MODULE 4:

Accident Progression & Source Term Analysis

Outline of Discussion

- Overview of severe accident progression and source term analysis
  - Type of calculations typically performed
  - Alternative computer codes
- Use of results in Level 2 PSA
  - Deterministic analysis as a technical basis for CET quantification

Severe Accident Computer Codes Support All Aspects of Level 2 PSA

- Thermal-hydraulic response/success criteria
  - Primary coolant inventory management, reactor pressure control & heat removal
- Time of major events
  - Onset of core damage
  - Time to exceed containment failure criteria
  - Available time for operator actions
- Evolution of severe accident phenomena
  - Core melt progression
  - Containment response
  - Fission product release/transport (source term)

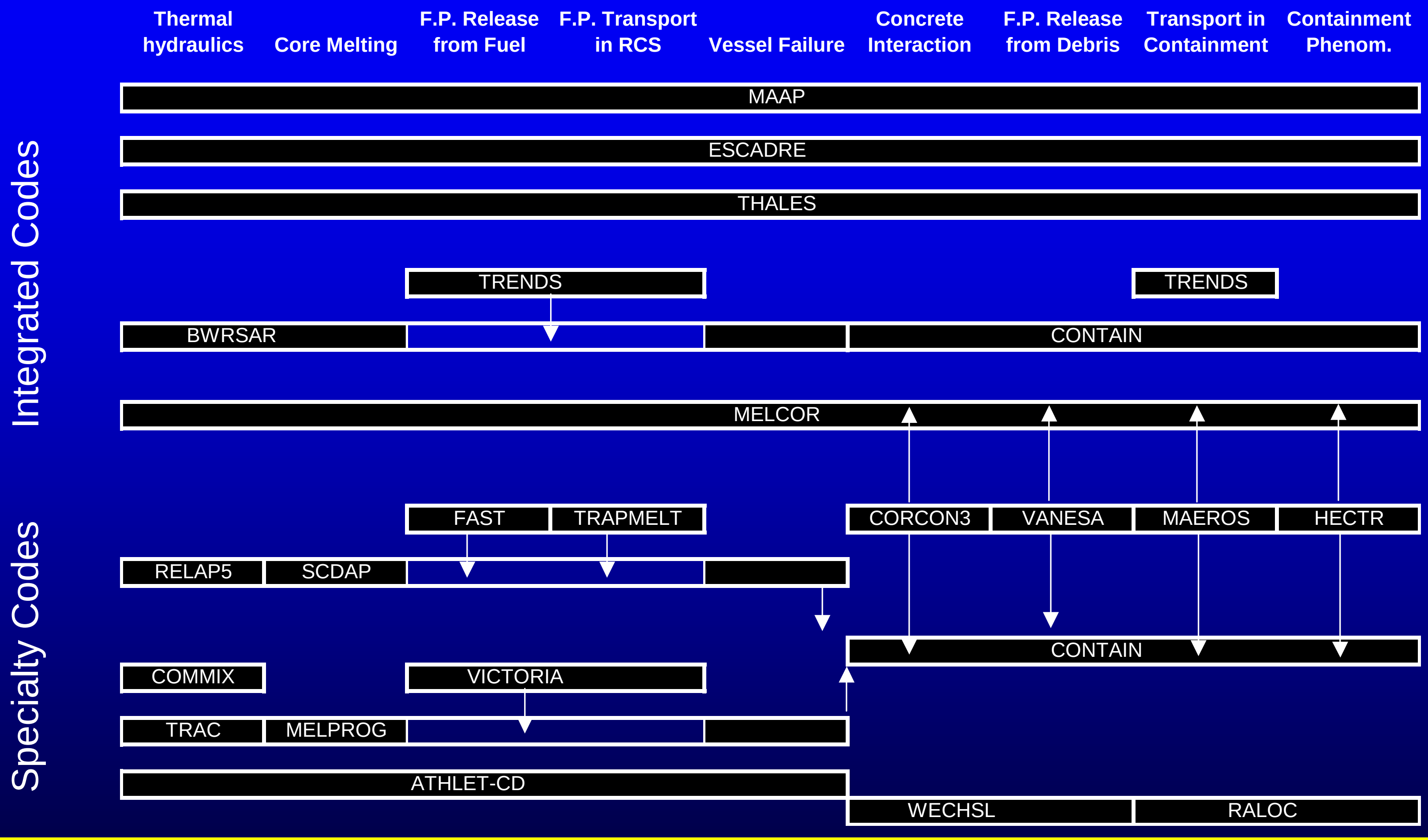
Alternative Ways Code Calculations Can Be Used

