Final Report: ScaleBlaster Test

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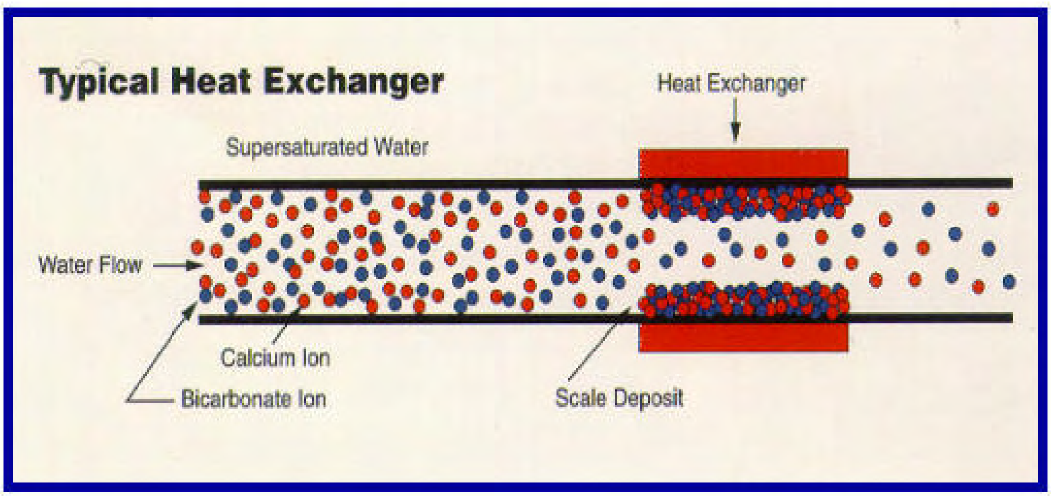
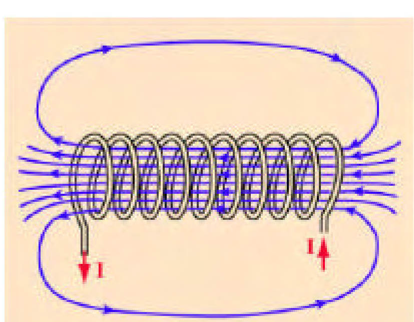
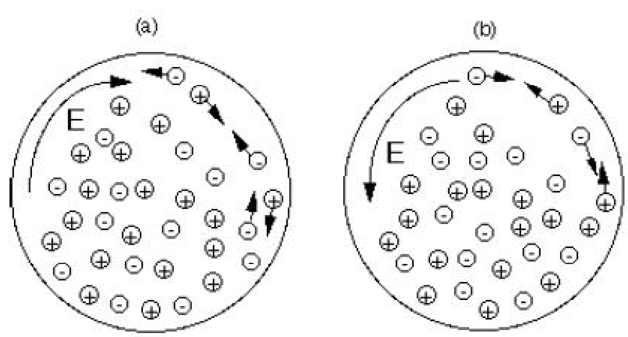
OVERVIEW OF SCALE BLASTER TECHNOLOGY

In the case of untreated water used for industrial purposes, precipitation and scale formation occur directly on heat transfer surfaces. This is a result the inverse solubility of $CaCO_3$ as a function of temperature. Particle growth is more pronounced in the proximity of or inside heat transfer equipment because of the solubility of these mineral ions decreases as a function of increased temperature.



In the Scale Blaster, induced electric fields are oriented with the pipe cross-section, i.e., normal to the magnetic fields that are oriented along the length of the pipe (see figure below).





Because the induced electric fields are changing direction at the frequency of the alternating current flowing through the coil wire, the positively and negatively charged ions experience a “clothes washer effect” of being pushed one way then the next. Because positively charged calcium ions and negatively charged carbonate ions are compelled to move in opposite directions with every pulse of the AC signal, the probability of collision and precipitation is said to increase significantly. This molecular agitation by induced electric fields is at the heart of the Scale Blaster’s application and water treatment. For the Scale Blaster to produce alternating electrical fields and molecular agitation, the two ends of the coil wire are simply connected to an electronic control unit. The coil should ideally be wrapped over any non-ferrous metal or plastic pipe, although CET has documented successful applications over some ferrous pipe as well. The electric field induced by the solenoid coil is present inside the pipe, without necessarily any need to cut the water-bearing pipe. The induced pulsating electric field is generated inside the pipe by Faraday’s Law:

$$\int E \cdot dS = -\frac{\partial}{\partial t}\int B \cdot dA$$

where E [V/m] is an induced electric field vector, S is a line vector along the circumferential direction, B [Wb/m^2] is a magnetic field strength vector, and A is the cross sectional area of the solenoid coil. The magnitude of induced electric field by a solenoid coil via Faraday’s Law was approximately 0.1-0.2 V/m. A sine wave signal, square wave signal or other alternating current signal must be generated by the control unit and driven through the cylindrically wrapped coil wire in order for the Scale Blaster coil to work. The control unit uses a variable, sweeping frequency, however it is important to note that if the frequency is pushed higher than 2,000 Hz, the pulse signal can degenerate into noise because the self-induction increases with the frequency.

