ATTACHMENT 3

DAY 3 - Handouts

<u>Day 3 - October 15, 2004</u> **Topic: Regulatory Tools**

0800 - 0815 Registration

0815 - 0830 Welcome/Fire Protection Tools Past, Present, and Future with NFPA 805 (Salley)

0830 - 0845 Related Public Questions

0845 - 0945 Fire Probabilistic Risk Assessment (Hyslop, Najafi - SAIC, Henneke - Duke)
-Joint Fire PRA Methodology
-ANS Fire Risk Standard

0945 - 1000 Related Public Questions

1000 - 1015 Break

1015 - 1115 Fire Modeling (Salley, Hill, Najafi - SAIC)
-NUREG 1805
-RES/EPRI Verification and Validation Project

1115 - 1130 Related Public Questions

Adjourn

FIRE PROTECTION TOOLS – PAST, PRESENT, FUTURE CONNECTION TO NFPA 805

Presentation at the NRC Public Meeting
Region II, Atlanta, Georgia
October 13 – 15, 2004

Mark Henry Salley, P.E.
Team Leader, Fire Research Team
Office of Nuclear Regulatory Research

U.S. Nuclear Regulatory Commission
Washington, DC 20555-0001

Prescriptive vs Performance Codes

- Prescriptive codes dictate a minimum level of protection
  - 3 Hour Rated Fire Barrier
  - 2 Hour Water Supply
- Performance codes are an engineering approach to fire protection on agreed fire safety goals, deterministic & probabilistic evaluation of fire, physical properties of the fire, and effectiveness of the design.

New Tools & Analysis Methods

- Risk-Informed, Performance-Based Codes require new tools & analysis methods to be effective.
- Fire Risk Evaluations
  - PSA/PRA
- Fire Modeling

New Terms - NFPA 805

- Completeness Uncertainty
- Model Uncertainty
- Parameter Uncertainty
- Probable Maximum Loss
- Uncertainty Analysis

More New Terms – NFPA 805

- Fire Model V&V
  - ASTM E 1355 "Evaluating the Predictive Capability of Deterministic Fire Models"
- Fire Scenario
  - Limiting Fire Scenarios
  - Maximum Expected Fire Scenarios

Team Approach

- NRC Office of Research
- National Laboratories (Sandia)
- EPRI (SAIC)
- Industry (Licensees)

Improved Technical Approach in U.S. NRC/EPRI Fire Risk Requantification Study

Presentation at NRC Public Meeting
Atlanta, Georgia, October 13 - 15, 2004

J.S. Hyslop
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NFPA 805

- 2.2.9 Plant Change Evaluation indicates a risk-informed evaluation shall be performed (Figure 2.2)
- 2.4 contains direction ("shall") with respect to Fire Models and Fire Risk Evaluations
- Appendix D provides useful information for fire risk evaluations

Expected Use Of Products

- A basis for risk-informed analyses (EPRI)
- Review guidance that RES will develop for NFPA 805 related changes
- ANS fire risk standard

Background and Scope

- Background
  - Memorandum of Understanding between NRC-RES and EPRI
  - Fire risk addendum
- Scope
- NUREG/CR-6850; EPRI 1008239
  - 1: Summary and Overview – ML042800183
  - 2: Detailed Methodology – ML042800196

Objectives

- Develop and demonstrate state of art fire risk analysis methods, tools, and data
  - Consolidate existing research
  - Limited extension of state-of-art
  - Field test
- Identify strengths and weaknesses
- Update corresponding fire risk estimates
- Develop risk insights
- Transfer the technology

Participants

- EPRI
- U.S. NRC
- Two volunteer pilot plants (PWR)
  - D.C. Cook, Millstone Unit 3
- Six non-pilot plant participants
- Further cooperation
  - One independent pilot plant – Diablo Canyon
- Pilot plant (BWR) recently added – Nine Mile Point

FRA Areas Addressed

- Fire data and ignition frequency
- Fire modeling
- Fire protection systems and features
- Plant response
  - Systems analysis
  - Circuit analysis
  - Human reliability analysis

Demonstration Studies

- Analyses performed jointly by NRC and EPRI using case examples from pilot plant FRA.
- Purpose:
  - Demonstrate that methods can be implemented
  - Acquire feedback
  - Technology transfer
- All 18 procedures demonstrated
- Demonstration studies in place of full update of plant FRA for initial pilots

