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Improved Antifoam Agents for SRS

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ILLINOIS INSTITUTE OF TECHNOLOGY

EM Waste Processing Technical Exchange

Session 10: Advanced Unit Operations and Scaling

EM Office of Environmental Management
safety ❖ performance ❖ cleanup ❖ closure

Print Close

Outline

- Needs/Benefits
- Background
- Scope
- Experimental/Method
- Results
- Future work

Needs/Benefits

Needs:

- **Increase waste processing (melter) throughput**

Benefits:

- **Maximize Boilup Rate during waste processing at boiling, resulting in an increase in a reduction in overall processing time.**
- **Minimize carryover of insoluble solids, resulting in less facility downtime due to foamover into condensate.**

Scope

Develop or Identify Improved antifoam agents for radioactive waste processing

- **Complete basic science needed to understand cause of foam formation and stability**
- **Develop list of commercial antifoam agents and test to determine effectiveness as antifoam agent and defoamer**
- **Develop new antifoam agent if commercial agents are inadequate for unique process conditions of radioactive waste.**
- **Demonstrate antifoam effectiveness in actual waste testing**

Background

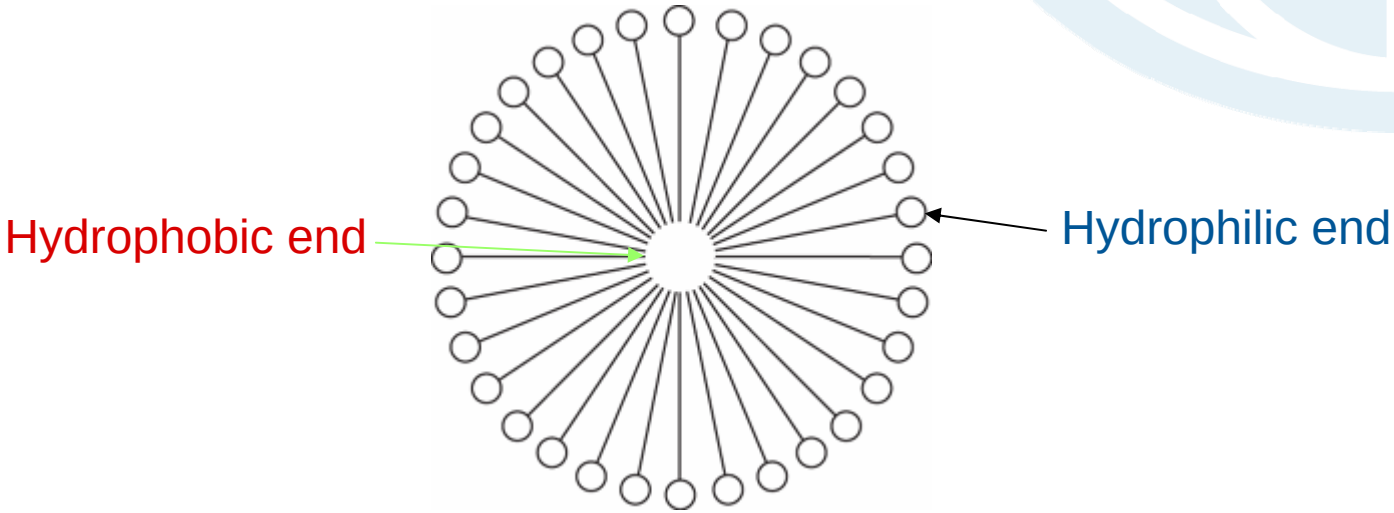
Previous work: Experimental Study of SRAT/SME Foaming by Illinois Institute of Technology, Lambert, D.P, Wasan, D.T., WSRC-TR-97-00378, October 1997

Objective: Development of Improved Antifoam for SRS's Defense Waste Processing Facility (DWPF) to minimize foam stability and minimize amount of antifoam used

Results: Antifoam Agent 747 implemented in DWPF Chemical Processing Cell from 2001 to present. Antifoam agent prepared for DWPF by Siovation, LLC, Lawrenceville, GA

Background: What causes foam?

Classical Foam is caused by surfactants in supernate

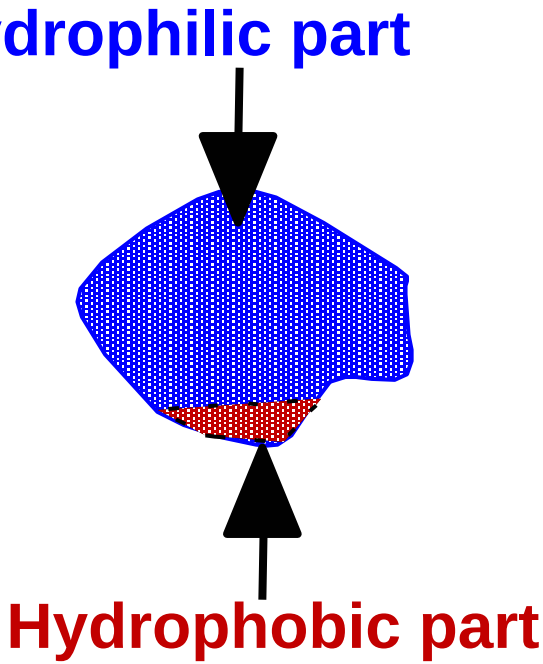


Surfactants have hydrophobic (hate water) and hydrophyllic (love water) end

Surfactant molecules line up to form stable film (bubble)

