Dependence of the Rate of Chemical Reaction of Water & Aluminum on Temperature

February 20, 2006

Table of contents

Acknowledgements

References:
1. US Patent 6,506,360 January 14, 2003 Andersen, et al.
2. US Patent 6,638,493 October 28, 2003 Andersen, et al.
3. US Patent 6,800,258 October 05, 2004 Andersen, et al.
4. International Clearinghouse for Hydrogen Based Commerce
5. Kuro5hin.org

My father helped me throughout the experiment in dealing with the lye and with dealing with mathematics in various tricky areas.

Abstract

I investigated the chemical reaction between water and aluminum. This chemical reaction, as explained by the Andersens in the above referenced patents, is a reaction between water and aluminum in the presence of sodium hydroxide(as a catalyst) to yield aluminum oxide and hydrogen. To be precise, I investigated the way temperature effected the speed of the reaction. This was to be determined by measuring the thickness of the aluminum with a pair of dial-calipers before and after the experiment.

I ran the experiment at three different temperatures; this was my independent variable. One was low, one was high, and one was medium in warmth. I had a Fluke 52 thermocouple machine to compare the “bath”(what we surrounded the lye solution with so as not to dilute it) temperatures with the “solution” temperatures.

I concluded that the rate of the reaction is very strongly dependant on the temperature.

Experiment

Problem/Purpose

How does temperature affect the aluminum + water = hydrogen + aluminum oxide reaction?
I hypothesized that the aluminum + water = hydrogen + aluminum oxide reaction would be faster at higher temperatures and slower at lower temperatures.

Materials

- Coffee can (reaction vessel)
- Three quart pot (held temperature bath)
- Three bars of .25” aluminum
- Red Devil Lye (sodium hydroxide)
- Water
- Ice
- Electric stove burner
- Garden hose
- Kitchen scale
- Dial calipers
- Fluke 52 thermocouple machine
- Fisher Scientific mercury thermometer
- PVC container for lye solution

Procedure

First the solution of lye and water was mixed. The Andersen et al. patents state that 18 % by weight lye in water is optimum. So that the same strength of lye in water solution could be used in all experiments, one large batch was produced to be used for all three experiments. I used 12 ounces of lye in 66 ounces of water. This was stored in the PVC container.

Test 1:
The coffee can was filled with lye-water a third of the way up after being put in the three quart pot. The three quarter pot was filled with water and ice. This would cause the lye water to be of similar temperature to the bath in the pot. There was a thermocouple wire in each liquid. When the temperatures were reasonably close to each other, I measured

the aluminum bar with the dial calipers and put it in the solution in the coffee can. At this point, I began timing the experiment, going back to check on it every few minutes to record temperatures. At the end of the test, I recorded temperatures and measured thickness of the aluminum.

Test 2:
The way I did test two was basically the same, with one difference. Instead of ice, I had a hose taped to a C-clamp. The hose would have water overflow from the pot to the ground and keep temperature consistent.

Test 3:
Test three was the last experiment. Rather than have stuff placed in the bath, the pot and can were placed above a portable burner. This made the temperature very hot. An unpredictable thing happened during this experiment, which is why it was cut short. The reaction generated enough heat that the temperature of the solution exceeded the temperature of the bath. The reaction wanted to run away and it very difficult to do a good job controlling temperature. Because I was afraid of the aluminum being consumed, I ended this experiment much earlier than the other two.