- Plant-specific analysis
  - Integral analysis for important sequences
  - Specialized models or experiments for plant-specific issues
- Adapt results from ‘reference plant’ analysis
  - Must demonstrate adequate ‘similarity’

Example Needs for Specialized Analysis

- Containment failure modes
  - Contact between molten debris and containment pressure boundary
  - Heat transfer near containment penetrations & other pressure boundary seals
- Containment loads
  - Hydrogen distribution / combustion
  - Debris / water distribution in containment
- In-vessel melt progression
  - Natural circulation phenomena
  - Potential for in-vessel recovery
- Fission product release phenomena
  - Water pool chemistry
- Secondary containment (auxiliary building) response

Computer Codes to Support Level 2 PSA



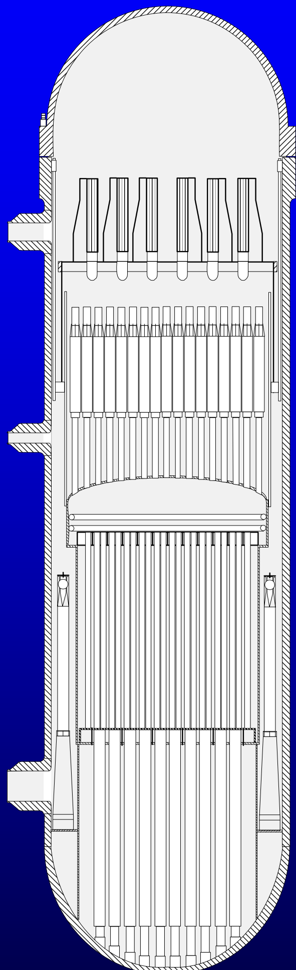
Selection of Accident Sequences for Analysis

- Plant damage state analysis
  - Dominant functional sequences
  - Low-frequency, high-consequence events
- Sensitivity calculations to evaluate effects of issues represented in the CET
  - Effects of accident mitigation systems
  - Modeling uncertainties
- Containment performance
  - Integrated accident progression-source term analysis for major PDS/containment failure alternatives

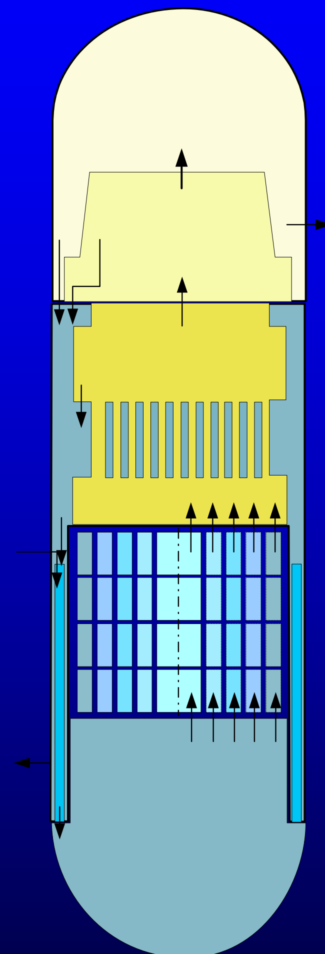
Example Use of Integral Code Calculations for CET Quantification

- **Example:**
  - **BWR/5 – Mark II Containment**
  - **Twin Unit (shared reactor building)**
- **Objectives of calculation**
  - **Determine plant response to station-blackout**
  - **Characterize order and timing of key events**
  - **Identify potential containment modes**
  - **Determine potential for H_2 combustion in reactor building**
  - **Identify major events controlling fission product release**
- **Code used for analysis: MELCOR**
  - **Could have used many other integrated codes**