Our Wastes often don't have surfactants

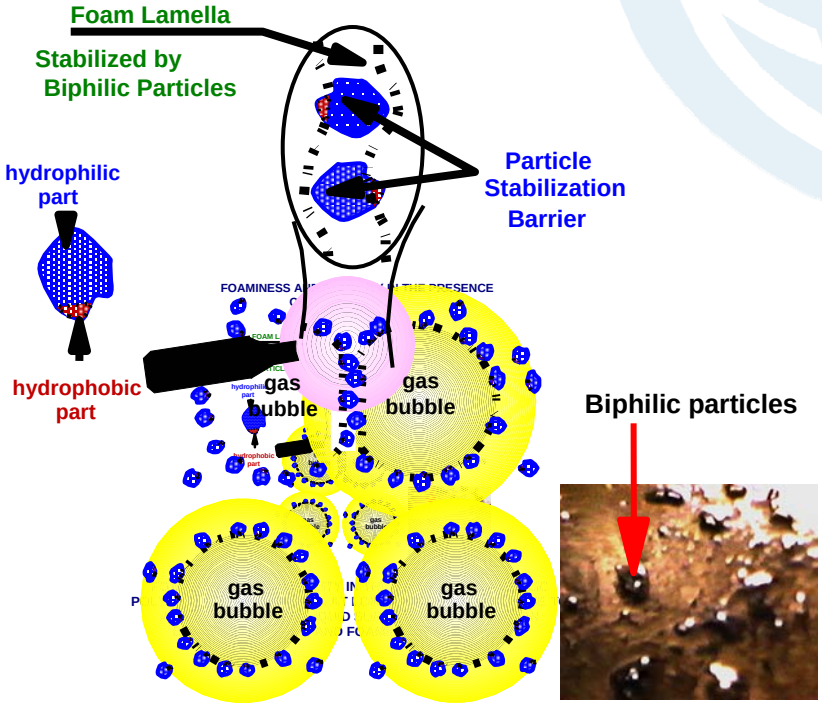
But they still foam



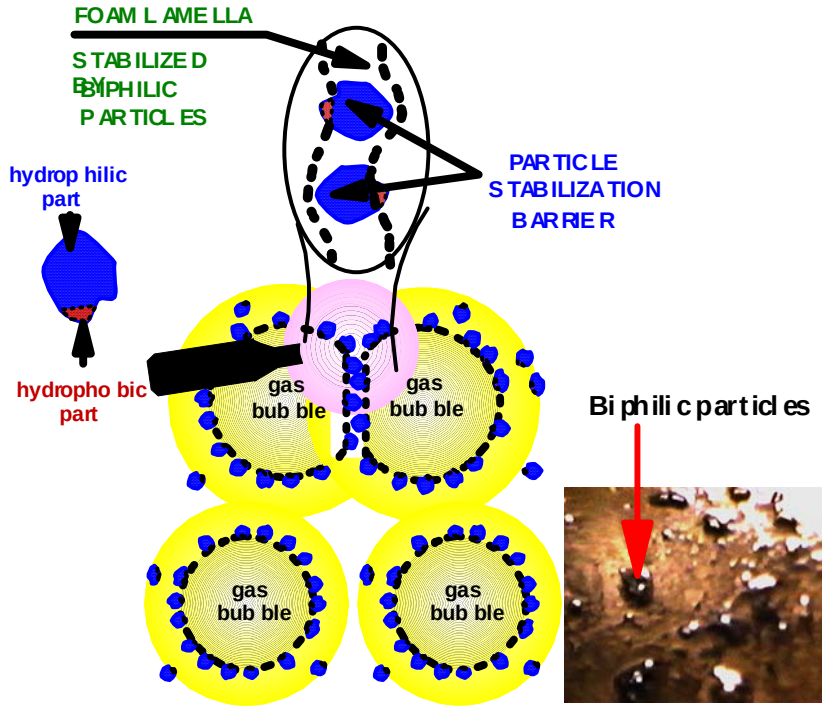
Insoluble solids

Metal Hydroxides

Foaminess and Stability in the Presence of Biphilic particles

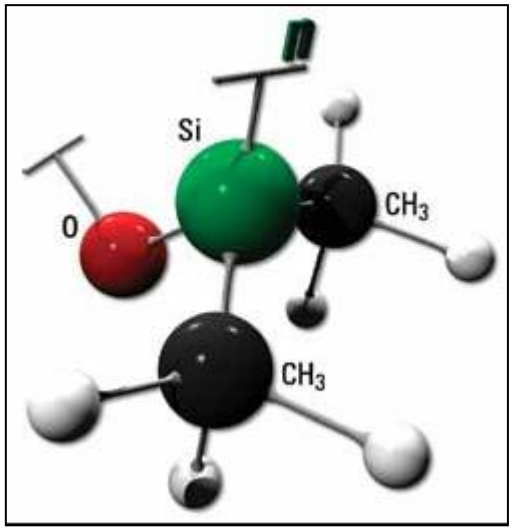


Foaminess and stability in the presence of biphilic polydispersed particles. At low concentrations, due to adsorption at gas/liquid surface, A stabilization barrier is formed and foaminess is increased

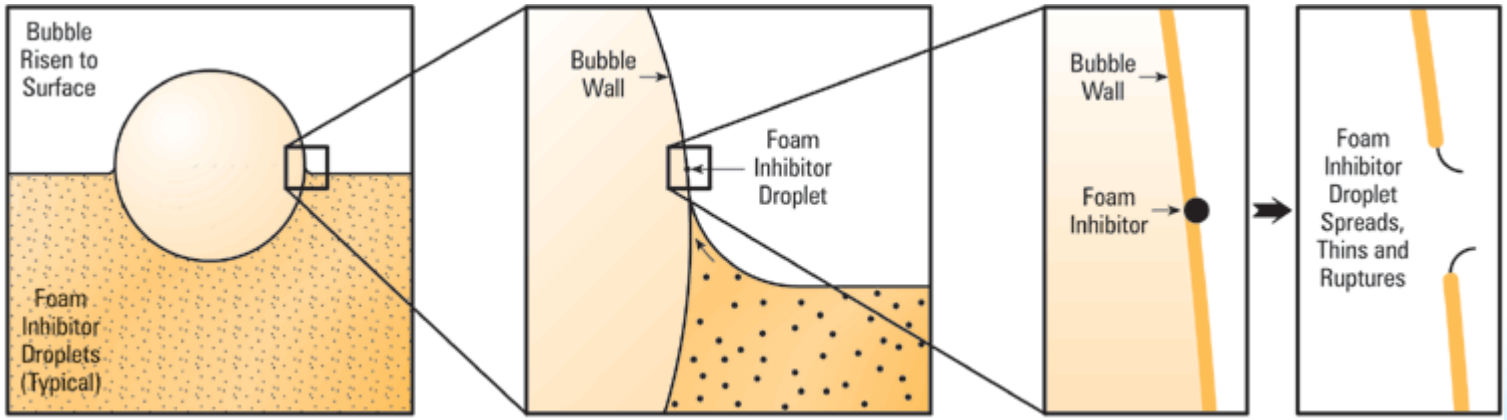


FOAMINESS AND STABILITY IN THE PRESENCE OF BIPHILIC POLYDISPERSED PARTICLES. AT LOW CONCENTRATIONS, DUE TO ADSORPTION AT GAS/LIQUID SURFACE, A STABILIZATION BARRIER IS FORMED AND FOAMINESS IS INCREASED

