RF Tests of Chemical Additives for Water Cooled Loads

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Karen Young, Luke Amer, Gerald Bolme, Caroline Bolton,

John Lyles, Phillip Torrez

AOT-RFE Group

Los Alamos National Laboratory

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Acknowledgements

- **This work is based on the work done at DESY from the following paper:**

  M. Ebert, F.R.Ullrich, "*Glycol Substitute for High Power RF Water Loads*", Particle Accelerator Conference, Knoxville, TN, 2005

- **The authors would like to thank Brent W. Chettle, owner and founder of WEST, Inc. of Santa Fe Springs, CA.**
  - Brent has been extremely helpful during these tests and was a consultant for this project.
  - He developed the chemical WEST C-441 for our specific application.

Outline

- Background
- Environmental Considerations
- Experimental Setup
- Experimental Results
- Conclusions
- New Water System Design

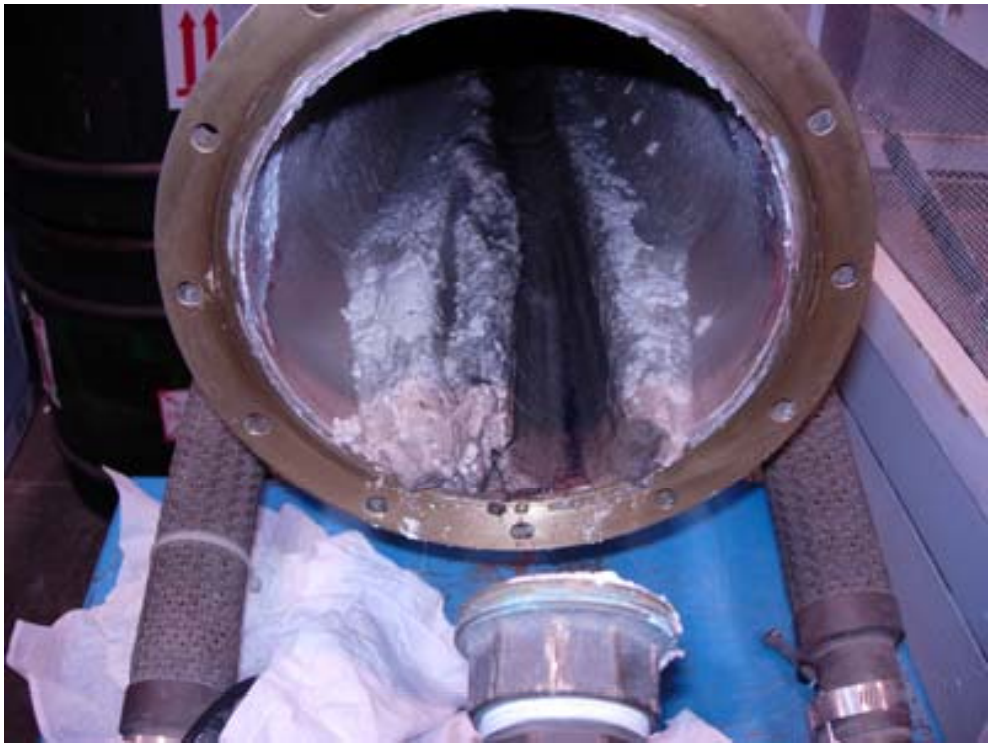
Background – Why can't we use DI water?

- **Demineralized water with a low resistivity can be used in RF loads, but the required length of the load is many wavelengths long. This type of load is used in SPS at 200 MHz.**
- **Ebert and Ullrich measured:**
  - The attenuation constant of pure water is about 17 dB/meter at 500 MHz at 25 Deg C.
  - The attenuation constant of a 30% glycol and 70 % water mixture is about 30 dB/meter at 500 MHz at 25 Deg C.

Background – Evaporative Cooling Towers

- **At LANSCE some 9 inch (22.9 cm) coaxial loads were cooled with water that circulates through an evaporative cooling tower. These loads are 3 MW peak power and 300 kW average power loads.**
- **This water contains many contaminants from the environment because it is openly exposed to air at the cooling tower.**

Background – Sludge Buildup in RF Components



Sludge in the 201 MHz Coaxial Load

- **The containments from the cooling tower ionized the water and made it a good RF absorber.**
- **The disadvantage is that this water is very dirty and a "sludge" builds up in the RF equipment.**
- **The RF equipment has to be cleaned every two years. The cleanings are time consuming and the cleaning abrasives can potentially damage the components.**

