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# TH 32 - Improving Realism in Fire Probabilistic Risk Assessments

## High Energy Arc Faults (HEAF)
[Operating Experience and Preliminary Experimental Results]

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## Discussion Topics

- Provide Overview of Project
- Operating Experience and Risk Insights
- Preliminary Test Results

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## What are HEAFs?

- High Energy Arc Faults (HEAF) are energetic or explosive electrical equipment faults characterized by rapid release of energy in the form of heat, light, vaporized metal and pressure increases due to high current arcs between energized electrical conductors or between energized electrical components and neutral or ground.
  - First phase: short, rapid release of electrical energy which may result in projectiles (from damaged electrical components or housing) and/or fire(s) involving the electrical device itself, as well as any external exposed combustibles, such as overhead exposed cable trays or nearby panels, that may be ignited during the energetic phase
  - Second phase, i.e., the ensuing fire(s): is treated similar to other postulated fires within the zone of influence

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## Current State-of-the-Art PRA Implementation Limitations

- Single methodology for all enclosures 480V to 4160V and above
- 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

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## Current State-of-the-Art Methodology

- NUREG/CR-6850, Appendix M (2005)
- Zone of Influence (ZOI) Method based on **one** well documented fire event at San Onofre in 2001
- Components within ZOI are assumed to instantly fail or ignite
- Input to fire PRA model
- Robinson and Onagawa events don't appear to fit this model

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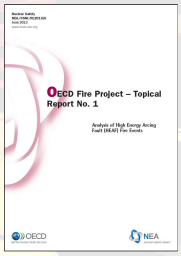
## International Cooperation

### Organisation for Economic Co-operation and Development (OECD) Nuclear Energy Agency (NEA)

- OECD FIRE Project - TOPICAL REPORT No. 1
  - Analysis of High Energy Arcing Faults, HEAF
  - NEA/CSNI/R(2013)6
    - http://www.oecd-nea.org/nsd/docs/2013/csni-r2013-6.pdf
- Significant contribution to risk
  - 48 out of the in total 415 fire events collected in the International NPP fire events database through mid-2012 represent HEAF induced fire events (over 10%)
- Need for future testing identified



## OECD –HEAF Members

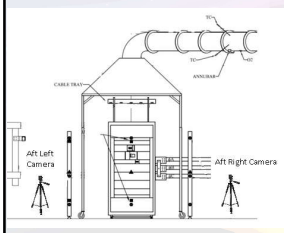
- Participation of 8 Member Countries
  - US NRC is the Lead Member Coordinating Testing

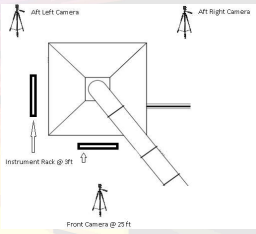
- Canadian Nuclear Safety Commission (CNSC), **Canada**
- The Institut de Radioprotection et de Sûreté Nucléaire (IRSN), **France**
- Radiation and Nuclear Safety Authority (STUK), **Finland**
- Gesellschaft für Anlagen- und Reaktorsicherheit (GRS) mbH, **Germany**
- Korea Institute of Nuclear Safety (KINS), **Korea** (Republic of)
- Central Research Institute of Electric Power (CRIEPI), **Japan**
- Japan Nuclear Regulatory Authority (NRA) **Japan**
- Consejo de Seguridad Nuclear (CSN), **Spain**
- United States Nuclear Regulatory Commission (USNRC) , **USA**

## Test Parameters

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

## Test Layout (Views)



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## Germany Test Enclosure Oil Filled Breaker (Oil Removed) (Copper Bus)

October 6th 2015; Front View

- 10 kV
- 15 kA
- 3 sec duration
- Oil was removed for the test due to safety concerns

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## Germany Test Enclosure Oil Filled Breaker (Oil Removed) (Copper Bus)

October 6th 2015; Front View

- Immediate ignition of internal combustible load
- 30 seconds to full cable tray ignition

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## Finland Test Enclosure (Aluminum Bus)

October 16th 2015; Pre-test

- Immediate ignition of internal combustible load
- Melted inconel plate thermocouples 3ft away
  - (Melting point 2540 – 2600 °F)
- Aluminum byproducts coated the KEMA test cell after the test causing shorting of other electrical components
- More Research needs to be performed

Before

Arc Location

After

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## Ongoing NRC/International Activity

- Testing just concluded in February 2016
- Data consolidation and analysis is currently being performed by the National Institute of Standards and Technology (NIST), NRC and partner Countries
- Next step will be overall evaluation of test the 27 separate test results
- Expect to have the International Report published in 2017