URS | **URS Safety Management Solutions**

CST Waste Tank Accident Analysis for a Post-Seismic Explosion Event

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M. Ray Yeung* – URS SMS
David C. Thoman – URS SMS
Kendra H. Barbour – Savannah River Remediation

*803.502.9886
*ray.yeung@wsms.com

Presentation Outline

- **Background**
- **Determination of Bounding Scenario(s)**
- **Technical Models**
  - Discussed at high level
  - Details in technical paper
- **Results and Discussion**
- **Concluding Remarks**

Background

- **Concentration, Storage, and Transfer (CST) Facility at SRS**
  - 51 underground storage waste tanks
  - 4 tank designs
    - Type I – 0.8 Million Gallons
    - Type II – 1.1 Million Gallons
    - Type III/IIIA - 1.4 Million Gallons
    - Type IV – 1.7 Million Gallons
  - 3 waste forms (one or more can exist in each tank as a layer)
    - Supernate (liquid salt solution)
    - Saltcake (precipitated solids plus interstitial supernate)
    - Sludge (insoluble solids plus interstitial supernate)
  - Flammability concerns primarily from hydrogen
  - Tanks ventilated to keep hydrogen vapor space concentration below lower flammability limit (LFL)

Background (continued)

- **Sources of Hydrogen**
  - Radiolytic generation from supernate, saltcake, and sludge
  - Trapped gas (including H_2) in sludge
  - Trapped gas (including H_2) in saltcake
- **Other flammable gas – trace amounts of organic vapors**

Background (continued)

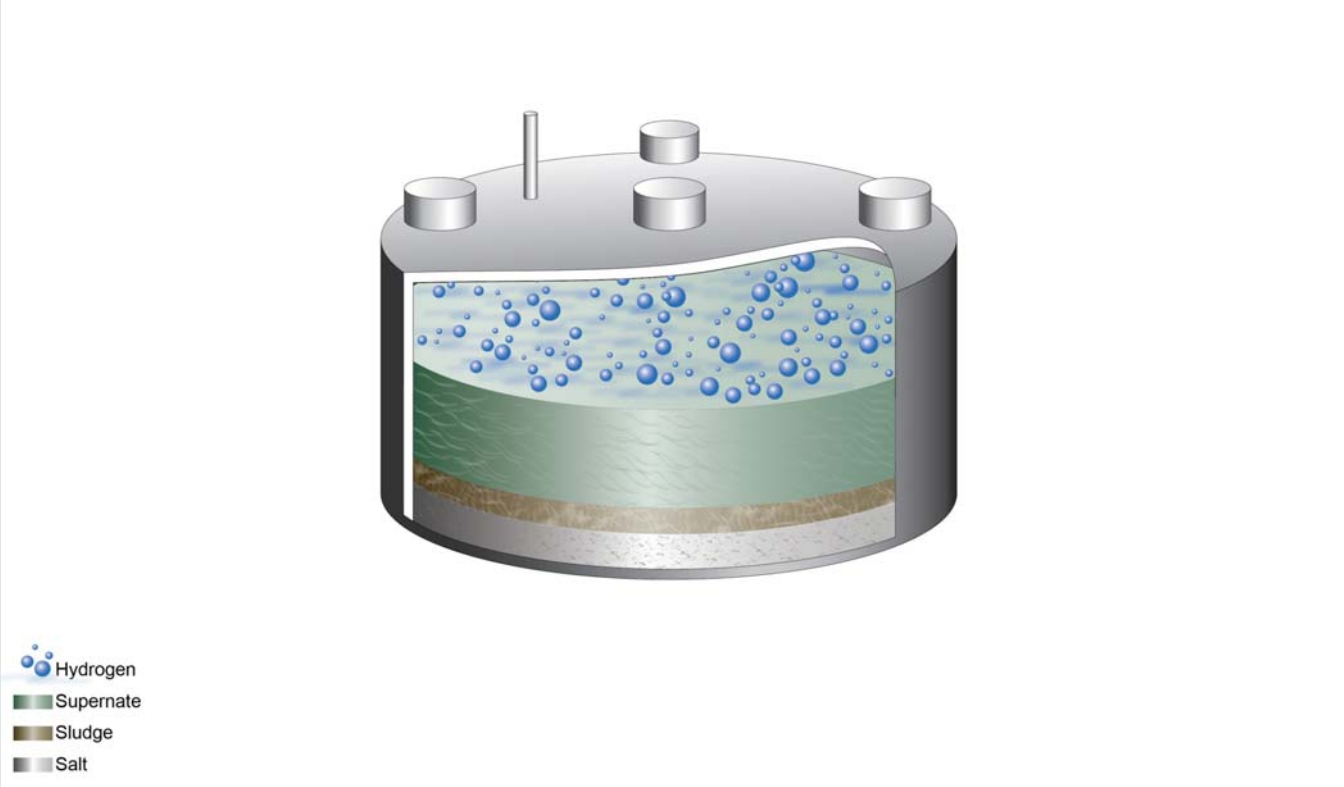
- **General Scenario Description**
  - Seismic event occurs releasing trapped H_2 gas from sludge and saltcake into tank vapor space
  - Ventilation fails leaving diurnal breathing as only mechanism to remove H_2 gas from vapor space
  - Hydrogen continues to build up in vapor space from radiolytic generation
  - Trace amounts of organic vapors also present in tank vapor space
  - Spark assumed present to ignite flammable gas mixture resulting in explosion (deflagration or detonation)
  - Waste aerosolized from explosion forces resulting in radiological source term release and doses to downwind receptors