Typical antifoam agent and mechanism



Basic Chemical Structure of Polydimethylpolysiloxane

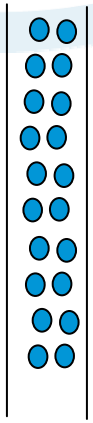


Mechanism of Antifoam Agent

Solid particles can stabilize thin film (foam)

Have to be the "right size"

- **Small enough to be inside film**
- **Uniform size works best (monodispersed)**



Particles can hinder draining of foam film

Particles layer (line up) to stabilize film

Result: Longer lived films and bubbles

Foams no stable: only a problem during processing

Our waste has lots of small particles

We create even more when the waste is evaporated

Challenges of Antifoam Agent Effectiveness

Effective at low concentrations

Long lifetime

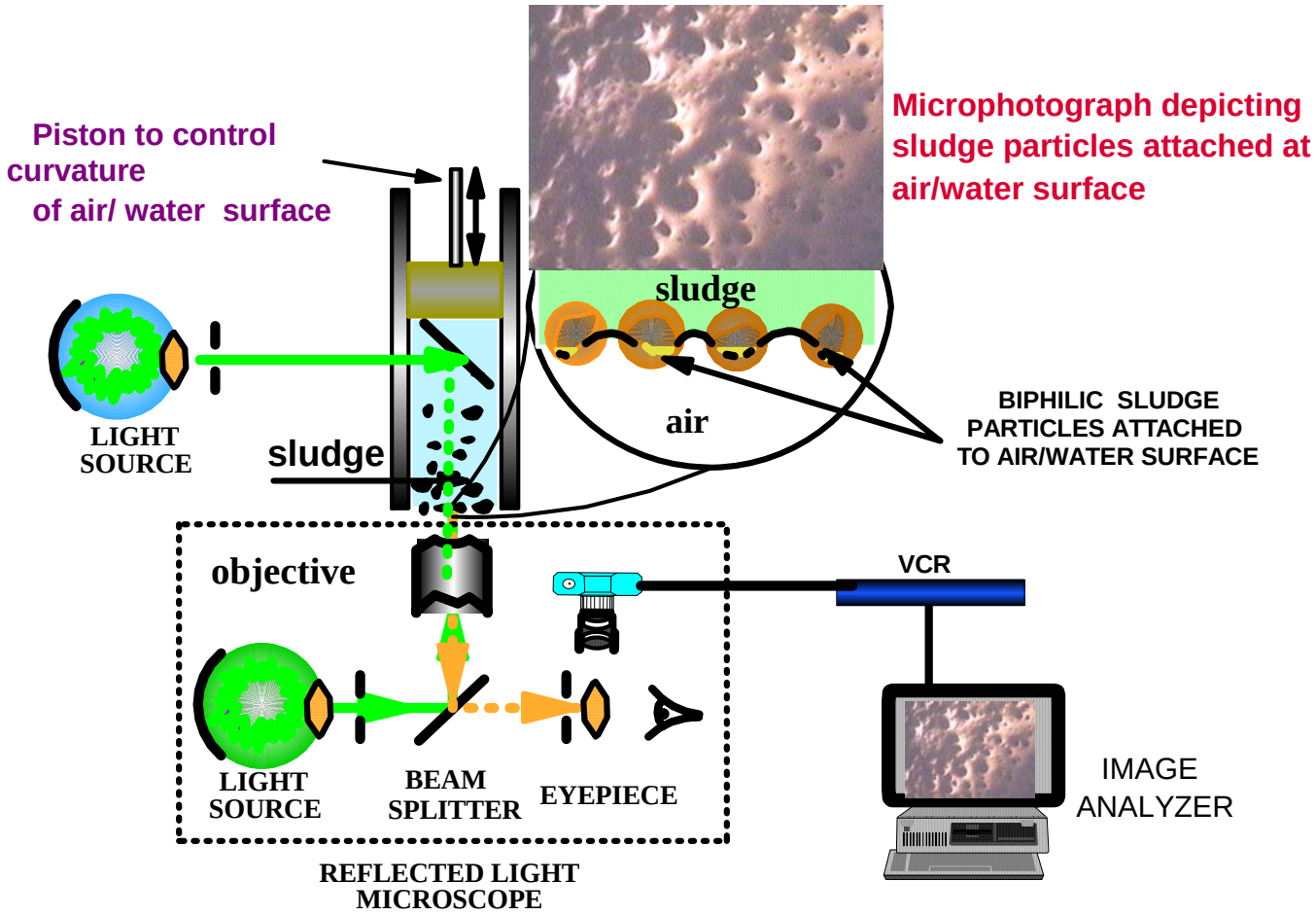
Chemical Stability

- **Stable throughout pH range of processing**
- **Stable at all processing temperatures**
- **No chemical attack by waste stream**

