Volunteer-Plant (VP) ECCS Vulnerability Assessment

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ATTACHMENT 9

Overview

- Objectives of Volunteer-Plant Analysis
- Plant Description
- Sump-Screen Head Loss
- Pool Transport
- Blow Down/Wash Down Debris Transport
- Debris Generation
- Break Location
- Current Insights

Objectives of Study

- Volunteer Plant study integrates all phenomenology info and analysis methods using best available plant specific data
- Illustrates one possible implementation of the Reg Guide
- Provides NRC a detailed standard of comparison for reviewing future submittals and NEI ground rules
- May provide a template for content of plant assessments with exaggerated detail needed for methodology insight
- Sets expectations for conservatism and application of data
- Will address all major accident scenario components BUT... will not analyze all industry conditions/configs
- 'Best Available' info will still require approximation and engineering judgment. Will improve as condition assessment and further head-loss analysis are completed

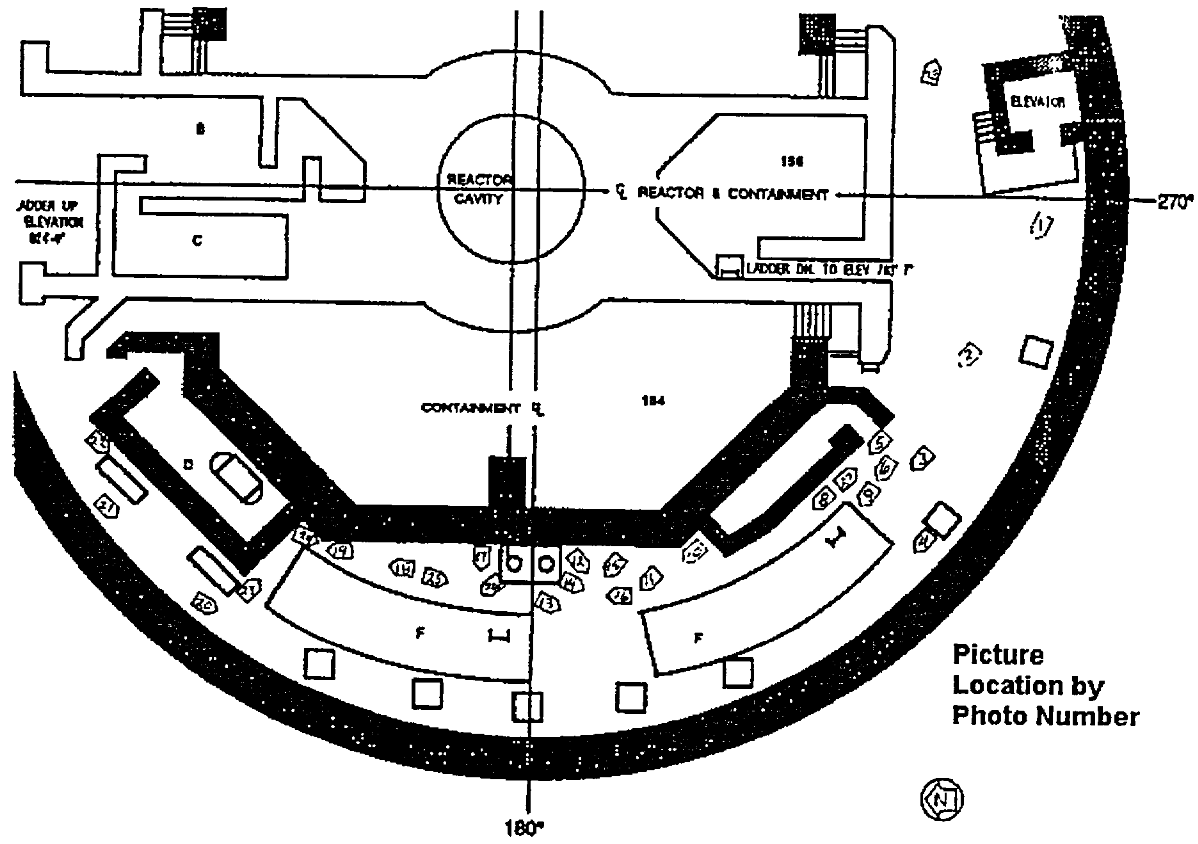
Required Plant Information

- **Water balance calculations**
  - Return flow locations and rates
  - Minimum pool depths for various break scenarios
  - ECCS flow rates for various break scenarios
- **ECCS pool geometry**
  - Flow velocity calculations
  - Identify dead sumps that trap debris
  - Scope pool dynamics
- **Piping layout and insulation applications by type**
- **Sump-screen geometry**
- **Plant cleanliness characterization (Latent Debris)**

