Thermal Storage Workshop for Parabolic Trough Power Systems

Testing Thermocline Filler Materials for Parabolic Trough Thermal Energy Storage Systems

February 20, 2003

Doug Brosseau
Senior Member of Technical Staff
National Solar Thermal Test Facility

DOE insignia and the acknowledgement statement MUST be used on the title slide of all presentation material distribute outside of Sandia.

Sandia is a multiprogram laboratory operated by Sandia Corporation, a Lockheed Martin Company, for the United States Department of Energy under contract DE-AC04-94AL85000.

Sandia National Laboratories

Thermocline Filler Material Testing

Premises

- **Integration of thermal energy storage will enhance dispatchability and value of parabolic trough solar energy systems**

- **Direct energy storage utilizing thermocline storage concepts appears to be the least cost option (per numerous studies by Flabeg Solar International, Kearney & Associates, NREL, Nexant, and Sandia)**

Sandia National Laboratories

Thermocline Filler Material Testing

Background Studies

- **Thermocline energy storage using molten nitrate salt as the direct heat transfer fluid, along with low-cost filler materials, was considered a feasible option in small-scale tests at Sandia**

- **Screening studies have been conducted to select candidate filler materials, and initial isothermal and thermal cycling tests have shown that quartzite rock in combination with silica sand appear compatible with nitrate salts, are low in cost, and widely available.**

Objectives

- **Conduct isothermal and thermal cycling tests to determine if the selected thermocline filler materials can withstand elevated temperatures in molten nitrate salts without decomposition.**

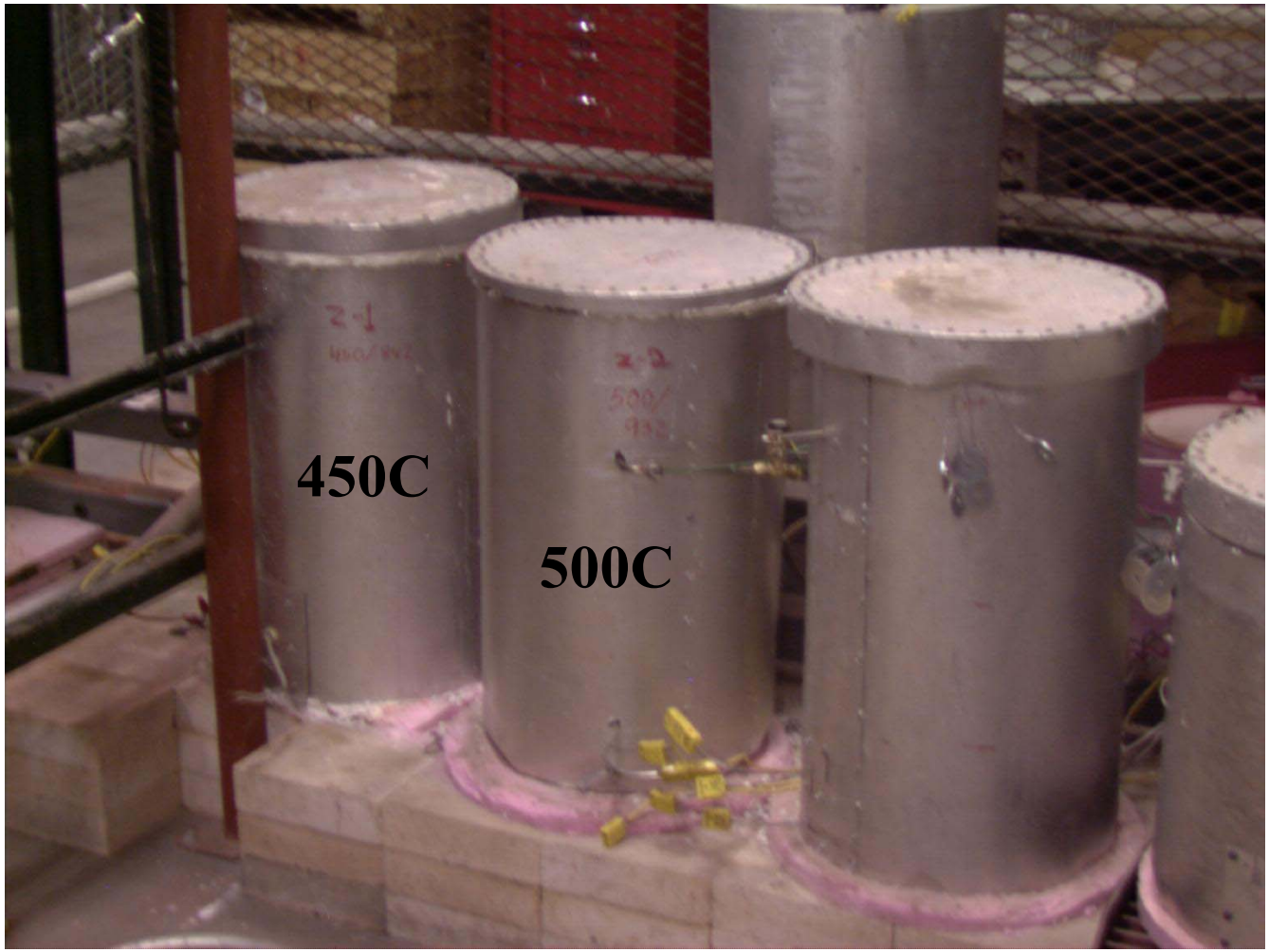
- **Consistent with industry trade studies, conduct tests and document experience, observations and results when utilizing a ternary molten salt formulation that offers a relatively low freezing point.**

