Assigning Seismic Design Category to Large Reactors: A Case Study of the ATR

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Disclaimer

• Approach presented here is under review
  – Not yet approved by management
  – Not submitted to DOE
DOE Large Reactor Seismic Design Criteria

DOE
- 10 CFR 830
- STD-1020
- STD-3009

ANS / ASCE
- ANS 2.26
- ASCE/SEI 43-05

NRC / SRP
- RG 1.70
- NUREG-0800
- RG 1.4, 1.183
## Approach to Severe Accident Analysis: Accident Type

<table>
<thead>
<tr>
<th>DOE</th>
<th>ANS</th>
<th>NRC</th>
</tr>
</thead>
<tbody>
<tr>
<td>Unmitigated: “meant to consider material quantity, form, location, dispersability, and interaction with available energy sources, but not to consider safety features (e.g., ventilation systems, fire suppression, etc.) which would prevent or mitigate a release”</td>
<td>Unmitigated: “shall be performed considering only the inherent physical or chemical characteristics of the hazardous material and the energy sources for dispersing the material.” (ANS 2.26)</td>
<td>Maximum Hypothetical: “result in hazards not exceeded by those from other accidents considered credible. Must address events that involve a substantial meltdown of the core with the subsequent release of appreciable quantities of fission products.” RG 1.183</td>
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## Approach to Severe Accident Analysis: Modeling Assumptions

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<tr>
<td>Only robust passive structures credited</td>
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<td>Single failures of active systems assumed. Additional failures assumed as to result in “substantial meltdown of the core and subsequent release”. However, the core is eventually quenched.</td>
</tr>
<tr>
<td>95th percentile meteorology and other conservatisms</td>
<td>mean values for the parameters related to material release, dispersal in the environment, and health consequences</td>
<td>95th percentile meteorology and other conservatisms</td>
</tr>
</tbody>
</table>
ATR Approach – DBA / Siting Criteria Analysis

• Quantity released to the environment is

\[ Q_{\text{env}} = Q_{\text{core}} \times f_{\text{core}} \times f_{\text{PCS}} \times f_{\text{building}} \]

Where: \( Q_{\text{core}} \) = core inventory at \( t=0 \)

\( f_{\text{core}} \) = fraction released from core

\( f_{\text{PCS}} \) = fraction released from primary coolant system

\( f_{\text{building}} \) = fraction released from building

• Source term for maximum hypothetical accident based upon NRC Alternate Source Term (AST) methods per Reg Guide 1.183

• Offsite dose calculations performed per Reg Guides 1.183 and 1.4
  – modeled passive holdup/retention in the rugged structure
  – Atmospheric dispersion using site-specific model developed by NOAA Field Research Division at INL
  – 2-hour dose at site boundary was 0.13 rem
ATR Approach – Seismic Design Categorization

- Previously categorized PC-4 per DOE-STD-1021 for > 200MW reactor
- Offsite dose based upon AST is very low
- Because AST credits some (impaired) safety system function, need to adjust for a true “unmitigated” accident
- Conservatively replaced AST source term ($f_{\text{core}}$) with entire core inventory at accident initiation
- No associated adjustments to the model (conservative)
- Continue to credit holdup/retention by the rugged structure
- Resulting postulated offsite dose for unmitigated accident is high
Umitigated Dose Evaluation

- DOE-STD-1189 does not provide quantitative guidance for SDC-4 and SDC-5

- Note in guidance for SDC-1 through SDC-3 states:
  “If the quantitative public criterion for SDC-3 of Table A-1 [Table 4 above] is exceeded significantly for any project (between one and two orders of magnitude) then the possibility that SDC-4 should be invoked must be considered on a case-by-case basis.”

- Since resulting dose meets this criterion, ATR should be considered SDC-4
ISSUES

• DOE STD-1189 abandons the mean-centered approach of ANS 2.26 and imposes the conservative approach of STD-3009.
  – For processes dominated by uncertainty such as atmospheric dispersion, mean-centered analyses are more reliable (although quantitative guidelines need to be adjusted lower)

• There is substantial data from experiments and actual events showing very low releases of most core radionuclides for reactor accidents
  – STD-3009 methods do not adequately account for this data
  – Reg Guide 1.183 AST method better models reactor severe accident data and experience
  – The gross approximation of substituting core inventory for the AST results in unreasonable doses by many radionuclides known to be minor in reactor accidents (such as large contribution by Lanthanides)

• HOWEVER -- SDC-4 seems appropriate for a 250 MW reactor on a large site