Environmental Management
safety ❖ performance ❖ cleanup ❖ closure

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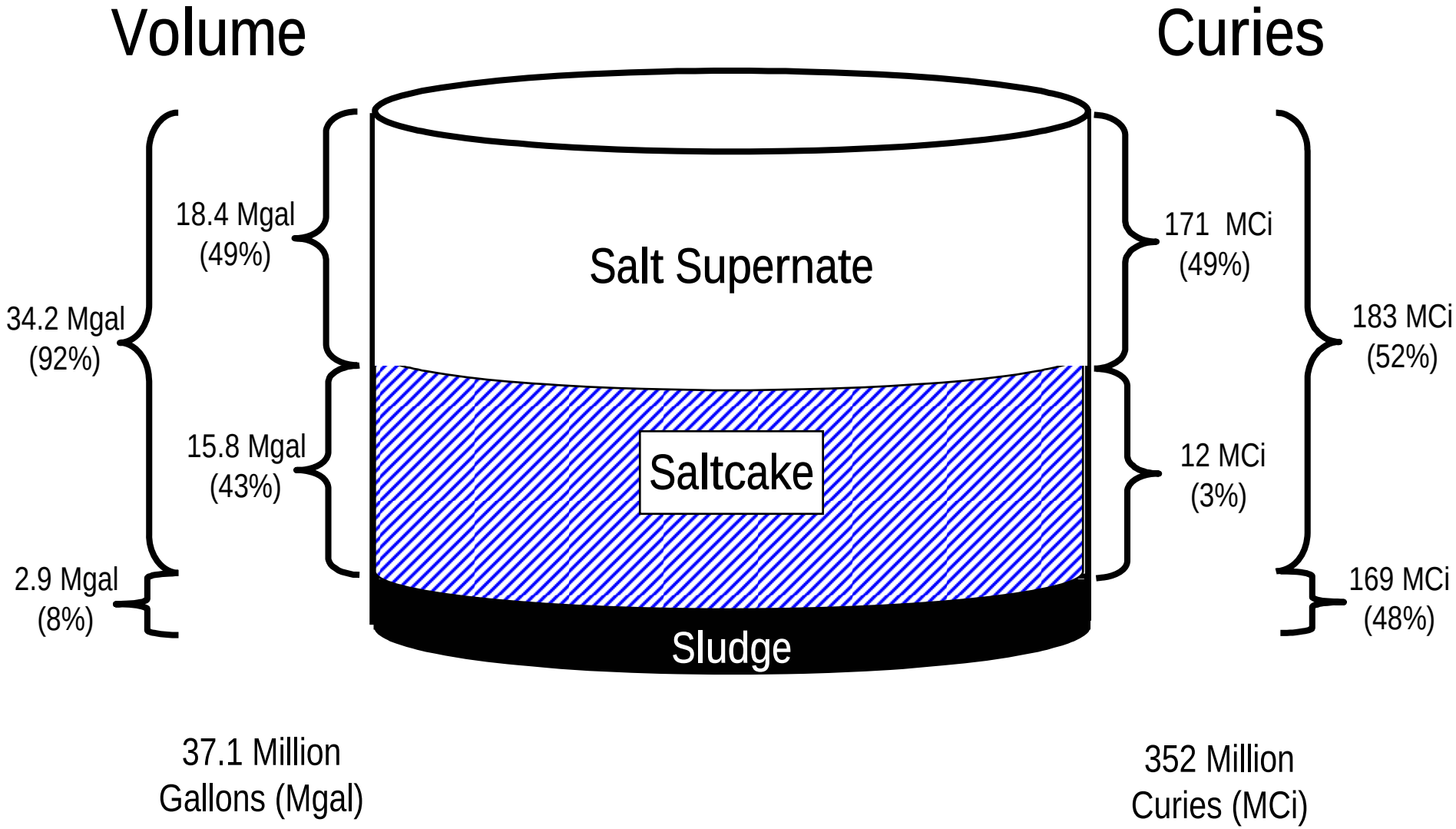
Blending in Nuclear Waste Tanks