Test Parameters

Isothermal Tests

- 1-year duration
- Nitrate salt mixture – 44 wt% $CaNO_3$, 12 wt% $NaNO_3$, 44 wt% KNO_3 also known as "HitecXL"
- Quartzite rock and silica sand – selected for testing
- 20 kg dry salt mixed and melted, containing 3 rock/sand sample baskets, at 450ºC.
- A second pot, same salt, identical rock/sand samples, at 500ºC.
- Two additional control pots, molten salt alone, at 450ºC and 500ºC.

Isothermal Apparatus



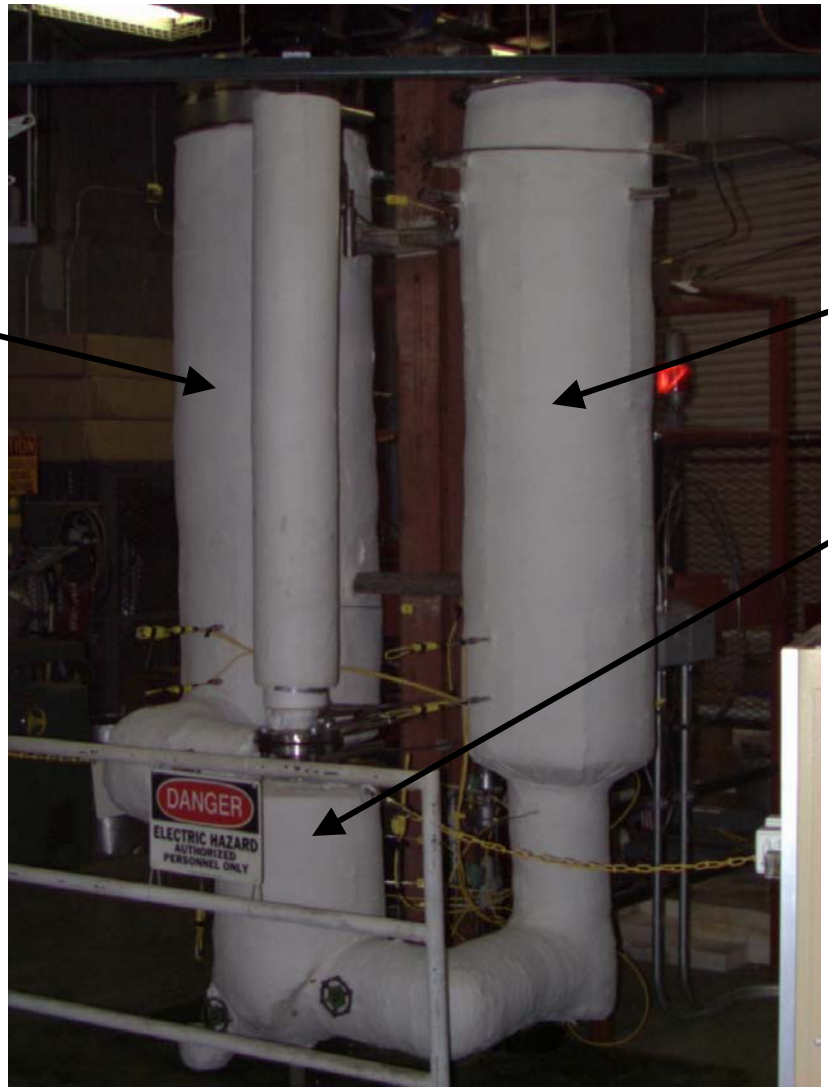
Sandia National Laboratories

Test Parameters

Thermal Cycling

- Test duration approximately 14 months
- 10,000 cycles, simulating about 30 years of day/night thermocline cycling
- 287ºC to 450ºC thermal cycling temperature range
- Each 1-hour cycle consists of a “cold” fill, cold soak, hot fill, and hot soak
- Same ternary molten nitrate salt mixture as isothermal tests
- Test chamber contains 2:1 ratio quartzite rock to silica sand

Thermal Cycling Apparatus



Sandia National Laboratories

Test Chamber – Thermal Cycling

All 316 SS

Test Chamber:

4” dia by 14” high

Sandia National Laboratories

Schedule, Periodic Assessment

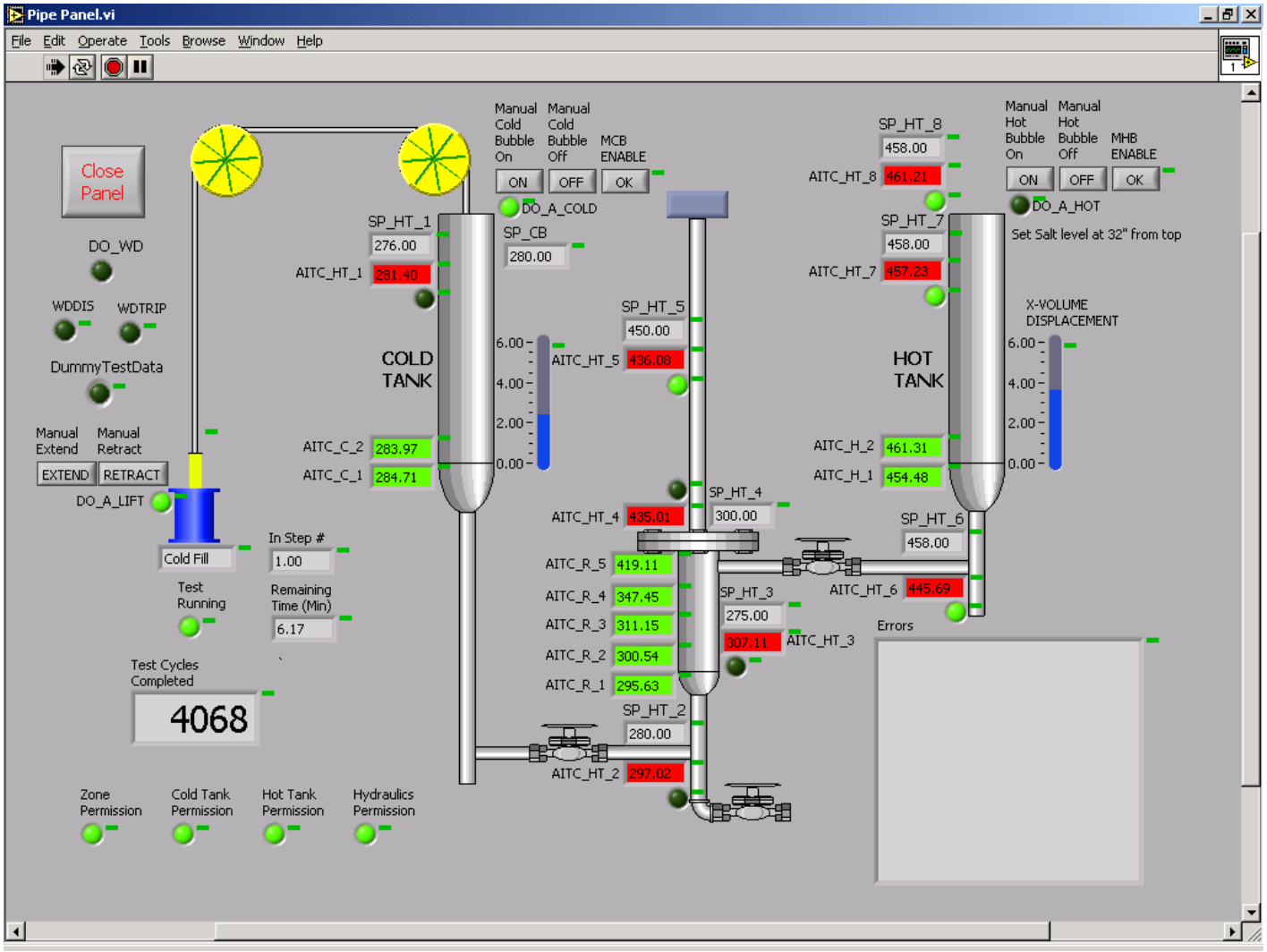
Isothermal

- **Test duration 1-year, completed by end of September 2003**
- **Monthly salt samples from all 4 pots for chemical analysis**
- **Rock/sand sample removal, rinsing, drying, weighing, and observations monthly – will conduct complete end-of-test analysis of filler condition**

Thermal Cycling

- **Test will be completed by early November 2003; 4000 cycles 2/14/2002**
- **Salt samples taken after each 1000 cycles for analysis**
- **Qualitative observations of rock/sand filler materials due to limited ability to shut down apparatus during the full test**
- **Complete end-of-test assessment and analysis of filler materials and salt.**

