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Foam Testing of an Alternative Antifoam Agent for the Processing of Radioactive Sludge in the Defense Waste Processing Facility

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FOAM TESTING OF AN ALTERNATIVE ANTIFOAM AGENT FOR THE PROCESSING OF RADIOACTIVE SLUDGE IN THE DEFENSE WASTE PROCESSING FACILITY

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Abstract

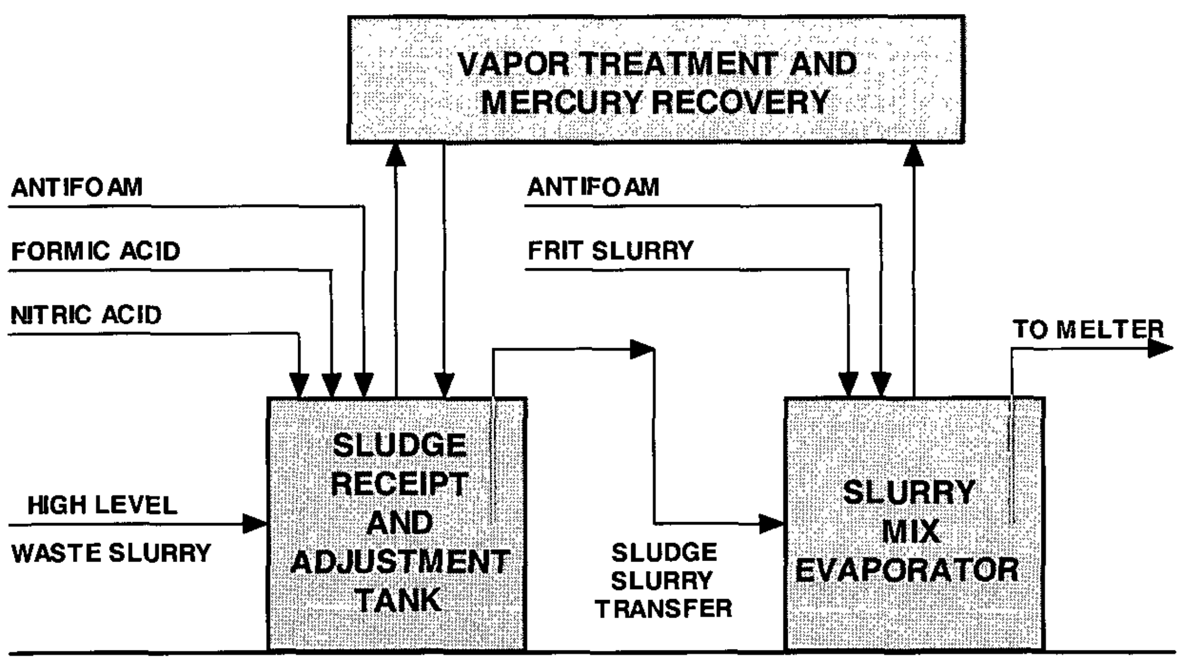
The Defense Waste Processing Facility (DWPF) at the Savannah River Site is responsible for immobilizing high level radioactive waste (HLW) as glass-filled steel canisters for permanent storage. In the DWPF facility, the HLW sludge undergoes chemical treatment to prepare it for vitrification in a melter. The generation of stable foams is possible during treatment. The current DWPF antifoam is ineffective in preventing and minimizing the formation of foam. The adverse consequences of excess foam can be severe enough to cause foam to exit the evaporator and collect in the condensate. A foamover will contaminate the relatively clean condensate with HLW solids. It can also potentially lead to the production of an unsuitable melter feed that would not make quality glass. Both of these consequences are costly and time consuming to correct.

A new antifoam was developed by the Illinois Institute of Technology, IIT, for DWPF in an attempt to minimize or eliminate the frequency of these foamovers. This antifoam was demonstrated to be superior to the existing DWPF antifoam in laboratory scale experiments. However, the DWPF evaporation heat flux was not achievable in the laboratory scale equipment. A $1/240^{th}$-scale pilot facility was built to achieve this heat flux and determine whether the existing or new antifoam was superior. The pilot facility was built out of glass to allow observation of the foam formation during processing. The experiments used a non-radioactive simulant slurry similar to HLW. The IIT antifoam was found to be much more effective than the DWPF antifoam at the current conditions of maximum foam formation. The IIT antifoam was comparable or superior to the present DWPF antifoam under all conditions tested. This report summarizes the results of the antifoam comparison testing.

INTRODUCTION

The Defense Waste Processing Facility (DWPF) has experienced problems with foaming in the Sludge Receipt and Adjustment Tank (SRAT) and Slurry Mix Evaporator (SME) during processing of high-level radioactive waste sludge, see Figure 1 below. Excessive foaming could potentially contaminate condensate with radioactive sludge. Controlling foaming by reducing the SRAT or SME boil-up flux negatively impacts DWPF by reducing throughput. Bench-scale development work, ~1/100,000th-scale, completed at the Illinois Institute of Technology, IIT, under the direction of Drs. Darsh Wasan and Alex Nikolov, concluded that their IIT747 antifoam is superior to the currently used Dow Corning 544 antifoam.

Figure 1. DWPF Chemical Processing Cell



A 1/240th-scale mockup of the DWPF process was used to conduct comparison tests of the two antifoams. The process simulation was configured in the Savannah River Site *Glass Feed Preparation System* (GFPS). Testing used a non-radioactive simulant of Tank 42 High Level Waste sludge, the current DWPF feed. Two complete and two partial runs of the GFPS were made. The two complete runs simulated both the SRAT and SME processing cycles. The first complete run used Dow Corning 544 antifoam. The second complete run used IIT747 antifoam. The two partial runs used Dow Corning 544 antifoam. These simulations only covered acid addition and the initial concentration phase of the SRAT cycle.

DISCUSSION

Experimental

Material Preparation

An analysis of DWPF routine sample results was used to characterize the Tank 42 HLW sludge being processed. Table I below gives the best estimate of the post-trim non-radioactive sludge simulant composition used in these tests as well as that of the target DWPF Tank 42 sludge. The actual match for aluminum is believed to be better than that shown in Table I, because of previously identified analytical biases. Routine DWPF samples are not analyzed for noble metals. Noble metals (Ag, Pd, Rh, and Ru) were added at 110% of concentrations determined from a single sample analysis of Tank 42 HLW.

