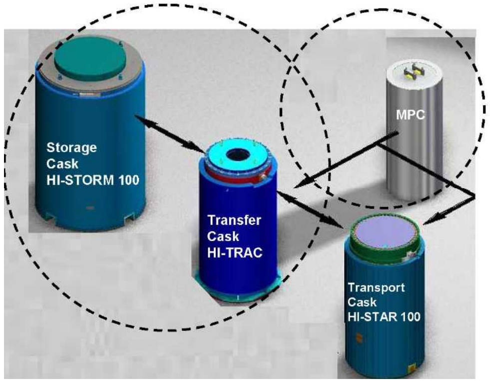
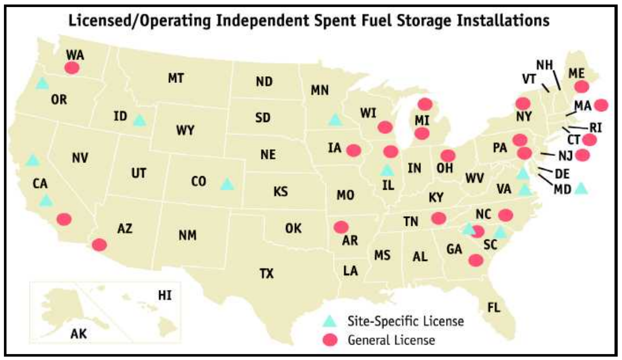
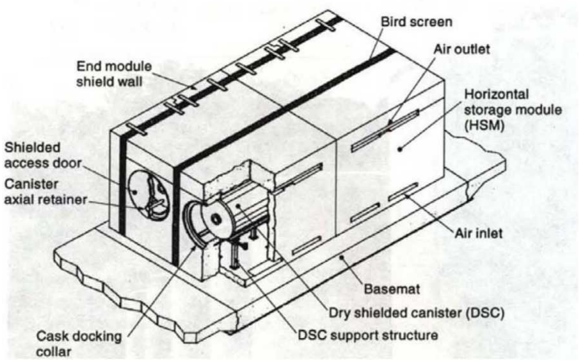
SAND2006-7074C

