Public Meeting to Discuss

# NUREG-2180
# DELORES-VEWFIRE

April 26, 2016 • 9:00 – 5:30

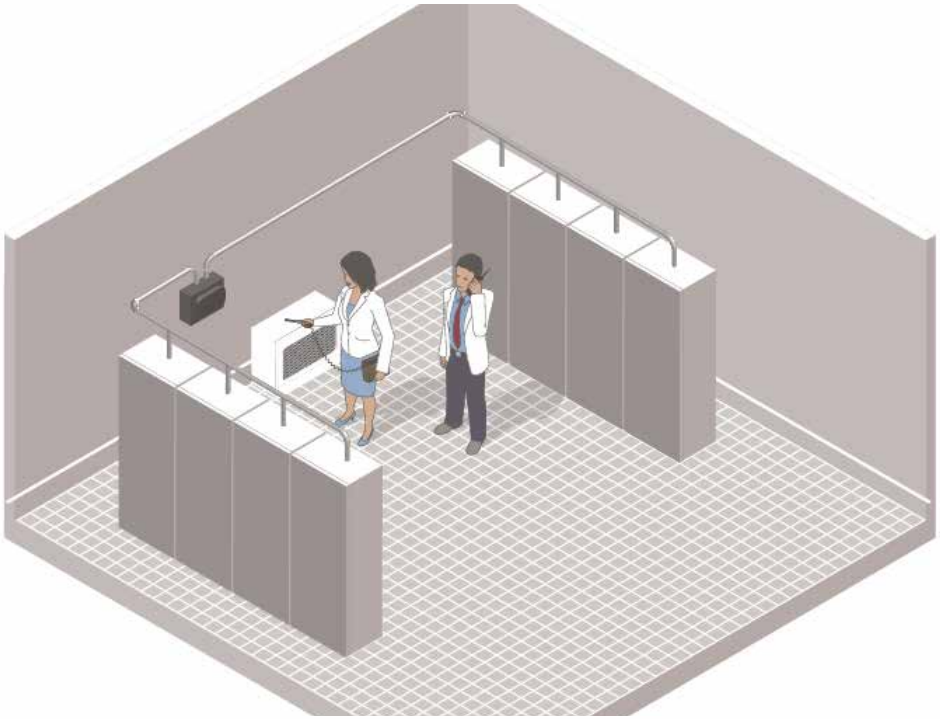
NRC Two White Flint North Auditorium

11545 Rockville Pike, Rockville MD

U.S.NRC
United States Nuclear Regulatory Commission
*Protecting People and the Environment*

# Purpose of Meeting

- Workshop to discuss data, methods, and tools related to very early warning smoke detection systems, NRC expectations, and future data collection needs.



**Category 3**

Public participation is actively sought for this type of meeting to fully engage the public in a discussion of regulatory issues.

# Agenda

| Time | Topic | Speaker | Report Section |
|---|---|---|---|
| 9:00 AM – 9:20 AM | NRC Opening Remarks | NRC/RES | - - - |
| 9:20 AM – 9:40 AM | NRC Overview of Research Project | NRC/RES | 1 |
| 9:40 AM – 10:00 AM | - Operating Experience Review (Data) | NRC/RES | 3 |
| 10:00 AM – 10:10 AM | BREAK | | - - - |
| 10:10 AM – 11:15 AM | - Testing approach and Results (Data) | NIST | 4 & 5 |
| 11:15 AM – 12:00 PM | - Overview of Risk Scoping Study (Method) | NRC/RES | 6 to 13 |
| 12:00 PM – 12:15 PM | Question and Answer Session | | - - - |
| 12:15 PM – 1:00 PM | LUNCH BREAK | | - - - |
| 1:00 PM – 1:55 PM | - Overview of Risk Scoping Study (Continued) | NRC/RES | 6 to 13 |
| 1:55 PM – 2:30 PM | Summary of Public Comments Received and Resolution | NRC/RES | - - - |
| 2:30 PM – 2:45 PM | Question and Answer Session | NRC/RES | - - - |
| 2:45 PM – 2:55 PM | BREAK | | - - - |
| 2:55 PM – 3:30 PM | Workshop on Event Tree Non-Suppression Estimation Spreadsheets (Tool) | NRC/RES | Apx. H |
| 3:30 PM – 4:30 PM | NRC expectation moving forward | NRC/NRR | - - - |
| 4:30 PM – 5:00 PM | Gathering system operating experience to confirm performance. | Industry | Apx. G |
| 5:00 PM – 5:30 PM | Question and Answer Session | | |

# Documents for Todays Meeting

Home > Public Involvement > Conferences and Symposia > **Public Meeting to Discuss Data, Methods, and Tools Related to Very Early Warning Smoke Detection Systems**

## Public Meeting to Discuss Data, Methods, and Tools Related to Very Early Warning Smoke Detection Systems, NRC Expectations, and Future Data Collection Needs

The NRC Office of Nuclear Regulatory Research (RES) will hold a public meeting to discuss data, methods, and tools developed in support of NUREG-2180, "Determining the Effectiveness, Limitations, and Operator Response for Very Early Warning Fire Detection Systems in Nuclear Facilities (DELORES_VEWFIRE)". Changes to the draft report, NRC's expectations on use, and future needs for data collection will also be discussed at this meeting.

*This page includes links to files in non-HTML format. See Plugins, Viewers, and Other Tools for more information.*

| | | |
|---|---|---|
| **Meeting Date:** | April 26, 2016 | |
| **Time:** | 9:00 AM to 5:30 PM | |
| **Location:** | NRC Two White Flint North Auditorium<br>11545 Rockville Pike<br>Rockville, MD | |
| **Category:** | This is a Category 3 meeting | |
| Please register if you plan to attend | | |
| **Contact:** | **Primary:**<br>Gabriel Taylor<br>301-415-0781<br>Gabriel.Taylor@nrc.gov | Kendra Wright<br>301-415-2403 |

**RELATED INFORMATION**

- Register
- Download Draft Report
- NUREG 2180 Event Tree Spreadsheet for In-Cabinet Fire Detection
- NUREG 2180 Event Tree Spreadsheet for Area-wide Fire Detection

# Welcome

Mark Henry Salley, P.E.
Branch Chief, Fire Research Branch
Division of Risk Analysis
Office Of Nuclear Regulatory Research

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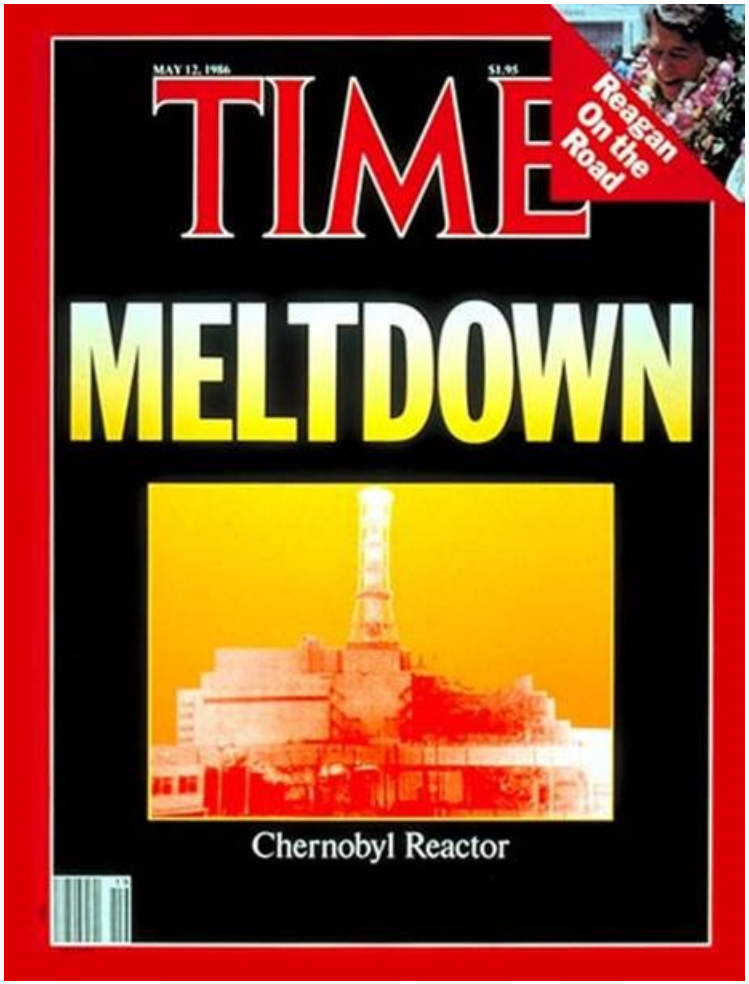
# This day in history




- 30 years ago one of the worst nuclear accidents occurred at Chernobyl Unit 4.

# NRC Commitment to Safety

- Fire Protection Regulations
  - Title 10 of the Code of Federal Regulations Part 50
    - General Design Criteria 3
    - Section 48
    - Appendix R
- National Fire Protection Association (NFPA) Standard 805, “Performance-Based Standard for Fire Protection for Light Water Reactor Electric Generating Plants,” 2001 Edition.

# Defense-in-Depth

- All fire protection programs at U.S. NPP are based on the concept of defense-in-depth
  - Appendix R and NFPA 805
  - Ensures both the probability and consequences of fires and explosions are minimized
- Three Echelons of Fire Protection Defense-in-Defense
  1. Prevent fires from starting
  2. Rapidly detect and suppress fire that do occur
  3. Design safety systems to ensure essential safety functions can be performed
- VEWFD System
  - Are the VEWFD Systems Fire Detection or Fire Prevention?
  - For this presentation VEWFD will be used interchangeable with “incipient fire detection”

# Research Project

- Operating Experience
- Site Visits
- Discussion with Vendor
- Discussion with EPRI
- Testing with NIST
- Probabilistic Risk Assessment (PRA)
- Human Factors
- Human Reliability Analysis (HRA)
- Communications
  - Draft Report for Public Comment
  - Presentations at Industry Forums
  - Todays meeting

# Introductions

- NUREG-2180 Research Team
  - Gabriel Taylor, P.E. – Project Manager (NRC/RES/FRB)
  - Nicholas Melly – Fire PRA (NRC/RES/FRB)
  - Dr. Amy D'Agostino – Human Factors (NRC/RES/HFRB)
  - Dr. Susan Cooper – Human Reliability Analysis (NRC/RES/HFRB)
  - Tom Cleary – Testing (NIST)
- Attendees
  - Introductions

# NRC Overview of Research Project

Gabriel Taylor

Office of Nuclear Regulatory Research

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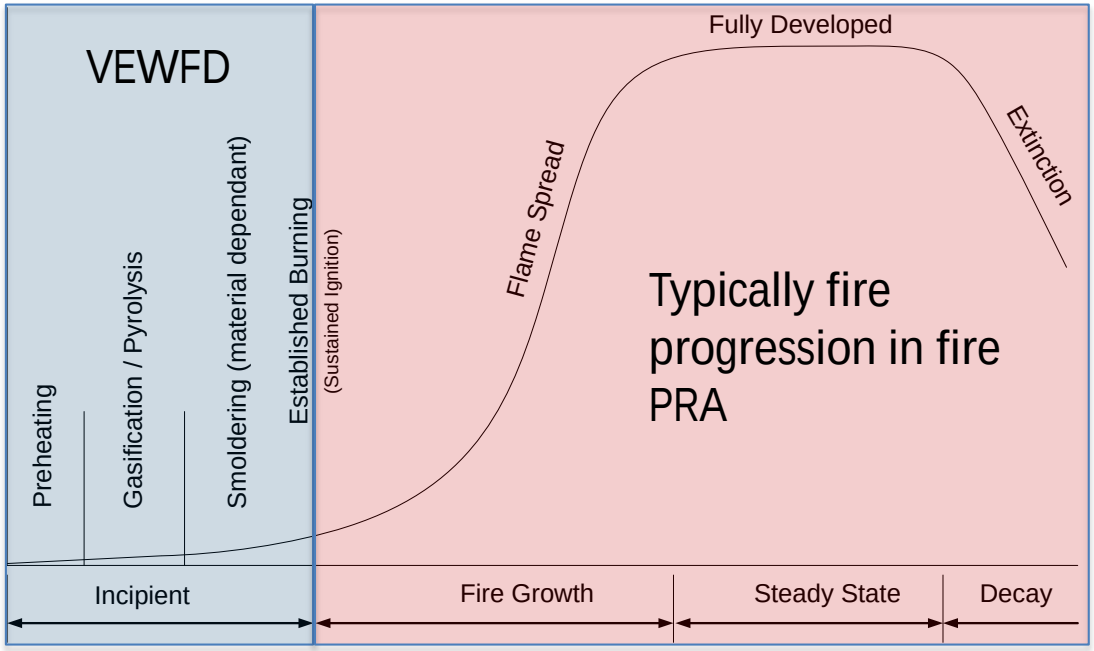
# Why VEWFD?

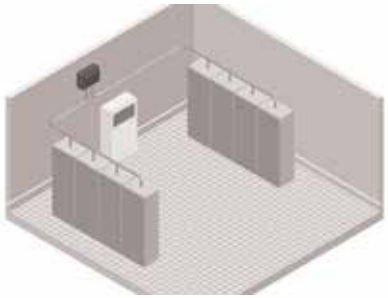
- Electrical enclosure fires "typically" do not rapidly ignite, but rather involve a slow component degradation phase
- VEWFD systems can be engineered to be more sensitive than conventional spot-type detection systems




- VEWFD systems refer to aspirated smoke detection (ASD) systems configured to meet NFPA 76 specifications.
- Added time for operator response = reduced risk
- These systems have been used before in IPEEE & exemptions

# What is a VEWFD system?

- As defined in NFPA 76
  - VEWFD systems : systems that detect low-energy fires before the fire conditions threaten telecommunications service.



To be considered a VEWFD system Section 8.5 “Fire Detection” specifies,

- sensor / port installation
- minimum sensitivity settings
- maximum transport times

# Overview of Research Project

- Need
  - Lack of data to support intended applications
    - National Fire Protection Association (NFPA) Std 805, Frequently Asked Question (FAQ) 08-0046, "Incipient Fire Detection Systems"
- Purpose
  - Evaluate and quantify the characteristics and benefits of very early warning fire detection (VEWFD) systems

# Project Objectives

A. To evaluate the effectiveness of smoke detection systems
   - This includes an evaluation of in-cabinet and area-wide applications.

B. To compare the performance of common smoke detection systems currently used in nuclear power plants (NPPs) to VEWFD systems

C. To evaluate the response and effectiveness of equipment used to locate a pre-fire source(s) through the use of human reliability analysis (HRA)

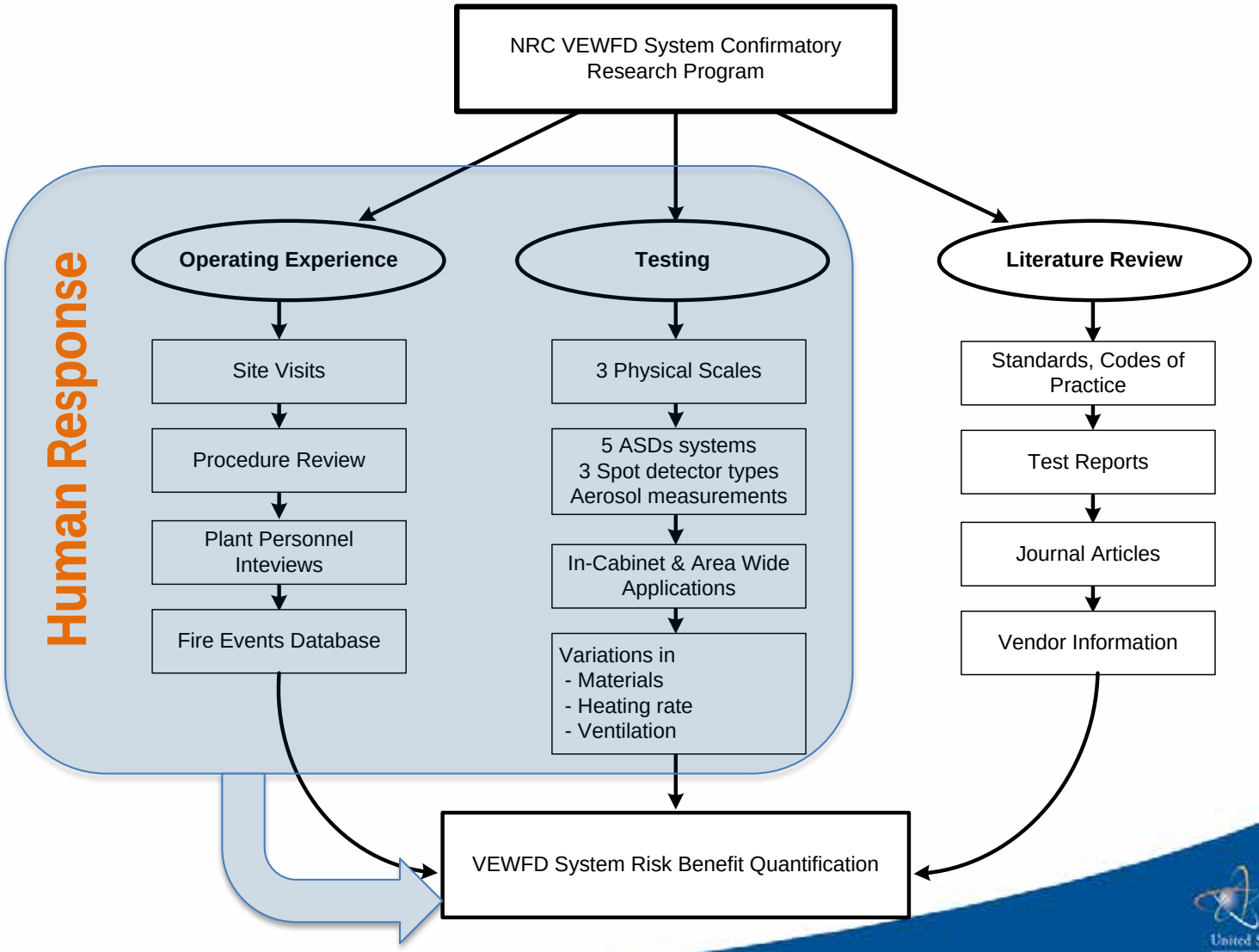
D. To evaluate ASD availability and reliability

E. To evaluate smoke detection system response to common products of combustion applicable to NPPs

F. To evaluate electrical cabinet layout and design effect on smoke detection system response

G. To evaluate the performance of smoke detection technologies in various applications, including in-cabinet and area-wide
   - The evaluation should support fire PRA applications and provide a technical basis and approach for updating the interim approach described in FAQ 08-0046, “Incipient Fire Detection Systems.”

# General Approach



# Report Structure

- Front Matter
  - Abstract, Table of Contents, Executive Summary
  - §1 Introduction
- Part I : Knowledge Base
- Part II : Risk Scoping Study
- Part III : Conclusions and Perspectives
- Appendices : A - H

# Part I : Knowledge Base

- Part I : Knowledge Base
  - §2 Fundamentals of Smoke Detection
  - §3 Operating Experience, Standards, Literature
  - §4 Experimental Approach
  - §5 Experimental Results

# Part II : Risk Scoping Study

- §6 Overview of Quantification Approach
- §7 Parameter Estimation Based on Part I
- §8 Timing Analysis
- §9 Human Factors Analysis
- §10 Human Reliability Analysis
- §11 Fire Suppression
- §12 Quantification of Smoke Detection Performance
- §13 Assumptions & Limitations

# Part III : Conclusions

- §14 Summary and Conclusions
- §15 Recommendations for Future Research
- §16 Definitions
- §17 References

# Appendices

- A : Viewgraphs from meeting with ASD Vendors
- B : Supporting Experimental Data
- C : Supporting information for human performance evaluation
- D : Evaluation of operating experience data
- E : Literature Review
- F : Quick Reference for parameters used in risk scoping study
- G : VEWFD system data collection
- H : User Guide for VEWFD event tree tool

# Operating Experience Review

Gabriel Taylor

Office of Nuclear Regulatory Research

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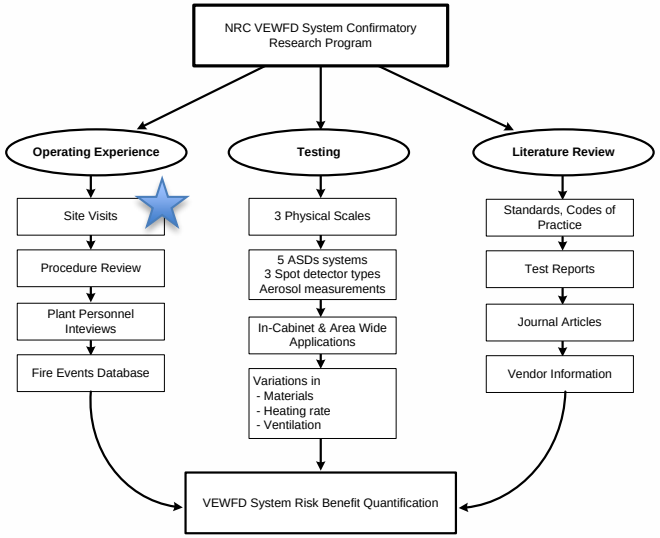
# Site Visits



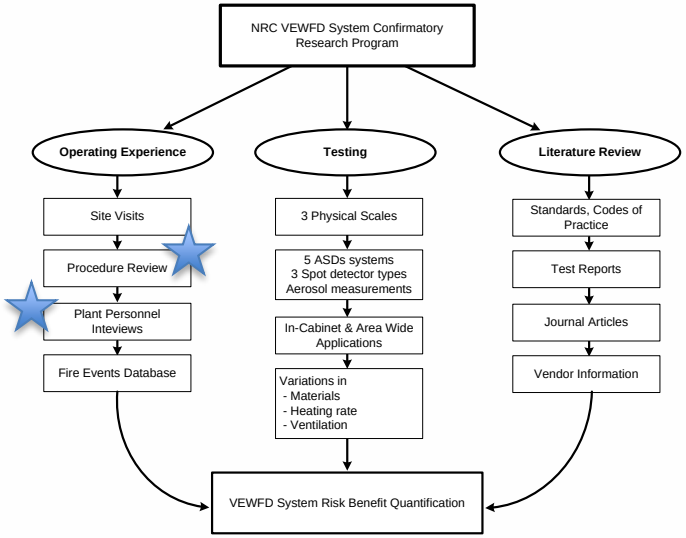

- US Nuclear
  - TMI, Robinson, Harris (x2)
- Non-US Nuclear
  - Bruce, Pickering, Darlington
    - Via Canadian Nuclear Safety Commission
- Non-Nuclear
  - NASA Goddard Space and Flight Center

# Inspection, Testing, and Maintenance

- Required to ensure expected performance
- USA
  - System start-up testing needs to be improved and consistent among vendors
  - Systems were partially unavailable for >1 year due to improper system installation and start-up (not all sampling ports were open)
- Canada
  - Systems require more frequent maintenance than originally expected as communicated from the vendor
  - New maintenance procedures had to be developed
  - As-designed vs as-built will affect performance
- European Standard
  - Requires higher tolerance on air flow reduction 30% vs 50%

# Procedure Review and Questionnaire

- EPRI facilitated information collection for sites using or planning to use VEWFD systems
- Focus on operator response and techniques used to locate incipient source



# EPRI Fire Events Database

- EPRI 1025284
  - "The Updated  Fire Events Database: Description of Content and Fire Event Classification Guidance"
  - Reviewed 267 events associated with electrical cabinet fires (Bin 15)
    - 70 events are classified as being important to risk
    - 197 events are classified as non-challenging and do not contribute to fire frequency estimates.
- More on this later

# Additional Operating Experience

- Navy
  - Communication with Naval Sea Systems Command Engineer indicated to no known US Navy ship employment of ASD system.
  - However, future ship designs are expected to use ASD systems in a limited number of special applications.

# Telecommunications

- Industry that developed NFPA 76, “Standard for the Fire Protection of Telecommunications Facilities.”
- Some telecommunication sponsored testing is publically available.
  - included in Literature Review
- Operating experience is considered proprietary.

# Testing Approach
# &
# Results

Thomas Cleary
National Institute of Standards and Technology

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# Outline

- Experimental Design Scope
- Smoke Source Development
- Experimental Configurations and Results
  - Laboratory Scale
  - Small Room Full Scale
  - Large Room Full Scale
- Evaluation of Test Results

# Experimental Design

- Incipient Smoke Source
  - Multiple materials, three heating ramps
- Multiple Detectors Examined
  - VEWFD ~ nominal 0.2 %/ft obsc.
    - Air Sampling Detectors (3 vendors, 5 models)
    - Sensitive spot laser photodetector (1 vendor)
  - Conventional ~ 1-2%/ft obsc.
    - Ionization and Photoelectric detectors
- Multiple test scales
  - 4 cabinet sizes
  - 2 room sizes
- Variations
  - Ventilation, smoke source location

| Test Series | Cabinet Dimensions |
|---|---|
| Laboratory Scale – small | 0.56 m by 0.61 m by 1.32 m tall |
| Laboratory Scale – large | 0.61 m by 0.61 m by 2.13 m tall |
| Small Room | 0.61 m by 0.61 m by 1.78 m tall<br>Single, 4- and 5-cabinet banks |
| Large Room | 0.74 m by 0.91 m by 2.11 m tall<br>Single and 3-cabinet banks |

# Materials Tested

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. For example, materials like XLPE, PCV and CSPE identified as in wide usage in NPPs (IAEA-TECDOC-1188)

| ID # | Name | Description of Material* |
|---|---|---|
| 1 | PVC wire (1) | Polyvinyl chloride insulated, 18 AWG wire, RoHS lead-free |
| 2 | PVC wire (2) | Polyvinyl chloride insulated, 14 AWG wire, RoHS lead-free |
| 3 | Silicone wire | Silicone insulated , 18 AWG wire, RoHS lead-free |
| 4 | PTFE wire | Polytetrafluoroethylene insulated, 14 AWG wire, lead free |
| 5 | XLPO wire (1) | Cross-linked polyolefin insulated, 12 AWG wire, lead free |
| 6 | XLPO wire (2) | Cross-linked polyolefin insulated, 12 AWG wire, lead free |
| 7 | XLPE wire | Cross-linked polyethylene insulated, 12 AWG wire, lead free (Synthetic Insulated Switchboard, SIS wire) |
| 8 | CSPE wire | Chlorosulfonated polyethylene insulated, 10 AWG wire , lead free |
| 9 | Epoxy PCB | FR4, glass-reinforced epoxy laminate circuit board |
| 10 | Phenolic TB | Phenolic barrier terminal block |
| 11 | Cable | NPP cable XLPE jacket, XLPO insulation 7 wire, 12 AWG wire |
| 12 | Resistor | 12 ohm, ¼ W, carbon film resistor |
| 13 | Capacitor | Small electrolytic can type |
| 14 | BS 6266 Wire | PVC, BS 6266 test wire |
| 15 | Shredded Paper | Copy paper run through paper shredder, ignited with a smouldering wick |

# Detector Technology

- Conventional Spot-Type Smoke Detectors
  - Ionization (ION)
  - Photoelectric, light scattering (PHOTO)
  - Laser photoelectric (sensitive spot, SS)
- Aspirated Smoke Detectors (ASD)
  - Cloud chamber (ASD2,ASD4)
  - Light scattering (ASD1, ASD3, ASD5)

# Detector Sensitivity

## Small scale laboratory tests

| Sensitivity Setting | ASD1 Detector / Port %/ft Obsc | ASD2 Detector / Port Particles/cm$^3$ | ASD3 Detector / Port %/ft Obsc | SS %/ft Obsc | ION %/ft Obsc | PHOTO %/ft Obsc |
|---|---|---|---|---|---|---|
| VEWFDS Pre-alert | 0.013 / 0.05 | $5.1x10^5$ / $2.0x10^6$ | 0.025 / 0.10 | - | - | - |
| VEWFDS Alert | 0.05 / 0.20 | $1.2x10^6$ / $4.8x10^6$ | 0.05 / 0.20 | 0.20 | - | - |
| VEWFDS Alarm | 0.25 / 1.00 | $1.5x10^6$ / $6.0x10^6$ | 0.25 / 1.00 | 1.00 | - | - |
| Conventional Pre-Alarm | - | - | - | - | 0.5 | 1.3 |
| Conventional Alarm | - | - | - | - | 1.0 | 2.1 |

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# Smoke Source

- Electrical fires are often preceded by some form of arcing or joule heating of electrical components where heat is typically conducted from a metallic electrical conductor to an insulating polymeric material.