Table I. Summary of Simulant Preparation Results

	Post-trim Sludge (110% Noble Metals)	DWPF Target Sludge (110% Noble Metals)
Ag, wt. %	0.040	0.040
Al, wt. %	7.679	8.590
Ba, wt. %	0.005	n/a
Ca, wt. %	2.553	2.510
Cr, wt. %	0.158	0.151
Cu, wt. %	0.047	0.042
Fe, wt. %	23.816	23.461
Hg, wt. %	1.050	1.050
K, wt. %	0.154	0.234
Mg, wt. %	1.209	1.287
Mn, wt. %	3.377	3.688
Na, wt. %	7.360	6.835
Ni, wt. %	0.312	0.352
Pb, wt. %	0.133	n/a
Pd, wt. %	0.002	0.002
Rh, wt. %	0.006	0.006
Ru, wt. %	0.023	0.023
Si, wt. %	0.879	0.987
Sr, wt. %	0.029	n/a
Ti, wt. %	0.023	0.031
U, wt. %	0.000	3.407
Zn, wt. %	0.148	n/a
Zr, wt. %	0.056	0.069
nitrite, mg/liter	7400	7200
nitrate, mg/liter	3200	3400
formate, mg/liter	120	500
chloride, mg/liter	90	n/a
sulfate, mg/liter	380	n/d
oxalate, mg/liter	240	n/a
base equiv @ pH 7	0.362M	0.132M
base equiv @ pH 5.5	0.462M	n/a

n/a = not analyzed
n/d = not detected

The vitrified product waste loading was set at 35 wt. % sludge on an oxide basis (this sets the quantity of glass frit added in the SME cycle). The redox target was 0.2 for the ratio Fe^{+2}/Fe_{total} (this sets the overall ratio of formic acid to nitric acid added during the combined SRAT and SME cycles). A value of 150% (50% excess) of the nominal acid requirement was selected based on current DWPF practice. Frit 200 (70% SiO_2, 12% B_2O_3, 11% Na_2O, 5% Li_2O, and 2% MgO as ~160 micron particles) was obtained from DWPF for use in the antifoam test runs. Fresh Dow Corning 544 antifoam was obtained from the vendor to support the test runs. A sufficient quantity of IIT747 antifoam was prepared at the Illinois Institute of Technology in Chicago to complete the corresponding antifoam test run. The amount of antifoam required for a run was based on a 100 mg/kg addition of antifoam every twelve hours of boiling during SRAT operation plus an addition immediately prior to acid addition at 93°C at the start of the SRAT cycle. Antifoam was also added at the start of the SME cycle and after every twelve hours of processing.

Experimental Equipment

The GFPS pilot plant was used to simulate the DWPF Chemical Processing Cell equipment at 1/240th-scale. See the simplified schematic below, Figure 2. The GFPS consists of two, baffled 50-gallon glass vessels equipped with heating and cooling coils. The vessel simulating both the DWPF SRAT and SME tanks has an air-driven agitator with two impellers. There are two glass shell-and-tube condensers. One uses water for cooling (SRAT Condenser), while the second uses a refrigerant at 1°C. Condensate is recirculated through a column packed with glass rings to recover condensable vapors from the exhaust gas.

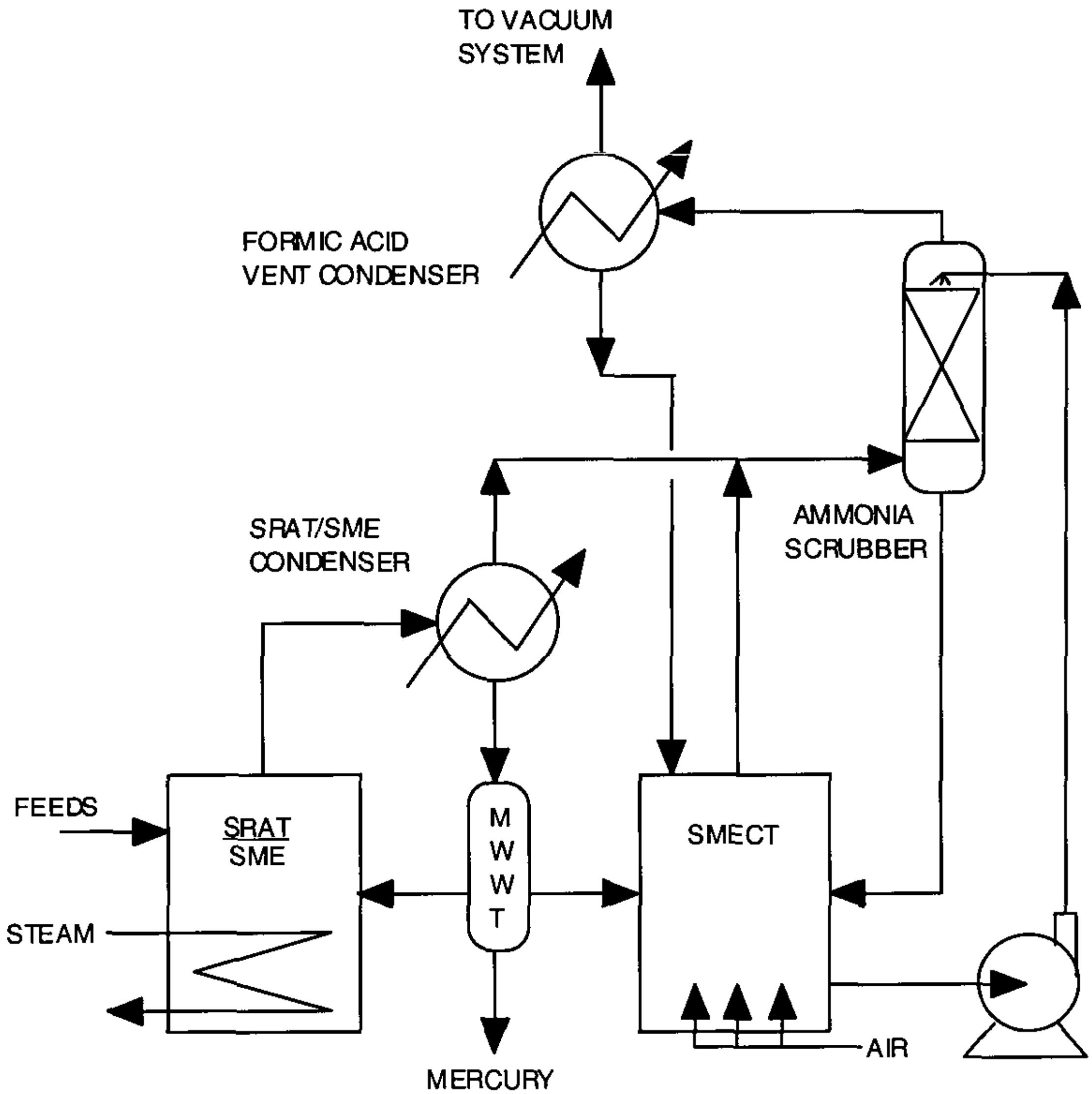


Figure 2. Schematic of the Glass Feed Preparation System.

Method

The first step in processing was to transfer the sludge simulant to the GFPS SRAT vessel. Antifoam was added to the system. The temperature of the SRAT contents was raised to 93°C at a prototypical rate of 1°C /minute. The ~50 wt. % nitric acid solution was metered in at about 30 mL/minute after the SRAT contents reached 93°C. After nitric acid addition was complete, ~90 wt. % formic acid was added at a similar rate. Total acid addition time was about four hours. Fresh antifoam was added upon completion of acid addition. The SRAT was brought to boiling under a slight vacuum. About 15 minutes at boiling were needed to heat up the overhead piping to steady temperatures. This was done at total reflux of condensate via the Mercury Water Wash Tank, MWWT, back to the SRAT.