Background (continued)

- **Preliminary Considerations**
  - Some tanks do not pose flammability concerns
    - Closed tanks - emptied to heel level and grouted
    - Tanks in the process of being closed – waste level low & vapor space large
  - Unmitigated consequences for some tanks exceed evaluation guideline for maximally-exposed offsite individual (MOI) at site boundary
  - Control Strategy
    - Database tracks waste levels in each tank, radionuclide inventory, calculated H_2 generation rates and other data
    - Tanks with rapid H_2 generation have been identified and extra control imposed of regular agitation to release trapped gas periodically
    - Waste levels in other tanks controlled to keep the calculated H_2 concentration in the vapor space from radiolysis at 4% H_2 or less at the end of 7 days
  - Mitigated analysis presented in this paper to cover the 39 tanks for which the 4% H_2 concentration control applies

Determination of Bounding Scenarios

- **Challenges of Determining Bounding Scenario(s)**
  - 4 Tank Designs
  - Up to 3 Waste Forms with Layers of Varying Thickness



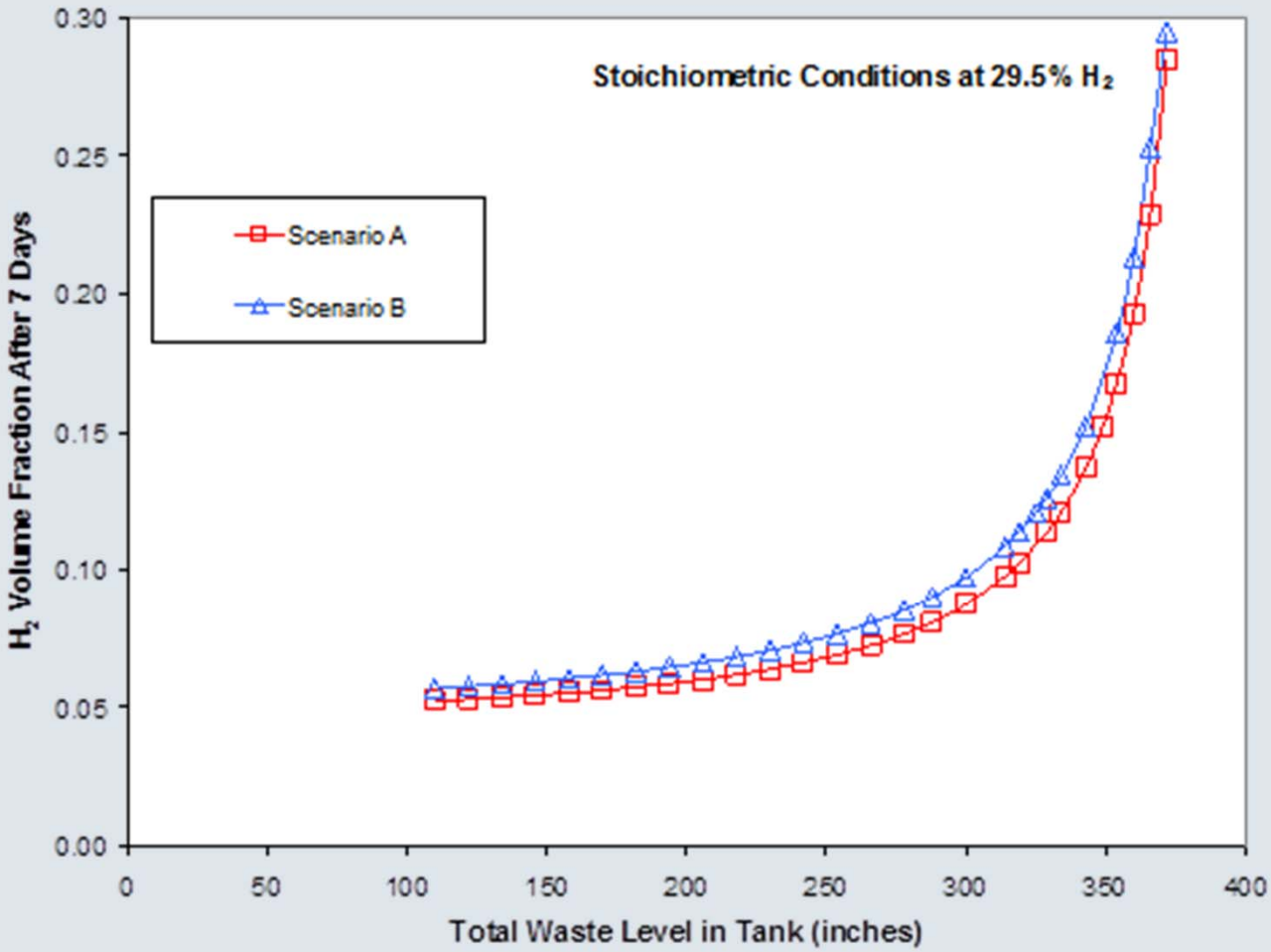
Determination of Bounding Scenarios (continued)

- **Considerations in Determining Bounding Scenario(s)**
  - Total waste levels up to fill limit of tank were considered (372" for Type III/IIIA)
  - Detonations produce larger source terms than deflagrations (~10x)