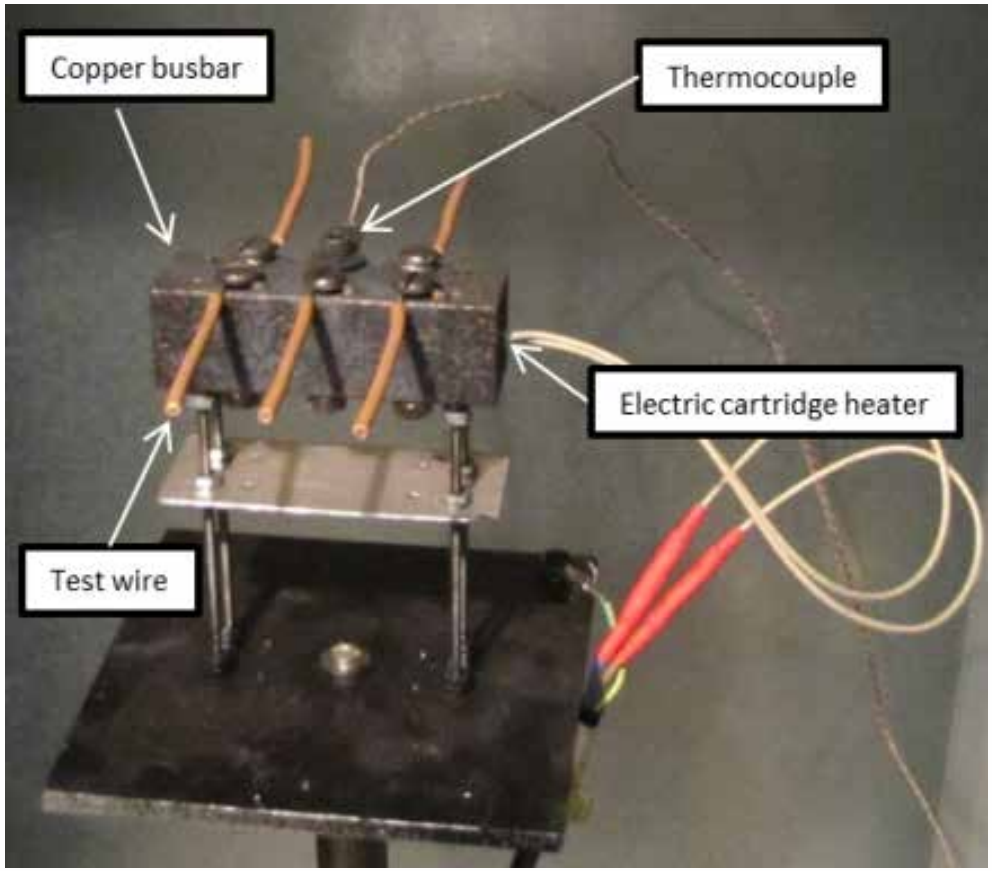
- Upon heating, insulating polymeric materials degrade, and pyrolysis products can condense into smoke particles, which in sufficient concentration can be detected.

- In order to assess the performance of VEWFDS, smoke sources were developed that mimic slow overheat conditions that degrade polymeric insulating materials and produce smoke prior to flaming combustion.

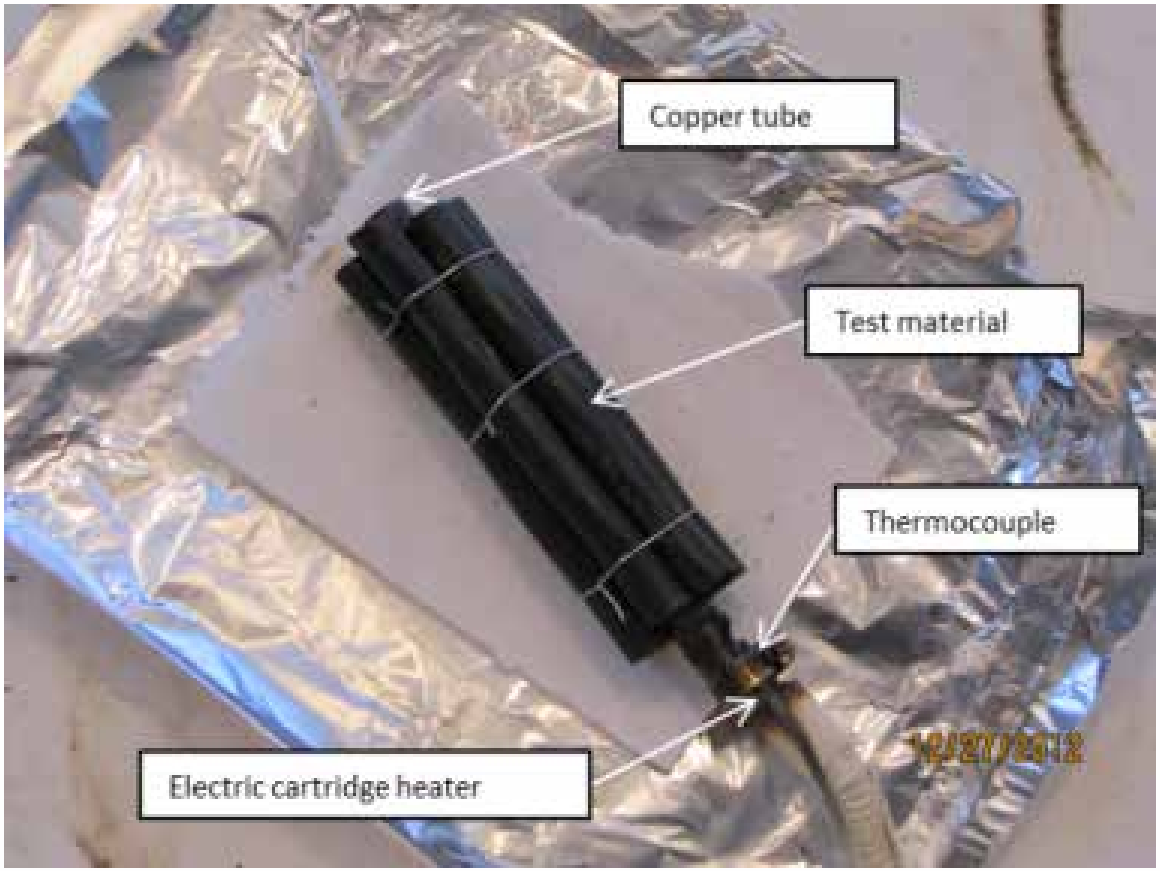
# Incipient Smoke Sources

- 500 Watt cylindrical electric cartridge heater inside copper bus bar block, or tube
- Smoke source materials attached to block or tube
- Control of block external surface temperature over the heating ramp period (HRP) profile
- Three HRPs selected: 15-minutes, 1-hr, 4-hr
- Block or tube temperature raises source materials to piloted ignition temperatures. No pilot source present in test. No material flaming in any experiments

# Incipient Smoke Source



# Incipient Smoke Source



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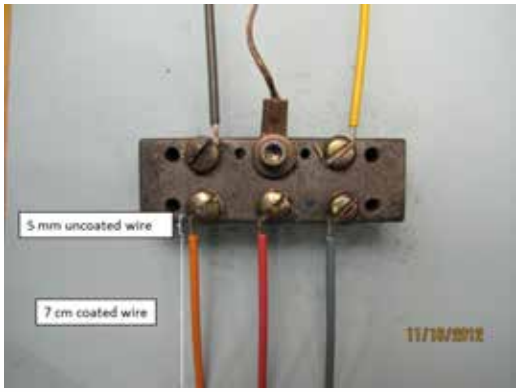
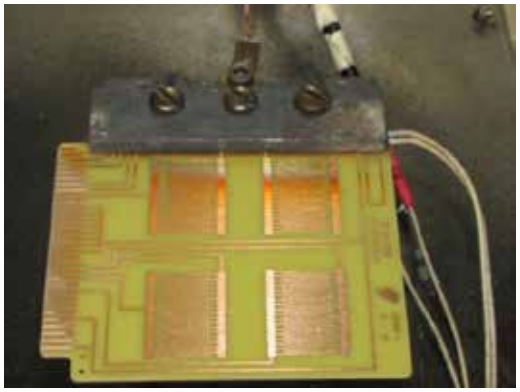
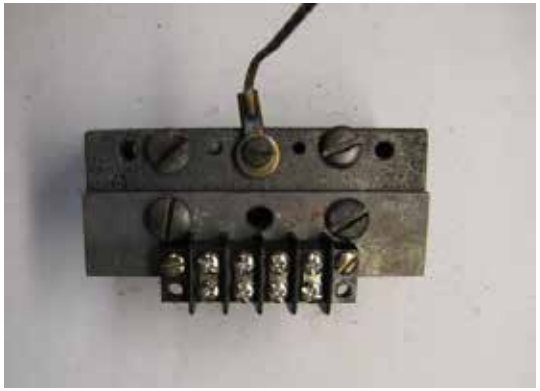
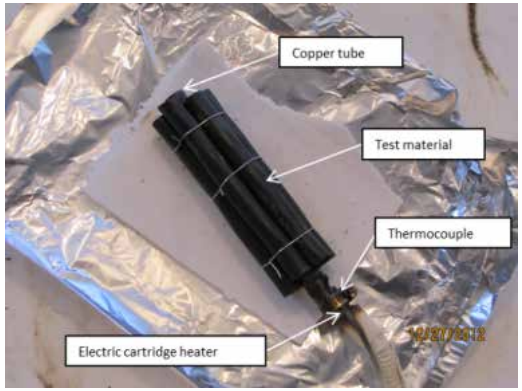


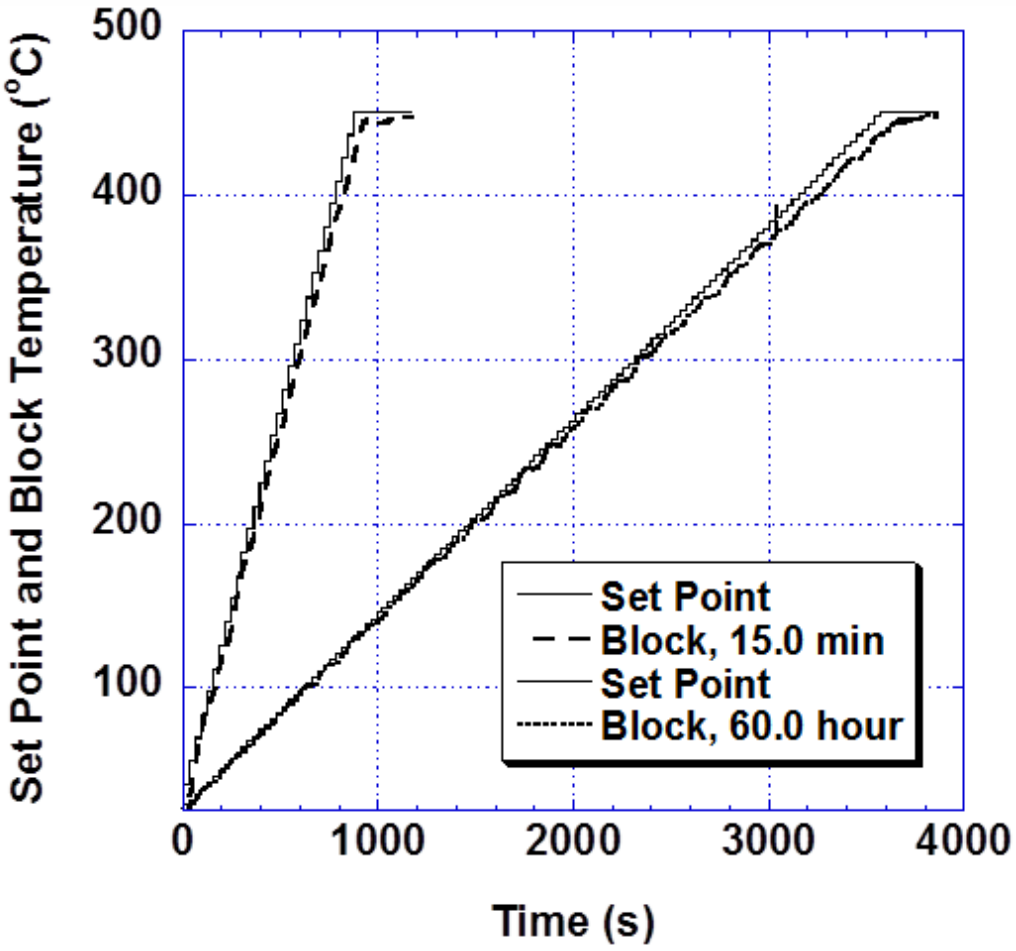







# Heat Source Control

**Block temperature for 15.0 min and 60.0 min heating ramp periods**

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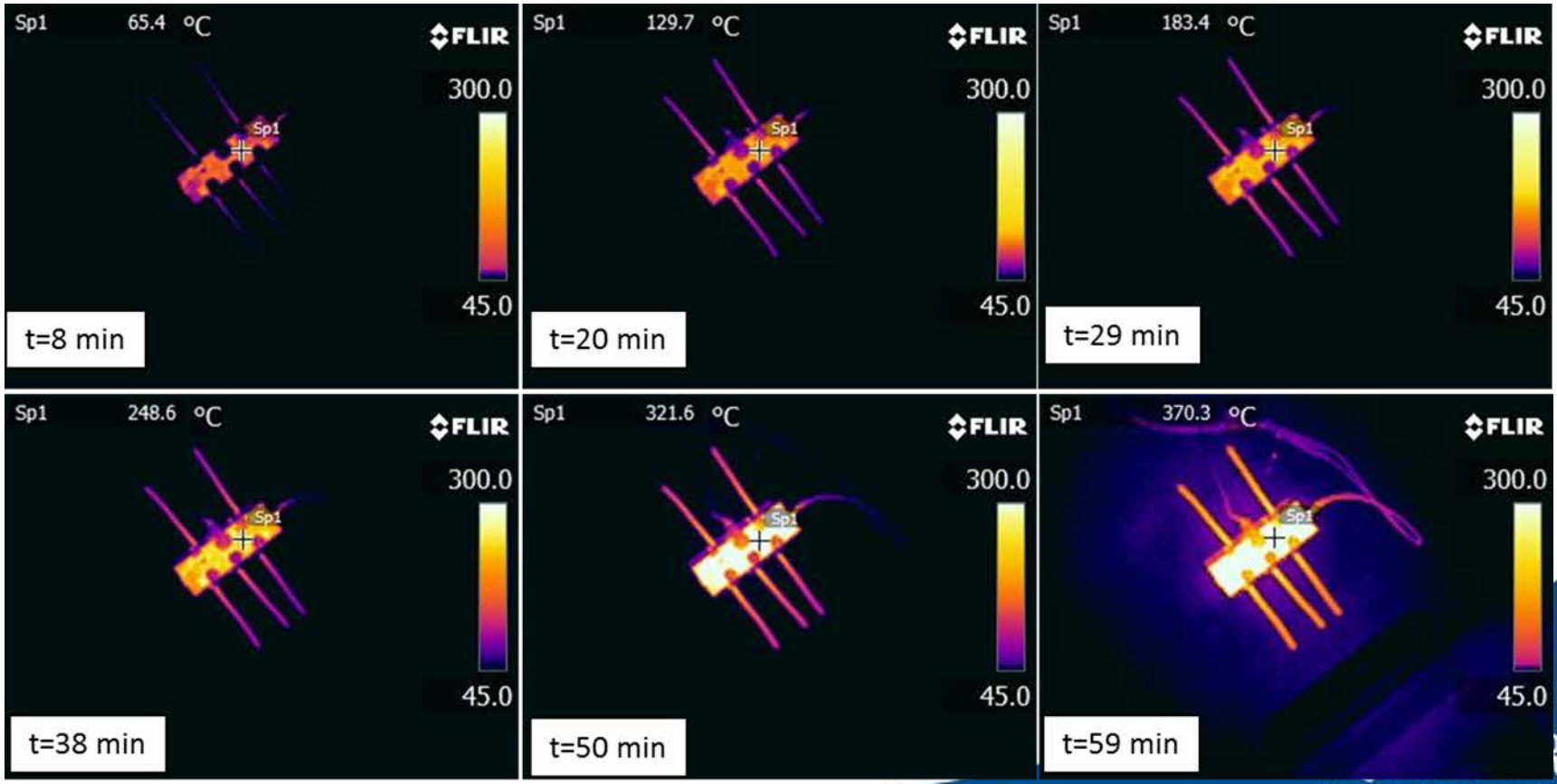
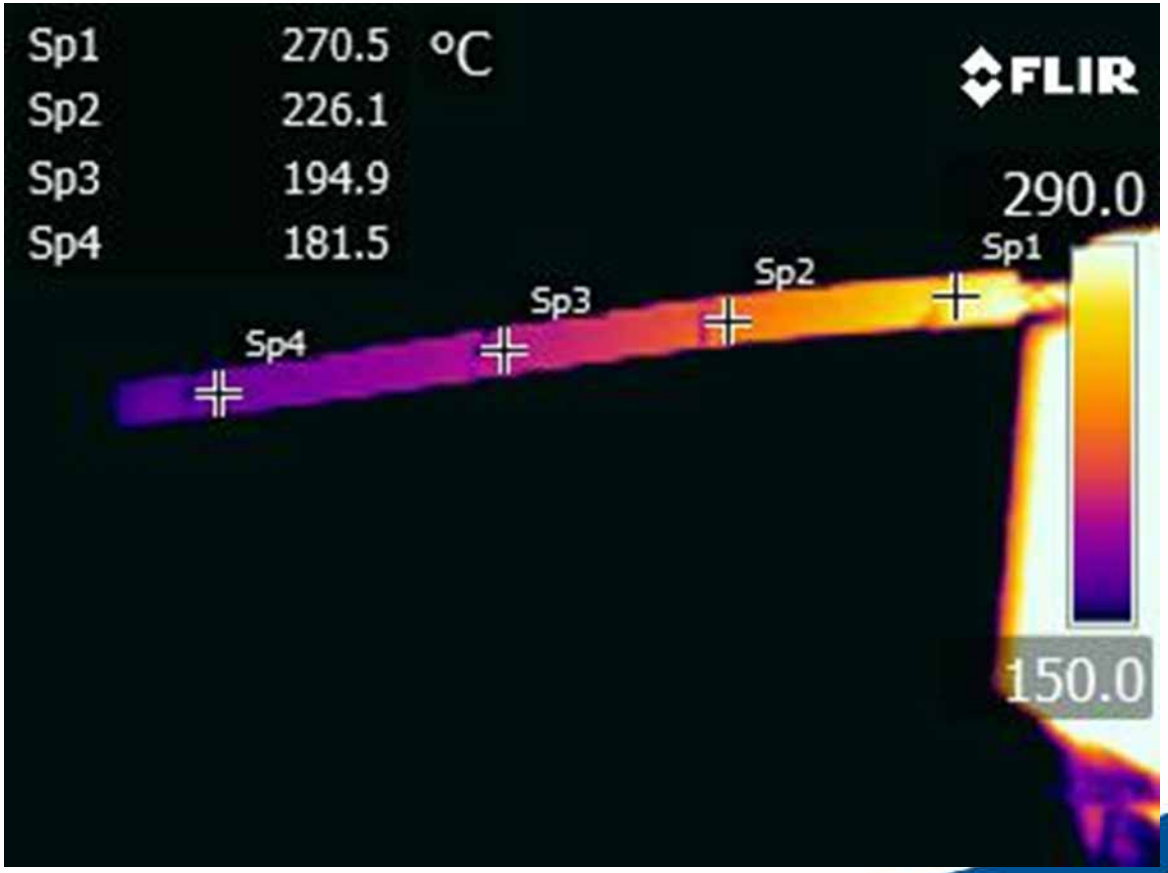
# Wire Heating

**Heating profiles for 12 gauge XLPE wires at various time steps during the heating process**



# Heat Source

**Thermal imaging camera temperature profile for a XLPE wire. The image was taken at the end of a 60 min. The bus bar temperature was 446 ºC.**

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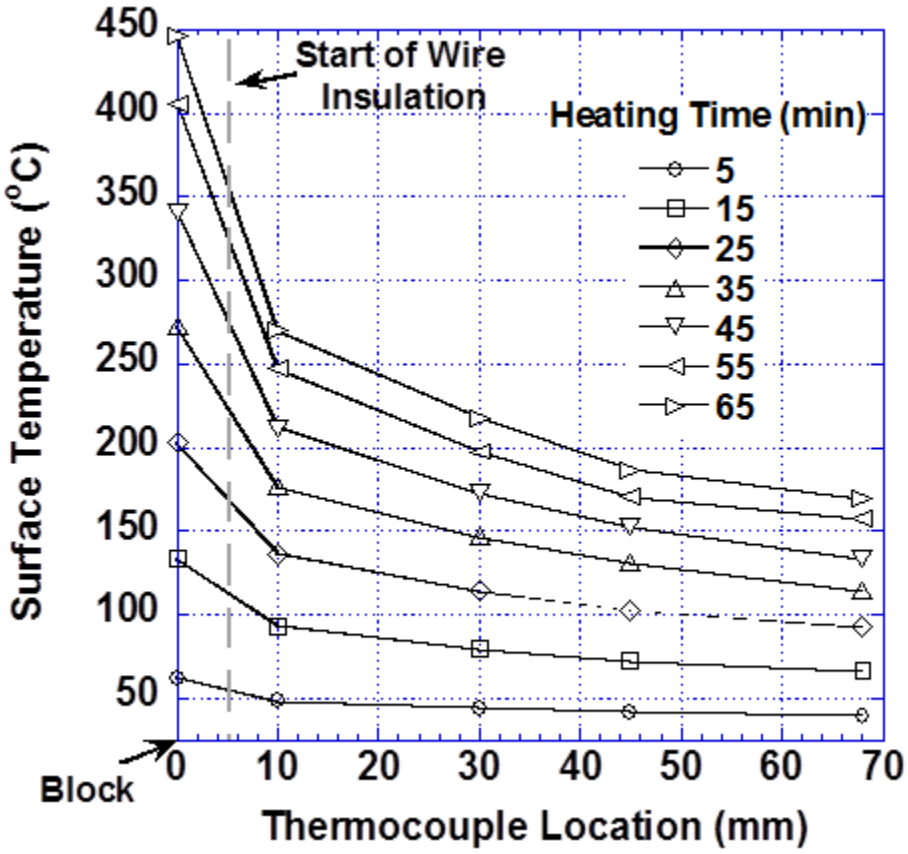
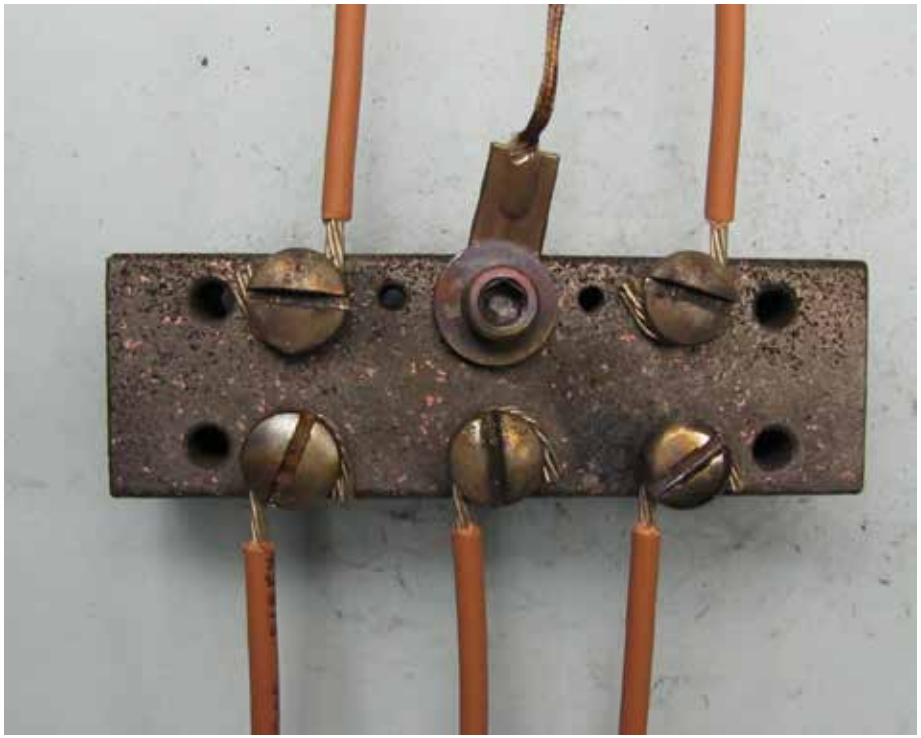
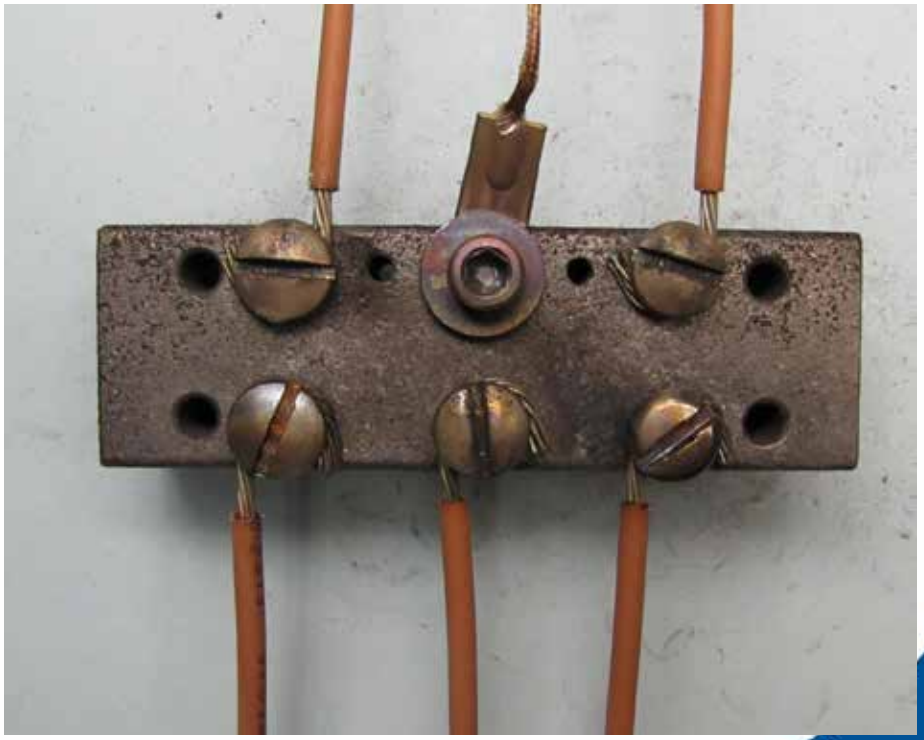
# Wire Insulation Temperature