Data

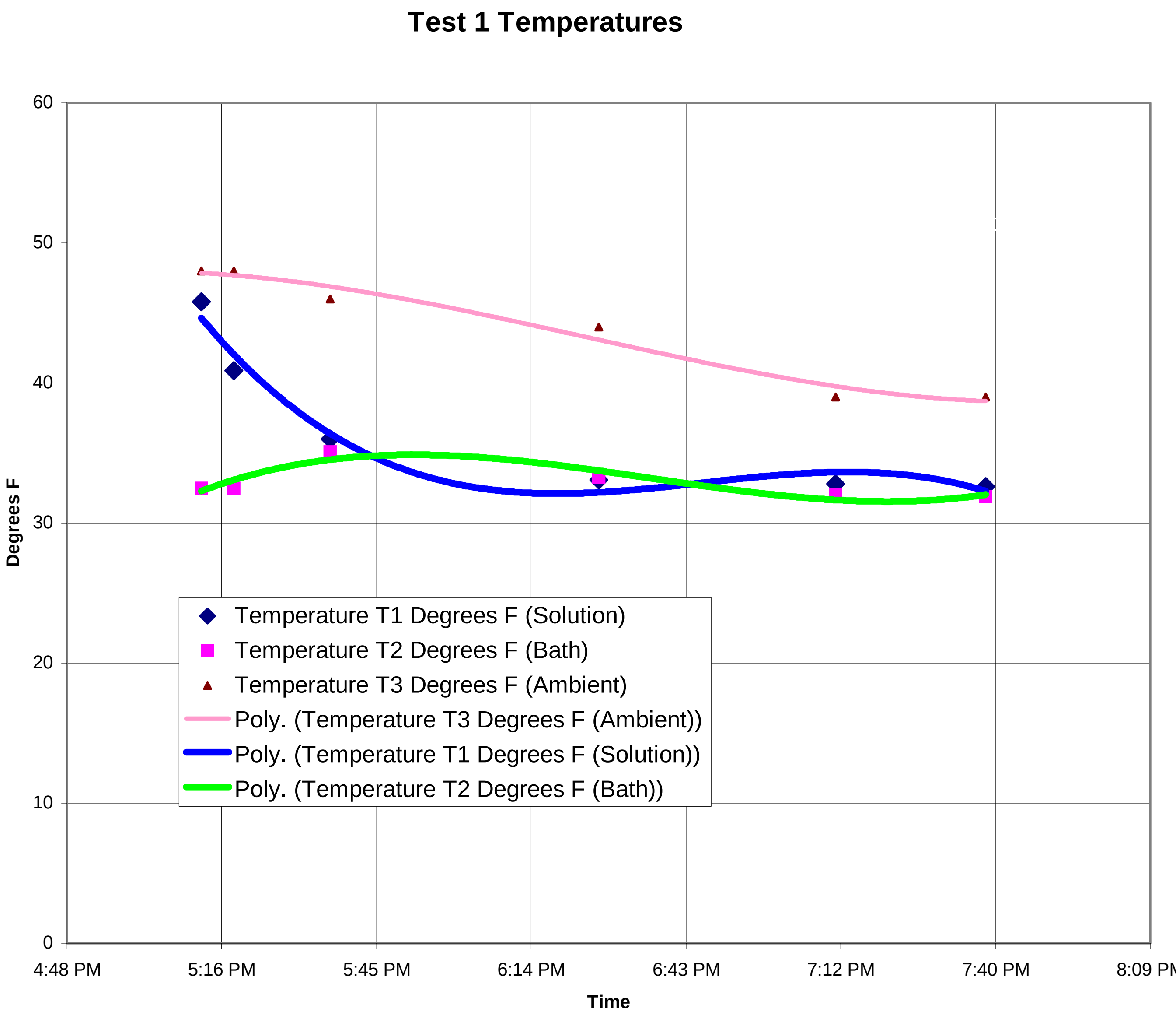
I found that my hypothesis was proven quite well by my experiments. The rate of reaction is strongly dependant on temperature.

Test 1:
In test 1, the temperatures were well controlled. The thickness of the aluminum at the start of the test was .258 in. After 2.5 hours, the thickness was .255 in. The erosion rate was .0012 in. per hour.

Time	Temperature T1 Degrees F (Solution)	Temperature T2 Degrees F (Bath)	Temperature T3 Degrees F (Ambient)
5:13 PM	45.8	32.5	48
5:19 PM	40.9	32.5	48
5:37 PM	36	35.1	46
6:27 PM	33.1	33.3	44
7:11 PM	32.8	32	39
7:39 PM	32.6	31.9	39

The aluminum was inserted at 5:19.