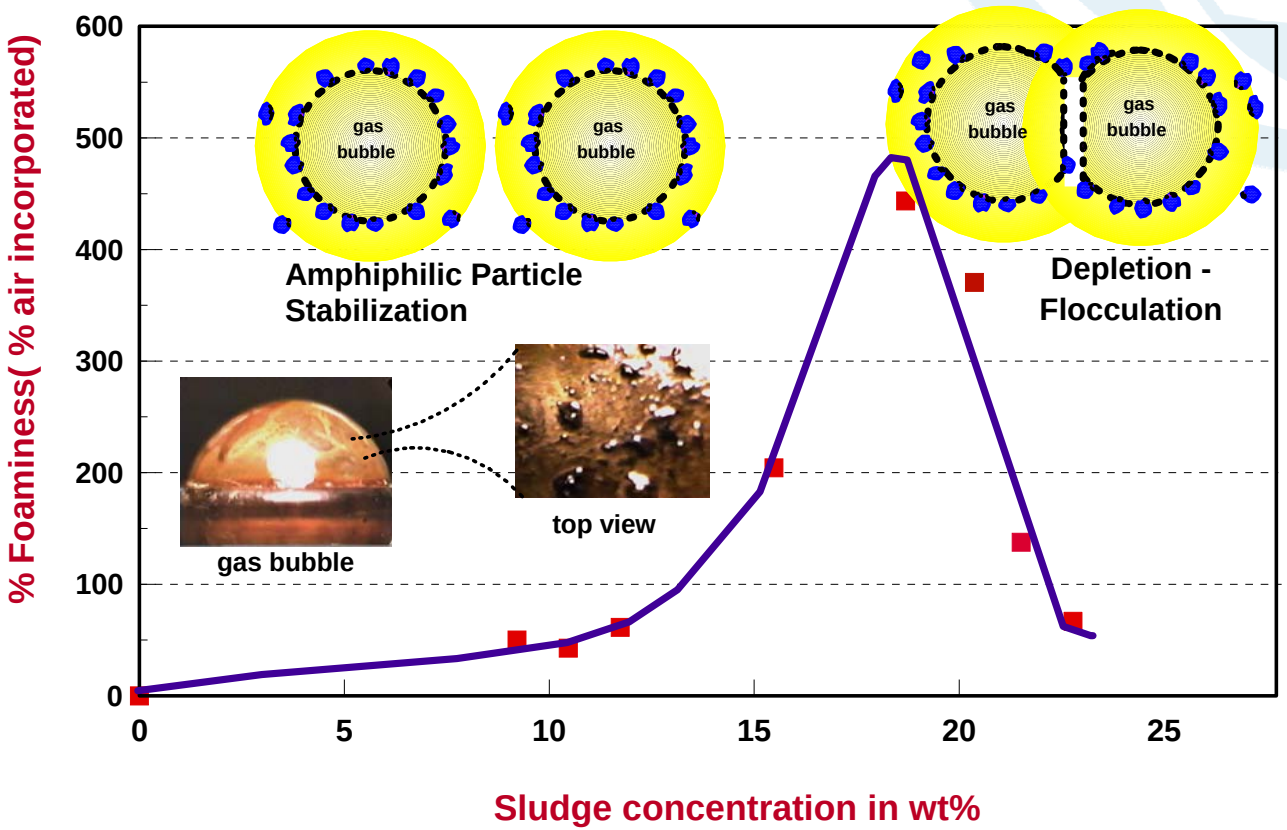
Radiation Stability

No downstream impacts

Characterize the number of biphilic and hydrophilic particles



Foam Lamella Stabilized by Amphiphilic Particles



Foam Stability Testing (supernate and slurries)

Perform foam testing experiments using Teclis Foam Analyzer.

Measure the flowing properties:

- **Solids content {total, undissolved, and soluble solids in supernate}**
- **Foam Stability**
- **% Foam**

Compare:

- **Foaminess and Foam Stability.**
- **Various antifoam concentration and addition frequencies**

Experimental/Method

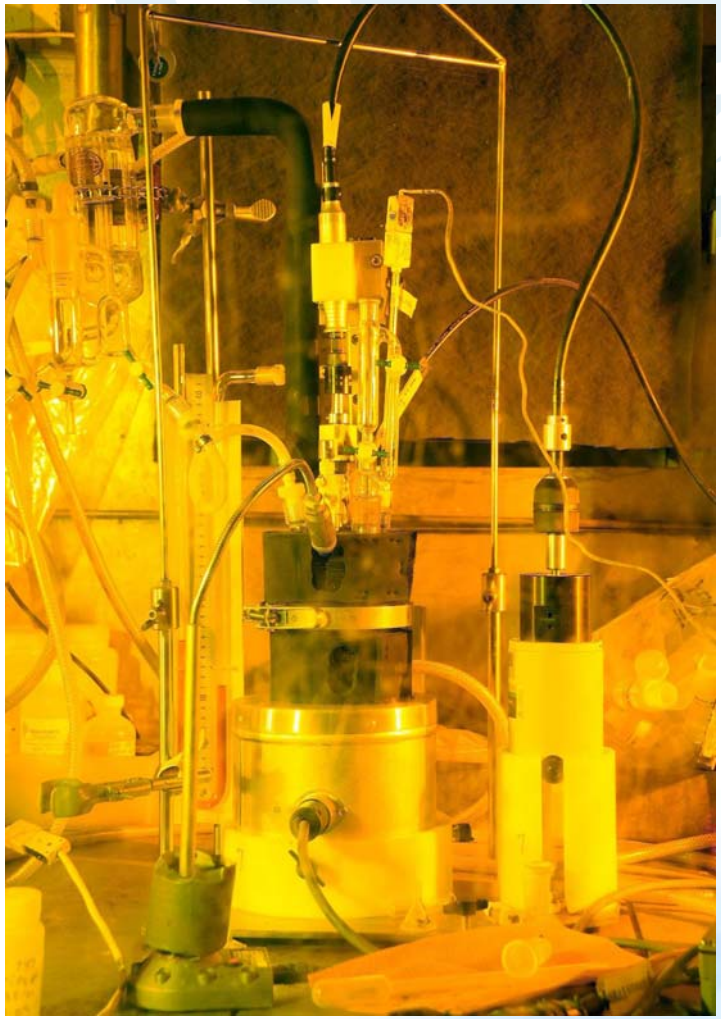
Perform experiments in SRNL Shielded Cells with Actual Waste.

