



U.S. NRC FIRE SAFETY RESEARCH ACTIVITIES

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U.S. Nuclear Regulatory Commission

NRC-RES/FRB
International Workshop on Fire PRA

Garching, Germany, April 28-30, 2014



High Priority Research Projects



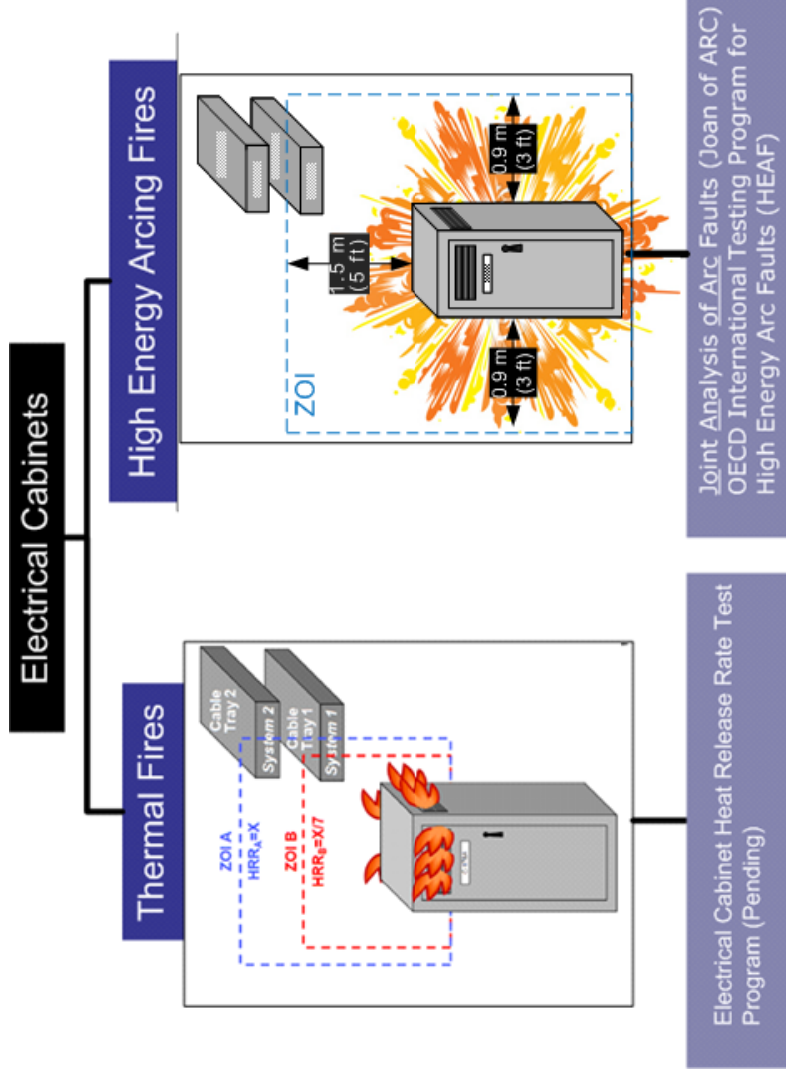
- Electrical Enclosure Heat Release Rate (HRR)
- Joint Analysis of Arc Faults (Joan of ARC) OECD International Testing Program for High Energy Arc Faults (HEAF)
- Very Early Warning Fire Detection Systems (VEWFDS) (Incipient detectors)

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Electrical Enclosures- Failure Modes