    - Explosions with H_2 concentrations ≥ 12% assumed to be detonations
    - Explosions with H_2 concentrations < 12% assumed to be deflagrations
  - Source term release is proportional to combustion energy
    - Combustion energy proportional to number of H_2 moles
    - Number of H_2 moles product of H_2 concentration and vapor space volume
  - Sludge and saltcake release trapped H_2 gas during seismic event
    - Saltcake has higher H_2 concentration and higher H_2 release fraction than sludge
    - Only H_2 in the top 40 inches of saltcake layer is released (Hanford study)
    - Specify reasonably bounding thickness for the sludge layer based on present conditions and future projections
    - Trapped H_2 gas expands ascending to surface (reduction of hydrostatic pressure)

Determination of Bounding Scenarios (continued)

- **Tank Type III/IIIA Design Analyzed**
  - Tank Type IV has larger vapor space volume
  - H_2 concentrations cannot reach ≥ 12% necessary for detonations based on preliminary calculations in Type IV tanks
  - Tank Type III/IIIA has next largest vapor space volume and H_2 concentrations can reach ≥ 12% necessary for detonations
- **Scenario A Waste Configurations**
  - 90 inches of sludge at bottom of tank (no saltcake layer)
  - Supernate level varied parametrically
- **Scenario B Waste Configurations**
  - 40 inches of saltcake at bottom of tank
  - 50 inches of sludge
  - Supernate level varied parametrically