Test 1 Temperatures

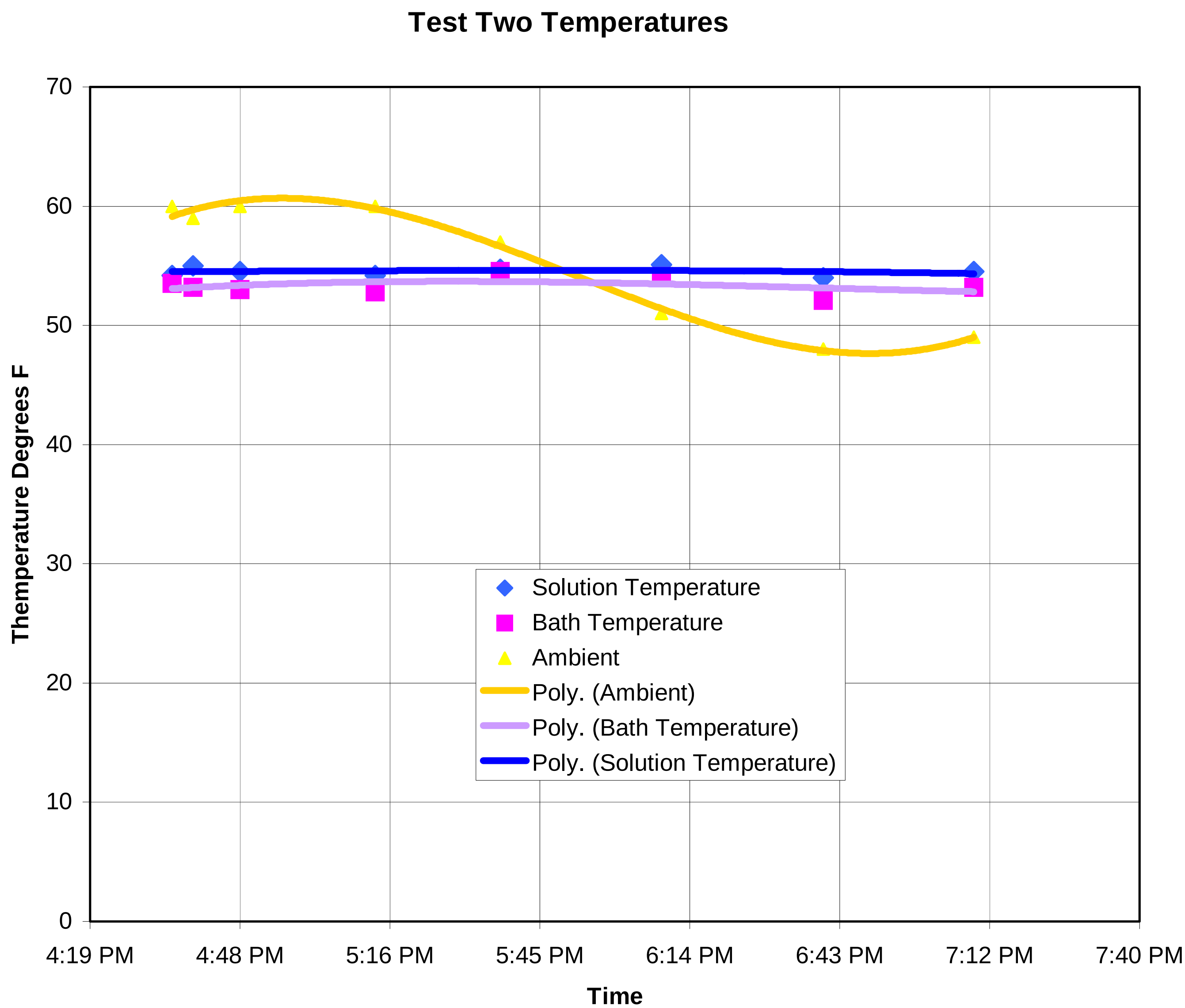


Test 2

Test 2 was also well controlled in temperature. The thickness of the aluminum at the start of the experiment was .257 in. The thickness at the end of 2.5 hours was .252 in. the erosion rate was .002 in. per hour.

Time	Temperature T1 Degrees F (Solution)	Temperature T2 Degrees F (Bath)	Temperature T3 Degrees F (Ambient)
4:35 PM	54.2	53.5	60
4:39 PM	55	53.2	59
4:48 PM	54.5	53	60
5:14 PM	54.2	52.8	60
5:38 PM	54.7	54.5	57
6:09 PM	55.1	54.1	51
6:40 PM	54	52.1	48
7:09 PM	54.5	53.2	49

The aluminum was put in the solution at 4:37.