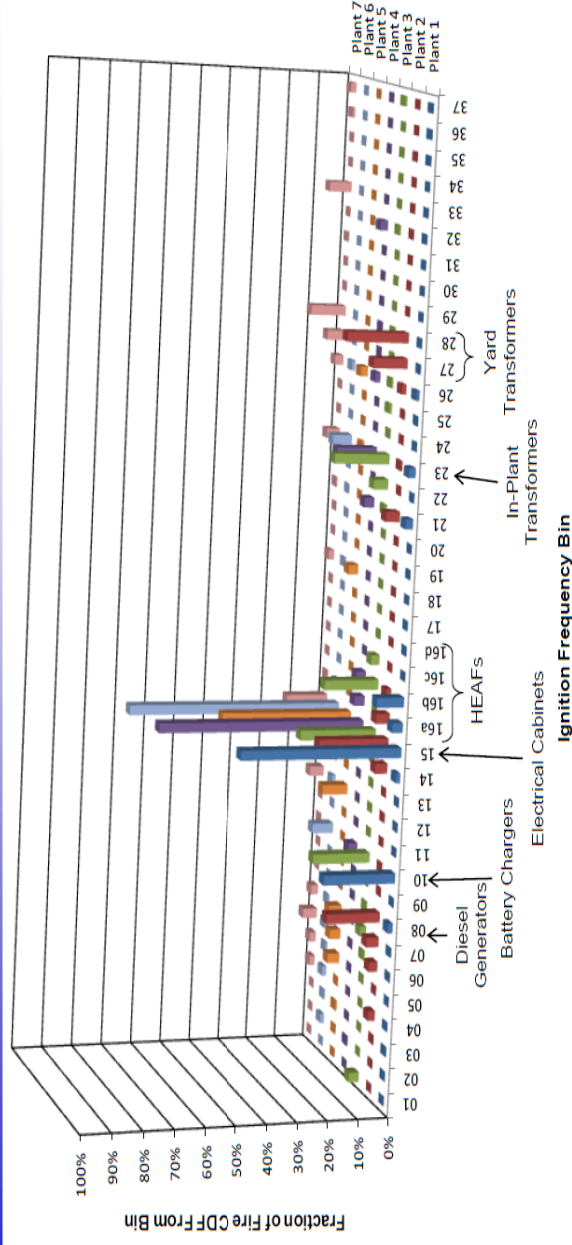


Methodology Challenges Risk driver for PRA analysis



- Presentation by EPRI for the ACRS December 13th 2010

Fire CDF Contribution by Ignition Source



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3



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Current Method

- Table G-1 in NUREG/CR-6850
- HRR for five different categories of electrical enclosures
- Based on selected values of the 75th and 98th percentile fires
- Developed in early 2000's by a panel of experts who considered actual fire events in NPPs and other industrial facilities, along with limited experimental data

Ignition Source	HRR kW		Gamma Distribution	
	75 th	98 th	α	β (kW)
Vertical cabinets with qualified cable, fire limited to one cable bundle	69	211	0.84	59.3
Vertical cabinets with qualified cable, fire in more than one cable bundle	211	702	0.7	216
Vertical cabinets with unqualified cable, fire limited to one cable bundle	90	211	1.6	41.5
Vertical cabinets with unqualified cable, fire in more than one cable bundle closed doors	232	464	2.6	67.8
Vertical cabinets with unqualified cable, fire in more than one cable bundle open doors	232	1002	0.46	386



Electrical Enclosure Testing Objectives



- Testing was performed with the National Institute of Standards and Technology (NIST) at the Naval Research Laboratory Chesapeake Bay Detachment
- Create enhanced categories based on more refined information
 - Combustible Loading
 - Predominant Fuel Type (Control Cabinet Cards, Thermoplastic Cable, etc.)
 - Ventilation Configuration (Forced Ventilation, Natural Ventilation etc.)
- Power
 - Medium voltage switchgear
 - Load centers
 - Motor control centers
 - Power distribution panels
 - Battery chargers
 - Inverters etc.
- Control
 - relay racks
 - reactor protection systems
 - auxiliary control panels
 - instrumentation racks
 - control room bench board panels
 - control room back panels



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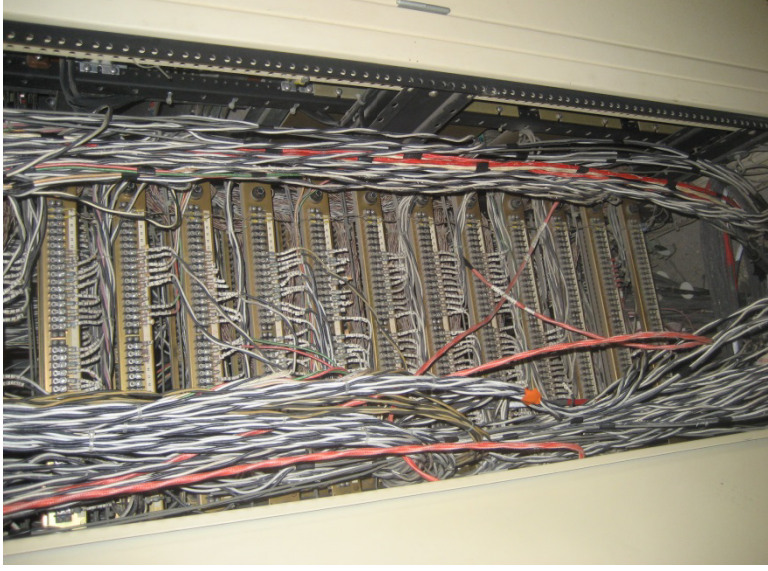
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Electrical Enclosure Combustible Loading



- Plant walkdowns used to create an extensive database loading conditions
- Cabinets will be “mocked up” in order to simulate in plant conditions
- Method will be developed for PRA application



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Cabinet Variations



Protection System Aux Cabinet 1



Front

Back

Protection System Aux Cabinet 2



Front

Back

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Currently Investigating Ignition Mechanisms



- Ignition scenarios consist of various combinations of a propane burner and a small pan of acetone 1kW – 30kW
- Ignition of fires will be done in such a way that fires reach an established burning condition (i.e. self sustaining)
- Acetone used for preheating the enclosures
 - Laboratory space was unheated; Temperatures below Freezing most test days



