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Evaluation of carbon materials for use in a direct carbon fuel cell

Gregory A. Hackett
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Evaluation of Carbon Materials for Use in a Direct Carbon Fuel Cell

Gregory A. Hackett

Thesis
Submitted to the College of Engineering
and Mineral Resources at
West Virginia University
in partial fulfillment of the requirements
for the degree of

Master of Science
in
Chemical Engineering

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Abstract

Evaluation of Carbon Materials for Use in a Direct Carbon Fuel Cell

Gregory A. Hackett

The Direct Carbon Fuel Cell (DCFC) is an efficient, environmentally friendly way to supply the United States with electrical power using its abundant coal reserves. The cell employs a process by which carbon is directly converted to electricity, without the need for combustion or gasification. The thermodynamic efficiency of a DCFC is 80%. The purpose of this research is to renovate fuel cell test stands provided by the US DOE, and to investigate the operation of the DCFC with a variety of solid carbons from several sources. The highly organized carbon form, graphite, is used as the benchmark of the research because of its availability and stability. Another form, which is produced at West Virginia University (WVU), uses different mixtures of Solvent Extracted Carbon Ore (SECO) and petroleum coke. The SECO is derived from coal and both it and the petroleum coke are low in ash, sulfur, and volatiles. Compared to graphite, the SECO is a less-ordered form of carbon. In addition, GrafTech, Inc. supplied a well-fabricated baked carbon rod for testing. The open cell voltage of the SECO rod reaches a maximum of 1.043V while the baked and graphite rods only reach 0.972V and 0.788V respectively. Typical power densities are in the range of 0.02 to 0.08 W/cm², while current densities were between 30 and 230 mA/cm². This suggests that coal can be used as a fuel source in DCFCs and will provide higher voltage than graphite.

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Chapter 1

Introduction

1.1 Motivation

Coal is the most abundant fossil fuel in the United States. The dependence upon coal as a fuel source continues to be widespread, as other natural resources remain in short supply. In 2004, West Virginia mines produced over 153 million tons of coal. [1] Therefore, it is logical to investigate a new process in which coal is used as a carbon source for direct conversion to electricity.

The direct carbon fuel cell (DCFC) has the potential to convert the chemical energy of carbon directly into electricity without the need for gasification or moving machinery. Moreover, these fuel cells are twice as fuel-efficient as coal-fired power plants, resulting in reduced carbon dioxide emissions per unit of electricity generated. These advantages, and the favorable thermodynamics of direct oxidation, result in thermodynamic efficiencies between 80 and 90%. The process produces almost pure carbon dioxide, which can be easily collected for downstream disposal using methods such as carbon sequestration. Carbon is not burned in air; therefore, the exhaust is free of nitrogen oxides (NO_x), eliminating many pollution issues caused by coal combustion.

Because of the absence of a need for smoke stacks, direct carbon fuel cells can easily be located in urban areas. Thus, DCFCs are more environmentally friendly than coal-fired power plants.

1.2 Research Objectives

The problem of converting chemical energy from solid fuels directly into electrical energy, without passing through the intermediate stages of thermal to mechanical and from mechanical to electrical energy, has been a popular topic for years. Carbon is a great resource on which to test this direct conversion procedure. Coal is an ideal carbon source for this purpose because of its abundance, and the lack of pollution when it is used in the DCFC.

The purpose behind this research is to compare the performance of different types of carbon materials for operation in a direct carbon fuel cell. The United States Department of Energy (DOE) was kind enough to supply West Virginia University with two surplus fuel cell test stands. The test stand is shown later in Figure 3.4. These are very sophisticated pieces of equipment but lacked detailed documentation. Therefore, the first objective of this research is to understand how the DOE test stands operate. Without basic knowledge of how the equipment works, the experimentation phase cannot be reached.

Second, because the DOE test stands are designed for investigation of solid-oxide fuel cells, modifications must be made to adapt them for use with the direct carbon fuel cell. Some of the equipment was replaced and updated. For example, the load cell (discussed later) was replaced and an electronic airflow controller was installed.

Third, to make the process more user-friendly, the data acquisition phase of the experimentation was computerized. Using the provided data logger, readings taken from the fuel cell were interfaced to the computer through LabView 6.0 software for real-time data acquisition.

Fourth, a design for the fuel cell and the other ancillary equipment was determined. The construction material of the fuel cell was based on electrical conductivity, corrosion resistance, and availability. From the chosen design, the fuel cell was constructed at West Virginia University (WVU) with help from Mr. Jim Hall, in the chemical engineering shop.

Once constructed, it was necessary to test the equipment to make sure that everything is operating as expected. The airflow was measured independently to create a calibration for the airflow rotometer. The system was vigorously tested for leaks. The voltages were carefully measured at different points in the system to assess various voltage drops. The safety features of the design were thoroughly examined.

Finally, graphite and different compositions of coal-derived fuel rods were evaluated and their performance recorded. The performance of these fuel rods was tested under varying conditions such as airflow rate, fuel cell operating temperature, and different types of molten electrolyte.

1.3 Research Tasks

In order to complete the work for this research efficiently, the overall objectives are broken down into individual tasks to be completed. The tasks are as follows: 1. a completion of a literature review to become familiar with other similar research, 2. an investigation of the electrochemical and physical processes behind the proposed process, 3. the equipment design, and completion of an experimental investigation for the process, and 4. an analysis of the generated data.

Chapter 2

Background

2.1 Patent Review

Dr. William W. Jacques was the first to obtain a patent for “Method of Converting Potential Energy of Carbon into Electrical Energy” on March 3, 1896. [2] In this patent, he explains his design for a direct carbon fuel cell, which immerses a carbon material into a bath of molten caustic soda (sodium hydroxide). Also, a “blast of air is forced into the molten sodium hydrate in such a manner that the sodium hydrate becomes saturated with oxygen.” He ran the apparatus between 400 and 500°C. The fuel cell at WVU is designed along these lines using the basic apparatus described by Dr. Jacques.

Philip V. Pesavento also has a patent based on a direct carbon fuel cell. The assignee of the patent is Scientific Application & Research Associates, Inc. (SARA). The patent was approved March 13, 2001. [3] In this design they claim to use an “anode basket” in which to place pulverized coal. They also use several molten electrolytes such as the hydroxides of aluminum, calcium, cesium, lithium, potassium, sodium, rubidium, strontium, and mixtures thereof. Along the same lines as Jacques, a “bubbler” is used to supply the oxygen to the cathode side of the cell. The addition of the anode basket relieves the requirement that the coal be machined into rods, a more efficient method of operation.

2.2 Literature Review

Sir William Grove first discovered the direct carbon fuel cell in 1839. Since then, researchers have attempted to perfect the invention. The first direct carbon fuel cell, as

shown in Figure 2.1, was built in 1896 by American engineer Dr. William W. Jacques, and was very simple and inexpensive. The cell used a steel pot filled with molten sodium hydroxide, through which air was bubbled. A carbon rod was placed into the molten sodium hydroxide electrolyte. The steel pot acted as the air cathode and the carbon rod acted as both the fuel and the anode.

Figure 2.1 - Line Art Depicting Dr. Jacques' Direct Carbon Fuel Cell [2]

Experiments conducted by Jacques included several different cells, electrolytes, and cathode materials. He then placed his most successful trials in a series of about 100 cells and generated over one kilowatt of electricity. The series produced a current density of $100\text{mA}/\text{cm}^2$ at 1VDC. It was also the first DCFC to be operated long term [4]. In his patent [2], Jacques claimed an efficiency of 82%; however, reviewers concluded that he had neglected thermal energy requirements for heating the electrolyte and the power needed to run his air pump. Their much-debated conclusion showed an overall efficiency of only 8%. Even so, the cell stack did indeed produce over a kilowatt of electricity.

Since then, researchers have struggled to reproduce Jacques' data. In his patent, he claimed to use pure iron from Norway for his pot. However, the reason Jacques' cell worked so well may be because the Norway iron contained a small percentage of titanium. As is presently known, iron-titanium oxides that form on the surface in the presence of molten metal hydroxides are degenerate semiconductors. These coatings hinder further corrosion and conduct electricity. There is also some speculation that the titanium catalyzes the cathodic reaction. The other researchers most likely failed because they used "better" steel from Germany, which did not contain titanium.

In the early 1970's during the oil crisis, the Stanford Research Institute (SRI) was funded to complete a carbon fuel cell. The research leader, Dr. Robert Weaver, was successful in proving that the electrochemical oxidation of carbon is feasible. The research group later tested several different types of carbons [5]. As shown in Figure 2.2, the group was able to demonstrate that a coal-derived anode was much more electrochemically active (i.e. gave a larger potential, as shown as a more negative voltage in the figure) than a graphite anode.

Figure 2.2 - Performance of Various Carbons in a Direct Carbon Fuel Cell [6]

2.3 Other Forms of Direct Carbon Fuel Cells

Other groups have tried fuel cells that do not use the same design or electrolyte as the Jacques' cell. Scientific Applications and Research Associates (SARA) has designed a cell that separates the electrolyte around the anode from the electrolyte around the cathode. The transport of hydroxide ions is allowed across an electrically insulating but ionically conducting separator. Also, a metallic basket type current collector is used along with particulate carbon fuel. This is accomplished using a porous ceramic or sintered porous metal basket that is isolated from the cathode. The basket also acts as the anode in this case. Thus different reactions can occur at each the anode and cathode without the electrolyte mixing.

The Lawrence Livermore National Laboratory has developed the direct conversion of carbon fuels in a cell with a molten carbonate electrolyte, the molten carbonate fuel cell, or MCFC. This method may be beneficial because of the ability of the reactions to consume carbonate at the anode and produce it at the cathode in the same mole ratio without any hindering side reactions.

CellTech Power has also been involved in fuel cell research. They have developed what they call “a unique device with the properties of a primary battery, a secondary battery, and a fuel cell [7].” They have developed this device to be run on multiple fuels, including solid carbon. CellTech claims that their device runs 60% more efficiently than solid-oxide fuel cells when using a carbon fuel. Figure 2.3 is a picture and schematic diagram of CellTech's design.

Figure 2.3 - Picture and Schematic Diagram of CellTech's Design

2.4 Electrochemical Process

The element carbon has an affinity for combining electrically with a large number of other chemical elements under a variety of conditions. In the DCFC, the exothermic reaction of carbon and oxygen is used to provide the necessary electrons from the system. Using a hydroxide electrolyte, the chemical reactions that occur with a carbon-based fuel in the DCFC are as follows:

Equation 2.1 is the overall reaction, and is the direct oxidation of carbon. Equation 2.2 is the reaction between the carbon fuel and the molten hydroxide electrolyte that occurs at the anode, showing that four electrons are produced per mole of carbon. Equation 2.3

represents the cathode reaction between the oxygen, water, and electrons that replenishes the hydroxide electrolyte. Moreover, the addition of water vapor increases the ionic conductivity in the electrolyte by adding polar molecules. Equation 2.4 is an undesired side reaction that consumes the electrolyte producing the carbonate ion. The carbonate ion will eventually poison the electrolyte as it increases in concentration relative to the hydroxide, causing the cell to fail. The occurrence of this reaction is minimized by the addition of excess water vapor, which will hydrolyze the carbonate atom, reforming the previously consumed hydroxide.

The maximum electrical energy that can be obtained from Equation 2.1 can be calculated from the free energy change involved in the reaction. For example, graphitic carbon reacts with gaseous oxygen at standard temperature and pressure (1atm, 25°C) resulting in the voltage given by the following relation:

$$\frac{\Delta G^\circ \times 4.18}{NF} = E^\circ \quad (2.5)$$

$$E_{cell} = E^\circ - \frac{RT}{NF} \cdot \ln \frac{[CO_2]}{[O_2]} \quad (2.6)$$

where ΔG° is the standard free energy change of Reaction 2.1, -94,260 cal/mol [8]; 4.18 is the constant relating calories and watt-seconds; N is the number of unit charges (moles of electrons) involved, four in this case; F is the Faraday constant, 96,494 coulombs per unit charge (moles of electrons), and E° is the standard voltage of a carbon cell, 1.01V. However, a more practical available voltage, E_{cell} , as calculated by J.F. Cooper, is about 0.8V, yielding a total efficiency of 0.80 [9]. Table 2.1 is a comparison of carbon, hydrogen, and methane, which are fuels used in various types of fuel cells. E° is the theoretical limit for oxidizing each of the listed reactants. The utilization energy is

defined as the fraction of fuel consumed in practical operation. ϵ_v is the fraction of the voltage available at the practical rate. When these values are multiplied, an actual efficiency results, showing carbon to be the most efficient of the three.

It should be noted that changing the temperature of the cell will not affect the voltage much because the value of ΔG (replaces ΔG° in Equation 2.5 for non-standard conditions) is only different from ΔG° by 16 calories at 1000°C and only about 10 calories at 600°C [8][10], which is the standard operating temperature for the cell in this project.

Table 2.1 - Comparison of Efficiencies of Different Fuels

Fuel	Theoretical Limit = $\Delta G^\circ(T)/\Delta H^\circ_{std}$	Utilization Energy, μ	V(i), V (i=0) = ϵ_v	Actual Efficiency = $[\Delta G^\circ(T)/\Delta H^\circ_{std}](\mu)(\epsilon_v)$
C	1.003	1.00	0.80	0.80
CH ₄	0.895	0.80	0.80	0.57
H ₂	0.700	0.80	0.80	0.45

Usually, the reactants are oxidized at the anode and reduced at the cathode, with platinum wire being used as an electrode. However, carbon does not ionize, and oxygen ionizes extremely slowly. These reactants can, however, react with ions in a molten electrolyte, in this case hydroxide (ionized) as shown in Equations 2.2 and 2.3. Often, platinum, iron, nickel, silver, copper, or some oxide are used as the cathode with the carbon used as the anode. In this research an iron-titanium alloy (98%-2%) was selected as the cathode material. This metal is ideal because of the small content of titanium that forms a complex with the ferrous oxides, preventing corrosion.

Chapter 3

Experimental

3.1 Direct Carbon Fuel Cell Design

A detailed schematic diagram of the designed fuel cell is given in Figure 3.1.

Figure 3.1 - Schematic Diagram of Direct Carbon Fuel Cell

An actual photograph of the constructed cell is shown below in Figure 3.2.

Figure 3.2 - Photograph of Constructed Direct Carbon Fuel Cell

As previously mentioned, the DCFC design, in the most basic sense, consists of a cathode and an anode. More specifically, carbon rods are used as the anode while an iron-titanium alloy (98%-2%) is used as the cathode. In this case, a molten electrolyte of sodium hydroxide (NaOH) supplies the hydroxide ions necessary for the anode half-reaction (Equation 2.2). The electrolyte is surrounded by the cathode, which is shaped into a can.

A schematic diagram of the fuel cell test stand is shown in Figure 3.3 along with an actual photograph of the test stand in Figure 3.4.

Figure 3.3 - Schematic Diagram of DCFC Test Stand Showing Location of Component Parts

Figure 3.4- Photograph of Fuel Cell Test Stand Donated by the U.S. DOE.

The oxygen supply, humidified air at 70°C, is pre-heated to the fuel cell operating temperature, and then is distributed to the cathode by means of a “spider-type” sparger. The spider (Figure 3.5) takes the air inlet and directs it toward the inner surface area of the can, supplying small bubbles of needed oxygen and water to the cathode half-reaction (Equation 2.3). An inconel wire (.041-inch OD) is used as a reference

Figure 3.5- Photograph of Spider Used for Gently Bubbling Air Along the Cathode

electrode for separate anode and cathode voltage measurements. A type-K thermocouple is placed in a ceramic thermal well (Omega Engineering, Inc. models KQIN-11611-12 and ORX-11614-6, respectively) to measure the electrolyte temperature for control purposes.

The fuel cell is heated to the desired operating temperature by means of two 1.25kW ceramic fiber heaters, supplied by Watlow, Inc. These are labeled “Cell Heaters” in Figure 3.3. The fuel cell and the preheated air tubing, “Air Pre-Heater” are well insulated to help prevent thermal losses.

As previously mentioned, the fuel cell test stands have been supplied by the United States Department of Energy for research use at West Virginia University. They required vigorous examination before they were put into use. The items discussed in this section are shown in the schematic diagram given as Figure 3.3. The stands contain temperature controllers, which are used to keep the cell and preheated air at a constant temperature (RKC Instruments models REX-P9 and REX-F4, respectively shown in Figure 3.6). Also included are an electronic flow controller for the air (located behind test stand), a humidifier for the air, and a scanning data logger produced by the Azonix Corporation (model ScannerPlus) (Figure 3.7). The electronic flow controller, manufactured by Alicat Scientific, Inc. (Figure 3.8) was added to control the airflow to the system at the precise value desired. The flow controller is model MC-02SLPM-D of the 16 Series, and regulates flows between 0 and 2 SLPM. The air is supplied from a cylinder of breathing quality air through a pressure regulator. A load cell, model number SDL 1103, supplied by Transistor Devices, Inc. (Figure 3.9) simulates a load on the fuel cell by drawing a user-specified current from the cell. All of this equipment adds up to a very comprehensive test stand on which to complete research on a DCFC.

Figure 3.6 - Fuel Cell Test Stand Temperature Controllers

Figure 3.7 - Azonix ScannerPlus Data Logger

Figure 3.8 - Alicat Scientific Air Flow Controller

Figure 3.9 - Transistor Devices, Inc. Load Cell (SDL 1103)

3.2 Experimental Design

The main objective of this research is to investigate the effects of different types of carbon-based fuel rods on fuel cell performance. In addition, the operating conditions were changed while using the same type of carbon rod. This allowed an assessment of both the effect of the rod type as well as the operating conditions. Most of the experiments were conducted with graphite rods. These rods were tested multiple times to investigate process variables such as air flow rate, fuel cell temperature, electrolyte changes and additives, and fuel cell modifications. The graphite rods were used more extensively than the others because more were available for use and were manufactured previously.

The experimental design is summarized below:

1. Graphite rod, $T = 600^{\circ}\text{C}$, Air Flow = 0.25 SLPM, NaOH electrolyte
2. Graphite rod, $T = 600^{\circ}\text{C}$, Air Flow = 0.50 SLPM, NaOH electrolyte
3. Graphite rod, $T = 600^{\circ}\text{C}$, Air Flow = 0.75 SLPM, NaOH electrolyte
4. Graphite rod, $T = 600^{\circ}\text{C}$, Air Flow = 0.90 SLPM, NaOH electrolyte
5. Graphite rod, $T = 625^{\circ}\text{C}$, Air Flow = 0.50 SLPM, NaOH electrolyte
6. Graphite rod, $T = 650^{\circ}\text{C}$, Air Flow = 0.50 SLPM, NaOH electrolyte
7. Graphite rod, $T = 675^{\circ}\text{C}$, Air Flow = 0.25 SLPM, NaOH electrolyte
8. Graphite rod, $T = 675^{\circ}\text{C}$, Air Flow = 0.50 SLPM, NaOH electrolyte
9. Graphite rod, $T = 675^{\circ}\text{C}$, Air Flow = 0.75 SLPM, NaOH electrolyte
10. Graphite rod, $T = 700^{\circ}\text{C}$, Air Flow = 0.50 SLPM, NaOH electrolyte
11. Graphite rod, $T = 600^{\circ}\text{C}$, Air Flow = 0.50 SLPM, $\text{Li}_2\text{CO}_3 + \text{Na}_2\text{CO}_3$ electrolyte
12. Graphite rod, $T = 600^{\circ}\text{C}$, Air Flow = 0.50 SLPM, NaOH + LiOH electrolyte
13. Petcoke Rod #11, $T = 600^{\circ}\text{C}$, Air Flow = 0.50 SLPM, NaOH electrolyte
14. Petcoke Rod #10, $T = 600^{\circ}\text{C}$, Air Flow = 0.50 SLPM, NaOH electrolyte
15. 25% SECO, 75% PetCoke Rod, $T = 600^{\circ}\text{C}$, Air Flow = 0.50 SLPM, NaOH el.

16. 50% SECO, 50% PetCoke Rod, $T = 600^{\circ}\text{C}$, Air Flow = 0.50 SLPM, NaOH el.
17. 75% SECO, 25% PetCoke Rod, $T = 600^{\circ}\text{C}$, Air Flow = 0.50 SLPM, NaOH el.
18. 100% SECO, $T = 600^{\circ}\text{C}$, Air Flow = 0.50 SLPM, NaOH electrolyte
19. GrafTech graphite rod, $T = 600^{\circ}\text{C}$, Air Flow = 0.50 SLPM, NaOH electrolyte
20. GrafTech baked rod, $T = 600^{\circ}\text{C}$, Air Flow = 0.50 SLPM, NaOH electrolyte

The carbon rods are different both in their composition and in the way that they were manufactured. The investigation will include a good sampling of rods that vary in one or both of these characteristics. The manufacture and analysis of each type of rod can be found in Section 3.5, Experimental Materials.

Some of the experiments were completed during the same experimental run. As long as the carbon rod and the electrolyte remain the same, the airflow rate and fuel cell temperature are variable during the experiment. This helps in keeping the supply cost down as well as the time necessary to complete the experimental phase of the research. Most tests were done with the sodium hydroxide electrolyte, but a few trials were made with mixed carbonate and hydroxide electrolytes (Runs #11 and #12).

Data analysis consists of plotting the generated cell voltage (V) versus the current density (mA/cm^2) that is drawn from the cell using the load cell, the so-called *i*-V curves. Current density is the current drawn over the surface area of the rod exposed to the electrolyte. This is used to normalize the data for rods of different diameter and surface area. Similarly, the power density is plotted versus the current density to assess the maximum power generated. Fuel cells are designed to operate at or below the power density maximum. At current densities below the power density maximum, voltage efficiency improves but power density falls. At current densities above the maximum, both voltage efficiency and power density fall. The slope of the cell voltage versus the

current density curve in the central region of the data supplies a value for the ohmic resistance of the fuel cell, the so-called area specific resistance (ASR). The ASR is an area-normalized resistance. It accounts for the fact that fuel cell resistance scales with area, thus allowing different size fuel cells to be compared.

A typical i - V curve is shown in Figure 3.10. A few points to notice about the curve are as follows: [12]

Figure 3.10 - Generic Fuel Cell i - V Curves with Specific Regions Highlighted

- The open circuit voltage (OCV) is the cell voltage at zero current.
- The initial decrease is due to the activation resistance.
- The voltage then falls less rapidly, and more linearly, and is due to ohmic resistance.
- There is usually a higher current density at which the voltage falls more rapidly, and is due to mass transport resistance.

In the first region, where the initial decrease is slightly steeper, the electrochemical reactions are slow at the electrode surface. When current densities are small, then the voltage losses are dominated by the slowness of the electrochemical reactions. This is called activation resistance. This is voltage lost in driving the chemical reaction that transfers the electrons to or from the electrode. In Figure 3.10, Curve A has faster electrochemical reactions than Curve B as shown in Figure 3.10.

In the second, more linear region, the ohmic resistance of the fuel cell is controlling. This region also has activation losses but it is dominated by the fact that the fuel cell has some resistance. This resistance is mostly found in the electrolyte and electrodes of the fuel cell. When the ohmic resistance is high, ionic and electronic conduction is hindered, which lowers the cell voltage. Electrons will travel more slowly through the fuel cell and more heat will be generated. The rest of these losses can be found in the electrode material and the interconnections of the cell. Curve A has a lower ohmic resistance than Curve B.

In the third, much steeper region, the reactants cannot get to the reaction site quickly enough, the so-called mass transport or diffusion resistance. If the reactants cannot get to the reaction site fast enough, then the rate of the electrochemical reactions is once again limited, due to the low concentration of reactant at the electrode surface. At very high current densities, more reactant has to be supplied so that more electrons can be generated. The difference in the curves is explained by the relative ease of the transport of reactants.

Equation 3.1 summarizes how the cell voltage is obtained after losses.

$$V = E^0 - \eta_{ACT} - \eta_{OHMIC} - \eta_{DIFF} \quad (3.1)$$

Here, V is the cell voltage, E^0 is the thermodynamic cell voltage, η_{ACT} is the activation voltage losses, η_{OHMIC} is the ohmic voltage losses, and η_{DIFF} is the concentration voltage losses.

3.3 Experimental Procedure

The actual experiments were conducted in the following manner at West Virginia University. The method described in this section is the basic operating procedure for a typical experiment and is not absolute. Different experiments may have required more attention to certain aspects of the procedure than others.

Because of the high heat capacity of water, the first order of business is to begin to heat the water tank used for humidification of the feed air, from room temperature to 70°C. This tank provides the water vapor to the airline required by the reaction at the cathode. The line from the humidifier to the pre-heater is heat-traced at 70°C to prevent the water from condensing.

While the tank is heating, the carbon rod apparatus is prepared. Careful attention must be paid so that the rod is not broken during this process. The metal surfaces on this apparatus are buffed with emery paper to ensure good electrical contact with a fresh metal surface. The cell is similarly cleaned (usually the day before) and the inside is buffed with a wire brush to remove any corroded or rusted portions of the interior. The spider is cleaned to remove any residual electrolyte that may have gotten caught in the openings during the previous run. The carbon rod is tightened into the apparatus using a collet fitted to the top plate of the fuel cell. The size of the collet depends on the outer diameter of the rod (usually 3/4"). Because electrical contact is very important in this experiment, the collet is firmly tightened using a vice and lever arm tool.

The fuel cell body is then mounted in the test stand and the airline is connected. The area around the cell and heaters is well insulated to minimize the heat loss from the cell. The airflow is then set to a predetermined rate by means of the electronic flow controller. Once it is confirmed that air is flowing, the solid electrolyte is added to the cell. The temperature controllers for both the air pre-heater and the cell heaters are set to the desired operating temperature and powered on.

When the solid electrolyte has melted (usually about 30 minutes), the carbon rod, previously mounted in the collet, is slowly immersed into the liquid electrolyte and then removed in order to record the submerged length of the rod. This is done because the height of the electrolyte varies from experiment to experiment. This value is then used to calculate the nominal surface area of the carbon rod, the side and bottom areas of a cylinder, which is exposed to the electrolyte, which, in turn, is used to normalize the current. Once the length is obtained, the rod is replaced into the cell. The rod is submerged at an extremely slow rate to alleviate some of the thermal shock from the temperature difference of the room temperature rod and the molten electrolyte.

Once the apparatus is assembled, the proper wires are connected to the anode, cathode, and reference electrode respectively with the other ends being connected to the load cell and the data collection devices. Before any experimental data are collected, it is confirmed that the proper temperatures have been reached and are steady, the cell voltage is in equilibrium and the equipment is functioning properly.

After everything has been checked for proper operation, the experimental data can be collected. The experimental parameters are set and the system is allowed time to reach equilibrium once more. Because most of the tests involve the evaluation of voltage

versus current density curves, the current drawn is increased in a step-wise manner from zero amps (open cell) to some maximum value determined by the experiment. Each datum point is recorded after 30 seconds of equilibrium time since it was found that the cell voltage and current stabilize very quickly, usually within a few seconds of being changed. The incremental change of the current drawn is usually 0.1 – 0.2A every 30 seconds and is adjusted on the load cell manually. Once the maximum value is reached (determined by a 0.200V reading at the cathode), the current is ramped down at about 0.5 – 1.0A every 30 seconds. The reason a value of 0.200V at the cathode signifies the maximum obtainable current is due to the fact that the cell voltage rapidly decreases at that point even with just a small increase in current. This is due to the transport limitations described earlier.

After again reaching open cell, the system is allowed time to recover (15-20 minutes) and another experiment can then be performed as long as the system is still functioning properly. If an experiment is to be run long term, the desired current is set and the cell is checked hourly to ensure proper operation so that it can be left unattended overnight.

After all the experiments have been completed on a particular carbon rod, the shutdown and cleanup procedure begins. The heaters are turned off and the air is allowed to flow to prevent the electrolyte from backing up into the air supply line. Once the fuel cell has cooled to a temperature near the melting point of the electrolyte (approximately 300°C for sodium hydroxide), the carbon rod apparatus is removed and the molten electrolyte is dumped into a tray so that it can solidify and be properly disposed of. Great

care must be taken in this procedure, as the cell is still extremely hot (300°C). Proper clothing, hand protection, eye protection, and face shielding must be worn.

After everything has been taken apart, the cell is once again cleaned and all the parts are prepared for the next experiment. With this procedure, it is possible to run an experiment every 1 – 2 days.

3.4 Experimental Safety

The described experiment poses several serious safety concerns that can be readily alleviated through proper procedures and precautions. Material safety and data sheets for all the chemicals in this study are included in the appendix.

First, proper eyewear and protective gloves should be worn at all times when dealing with corrosive chemicals such as sodium hydroxide. When handling the hot fuel cell, it is extremely important to wear high temperature heat resistant gloves. Severe burns occur when skin is exposed to temperatures around 600°C.

Second, when dealing with molten chemicals, there is always a risk of spatter or spilling. Acrylic panels have been placed around the fuel cell testing area shown in Figure 3.4, located on the right side of the diagram. These are removable when it is necessary to adjust the fuel cell. While in operation, these shields are always to be in place. Molten sodium hydroxide, other than being at 600+°C, is highly corrosive and will cause damage upon exposure to skin or nearby equipment.

Third, an emergency electrical shut-off switch is installed. Some of these experiments require long-term runs. Therefore, if something malfunctions in the middle of the night, the emergency shut-off is clearly labeled so that anyone can shut down the system immediately.

Fourth, exhaust fumes may contain sodium hydroxide vapors or other potential hazards. A fan-powered duct has been routed from just above the fuel cell to the nearest fume hood to insure that none of these fumes escapes into the surrounding air in the laboratory.

Fifth, to prevent the heaters from overshooting the set point by an extreme amount, the temperature controllers include an over temperature protection system that will immediately shut off the heaters in the event that the preset high-limit temperature is reached. Also, to prevent the water from condensing in the airlines, heat tapes and insulation have been wrapped around the line carrying the humidified air from the humidification tank to the air pre-heater to keep it at the proper temperature.

Finally, when dealing with electricity, one must be sure not to short out the system or touch any exposed wires that have a current running through them. Although measures are taken to insulate any wires from exposure, there is always the possibility of an exposed connection. Therefore, users must heed caution and always be able to see where their hands are being placed. Safety is very important in any experimental process and was not taken lightly in these experiments.

3.5 *Experimental Materials*

3.5.1 Carbon Rod Production

The graphite rods tested in these experiments were remaining from a previous project and were found in a large quantity at WVU. The place or method of manufacture is not known. The only thing known about these is the resistivity (discussed later) and that the rods are well made.

The coal-derived rods were made at WVU using a combination of Solvent Extracted Carbon Ore (SECO), petroleum coke (PetCoke), and a coal tar binder pitch that binds the SECO and PetCoke together. SECO is a low-ash extract material that is produced at WVU by solvent extraction of raw coal using N-methylpyrrolidone as the solvent. Petroleum coke is an anisotropic carbon produced in a delayed coker at the refinery. It has a low electrical resistivity, making it ideal for use as an anode material. Some of the rods were created as pure PetCoke (no SECO in mixture) at a composition of (80% PetCoke/20% binder pitch). These rods were pressed in a heated mold at 200°C and then calcined to 1000°C. They were used in Runs #13 and #14. Other rods were made by the same procedure and included different compositions of SECO and PetCoke, using a 15% coal tar binder pitch to hold the mixture together. It should be noted that the rods produced in this manner had visible cracks in the surface and had some variation in their quality. The production of these rods was the subject of a previous M.S. thesis at WVU. [13]

The GrafTech rods were either baked or graphitized and were produced by GrafTech, Inc., which specializes in the production of synthetic graphite. West Virginia University has a good working relationship with GrafTech and these rods were provided free of charge by Mr. Doug Miller. The rods produced by GrafTech did not have any visible cracks and were well made. The baked rods were made from premium petroleum coke and binder pitch. They were baked at 1000°C but not graphitized.

3.5.2 Carbon Rod Resistivity

In the fuel cell design used for this work, the carbon rod is both the fuel and the anode. Therefore, it must be able to carry electricity fairly well in order for the system to

work. The resistivity of the rods is the physical parameter that indicates how well they are able to carry electricity in comparison to each other. The resistivity of a representative rod of each type was measured and recorded using a standard four-point apparatus available at WVU. This apparatus contains a power supply, a current meter, a variable resistor, a voltmeter, and a carbon rod holder consisting of two copper plates on both ends to make electrical contact with the rod. With this information, the resistivity of the rod can be calculated. A picture of the resistivity apparatus is shown below in Figure 3.11.

A Keithley Model 2000 multi-meter (in current mode) in series with the carbon fuel rod measures the current. The voltage drop across the rod is measured with a second digital multi-meter (same model, in voltage mode) that is connected to the rod by two pointed contact pins over a precisely measured distance. The variable resistor allows for control of the current in the circuit. A schematic diagram of this method is shown in Figure 3.12. The resistivity can then be calculated using the following relation:

$$\rho = \left(\frac{V}{I} \right) \left(\frac{A_{CS}}{L} \right) (10^3) \quad (3.2)$$

The resistivity, ρ ($\mu\Omega \cdot m$) is found by taking the voltage, V (V) to current, I (A) ratio and multiplying by the ratio of the rod's cross-sectional area, A_{CS} (mm^2) to the length between contact points, L (mm). Finally, multiplying by 10^3 converts to the desired units of ($\mu\Omega \cdot m$) for resistivity.

Figure 3.11 - Carbon Rod Resistivity Testing Apparatus

Figure 3.12 - Schematic Diagram of Four Point Method for Testing Resistivity

Chapter 4

Results and Discussion

4.1 Experimental Analysis

4.1.1 Equipment Analysis

In this section, the results of the experimental procedure and some unanticipated events are discussed.

The test stand has been successfully modified from a solid-oxide fuel cell to a direct carbon fuel cell. The equipment that was replaced (as discussed previously) all functioned properly. After experimenting with the test stand for an extended period of time, it became easier to manipulate the system to meet the needs of the project. The computer system allowed data points to be collected electronically, saving a lot of time compared to hand written data.

The data were accurate because several conditions of the cell could be monitored simultaneously, giving a clearer sense of what was occurring within the cell at a specific moment, as opposed to reading meters and recording values individually. In this sense, human error was alleviated for the data collection.

4.1.2 Safety Analysis

During a few runs, the molten electrolyte erupted out of the cell. The cause of this is not well understood, but there are a few hypotheses, as discussed below.

One hypothesis for this occurrence could be an air pressure buildup. At the time of the first occurrence, the air was fed from the “house air” line at WVU that is connected to all of the laboratories in the building. The remedy for this was to install a breathing

quality air cylinder and pressure regulator directly to the system to alleviate any pressure buildups. This would also take care of any purity issues, as it was suspected that excess moisture was in the house airline. However, this solution did not solve the problem.

A second hypothesis is that while the load cell was set to a current of zero, a static charge built up between the anode and the cathode. This would likely happen because with the load cell turned off, the flow of electrons is stopped. The chemical reactions were ongoing and electrons were still being produced and consumed at the anode and cathode respectively. After the charges increased to a certain point, it is believed that a spark may have formed causing the major disruption within the cell, which led to molten electrolyte being expelled up to 15 feet away from the experiment. This prompted the installation of acrylic sheets around the cell for shielding.

As a remedy to this problem, the load cell was never actually turned off, but set at the lowest possible current setting. By keeping the electrons flowing, the static charge should not build up. After using this method, only one further eruption occurred and it was small in comparison.

4.2 Fuel Rod Overview

A summary of all results from the experimental setup discussed previously is given below as Table 4.1.

Table 4.1- Summary of Results from Experimental Design

Run	Open Cell Voltage (V)	Maximum Current Density (mA/cm ²)	Maximum Power Density (W/cm ²)	Area Specific Resistance ($\Omega \times \text{cm}^2$)	Active Surface Area (cm ²)	Resistance (Ω)
1	0.751	230	0.066	2.91	50.5	0.058
2	0.767	207	0.068	2.75	49.5	0.056
3	0.779	175	0.065	2.74	50.5	0.054
4	0.788	105	0.048	2.50	54.5	0.046
5	0.757	133	0.057	2.00	51.9	0.039
6	0.760	170	0.073	1.60	51.9	0.031
7	0.773	183	0.062	2.60	51.9	0.050
8	0.735	185	0.048	3.00	51.9	0.058
9	0.770	197	0.084	1.60	51.9	0.031
10	0.729	214	0.062	2.20	51.9	0.042
11	NO DATA COLLECTED					
12	NO DATA COLLECTED					
13	0.963	53	0.033	4.30	60.6	0.071
14	0.981	48	0.032	4.20	43.7	0.096
15	ROD BROKE OFF AT ELECTROLYTE SURFACE					
16	0.963	31	0.020	8.10	71.7	0.113
17	ROD DID NOT SURVIVE EXPERIMENT PREPARATION					
18	1.044	35	0.024	7.55	66.5	0.114
19	0.705	107	0.041	2.20	41.3	0.053
20	0.972	38	0.026	4.20	65.2	0.064

4.2.1 Graphite Rods

The graphite rods operated very well in the DCFC. The method in which they were manufactured allowed for reliable experiments to be conducted. Also, because of their stability, it was possible to run multiple types of experiments, changing the process variables without the rod degrading. The graphite rods left the electrolyte fairly clear after finishing an experiment, which shows that not much particulate carbon was dissolving into the electrolyte. Any carbon that was missing from the surface of the rod was therefore, reacting with the hydroxide to form electrical power.