Foam height data collection began once the system was boiling at constant SRAT vapor temperature. A *Foam Test* consisted of a period of time under reflux at constant wt. % total solids. A liquid baseline level was obtained at about 96°C for each test. Pseudo-steady state foam heights were measured versus time at selected boil-up fluxes. A foam test usually included foam height measurements at three different boil-up fluxes, 27%, 61%, and 107% of the maximum DWPF boil-up flux of 216 kg/hr/m^2 (a vigorous boil).

Pseudo-steady state foam height data at a single boil-up flux was taken for twenty minutes. The foam layer rose or fell quickly to a new level within two to three minutes whenever the boil-up flux was changed. The top of the foam layer would appear to oscillate about a steady mean value for the balance of the twenty minutes, i.e. a pseudo-steady state foam was formed. After the twenty minutes had elapsed, the boil-up flux would be adjusted to a new setting, and another data set would be obtained.

After the first Foam Test came a series of concentration steps as well as a non-prototypical dilution step of the SRAT contents. Additional foam tests were conducted following each of these. The dilution step allowed retesting one or two of the earlier total solids concentrations. This permitted some examination of the effect of time-dependent background processes on foam heights. SRAT cycle pseudo-steady state foam tests occurred at roughly 18, 21 and 26 wt. % total solids. Dynamic, or time dependent, foam height data was obtained during some of the concentration steps in between the pseudo-steady state tests. The dynamic foam height data provided a more detailed look at the effect of wt. % total solids on foaminess. Unfortunately these foam heights were subject to greater uncertainty because the non-boiling liquid level is determined by material balance rather than direct measurement.

A simulation of the DWPF SME cycle followed the SRAT cycle. A combination of Frit 200, water, and formic acid was added to the main process vessel. The contents were brought to boiling and concentrated to reduce volume and make room for a second frit addition. At the end of the concentration period, a second frit-water-formic acid addition was made. The SME was then brought to boiling and concentrated to the final total solids loading target, ~47%.

RESULTS

Qualitative Observations

A number of noteworthy qualitative observations arose during the course of the antifoam experimental work. Some of these include:

- Uncontrolled foaming can occur during virtually any point in the SRAT or SME cycle, if there is no antifoam or if enough time has elapsed since the last antifoam addition.
- Adding IIT747 antifoam to a system already foaming uncontrollably brings the system back under moderate to effective foam control.
- Fresh Dow Corning 544 antifoam at 100 mg/kg *is not effective* at controlling foaming when the SRAT is first brought to boiling at 61-107% of the DWPF boil-up flux. Fresh IIT747 antifoam at 100 mg/kg *is effective* at controlling foaming when the SRAT is first brought to boiling at 107% of the DWPF maximum boil-up flux.

- Dow Corning 544 and IIT747 antifoam are only moderately effective at controlling foaming in the latter part of the SRAT cycle and are roughly comparable to each other. Some foam, less than 30 cm, was present, but it was not increasing in thickness over time.
- IIT747 antifoam at 100 mg/kg added early in the morning of a SRAT cycle processing day remained effective at controlling foam during 10.5 consecutive hours of processing at elevated temperature (the entire duration of the day's testing).

Quantitative Observations

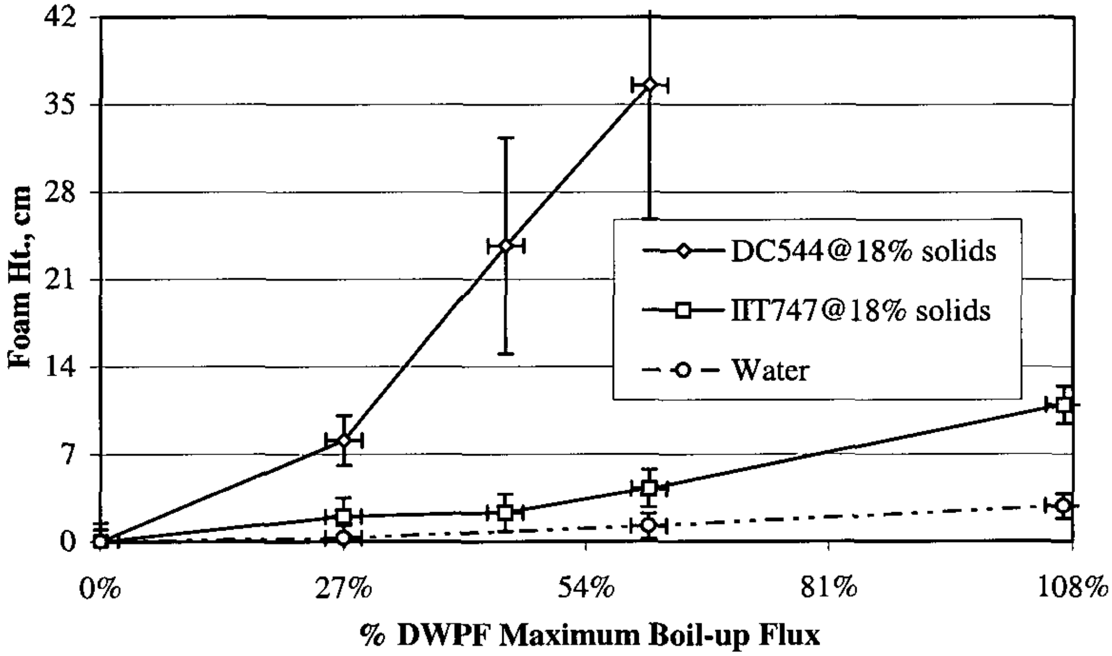
The discussion of quantitative foam height observations will be divided into five sections. All SRAT foam height data at about 18.2 wt. % total solids will be discussed under *SRAT Foam Test #1*. All SRAT data at about 21.4 wt. % total solids will be discussed under *SRAT Foam Test #2*. All SRAT data at about 26.5 wt. % total solids will be discussed under *SRAT Foam Test #3*. Foam height data from the SRAT concentration steps in between these Foam Tests will be discussed fourth. SME cycle data will be discussed last. In the discussion that follows DC544 will be short for Dow Corning 544 antifoam and IIT747 will be short for IIT747 antifoam.

SRAT Foam Test #1

Four pseudo-steady state Foam Tests were run at approximately 18.2 wt. % total solids (the value following acid addition) at the start of SRAT cycle boiling. These foam tests were always the initial foam test of a run because of the low solids loading. There were three repetitions of the initial DC544 test, each starting with fresh simulant, acids, etc. These foam height results were averaged.

Figure 3 below gives a graphical comparison of foam height data from the simulations comprising SRAT Foam Test #1. Data for boiling water is shown for comparison purposes. The foam height scale zero represents the baseline liquid level at 96°C of about 79 cm. The vessel lid is at 41.5 cm above the baseline liquid level.

Figure 3. SRAT Foam Test #1



Considerable foaming was observed in all tests with DC544 even though antifoam had been added within the past one to two hours. The original plan called for testing at 27%, 61%, and 107% of the DWPF maximum boil-up flux. In none of these three tests were we able to raise the boil-up flux to 107% and hold it there, since foam filled the SRAT at lower fluxes. Tests at 45% of the DWPF maximum boil-up flux were substituted for tests at 107%.