**Wire insulation surface temperatures for a XLPE wire**



# Before and After Heating



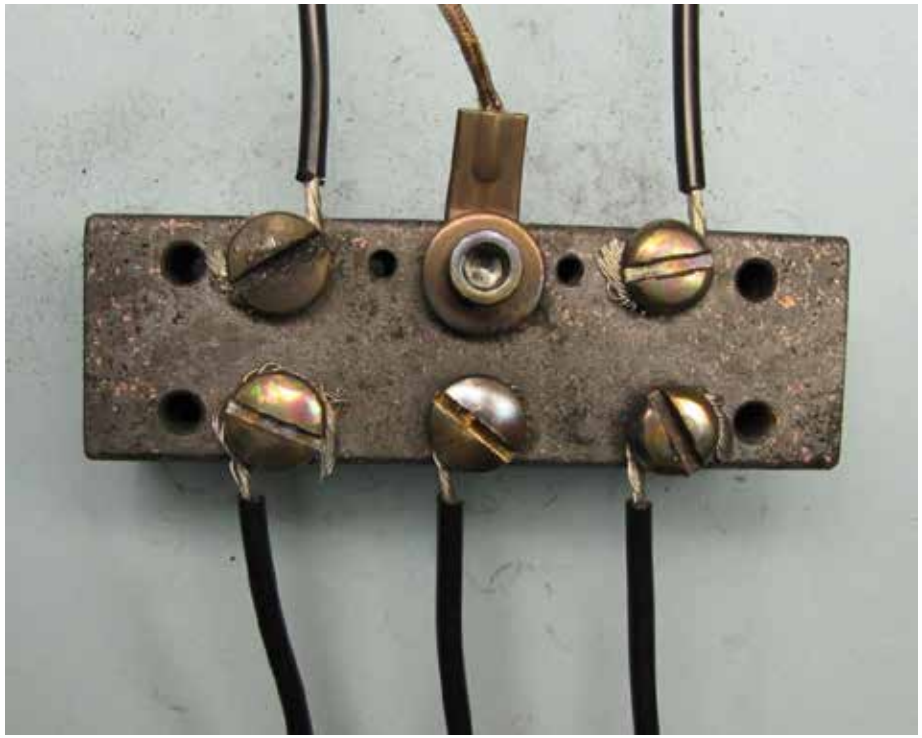


**XLPE - 15 min HRP**

# Before and After Heating

**CSPE - 15 min HRP**

# Before and After Heating



**PVC - 15 min HRP**

# Piloted Ignition Study

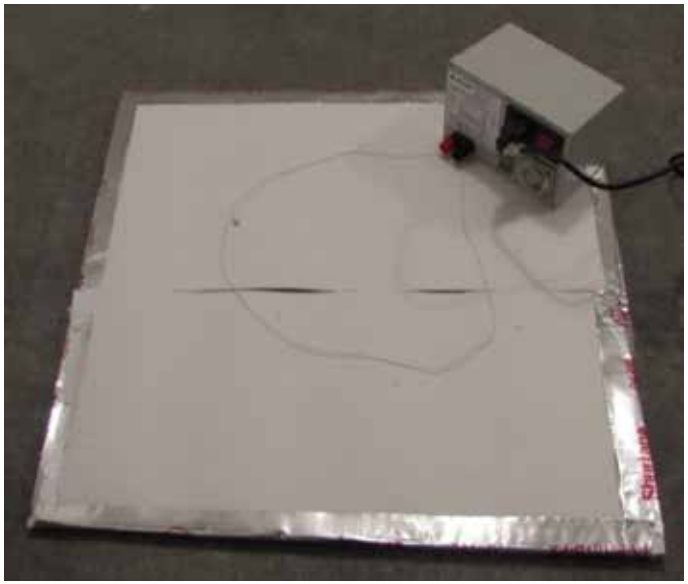
**After fixed heating time, wire insulation subjected to a 5 sec flame exposure, burning time noted**

# Piloted Ignition Study

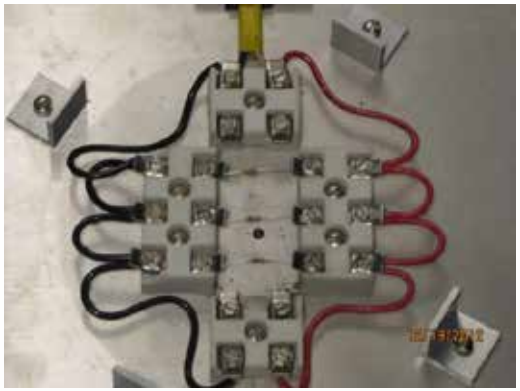
| Heating Period (s) (15 minute HRP) | Block Temperature (°C) | Persistent Burn Time (s) | | |
|---|---|---|---|---|
| | | XLPE | CSPE | PVC2 |
| 1,200 | 480 | 28 | 45 | 7 |
| 1,200 | 480 | 20 | 53 | 5 |
| 1,200 | 480 | 31 | 52 | 5 |
| 1,200 | 480 | | | 4 |
| 900 | 435 | 17 | 38 | 3 |
| 900 | 435 | 36 | 26 | 2 |
| 900 | 435 | 18 | 32 | 3 |
| 900 | 435 | | | 5 |
| 600 | 300 | 17 | 1 | 1 |
| 600 | 300 | 11 | 0 | 1 |
| 600 | 300 | 13 | 0 | 0 |
| 500 | 250 | 1 | | 0 |
| 500 | 250 | 1 | | 0 |
| 500 | 250 | 0 | | 0 |

**Materials at or before end of heating ramp period do not auto-ignite, but will ignite with a pilot**

# Short Duration Smoke Sources

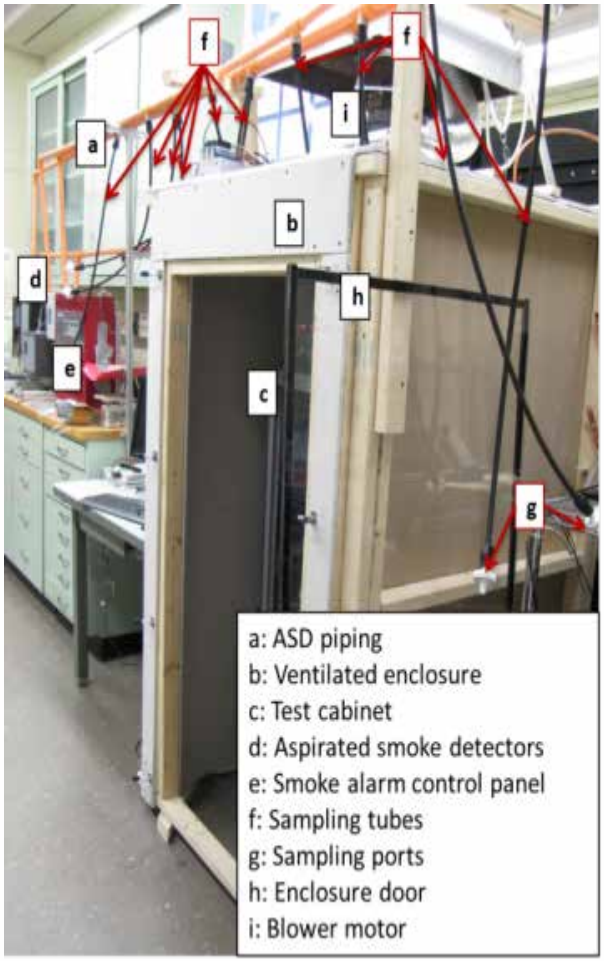


**A single wire test was setup following the British Standard 6266**

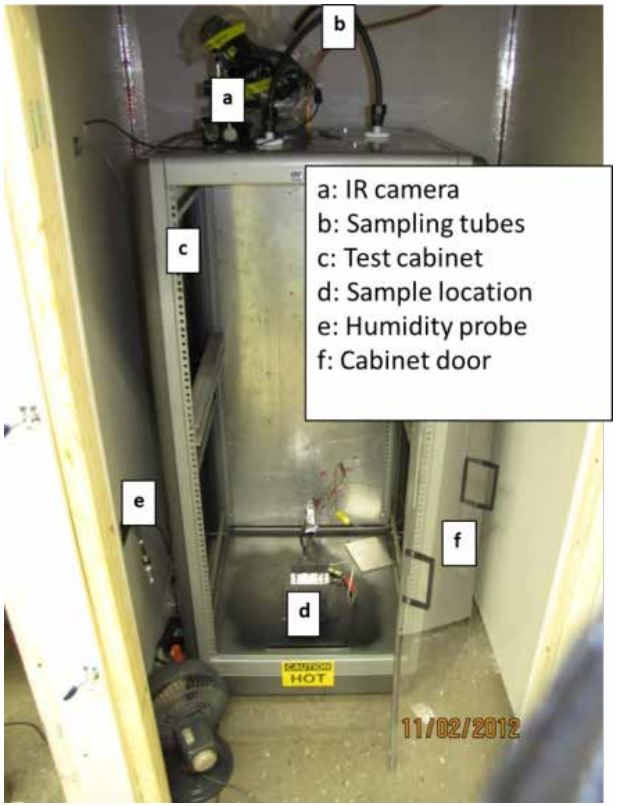


**Resistors and capacitors electrically energized to failure**

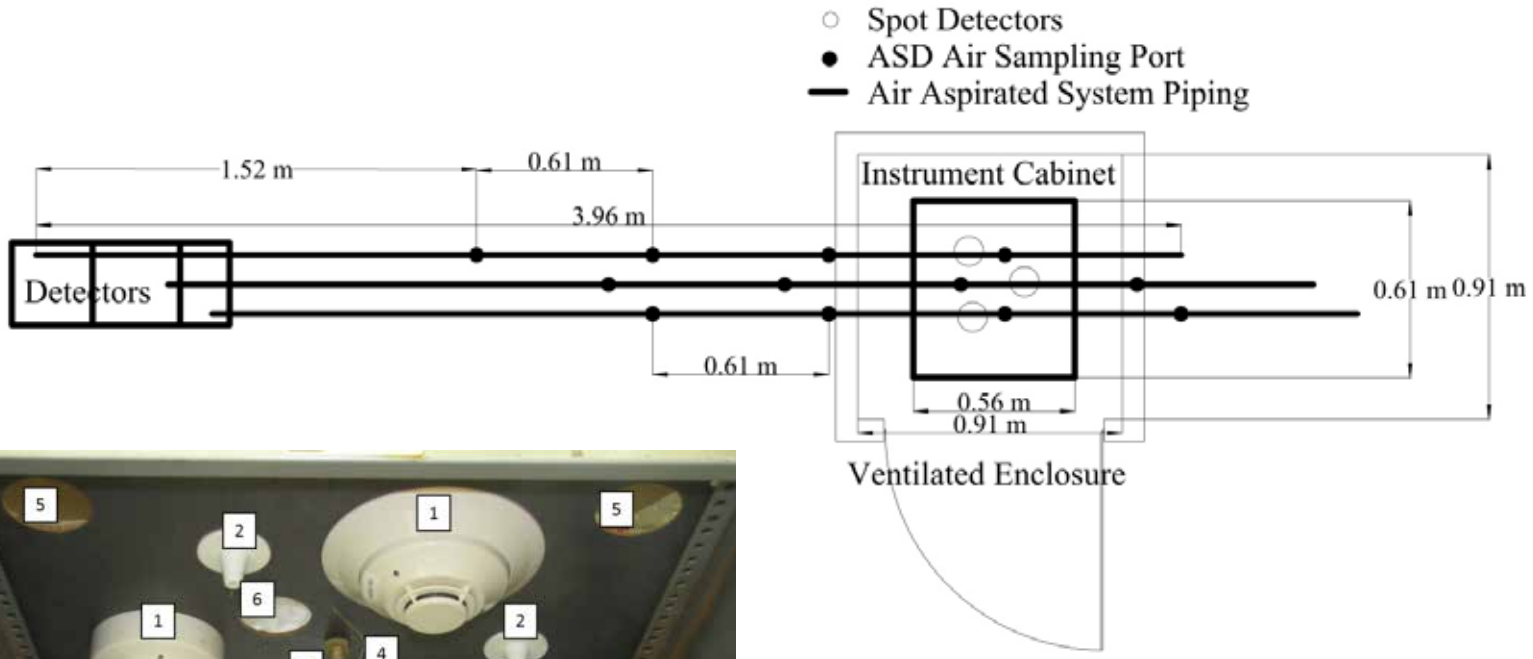
# Small-Scale Laboratory

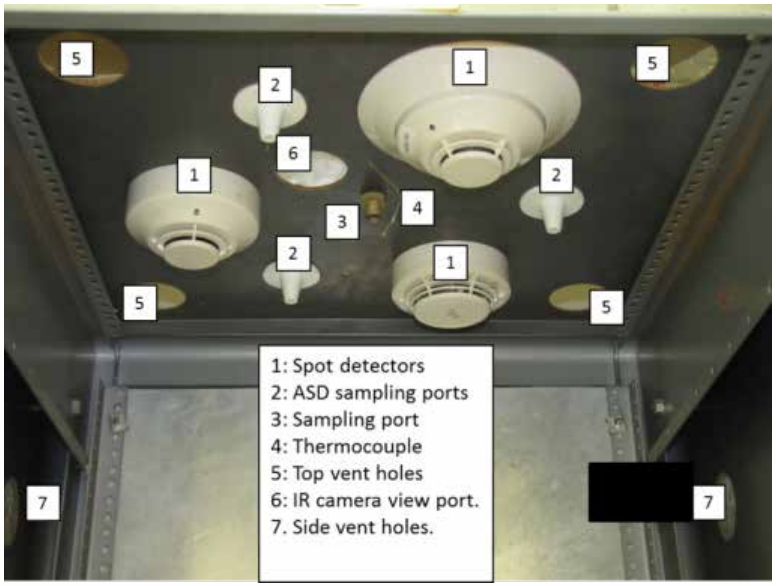



**103 tests**



# Experimental Setup



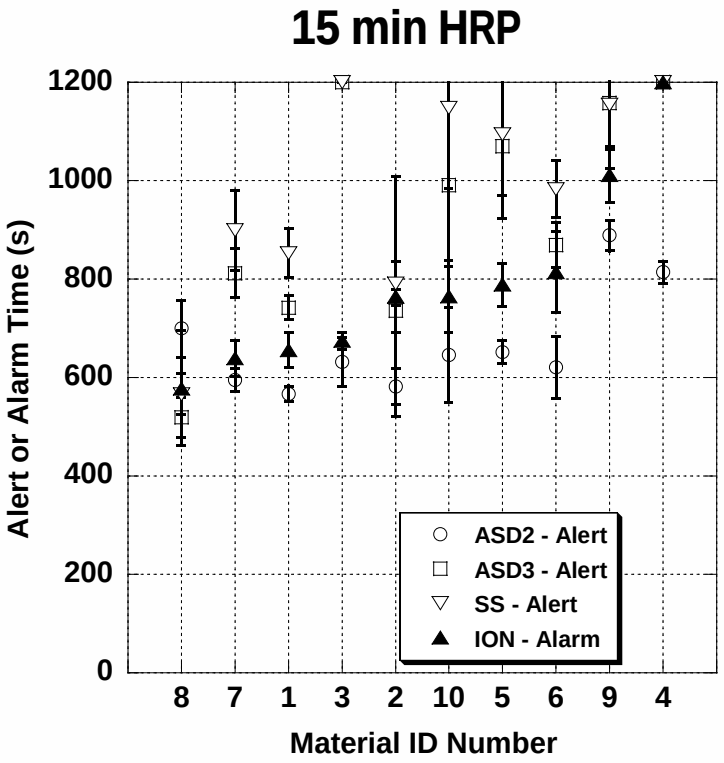



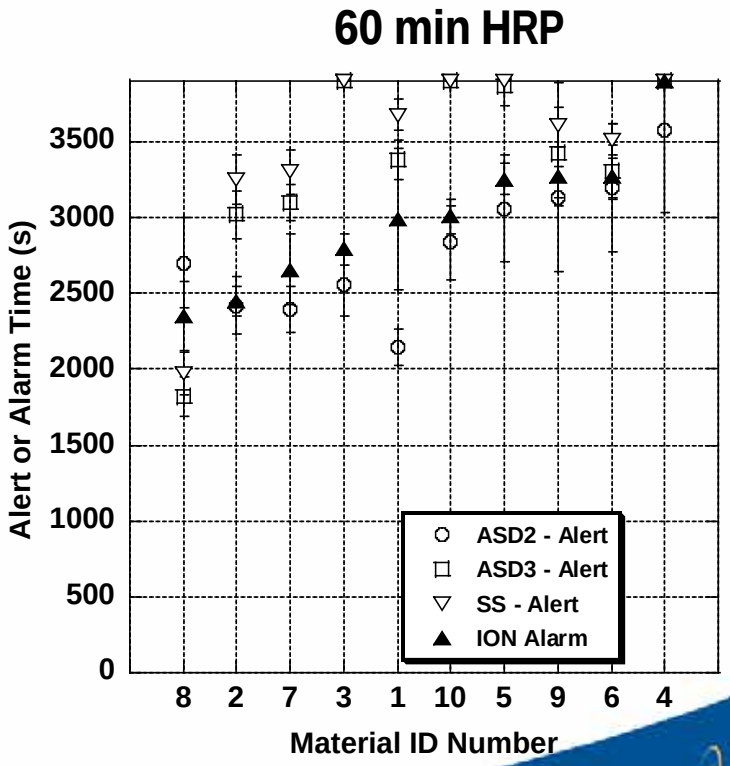
# Small Scale Laboratory Parameters

| Area monitored/ source location | Parameter | Variations |
|---|---|---|
| In-cabinet | Materials | 10 |
| | Heating rate | 3 |
| | Cabinet ventilation scheme | Natural, top or size ventilation |
| | Cabinet size | Single size |
| | Source location | floor |
| | Room ventilation | Enclosure ventilated |
| | | |

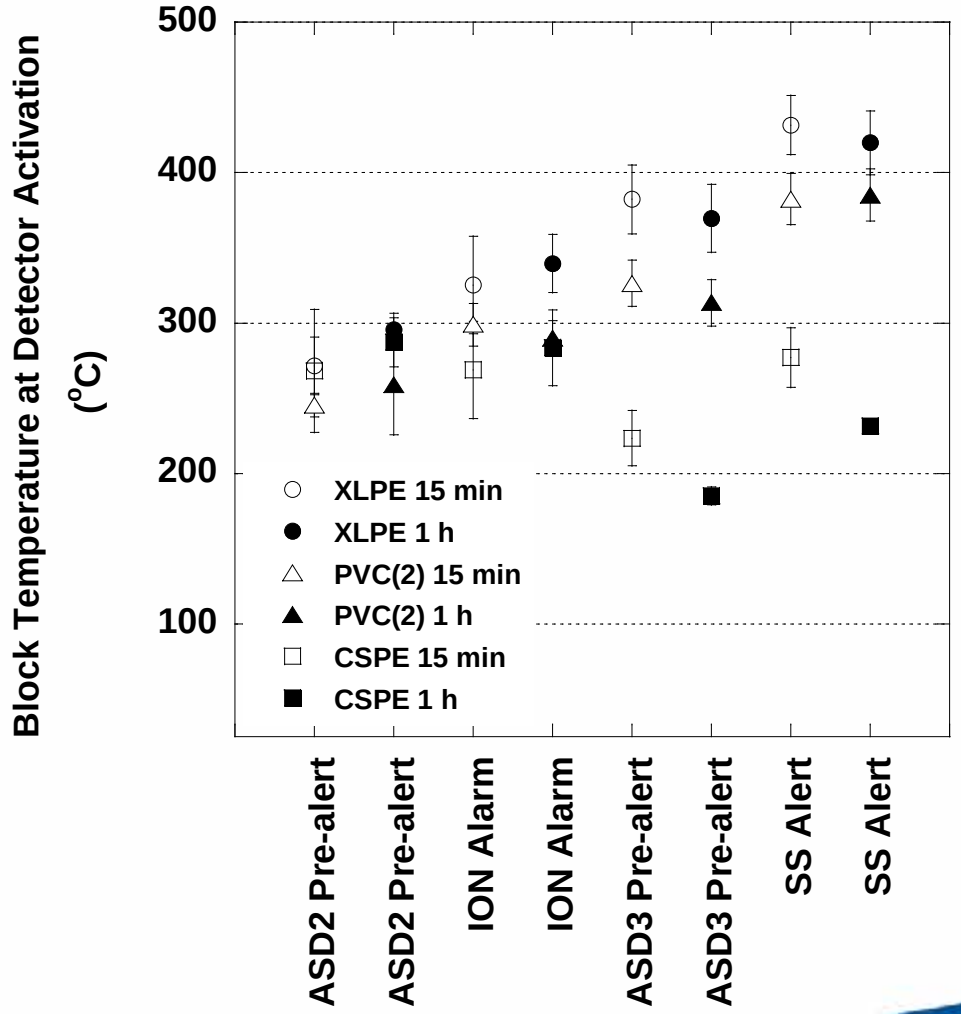
# Time to Alert or Alarm

- ASD2 – Cloud Chamber, ASD3 – Light Scattering
- Response trend ASD2 < ION < ASD3 < Sensitive Spot (SS)
- Only ASD2 responded to PTFE source, ASD3 and SS did not respond to Silicone



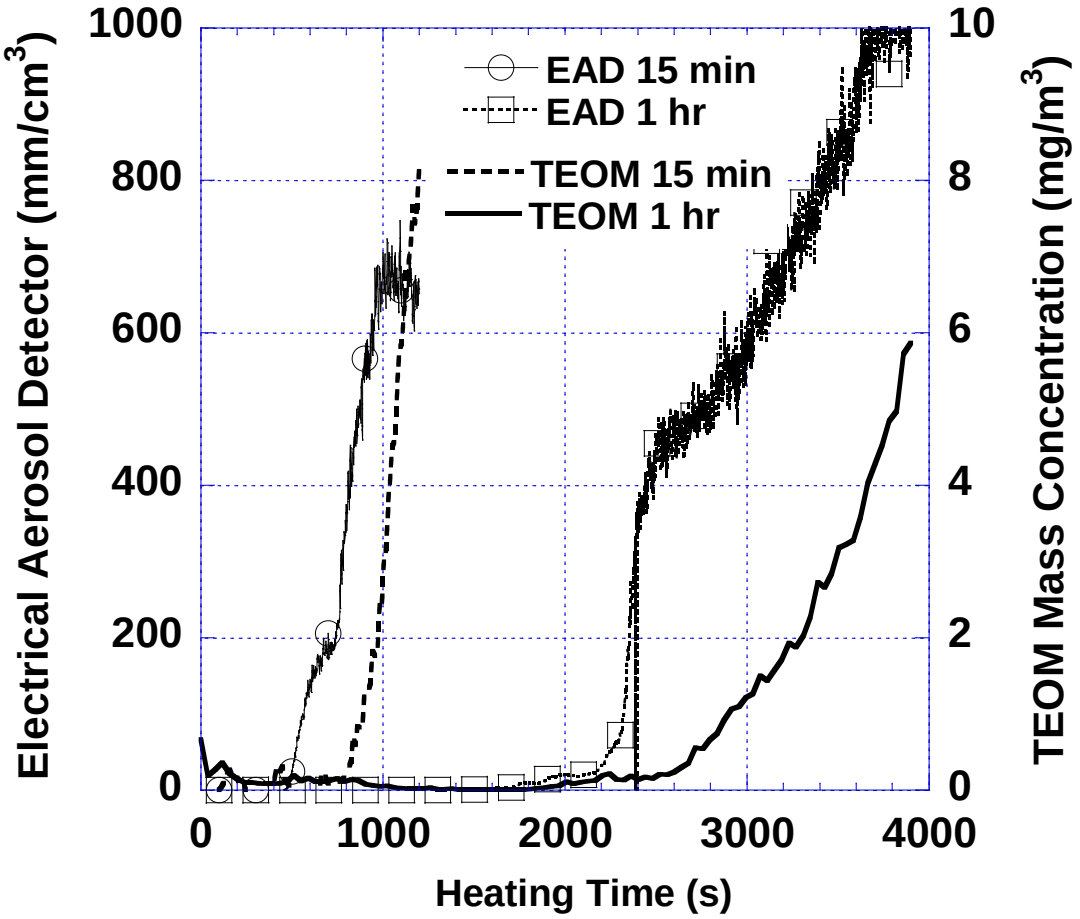
# Block Temperature at Alert/Alarm




ASD2 and ION respond at higher average block temperature when HRP increases from 15 min to 60 min, while the trend is reverses for ASD3 and SS

# Smoke Concentration Measurements

**Smoke concentration for XLPE insulated conductor experiments**

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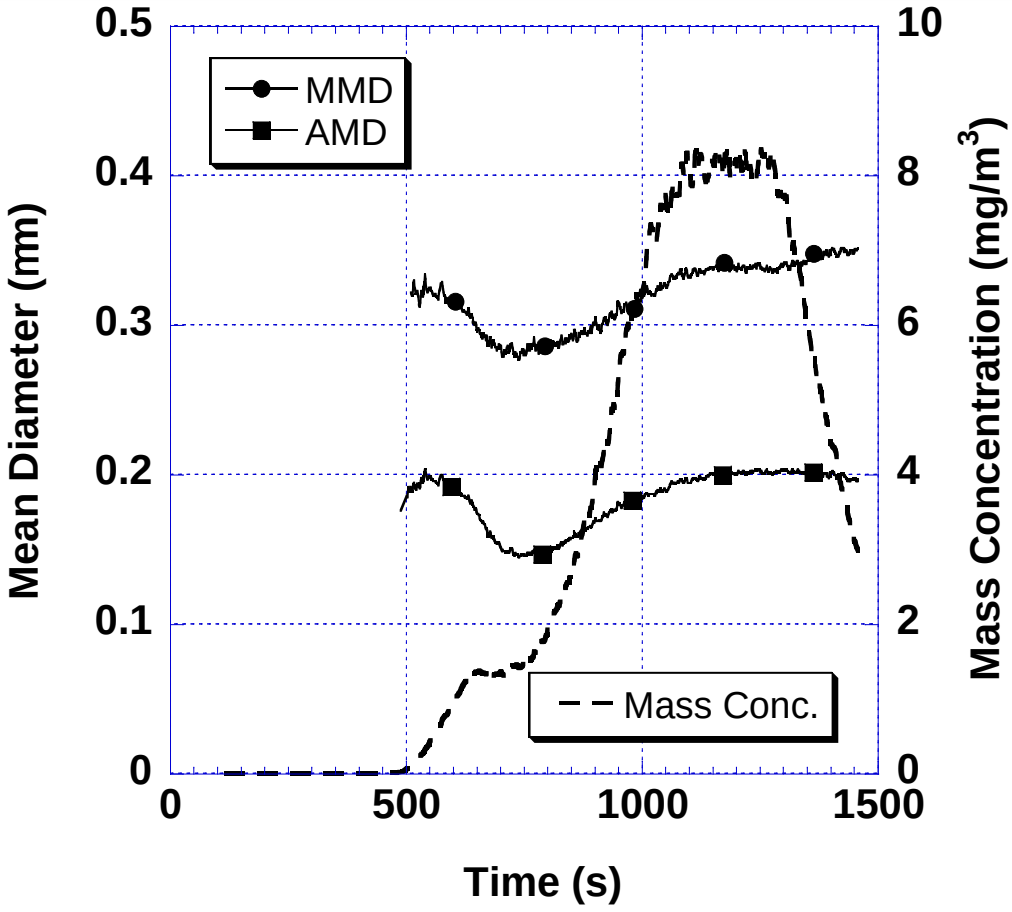
# Smoke Particle Size