The maximum open-circuit voltage (OCV) from a graphite rod was a value of 0.788V. This value for the graphite rods was not as high as obtained from the coal-derived rods, as previously noted in the literature. A summary of the runs involving graphite fuel rods is given below in Table 4.2.

Table 4.2 - Summary of Results for Runs Using Graphite Fuel Rods

Run	Open Cell Voltage (V)	Maximum Current Density (mA/cm ²)	Maximum Power Density (W/cm ²)	Area Specific Resistance ($\Omega \times \text{cm}^2$)	Active Surface Area (cm ²)	Resistance (Ω)
1	0.751	230	0.066	2.91	50.5	0.058
2	0.767	207	0.068	2.75	49.5	0.056
3	0.779	175	0.065	2.74	50.5	0.054
4	0.788	105	0.048	2.50	54.5	0.046
5	0.757	133	0.057	2.00	51.9	0.039
6	0.760	170	0.073	1.60	51.9	0.031
7	0.773	183	0.062	2.60	51.9	0.050
8	0.735	185	0.048	3.00	51.9	0.058
9	0.770	197	0.084	1.60	51.9	0.031
10	0.729	214	0.062	2.20	51.9	0.042
11	NO DATA COLLECTED					
12	NO DATA COLLECTED					
19	0.705	107	0.041	2.20	41.3	0.053

Conditions for Runs #1, #2, and #3 were repeated throughout the experimentation process. Therefore, several values were obtained that are not recorded in Table 4.2. The area specific resistance (ASR), active surface area, and resistance are reported as average values of these repetitions. The active surface area is the amount of the fuel rod that is in contact with the electrolyte, where the anode reaction occurs, and is used to normalize the ASR data because the various runs had different active surface areas.

The results of the graphite runs are given below as Figure 4.1, Figure 4.2, Figure 4.3, Figure 4.4, Figure 4.5, Figure 4.7, Figure 4.9, and Figure 4.10. It is interesting to note that all of the graphite runs have the same shape for their *i*-V curve. This is the shape that was discussed previously. The curves all drop quickly at the smaller currents

due to the activation resistance. They continue to decrease in a linear fashion due to the ohmic resistance of the cell. Finally, the voltage decreases drastically at high currents due to the concentration or transport limitation being reached. The fuel cell power density increases with increasing current density, reaches a maximum, and then falls at still higher current densities.

These results, which all showed the same trend, were sometimes very different in magnitude. The run shown as Figure 4.1 was the first attempt and was terminated prior to reaching the maximum power density. This explains why the basic trend was not obtained. The run displayed in Figure 4.2, produced the most current, and therefore, produced a high power density. Each of these runs showed slightly different results and this may be due to some coating of the rods (which is discussed later), poisoned electrolyte (due to cell corrosion), etc. What is important to note is that the trends are similar and produce nearly the same voltages and power.

Long-term runs for some graphite experiments were conducted to investigate the long-term effects of the DCFC. These results are given in Figure 4.6, Figure 4.8, Figure 4.11, and Figure 4.13. In Figure 4.6, a constant current of 2.0A was set and the cell is allowed to run for an extended period of time (~17 hours). This graphite rod held up well and only degraded slightly after 17 hours. It should be noted that for the long-term testing, the active surface area of the rod was assumed to remain constant over the entire course of the test. In reality, this is not the case as the rod diameter decreases as more carbon reacts. Since there is no easy way to follow the change in area, it was taken as constant.

In Figure 4.8, a constant current of 2.0A was also set. However, in this case, the cell voltage degrades much quicker. There was a coating on the surface of this rod that most likely hindered the reaction at the rod's surface. Therefore, the reaction could not take place at this current. After shutting off the load (current), the cell recovered to 0.700V. Once the current was turned back on, cell voltage decreased drastically. This reinforces the idea that the coating of the anode that was causing the problem.

In Figure 4.11, a constant current of 1.5A was set. After a small initial decrease, the cell recovered and produced a constant voltage over the remaining 15 hours. This run proved to be the most stable of the long-term runs as the voltage decrease over time was minimal.

In Figure 4.13, a constant current of 1.0A was set. The cell seems to struggle throughout the long term run, holding steady for the first 12 hours and slowly decreasing cell voltage over the next 9 hours. During this long-term run, a large pressure buildup was noticed and the airflow rate was stuck at 0.075 SLPM, which was way below the set point of 0.50 SLPM.

Figure 4.1 - Results of Initial Graphite Experiment Subject to the Conditions of Runs #1, #2, and #3

Figure 4.2 - Results of Graphite Experiment Subject to the Conditions of Runs #1, #2, and #3

Figure 4.3 - Results of Graphite Experiment Subject to the Conditions of Runs #1, #2, and #3

Figure 4.4 - Results of Graphite Experiment Subject to the Conditions of Runs #1, #2, and #3

Figure 4.5 - Results of Graphite Experiment Subject to the Conditions of Runs #1, #2, and #3

Figure 4.6 – Long-Term Results for Graphite Experiment Subject to Condition of Run #1

Figure 4.7 - Results of Graphite Experiment Subject to the Conditions of Runs #1, #2, #3, and #4

Figure 4.8 – Long-Term Results of Graphite Experiment Subject to the Conditions of Run #2

Figure 4.9 - Results of Graphite Experiment Subject to the Conditions of Runs #1, #2, and

#3

Figure 4.10 - Results of Graphite Experiment Subject to the Conditions of Run #2

Figure 4.11 – Long-Term Results for Graphite Experiment Subject to the Conditions of Run #2

Figure 4.12 - Results of GrafTech Graphite Rod from Run #19

Figure 4.13 – Long-Term Results for GrafTech Graphite Rod from Run #19

Runs #11 and #12 involved an electrolyte other than sodium hydroxide. The runs did not provide any meaningful data other than the knowledge that the use of other electrolytes was unsuccessful. For both of these runs, the cell did not produce any voltage. This is discussed further in Section 4.3.7, Effect of Electrolyte.

The GrafTech graphite rod (Run #19) results show that the rod performance is about the same as the other graphite rods. The results of this run are given in Figure 4.12. The cell voltage degraded over time, as shown in Figure 4.13, the long term results for this experiment that were discussed above. It is unknown why the performance with this rod deteriorated so quickly. The GrafTech rods were expected to be of very high quality. Because only one of these rods were tested, it is hard to say whether or not this rod was superior. However, the point of running this rod as a separate experiment was because

GrafTech is a well-known manufacturer of graphite electrodes. Therefore, because GrafTech's rod operated about the same as the other graphite rods, there is even more confidence in the results obtained from the other graphite rods.

4.2.2 Coal-Derived Rods

The results from the coal-derived rods are shown in Table 4.3. As can be seen, the coal-derived rods produced a higher open-circuit voltage as compared to the graphite rods. This is because the molecular alignment in the coal-derived rods is not as organized as in the graphite rods and the carbon is more accessible for reaction. Therefore, there are more active reaction sites on the coal-derived rods and hence these rods show a higher electrochemical activity.

Table 4.3 - Summary of Results for Runs Using Coal-Derived Fuel Rods

Run	Open Cell Voltage (V)	Maximum Current Density (mA/cm²)	Maximum Power Density (W/cm²)	Area Specific Resistance ($\Omega \times \text{cm}^2$)	Active Surface Area (cm²)	Resistance (Ω)
13	0.963	53	0.033	4.30	60.6	0.071
14	0.981	48	0.032	4.20	43.7	0.096
15	ROD BROKE OFF AT ELECTROLYTE SURFACE					
16	0.963	31	0.020	8.10	71.7	0.113
17	ROD DID NOT SURVIVE EXPERIMENT PREPARATION					
18	1.044	35	0.024	7.55	66.5	0.114
20	0.972	38	0.026	4.20	65.2	0.064

The method in which the rods were produced led to a problem. The rods seemed to physically degrade in the cell. Therefore, these rods did not last as long as the graphite rods while in the electrolyte. After an experiment had been run, the electrolyte turned black. There also seemed to be a carbon buildup around the surface of the molten electrolyte clinging to the surface of the cell body. This buildup also occurred at the

point on the rod that was at the top surface of the electrolyte. A portion of this buildup has been analyzed and it seems to be the electrolyte and some iron corroded from the cell body. Two scanning electron micrographs of these deposits are included below as Figure 4.14 and Figure 4.15.

Figure 4.14 - SEM Image of Carbon Fuel Rod with C/NaOH/Fe Buildup (×6000)

Figure 4.15 - SEM Image of Carbon Fuel Rod with C/NaOH/Fe Buildup ($\times 1500$)

In Run #15, the rod did not last long enough for any data to be collected. The rod broke off at the electrolyte surface and sank into the cell, causing the active surface area to be zero. In Run #17, no run was actually conducted. This rod did not survive the assembly process and broke before it could be inserted into the fuel cell.

The following figures are the results of the runs involving the non-graphitized coal-derived fuel rods. The results from the 100% PetCoke rods (Runs #13 and #14) are given in Figure 4.16 and Figure 4.17, respectively. The results show the same trend as the experiments with the graphite rods, except for the cell voltages, which are appreciably higher, as seen in Table 4.3. Results for the 100% SECO rod (Run #18) are given as Figure 4.19. The results for the 50% SECO/50% PetCoke rod (Run #16) are given as Figure 4.21. The reason for there being only one run here is because the rod degraded very quickly and the other results are unreliable.

Long term run results for the non-graphite rods are given below in Figure 4.18, Figure 4.20, Figure 4.22, and Figure 4.24. In Figure 4.18, the current was set at 0A and allowed to run long term. In this case, the cell voltage decreased steadily over time. After 200 minutes, the cell voltage had reached zero. When the cell was taken apart, the rod was broken into several pieces, making the active surface area very small; therefore, smaller amounts of voltage could be drawn as the rod degraded. In Figure 4.20, the 100% SECO rod was run at a constant current of 0.5A. The rod produced a steady cell voltage for about an hour, and then the cell voltage quickly decreased. Once again, the rod had degraded and broke into pieces in the cell. In Figure 4.22, the 50% SECO/50% PetCoke rod showed about the same results as the 100% SECO rod. Again, the rod had degraded in the cell.

Figure 4.16 - Results of 100% PetCoke Rod from Run #13

Figure 4.17 - Results of 100% PetCoke Rod from Run #14

Figure 4.18 - Long Term Results for 100% PetCoke Rod Run from Run #14

Figure 4.19 - Results of 100% SECO Rod from Run #18

Figure 4.20 - Long Term Results for 100% SECO Rod Run from Run #18

Figure 4.21 - Results for 50% SECO/ 50% PetCoke Rod from Run #16

Figure 4.22 - Long Term Results for 50/50 SECO-PetCoke Rod Run from Run #16

In Figure 4.23, the results of the GrafTech baked rod are presented. In order to investigate the degradation of the coal-derived rods, a rod made from premium petroleum coke and binder pitch was supplied by GrafTech. In Figure 4.24, the rod provided by GrafTech also shows degradation over time. However, this degradation was much slower than the WVU rods as the run was conducted for 22 hours. Instead of breaking off into large chunks, this rod slowly disintegrated into the electrolyte, making it black with carbon particles. This shows that the manufacture method was a problem for the WVU rods but is not a problem if the rods are carefully made. Once again, the rods produced at GrafTech are manufactured commercially, so their technique is proven and well-established.

The speculation as to why the coal-derived rods fell apart is due to the binder pitch that holds the rods together. It is theorized that this binder pitch is preferentially reacting in the baked rods. Therefore, it is unable to hold the rods together after it has reacted. Binder pitch is used in both the WVU and GrafTech baked rods and the same behavior was noted for all these rods. Binder pitch is also a part of the graphite rods but is converted to graphite during the graphitization and hence is no longer as reactive as it is in the baked rods.

4.3 Data Discussion

4.3.1 Resistivity Calculations

The resistivity of the rods was calculated using the method described in Section 3.5.2, Carbon Rod Resistivity. (See the summarized calculations in Table 4.4). It can be seen that the coal-derived rods have a higher resistivity than the graphite rods. The variability of the resistivity for the SECO/PetCoke rods can be due to the composition of

the rods but more probably due to the technique used in their manufacture. The pressing of the rods in the laboratory was shown to be problematic and resulted in rods of inconsistent quality. Nonetheless, the resistivity of these rods is still quite low and they performed well, albeit for a shorter time, in the DCFC.

Table 4.4 - Calculated Resistivity for Tested Rods

Rod	Resistivity ($\mu\Omega\cdot\text{m}$)
Graphite	6.201
GrafTech Graphite	8.670
0% SECO / 100% PetCoke	52.720
25% SECO / 75% PetCoke	137.250
50% SECO / 50% PetCoke	139.920
75% SECO / 25% PetCoke	78.600
100% SECO / 0% PetCoke	81.900
GrafTech Baked Rod	60.101

The graphite rods show a low resistivity and the calculated values are comparable to the average literature value of $7.837 \mu\Omega\cdot\text{m}$ [14]. The resistivity of the blended rods resulted in a bell-shaped profile. The expectation was for the resistivity to increase exponentially with increasing SECO content since the SECO is coal-derived and should have a higher resistance than the PetCoke. Instead, the 50% blend resulted in the highest resistivity, and therefore had the highest ASR as shown in Table 4.3. The ASR for the graphite rods was about half of the ASR for coal, reflecting the higher resistivity of the coal rods. The results from Table 4.4 are plotted below in Figure 4.25, illustrating the bell-shaped curve generated with data of increasing SECO content. This behavior is most likely due to difficulties associated with the manufacture of the rods rather than the inherent resistance of the cokes. However, the very low resistance of the pure SECO rod

is an unexpected result and indicates that coke made from SECO has a resistance comparable to that of PetCoke.

Figure 4.25 - Resistivity of Coal-Derived Rods as a Function of SECO Content

4.3.2 Reproducibility

Several of the experiments were conducted more than once to ensure that the data were reproducible, as demonstrated in the previous sections. It is essential in any research to prove that the data are reliable. The data obtained during the same experimental run was, in fact, reproducible as shown in Figure 4.26. In this experiment, four separate runs were conducted at the same conditions, with a stepwise increase in current. Between runs, the cell was allowed approximately 30 minutes of recovery so that the starting conditions would be the same as the first run. This recovery time was required because once the system was set to open-circuit, the voltage did not immediately return to the open-circuit value obtained in the previous run suggesting some major

physical or electrical relaxation in the cell. The response to small perturbations is instantaneous, but the response to larger perturbations is not as fast. The results show that the data are readily reproduced when the experimental runs are completed in the same day.

It can also be shown that using runs conducted at different times, the same basic trend in the data can be obtained for the graphite rods. In some cases, more current was drawn, as shown by the higher values of the current density, illustrated in Figure 4.27. In this series of experiments, constant cell conditions were maintained on runs conducted on different days. In the ohmic resistance region, the difference between the voltages generated for these three days is 11% at 50 mA/cm². In the unstable mass transport region, the difference was larger at 25% at 90 mA/cm². The results at the higher current densities show a larger percent difference. It is likely due to slight differences in the graphite rods (the rods were unused at the beginning of each run). Also, because the cell was taken apart after each run, the assembly and connections may have been slightly different. However, the data generated by this research are reproducible, and therefore, reliable.

Figure 4.26 - Reproducibility of Data Generated During the Same Run

Figure 4.27 - Reproducibility of Data Generated During Duplicate Runs

4.3.3 Duplication of Data Provided by SARA

Research conducted at SARA found that the coal-derived rods produce more voltage than graphite rods, as is the finding in this work. SARA used the following figure to show their findings.

The experiment shown in Figure 4.28 was conducted for the first 100 hours with a coal-derived fuel rod. The remaining 70 hours was conducted with a graphite fuel rod. It can be seen that at the interface between the two, there is an abrupt drop-off in cell voltage mainly due to the change in the anode potential. Therefore, SARA's findings agree with those herein and show that coal-derived rods produced more voltage than the graphite rods.

Figure 4.28 - Results of SARA's Findings Comparing Coal-Derived Fuel to Graphite

4.3.4 Effect of Temperature

During one of the tests with the graphite rods, the cell temperature was varied stepwise from 600°C to 700°C and the i -V scans were made. The results indicate that the increase in temperature clearly causes an increase in performance in the cell, as shown in Figure 4.29 and Figure 4.30. However, there is a maximum temperature at which the temperature effect ceases to increase performance. It appears that the reaction is optimized at around 675°C, according to these data. Data at 700°C show that the cell voltage is less, even though more current is drawn than at the lower temperatures.

Figure 4.29 - Effect of Temperature on Voltage Output and Power Density from Runs #4, #5, #6, #8, and #10 (Trial 1)

Figure 4.30 - Effect of Temperature on Voltage Output and Power Density from Runs #4, #5, #6, and #8 (Trial 2)

The same can be seen for the power output in this case, as illustrated in Figure 4.29 and Figure 4.30. The maximum power is obtained at 675°C after a trend of increasing performance. The power output at 700°C is lower, and therefore it appears that the optimum temperature for power output is also around 675°C, even though more current is drawn at 700°C.

Although the values of E° obtained for different temperatures in Equation 4.1 are similar (see Section 2.4), the values for E_{cell} obtained experimentally clearly show that temperature has more of an effect than originally anticipated. From the above equation, it seems logical that raising the temperature increases the voltage of the cell, which is seen in the increase in cell voltage from 600°C to 675°C. This is due to the natural log of the

ratio of the partial pressures of CO₂ and O₂ being negative (because the partial pressure of CO₂ in the inlet gas is small compared to O₂, assuming a well-mixed environment. At the higher temperature, there may be more CO₂ produced in the cell, which would cause the voltage output to decrease at even higher temperatures.

$$E_{cell} = E^{\circ} - \frac{RT}{NF} \cdot \ln \frac{[CO_2]}{[O_2]} \quad (4.1)$$

It should be noted that this equation holds for C reacting with gaseous O₂ to make gaseous CO₂, a situation that is not present in these experiments. However, this equation is frequently cited in the literature and may be relevant when using the concentrations of gaseous O₂ and CO₂ in the electrolyte.

A trend of how the OCV changed with respect to the temperature is given in Figure 4.31. The ASR shows the opposite trend of the OCV. When the ASR is at a minimum, the OCV reaches a maximum. This makes sense because when there is less ohmic resistance, the ionic and electronic conduction is higher, leading to increased cell voltage. The ASR varied in this experiment from 1.6 Ω-cm² to 2.2 Ω-cm², since this test was conducted using graphite rods.

Figure 4.31 - Trends of Open Cell Voltage and Area Specific Resistance versus Fuel Cell Temperature Using a Graphite Rod

4.3.5 Effect of Airflow Rate

The effect of the airflow rate into the cell influences the performance of the cell as shown below in Figure 4.32 and Figure 4.33. There is a clear peak at 0.50 SLPM where the maximum performance is obtained at 675°C, while the optimum performance at 600°C appears to be at higher airflow rates.

At a flow rate below the optimum airflow value (0.25 SLPM), the optimum amount of air is not being supplied for the reaction. Referring to Equation 4.1, supplying more oxygen into the system would cause the natural log of the ratio to be more negative, causing the cell voltage to increase.

At a flow rate above the optimum airflow value (0.75 SLPM), the air is either flowing too quickly for the reaction to occur optimally, or it may be that the bubbles emanating from the spider are too large. This causes the surface area for the cathode reaction to be smaller because the air is occupying a large amount of the cathode surface, resulting in less contact between the reactants.

Figure 4.32 - Effect of Airflow Rate on Voltage Output and Power Density at 675°C

Figure 4.33 - Effect of Airflow Rate on Voltage Output and Power Density at 600°C

Oxygen is required at the cathode, as seen in Equation 4.2, and is supplied in this process through the air feed. This equation shows that the airflow directly effects the cathode half-cell reaction. This is where the electrons are reintroduced into the system, react with the humidified air and replenish the hydroxide ions that are consumed at the anode.

The trends of OCV and ASR with the airflow rate are given in Figure 4.34 for the graphite rod. It can be seen here that the open cell voltage decreases steadily as airflow rate is increased. However, as shown in Figure 4.32, the voltage decreases faster at 0.25 SLPM than it does at 0.50 SLPM, catching up at about 35 mA/cm². The ASR shows the same trend as it did for the temperature study, with the minimum correlating to a

maximum in cell voltage (not OCV, in this case). The minimum resistance is at an airflow rate of 0.50 SLPM. Further data are provided in the presentation of the graphite rod results above.

Figure 4.34 - Trends of Open Cell Voltage and Area Specific Resistance Using a Graphite Rod when Airflow Rate is Varied (taken from data of Figure 4.32)

4.3.6 Effect of Fuel Rod Composition

Table 4.5 is a summary of the main results obtained from the different fuels.

Table 4.5- Summary of Results by Carbon Fuel Rod

Rod (Run #)	Maximum OCV (V)	Maximum Current Density (mA/cm^2)	Maximum Power Density (W/cm^2)	Area Specific Resistance ($\Omega \times \text{cm}^2$)	Resistance (Ω)
Graphite (4)	0.788	230	0.084	2.59	0.054
WVU Coal-Derived (18)	1.043	61	0.038	5.90	0.108
GrafTech Baked (20)	0.972	38	0.026	4.20	0.065

The best voltage output was obtained using the WVU coal-derived rods, specifically, the rod used in Run #18 (Section 3.2), composed of pure SECO. The

GrafTech baked rod also reached nearly 1.0V. Recall that the standard potential for the oxidation of carbon is 1.01V. The SECO rod recorded a voltage slightly over the standard potential, probably due to reactions of some impurities or the binder pitch used in the rod.

The trends in the OCV and ASR for the SECO blend rods are given below in Figure 4.35. It can be seen that the OCV is the highest at about 100% SECO content. The OCV is the lowest where the ASR is at its maximum, as expected. Once again, the ohmic resistance hinders ionic and electronic conduction in the electrolyte and electrodes, and therefore lowers cell voltage.

Figure 4.35 - Trends of Open Cell Voltage and Area Specific Resistance versus Percentage of SECO Content

The most current was drawn from the graphite rods, due to the ordered molecular structure of graphite and the stability of the rod over time. The graphite rods clearly allow more current to be drawn per unit of surface area because of their low ohmic resistance (recall ASR is a measurement of ohmic resistance). Therefore, more power is

produced from graphite rods in this case because power is the product of current times voltage. Power is the most important parameter in evaluating a fuel cell. The resistance of the coal-derived rods is almost twice as much as that of graphite. Hence ohmic heating in the coal-derived rods, dissipates more power, so less current can be drawn. This explains why higher current could be drawn from graphite despite the lower OCV.

4.3.7 Effect of Electrolyte

An attempt was made to try electrolytes other than the sodium hydroxide that was used in most of the experiments. However, these tests did not produce any positive results. Using lithium hydroxide (LiOH) did not allow the cell to produce a steady voltage. A mole ratio of 1.64:1 NaOH to LiOH, the eutectic mixture suggested in literature, was used for Run #12. The phase diagram for this mixture is given in Figure 4.36. The use of the eutectic mixture in this case was to reproduce some alternate experimental conditions examined at SARA.

The use of carbonate electrolytes did not produce any cell voltage whatsoever. The eutectic of a 1:1 mole ratio of Li_2CO_3 and Na_2CO_3 was used to lower the melting point of the mixture to 510°C , slightly below the operating temperature of 600°C . The diagram for this mixture is given in Figure 4.37. The eutectic melted at the proper temperature; however, the experiment did not produce any results. The reason may be due to the fact that carbonate reactions do not involve the use of water molecules. As the setup was made to include humidified air to the cell, this may have caused the problems that were experienced. Using dry air directly may have solved the problem, but it would require that the test stand be taken apart to bypass the water tank. Further experiments using alternate electrolytes were not conducted and were beyond the scope of this work.

Figure 4.36 – Phase Diagram Showing Eutectic Mixture for NaOH and LiOH

Figure 4.37 – Phase Diagram Showing Eutectic Mixture for Li_2CO_3 and Na_2CO_3

Chapter 5

Conclusions

Using carbon rods as a fuel source, the direct carbon fuel cell produced electricity as predicted. The following conclusions can be drawn from the work:

- The test stands provided by the U.S. Department of Energy were carefully studied. The modifications necessary to transition the stand from SOFC to DCFC were successfully completed.
- Graphite rods were used to evaluate the system. They provided reliable and reproducible data and ensured proper operation of the system.
- Rods derived from coal were successfully tested in the system
- The effects of temperature, airflow, electrolyte, long-term exposure, and different rods were investigated and showed that cell performance peaks at about 675°C and 0.50 SLPM with NaOH as the electrolyte. Graphite rods had better long-term results as they contained no binder pitch.
- The fuel cell performance was evaluated via *i*-V curves, which can be used to investigate different types of resistances such as activation, ohmic, and transport resistances. Graphite rods produced open cell voltages of up to 0.788V and current densities up to 230 mA/cm² while coal-derived rods produced open cell voltages of 1.044V and only 50 mA/cm² in current density.
- The fuel cell performance was evaluated by comparing plots of power densities, which can be used to evaluate the current needed for peak power output. Graphite rods produced 0.084 W/cm² while coal-derived rods were

only able to produce 0.041 W/cm² because of their higher ASR (~4-8 $\Omega \times \text{cm}^2$ as opposed to ~2 $\Omega \times \text{cm}^2$).

- Binder pitch is attacked preferentially in the reaction. Therefore, the baked coal-derived rods crumbled over time in the electrolyte.
- GrafTech baked rods were tested to investigate whether the method of manufacture influenced the behavior of the coal-derived rods. These rods were not able to stand long-term runs due to the binder pitch preferentially reacting.

Chapter 6

Recommendations

This technology is extremely promising. Further work should be conducted to find a way around using rods. The process of making the rods is time consuming, expensive, and energy inefficient. A method of inserting raw coal into the cell would save both time and money in the future. This would also solve the problem of the rods disintegrating in the cell. If this did not happen, it would be more likely that more power would be produced from the coal-derived rods than the graphite rods.

The test stands could be modified to handle a molten carbonate fuel cell design. The electrolyte may allow better cell performance and should be considered an important factor in a DCFC.

The cell could be modified to allow the electrolyte to be reused. With the carbon anode directly immersed into the electrolyte, particulate matter contaminates the electrolyte slowly rendering it ineffective. In future applications, it may be feasible to remove and replace electrolyte while the cell is in use. This would save valuable time and energy. Perhaps a method of electrolyte filtration would be effective.

In order for the cell to be more efficient, some of the following could be investigated.

- To reduce activation losses
 - The use of a catalyst in the electrolyte.
 - Increase the surface area of the anode and cathode by making it rougher
 - Use enriched air with higher oxygen concentration to increase reactant concentration
 - Investigate pressure effects
- To reduce ohmic losses

- Use a highly conductive metal for the cathode and a highly conductive electrolyte
 - Reducing the space between the cathode and anode
- To reduce mass transport losses
 - Introduce a “spider” that makes smaller bubbles, perhaps more legs
 - Have the bubbles pass through a fine wire mesh to prevent large bubbles
 - Run as low airflow rates as possible

Chapter 7

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Chapter 8

Appendix A – Graphite Rods Raw Data

Graphite Rod, Air Flow Rate Varied, T = 600°C, 11/22/2005

RM = 40			RM = 50			RM = 65 (1)			RM = 65 (2)		
I/SA	V _{CELL}	P/SA	I/SA	V _{CELL}	P/SA	I/SA	V _{CELL}	P/SA	I/SA	V _{CELL}	P/SA
0.000	0.717	0.000	0.000	0.719	0.000	0.000	0.728	0.000	0.000	0.737	0.000
2.819	0.707	0.002	2.819	0.707	0.002	2.819	0.719	0.002	2.819	0.731	0.002
5.639	0.697	0.004	5.639	0.696	0.004	5.639	0.716	0.004	5.639	0.722	0.004
8.458	0.686	0.006	8.458	0.683	0.006	8.458	0.705	0.006	8.458	0.709	0.006
11.277	0.675	0.008	11.277	0.671	0.008	11.277	0.691	0.008	11.277	0.698	0.008
14.096	0.663	0.009	14.096	0.660	0.009	14.096	0.678	0.010	14.096	0.687	0.010
16.916	0.652	0.011	19.735	0.637	0.013	16.916	0.667	0.011	16.916	0.678	0.011
19.735	0.641	0.013	22.554	0.626	0.014	19.735	0.656	0.013	16.916	0.674	0.011
22.554	0.629	0.014	25.374	0.614	0.016	22.554	0.644	0.015	19.735	0.625	0.012
25.374	0.618	0.016	28.193	0.603	0.017	25.374	0.631	0.016	19.735	0.658	0.013
28.193	0.606	0.017	31.012	0.590	0.018	28.193	0.621	0.018	19.735	0.662	0.013
31.012	0.596	0.018	33.831	0.580	0.020	31.012	0.608	0.019	22.554	0.631	0.014
33.831	0.585	0.020	36.651	0.568	0.021	33.831	0.597	0.020	22.554	0.649	0.015
36.651	0.573	0.021	39.470	0.557	0.022	36.651	0.586	0.021	22.554	0.651	0.015
39.470	0.562	0.022	42.289	0.547	0.023	39.470	0.575	0.023	25.374	0.631	0.016
42.289	0.552	0.023	45.109	0.536	0.024	42.289	0.565	0.024	25.374	0.641	0.016
45.109	0.540	0.024	47.928	0.525	0.025	45.109	0.554	0.025	28.193	0.630	0.018
47.928	0.529	0.025	50.747	0.515	0.026	47.928	0.543	0.026	31.012	0.621	0.019
50.747	0.518	0.026	53.566	0.504	0.027	50.747	0.532	0.027	33.831	0.610	0.021
53.566	0.507	0.027	56.386	0.493	0.028	53.566	0.522	0.028	39.470	0.591	0.023
56.386	0.496	0.028	59.205	0.482	0.029	56.386	0.512	0.029	42.289	0.579	0.024
59.205	0.484	0.029	62.024	0.472	0.029	59.205	0.500	0.030	47.928	0.560	0.027
62.024	0.473	0.029	64.844	0.461	0.030	62.024	0.490	0.030	53.566	0.539	0.029
64.844	0.463	0.030	67.663	0.450	0.030	64.844	0.480	0.031	56.386	0.530	0.030
67.663	0.451	0.031	70.482	0.440	0.031	67.663	0.470	0.032	59.205	0.520	0.031
70.482	0.440	0.031	73.301	0.430	0.032	70.482	0.460	0.032	64.844	0.501	0.032
73.301	0.428	0.031	76.121	0.420	0.032	73.301	0.450	0.033	67.663	0.490	0.033
76.121	0.417	0.032	78.940	0.409	0.032	76.121	0.439	0.033	67.663	0.492	0.033
78.940	0.405	0.032	81.759	0.399	0.033	78.940	0.430	0.034	70.482	0.481	0.034
81.759	0.395	0.032	84.579	0.389	0.033	81.759	0.420	0.034	73.301	0.475	0.035
84.579	0.384	0.032	88.807	0.373	0.033	84.579	0.410	0.035	76.121	0.466	0.035
88.807	0.370	0.033				88.807	0.396	0.035	78.940	0.458	0.036
									81.759	0.448	0.037
									84.579	0.439	0.037
									87.398	0.430	0.038
									90.217	0.421	0.038
									93.036	0.412	0.038
									164.646	0.193	0.032

Graphite Rod, Air Flow Rate Varied, T = 600°C, 12/6/2005

RM = 20			RM = 40			RM = 50			RM = 65		
I/SA	VCELL	P/SA	I/SA	VCELL	P/SA	I/SA	VCELL	P/SA	I/SA	VCELL	P/SA
0.000	0.670	0.000	0.000	0.652	0.000	0.000	0.678	0.000	0.000	0.699	0.000
0.000	0.697	0.000	0.000	0.676	0.000	0.000	0.700	0.000	0.000	0.707	0.000
0.000	0.686	0.000	2.722	0.646	0.002	2.722	0.675	0.002	0.000	0.707	0.000
2.722	0.660	0.002	5.444	0.637	0.003	5.444	0.669	0.004	2.819	0.694	0.002
4.083	0.655	0.003	8.165	0.634	0.005	8.165	0.666	0.005	5.639	0.688	0.004
5.444	0.648	0.004	10.887	0.627	0.007	10.887	0.659	0.007	8.458	0.681	0.006
5.444	0.677	0.004	13.609	0.619	0.008	13.609	0.654	0.009	11.277	0.675	0.008
8.165	0.637	0.005	16.331	0.613	0.010	13.609	0.664	0.009	14.096	0.669	0.009
10.887	0.629	0.007	19.053	0.608	0.012	16.331	0.648	0.011	16.916	0.664	0.011
13.609	0.620	0.008	21.775	0.602	0.013	19.053	0.644	0.012	19.735	0.660	0.013
13.609	0.648	0.009	24.496	0.598	0.015	21.775	0.638	0.014	22.554	0.653	0.015
16.331	0.613	0.010	27.218	0.593	0.016	24.496	0.632	0.015	25.374	0.647	0.016
19.053	0.606	0.012	27.218	0.619	0.017	27.218	0.628	0.017	28.193	0.642	0.018
21.775	0.599	0.013	32.662	0.582	0.019	27.218	0.634	0.017	28.193	0.641	0.018
24.496	0.591	0.014	35.384	0.579	0.020	29.940	0.624	0.019	28.193	0.636	0.018
27.218	0.584	0.016	40.827	0.569	0.023	32.662	0.620	0.020	31.012	0.636	0.020
27.218	0.605	0.016	40.827	0.592	0.024	35.384	0.615	0.022	33.831	0.631	0.021
29.940	0.577	0.017	46.271	0.559	0.026	38.106	0.611	0.023	36.651	0.626	0.023
32.662	0.570	0.019	51.715	0.551	0.028	40.827	0.606	0.025	39.470	0.620	0.024
35.384	0.562	0.020	54.437	0.547	0.030	40.827	0.606	0.025	42.289	0.616	0.026
35.384	0.563	0.020	54.437	0.566	0.031	43.549	0.602	0.026	45.109	0.611	0.028
38.106	0.557	0.021	59.880	0.538	0.032	46.271	0.596	0.028	50.747	0.601	0.030
40.827	0.550	0.022	65.324	0.531	0.035	48.993	0.593	0.029	56.386	0.593	0.033
40.827	0.568	0.023	70.768	0.524	0.037	51.715	0.589	0.030	62.024	0.583	0.036
43.549	0.546	0.024	76.211	0.515	0.039	54.437	0.585	0.032	67.663	0.574	0.039
46.271	0.539	0.025	81.655	0.509	0.042	54.437	0.580	0.032	73.301	0.564	0.041
48.993	0.534	0.026	81.655	0.519	0.042	57.158	0.580	0.033	78.940	0.556	0.044
51.715	0.528	0.027	87.099	0.501	0.044	59.880	0.577	0.035	84.579	0.547	0.046
54.437	0.523	0.028	95.264	0.490	0.047	65.324	0.568	0.037	90.217	0.538	0.049
54.437	0.536	0.029	95.264	0.497	0.047	68.046	0.564	0.038	95.856	0.528	0.051
57.158	0.516	0.029	100.708	0.482	0.049	73.489	0.556	0.041	101.494	0.520	0.053
59.880	0.512	0.031	106.151	0.475	0.050	76.211	0.553	0.042	107.133	0.511	0.055
62.602	0.507	0.032	108.873	0.474	0.052	81.655	0.544	0.044	112.771	0.503	0.057
65.324	0.502	0.033	111.595	0.468	0.052	81.655	0.530	0.043	118.410	0.493	0.058
68.046	0.498	0.034	111.595	0.468	0.052	87.099	0.539	0.047	124.048	0.485	0.060
68.046	0.506	0.034	117.039	0.463	0.054	92.542	0.532	0.049	129.687	0.474	0.061
70.768	0.492	0.035	122.482	0.455	0.056	95.264	0.510	0.049	129.687	0.472	0.061
73.489	0.488	0.036	127.926	0.448	0.057	97.986	0.524	0.051	135.326	0.460	0.062
76.211	0.481	0.037	133.370	0.441	0.059	103.430	0.515	0.053	140.964	0.450	0.063
78.933	0.476	0.038	136.091	0.436	0.059	108.873	0.507	0.055	146.603	0.440	0.065
81.655	0.471	0.038	136.091	0.432	0.059	108.873	0.489	0.053	152.241	0.420	0.064
81.655	0.478	0.039	141.535	0.429	0.061	114.317	0.497	0.057	157.880	0.411	0.065
84.377	0.466	0.039	149.701	0.420	0.063	114.317	0.498	0.057	163.518	0.395	0.065
87.099	0.462	0.040	155.144	0.411	0.064	119.760	0.489	0.059	163.518	0.374	0.061
89.820	0.456	0.041	163.310	0.400	0.065	125.204	0.480	0.060	169.157	0.356	0.060
92.542	0.450	0.042	163.310	0.387	0.063	130.648	0.473	0.062	174.796	0.320	0.056
95.264	0.443	0.042	176.919	0.381	0.067	136.091	0.463	0.063			