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EPRI/NRC Methods Panel



- EPRI participate under the NRC-RES/ EPRI Memorandum of Understanding (MOU) collaborative research agreement
- Data obtained from this test series will provided to an expert panel which will evaluate first order impacts on HRR such as;
 - Fuel Load
 - Cabinet binning
 - Ventilation
 - Fire growth rate/profile
 - Fire location within a cabinet
 - Fire propagation to adjacent cabinets
- **Revise Distributions contained in table G-1 of NUREG/CR-6850**

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High Energy Arc Fault (HEAF) Current State-of-the-Art



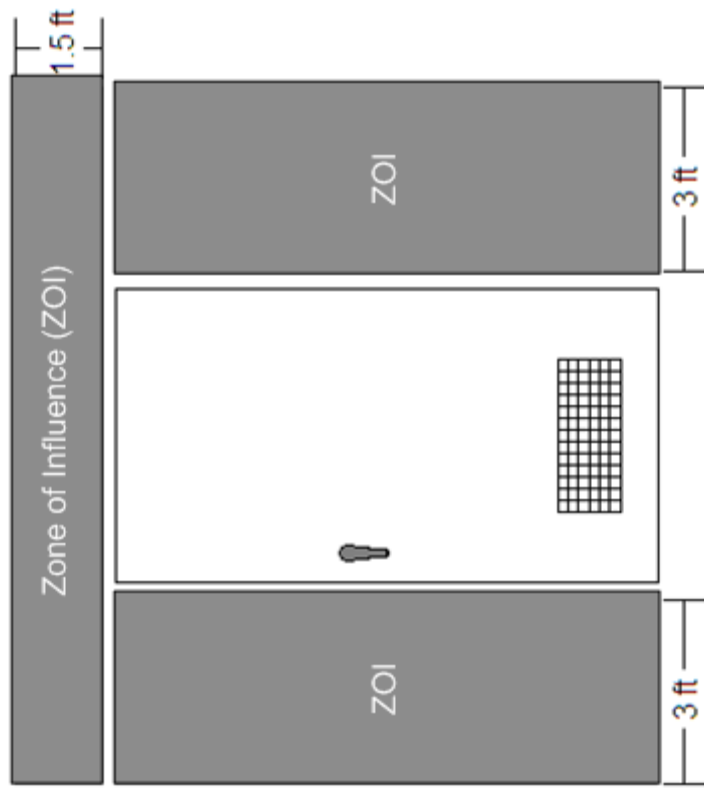
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UNITED STATES NUCLEAR REGULATORY COMMISSION
Protecting People and the Environment

- Same Zone of Influence (ZOI) treatment for all enclosures 480V to 4160V
- Initial arcing fault can cause destructive unrecoverable damage to the faulting device
- Copper ejecta and plasma and/or mechanical shock will cause adjoining/adjacent equipment to trip open
- Assumes next upstream over-current protection device will trip open
 - Robinson 2010 event illustrated the potential for failure of the upstream breaker and extended consequence

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 ZOI
- Components within ZOI are assumed to instantly fail or ignite
- This becomes the input to fire PRA model
- How well do the Robinson and Onagawa events fit this model?