**Electrical Low Pressure Impactor XLPE insulated conductor experiment**

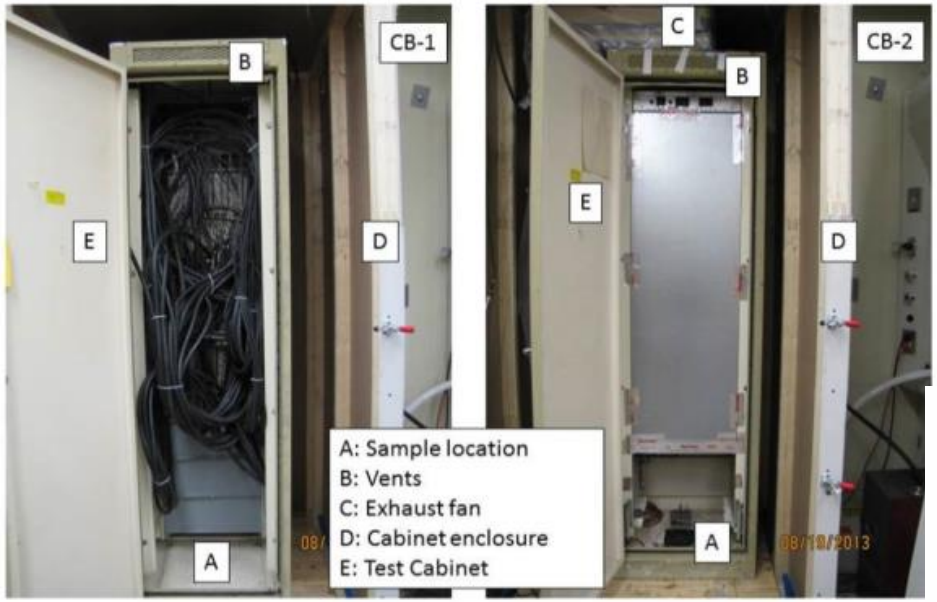


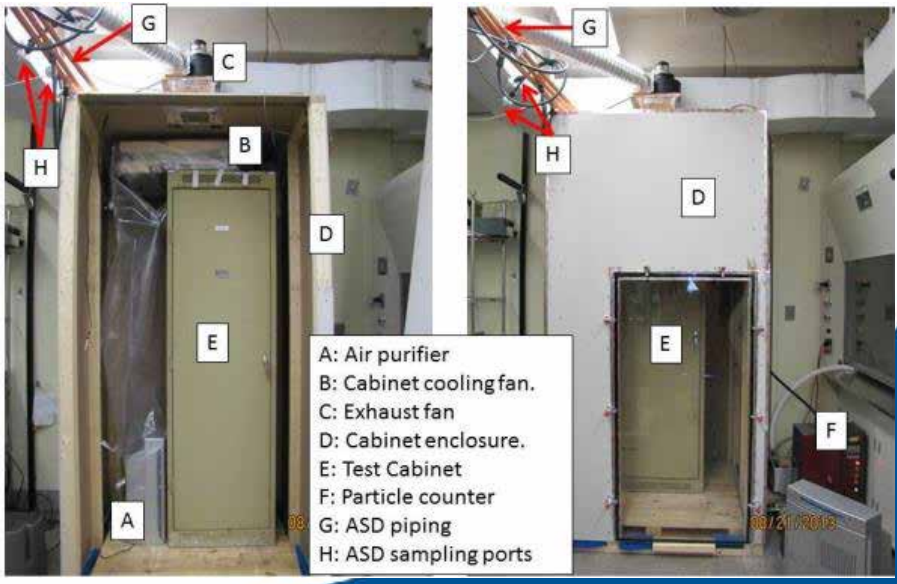
# Smoke Source Measurements

- Arithmetic mean diameter (AMD) and mass mean diameter (MMD) averaged over the 5 min soak time for 15 min heating rate period tests.
  - AMD and MMD of wire sources spans a diameter range of about a factor of 3
  - Down-selected three wires covering a range of sizes for follow-on experiments

| ID # | Name | AMD (μm) | MMD (mm) |
|---|---|---|---|
| 1 | PVC wire (1) | 0.12 | 0.27 |
| 2 | PVC wire (2) | 0.11 | 0.26 |
| 3 | Silicone wire | 0.14 | 0.23 |
| 4 | PTFE wire | 0.10 | 0.21 |
| 5 | XLPO wire (1) | 0.13 | 0.21 |
| 6 | XLPO wire (2) | 0.23 | 0.45 |
| 7 | XLPE wire | 0.20 | 0.33 |
| 8 | CSPE wire | 0.33 | 0.64 |

# Laboratory Nuclear Cabinets





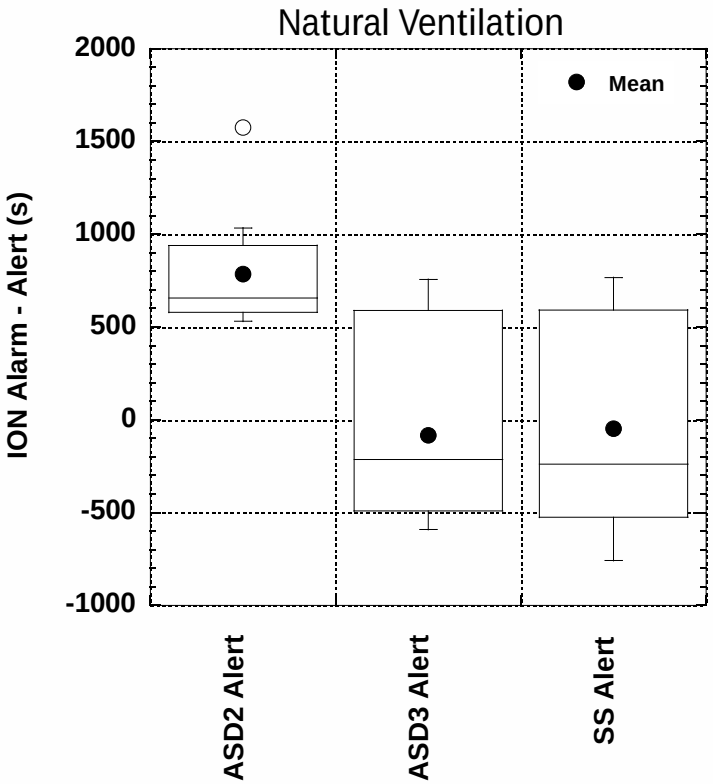

- 59 Tests
- Cabinets procured from Bellefonte
- Natural and Force Ventilated
- Internal Loading

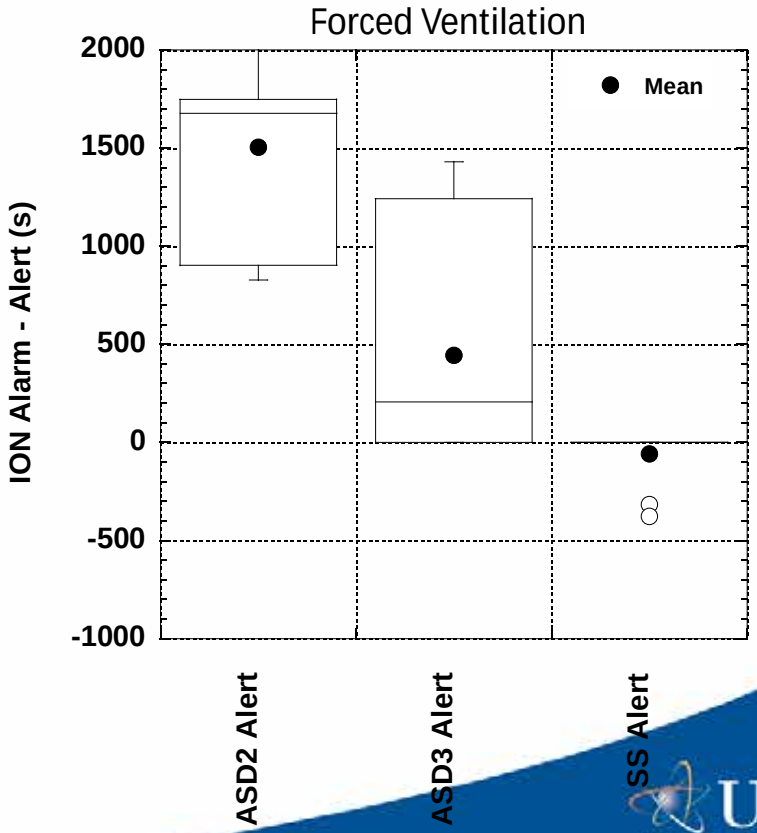
# Nuclear Cabinet Parameters

| Area monitored/ source location | Parameter | Variations |
|---|---|---|
| In-cabinet | Materials | PVC2, XLPE, CSPE and PCB |
| | Heating rate | 3 |
| | Cabinet ventilation scheme | Natural, forced |
| | Cabinet size | ~ Single size |
| | Source location | floor |
| | Room ventilation | Enclosure ventilated |
| | | |

# Laboratory Nuclear Cabinets

For 65 min HRP, in naturally ventilated cabinet only ASD2 responded before ION in all experiments. In forced ventilation cabinet both ASDs reponded before ION on average

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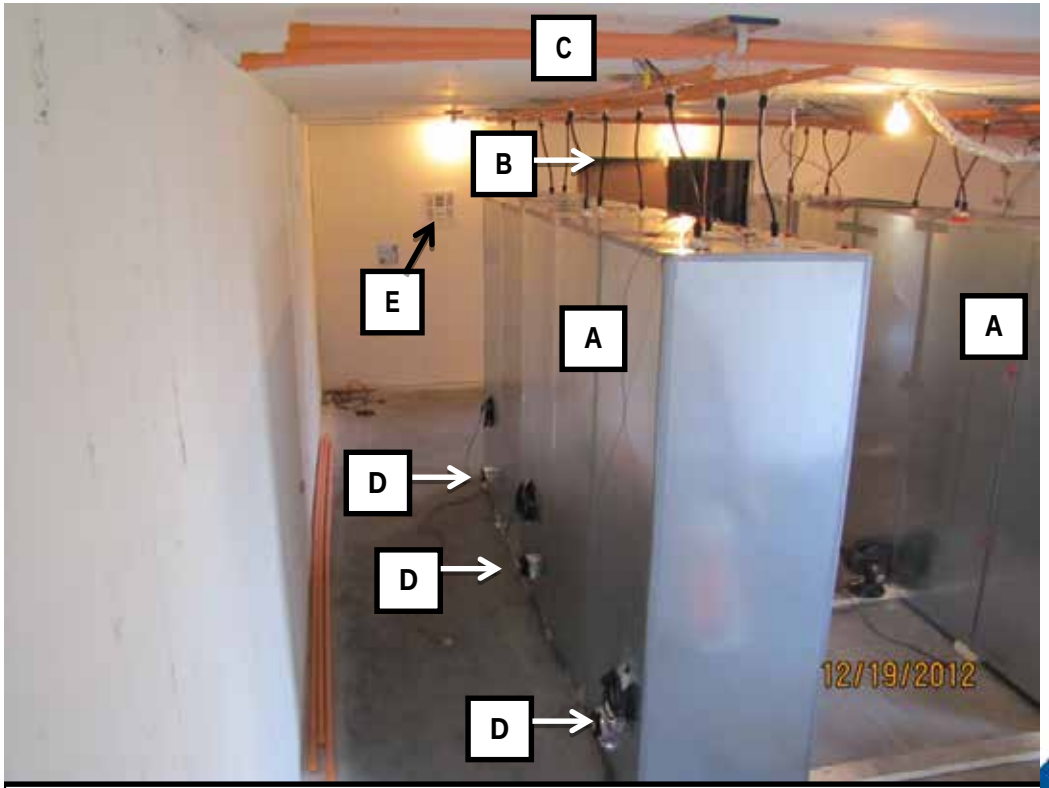
# Small Room Tests

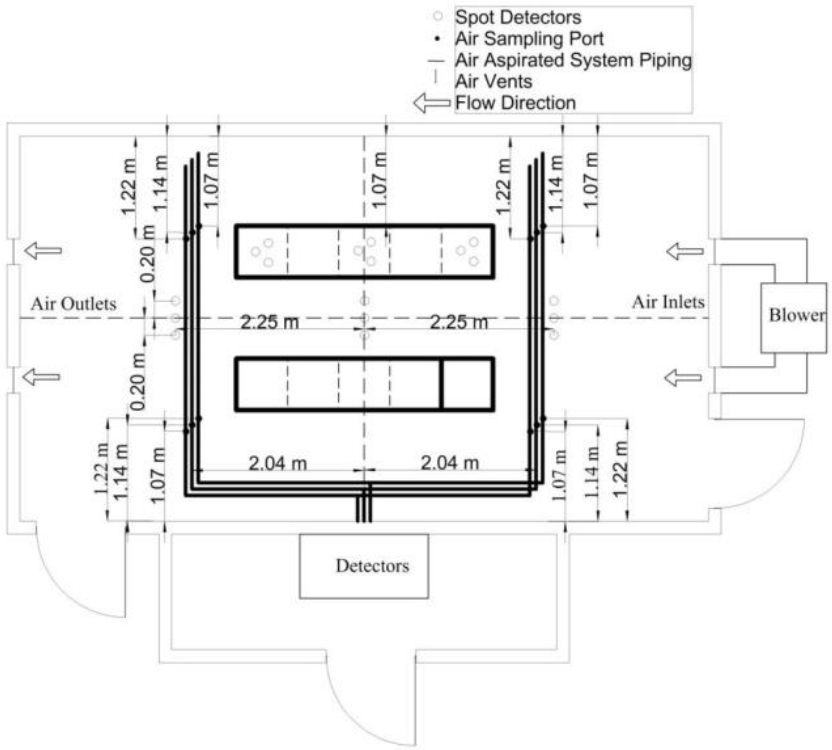
- 61 Tests, In-cabinet
- 48 Tests, Area Wide
- 400 Sq. Ft., 8 Ft. Ceilings
- Cabinet bank size varied (single, four, five cabinet bank)
- Natural and Forced cabinet and room ventilations
- Similar to configuration found at Robinson

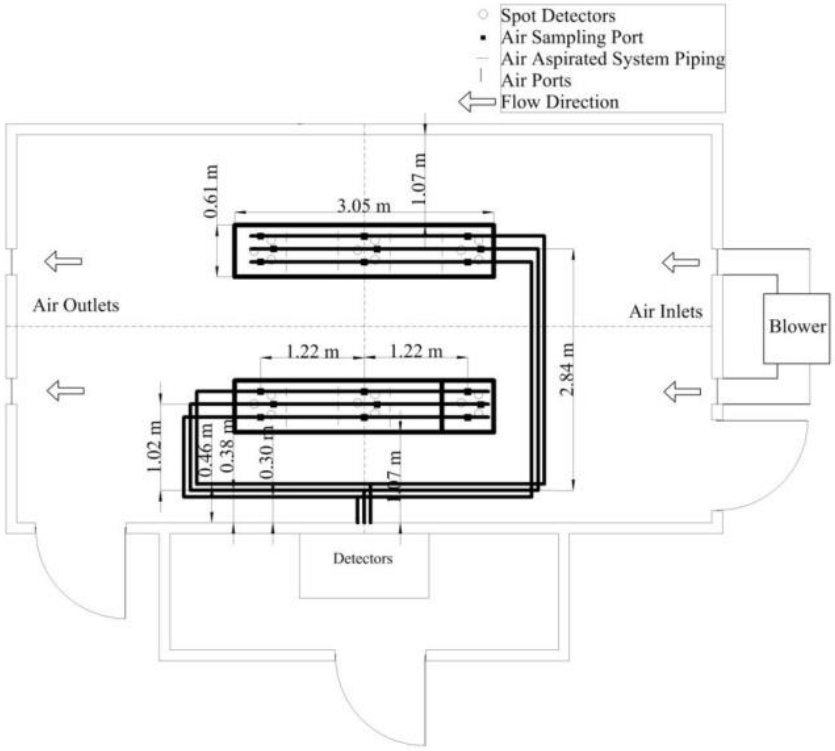
# Small Room Tests



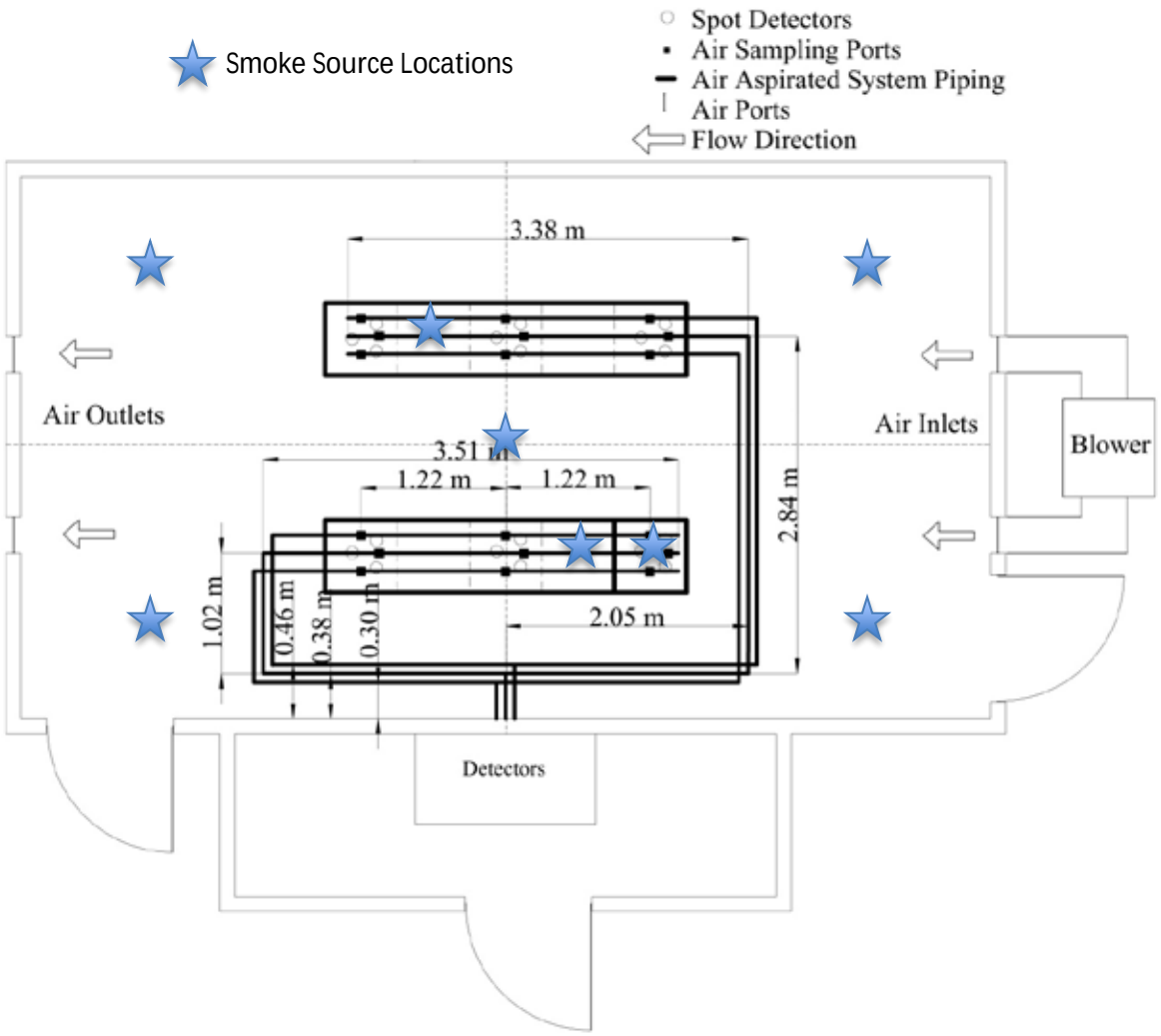

A: Cabinet mock-ups
B: Sampling tubes
C: ASD pipes
D: Cabinet ventilation fans
E: Room ventilation air inlet

# Small Room : VEWFD layout



# Small Room Smoke Source Location

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# Small Room Parameters

| Area monitored/ source location | Parameter | Variations |
|---|---|---|
| In-cabinet | Material | PVC2,XLPE, CSPE and PCB |
| | Heating rate | 3 |
| | Cabinet ventilation scheme | 2 (Natural,Forced) |
| | Cabinet size | 3 (Single or multiple) |
| | Source location | 2 |
| | Room ventilation | 2 (0,~7.5 ACH) |
| Area-wide | Material | 4 |
| | Heating rate | 3 |
| | Source location | 5 |
| | Room ventilation | 2 (0,~7.5 ACH) |

# Small Room Smoldering Paper Test

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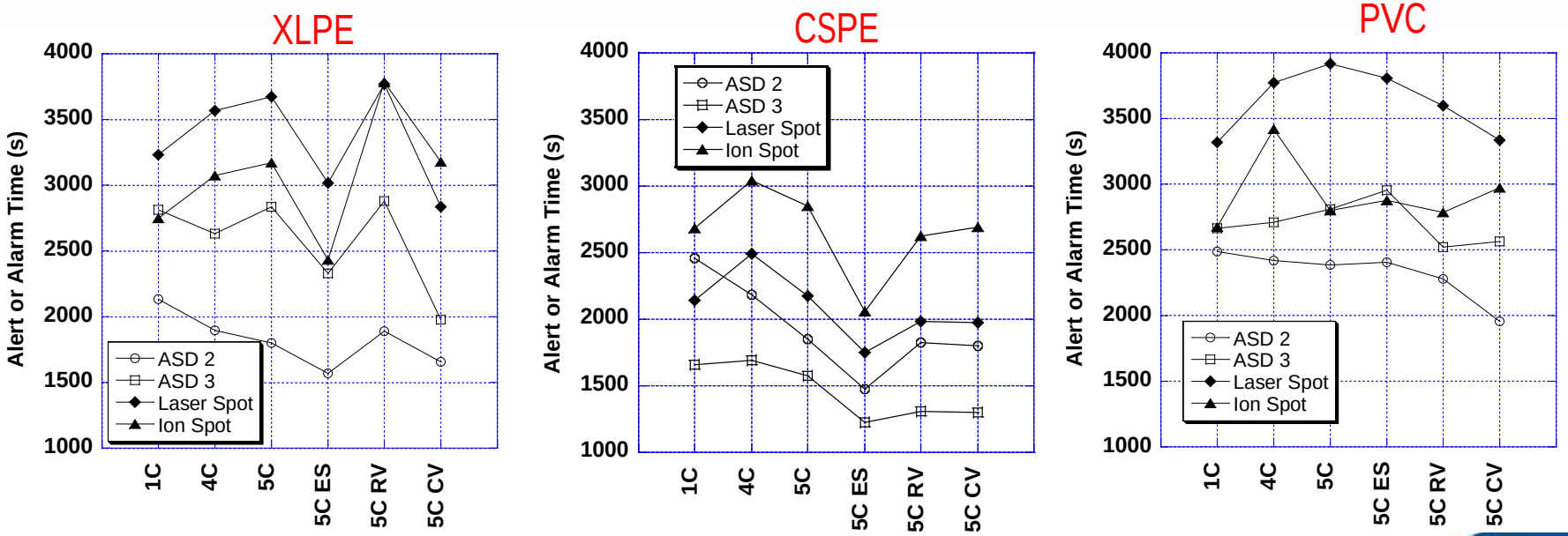
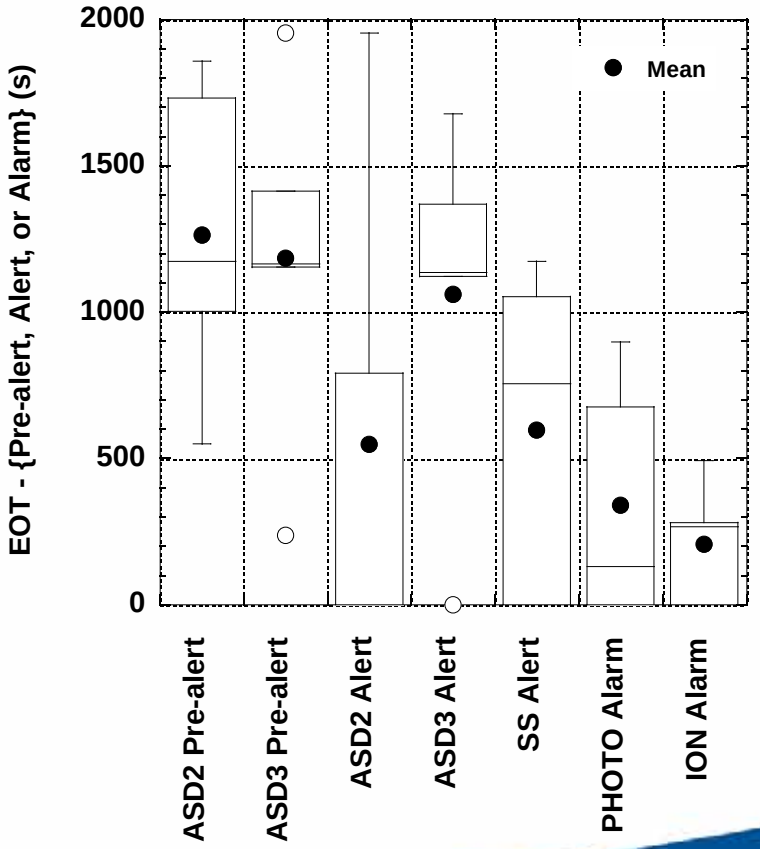
# Small Room In-cabinet Results

- On average, ASDs respond before ION or SS detectors (65 min HRP shown).
- The trend for the different configurations is somewhat detector dependent and source dependent.

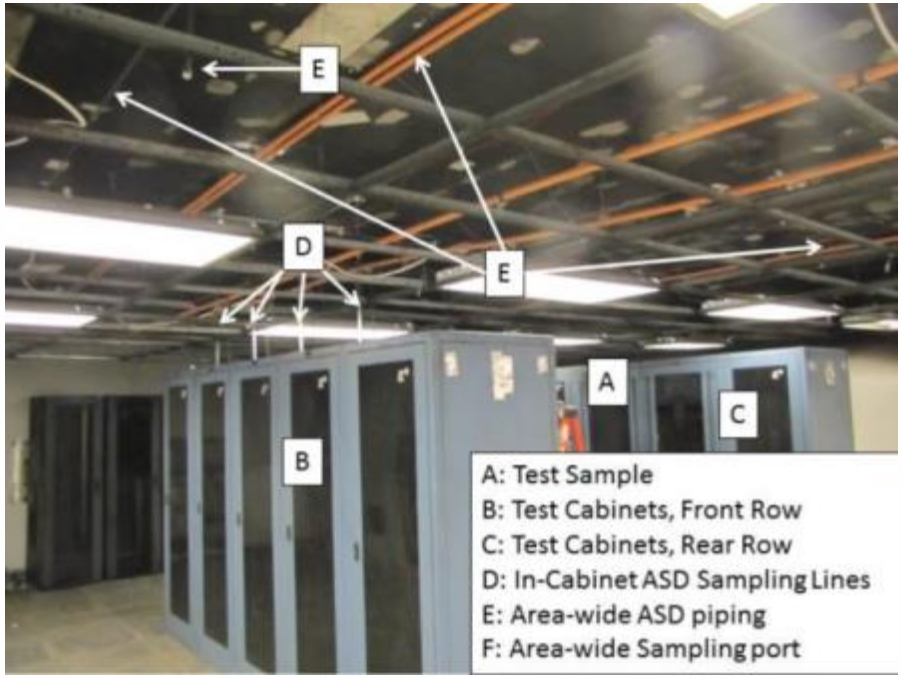


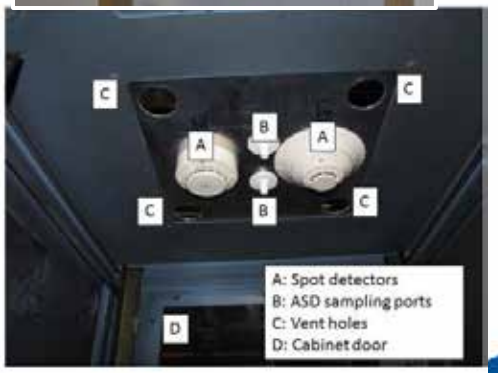
# Small Room Area-wide Results

- On average, ASDs and SS Alert before ION Alarms (65 min HRP).
- The SS, PHOTO and ION alarms did not respond before the end of the test in two of five experiments



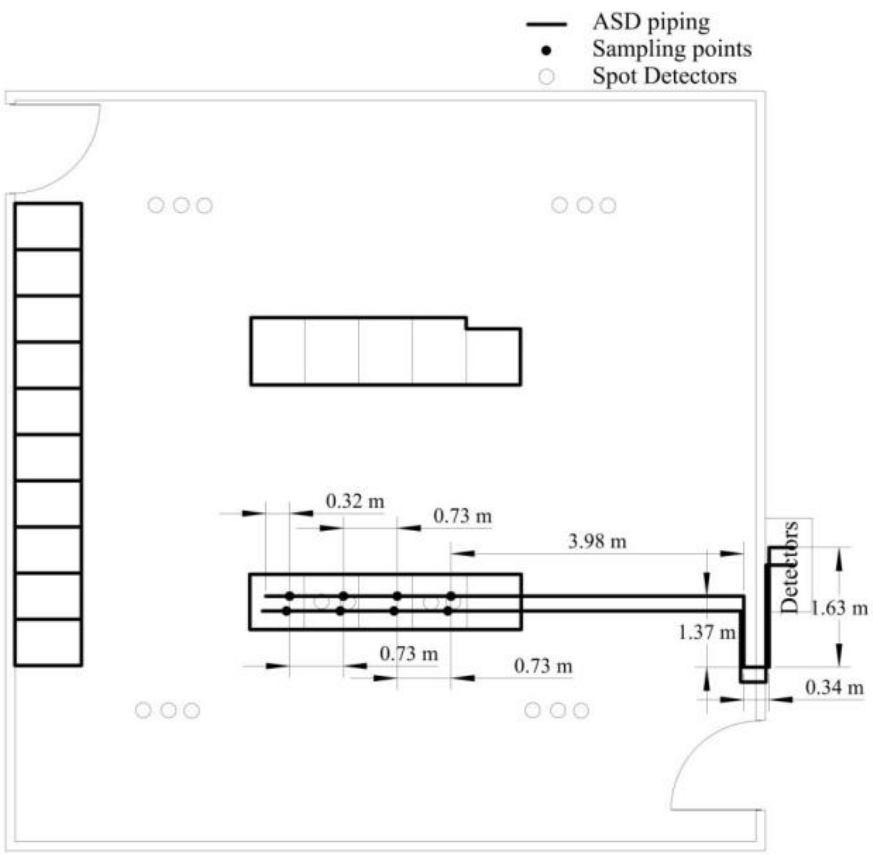
# Large Room Tests

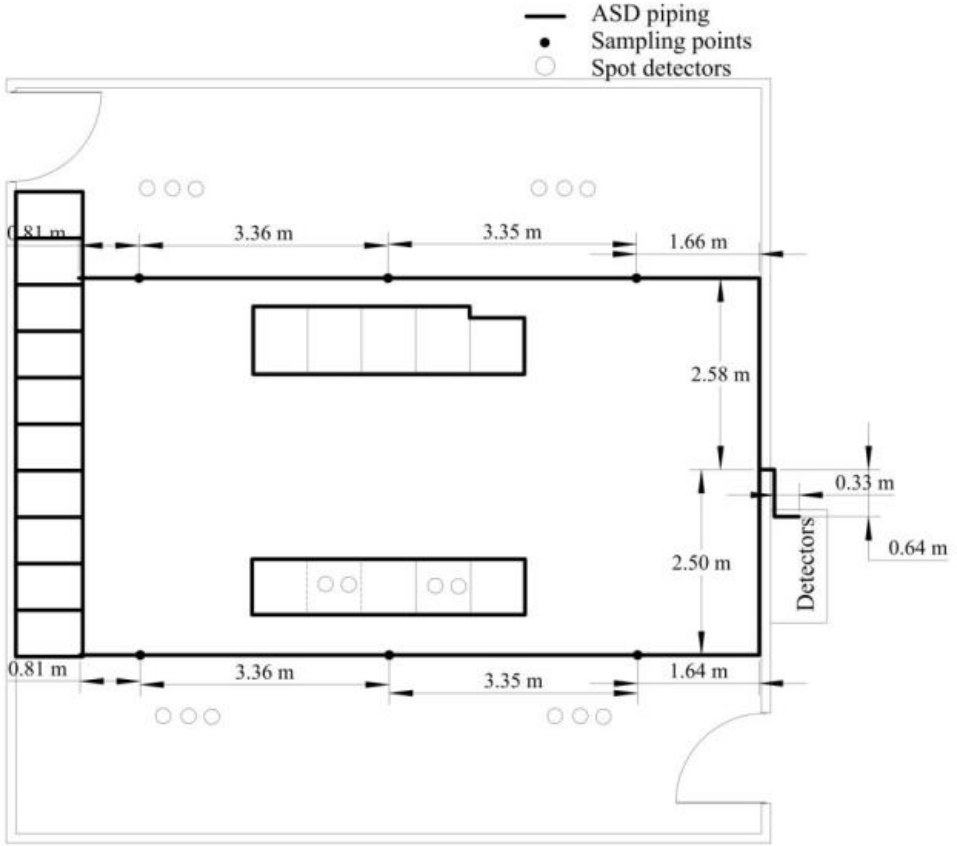





- 3 zones per ASD
  - In-Cabinet, Area-wide ceiling, and Area-wide air return grill
- 77 Tests
- 1000 Sq. Ft.