95.264	0.450	0.043	185.084	0.368	0.068	136.091	0.444	0.060
97.986	0.438	0.043	195.972	0.350	0.069	141.535	0.454	0.064
100.708	0.431	0.043	204.137	0.336	0.069	146.979	0.444	0.065
103.430	0.427	0.044	217.746	0.311	0.068	152.422	0.433	0.066
106.151	0.420	0.045	227.273	0.285	0.065	157.866	0.423	0.067
108.873	0.414	0.045	229.995	0.285	0.066	157.866	0.421	0.066
108.873	0.424	0.046				163.310	0.409	0.067
111.595	0.409	0.046				174.197	0.391	0.068
114.317	0.403	0.046				179.641	0.372	0.067
117.039	0.392	0.046				185.084	0.360	0.067
119.760	0.388	0.046				190.528	0.343	0.065
122.482	0.380	0.047				197.333	0.325	0.064
122.482	0.398	0.049				204.137	0.303	0.062
127.926	0.368	0.047				206.859	0.261	0.054
130.648	0.359	0.047						
133.370	0.351	0.047						
136.091	0.342	0.047						
136.091	0.371	0.050						
138.813	0.336	0.047						
141.535	0.326	0.046						
144.257	0.316	0.046						
146.979	0.310	0.046						
149.701	0.299	0.045						
152.422	0.289	0.044						
155.144	0.282	0.044						
157.866	0.273	0.043						
160.588	0.258	0.041						
163.310	0.249	0.041						
166.032	0.238	0.040						
174.197	0.216	0.038						

Graphite Rod, Air Flow Rate Varied, T = 600°C, 12/14/2005

RM = 20, T = 600			RM = 40, T = 600			RM = 50, T = 600			RM = 65, T = 600		
I/SA	VCELL	P/SA	I/SA	VCELL	P/SA	I/SA	VCELL	P/SA	I/SA	VCELL	P/SA
0.000	0.653	0.000	0.000	0.701	0.000	0.000	0.730	0.000	0.000	0.711	0.000
0.000	0.653	0.000	0.000	0.743	0.000	0.000	0.731	0.000	0.000	0.727	0.000
0.000	0.715	0.000	1.754	0.697	0.001	1.754	0.725	0.001	1.754	0.708	0.001
1.754	0.645	0.001	3.509	0.690	0.002	3.509	0.718	0.003	3.509	0.702	0.002
3.509	0.638	0.002	5.263	0.684	0.004	5.263	0.711	0.004	5.263	0.694	0.004
5.263	0.632	0.003	7.018	0.679	0.005	7.018	0.704	0.005	7.018	0.692	0.005
7.018	0.633	0.004	8.772	0.673	0.006	8.772	0.699	0.006	8.772	0.687	0.006
7.018	0.623	0.004	8.772	0.705	0.006	10.526	0.692	0.007	10.526	0.682	0.007
8.772	0.623	0.005	10.526	0.669	0.007	12.281	0.688	0.008	12.281	0.679	0.008
8.772	0.619	0.005	12.281	0.663	0.008	14.035	0.680	0.010	14.035	0.674	0.009
10.526	0.613	0.006	14.035	0.660	0.009	15.789	0.676	0.011	15.789	0.669	0.011
12.281	0.606	0.007	15.789	0.655	0.010	17.544	0.670	0.012	17.544	0.664	0.012
14.035	0.599	0.008	17.544	0.652	0.011	17.544	0.674	0.012	17.544	0.673	0.012
15.789	0.606	0.010	17.544	0.671	0.012	19.298	0.664	0.013	19.298	0.660	0.013

17.544	0.594	0.010	19.298	0.647	0.012	21.053	0.659	0.014	21.053	0.655	0.014
17.544	0.611	0.011	21.053	0.643	0.014	22.807	0.655	0.015	22.807	0.652	0.015
19.298	0.592	0.011	22.807	0.640	0.015	24.561	0.649	0.016	24.561	0.647	0.016
21.053	0.576	0.012	24.561	0.636	0.016	26.316	0.644	0.017	26.316	0.643	0.017
22.807	0.570	0.013	26.316	0.633	0.017	28.070	0.638	0.018	28.070	0.640	0.018
24.561	0.563	0.014	26.316	0.641	0.017	29.825	0.633	0.019	29.825	0.636	0.019
26.316	0.564	0.015	28.070	0.629	0.018	31.579	0.628	0.020	31.579	0.632	0.020
28.070	0.554	0.016	29.825	0.632	0.019	33.333	0.623	0.021	33.333	0.628	0.021
29.825	0.549	0.016	31.579	0.628	0.020	35.088	0.619	0.022	35.088	0.624	0.022
29.825	0.549	0.016	33.333	0.625	0.021	35.088	0.619	0.022	35.088	0.628	0.022
31.579	0.546	0.017	35.088	0.621	0.022	36.842	0.615	0.023	36.842	0.620	0.023
33.333	0.544	0.018	35.088	0.610	0.021	38.596	0.609	0.024	38.596	0.618	0.024
35.088	0.535	0.019	35.088	0.611	0.021	40.351	0.605	0.024	40.351	0.614	0.025
35.088	0.541	0.019	36.842	0.618	0.023	42.105	0.602	0.025	42.105	0.610	0.026
36.842	0.529	0.019	38.596	0.614	0.024	43.860	0.597	0.026	43.860	0.606	0.027
38.596	0.524	0.020	40.351	0.610	0.025	45.614	0.592	0.027	45.614	0.602	0.027
40.351	0.522	0.021	42.105	0.606	0.026	47.368	0.587	0.028	47.368	0.600	0.028
42.105	0.515	0.022	43.860	0.602	0.026	49.123	0.583	0.029	49.123	0.596	0.029
43.860	0.512	0.022	43.860	0.580	0.025	50.877	0.579	0.029	50.877	0.593	0.030
43.860	0.505	0.022	45.614	0.599	0.027	52.632	0.575	0.030	52.632	0.589	0.031
45.614	0.509	0.023	47.368	0.594	0.028	52.632	0.569	0.030	52.632	0.585	0.031
47.368	0.507	0.024	49.123	0.592	0.029	56.140	0.566	0.032	56.140	0.582	0.033
49.123	0.501	0.025	50.877	0.588	0.030	59.649	0.559	0.033	59.649	0.575	0.034
50.877	0.497	0.025	52.632	0.584	0.031	63.158	0.550	0.035	63.158	0.568	0.036
52.632	0.492	0.026	52.632	0.552	0.029	66.667	0.543	0.036	66.667	0.562	0.037
52.632	0.473	0.025	56.140	0.575	0.032	70.175	0.536	0.038	70.175	0.555	0.039
54.386	0.490	0.027	59.649	0.569	0.034	70.175	0.519	0.036	70.175	0.544	0.038
56.140	0.482	0.027	61.404	0.526	0.032	70.175	0.522	0.037	73.684	0.548	0.040
57.895	0.477	0.028	63.158	0.559	0.035	73.684	0.527	0.039	77.193	0.541	0.042
59.649	0.478	0.029	66.667	0.553	0.037	77.193	0.519	0.040	80.702	0.535	0.043
61.404	0.474	0.029	70.175	0.547	0.038	80.702	0.512	0.041	84.211	0.528	0.044
63.158	0.464	0.029	70.175	0.493	0.035	84.211	0.503	0.042	87.719	0.522	0.046
64.912	0.456	0.030	70.175	0.497	0.035	87.719	0.496	0.044	87.719	0.501	0.044
66.667	0.455	0.030	73.684	0.540	0.040	91.228	0.488	0.045	91.228	0.516	0.047
68.421	0.455	0.031	77.193	0.532	0.041	94.737	0.480	0.045	94.737	0.508	0.048
70.175	0.452	0.032	80.702	0.524	0.042	98.246	0.475	0.047	98.246	0.501	0.049
70.175	0.404	0.028	84.211	0.517	0.044	100.000	0.467	0.047	101.754	0.495	0.050
71.930	0.450	0.032	87.719	0.509	0.045	100.000	0.466	0.047	101.754	0.492	0.050
73.684	0.431	0.032	91.228	0.500	0.046	101.754	0.461	0.047	105.263	0.485	0.051
75.439	0.441	0.033	94.737	0.488	0.046	105.263	0.455	0.048	108.772	0.477	0.052
75.439	0.425	0.032	98.246	0.479	0.047	108.772	0.446	0.049	112.281	0.47	0.053
77.193	0.428	0.033	101.754	0.461	0.047	112.281	0.434	0.049	115.789	0.463	0.054
77.193	0.439	0.034	105.263	0.445	0.047	115.789	0.424	0.049	119.298	0.455	0.054
78.947	0.432	0.034	108.772	0.429	0.047	119.298	0.417	0.050	122.807	0.445	0.055
78.947	0.370	0.029	112.281	0.413	0.046	122.807	0.406	0.050	126.316	0.437	0.055
80.702	0.428	0.035	115.789	0.335	0.039	126.316	0.395	0.050	129.825	0.426	0.055
82.456	0.400	0.033	115.789	0.34	0.039	129.825	0.380	0.049	133.333	0.416	0.055
84.211	0.420	0.035	122.807	0.237	0.029	133.333	0.365	0.049	136.842	0.405	0.055
85.965	0.377	0.032				136.842	0.345	0.047	140.351	0.39	0.055
87.719	0.412	0.036				140.351	0.33	0.046	143.860	0.373	0.054

89.474	0.405	0.036	143.860	0.282	0.041	147.368	0.343	0.051
91.228	0.383	0.035				150.877	0.316	0.048
92.982	0.388	0.036						
94.737	0.388	0.037						
96.491	0.371	0.036						
96.491	0.296	0.029						
98.246	0.369	0.036						
100.000	0.360	0.036						
100.175	0.367	0.037						
101.754	0.350	0.036						
103.509	0.351	0.036						
105.263	0.328	0.035						
107.018	0.328	0.035						
108.772	0.328	0.036						
110.526	0.325	0.036						
112.281	0.312	0.035						
114.035	0.309	0.035						
114.035	0.302	0.034						
115.789	0.299	0.035						
117.544	0.28	0.033						
119.298	0.266	0.032						
121.053	0.266	0.032						
122.807	0.256	0.031						
124.561	0.242	0.030						
126.316	0.298	0.038						
128.070	0.244	0.031						

Graphite Rod, Air Flow Rate Varied, T = 600°C, 1/12/2006

RM = 40 (1), T = 600			RM = 40 (2), T = 600			RM = 50, T = 600			RM = 65, T = 600		
I/SA	VCELL	P/SA	I/SA	VCELL	P/SA	I/SA	VCELL	P/SA	I/SA	VCELL	P/SA
1.155	0.683	0.001	1.155	0.747	0.001	1.155	0.748	0.001	1.155	0.756	0.001
1.155	0.727	0.001	3.851	0.738	0.003	1.348	0.730	0.001	3.851	0.748	0.003
3.851	0.675	0.003	5.776	0.733	0.004	3.851	0.723	0.003	5.776	0.744	0.004
5.776	0.668	0.004	7.701	0.728	0.006	5.776	0.718	0.004	7.701	0.740	0.006
7.701	0.662	0.005	9.626	0.722	0.007	7.701	0.714	0.005	9.626	0.735	0.007
9.626	0.656	0.006	11.552	0.716	0.008	9.626	0.709	0.007	11.552	0.730	0.008
9.626	0.698	0.007	13.477	0.710	0.010	11.552	0.705	0.008	13.477	0.725	0.010
10.974	0.644	0.007	15.402	0.705	0.011	13.477	0.698	0.009	15.402	0.721	0.011
10.974	0.652	0.007	17.328	0.699	0.012	15.402	0.695	0.011	15.402	0.721	0.011
11.552	0.649	0.007	19.253	0.694	0.013	17.328	0.690	0.012	17.328	0.715	0.012
13.477	0.642	0.009	21.178	0.689	0.015	19.253	0.686	0.013	19.253	0.710	0.014
14.440	0.683	0.010	23.104	0.683	0.016	21.178	0.695	0.013	21.178	0.706	0.015
15.402	0.638	0.010	25.029	0.679	0.017	23.104	0.682	0.014	23.104	0.702	0.016
17.328	0.633	0.011	26.954	0.672	0.018	25.029	0.677	0.016	25.029	0.697	0.017
19.253	0.628	0.012	28.879	0.668	0.019	26.954	0.673	0.017	26.954	0.694	0.019
19.253	0.667	0.013	30.805	0.663	0.020	28.879	0.669	0.018	26.954	0.689	0.019
21.178	0.621	0.013	32.730	0.659	0.022	30.805	0.665	0.019	28.879	0.684	0.020
23.104	0.616	0.014	34.655	0.653	0.023	32.730	0.660	0.020	30.805	0.680	0.021
24.066	0.655	0.016	36.581	0.650	0.024	34.655	0.656	0.021	32.730	0.676	0.022
25.029	0.611	0.015	38.506	0.645	0.025	36.581	0.653	0.023	34.655	0.672	0.023
26.954	0.606	0.016	40.431	0.640	0.026		0.649	0.024	36.581	0.669	0.024

28.879	0.601	0.017	42.357	0.636	0.027	38.506	0.644	0.025	38.506	0.664	0.026
28.879	0.640	0.018	44.282	0.632	0.028	40.431	0.640	0.026	40.431	0.661	0.027
30.805	0.596	0.018	46.207	0.625	0.029	42.357	0.636	0.027	42.357	0.658	0.028
32.730	0.590	0.019	48.132	0.622	0.030	44.282	0.632	0.028	44.282	0.654	0.029
33.693	0.629	0.021	50.058	0.618	0.031	48.132	0.624	0.030	46.207	0.649	0.030
34.655	0.586	0.020	51.983	0.612	0.032	50.058	0.620	0.031	48.132	0.646	0.031
36.581	0.582	0.021	53.908	0.609	0.033	51.983	0.617	0.032	50.058	0.642	0.032
38.506	0.578	0.022	55.834	0.605	0.034	53.908	0.613	0.033	51.983	0.638	0.033
38.506	0.617	0.024	57.759	0.598	0.035	55.834	0.609	0.034	53.908	0.634	0.034
40.431	0.574	0.023	61.610	0.591	0.036	57.759	0.605	0.035	55.834	0.630	0.035
42.357	0.568	0.024	65.460	0.580	0.038	59.684	0.601	0.036	57.759	0.626	0.036
44.282	0.567	0.025	69.311	0.577	0.040	61.610	0.598	0.037	61.610	0.619	0.038
46.207	0.561	0.026	73.161	0.566	0.041	65.460	0.589	0.039	65.460	0.612	0.040
48.132	0.556	0.027	77.012	0.559	0.043	69.311	0.581	0.040	69.311	0.604	0.042
48.132	0.593	0.029	80.863	0.550	0.044	73.161	0.574	0.042	73.161	0.597	0.044
50.058	0.553	0.028	84.713	0.543	0.046	77.012	0.566	0.044	77.012	0.589	0.045
51.983	0.550	0.029	88.564	0.531	0.047	80.863	0.557	0.045	80.863	0.582	0.047
53.908	0.546	0.029	92.414	0.518	0.048	84.713	0.549	0.047	84.713	0.574	0.049
55.834	0.543	0.030	94.340	0.518	0.049	86.638	0.545	0.047	86.638	0.569	0.049
57.759	0.539	0.031	96.265	0.515	0.050	88.564	0.538	0.048	88.564	0.565	0.050
57.759	0.572	0.033	96.265	0.515	0.050	92.414	0.529	0.049	92.414	0.555	0.051
59.684	0.533	0.032	100.116	0.503	0.050	94.340	0.522	0.049	96.265	0.546	0.053
61.610	0.530	0.033	103.966	0.493	0.051	96.265	0.536	0.052	98.190	0.544	0.053
65.460	0.524	0.034	107.817	0.484	0.052	96.265	0.518	0.050	100.116	0.538	0.054
67.385	0.550	0.037	111.667	0.462	0.052	100.116	0.506	0.051	103.966	0.528	0.055
69.311	0.512	0.035	115.518	0.462	0.053	103.966	0.490	0.051	105.891	0.523	0.055
73.161	0.508	0.037	119.369	0.450	0.054	105.891	0.486	0.051	107.817	0.516	0.056
77.012	0.500	0.039	123.027	0.430	0.053	107.817	0.508	0.055	109.742	0.507	0.056
77.012	0.531	0.041	125.144	0.420	0.053	107.817	0.479	0.052	111.667	0.503	0.056
80.863	0.490	0.040	128.995	0.388	0.050	107.817	0.486	0.052	115.518	0.487	0.056
84.713	0.486	0.041	132.846	0.372	0.049	109.742	0.467	0.051	117.058	0.478	0.056
86.638	0.512	0.044	134.963	0.350	0.047	111.667	0.486	0.054	115.518	0.478	0.055
88.564	0.478	0.042				111.667	0.488	0.054	117.443	0.464	0.054
92.414	0.470	0.043				113.593	0.436	0.050	119.369	0.453	0.054
96.265	0.460	0.044				115.518	0.470	0.054	121.294	0.433	0.053
96.265	0.490	0.047				115.518	0.408	0.047	125.144	0.4	0.050
100.116	0.452	0.045				117.443	0.384	0.045	127.070	0.33	0.042
103.966	0.440	0.046									
107.817	0.426	0.046									
111.667	0.420	0.047									
111.667	0.424	0.047									
115.518	0.415	0.048									
115.518	0.416	0.048									
119.369	0.411	0.049									
123.219	0.389	0.048									
127.070	0.380	0.048									
130.920	0.372	0.049									
134.771	0.366	0.049									
134.771	0.320	0.043									
138.621	0.355	0.049									
142.472	0.340	0.048									
146.323	0.323	0.047									
148.248	0.316	0.047									
150.173	0.305	0.046									
154.024	0.290	0.045									

Graphite Rod, Air Flow Rate Varied, T = 600°C, 1/25/2006

RM = 40, T = 600			RM = 50, T = 600			RM = 65, T = 600		
I/SA	VCELL	P/SA	I/SA	VCELL	P/SA	I/SA	VCELL	P/SA
0.322	0.728	0.000	0.242	0.746	0.000	0.322	0.728	0.000
0.967	0.696	0.001	0.242	0.742	0.000	0.322	0.732	0.000
0.967	0.703	0.001	0.322	0.746	0.000	0.322	0.729	0.000
0.967	0.694	0.001	0.322	0.741	0.000	0.322	0.753	0.000
1.450	0.687	0.001	0.967	0.709	0.001	0.322	0.749	0.000
3.142	0.684	0.002	0.967	0.709	0.001	1.531	0.728	0.001
4.753	0.673	0.003	0.967	0.708	0.001	3.142	0.726	0.002
6.364	0.672	0.004	1.531	0.704	0.001	3.142	0.723	0.002
7.975	0.658	0.005	3.142	0.695	0.002	3.142	0.723	0.002
7.975	0.696	0.006	4.833	0.693	0.003	4.753	0.718	0.003
9.667	0.656	0.006	6.364	0.687	0.004	6.444	0.718	0.005
11.197	0.652	0.007	7.975	0.681	0.005	7.975	0.725	0.006
12.889	0.650	0.008	7.975	0.718	0.006	8.055	0.709	0.006
14.500	0.644	0.009	9.667	0.678	0.007	9.586	0.702	0.007
16.111	0.640	0.010	11.278	0.670	0.008	9.586	0.702	0.007
16.191	0.661	0.011	12.808	0.664	0.009	11.278	0.699	0.008
17.641	0.634	0.011	14.580	0.660	0.010	12.808	0.691	0.009
19.333	0.628	0.012	16.030	0.655	0.010	14.500	0.690	0.010
19.333	0.627	0.012	16.111	0.680	0.011	16.111	0.687	0.011
20.944	0.626	0.013	17.641	0.650	0.011	16.111	0.697	0.011
22.636	0.619	0.014	19.333	0.644	0.012	17.722	0.680	0.012
24.166	0.614	0.015	20.944	0.638	0.013	19.333	0.675	0.013
24.166	0.629	0.015	22.636	0.634	0.014	20.864	0.671	0.014
25.777	0.608	0.016	24.086	0.649	0.016	22.636	0.669	0.015
27.388	0.604	0.017	24.166	0.628	0.015	24.166	0.662	0.016
29.080	0.599	0.017	25.777	0.623	0.016	24.247	0.667	0.016
30.691	0.592	0.018	27.388	0.619	0.017	25.858	0.660	0.017
32.222	0.588	0.019	29.080	0.612	0.018	27.469	0.653	0.018
32.222	0.598	0.019	30.611	0.609	0.019	29.000	0.648	0.019
33.913	0.580	0.020	32.302	0.605	0.020	30.691	0.644	0.020
35.524	0.576	0.020	32.302	0.618	0.020	32.222	0.639	0.021
37.135	0.571	0.021	33.833	0.599	0.020	32.222	0.639	0.021
38.747	0.565	0.022	35.444	0.596	0.021	33.833	0.637	0.022
40.438	0.560	0.023	37.216	0.590	0.022	35.524	0.633	0.022
40.438	0.564	0.023	38.747	0.586	0.023	37.135	0.630	0.023
41.969	0.556	0.023	40.277	0.588	0.024	38.666	0.625	0.024
43.580	0.549	0.024	40.358	0.581	0.023	40.277	0.607	0.024
45.110	0.546	0.025	41.969	0.578	0.024	40.358	0.618	0.025
46.802	0.536	0.025	43.580	0.573	0.025	41.969	0.615	0.026
48.413	0.529	0.026	45.191	0.570	0.026	43.580	0.611	0.027
48.494	0.534	0.026	46.802	0.566	0.026	45.191	0.606	0.027
51.635	0.520	0.027	48.413	0.552	0.027	46.802	0.601	0.028
54.938	0.504	0.028	48.494	0.561	0.027	48.413	0.575	0.028
56.630	0.500	0.028	48.574	0.586	0.028	48.494	0.596	0.029
58.160	0.494	0.029	50.024	0.558	0.028	50.105	0.592	0.030
61.463	0.487	0.030	51.716	0.554	0.029	51.716	0.588	0.030
64.524	0.460	0.030	53.246	0.550	0.029	53.327	0.582	0.031
64.604	0.474	0.031	54.857	0.547	0.030	56.469	0.571	0.032
67.827	0.467	0.032	56.549	0.542	0.031	56.549	0.535	0.030
71.049	0.459	0.033	56.630	0.518	0.029	58.160	0.565	0.033
72.740	0.415	0.030	58.160	0.536	0.031	59.771	0.560	0.033

74.271	0.443	0.033	59.691	0.534	0.032	62.913	0.544	0.034
77.574	0.432	0.034	61.463	0.528	0.032	64.604	0.536	0.035
80.715	0.420	0.034	62.993	0.525	0.033	64.604	0.487	0.031
80.796	0.363	0.029	64.604	0.520	0.034	66.296	0.529	0.035
84.018	0.408	0.034	64.604	0.474	0.031	67.907	0.524	0.036
87.240	0.387	0.034	67.827	0.510	0.035	70.968	0.511	0.036
90.462	0.375	0.034	71.049	0.503	0.036	73.385	0.356	0.026
90.543	0.305	0.028	72.660	0.426	0.031	74.271	0.489	0.036
93.765	0.360	0.034	74.271	0.490	0.036	77.574	0.445	0.035
95.376	0.300	0.029	75.963	0.483	0.037	80.796	0.390	0.032
96.907	0.280	0.027	77.493	0.477	0.037	84.018	0.339	0.028
98.759	0.239	0.024	80.715	0.356	0.029			
			80.796	0.459	0.037			
			84.099	0.446	0.038			
			87.240	0.431	0.038			
			88.851	0.317	0.028			
			90.462	0.395	0.036			
			93.685	0.333	0.031			
			96.907	0.253	0.025			

Time	Temp (°C)	VCCELL	VANODE	VCATHODE	I (A)	I (mA)	I/SA
16:50:00	600	0.607	-0.662	-0.055	2.000	2000	32.222
16:55:00	600	0.612	-0.661	-0.049	2.000	2000	32.222
17:00:00	600	0.619	-0.664	-0.045	2.000	2000	32.222
17:05:00	600	0.618	-0.662	-0.044	2.000	2000	32.222
17:10:00	599	0.620	-0.662	-0.042	2.000	2000	32.222
17:15:00	599	0.620	-0.663	-0.043	2.000	2000	32.222
17:20:00	599	0.620	-0.663	-0.043	2.000	2000	32.222
17:25:00	600	0.619	-0.663	-0.044	2.000	2000	32.222
17:30:00	599	0.621	-0.663	-0.042	2.000	2000	32.222
17:35:00	600	0.618	-0.663	-0.045	2.000	2000	32.222
17:40:00	599	0.617	-0.659	-0.042	2.000	2000	32.222
17:45:00	600	0.616	-0.661	-0.045	2.000	2000	32.222
17:50:00	600	0.615	-0.661	-0.046	2.000	2000	32.222
17:55:00	599	0.616	-0.661	-0.045	2.000	2000	32.222
18:00:00	600	0.616	-0.663	-0.047	2.000	2000	32.222
18:05:00	600	0.618	-0.663	-0.045	2.000	2000	32.222
18:10:00	599	0.619	-0.663	-0.044	2.000	2000	32.222
18:15:00	600	0.619	-0.666	-0.047	2.000	2000	32.222
18:20:00	599	0.621	-0.666	-0.045	2.000	2000	32.222
18:25:00	599	0.618	-0.665	-0.047	2.000	2000	32.222
18:30:00	600	0.620	-0.667	-0.047	2.000	2000	32.222
18:35:00	600	0.619	-0.665	-0.046	2.000	2000	32.222
18:40:00	599	0.621	-0.666	-0.045	2.000	2000	32.222
18:45:00	599	0.619	-0.666	-0.047	2.000	2000	32.222
18:50:00	599	0.619	-0.666	-0.047	2.000	2000	32.222
18:55:00	599	0.619	-0.665	-0.046	2.000	2000	32.222
19:00:00	599	0.619	-0.667	-0.048	2.000	2000	32.222
19:05:00	599	0.622	-0.669	-0.047	2.000	2000	32.222
19:10:00	599	0.621	-0.668	-0.047	2.000	2000	32.222
19:15:00	599	0.623	-0.668	-0.045	2.000	2000	32.222
19:20:00	599	0.622	-0.669	-0.047	2.000	2000	32.222
19:25:00	599	0.623	-0.669	-0.046	2.000	2000	32.222
19:30:00	599	0.622	-0.668	-0.046	2.000	2000	32.222
19:35:00	599	0.622	-0.670	-0.048	2.000	2000	32.222
19:40:00	599	0.622	-0.671	-0.049	2.000	2000	32.222
19:45:00	599	0.624	-0.668	-0.044	2.000	2000	32.222
19:50:00	599	0.624	-0.671	-0.047	2.000	2000	32.222
19:55:00	599	0.624	-0.671	-0.047	2.000	2000	32.222
20:00:00	599	0.626	-0.671	-0.045	2.000	2000	32.222
20:05:00	599	0.624	-0.671	-0.047	2.000	2000	32.222

20:10:00	600	0.625	-0.671	-0.046	2.000	2000	32.222
20:15:00	600	0.625	-0.671	-0.046	2.000	2000	32.222
20:20:00	600	0.624	-0.672	-0.048	2.005	2005	32.302
20:25:00	599	0.627	-0.673	-0.046	2.000	2000	32.222
20:30:00	599	0.626	-0.672	-0.046	2.000	2000	32.222
20:35:00	599	0.624	-0.673	-0.049	2.005	2005	32.302
20:40:00	600	0.625	-0.671	-0.046	2.005	2005	32.302
20:45:00	600	0.626	-0.673	-0.047	2.000	2000	32.222
20:50:00	600	0.625	-0.673	-0.048	2.005	2005	32.302
20:55:00	599	0.628	-0.675	-0.047	2.000	2000	32.222
21:00:00	600	0.627	-0.674	-0.047	2.000	2000	32.222
21:05:00	600	0.628	-0.674	-0.046	2.000	2000	32.222
21:10:00	599	0.626	-0.675	-0.049	2.005	2005	32.302
21:15:00	600	0.627	-0.674	-0.047	2.000	2000	32.222
21:20:00	600	0.629	-0.674	-0.045	2.005	2005	32.302
21:25:00	599	0.628	-0.676	-0.048	2.000	2000	32.222
21:30:00	599	0.628	-0.676	-0.048	2.000	2000	32.222
21:35:00	600	0.628	-0.676	-0.048	2.005	2005	32.302
21:40:00	600	0.629	-0.676	-0.047	2.005	2005	32.302
21:45:00	600	0.628	-0.676	-0.048	2.005	2005	32.302
21:50:00	600	0.629	-0.676	-0.047	2.005	2005	32.302
21:55:00	600	0.629	-0.676	-0.047	2.005	2005	32.302
22:00:00	600	0.629	-0.675	-0.046	2.005	2005	32.302
22:05:00	599	0.629	-0.676	-0.047	2.005	2005	32.302
22:10:00	600	0.627	-0.674	-0.047	2.005	2005	32.302
22:15:00	599	0.629	-0.676	-0.047	2.005	2005	32.302
22:20:00	599	0.628	-0.675	-0.047	2.005	2005	32.302
22:25:00	599	0.628	-0.675	-0.047	2.005	2005	32.302
22:30:00	600	0.626	-0.675	-0.049	2.005	2005	32.302
22:35:00	599	0.628	-0.676	-0.048	2.005	2005	32.302
22:40:00	600	0.627	-0.676	-0.049	2.005	2005	32.302
22:45:00	600	0.628	-0.676	-0.048	2.005	2005	32.302
22:50:00	600	0.626	-0.675	-0.049	2.005	2005	32.302
22:55:00	600	0.627	-0.674	-0.047	2.005	2005	32.302
23:00:00	600	0.626	-0.675	-0.049	2.005	2005	32.302
23:05:00	600	0.626	-0.674	-0.048	2.005	2005	32.302
23:10:00	600	0.626	-0.676	-0.050	2.005	2005	32.302
23:15:00	599	0.625	-0.672	-0.047	2.005	2005	32.302
23:20:00	600	0.625	-0.674	-0.049	2.005	2005	32.302
23:25:00	600	0.624	-0.673	-0.049	2.005	2005	32.302
23:30:00	599	0.624	-0.672	-0.048	2.005	2005	32.302
23:35:00	600	0.624	-0.672	-0.048	2.005	2005	32.302
23:40:00	600	0.623	-0.672	-0.049	2.005	2005	32.302
23:45:00	600	0.623	-0.673	-0.050	2.005	2005	32.302
23:50:00	600	0.622	-0.673	-0.051	2.005	2005	32.302
23:55:00	600	0.622	-0.670	-0.048	2.005	2005	32.302
00:00:00	600	0.624	-0.672	-0.048	2.005	2005	32.302
00:05:00	599	0.624	-0.674	-0.050	2.005	2005	32.302
00:10:00	600	0.623	-0.673	-0.050	2.005	2005	32.302
00:15:00	600	0.622	-0.673	-0.051	2.005	2005	32.302
00:20:00	600	0.622	-0.673	-0.051	2.005	2005	32.302
00:25:00	600	0.623	-0.672	-0.049	2.005	2005	32.302
00:30:00	600	0.621	-0.673	-0.052	2.005	2005	32.302
00:35:00	599	0.622	-0.671	-0.049	2.005	2005	32.302
00:40:00	600	0.622	-0.671	-0.049	2.005	2005	32.302
00:45:00	600	0.621	-0.671	-0.050	2.005	2005	32.302
00:50:00	600	0.622	-0.672	-0.050	2.005	2005	32.302
00:55:00	600	0.623	-0.672	-0.049	2.005	2005	32.302
01:00:00	600	0.622	-0.672	-0.050	2.005	2005	32.302
01:05:00	600	0.622	-0.671	-0.049	2.005	2005	32.302
01:10:00	600	0.622	-0.670	-0.048	2.005	2005	32.302
01:15:00	600	0.621	-0.672	-0.051	2.005	2005	32.302
01:20:00	600	0.620	-0.670	-0.050	2.005	2005	32.302

01:25:00	600	0.620	-0.670	-0.050	2.005	2005	32.302
01:30:00	600	0.620	-0.671	-0.051	2.005	2005	32.302
01:35:00	600	0.621	-0.671	-0.050	2.005	2005	32.302
01:40:00	600	0.620	-0.670	-0.050	2.005	2005	32.302
01:45:00	600	0.621	-0.671	-0.050	2.005	2005	32.302
01:50:00	600	0.620	-0.670	-0.050	2.005	2005	32.302
01:55:00	600	0.620	-0.671	-0.051	2.005	2005	32.302
02:00:00	600	0.619	-0.670	-0.051	2.005	2005	32.302
02:05:00	600	0.619	-0.671	-0.052	2.005	2005	32.302
02:10:00	600	0.619	-0.670	-0.051	2.005	2005	32.302
02:15:00	600	0.616	-0.668	-0.052	2.005	2005	32.302
02:20:00	599	0.614	-0.666	-0.052	2.005	2005	32.302
02:25:00	600	0.613	-0.665	-0.052	2.005	2005	32.302
02:30:00	600	0.612	-0.665	-0.053	2.005	2005	32.302
02:35:00	600	0.613	-0.664	-0.051	2.005	2005	32.302
02:40:00	600	0.611	-0.663	-0.052	2.005	2005	32.302
02:45:00	600	0.603	-0.660	-0.057	2.005	2005	32.302
02:50:00	601	0.606	-0.660	-0.054	2.005	2005	32.302
02:55:00	599	0.602	-0.657	-0.055	2.005	2005	32.302
03:00:00	600	0.600	-0.657	-0.057	2.005	2005	32.302
03:05:00	600	0.606	-0.658	-0.052	2.005	2005	32.302
03:10:00	599	0.597	-0.653	-0.056	2.005	2005	32.302
03:15:00	600	0.600	-0.652	-0.052	2.005	2005	32.302
03:20:00	600	0.597	-0.652	-0.055	2.005	2005	32.302
03:25:00	600	0.587	-0.649	-0.062	2.005	2005	32.302
03:30:00	600	0.586	-0.647	-0.061	2.005	2005	32.302
03:35:00	600	0.594	-0.648	-0.054	2.005	2005	32.302
03:40:00	598	0.613	-0.653	-0.040	2.005	2005	32.302
03:45:00	601	0.618	-0.666	-0.048	2.005	2005	32.302
03:50:00	600	0.613	-0.662	-0.049	2.005	2005	32.302
03:55:00	600	0.600	-0.656	-0.056	2.000	2000	32.222
04:00:00	600	0.616	-0.663	-0.047	2.005	2005	32.302
04:05:00	601	0.612	-0.662	-0.050	2.005	2005	32.302
04:10:00	599	0.606	-0.659	-0.053	2.005	2005	32.302
04:15:00	600	0.606	-0.656	-0.050	2.005	2005	32.302
04:20:00	601	0.607	-0.658	-0.051	2.005	2005	32.302
04:25:00	600	0.599	-0.654	-0.055	2.005	2005	32.302
04:30:00	600	0.599	-0.653	-0.054	2.005	2005	32.302
04:35:00	601	0.607	-0.651	-0.044	2.005	2005	32.302
04:40:00	601	0.597	-0.654	-0.057	2.005	2005	32.302
04:45:00	600	0.595	-0.651	-0.056	2.000	2000	32.222
04:50:00	600	0.590	-0.648	-0.058	2.000	2000	32.222
04:55:00	600	0.587	-0.646	-0.059	2.000	2000	32.222
05:00:00	600	0.584	-0.645	-0.061	2.000	2000	32.222
05:05:00	598	0.583	-0.637	-0.054	2.000	2000	32.222
05:10:00	599	0.563	-0.647	-0.084	2.000	2000	32.222
05:15:00	601	0.529	-0.635	-0.106	2.000	2000	32.222
05:20:00	595	0.578	-0.614	-0.036	2.000	2000	32.222
05:25:00	604	0.558	-0.654	-0.096	2.000	2000	32.222
05:30:00	599	0.606	-0.660	-0.054	2.000	2000	32.222
05:35:00	601	0.579	-0.649	-0.070	2.000	2000	32.222
05:40:00	600	0.611	-0.661	-0.050	2.000	2000	32.222
05:45:00	601	0.600	-0.651	-0.051	2.000	2000	32.222
05:50:00	599	0.593	-0.642	-0.049	2.000	2000	32.222
05:55:00	600	0.595	-0.643	-0.048	2.000	2000	32.222
06:00:00	600	0.595	-0.643	-0.048	2.000	2000	32.222
06:05:00	600	0.592	-0.641	-0.049	2.000	2000	32.222
06:10:00	600	0.594	-0.642	-0.048	2.000	2000	32.222
06:15:00	600	0.595	-0.642	-0.047	2.000	2000	32.222
06:20:00	600	0.597	-0.644	-0.047	2.000	2000	32.222
06:25:00	600	0.595	-0.643	-0.048	2.000	2000	32.222
06:30:00	600	0.595	-0.644	-0.049	2.000	2000	32.222
06:35:00	600	0.593	-0.641	-0.048	2.000	2000	32.222