The Scale Blaster forces scale particles to precipitate in the bulk water in the form of particulate fouling, whereas without treatment, scale precipitation occurs directly on the heat transfer surfaces. Mineral fouling in the latter case forms calcite structures which are hardened by the application of heat. In the case of the Scale Blaster on the other hand, after $CaCO_3$ particles are produced in the bulk water, they cluster and grow in size.

PROJECT OBJECTIVES

The objective of the project was to test and evaluate the efficacy of the CET Scale Blaster unit in preventing mineral fouling using the ASHRAE protocol in a lab-scale cooling tower application. The goal of the PWT Center was to evaluate the performance of the Scale Blaster unit using water analyses, fouling resistance calculations, time-history photos, laser particle counts and scanning electron microscopy (SEM).

PROJECT DELIVERABLES

The following deliverables were noted in the proposal for this project dated December 8, 2004:

- Fouling resistance over time with each case
- Conductivity data over time

- Water analyses
- Laser particle count
- SEM analysis
- Time-history photos
- Discussion and conclusion

SCALE BLASTER TECHNICAL PERFORMANCE

Comparison of fouling resistances over time between the Baseline and Scale Blaster test runs revealed a dramatic difference between the behavior of the Scale Blaster and no-treatment. Under rigorous conditions and a controlled environment, the Scale Blaster effectively demonstrated that it prevented mineral fouling from occuring on a heat exchanger. Fouling was controlled by the Scale Blaster on the heat exchanger to a near-negligible level in this lab study. This heat exchanger, implemented in a lab-scale cooling tower test system using the ASHRAE protocol, simulated condenser tubes in a chiller attached to a cooling tower for HVAC or process cooling applications.

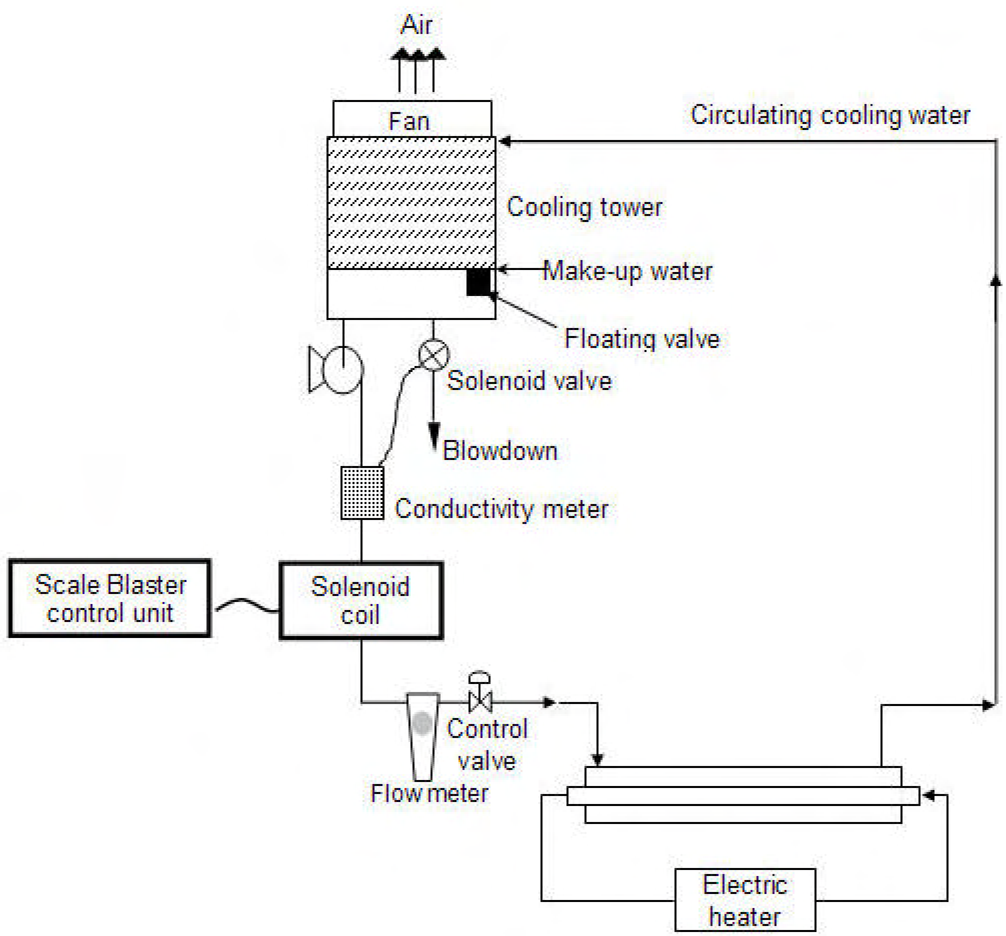
The fact that water analyses showed virtually no significant chemistry differences between the Baseline and Scale Blaster runs confirmed the mechanism of action of solenoid-coil-type PWT systems. The water chemistry was not significantly altered by the Scale Blaster. Rather calcium carbonate dissolved in solution was precipitated by the electric fields and forced into suspension as particulate matter.

The laser particle count analysis, among the first of its kind for such a laboratory cooling tower PWT study, provided strong validation of the mechanism of action of the Scale Blaster, along with strong confirmation of the Scale Blaster's high level of efficacy.