Pipe Panel



Sandia National Laboratories

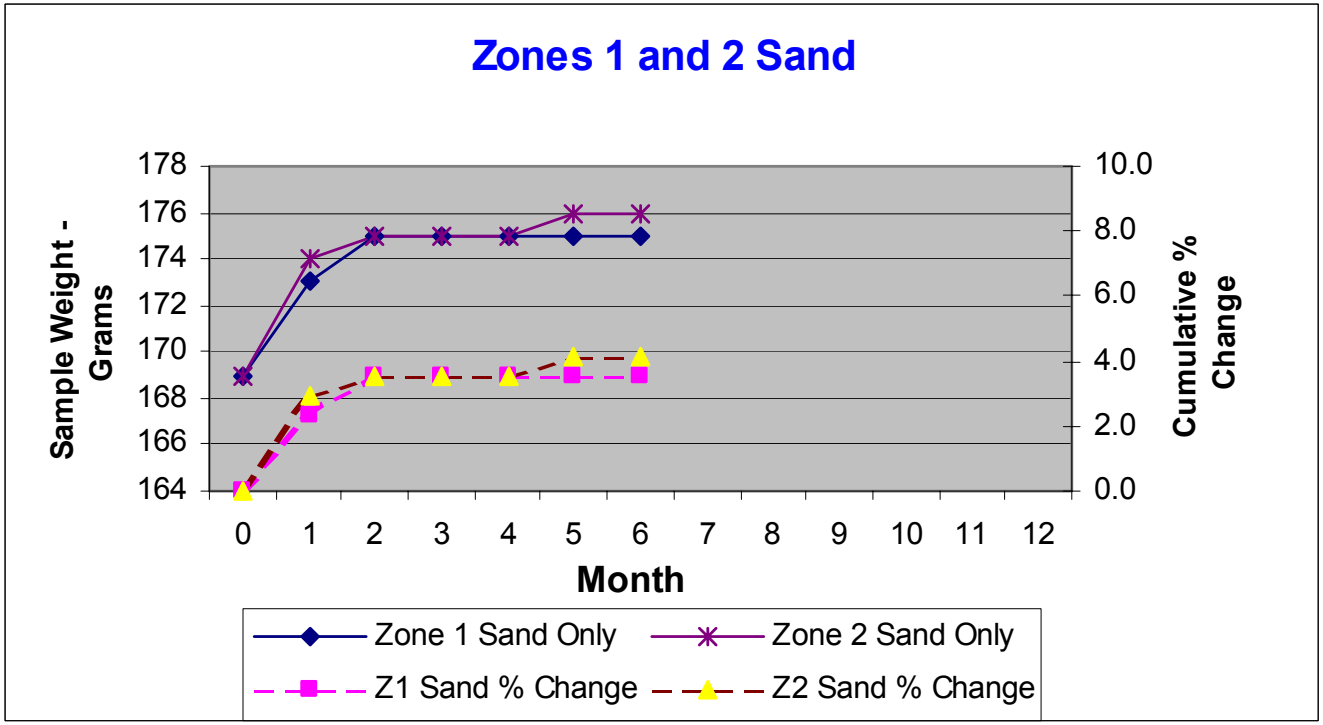
Plots Panel

Sandia National Laboratories

Observations to Date

- No significant operational problems with the test apparatus
- Thus far, quartzite rock and silica sand appear to be holding up quite well, with no significant signs of crumbling or deterioration
- Slight initial sample weight increases (1.5 to 4 percent) have leveled off (see sample plot)

