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A Methodology for Performing Consequence Analysis for Multi-Unit/Spent Fuel Pool Source Terms

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Outline



- MELCOR Accident Consequence Code System (MACCS)
- Concepts for Multi-Unit Consequence Analysis
- Process for Multi-Unit Consequence Analysis
- Summary

MACCS Is a Tool for Level-3 Consequence Analysis



- Developed as NRC's tool for evaluating the consequences of atmospheric releases
- PSAs and other severe accident studies (NUREG-1150, SOARCA)
 - Risks from operating a facility
 - Relative importance of the risk contributors
 - Insights on potential safety improvements
- NEPA Studies (National Environmental Policy Act) such as: License extension and new reactor applications
 - Environmental Impact Statements (EISs)
 - Results are typically used to compare the accident risks posed by various alternatives
 - Severe Accident Mitigation Alternatives (SAMAs) and Design Alternative (SAMDAs) required for license renewal and for new licenses

MACCS Models and Capabilities



- Models treat
 - Atmospheric transport and deposition onto the ground
 - Statistical effect of variability in weather
 - Dose pathways for cloudshine, groundshine, inhalation, ingestion, and deposition onto skin
 - Protective actions during emergency, intermediate, and long-term phases
- Calculates offsite consequences
 - Doses
 - Health effects
 - Economic costs
 - Land contamination

WinMACCS Calculation Framework for a Level-3 PSA Analysis





Requirements to Support Multi-Unit Consequence Analyses



- Ability to treat multiple, overlapping source terms
 - Different accident initiation times
 - Different release signatures
 - Different isotopic inventories
- Spent fuel pools present a special case
 - Multiple fuel cooling times (different inventories)
 - Release signature may be a function of cooling time
- Overall release may continue for more than a week

Concepts for Multi-Unit Consequence Analysis Source Terms



- Multiple source terms can generally be evaluated independently
 - Initiating events may be simultaneous or time-offset
 - Initiating events may be common cause, dependent, or independent
 - Units may share equipment
- Source term is estimated for each unit and spent fuel pool
 - When initiating events are time-offset, offset may be variable or uncertain

Concepts for Multi-Unit Consequence Analysis Multiple Timelines



- Accident initiation times (i.e., reactor shutdown) can differ between units
- Radioactive decay begins at shutdown at each unit
- Release timing is relative to reactor shutdown
- Each release is represented by multiple plume segments



Overall Time Line

Concepts for Multi-Unit Consequence Analysis Multiple Inventories



- Release fractions are relative to inventory
 - MELCOR does not model isotopic inventories
 - Fission product behavior is calculated by chemical class, e.g., Cs, I,...
 - Tracks masses of chemical groups
 - Tracks decay heat associated with chemical groups
- MELCOR was modified to better treat spent fuel pools
 - Release fractions can be estimated by ring
 - MelMACCS can associate each ring with a different isotopic inventory
- A general treatment needs to associate release fractions with a specific inventory

Process for Multi-Unit Consequence Analysis Unit Source Terms



- For each unit
 - An isotopic inventory is calculated or estimated with ORIGEN
 - Release fractions are estimated for each chemical class by MELCOR
- MelMACCS is run separately for each unit



Process for Multi-Unit Consequence Analysis Spent Fuel Pool Source Terms



- For each spent fuel pool
 - An isotopic inventory is estimated for each ring with ORIGEN
 - Release fractions are calculated by chemical class and by ring with MELCOR
- MelMACCS is run once for a spent fuel pool
 - Separate source term files are based on release fractions by ring



Process for Multi-Unit Consequence Analysis Integrating Multiple Source Terms



- Time offsets account for delays between initiating events
- Radioactive decay is relative to each initiating event



Process for Multi-Unit Consequence Analysis Calculating Consequences



- User enters times for each initiating event
- MACCS calculates atmospheric transport and dispersion for each unit or spent fuel pool
- Results are superposed to estimate consequences

🗈 Time Offsets 📃 📼 💌
Enter Comments
NUM_SOURCES (-)
Source Time Offset (day) 1 0 2 0.4 3 1.5 4 2 * * Real [0., 30.]; Nrows = NUM_SOURCES (NUM_SOURCES = UNDEFINED) days Time offset for each of the source term files. Upperbound of 2592000 (s) corresponds to 30 days.
Change Units Make Uncertain OK Cancel

Summary



- A framework has been developed for evaluating multi-unit accident
- A source term is calculated independently for each unit
- Multiple source terms are calculated for a spent fuel pool
- WinMACCS/MACCS integrates the source terms into a single calculation