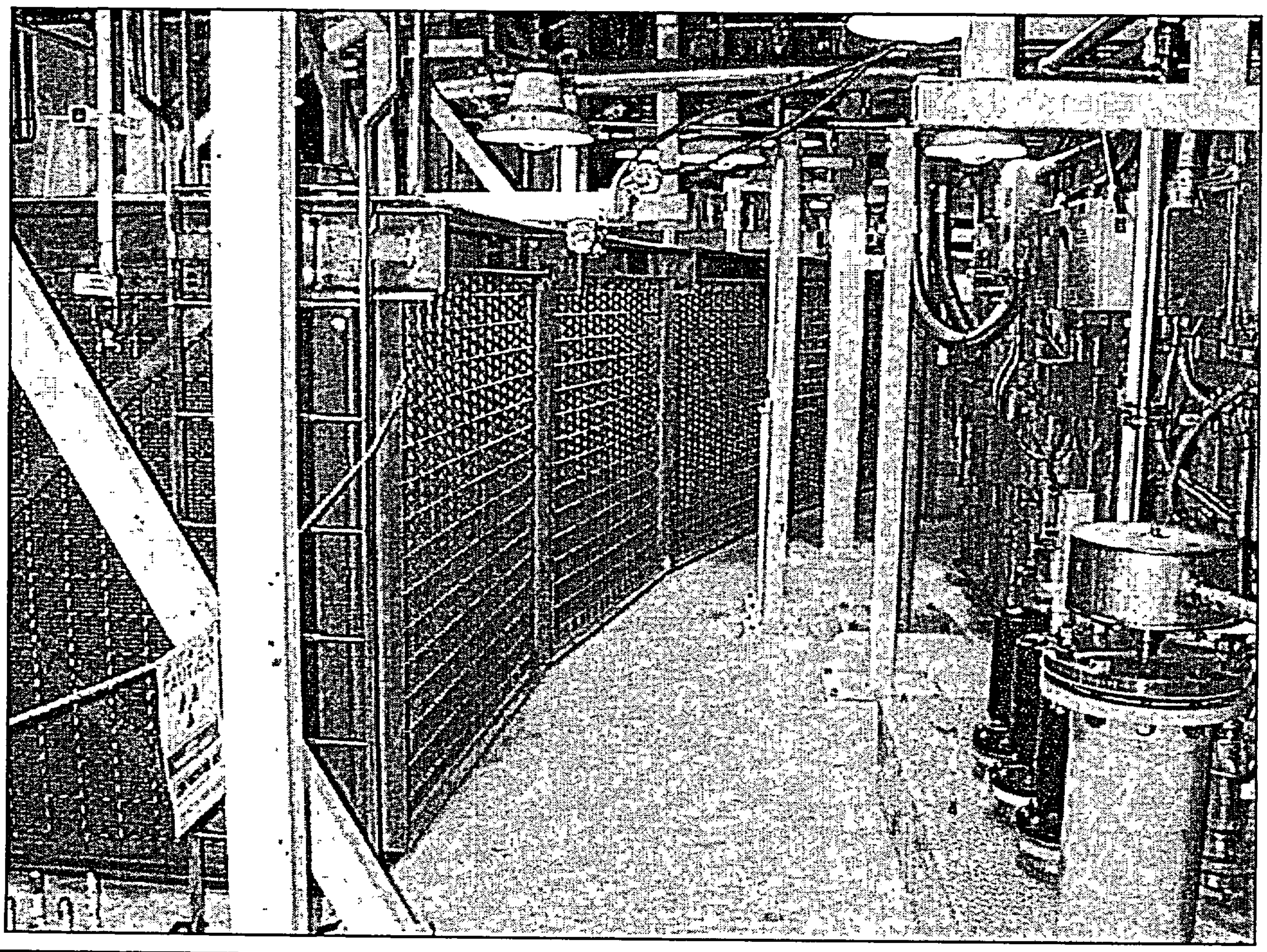
VP Geometry Features

- **Large dry containment (133 ft diam), four loop, 'remote' sumps**
- **Raised steam generator compartments**
  - Continual falling water sweeps compartment floor
  - Compartment opposite break cannot accept debris during fill phase
  - No damping of falling water. Momentum directed to annulus
- **Two adjacent roughly equivalent sump cages (260 ft^2 total)**
  - Very close to one steam generator compartment outlet
- **Sump-screen curb (4 in)**
  - Effective at stopping RMI unless severe piling occurs
  - Reduces effective pool depth
- **Nonsubmerged vertical sump screens 4.75 ft above curb**
  - Failure criteria ~1/2 pool depth above curb (ft H_2O)
- **Fall height from upper level drains ~10 ft**
- **Spray return drains adjacent to vertical sump screens**
- **Reactor cavity with curb and partial steel-plate cover**