Sample Weight Changes

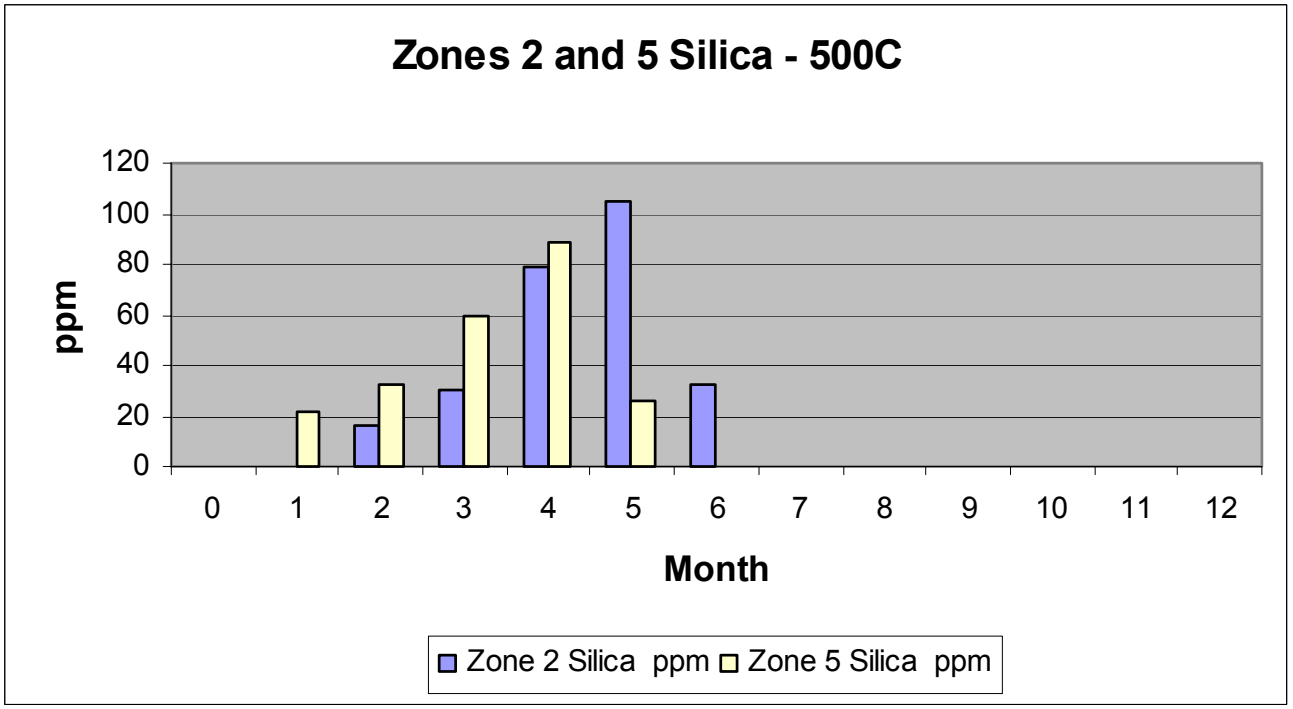


Sandia National Laboratories

Observations - Silica

- **Silica levels have slowly gone up, but are still quite low (see plots).**

Isothermal Silica Changes

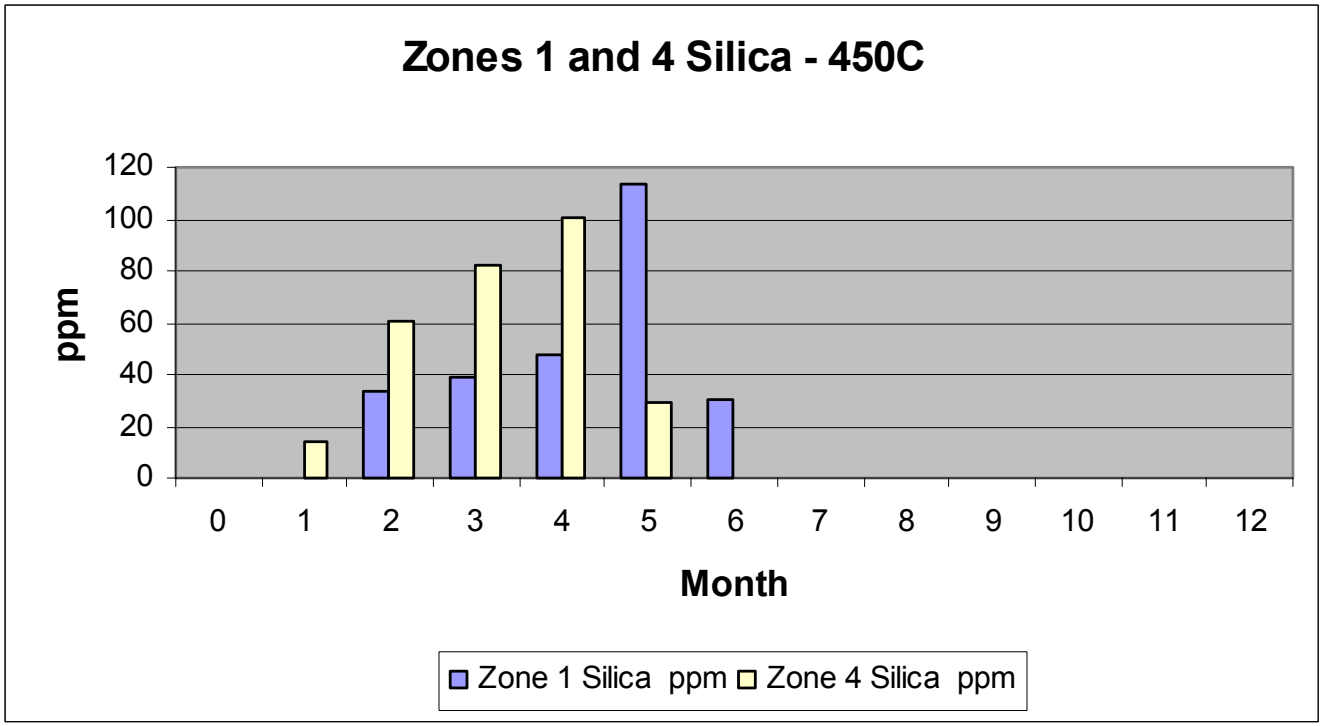


Notes:

1. Zone 2 contains rock/sand; Zone 5 is a control with no rock sand samples
2. Incomplete data, as month 6 chem analyses have not yet been completed.