# Large Room : VEWFD Layout



# Cable Incipient Smoke Source

# Large Room Parameters

**Single-zone test parameters**

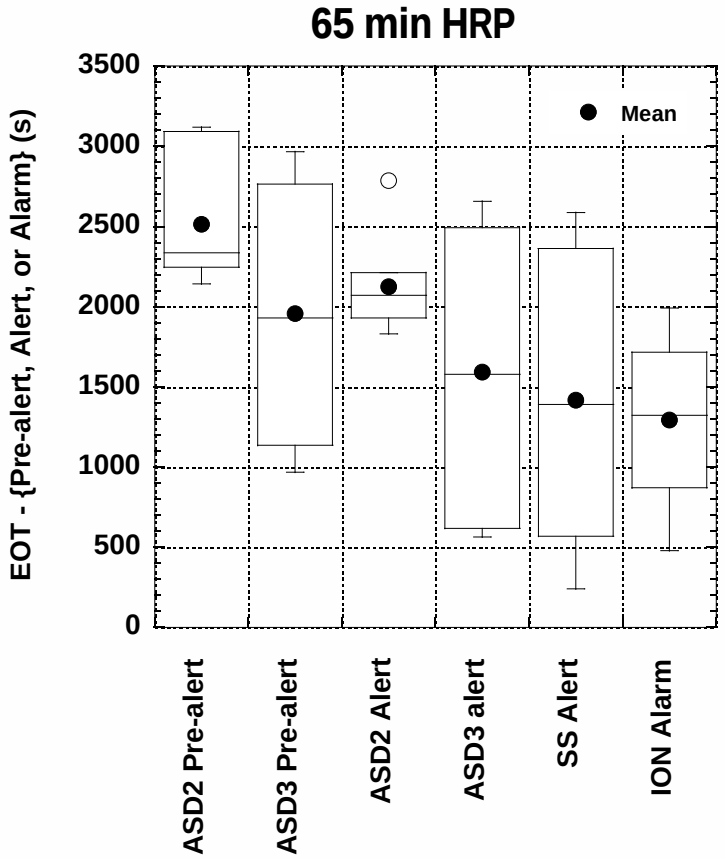
| Area monitored/ source location | Parameter | Variations |
|---|---|---|
| In-cabinet | Material | 2 - XLPE, CSPE |
| | Heating rate | 3 |
| | Ventilation scheme | 1 (Natural) |
| | Cabinet size | 2 (Single or multiple) |
| | Source location | 2 |
| | Room ventilation | 2 (0,7.5 ACH) |

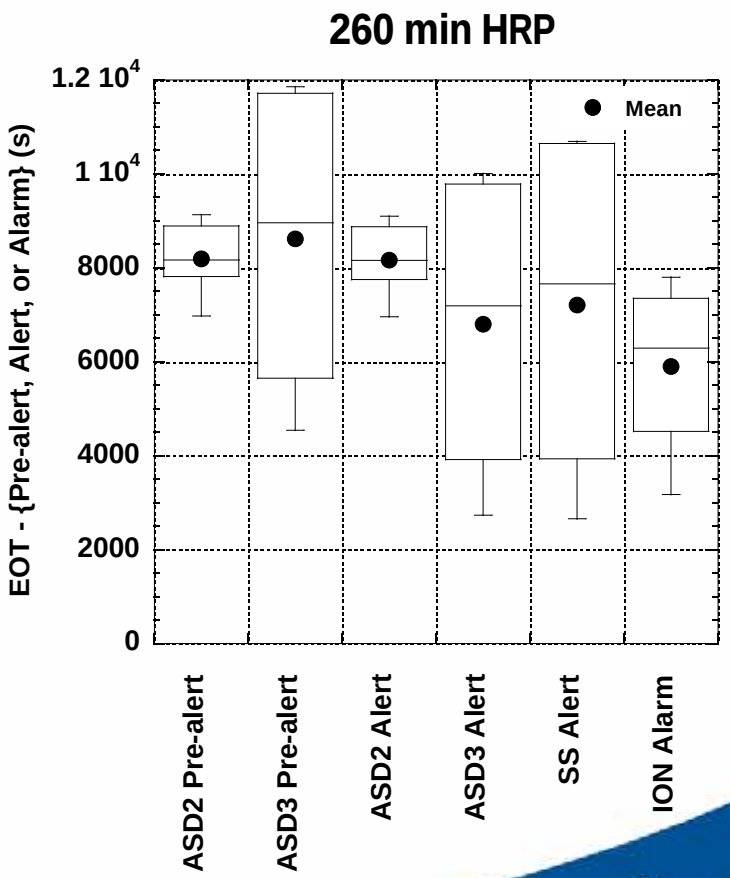
**Multi-zone test parameters**

| Area monitored/ source location | Parameter | Variations |
|---|---|---|
| In-cabinet | Material | 2 - XLPE, CSPE |
| | Heating rate | 3 |
| | Ventilation scheme | 1 (Natural) |
| | Cabinet size | 2 (Single or multiple) |
| | Source location | 1 |
| | Room ventilation | 3 (0,7.5,12 ACH) |
| Area-wide | Material | 3- XLPE, CSPE, Cable |
| | Heating rate | 3 |
| | Source location | 5 |
| | Room ventilation | 3 (0,7.5,12 ACH) |

# Large Room In-cabinet Results

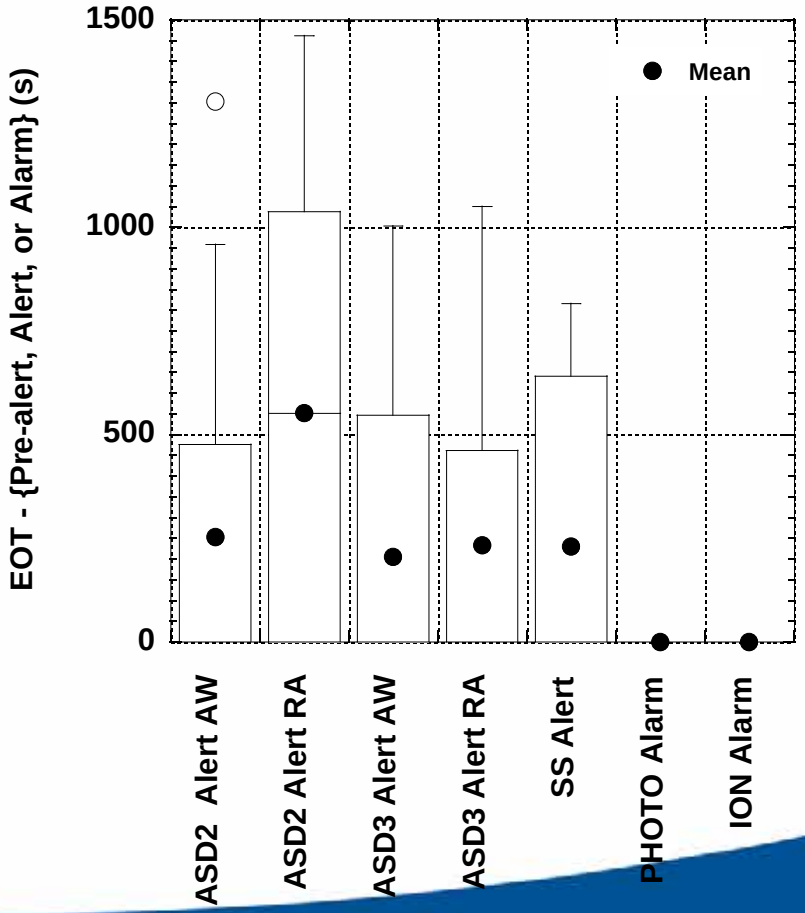
**Single Zone, ASDs and SS respond before ION detector on average**



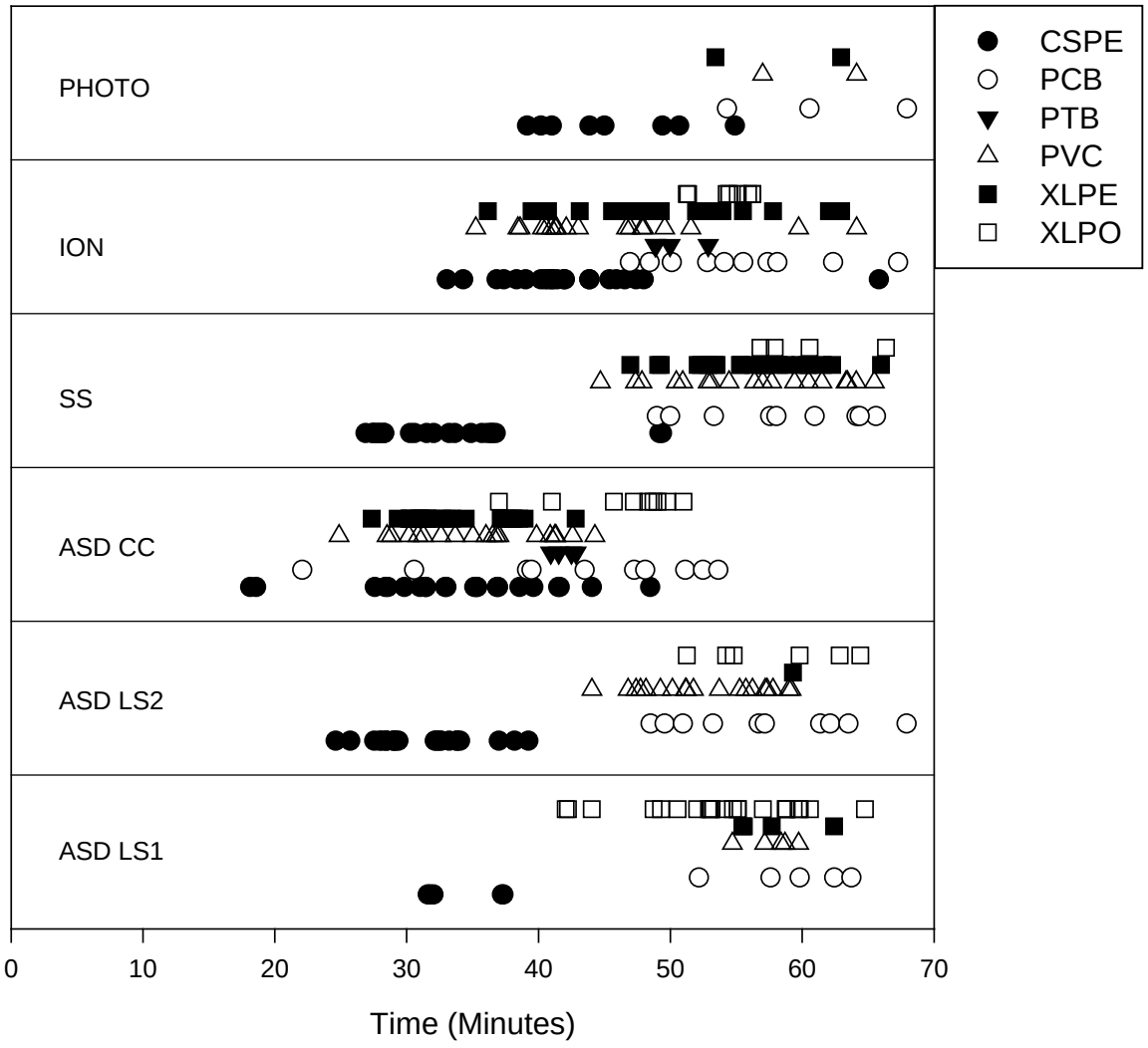



# Large Room Area-wide Results

- **On average, return air zone responded before area-wide zone (65 min HRP)**
- **PHOTO and ION did not reach Alarm**

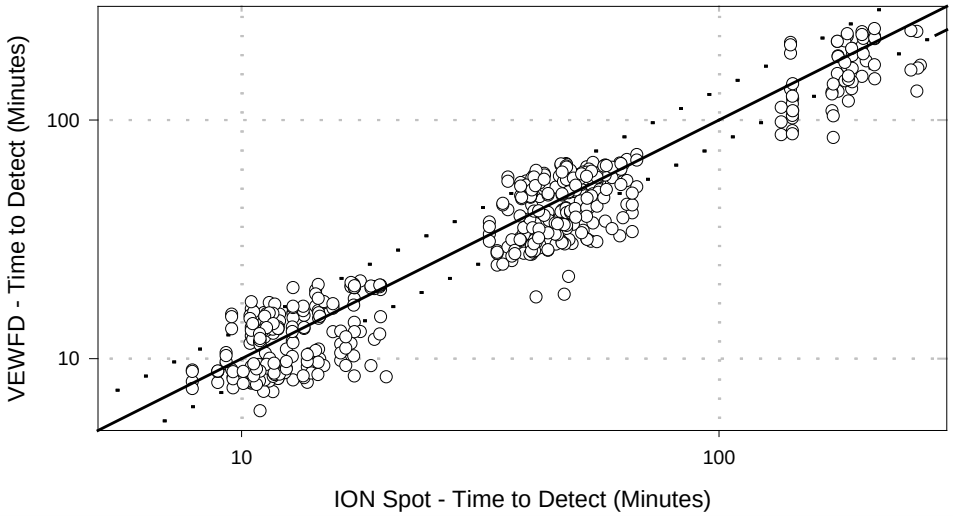


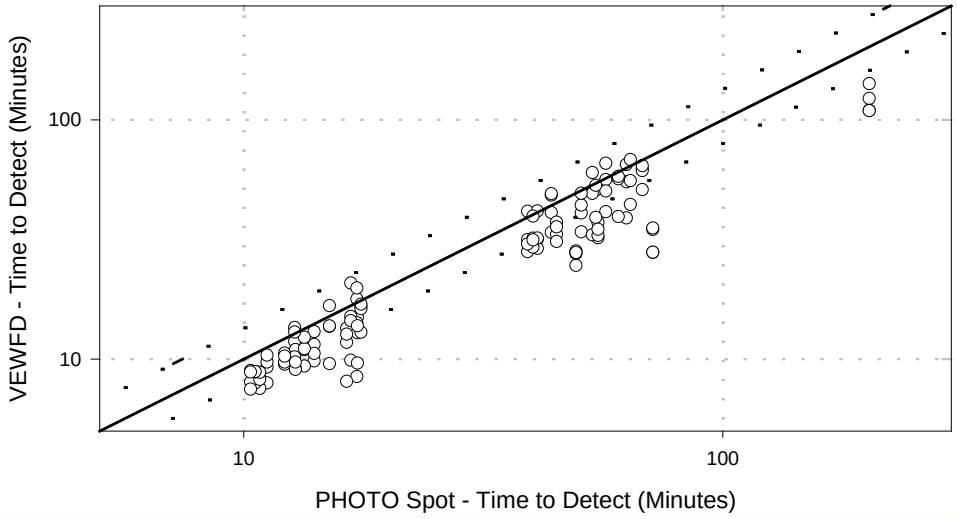
# Evaluation of Test Results




**Detector response to selected materials (In-cabinet, natural ventilation, 1-hour HRP)**

# Evaluation of Test Results



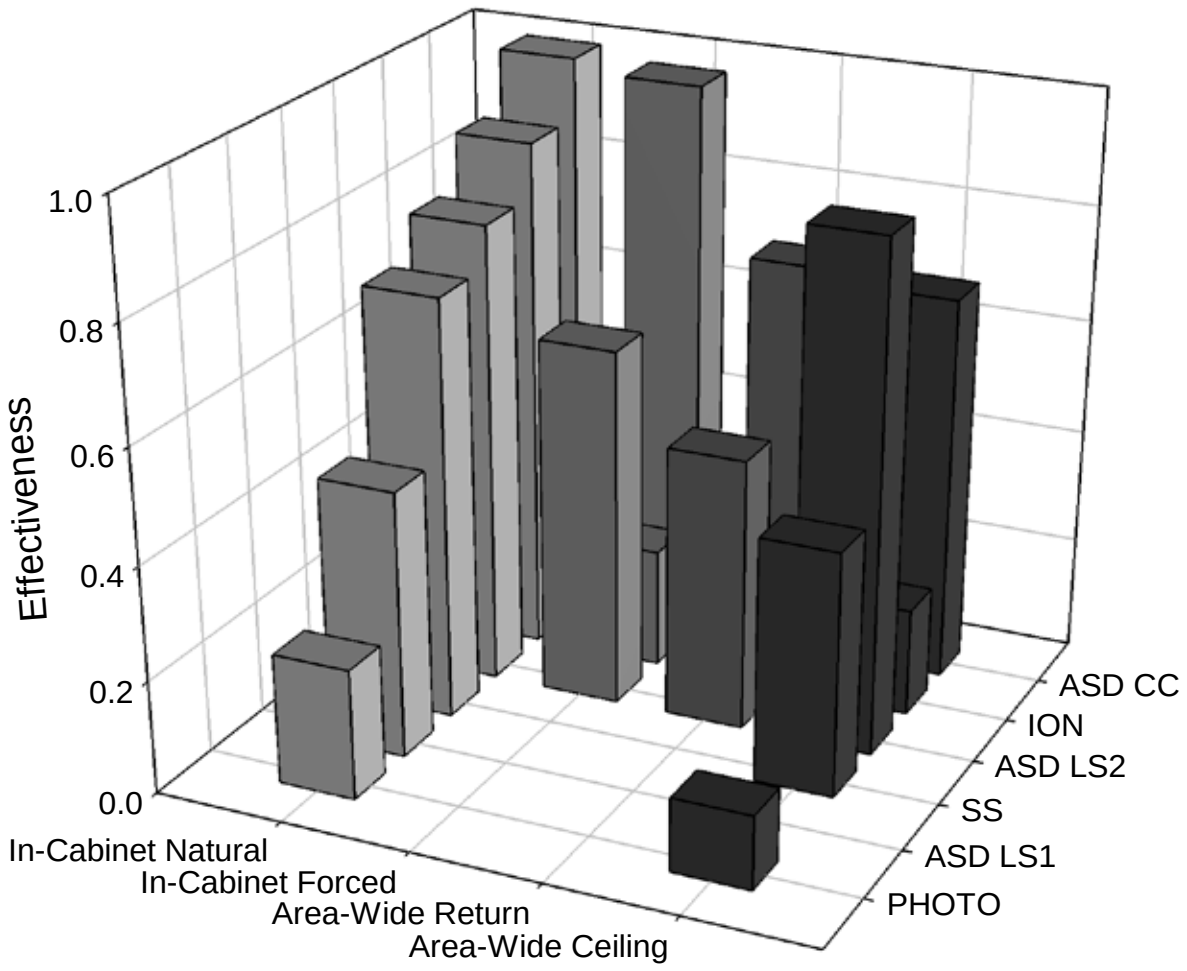

**Conventional detector versus VEWFD alert (in-cabinet, natural ventilation)**

# Evaluation of Test Results

**Summary of Average Difference in Time to Detection Between Conventional and VEWFD Systems (Negative Values Represent Conventional Spot Responding on Average before VEWFD Systems)**

| | ION | | PHOTO | |
|---|---|---|---|---|
| | Mean | 5th/95th Percentile | Mean | 5th/95th Percentile |
| ALL VEWFD | **2.9%** | -39.8/38.0% | **19.3%** | -10.7/50.4% |
| ALL ASD | **6.7%** | -38.8/40.0% | **20.6%** | -10.5/50.6% |
| ASD LS1 | **- 15.7%** | -54.4/29.5% | **12.1%** | -18.7/45.7% |
| ASD LS2 | **-0.1%** | -27.6/35.3% | **23.6%** | 4.0/53.9% |
| ASD CC | **23.5%** | 3.4/47.7% | **25.9%** | -7.6/50.8% |
| SS | **-7.9%** | -41.1/30.0% | **15.2%** | -13.4/52.6% |

# Evaluation of Test Results




Note: No data for ION area-wide return

# Overview of Risk Scoping Study

Nicholas Melly & Gabriel Taylor
Office of Nuclear Regulatory Research

U.S.NRC
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*Protecting People and the Environment*

# Overview of Fire PRA Model

$$CDF = \sum_i \lambda_I \left[ \sum_j p_{ed,j|i} \left( \sum_k p_{CD,k|i,j} \right) \right] = \sum_i CDF_i$$

Individual fire scenario CDF is:

$$CDF_i = \lambda_i \times SF_i \times P_{ns,j|i} \times p_{CD,k|i,j}$$

where,

- $\lambda_i$ Frequency of fire scenario *i*
- $SF_i$ severity factor for fire source *i*
- $P_{ns,j|i}$ probability of non-suppression before damage to target set j given ignition source *I*
- $P_{CD,k|i,j}$ Conditional probability of core damage caused by plant response scenario *k* given fire scenario *i* and damage target set *j*

# Review of previous approaches

- NUREG/CR-6850, Appendix P
  - Suppression / Detection Event tree
    - with manual suppression curves
      - $\Pr(T > t) = e^{-\lambda(t+5)}$, with t = $t_{dam}$ - $t_{fb}$ - $t_{det}$
- Supplement 1, Section 14, "Manual Non-suppression Probability (FAQ 08-0050)"
  - Updated λ estimates and adjustment factor
    - $P_{ns}(t) = \exp[-\lambda(t \cdot C_s)]$
    - $C_s = \left[\frac{\langle T_{fb-s}\rangle - \langle T_{fb-t}\rangle}{\langle T_{fb-s}\rangle + \langle T_{fb-t}\rangle}\right]$
    - t = $t_{dam}$ - $t_{det}$

# Review of previous approaches (cont.)

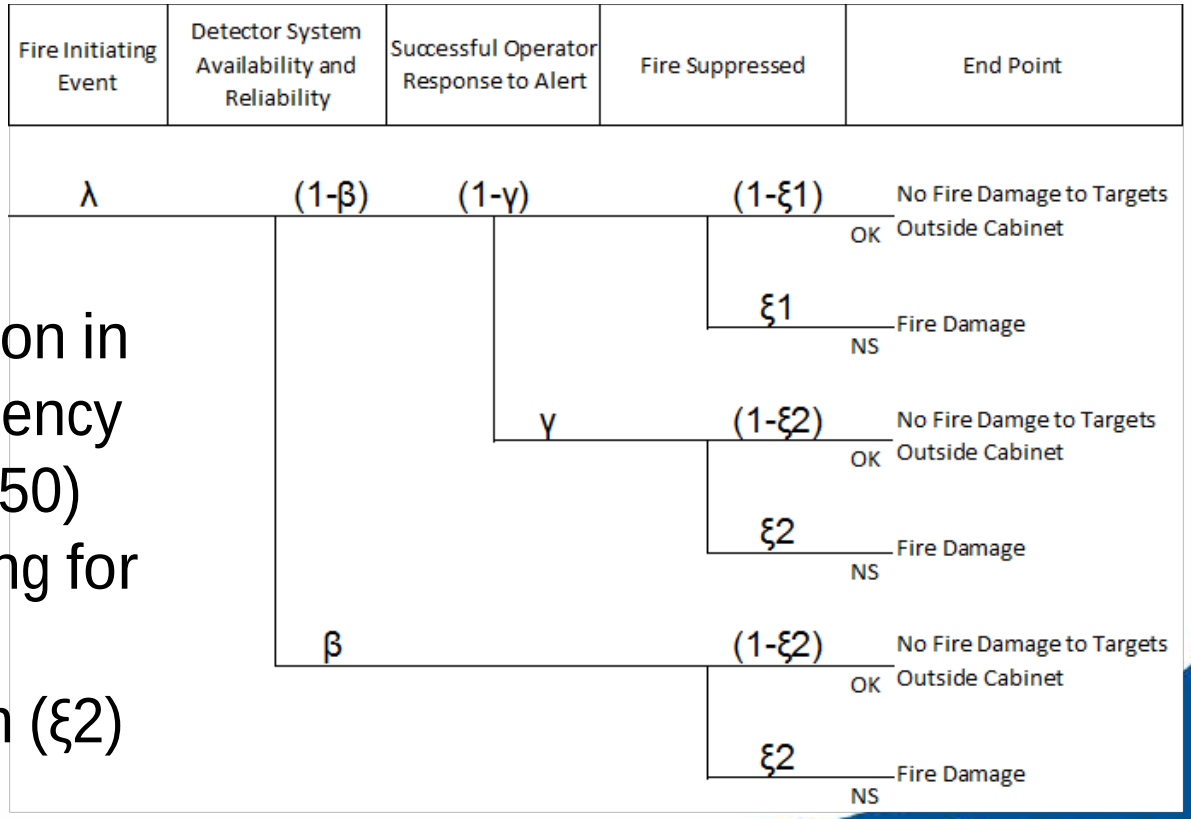
- EPRI 1016735 Fire PRA Methods Enhancements
  - Section 3 method for quantifying the performance of aspirating smoke detection

$$\lambda\omega_{VEWFD} = \lambda\omega(1 - \mu RP)$$

    - μ : the fraction of ignition source components in a location that are effectively covered by the very early warning fire detection (VEWFD) system, represented as (μ)
    - R : availability and reliability of VEWFD system in a location, and
    - P : the pre-emptive suppression probability
  - Examples indicate reduction in the fire ignition frequency from $5x10^{-01}$ to $6x10^{-03}$