G.E. BWR/5 Reactor Configuration

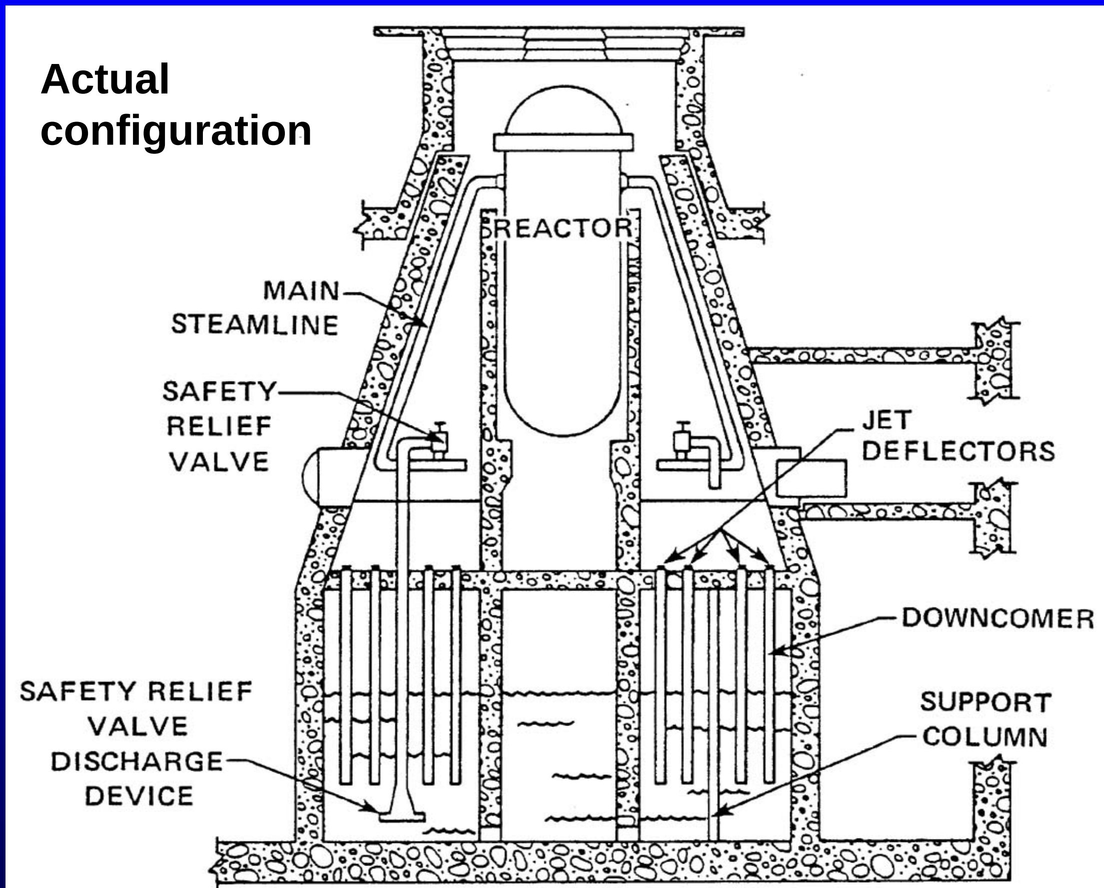


Actual configuration
Upper plenum
Steam dryers
Steam separators
Downcomer
Core
Jet pumps
Control rod guide tubes
Lower head