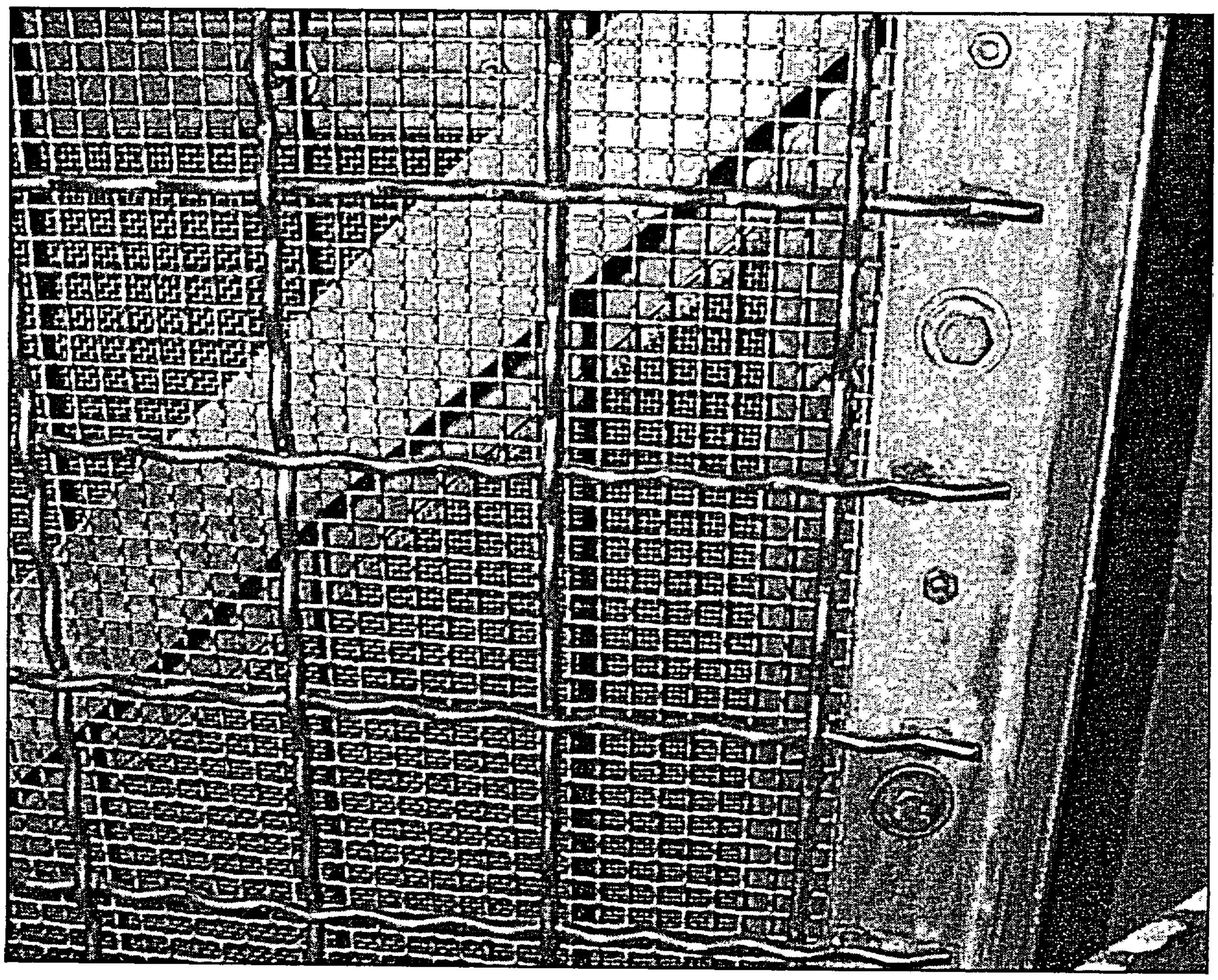
Sump Pool Plan View



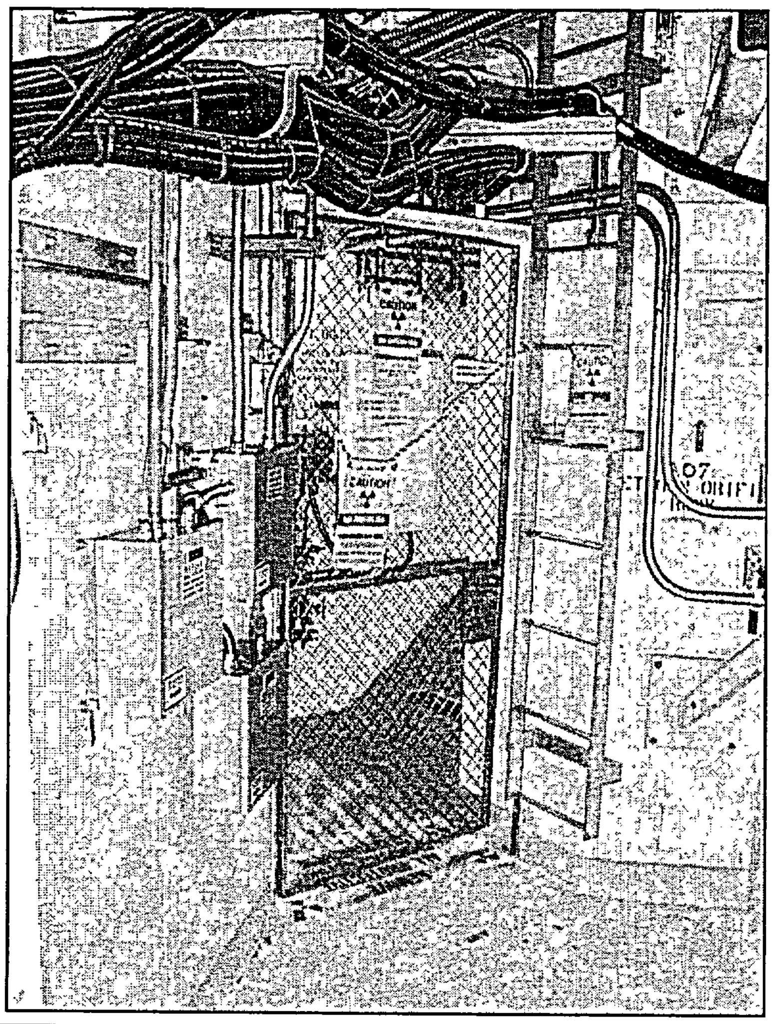
Sump Cages



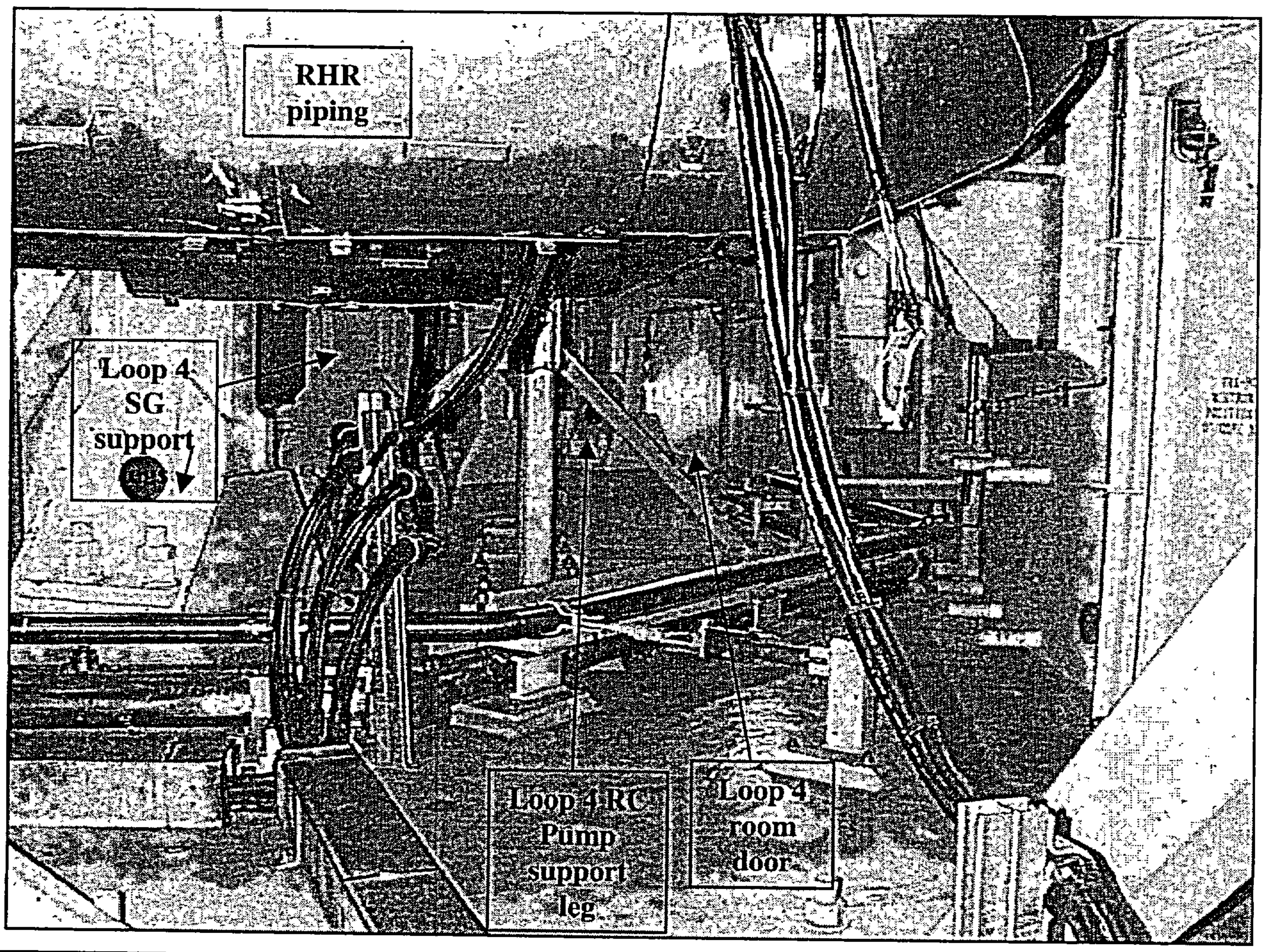
Sump-Screen Construction



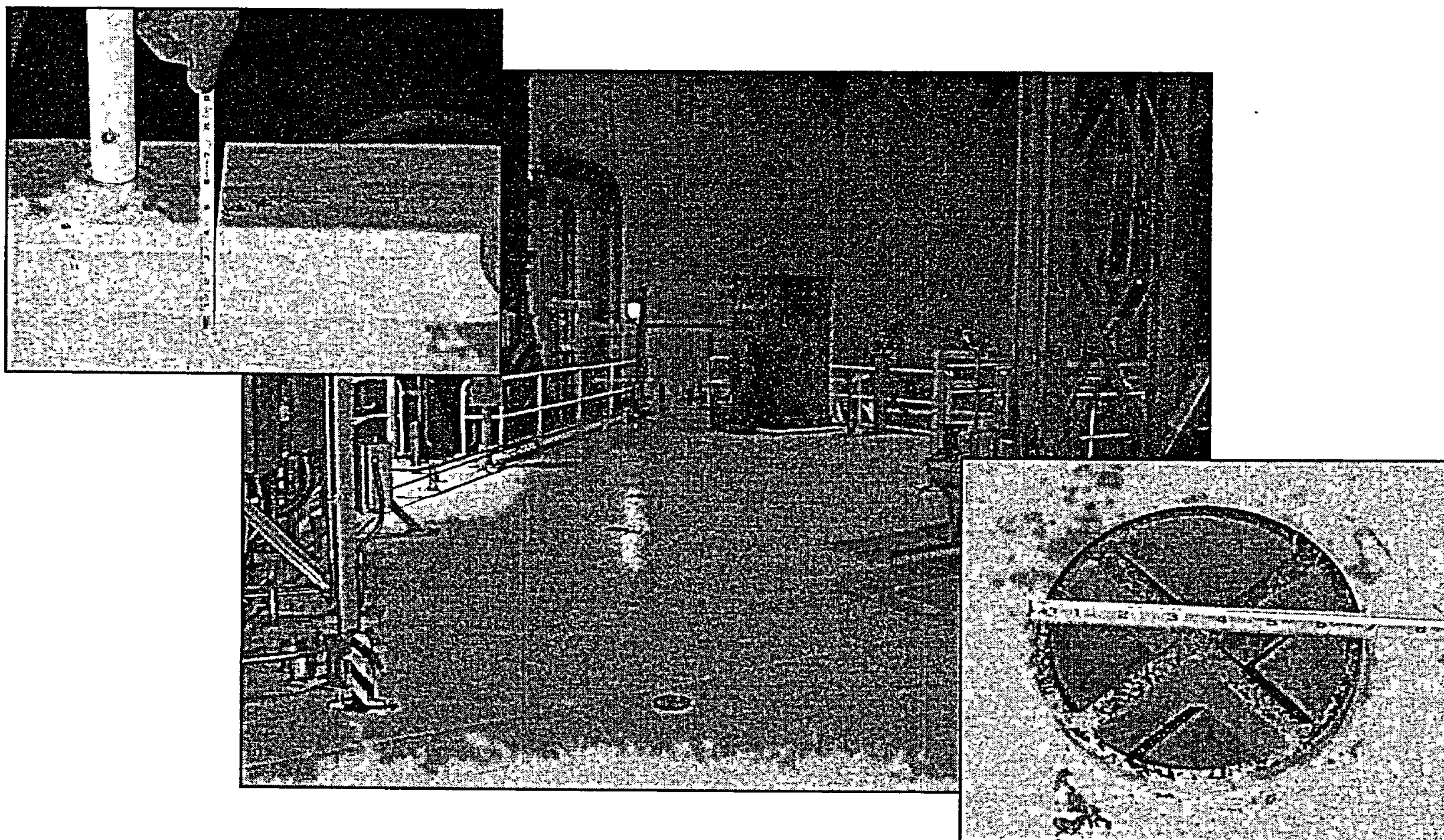
SG Compartment Entry



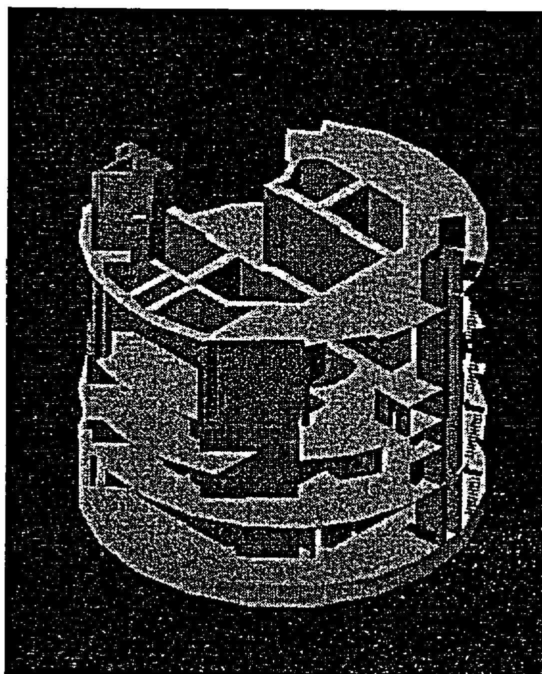
Steam Generator Compartment



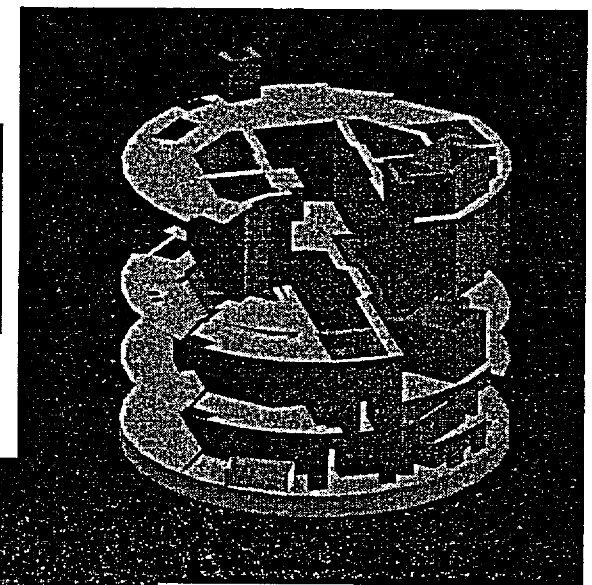
Floor Drains and Curbing

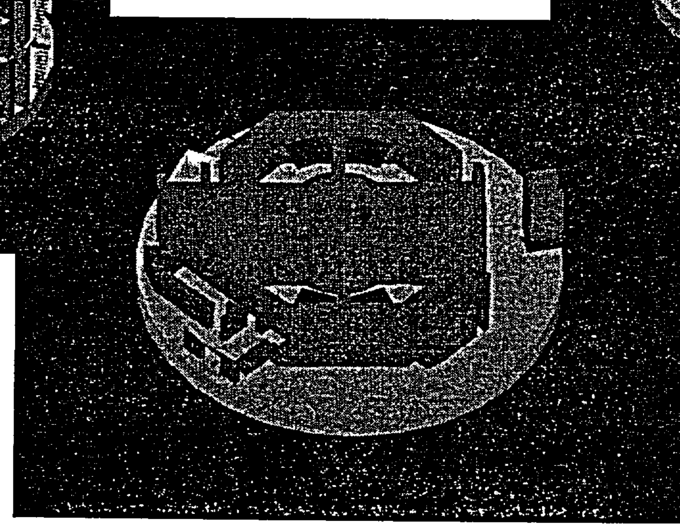


Concrete Structures

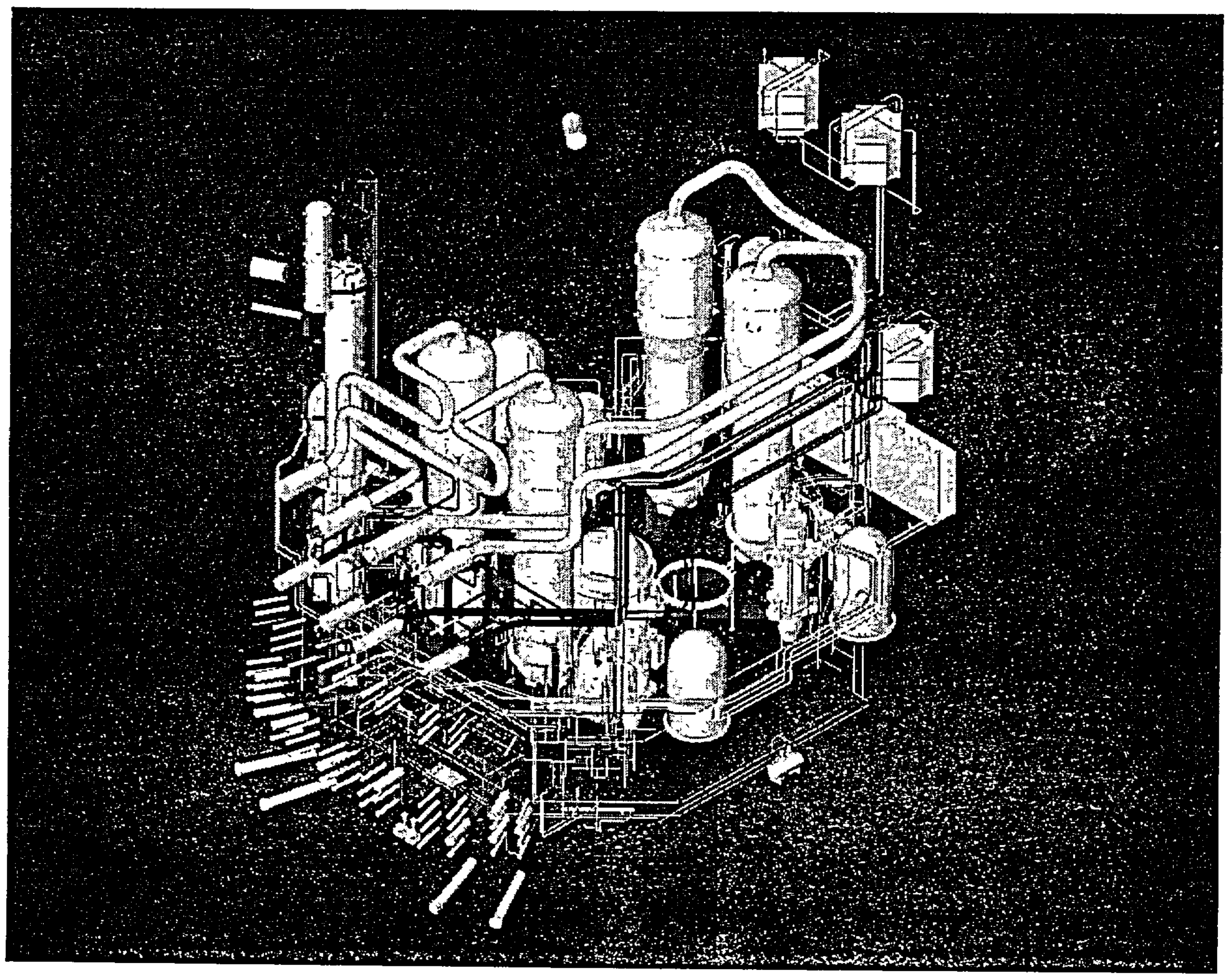


CAD model constructed by tracing plan view of each level