In all three DC544 tests at 27% flux (four data points since one trial was repeated) the foam was dynamically stable, and about 7.5 to 9 cm deep. At a flux of 45%, the foam height varied between 13 and 31 cm in the three tests. Foam rose to just below the lid, or about 41.5 cm high, at a flux of 61% in the first DC544 test. Foam height steadied out enough to complete the twenty minute test. During the third DC544 test, the foam rose nearly as high as the lid as soon as the flux was increased to 56%, and no foam test could be completed at 61%. The foaming tendency throughout the second DC544 test was lower (no cause identified), and only about 25 cm of foam formed at the 61% flux. After this, the boil-up flux rate was increased gradually to 82% at which point the foam again filled the SRAT.

Very little foaming was observed in the comparable tests with IIT747. A foam test was successfully completed at 107% of the DWPF maximum boil-up flux with only about 11 cm of foam, i.e. less than that observed at 45% flux with Dow Corning 544 antifoam. Foam heights were even less at lower boil-up fluxes. After completing the initial IIT747 test, the GFPS was shut down for twelve hours. When the GFPS was brought back on-line (same simulant batch), considerable foaming was observed at 27% DWPF maximum boil-up flux. This was interpreted to mean that the antifoam had lost its effectiveness. Fresh antifoam was added, and the foam collapsed. Repeated foam tests at 27 and 61% boil-up flux showed less foam than was observed at those fluxes on the previous day.

The overall differences between Dow Corning 544 antifoam and IIT747 antifoam were very pronounced in SRAT Foam Test #1. DC544 was ineffective at controlling foam height as boil-up flux was increased to the DWPF maximum. At constant flux, DC544 may have at least kept the rate of increase in foam height versus time at a negligible rate, i.e. preventing uncontrolled foam growth. IIT747 was *extremely effective* at controlling foam height and growth under the conditions in Foam Test #1.

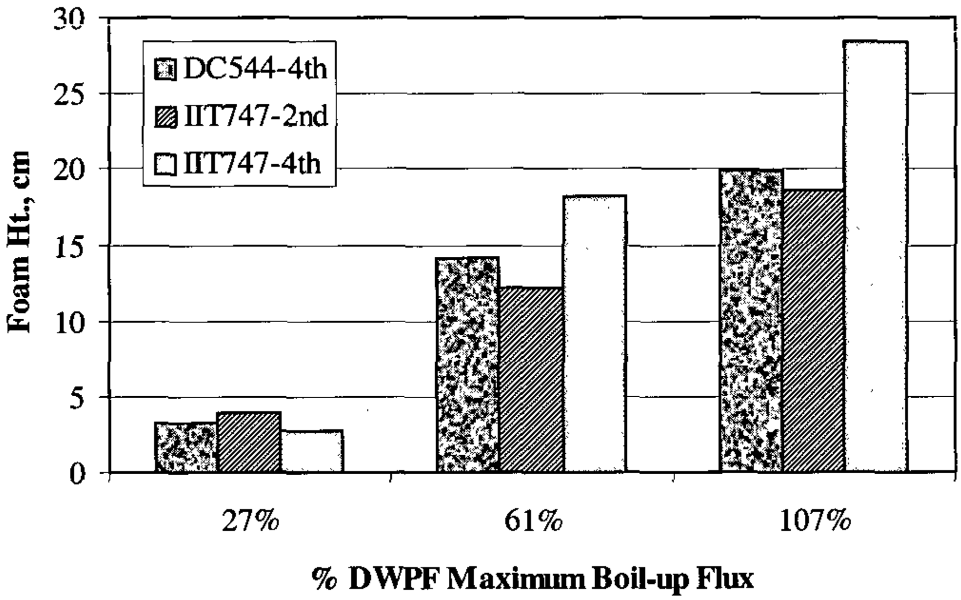
All of the foams described above were transient foams that required a continuous boil-up flux to sustain themselves. They collapsed quickly when the boiling vapor supply was removed. These foams were very thick in appearance and seemed to incorporate a large amount of liquid slurry. They were visually opaque over less than one centimeter paths. There were many bubbles in the 0.2-0.5 mm diameter range.

SRAT Foam Test #2

Three pseudo-steady state foam tests were run at approximately 21.4 wt. % total solids during the middle of the SRAT cycle. One test used DC544 and occurred as the fourth foam test in that run. Two tests came from the run with IIT747. These were the second and fourth foam tests in that run. The DC544 test and the fourth IIT747 test occurred following a dilution of the SRAT contents from ~26 wt. % total solids back to 21.4 wt. % total solids. All three 21.4 % foam tests successfully studied foam height at 27%, 61%, and 107% of the DWPF maximum boil-up flux.

Figure 4 presents a side-by-side comparison of foam heights from the three pseudo-steady state boil-up flux tests. The fourth IIT747 test data is the most directly comparable to the DC544 data, although all three are at essentially the same wt. % total solids. Those two tests underwent approximately the same amount of steam stripping and have similar nitrite ion concentrations (130 mg/liter and 190 mg/liter for DC544 and IIT747 respectively, versus 2800 mg/liter following acid addition). Roughly equivalent mercury concentrations can be expected for this pair based on the steam stripping equivalence.