Sandia National Laboratories

Isothermal Silica Changes

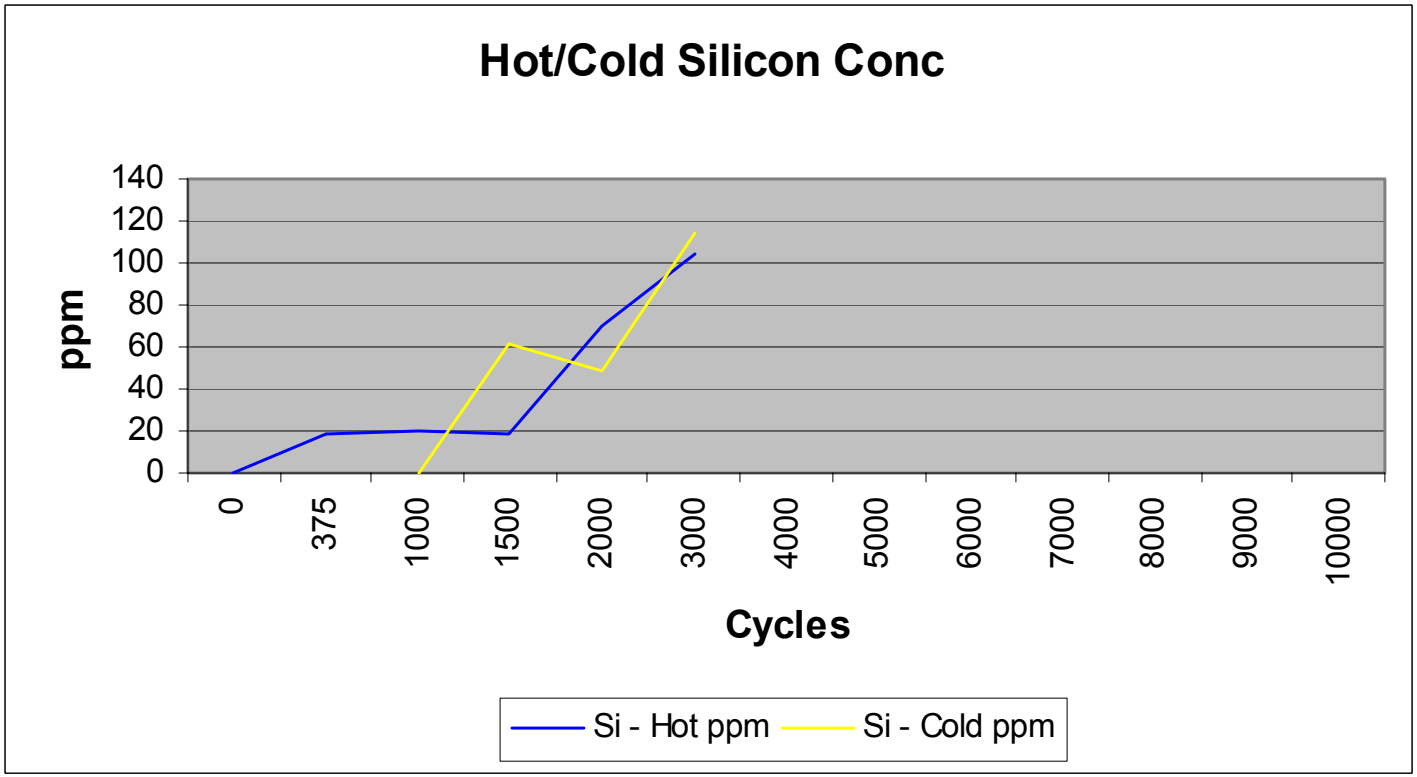


Notes:

1. Zone 1 contains rock/sand; Zone 4 is a control with no rock sand samples
2. Incomplete data, as month 6 chem analyses has not yet been completed.