Bob Leishear
Savannah River Remediation
Salt Disposition Engineering

November 17, 2010

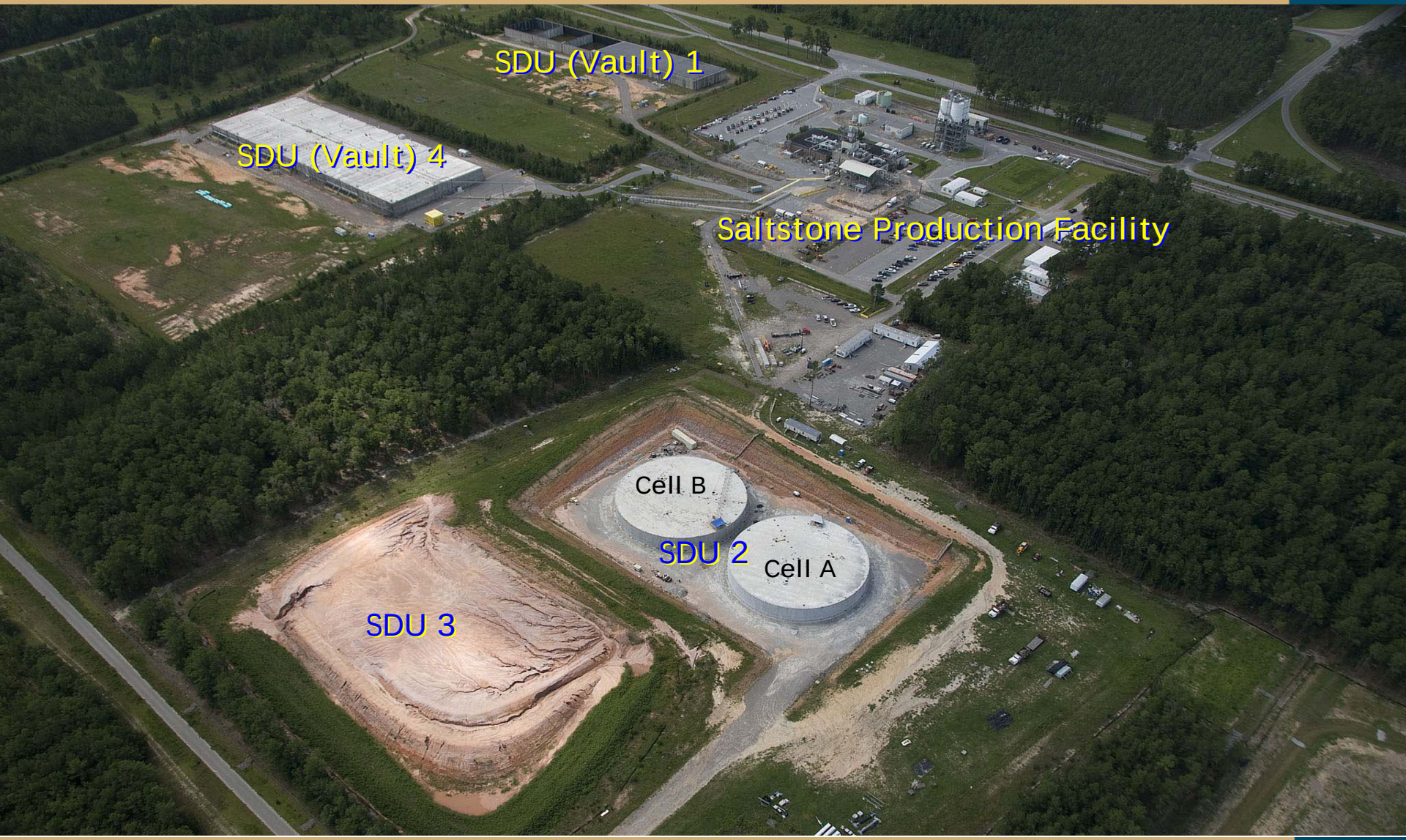
Blending in Nuclear Waste Tanks



Blending in Nuclear Waste Tanks

Sample of Vitrified Radioactive Glass

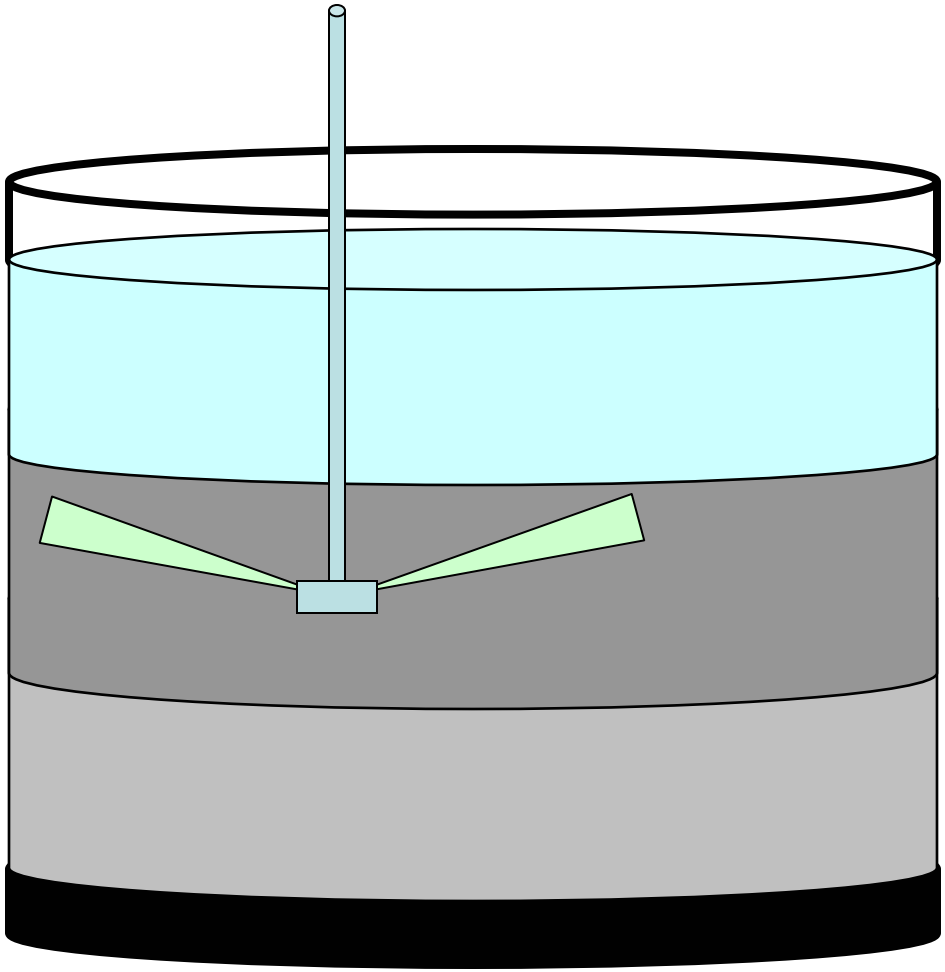
Blending in Nuclear Waste Tanks



Blending in Nuclear Waste Tanks

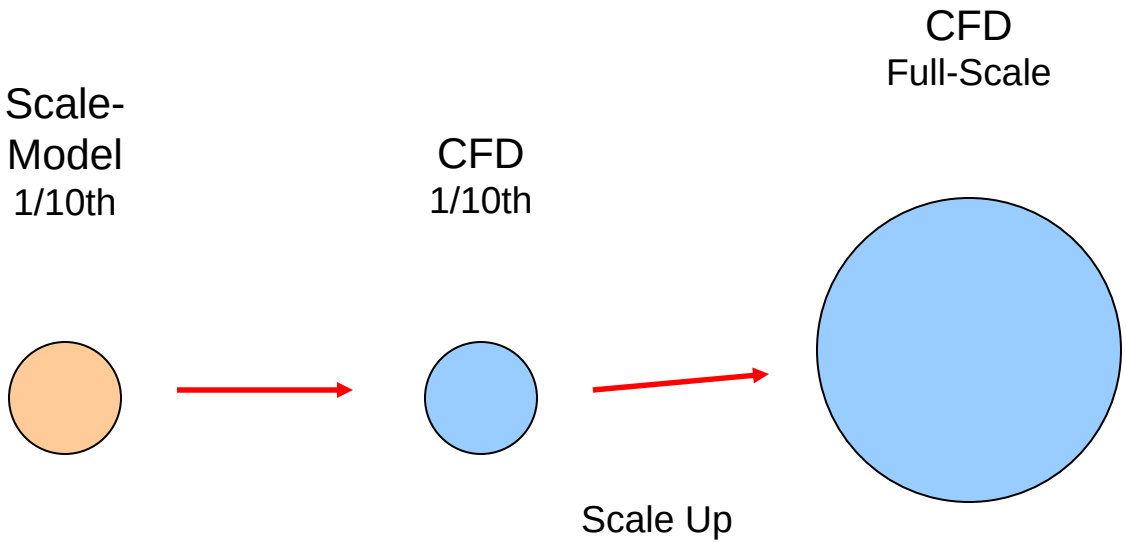
Blending in Nuclear Waste Tanks

Salt
Feed
Solutions

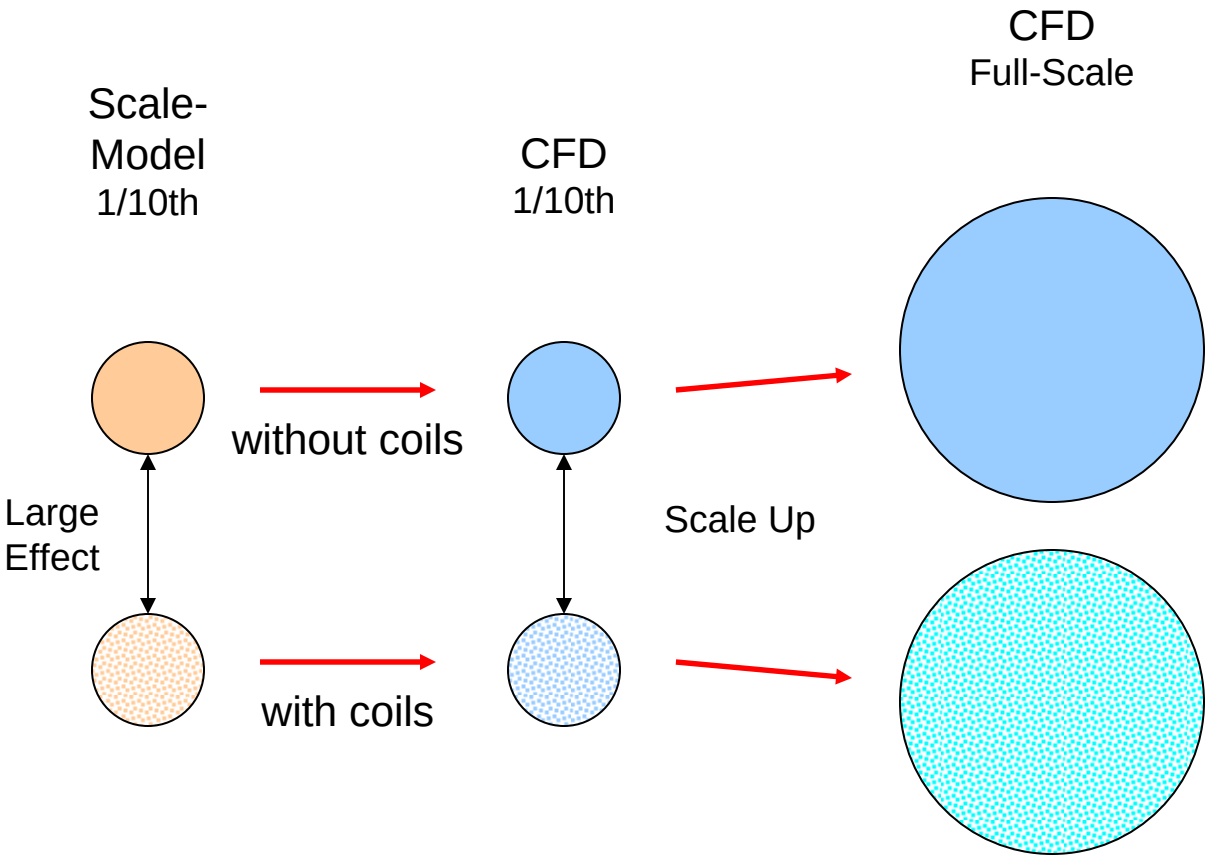


Sludge

Experimental Strategy



Experimental Strategy



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Blending in Nuclear Waste Tanks, Blending Pump Models