Recent HEAF Events in US NPPs



Waterford 1995



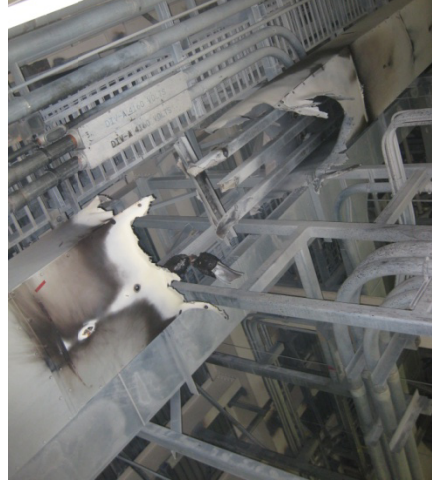
Diablo Canyon 2000



Prairie Island
2001



Robinson 2010



Columbia 2009



SONGS 2001

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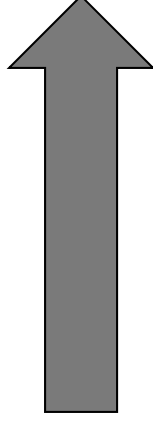
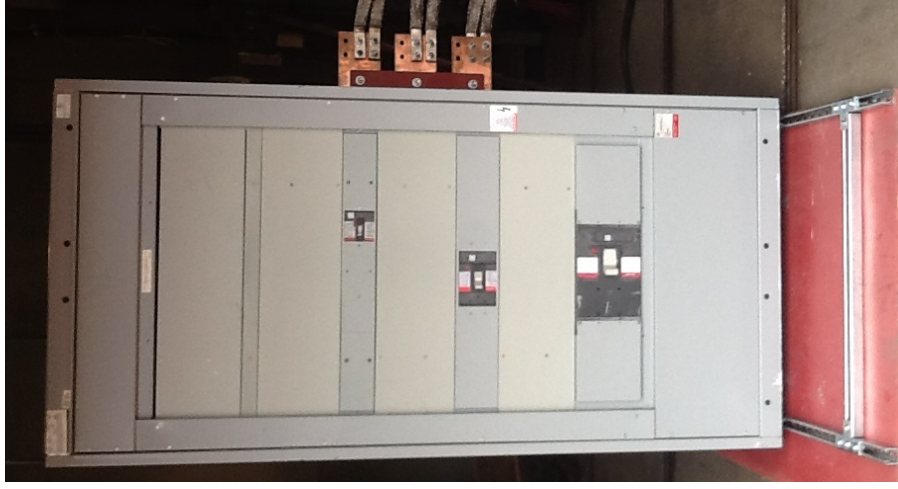
Onagawa, Japan Event March 2011



- Onagawa Event (March 11, 2011)
- 2 HEAFs
 - Seismic Induced HEAF
 - Possibly combustion products
- Multiple sections of Medium Voltage switchgear damaged
- Fire could not be suppressed and was allowed to burn out (~7hrs)
- Led JNES to perform confirmatory testing on HEAF



JNES/SAIC Phase 1 Testing



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JNES Test 1 480V



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JNES Test 2 480V- Plasma Effect



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NRC/OECD Test Plan



- The Organization for Economic Co-operation and Development (OECD)
- Testing will be performed at the KEMA test facility in Chalfont, Pennsylvania, USA
- Evaluate conditions that may influence failure characteristics
- Advance the understanding of physical dynamics of HEAFs and update NUREG/CR-6850, Appendix M (2005)
- Focus on obtaining data and information to improve zone of influence (ZOI) model



Test Parameters



- Relevant Information
 - Voltage
 - Power Level
 - Damage Zone
 - Blast Damage vs. Enduring Fire Damage
 - Event Duration
 - Furthest extent of damage
 - Thermal (i.e. ensuing fire damage / smoke damage)
 - Physical (i.e. thrown cabinet door, shrapnel)



Very Early Warning Fire Detection Systems (VEWFDS) (Incipient detectors)

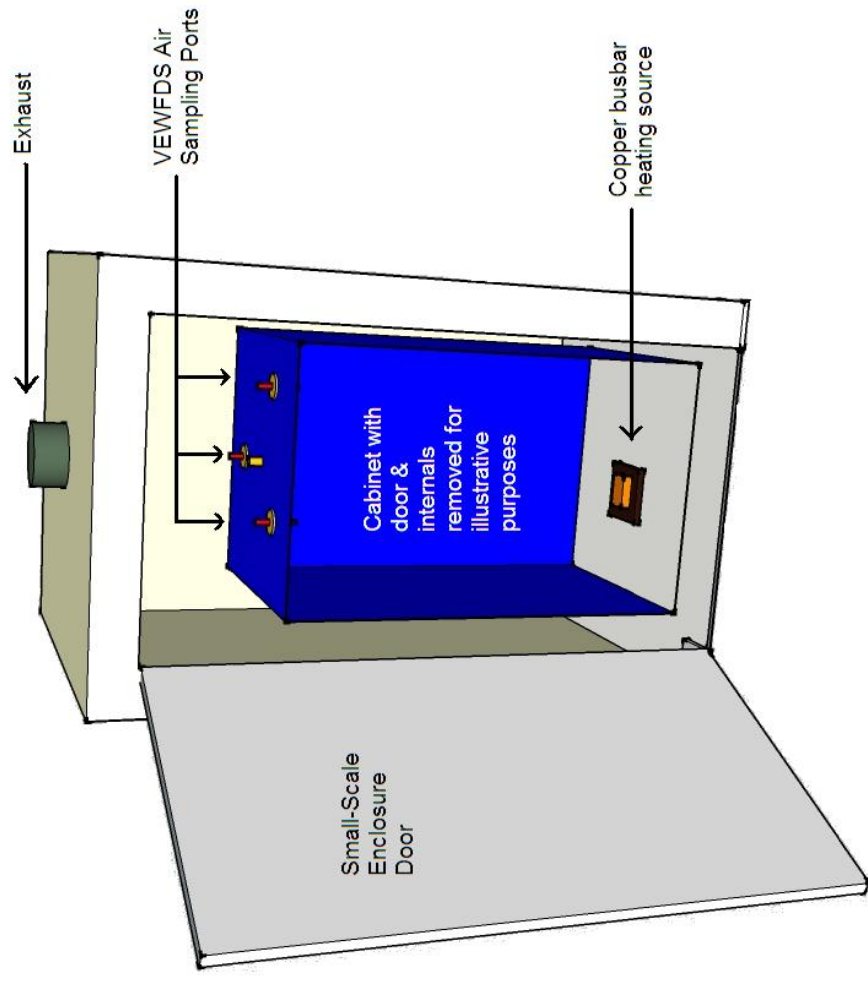


- Literature Review
- Site Visits
- Laboratory Cabinet Experiments
- Room-scale, Single Zone Experiments - Cabinet and Area Wide
- Room-scale, Multi-zone Experiments – Cabinet and Area Wide.