Background - Alternatives

- 70 % water and 30% glycol mixture has been used in loads.
  - ➔ but…The water glycol mixture can be difficult and expensive to dispose of because environmental regulations.
- Water ionized by from the evaporative cooling tower has been used in loads.
  - ➔ but…This water builds up a sludge in the RF equipment that needs to be cleaned every two years.
- A 30% soda water mixture has been used in loads by Continental Electronics.
  - ➔ but…This water can be difficult to dispose off.
- DI water has been used in loads.
  - ➔ but…The attenuation constant of DI water is low, so the required length of the load is very long at 201 MHz. The return loss is high.
- **So in 2003 Ebert and Ullrich found an alternative, Corrshield MD4151.**

Background - Corrshield MD 4151

- Ebert and Ullrich found that < 0.1% of Corrshield mixed into DI water resulted in a better RF absorption than a 30% glycol 70% water mixture.
- Corrshield MD4151:
  - Made by GE-Betz
  - A sodium molybdate based corrosion inhibitor developed for closed loop hot water systems.
  - <25% sodium molybdate
  - 0.5 – 2.0% sodium-hydroxide
  - Contains Benzotriazole (BZT), a corrosion inhibitor for yellow metals, principally copper.
- In 2004 at DESY, they replaced the cooling water with a 0.4% Corrshield into DI water.
- They found that the optimal dosage for a minimum change in the attenuation constant with respect to temperature is 0.12% Corrshield.

Environmental Considerations

- In the summer of 2007, we began looking for an alternative to the cooling tower water for our 201 MHz test stand load.
- Based, on Eberts and Ullrich's work with Corrshield, we began by testing Corrshield. Our local GE representative said that Corrshield MD5141 was only available in Europe and that the American equivalent is Corrshield MD401.
- A sample of 0.1% Corrshield MD401 into DI water barely passed our environment test to pour into the sanitary drain.
- A sample of 0.5% Corrshield MD401 failed the environmental tests to dispose of into the sanitary drain.