06:40:00	600	0.594	-0.643	-0.049	2.000	2000	32.222
06:45:00	600	0.595	-0.644	-0.049	2.000	2000	32.222
06:50:00	600	0.596	-0.645	-0.049	2.000	2000	32.222
06:55:00	600	0.596	-0.646	-0.050	2.000	2000	32.222
07:00:00	600	0.598	-0.647	-0.049	2.000	2000	32.222
07:05:00	600	0.596	-0.646	-0.050	2.000	2000	32.222
07:10:00	600	0.596	-0.647	-0.051	2.000	2000	32.222
07:15:00	600	0.598	-0.648	-0.050	2.000	2000	32.222
07:20:00	600	0.598	-0.648	-0.050	2.000	2000	32.222
07:25:00	600	0.598	-0.648	-0.050	2.000	2000	32.222
07:30:00	600	0.599	-0.649	-0.050	2.000	2000	32.222
07:35:00	600	0.599	-0.651	-0.052	2.000	2000	32.222
07:40:00	600	0.597	-0.650	-0.053	2.000	2000	32.222
07:45:00	600	0.598	-0.650	-0.052	2.000	2000	32.222
07:50:00	600	0.595	-0.650	-0.055	2.000	2000	32.222
07:55:00	600	0.598	-0.650	-0.052	2.000	2000	32.222
08:00:00	600	0.597	-0.650	-0.053	2.000	2000	32.222
08:05:00	600	0.598	-0.651	-0.053	2.000	2000	32.222
08:10:00	600	0.598	-0.651	-0.053	1.995	1995	32.141
08:15:00	600	0.597	-0.650	-0.053	1.995	1995	32.141
08:20:00	600	0.600	-0.652	-0.052	1.995	1995	32.141
08:25:00	600	0.599	-0.651	-0.052	1.995	1995	32.141
08:30:00	600	0.599	-0.651	-0.052	1.995	1995	32.141
08:35:00	600	0.599	-0.652	-0.053	2.000	2000	32.222
08:40:00	600	0.598	-0.651	-0.053	2.000	2000	32.222
08:45:00	600	0.597	-0.650	-0.053	1.995	1995	32.141
08:50:00	600	0.596	-0.650	-0.054	2.000	2000	32.222
08:55:00	600	0.596	-0.649	-0.053	2.000	2000	32.222
09:00:00	600	0.589	-0.646	-0.057	2.000	2000	32.222
09:05:00	600	0.578	-0.640	-0.062	1.995	1995	32.141
09:10:00	597	0.615	-0.656	-0.041	1.995	1995	32.141
09:15:00	602	0.607	-0.669	-0.062	2.010	2010	32.383
09:20:00	599	0.600	-0.657	-0.057	2.010	2010	32.383
09:25:00	600	0.599	-0.652	-0.053	2.005	2005	32.302
09:30:00	601	0.596	-0.649	-0.053	2.010	2010	32.383
09:35:00	600	0.564	-0.637	-0.073	2.000	2000	32.222
09:40:00	600	0.543	-0.627	-0.084	2.000	2000	32.222
09:45:00	600	0.536	-0.623	-0.087	2.000	2000	32.222
09:50:00	600	0.573	-0.628	-0.055	2.000	2000	32.222
09:55:00	605	0.446	-0.602	-0.156	2.000	2000	32.222
10:00:00	599	0.474	-0.555	-0.081	2.000	2000	32.222

Graphite Rod, Air Flow Rate Varied, T = 600°C, 2/8/2006

Flow = 0.40, T = 600			Flow = 0.50, T = 600			Flow = 0.75, T = 600			Flow = 0.90, T = 600		
I/SA	VCELL	P/SA	I/SA	VCELL	P/SA	I/SA	VCELL	P/SA	I/SA	VCELL	P/SA
0.551	0.696	0.000	0.551	0.738	0.000	0.459	0.779	0.000	0.459	0.788	0.000
0.551	0.694	0.000	0.551	0.739	0.000	0.459	0.779	0.000	0.551	0.766	0.000
0.551	0.703	0.000	0.551	0.739	0.000	0.551	0.761	0.000	0.551	0.777	0.000
0.551	0.748	0.000	0.551	0.740	0.000	0.551	0.762	0.000	0.551	0.777	0.000
0.551	0.751	0.000	0.551	0.742	0.000	0.551	0.765	0.000	0.551	0.779	0.000
1.652	0.694	0.001	0.551	0.767	0.000	0.551	0.766	0.000	3.672	0.769	0.003
3.580	0.685	0.002	0.551	0.765	0.000	0.551	0.767	0.000	7.252	0.757	0.005
5.508	0.678	0.004	0.643	0.740	0.000	0.551	0.767	0.000	9.179	0.759	0.007
7.252	0.671	0.005	1.652	0.736	0.001	0.551	0.769	0.000	10.923	0.747	0.008
8.996	0.663	0.006	3.580	0.730	0.003	1.744	0.764	0.001	14.687	0.737	0.011
9.088	0.714	0.006	3.672	0.729	0.003	3.580	0.760	0.003	18.267	0.726	0.013
10.923	0.668	0.007	5.416	0.724	0.004	5.508	0.754	0.004	18.267	0.730	0.013
12.759	0.657	0.008	7.160	0.718	0.005	7.252	0.749	0.005	22.122	0.717	0.016

14.687	0.650	0.010	9.088	0.733	0.007	9.179	0.744	0.007	25.610	0.708	0.018
16.615	0.650	0.011	9.179	0.711	0.007	9.179	0.748	0.007	25.610	0.708	0.018
18.267	0.640	0.012	11.015	0.706	0.008	11.015	0.738	0.008	27.630	0.703	0.019
18.359	0.677	0.012	12.851	0.702	0.009	12.851	0.734	0.009	29.282	0.699	0.020
20.195	0.632	0.013	14.595	0.696	0.010	14.595	0.728	0.011	33.138	0.689	0.023
22.030	0.628	0.014	16.431	0.689	0.011	16.431	0.723	0.012	36.717	0.680	0.025
23.958	0.625	0.015	18.359	0.685	0.013	18.359	0.718	0.013	36.901	0.675	0.025
25.702	0.620	0.016	18.451	0.695	0.013	18.359	0.717	0.013	40.481	0.671	0.027
27.538	0.612	0.017	20.286	0.679	0.014	20.195	0.713	0.014	44.153	0.663	0.029
27.630	0.643	0.018	22.030	0.674	0.015	22.030	0.707	0.016	45.989	0.649	0.030
29.466	0.610	0.018	23.775	0.669	0.016	23.866	0.702	0.017	47.733	0.654	0.031
31.210	0.605	0.019	25.702	0.665	0.017	25.702	0.697	0.018	51.588	0.645	0.033
33.138	0.599	0.020	25.702	0.665	0.017	27.630	0.691	0.019	55.076	0.637	0.035
34.882	0.595	0.021	27.538	0.660	0.018	27.722	0.688	0.019	55.076	0.636	0.035
36.717	0.591	0.022	27.538	0.658	0.018	29.466	0.685	0.020	55.168	0.623	0.034
36.717	0.610	0.022	27.538	0.663	0.018	31.210	0.680	0.021	58.932	0.627	0.037
38.553	0.586	0.023	29.282	0.653	0.019	33.046	0.675	0.022	62.695	0.617	0.039
40.389	0.581	0.023	31.210	0.649	0.020	34.882	0.670	0.023	64.439	0.593	0.038
42.317	0.577	0.024	33.138	0.643	0.021	36.901	0.664	0.025	66.183	0.609	0.040
44.153	0.572	0.025	34.882	0.639	0.022	36.901	0.659	0.024	69.855	0.600	0.042
45.897	0.568	0.026	36.626	0.634	0.023	38.553	0.660	0.025	73.619	0.560	0.041
46.080	0.574	0.026	36.717	0.631	0.023	40.481	0.653	0.026	73.710	0.589	0.043
47.824	0.562	0.027	38.645	0.629	0.024	42.317	0.649	0.027	77.290	0.580	0.045
49.752	0.558	0.028	40.481	0.624	0.025	44.153	0.645	0.028	77.290	0.579	0.045
51.496	0.553	0.028	42.317	0.620	0.026	45.989	0.639	0.029	77.290	0.577	0.045
53.424	0.549	0.029	44.061	0.615	0.027	45.989	0.631	0.029	77.290	0.575	0.044
55.168	0.546	0.030	45.897	0.611	0.028	47.824	0.634	0.030	80.870	0.566	0.046
55.260	0.540	0.030	45.897	0.600	0.028	49.752	0.629	0.031	82.890	0.525	0.044
58.840	0.533	0.031	47.733	0.605	0.029	51.496	0.625	0.032	84.726	0.554	0.047
62.603	0.527	0.033	49.660	0.599	0.030	53.424	0.620	0.033	88.397	0.543	0.048
64.439	0.506	0.033	51.496	0.596	0.031	55.352	0.615	0.034	92.069	0.480	0.044
66.183	0.518	0.034	53.332	0.589	0.031	55.352	0.601	0.033	92.161	0.521	0.048
70.039	0.507	0.036	55.260	0.585	0.032	58.932	0.606	0.036	95.833	0.503	0.048
73.710	0.496	0.037	55.260	0.564	0.031	62.603	0.597	0.037	99.413	0.473	0.047
73.894	0.463	0.034	57.004	0.581	0.033	64.439	0.570	0.037	103.084	0.432	0.045
77.290	0.485	0.037	58.932	0.575	0.034	66.275	0.589	0.039	104.920	0.396	0.042
80.962	0.475	0.038	62.603	0.566	0.035	69.947	0.580	0.041			
82.890	0.419	0.035	64.439	0.531	0.034	73.619	0.566	0.042			
84.634	0.462	0.039	66.275	0.557	0.037	73.619	0.536	0.039			
88.397	0.451	0.040	69.947	0.545	0.038	77.290	0.556	0.043			
92.069	0.441	0.041	73.527	0.535	0.039	81.054	0.544	0.044			
92.161	0.379	0.035	73.710	0.492	0.036	82.890	0.495	0.041			
95.741	0.422	0.040	77.382	0.523	0.040	84.634	0.531	0.045			
95.833	0.414	0.040	81.054	0.511	0.041	88.305	0.516	0.046			
99.504	0.405	0.040	82.798	0.440	0.036	91.977	0.497	0.046			
103.176	0.379	0.039	84.634	0.502	0.042	92.069	0.451	0.042			
103.176	0.376	0.039	88.397	0.485	0.043	95.741	0.479	0.046			
103.176	0.306	0.032	91.977	0.384	0.035	99.413	0.455	0.045			
105.012	0.330	0.035	92.161	0.468	0.043	103.176	0.417	0.043			
106.664	0.351	0.037	95.741	0.454	0.043	106.756	0.352	0.038			
108.592	0.301	0.033	99.504	0.420	0.042						
			103.176	0.336	0.035						
			110.152	0.186	0.020						

Graphite Rod, Long Term Run, Air Flow Rate = 0.50 SLPM, T = 600°C, 2/8/2006

Time	Temp (°C)	VCELL	VANODE	VCATHODE	I (A)	I (mA)	I/SA
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15:55:00	600	0.678	-0.714	-0.036	2.000	2000	36.717
16:00:00	600	0.678	-0.714	-0.036	2.000	2000	36.717
16:05:00	599	0.678	-0.715	-0.037	2.000	2000	36.717
16:10:00	600	0.679	-0.715	-0.036	2.000	2000	36.717
16:15:00	600	0.680	-0.716	-0.036	2.000	2000	36.717
16:20:00	600	0.680	-0.716	-0.036	2.000	2000	36.717
16:25:00	600	0.680	-0.716	-0.036	2.000	2000	36.717
16:30:00	600	0.677	-0.715	-0.038	2.000	2000	36.717
16:35:00	600	0.677	-0.713	-0.036	2.000	2000	36.717
16:40:00	599	0.675	-0.711	-0.036	2.000	2000	36.717
16:45:00	600	0.674	-0.710	-0.036	2.000	2000	36.717
16:50:00	600	0.673	-0.709	-0.036	2.000	2000	36.717
16:55:00	599	0.673	-0.709	-0.036	2.000	2000	36.717
17:00:00	599	0.673	-0.708	-0.035	2.000	2000	36.717
17:05:00	600	0.673	-0.709	-0.036	2.000	2000	36.717
17:10:00	599	0.673	-0.708	-0.035	2.000	2000	36.717
17:15:00	599	0.673	-0.708	-0.035	2.000	2000	36.717
17:20:00	600	0.674	-0.709	-0.035	2.000	2000	36.717
17:25:00	599	0.674	-0.708	-0.034	2.000	2000	36.717
17:30:00	599	0.672	-0.707	-0.035	2.000	2000	36.717
17:35:00	600	0.672	-0.707	-0.035	2.000	2000	36.717
17:40:00	599	0.672	-0.707	-0.035	2.000	2000	36.717
17:45:00	599	0.670	-0.704	-0.034	2.000	2000	36.717
17:50:00	600	0.667	-0.702	-0.035	2.000	2000	36.717
17:55:00	599	0.666	-0.700	-0.034	2.000	2000	36.717
18:00:00	600	0.663	-0.698	-0.035	2.000	2000	36.717
18:05:00	600	0.662	-0.696	-0.034	2.000	2000	36.717
18:10:00	600	0.660	-0.694	-0.034	2.000	2000	36.717
18:15:00	599	0.657	-0.691	-0.034	2.000	2000	36.717
18:20:00	600	0.653	-0.688	-0.035	2.000	2000	36.717
18:25:00	599	0.650	-0.684	-0.034	2.000	2000	36.717
18:30:00	599	0.647	-0.679	-0.032	2.000	2000	36.717
18:35:00	600	0.642	-0.674	-0.032	2.000	2000	36.717
18:40:00	599	0.638	-0.669	-0.031	2.000	2000	36.717
18:45:00	599	0.634	-0.665	-0.031	2.000	2000	36.717
18:50:00	600	0.632	-0.662	-0.030	2.000	2000	36.717
18:55:00	599	0.627	-0.657	-0.030	2.000	2000	36.717
19:00:00	599	0.622	-0.652	-0.030	2.000	2000	36.717
19:05:00	600	0.617	-0.648	-0.031	2.000	2000	36.717
19:10:00	600	0.613	-0.643	-0.030	2.000	2000	36.717
19:15:00	599	0.608	-0.637	-0.029	2.000	2000	36.717
19:20:00	600	0.602	-0.631	-0.029	2.000	2000	36.717
19:25:00	600	0.594	-0.622	-0.028	2.000	2000	36.717
19:30:00	599	0.586	-0.614	-0.028	2.000	2000	36.717
19:35:00	600	0.583	-0.611	-0.028	2.000	2000	36.717
19:40:00	600	0.574	-0.602	-0.028	2.000	2000	36.717
19:45:00	599	0.568	-0.596	-0.028	2.000	2000	36.717
19:50:00	599	0.560	-0.588	-0.028	2.000	2000	36.717
19:55:00	600	0.551	-0.578	-0.027	2.000	2000	36.717
20:00:00	599	0.543	-0.571	-0.028	2.000	2000	36.717
20:05:00	599	0.541	-0.569	-0.028	2.000	2000	36.717
20:10:00	600	0.532	-0.560	-0.028	2.000	2000	36.717
20:15:00	599	0.523	-0.551	-0.028	2.000	2000	36.717
20:20:00	599	0.514	-0.543	-0.029	2.000	2000	36.717
20:25:00	600	0.505	-0.533	-0.028	2.000	2000	36.717
20:30:00	600	0.497	-0.526	-0.029	2.000	2000	36.717
20:35:00	599	0.483	-0.512	-0.029	2.000	2000	36.717
20:40:00	600	0.478	-0.508	-0.030	2.000	2000	36.717
20:45:00	600	0.471	-0.500	-0.029	2.000	2000	36.717
20:50:00	599	0.461	-0.491	-0.030	2.000	2000	36.717
20:55:00	600	0.458	-0.487	-0.029	2.000	2000	36.717
21:00:00	600	0.447	-0.477	-0.030	2.000	2000	36.717
21:05:00	599	0.444	-0.474	-0.030	2.000	2000	36.717

21:10:00	599	0.436	-0.466	-0.030	2.000	2000	36.717
21:15:00	600	0.429	-0.459	-0.030	2.000	2000	36.717
21:20:00	599	0.427	-0.457	-0.030	2.005	2005	36.809
21:25:00	599	0.423	-0.453	-0.030	2.005	2005	36.809
21:30:00	600	0.418	-0.449	-0.031	2.000	2000	36.717
21:35:00	600	0.410	-0.441	-0.031	2.000	2000	36.717
21:40:00	599	0.402	-0.432	-0.030	2.000	2000	36.717
21:45:00	599	0.398	-0.429	-0.031	2.000	2000	36.717
21:50:00	600	0.397	-0.427	-0.030	2.005	2005	36.809
21:55:00	599	0.394	-0.424	-0.030	2.005	2005	36.809
22:00:00	599	0.395	-0.426	-0.031	2.000	2000	36.717
22:05:00	600	0.394	-0.423	-0.029	2.005	2005	36.809
22:10:00	600	0.389	-0.419	-0.030	2.000	2000	36.717
22:15:00	599	0.388	-0.417	-0.029	2.000	2000	36.717
22:20:00	599	0.376	-0.407	-0.031	2.000	2000	36.717
22:25:00	600	0.373	-0.403	-0.030	2.000	2000	36.717
22:30:00	599	0.369	-0.399	-0.030	2.000	2000	36.717
22:35:00	599	0.364	-0.393	-0.029	2.000	2000	36.717
22:40:00	600	0.358	-0.386	-0.028	2.005	2005	36.809
22:45:00	600	0.357	-0.385	-0.028	2.005	2005	36.809
22:50:00	600	0.350	-0.379	-0.029	2.005	2005	36.809
22:55:00	599	0.357	-0.387	-0.030	2.005	2005	36.809
23:00:00	599	0.351	-0.381	-0.030	2.000	2000	36.717
23:05:00	600	0.373	-0.403	-0.030	2.005	2005	36.809
23:10:00	600	0.375	-0.406	-0.031	2.000	2000	36.717
23:15:00	599	0.381	-0.411	-0.030	2.000	2000	36.717
23:20:00	599	0.378	-0.408	-0.030	2.000	2000	36.717
23:25:00	600	0.375	-0.406	-0.031	2.000	2000	36.717
23:30:00	599	0.362	-0.392	-0.030	2.005	2005	36.809
23:35:00	600	0.386	-0.416	-0.030	2.000	2000	36.717
23:40:00	600	0.385	-0.415	-0.030	2.005	2005	36.809
23:45:00	600	0.383	-0.414	-0.031	2.005	2005	36.809
23:50:00	599	0.395	-0.426	-0.031	2.005	2005	36.809
23:55:00	599	0.388	-0.419	-0.031	2.000	2000	36.717
00:00:00	600	0.391	-0.422	-0.031	2.005	2005	36.809
00:05:00	600	0.389	-0.419	-0.030	2.005	2005	36.809
00:10:00	600	0.388	-0.418	-0.030	2.005	2005	36.809
00:15:00	599	0.387	-0.418	-0.031	2.005	2005	36.809
00:20:00	599	0.395	-0.426	-0.031	2.000	2000	36.717
00:25:00	599	0.391	-0.422	-0.031	2.000	2000	36.717
00:30:00	599	0.385	-0.416	-0.031	2.000	2000	36.717
00:35:00	600	0.386	-0.418	-0.032	2.000	2000	36.717
00:40:00	600	0.387	-0.418	-0.031	2.005	2005	36.809
00:45:00	599	0.382	-0.415	-0.033	2.005	2005	36.809
00:50:00	600	0.395	-0.426	-0.031	2.005	2005	36.809
00:55:00	600	0.399	-0.431	-0.032	2.005	2005	36.809
01:00:00	599	0.395	-0.427	-0.032	2.005	2005	36.809
01:05:00	600	0.392	-0.425	-0.033	2.005	2005	36.809
01:10:00	600	0.399	-0.431	-0.032	2.005	2005	36.809
01:15:00	599	0.402	-0.434	-0.032	2.005	2005	36.809
01:20:00	599	0.400	-0.433	-0.033	2.005	2005	36.809
01:25:00	600	0.399	-0.432	-0.033	2.005	2005	36.809
01:30:00	599	0.404	-0.436	-0.032	2.005	2005	36.809
01:35:00	600	0.403	-0.436	-0.033	2.005	2005	36.809
01:40:00	600	0.401	-0.433	-0.032	2.005	2005	36.809
01:45:00	599	0.405	-0.437	-0.032	2.005	2005	36.809
01:50:00	600	0.405	-0.437	-0.032	2.005	2005	36.809
01:55:00	600	0.401	-0.435	-0.034	2.005	2005	36.809
02:00:00	599	0.401	-0.434	-0.033	2.005	2005	36.809
02:05:00	599	0.403	-0.436	-0.033	2.005	2005	36.809
02:10:00	600	0.408	-0.440	-0.032	2.005	2005	36.809
02:15:00	600	0.398	-0.431	-0.033	2.005	2005	36.809
02:20:00	599	0.399	-0.433	-0.034	2.005	2005	36.809

02:25:00	600	0.399	-0.432	-0.033	2.005	2005	36.809
02:30:00	600	0.397	-0.430	-0.033	2.005	2005	36.809
02:35:00	600	0.397	-0.431	-0.034	2.005	2005	36.809
02:40:00	599	0.388	-0.421	-0.033	2.005	2005	36.809
02:45:00	600	0.384	-0.417	-0.033	2.005	2005	36.809
02:50:00	600	0.374	-0.406	-0.032	2.005	2005	36.809
02:55:00	599	0.361	-0.394	-0.033	2.005	2005	36.809
03:00:00	599	0.353	-0.386	-0.033	2.005	2005	36.809
03:05:00	600	0.339	-0.372	-0.033	2.005	2005	36.809
03:10:00	600	0.335	-0.368	-0.033	2.005	2005	36.809
03:15:00	599	0.323	-0.356	-0.033	2.005	2005	36.809
03:20:00	600	0.371	-0.404	-0.033	2.005	2005	36.809
03:25:00	600	0.364	-0.398	-0.034	2.005	2005	36.809
03:30:00	600	0.367	-0.400	-0.033	2.005	2005	36.809
03:35:00	599	0.359	-0.392	-0.033	2.005	2005	36.809
03:40:00	599	0.357	-0.390	-0.033	2.005	2005	36.809
03:45:00	600	0.343	-0.376	-0.033	2.005	2005	36.809
03:50:00	600	0.340	-0.373	-0.033	2.005	2005	36.809
03:55:00	600	0.341	-0.374	-0.033	2.005	2005	36.809
04:00:00	600	0.332	-0.364	-0.032	2.005	2005	36.809
04:05:00	600	0.323	-0.356	-0.033	2.005	2005	36.809
04:10:00	599	0.310	-0.343	-0.033	2.005	2005	36.809
04:15:00	600	0.302	-0.335	-0.033	2.005	2005	36.809
04:20:00	600	0.293	-0.325	-0.032	2.005	2005	36.809
04:25:00	599	0.290	-0.322	-0.032	2.005	2005	36.809
04:30:00	599	0.277	-0.308	-0.031	2.005	2005	36.809
04:35:00	600	0.260	-0.291	-0.031	2.005	2005	36.809
04:40:00	600	0.247	-0.278	-0.031	2.005	2005	36.809
04:45:00	600	0.231	-0.262	-0.031	2.005	2005	36.809
04:50:00	600	0.211	-0.243	-0.032	2.005	2005	36.809
04:55:00	600	0.194	-0.224	-0.030	2.000	2000	36.717
05:00:00	600	0.162	-0.192	-0.030	2.000	2000	36.717
05:05:00	600	0.141	-0.171	-0.030	2.000	2000	36.717
05:10:00	600	0.114	-0.144	-0.030	2.000	2000	36.717
05:15:00	600	0.066	-0.096	-0.030	1.915	1915	35.157
05:20:00	599	0.054	-0.082	-0.028	1.770	1770	32.495
05:25:00	600	0.045	-0.068	-0.023	1.555	1555	28.548
05:30:00	600	0.044	-0.067	-0.023	1.510	1510	27.722
05:35:00	599	0.040	-0.061	-0.021	1.355	1355	24.876
05:40:00	600	0.033	-0.052	-0.019	1.100	1100	20.195
05:45:00	600	0.035	-0.054	-0.019	1.155	1155	21.204
05:50:00	599	0.033	-0.051	-0.018	1.160	1160	21.296
05:55:00	600	0.031	-0.048	-0.017	1.030	1030	18.909
06:00:00	600	0.031	-0.048	-0.017	1.050	1050	19.277
06:05:00	599	0.027	-0.043	-0.016	0.960	960	17.624
06:10:00	600	0.028	-0.044	-0.016	0.995	995	18.267
06:15:00	600	0.028	-0.044	-0.016	0.965	965	17.716
06:20:00	600	0.026	-0.041	-0.015	0.875	875	16.064
06:25:00	600	0.029	-0.045	-0.016	0.945	945	17.349
06:30:00	600	0.029	-0.045	-0.016	0.945	945	17.349
06:35:00	600	0.027	-0.043	-0.016	0.855	855	15.697
06:40:00	599	0.025	-0.040	-0.015	0.825	825	15.146
06:45:00	600	0.029	-0.045	-0.016	0.955	955	17.533
06:50:00	600	0.025	-0.040	-0.015	0.830	830	15.238
06:55:00	599	0.032	-0.049	-0.017	0.965	965	17.716
07:00:00	600	0.028	-0.044	-0.016	0.985	985	18.083
07:05:00	600	0.027	-0.042	-0.015	0.925	925	16.982
07:10:00	599	0.024	-0.039	-0.015	0.950	950	17.441
07:15:00	600	0.024	-0.039	-0.015	0.865	865	15.880
07:20:00	600	0.029	-0.045	-0.016	0.945	945	17.349
07:25:00	599	0.027	-0.042	-0.015	0.870	870	15.972
07:30:00	600	0.026	-0.041	-0.015	0.855	855	15.697
07:35:00	600	0.027	-0.042	-0.015	0.910	910	16.706

07:40:00	600	0.028	-0.045	-0.017	0.975	975	17.900
07:45:00	599	0.026	-0.042	-0.016	0.900	900	16.523
07:50:00	600	0.029	-0.045	-0.016	0.915	915	16.798
07:55:00	600	0.027	-0.043	-0.016	0.955	955	17.533
08:00:00	600	0.027	-0.042	-0.015	1.005	1005	18.451
08:05:00	600	0.029	-0.044	-0.015	0.955	955	17.533
08:10:00	600	0.028	-0.044	-0.016	0.945	945	17.349
08:15:00	600	0.028	-0.043	-0.015	0.940	940	17.257
08:20:00	600	0.029	-0.044	-0.015	0.930	930	17.074
08:25:00	600	0.029	-0.044	-0.015	0.890	890	16.339

Graphite Rod, Air Flow Rate Varied, T = 600°C, 2/21/2006

0.50 SLPM			0.25 SLPM			0.75 SLPM		
I/SA	VCELL	P/SA	I/SA	VCELL	P/SA	I/SA	VCELL	P/SA
0.459	0.690	0.000	0.367	0.727	0.000	0.275	0.727	0.000
0.459	0.687	0.000	0.367	0.725	0.000	0.367	0.681	0.000
0.459	0.696	0.000	0.826	0.745	0.001	0.367	0.687	0.000
0.459	0.692	0.000	0.826	0.742	0.001	0.367	0.734	0.000
0.459	0.690	0.000	1.744	0.732	0.001	0.367	0.733	0.000
0.734	0.738	0.001	3.580	0.723	0.003	0.367	0.731	0.000
0.826	0.744	0.001	7.252	0.704	0.005	1.744	0.688	0.001
0.826	0.727	0.001	9.179	0.696	0.006	3.580	0.679	0.002
1.744	0.688	0.001	9.179	0.692	0.006	5.508	0.671	0.004
3.672	0.681	0.003	10.923	0.686	0.007	7.252	0.672	0.005
5.416	0.676	0.004	12.851	0.677	0.009	9.271	0.673	0.006
7.252	0.663	0.005	14.687	0.666	0.010	11.015	0.661	0.007
9.088	0.663	0.006	16.431	0.658	0.011	12.943	0.661	0.009
10.923	0.657	0.007	18.267	0.650	0.012	14.687	0.665	0.010
12.759	0.650	0.008	20.195	0.643	0.013	16.615	0.659	0.011
14.595	0.645	0.009	22.030	0.635	0.014	18.359	0.655	0.012
16.523	0.639	0.011	23.958	0.626	0.015	22.122	0.649	0.014
18.359	0.635	0.012	25.702	0.622	0.016	23.866	0.640	0.015
18.359	0.660	0.012	27.538	0.613	0.017	25.794	0.639	0.016
20.195	0.630	0.013	29.374	0.607	0.018	27.538	0.631	0.017
21.939	0.625	0.014	31.302	0.600	0.019	29.558	0.631	0.019
23.866	0.621	0.015	33.046	0.592	0.020	31.302	0.628	0.020
25.702	0.615	0.016	36.717	0.579	0.021	33.138	0.621	0.021
27.630	0.611	0.017	40.389	0.566	0.023	34.973	0.616	0.022
29.374	0.609	0.018	44.061	0.552	0.024	36.809	0.611	0.022
31.210	0.600	0.019	47.733	0.541	0.026	40.389	0.605	0.024
33.138	0.597	0.020	49.660	0.532	0.026	44.061	0.595	0.026
34.973	0.592	0.021	53.332	0.520	0.028	45.897	0.590	0.027
36.809	0.586	0.022	55.260	0.514	0.028	49.569	0.582	0.029
38.645	0.582	0.022	58.840	0.500	0.029	51.496	0.575	0.030
40.481	0.579	0.023	62.787	0.489	0.031	53.424	0.572	0.031
42.317	0.577	0.024	66.275	0.476	0.032	55.168	0.567	0.031
44.153	0.577	0.025	69.947	0.463	0.032	57.096	0.562	0.032
45.897	0.575	0.026	73.710	0.446	0.033	59.023	0.557	0.033
47.824	0.572	0.027	77.290	0.435	0.034	60.767	0.552	0.034
49.660	0.567	0.028	82.798	0.414	0.034	64.531	0.540	0.035
51.496	0.563	0.029	86.470	0.398	0.034	68.019	0.534	0.036
53.332	0.559	0.030	90.233	0.375	0.034	71.783	0.523	0.038
55.260	0.553	0.031	95.741	0.337	0.032	75.454	0.514	0.039
55.260	0.533	0.029	97.668	0.328	0.032	77.198	0.508	0.039

58.932	0.546	0.032	103.084	0.289	0.030	80.962	0.498	0.040
62.511	0.536	0.034				84.817	0.486	0.041
66.183	0.526	0.035				88.305	0.474	0.042
69.855	0.518	0.036				92.069	0.455	0.042
73.527	0.506	0.037				95.741	0.444	0.043
77.290	0.497	0.038				99.504	0.405	0.040
80.962	0.485	0.039				103.084	0.379	0.039
84.634	0.477	0.040				106.848	0.326	0.035
88.305	0.460	0.041						
92.069	0.444	0.041						
95.741	0.422	0.040						
99.413	0.387	0.038						
103.084	0.358	0.037						
106.756	0.287	0.031						

Graphite Rod, Long Term Run, Air Flow Rate = 0.50 SLPM, T = 600°C, 2/21/2006

Time	Temp (°C)	VCELL	VANODE	VCATHODE	I (A)	I (mA)	I/SA
14:20:00	598	0.611	-0.647	-0.036	2.000	2000	36.717
14:25:00	598	0.612	-0.647	-0.035	2.005	2005	36.809
14:30:00	599	0.613	-0.649	-0.036	2.005	2005	36.809
14:35:00	598	0.623	-0.659	-0.036	2.005	2005	36.809
14:40:00	598	0.620	-0.657	-0.037	2.005	2005	36.809
14:45:00	599	0.616	-0.652	-0.036	2.005	2005	36.809
14:50:00	599	0.620	-0.655	-0.035	2.005	2005	36.809
14:55:00	598	0.617	-0.653	-0.036	2.005	2005	36.809
15:00:00	598	0.618	-0.655	-0.037	2.005	2005	36.809
15:05:00	599	0.617	-0.652	-0.035	2.005	2005	36.809
15:10:00	598	0.618	-0.654	-0.036	2.005	2005	36.809
15:15:00	598	0.620	-0.656	-0.036	2.005	2005	36.809
15:20:00	599	0.621	-0.659	-0.038	2.005	2005	36.809
15:25:00	599	0.619	-0.657	-0.038	2.005	2005	36.809
15:30:00	598	0.621	-0.656	-0.035	2.005	2005	36.809
15:35:00	599	0.630	-0.669	-0.039	2.005	2005	36.809
15:40:00	599	0.626	-0.663	-0.037	2.005	2005	36.809
15:45:00	598	0.624	-0.660	-0.036	2.005	2005	36.809
15:50:00	598	0.625	-0.661	-0.036	2.005	2005	36.809
15:55:00	599	0.625	-0.662	-0.037	2.005	2005	36.809
16:00:00	598	0.633	-0.669	-0.036	2.005	2005	36.809
16:05:00	598	0.631	-0.668	-0.037	2.005	2005	36.809
16:10:00	599	0.635	-0.673	-0.038	2.005	2005	36.809
16:15:00	599	0.631	-0.669	-0.038	2.005	2005	36.809
16:20:00	598	0.627	-0.664	-0.037	2.005	2005	36.809
16:25:00	598	0.629	-0.668	-0.039	2.005	2005	36.809
16:30:00	598	0.634	-0.671	-0.037	2.005	2005	36.809
16:35:00	598	0.635	-0.672	-0.037	2.005	2005	36.809
16:40:00	598	0.652	-0.691	-0.039	2.005	2005	36.809
16:45:00	598	0.636	-0.674	-0.038	2.005	2005	36.809
16:50:00	599	0.635	-0.672	-0.037	2.005	2005	36.809
16:55:00	598	0.634	-0.673	-0.039	2.005	2005	36.809
17:00:00	598	0.635	-0.672	-0.037	2.005	2005	36.809
17:05:00	598	0.636	-0.675	-0.039	2.005	2005	36.809
17:10:00	598	0.636	-0.672	-0.036	2.005	2005	36.809
17:15:00	598	0.635	-0.672	-0.037	2.005	2005	36.809
17:20:00	598	0.633	-0.671	-0.038	2.005	2005	36.809
17:25:00	598	0.629	-0.666	-0.037	2.005	2005	36.809
17:30:00	598	0.632	-0.670	-0.038	2.005	2005	36.809
17:35:00	598	0.632	-0.669	-0.037	2.005	2005	36.809
17:40:00	598	0.641	-0.678	-0.037	2.005	2005	36.809
17:45:00	598	0.638	-0.676	-0.038	2.005	2005	36.809
17:50:00	598	0.635	-0.673	-0.038	2.005	2005	36.809