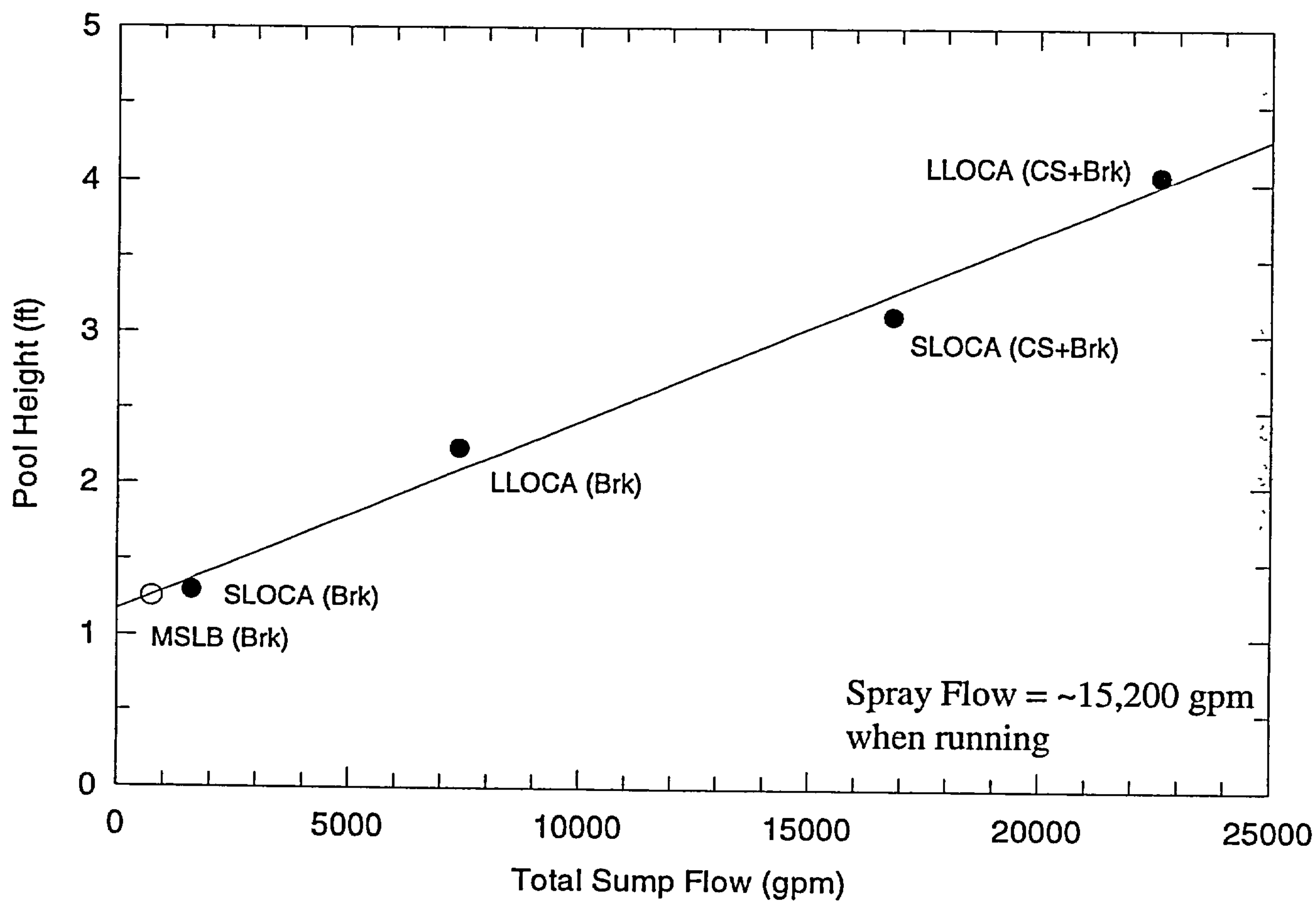




Piping and Equipment Model



Ranges of Sump Flow



Preliminary Head-Loss Results

Volunteer Plant Containment Pool Flow Analysis

Observations Regarding CFD

- **Good qualitative agreement between CFD models of fill/steady-state velocities and Tank Experiments**
- **Ancillary sources representing containment spray return paths can dominate pool activity**
- **Quantitative flow maps provide access to an approximate, yet tractable estimate of transport fraction**
  - Logic maps and engineering judgment will be needed to consider fractions and characteristics of debris returned to the pool via various paths
- **Uncertainties in location and timing of debris entering pool limit the need for a high fidelity model of debris transport**

Area > threshold velocity proportional to degradation and transport for initial uniform distribution of fill-up phase debris

Transitional Pool Flow Sequence

Event	Characteristics
Break Occurs	Jet impingement, steam expansion, water to bare floor with sheet flow directed away from break. Highest transport velocities. Initial deposition pattern in dead areas and sumps.
Sprays Trip	Spray runoff accumulates and washdown begins, Sheet cover complete. Sumps fill via directed flow. Deposition pattern modified by splash zones
Max Spray Return	Maximum energy in minimum pool depth (~inches). No directed flow. Pool begins to fill. Max degradation. Pseudostable deposition pattern develops.
Lower Sumps Full	Directed flow begins to develop. Deposition pattern modified in vicinity of sump. Suspended debris collected very quickly. Steady-state flow pattern established.