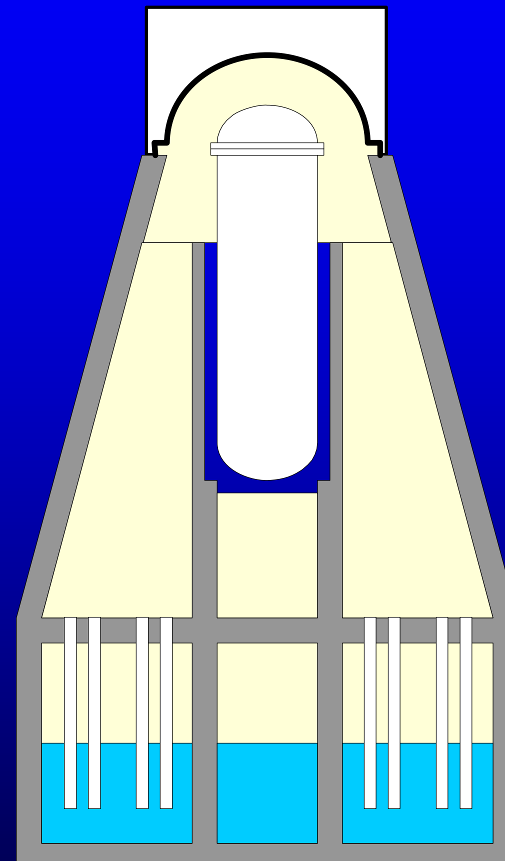


Computer model
Upper plenum
Steam dryers
Steam separators
Downcomer
Core
Jet pumps
Lower plenum