17:55:00	599	0.635	-0.673	-0.038	2.005	2005	36.809
18:00:00	598	0.633	-0.670	-0.037	2.005	2005	36.809
18:05:00	598	0.632	-0.669	-0.037	2.005	2005	36.809
18:10:00	599	0.631	-0.669	-0.038	2.005	2005	36.809
18:15:00	598	0.633	-0.671	-0.038	2.005	2005	36.809
18:20:00	598	0.632	-0.670	-0.038	2.005	2005	36.809
18:25:00	598	0.633	-0.672	-0.039	2.005	2005	36.809
18:30:00	598	0.632	-0.669	-0.037	2.005	2005	36.809
18:35:00	598	0.653	-0.689	-0.036	2.005	2005	36.809
18:40:00	598	0.638	-0.678	-0.040	2.005	2005	36.809
18:45:00	599	0.639	-0.676	-0.037	2.005	2005	36.809
18:50:00	598	0.634	-0.671	-0.037	2.005	2005	36.809
18:55:00	598	0.636	-0.675	-0.039	2.010	2010	36.901
19:00:00	598	0.635	-0.672	-0.037	2.005	2005	36.809
19:05:00	598	0.634	-0.672	-0.038	2.005	2005	36.809
19:10:00	598	0.635	-0.672	-0.037	2.010	2010	36.901
19:15:00	598	0.642	-0.679	-0.037	2.010	2010	36.901
19:20:00	599	0.641	-0.678	-0.037	2.005	2005	36.809
19:25:00	598	0.636	-0.674	-0.038	2.005	2005	36.809
19:30:00	598	0.636	-0.674	-0.038	2.005	2005	36.809
19:35:00	599	0.635	-0.673	-0.038	2.010	2010	36.901
19:40:00	598	0.634	-0.671	-0.037	2.005	2005	36.809
19:45:00	598	0.636	-0.673	-0.037	2.005	2005	36.809
19:50:00	598	0.634	-0.672	-0.038	2.005	2005	36.809
19:55:00	599	0.635	-0.672	-0.037	2.005	2005	36.809
20:00:00	598	0.633	-0.671	-0.038	2.005	2005	36.809
20:05:00	598	0.641	-0.680	-0.039	2.005	2005	36.809
20:10:00	598	0.637	-0.674	-0.037	2.005	2005	36.809
20:15:00	598	0.637	-0.674	-0.037	2.005	2005	36.809
20:20:00	598	0.636	-0.673	-0.037	2.005	2005	36.809
20:25:00	598	0.636	-0.674	-0.038	2.005	2005	36.809
20:30:00	599	0.636	-0.674	-0.038	2.005	2005	36.809
20:35:00	598	0.647	-0.684	-0.037	2.010	2010	36.901
20:40:00	598	0.642	-0.680	-0.038	2.010	2010	36.901
20:45:00	598	0.637	-0.674	-0.037	2.005	2005	36.809
20:50:00	598	0.640	-0.678	-0.038	2.010	2010	36.901
20:55:00	599	0.636	-0.674	-0.038	2.010	2010	36.901
21:00:00	599	0.636	-0.673	-0.037	2.005	2005	36.809
21:05:00	598	0.635	-0.673	-0.038	2.010	2010	36.901
21:10:00	598	0.635	-0.672	-0.037	2.010	2010	36.901
21:15:00	599	0.637	-0.674	-0.037	2.010	2010	36.901
21:20:00	599	0.649	-0.685	-0.036	2.010	2010	36.901
21:25:00	598	0.642	-0.680	-0.038	2.010	2010	36.901
21:30:00	599	0.641	-0.680	-0.039	2.010	2010	36.901
21:35:00	598	0.637	-0.675	-0.038	2.010	2010	36.901
21:40:00	598	0.638	-0.677	-0.039	2.010	2010	36.901
21:45:00	598	0.642	-0.679	-0.037	2.010	2010	36.901
21:50:00	598	0.638	-0.676	-0.038	2.010	2010	36.901
21:55:00	598	0.635	-0.672	-0.037	2.010	2010	36.901
22:00:00	598	0.636	-0.673	-0.037	2.010	2010	36.901
22:05:00	598	0.634	-0.672	-0.038	2.010	2010	36.901
22:10:00	599	0.636	-0.674	-0.038	2.010	2010	36.901
22:15:00	598	0.637	-0.675	-0.038	2.010	2010	36.901
22:20:00	598	0.643	-0.683	-0.040	2.010	2010	36.901
22:25:00	599	0.641	-0.680	-0.039	2.010	2010	36.901
22:30:00	598	0.636	-0.673	-0.037	2.010	2010	36.901
22:35:00	598	0.636	-0.673	-0.037	2.010	2010	36.901
22:40:00	599	0.635	-0.673	-0.038	2.010	2010	36.901
22:45:00	598	0.635	-0.673	-0.038	2.010	2010	36.901
22:50:00	598	0.637	-0.675	-0.038	2.010	2010	36.901
22:55:00	599	0.634	-0.673	-0.039	2.010	2010	36.901
23:00:00	598	0.636	-0.673	-0.037	2.010	2010	36.901
23:05:00	598	0.643	-0.680	-0.037	2.010	2010	36.901

23:10:00	599	0.641	-0.679	-0.038	2.010	2010	36.901
23:15:00	598	0.641	-0.679	-0.038	2.010	2010	36.901
23:20:00	598	0.635	-0.672	-0.037	2.010	2010	36.901
23:25:00	599	0.635	-0.673	-0.038	2.010	2010	36.901
23:30:00	599	0.636	-0.674	-0.038	2.010	2010	36.901
23:35:00	598	0.635	-0.672	-0.037	2.010	2010	36.901
23:40:00	598	0.636	-0.674	-0.038	2.010	2010	36.901
23:45:00	598	0.639	-0.677	-0.038	2.010	2010	36.901
23:50:00	598	0.638	-0.678	-0.040	2.010	2010	36.901
23:55:00	599	0.635	-0.673	-0.038	2.010	2010	36.901
00:00:00	598	0.635	-0.673	-0.038	2.010	2010	36.901
00:05:00	598	0.634	-0.672	-0.038	2.010	2010	36.901
00:10:00	599	0.635	-0.673	-0.038	2.010	2010	36.901
00:15:00	598	0.633	-0.671	-0.038	2.010	2010	36.901
00:20:00	598	0.634	-0.671	-0.037	2.010	2010	36.901
00:25:00	599	0.639	-0.677	-0.038	2.010	2010	36.901
00:30:00	598	0.637	-0.675	-0.038	2.010	2010	36.901
00:35:00	598	0.635	-0.673	-0.038	2.010	2010	36.901
00:40:00	598	0.635	-0.673	-0.038	2.010	2010	36.901
00:45:00	598	0.634	-0.673	-0.039	2.010	2010	36.901
00:50:00	598	0.635	-0.673	-0.038	2.010	2010	36.901
00:55:00	599	0.640	-0.678	-0.038	2.010	2010	36.901
01:00:00	598	0.638	-0.676	-0.038	2.010	2010	36.901
01:05:00	598	0.637	-0.675	-0.038	2.010	2010	36.901
01:10:00	599	0.638	-0.676	-0.038	2.010	2010	36.901
01:15:00	598	0.634	-0.673	-0.039	2.010	2010	36.901
01:20:00	598	0.635	-0.673	-0.038	2.010	2010	36.901
01:25:00	598	0.633	-0.671	-0.038	2.010	2010	36.901
01:30:00	598	0.632	-0.670	-0.038	2.010	2010	36.901
01:35:00	598	0.635	-0.672	-0.037	2.010	2010	36.901
01:40:00	598	0.635	-0.674	-0.039	2.010	2010	36.901
01:45:00	598	0.633	-0.671	-0.038	2.010	2010	36.901
01:50:00	598	0.636	-0.674	-0.038	2.010	2010	36.901
01:55:00	598	0.633	-0.671	-0.038	2.010	2010	36.901
02:00:00	598	0.637	-0.676	-0.039	2.010	2010	36.901
02:05:00	598	0.637	-0.674	-0.037	2.010	2010	36.901
02:10:00	599	0.638	-0.677	-0.039	2.010	2010	36.901
02:15:00	598	0.633	-0.671	-0.038	2.010	2010	36.901
02:20:00	598	0.630	-0.667	-0.037	2.010	2010	36.901
02:25:00	599	0.631	-0.669	-0.038	2.010	2010	36.901
02:30:00	598	0.632	-0.670	-0.038	2.010	2010	36.901
02:35:00	598	0.631	-0.669	-0.038	2.010	2010	36.901
02:40:00	599	0.632	-0.670	-0.038	2.010	2010	36.901
02:45:00	598	0.632	-0.671	-0.039	2.010	2010	36.901
02:50:00	598	0.639	-0.677	-0.038	2.010	2010	36.901
02:55:00	599	0.635	-0.674	-0.039	2.010	2010	36.901
03:00:00	599	0.632	-0.671	-0.039	2.010	2010	36.901
03:05:00	598	0.631	-0.669	-0.038	2.010	2010	36.901
03:10:00	598	0.630	-0.668	-0.038	2.010	2010	36.901
03:15:00	598	0.631	-0.669	-0.038	2.010	2010	36.901
03:20:00	598	0.629	-0.666	-0.037	2.010	2010	36.901
03:25:00	598	0.628	-0.666	-0.038	2.010	2010	36.901
03:30:00	598	0.629	-0.667	-0.038	2.010	2010	36.901
03:35:00	598	0.627	-0.666	-0.039	2.010	2010	36.901
03:40:00	597	0.631	-0.672	-0.041	2.010	2010	36.901
03:45:00	598	0.630	-0.670	-0.040	2.010	2010	36.901
03:50:00	599	0.629	-0.668	-0.039	2.010	2010	36.901
03:55:00	598	0.628	-0.667	-0.039	2.010	2010	36.901
04:00:00	598	0.630	-0.669	-0.039	2.010	2010	36.901
04:05:00	598	0.628	-0.668	-0.040	2.010	2010	36.901
04:10:00	598	0.628	-0.667	-0.039	2.010	2010	36.901
04:15:00	598	0.630	-0.669	-0.039	2.010	2010	36.901
04:20:00	598	0.629	-0.668	-0.039	2.010	2010	36.901

04:25:00	598	0.630	-0.668	-0.038	2.010	2010	36.901
04:30:00	598	0.630	-0.669	-0.039	2.010	2010	36.901
04:35:00	598	0.636	-0.676	-0.040	2.010	2010	36.901
04:40:00	598	0.632	-0.672	-0.040	2.010	2010	36.901
04:45:00	598	0.629	-0.668	-0.039	2.010	2010	36.901
04:50:00	598	0.629	-0.668	-0.039	2.010	2010	36.901
04:55:00	598	0.628	-0.667	-0.039	2.010	2010	36.901
05:00:00	599	0.627	-0.666	-0.039	2.010	2010	36.901
05:05:00	598	0.627	-0.667	-0.040	2.010	2010	36.901
05:10:00	598	0.624	-0.668	-0.044	2.010	2010	36.901
05:15:00	598	0.626	-0.668	-0.042	2.010	2010	36.901
05:20:00	598	0.628	-0.669	-0.041	2.010	2010	36.901
05:25:00	598	0.627	-0.668	-0.041	2.010	2010	36.901
05:30:00	598	0.626	-0.667	-0.041	2.010	2010	36.901
05:35:00	598	0.622	-0.663	-0.041	2.010	2010	36.901
05:40:00	598	0.621	-0.661	-0.040	2.010	2010	36.901
05:45:00	599	0.622	-0.662	-0.040	2.010	2010	36.901
05:50:00	598	0.620	-0.661	-0.041	2.010	2010	36.901
05:55:00	598	0.619	-0.659	-0.040	2.010	2010	36.901
06:00:00	598	0.621	-0.662	-0.041	2.010	2010	36.901
06:05:00	598	0.620	-0.660	-0.040	2.010	2010	36.901
06:10:00	598	0.621	-0.661	-0.040	2.010	2010	36.901
06:15:00	598	0.619	-0.661	-0.042	2.010	2010	36.901
06:20:00	598	0.618	-0.660	-0.042	2.010	2010	36.901
06:25:00	598	0.618	-0.659	-0.041	2.010	2010	36.901
06:30:00	598	0.618	-0.660	-0.042	2.010	2010	36.901
06:35:00	598	0.618	-0.659	-0.041	2.010	2010	36.901
06:40:00	598	0.618	-0.659	-0.041	2.010	2010	36.901
06:45:00	598	0.618	-0.659	-0.041	2.010	2010	36.901
06:50:00	598	0.618	-0.658	-0.040	2.010	2010	36.901
06:55:00	598	0.617	-0.658	-0.041	2.010	2010	36.901
07:00:00	598	0.615	-0.656	-0.041	2.010	2010	36.901
07:05:00	598	0.617	-0.657	-0.04	2.01	2010	36.901
07:10:00	598	0.616	-0.657	-0.041	2.01	2010	36.901
07:15:00	598	0.616	-0.658	-0.042	2.01	2010	36.901
07:20:00	598	0.615	-0.655	-0.04	2.005	2005	36.809
07:25:00	598	0.613	-0.654	-0.041	2.005	2005	36.809
07:30:00	598	0.616	-0.658	-0.042	2.005	2005	36.809
07:35:00	598	0.614	-0.655	-0.041	2.005	2005	36.809
07:40:00	598	0.611	-0.660	-0.049	2.005	2005	36.809
07:45:00	598	0.611	-0.656	-0.045	2.005	2005	36.809
07:50:00	598	0.613	-0.656	-0.043	2.005	2005	36.809
07:55:00	598	0.612	-0.653	-0.041	2.005	2005	36.809
08:00:00	598	0.611	-0.652	-0.041	2.005	2005	36.809
08:05:00	598	0.611	-0.652	-0.041	2.005	2005	36.809
08:10:00	598	0.613	-0.653	-0.04	2.010	2010	36.901
08:15:00	598	0.611	-0.652	-0.041	2.005	2005	36.809
08:20:00	598	0.611	-0.651	-0.04	2.005	2005	36.809
08:25:00	598	0.612	-0.654	-0.042	2.005	2005	36.809
08:30:00	598	0.610	-0.651	-0.041	2.005	2005	36.809
08:35:00	598	0.612	-0.653	-0.041	2.005	2005	36.809
08:40:00	598	0.615	-0.657	-0.042	2.005	2005	36.809
08:45:00	598	0.611	-0.654	-0.043	2.005	2005	36.809
08:50:00	598	0.610	-0.651	-0.041	2.005	2005	36.809
08:55:00	598	0.609	-0.650	-0.041	2.005	2005	36.809
09:00:00	598	0.609	-0.651	-0.042	2.005	2005	36.809
09:05:00	598	0.609	-0.651	-0.042	2.005	2005	36.809
09:10:00	598	0.609	-0.651	-0.042	2.005	2005	36.809
09:15:00	598	0.610	-0.652	-0.042	2.005	2005	36.809
09:20:00	598	0.609	-0.651	-0.042	2.005	2005	36.809
09:25:00	598	0.607	-0.649	-0.042	2.005	2005	36.809
09:30:00	598	0.609	-0.652	-0.043	2.005	2005	36.809
09:35:00	598	0.607	-0.650	-0.043	2.005	2005	36.809

09:40:00	598	0.606	-0.649	-0.043	2.005	2005	36.809
09:45:00	598	0.607	-0.650	-0.043	2.005	2005	36.809
09:50:00	598	0.606	-0.648	-0.042	2.005	2005	36.809
09:55:00	598	0.606	-0.649	-0.043	2.005	2005	36.809
10:00:00	598	0.606	-0.650	-0.044	2.005	2005	36.809
10:05:00	598	0.608	-0.651	-0.043	2.005	2005	36.809
10:10:00	598	0.606	-0.649	-0.043	2.005	2005	36.809
10:15:00	599	0.606	-0.650	-0.044	2.005	2005	36.809
10:20:00	598	0.605	-0.647	-0.042	2.005	2005	36.809
10:25:00	598	0.605	-0.648	-0.043	2.005	2005	36.809
10:30:00	598	0.605	-0.648	-0.043	2.01	2010	36.901

Graphite Rod, Air Flow Rate = 0.50 SLPM, T = 600°C, 3/8/2006

0.50 SLPM (1)			0.50 SLPM (2)		
I/SA	VCELL	P/SA	I/SA	VCELL	P/SA
0.090	0.736	0.000	0.090	0.767	0.000
0.090	0.735	0.000	0.090	0.766	0.000
0.090	0.736	0.000	0.090	0.766	0.000
0.090	0.751	0.000	0.090	0.757	0.000
0.090	0.752	0.000	0.090	0.760	0.000
0.090	0.754	0.000	0.090	0.763	0.000
2.255	0.730	0.002	0.090	0.764	0.000
4.511	0.726	0.003	2.255	0.760	0.002
6.766	0.722	0.005	4.511	0.752	0.003
9.021	0.716	0.006	6.766	0.746	0.005
11.322	0.713	0.008	9.021	0.738	0.007
13.532	0.711	0.010	11.322	0.731	0.008
15.832	0.713	0.011	13.577	0.724	0.010
18.088	0.708	0.013	15.832	0.716	0.011
20.343	0.703	0.014	18.088	0.710	0.013
22.598	0.698	0.016	20.343	0.703	0.014
24.853	0.693	0.017	22.598	0.698	0.016
27.109	0.688	0.019	24.853	0.689	0.017
29.364	0.681	0.020	27.109	0.684	0.019
31.619	0.676	0.021	29.364	0.675	0.020
33.875	0.669	0.023	31.619	0.669	0.021
36.130	0.663	0.024	33.875	0.664	0.022
38.385	0.657	0.025	36.130	0.657	0.024
40.641	0.652	0.026	38.385	0.650	0.025
42.896	0.647	0.028	40.641	0.643	0.026
45.151	0.642	0.029	42.896	0.638	0.027
47.406	0.639	0.030	45.151	0.631	0.028
49.662	0.635	0.032	47.406	0.624	0.030
51.962	0.631	0.033	49.662	0.617	0.031
54.172	0.625	0.034	51.962	0.611	0.032
56.428	0.621	0.035	54.172	0.604	0.033
58.683	0.617	0.036	56.473	0.598	0.034
60.983	0.612	0.037	58.683	0.591	0.035
63.194	0.608	0.038	60.983	0.585	0.036
65.494	0.604	0.040	63.239	0.579	0.037
67.749	0.598	0.041	65.494	0.569	0.037
70.005	0.593	0.042	67.749	0.562	0.038
72.260	0.589	0.043	70.005	0.556	0.039
74.515	0.587	0.044	72.260	0.547	0.040
76.770	0.584	0.045	74.515	0.537	0.040
79.026	0.578	0.046	76.770	0.533	0.041

81.281	0.574	0.047	79.026	0.519	0.041
83.536	0.570	0.048	81.281	0.509	0.041
85.792	0.567	0.049	83.536	0.497	0.042
88.047	0.561	0.049	85.792	0.491	0.042
90.302	0.557	0.050	88.047	0.477	0.042
92.558	0.553	0.051	90.302	0.457	0.041
94.813	0.548	0.052	92.558	0.431	0.040
97.068	0.545	0.053	94.813	0.414	0.039
99.323	0.539	0.054	97.068	0.395	0.038
101.579	0.537	0.055	99.323	0.346	0.034
103.834	0.529	0.055	101.579	0.283	0.029
106.089	0.527	0.056			
108.345	0.520	0.056			
110.645	0.514	0.057			
112.900	0.509	0.057			
115.111	0.507	0.058			
117.366	0.501	0.059			
119.666	0.495	0.059			
121.922	0.488	0.059			
124.177	0.478	0.059			
126.432	0.476	0.060			
128.687	0.459	0.059			
130.943	0.452	0.059			
133.198	0.435	0.058			
135.453	0.431	0.058			
137.709	0.394	0.054			
139.964	0.363	0.051			

Graphite Rod, Long Term Run, Air Flow Rate = 0.50 SLPM, T = 600°C, 3/8/2006

Temp (°C)	VCELL	VANODE	VCATHODE	I (A)	I (mA)	I/SA
600	0.690	-0.717	-0.027	1.502	1502	33.875
600	0.688	-0.716	-0.028	1.502	1502	33.875
600	0.689	-0.716	-0.027	1.502	1502	33.875
600	0.687	-0.714	-0.027	1.502	1502	33.875
600	0.685	-0.711	-0.026	1.502	1502	33.875
600	0.682	-0.708	-0.026	1.502	1502	33.875
600	0.680	-0.706	-0.026	1.502	1502	33.875
600	0.676	-0.702	-0.026	1.502	1502	33.875
600	0.671	-0.696	-0.025	1.502	1502	33.875
600	0.663	-0.688	-0.025	1.502	1502	33.875
600	0.657	-0.682	-0.025	1.502	1502	33.875
600	0.650	-0.674	-0.024	1.502	1502	33.875
600	0.638	-0.663	-0.025	1.502	1502	33.875
600	0.629	-0.653	-0.024	1.502	1502	33.875
600	0.623	-0.647	-0.024	1.502	1502	33.875
600	0.616	-0.641	-0.025	1.502	1502	33.875
600	0.609	-0.633	-0.024	1.502	1502	33.875
600	0.603	-0.629	-0.026	1.502	1502	33.875
600	0.596	-0.620	-0.024	1.502	1502	33.875
600	0.592	-0.617	-0.025	1.502	1502	33.875
600	0.586	-0.611	-0.025	1.502	1502	33.875
600	0.584	-0.609	-0.025	1.502	1502	33.875
600	0.582	-0.606	-0.024	1.502	1502	33.875
600	0.572	-0.596	-0.024	1.502	1502	33.875
600	0.571	-0.595	-0.024	1.502	1502	33.875
600	0.564	-0.588	-0.024	1.502	1502	33.875

600	0.566	-0.590	-0.024	1.502	1502	33.875
600	0.564	-0.588	-0.024	1.502	1502	33.875
600	0.710	-0.734	-0.024	1.502	1502	33.875
600	0.665	-0.692	-0.027	1.502	1502	33.875
600	0.660	-0.688	-0.028	1.502	1502	33.875
600	0.666	-0.691	-0.025	1.502	1502	33.875
600	0.669	-0.694	-0.025	1.502	1502	33.875
600	0.669	-0.695	-0.026	1.502	1502	33.875
600	0.669	-0.694	-0.025	1.502	1502	33.875
600	0.671	-0.697	-0.026	1.502	1502	33.875
600	0.671	-0.697	-0.026	1.502	1502	33.875
600	0.671	-0.696	-0.025	1.502	1502	33.875
600	0.670	-0.696	-0.026	1.502	1502	33.875
600	0.671	-0.696	-0.025	1.502	1502	33.875
600	0.674	-0.700	-0.026	1.502	1502	33.875
600	0.671	-0.698	-0.027	1.502	1502	33.875
600	0.669	-0.695	-0.026	1.502	1502	33.875
600	0.671	-0.698	-0.027	1.502	1502	33.875
600	0.672	-0.699	-0.027	1.502	1502	33.875
600	0.673	-0.699	-0.026	1.502	1502	33.875
600	0.672	-0.698	-0.026	1.502	1502	33.875
600	0.676	-0.702	-0.026	1.502	1502	33.875
600	0.676	-0.703	-0.027	1.502	1502	33.875
600	0.674	-0.700	-0.026	1.502	1502	33.875
600	0.676	-0.703	-0.027	1.502	1502	33.875
600	0.677	-0.703	-0.026	1.502	1502	33.875
600	0.679	-0.705	-0.026	1.502	1502	33.875
600	0.678	-0.704	-0.026	1.502	1502	33.875
600	0.678	-0.704	-0.026	1.502	1502	33.875
600	0.677	-0.704	-0.027	1.502	1502	33.875
600	0.679	-0.705	-0.026	1.502	1502	33.875
600	0.680	-0.707	-0.027	1.502	1502	33.875
600	0.688	-0.714	-0.026	1.502	1502	33.875
600	0.686	-0.713	-0.027	1.502	1502	33.875
600	0.686	-0.712	-0.026	1.502	1502	33.875
600	0.686	-0.712	-0.026	1.502	1502	33.875
600	0.686	-0.712	-0.026	1.502	1502	33.875
600	0.685	-0.711	-0.026	1.502	1502	33.875
600	0.687	-0.713	-0.026	1.502	1502	33.875
600	0.686	-0.713	-0.027	1.502	1502	33.875
600	0.686	-0.713	-0.027	1.502	1502	33.875
600	0.685	-0.712	-0.027	1.502	1502	33.875
600	0.684	-0.711	-0.027	1.502	1502	33.875
600	0.684	-0.711	-0.027	1.502	1502	33.875
600	0.683	-0.710	-0.027	1.502	1502	33.875
600	0.684	-0.710	-0.026	1.502	1502	33.875
600	0.678	-0.706	-0.028	1.502	1502	33.875
600	0.677	-0.704	-0.027	1.502	1502	33.875
600	0.675	-0.702	-0.027	1.502	1502	33.875
600	0.673	-0.700	-0.027	1.502	1502	33.875
600	0.671	-0.699	-0.028	1.502	1502	33.875
600	0.670	-0.699	-0.029	1.502	1502	33.875
600	0.667	-0.694	-0.027	1.502	1502	33.875
600	0.665	-0.693	-0.028	1.502	1502	33.875
600	0.669	-0.698	-0.029	1.502	1502	33.875
600	0.668	-0.697	-0.029	1.502	1502	33.875
600	0.668	-0.696	-0.028	1.502	1502	33.875
600	0.667	-0.695	-0.028	1.502	1502	33.875
600	0.668	-0.696	-0.028	1.502	1502	33.875
600	0.668	-0.696	-0.028	1.502	1502	33.875
600	0.666	-0.694	-0.028	1.502	1502	33.875
600	0.668	-0.697	-0.029	1.502	1502	33.875
600	0.667	-0.695	-0.028	1.502	1502	33.875

600	0.665	-0.693	-0.028	1.502	1502	33.875
600	0.667	-0.695	-0.028	1.502	1502	33.875
600	0.667	-0.697	-0.030	1.502	1502	33.875
600	0.667	-0.696	-0.029	1.502	1502	33.875
600	0.667	-0.695	-0.028	1.502	1502	33.875
600	0.668	-0.696	-0.028	1.502	1502	33.875
600	0.666	-0.695	-0.029	1.502	1502	33.875
600	0.668	-0.696	-0.028	1.502	1502	33.875
600	0.667	-0.695	-0.028	1.502	1502	33.875
600	0.667	-0.696	-0.029	1.502	1502	33.875
600	0.667	-0.696	-0.029	1.502	1502	33.875
600	0.668	-0.696	-0.028	1.502	1502	33.875
600	0.667	-0.696	-0.029	1.502	1502	33.875
600	0.667	-0.696	-0.029	1.502	1502	33.875
600	0.669	-0.698	-0.029	1.502	1502	33.875
600	0.667	-0.696	-0.029	1.502	1502	33.875
600	0.667	-0.697	-0.030	1.502	1502	33.875
600	0.669	-0.698	-0.029	1.502	1502	33.875
600	0.666	-0.695	-0.029	1.502	1502	33.875
600	0.668	-0.697	-0.029	1.502	1502	33.875
600	0.667	-0.696	-0.029	1.502	1502	33.875
600	0.666	-0.695	-0.029	1.502	1502	33.875
600	0.666	-0.696	-0.030	1.502	1502	33.875
600	0.667	-0.696	-0.029	1.502	1502	33.875
600	0.666	-0.695	-0.029	1.502	1502	33.875
600	0.668	-0.698	-0.030	1.502	1502	33.875
600	0.670	-0.699	-0.029	1.502	1502	33.875
600	0.670	-0.699	-0.029	1.502	1502	33.875
600	0.670	-0.699	-0.029	1.502	1502	33.875
600	0.669	-0.699	-0.030	1.502	1502	33.875
600	0.670	-0.700	-0.030	1.502	1502	33.875
600	0.669	-0.699	-0.030	1.502	1502	33.875
600	0.668	-0.699	-0.031	1.502	1502	33.875
600	0.671	-0.701	-0.030	1.502	1502	33.875
600	0.671	-0.701	-0.030	1.502	1502	33.875
600	0.673	-0.704	-0.031	1.502	1502	33.875
600	0.674	-0.705	-0.031	1.502	1502	33.875
600	0.676	-0.707	-0.031	1.502	1502	33.875
600	0.674	-0.704	-0.030	1.502	1502	33.875
600	0.675	-0.707	-0.032	1.502	1502	33.875
600	0.675	-0.706	-0.031	1.502	1502	33.875
600	0.675	-0.707	-0.032	1.502	1502	33.875
600	0.675	-0.705	-0.030	1.502	1502	33.875
600	0.673	-0.704	-0.031	1.502	1502	33.875
600	0.678	-0.708	-0.030	1.502	1502	33.875
600	0.677	-0.707	-0.030	1.502	1502	33.875
600	0.677	-0.707	-0.030	1.502	1502	33.875
600	0.677	-0.708	-0.031	1.502	1502	33.875
600	0.678	-0.709	-0.031	1.502	1502	33.875
600	0.676	-0.707	-0.031	1.502	1502	33.875
600	0.677	-0.708	-0.031	1.502	1502	33.875
600	0.676	-0.708	-0.032	1.502	1502	33.875
600	0.676	-0.707	-0.031	1.502	1502	33.875
600	0.677	-0.708	-0.031	1.502	1502	33.875
600	0.675	-0.707	-0.032	1.502	1502	33.875
600	0.676	-0.707	-0.031	1.502	1502	33.875
600	0.675	-0.708	-0.033	1.502	1502	33.875
600	0.675	-0.706	-0.031	1.502	1502	33.875
600	0.674	-0.708	-0.034	1.502	1502	33.875
600	0.675	-0.706	-0.031	1.502	1502	33.875
600	0.677	-0.708	-0.031	1.502	1502	33.875
600	0.673	-0.705	-0.032	1.502	1502	33.875
600	0.673	-0.703	-0.030	1.502	1502	33.875

600	0.674	-0.705	-0.031	1.502	1502	33.875
600	0.676	-0.708	-0.032	1.502	1502	33.875
600	0.677	-0.708	-0.031	1.502	1502	33.875
600	0.677	-0.708	-0.031	1.502	1502	33.875
600	0.677	-0.709	-0.032	1.502	1502	33.875
600	0.677	-0.708	-0.031	1.502	1502	33.875
600	0.676	-0.708	-0.032	1.502	1502	33.875
600	0.676	-0.707	-0.031	1.502	1502	33.875
600	0.675	-0.706	-0.031	1.502	1502	33.875
600	0.675	-0.706	-0.031	1.502	1502	33.875
600	0.675	-0.707	-0.032	1.502	1502	33.875
600	0.675	-0.707	-0.032	1.502	1502	33.875
600	0.675	-0.706	-0.031	1.502	1502	33.875
600	0.676	-0.708	-0.032	1.502	1502	33.875
600	0.673	-0.705	-0.032	1.502	1502	33.875
600	0.674	-0.705	-0.031	1.502	1502	33.875
600	0.673	-0.706	-0.033	1.502	1502	33.875
600	0.675	-0.707	-0.032	1.502	1502	33.875
600	0.675	-0.707	-0.032	1.502	1502	33.875
600	0.673	-0.704	-0.031	1.502	1502	33.875
600	0.670	-0.703	-0.033	1.502	1502	33.875
600	0.670	-0.703	-0.033	1.502	1502	33.875
600	0.670	-0.703	-0.033	1.502	1502	33.875
600	0.671	-0.704	-0.033	1.502	1502	33.875
600	0.670	-0.702	-0.032	1.502	1502	33.875
600	0.669	-0.702	-0.033	1.502	1502	33.875
600	0.671	-0.703	-0.032	1.502	1502	33.875
600	0.669	-0.701	-0.032	1.502	1502	33.875
600	0.669	-0.702	-0.033	1.502	1502	33.875
600	0.669	-0.702	-0.033	1.502	1502	33.875
600	0.667	-0.700	-0.033	1.502	1502	33.875
600	0.669	-0.701	-0.032	1.502	1502	33.875
600	0.667	-0.699	-0.032	1.502	1502	33.875
600	0.666	-0.698	-0.032	1.502	1502	33.875
600	0.666	-0.698	-0.032	1.502	1502	33.875
600	0.666	-0.698	-0.032	1.502	1502	33.875
600	0.666	-0.698	-0.032	1.502	1502	33.875
600	0.668	-0.700	-0.032	1.502	1502	33.875
600	0.667	-0.699	-0.032	1.502	1502	33.875
600	0.669	-0.702	-0.033	1.502	1502	33.875
600	0.669	-0.701	-0.032	1.502	1502	33.875
600	0.668	-0.699	-0.031	1.502	1502	33.875
600	0.666	-0.699	-0.033	1.502	1502	33.875
600	0.668	-0.699	-0.031	1.502	1502	33.875
600	0.667	-0.699	-0.032	1.502	1502	33.875
600	0.667	-0.698	-0.031	1.502	1502	33.875
600	0.667	-0.698	-0.031	1.502	1502	33.875
600	0.666	-0.698	-0.032	1.502	1502	33.875
600	0.665	-0.697	-0.032	1.502	1502	33.875
600	0.667	-0.698	-0.031	1.502	1502	33.875
600	0.664	-0.696	-0.032	1.502	1502	33.875
600	0.663	-0.695	-0.032	1.502	1502	33.875
600	0.665	-0.697	-0.032	1.502	1502	33.875
600	0.663	-0.696	-0.033	1.502	1502	33.875
600	0.665	-0.697	-0.032	1.502	1502	33.875
600	0.663	-0.697	-0.032	1.502	1502	33.875
600	0.663	-0.696	-0.033	1.502	1502	3

600	0.663	-0.695	-0.032	1.502	1502	33.875
600	0.663	-0.694	-0.031	1.502	1502	33.875
600	0.662	-0.694	-0.032	1.502	1502	33.875
600	0.764	-0.771	-0.007	0.004	4	0.090
600	0.764	-0.772	-0.008	0.004	4	0.090