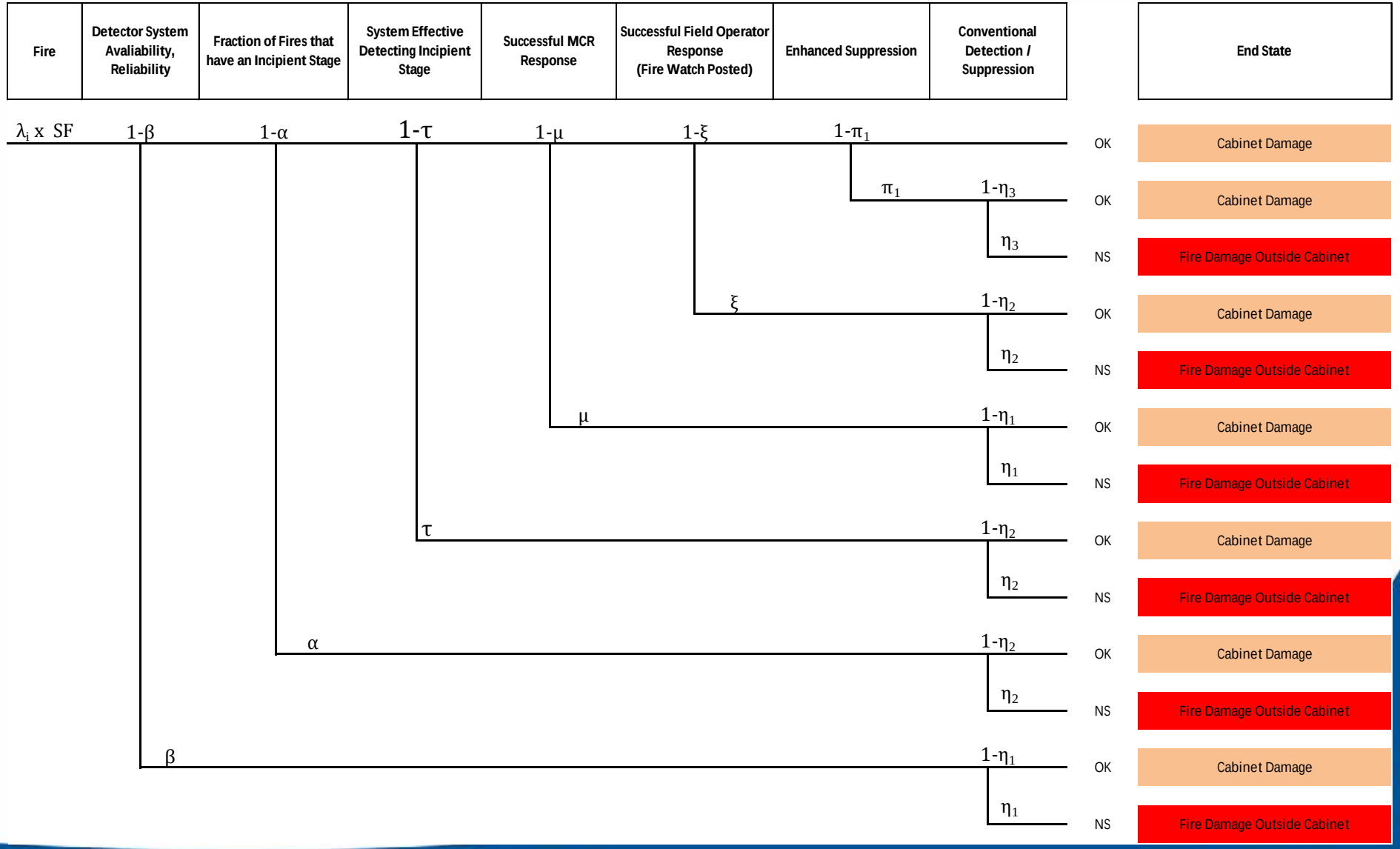
# FAQ 08-0046

- Adaptation of EPRI approach
- Interim position




- Minimum reduction in fire ignition frequency $2x10^{-02}$ (factor of 50) without accounting for redundant fire protection system (ξ2)

# NUREG-2180 Approach



# Parameter Estimation : 1-α

| Fire | Detector System Avaliability, Reliability | Fraction of Fires that have an Incipient Stage | System Effective Detecting Incipient Stage | Successful MCR Response | Successful Field Operator Response (Fire Watch Posted) | Enhanced Suppression | Conventional Detection / Suppression | End State |
|---|---|---|---|---|---|---|---|---|

- Fraction of potentially challenging or greater fires that have an incipient stage of greater than or equal to 30 minutes
- Used to bin fast vs. slow developing fires
  - not fire growth
- Operating experience has show that most, but not all, electrical cabinet fires that are risk relevant exhibit an incipient stage.

Section 7.1

# Operating Experience

- Scarce documentation of incipient stage
  - Long duration allows for other means of identification
  - Not all failures that create an incipient stage condition lead to fires
    - No fire, no need to document
  - Not in the business to document fire events
    - Especially this stage of fire events

# Parameter Estimate : α

Table 7-1

| Category | Incipient stage Detectable by VEWFD System | | | Total # Events | Fraction (alpha) Mean [lower/upper] |
|---|---|---|---|---|---|
| | Yes | No | Undetermined | | |
| Power Cabinets# | 16.5 | 16 | 22.5 | 55 | **0.50** [0.36 / 0.64] |
| Low Voltage Control Cabinets | 6 | 2 | 5 | 13 | **0.28** [0.08 / 0.54] |

# Power cabinets include electrical distribution electrical enclosures such as motor control centers, load centers, distribution panels, and switchgear

Developed based on rules defined in report, numerous iterations, and reviewed by program office staff.

# Parameter Estimation : β

| Fire | Detector System Avaliability, Reliability | Fraction of Fires that have an Incipient Stage | System Effective Detecting Incipient Stage | Successful MCR Response | Successful Field Operator Response (Fire Watch Posted) | Enhanced Suppression | Conventional Detection / Suppression | End State |
|---|---|---|---|---|---|---|---|---|

- "β" → $3.6 \times 10^{-3}$ /rx. yr.
  - Represents the combined unavailability and unreliability of a smoke detection system to perform its intended design function.
  - Unavailability based on EPRI report and updated information obtained from site visits
  - Unreliability based on US operating experience (EPRI report updated with site visit info), German data, and ASD Vendor information.

Section 7.2

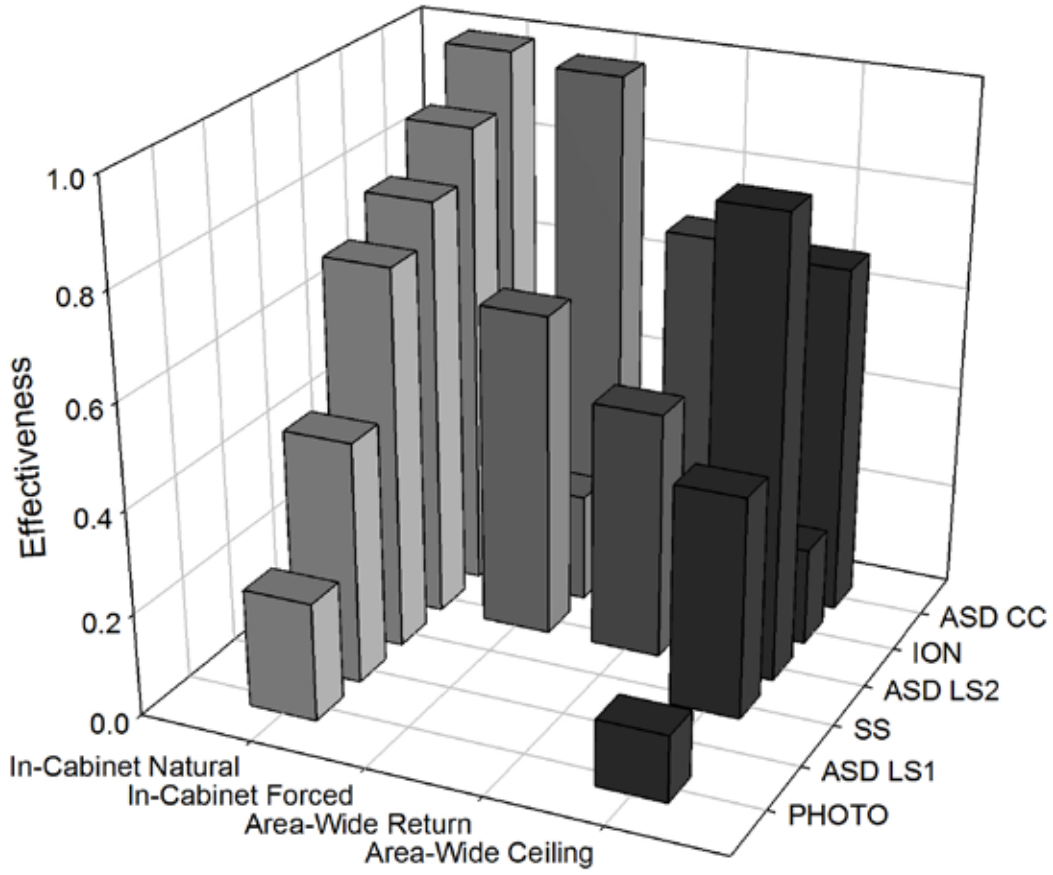
# Parameter Estimation : τ

| Fire | Detector System Avaliability, Reliability | Fraction of Fires that have an Incipient Stage | System Effective Detecting Incipient Stage | Successful MCR Response | Successful Field Operator Response (Fire Watch Posted) | Enhanced Suppression | Conventional Detection / Suppression | End State |
|---|---|---|---|---|---|---|---|---|

- System effectiveness (1-τ)
  - Measure of how well a design solution will perform or operate during the pre-flaming (incipient) phase
  - PRA uses complement : in-effectiveness “τ” (tau)
  - Estimate based on system performance via test data (Section 5)
  - Estimates specific to
    - Detector Type
    - Cabinet or Room Ventilation Configuration
    - Application

Section 7.2.3

# Graphical Representation of System Effectiveness



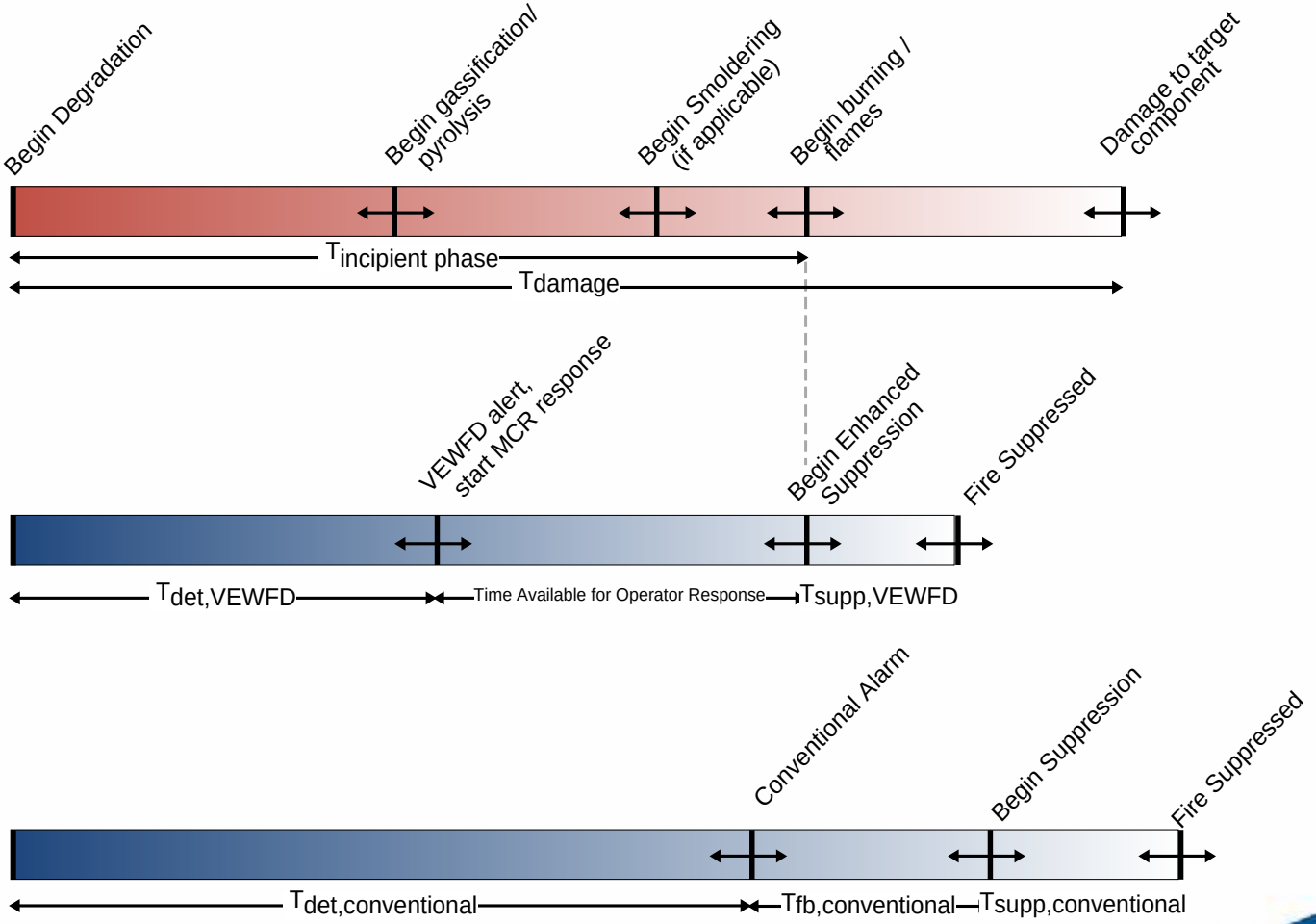

Note: No data for ION area-wide return

# Timing Analysis

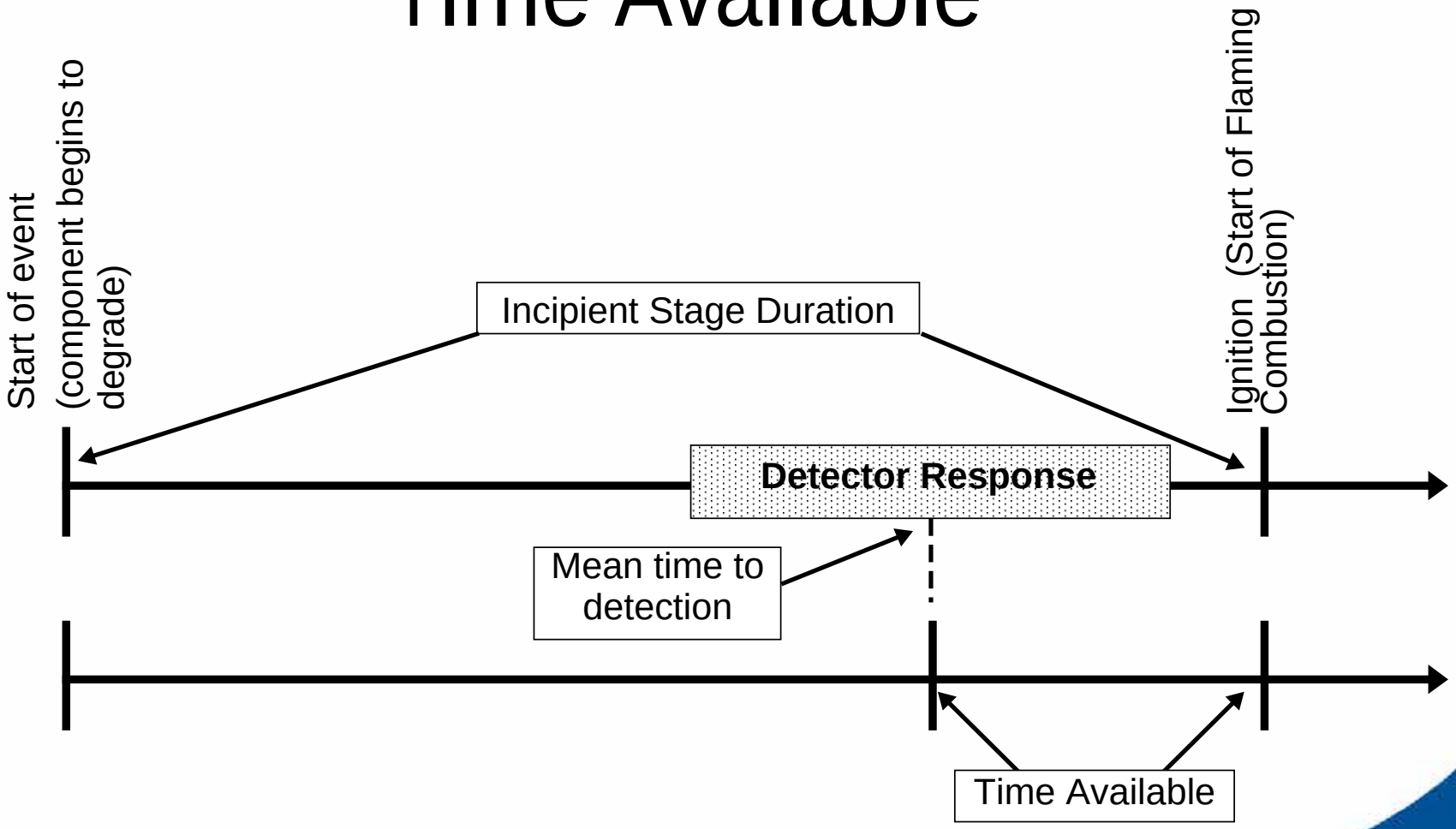
- Fire PRA Detection and Suppression Analysis is a Timing Analysis

- More time available to respond to a fire prior to damage equates to lower risk estimates.

# ***Generic*** Fire Scenario Timelines



# Time Available

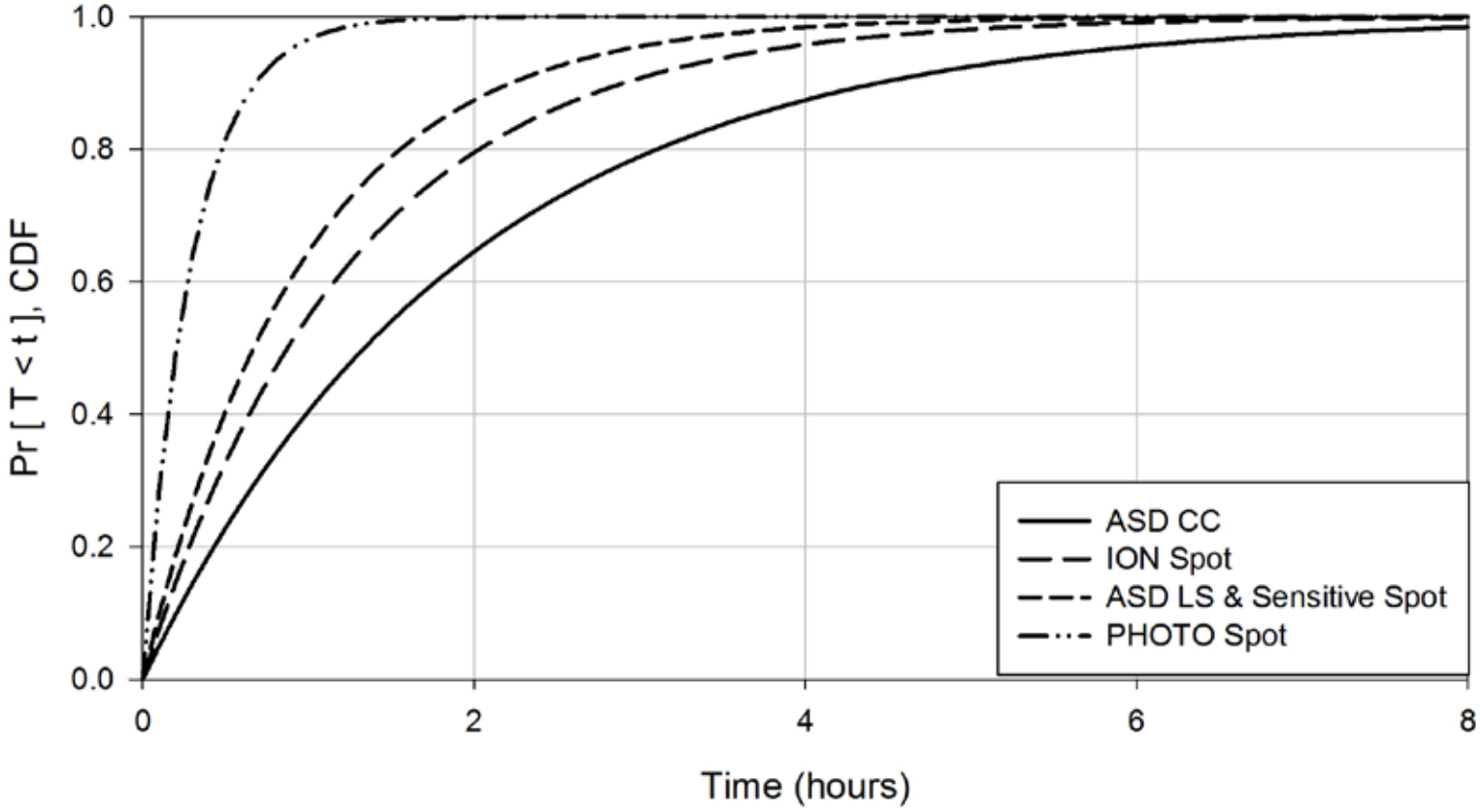


# Time Available – Operating Experience

| Event | Incipient stage (Hours) | Time Available for Operator Response (Hours) | | | |
|---|---|---|---|---|---|
| | | CC | LS-SS | ION | PHOTO |
| EPRI FEDB 161 | 0.5 | 0.26* | 0.13* | 0.17* | 0.04* |
| EPRI FEDB 50836 | 0.9 | 0.47* | 0.23* | 0.31* | 0.07* |
| SNL z-machine | 0.98 | 0.51* | 0.26* | 0.33* | 0.08* |
| 2014 Event | | 1.12 | 0.56* | 0.73* | 0.17* |
| 2013 Event | | 2.75 | 1.38* | 1.80* | 0.42* |
| EPRI FEDB 10647 | 7 | 3.64* | 1.82* | 2.38* | 0.56* |
| 2015 Event | | 4.75[Ŧ] | 2.38* | 3.11* | 0.73* |
| Lambda | | 0.518 | 1.036 | 0.793 | 3.382 |

- Review of Operating Experience to identify
  - Incipient phase duration, or
  - Time between VEWFD alert and flaming conditions

# Time Available Curves

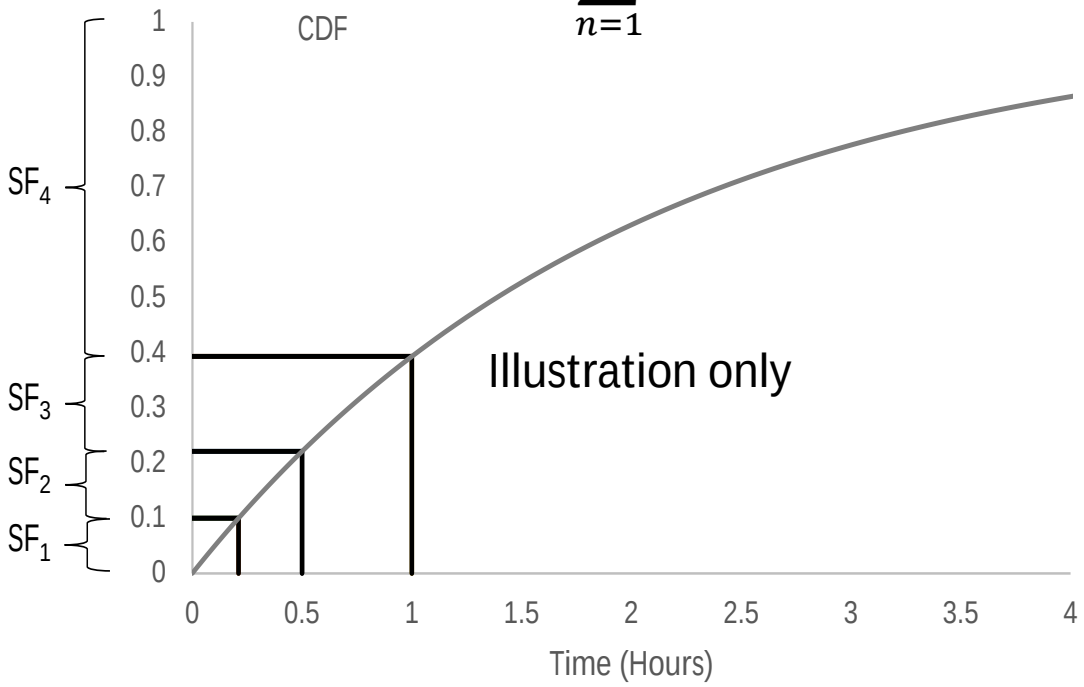



Time available between system response (alert VEWFD; alarm ION/PHOTO) and ignition

# Time Available Curves Support HRA

- Use distinct points to estimate split fractions

$$Total\ HEP = \sum_{n=1}^{4} (SF_n) x (Base\ HEP)$$




$SF_1$ fixed at 0.10

$$t_{10^{th}} = \left(\frac{-1}{\lambda}\right) \cdot \ln(1 - 0.1)$$

$$SF_2 = e^{-\lambda \cdot t_{10^{th}}} - e^{-\lambda \cdot 0.5}$$

$$SF_3 = e^{-\lambda \cdot 0.5} - e^{-\lambda}$$

$$SF_4 = e^{-\lambda}$$

HEP = Human Error Probability

# Question and Answer

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# Lunch Break

# Continuation of Risk Scoping Study Overview

Human Factor Analysis

&

Human Reliability Analysis

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# Human Response: Human Factors & Human Reliability Analysis

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&
Dr. Amy D'Agostino
Office of Nuclear Regulatory Research

U.S.NRC
United States Nuclear Regulatory Commission
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# HUMAN RESPONSE

- Response to incipient fire detectors relies solely on human actions (no automatic system actuations)
- Two components to addressing human response:
  - Human Factors (HF) Analysis
  - Human Reliability Analysis (HRA)
- HF analysis supports HRA
- Objective:
  - Support PRA for crediting use of VEWFDS
  - Provide improved and more detailed HRA