Qualitative Human Reliability Analysis for Spent Fuel Handling

NPIC & HMIT 2006
ANS Winter Meeting 2006







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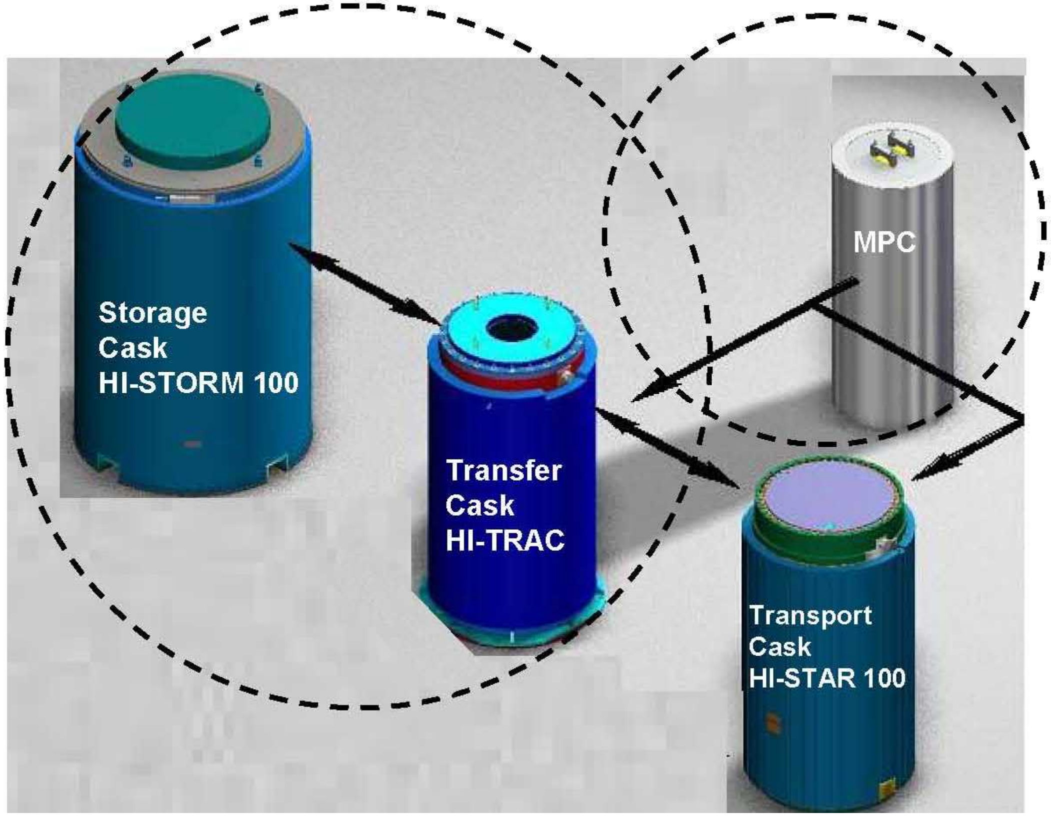
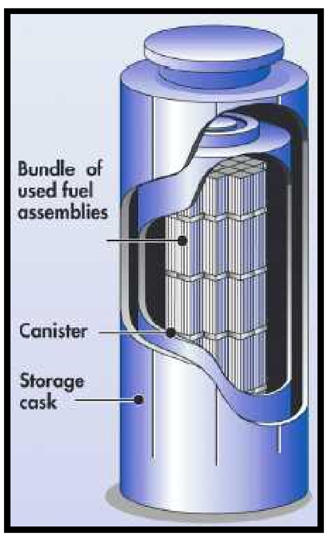
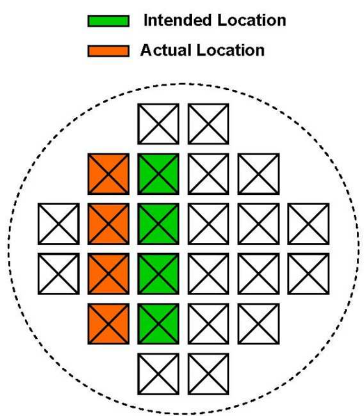
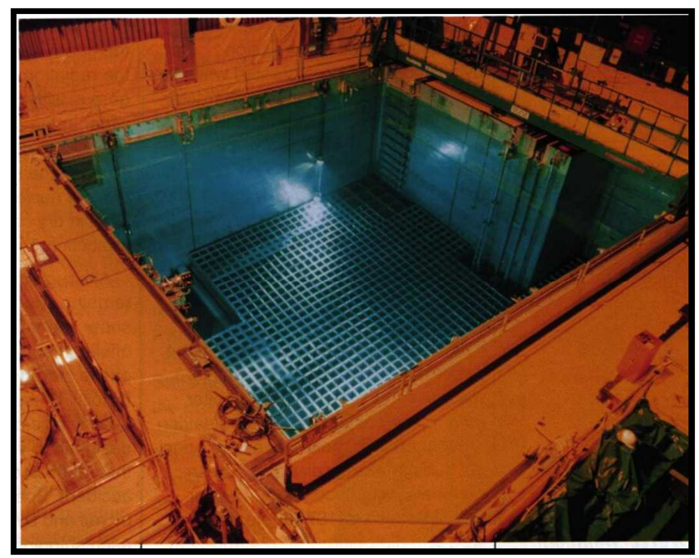
Overview

- Goals of the preliminary, scoping study
- Human performance analysis approach
- Human Failure Events (HFEs) Scenario Groupings
- General Human Performance Vulnerabilities
- Detailed Examination of one HFE scenario


Storage
Cask
HI-STORM 100
Transfer
Cask
HI-TRAC
MPC
Transport
Cask
HI-STAR 100


Bundle of
used fuel
assemblies
Canister
Storage
cask


Intended Location
Actual Location



Goals of the Analysis

- Qualitative & Scoping-Level Study, without PRA context & was not plant specific
- Goals:
  - Answer the question: What should be included in a qualitative HRA for spent fuel & cask handling to effectively capture the range of human performance problems that could contribute to a misload and/or cask drop? What might be the consequences?
  - Demonstrate that ATHEANA can be usefully applied to these situations
    - NUREG-1792, Good Practices for Implementing HRA
    - NUREG-1624, Rev. 1, Technical Basis and Implementation Guidelines for ATHEANA
  - Improve understanding of human performance for these activities to enhance a subsequent, detailed qualitative HRA for a specific plant