Time-history photos provided a good naked-eye confirmation of Scale Blaster performance. SEM photography showed what appeared to be calcite formation on the Baseline test and a uniform layer of colloidal particles on the Scale Blaster test, which would be as expected. However the SEM photos were not conclusive.

System Schematic

The following is a block-diagram of the laboratory-scale cooling tower that was used for this study. This system utilizes an electric heater to heat glycol (simulating hot water) in the inner tube of a simple, copper tube-in-tube heat exchanger. Room-temperature water on the outside of the tube-in-tube heat exchanger served as circulating cooling water flowing through the cooling tower. A PC-based, real-time data acquisition system was used to measure four temperatures at the hot and cold inlet and outlet of the test heat exchanger. This data was used to determine the fouling resistance, or fouling on the test heat exchanger.



This system deviated from the ASHRAE protocol in that a tube-in-tube heat exchanger was used instead of a flat plate heat exchanger as in the case of the ASHRAE protocol.

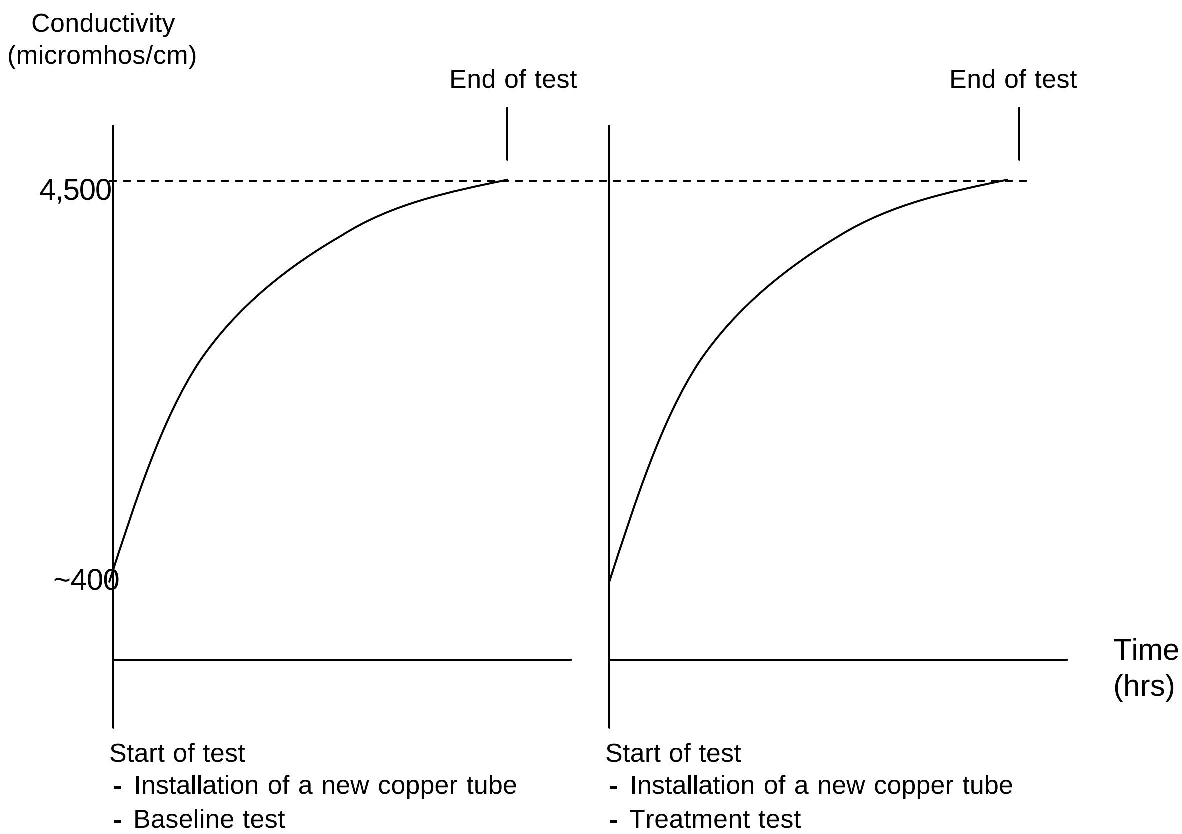
Test Procedures

- Test Conditions
- Conductivity Regime
- Procedures

TEST CONDITIONS

1. The flow rate of cooling water was set to be 2 gpm.
2. The velocity of cooling water across the test heat exchanger was 1.08 m/s.
3. The system was cleaned by thorough chlorination and rinsing prior to each test.
4. Hot side was set at 100°C, and cooling inlet temperature was about 24°C.
5. To eliminate biofouling as a variable, biocide glutaraldehyde was added periodically.

CONDUCTIVITY REGIME



The above figure represents the electric conductivity regime utilized for this test. This study was a “no-blowdown” test, which provided a more aggressive water chemistry than using conductivity setpoints. Well-water in Phoenixville, Pennsylvania had a conductivity of between 400-450 micromhos/cm, and through evaporation, was cycled up to 10. Bio-control was conducted by adding 0.5 ounces of 15% glutaraldehyde solution into 10 gallons sump water daily.