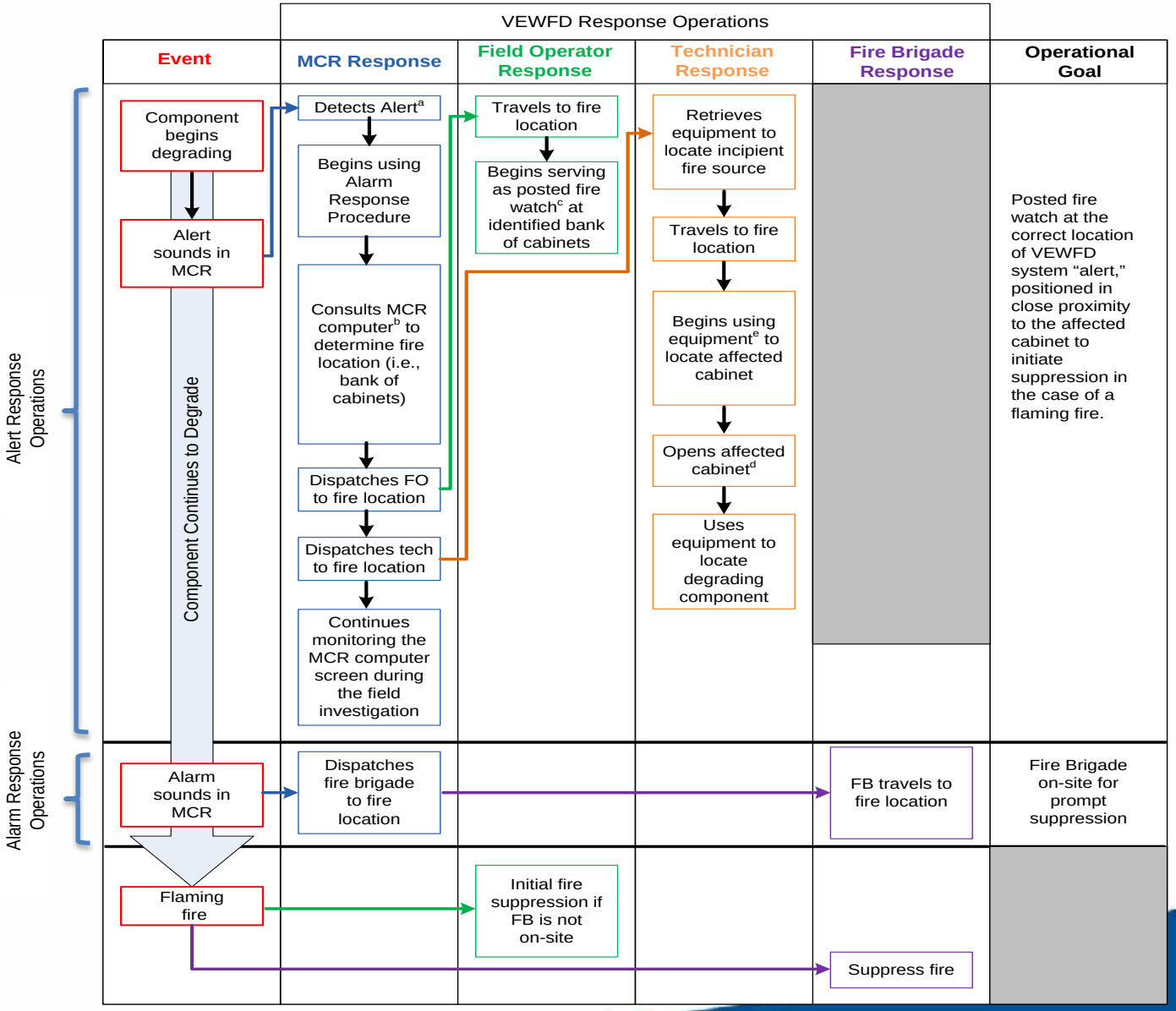
# HUMAN RESPONSE (continued)

- Scope limitations:
  - Focused on in-cabinet installations, suppression strategies
    - In particular, suppression provided more quickly than that for traditional fire detector installations
  - Fire suppression activities are not modeled by HRA
  - Human response includes only main control room (MCR) operators, field operators, and technician (for use of portable “sniffers”)

# HUMAN FACTORS

- Objectives (in support of HRA)
  - Identify personnel tasks (i.e. human actions) involved in the planned response to ASD VEWFD alerts and alarms
  - Identify human factors considerations that may adversely affect performance of personnel tasks
- Approach
  - Document review
  - Expert consultation
  - Site visits
- Results
  - Identified  fundamental tasks involved in the planned response
  - Identified variations in planned response and system implementation
  - Identified factors that may adversely affect personnel task performance

# HUMAN FACTORS

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# HUMAN FACTORS

- Factors that may adversely affect performance
  - Special equipment
  - Human-system interface
  - Procedures
  - Training
  - Staffing
  - Communications
  - Complexity
  - Workload, pressure and stress

# HUMAN RELIABILITY ANALYSIS (HRA)

- Two human failure events (HFEs) modeled:
  - Failure of MCR operators to respond expeditiously to incipient fire detector alarm
  - Failure of field operator & technician to expeditiously respond such that field operator is positioned to provide fire suppression capability
- Endpoints of event trees for these HFEs must match to fire suppression capability for MCR
- HRA does not model fire suppression; non-suppression curves selected in a separate task

# HRA (continued)

- **Traditional HRA used:**
  - Process/approach similar to NUREG-1921
  - Existing HRA quantification methods used (e.g., SPAR-H, CBDT)
- **However, this is NOT a traditional HRA context**
  - All human actions are taken without a reactor trip (while typical HRA focuses on post-reactor trip)
  - Very limited use of  & data for VEWFDS in US NPPs
  - No standards or requirements exist for this response/context (which usually is a strong influence on HRA)

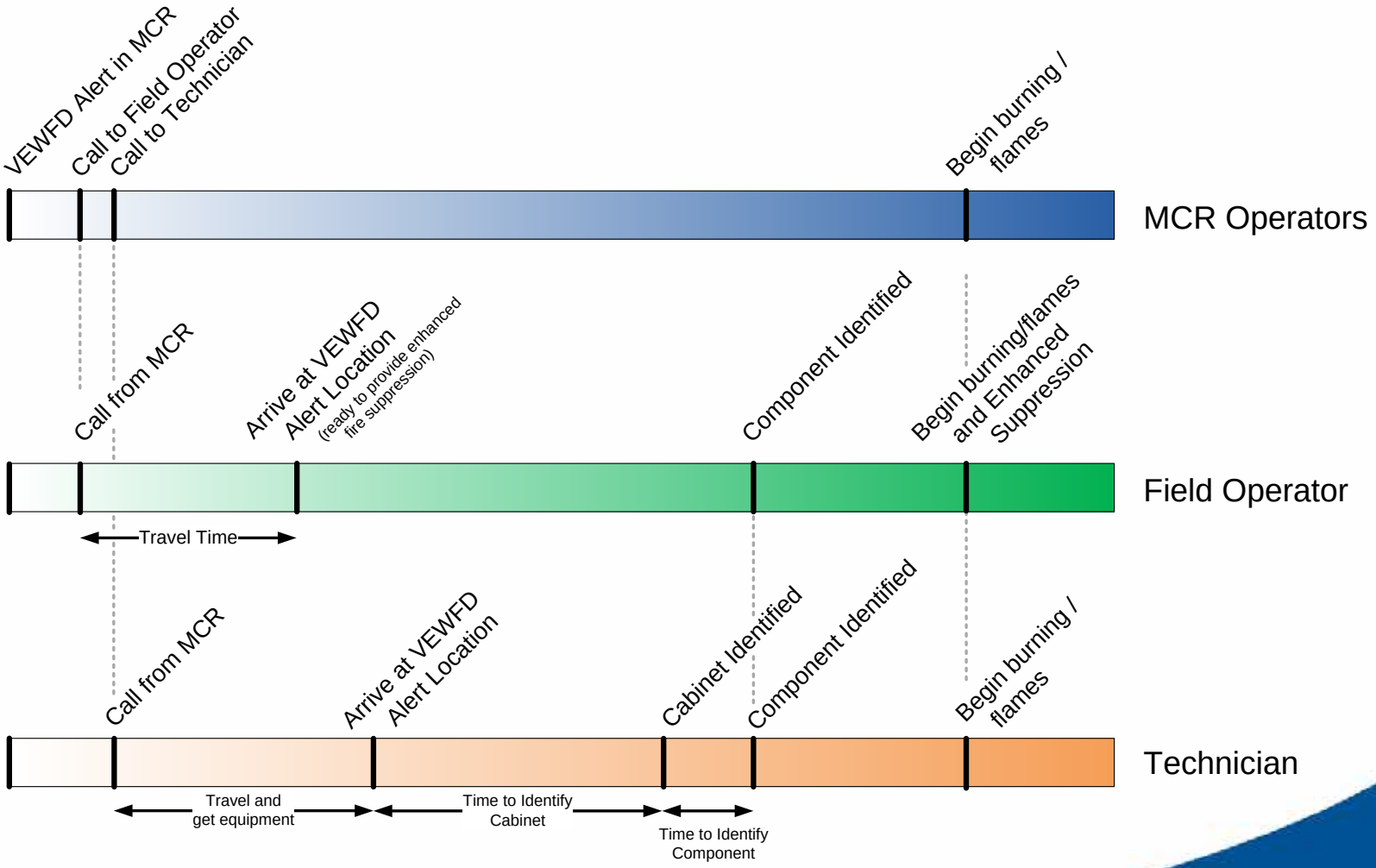
# HRA (continued)

- HRA (qualitative & quantitative):
  - Not based on a specific plant
  - Information on alarm response, procedures, training, & so forth mostly based on inputs from two NPPs
  - Time required estimates based on NPP inputs
  - Time available estimates based on data & detector performance (discussed earlier)
  - A few assumptions were made

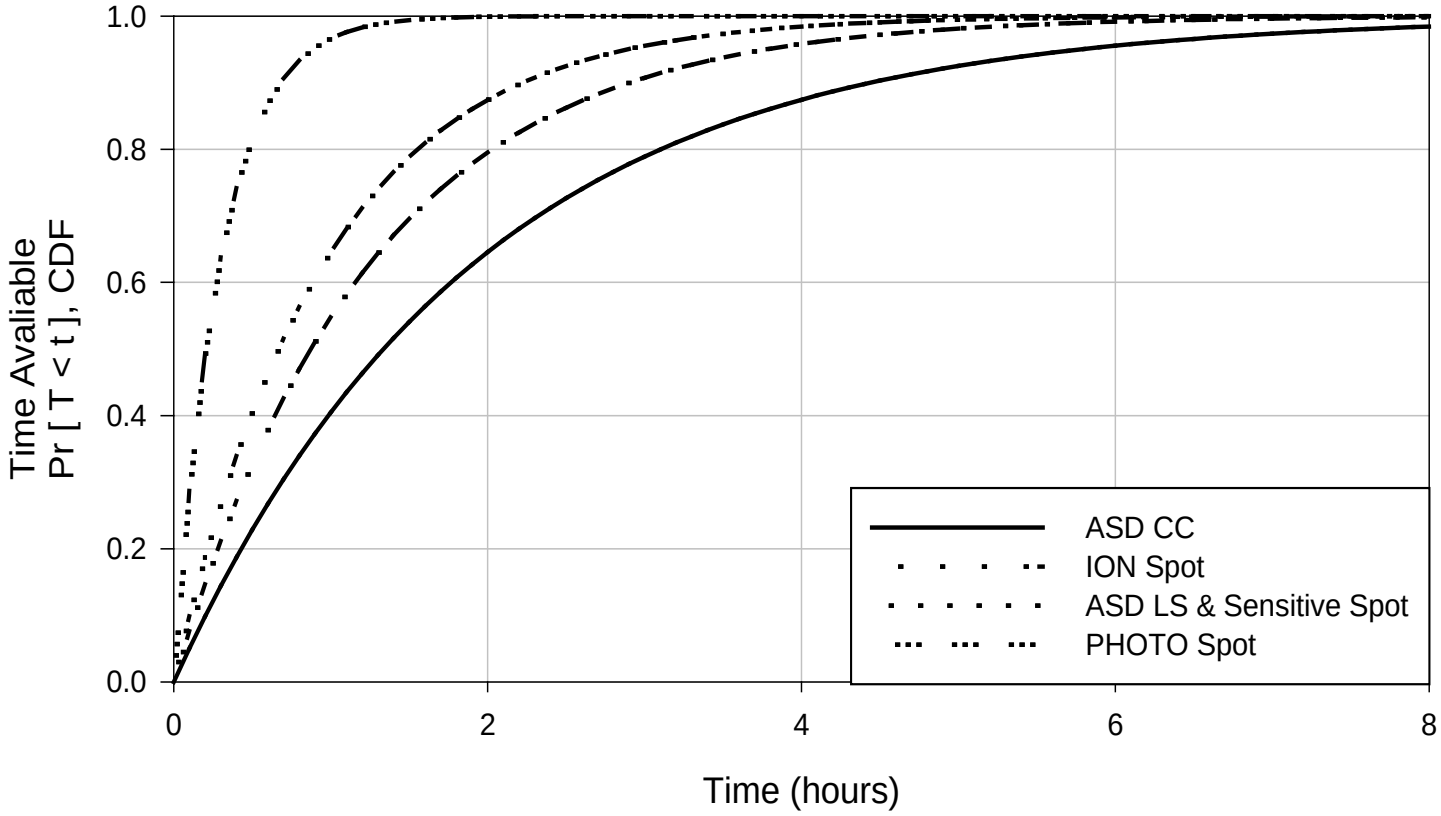
# HRA (continued)

- **Key factor for HRA: Urgent/rapid operator response is needed due to current time available information**
  - Time available estimates (developed from fire events data and detector testing) are given as distributions
  - Distributions are generally centered at 1 hour, BUT show significant contributions for times less than 1 hour
    - HRA use of an average time of 1 hour cannot be justified
    - This HRA used a distribution sampling approach, starting with 90% confidence that the incipient phase has not ended
    - For some detectors, time available associated with 90% confidence is short
  - Operator response must be "designed" to be this fast (and reliable)
    - Incipient detector response (for operators and technician) must be highest priority with respect to other activities, alarms, etc. (as long as there is no reactor trip)
    - This HRA models a "fast" operator response (focusing on arrival at "alert" location of field operator who has been trained in: 1) fire suppression capability and 2) understanding incipient fire detectors

# HRA Timelines



# HRA Timing: Cumulative probability distribution for time available



# HRA: Example Feasibility Assessments

**Table 10-5. Feasibility Assessment for ADS VEWFD, Cloud Chamber**

| Time required | Sample | Time available from alert | Feasible? |
|---|---|---|---|
| 3-10 minutes | 1 | 0-12 minutes* | Yes |
| | 2 | >12 minutes AND <30 minutes** | Yes |
| | 3 | > 30 minutes AND < ~1 hour** | Yes |
| | 4 | > ~ 1 hour** | Yes |

* From Section 10.4.2.1, this is the definition of this sample point

** From Section 10.4.2.1, this is the result from the cumulative distribution function associated with the definition of this sample point

**Table 10-6. Feasibility Assessment for Conventional Spot-Type, ION Detector**

| Time required | Sample | Time available from alert | Feasible? |
|---|---|---|---|
| 3-10 minutes | 1 | 0-8 minutes* | Partial |
| | 2 | > 8 minutes AND < 30 minutes** | Partial |
| | 3 | > 30 minutes AND < ~1 hour** | Yes |
| | 4 | > ~ 1 hour** | Yes |

* From Section 10.4.2.1, this is the definition of this sample point

** From Section 10.4.2.1, this is the result from the cumulative distribution function associated with the definition of this sample point

# HRA Quantification

- Base human error probabilities (HEPs) developed for each HFE using qualitative analysis results
  - Section 10.6.1 describes base HEP development for MCR operator response = 1E-4
  - Section 10.6.1.2 describes basis for field operator response = 1E-3
- Final results:
  - MCR operator response HEP = 1E-4
  - Field operator response HEP – adjusted by feasibility & time available versus time required

# HRA: Example Results

## Table 10-9. HEP Calculations for ASD VEWFD, Cloud Chamber

| Sample | Time available from alert | Split Fraction from Table 10-1 | Base HEP | Base HEP x Split Fraction |
|---|---|---|---|---|
| 1 | 0-12 minutes* | 0.1 | $1x10^{-03}$ | $1.0x10^{-04}$ |
| 2 | >12 minutes AND <30 minutes** | 0.13 | $1x10^{-03}$ | $1.3x10^{-04}$ |
| 3 | > 30 minutes AND < ~1 hour** | 0.17 | $1x10^{-03}$ | $1.7x10^{-04}$ |
| 4 | > ~ 1 hour** | 0.60 | $1x10^{-04}$ | $6.0x10^{-05}$ |
| **TOTAL HEP (ξ)** | | | | $4.6x10^{-04}$ |

* From Section 10.4.2.1, this is the definition of this sample point

** From Section 10.4.2.1, this is the result from the cumulative distribution function associated with the definition of this sample point

## Table 10-10. HEP Calculations for Conventional Spot-Type, ION Detector

| Sample | Time available from alert | Split Fraction from Table 10-2 | Base HEP | Base HEP x Split Fraction |
|---|---|---|---|---|
| 1 | 0-8 minutes* | 0.10 | 0.10*** | $1x10^{-02}$ |
| 2 | > 8 minutes AND < 30 minutes** | 0.23 | $3x10^{-02}$*** | $6.9x10^{-03}$ |
| 3 | > 30 minutes AND < ~1 hour** | 0.22 | $1 x10^{-03}$ | $2.2x10^{-04}$ |
| 4 | > ~ 1 hour** | 0.45 | $1 x10^{-04}$ | $4.5x10^{-05}$ |
| **TOTAL HEP (ξ)** | | | | $1.7x10^{-02}$ |

* From Section 10.4.2.1, this is the result from the cumulative distribution function associated with the definition of this sample point

** From Section 10.4.2.1, this is the definition of this sample point

*** Partially feasible.

# Fire Suppression

Nicholas Melly

Office of Nuclear Regulatory Research

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# Fire Risk Quantification

- Fire Scenario Risk Equation

$$\lambda \times SF \times \mathbf{P_{ns}} \times CCDP$$

- $\lambda$ : fire ignition frequency
- SF : severity factor (fire modeling)
- $P_{ns}$ : Probability of non-suppression
- CCDP : Conditional Core Damage Probability

# Application/Assumptions

- The probability of non-suppression estimates developed from the approach presented previously are only applicable to target damage sets located outside of the electrical enclosure. That is, the VEWFD system ONLY impacts the adverse consequences related to cabinet fires resulting in fire growth outside the initiating electrical enclosure which could damage secondary combustibles and targets.

- In the previous equation, $P_{ns}$ should only be applied to targets outside of the enclosure
- Targets within the enclosure should be assumed damaged with the onset of the fire condition

# Enhanced Fire Suppression

| Fire | Detector System Avaliability, Reliability | Fraction of Fires that have an Incipient Stage | System Effective Detecting Incipient Stage | Successful MCR Response | Successful Field Operator Response (Fire Watch Posted) | Enhanced Suppression | Conventional Detection / Suppression | End State |
|---|---|---|---|---|---|---|---|---|

- Defined in report as
  - providing fire suppression capability earlier than typical conventional systems allow. With respect to operator response to very early warning fire detection systems, this implies arriving at the location of a potential fire threat with suppression capability prior to that threat transitioning to a flaming condition. This differs from prompt detection, as used in fire PRA suppression-detection analysis.

# Parameter Estimation : π

- π represents failure of enhanced suppression
- π1 (in-cabinet) : represents the probability that, given **success** of the technician/field operator to respond to the VEWFD "alert," suppression has failed to limit the fire damage to the enclosure of origin. The field operator in the area of the cabinet responsible for the VEWFD system alert fails to promptly suppress the fire quickly enough to prevent damage to PRA targets outside the cabinet.
- The MCR curve (λ=0.324) should be used for this case.

# Parameter Estimation : π (Cont.)

- π2 (area-wide) : represents the probability that, given **success** of the technician/field operator in the room responsible for the VEWFD system alert, suppression activities fail to prevent damage to PRA targets outside the cabinet.
- A newly developed non-suppression probability curve should be used with λ = 0.194.
  - This value is based upon an analysis of fire events from the Updated Fire Events Database (Ref. 63).

# Conventional Fire Suppression

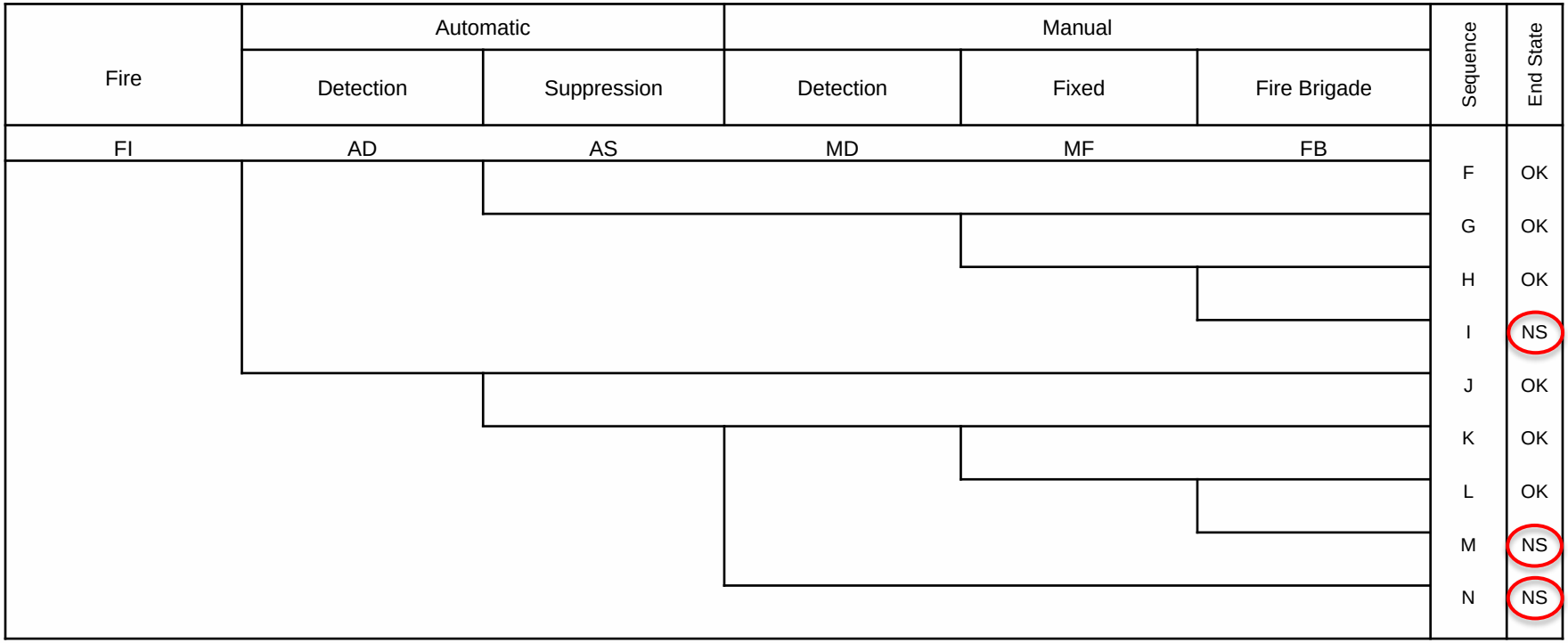
- "η1" represents the failure probability of redundant detection and/or automatic suppression systems, given that the VEWFD system has failed.
- "η2" represents the failure probability of redundant detection and/or automatic suppression systems, given that the VEWFD system was not able to provide enhanced detection.
- "η3" represents the failure of an independent automatic fire suppression system

# Conventional Fire Suppression

| Fire | Detector System Avaliability, Reliability | Fraction of Fires that have an Incipient Stage | System Effective Detecting Incipient Stage | Successful MCR Response | Successful Field Operator Response (Fire Watch Posted) | Enhanced Suppression | Conventional Detection / Suppression | End State |
|---|---|---|---|---|---|---|---|---|

- Credited when
  - VEWFD unavailable/unreliable (β) : η1
  - Fire lacks incipient stage (α) : η2
  - VEWFD ineffective at detection during incipient stage (τ) : η2
  - MCR response failures (μ) : η1
  - Field operator/technician failure (ξ) : η2

# Conventional Fire Suppression Estimation




| Sequence | Detection | Suppression |
|---|---|---|
| F | Automatic detection by<br>· Heat detectors<br>· Smoke detectors | Fire suppression by an automatically actuated fixed system |
| G | | Fire suppression by a manually actuated fixed system |
| H | | Fire suppression by the fire brigade |
| I | | Fire damage to target items |
| J | Delayed detection by<br>· Roving fire watch<br>· Control room verification | Fire suppression by an automatically actuated fixed system |
| K | | Fire suppression by a manually actuated fixed system |
| L | | Fire suppression by the fire brigade |
| M | | Fire damage to target items |
| N | Fire damage to target items | |

# Summary of Public Comments Received and Resolution

Gabriel Taylor

Office of Nuclear Regulatory Research

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# Draft for Public Comment

- July 7, 2015
  - Draft report for comment issued for public comment
  - 60-day public comment period
    - Closed September 8th
  - Federal Register Notice (80 FR 38755)
  - Docket ID #: NRC-2015-0112
    - https://www.regulations.gov

# Comments Received

- 207 external comments from
  - Building Reports
  - Electric Power Research Institute
  - Exelon Generation
  - National Fire Protection Association
  - Nuclear Energy Institute
  - Safe Fire Detection
- 45 internal comments
  - NRC staff and contractor

# Comment Breakdown

- 47 were duplicate comments
- Remaining 205 comments,
  - Clarification (63)
  - Technical (85)
  - Editorial (55)
  - Supplemental Information (2)
    - Duke operating experience

# 1 Sensitivity Testing

- Several comments suggested that testing per NFPA 76 Annex B or vendor methods serve as a “tuning test” or verification of obscuration level for alert (0.2% obsc./ft.) and alarm (1.0% obsc./ft.).

# Response to Sensitivity Comments

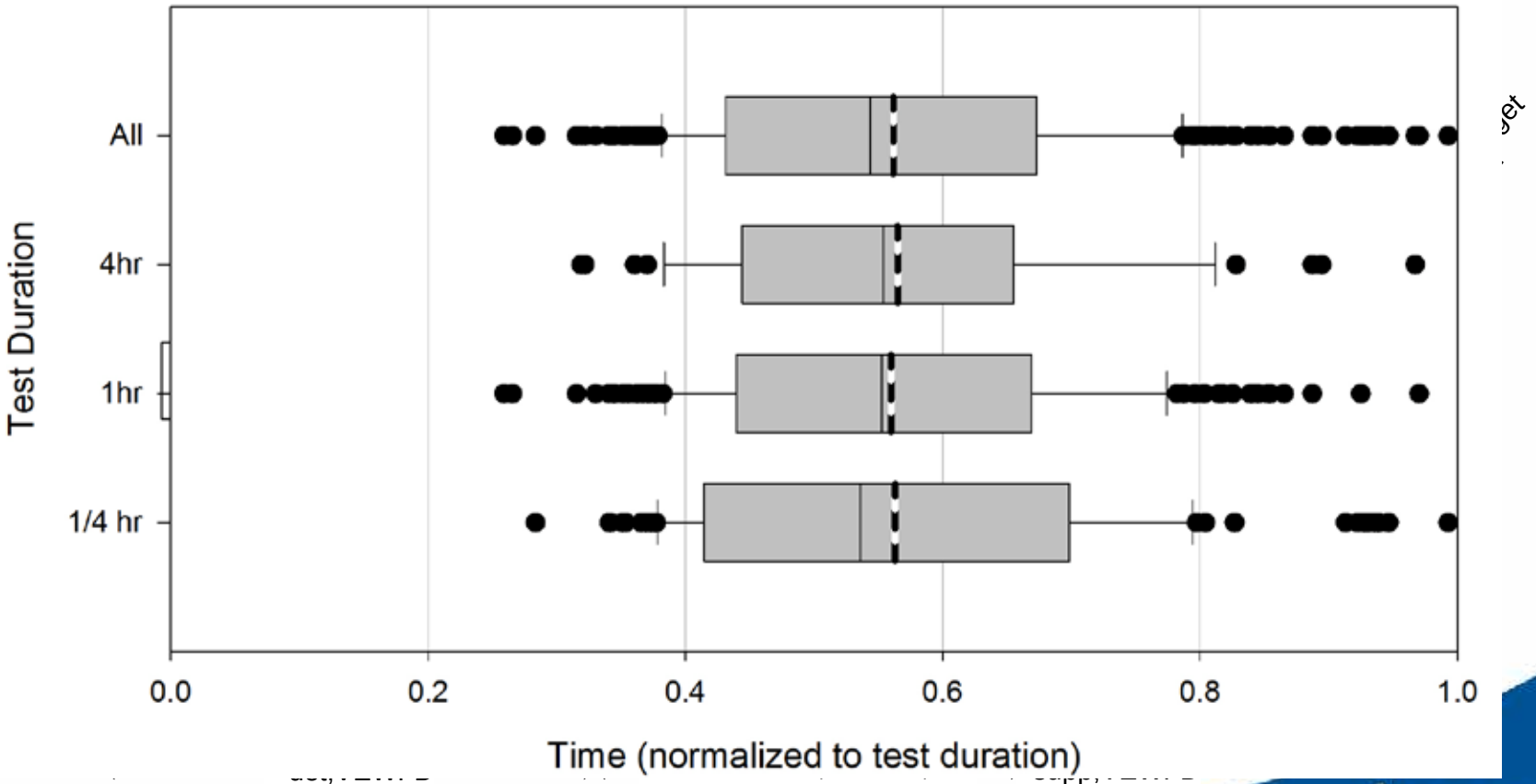
- NFPA 76 Annex B testing is a performance (functionality) test, NOT a sensitivity test.
  - The intent of that procedure is to ensure that the system responds (functional) and to ensure transport times are met.
  - The smoke source used in Annex B tests is designed to provide sufficient aerosol for a VEW or EW system to response, but not so much smoke that it would negatively affect the electrical components in the room.
- Sensitivity tests are prescribed in standards such as UL 268/217.