Engineering and Design:	**SRNL:**	**PI's:**	R. Leishear, M. Fowley, M. Poirier, Si Lee
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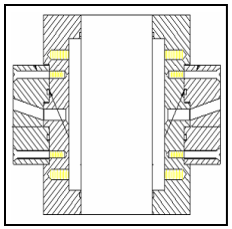
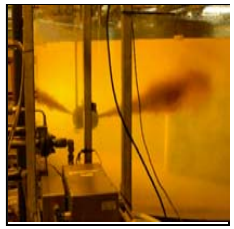
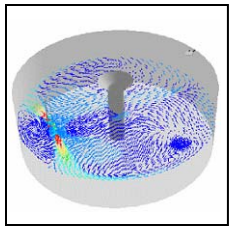
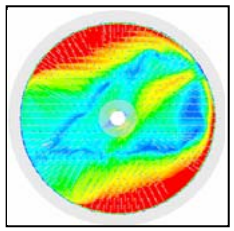
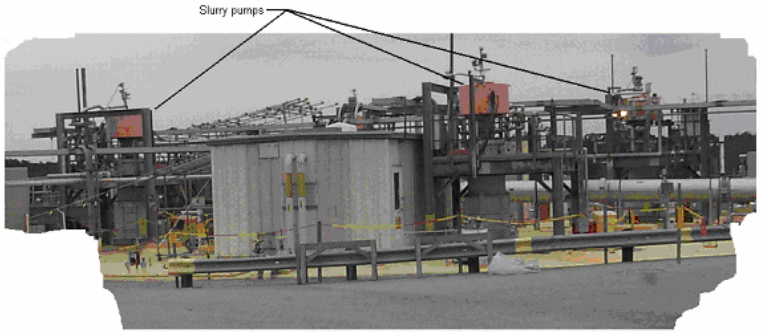
	SRR:		K. Parkinson, R. Ervin
Management:	**SRNL:**		S. Marra, B. Giddings, D. Sumpter
	SRR:		K. Harp, W. Van Pelt

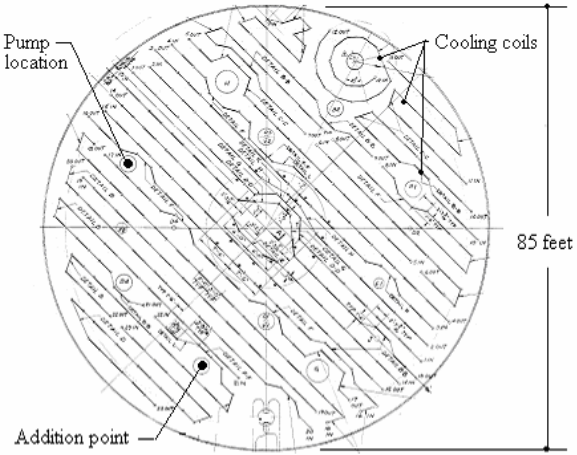



Waste Tank, Full Scale

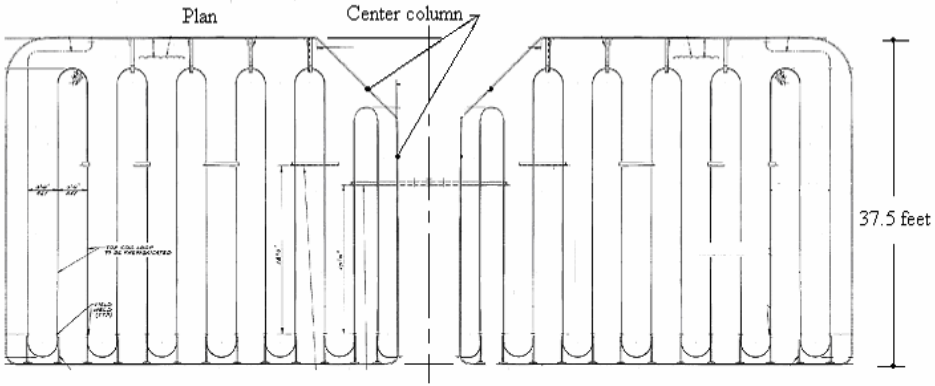
- **1.3 million gallon nuclear waste tanks**
- **Blend 300,000 - 800,000 gallon salt solutions in SRS nuclear waste tanks, with and without cooling coils.**