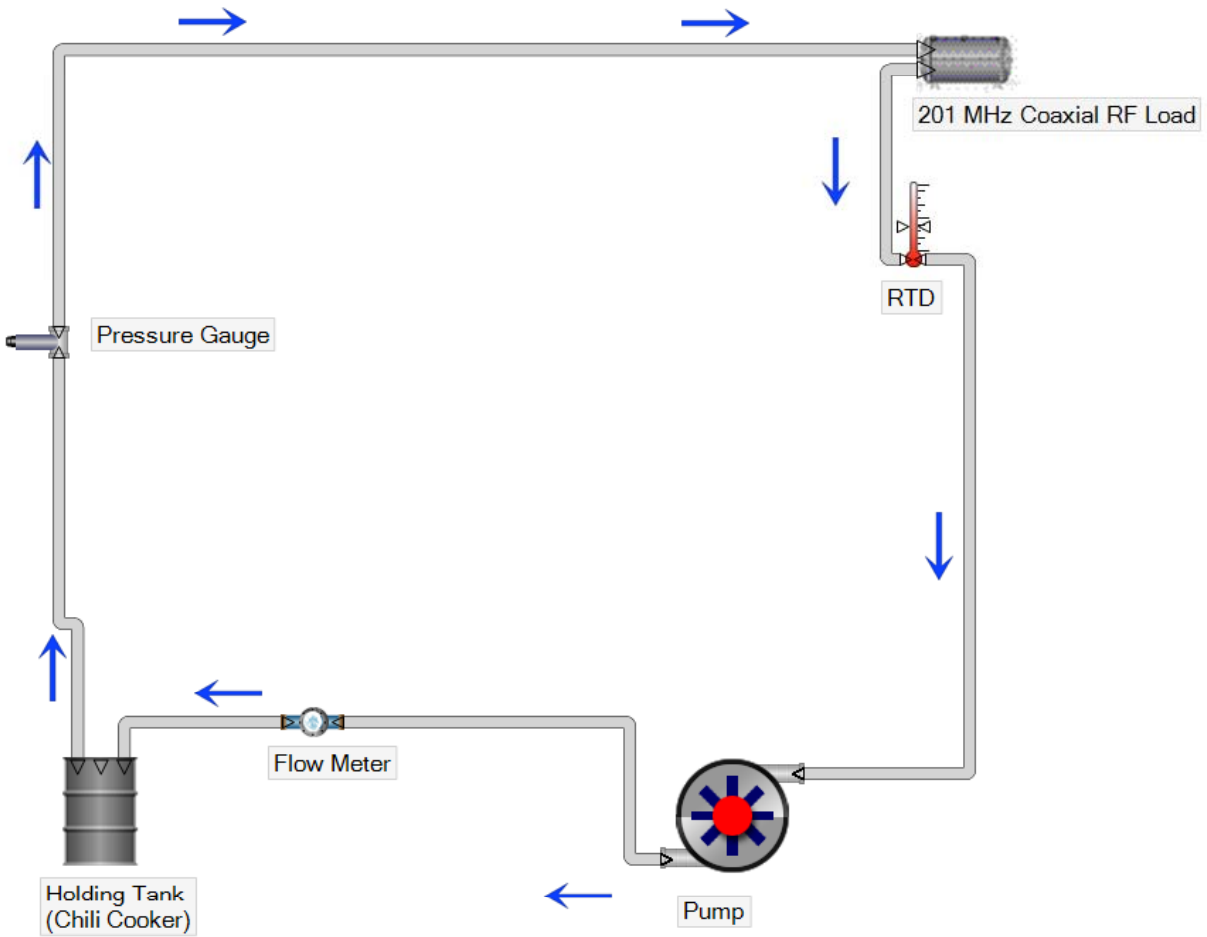
Environmental Considerations

- **The 0.5% Corrshield sample flunked the Waste Acceptance Criteria because it was killing the "good" bacteria in the sanitary sewer system. The 0.1% just barley passed.**
- **We suspect that benzotriazole (BZT), a component in Corrshield, is causing the toxicity.**
- **Brent Chettle, WEST, Inc. developed a chemical, WEST C-441 for us that would be a good RF absorber and that was able to pass our environmental tests.**
- **WEST C-441:**
  - **20% Sodium Nitrite ($NaNO_2$) based solution**
  - **buffered to a slightly alkaline pH with sodium silicate**
  - **contains a Telomer polymeric copper corrosion inhibitor in lieu of BZT**

Sanitary Waste System Waste Acceptance Criteria (SWS WAC)

Sample	pH	COD Chemical Oxygen Demmand	MTX Screen Microtox (% Effect)	MTX EC_{50} Microtox (% Concentration)	TSS Total Suspended Solids (mg/l)	TDS Total Disolved Solids (mg/l)	Overall Result
SWS WAC Requirement	5.5-11	< 500	<= 50%	> 25%	< 300	< 1000	
0.1% wt. Corrshield	10.2	41	50	44	.95	309	Pass
0.5% wt. Corrshield	11.15	163	74	10.81	<2	1532	Fail
0.1% wt. WEST C-441	9.43	59	25	Not Required	2	225	Pass

Experimental Set Up for Low Power Tests



Experimental Setup

- **We measured the return loss of both Corrshield MD401 and WEST C-441 while varying the concentration and the temperature at 201.25 MHz and the harmonics.**
- **We varied the temperature from 55 Deg F (13 Deg C) to 130 Deg F (54 Deg C).**
- **We varied the concentration from 0% to 0.1% by weight. With the Corrshield MD401, we were limited to 0.1% because of the Waste Acceptance Criteria test results.**