Measure the flowing properties:

- **Solids content {total, undissolved, and soluble solids in supernate}**
- **pH**
- **Foam Stability**
- **% Foam**

Compare:

- **Foaminess and Foam Stability.**
- **Various antifoam concentration and addition frequencies**



DWPF Antifoam Problems

Antifoam developed for acidic and neutral conditions

- **ARP processing requires caustic processing**
- **More antifoam 747 required to control foam (4x)**

Antifoam not working well during acid addition

- **Long acid addition time degrades antifoam**

Processing times increased (high Hg) requiring more antifoam

Antifoam not as effective as first produced

- **New procurement specifications will resolve**

DWPF Antifoam Requirements

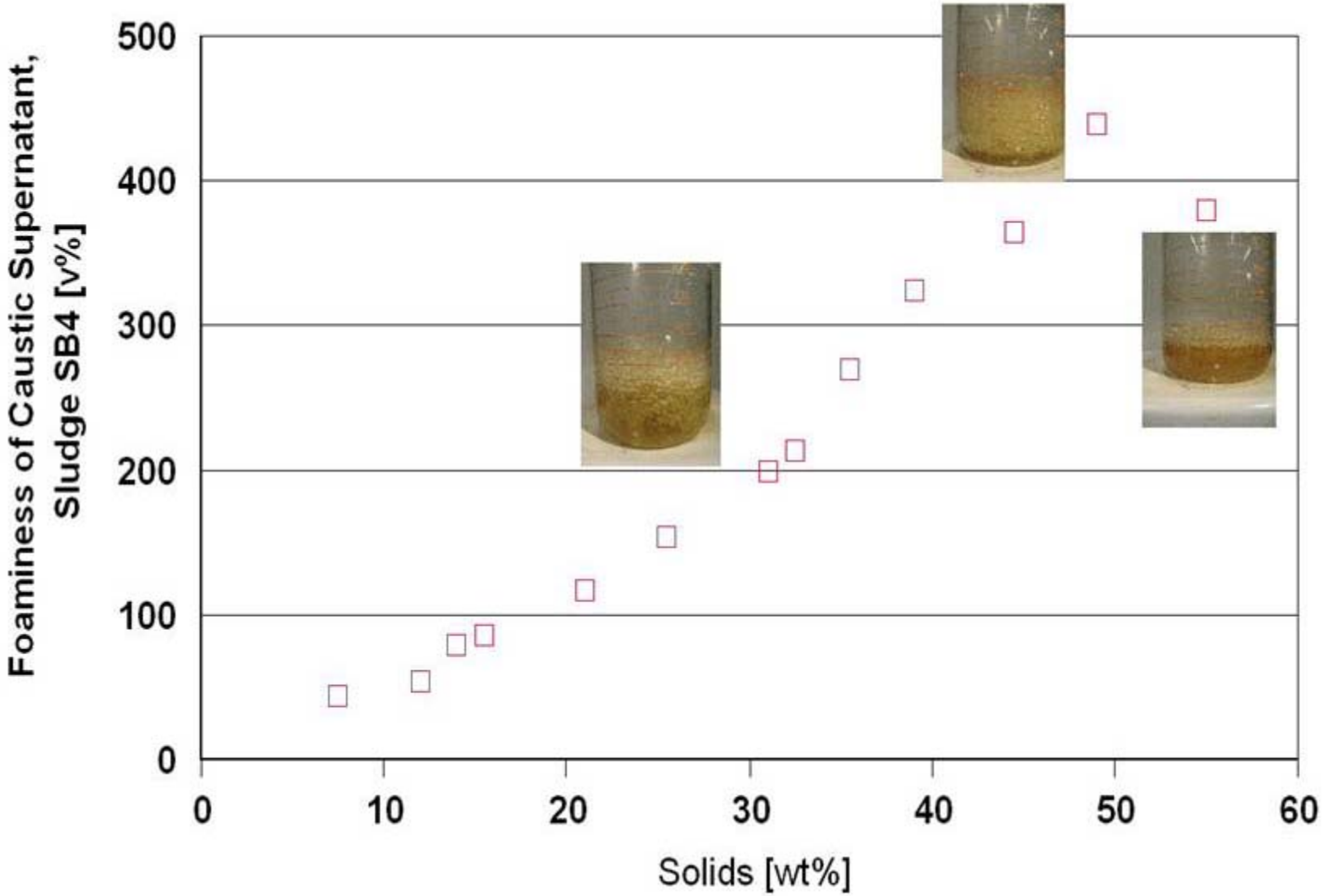
DWPF needs to increase processing rate

- **Foaming can't be a bottleneck for process**
- **Improved antifoam should lead to less antifoam consumption and faster processing rates**