Sandia National Laboratories

Thermal Cycling Silica Change



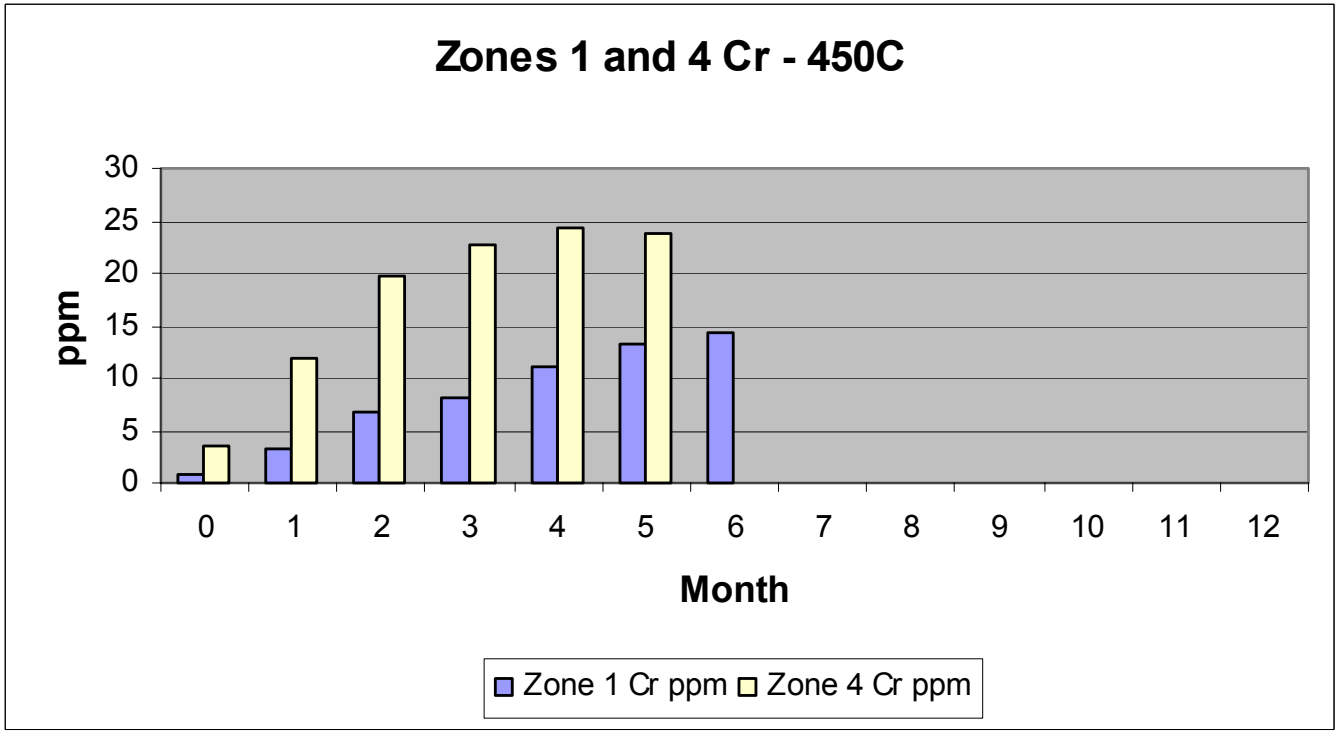
Sandia National Laboratories

Observations – Chromium Changes

- **Chromium levels have increased due to leaching from stainless steel apparatus as well as sample baskets (see plots).**

- **This leaching was particularly evident this past month for Zone 2 samples baskets at 500C, which required replacement.**