PROCEDURES

Baseline and Scale Blaster tests were planned for this project. Four weeks were allotted for each test run. Actual testing time was 11-12 days, however additional time was provided for setup and maintenance of the cooling tower rig, as well as data analysis. In this study, re-tests were necessary in the case of the Scale Blaster run.

Before each test run, the cooling tower was physically cleaned with a high-powered pressure washer and brushes, then drained and evacuated using a large vacuum. Chlorinated water was then run through the heat exchanger tubes and cooling tower (approx 5 ppm chlorine for 4 hours). The system was then drained, flushed and drained again.

Operationally, no blowdown system or conductivity setpoint was utilized for this study. This was to provide more aggressive fouling conditions and examine the Scale Blaster’s performance more aggressively. When the Baseline fouling resistance reached an asymptotic value (i.e., the test section was severely fouled), the baseline test was deemed finished. This occurred as expected within the 8-14 day expected timeframe, in this case, after 11 days.

Flow velocity was set at 3 ft/sec. A chemical biocide (glutaraldehyde) was used for all tests in order to isolate the mineral fouling effect from biofouling. One (1) ounce of 15% glutaraldehyde solution was deposited into the sump, using a graduated syringe, every 48 hours. Water conductivity and fouling resistance was measured throughout each run using a real-time data acquisition system connected to a PC. Time-history photos were taken using a digital camera. Laser particle counts measuring the number of particles from 0.5-100 micron in diameter were performed at the beginning and end of runs, as well as twice during testing. SEM analyses were performed on the deposits.

Between the Baseline and Scale Blaster tests, a clean copper tube was installed in the heat transfer test section, and fresh well water was evaporated and concentrated after system chlorination and cleaning. Flow rate was again set at 3 ft/sec and a biocide used during the test. All criteria and test parameters were identical to the Baseline run.

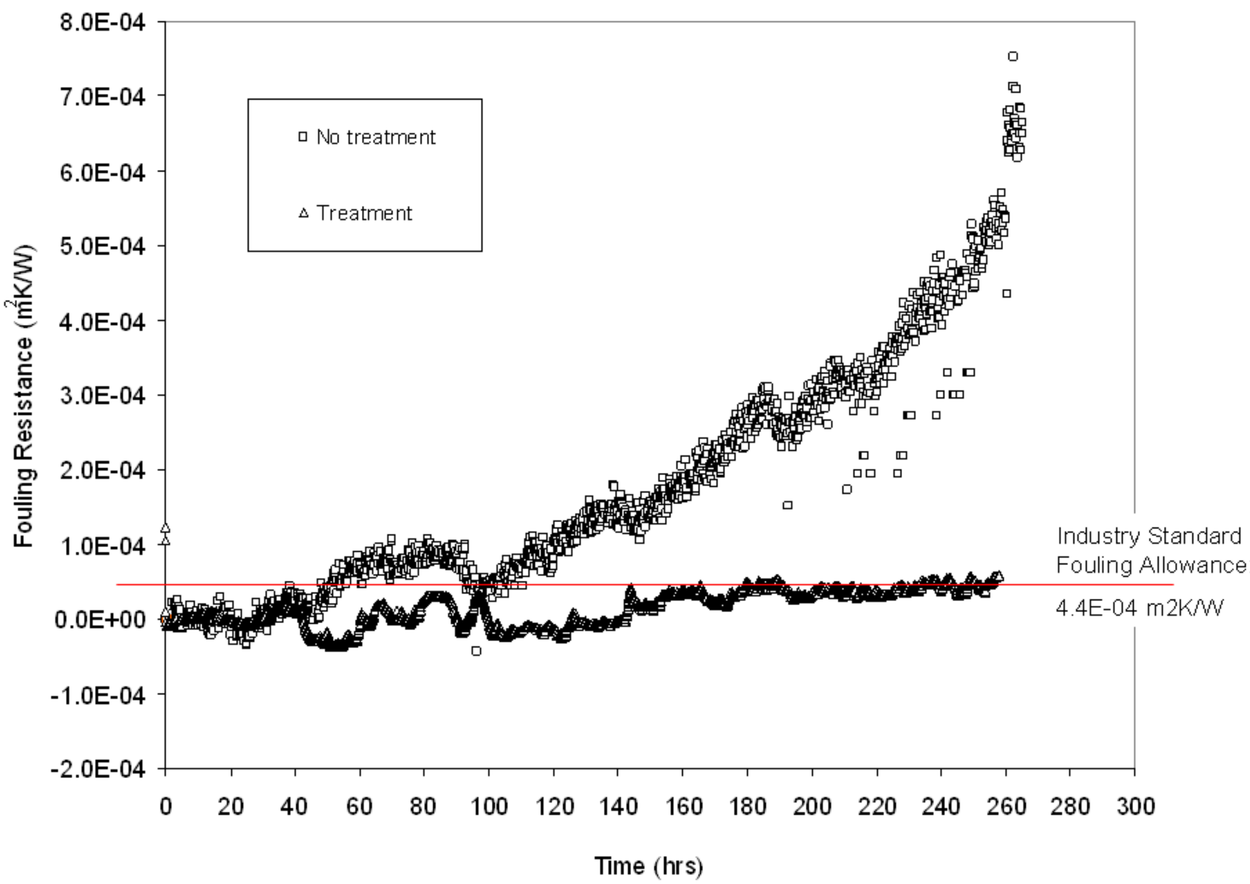
Water Analyses

The table below describes the results of water chemistry analysis for makeup (supply) water used at the beginning of the runs, and Baseline and Scale Blaster test water collected from the end of each test run:

	Makeup	Baseline	Scale Blaster
Total alkalinity (ppm)	120	260	240
Chloride (ppm)	125	1240	1320
Total hardness (ppm)	190	1720	1680
Calcium (ppm)	170	1360	1240
Magnesium (ppm)	20	360	440
pH	6.8	6.9	7.2
Conductivity (micromhos/cm)	445	4600	4550

Fouling Results

The figure below provides key data for fouling resistance over time for both the Baseline test and Scale Blaster test. The Baseline fouling curve shows a continuous increase with time, whereas the Scale Blaster test maintains a lower level of fouling resistance with a very slow increase.



After 11 days, the Baseline test achieved asymptotic values of fouling resistance, whereas the Scale Blaster was able to keep the fouling resistance at below the industry-standard clean values, approximately zero or negligible fouling after the same amount of time as the Baseline and all other conditions held equal.

Laser Particle Count Results

- Overview
- Raw Data
- Analysis of Data

OVERVIEW

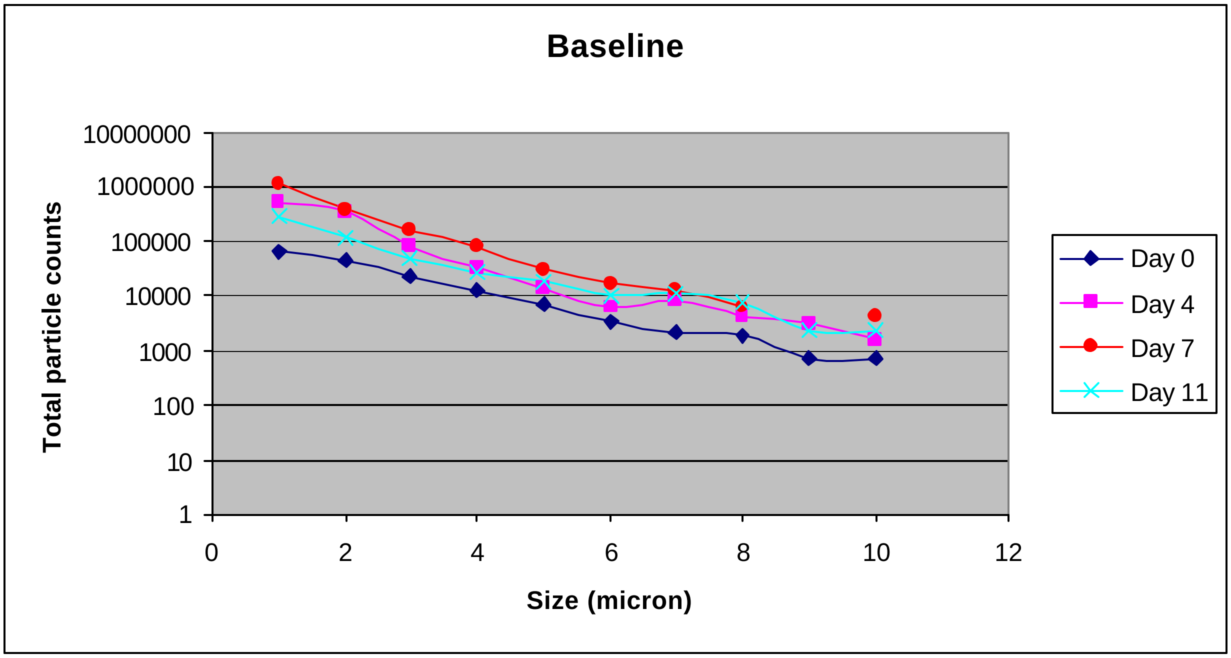
The PWT Center outsourced laser particle counts to an outside firm. Water samples were collected in pre-purchased sampling bottles and delivered to the vendor by overnight delivery. Data was emailed by the morning of the following day.

