Fire PRA Application Topics

USNRC Fire Risk Methods Research Workshop
August 23-24, 2001

Presented by:
Steve Nowlen
Sandia National Laboratories

Sandia is a multi-program laboratory operated by Sandia Corporation, a Lockheed Martin Company, for the United States Department of Energy under contract DE-AC04-94AL85000.

Sandia National Laboratories

By its nature, this talk is negative

- You have seen a discussion of what is fire PRA - we now turn to application topics and challenges
- Don’t take this as a condemnation of fire PRA
- Fire PRA is a tool that can be applied with reasonable confidence to various situations
- But there are still challenges out there:
  - some areas are not fully developed
  - some areas remain controversial
  - some areas have high uncertainty
- This discussion focuses on these remaining challenges

Sandia National Laboratories

Where do we have confidence in existing methods:

- General structure of a fire PRA
  - appears to fit actual events well
- Qualitative area screening methods
- General approach to development of fire analysis scenarios
  - appears to fit actual events well
- Fire frequency estimation - with some caveats:
  - partitioning/severity factors
  - reporting consistency
- Plant model - with caveats:
  - circuit analysis
  - human reliability analysis
- Conservative quantitative screening methods

Sandia National Laboratories

Where are the challenges being identified:

- **Many methodological challenges were identified in the IPEEE process**
  - **IPEEE insights report**
  - **USNRC-sponsored review of the EPRI Fire PRA Implementation Guide and the Generic RAIs**
- **PRA methods improvement areas have also been brought out elsewhere including:**
  - **SNL letter report of Feb. 1996 - Fire Risk Methods Need Areas**
  - **“Research Needs in Fire Risk Assessment,” USNRC WRSIM, 1997**
  - **SECY 98-230 - “Insights from NRC Research on Fire Protection and Related Issues," dated October 2, 1998.**
  - **SECY 98-247 - “Risk-Informed, Performance-Based Fire Protection At Nuclear Power Plants,” dated October 27, 1998**

Sandia National Laboratories

What are the challenges:

- The previous talk touched on unresolved concerns in each aspect of fire PRA quantification
- This presentation will discuss:
  - FPRAIG generic RAIs
  - severity factor applications
  - human performance analysis
  - main control room analysis
  - energetic electrical faults
  - turbine building fire risk

Sandia National Laboratories

What are the challenges (2)

- **Tomorrow you will hear about how we are addressing challenges in the following areas:**
  - **circuit analysis**
  - **cable failure modes and effects**
  - **fire modeling**
  - **frequency of challenging fires**
  - **fire detection and suppression**
  - **learning risk methods lessons from past events**

Sandia National Laboratories

The FPRAIG review

- **Review conducted as a part of IPEEE program**
- **Review identified a number of potential areas of methodological concern**
- **16 specific concerns were developed into generic RAIs:**

1 - Human reliability values used in screening
2 - Heat loss factors
3 - Cable fire propagation model
4 - Control room evacuation
5 - Manual/automatic suppression dependencies
6 - Seismic/fire interactions
7 - Control system interactions
8 - Manual fire fighting
9 - Equipment damage by suppressants
10 - Special accident initiators
11 - Screening enclosed ignition sources
12 - Panel fire heat release rates
13 - Screening of fire sources based on non-combustible shields
14 - Screening of transient fuel sources
15 - Criteria for fire suppression
16 - Piloted cable ignition temperature

Sandia National Laboratories

FPRAIG Generic RAIS (2)

- **Each of the generic RAIs was resolved in the context of the IPEEE process**
  - **identify potential vulnerabilities**
  - **gain and understanding of severe accident risk**
- **Debates remain in some areas when it comes to future risk-informed applications**
- **Topics not fully resolved:**

3 - Cable fire propagation model
4 - Control room evacuation
6 - Seismic/fire interactions
7 - Control system interactions
8 - Manual fire fighting
9 - Equipment damage by suppressants
11 - Screening enclosed ignition sources
12 - Panel fire heat release rates

Sandia National Laboratories

Severity factor applications

- **Definition of severity factor:**

  a value used to adjust/reduce fire frequency to reflect the observation that not all fires lead to substantial fire safety and/or nuclear safety challenges

- **Example:**

  if 50% of all fires (in a particular class of fires) self-extinguished with no active intervention required and caused no damage beyond the initiating component, then:

  - **one might reduce the fire frequency by 1/2 to reflect this observation by using a 0.5 severity factor**

- **Alternative approach with the same effect:**

  screen the "benign" events from the event set and re-calculate fire frequency

Severity factor applications (2)
Wide use of severity factors in IPEEEs

- Used to account for a range of behaviors:
  - self-extinguishing fires
  - severe vs. benign fires
  - fires requiring manual fire brigade response
  - fires requiring use of a hose stream to suppress
  - chance that fire would spread beyond the initiating component
  - chance that a fire would escape from an electrical panel
  - likelihood of a severe MCR fire
- To understand the results when severity factors come into play, you need to understand basis being applied in that given case