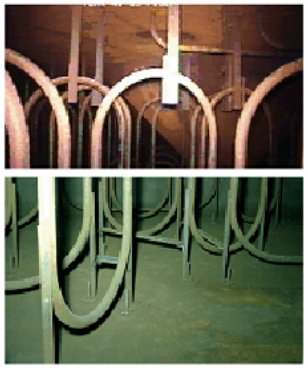
Tank Top



Plan View



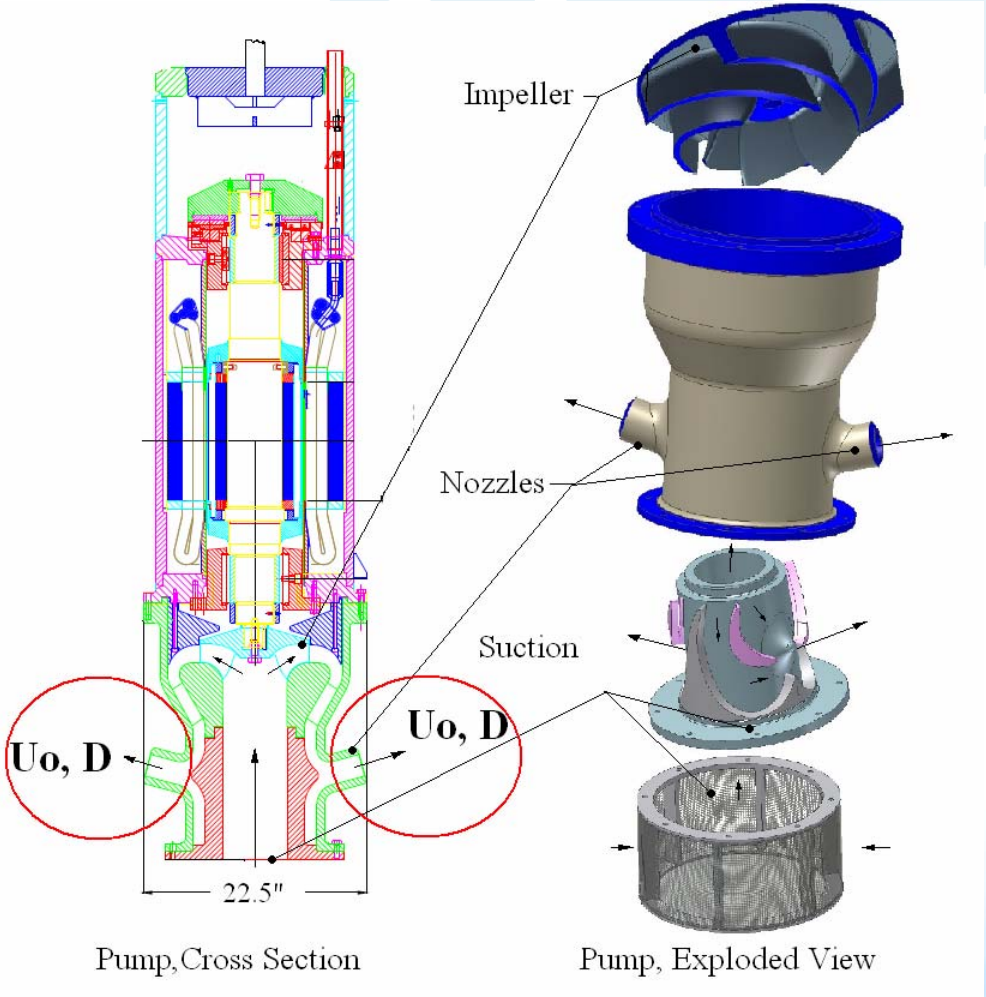
Elevation



Cooli ng Coils

Blender Pump Requirements

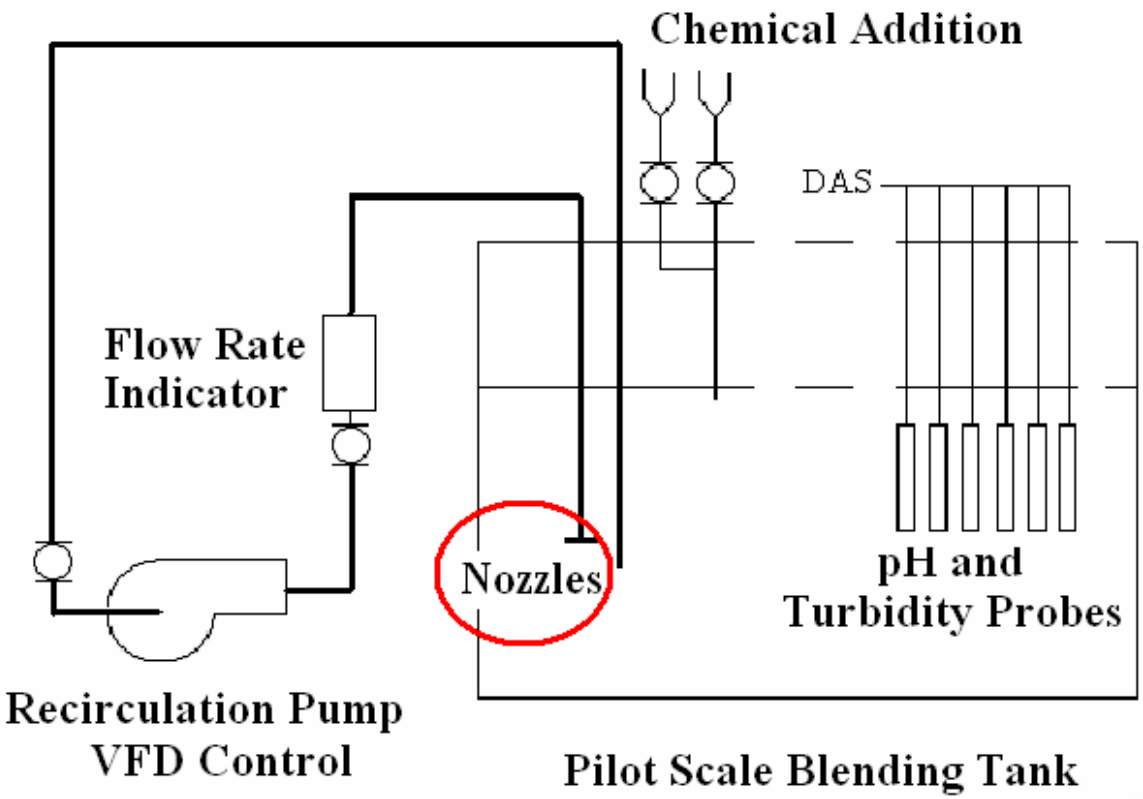
- **Specifications**
  - **24 hour maximum blending time.**
  - **To prevent release of radiolytically generated hydrogen, negligible sludge disturbance is required, where sludge consists of the settled solids in nuclear waste tanks.**
- **SRNL to recommend:**
  - **Number of pumps**
  - **Blending Time**
  - **UoD**
    - Uo is the nozzle velocity.
    - D is the nozzle diameter.



Full Scale Blender Pump

SRNL Test Setup

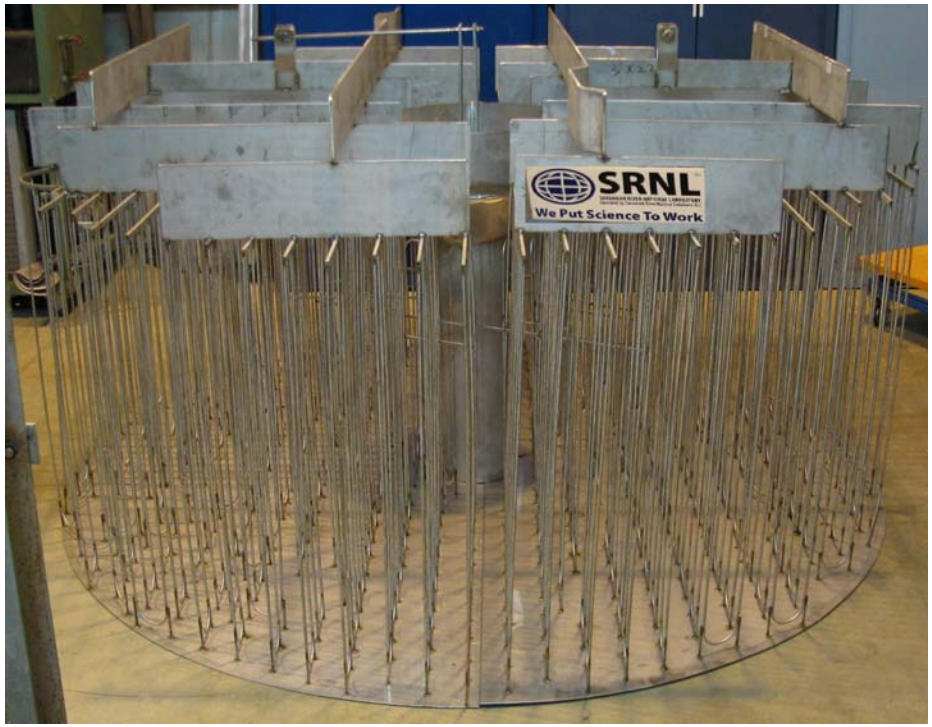
- Different scaled pump nozzle designs varied D
- Variable flow rates varied Uo.
- pH probes monitored blending times.
- Turbidity probes monitored sludge disturbance.



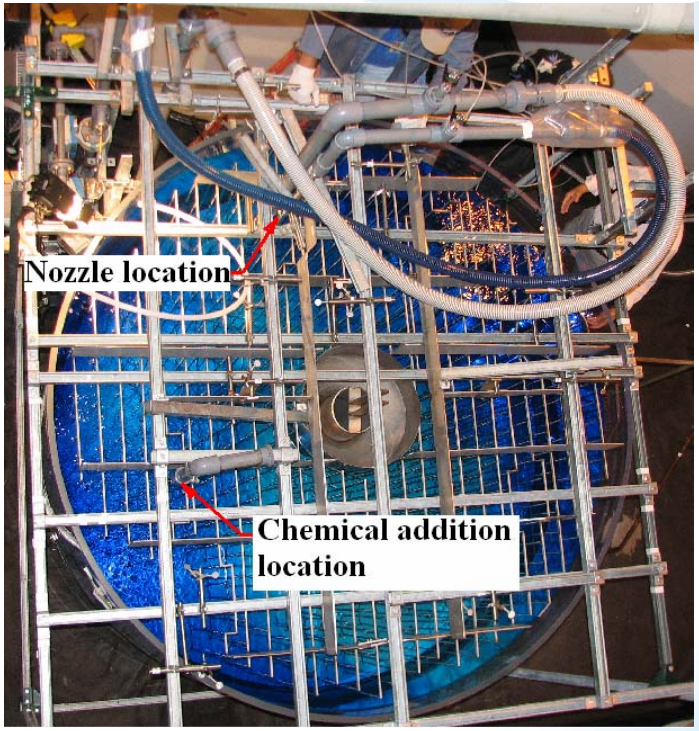
P&ID

Testing: Techniques and Acceptance Criteria

- **Eight foot diameter scale model was used to evaluate blending effectiveness and sludge disturbance.**
- **Removable coils for testing with or without coils.**
- **16 days from start to testing; 6 weeks to finish 38 tests.**