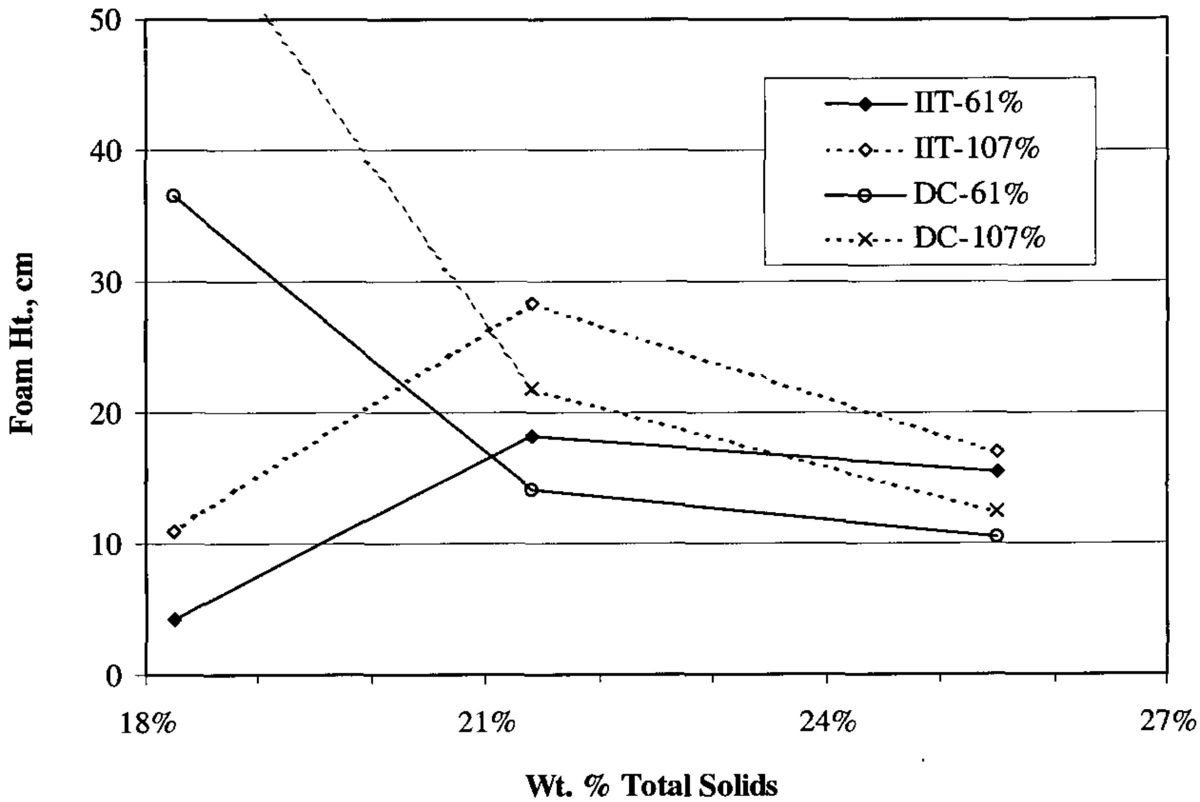
Figure 4. SRAT Foam Test #2



Both antifoams were only moderately effective at controlling foam height over the range of boil-up fluxes studied, i.e. kept foam height under ~30 cm. Neither antifoam was effective at eliminating the foam, i.e. limiting the foam height to just 4-8 cm. This could be due to aging of the antifoam. One explanation for the greater foam heights at 61% and 107% in the fourth IIT747 test versus the second IIT747 test could be that the antifoam was 2.7-3.7 hours old during the second test, while it was 7.2-8.2 hours old during the fourth test.

Observed foam heights at 61% and 107% flux were greater at 21.4 wt. % total solids than at 18.2 % for the IIT747 simulation. Conversely, foam heights at 61% (and implicitly at 107%) flux decreased in the runs with DC544 as the system went from 18.2 to 21.4 wt. % total solids. See Figure 5.

Figure 5. Antifoam Comparison at Various Wt. % Solids

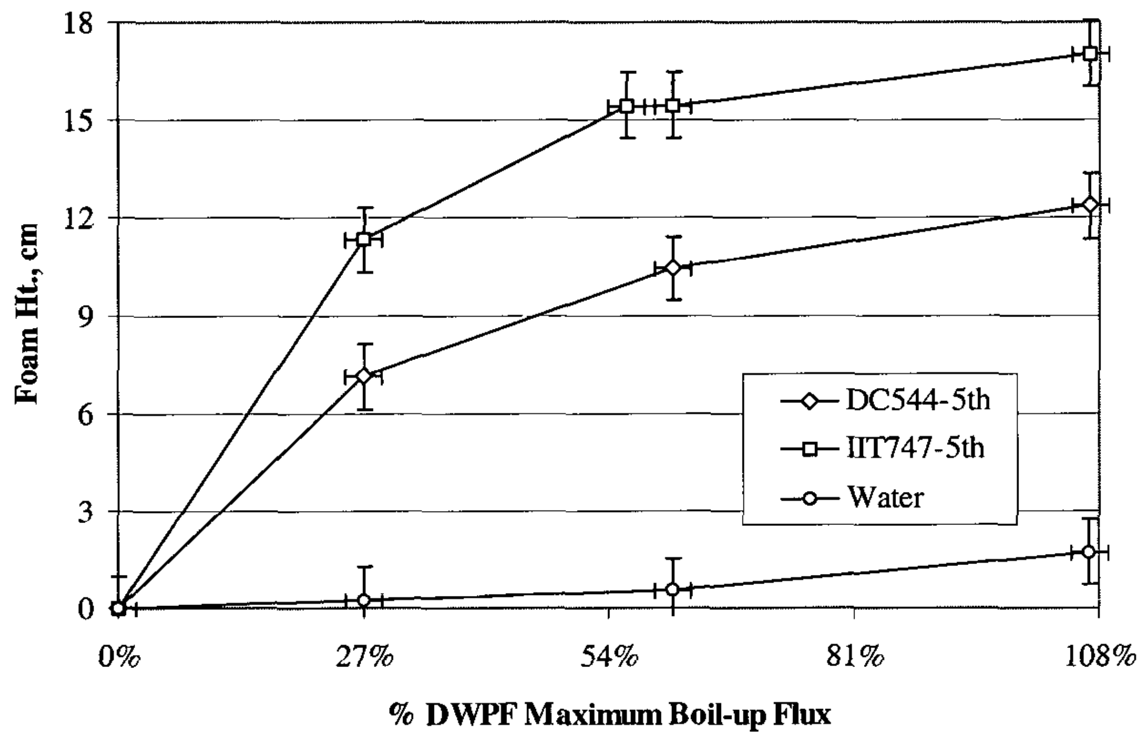


SRAT Foam Test #3

Four pseudo-steady state foam tests were run at approximately 26.5 wt. % total solids, two with each antifoam. These tests were in the middle and at the end of the SRAT cycle. All four tests successfully studied foam height at 27%, 61% and 107% of the DWPF maximum boil-up flux. Qualitatively the 26 wt. % total solids foam was described as being more frothy and having larger bubbles (up to 1.3 cm diameter).

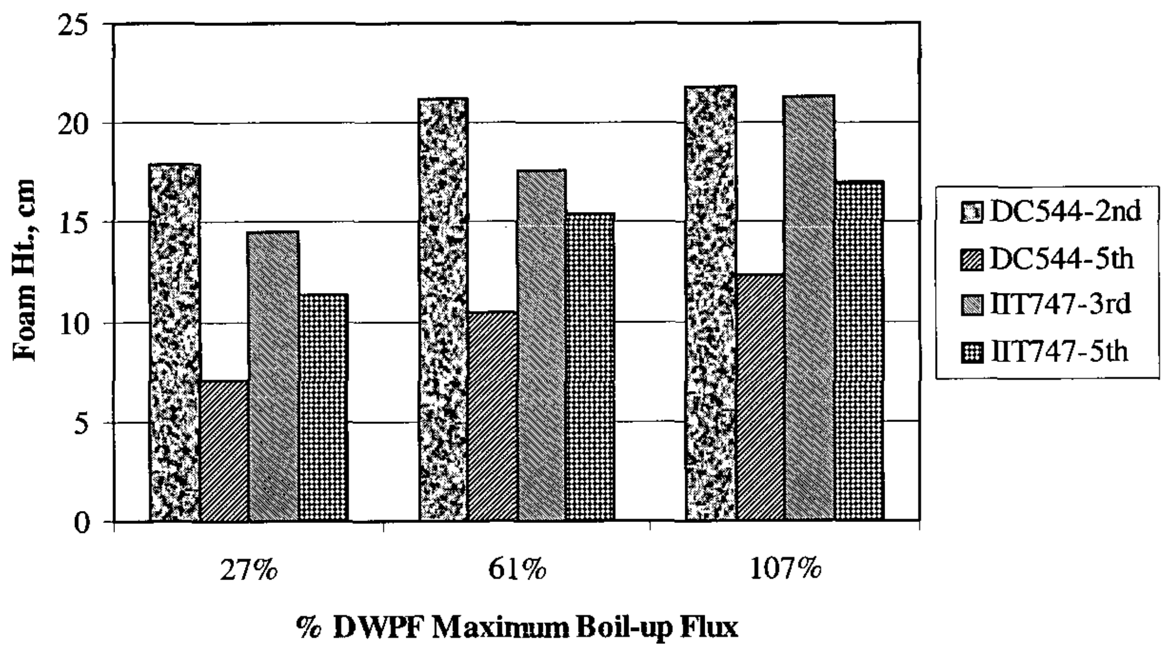
The fifth Dow Corning test data and the fifth IIT747 test data are the most comparable. The fifth IIT747 test was designed so that the total pounds of steam evaporated from the SRAT at the start of the test matched as closely as possible the equivalent total for the fifth Dow Corning 544 test. The actual match was 56,700 vs. 54,500 kg steam at DWPF-scale. Mercury concentration was also roughly equivalent for this pair, 0.0593 wt. % vs. 0.0674 wt. %. Data from this pair of Foam Tests along with data taken with boiling water are compared in Figure 6 below. Unfortunately the antifoam ages were not the same. The Dow Corning 544 antifoam was 400 minutes old while the IIT747 antifoam was 570 minutes old at the start of the respective one hour long foam tests. The IIT747 antifoam at the end of the last SRAT foam test had been at boiling conditions for over ten hours with no supplemental additions.