Antifoam contract with Wasan/Nikolov studied foaming during caustic boiling

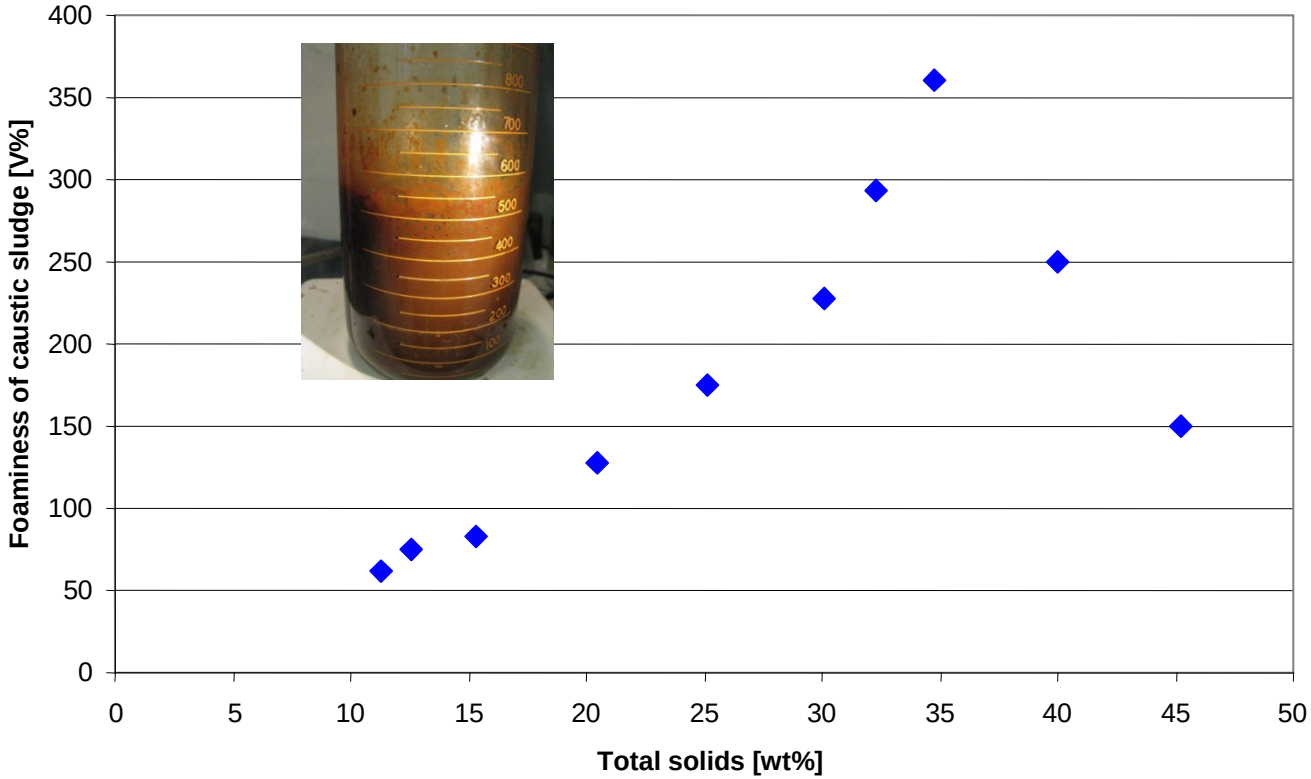
- **Results will be discussed**

Foaminess of caustic supernatant vs. solids during boiling



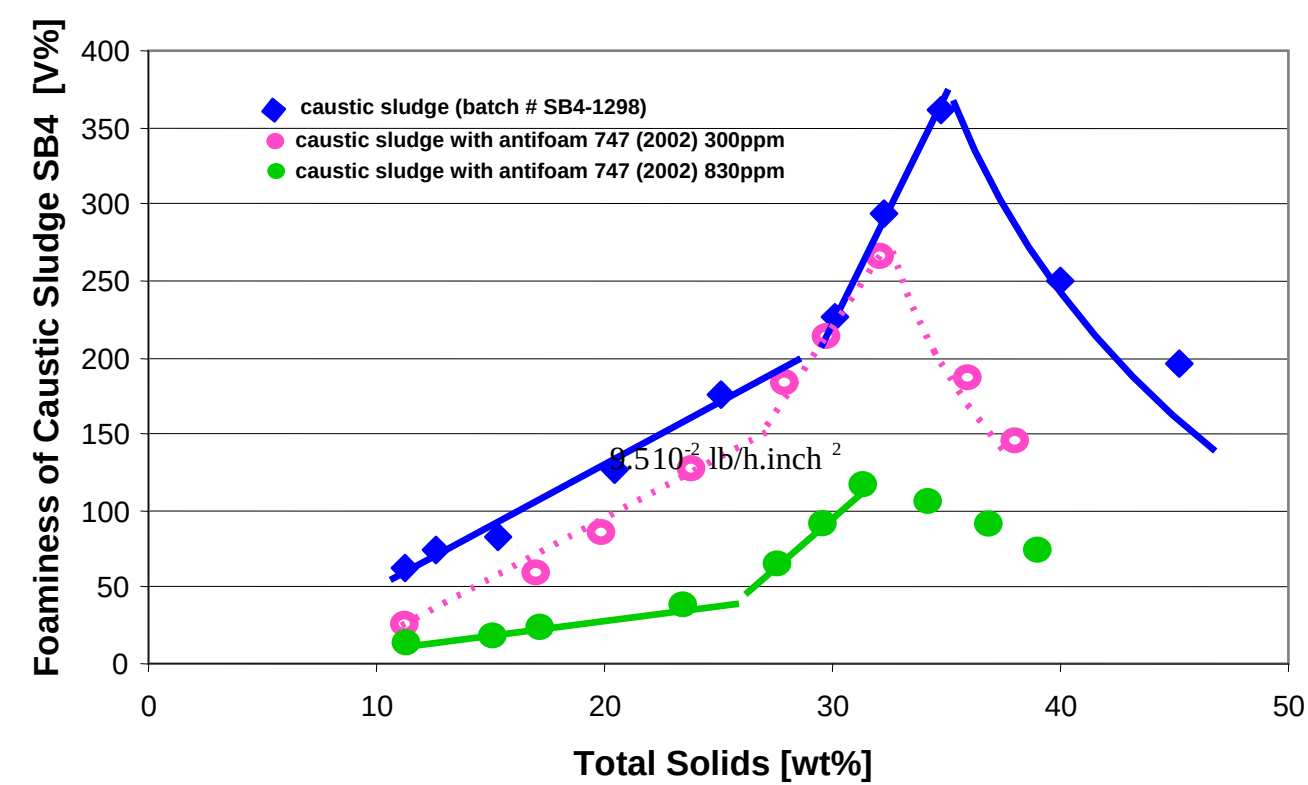
Supernatant initial volume 200 ml flux: 9.5 10 $^{-2}$ lb/h.inch^2

