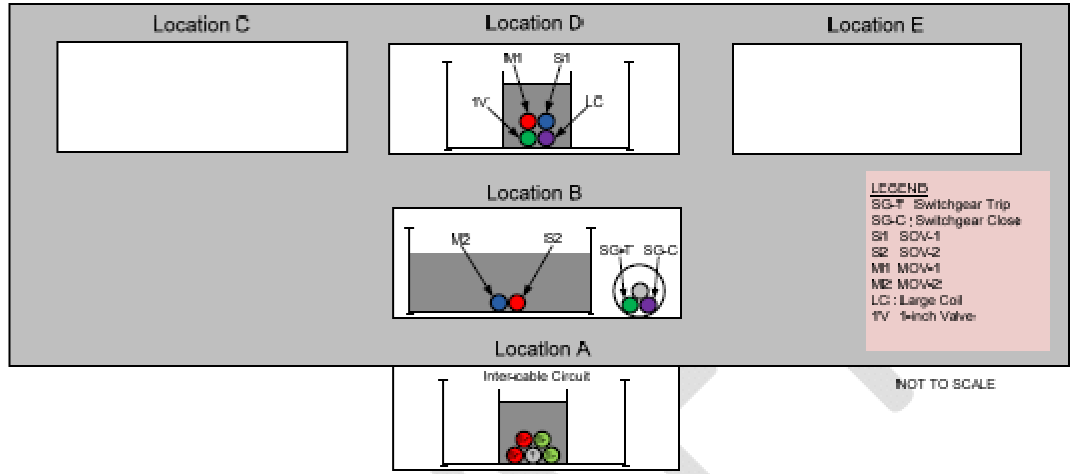


Figure 5-12. Intermediate scale test 3 cable loading

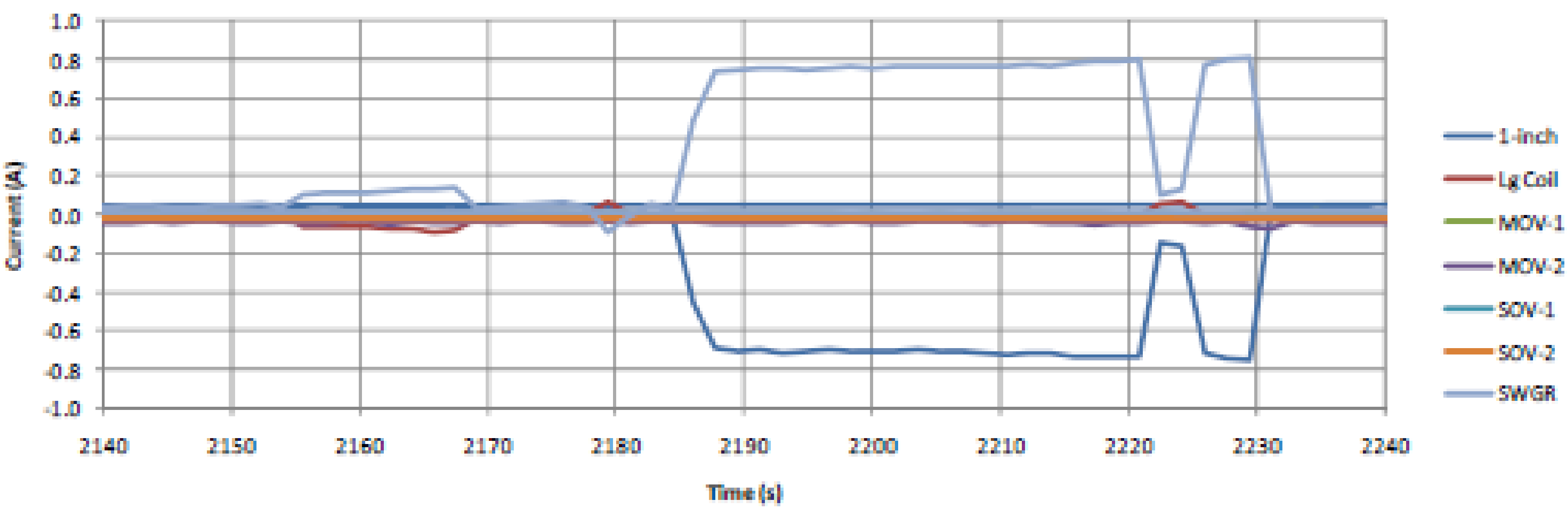


Figure 5-14. Outstanding current shorting in Intermediate Scale Test #3, between 1-inch valve and SwGr-T