Cooling Coil and Center Column Models

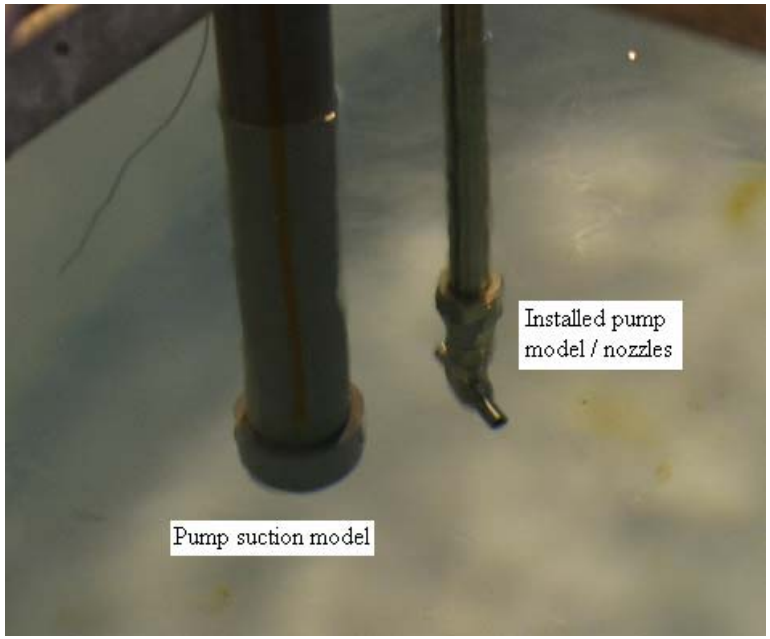


Pilot Scale Tank Model 1/10.85

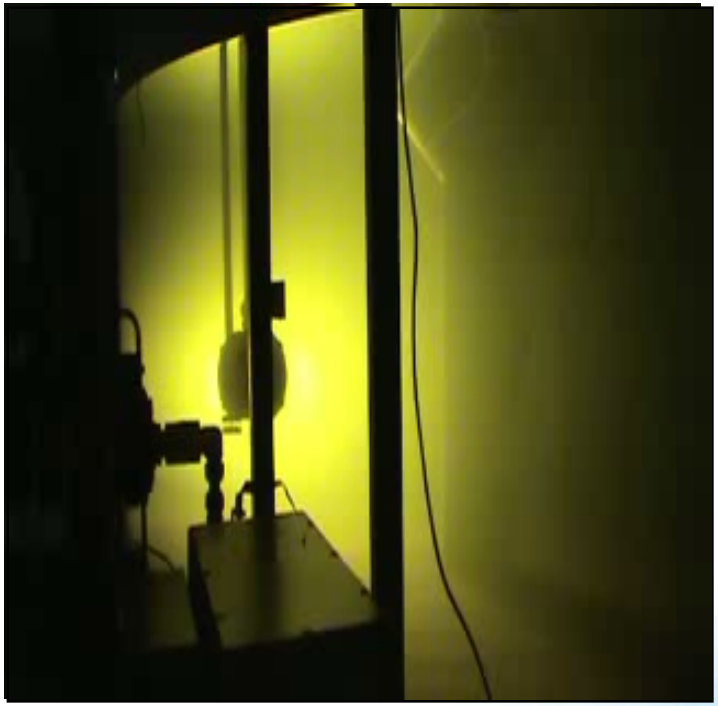
BLENDING: Pump Models

- **Existing waste tank mixing pumps were scaled down to evaluate mixing effects.**
- **Tests were performed using different nozzle designs, nozzle positions, and flow rates.**

Pump Nozzle Models



Suction and Pump Nozzles



Final Blending Pump Model

Click on Photo Above to Play Video

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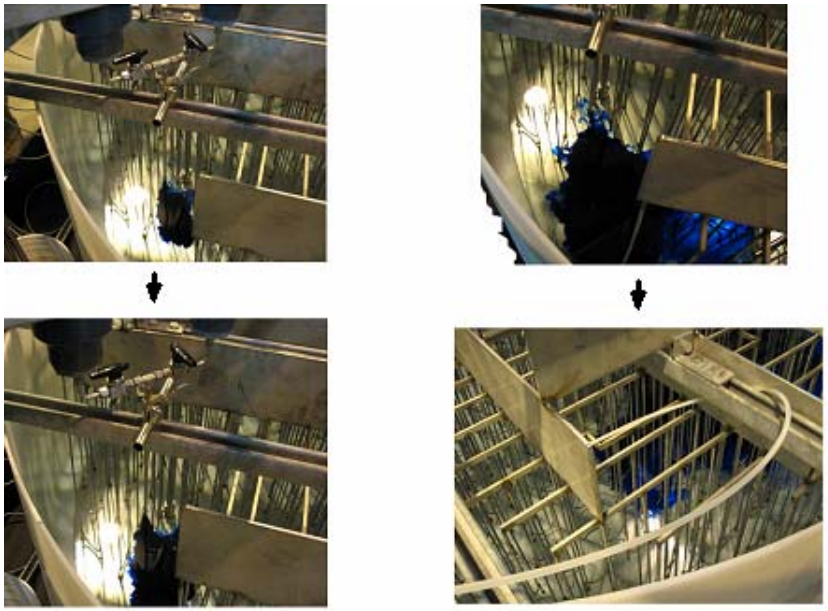
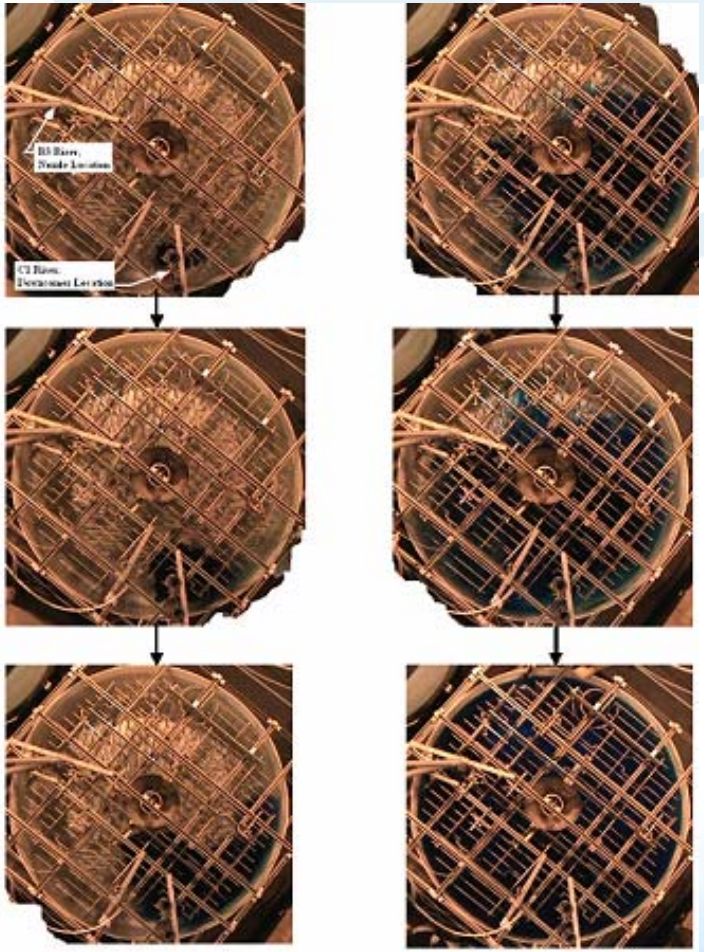
Blue Dye Blending Results