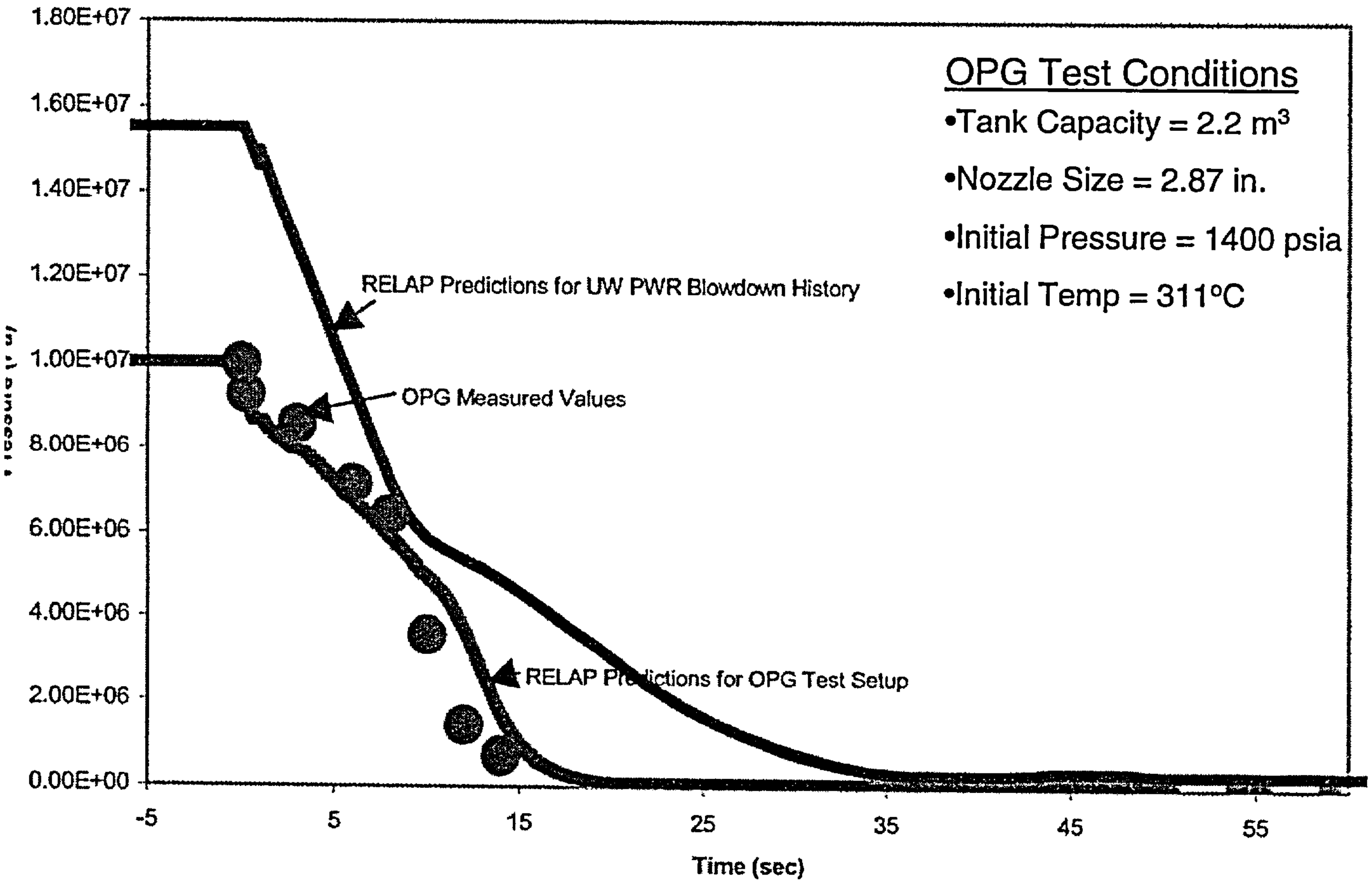
Dead sump sheltering is only significant sequester

Key Transport Test Observations

- Cal-Sil and fiber were able to form a thin bed on a ¼-in mesh vertical screen at nominal approach velocity
- Fiber flocks that enter turbulent splash zones are effectively shredded to transportable sizes
- Individual fibers are suspended and continue to collect for many hours
- Shear forces between higher and lower pool velocity zones are capable of slowly degrading piles of fiber flocks