Isothermal Chromium Changes

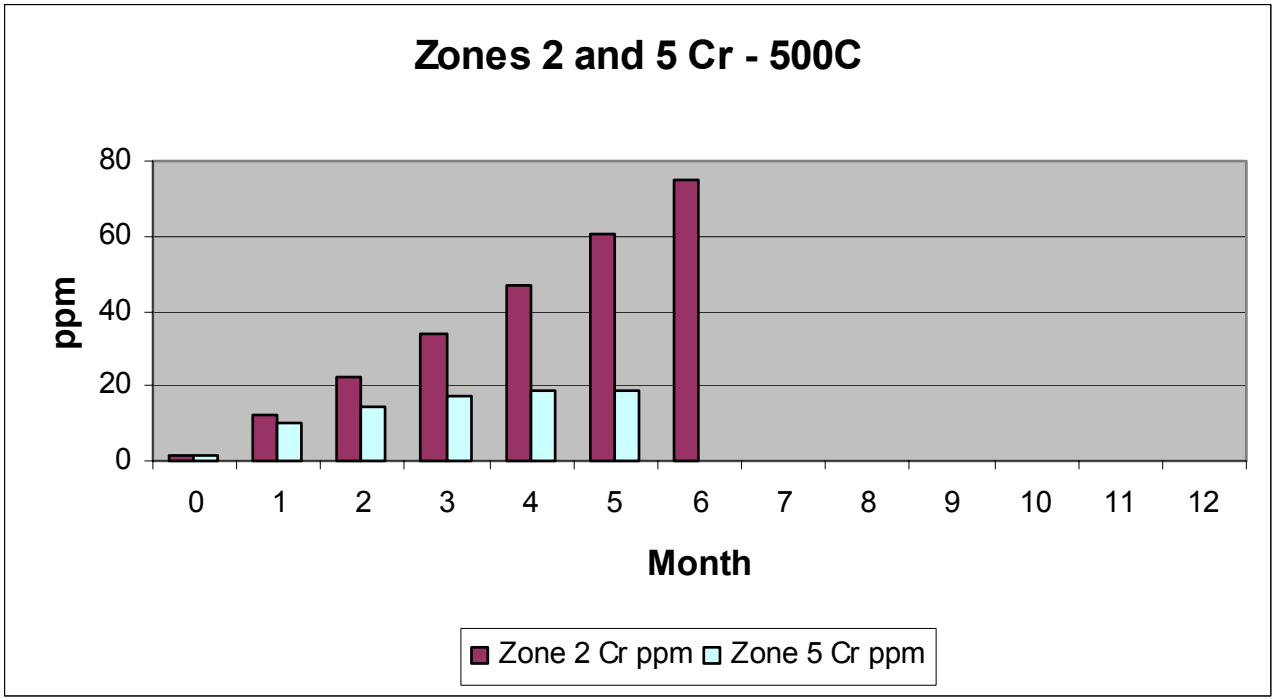


Notes:

1. Zone 1 contains rock/sand; Zone 4 is a control with no rock sand samples
2. Incomplete data, as month 6 chem analyses have not yet been completed.

Sandia National Laboratories

Isothermal Chromium Changes

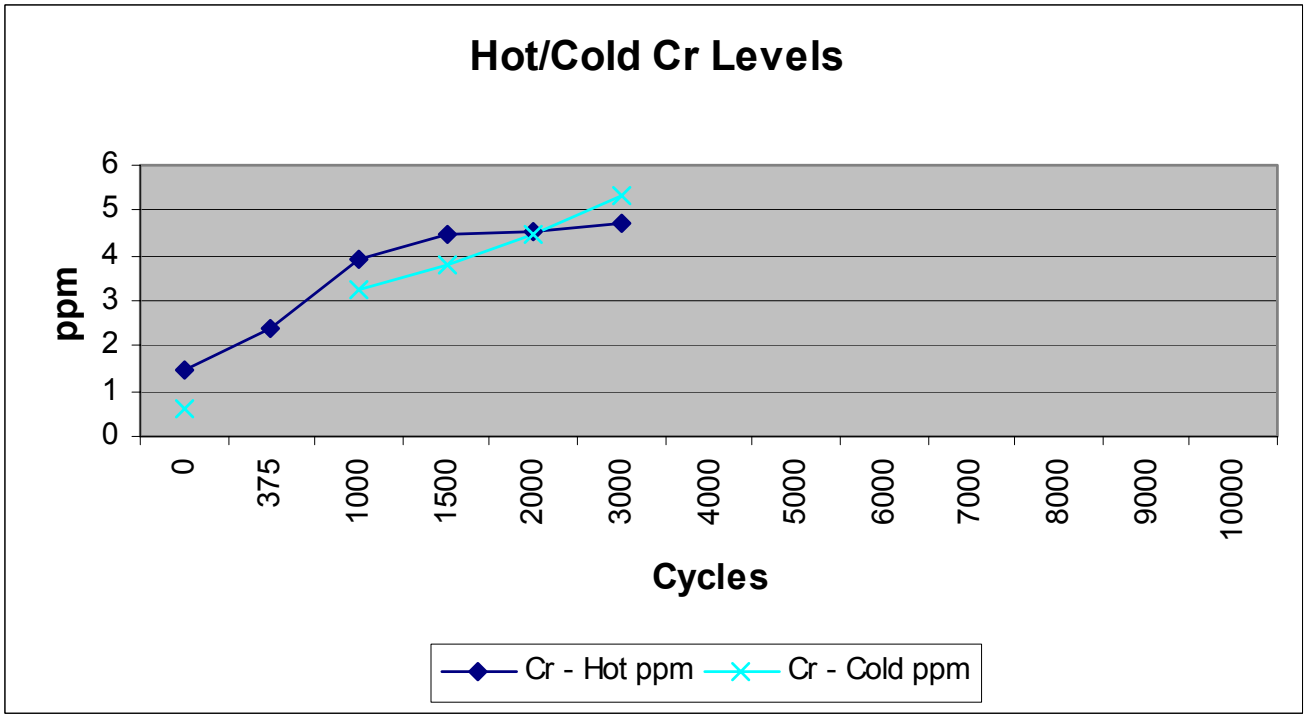


Notes:

1. Zone 2 contains rock/sand; Zone 5 is a control with no rock sand samples
2. Incomplete data, as month 6 chem analyses have not yet been completed.

Sandia National Laboratories

Thermal Cycling Chromium



Sandia National Laboratories

Tentative Conclusions

- **Quartzite rock/silica sand appear to be excellent filler materials, but testing is less than half completed.**
- **There are lessons, and more testing recommended, using the ternary molten salt formulation and understanding its decomposition processes, as well as piping/tank/valve material interactions.**
- **Need more study on nitrate salts, optimum mixtures, engineering properties, freeze/thaw behavior, plus….**
- **Potential long-term, large-scale operational issues that need to be studied. For instance, if the filler materials tend to gain weight/volume in a closed thermocline tank, need to assess the affect on design and operation.**