- **Blue dye tests used to observe blending and determine pH probe locations.**
- **Acid and base additions were used to conservatively model tank mixing.**



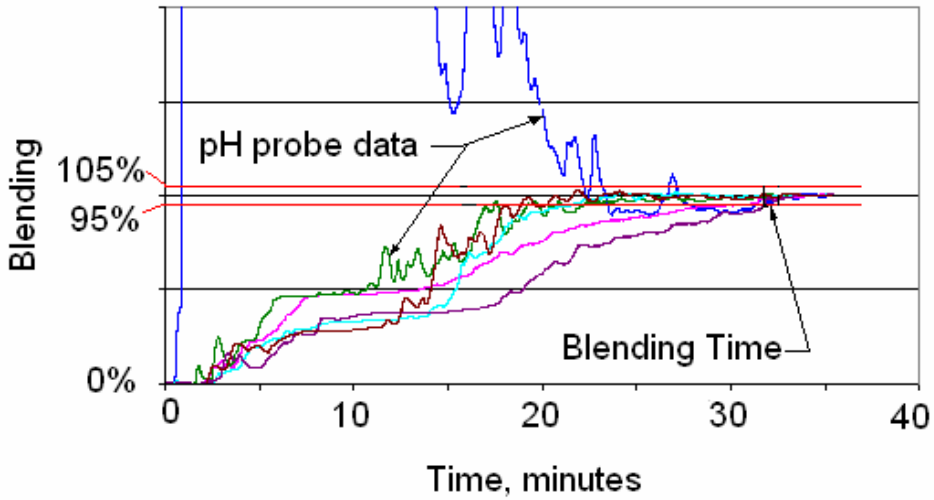
Initial Dye Addition



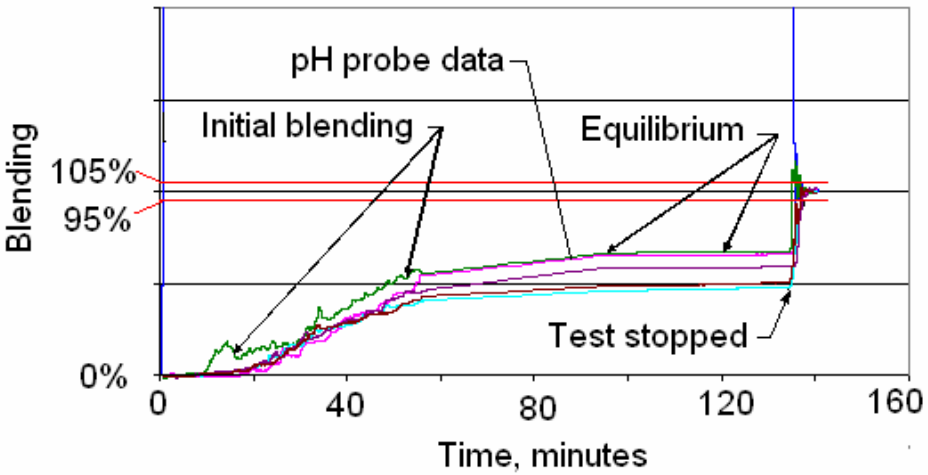
Blending

Typical Test Results: 95% Blending

- **All of the tank contents within 5% of the concentration range.**
- **pH probes monitored blending of small additions of acid and base solutions to a pilot scale tank.**
- **Data was normalized and pH was converted to concentration.**