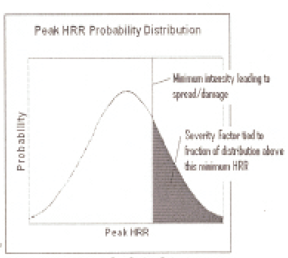
Advances

- Fire frequency
  - Prior condition:
    - Widespread use of severity factors to "correct" base fire frequencies
    - Room-based frequencies
  - New condition
    - Now limited to potentially challenging fires
    - Increased use of component fire frequency

Advances (cont.)

- Distributions of peak heat release rate (HRR)
  - Prior condition: Each source had single HRR and severity factor
  - Distributions developed based upon available data and experience
    - For each major fire ignition source type
    - Includes low frequency/high intensity values
    - Severity factor tied explicitly to intensity
  - Treatment of fire frequency/severity factor avoids double count with suppression

Conceptual HRR/severity factor



Advances (cont.)

- Detection/manual suppression
  - A common approach: consideration of only fire brigade response time
  - Historical data approach
    - New approach ensures explicit treatment of long duration fires
  - Duration curves binned by component or location

Advances (cont.)

- Plant safe shutdown response model
  - Resolve difference between emergency operating procedures and plant safe shutdown procedures
    - Ensures equipment out of service is captured
  - Refine treatment of spurious operations and fire-specific operator actions

Status

- Industry peer review completed
- Pilot application & testing of methodology
  - Limited testing of all procedures by EPRI/NRC at PWR
  - On-going use of methodology at another PWR
  - Full testing by EPRI/NRC at BWR planned in CY04-06
- Milestones

Draft report for comment	October 04
ACRS review	Spring 05
Publication	Summer 05
Joint EPRI/NRC Fire PRA Workshop (preliminary)	Spring 05
Revision of publication based on BWR pilot (tentative)	TBD

BACKGROUND

Procedures

- 1- Plant partitioning
- 2- Selection of critical equipment
- 3- Selection of circuits
- 4- Qualitative screening
- 5- Plant fire-induced risk model
- 6- Fire ignition frequency
- 12- Post-fire HRA screening
- 7A- Quantitative screening 1
- 8- Scoping fire modeling
- 7B- Quantitative screening 2

Procedures (cont.)

9- Detailed circuit failure analysis
10- Circuit failure mode and likelihood analysis
11- Detailed fire modeling
13- Seismic-fire interactions
14- Fire risk quantification
12B- Post fire HRA – detailed and recovery
15- Uncertainty and sensitivity analysis
16- Fire PRA documentation

EPRI/NRC-RES FIRE PRA METHODOLOGY FOR NUCLEAR POWER FACILITIES

Bijan Najafi (SAIC)

October 13-15, 2004
NRC Public Meeting
Region II, Atlanta GA.
Topic: Regulatory Tools

PROJECT TEAM

- Covers all technical disciplines critical to Fire PRA
  - Technical Lead: B. Najafi, S. Nowlen
  - General PRA & plant systems analysis: A. Kolaczkowski, R. Anoba
  - Circuit Analysis and Appendix R: D. Funk, F. Wyant
  - Human Reliability Analysis: J. Forrester, W. Hannaman, A. Kolaczkowski
  - Fire analysis: F. Joglar, M. Kazarians
  - Consultants: A. Mosleh, D. Bley
- Collectively, over 200 years of relevant experience
- Principal authors of documented Fire PRA methods in US for the past 2 decades
- This Methodology reflects the consensus of this team, EPRI and NRC-RES

PROJECT REVIEW

- Individual procedures have been:
  - Reviewed internal to the development team
  - Tested at one or more pilot plants to ensure:
    - Ease of application
    - Reasonableness of results and resources required, and
    - Adequacy of documentation
  - Reviewed by a peer review team
    - Limited active participation