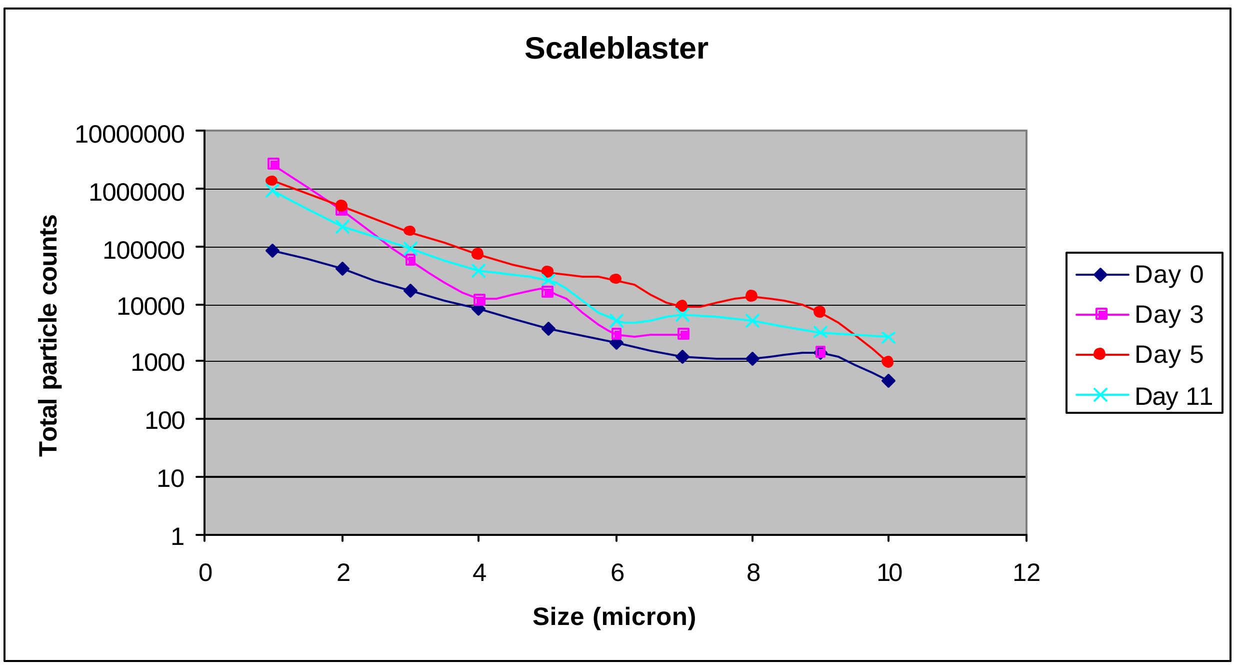
Laser particle counts were performed four times during each test run. Particles of 0.5-100 microns in size were counted. The "near angle light scatter" method was used for laser particle count, passing a revolving laser beam through the walls of a chamber holding water. The analog signals generated by the laser pulses were then routed to a computer and digitized. The number as well as size of the particles in suspension were counted.

RAW DATA

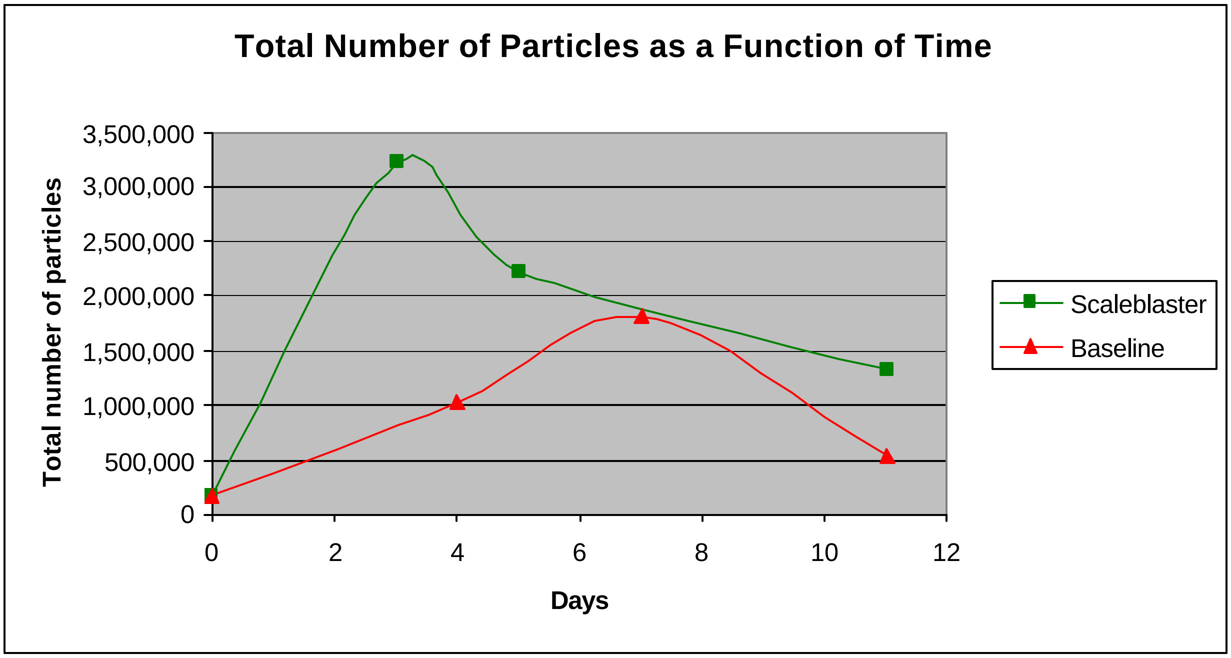
The raw data for laser particle counts provided the size and number of particles. Nearly all of the particles were in the range of 0.5-10 microns in size and which was the focus of this study. The raw data for the laser particle counts below show four separate curves representing four particle count tests for each run. In the case of the Baseline test run, the number of particles increased from the first test at Day 0 (dark blue curve), to Day 4 (purple curve), to Day 7 (red curve), to Day 11 (light blue curve). The same was true for the Scale Blaster test.