Mark II Containment Configuration



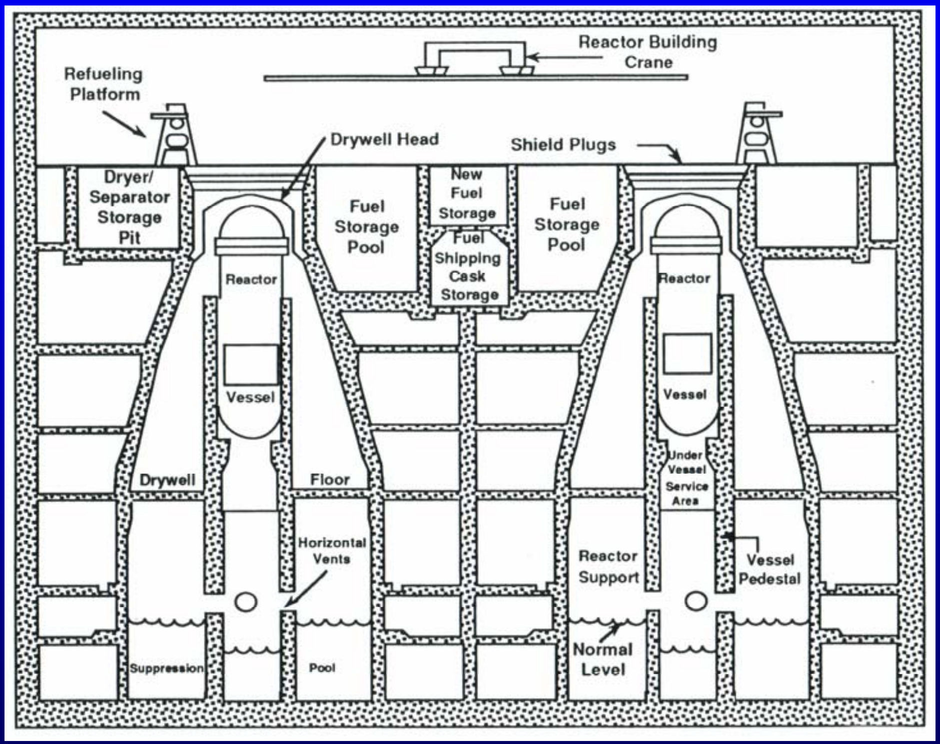
Computer Model



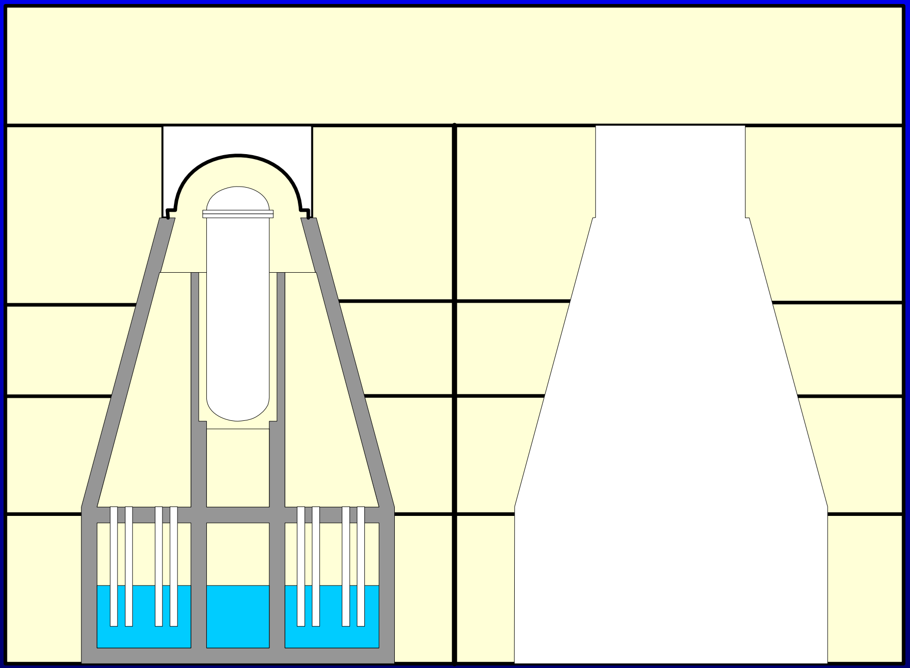
Secondary Containment Configuration

2-Unit plant

Actual configuration



Computer Model



Summary of Key Results
(In-vessel phenomena)

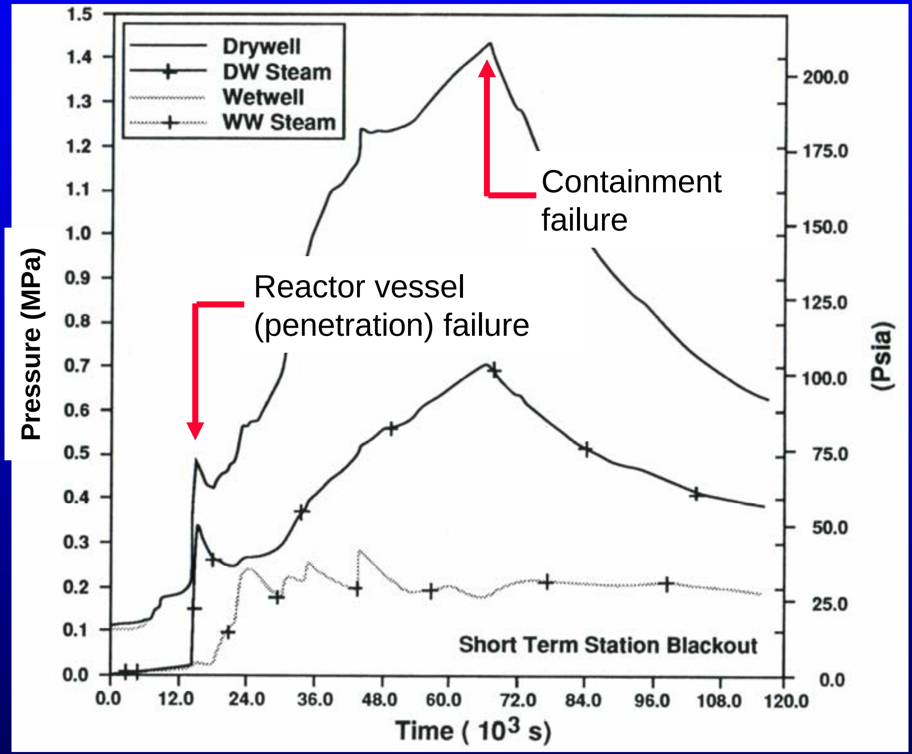
- Core damage begins 75 minutes after loss of ac power
- Approx. 1100 kg of hydrogen generated by in-vessel oxidation of Zr-clad and steel
- Reactor vessel breach (penetration failure) occurs less than 3 hours after core damage begins
- Debris released to reactor pedestal over 5-hour period
- Retention of fission products in reactor vessel is substantial
  - 20-50% of volatile species retained
  - 70-80% of semi-volatile species retained

Summary of Key Results
(Ex-vessel phenomena)