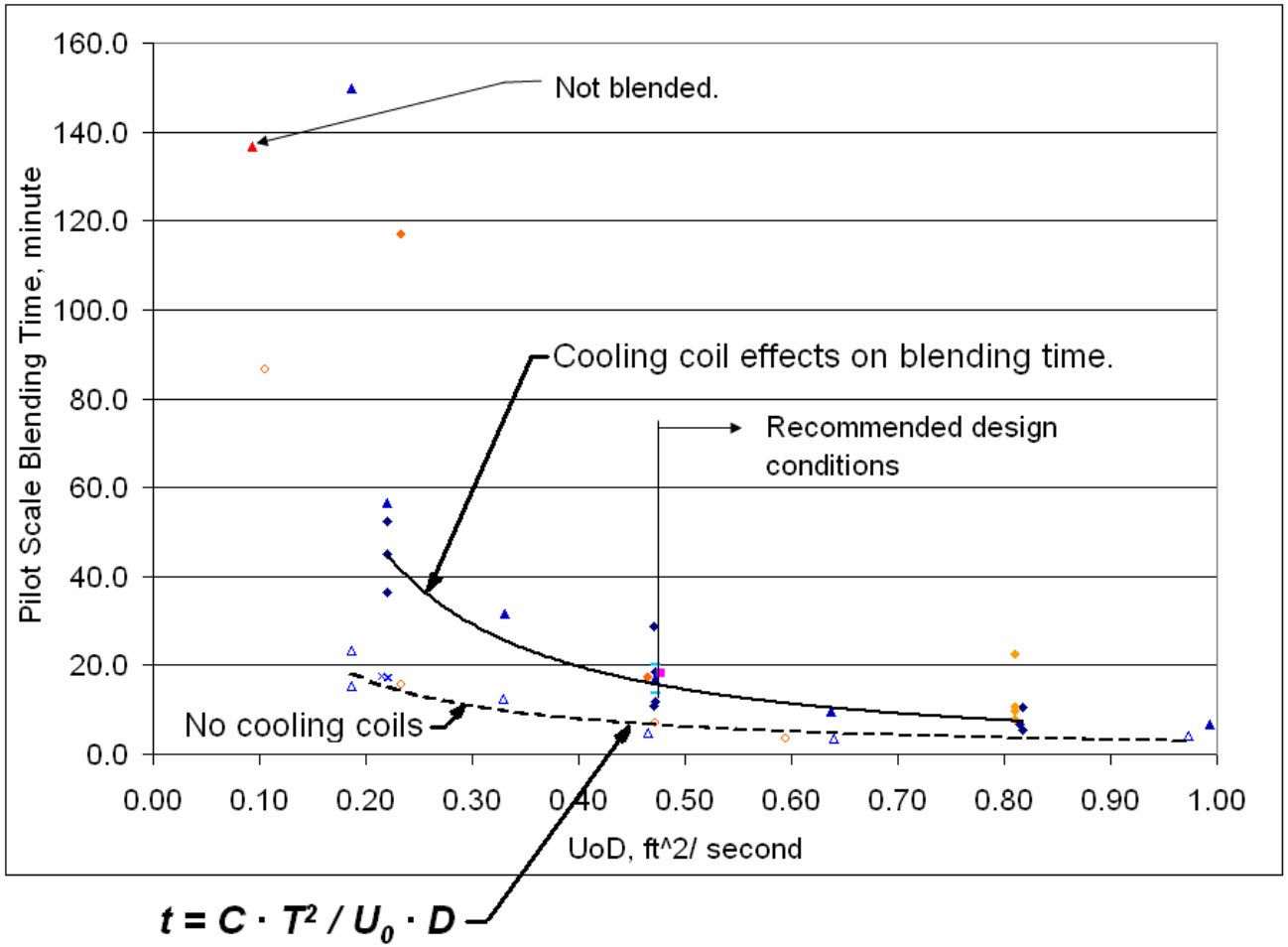
Typical Blending Test Result



Inadequate Blending

Blending Summary

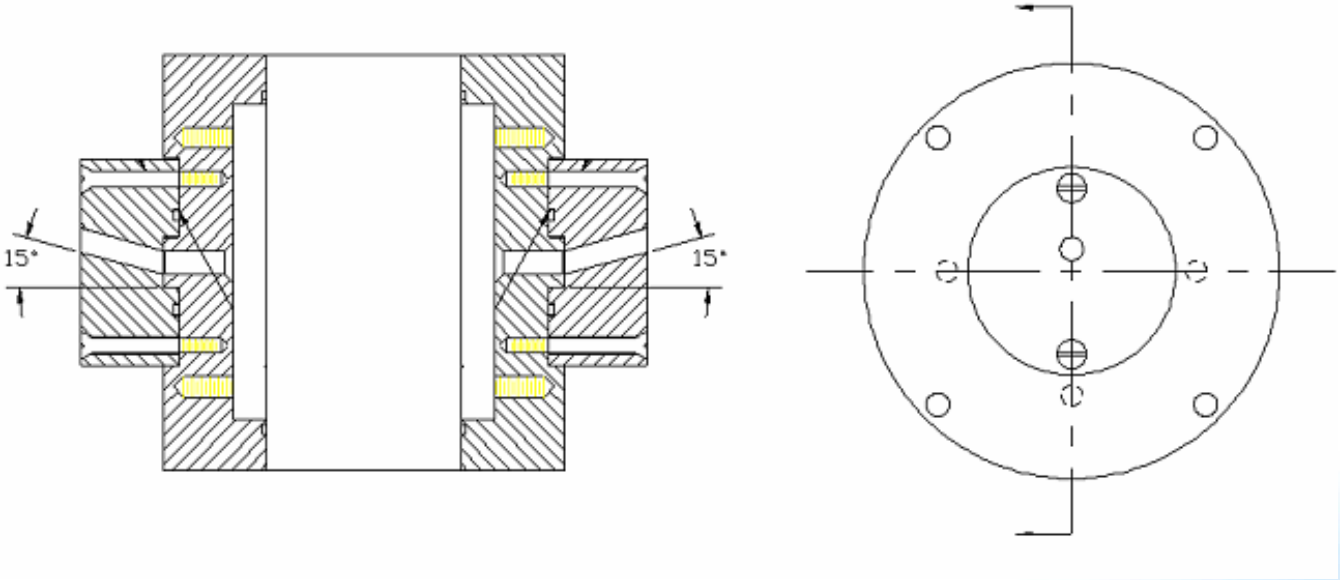
- **Low velocities and UoD affected blending.**
- **Coils affected blending times.**
- **Tank without coils was consistent with theory.**
- **Larger UoD improves blending; smaller UoD disturbs less sludge.**



UoD vs. Blending Time

Sludge Disturbance

- **Some pump designs scoured sludge in the pilot scale tank, where sludge disturbance scaled up to 3000 to 4000 gallons.**
- **Several pump nozzle designs were investigated at different orientations: 15º up; 15º inward; 30º inward; 45º inward; 15º up and inward.**
- **A single pump with dual opposing nozzles pointing upward at 15º from horizontal was selected from test results.**



Pump Model

U

Sludge Settling Affects Sludge Disturbance

- **Settling time affects sludge disturbance.**

140 Hour Settling Time

Sludge Only

Initial mixing

16 Hour Settling Time

0.5% Sludge

Sludge Plus Supernate

Settling Tests

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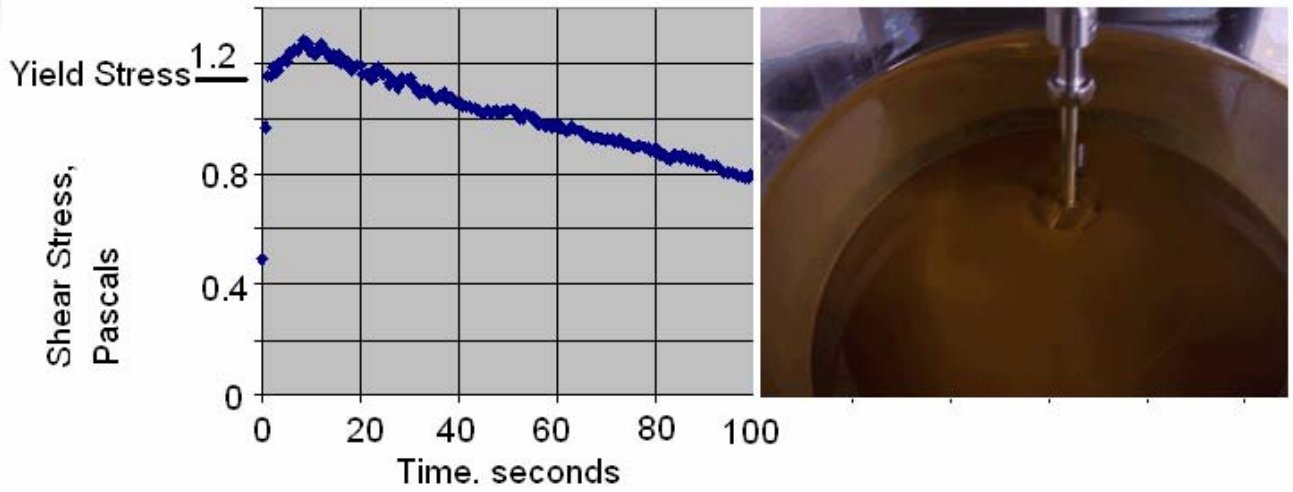
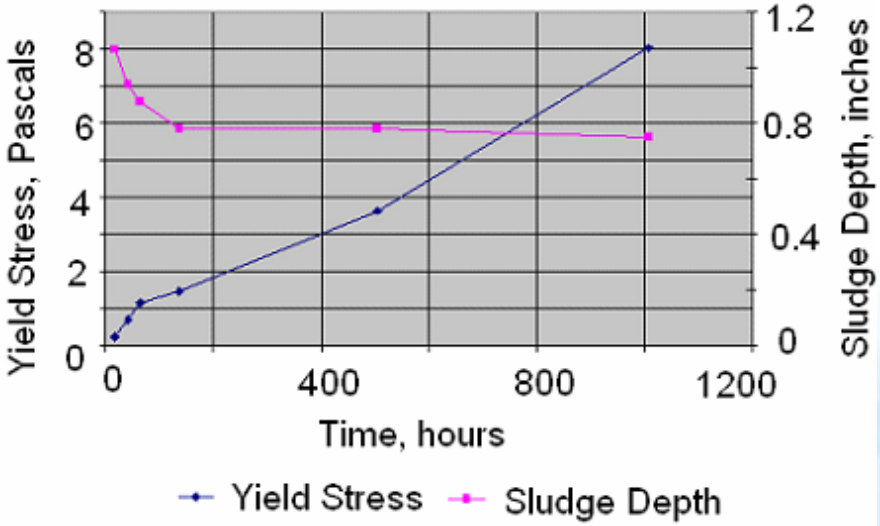
Sludge Properties Affect Sludge Disturbance



Rheology Testing

- **Low yield stress sludge, and no yield stress supernate, i.e., like mixing water over milk**
- **Time dependent material properties.**
- **Settling time required before blending.**