Containment Airborne/Washdown Debris Transport Methodology

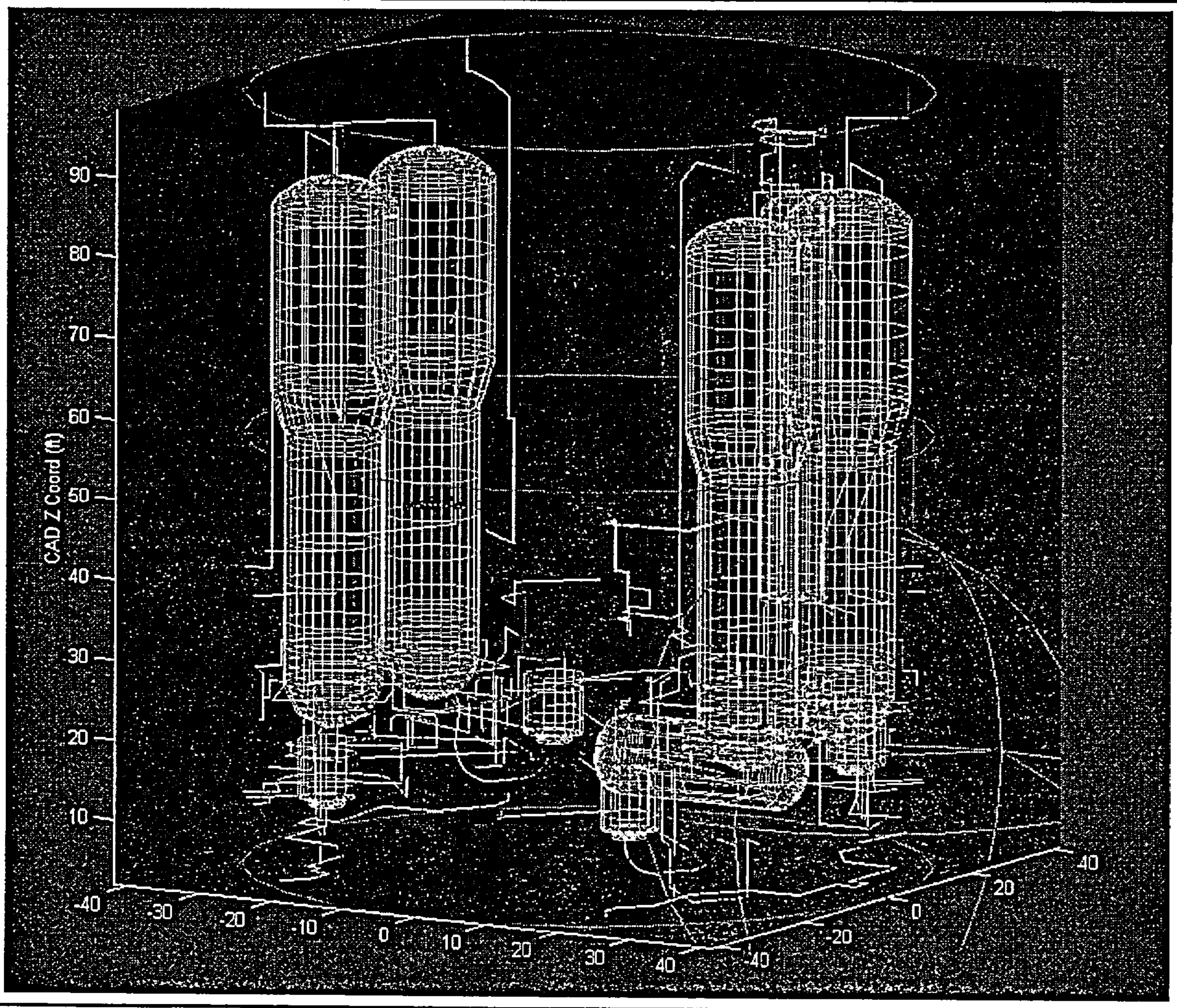
Two-Phase Debris Generation



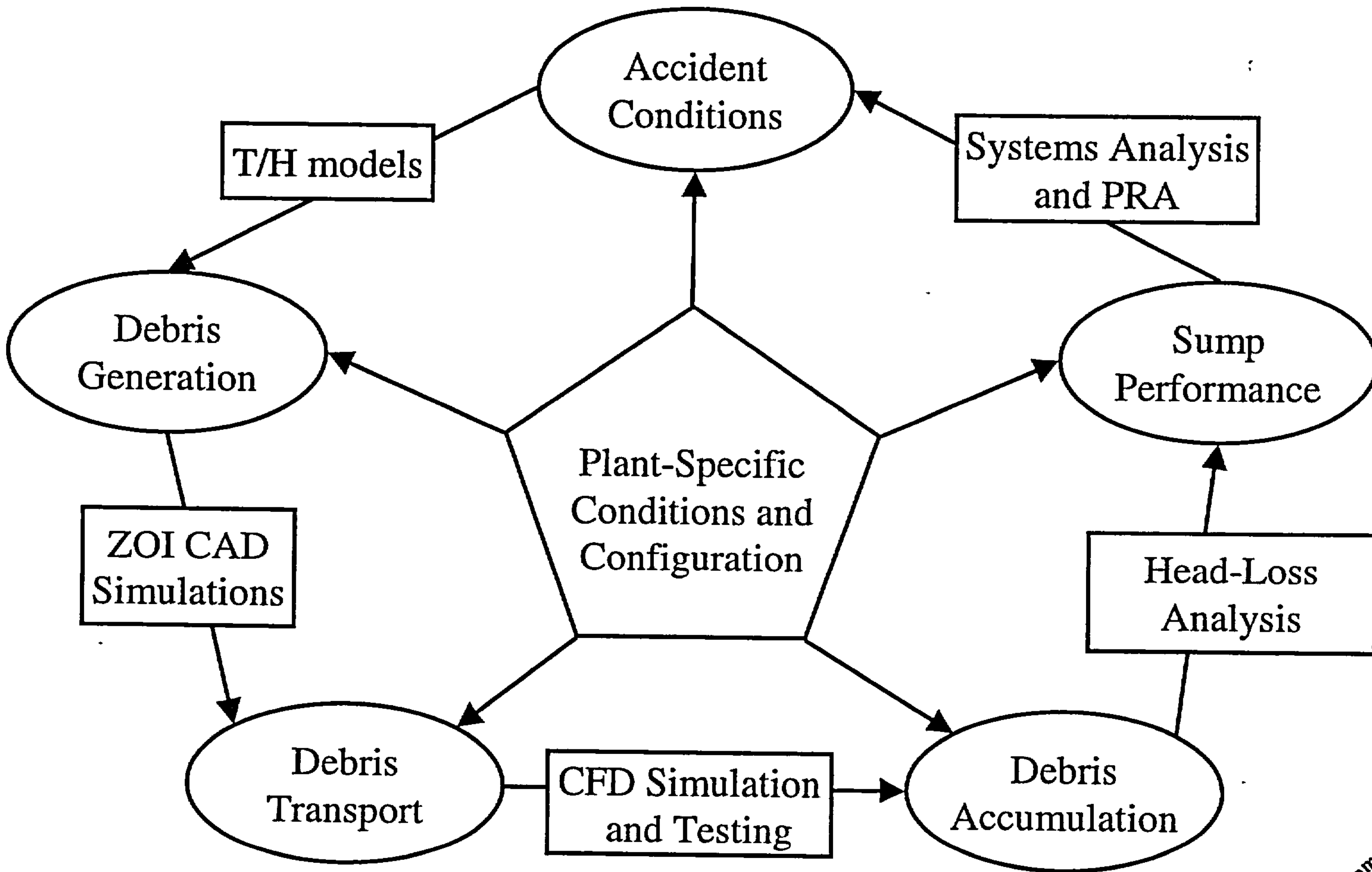
Rederived ZOI (NUREG/CR-6762-3)

- **Rederived using OPG data and equivalent spherical pressure volume compared to ANSI/ANS-58.2 and EPRI jet models**
- **Slightly increased ZOI size**
  - Nukon: 12-D (PWR) vs 10-D (BWR)
  - Cal-Sil: 8-D (PWR) vs 6- D (BWR)
- **Higher fraction of fines**
  - Nukon: 29% (BWR) vs 40% (PWR)
  - Cal-Sil: ≈ 0% (BWR) vs 30% (PWR)

Survey of Break Locations



Integrated Vulnerability Assessment



Required Skill Set

- **Familiarity with containment**
  - Visual understanding of spray and floor water flow paths
- **Understanding of water levels and pump-flow rates as related to EOPs**
- **Competent application of BLOCKAGE or other implementation of NUREG/CR-6224 head-loss correlation**
  - All plants should start by understanding current sump vulnerability
- **Understanding of ZOD correlations to scope break locations**
- **Knowledge of applied insulation types and ability to query/manipulate electronic spatial information**
  - CAD models desirable, but not critical
- **Awareness of debris generation and head-loss data**
  - Identify unique materials and plan for characterization

Methodology Insights

- **Must design/adapt screens to defeat thin-bed formation**
  - Transverse bulk and inlet flows to sweep or 'self-clean' surface
    - Stacked disks, crenulated plates, etc.
  - Complex filter surface to fragment fiber layer
- **Can mitigate to protect against large debris volumes**
  - Reducing insulation volume
  - Increase screen area with compact high surface modifications
  - Intermediate gates at pool level
  - Divert fill-up flow towards dead sumps/cavities
- **Always maximize pool depth**
  - Especially important for nonsubmerged screens
  - Run sprays for breaks of all sizes?
- **Special attention to cleanliness at pool level for small break/no spray**
- **Fill-up retention in dead sumps is perhaps the only important pool-transport reduction factor**

Mitigation Strategies

Preserve Integrated Safety Plan!

- **Submerge screens without compromising area**
  - Utilizes full NPSH margin of mechanical pumps
- **Avoid horizontal screens below grade**
- **Test and approve back-flush/throttle cycles to dislodge compacted debris**
- **Midstream debris screens to intercept steady-state flow channels**
- **Plant cleanliness programs**
- **Modification of insulation types**
  - With due care not to increase resident loading
- **Active mechanical sweep and collect concepts**
- **Innovative porous media designs on top of existing screens**