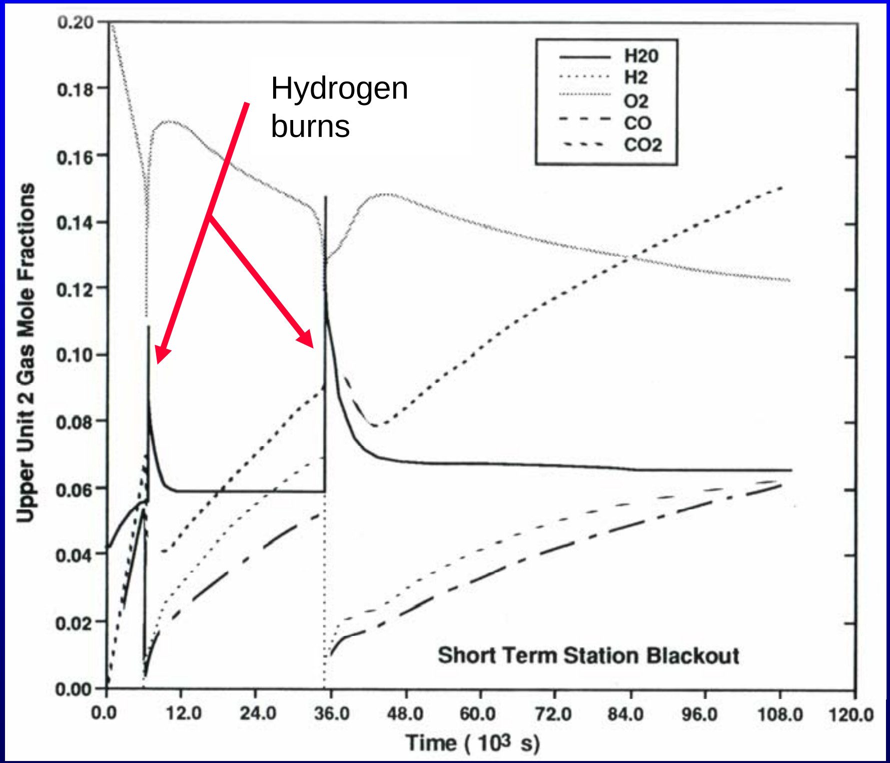
- Concrete ablation due to corium-concrete interactions (CCI) exceeded wetwell pedestal wall thickness
- Approx. 1000 kg of hydrogen produced from oxidation of Zr and steel during CCI
- Reactor building combustion predicted
- Concrete degassing important contributor to increases in containment pressure
  - Containment over-pressure failure predicted to occur approx. 18 hrs after initiating event
  - Steam condensation on structures slows pressure rise
- Suppression pool subcooled until containment failure