H_2 Concentration as Function of Waste Level



- **Higher H2 concentrations with Scenario B (saltcake 40" & sludge 50")**
- **Adding supernate**
  - Increases total waste level and hydrostatic pressure (trapped gas expands as rises through waste layers to vapor space)
  - Does not add H_2
  - Reduces vapor space
    - H_2 moles from trapped gas confined to smaller volume

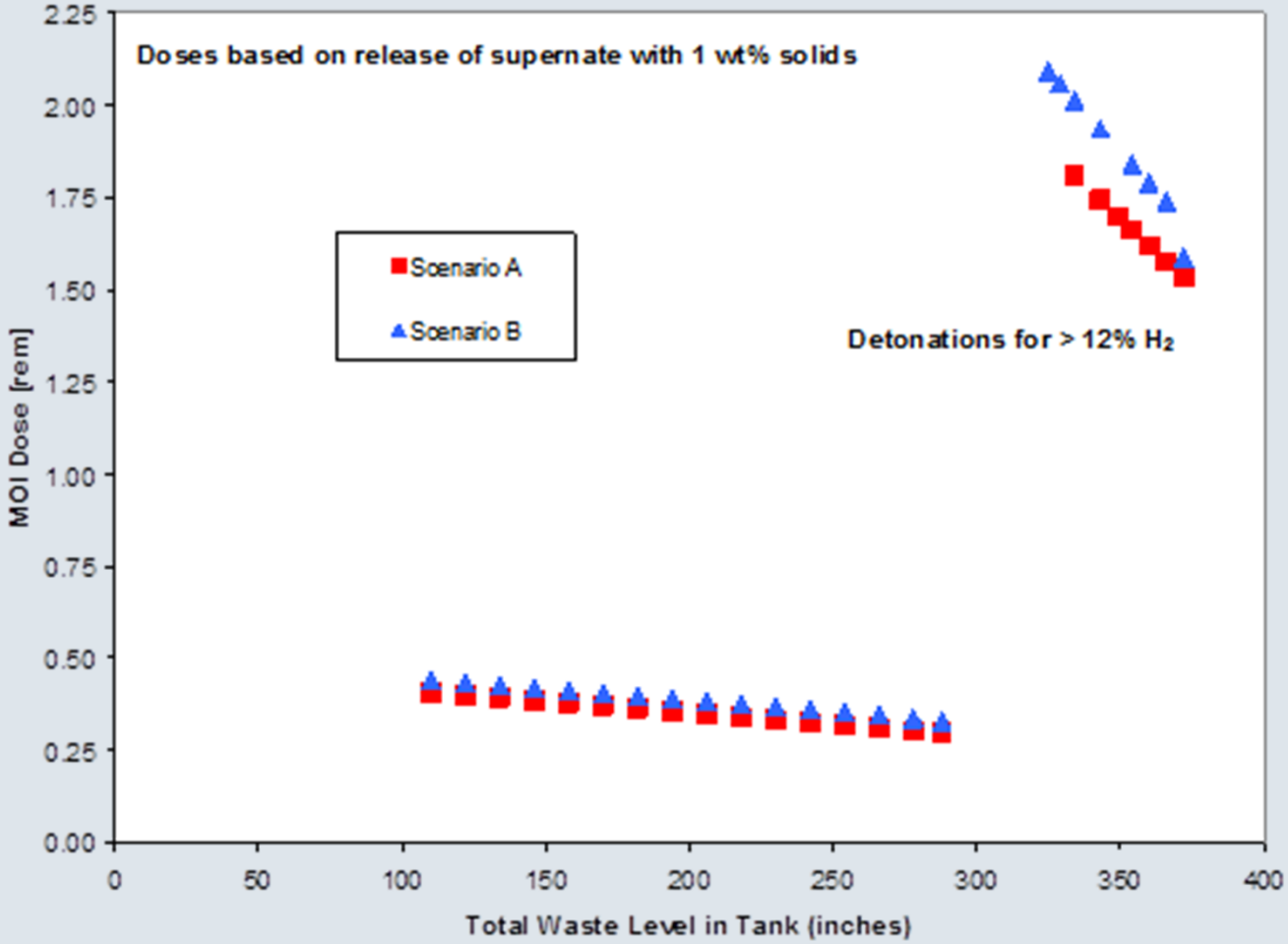
Technical Model for Deflagration

- **SRS-developed Deflagration Model**
- **Primary Aerosol Generation Mechanism**
  - Bubble entrainment caused by the radiative heat transfer at the liquid surface
  - Surface phenomena
    - Released aerosols primarily supernate (top layer)
    - 1 wt% sludge solids assumed
  - Source term release is proportional to combustion energy and combustion energy proportional to number of H_2 moles in the tank vapor space
- **Calculations use reasonably bounding physical properties (e.g., densities) and radiological compositions for supernate and sludge solids**

Technical Model for Detonation

- **TNT Equivalent Model from DOE-HDBK-3010**
- **Primary Aerosol Generation Mechanism**
  - Shock wave aerosolization
  - Milliseconds for passage of detonation pressure
    - Released aerosols primarily supernate (top layer)
    - 1 wt% sludge solids assumed
  - Source term release is proportional to combustion energy and combustion energy proportional to number of H_2 moles in the tank vapor space
- **Calculations use reasonably bounding physical properties (e.g., densities) and radiological compositions for supernate and sludge solids**

Dose Results



- **Higher doses with Scenario B (saltcake 40" & sludge 50")**
- **Adding supernate**
  - H_2 concentration reaches 12% > 320 inches total waste
    - Detonation limit
    - ~10x increase in consequences
  - Reduces vapor space