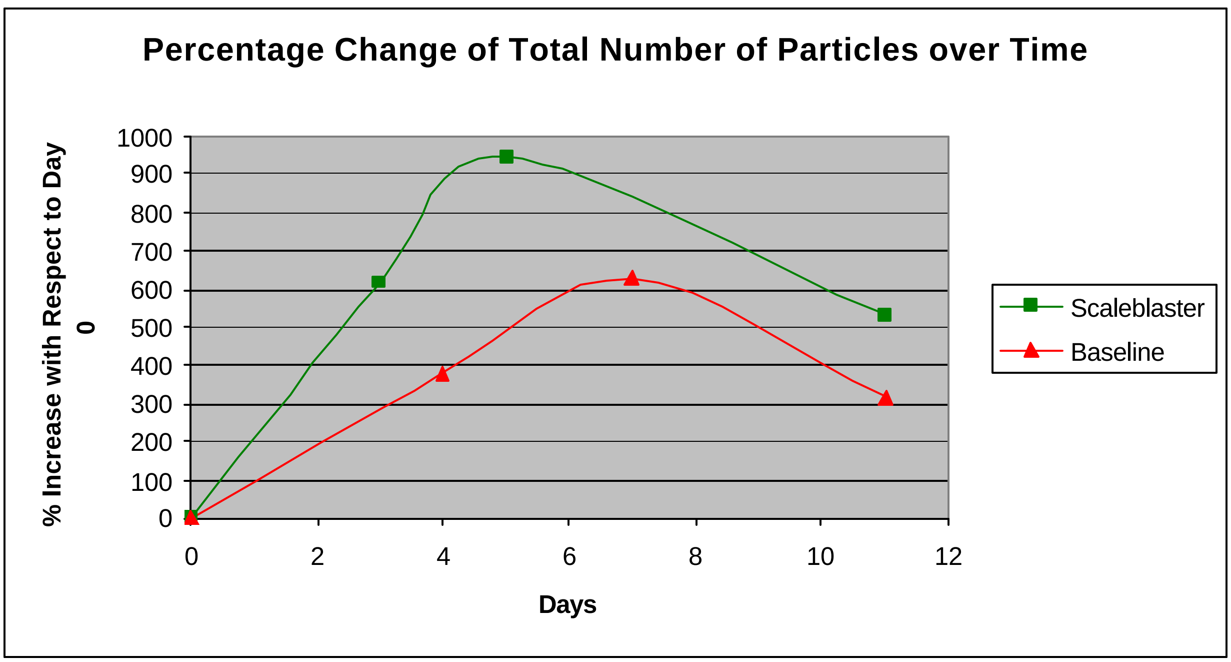
The general trend obs erved was that the overall number of particles increased from the beginning of each test to the middle part of each test, after which the number of particles started to taper off and fall. The raw data is accordance with what might be expected under conditions where conductivity was rising quickly from 400 to 4000 micromhos/cm in a cooling tower system. More particles were observed to be formed with time because of higher mineral concentrations over time.


Baseline
Total particle counts
10000000
1000000
100000
10000
1000
100
10
1
0
2
4
6
8
10
12
Size (micron)
Day 0
Day 4
Day 7
Day 11


Scaleblaster
Total particle counts
10000000
1000000
100000
10000
1000
100
10
1
0
2
4
6
8
10
12
Size (micron)
Day 0
Day 3
Day 5
Day 11

ANALYSIS OF DATA





The two graphs above provide more detailed analyses of the laser particle count data. In the first graph, total number of particles was plotted against time. The second graph shows the percent change of the total number of particles with respect to initial particle count at Day 0. Total number of particles was determined by adding up the number of particles for each size between 0.5 and 10 microns, each in 1-micron increments. The Scale Blaster generated a dramatically higher overall number of particles than the Baseline test, at Day 3, over 300% higher.

However more revealing perhaps is the higher rate of particle formation with respect to initial particle count at Day 0, respectively. The Scale Blaster generated more particles, faster than the Baseline test.

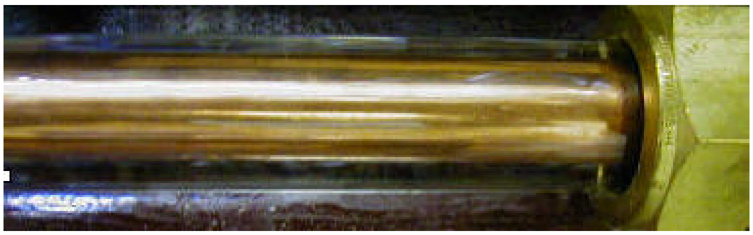
The primary purpose of the laser particle count was to validate or invalidate the mechanism of action of the Scale Blaster (and solenoid coil technologies in general), as bulk precipitation. According to the theory of how the Scale Blaster works (held by the PWT Center and its principals), one would expect to see more particle formation and faster particle formation in the Scale Blaster case, as evidenced by the data above.