Laboratory Cabinet Experiments

- Experimental design specifies a limited number of materials that are thought to be representative of a range of chemical compositions likely to be some of the first materials producing smoke in incipient fires



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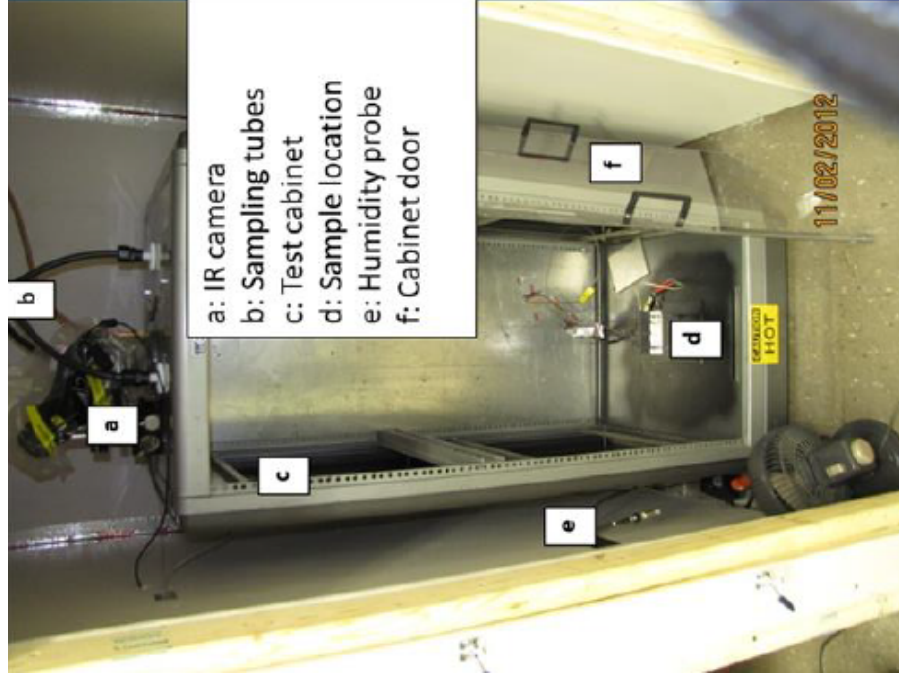
Materials



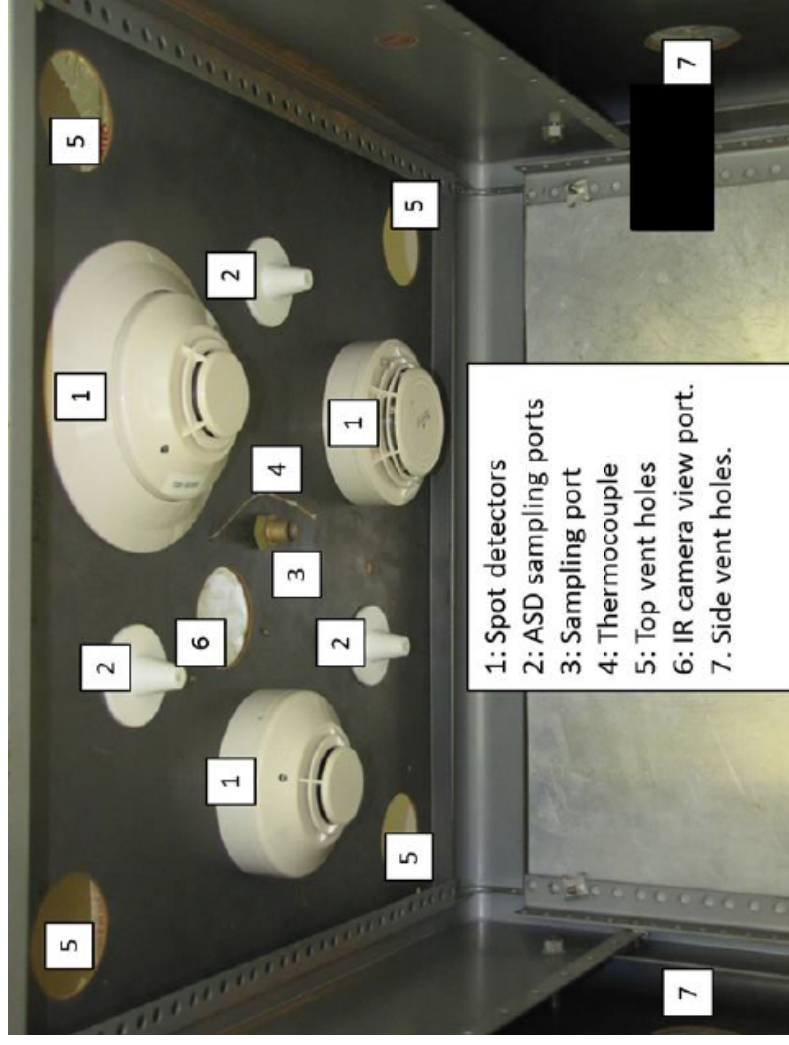
Table 2. Materials	
#	Material Description
1	PTFE wire Polytetrafluoroethylene jacketed and insulated, 7 conductor cable, 14 AWG stranded wire. NPP Cable (ChristiFire2 805)
2	XLPE/XLPO cable Cross-linked polyethylene jacket, cross-linked polyolefin insulated, 7 conductor cable, 12 AWG stranded wire. NPP cable (ChristiFire2 806)
3	XLPE wire Cross-linked polyethylene insulated, 12 AWG, stranded wire. NPP Synthetic Insulated Switchboard (SIS) wire (ChristiFire2 823)
4	XLPO wire Cross-linked polyolefin insulated, 12 AWG, stranded wire
5	CSPE wire Chlorosulfonated Polyethelene insulated, 10 AWG, stranded wire
6	PVC 18 AWG wire Polyvinyl chloride insulated, 18 AWG, stranded wire
7	PVC 14 AWG wire Polyvinyl chloride insulated, 14 AWG, stranded wire
8	Silicone wire Silicone insulated, 18 AWG, stranded lead wire
10	Terminal strip Phenolic barrier terminal block
11	PCB FR4, glass-reinforced epoxy laminate printed circuit board
12	Resistor 12 ohm, ¼ W, carbon film (Fire Industry Association's Code of Practice for Design, Installation, Commissioning and Maintenance of Aspiring Smoke Detector (ASD) Systems.)
13	Capacitor Electrolytic can
14	Shredded paper Cellulosic
15	Heated Wire Test PVC, (BS 6266)