Foaminess of caustic sludge vs. total solids during boiling



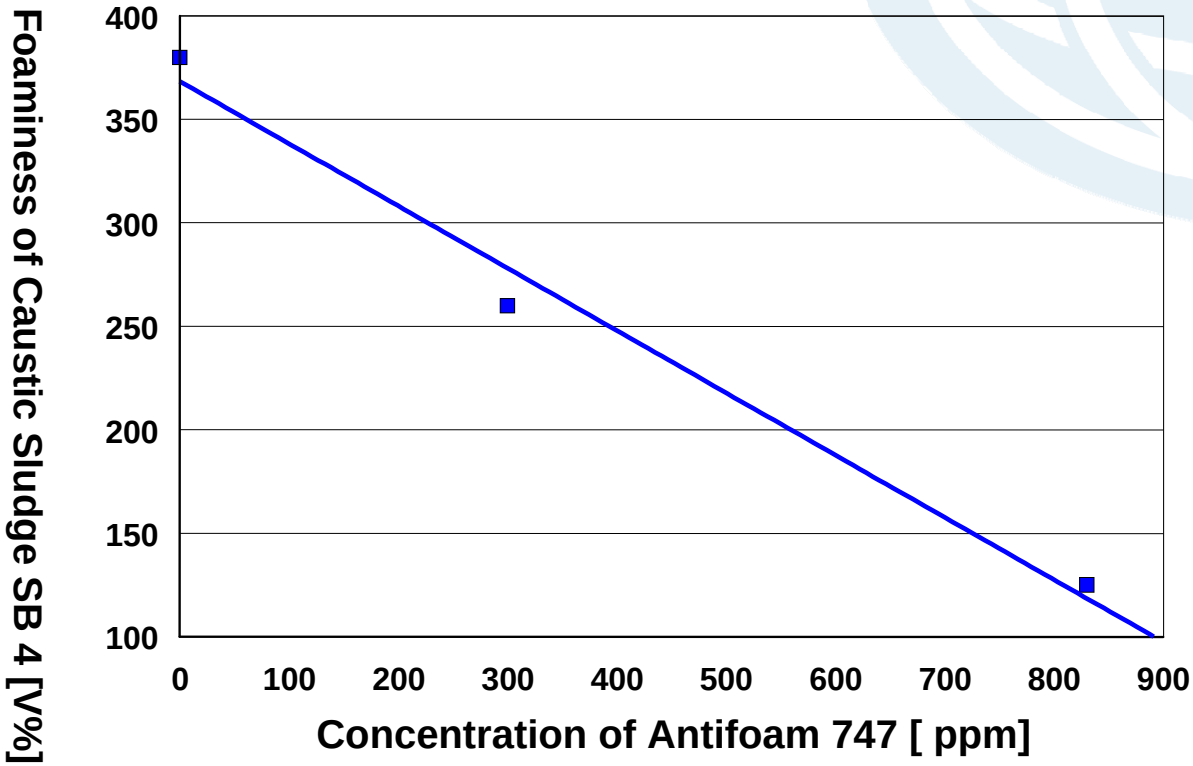
Sludge initial volume 300 ml flux: $9.5\ 10^{-2}$ lb/h.inch ^{2}

Foaminess of caustic sludge vs. antifoam 747

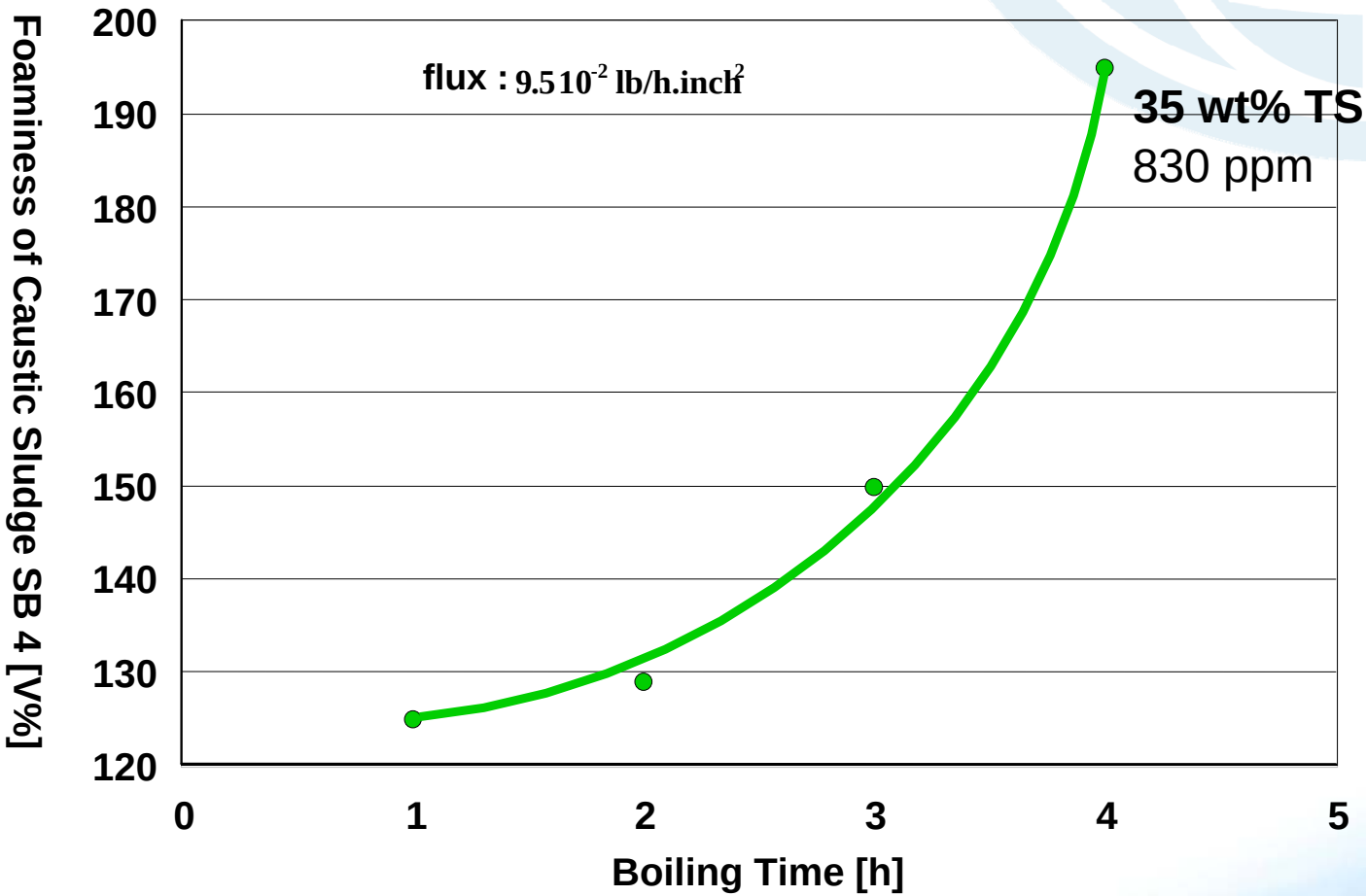


Sludge initial volume 300 ml flux: $9.5 10^{-2}$ lb/h.inch ^{2}
Boiling time for each run 50-55 min.

Foaminess of Caustic Sludge vs. Concentration of Antifoam 747



Foaminess of Sludge vs. Boiling Time in the Presence of DeBourg Antifoam 747



Future Work

- **Development of improved antifoam agents for ORP LAW evaporation, SRS Tank 48, and SRS Saltstone.**
- **Testing effective antifoam agents on actual samples during processing in SRNL shielded cells.**

Backups

Background

Previous work: Final Report: Illinois Institute of Technology Antifoam Recommendation to SRTC, WSRC-TR-2000-00297 Lambert, D.P., 2000 Oct 17. This report is a summary of the basic research necessary to understand the cause of foaming in the Small Tank Tetraphenylborate Process (STTP) and to develop a short list of antifoaming and defoaming agents.