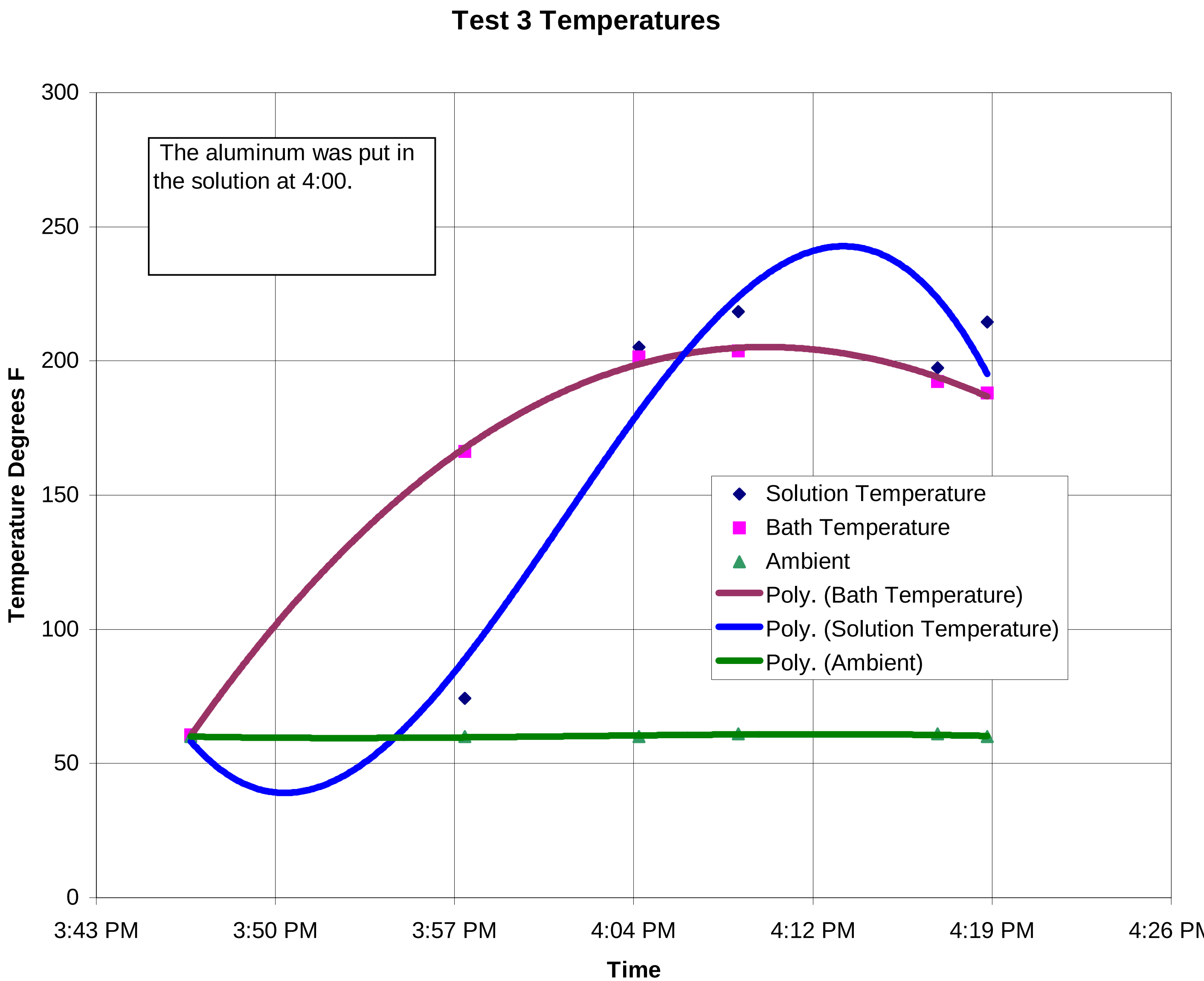


Test 3

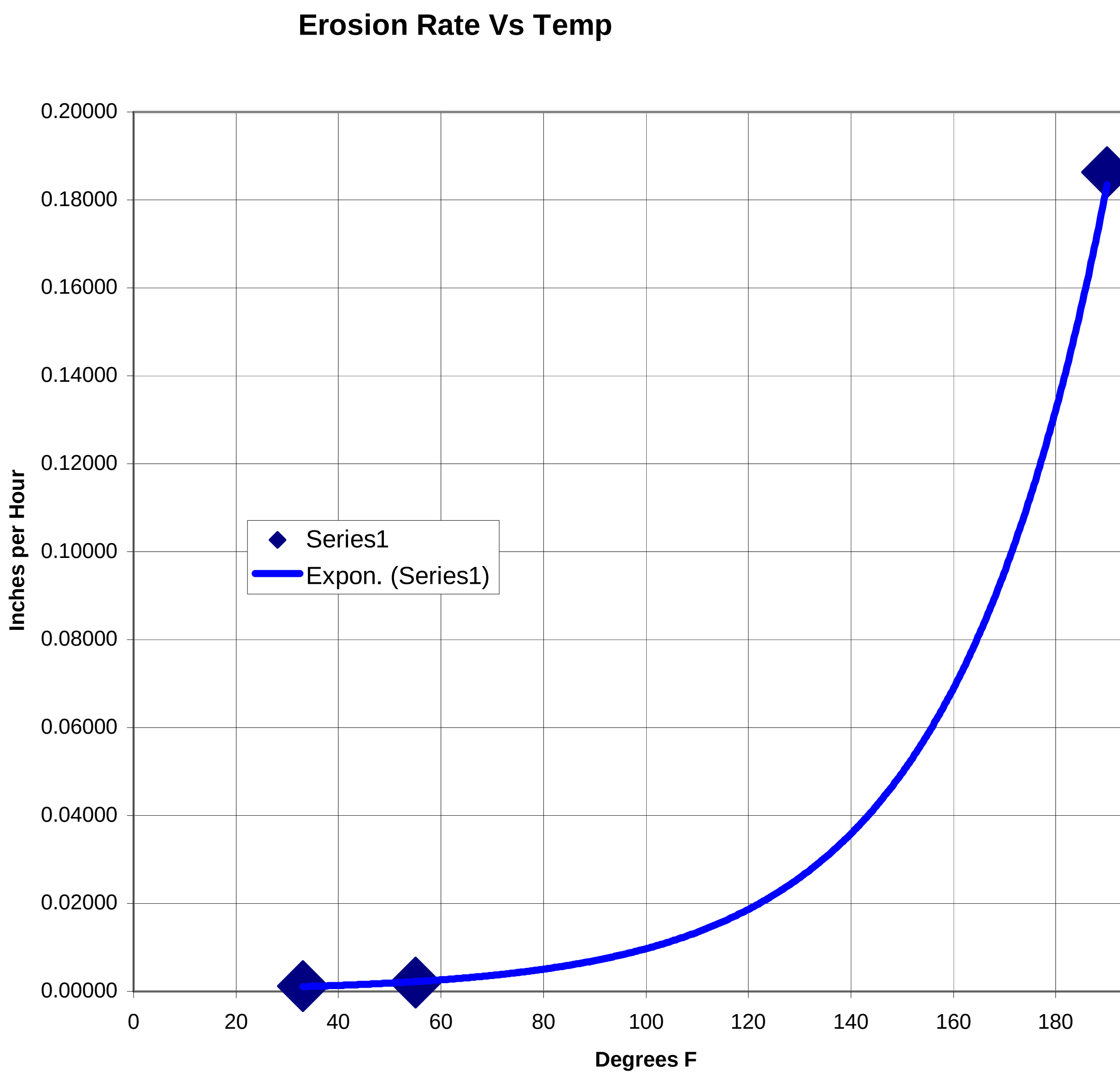
Test three produced surprisingly violent results, with foaming and bubbling of the solution. It was impossible to hold the temperature steady, but it was consistently high. The aluminum initially measured .257 in. and after 22 minutes measured .198 in. The erosion rate was .186 in per hour.

Time	Temperature T1 Degrees F (Solution)	Temperature T2 Degrees F (Bath)	Temperature T3 Degrees F (Ambient)
3:47 PM	60.5	60.6	60
3:58 PM	74.3	166.2	60
4:05 PM	205.1	201.5	60
4:09 PM	218.4	203.7	61
4:17 PM	197.5	192.4	61
4:19 PM	214.6	188.1	60

The aluminum was put in the solution at 4:00.



Test Number	Time of Test Hours	Initial Plate Thickness Inches	Final Plate Thickness Inches	Erosion Inches	Erosion Rate Inches/Hour	Typical Test Temp. F
1	2.500	0.258	0.255	0.003	0.00120	33
2	2.500	0.257	0.252	0.005	0.00200	55
3	0.317	0.257	0.198	0.059	0.18632	190


Erosion Rate Vs Temp
0.20000
0.18000
0.16000
0.14000
0.12000
0.10000
0.08000
0.06000
0.04000
0.02000
0.00000
Inches per Hour
Series1
Expon. (Series1)
0
20
40
60
80
100
120
140
160
180
Degrees F

Conclusions:

The results were more extreme than I expected, particularly when it came to the third experiment. In the first and second experiments only modest change between the two, but that wasn't so in the third. Experiment number three was generating it's own heat after the stove had been turned off. It bubled and seethed, aluminum oxide melting in the steaming solution and overflowing into the bath, making it look like a deadly witch's brew.

I conclude that my hypothesis was proven, and warmer temperatures cause more extreme results in the reaction.