# 2 30-minute Threshold

- Several comments on the justification of the 30-minutes threshold for developing the estimate of "α" fraction of fires that have an incipient stage.

# Response to 30 Minutes Assumption

Figure 8-2. Summary of ASD VEWFD in-cabinet test results showing normalized time of alert



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# 3 Operating Experience

- Roughly 15% of electrical cabinet fires are detected by fixed detection systems. Most of the remaining fires are detected by plant personnel or other control room indications. Therefore, it is likely that the installation of incipient detection systems would increase the number of fires detected by fixed detection systems. There has been substantial industry OE with respect to incipient detection that suggest early component failures are being detected on a more frequent basis.

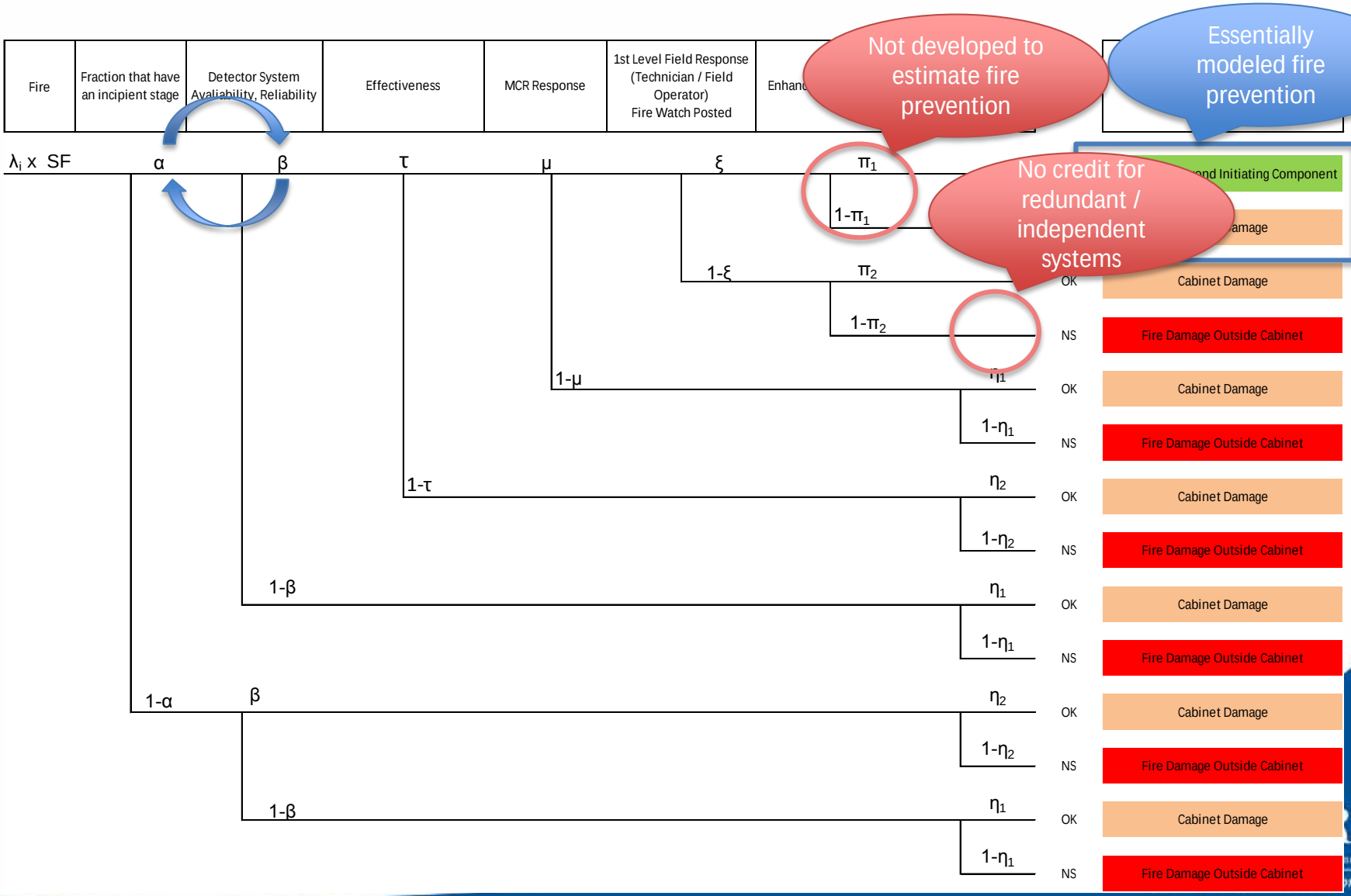
# Response on Operating Experience

- Consistent collection of operating experience (OpE) moving forward is important
  - Analysis of OpE should allow for comparisons between VEWFD protected and non-VEWFD protected equipment.
  - System ‘alert’ with identification of over heating component doesn’t necessarily equate to a fire per definition of fire ignition frequency.

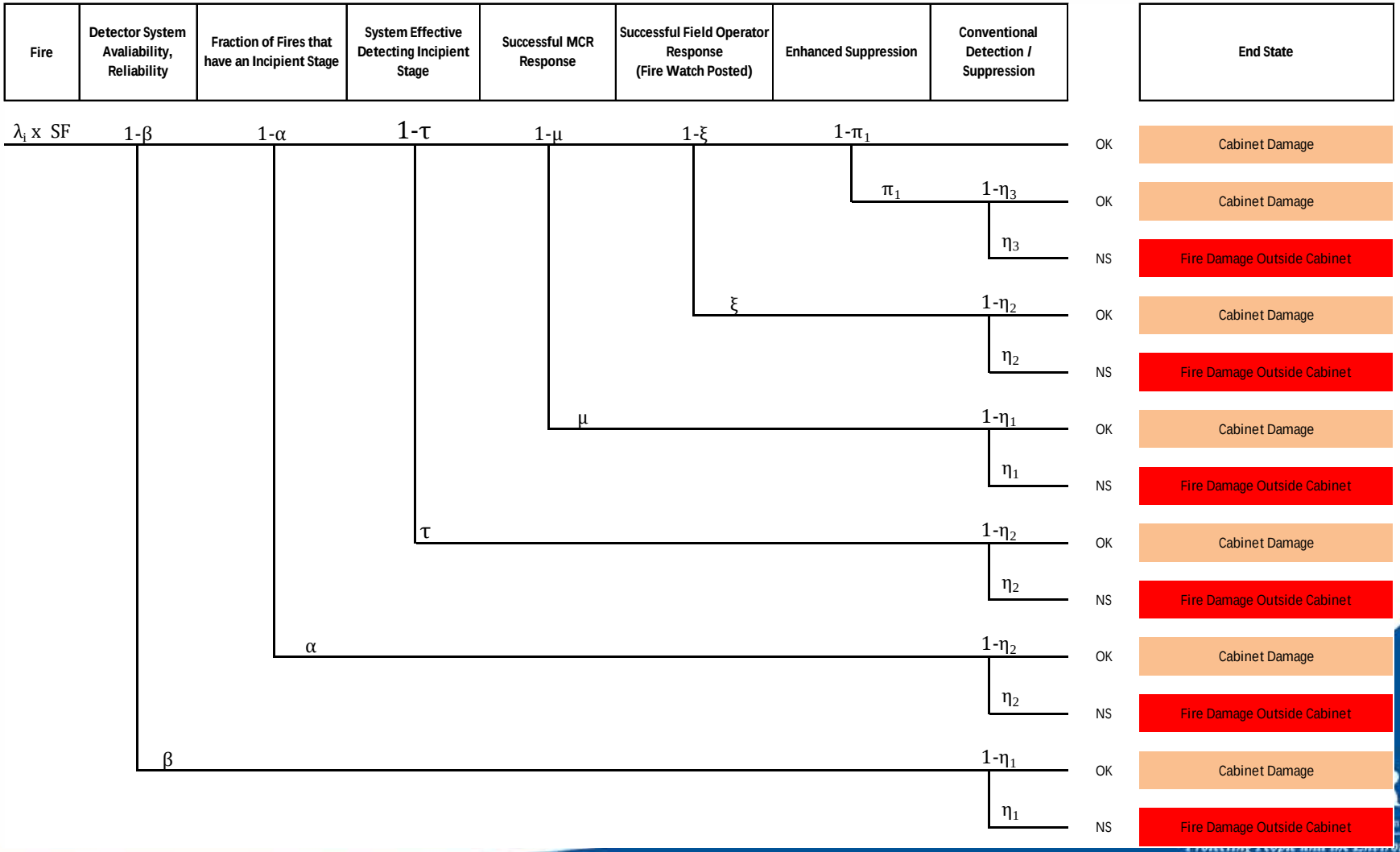
# 4 Changes to Event Tree Structure

- Several comments and regulatory application of draft ET identified potential improvements
- Several changes were made.
  - Top end state
  - Credit redundant system when enhanced suppression fails (1-π2)
  - Convention (fail states are greek letters)

# Draft Event Tree (In-cabinet)



# Final Event Tree (In-cabinet)



# Question and Answer

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# Workshop on Event Tree Non-Suppression Estimation Spreadsheet

Gabriel Taylor / Nicholas Melly

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# Need and Objective

- Numerous parameter developed and used in the risk scoping study.
- Public comment identified issues with quickly identifying parameters to use in practice.
- Automate the estimation of non-suppression probability
  - Drop down menus
  - Field entries

# Format

- Two Sheets (in-cabinet; area-wide)
- Follows NUREG-1805 approach
  - Inputs
  - Results
  - Solved Event Trees
- Estimates the $P_{ns}$ for damage outside cabinet
- Application specific damage states not addressed.

# Appendix H

- User guide for VEWFD event tree non-suppression probability calculation tool
- Provides a step-by-step procedure for using the excel spreadsheets.

# Appendix F

- Quick reference for Parameters used in Risk Scoping Study
  - Parameter estimates presented in table format for quick look-up.

**Table F-4. Human Error Probability (HEP) for ASD VEWFD Cloud Chamber Detectors – Parameters "μ" and "ξ"**

| Detector Type | Total Human Error Probability Estimates | | |
|---|---|---|---|
| | MCR (μ) | Field Operator (ξ) | |
| | | In-Cabinet | Area-Wide |
| ASD VEWFD Cloud Chamber (**CC**) | $1x10^{-04}$ | $4.6x10^{-04}$ | 1.0◊ |
| Ionization spot (**ION**) | | $4.6x10^{-02}$ | |
| ASD VEWFD Light Scattering (**LS**) and VEWFD Light Scattering Sensitive Spot (**SS**) | | $1.7x10^{-02}$ | |

◊ the variability of area-wide applications does not permit the development of a generic field operator HEP. As such, an HEP of 1.0 is assumed. If a scenario specific analysis were conducted following the process outlined in Section 10, the result of such an analysis may support using a value other than 1.0.

# In-Cabinet Spreadsheet

- Worksheet walk-through

# In-Cabinet Example

- Scenario
  - Licensee is considering the installation of a VEWFD system to protect a relay rack.
    - Multiple cabinets in a bank with communicating air space
  - Relay rack is in a room that already had automatic fire detection (Ion spots at ceiling) and a cross-zoned detection system that automatically actuates a Halon system.
  - Fire modeling estimates the redundant fire detection system actuates in less than one minute, with target damage in 14 minutes.
  - Fire brigade response time is ~ 10 minutes

# In-cabinet Example Cont.

- Estimate the $P_{ns}$ using
  - Existing NUREG/CR-6850 Appendix P method
  - FAQ 08-0046
  - NUREG-2180
- What if Halon system is not credited

# NUREG/CR-6850 method

- *No Credit for Prompt detection/suppression*
- *5 minute bonus for in-cabinet detector*
- *Manual NSP*
  - $\Pr(T > t) = e^{-\lambda t}$
    - $t=t_{dam}-t_{det}+t_{bonus}=14-1+5 = 18$ minutes
    - $\lambda = 0.098$ (NUREG-2169)
- Manual NSP=0.17
- Solving Apx P. ET
  - $P_{ns}$ = 5.8x10$^{-02}$ (w/Halon)
    2.1x10$^{-01}$ (w/o Halon)

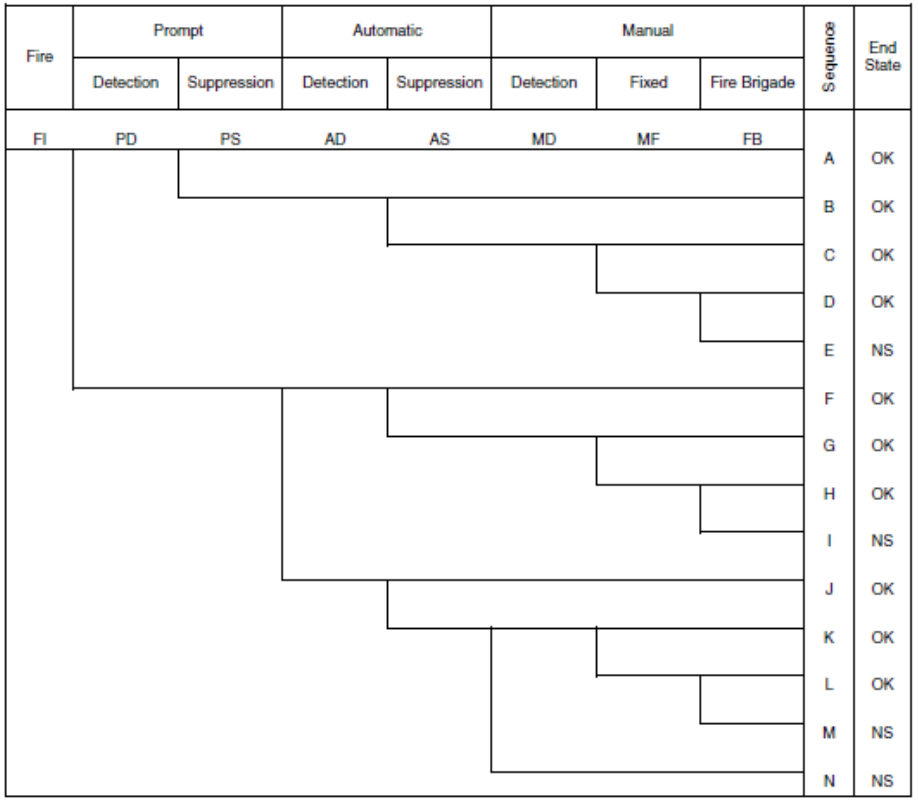
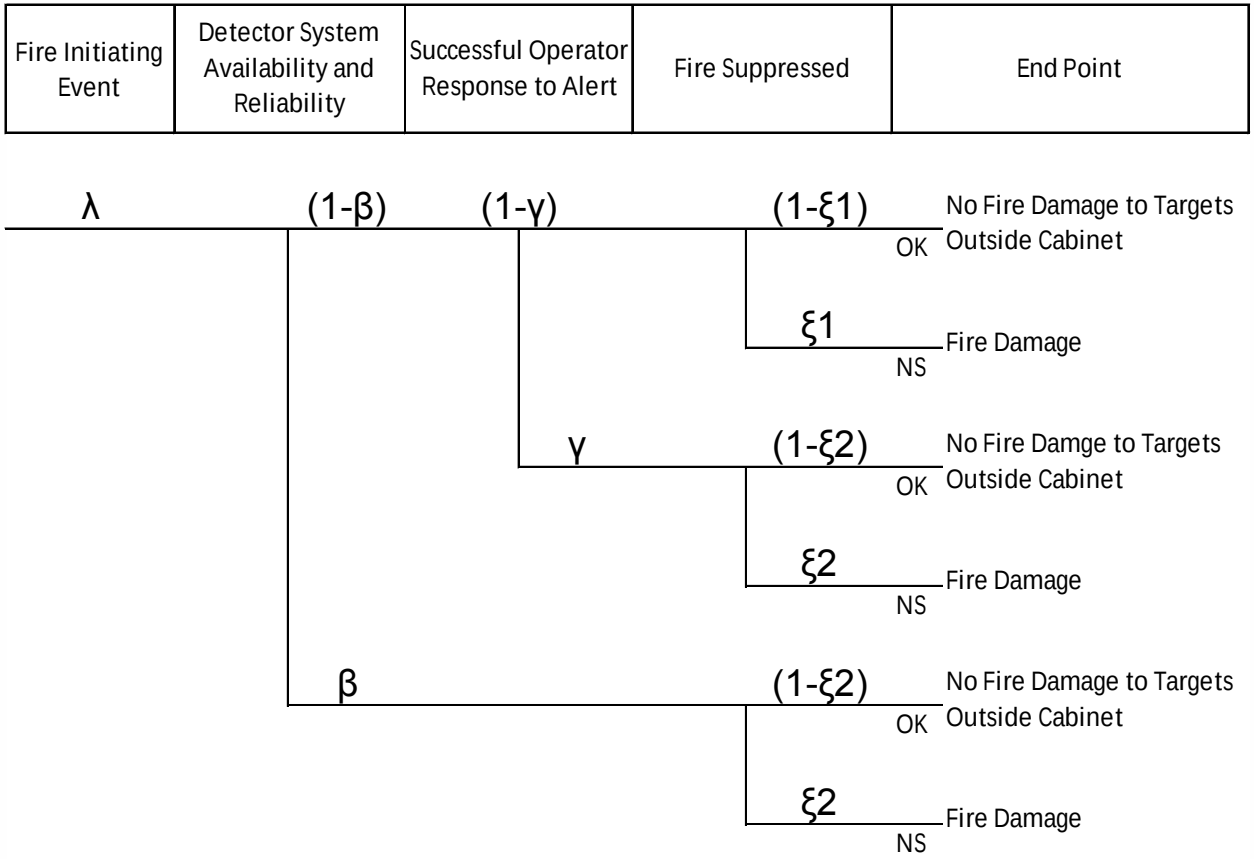



**Figure P-1**
**Detection Suppression Event Tree NS – Failure of Suppression Activities**
**OK – Success of Suppression Activities**

# FAQ 08-0046




- $\beta = 1x10^{-02}$
- $\gamma = 1x10^{-02}$
- $\xi1 = 1x10^{-03}$
- $\xi2 = 1$ if not crediting redundant systems
- $\xi2 = 6x10^{-02}$ if crediting redundant systems

$P_{ns} = 2x10^{-02}$ or $2x10^{-03}$

# NUREG-2180

- With Halon

Total Non-Suppression Probability : 4.0E-03 Calculate

- w/o Halon

Total Non-Suppression Probability : 8.0E-02 Calculate

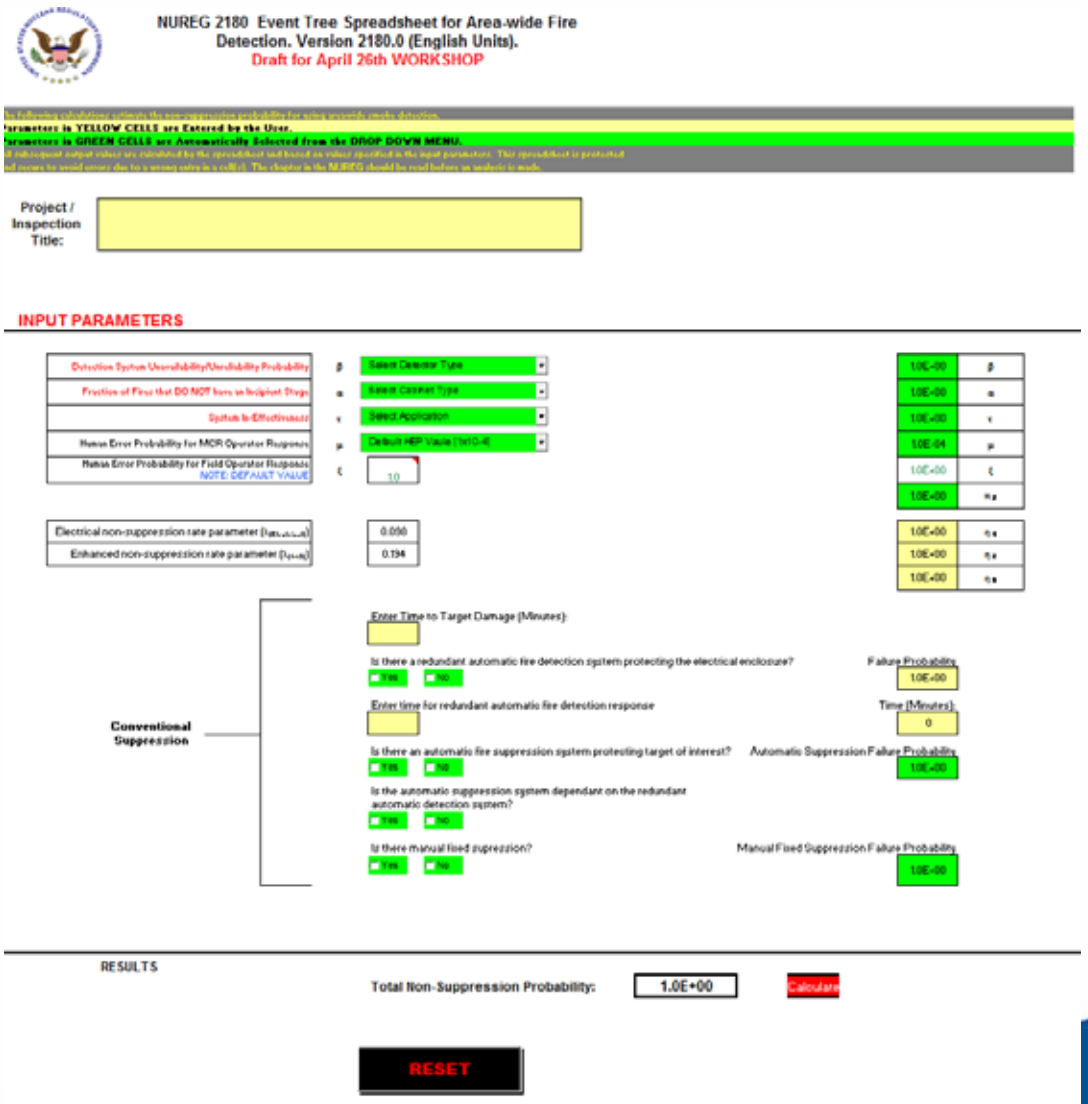
# Comparison of Results

| | NUREG/CR-6850 w/ 5 minute bonus | FAQ 08-0046 w/o redundant detection | FAQ 08-0046 with redundant detection | NUREG-2180 |
|---|---|---|---|---|
| With Halon | $6x10^{-02}$ | $2x10^{-02}$ | $2x10^{-03}$ | $4x10^{-03}$ |
| Without Halon | $2x10^{-01}$ | $2x10^{-02}$ | $5x10^{-03}$ | $8x10^{-02}$ |

Values are conditional pr… …uppression probability)

VEWFD credit does not change regardless of hazard.
Suppression / Detection Analysis is a Timing Analysis.

# Area-wide Spreadsheet




- Worksheet walk-through

# Regulatory Expectations Related to NUREG-2180

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# Existing Guidance

- National Fire Protection Association (NFPA) Standard 805 Frequently Asked Question (FAQ) 08-0046
  - Ø Will be replaced by NUREG-2180
  - Ø Will no longer be acceptable for use
  - Ø Licensees to evaluate the impact of new information on PRA in accordance with license conditions and Regulatory Guide 1.200
- NUREG/CR-6850
  - Ø Remains acceptable for use

# Regulatory Considerations

Ensure that VEWFDS credited using the methodology presented in NUREG-2180 match the tested or modeled configurations described in NUREG-2180.

- Such implementation would include but not be limited to system settings, design configurations, and procedural responses such as posting a continuous fire watch for system alerts and alarms.

# Regulatory Considerations (cont.)

The methodology contained in NUREG-2180 for crediting VEWFDS is only applicable for systems that are designed, installed, and maintained in accordance with recognized standards.

- For example, NFPA 72 and NFPA 76, and set up to provide Alert thresholds of at least 0.2 percent per foot obscuration (effective sensitivity at each port) and Alarm thresholds of at least 1 percent per foot of obscuration (effective sensitivity at each port).

# Regulatory Considerations (cont.)

The methodology contained in NUREG-2180 is considered to represent a generic approach.

- However, licensees choosing to modify, extrapolate, or interpret the data included in NUREG-2180 (e.g., use of plant specific information to obtain additional credit), should consider appropriate analysis tools and processes for new methods including peer reviews and NRC staff review before applying the methods.

# Questions

# VEWFD Comments and Data Collection Industry Feedback and Plans

Jeff Ertman

Duke Energy

# High-Level Report Comments

- Report identified operational goals as
  - Prevent the spread of fire to external targets
  - De-energize the suspect equipment.
- Neither goal beneficial for main control board applications
- Opportunity for further improvement to realism

# Report Comments

- Report considers everything in that cabinet to be lost at first sight of flame
- Any act of suppression is assumed to damage everything in the cabinet
  - May be true for dry chemical and CO2 extinguishers
  - Not true for portable Halon extinguishers
  - See FAA/CAA acceptance of their use on aircraft fires
- Credit for use of portable Halon extinguishers at the first sight of flame could limit damage to just the component

# Overview Data Collection

- Use of VEWFD Systems
- Current Fire Protection Data Collection Efforts
- VEWSD Data Collection Needs
- Finalize reporting template
- Collect data and keep on NEI Webboard
- Every 3-5 years pull data and combined with FEDB update

# Use of VEWFD Systems

- Currently 10 Plants known to have incipient detection systems installed/planned
- SAFE, VESDA are the predominate manufacturers
- Realistic Fire PRA treatment important to the industry (not just NFPA 805 plants)
  - Latest Draft NUREG improves the treatment

# Current Fire Data Collection Efforts

- INPO collects fire incident data for US NPPs through their ICES database
- Basic criteria for inclusion of fire events:
  - Fire events occurring in relevant NPP owner controlled locations that meet at least of the following definitions:
    - *Events that result in visible flaming, evidence of prior flaming, or charring—Events that only involved overheating, steam leaks, smoldering receptacle cans, or unfounded odors are not required to be reported as fire events.*
    - *Events that involve the use of manual fire suppression activities or valid actuation of an automatic fire suppression system (false or spurious actuations or alarms do not require reporting of fire events).*
    - *Events that involve arcing or arc flash that can cause damage to the device or component itself or to adjacent equipment.*

# VEWFDS Data Collection Needs

- Current industry data collection captures response to fire incidents where incipient detection is the method of detection
- Does not:
  - Capture OE where incipient may prevent a fire from occurring (overheating is NOT a fire)
  - Timing of plant response to fire
    - Time when plant personnel respond to alert
    - Time to detect overheating component
    - Time incipient condition mitigated

# VEWFD Reporting Template Content

- Time of initial detection
- Time of arrival at location
- Time component identified
- Time component de-energized / incipient condition mitigated
- Time fire confirmed
- Time of manual suppression actuation
- Time fire was under control
- Time of fire brigade dispatch

# Collect Data / NEI Webboard

- Finalize Data Collection Template
- Store Reports in NEI Webboard
- Up and Running in 60 days
- Permanent storage solution in EPRI's Fire Events Database
  - Periodically updated at 3-5 year intervals to track and trend fire ignition frequencies and manual non suppression probabilities

# Conclusions

- Encouraged by changes to this draft that provides improved credit of VEWFD
- Data collection is key to continued improvements in treatment of VEWFD in the Fire PRA
- Need to treat as a living document and continuously update with OE to support realistic treatment in plant PRAs

# Final Question and Answer Session

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# Question Submitted from Vendor

- Is it appropriate to conclude that since the software tools associated with VEWFD systems are not U/L or FM listed to determine both transport time and sensitivity that the VEWFD system meet the minimum requirements by conducting a physical validation test at each sample port/pipe to assure the performance criteria in NFPA 76 and FAQ 08-0046 are being met?

# Response to Comment

- UL listing / FM approvals do not ensure that the install system meet the minimum sensitivity settings, but that the system can be capable of detecting smoke/aerosol less than 0.5%/ft obsc..
- ASD systems are configurable, there is a need for justification, be it reference documents or engineering analysis that support the “actual” system design and settings (sampling port sensitivities) back to either the listing or other data supporting the sensitivity setting.
  - Provide assurance that system is configured as VEWFD