Images

- Time-History Photos
- Scanning Electron Microscopy

TIME-HISTORY PHOTOS

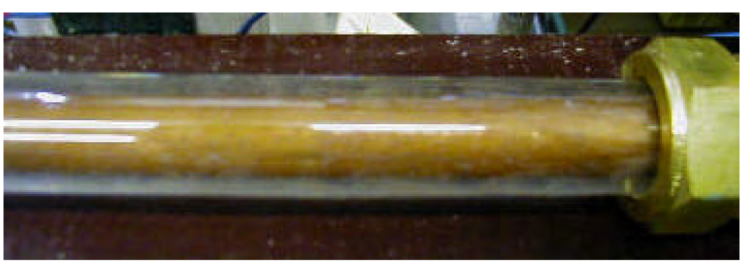
Baseline, Day 0



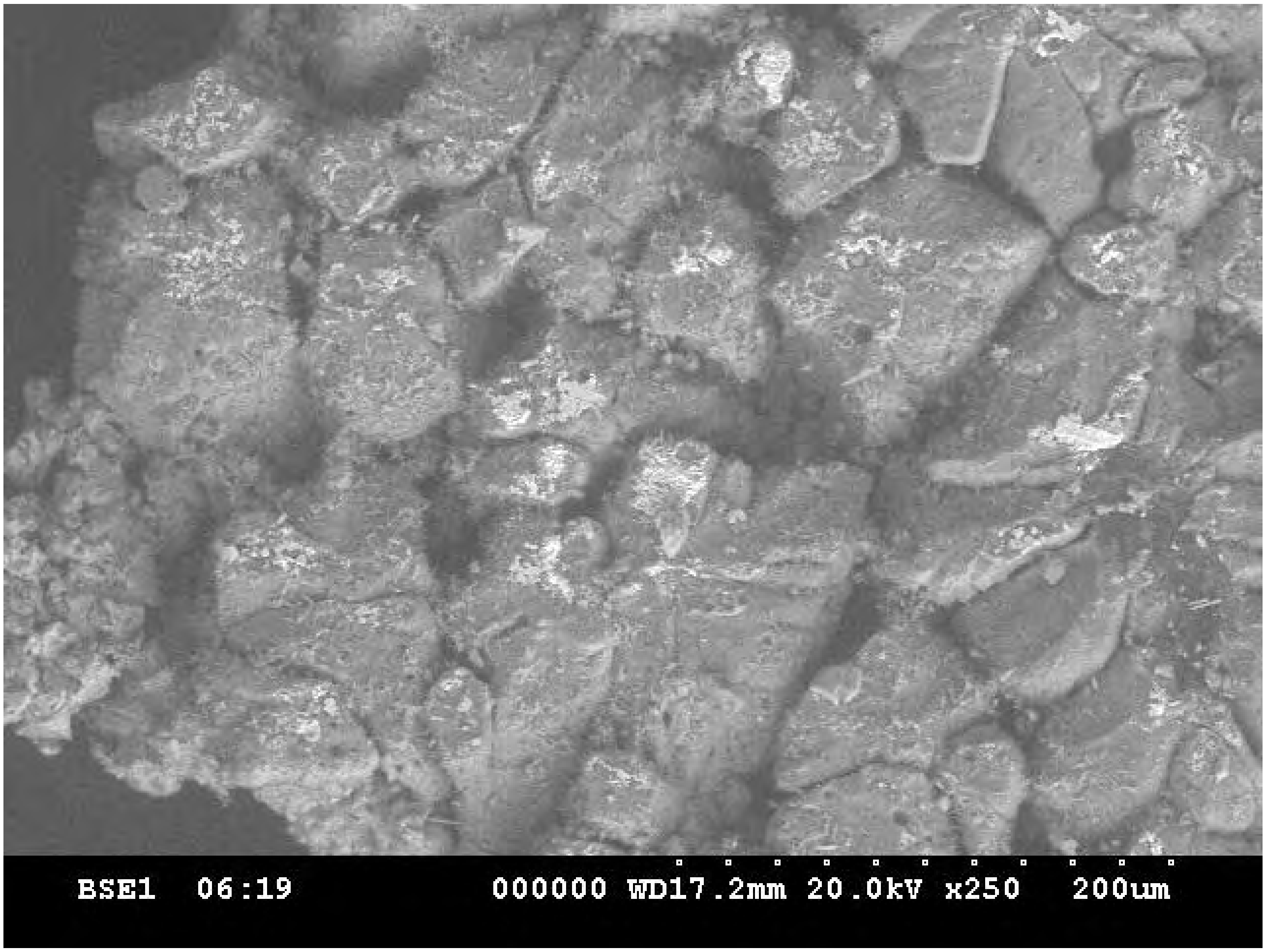
Baseline, Day 11

Scale Blaster, Day 0

Scale Blaster, Day 11



SCANNING ELECTRON MICROSCOPY



The above image was taken of dried deposits of Baseline test deposition using an SEM camera at 250x magnification. The image of scale seen is typical calcite formation having the granular composition of crystallization fouling.

The below image was taken of whitish deposits dried and collected from the surface of the Scale Blaster test heat exchanger. The 250x SEM photo appears to show one uniform scale layer comprised of colloidal particles that have settled onto pipe surface, which would reflect bulk particulate fouling caused by the solenoid coil, rather than crystallization fouling in the case of no treatment.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