Objective: Development of Antifoam one of the three proposed Salt Processing Flowsheets at SRS to minimize foam stability

Results: Antifoam Agent B52 was recommended for use in the Small Tank Tetraphenylborate Process (since abandoned) and is currently used for SRS's Tank 48 Fluidized Bed Steam Reforming Process

Background

Title	Co-author(s)	Date	Comments
Foaming and Antifoaming in a Gas-Liquid Finely Divided Particulate System	K. Vijayaraghavan, A. Nikolov, D. Wasan, T.B. Calloway, and M.E. Stone	2005	Manuscript summarizing the fundamental science discoveries related to particle size and homogeneity in understanding the cause of foaming in SRS high level radioactive waste. Peer reviewed manuscript was published in the Journal of Chinese Institute of Chemical Engineers 26 (1) 37-41 (2005).
Foaming and Antifoaming in Radioactive Waste Pretreatment and Immobilization Processes	D. Wasan, A. Nikolov, K. Vijayaraghavan, T.B. Calloway and M.E. Stone	2005	An understanding of the cause for the foam stability in radioactive waste processing led to the development of two antifoaming agents for SRS and identification of a third for Hanford Low Level Waste evaporation. Presented at the AIChE Annual Meeting.
Gas and Oil Retention in Waste Slurries: Role of Particle Interactions	A. Nikolov, D. Wasan, M.E. Stone and T.B. Calloway	2005	Summary of the fundamental science that was understood as a result of multi-year support of foaming in radioactive waste processing. Small particles stabilize the foam film leading to excessive foam. Presented at the AIChE Annual Meeting.
Antifoam Agent Development for the Harsh Environment in High Level Radioactive Waste Processing	T.B. Calloway and D.C. Koopman	2003	Invited talk summarizing the development of unique antifoam agents for the DWPF Chemical Processing Cell. Development required cooperation and communication between academia and SRNL Researchers. Presented at the Session Honoring Darsh Wasan, developer of IIT 747 Antifoam, at the AIChE Annual Meeting.
Foaming in Simulated Radioactive Waste	S.K.Bindal, A. Nikolov, D. Wasan and D.C. Koopman	2001	Manuscript summarizing the fundamental science discoveries needed to understand the cause of foaming in SRS high level radioactive waste. Peer reviewed manuscript was published in the Journal of Environmental Science and Technology 2001, Volume 35, Number 19.

Background

Title	Co-author(s)	Date	Comments
Foam Testing of an Alternative Antifoam Agent for the Processing of Radioactive Sludge in the Defense Waste Processing Facility	D.C. Koopman	2000	Report and presentation summarizing the testing completed to qualify an improved antifoam agency for use in DWPF using radioactive waste in the DWPF Shielded Cells.
Testing of an Alternative Antifoam Agent for the Processing of Radioactive Sludge in Defense Waste Processing Facility	D.C. Koopman	2000	IIT developed a new antifoam agent for DWPF (Antifoam 747). Before implementing this in DWPF, extensive testing was completed to ensure it did not impact DWPF processing or downstream processing. The results with the recommendation to switch to this new antifoam were presented at the AIChE Spring National Meeting.
Fate of IIT B52 Antifoam Agent Across the Small Tank Tetraphenylborate Process	T.B. Calloway and M.A. Baich	2001	An antifoam agent was developed for the Small Tank Tetraphenylborate Process, one of the three alternatives being considered for salt processing alternatives. Testing was completed to understand where in downstream processing the antifoam agent would accumulate and whether it would create processing difficulties.
Hydrogen Generation and Foaming during Tests in the GFPS Simulating DWPF Operations with Tank 42 Sludge and CST	D.C. Koopman	2001	One of the Salt Processing alternatives was a crystalline silicotitanate (CST) process for removing cesium from the salt waste. The CST product would be fed to DWPF in the SRAT. Testing was completed to evaluate processing issues such as hydrogen generation and foaming.
Illinois Institute of Technology Report IITB52 Antifoamer for Alternative Salt Process	D. Wasan and A. Nikolov	2001	IIT invented an antifoam for controlling foaming during the Small Tank Tetraphenylborate Process. This antifoam was much more effective than commercial antifoams. This antifoam is still part of the Tank 48 processing flowsheet for Steam Reforming and wet air oxidation (the two alternatives for Tank 48 processing).

Background

Title	Co-author(s)	Date	Comments
Fate of IITB52 Antifoam Agent Across the Precipitation Concentration Washing and Hydrolysis Cycles	T.L. White	2000	Results of testing to understand what happens to the degradation products of the IITB52 antifoam agent during the precipitation, concentration, washing and hydrolysis processes in the Small Tank Tetraphenylborate Process. The report included the specifics of the analytical technique developed to track the antifoam.
Final Report Illinois Institute of Technology Antifoam Recommendation to SRTC	D. Wasan and A. Nikolov	2000	Final report regarding IIT's invention of an improved antifoam agent for DWPF's Chemical Processing Cell. This report summarized the basic science used by IIT to understand the cause of the foaming during processing allowing them to develop an antifoam agent targeted to minimize foam.
Sludge Batch 2 Macrobatch 3 Flowsheet Studies with Simulants	D.C. Koopman	2000	Report Recommending Chemical Processing Flowsheet for DWPF's 3rd batch of sludge (SB2 or MB3).
Testing of Irradiated and Nonirradiated IIT747 Antifoam in Simulated Sludge Processing		2000	Sludge with added IIT747 was irradiated and tested to ensure that the antifoam efficiency was not impacted by the radiation field. The antifoam agent was not impacted by the expected radiation in the Small Tank Tetraphenylborate Process.
Impact of the Surfactant Surfynol 420 On the Precipitate Hydrolysis Process	S. Young, H.B. Shah and R.E. Edwards	1995	A new antifoam agent, Surfynol 420 was evaluated as an improvement to another Surfynol product that had been used throughout precipitate hydrolysis testing. The new antifoam agent was a significant improvement.