Graphite Rod, Air Flow Rate = 0.50 SLPM, T is Varied, 3/15/2006

T = 600			T = 625			T = 650			T = 675			T = 700		
I/SA	VCELL	P/SA	I/SA	VCELL	P/SA	I/SA	VCELL	P/SA	I/SA	VCELL	P/SA	I/SA	VCELL	P/SA
0.039	0.704	0.000	0.039	0.732	0.000	0.039	0.759	0.000	0.077	0.765	0.000	0.077	0.723	0.000
0.039	0.705	0.000	0.039	0.733	0.000	0.039	0.760	0.000	0.077	0.768	0.000	0.077	0.724	0.000
0.039	0.702	0.000	0.039	0.733	0.000	0.039	0.758	0.000	0.077	0.769	0.000	0.077	0.729	0.000
0.039	0.759	0.000	0.077	0.757	0.000	0.077	0.759	0.000	0.077	0.768	0.000	0.077	0.742	0.000
0.039	0.756	0.000	0.077	0.757	0.000	0.077	0.762	0.000	0.077	0.761	0.000	0.077	0.746	0.000
1.926	0.700	0.001	0.077	0.758	0.000	1.926	0.754	0.001	0.077	0.768	0.000	3.851	0.723	0.003
3.851	0.695	0.003	1.926	0.728	0.001	3.851	0.751	0.003	0.077	0.770	0.000	7.741	0.712	0.006
5.777	0.689	0.004	3.851	0.727	0.003	5.777	0.749	0.004	1.926	0.764	0.001	11.554	0.719	0.008
7.703	0.680	0.005	5.777	0.720	0.004	7.703	0.744	0.006	3.851	0.762	0.003	15.444	0.706	0.011
9.667	0.677	0.007	7.703	0.713	0.005	9.667	0.742	0.007	5.777	0.760	0.004	19.295	0.697	0.013
11.593	0.674	0.008	9.667	0.712	0.007	11.593	0.739	0.009	7.741	0.758	0.006	23.147	0.692	0.016
13.518	0.666	0.009	11.593	0.707	0.008	13.518	0.734	0.010	9.667	0.754	0.007	26.998	0.685	0.018
15.444	0.662	0.010	13.518	0.705	0.010	15.444	0.733	0.011	11.593	0.749	0.009	30.849	0.675	0.021
17.370	0.656	0.011	15.444	0.700	0.011	17.370	0.729	0.013	13.518	0.746	0.010	34.701	0.666	0.023
19.295	0.653	0.013	17.370	0.694	0.012	19.295	0.725	0.014	15.444	0.745	0.012	38.552	0.656	0.025
21.221	0.649	0.014	19.295	0.691	0.013	21.221	0.722	0.015	17.370	0.739	0.013	42.442	0.649	0.028
23.147	0.643	0.015	21.221	0.687	0.015	23.147	0.719	0.017	19.295	0.740	0.014	48.219	0.642	0.031
25.072	0.639	0.016	23.147	0.683	0.016	25.072	0.715	0.018	21.221	0.736	0.016	53.996	0.628	0.034
26.998	0.632	0.017	25.072	0.679	0.017	26.998	0.711	0.019	23.147	0.732	0.017	59.773	0.621	0.037
28.924	0.632	0.018	26.998	0.673	0.018	28.924	0.707	0.020	25.072	0.729	0.018	65.550	0.611	0.040
30.849	0.626	0.019	28.924	0.669	0.019	30.849	0.705	0.022	26.998	0.727	0.020	71.327	0.600	0.043
32.775	0.622	0.020	30.849	0.666	0.021	32.813	0.701	0.023	28.924	0.724	0.021	77.104	0.589	0.045
34.701	0.618	0.021	32.813	0.664	0.022	34.701	0.698	0.024	30.849	0.721	0.022	82.919	0.578	0.048
36.626	0.614	0.022	34.701	0.660	0.023	36.626	0.694	0.025	32.775	0.717	0.023	88.696	0.567	0.050
38.552	0.610	0.024	36.626	0.653	0.024	38.552	0.691	0.027	34.701	0.715	0.025	94.473	0.554	0.052
40.516	0.608	0.025	38.552	0.652	0.025	40.478	0.689	0.028	36.626	0.712	0.026	100.212	0.544	0.055
42.403	0.603	0.026	40.516	0.647	0.026	42.403	0.685	0.029	38.590	0.710	0.027	106.027	0.527	0.056
44.367	0.598	0.027	42.403	0.643	0.027	44.367	0.683	0.030	40.478	0.708	0.029	111.804	0.511	0.057
46.255	0.596	0.028	44.367	0.640	0.028	46.255	0.679	0.031	42.442	0.704	0.030	117.581	0.498	0.059
48.219	0.591	0.028	46.255	0.637	0.029	48.219	0.677	0.033	44.367	0.703	0.031	123.358	0.483	0.060
50.106	0.587	0.029	48.219	0.632	0.030	50.106	0.673	0.034	46.255	0.700	0.032	129.135	0.469	0.061
52.070	0.583	0.030	50.106	0.630	0.032	52.070	0.670	0.035	48.219	0.697	0.034	134.912	0.452	0.061
53.996	0.579	0.031	52.070	0.626	0.033	53.996	0.666	0.036	50.144	0.694	0.035	140.689	0.438	0.062
55.921	0.575	0.032	53.957	0.622	0.034	55.921	0.664	0.037	52.070	0.691	0.036	146.466	0.420	0.062
57.847	0.570	0.033	55.921	0.619	0.035	57.847	0.659	0.038	53.996	0.688	0.037	152.243	0.407	0.062
61.698	0.561	0.035	57.847	0.614	0.036	61.698	0.654	0.040	55.921	0.685	0.038	158.059	0.385	0.061
65.550	0.554	0.036	61.698	0.606	0.037	65.550	0.648	0.042	57.847	0.682	0.039	163.836	0.371	0.061
69.401	0.545	0.038	65.550	0.598	0.039	69.401	0.642	0.045	61.698	0.675	0.042	169.613	0.359	0.061
73.252	0.536	0.039	69.401	0.588	0.041	73.252	0.636	0.047	65.550	0.669	0.044	175.390	0.338	0.059
77.104	0.528	0.041	73.252	0.582	0.043	77.104	0.629	0.048	69.401	0.664	0.046	181.167	0.326	0.059
80.955	0.517	0.042	77.104	0.578	0.045	80.955	0.622	0.050	73.252	0.659	0.048	186.944	0.307	0.057
84.806	0.506	0.043	80.955	0.571	0.046	84.845	0.616	0.052	77.104	0.652	0.050	192.721	0.290	0.056
88.696	0.494	0.044	84.806	0.561	0.048	88.658	0.610	0.054	80.955	0.647	0.052	196.572	0.272	0.053
92.548	0.480	0.044	88.658	0.554	0.049	92.548	0.603	0.056	84.806	0.640	0.054	200.424	0.269	0.054
96.399	0.449	0.043	92.548	0.543	0.050	96.399	0.596	0.057	88.658	0.632	0.056	204.275	0.258	0.053
100.212	0.395	0.040	96.399	0.538	0.052	100.250	0.591	0.059	92.548	0.626	0.058	208.126	0.239	0.050
102.176	0.396	0.040	100.250	0.528	0.053	104.102	0.583	0.061	96.399	0.621	0.060	211.978	0.225	0.048
104.102	0.363	0.038	104.102	0.522	0.054	107.953	0.575	0.062	100.250	0.615	0.062	213.903	0.212	0.045
106.027	0.327	0.035	107.953	0.509	0.055	111.804	0.568	0.064	104.102	0.609	0.063			
			111.804	0.496	0.055	115.656	0.561	0.065	107.953	0.602	0.065			
			115.656	0.489	0.057	119.507	0.551	0.066	111.804	0.596	0.067			
			119.507	0.475	0.057	123.358	0.547	0.067	115.656	0.588	0.068			
			123.358	0.454	0.056	127.210	0.535	0.068	119.507	0.581	0.069			
			127.210	0.438	0.056	131.061	0.530	0.069	123.358	0.576	0.071			
			131.061	0.400	0.052	134.912	0.521	0.070	127.210	0.565	0.072			
			132.987	0.378	0.050	138.764	0.511	0.071	131.061	0.562	0.074			

142.615	0.500	0.071	134.912	0.555	0.075
146.505	0.488	0.071	138.764	0.547	0.076
150.318	0.479	0.072	142.615	0.542	0.077
154.208	0.471	0.073	146.466	0.531	0.078
158.059	0.456	0.072	150.318	0.525	0.079
159.985	0.444	0.071	154.208	0.517	0.080
161.910	0.420	0.068	158.059	0.512	0.081
163.836	0.422	0.069	161.910	0.501	0.081
165.762	0.405	0.067	165.762	0.494	0.082
167.687	0.391	0.066	169.613	0.487	0.083
169.613	0.369	0.063	173.464	0.474	0.082
			177.316	0.464	0.082
			181.167	0.461	0.084
			185.018	0.448	0.083
			186.944	0.436	0.082
			188.870	0.425	0.080
			190.795	0.424	0.081
			192.721	0.419	0.081
			194.647	0.401	0.078
			196.572	0.399	0.078

Graphite Rod, Long Term Run, Air Flow Rate = 0.50 SLPM, T = 650°C, 3/15/2006

Temp (°C)	VCELL	VANODE	VCATHODE	I (A)	I (mA)	I/SA
647	0.636	-0.662	-0.026	1.502	1502	28.924
640	0.637	-0.665	-0.028	1.502	1502	28.924
652	0.620	-0.647	-0.027	1.502	1502	28.924
651	0.607	-0.633	-0.026	1.502	1502	28.924
648	0.597	-0.623	-0.026	1.502	1502	28.924
650	0.588	-0.614	-0.026	1.502	1502	28.924
650	0.582	-0.608	-0.026	1.502	1502	28.924
649	0.578	-0.604	-0.026	1.502	1502	28.924
649	0.577	-0.602	-0.025	1.502	1502	28.924
649	0.572	-0.598	-0.026	1.502	1502	28.924
649	0.568	-0.594	-0.026	1.502	1502	28.924
649	0.568	-0.594	-0.026	1.502	1502	28.924
649	0.566	-0.592	-0.026	1.502	1502	28.924
649	0.567	-0.592	-0.025	1.502	1502	28.924
649	0.570	-0.596	-0.026	1.502	1502	28.924
649	0.572	-0.598	-0.026	1.502	1502	28.924
649	0.571	-0.596	-0.025	1.502	1502	28.924
649	0.580	-0.606	-0.026	1.502	1502	28.924
649	0.587	-0.613	-0.026	1.502	1502	28.924
649	0.600	-0.626	-0.026	1.502	1502	28.924
649	0.611	-0.637	-0.026	1.502	1502	28.924
649	0.620	-0.645	-0.025	1.502	1502	28.924
649	0.627	-0.653	-0.026	1.502	1502	28.924
649	0.631	-0.657	-0.026	1.502	1502	28.924
649	0.635	-0.661	-0.026	1.502	1502	28.924
649	0.636	-0.662	-0.026	1.502	1502	28.924
649	0.635	-0.660	-0.025	1.502	1502	28.924
649	0.636	-0.662	-0.026	1.502	1502	28.924
649	0.630	-0.656	-0.026	1.502	1502	28.924
649	0.626	-0.652	-0.026	1.502	1502	28.924
649	0.622	-0.647	-0.025	1.502	1502	28.924
649	0.619	-0.644	-0.025	1.502	1502	28.924
649	0.614	-0.639	-0.025	1.502	1502	28.924
649	0.613	-0.638	-0.025	1.502	1502	28.924
650	0.608	-0.634	-0.026	1.502	1502	28.924
649	0.603	-0.628	-0.025	1.502	1502	28.924
649	0.601	-0.627	-0.026	1.502	1502	28.924
649	0.593	-0.619	-0.026	1.502	1502	28.924

649	0.586	-0.611	-0.025	1.502	1502	28.924
649	0.578	-0.603	-0.025	1.502	1502	28.924
649	0.562	-0.588	-0.026	1.502	1502	28.924
649	0.559	-0.585	-0.026	1.502	1502	28.924
650	0.621	-0.647	-0.026	1.502	1502	28.924
649	0.604	-0.630	-0.026	1.502	1502	28.924
650	0.571	-0.597	-0.026	1.502	1502	28.924
649	0.583	-0.610	-0.027	1.502	1502	28.924
649	0.650	-0.676	-0.026	1.502	1502	28.924
650	0.629	-0.656	-0.027	1.502	1502	28.924
649	0.596	-0.622	-0.026	1.502	1502	28.924
649	0.575	-0.602	-0.027	1.502	1502	28.924
650	0.589	-0.615	-0.026	1.502	1502	28.924
649	0.601	-0.628	-0.027	1.502	1502	28.924
649	0.604	-0.631	-0.027	1.502	1502	28.924
649	0.659	-0.686	-0.027	1.502	1502	28.924
650	0.620	-0.646	-0.026	1.502	1502	28.924
649	0.579	-0.605	-0.026	1.502	1502	28.924
649	0.553	-0.579	-0.026	1.502	1502	28.924
650	0.568	-0.595	-0.027	1.502	1502	28.924
649	0.561	-0.587	-0.026	1.502	1502	28.924
649	0.579	-0.605	-0.026	1.502	1502	28.924
649	0.630	-0.656	-0.026	1.502	1502	28.924
650	0.600	-0.626	-0.026	1.502	1502	28.924
649	0.576	-0.601	-0.025	1.502	1502	28.924
649	0.587	-0.612	-0.025	1.502	1502	28.924
649	0.581	-0.607	-0.026	1.502	1502	28.924
650	0.556	-0.581	-0.025	1.502	1502	28.924
649	0.581	-0.606	-0.025	1.502	1502	28.924
649	0.563	-0.588	-0.025	1.502	1502	28.924
649	0.559	-0.584	-0.025	1.502	1502	28.924
649	0.580	-0.605	-0.025	1.502	1502	28.924
650	0.585	-0.610	-0.025	1.502	1502	28.924
649	0.588	-0.613	-0.025	1.502	1502	28.924
650	0.579	-0.603	-0.024	1.502	1502	28.924
650	0.565	-0.590	-0.025	1.502	1502	28.924
650	0.545	-0.570	-0.025	1.502	1502	28.924
649	0.551	-0.576	-0.025	1.502	1502	28.924
649	0.564	-0.590	-0.026	1.502	1502	28.924
649	0.590	-0.616	-0.026	1.502	1502	28.924
649	0.568	-0.594	-0.026	1.502	1502	28.924
649	0.568	-0.594	-0.026	1.502	1502	28.924
649	0.561	-0.587	-0.026	1.502	1502	28.924
649	0.557	-0.583	-0.026	1.502	1502	28.924
650	0.543	-0.569	-0.026	1.502	1502	28.924
649	0.534	-0.560	-0.026	1.502	1502	28.924
649	0.516	-0.541	-0.025	1.502	1502	28.924
649	0.501	-0.526	-0.025	1.502	1502	28.924
649	0.487	-0.512	-0.025	1.502	1502	28.924
650	0.478	-0.504	-0.026	1.502	1502	28.924
649	0.468	-0.493	-0.025	1.502	1502	28.924
649	0.458	-0.483	-0.025	1.502	1502	28.924
649	0.452	-0.477	-0.025	1.502	1502	28.924
649	0.441	-0.466	-0.025	1.502	1502	28.924
649	0.433	-0.458	-0.025	1.502	1502	28.924
649	0.423	-0.448	-0.025	1.502	1502	28.924
649	0.421	-0.446	-0.025	1.502	1502	28.924
649	0.415	-0.440	-0.025	1.502	1502	28.924
650	0.403	-0.428	-0.025	1.502	1502	28.924
649	0.403	-0.428	-0.025	1.502	1502	28.924
650	0.394	-0.418	-0.024	1.502	1502	28.924
650	0.385	-0.410	-0.025	1.502	1502	28.924
649	0.372	-0.397	-0.025	1.502	1502	28.924

649	0.368	-0.393	-0.025	1.502	1502	28.924
650	0.370	-0.394	-0.024	1.502	1502	28.924
650	0.357	-0.381	-0.024	1.502	1502	28.924
649	0.356	-0.380	-0.024	1.502	1502	28.924
649	0.349	-0.374	-0.025	1.502	1502	28.924
650	0.350	-0.375	-0.025	1.502	1502	28.924
650	0.336	-0.360	-0.024	1.502	1502	28.924
649	0.339	-0.363	-0.024	1.502	1502	28.924
650	0.349	-0.373	-0.024	1.502	1502	28.924
650	0.341	-0.366	-0.025	1.502	1502	28.924
649	0.334	-0.358	-0.024	1.502	1502	28.924
649	0.321	-0.345	-0.024	1.502	1502	28.924
650	0.303	-0.328	-0.025	1.502	1502	28.924
649	0.306	-0.332	-0.026	1.502	1502	28.924
649	0.297	-0.322	-0.025	1.502	1502	28.924
650	0.276	-0.301	-0.025	1.502	1502	28.924
649	0.269	-0.294	-0.025	1.502	1502	28.924
650	0.253	-0.278	-0.025	1.502	1502	28.924
650	0.243	-0.268	-0.025	1.502	1502	28.924
649	0.248	-0.273	-0.025	1.502	1502	28.924
649	0.236	-0.262	-0.026	1.502	1502	28.924
650	0.207	-0.232	-0.025	1.502	1502	28.924
650	0.204	-0.229	-0.025	1.502	1502	28.924
649	0.199	-0.224	-0.025	1.502	1502	28.924
649	0.173	-0.198	-0.025	1.502	1502	28.924
649	0.168	-0.193	-0.025	1.502	1502	28.924
649	0.143	-0.168	-0.025	1.502	1502	28.924
650	0.129	-0.154	-0.025	1.502	1502	28.924
649	0.091	-0.115	-0.024	1.502	1502	28.924
649	0.062	-0.086	-0.024	1.502	1502	28.924
650	0.053	-0.078	-0.025	1.502	1502	28.924
649	0.019	-0.044	-0.025	1.502	1502	28.924
649	0.018	-0.043	-0.025	1.466	1466	28.230
650	0.018	-0.042	-0.024	1.420	1420	27.345
650	0.017	-0.041	-0.024	1.432	1432	27.576
650	0.017	-0.039	-0.022	1.308	1308	25.188
650	0.017	-0.039	-0.022	1.318	1318	25.380
650	0.016	-0.038	-0.022	1.322	1322	25.457
649	0.014	-0.035	-0.021	1.142	1142	21.991
650	0.015	-0.036	-0.021	1.158	1158	22.299
650	0.015	-0.035	-0.020	1.050	1050	20.220
649	0.015	-0.036	-0.021	1.150	1150	22.145
650	0.015	-0.036	-0.021	1.084	1084	20.874
650	0.014	-0.035	-0.021	1.140	1140	21.953
650	0.015	-0.034	-0.019	1.070	1070	20.605
650	0.014	-0.033	-0.019	1.104	1104	21.259
650	0.014	-0.034	-0.020	1.092	1092	21.028
650	0.014	-0.033	-0.019	1.038	1038	19.988
650	0.013	-0.032	-0.019	0.986	986	18.987
650	0.013	-0.031	-0.018	0.970	970	18.679
649	0.012	-0.030	-0.018	1.000	1000	19.257
650	0.012	-0.029	-0.017	0.900	900	17.331
650	0.011	-0.027	-0.016	0.854	854	16.445
650	0.010	-0.026	-0.016	0.800	800	15.405
650	0.013	-0.028	-0.015	0.768	768	14.789
649	0.013	-0.031	-0.018	0.992	992	19.103
650	0.013	-0.031	-0.018	0.926	926	17.832
650	0.012	-0.029	-0.017	0.952	952	18.332
649	0.011	-0.028	-0.017	0.898	898	17.293
650	0.010	-0.025	-0.015	0.806	806	15.521
650	0.010	-0.025	-0.015	0.726	726	13.980
649	0.011	-0.026	-0.015	0.728	728	14.019
650	0.015	-0.032	-0.017	0.800	800	15.405

650	0.015	-0.039	-0.024	1.134	1134	21.837
650	0.016	-0.040	-0.024	1.146	1146	22.068
650	0.017	-0.041	-0.024	1.218	1218	23.455
650	0.017	-0.042	-0.025	1.216	1216	23.416
649	0.020	-0.045	-0.025	1.314	1314	25.303
650	0.139	-0.166	-0.027	1.446	1446	27.845
650	0.217	-0.244	-0.027	1.502	1502	28.924
649	0.256	-0.283	-0.027	1.502	1502	28.924
650	0.290	-0.317	-0.027	1.502	1502	28.924
650	0.300	-0.327	-0.027	1.502	1502	28.924
650	0.297	-0.325	-0.028	1.502	1502	28.924
650	0.321	-0.349	-0.028	1.502	1502	28.924
650	0.307	-0.335	-0.028	1.502	1502	28.924
650	0.308	-0.336	-0.028	1.502	1502	28.924
649	0.296	-0.323	-0.027	1.502	1502	28.924
650	0.287	-0.315	-0.028	1.502	1502	28.924
650	0.285	-0.313	-0.028	1.502	1502	28.924
649	0.300	-0.328	-0.028	1.502	1502	28.924
650	0.316	-0.344	-0.028	1.502	1502	28.924
650	0.303	-0.331	-0.028	1.502	1502	28.924
649	0.313	-0.341	-0.028	1.502	1502	28.924
650	0.329	-0.357	-0.028	1.502	1502	28.924
650	0.344	-0.372	-0.028	1.502	1502	28.924
650	0.325	-0.352	-0.027	1.502	1502	28.924
650	0.335	-0.363	-0.028	1.502	1502	28.924
650	0.384	-0.412	-0.028	1.502	1502	28.924
650	0.394	-0.421	-0.027	1.502	1502	28.924
649	0.407	-0.433	-0.026	1.502	1502	28.924
650	0.415	-0.442	-0.027	1.502	1502	28.924
650	0.417	-0.443	-0.026	1.502	1502	28.924
649	0.434	-0.460	-0.026	1.502	1502	28.924
650	0.439	-0.465	-0.026	1.502	1502	28.924
650	0.454	-0.480	-0.026	1.502	1502	28.924
650	0.462	-0.487	-0.025	1.502	1502	28.924

Graphite Rod, Air Flow Rate = 0.50 SLPM, T is Varied, 3/20/2006

T = 600			T = 625			T = 650			T = 675		
I/SA	VCELL	P/SA	I/SA	VCELL	P/SA	I/SA	VCELL	P/SA	I/SA	VCELL	P/SA
0.000	0.707	0.000	0.073	0.735	0.000	0.073	0.756	0.000	0.073	0.742	0.000
0.000	0.711	0.000	0.073	0.735	0.000	0.073	0.759	0.000	0.073	0.744	0.000
0.000	0.709	0.000	0.073	0.736	0.000	0.073	0.748	0.000	0.073	0.738	0.000
0.073	0.748	0.000	0.073	0.750	0.000	3.672	0.750	0.003	0.073	0.749	0.000
0.073	0.748	0.000	0.073	0.751	0.000	7.345	0.740	0.005	3.672	0.734	0.003
3.672	0.700	0.003	3.672	0.723	0.003	11.054	0.731	0.008	7.382	0.727	0.005
7.382	0.689	0.005	7.345	0.713	0.005	14.726	0.722	0.011	11.054	0.718	0.008
11.054	0.672	0.007	11.054	0.704	0.008	18.399	0.715	0.013	14.690	0.712	0.010
14.726	0.662	0.010	14.726	0.693	0.010	22.071	0.707	0.016	18.399	0.702	0.013
18.399	0.654	0.012	18.399	0.687	0.013	25.744	0.700	0.018	22.071	0.696	0.015
22.071	0.646	0.014	22.071	0.676	0.015	29.416	0.693	0.020	25.744	0.687	0.018
25.744	0.633	0.016	25.744	0.668	0.017	33.089	0.686	0.023	29.416	0.679	0.020
29.416	0.626	0.018	29.416	0.661	0.019	36.761	0.680	0.025	33.089	0.670	0.022
33.089	0.616	0.020	33.089	0.652	0.022	40.433	0.674	0.027	36.761	0.660	0.024
36.761	0.608	0.022	36.761	0.644	0.024	44.106	0.667	0.029	40.433	0.650	0.026
40.433	0.599	0.024	40.433	0.636	0.026	47.778	0.661	0.032	44.106	0.638	0.028
44.106	0.591	0.026	44.106	0.629	0.028	51.487	0.654	0.034	47.815	0.625	0.030
47.815	0.582	0.028	47.815	0.622	0.030	55.160	0.648	0.036	51.487	0.612	0.032

51.487	0.575	0.030	51.487	0.614	0.032	60.668	0.640	0.039	55.160	0.598	0.033
55.160	0.567	0.031	55.160	0.608	0.034	66.177	0.629	0.042	58.832	0.584	0.034
58.832	0.559	0.033	55.160	0.607	0.033	71.686	0.619	0.044	62.505	0.566	0.035
62.505	0.550	0.034	60.668	0.597	0.036	77.194	0.611	0.047	66.177	0.549	0.036
66.177	0.541	0.036	66.177	0.586	0.039	82.740	0.602	0.050	69.849	0.532	0.037
69.849	0.532	0.037	71.686	0.575	0.041	88.248	0.593	0.052	73.522	0.517	0.038
73.522	0.523	0.038	77.194	0.565	0.044	93.757	0.584	0.055	77.194	0.495	0.038
77.194	0.514	0.040	82.740	0.554	0.046	99.266	0.573	0.057	80.867	0.479	0.039
80.867	0.504	0.041	88.212	0.542	0.048	104.774	0.562	0.059	84.539	0.463	0.039
84.576	0.494	0.042	93.757	0.531	0.050	110.283	0.549	0.061	88.212	0.446	0.039
88.212	0.485	0.043	99.266	0.518	0.051	115.791	0.535	0.062	91.921	0.432	0.040
91.921	0.472	0.043	104.774	0.509	0.053	121.300	0.521	0.063	95.593	0.437	0.042
95.593	0.459	0.044	110.283	0.495	0.055	126.809	0.509	0.065	99.266	0.429	0.043
99.266	0.446	0.044	115.791	0.481	0.056	132.317	0.494	0.065	102.938	0.427	0.044
102.938	0.425	0.044	121.300	0.463	0.056	137.863	0.484	0.067	106.610	0.414	0.044
106.610	0.405	0.043	126.809	0.448	0.057	143.335	0.472	0.068	110.283	0.404	0.045
110.283	0.370	0.041	132.317	0.420	0.056	143.371	0.472	0.068	113.955	0.398	0.045
113.955	0.310	0.035	135.990	0.411	0.056	147.044	0.457	0.067	117.628	0.385	0.045
			139.699	0.395	0.055	150.716	0.450	0.068	121.300	0.371	0.045
			141.498	0.375	0.053	154.389	0.446	0.069	124.972	0.363	0.045
			143.335	0.352	0.050	156.225	0.441	0.069	128.645	0.348	0.045
						158.061	0.433	0.068	128.645	0.345	0.044
						159.897	0.422	0.067	132.317	0.340	0.045
						161.733	0.423	0.068	136.026	0.328	0.045
						163.570	0.405	0.066	139.699	0.320	0.045
									143.335	0.310	0.044
									147.044	0.296	0.044
									150.716	0.290	0.044
									154.389	0.277	0.043
									158.061	0.267	0.042
									161.733	0.257	0.041
									165.406	0.246	0.041
									169.078	0.236	0.040
									172.751	0.225	0.039
									176.423	0.215	0.038
									178.259	0.204	0.036
									180.095	0.193	0.035
									181.932	0.183	0.033
									183.768	0.172	0.032
									185.604	0.162	0.030
									187.440	0.151	0.028
									189.277	0.141	0.027
									191.113	0.130	0.025
									192.949	0.120	0.023
									194.785	0.109	0.021

GrafTech Graphite Rod, Air Flow Rate = 0.50 SLPM, T = 600°C, 3/28/2006

Run 1			Run 2		
I/SA	VCELL	P/SA	I/SA	VCELL	P/SA
0.048	0.672	0.000	0.048	0.678	0.000
0.048	0.675	0.000	0.097	0.681	0.000
0.097	0.702	0.000	0.097	0.681	0.000

0.097	0.705	0.000	0.097	0.695	0.000
2.420	0.668	0.002	0.097	0.698	0.000
4.840	0.662	0.003	2.420	0.675	0.002
7.260	0.657	0.005	4.840	0.664	0.003
9.681	0.648	0.006	7.260	0.660	0.005
12.149	0.644	0.008	9.681	0.655	0.006
14.521	0.635	0.009	12.149	0.651	0.008
16.989	0.631	0.011	14.569	0.643	0.009
19.409	0.625	0.012	19.361	0.636	0.012
21.830	0.622	0.014	24.250	0.627	0.015
24.250	0.617	0.015	29.090	0.613	0.018
26.670	0.611	0.016	33.930	0.604	0.020
29.090	0.606	0.018	38.771	0.593	0.023
31.510	0.602	0.019	43.611	0.581	0.025
33.930	0.598	0.020	48.451	0.573	0.028
36.350	0.593	0.022	53.291	0.560	0.030
38.771	0.588	0.023	58.132	0.553	0.032
41.191	0.583	0.024	62.972	0.541	0.034
43.611	0.574	0.025	67.861	0.526	0.036
46.031	0.572	0.026	72.701	0.514	0.037
48.451	0.564	0.027	72.701	0.512	0.037
50.871	0.560	0.028	77.541	0.495	0.038
53.291	0.558	0.030	82.381	0.485	0.040
55.712	0.551	0.031	87.222	0.464	0.040
58.132	0.545	0.032	92.062	0.446	0.041
60.552	0.538	0.033	94.482	0.432	0.041
62.972	0.536	0.034	96.902	0.411	0.040
65.440	0.530	0.035	99.322	0.393	0.039
67.861	0.523	0.035	101.742	0.350	0.036
70.281	0.515	0.036	104.163	0.317	0.033
72.701	0.511	0.037			
75.121	0.505	0.038			
77.541	0.495	0.038			
79.961	0.488	0.039			
82.381	0.478	0.039			
84.802	0.471	0.040			
87.222	0.459	0.040			
89.642	0.450	0.040			
92.062	0.440	0.041			
94.482	0.429	0.041			
96.902	0.413	0.040			
99.322	0.392	0.039			
101.742	0.367	0.037			
104.163	0.333	0.035			
106.583	0.298	0.032			

GrafTech Graphite Rod, Long Term Run, Air Flow Rate = 0.50 SLPM, T = 600°C,
3/28/2006

Temp (°C)	VCELL	VANODE	VCATHODE	I (A)	I (mA)	I/SA	Time (min)
600	0.627	-0.655	-0.028	1.002	1002	24.250	0
600	0.625	-0.656	-0.031	1.002	1002	24.250	2

600	0.622	-0.651	-0.029	1.002	1002	24.250	4
600	0.622	-0.652	-0.030	1.002	1002	24.250	6
600	0.625	-0.654	-0.029	1.002	1002	24.250	8
600	0.623	-0.652	-0.029	1.002	1002	24.250	10
600	0.621	-0.649	-0.028	1.002	1002	24.250	12
600	0.625	-0.654	-0.029	1.002	1002	24.250	14
600	0.624	-0.653	-0.029	1.002	1002	24.250	16
600	0.623	-0.652	-0.029	1.002	1002	24.250	18
600	0.623	-0.652	-0.029	1.002	1002	24.250	20
600	0.625	-0.655	-0.030	1.002	1002	24.250	22
600	0.620	-0.650	-0.030	1.002	1002	24.250	24
600	0.625	-0.655	-0.030	1.002	1002	24.250	26
600	0.624	-0.653	-0.029	1.002	1002	24.250	28
600	0.627	-0.657	-0.030	1.002	1002	24.250	30
600	0.625	-0.654	-0.029	1.002	1002	24.250	32
600	0.628	-0.658	-0.030	1.002	1002	24.250	34
600	0.624	-0.653	-0.029	1.002	1002	24.250	36
600	0.625	-0.655	-0.030	1.002	1002	24.250	38
600	0.628	-0.658	-0.030	1.002	1002	24.250	40
600	0.626	-0.655	-0.029	1.002	1002	24.250	42
599	0.628	-0.659	-0.031	1.002	1002	24.250	44
600	0.628	-0.659	-0.031	1.002	1002	24.250	46
600	0.627	-0.657	-0.030	1.002	1002	24.250	48
600	0.623	-0.653	-0.030	1.002	1002	24.250	50
600	0.628	-0.658	-0.030	1.002	1002	24.250	52
600	0.627	-0.657	-0.030	1.002	1002	24.250	54
600	0.631	-0.663	-0.032	1.002	1002	24.250	56
600	0.628	-0.659	-0.031	1.002	1002	24.250	58
600	0.626	-0.656	-0.030	1.002	1002	24.250	60
600	0.630	-0.661	-0.031	1.002	1002	24.250	62
600	0.631	-0.662	-0.031	1.002	1002	24.250	64
600	0.630	-0.661	-0.031	1.002	1002	24.250	66
600	0.628	-0.659	-0.031	1.002	1002	24.250	68
600	0.630	-0.660	-0.030	1.002	1002	24.250	70
599	0.626	-0.656	-0.030	1.002	1002	24.250	72
599	0.629	-0.660	-0.031	1.002	1002	24.250	74
600	0.626	-0.657	-0.031	1.002	1002	24.250	76
600	0.628	-0.659	-0.031	1.002	1002	24.250	78
600	0.631	-0.663	-0.032	1.002	1002	24.250	80
600	0.629	-0.661	-0.032	1.002	1002	24.250	82
600	0.630	-0.661	-0.031	1.002	1002	24.250	84
600	0.628	-0.659	-0.031	1.002	1002	24.250	86
600	0.631	-0.662	-0.031	1.002	1002	24.250	88
599	0.629	-0.660	-0.031	1.002	1002	24.250	90
599	0.630	-0.661	-0.031	1.002	1002	24.250	92
600	0.628	-0.659	-0.031	1.002	1002	24.250	94
600	0.627	-0.657	-0.030	1.002	1002	24.250	96
600	0.629	-0.660	-0.031	1.002	1002	24.250	98
600	0.630	-0.661	-0.031	1.002	1002	24.250	100
600	0.631	-0.662	-0.031	1.002	1002	24.250	102
600	0.631	-0.662	-0.031	1.002	1002	24.250	104
599	0.631	-0.662	-0.031	1.002	1002	24.250	106
599	0.629	-0.660	-0.031	1.002	1002	24.250	108
600	0.629	-0.661	-0.032	1.002	1002	24.250	110
600	0.631	-0.662	-0.031	1.002	1002	24.250	112
600	0.632	-0.663	-0.031	1.002	1002	24.250	114
600	0.632	-0.663	-0.031	1.002	1002	24.250	116
600	0.631	-0.662	-0.031	1.002	1002	24.250	118
600	0.631	-0.662	-0.031	1.002	1002	24.250	120
600	0.632	-0.663	-0.031	1.002	1002	24.250	122
600	0.631	-0.662	-0.031	1.002	1002	24.250	124
599	0.633	-0.664	-0.031	1.002	1002	24.250	126
599	0.631	-0.662	-0.031	1.002	1002	24.250	128

600	0.631	-0.662	-0.031	1.002	1002	24.250	130
600	0.631	-0.663	-0.032	1.002	1002	24.250	132
600	0.632	-0.664	-0.032	1.002	1002	24.250	134
600	0.633	-0.664	-0.031	1.002	1002	24.250	136
600	0.635	-0.666	-0.031	1.002	1002	24.250	138
600	0.631	-0.662	-0.031	1.002	1002	24.250	140
600	0.633	-0.664	-0.031	1.002	1002	24.250	142
599	0.632	-0.663	-0.031	1.002	1002	24.250	144
600	0.633	-0.665	-0.032	1.002	1002	24.250	146
600	0.633	-0.665	-0.032	1.002	1002	24.250	148
600	0.633	-0.664	-0.031	1.002	1002	24.250	150
600	0.631	-0.662	-0.031	1.002	1002	24.250	152
600	0.634	-0.665	-0.031	1.002	1002	24.250	154
600	0.632	-0.663	-0.031	1.002	1002	24.250	156
600	0.632	-0.663	-0.031	1.002	1002	24.250	158
600	0.631	-0.662	-0.031	1.002	1002	24.250	160
600	0.633	-0.664	-0.031	1.002	1002	24.250	162
600	0.637	-0.668	-0.031	1.002	1002	24.250	164
600	0.634	-0.666	-0.032	1.002	1002	24.250	166
600	0.635	-0.666	-0.031	1.002	1002	24.250	168
600	0.635	-0.666	-0.031	1.002	1002	24.250	170
600	0.635	-0.667	-0.032	1.002	1002	24.250	172
600	0.634	-0.666	-0.032	1.002	1002	24.250	174
600	0.634	-0.666	-0.032	1.002	1002	24.250	176
600	0.635	-0.668	-0.033	1.002	1002	24.250	178
600	0.633	-0.665	-0.032	1.002	1002	24.250	180
600	0.635	-0.667	-0.032	1.002	1002	24.250	182
600	0.636	-0.667	-0.031	1.002	1002	24.250	184
600	0.636	-0.667	-0.031	1.002	1002	24.250	186
600	0.637	-0.669	-0.032	1.002	1002	24.250	188
600	0.635	-0.667	-0.032	1.002	1002	24.250	190
600	0.637	-0.668	-0.031	1.002	1002	24.250	192
600	0.635	-0.666	-0.031	1.002	1002	24.250	194
600	0.635	-0.666	-0.031	1.002	1002	24.250	196
600	0.637	-0.668	-0.031	1.002	1002	24.250	198
600	0.635	-0.665	-0.030	1.002	1002	24.250	200
600	0.635	-0.666	-0.031	1.002	1002	24.250	202
600	0.636	-0.667	-0.031	1.002	1002	24.250	204
600	0.636	-0.667	-0.031	1.002	1002	24.250	206
600	0.641	-0.672	-0.031	1.002	1002	24.250	208
600	0.633	-0.665	-0.032	1.002	1002	24.250	210
600	0.636	-0.667	-0.031	1.002	1002	24.250	212
600	0.637	-0.668	-0.031	1.002	1002	24.250	214
600	0.636	-0.668	-0.032	1.002	1002	24.250	216
600	0.638	-0.669	-0.031	1.002	1002	24.250	218
600	0.638	-0.669	-0.031	1.002	1002	24.250	220
599	0.635	-0.666	-0.031	1.002	1002	24.250	222
600	0.637	-0.669	-0.032	1.002	1002	24.250	224
600	0.636	-0.667	-0.031	1.002	1002	24.250	226
600	0.637	-0.669	-0.032	1.002	1002	24.250	228
600	0.637	-0.668	-0.031	1.002	1002	24.250	230
600	0.635	-0.667	-0.032	1.002	1002	24.250	232
600	0.635	-0.667	-0.032	1.002	1002	24.250	234
600	0.636	-0.667	-0.031	1.002	1002	24.250	236
600	0.636	-0.667	-0.031	1.002	1002	24.250	238
599	0.635	-0.666	-0.031	1.002	1002	24.250	240
599	0.637	-0.669	-0.032	1.002	1002	24.250	242
600	0.636	-0.667	-0.031	1.002	1002	24.250	244
600	0.638	-0.670	-0.032	1.002	1002	24.250	246
600	0.637	-0.668	-0.031	1.002	1002	24.250	248
600	0.637	-0.668	-0.031	1.002	1002	24.250	250
600	0.638	-0.669	-0.031	1.002	1002	24.250	252
600	0.637	-0.670	-0.033	1.002	1002	24.250	254