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Ground Equivalent Hot Shorts

- Observed in 8 of 12 intermediate scale tests
- Also observed in small-scale penlight tests
- Evolution will be included in Data Consolidation Report

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Summary/Additional Information

- Collaboration with EPRI is valuable
- Multiple shorts to ground can cause spurious actuations for ungrounded circuits with common power supplies
- Ungrounded dc test data was complex to evaluate and extended the report issuance

Kerite Cable Research

Gabriel Taylor
Office of Nuclear Regulatory Research
Fire Research Branch

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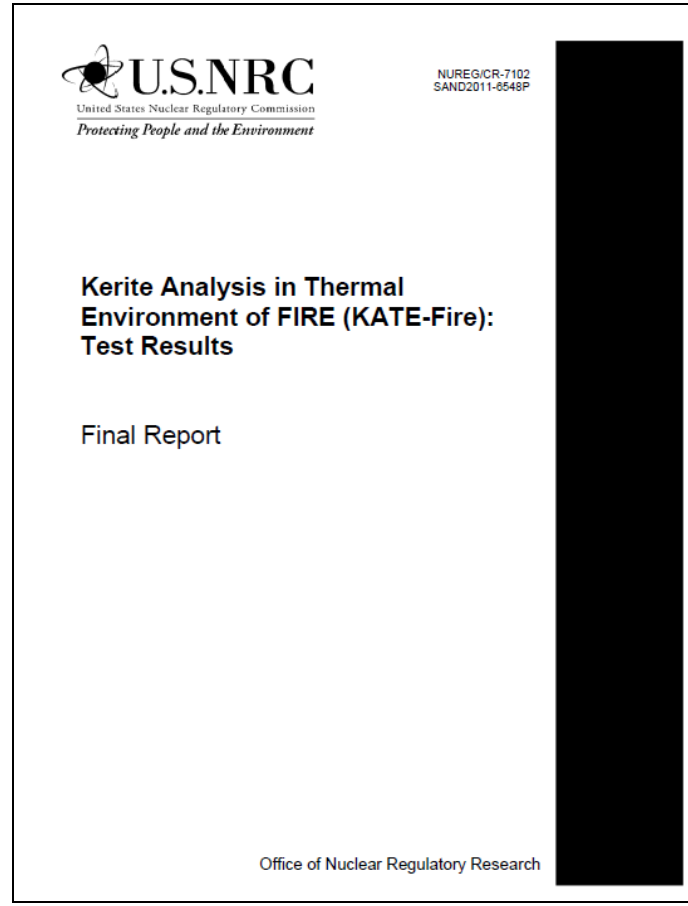
NUREG/CR-7102

- KATE-Fire
  - Kerite Analysis in Thermal Environment of Fire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NUREG/CR-7102
SAND2011-6548P

Kerite Analysis in Thermal Environment of FIRE (KATE-Fire): Test Results

Final Report

Office of Nuclear Regulatory Research

- Kerite electrical functionality testing to determine failure threshold

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Problem Statement

- Kerite-FR is chemically a thermo-set (TS) material
- Typical thermo-set material thermal threshold
  - 330°C (625°F)
- Historical data identify low temperature failures of Kerite-FR
  - Severe Accident Qualification Testing 153-171°C (307-340°F)
  - SCE&G Kaowool Testing 183-329°C (361-624°F)

FAQ 08-0053

- Proposes Kerite should be treated as a Thermoset material
- Several NRC Documents state that Kerite FR should be treated as a Thermoplastic (TP – threshold of 205°C [400°F])
  - NUREG/CR-6850, errata
  - IMC 0308, Attachment 3, Appendix F
  - NUREG-1805

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DESIREE-Fire

- dc circuit testing was in process and could easily be configured to test Kerite-FR cables
- EPRI requested and received numerous cable samples from industry
- Results from DESIREE-FIRE tests alone were inconclusive

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Kerite Testing

- Additional Samples were obtained from industry
- Phenomena causing shorts identified as
  - Conductive liquid
  - Insulation cracking during heat exposure
- All data processed and compiled into NUREG/CR-7102