Laboratory Cabinet Experiments



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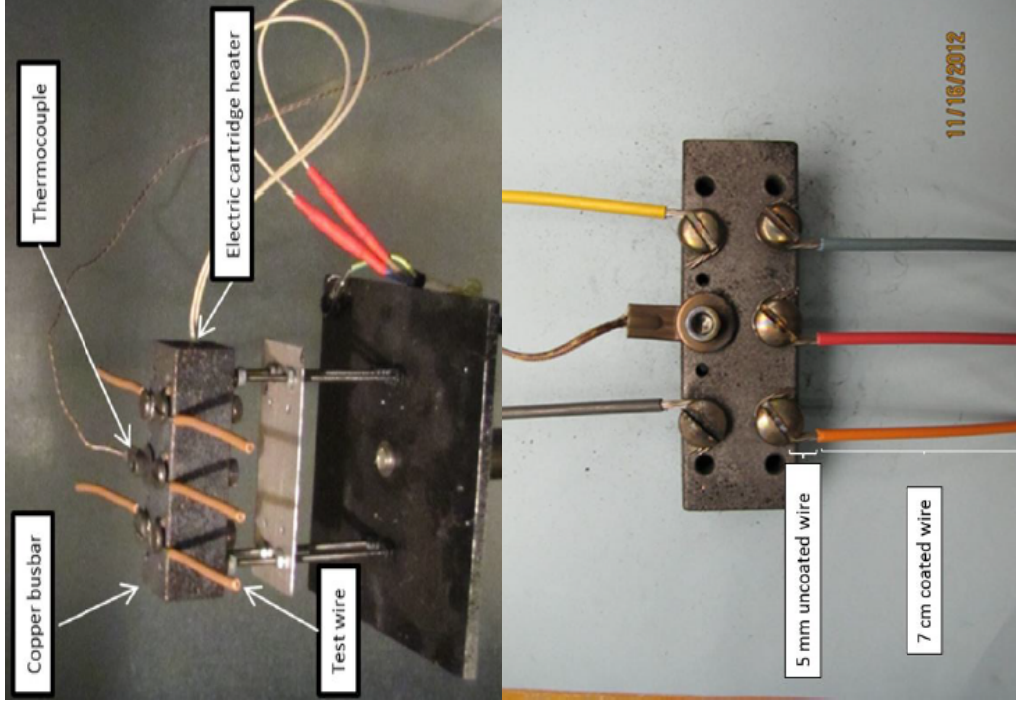


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Incipient Heating Apparatus

- Pan head screws torqued to fixed value
- 500 W cartridge heater, thermocouple used for feedback control

