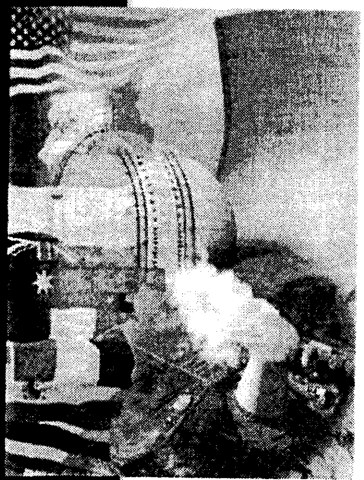

Challenges in use of State-of-the-Art Fire Modeling Tools in Nuclear Power Plant Applications

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Outline

- Introduction
- Fire modeling issues in nuclear power plants
  - Areas where fire modeling can be applied
  - Areas for future research

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- Prioritize fire modeling issues in nuclear power plants
- Identify areas where future research can reduce the uncertainty associated with these fire modeling issues

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- Technical issues discussed in this presentation are based on the capabilities of models evaluated in EPRI's fire modeling project.
  - MAGIC
  - CFAST
  - CompBrnIIIe
  - FIVE

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EPRI Fire Modeling Project

- EPRI's Fire Modeling project provides guidance in using fire models including hand calculations and selected zone models
  - FIVE
  - COMPBRN-IIIe
  - CFAST
  - MAGIC
- Our conclusions are limited to lessons learned while using the models.
- Some conclusions may apply to other models, including computational fluid dynamics (CFD)

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Areas Where Fire Modeling can be Applied (Based on examined models)

- *Either there is confidence in the modeling tools OR estimates are adequate to support anticipated applications*

1. Thermal effects of plumes, ceiling jets and radiation
2. General room heat up, and hot gas layer
3. Elevated fires and oxygen depletion
4. Multiple fires
5. Multi-compartments: corridors and multi-levels
6. Smoke migration, generation and density
7. Partial barriers and shields
8. Fire detection

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- This is typical of many scenarios in NPPs where critical targets are located in close proximity of fire source
- Fire conditions, including temperature and heat flux in these areas can be estimated using hand calculations
- Hand calculations and zone models can be use to evaluate target response

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- Larger, less congested plant areas
- These temperatures can be estimated with hand calculations and zone models
- Zone models are recommended in cases where natural and mechanical ventilation are part of the scenario

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Elevated Fires and Oxygen Depletion

- Typical of cable tray fires
- Zone models can simulate oxygen depletion and elevated fires
- The amount of oxygen available for combustion is an indication of the capacity of the fire to burn
- Combustion in low oxygen environments is subject of research

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Multiple Fires

- Scenarios involving intervening combustibles, such as transients and cables
- CFAST and MAGIC can simulate multiple fires
- Fires other that the pilot can be ignited based on time, temperature and heat flux
- The effects of multiple plumes is captured

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[illegible]

- Common fire scenarios in auxiliary or turbine building
- Sometimes approximated with larger combined or smaller separated enclosures
- Zone models can simulate fire conditions in multiple rooms
- CFAST and MAGIC have the capability of connecting rooms with vertical and horizontal openings
- MAGIC provides an image of the geometry that is useful when developing input files in multi-compartment scenarios

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[illegible]

- Fires in the main control room specially those resulting in evacuation
- Smoke generation for the most part is plume entrainment
- Migration refers to the smoke movement between compartments
- CFAST estimates products of combustion based on yields

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Partial Barriers and Shields

- Used mostly as radiation shield to protect against large fire source such as reactor coolant pump
- Magic can simulate radiation barriers (targets in lower layer)
- Barriers have no thermal behavior
- Once targets are immersed in the smoke, they are heated mostly by convection heat transfer.

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Fire Detection

- Only a model for heat detection is available: DETACT
- Models for heat detection assumes well defined ceiling jets
- DETACT can be used for smoke detection - ?? - Smoke detectors are designed to operate before well established ceiling jets.
- Some hand calculations for smoke detection are also available

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- *Some of these issues are not amenable to analytical solutions*
  1. Cable fires
  2. Fire growth inside the main control board
  3. Fire propagation between control panels
  4. High energy fires
  5. Fire suppression
  6. Hydrogen or liquid spray fires
- *Current EPRI methods rely on empirical models based on a combination of operating experience and fire tests*

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- Important in NPP applications since cables are major contributor to potential fire growth
- Fire propagation or flame spread throughout cable trays can not be modeled.
- Currently EPRI methods use empirical models based on cable fire tests

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Fire Growth Inside the Main Control Board

- Such fires can be critical to safety
- The combustion process in low oxygen environments is still subject of research
- Little empirical data to support the extent and timing of fire spread

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Fire Propagation Between Control Panels

- This is critical where source and target are both electrical panels such as control room and electrical equipment rooms
- These scenarios could be critical to safety
- Although zone models can simulate multiple fires based on heat flux or ignition temperature, specification of required parameters is usually uncertain.
- The problem of ignition of internal components in electrical cabinets can not be addressed with current models
- Current EPRI methods use empirical models based on electrical cabinet fire tests.

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[illegible]

- Such events are result of electrical faults in high voltage switchgears and transformers (more of a concern when indoors)
- The intensity and effects of explosions can not be predicted with fire models
- Currently we use empirical evidence suggesting that explosions can occur in high energy cabinets. Sustained fires after the explosion have been observed. Thermal effects of these fires can be assessed with existing fire models

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Fire Suppression

- Automatic and manual suppression are one of the primary feature (in addition to barriers) to mitigate consequences of fire in NPPs
- Only CFAST can simulate water based fire suppression with some restrictive assumptions
- Effects of gaseous suppression systems can not be simulated with current models
- Effectiveness of suppression systems in deep-seeded fires
- EPRI methods relies on codes/standards to demonstrate effectiveness

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Hydrogen or liquid spray fires

- Not very critical based of operating experience
- Fire models assume fires as a point source of heat release. Effects of jet fires can not be predicted
- Little empirical data to support a model

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Conclusions

- Issues that may not be amenable to analytical solutions
  - Fire growth inside control room main control board
    - CFD codes may have the capability, the scenario description is questionable
  - High energy fires
    - Prediction of consequences of initial blast require different type of models
  - Hydrogen or liquid spray fires
    - ?? ?? ?? ??
- Areas for improvement in current codes
  - Cable fires
  - Fire suppression
  - Panel to panel fire growth

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- Areas of application
  - Thermal effects of plumes, ceiling jets and flame radiation
  - Room heat up, and hot gas layer
  - Elevated fires and oxygen depletion
  - Multiple fires
  - Multi-compartments: corridors and multi-levels
  - Smoke generation and migration
  - Partial barriers and shields
  - Fire detection
- Areas for future research
  - Cable fires
  - Fire growth inside the main control board
  - Fire propagation between control panels
  - High energy fires
  - Fire suppression
  - Hydrogen or liquid spray fires

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- Pacific Gas & Electric
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