Figure 6. SRAT Foam Test #3



The third IIT747 test was intended to be a comparison in time for the fifth. The second DC544 test served roughly the same purpose for the fifth DC544 test. Overall SRAT Foam Test #3 foam was quite different from that in all other SRAT and SME cycle foam tests, being fairly insensitive to boil-up flux without being shallow. In all other tests the deep foams were very sensitive to boil-up flux while the shallow foams (<7-10 cm) were comparatively insensitive to the boil-up flux. The SRAT Foam Test #3 foams included the deepest foams observed at the 27% of DWPF maximum boil-up flux as well as some of the deepest foams observed during the IIT747 antifoam test. In any case, it was visibly clear that foaming remained under control, i.e. less than 30 cm, with either antifoam in all four tests in Foam Test #3. Figure 7 below gives a comparison of the observed foam heights at the three boil-up fluxes studied for all four sets of simulant slurry data.

Figure 7. SRAT Foam Test #3



The later data set for both antifoams showed a lower foam height than the earlier data. The time since antifoam was last added was almost identical for the two DC544 tests. Conversely, the IIT747 antifoam in the fifth test was almost six hours older than in the third test. This combination of data seems to indicate that the SRAT simulant slurry was becoming less foamy with increasing processing time. The summary data in Figure 5 above appears to indicate this trend as well. (In Figure 5 the data at 26 wt. % total solids came from the later foam tests in SRAT Foam Test #3.) Antifoam aging effects seem to be superimposed on this general trend.

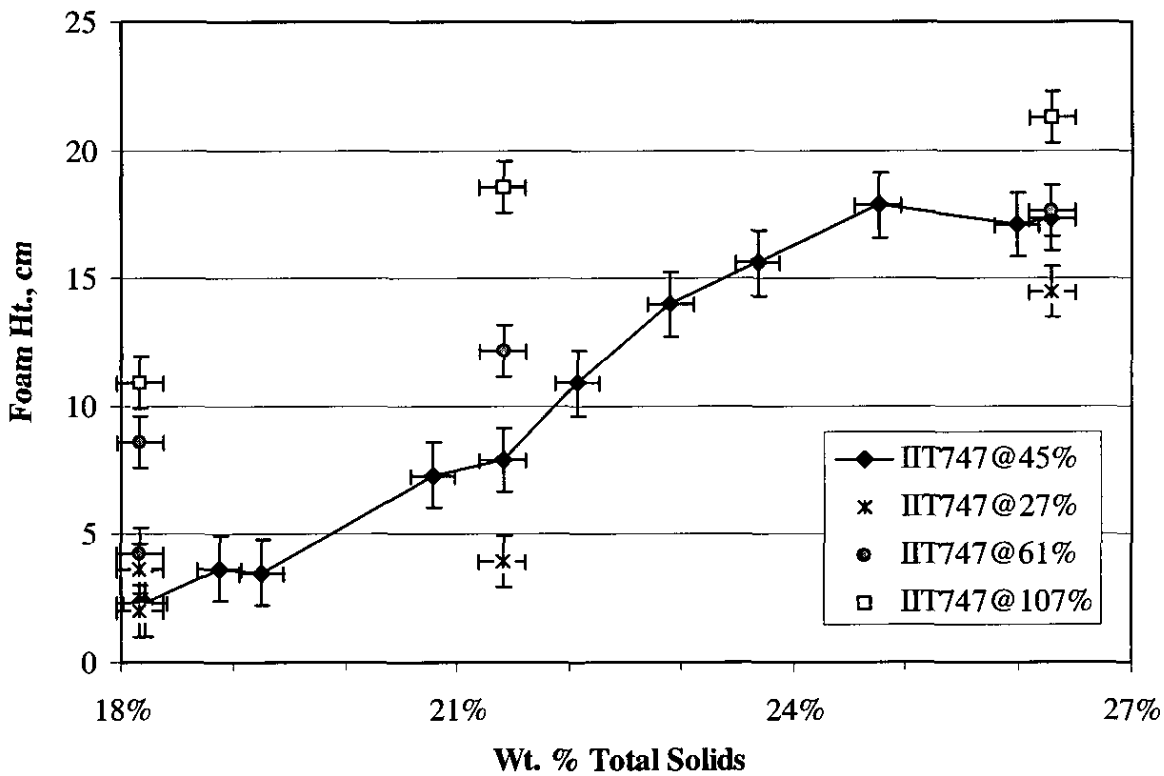
The only conflicting data to a trend toward decreasing foaminess came from SRAT Foam Test #2 at 61% and 107% of the DWPF maximum boil-up flux during the second and fourth IIT747 tests. Here the later test showed more foaminess than the earlier test. This reversed trend might be primarily due to increased antifoam age (161 minutes since antifoam was added at the start of the second test versus 431 minutes at the start of the fourth test). The more processed slurry at the time of the fourth IIT747 test might still be intrinsically less foamy than the second. By the end of the fifth IIT747 test, the antifoam had been in the SRAT for 10.5 hours, all at boiling. This was the longest continuous period at boiling without adding fresh antifoam and sets a lower limit for the useful life of a 100 mg/kg slurry addition of IIT747 antifoam.