    - Fewer H_2 moles from imposed 4% H_2 concentration (radiolytic) control
    - No effect on trapped gas H_2 moles

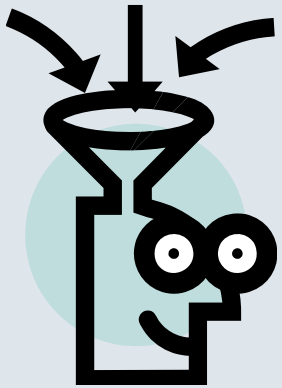
Summary of Results

- **Higher Consequences with Scenario B (saltcake 40” & sludge 50”) than with Scenario A (no saltcake & sludge 90”)**
  - Saltcake has higher trapped H_2 concentration
  - Saltcake has higher H_2 release fraction

Summary of Results (continued)

- **Highest Consequences Occur At Optimal Liquid Waste Level**
  - Level associated with H_2 concentration exactly 12% (detonation limit)
  - Detonations have ~10 times higher consequences than deflagrations
  - At higher liquid levels:
    - H_2 concentrations higher
    - Number of H_2 moles lower because less vapor space
      - In reality, number of H_2 moles increases with increasing waste levels
      - 4% H_2 concentration control for radiolytic generation decouples relationship between waste level and radiolytic H_2 generation
    - Consequences lower (proportional to number of H_2 moles)

Concluding Remarks

- **Successfully Navigated Challenges of Determining Bounding Scenario and Maximum Mitigated Consequences to MOI**
  - Type III/IIIA tanks determined to be largest tank type for which H_2 concentration could reach 12% (detonation limit)
  - Saltcake layer limited to 40 inches (only H_2 in the top 40 inches of saltcake layer is released)
  - Thickness for the sludge layer based on present storage conditions and future projections
  - The 7-day 4% H_2 concentration control for radiolytic generation incorporated (mitigated analysis)
  - Reasonably bounding physical properties (e.g., densities) and radiological compositions for supernate and sludge solids used in calculations
  - Supernate level varied parametrically to determine optimal level for maximum consequences

Questions?