Analysis Approach

- Intentionally unconstrained to a particular HRA technique; yet enough detail for starting a state-of-the-art HRA
- Identification & review of spent fuel handling (SFH) and dry cask storage operations (DCSO) – e.g., NRC, EPRI, HI-STORM 100 FSAR, NUREG-1774, A survey of crane operating experience at U.S. Nuclear Power Plants from 1968 through 2002
- Subject matter expert (SME) interviews
- Performed initial, scoping, qualitative, ATHEANA-type HRA of SFH & DCSO
  - Define HFE Scenario Groupings (misload & cask drop emphasis)
  - Define Phases of Operation – capture latent and active human performance issues & facilitate high-level comparisons of consequences & likelihoods
  - Discover how & why these events might occur given current understandings of human performance
  - HFEs, unsafe actions (UAs), error forcing context (EFC) descriptions ~ generic / implicit

Phases of Dry Cask Storage Operations

One proposed structure (NRC)

1) **Handling**
   - cask lowered into the pit
   - MPC in storage cask is moved out of secondary containment
2) **Transfer**
   - as MPC in storage cask passes 2^{ndary} containment
   - storage cask on ISFSI pad
3) **Storage**
   - monitoring & surveillance for 20 years or more

Another proposed structure (EPRI)

1) **Cask Loading**
   - 1^{st} fuel assembly into cask
   - cask drained, dried, inerted & sealed
2) **Cask Transfer**
   - placement of cask on transport vehicle
   - storage cask on ISFSI pad
3) **Cask Storage & Monitoring**
   - monitoring & surveillance for 20 years or more

Previous analyses did not provide a thorough investigation of contexts in which failures may occur

Phases used in this analysis

1) **Fuel Load Planning**
   - generate fuel move plan
   - dependent upon previous outages
2) **Cask ops. pers. & equip. prep.**
   - training, staffing, inspection, test, maintenance,
3) **Cask prep. & positioning**
   - cask brought into plant
   - cask into loading pit
4) **Cask Loading (CA)**
   - 1^{st} fuel assembly into cask
   - cask drained, dried, inerted & sealed
5) **Loaded cask transfer w/in structure (CA)**
   - move from cask prep. area
   - cask coupled to transporter
6) **Loaded cask transfer outside structure (CA)**
   - cask coupled to transporter
   - cask emplaced at ISFSI pad
7) **Loaded Cask Storage & Monitoring (CA)**
   - ends when cask contents are moved off-site (20++ years)

CA = particularly helpful for consequence analysis

Seven HFE Scenario Grouping Categories

1. Scenarios before and during fuel loading
2. Scenarios during cask movements from spent fuel pool to preparation area
3. Scenarios during multipurpose canister (MPC) and transfer cask sealing operations
4. Scenarios during cask movement from preparation area to transfer pit
5. Scenarios during MPC movement from transfer cask down to storage cask
6. Scenarios during storage cask movement from transfer pit to ISFSI pad
7. Scenarios during monitoring and storage at the ISFSI

General Human Performance Vulnerabilities

- Unchallenging activities – relatively simple, slow, tedious
- Limited indicators, procedures, & job aids – mainly visual cues
- Visual challenges – observation points, refraction & reflection
- Communication difficulties – background noise, circuit discipline, biases
- Time pressure – missing scheduled milestones
- Quality assurance esp. configuration control
- Trust – "I trust so I don't look closely versus you can trust me to catch your errors"
- Decision making biases based on perception of loss
- Time of day & shift work
- Pace of operations
- Team dynamics – similar domain as crew resource management
- Large number of manual operations
- Other ergonomic issues – cramped workspaces (refueling bridge, crane cab, welding positions, etc.), clothing, temperature & humidity, etc.

<u>1st Scenario</u>: Failure to identify a fuel misload event

→ within <u>3rd HFE Scenario Grouping</u>: MPC and transfer cask sealing ops.