SRAT Foam Heights During Concentrations

Based on findings from the pseudo-steady state foam tests, the analysis was extended into the periods of concentration that occurred between several of the tests discussed above. The SRAT contents must transition from one set of foam heights and wt. % total solids to another. This transition was not necessarily monotonic. The position of the top of the SRAT foam was recorded versus time as the SRAT contents were concentrated between the tests. Data on condensate receipt tank (SMECT) level and SRAT steam coil flow were combined to calculate the reduction in mass of the SRAT contents corresponding to each foam height reading. The necessary additional baseline liquid levels were interpolated from the nearest measured baseline levels making it possible to determine a foam height.

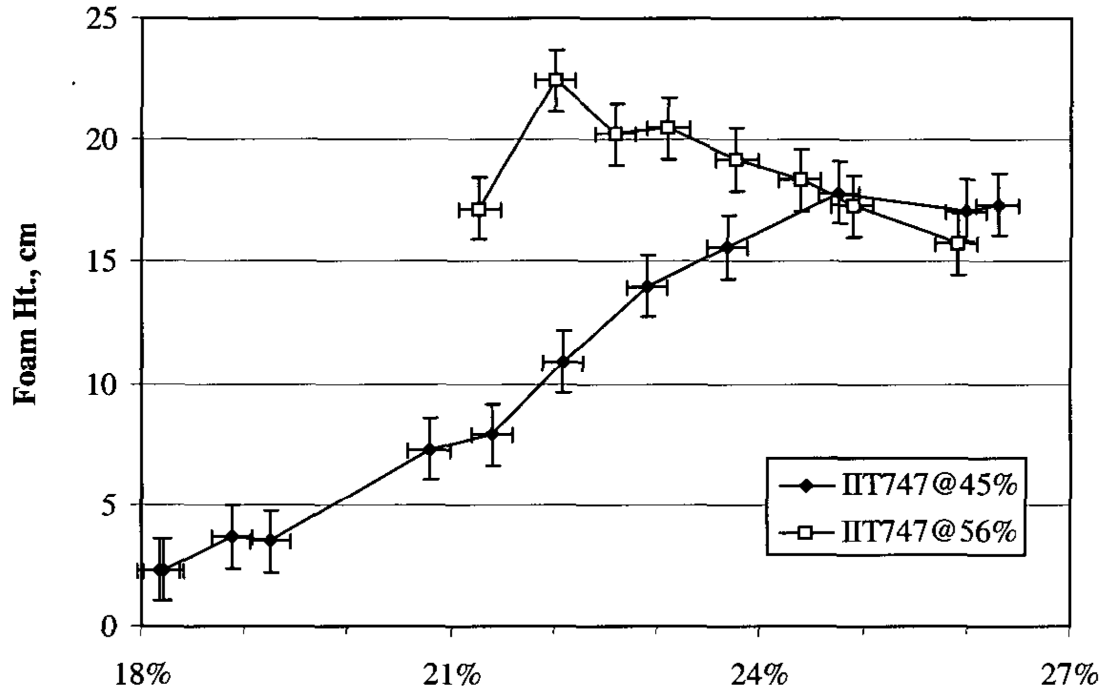
SRAT concentrations generally occurred at about 27-75% of the DWPF maximum boil-up flux. This was related to certain geometric differences between the GFPS and DWPF. The scaled DWPF maximum boil-up flux converted to kg/hr and scaled by 1/240 gives a GFPS boil-up flux of only 27% the DWPF maximum boil-up flux. The boil-up flux was controlled closer to that rate in order to keep chemical and stripping processes synchronized with DWPF processing. Figure 8 shows data taken concentrating between the first, second, and third IIT747 foam tests. Note that the system was refluxed for about an hour during the second IIT747 foam test (in the middle of this plot). Most of the concentration was done at a boil-up flux of about 45% of the DWPF maximum. As can be seen in the figure, the foam height increased with increasing wt. % total solids until about 24 wt. %.

Figure 8. Initial Concentration



Following the third IIT747 foam test (after the initial concentration above), the SRAT was diluted back to 21.3 wt. % total solids with water. The fourth IIT747 foam test was run, followed by a concentration at 56% of the DWPF maximum boil-up flux to 26.5 wt. % total solids. This data spans part of the wt. % total solids range given in Figure 8 above. Figure 9 compares the foam height results for the two concentrations.

Figure 9. SRAT Concentration Comparison



The most obvious feature of Figure 9 is that the position of any maximum in foaminess versus wt. % total solids seems to have shifted from 24-25% with the 45% flux to 22-23% with the 56% flux. This phenomenon could be due to any of a number of factors such as mercury concentration, gas evolution rate, nitrite ion destruction, processing dependent dissolution or precipitation of species, particle agglomeration, etc.

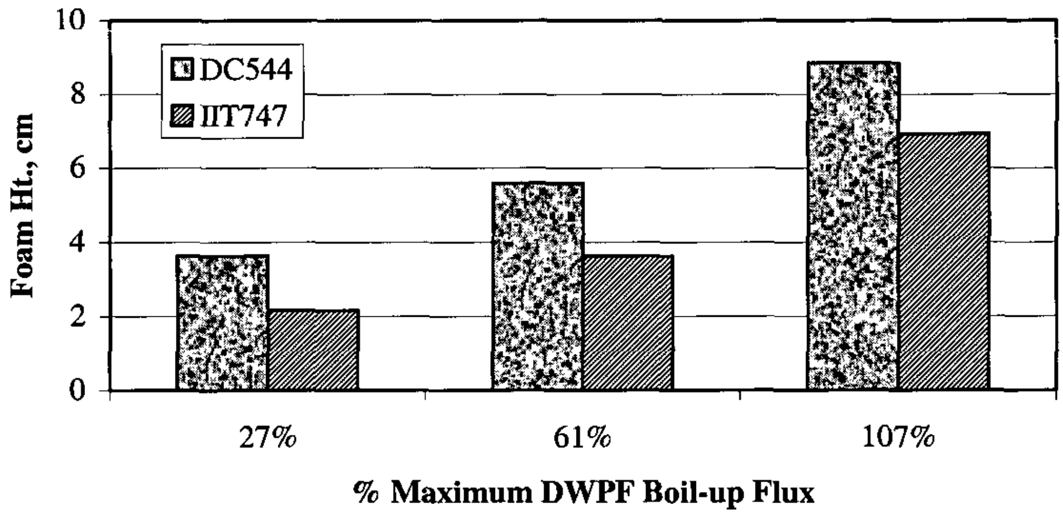
In comparing data for the first and second DC544 tests at 61% of the maximum DWPF boil-up flux, the foam height has decreased from ~36 cm to 14 cm upon concentration, i.e. the maximum foam height must fall at a wt. % total solids less than 21.4. Note that at no time in the experiments was foam height observed to decrease as boil-up flux increased at constant wt. % total solids and processing time. There were, however, one or two instances where increasing the boil-up flux did not appear to cause a detectable increase in the foam height. The above data strongly suggests that the wt. % total solids giving maximum foaminess in the simulant system does depend on the boil-up flux.

SME Foam Tests

Foam tests in the SME cycle were conducted after the first frit addition, after concentration following the first frit addition, and after the second frit addition. Foaming was effectively controlled by 100 mg/kg slurry concentrations of both antifoams during the SME cycle. Foam heights rarely exceeded 8 cm.