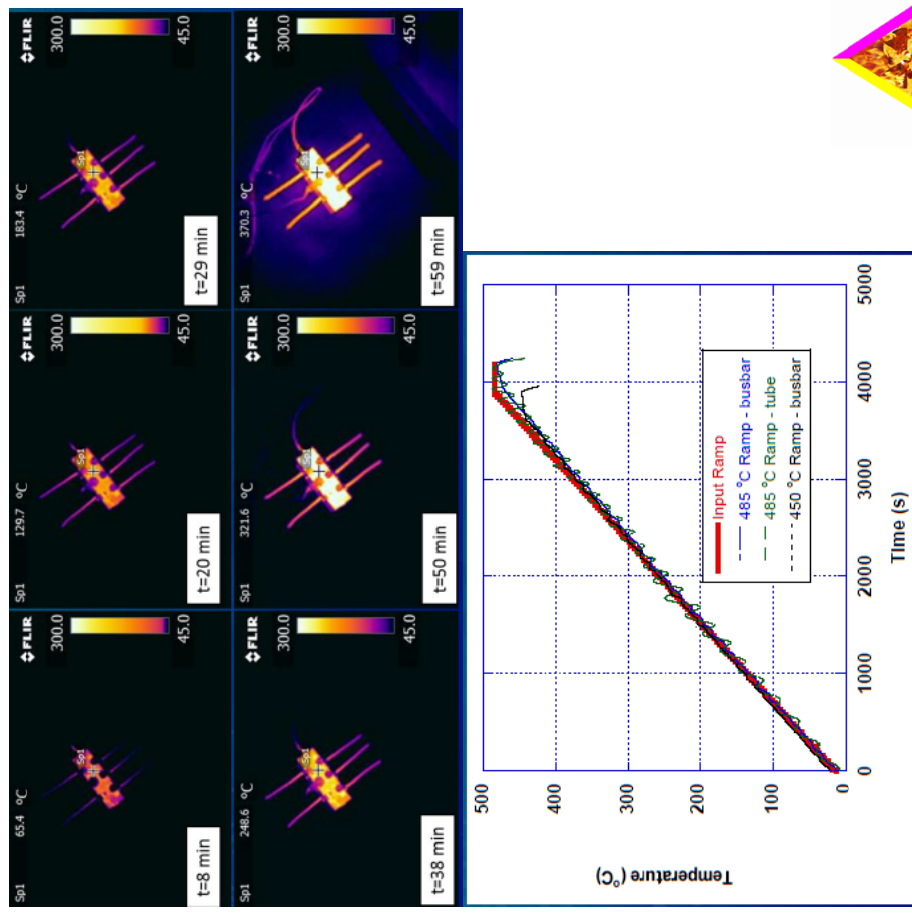


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Heating Profiles

- Heating profiles for 12 gauge XLPE wires at various time steps during the heating process. The temperature of the block can be seen in the top left corner in each image.
- Busbar and Copper Tube Temperatures Following 4 hour Set point Ramp



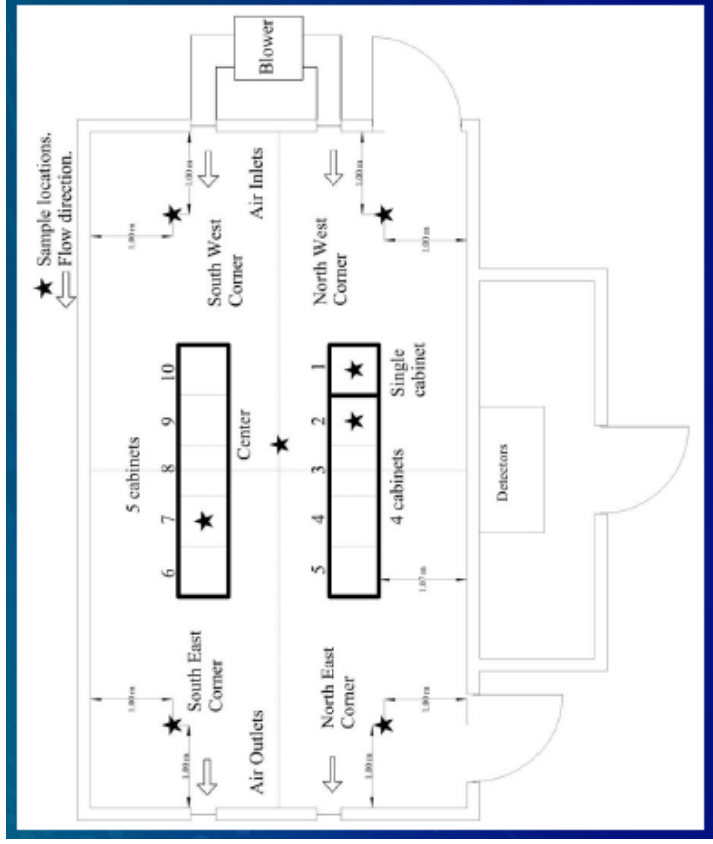
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Single Zone Experiments - Cabinet and Area Wide