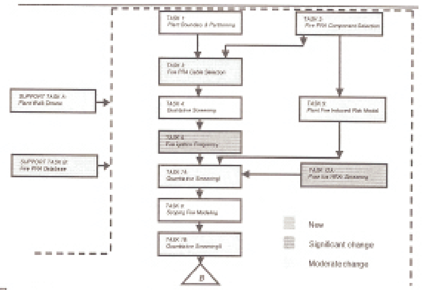
EPRI 1008239 / NUREG/CR-6850

- Volume 1: Summary
  - Program and technical overview
    - General scope, assumption and technical positions
    - Estimated resources
  - Conclusions
    - Areas of improvement in the past Fire PRA methods
    - Current state-of-the-art, limitations and their importance
    - Insights and observations
    - Recommendations
- Volume 2: Detailed methodology

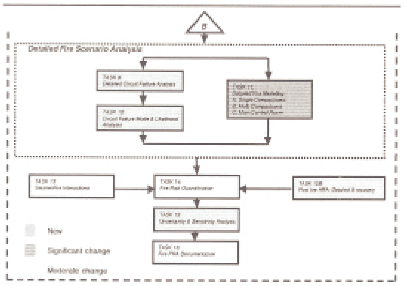
METHODOLOGY

- The methodology is presented in the form technical task procedures within a an overall process
- The process is intended as a guide and should fit most cases, however the user may adopt based on plant-specific information and desired applications
- Procedures cover the following technical areas
  - Selection of plant analysis boundary and partitioning
  - Fire PRA component selection and risk model
  - Circuit/cable selection, routing and failure modes analysis
  - Screening, qualitative and quantitative
  - Fire ignition frequency
  - Fire modeling
  - Post-fire human reliability analysis (HRA)
  - Seismic-fire interactions, and
  - Fire risk quantification, including uncertainties, and documentation

OVERVIEW OF FIRE PRA PROCESS



OVERVIEW OF FIRE PRA PROCESS (CONT.)



PROCEDURE CONTENT

1. Purpose
2. Scope
3. Background information: General approach and assumptions
4. Interfaces: Input/output to other tasks, plant and other information needed, walk-downs
5. Procedure: Step-by-step instructions for conduct of the technical task
6. Uncertainty: Sources of uncertainty and issues driving them
7. References

Appendices: Technical bases, data, examples, special models or instructions, tools or databases

KEY TECHNICAL TASKS: Circuit/cable selection, routing and failure modes analysis (Tasks 3, 9, & 10)

- Stand-alone approach for cable selection and analysis within the context of risk
  - Past U.S. methods relied on existing plant analyses such as Appendix R safe shutdown analysis
  - Prepared with the recognition of other documents addressing related technical area(s)
- Multiple spurious actuations of equipment and instruments
- Probabilistic Circuit Failure Modes and Likelihood
  - Important where redundant cables are affected by the same fire such as main control room
  - Use fire testing (2002) by EPRI and NEI with NRC participation

KEY TECHNICAL TASKS: Post-fire Human Reliability Analysis (Task 12)

- Focus on the Screening HRA
  - Rule-based (in the absence of detailed fire scenario information) quantitative screening approach
  - Fire conditions; environment and accessibility
  - Fire-induced component/system faults, such as spurious actuations
  - Location and timing to diagnose and perform the required actions
  - Availability of the crew to perform the actions, not impacted by dual responsibilities
- Not a stand-alone manual for fire HRA
  - Use of existing HRA methods in fire conditions
    - Fire performance shaping factors (PSF) defined and described
    - These PSFs generally lineup with the criteria in the Manual Action Rule
  - Area of possible further improvement: Link between fire PSF and best-estimate HEPs not developed
- Special Case: Main Control Room (MCR) abandonment
  - Additional considerations as part of PSF evaluation, e.g. potential confusion about the need to evacuate the MCR

KEY TECHNICAL TASKS: Fire Modeling (Tasks 8 & 11)

- Characterization of ignition source heat release rate (HRR)
- Damage criteria
- Fire suppression analysis
- Special models
  - High Energy Arcing Faults
  - Cable Fires
  - Fire growth inside the main control board
  - Fire propagation between control panels
  - Turbine/generator fires
  - Smoke damage

PUBLIC REVIEW

- While review of the entire document is desirable, focus on Key Technical Areas is recommended
  - Component and circuit selection and analyses (tasks 2, 3, 5, 9, and 10)
  - Post-fire HRA (task 12), and
  - Fire modeling (tasks 8 and 11)
- Have the review done by your technical area specialist
  - e.g., review of circuit related procedures (3, 9, and 10) by your App R engineers
- We encourage feedback that:
  - Can improve technical accuracy
  - Can make the methodology easier and more efficient to use
  - Is specific with recommended alternatives or changes to the text