The total solids concentration in the SME following the first frit addition was about 28%. Fresh antifoam was always added after this frit addition. The initial SME cycle foam tests (sixth overall foam tests) with each antifoam were performed at this point in the cycle. Figure 10 presents the foam height data at 27%, 61%, and 107% of the DWPF maximum boil-up flux. The total solids content in these two tests is very similar to the solids concentration in SRAT Foam Test #3. The system volume was quite a bit larger than at the end of the SRAT cycle, however, about 41% more by mass, following frit addition. The physical nature of the solids also changed dramatically once frit was added. The solids became larger on average and the ratio of soluble to insoluble solids fell. This combination of factors led to a significant reduction in observed foam height at all fluxes versus those in SRAT Foam Test #3. This tends to confirm IIT observations that foam height is enhanced by the small particles in the system.

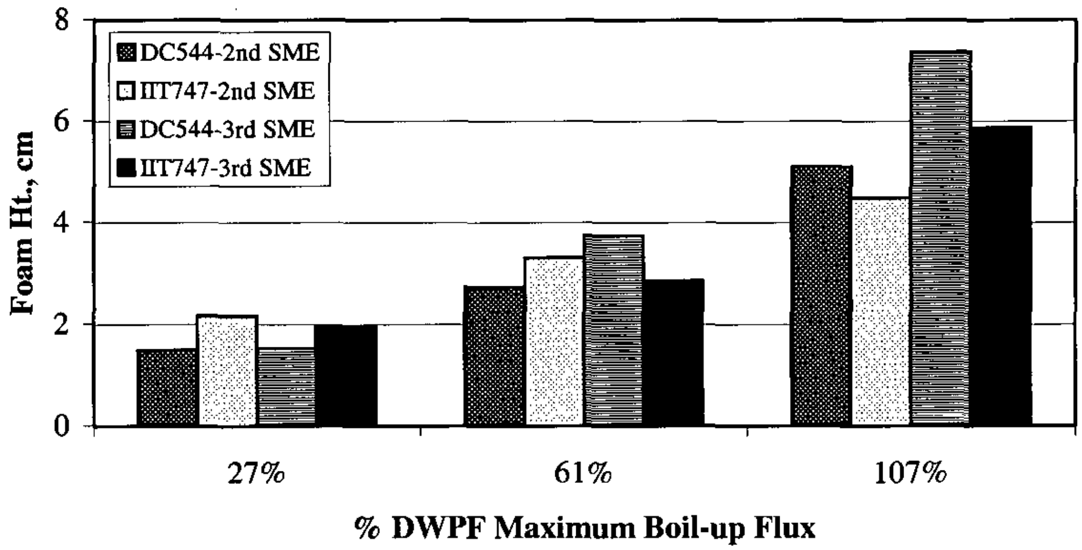
Figure 10. Initial SME Foam Test



After the initial SME foam test, the slurry was concentrated to a total solids concentration of about 39 wt. %. A second SME foam test with both DC544 and IIT747 was performed. The net composition of frit-water-formic acid slurry happens to be about 35 wt. % total solids, i.e. nearly the same as the SME slurry. Consequently, after making the second frit addition, the total solids concentration only dropped to about 38% (nearly the same as before the addition). The third SME cycle foam tests were then performed. The average size of the particles and the ratio of insoluble to soluble solids both increased from the second to the third SME cycle foam tests.

Figure 11 presents the results from both pairs of SME cycle foam tests at 38-39 wt. % total solids. Foaming was being effectively controlled in all tests. Minimum uncertainty in the foam height calculation should be taken as about ±1-2 cm when comparing between different tests (due to inherent problems in determining the baseline liquid level). Within a given test at three fluxes, the uncertainty in comparing is much less, however, since all foam heights assume the same baseline position. Consequently, it would be legitimate to say the foam height increased with increasing flux. It would not be legitimate to say that the third SME test with Dow Corning 544 antifoam had more foam then the second SME test at 61% flux. The 0.6 cm difference contains too much uncertainty.

Figure 11. SME Foam Tests at 38-39 wt. % Solids



A fourth test with IIT747 was made at the end of the SME cycle at 61% and 107% of the DWPF maximum boil-up flux (about 47 wt. % total solids). Foam heights were 2.8 ± 0.5 and 7.6 ± 0.5 cm respectively, i.e. similar to the other SME data with IIT747. Concentration period foam height data taken between the above SME pseudo-steady state foam tests have shown almost as large an uncertainty as foam height, but regress with small negative slopes suggesting that the foam height is decreasing with increasing wt. % total solids and/or processing time.

Mercury Effects

The SRAT was charged with 188.6 g of mercury in the form of HgO prior to each run (0.15 wt. % in the slurry following acid addition). Mercury oxide appeared to reduce to elemental mercury during formic acid addition (second acid added) at 93°C early in the SRAT cycle. A gray film formed on top of the SRAT contents near the end of formic acid addition. This film is believed to be rich in mercury. This film disappears during the first few hours of boiling under the testing conditions, i.e. was nearly gone before the second SRAT cycle foam test in all test runs. Colloidal mercury droplets could easily enhance the foaminess of the SRAT, and there is new visual evidence that something is present. The marked superiority of the IIT747 antifoam to the Dow Corning antifoam, when the SRAT first goes to boiling, may be due to differences in their relative effectiveness in mitigating a mercury-rich foam (rather than a sludge-rich foam).

CONCLUSIONS

It is recommended that DWPF seriously consider switching to IIT747 antifoam once a suitable supply source has been identified. This recommendation is conditional, since there are several unresolved issues at this time. These include the effective lifetime of the antifoam, both in simulated waste and in real waste; the effect of radiation on the performance of the antifoam; and the effect of differences in rheological properties between the simulated and real waste on the foam height.

The IIT747 antifoam is significantly superior to Dow Corning 544 antifoam when it matters the most, i.e. at the onset of SRAT boiling following acid addition (lowest wt. % total solids or SRAT Foam Test #1 conditions). This situation coincides with the maximum liquid level in the full-scale DWPF SRAT and the corresponding smallest vapor space. At other times in both the SRAT and SME cycles the IIT747 antifoam appears to be comparable in its ability to control foaming to Dow Corning 544 antifoam. IIT747 antifoam does not always control foam height at a lower number than Dow Corning 544 antifoam, but the foam heights are, at worst, similar. IIT747 antifoam is also capable of collapsing foams that have already formed.

The effective processing lifetime of a 100 mg/kg addition of IIT747 antifoam will probably exceed ten hours in DWPF. The data suggest that there might be a detectable drop in the effectiveness of the antifoam by the seventh hour of boiling in the SRAT cycle, but the antifoam was still sufficiently effective to prevent a foam over. Further tests should be run with the primary goal of establishing the effective lifetime of various charges of IIT747 antifoam.

The SRAT appears to become intrinsically less foamy as the chemical reactions go to completion. The SRAT conditions giving rise to maximum foaminess coincide with high boil-up flux and low wt. % total solids when Dow Corning 544 antifoam is used. The SRAT conditions giving rise to maximum foaminess are high boil-up flux and intermediate wt. % total solids when IIT747 antifoam is used.