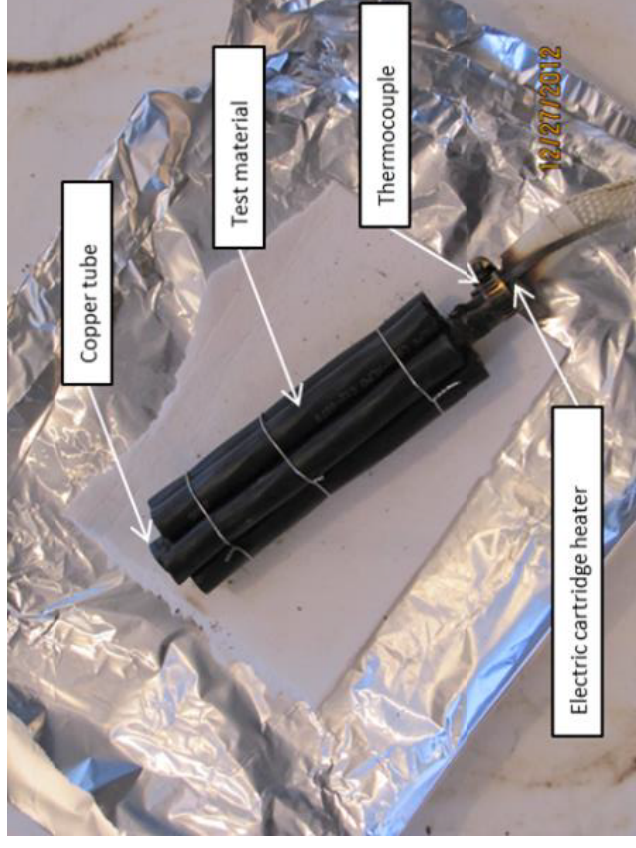


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Area Wide Smoke Source Multi-conductor Cables

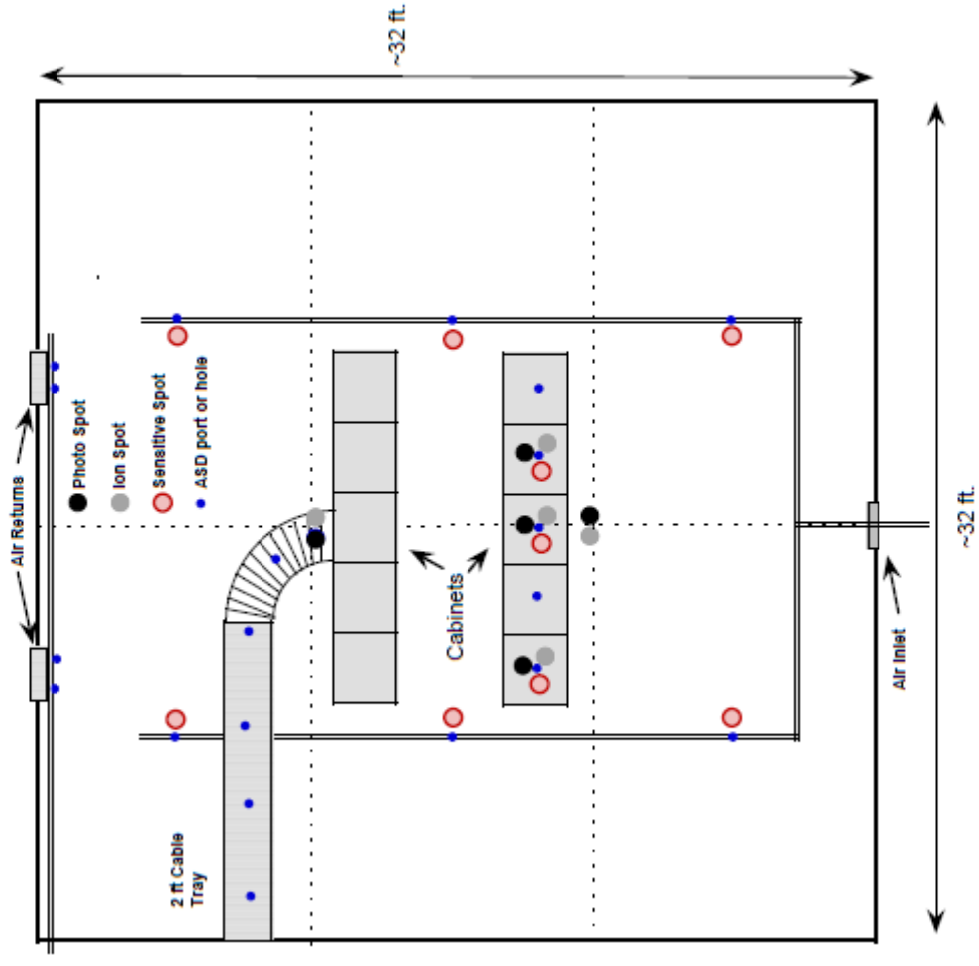


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Multi-zone Experiments – Cabinet and Area Wide



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Thank You!

Questions?

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