CONCLUSIONS: LIMITATIONS OF THE STATE-OF-THE-ART

- Our work identifies some areas of limitation:
  - Number of combined fire-induced spurious operations
  - Dynamic versus static modeling of fire damage and operator response
  - Limitations in Internal Events analysis that carry over to fire, e.g., model uncertainty
  - Multiple Fires
  - Multiple Initiating Events from the same root cause, e.g., fire and flood or fire and earthquake
  - Smoke Damage
  - Administrative Aspects of the Fire Protection Program
  - Effectiveness of Fire Protection Systems and Passive Fire Barriers
- Even though it is not possible to know the exact impact, where possible we adjust the approach to ensure that the risk is not under-predicted

CONCLUSIONS: INSIGHTS

- While individual procedures have been tested, a full testing of the methodology is not yet completed
  - Full BWR pilot at Nine Mile Point Unit 1 anticipated in 2005/2006
- Resource estimates: In the absence of a full test of the methodology, based on collective experience of the authors with the past and this method (demonstration studies)
  - Best estimate range: 4000 – 7000 hours
  - The lower end is based on a large number of positive factors in the quality of the plant analyses and the desired sophistication of the Fire PRA
  - The upper bound should be interpreted as an industry average
  - The largest source of uncertainty in the estimate of resources is for cable/circuit selection and routing and to a lesser extent the circuit failure modes analysis

CONCLUSIONS: PERSPECTIVE

- Fire Risk
  - IPEEE Program

    Fire-induced core damage frequencies range from 4E-8 to 2E-4/RxYr, with vast majority between 1E-6 and 1E-4/RxYr

    Fire contribution to the combined fire and internal events risk range from 1% to 90%
  - While industry-wide perspectives are not expected to change significantly plant-specific perspectives could be impacted by this method
- Relative importance of fire scenarios, locations or fire protection systems/features
  - IPEEE Program

    nearly 1 of every 3 studies, reported the risk associated with control room fires as the highest contributor to the fire risk with switchgear rooms a close second
  - Relatively few industry-wide trends are anticipated with respect to changes in the relative risk importance rankings
  - Plant-specific changes on the other hand are more likely

ANS Fire PRA Standard Development

Dennis Henneke
Duke Power Company

Outline

- Why is the Fire PRA Standard Important?
- Inputs to the Fire Standard
- Status
- Issues?
- Questions?

Why is the Fire PRA Standard Important?

- Fire Risk represents around 30% of the Core Damage Risk for an average plant.
  - Many plants report Fire Risk greater than the total for other internal events risk.
  - Most Plants have a limited analysis of fire risk in response to the IPEEE process.
- Future Risk Applications and Issue Resolution will most likely require detailed Fire PRA.
  - Plant specific issue resolution for associated circuits/multiple hot shorts for issues not screened in Fire SDP or using NEI 00-01
  - Risk Applications affected by Fire PRA results
  - Plant-Specific Fire Issues, Phase III Fire Significance Determination Process
  - **Risk-Informed Fire Protection (NFPA805)**

Inputs to the Standard

- EPRI/NRC Fire PRA Requantification Project
- Previous Fire PRA Methods:
  - FIVE/EPRI Fire PRA Methods
- EPRI Fire Testing and NEI-00-01: Probability for Spurious Operation.
  - This is included in the Requantification Project.
- EPRI and NRC Fire Modeling Projects

Status

- Writing of the Standard is continuing, with roughly 75% of the technical sections completed as a first draft.
  - Internal to Writing Group
  - Additional meetings scheduled for 2004 and early 2005
- Will provide a draft to the ANS RISC Committee early in 2005.
- Public Comment period in 2005.

Duke Power.

Issues

- The Standard will rely heavily on the requantification project.
  - Requantification methods will represent highest category for the standard (Cat. 3) – in most cases.
  - Public Comment Period began in October.
  - No full pilot applications performed
    - Full Pilot scheduled for 2005 – with rewrite of the requantification procedures scheduled for end of 2005. Schedule slip is possible.
  - May need to modify the standard at that time.

Duke Power.