Containment Thermodynamic Response

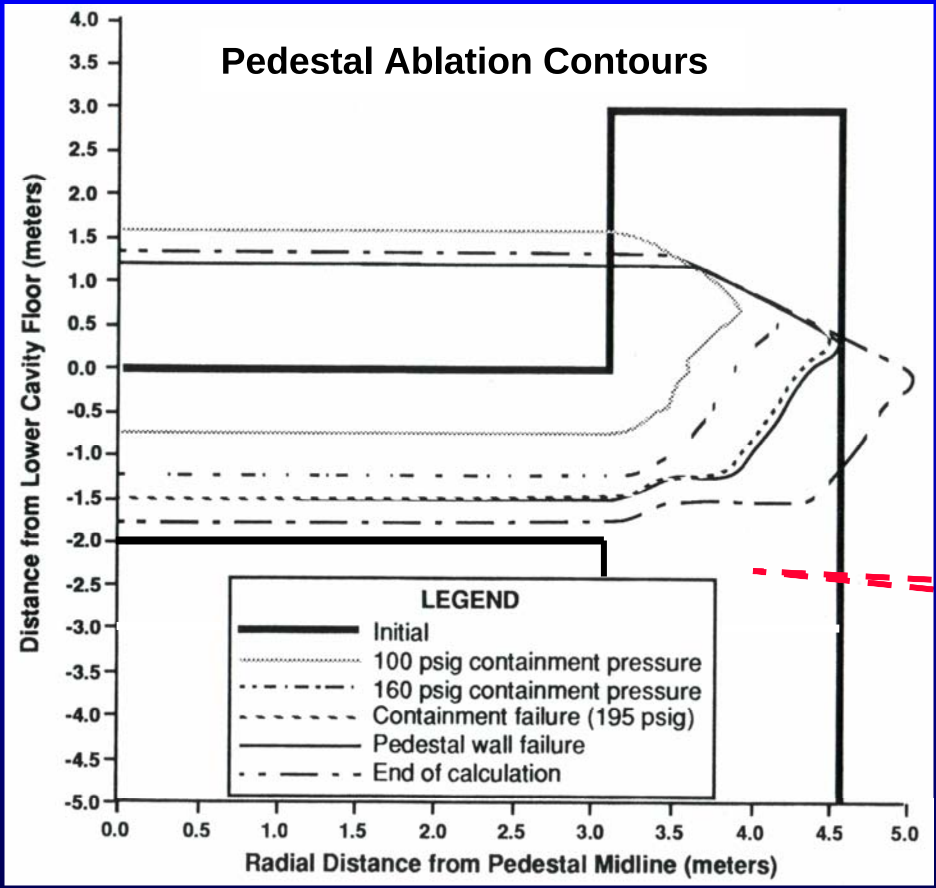
Primary Containment

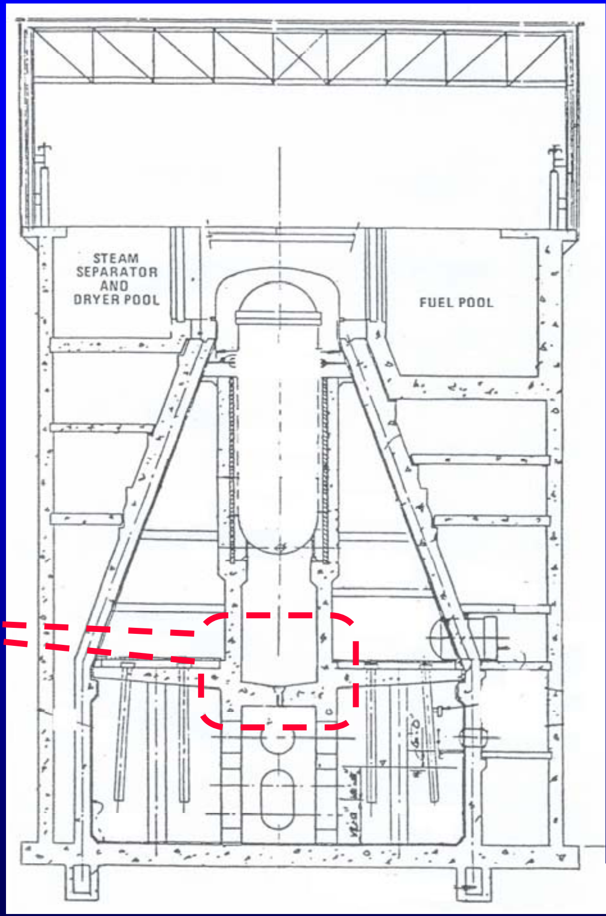


Reactor Building

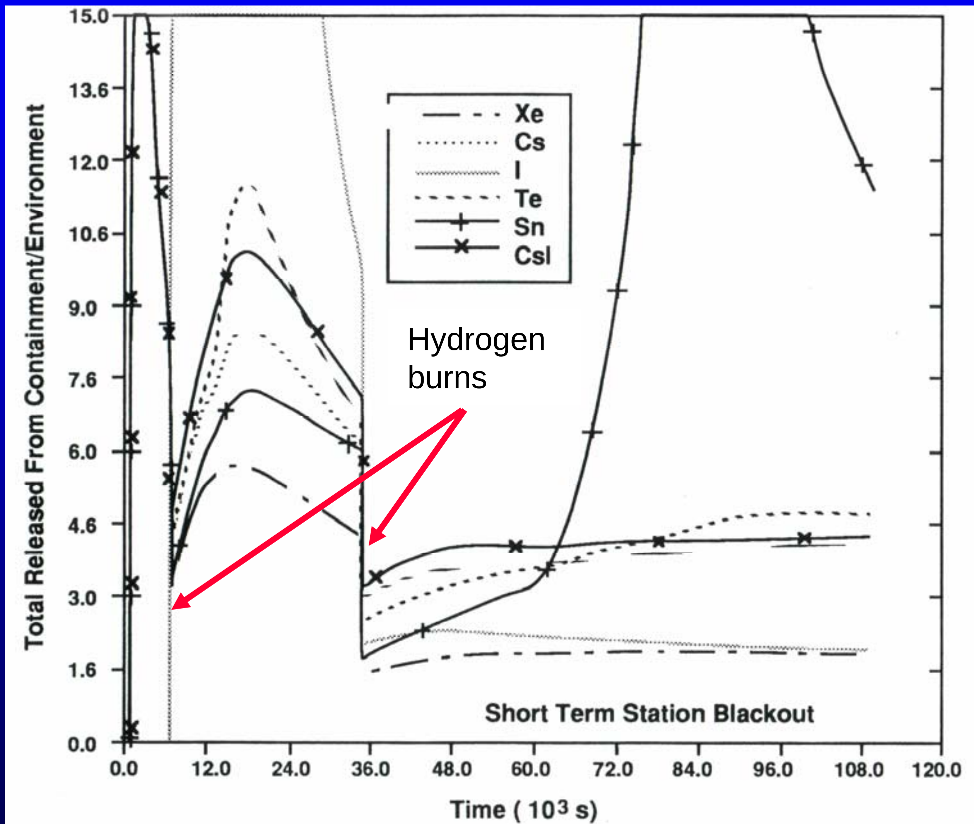


Concrete Attack in Reactor Pedestal



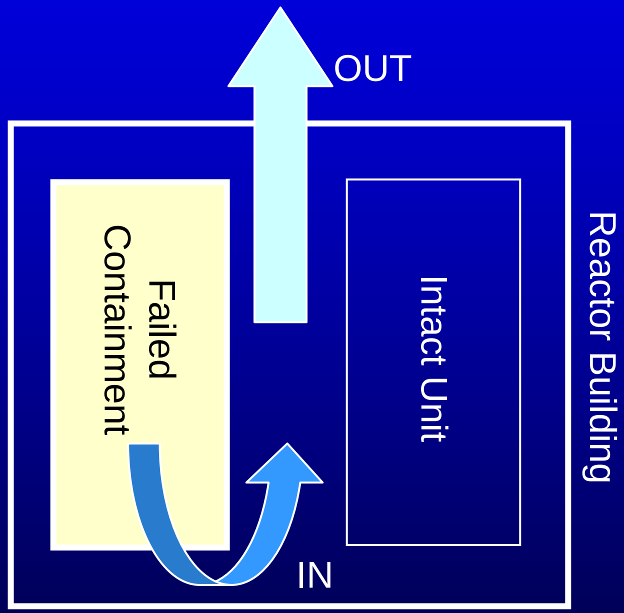


Fission Product Retention in the Reactor Building



Decontamination Factor

DF = mass in/mass out



Results Useful for CET Quantification

- Time is available to restore coolant injection after core damage begins and terminate the accident inside the reactor vessel
  - Extend offsite power recovery analysis into the Level 2
- Containment failure most likely to occur by slow over-pressure (18 hrs after initiating event)
  - Alternative: lateral penetration of reactor pedestal by core debris might also cause reactor vessel to shift position and damage piping penetrations (also ~18 hrs)

Results Useful for Source Term Analysis

- Hydrogen combustion likely to occur in the reactor building
  - Reduces effectiveness of building to retain fission products
- Suppression pool remains subcooled through accident
  - Fission product scrubbing in pool very effective in reducing aerosol mass available for release to the environment

Summary

- Integrated severe accident progression and radionuclide release/transport calculations provide the primary basis for supporting CET quantification and source term assessment
  - Sensitivity calculations are necessary to support confidence in results obtained from baseline calculations
  - Calculations should address wide range of accident sequences
- Specialized models may be necessary to address issues not modeled in integrated codes
  - Dynamic loads (hydrogen detonations, steam explosions)
  - Phenomena influenced by multi-dimensional flow fields