600	0.637	-0.669	-0.032	1.002	1002	24.250	256
600	0.637	-0.668	-0.031	1.002	1002	24.250	258
600	0.637	-0.669	-0.032	1.002	1002	24.250	260
600	0.638	-0.669	-0.031	1.002	1002	24.250	262
600	0.638	-0.669	-0.031	1.002	1002	24.250	264
600	0.637	-0.667	-0.030	1.002	1002	24.250	266
600	0.640	-0.671	-0.031	1.002	1002	24.250	268
600	0.636	-0.667	-0.031	1.002	1002	24.250	270
599	0.640	-0.671	-0.031	1.002	1002	24.250	272
599	0.635	-0.666	-0.031	1.002	1002	24.250	274
600	0.636	-0.667	-0.031	1.002	1002	24.250	276
600	0.636	-0.667	-0.031	1.002	1002	24.250	278
600	0.638	-0.669	-0.031	1.002	1002	24.250	280
600	0.639	-0.670	-0.031	1.002	1002	24.250	282
600	0.638	-0.669	-0.031	1.002	1002	24.250	284
600	0.635	-0.667	-0.032	1.002	1002	24.250	286
600	0.634	-0.665	-0.031	1.002	1002	24.250	288
600	0.636	-0.668	-0.032	1.002	1002	24.250	290
600	0.638	-0.670	-0.032	1.002	1002	24.250	292
600	0.638	-0.670	-0.032	1.002	1002	24.250	294
600	0.636	-0.667	-0.031	1.002	1002	24.250	296
600	0.642	-0.673	-0.031	1.002	1002	24.250	298
600	0.636	-0.667	-0.031	1.002	1002	24.250	300
600	0.638	-0.670	-0.032	1.002	1002	24.250	302
600	0.637	-0.668	-0.031	1.002	1002	24.250	304
600	0.637	-0.669	-0.032	1.002	1002	24.250	306
600	0.639	-0.671	-0.032	1.002	1002	24.250	308
600	0.639	-0.670	-0.031	1.002	1002	24.250	310
600	0.638	-0.670	-0.032	1.002	1002	24.250	312
600	0.639	-0.670	-0.031	1.002	1002	24.250	314
600	0.637	-0.668	-0.031	1.002	1002	24.250	316
600	0.637	-0.669	-0.032	1.002	1002	24.250	318
600	0.637	-0.668	-0.031	1.002	1002	24.250	320
600	0.638	-0.669	-0.031	1.002	1002	24.250	322
600	0.639	-0.670	-0.031	1.002	1002	24.250	324
600	0.640	-0.671	-0.031	1.002	1002	24.250	326
600	0.638	-0.669	-0.031	1.002	1002	24.250	328
600	0.639	-0.670	-0.031	1.002	1002	24.250	330
600	0.640	-0.672	-0.032	1.002	1002	24.250	332
600	0.638	-0.669	-0.031	1.002	1002	24.250	334
600	0.638	-0.669	-0.031	1.002	1002	24.250	336
600	0.639	-0.671	-0.032	1.002	1002	24.250	338
600	0.639	-0.670	-0.031	1.002	1002	24.250	340
600	0.637	-0.668	-0.031	1.002	1002	24.250	342
600	0.636	-0.667	-0.031	1.002	1002	24.250	344
600	0.636	-0.667	-0.031	1.002	1002	24.250	346
600	0.639	-0.670	-0.031	1.002	1002	24.250	348
600	0.638	-0.670	-0.032	1.002	1002	24.250	350
600	0.638	-0.669	-0.031	1.002	1002	24.250	352
600	0.636	-0.668	-0.032	1.002	1002	24.250	354
600	0.639	-0.670	-0.031	1.002	1002	24.250	356
600	0.638	-0.669	-0.031	1.002	1002	24.250	358
600	0.637	-0.668	-0.031	1.002	1002	24.250	360
600	0.638	-0.669	-0.031	1.002	1002	24.250	362
600	0.639	-0.671	-0.032	1.002	1002	24.250	364
600	0.639	-0.671	-0.032	1.002	1002	24.250	366
600	0.638	-0.669	-0.031	1.002	1002	24.250	368
600	0.635	-0.666	-0.031	1.002	1002	24.250	370
600	0.639	-0.670	-0.031	1.002	1002	24.250	372
600	0.639	-0.670	-0.031	1.002	1002	24.250	374
600	0.637	-0.668	-0.031	1.002	1002	24.250	376
600	0.638	-0.668	-0.030	1.002	1002	24.250	378
600	0.636	-0.666	-0.030	1.002	1002	24.250	380

600	0.636	-0.667	-0.031	1.002	1002	24.250	382
600	0.637	-0.668	-0.031	1.002	1002	24.250	384
600	0.637	-0.668	-0.031	1.002	1002	24.250	386
600	0.639	-0.670	-0.031	1.002	1002	24.250	388
600	0.639	-0.670	-0.031	1.002	1002	24.250	390
600	0.638	-0.669	-0.031	1.002	1002	24.250	392
600	0.638	-0.669	-0.031	1.002	1002	24.250	394
600	0.637	-0.667	-0.030	1.002	1002	24.250	396
600	0.636	-0.667	-0.031	1.002	1002	24.250	398
600	0.637	-0.668	-0.031	1.002	1002	24.250	400
600	0.638	-0.670	-0.032	1.002	1002	24.250	402
601	0.640	-0.672	-0.032	1.002	1002	24.250	404
600	0.639	-0.671	-0.032	1.002	1002	24.250	406
600	0.637	-0.669	-0.032	1.002	1002	24.250	408
600	0.635	-0.667	-0.032	1.002	1002	24.250	410
600	0.637	-0.669	-0.032	1.002	1002	24.250	412
600	0.638	-0.669	-0.031	1.002	1002	24.250	414
600	0.635	-0.667	-0.032	1.002	1002	24.250	416
600	0.638	-0.669	-0.031	1.002	1002	24.250	418
600	0.638	-0.670	-0.032	1.002	1002	24.250	420
600	0.638	-0.670	-0.032	1.002	1002	24.250	422
600	0.632	-0.663	-0.031	1.002	1002	24.250	424
600	0.637	-0.668	-0.031	1.002	1002	24.250	426
600	0.638	-0.669	-0.031	1.002	1002	24.250	428
600	0.637	-0.669	-0.032	1.002	1002	24.250	430
600	0.636	-0.667	-0.031	1.002	1002	24.250	432
600	0.638	-0.669	-0.031	1.002	1002	24.250	434
600	0.637	-0.668	-0.031	1.002	1002	24.250	436
600	0.638	-0.669	-0.031	1.002	1002	24.250	438
600	0.636	-0.667	-0.031	1.002	1002	24.250	440
600	0.637	-0.668	-0.031	1.002	1002	24.250	442
600	0.637	-0.668	-0.031	1.002	1002	24.250	444
600	0.636	-0.667	-0.031	1.002	1002	24.250	446
600	0.637	-0.668	-0.031	1.002	1002	24.250	448
600	0.636	-0.667	-0.031	1.002	1002	24.250	450
600	0.637	-0.668	-0.031	1.002	1002	24.250	452
600	0.635	-0.666	-0.031	1.002	1002	24.250	454
600	0.638	-0.669	-0.031	1.002	1002	24.250	456
600	0.637	-0.668	-0.031	1.002	1002	24.250	458
600	0.636	-0.667	-0.031	1.002	1002	24.250	460
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600	0.637	-0.668	-0.031	1.002	1002	24.250	464
600	0.637	-0.668	-0.031	1.002	1002	24.250	466
600	0.637	-0.669	-0.032	1.002	1002	24.250	468
600	0.637	-0.668	-0.031	1.002	1002	24.250	470
600	0.637	-0.668	-0.031	1.002	1002	24.250	472
600	0.635	-0.667	-0.032	1.002	1002	24.250	474
600	0.637	-0.669	-0.032	1.002	1002	24.250	476
600	0.636	-0.667	-0.031	1.002	1002	24.250	478
600	0.637	-0.668	-0.031	1.002	1002	24.250	480
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601	0.637	-0.668	-0.031	1.002	1002	24.250	486
600	0.637	-0.668	-0.031	1.002	1002	24.250	488
600	0.635	-0.667	-0.032	1.002	1002	24.250	490
600	0.635	-0.667	-0.032	1.002	1002	24.250	492
600	0.638	-0.670	-0.032	1.002	1002	24.250	494
600	0.635	-0.667	-0.032	1.002	1002	24.250	496
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601	0.637	-0.669	-0.032	1.002	1002	24.250	500
600	0.638	-0.669	-0.031	1.002	1002	24.250	502
600	0.638	-0.670	-0.032	1.002	1002	24.250	504
600	0.635	-0.666	-0.031	1.002	1002	24.250	506

600	0.636	-0.667	-0.031	1.002	1002	24.250	508
600	0.637	-0.668	-0.031	1.002	1002	24.250	510
600	0.638	-0.669	-0.031	1.002	1002	24.250	512
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600	0.636	-0.667	-0.031	1.002	1002	24.250	516
600	0.636	-0.668	-0.032	1.002	1002	24.250	518
600	0.638	-0.670	-0.032	1.002	1002	24.250	520
600	0.637	-0.668	-0.031	1.002	1002	24.250	522
600	0.636	-0.667	-0.031	1.002	1002	24.250	524
600	0.636	-0.668	-0.032	1.002	1002	24.250	526
600	0.636	-0.668	-0.032	1.002	1002	24.250	528
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600	0.636	-0.668	-0.032	1.002	1002	24.250	532
600	0.638	-0.670	-0.032	1.002	1002	24.250	534
600	0.637	-0.669	-0.032	1.002	1002	24.250	536
600	0.635	-0.667	-0.032	1.002	1002	24.250	538
600	0.633	-0.665	-0.032	1.002	1002	24.250	540
600	0.638	-0.669	-0.031	1.002	1002	24.250	542
600	0.635	-0.666	-0.031	1.002	1002	24.250	544
600	0.638	-0.670	-0.032	1.002	1002	24.250	546
600	0.636	-0.668	-0.032	1.002	1002	24.250	548
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600	0.636	-0.667	-0.031	1.002	1002	24.250	562
600	0.637	-0.669	-0.032	1.002	1002	24.250	564
600	0.636	-0.668	-0.032	1.002	1002	24.250	566
600	0.636	-0.667	-0.031	1.002	1002	24.250	568
600	0.637	-0.669	-0.032	1.002	1002	24.250	570
600	0.634	-0.665	-0.031	1.002	1002	24.250	572
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600	0.636	-0.668	-0.032	1.002	1002	24.250	592
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600	0.635	-0.666	-0.031	1.002	1002	24.250	596
600	0.637	-0.669	-0.032	1.002	1002	24.250	598
600	0.638	-0.670	-0.032	1.002	1002	24.250	600
600	0.638	-0.669	-0.031	1.002	1002	24.250	602
600	0.636	-0.668	-0.032	1.002	1002	24.250	604
600	0.637	-0.669	-0.032	1.002	1002	24.250	606
600	0.637	-0.668	-0.031	1.002	1002	24.250	608
600	0.635	-0.666	-0.031	1.002	1002	24.250	610
600	0.637	-0.669	-0.032	1.002	1002	24.250	612
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600	0.634	-0.665	-0.031	1.002	1002	24.250	616
600	0.636	-0.668	-0.032	1.002	1002	24.250	618
600	0.636	-0.668	-0.032	1.002	1002	24.250	620
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600	0.635	-0.667	-0.032	1.002	1002	24.250	630
600	0.635	-0.666	-0.031	1.002	1002	24.250	632

600	0.634	-0.665	-0.031	1.002	1002	24.250	634
600	0.637	-0.670	-0.033	1.002	1002	24.250	636
600	0.635	-0.667	-0.032	1.002	1002	24.250	638
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600	0.634	-0.666	-0.032	1.002	1002	24.250	646
600	0.636	-0.667	-0.031	1.002	1002	24.250	648
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600	0.633	-0.664	-0.031	1.002	1002	24.250	658
600	0.635	-0.667	-0.032	1.002	1002	24.250	660
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600	0.634	-0.666	-0.032	1.002	1002	24.250	666
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599	0.635	-0.666	-0.031	1.002	1002	24.250	680
599	0.634	-0.665	-0.031	1.002	1002	24.250	682
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601	0.631	-0.663	-0.032	1.002	1002	24.250	692
600	0.636	-0.667	-0.031	1.002	1002	24.250	694
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600	0.632	-0.663	-0.031	1.002	1002	24.250	704
600	0.633	-0.665	-0.032	1.002	1002	24.250	706
600	0.633	-0.665	-0.032	1.002	1002	24.250	708
600	0.631	-0.663	-0.032	1.002	1002	24.250	710
600	0.632	-0.664	-0.032	1.002	1002	24.250	712
600	0.630	-0.662	-0.032	1.002	1002	24.250	714
600	0.630	-0.662	-0.032	1.002	1002	24.250	716
600	0.630	-0.661	-0.031	1.002	1002	24.250	718
600	0.630	-0.662	-0.032	1.002	1002	24.250	720
600	0.629	-0.661	-0.032	1.002	1002	24.250	722
600	0.630	-0.662	-0.032	1.002	1002	24.250	724
600	0.629	-0.660	-0.031	1.002	1002	24.250	726
600	0.630	-0.661	-0.031	1.002	1002	24.250	728
600	0.629	-0.661	-0.032	1.002	1002	24.250	730
600	0.628	-0.659	-0.031	1.002	1002	24.250	732
600	0.629	-0.660	-0.031	1.002	1002	24.250	734
600	0.628	-0.659	-0.031	1.002	1002	24.250	736
600	0.629	-0.660	-0.031	1.002	1002	24.250	738
600	0.629	-0.661	-0.032	1.002	1002	24.250	740
600	0.627	-0.658	-0.031	1.002	1002	24.250	742
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600	0.626	-0.658	-0.032	1.002	1002	24.250	746
600	0.625	-0.657	-0.032	1.002	1002	24.250	748
600	0.625	-0.657	-0.032	1.002	1002	24.250	750
600	0.628	-0.660	-0.032	1.002	1002	24.250	752
600	0.626	-0.658	-0.032	1.002	1002	24.250	754
600	0.626	-0.658	-0.032	1.002	1002	24.250	756
600	0.622	-0.654	-0.032	1.002	1002	24.250	758

600	0.627	-0.659	-0.032	1.002	1002	24.250	760
600	0.625	-0.657	-0.032	1.002	1002	24.250	762
600	0.625	-0.657	-0.032	1.002	1002	24.250	764
600	0.622	-0.655	-0.033	1.002	1002	24.250	766
600	0.625	-0.657	-0.032	1.002	1002	24.250	768
600	0.623	-0.655	-0.032	1.002	1002	24.250	770
600	0.623	-0.655	-0.032	1.002	1002	24.250	772
600	0.623	-0.655	-0.032	1.002	1002	24.250	774
600	0.621	-0.653	-0.032	1.002	1002	24.250	776
600	0.624	-0.656	-0.032	1.002	1002	24.250	778
600	0.621	-0.653	-0.032	1.002	1002	24.250	780
600	0.620	-0.652	-0.032	1.002	1002	24.250	782
600	0.623	-0.655	-0.032	1.002	1002	24.250	784
600	0.620	-0.652	-0.032	1.002	1002	24.250	786
600	0.621	-0.653	-0.032	1.002	1002	24.250	788
600	0.619	-0.652	-0.033	1.002	1002	24.250	790
600	0.620	-0.652	-0.032	1.002	1002	24.250	792
600	0.619	-0.651	-0.032	1.002	1002	24.250	794
600	0.618	-0.650	-0.032	1.002	1002	24.250	796
600	0.620	-0.653	-0.033	1.002	1002	24.250	798
600	0.620	-0.652	-0.032	1.002	1002	24.250	800
600	0.619	-0.651	-0.032	1.002	1002	24.250	802
600	0.619	-0.652	-0.033	1.002	1002	24.250	804
600	0.618	-0.650	-0.032	1.002	1002	24.250	806
600	0.617	-0.649	-0.032	1.002	1002	24.250	808
600	0.618	-0.651	-0.033	1.002	1002	24.250	810
600	0.617	-0.649	-0.032	1.002	1002	24.250	812
600	0.619	-0.651	-0.032	1.002	1002	24.250	814
600	0.618	-0.650	-0.032	1.002	1002	24.250	816
600	0.617	-0.650	-0.033	1.002	1002	24.250	818
600	0.617	-0.649	-0.032	1.002	1002	24.250	820
600	0.618	-0.650	-0.032	1.002	1002	24.250	822
600	0.616	-0.648	-0.032	1.002	1002	24.250	824
600	0.613	-0.645	-0.032	1.002	1002	24.250	826
599	0.619	-0.651	-0.032	1.002	1002	24.250	828
600	0.616	-0.649	-0.033	1.002	1002	24.250	830
600	0.613	-0.645	-0.032	1.002	1002	24.250	832
600	0.613	-0.645	-0.032	1.002	1002	24.250	834
600	0.614	-0.646	-0.032	1.002	1002	24.250	836
600	0.615	-0.647	-0.032	1.002	1002	24.250	838
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600	0.616	-0.648	-0.032	1.002	1002	24.250	844
600	0.613	-0.646	-0.033	1.002	1002	24.250	846
600	0.612	-0.644	-0.032	1.002	1002	24.250	848
600	0.614	-0.646	-0.032	1.002	1002	24.250	850
600	0.614	-0.646	-0.032	1.002	1002	24.250	852
600	0.613	-0.645	-0.032	1.002	1002	24.250	854
600	0.614	-0.647	-0.033	1.002	1002	24.250	856
600	0.613	-0.646	-0.033	1.002	1002	24.250	858
600	0.615	-0.646	-0.031	1.002	1002	24.250	860
600	0.614	-0.647	-0.033	1.002	1002	24.250	862
600	0.614	-0.646	-0.032	1.002	1002	24.250	864
600	0.614	-0.646	-0.032	1.002	1002	24.250	866
600	0.614	-0.646	-0.032	1.002	1002	24.250	868
600	0.613	-0.646	-0.033	1.002	1002	24.250	870
600	0.614	-0.647	-0.033	1.002	1002	24.250	872
600	0.615	-0.647	-0.032	1.002	1002	24.250	874
600	0.613	-0.646	-0.033	1.002	1002	24.250	876
600	0.610	-0.643	-0.033	1.002	1002	24.250	878
600	0.612	-0.644	-0.032	1.002	1002	24.250	880
600	0.612	-0.644	-0.032	1.002	1002	24.250	882
600	0.615	-0.648	-0.033	1.002	1002	24.250	884

600	0.612	-0.645	-0.033	1.002	1002	24.250	886
600	0.611	-0.644	-0.033	1.002	1002	24.250	888
600	0.611	-0.644	-0.033	1.002	1002	24.250	890
600	0.615	-0.648	-0.033	1.002	1002	24.250	892
600	0.613	-0.645	-0.032	1.002	1002	24.250	894
600	0.612	-0.645	-0.033	1.002	1002	24.250	896
600	0.614	-0.647	-0.033	1.002	1002	24.250	898
600	0.612	-0.645	-0.033	1.002	1002	24.250	900
600	0.613	-0.645	-0.032	1.002	1002	24.250	902
600	0.611	-0.644	-0.033	1.002	1002	24.250	904
600	0.611	-0.643	-0.032	1.002	1002	24.250	906
600	0.611	-0.644	-0.033	1.002	1002	24.250	908
600	0.611	-0.644	-0.033	1.002	1002	24.250	910
600	0.612	-0.644	-0.032	1.002	1002	24.250	912
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600	0.611	-0.643	-0.032	1.002	1002	24.250	916
600	0.610	-0.642	-0.032	1.002	1002	24.250	918
600	0.610	-0.643	-0.033	1.002	1002	24.250	920
600	0.609	-0.642	-0.033	1.002	1002	24.250	922
599	0.612	-0.644	-0.032	1.002	1002	24.250	924
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600	0.611	-0.644	-0.033	1.002	1002	24.250	928
600	0.611	-0.644	-0.033	1.002	1002	24.250	930
600	0.611	-0.643	-0.032	1.002	1002	24.250	932
600	0.612	-0.645	-0.033	1.002	1002	24.250	934
600	0.608	-0.641	-0.033	1.002	1002	24.250	936
600	0.606	-0.638	-0.032	1.002	1002	24.250	938
600	0.607	-0.640	-0.033	1.002	1002	24.250	940
600	0.607	-0.639	-0.032	1.002	1002	24.250	942
600	0.609	-0.641	-0.032	1.002	1002	24.250	944
600	0.606	-0.639	-0.033	1.002	1002	24.250	946
600	0.609	-0.642	-0.033	1.002	1002	24.250	948
600	0.610	-0.643	-0.033	1.002	1002	24.250	950
600	0.607	-0.639	-0.032	1.002	1002	24.250	952
600	0.605	-0.637	-0.032	1.002	1002	24.250	954
600	0.607	-0.640	-0.033	1.002	1002	24.250	956
599	0.607	-0.640	-0.033	1.002	1002	24.250	958
600	0.606	-0.638	-0.032	1.002	1002	24.250	960
600	0.605	-0.638	-0.033	1.002	1002	24.250	962
600	0.605	-0.638	-0.033	1.002	1002	24.250	964
600	0.605	-0.637	-0.032	1.002	1002	24.250	966
600	0.606	-0.639	-0.033	1.002	1002	24.250	968
600	0.607	-0.639	-0.032	1.002	1002	24.250	970
600	0.605	-0.638	-0.033	1.002	1002	24.250	972
600	0.607	-0.640	-0.033	1.002	1002	24.250	974
600	0.606	-0.639	-0.033	1.002	1002	24.250	976
600	0.607	-0.640	-0.033	1.002	1002	24.250	978
600	0.606	-0.638	-0.032	1.002	1002	24.250	980
600	0.606	-0.639	-0.033	1.002	1002	24.250	982
600	0.602	-0.634	-0.032	1.002	1002	24.250	984
600	0.603	-0.636	-0.033	1.002	1002	24.250	986
600	0.605	-0.638	-0.033	1.002	1002	24.250	988
600	0.604	-0.637	-0.033	1.002	1002	24.250	990
600	0.605	-0.638	-0.033	1.002	1002	24.250	992
600	0.605	-0.638	-0.033	1.002	1002	24.250	994
600	0.603	-0.636	-0.033	1.002	1002	24.250	996
600	0.604	-0.637	-0.033	1.002	1002	24.250	998
600	0.603	-0.636	-0.033	1.002	1002	24.250	1000
600	0.602	-0.635	-0.033	1.002	1002	24.250	1002
600	0.600	-0.633	-0.033	1.002	1002	24.250	1004
600	0.599	-0.632	-0.033	1.002	1002	24.250	1006
600	0.598	-0.631	-0.033	1.002	1002	24.250	1008
600	0.599	-0.632	-0.033	1.002	1002	24.250	1010

600	0.598	-0.630	-0.032	1.002	1002	24.250	1012
600	0.597	-0.630	-0.033	1.002	1002	24.250	1014
600	0.598	-0.631	-0.033	1.002	1002	24.250	1016
600	0.595	-0.628	-0.033	1.002	1002	24.250	1018
600	0.598	-0.631	-0.033	1.002	1002	24.250	1020
600	0.591	-0.624	-0.033	1.002	1002	24.250	1022
600	0.595	-0.629	-0.034	1.002	1002	24.250	1024
600	0.594	-0.628	-0.034	1.002	1002	24.250	1026
600	0.591	-0.624	-0.033	1.002	1002	24.250	1028
600	0.592	-0.626	-0.034	1.002	1002	24.250	1030
600	0.590	-0.623	-0.033	1.002	1002	24.250	1032
600	0.591	-0.624	-0.033	1.002	1002	24.250	1034
600	0.591	-0.625	-0.034	1.002	1002	24.250	1036
600	0.589	-0.622	-0.033	1.002	1002	24.250	1038
599	0.591	-0.624	-0.033	1.002	1002	24.250	1040
599	0.589	-0.623	-0.034	1.002	1002	24.250	1042
600	0.588	-0.622	-0.034	1.002	1002	24.250	1044
600	0.588	-0.622	-0.034	1.002	1002	24.250	1046
600	0.587	-0.621	-0.034	1.002	1002	24.250	1048
600	0.587	-0.621	-0.034	1.002	1002	24.250	1050
600	0.588	-0.622	-0.034	1.002	1002	24.250	1052
600	0.586	-0.619	-0.033	1.002	1002	24.250	1054
600	0.583	-0.617	-0.034	1.002	1002	24.250	1056
600	0.586	-0.620	-0.034	1.002	1002	24.250	1058
600	0.585	-0.619	-0.034	1.002	1002	24.250	1060
600	0.585	-0.619	-0.034	1.002	1002	24.250	1062
600	0.583	-0.617	-0.034	1.002	1002	24.250	1064
600	0.581	-0.614	-0.033	1.002	1002	24.250	1066
600	0.583	-0.616	-0.033	1.002	1002	24.250	1068
600	0.580	-0.613	-0.033	1.002	1002	24.250	1070
600	0.580	-0.613	-0.033	1.002	1002	24.250	1072
600	0.581	-0.615	-0.034	1.002	1002	24.250	1074
600	0.580	-0.613	-0.033	1.002	1002	24.250	1076
600	0.581	-0.615	-0.034	1.002	1002	24.250	1078
600	0.582	-0.618	-0.036	1.002	1002	24.250	1080
600	0.580	-0.614	-0.034	1.002	1002	24.250	1082
600	0.579	-0.614	-0.035	1.002	1002	24.250	1084
600	0.579	-0.614	-0.035	1.002	1002	24.250	1086
600	0.580	-0.616	-0.036	1.002	1002	24.250	1088
600	0.580	-0.616	-0.036	1.002	1002	24.250	1090
600	0.578	-0.615	-0.037	1.002	1002	24.250	1092
600	0.578	-0.614	-0.036	1.002	1002	24.250	1094
600	0.576	-0.611	-0.035	1.002	1002	24.250	1096
600	0.576	-0.611	-0.035	1.002	1002	24.250	1098
600	0.576	-0.612	-0.036	1.002	1002	24.250	1100
601	0.576	-0.612	-0.036	1.002	1002	24.250	1102
601	0.576	-0.613	-0.037	1.002	1002	24.250	1104
601	0.576	-0.613	-0.037	1.002	1002	24.250	1106
600	0.574	-0.611	-0.037	1.002	1002	24.250	1108
600	0.575	-0.611	-0.036	1.002	1002	24.250	1110
600	0.573	-0.609	-0.036	1.002	1002	24.250	1112
600	0.573	-0.610	-0.037	1.002	1002	24.250	1114
600	0.572	-0.610	-0.038	1.002	1002	24.250	1116
600	0.572	-0.609	-0.037	1.002	1002	24.250	1118
600	0.571	-0.608	-0.037	1.002	1002	24.250	1120
600	0.570	-0.608	-0.038	1.002	1002	24.250	1122
600	0.569	-0.607	-0.038	1.002	1002	24.250	1124
600	0.569	-0.606	-0.037	1.002	1002	24.250	1126
600	0.568	-0.606	-0.038	1.002	1002	24.250	1128
600	0.567	-0.604	-0.037	1.002	1002	24.250	1130
600	0.568	-0.606	-0.038	1.002	1002	24.250	1132
600	0.569	-0.607	-0.038	1.002	1002	24.250	1134
600	0.566	-0.605	-0.039	1.002	1002	24.250	1136

600	0.567	-0.605	-0.038	1.002	1002	24.250	1138
600	0.566	-0.604	-0.038	1.002	1002	24.250	1140
600	0.566	-0.604	-0.038	1.002	1002	24.250	1142
600	0.565	-0.603	-0.038	1.002	1002	24.250	1144
600	0.565	-0.604	-0.039	1.002	1002	24.250	1146
600	0.564	-0.604	-0.040	1.002	1002	24.250	1148
600	0.565	-0.605	-0.040	1.002	1002	24.250	1150
600	0.564	-0.604	-0.040	1.002	1002	24.250	1152
600	0.564	-0.603	-0.039	1.002	1002	24.250	1154
600	0.562	-0.602	-0.040	1.002	1002	24.250	1156
600	0.562	-0.603	-0.041	1.002	1002	24.250	1158
600	0.559	-0.601	-0.042	1.002	1002	24.250	1160
600	0.562	-0.602	-0.040	1.002	1002	24.250	1162
600	0.561	-0.603	-0.042	1.002	1002	24.250	1164
600	0.560	-0.601	-0.041	1.002	1002	24.250	1166
600	0.560	-0.601	-0.041	1.002	1002	24.250	1168
600	0.560	-0.601	-0.041	1.002	1002	24.250	1170
600	0.559	-0.601	-0.042	1.002	1002	24.250	1172
600	0.558	-0.601	-0.043	1.002	1002	24.250	1174
600	0.558	-0.599	-0.041	1.002	1002	24.250	1176
600	0.555	-0.597	-0.042	1.002	1002	24.250	1178
599	0.555	-0.597	-0.042	1.002	1002	24.250	1180
600	0.554	-0.596	-0.042	1.002	1002	24.250	1182
600	0.555	-0.597	-0.042	1.002	1002	24.250	1184
600	0.553	-0.596	-0.043	1.002	1002	24.250	1186
600	0.553	-0.595	-0.042	1.002	1002	24.250	1188
600	0.553	-0.595	-0.042	1.002	1002	24.250	1190
599	0.553	-0.596	-0.043	1.002	1002	24.250	1192
599	0.553	-0.596	-0.043	1.002	1002	24.250	1194
600	0.552	-0.597	-0.045	1.002	1002	24.250	1196
600	0.551	-0.598	-0.047	1.002	1002	24.250	1198
600	0.551	-0.598	-0.047	1.002	1002	24.250	1200
601	0.551	-0.598	-0.047	1.002	1002	24.250	1202
600	0.549	-0.596	-0.047	1.002	1002	24.250	1204
601	0.548	-0.596	-0.048	1.002	1002	24.250	1206
601	0.549	-0.598	-0.049	1.002	1002	24.250	1208
600	0.550	-0.598	-0.048	1.002	1002	24.250	1210
601	0.549	-0.597	-0.048	1.002	1002	24.250	1212
601	0.548	-0.596	-0.048	1.002	1002	24.250	1214
600	0.548	-0.598	-0.050	1.002	1002	24.250	1216
600	0.547	-0.597	-0.050	1.002	1002	24.250	1218
601	0.546	-0.595	-0.049	1.002	1002	24.250	1220
601	0.547	-0.596	-0.049	1.002	1002	24.250	1222
600	0.544	-0.595	-0.051	1.002	1002	24.250	1224
600	0.544	-0.595	-0.051	1.002	1002	24.250	1226
600	0.546	-0.595	-0.049	1.002	1002	24.250	1228
600	0.543	-0.595	-0.052	1.002	1002	24.250	1230
600	0.550	-0.593	-0.043	1.002	1002	24.250	1232
601	0.549	-0.598	-0.049	1.002	1002	24.250	1234
600	0.547	-0.596	-0.049	1.002	1002	24.250	1236
600	0.548	-0.595	-0.047	1.002	1002	24.250	1238
600	0.543	-0.595	-0.052	1.002	1002	24.250	1240
600	0.543	-0.593	-0.050	1.002	1002	24.250	1242
600	0.545	-0.594	-0.049	1.002	1002	24.250	1244
600	0.540	-0.594	-0.054	1.002	1002	24.250	1246
601	0.538	-0.593	-0.055	1.002	1002	24.250	1248
600	0.535	-0.593	-0.058	1.002	1002	24.250	1250
601	0.534	-0.592	-0.058	1.002	1002	24.250	1252
600	0.530	-0.590	-0.060	1.002	1002	24.250	1254
600	0.533	-0.590	-0.057	1.002	1002	24.250	1256
600	0.530	-0.589	-0.059	1.002	1002	24.250	1258
601	0.527	-0.586	-0.059	1.002	1002	24.250	1260
600	0.524	-0.590	-0.066	1.002	1002	24.250	1262

601	0.523	-0.587	-0.064	1.002	1002	24.250	1264
600	0.526	-0.584	-0.058	1.002	1002	24.250	1266
600	0.527	-0.586	-0.059	1.002	1002	24.250	1268
600	0.518	-0.585	-0.067	1.002	1002	24.250	1270
600	0.516	-0.585	-0.069	1.002	1002	24.250	1272
601	0.509	-0.584	-0.075	1.002	1002	24.250	1274
600	0.534	-0.590	-0.056	1.002	1002	24.250	1276
600	0.516	-0.588	-0.072	1.002	1002	24.250	1278
601	0.508	-0.585	-0.077	1.002	1002	24.250	1280
601	0.512	-0.584	-0.072	1.002	1002	24.250	1282
600	0.524	-0.584	-0.060	1.002	1002	24.250	1284
600	0.509	-0.582	-0.073	1.002	1002	24.250	1286
600	0.514	-0.584	-0.070	1.002	1002	24.250	1288
600	0.512	-0.582	-0.070	1.002	1002	24.250	1290

Appendix B – Coal-Derived Rods Raw Data

Coal-Derived Rod #11 (100% PetCoke), Air Flow Rate is Varied, T = 600°C, 2/28/2006

0.50 SLPM			0.75 SLPM			0.90 SLPM		
I/SA	VCELL	P/SA	I/SA	VCELL	P/SA	I/SA	VCELL	P/SA
0.033	0.936	0.000	0.000	0.974	0.000	0.000	0.975	0.000
0.066	0.936	0.000	0.000	0.977	0.000	0.000	0.975	0.000
0.066	0.936	0.000	0.000	0.978	0.000	0.000	0.985	0.000
0.066	0.936	0.000	0.000	0.978	0.000	0.066	0.983	0.000
0.066	0.937	0.000	0.066	0.958	0.000	0.066	0.986	0.000
0.066	0.956	0.000	0.066	0.959	0.000	0.066	0.986	0.000
0.066	0.961	0.000	0.066	0.959	0.000	0.066	0.987	0.000
0.066	0.963	0.000	0.066	0.960	0.000	0.066	0.986	0.000
0.066	0.964	0.000	1.649	0.955	0.002	1.649	0.979	0.002
1.649	0.932	0.002	3.298	0.949	0.003	1.649	0.977	0.002
3.298	0.925	0.003	4.947	0.944	0.005	3.298	0.971	0.003
4.947	0.921	0.005	6.596	0.937	0.006	4.947	0.963	0.005
6.596	0.913	0.006	8.278	0.932	0.008	6.596	0.963	0.006
8.278	0.907	0.008	8.278	0.939	0.008	8.278	0.965	0.008
8.278	0.915	0.008	9.894	0.927	0.009	8.278	0.947	0.008
9.927	0.902	0.009	11.577	0.921	0.011	8.278	0.951	0.008
11.577	0.896	0.010	13.193	0.916	0.012	9.927	0.953	0.009
13.193	0.890	0.012	14.875	0.910	0.014	11.577	0.944	0.011
14.875	0.883	0.013	16.524	0.905	0.015	13.193	0.935	0.012
16.524	0.877	0.014	16.524	0.903	0.015	14.875	0.932	0.014
16.524	0.875	0.014	18.173	0.898	0.016	16.524	0.912	0.015
18.173	0.869	0.016	18.173	0.898	0.016	18.173	0.920	0.017
19.822	0.863	0.017	19.822	0.892	0.018	18.173	0.918	0.017
21.471	0.857	0.018	21.471	0.886	0.019	19.822	0.913	0.018
23.120	0.851	0.020	23.120	0.880	0.020	21.471	0.906	0.019
24.769	0.847	0.021	24.769	0.874	0.022	23.120	0.897	0.021
24.769	0.826	0.020	24.769	0.863	0.021	24.769	0.889	0.022
26.418	0.839	0.022	26.418	0.868	0.023	24.769	0.873	0.022
28.067	0.831	0.023	28.067	0.863	0.024	26.418	0.881	0.023
29.716	0.824	0.024	29.716	0.856	0.025	28.067	0.875	0.025
31.365	0.819	0.026	31.365	0.850	0.027	29.716	0.868	0.026
33.015	0.811	0.027	31.365	0.849	0.027	31.365	0.860	0.027
33.015	0.774	0.026	33.015	0.842	0.028	33.015	0.854	0.028
34.664	0.804	0.028	33.015	0.818	0.027	33.015	0.827	0.027
36.313	0.795	0.029	34.664	0.836	0.029	34.664	0.846	0.029
37.995	0.784	0.030	36.313	0.830	0.030	36.313	0.838	0.030
39.611	0.775	0.031	37.962	0.822	0.031	37.962	0.833	0.032
41.260	0.762	0.031	39.611	0.814	0.032	39.611	0.826	0.033
41.293	0.704	0.029	41.260	0.808	0.033	41.260	0.818	0.034
42.909	0.744	0.032	41.293	0.767	0.032	41.293	0.769	0.032
44.558	0.700	0.031	42.909	0.798	0.034	42.909	0.803	0.034
46.240	0.693	0.032	44.591	0.790	0.035	44.558	0.785	0.035
47.889	0.681	0.033	46.207	0.778	0.036	46.207	0.766	0.035
49.538	0.666	0.033	47.889	0.767	0.037	47.889	0.753	0.036
51.187	0.633	0.032	49.538	0.754	0.037	49.538	0.744	0.037
52.836	0.587	0.031	49.538	0.687	0.034	49.538	0.694	0.034
			51.187	0.742	0.038	51.187	0.731	0.037
			52.836	0.726	0.038	52.836	0.706	0.037
			54.485	0.699	0.038	54.485	0.676	0.037
			56.135	0.681	0.038	56.135	0.640	0.036