Rheology Test Results

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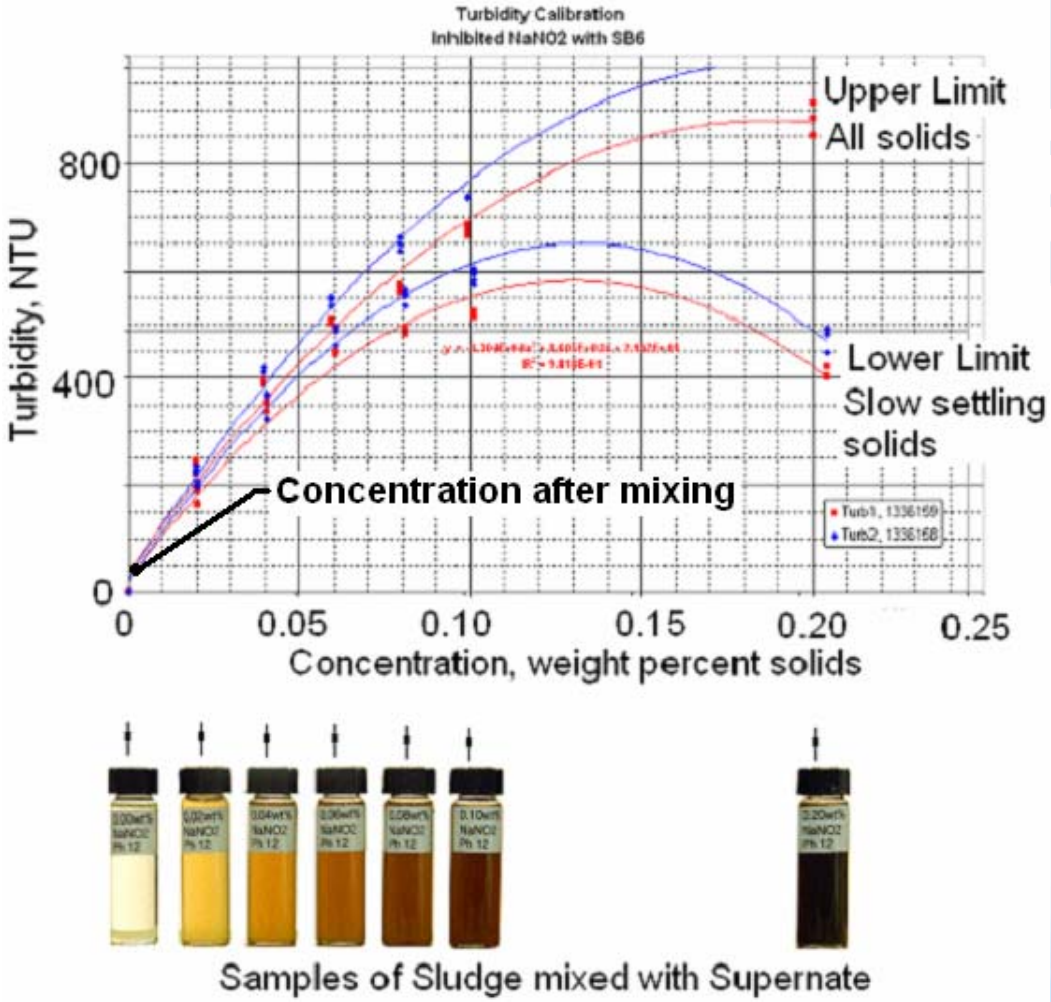
Measurement of Sludge Disturbance

- **Acceptance criteria for sludge disturbance was that the sludge level did not decrease in 24 hours.**
- **Turbidity was used to quantify the amount of material in solution.**
- **Less than 0.002 weight percent solids in solution at pilot scale.**



Turbidity vs. Weight Percent Solids

Sludge Disturbance Testing and Summary

- **UoD and pump designs were varied to find minimal sludge disturbance.**
- **UoD for sludge disturbance compared to blending test results.**
- **Sludge level did not decrease during testing with 15º upward nozzles.**

Click on Photo Above to Play Video

Minimal Sludge Disturbance in Pilot Scale Tank

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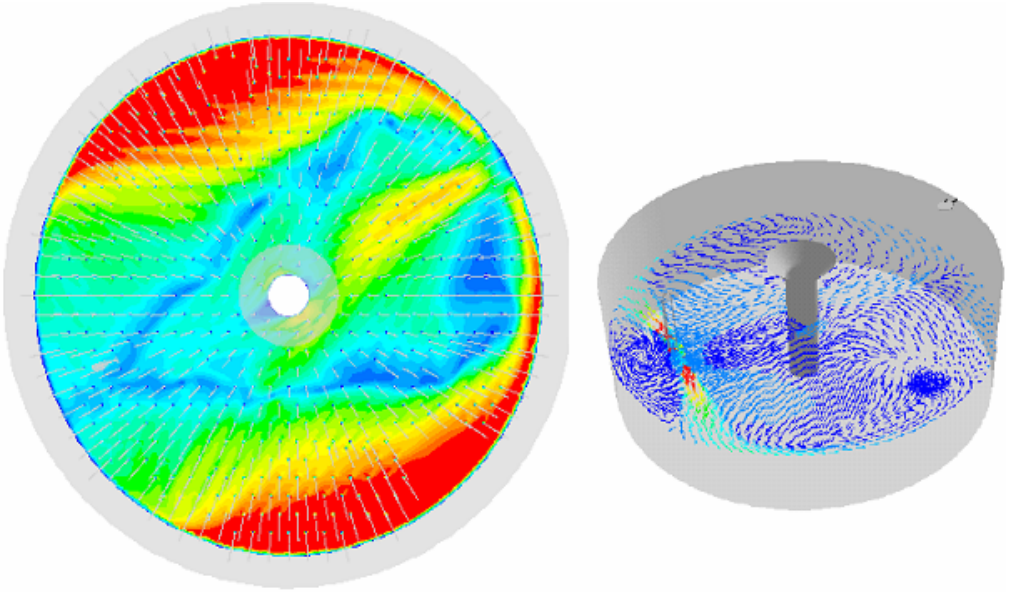
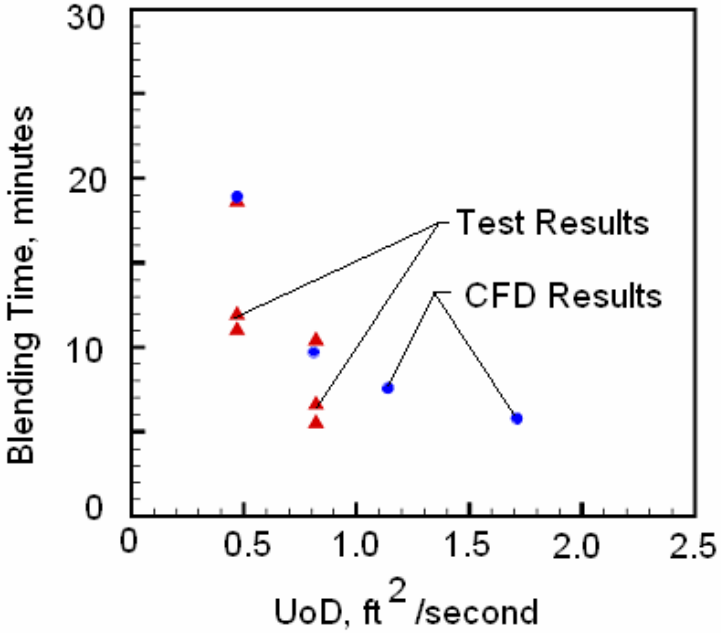
CFD, Single Phase Fluid Modeling

- **CFD modeling compared to experimental results.**
- **CFD and pilot scale blending times are comparable for tanks with and without coils.**
- **Sludge disturbance will be scaled up with CFD models, and benchmarked against experimental results at pilot scale.**



CFD: Pilot Scale, Tee Nozzle, Water



Experimental vs. CFD Results

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Conclusions

Designed, built, and fabricated the test equipment in 16 work days.

- Six weeks to completion of initial 38 tests.
- Total of 120 pilot scale tests, 30 CFD models, and 240 material property tests are complete, or in process.

- **95% blending can be achieved in less than 12 hours.**
  - Estimate from in-process test results.
  - Blending time at full scale will be checked from calculations in process.
  - Three to four days typically required to blend tank contents.
- **Recommendation to use one, non-rotating, pump instead of two for each of three tanks.** (Pump cost per tank > 1 million dollars)
  - Pump design parameters provided to SRR: nozzle velocity, nozzle diameter, nozzle angle from horizontal, and pump orientation with respect to the tank wall.
- **Sludge disturbance was controlled at pilot scale.**
  - Numerous models investigated.
  - Sludge disturbance at full scale will be established using CFD modeling and pilot scale test results.