Sandia National Laboratories

Severity factor applications (3)
Tends to yield generic answers:

- Based on generic data
  - analysis of a large population of similar events
  - assumes that the generic population is representative of the specific scenario under analysis
- May not be true for all cases nor for all SF applications
  - fire CDF often depends on very specific features of a compartment or fire scenario that may not be reflected in historical event data

Sandia National Laboratories

Severity factor applications (4)
May double-count mitigating factors:

- Severity factors may incorporate aspects of other location partitioning factors:
  - an actual fire's impact reflects in part where the fire occurrs
  - fire PRA specifically considers fire location
    - room fire frequencies, source fire frequencies, location partitioning factors, area ratios, etc.
    - fires in benign locations generally screen
  - hence, severity factors and location partitioning factors may overlap

Sandia National Laboratories

Severity factor applications (5)
May double-count mitigating factors:

- Severity factors often reflect aspects of fire suppression:
  - prompt suppression by fire watches
  - self-extinguished fires (little or no damage)
  - only fires requiring use of a hose stream might be considered potentially challenging
  - must take care in subsequent suppression analysis
- Screening/parsing of the fire event set:
  - when estimating fire frequency only a subset of the overall event data is used
  - severity factors need to use a consistent event set

Human reliability analysis (HRA)

- Human performance in fires is typically based on internal events with performance shaping factors (PSF)
- No strong technical basis for assigning PSF values
- Most of the IPEEEs did not include detailed HRA
  - generally applied IPE internal events actions/reliability directly
  - may have applied performance shaping factors
  - typically reviewed credited human actions for applicability to fire scenario

Sandia National Laboratories

HRA challenges:

- Analysis of MCR and post-abandonment scenarios often simplistic
  - self-induced station blackout procedures
  - distributed vs. centralized remote shutdown
  - abandonment criteria/timing
  - pre-abandonment MCR actions
- Generally assume in-MCR actions not impacted by ex-MCR fires - how true?
  - smoke, confusion, excitement

Sandia National Laboratories

HRA challenges (2)

- Fire brigade response
  - IPEEEs often assumed a maximum fire response time based on fire drills
  - often limited fire duration to this response time
  - interactions with severity factors not generally considered - may be facing a more challenging fire upon arrival
  - potential for fire brigade errors not addressed
  - other possible factors not considered
    - two-in, two-out rules
    - situation assessment
    - attack planning

Sandia National Laboratories

Main control room analysis

- Two types of contributing scenarios:
  - in-room fires with out abandonment
  - abandonment
- For non-abandonment:
  - damage generally limited to one panel or panel section
  - rates and maximum extent of fire spread not well known
- For abandonment, CDF driven by two main factors:
  - conditional abandonment probability
  - reliability of remote shutdown

Sandia National Laboratories

Main Control Room analysis (cont.)

- **Challenges:**
  - **fire sizes - extent and rate of spread**
  - **abandonment conditions/likelihood**
  - **remote shutdown reliability**
  - **control interactions / circuit analysis**

Sandia National Laboratories

Energetic electrical faults

- Some electrical faults/fires involve large releases of electrical energy
  - switchgear
  - transformers
  - electrical busses
  - MCC, breakers, and other electrical panels?
- This is not the typical fire we consider in fire PRA
  - how frequent are such events
  - what equipment / where
  - unique damage - shrapnel, pressure, shock
  - unique fire fighting challenges

Sandia National Laboratories

Turbine building fire risk

- Two IPEEEs found a potential fire vulnerability
  - both were related to TB fires
  - both were resolved
- TB clearly presents unique fire hazards
  - high pressure, high temperature oil
  - hydrogen
- Past PRAs generally found TB to be low risk
  - for many plants strictly related to power generation
- New insights indicate on case-specific basis, TB may be important risk contributor
  - critical question: what's there?

Sandia National Laboratories

Circuit Analysis

- Circuit analysis continues to be a fire risk analysis challenge
- Insights have been gained through analysis, testing, event review, and inspections
- Putting this to work in a PRA remains a challenge
  - terminology - be sure we are all on the same page
  - how do we identify the circuits that count - plant model
  - how should be do screening - fire areas and circuits
  - how do we assign probabilities of various circuit fault modes to specific circuits - what are the factors
  - how will operators respond - will they recognize and diagnose the problems
- Much more is on the agenda for tomorrow

Sandia National Laboratories

Conclusions

- Fire PRA can be used with reasonable confidence in various applications and situations
- A number of methodological challenges remain
- PRA methods need to rise to this challenge
- Much work is underway both through the USNRC and through parallel industry efforts
- Stay tuned...

Sandia National Laboratories