Issues

- Circuit Issues/Hot Shorts
  - A significant amount of the effort for a state-of-the-art Fire PRA will be involved in analyzing hot shorts:
    - Cable tracing
    - Scenario development, including Fire PRA specific scenarios and new failure modes in the PRA model.
    - Fire modeling to determine scenario likelihood

Duke Power.

Questions?

Duke Power.

FIRE MODELING

Presentation at the NRC Public Meeting
Region II, Atlanta, Georgia
October 13 – 15, 2004

Mark Henry Salley, P.E.
Team Leader, Fire Research Team
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U.S. Nuclear Regulatory Commission
Washington, DC 20555-0001

Overview- What is FDT^s?

- FDT^s are a series of Microsoft Excel® spreadsheets issued with **NUREG-1805, "Quantitative Fire Hazard Analysis Methods for the U.S. Nuclear Regulatory Commission Fire Protection Inspection Program."**
- The primary goal of FDT^s was to be a training tool to teach NRC Fire Protection Inspectors an **Introduction to Fire Dynamics.**
- The secondary goal of FDT^s was to be used in plant inspections and support other programs that required Fire Dynamics knowledge such as, SDP and NFPA 805.

History

- Draft **NUREG-1805** (two volumes) was developed over a 3 year period working with NRC Fire Protection Inspectors and was published in June 2003 for public comments and technical review.
- FDT^s are modeled after the U.S. Bureau of Alcohol, Tobacco, Firearms, and Explosives (ATF&E) Fire and Arson Certified Fire Investigation Program
- Selected a series of state-of-the-art **Fire Dynamics Correlations** from *SFPE Handbook of Fire Protection Engineering, NFPA Fire Protection Handbook*, and other relevant **Fire Dynamics** text.
  - Customized for nuclear power plants applications
  - Appropriate physical properties
- New spreadsheets were added as a part of the review.
- Final NUREG-1805 will be published in **October 2004**.

Features of FDT^s

- User-friendly, **Pre-Programmed** Microsoft Excel® based on **Fire Dynamics** equation/correlations.
  - Quick application of **Fire Dynamics** principles found in state-of-the-art ***Fire Protection Handbooks***
  - Spreadsheets are protected to **Prevent Tampering**
  - **Automatic Unit Conversion**
  - Related **Material Fire Properties Data** for materials commonly found in nuclear power plants listed within each spreadsheet
  - **Reduces Input Errors** from inaccurate manual entries by using **Pull-Down Menus** which allow the user to select material fire property data
  - Provides for quick iterations with easy data entry in the spreadsheets to provide first order Fire Dynamics estimates.
- Spreadsheets are available in English and SI Units.

New Features of FDT^s Based on Comments

- User Specified Value option was added in **Material Fire Properties Data** table.
- Input parameters information was modified to be more User Friendly.
- Calculate button was added in all spreadsheets.
- Additional information block was added for user to describe specific fire scenario being analyzed.
- Revision Log table was added to maintain spreadsheet version and issue date.

List of FDT^s Spreadsheets

- 02.1_Temperature_NV.xls
- 02.2_Temperature_FV.xls
- 02.3_Temperature_CC.xls
- 03_HRR_Flame_Height_Burning_Duration_Calculation.xls
- 04_Flame_Height_Calculations.xls
- 05.1_Heat_Flux_Calculations_Wind_Free.xls
- 05.2_Heat_Flux_Calculations_Wind.xls
- 05.3_Thermal_Radiation_From_Hydrocarbon_Fireballs.xls
- 06_Ignition_Time_Calculations.xls
- 07_Cable_HRR_Calculations.xls
- 08_Burning_Duration_Solid.xls
- 09_Plume_Temperature_Calculations.xls
- 10_Detector_Activation_Time.xls
- 13_Compartment_Flashover_Calculations.xls
- 14_Compartment_Over_Pressure_Calculations.xls
- 15_Explosion_Calculations.xls
- 16_Battery_Room_Flammable_Gas_Conc.xls
- 17.1_FR_Beams_Columns_Substitution_Correlation.xls
- 17.2_FR_Beams_Columns_Quasi_Steady_State_Spray_Insulated.xls
- 17.3_FR_Beams_Columns_Quasi_Steady_State_Board_Insulated.xls
- 17.4_FR_Beams_Columns_Quasi_Steady_State_Uninsulated.xls
- 18_Visibility_Through_Smoke.xls

Evolution of Quantifying Fire Scenarios in Nuclear Power Plants

Past

- **Fire load** expressed in (BTU/ft²) does not consider other factors which greatly affect the compartment fire intensity such as **Compartment Volume, Heat Transfer Characteristics of the Enclosure Boundaries, and Ventilation Openings**.

