Assessment of Phenomenological Uncertainties in Level 2 PRAs

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“The value of what one knows is doubled if one confesses to not knowing what one does not know”

Arthur Schopenhauer
OUTLINE

- Overview of PRA Process
- Phenomenological Uncertainties in Severe Accident Progression Analysis
- Uncertainties Associated with Source Term Analysis
- Risk Importance Measures for Phenomenological Issues
Elements of the PRA Analytical Process

- Core-Damage Accident Frequency Analysis
  - Plant Damage States
  - Accident Progression and Containment Performance Analysis
    - Accident Progression Bins
    - Source Term Analysis
      - Source Term Groups
      - Offsite Consequences Analysis
        - Consequences Measures
        - Risk Integration

--- Level 1

--- Level 2

--- Level 3
Severe Accident Progression

Phenomenological Issues & Containment Failure Mechanisms

**Plant Damage State Attributes**
- Status of Containment at Onset of Core Damage
- Status of RCS (pressure, ...)
- Electric Power Status
- Status of Reactor Core Cooling System
- Status of Containment Systems (sprays, igniters, ...)

**Phenomenological Issues**
- Thermally Induced SGTR
- Thermally Induced Hot Leg Failure
- In-Vessel Steam Explosion
- Ex-Vessel Steam Explosion
- Bottom Head Failure
- Hydrogen Generation
- Core Debris Coolability
- Core-Concrete Interaction
- Hydrogen Combustion

**Containment Failure Mechanisms**
- Isolation Failure
- Bypass
- Rapid Steam Pressure Rises and Missiles
- Failure by Direct Contact with Core Debris
- Basemat Meltdown
- Overpressurization Failure

**Severe Accident Recovery Actions**
Conditional Probability of Accident Progression Bins for Internal Events at Zion

Accident Progression Bin (APB)

- Isolation Failure
- Early CF
- Late CF
- Bypass
- No CF

Updated Evaluations vs. NUREG-1150 Results
Conditional Probability of Accident Progression Bins for Internal Events at Peach Bottom

![Bar Chart](chart.png)

- Early WWF
- Early DWF
- Late WWF
- Late DWF
- Venting
- No CF

Accident Progression Bin (APB)

- Updated Evaluations
- NUREG-1150 Results
**Source Term Analysis**

**Source Term Issues and In-Containment Removal Mechanisms**

**In-Containment Source Term Issues**

1. Core Heat Up & Fuel Cladding Failure
   - Gap Activity Release
   - Retention in the RCS
   - Release from Fuel into the RCS

2. In-Vessel Core Degradation
   - Release Due to HPME
   - Release Due to Ex-Vessel SE
   - Releases Due to CCI

3. RPV Bottom Head Failure
   - Ex-Vessel Release into the Containment
   - Late In-Vessel Release into the Containment

4. Core-Concrete Interactions
   - Late Revolatilization

**Containment Failure Mode and Mechanism**

- Early In-Vessel Release into the Containment (or Bypass Release)

**Status of Containment Systems**

- Status of Containment Systems (sprays, water in cavity/peDESTAL, ....)

**In-Containment Removal Mechanisms**

- Natural Aerosol Deposition
- Scrubbing in BWR Suppression Pools
- Aerosol Removal by Sprays
- Scrubbing of CCI Releases by Overlying Water
- Aerosol Removal by Ice Condenser

**Environmental Source Term**
Uncertainty Distributions for Early In-Vessel Releases into the Containment

PWR, Low RCS Pressure (NUREG/CR-5747)
It is desirable to assign some ranking of “risk importance” among various phenomenological issues that are considered in a plant PRA model.

Risk importance measures for phenomenological issues can be useful for assessing potential accident management strategies as well as for developing research priorities to reduce the overall uncertainty.
Risk Importance Measures Commonly Used for Ranking PRA Basic Events or SSCs

Risk Achievement Worth, RAW

\[ \text{RAW}_i = \frac{R_{i^+}}{R_0} \]

Fussell - Vesely, FV

\[ \text{FV}_i = \frac{(R_0 - R_{i^-})}{R_0} \]

Risk Reduction Worth, RRW

\[ \text{RRW}_i = \frac{R_{i^-}}{R_0} \]

where:

\[ R_{i^+} = \text{overall risk with the probability of basic event } i \text{ set to 1 (the event has occurred or the equipment is failed)} \]

\[ R_{i^-} = \text{overall risk with the probability of basic event } i \text{ set to 0 (the event is impossible or the equipment is totally reliable)} \]

\[ R_0 = \text{overall base-case risk} \]
Risk Importance Measures for Post Core-damage Mitigation Systems in AP1000 Design
Risk Importance Measures of Severe Accident Phenomena in AP1000 Design

Phenomenological Issue

- In-Vessel Melting Retention
- CF by Diffusion Flame
- CF by Early DDT
- CF by Hydrogen DF
- CF by Int. DDT

Chart shows risk importance measures for different phenomena.
An assessment of the phenomenological uncertainties associated with Level 2 PRAs was presented.

Development of risk importance measures for phenomenological issues was also discussed.