Kerite Test Cables

- 2/C 10 AWG FR-III/FR & 12 AWG FR/FR
- 3/C 6 AWG HTK/FR
- 4/C 10 AWG FR-III/FR
- 5/C 12 AWG FR/FR
- 7/C 12 AWG FR/FR
- 9/C 14 AWG FR/FR
- 10/C 12 AWG FR/FR & 14 AWG FRII/FR
- 12/C 12 AWG FR-III/FR
- 15/C 12 AWG FR/FR

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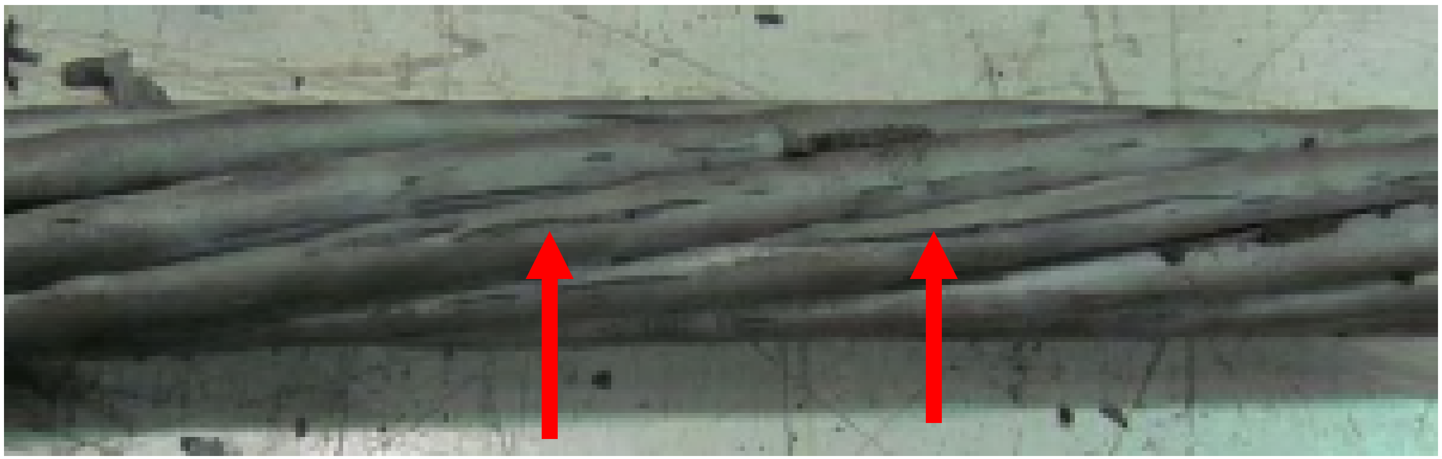
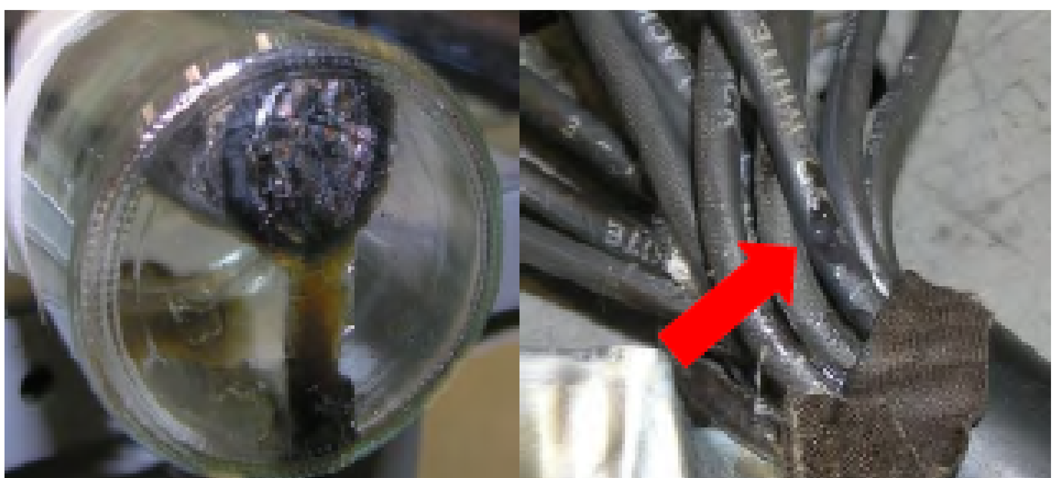
Kerite FR Failure Modes