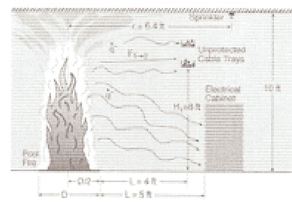
Present

- FDT[s] is a training tool that can be used to teach **Fire Dynamics** and develop **First Order Fire Dynamics Evaluation** in actual commercial nuclear power plant applications.

Future

- **NFPA 805**, Performance Based Standard for Fire Protection for Light Water Reactor Electric Generating Plants will use detailed **Fire Modeling Calculations**.

Fire Scenario



Future FDT[s] Updates

Future updates, corrections, or new FDT[s] spreadsheets will be posted on NRC's external website within the Fire Protection section at: http://www.nrc.gov/reactors/operating/ops-experience/fire-protection.html

Conclusion & Invitation

- NUREG-1805 provides a basic Introduction to Fire Dynamics for nuclear power plant applications.
- NUREG-1805 provides tools and methods that can be used in actual nuclear power plant Fire Hazard Analysis (FHA)
- Part of EPRI Fire Modeling Workshops
- The Office of Nuclear Reactor Regulation (NRR) plans to conduct a public meeting on the NUREG-1805 on November 23 and 24, 2004, at which time the NRR staff will make presentations, Introducing FDT[s] and Its Features." NRR welcome all interested stakeholders to the November 2004 public meeting at NRC Headquarters.

Fire Model Verification and Validation for Nuclear Power Plant Applications

Presentation at NRC Public Meeting Region II, Atlanta GA. October 13-15, 2004

Kendra L. Hill
Reliability & Risk Engineer,
Fire Research Team
Office of Nuclear Regulatory Research

U.S. Nuclear Regulatory Commission
Washington, DC 20555-0001

Purpose of the V&V

- Provide the technical basis for regulatory positions that will be contained in the upcoming regulatory guide
  - Evaluate specific fire models
  -
  - Define limits of the models

NRC-RES Activities in support of V&V

- Established Interagency NRC & NIST Agreement
- Co-Organized ICFMP to evaluate fire models for NPP applications
- Conducted a test program in collaboration with NIST
- Initiated a 5-Year collaborative program with IRSN of France for validating multi-compartment fire analysis

NRC V&V Effort

- Joint effort between the NRC and EPRI
- RES is V&V three fire models for application in NFPA 805
  - Fire Dynamics Tools (FDT^s)
  - Consolidated Model of Fire Growth and Smoke Transport (CFAST)
  - Fire Dynamics Simulator (FDS)
- EPRI is V&V FIVE Rev. 1 & MAGIC

V&V Approach

- Follows the guidelines outlined in ASTM E 1355-04, "Evaluating the Predictive Capability of Deterministic Fire Models," [ASTM, 2004]

Areas of evaluation

- Defining the model and scenarios for which the evaluation is to be conducted
- Assessing the appropriateness of the theoretical basis and assumptions used in the model
- Assessing the mathematical and numerical robustness of the model
- Validating each model by quantifying the uncertainty and accuracy of the model results

Methodology

1. Establish a list of fire scenarios for which fire models will be applied in NPPs.
2. Summarize this list of fire scenarios available for benchmarking and validation exercises.
3. Map the validation test series for the fire scenarios developed in Step 1.