Experimental Setup

RF Load Water Inlet and Outlets

Network Analyzer and RF Load

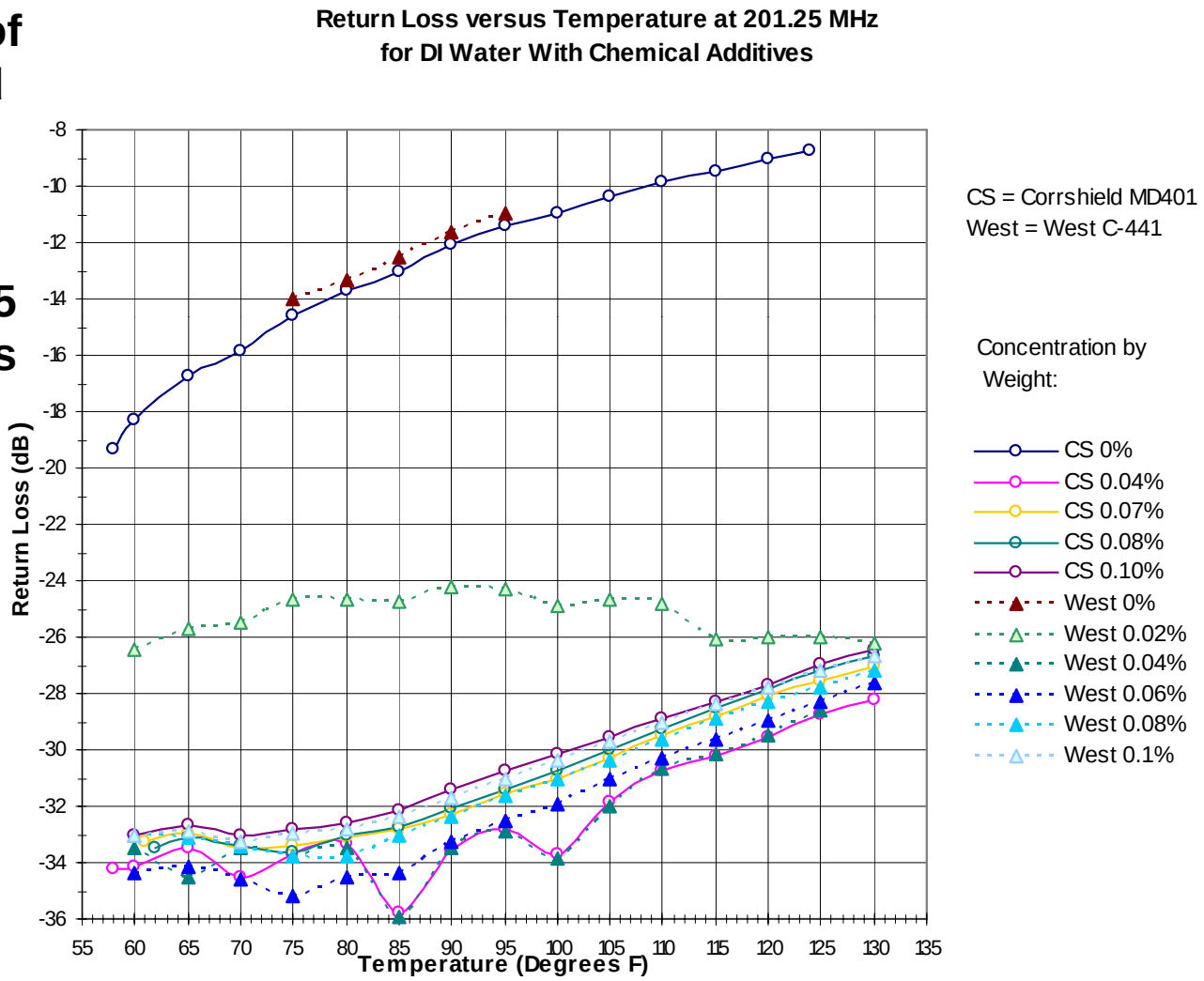
Experimental Setup

- **A HACH spectrometer DR-2010 was used to measure the concentration by weight of the chemical additive.**
- **To measure the concentration of Corrshield MD401, the amount of molybdate in parts per million was measured and then scaled to the ratio of molybdate to Corrshield MD401.**
- **To measure the concentration of West C-441, the amount of nitrite was measured and then scaled to the ratio of nitrite to West C-441.**
- **The holding tank, a “chili cooker”, was used to heat and cool the water.**

Holding tank with heater element, flow meter and pump

Experimental Results

- **The RF performance of Corrshield MD401 and WEST C-441 is very similar.**
- **A good RF match (> 25 dB) at all temperatures was obtained at concentrations of 0.04% or greater.**
- **The RF match was better at lower temperatures, but is still acceptable at higher temperatures.**



Experimental Results

- We operate at 201.25 MHz so the data at this frequency is shown.
- Data was also taken at the frequencies where harmonic power is often seen (402.5 MHz, 603.75 MHz and 805 MHz). The data had the best return loss at 201.25 MHz. At the higher frequencies, the return loss tended to have more fluctuations with temperature.
- The return loss of the DI water with no chemical varied with temperature between –20 dB and –8db and was not acceptable.
- With as little as 0.02% concentration of WEST C-441 the return loss became sufficient. Between 0.02% and 0.04%, it improved significantly.
- With both chemicals, between 0.04% and 0.1%, the reflection coefficient increased, but only by a small amount.

Conclusions

- **We will proceed by using 0.1% of WEST C-441. We did not test WEST C-441 at concentrations above 0.1% because we could not test Corrshield MD401 at concentrations above 0.1%.**
- **Next summer, we will repeat these tests for WEST C-441 at concentrations from 0.1% to 1% to see if the RF performance is still good.**
- **We would like to be able to use optimal concentration of WEST C-441 for corrosion inhibition, if possible. Fair corrosion protection is 0.35%, and excellent corrosion protection is > .6%.**
- **We installed a new closed loop system to be able to use WEST C-441 in our loads and avoid the issues that come with the cooling tower water.**

New Ionized Water System

- **A new closed loop water system was installed for the 201 RF test stand.**
- **It is isolated from the cooling tower water by the heat exchangers.**

- **The water systems contains a “shot feeder” so we can easily add the WEST C-441 and take samples to measure the concentration.**

New ETL Water Systems