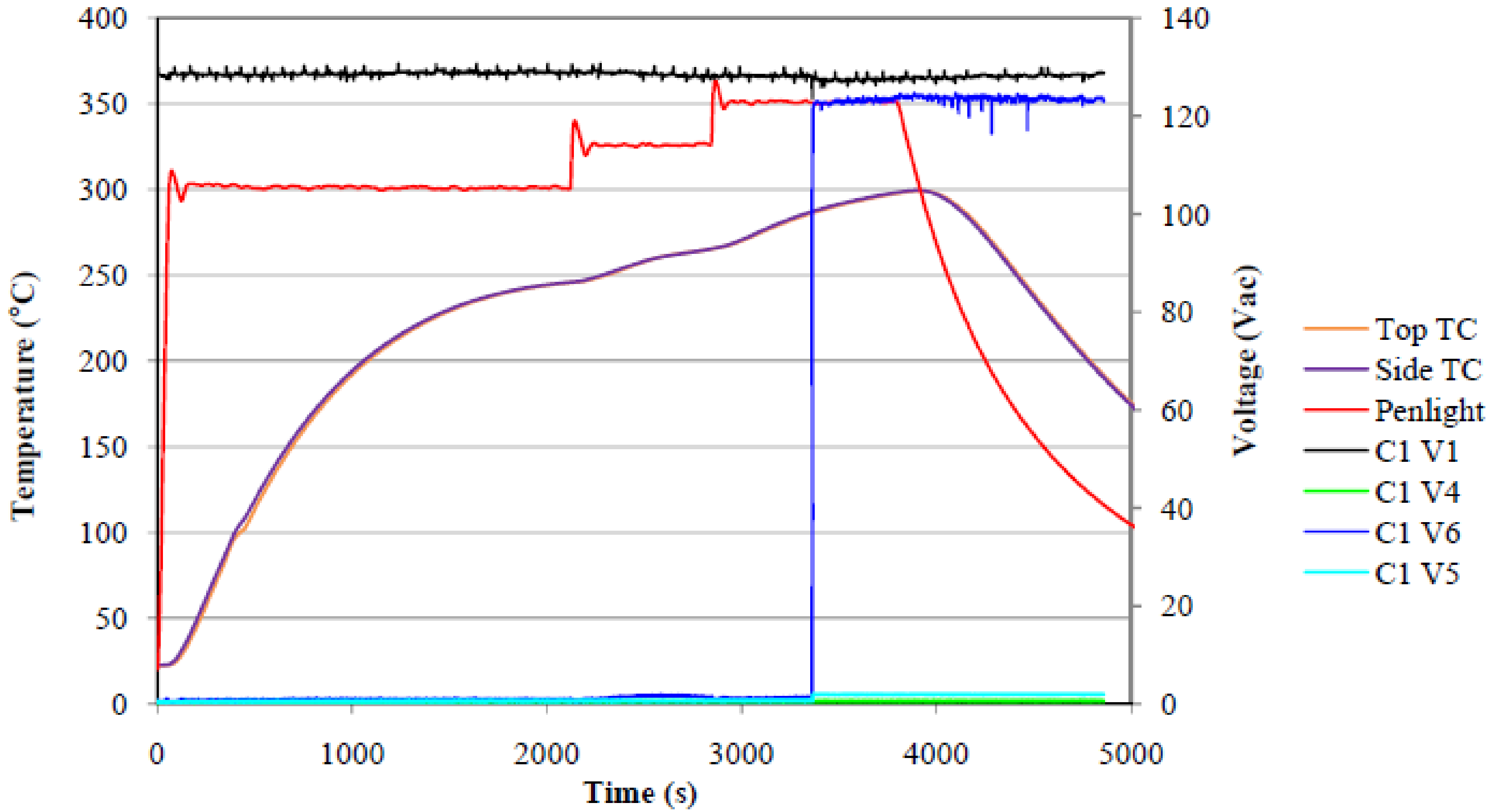
- Early Failures Kerite-FR
  - Early degradation (247-317ºC) (477-603°F)
    - Liquid material
    - Insulation cracking
  - Cable Failure (277-311ºC) (531-592°F)
- Recovery (317ºC upwards) (603°F)
- Outright cable failure >370ºC (698°F)
- Kerite-FR-II, FR-III, & HT >330°C (626°F)

Insulation Cracks & Liquid





Early Degradation Failure Example



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Kerite-FR Report

- NUREG/CR-7102, “KERITE Analysis in Thermal Environment of FIRE (KATE-FIRE)”
- Published December 2011
- NRR developing closure memo for FAQ-08-0053