Scenario Definition

- Per Section 6.2.2 of the ASTME guidance:
  - A fire scenario definition should include a complete description of the phenomena of interest in the evaluation to facilitate appropriate application of the model
- A set of 12 NPP fire scenarios was chosen for inclusion in the V&V

Scenario Selection

- Review of the range of possible configurations in NPPs that contribute to fire scenarios
- Identification of potentially risk significant fire scenarios through review of IPEEE submittals
- Examination of past industry experience with fire modeling

Scenarios Selected for Evaluation

- 1. Switchgear room
- 2. Cable spreading room
- 3. Control room
- 4. Pump room
- 5. Turbine hall
- 6. Multi-compartment corridor
- 7. Multi-level building
- 8. Containment, PWR
- 9. Outdoors
- 10. Battery room
- 11. Diesel Generator room
- 12. Computer room

Fire Scenario Technical Parameters

- Fire/Ignition Source
- Fire Type
- Heat Release Rate (HRR) profile
- Enclosure Geometry
- Ventilation Conditions
- Targets

Next Steps

- Match the selected scenarios to validation studies
- Determine the accuracies of the models when applied to the selected NPP fire scenarios

Document Availability

- Working Drafts of the V&V Main Report and CFAST V&V (Volume 2) publicly available for viewing at NRC public website
- ADAMS accession # ML042810552

V & V STUDIES FOR SELECTED FIRE MODELS – ISSUES AND CHALLENGES

Bijan Najafi (SAIC)

October 13-15, 2004
NRC Public Meeting
Region II, Atlanta GA
Topic: Regulatory Tools

BACKGROUND

- NFPA 805 requires fire models to be acceptable to AHJ and be "verified and validated" (V&V)
- EPRI is working with NRC-RES to respond to this requirement
  - In accordance with the ASTM 1355 which provides guidance for conducting V&V studies for fire models
- ASTM 1355 requires the following information for a V&V study:
  - Definition of fire scenarios for which the V&V is conducted
  - Theoretical description of the model
  - Evaluation of the mathematical and numerical robustness
  - Sensitivity analysis
  - **Verification and Validation analysis**

OBJECTIVES

- Gain understanding on the predictive capability of these models for typical NPP fire scenarios
- Develop quantitative estimates of uncertainty that are:
  - technically defensible AND
  - useful in a RI/PB environment

UNCERTAINTY QUANTIFICATION IN ASTM 1355

- ASTM 1355 does not require a specific index qualifying results of the V&V study.
- ASTM 1355 - Some quantification methods are suggested
  - Comparison and reporting the delta
  - Does not deal with multiple evidence and quality/associated with each evidence
- ASTM 1355, section 11.3.1 – *"Whenever possible, the use of subjective judgment should be avoided and results should be expressed in quantitative terms"*

MODEL UNCERTAINTY

- This is fundamentally a model uncertainty problem
- Model uncertainty refers to the uncertainty in the output of the model given its idealization, theoretical development, and mathematical form
- Parameter uncertainty is considered separately
  - ASTM 1355 requires test of the model range of applicability through sensitivity analysis
- There are various statistical techniques for determining model uncertainty
  - Range from very simple to very sophisticated ones.
- The critical challenge in the V&V project is selection of appropriate technique

MODEL UNCERTAINTY

- Recent research suggests that estimating modeling uncertainty requires:
  - Information about the model
    - Confidence in the model – quantitative or qualitative evidence on the credibility of a model in estimating the fire phenomena of interest
    - Applicability of the model – quantitative or qualitative evidence on the applicability or relevance of a model to a postulated fire scenario
  - Information from the model
    - Model predictions in comparison with experiments

ISSUES & CHALLENGES

- Fire tests do not match ALL the conditions of typical NPP fire scenarios
- Judgment is necessary to map available experiments to NPP scenarios
- So, the answer lies in:
  - Understanding the physics
    1. Appropriateness of the model to the fire scenario
  - Comparison with available experiments
    2. Appropriateness of the experiment to the fire scenario,
    3. Model performance in predicting experimental outcomes
  - And a method to combine these various elements

ISSUES & CHALLENGES

Research Group

1. Appropriateness of the model to the fire scenario
   - Experience and perspective in model development to qualify/quantify confidence in model prediction
2. Appropriateness of the experiment to the NPP fire scenario
   - Experience and perspective with NPP fire modeling to qualify/quantify

Error Analysis

3. Performance of the model in predicting experimental outcomes
   - This is currently in progress

Statistical Method

- And a method to combine these various elements
  - We are examining possible methods

SUMMARY

- Project has laid the ground work through
  - Definition of fire scenarios and ranges of conditions
  - Selection and comparison of fire experiments with model predictions
- The challenge ahead is:
  - Selection of a methodology to develop defensible, preferably quantitative, ranges on the model prediction for NPP fire scenarios