→ within <u>4th Phase of Operation</u>: Cask Loading

HFE Group	HFE Group Description	Scenario	Vulnerabilities
3	MPC and transfer cask sealing operations.	1. Failure to identify a fuel misload event 2. Human initiated fire event–welded cask 3. Failure leaves leak path existing at the end of sealing and preparation activities–welded cask 4. Failure leads to impending leak path due to undetected problem during sealing and preparation activities–welded cask 5. Failure leads to impending leak path due to undetected problem during sealing and preparation activities–bolted cask	• Biases based on perception of loss • Limited nature of procedures • Time of day & shift work • Pace of operations • Visual challenges • Perceived time pressure • Omission in hazard analysis • Improper training • Overconfidence • Lapse • Other ergonomic issues (welder's helmet)

Failure to identify a fuel misload event

- Definition & interpretation of issue being analyzed
  - Simplified operation description
  - Reason for analysis
  - Potential consequences
- Base case scenario
  - Initial conditions
- General human performance vulnerability concerns
  - Pace of operations, limited nature of procedures, time of day & shift work, ...
- Specific scenarios
- Description of the example scenario: failure to identify a fuel misload event
- Specific human performance vulnerability concerns

Failure to identify a fuel misload event

- Definition & interpretation of issue being analyzed
  - Simplified operation description
    - MPC is loaded, with MPC lid in position & MPC is inside transfer cask; after closure the MPC will be ready for emplacement in storage cask
  - Reason for analysis
    - Potential for identifying a misload event
    - Potential for a human initiated fire
    - Potential to leave a leak path or “soon to be present” leak path
  - Potential consequences
    - Misload may lead to degradation of fuel & MPC
    - Fire during closure may release fission products to building and possibly out of building
    - Emergence of leak path at ISFSI could impact public health

Failure to identify a fuel misload event

- Base case scenario – initial conditions:
  - Loaded MPC in transfer cask is properly positioned in preparation area with surrounding scaffolding
  - MPC lid has been placed into position, but is merely resting unsecured on MPC shell
  - Personnel are decontaminating the top portion of cask & MPC; preparing to install gamma shielding (e.g., ring or other barrier)

- General human performance vulnerability concerns
  - Decision making biases based on perception of loss
    - Seeking the simple, non-loss threatening alternative
      - Swiped too close
      - Welding delay
    - Avoiding the complex, loss-threatening explanation(s)
      - Oh, no possible misload

    <u>Perceived Losses may include</u>: loss of time; lost of respect for those who ‘messed up & got us into this situation’; potential loss related to damaging fuel that then leads to a fission product release

  - Limited nature of procedures
  - Time of day & shift work
  - Pace of operations
  - Visual Challenges
  - Other ergonomic issues

Failure to identify a fuel misload event

- Specific scenario description
  - Preparation worker does not decontaminate lid properly
  - Radiation worker detects high radiation levels
  - Welding equipment delay
  - Excessive temperatures during draining and purging are attributed to delay
  - Lack of evidence of excessive cooling in the vacuum lines is positively received by personnel
  - Early pressurization with helium is not noticed

Failure to identify a fuel misload event

- Potential Human Performance vulnerabilities
  - Lack of detailed procedures without appropriate thresholds for alarm
  - Equipment calibration errors
  - Perceived time pressure
  - Ease of finding a simple, non-less threatening alternate explanation to a situation, instead of attending to a complex, loss-threatening explanation:
    - RP person detecting & explaining away high radiation levels after the re-decontamination of the lid
    - The draining, drying, purging, drying, and backfilling personnel who choose the explanation of a “welding delay” leading to excessive temperatures

Conclusions / Accomplishments

- ✓ Investigate what should be included in a qualitative HRA for spent fuel & cask handling operations to capture the range of human performance problems that may occur
- ✓ ATHEANA approach works for this type of operation
  - ➢ Identified potential scenarios
  - ➢ Identified context for operational errors
  - ➢ Identified key operational errors
  - ➢ Identified vulnerabilities that contribute to errors
- ✓ Although generic & performed without a PRA or plant-specific context; it is argued that improved understanding from this preliminary scoping study will enhance the ability to carry out a detailed qualitative SFH & DCSO HRA for a specific plant