57.784	0.654	0.038	57.784	0.591	0.034
59.433	0.612	0.036			
61.082	0.561	0.034			

Coal-Derived Rod #10 (100% PetCoke), Air Flow Rate is Varied, T = 600°C, 3/2/2006

0.50 SLPM			0.75 SLPM			0.90 SLPM			0.50 SLPM (2)		
I/SA	VCELL	P/SA	I/SA	VCELL	P/SA	I/SA	VCELL	P/SA	I/SA	VCELL	P/SA
0.092	0.979	0.000	0.092	0.993	0.000	0.092	1.003	0.000	0.092	0.978	0.000
0.092	0.980	0.000	0.092	0.995	0.000	0.092	1.004	0.000	0.092	0.981	0.000
0.092	0.981	0.000	0.092	0.996	0.000	0.092	1.004	0.000	2.289	0.965	0.002
0.092	0.946	0.000	0.092	0.997	0.000	0.092	0.967	0.000	4.578	0.949	0.004
0.092	0.964	0.000	0.092	0.997	0.000	0.092	0.983	0.000	6.867	0.932	0.006
2.289	0.975	0.002	0.092	0.998	0.000	0.092	0.990	0.000	9.155	0.911	0.008
4.578	0.968	0.004	0.092	0.998	0.000	0.092	0.998	0.000	11.490	0.887	0.010
6.867	0.961	0.007	0.092	0.998	0.000	0.092	0.997	0.000	13.779	0.861	0.012
9.155	0.953	0.009	0.092	0.998	0.000	2.289	0.998	0.002	16.068	0.822	0.013
11.490	0.945	0.011	0.092	0.998	0.000	4.578	0.991	0.005	18.357	0.769	0.014
13.779	0.935	0.013	0.092	0.950	0.000	6.867	0.983	0.007	20.645	0.716	0.015
16.068	0.926	0.015	0.092	0.975	0.000	9.155	0.975	0.009	22.934	0.651	0.015
18.357	0.918	0.017	0.092	0.984	0.000	11.490	0.967	0.011			
20.645	0.910	0.019	2.289	0.992	0.002	13.779	0.959	0.013			
22.934	0.901	0.021	4.578	0.985	0.005	16.068	0.950	0.015			
25.223	0.890	0.022	6.867	0.977	0.007	18.357	0.942	0.017			
27.512	0.880	0.024	9.155	0.970	0.009	20.645	0.932	0.019			
29.801	0.868	0.026	11.490	0.963	0.011	22.934	0.923	0.021			
32.090	0.857	0.028	13.779	0.954	0.013	25.223	0.909	0.023			
34.379	0.840	0.029	16.068	0.946	0.015	27.512	0.886	0.024			
36.667	0.826	0.030	18.357	0.938	0.017	29.801	0.864	0.026			
39.002	0.804	0.031	20.645	0.929	0.019	32.090	0.837	0.027			
41.245	0.774	0.032	22.934	0.920	0.021	34.379	0.804	0.028			
43.534	0.735	0.032	25.223	0.910	0.023	36.667	0.770	0.028			
45.823	0.673	0.031	27.512	0.898	0.025	38.956	0.699	0.027			
48.112	0.601	0.029	29.801	0.889	0.026	41.245	0.598	0.025			
			32.090	0.875	0.028						
			34.379	0.859	0.030						
			36.667	0.844	0.031						
			38.956	0.825	0.032						
			41.245	0.796	0.033						
			43.534	0.761	0.033						
			45.823	0.671	0.031						
			48.157	0.536	0.026						

Coal-Derived Rod #10 (100% PetCoke), Long Term Run, Air Flow Rate = 0.5 SLPM, T = 600°C, 3/2/2006

Time	Temp (°C)	VCELL	VANODE	VCATHODE	I (A)	I (mA)	I/SA
12:21:30	600	0.786	-0.798	-0.012	0.004	4	0.066

12:22:00	600	0.900	-0.889	0.011	0.004	4	0.066
12:22:30	600	0.896	-0.877	0.019	0.004	4	0.066
12:23:00	600	0.903	-0.885	0.018	0.004	4	0.066
12:23:30	600	0.898	-0.869	0.029	0.004	4	0.066
12:24:00	600	0.899	-0.877	0.022	0.004	4	0.066
12:24:30	600	0.896	-0.849	0.047	0.004	4	0.066
12:25:00	600	0.896	-0.845	0.051	0.004	4	0.066
12:25:30	600	0.893	-0.847	0.046	0.004	4	0.066
12:26:00	600	0.893	-0.841	0.052	0.004	4	0.066
12:26:30	600	0.891	-0.837	0.054	0.004	4	0.066
12:27:00	600	0.896	-0.844	0.052	0.004	4	0.066
12:27:30	600	0.878	-0.820	0.058	0.004	4	0.066
12:28:00	600	0.893	-0.827	0.066	0.004	4	0.066
12:28:30	600	0.893	-0.817	0.076	0.004	4	0.066
12:29:00	600	0.893	-0.826	0.067	0.004	4	0.066
12:29:30	600	0.895	-0.819	0.076	0.004	4	0.066
12:30:00	600	0.896	-0.826	0.070	0.004	4	0.066
12:30:30	600	0.897	-0.820	0.077	0.004	4	0.066
12:31:00	600	0.892	-0.803	0.089	0.004	4	0.066
12:31:30	600	0.796	-0.696	0.100	0.004	4	0.066
12:32:00	600	0.891	-0.796	0.095	0.004	4	0.066
12:32:30	600	0.891	-0.789	0.102	0.004	4	0.066
12:33:00	600	0.892	-0.790	0.102	0.004	4	0.066
12:33:30	600	0.654	-0.534	0.120	0.004	4	0.066
12:34:00	600	0.892	-0.781	0.111	0.004	4	0.066
12:34:30	600	0.889	-0.763	0.126	0.004	4	0.066
12:35:00	600	0.890	-0.746	0.144	0.004	4	0.066
12:35:30	600	0.885	-0.755	0.130	0.004	4	0.066
12:36:00	600	0.884	-0.741	0.143	0.004	4	0.066
12:36:30	600	0.884	-0.713	0.171	0.004	4	0.066
12:37:00	600	0.766	-0.592	0.174	0.004	4	0.066
12:37:30	600	0.879	-0.697	0.182	0.004	4	0.066
12:38:00	600	0.885	-0.715	0.170	0.004	4	0.066
12:38:30	600	0.881	-0.716	0.165	0.004	4	0.066
12:39:00	600	0.880	-0.690	0.190	0.004	4	0.066
12:39:30	600	0.877	-0.690	0.187	0.004	4	0.066
12:40:00	600	0.875	-0.680	0.195	0.004	4	0.066
12:40:30	600	0.874	-0.671	0.203	0.004	4	0.066
12:41:00	600	0.874	-0.663	0.211	0.004	4	0.066
12:41:30	600	0.860	-0.652	0.208	0.004	4	0.066
12:42:00	600	0.871	-0.655	0.216	0.004	4	0.066
12:42:30	600	0.867	-0.661	0.206	0.004	4	0.066
12:43:00	600	0.869	-0.657	0.212	0.004	4	0.066
12:43:30	600	0.872	-0.656	0.216	0.004	4	0.066
12:44:00	600	0.872	-0.653	0.219	0.004	4	0.066
12:44:30	600	0.876	-0.644	0.232	0.004	4	0.066
12:45:00	600	0.868	-0.654	0.214	0.004	4	0.066
12:45:30	600	0.873	-0.642	0.231	0.004	4	0.066
12:46:00	600	0.873	-0.637	0.236	0.004	4	0.066
12:46:30	600	0.871	-0.638	0.233	0.004	4	0.066
12:47:00	600	0.870	-0.629	0.241	0.004	4	0.066
12:47:30	600	0.862	-0.620	0.242	0.004	4	0.066
12:48:00	600	0.861	-0.619	0.242	0.004	4	0.066
12:48:30	600	0.864	-0.610	0.254	0.004	4	0.066
12:49:00	600	0.864	-0.606	0.258	0.004	4	0.066
12:49:30	600	0.858	-0.608	0.250	0.004	4	0.066
12:50:00	600	0.861	-0.586	0.275	0.004	4	0.066
12:50:30	600	0.856	-0.592	0.264	0.004	4	0.066
12:51:00	600	0.860	-0.593	0.267	0.004	4	0.066
12:51:30	600	0.858	-0.585	0.273	0.004	4	0.066
12:52:00	600	0.858	-0.581	0.277	0.004	4	0.066
12:52:30	600	0.853	-0.570	0.283	0.004	4	0.066
12:53:00	600	0.851	-0.555	0.296	0.004	4	0.066

12:53:30	600	0.850	-0.548	0.302	0.004	4	0.066
12:54:00	600	0.851	-0.529	0.322	0.004	4	0.066
12:54:30	600	0.852	-0.520	0.332	0.004	4	0.066
12:55:00	600	0.853	-0.496	0.357	0.004	4	0.066
12:55:30	600	0.854	-0.502	0.352	0.004	4	0.066
12:56:00	600	0.853	-0.502	0.351	0.004	4	0.066
12:56:30	600	0.843	-0.480	0.363	0.004	4	0.066
12:57:00	600	0.845	-0.476	0.369	0.004	4	0.066
12:57:30	600	0.840	-0.462	0.378	0.004	4	0.066
12:58:00	600	0.841	-0.448	0.393	0.004	4	0.066
12:58:30	600	0.832	-0.451	0.381	0.004	4	0.066
12:59:00	600	0.697	-0.311	0.386	0.004	4	0.066
12:59:30	600	0.818	-0.440	0.378	0.004	4	0.066
13:00:00	600	0.813	-0.431	0.382	0.004	4	0.066
13:00:30	600	0.811	-0.412	0.399	0.004	4	0.066
13:01:00	600	0.806	-0.415	0.391	0.004	4	0.066
13:01:30	600	0.779	-0.398	0.381	0.004	4	0.066
13:02:00	600	0.780	-0.396	0.384	0.004	4	0.066
13:02:30	600	0.745	-0.382	0.363	0.004	4	0.066
13:03:00	600	0.723	-0.382	0.341	0.004	4	0.066
13:03:30	600	0.655	-0.388	0.267	0.004	4	0.066
13:04:00	600	0.653	-0.384	0.269	0.004	4	0.066
13:04:30	600	0.606	-0.377	0.229	0.004	4	0.066
13:05:00	600	0.495	-0.319	0.176	0.004	4	0.066
13:05:30	600	0.540	-0.346	0.194	0.004	4	0.066
13:06:00	600	0.540	-0.284	0.256	0.004	4	0.066
13:06:30	600	0.533	-0.249	0.284	0.004	4	0.066
13:07:00	600	0.689	-0.343	0.346	0.004	4	0.066
13:07:30	600	0.721	-0.344	0.377	0.004	4	0.066
13:08:00	600	0.742	-0.325	0.417	0.004	4	0.066
13:08:30	600	0.760	-0.296	0.464	0.004	4	0.066
13:09:00	600	0.767	-0.266	0.501	0.004	4	0.066
13:09:30	600	0.768	-0.251	0.517	0.004	4	0.066
13:10:00	600	0.739	-0.222	0.517	0.004	4	0.066
13:10:30	600	0.768	-0.250	0.518	0.004	4	0.066
13:11:00	600	0.780	-0.250	0.530	0.004	4	0.066
13:11:30	600	0.647	-0.120	0.527	0.004	4	0.066
13:12:00	600	0.776	-0.250	0.526	0.004	4	0.066
13:12:30	600	0.784	-0.249	0.535	0.004	4	0.066
13:13:00	600	0.774	-0.244	0.530	0.004	4	0.066
13:13:30	600	0.778	-0.244	0.534	0.004	4	0.066
13:14:00	600	0.768	-0.245	0.523	0.004	4	0.066
13:14:30	600	0.768	-0.243	0.525	0.004	4	0.066
13:15:00	600	0.769	-0.241	0.528	0.004	4	0.066
13:15:30	600	0.763	-0.239	0.524	0.004	4	0.066
13:16:00	600	0.100	0.420	0.520	0.004	4	0.066
13:16:30	600	0.759	-0.241	0.518	0.004	4	0.066
13:17:00	600	0.757	-0.238	0.519	0.004	4	0.066
13:17:30	600	0.749	-0.236	0.513	0.004	4	0.066
13:18:00	600	0.750	-0.234	0.516	0.004	4	0.066
13:18:30	600	0.742	-0.211	0.531	0.004	4	0.066
13:19:00	600	0.737	-0.230	0.507	0.004	4	0.066
13:19:30	600	0.734	-0.234	0.500	0.004	4	0.066
13:20:00	600	0.722	-0.226	0.496	0.004	4	0.066
13:20:30	600	0.724	-0.229	0.495	0.004	4	0.066
13:21:00	600	0.728	-0.229	0.499	0.004	4	0.066
13:21:30	600	0.716	-0.218	0.498	0.004	4	0.066
13:22:00	600	0.718	-0.208	0.510	0.004	4	0.066
13:22:30	600	0.716	-0.218	0.498	0.004	4	0.066
13:23:00	600	0.719	-0.219	0.500	0.004	4	0.066
13:23:30	600	0.710	-0.222	0.488	0.004	4	0.066
13:24:00	600	0.694	-0.218	0.476	0.004	4	0.066
13:24:30	600	0.702	-0.217	0.485	0.004	4	0.066

13:25:00	600	0.699	-0.222	0.477	0.004	4	0.066
13:25:30	600	0.686	-0.219	0.467	0.004	4	0.066
13:26:00	600	0.690	-0.198	0.492	0.004	4	0.066
13:26:30	600	0.683	-0.220	0.463	0.004	4	0.066
13:27:00	600	0.683	-0.213	0.470	0.004	4	0.066
13:27:30	600	0.672	-0.212	0.460	0.004	4	0.066
13:28:00	600	0.665	-0.208	0.457	0.004	4	0.066
13:28:30	600	0.636	-0.180	0.456	0.004	4	0.066
13:29:00	600	0.639	-0.199	0.440	0.004	4	0.066
13:29:30	600	0.638	-0.197	0.441	0.004	4	0.066
13:30:00	600	0.635	-0.200	0.435	0.004	4	0.066
13:30:30	600	0.639	-0.192	0.447	0.004	4	0.066
13:31:00	600	0.637	-0.193	0.444	0.004	4	0.066
13:31:30	600	0.635	-0.198	0.437	0.004	4	0.066
13:32:00	600	0.071	0.368	0.439	0.004	4	0.066
13:32:30	600	0.619	-0.190	0.429	0.004	4	0.066
13:33:00	600	0.585	-0.167	0.418	0.004	4	0.066
13:33:30	600	0.588	-0.174	0.414	0.004	4	0.066
13:34:00	600	0.586	-0.162	0.424	0.006	6	0.099
13:34:30	600	0.586	-0.153	0.433	0.004	4	0.066
13:35:00	600	0.578	-0.160	0.418	0.004	4	0.066
13:35:30	600	0.292	0.137	0.429	0.004	4	0.066
13:36:00	600	0.489	-0.070	0.419	0.004	4	0.066
13:36:30	600	0.567	-0.133	0.434	0.004	4	0.066
13:37:00	600	0.550	-0.152	0.398	0.004	4	0.066
13:37:30	600	0.544	-0.156	0.388	0.004	4	0.066
13:38:00	600	0.533	-0.143	0.390	0.004	4	0.066
13:38:30	600	0.515	-0.141	0.374	0.004	4	0.066
13:39:00	600	0.500	-0.139	0.361	0.004	4	0.066
13:39:30	600	0.481	-0.136	0.345	0.004	4	0.066
13:40:00	600	0.466	-0.140	0.326	0.004	4	0.066
13:40:30	600	0.363	-0.038	0.325	0.006	6	0.099
13:41:00	600	0.429	-0.109	0.320	0.004	4	0.066
13:41:30	600	0.104	0.216	0.320	0.004	4	0.066
13:42:00	600	0.444	-0.131	0.313	0.004	4	0.066
13:42:30	600	0.090	0.211	0.301	0.004	4	0.066
13:43:00	600	0.419	-0.132	0.287	0.004	4	0.066
13:43:30	600	0.367	-0.084	0.283	0.004	4	0.066
13:44:00	600	0.402	-0.130	0.272	0.004	4	0.066
13:44:30	600	0.245	0.033	0.278	0.004	4	0.066
13:45:00	600	0.385	-0.119	0.266	0.004	4	0.066
13:45:30	600	0.391	-0.123	0.268	0.004	4	0.066
13:46:00	600	0.242	0.004	0.246	0.004	4	0.066
13:46:30	600	0.354	-0.117	0.237	0.004	4	0.066
13:47:00	600	0.362	-0.122	0.240	0.004	4	0.066
13:47:30	600	0.356	-0.107	0.249	0.004	4	0.066
13:48:00	600	0.357	-0.117	0.240	0.004	4	0.066
13:48:30	600	0.321	-0.085	0.236	0.036	36	0.594
13:49:00	600	0.342	-0.117	0.225	0.036	36	0.594
13:49:30	600	0.346	-0.119	0.227	0.036	36	0.594
13:50:00	600	0.334	-0.115	0.219	0.036	36	0.594
13:50:30	600	0.330	-0.106	0.224	0.036	36	0.594
13:51:00	600	0.332	-0.119	0.213	0.036	36	0.594
13:51:30	600	0.326	-0.111	0.215	0.036	36	0.594
13:52:00	600	0.297	-0.084	0.213	0.038	38	0.627
13:52:30	600	0.329	-0.116	0.213	0.036	36	0.594
13:53:00	600	0.296	-0.087	0.209	0.004	4	0.066
13:53:30	600	0.323	-0.113	0.210	0.004	4	0.066
13:54:00	600	0.319	-0.112	0.207	0.004	4	0.066
13:54:30	600	0.319	-0.113	0.206	0.004	4	0.066
13:55:00	600	0.315	-0.107	0.208	0.004	4	0.066
13:55:30	600	0.315	-0.104	0.211	0.004	4	0.066
13:56:00	600	0.319	-0.113	0.206	0.004	4	0.066

13:56:30	600	0.314	-0.113	0.201	0.004	4	0.066
13:57:00	600	0.311	-0.109	0.202	0.004	4	0.066
13:57:30	600	0.088	0.115	0.203	0.004	4	0.066
13:58:00	600	0.309	-0.104	0.205	0.004	4	0.066
13:58:30	600	0.309	-0.107	0.202	0.004	4	0.066
13:59:00	600	0.303	-0.104	0.199	0.004	4	0.066
13:59:30	600	0.309	-0.113	0.196	0.004	4	0.066
14:00:00	600	0.301	-0.103	0.198	0.004	4	0.066
14:00:30	600	0.036	0.164	0.200	0.004	4	0.066
14:01:00	600	0.299	-0.103	0.196	0.004	4	0.066
14:01:30	600	0.294	-0.102	0.192	0.004	4	0.066
14:02:00	600	0.176	0.026	0.202	0.004	4	0.066
14:02:30	600	0.216	-0.015	0.201	0.004	4	0.066
14:03:00	600	0.298	-0.102	0.196	0.004	4	0.066
14:03:30	600	0.294	-0.096	0.198	0.004	4	0.066
14:04:00	600	0.294	-0.100	0.194	0.004	4	0.066
14:04:30	600	0.290	-0.098	0.192	0.004	4	0.066
14:05:00	600	0.289	-0.097	0.192	0.004	4	0.066
14:05:30	600	0.183	0.014	0.197	0.004	4	0.066
14:06:00	600	0.287	-0.096	0.191	0.004	4	0.066
14:06:30	600	0.295	-0.098	0.197	0.004	4	0.066
14:07:00	600	0.288	-0.094	0.194	0.004	4	0.066
14:07:30	600	0.155	0.034	0.189	0.004	4	0.066
14:08:00	600	0.282	-0.093	0.189	0.004	4	0.066
14:08:30	600	0.284	-0.088	0.196	0.004	4	0.066
14:09:00	600	0.280	-0.089	0.191	0.004	4	0.066
14:09:30	600	0.208	-0.021	0.187	0.004	4	0.066
14:10:00	600	0.281	-0.095	0.186	0.004	4	0.066
14:10:30	600	0.257	-0.074	0.183	0.004	4	0.066
14:11:00	600	0.276	-0.094	0.182	0.004	4	0.066
14:11:30	600	0.273	-0.091	0.182	0.004	4	0.066
14:12:00	600	0.275	-0.095	0.18	0.004	4	0.066
14:12:30	600	0.278	-0.099	0.179	0.004	4	0.066
14:13:00	600	0.266	-0.091	0.175	0.004	4	0.066
14:13:30	600	0.002	0.177	0.179	0.004	4	0.066
14:14:00	600	0.271	-0.095	0.176	0.004	4	0.066
14:14:30	600	0.272	-0.091	0.181	0.004	4	0.066
14:15:00	600	0.265	-0.082	0.183	0.004	4	0.066
14:15:30	600	0.110	0.063	0.173	0.004	4	0.066
14:16:00	600	0.136	0.034	0.17	0.004	4	0.066
14:16:30	600	0.252	-0.085	0.167	0.004	4	0.066
14:17:00	600	0.255	-0.090	0.165	0.004	4	0.066
14:17:30	600	0.161	0.017	0.178	0.004	4	0.066
14:18:00	600	0.253	-0.091	0.162	0.004	4	0.066
14:18:30	600	0.238	-0.090	0.148	0.004	4	0.066
14:19:00	600	0.236	-0.091	0.145	0.004	4	0.066
14:19:30	600	0.235	-0.094	0.141	0.004	4	0.066
14:20:00	600	0.156	-0.024	0.132	0.004	4	0.066
14:20:30	600	0.223	-0.096	0.127	0.004	4	0.066
14:21:00	600	0.214	-0.093	0.121	0.004	4	0.066
14:21:30	600	0.209	-0.097	0.112	0.004	4	0.066
14:22:00	600	0.200	-0.093	0.107	0.004	4	0.066
14:22:30	600	0.192	-0.092	0.1	0.004	4	0.066
14:23:00	600	0.168	-0.079	0.089	0.004	4	0.066
14:23:30	600	0.184	-0.091	0.093	0.004	4	0.066
14:24:00	600	0.179	-0.090	0.089	0.004	4	0.066
14:24:30	600	0.170	-0.097	0.073	0.004	4	0.066
14:25:00	600	0.170	-0.100	0.07	0.004	4	0.066
14:25:30	600	0.028	0.039	0.067	0.004	4	0.066
14:26:00	600	0.158	-0.099	0.059	0.004	4	0.066
14:26:30	600	0.155	-0.100	0.055	0.004	4	0.066
14:27:00	600	0.089	-0.033	0.056	0.004	4	0.066
14:27:30	600	0.141	-0.097	0.044	0.004	4	0.066

14:28:00	600	0.037	-0.004	0.033	0.004	4	0.066
14:28:30	600	0.122	-0.096	0.026	0.004	4	0.066
14:29:00	600	0.119	-0.091	0.028	0.004	4	0.066
14:29:30	600	0.010	0.012	0.022	0.004	4	0.066
14:30:00	600	0.115	-0.096	0.019	0.004	4	0.066
14:30:30	600	0.121	-0.108	0.013	0.004	4	0.066
14:31:00	600	0.102	-0.094	0.008	0.004	4	0.066
14:31:30	600	0.101	-0.096	0.005	0.004	4	0.066
14:32:00	600	0.098	-0.097	0.001	0.004	4	0.066
14:32:30	600	0.099	-0.094	0.005	0.004	4	0.066
14:33:00	600	0.093	-0.094	-0.001	0.004	4	0.066
14:33:30	600	0.013	-0.016	-0.003	0.004	4	0.066
14:34:00	600	0.093	-0.094	-0.001	0.004	4	0.066
14:34:30	600	0.087	-0.095	-0.008	0.004	4	0.066
14:35:00	600	0.09	-0.099	-0.009	0	0	0.000
14:35:30	600	0.079	-0.089	-0.01	0.004	4	0.066
14:36:00	600	0.058	-0.068	-0.01	0.004	4	0.066
14:36:30	600	0.085	-0.096	-0.011	0.004	4	0.066
14:37:00	600	0.091	-0.100	-0.009	0.004	4	0.066
14:37:30	600	0.085	-0.097	-0.012	0.004	4	0.066
14:38:00	600	0.084	-0.097	-0.013	0.004	4	0.066
14:38:30	600	0.082	-0.091	-0.009	0.004	4	0.066
14:39:00	600	0.025	-0.040	-0.015	0.004	4	0.066
14:39:30	600	0.088	-0.101	-0.013	0.004	4	0.066
14:40:00	600	0.068	-0.084	-0.016	0.004	4	0.066
14:40:30	600	0.012	-0.026	-0.014	0.004	4	0.066
14:41:00	600	0.033	-0.049	-0.016	0.004	4	0.066
14:41:30	600	0.064	-0.082	-0.018	0.004	4	0.066
14:42:00	600	0.041	-0.051	-0.01	0.004	4	0.066
14:42:30	600	0.073	-0.094	-0.021	0.004	4	0.066
14:43:00	600	0.079	-0.095	-0.016	0.004	4	0.066
14:43:30	600	0.075	-0.090	-0.015	0.004	4	0.066
14:44:00	600	0.008	-0.027	-0.019	0.004	4	0.066
14:44:30	600	0.073	-0.092	-0.019	0.004	4	0.066
14:45:00	600	0.078	-0.096	-0.018	0.002	2	0.033
14:45:30	600	0.009	-0.033	-0.024	0.002	2	0.033
14:46:00	600	0.067	-0.091	-0.024	0.002	2	0.033
14:46:30	600	0.018	-0.046	-0.028	0.002	2	0.033
14:47:00	600	0.046	-0.074	-0.028	0.002	2	0.033
14:47:30	600	0.066	-0.094	-0.028	0.002	2	0.033
14:48:00	600	0.015	-0.046	-0.031	0.002	2	0.033
14:48:30	600	0.05	-0.083	-0.033	0.002	2	0.033
14:49:00	600	0.06	-0.095	-0.035	0.004	4	0.066
14:49:30	600	0.036	-0.071	-0.035	0.004	4	0.066
14:50:00	600	0.056	-0.093	-0.037	0.004	4	0.066
14:50:30	600	0.052	-0.091	-0.039	0.004	4	0.066
14:51:00	600	0.03	-0.070	-0.04	0.004	4	0.066
14:51:30	600	0.048	-0.091	-0.043	0.004	4	0.066
14:52:00	600	0.05	-0.088	-0.038	0.004	4	0.066
14:52:30	600	0.026	-0.073	-0.047	0.002	2	0.033
14:53:00	600	0.036	-0.081	-0.045	0.004	4	0.066
14:53:30	600	0.032	-0.079	-0.047	0.004	4	0.066
14:54:00	600	0.045	-0.093	-0.048	0.004	4	0.066
14:54:30	600	0.033	-0.083	-0.05	0.004	4	0.066
14:55:00	600	0.015	-0.070	-0.055	0.004	4	0.066
14:55:30	600	0.039	-0.094	-0.055	0.004	4	0.066
14:56:00	600	0.04	-0.096	-0.056	0.004	4	0.066
14:56:30	600	0.038	-0.093	-0.055	0.004	4	0.066
14:57:00	600	0.036	-0.093	-0.057	0.004	4	0.066
14:57:30	600	0.034	-0.094	-0.06	0.004	4	0.066
14:58:00	600	0.034	-0.094	-0.06	0.004	4	0.066
14:58:30	600	0.003	-0.063	-0.06	0.004	4	0.066
14:59:00	600	0.001	-0.062	-0.061	0.004	4	0.066

14:59:30	600	0.03	-0.090	-0.06	0.004	4	0.066
15:00:00	600	0	-0.060	-0.06	0.004	4	0.066
15:00:30	600	0.036	-0.098	-0.062	0.004	4	0.066

Coal-Derived Rod (100% SECO), Air Flow Rate = 0.50 SLPM, T = 600°C, 3/22/2006

	Run 1			Run 2		
I/SA	VCELL	P/SA	I/SA	VCELL	P/SA	
0.000	1.034	0.000	0.030	1.043	0.000	
0.030	1.032	0.000	0.030	1.044	0.000	
0.030	0.986	0.000	0.030	0.991	0.000	
0.030	1.012	0.000	0.030	1.017	0.000	
1.505	1.028	0.002	1.505	1.037	0.002	
3.010	1.021	0.003	3.010	1.029	0.003	
4.515	1.012	0.005	6.050	1.012	0.006	
6.020	1.003	0.006	9.029	0.993	0.009	
7.555	0.994	0.008	12.069	0.974	0.012	
9.029	0.985	0.009	15.079	0.953	0.014	
10.564	0.975	0.010	18.089	0.930	0.017	
12.039	0.965	0.012	21.099	0.905	0.019	
13.574	0.955	0.013	24.108	0.878	0.021	
15.079	0.944	0.014	27.118	0.840	0.023	
16.584	0.933	0.015	30.128	0.794	0.024	
18.089	0.920	0.017	33.138	0.733	0.024	
19.594	0.907	0.018	34.673	0.655	0.023	
21.099	0.894	0.019				
22.603	0.879	0.020				
24.108	0.860	0.021				
25.613	0.840	0.022				
27.118	0.815	0.022				
28.623	0.782	0.022				
30.128	0.744	0.022				
31.633	0.682	0.022				
31.663	0.608	0.019				

Coal-Derived Rod (100% SECO), Long Term Run, Air Flow Rate = 0.50 SLPM, T = 600°C, 3/22/2006

Temp (°C)	VCELL	VANODE	VCATHODE	I (A)	I (mA)	I/SA	Time (min)
601	1.002	-1.028	-0.026	0.502	502	7.555	0
601	0.998	-1.022	-0.024	0.502	502	7.555	2
601	0.998	-1.024	-0.026	0.502	502	7.555	4
601	0.999	-1.024	-0.025	0.502	502	7.555	6
601	0.998	-1.022	-0.024	0.502	502	7.555	8
601	0.998	-1.023	-0.025	0.502	502	7.555	10
601	0.997	-1.024	-0.027	0.502	502	7.555	12
601	0.996	-1.024	-0.028	0.502	502	7.555	14
601	0.997	-1.023	-0.026	0.502	502	7.555	16
601	0.997	-1.022	-0.025	0.502	502	7.555	18
601	0.998	-1.025	-0.027	0.502	502	7.555	20
601	0.997	-1.022	-0.025	0.502	502	7.555	22
601	0.996	-1.021	-0.025	0.502	502	7.555	24
601	0.994	-1.021	-0.027	0.502	502	7.555	26
601	0.994	-1.020	-0.026	0.502	502	7.555	28

601	0.991	-1.020	-0.029	0.502	502	7.555	30
601	0.994	-1.021	-0.027	0.502	502	7.555	32
600	0.994	-1.018	-0.024	0.502	502	7.555	34
600	0.993	-1.022	-0.029	0.502	502	7.555	36
600	0.993	-1.019	-0.026	0.502	502	7.555	38
601	0.991	-1.019	-0.028	0.502	502	7.555	40
601	0.991	-1.013	-0.022	0.502	502	7.555	42
601	0.989	-1.015	-0.026	0.502	502	7.555	44
601	0.989	-1.015	-0.026	0.502	502	7.555	46
601	0.988	-1.013	-0.025	0.502	502	7.555	48
601	0.986	-1.015	-0.029	0.502	502	7.555	50
601	0.985	-1.012	-0.027	0.502	502	7.555	52
600	0.983	-1.011	-0.028	0.502	502	7.555	54
600	0.98	-1.012	-0.032	0.502	502	7.555	56
600	0.98	-1.008	-0.028	0.502	502	7.555	58
601	0.98	-1.005	-0.025	0.502	502	7.555	60
601	0.974	-0.996	-0.022	0.502	502	7.555	62
601	0.912	-0.943	-0.031	0.502	502	7.555	64
601	0.817	-0.869	-0.052	0.502	502	7.555	66
601	0.777	-0.849	-0.072	0.502	502	7.555	68
600	0.767	-0.843	-0.076	0.502	502	7.555	70
600	0.635	-0.709	-0.074	0.502	502	7.555	72
600	0.469	-0.569	-0.1	0.502	502	7.555	74
600	0.35	0.044	0.394	0.502	502	7.555	76
601	0.257	0.081	0.338	0.502	502	7.555	78
601	0.232	0.086	0.318	0.502	502	7.555	80
601	0.217	0.084	0.301	0.502	502	7.555	82
601	0.219	0.078	0.297	0.500	500	7.524	84

Coal-Derived Rod (50/50% SECO/PetCoke), Air Flow Rate = 0.50 SLPM, T = 600°C,
3/23/2006

Run 1		
I/SA	VCELL	P/SA
0.028	0.963	0.000
0.028	0.932	0.000
0.028	0.950	0.000
1.396	0.955	0.001
2.791	0.948	0.003
4.187	0.940	0.004
5.583	0.932	0.005
7.006	0.922	0.006
8.374	0.914	0.008
9.798	0.905	0.009
11.193	0.895	0.010
12.589	0.885	0.011
13.985	0.877	0.012
15.380	0.865	0.013
16.776	0.854	0.014
18.172	0.843	0.015
19.567	0.830	0.016
20.963	0.816	0.017
22.359	0.803	0.018
23.754	0.790	0.019
25.150	0.767	0.019

26.546	0.743	0.020
27.941	0.714	0.020
29.337	0.677	0.020
30.733	0.629	0.019
30.733	0.594	0.018

Coal-Derived Rod (50/50% SECO/PetCoke), Long Term Run, Air Flow Rate = 0.50
SLPM, T = 600°C, 3/23/2006

Temp (°C)	VCELL	VANODE	VCATHODE	I (A)	I (mA)	I/SA	Time (min)
599	0.970	-0.986	-0.016	0.002	2	0.028	2
598	0.925	-0.955	-0.030	0.502	502	7.006	4
598	0.921	-0.950	-0.029	0.502	502	7.006	6
598	0.922	-0.955	-0.033	0.502	502	7.006	8
598	0.922	-0.954	-0.032	0.502	502	7.006	10
598	0.924	-0.958	-0.034	0.502	502	7.006	12
598	0.927	-0.956	-0.029	0.502	502	7.006	14
598	0.928	-0.959	-0.031	0.502	502	7.006	16
598	0.932	-0.965	-0.033	0.502	502	7.006	18
598	0.933	-0.964	-0.031	0.502	502	7.006	20
598	0.934	-0.969	-0.035	0.502	502	7.006	22
598	0.935	-0.970	-0.035	0.502	502	7.006	24
598	0.937	-0.970	-0.033	0.502	502	7.006	26
598	0.937	-0.969	-0.032	0.502	502	7.006	28
598	0.937	-0.972	-0.035	0.502	502	7.006	30
598	0.938	-0.972	-0.034	0.500	500	6.978	32
598	0.937	-0.975	-0.038	0.502	502	7.006	34
598	0.936	-0.972	-0.036	0.502	502	7.006	36
598	0.934	-0.974	-0.040	0.502	502	7.006	38
598	0.935	-0.972	-0.037	0.502	502	7.006	40
598	0.932	-0.969	-0.037	0.502	502	7.006	42
598	0.931	-0.972	-0.041	0.500	500	6.978	44
598	0.927	-0.962	-0.035	0.502	502	7.006	46
598	0.924	-0.966	-0.042	0.500	500	6.978	48
599	0.919	-0.966	-0.047	0.502	502	7.006	50
598	0.908	-0.951	-0.043	0.502	502	7.006	52
598	0.899	-0.936	-0.037	0.502	502	7.006	54
598	0.891	-0.941	-0.050	0.502	502	7.006	56
598	0.877	-0.937	-0.060	0.502	502	7.006	58
598	0.862	-0.925	-0.063	0.502	502	7.006	60
598	0.845	-0.889	-0.044	0.500	500	6.978	62
598	0.816	-0.871	-0.055	0.502	502	7.006	64
598	0.785	-0.829	-0.044	0.500	500	6.978	66
598	0.762	-0.815	-0.053	0.502	502	7.006	68
598	0.738	-0.740	-0.002	0.502	502	7.006	70
598	0.698	-0.722	-0.024	0.502	502	7.006	72
598	0.676	-0.698	-0.022	0.502	502	7.006	74
598	0.653	-0.672	-0.019	0.502	502	7.006	76
598	0.615	-0.647	-0.032	0.502	502	7.006	78
598	0.577	-0.607	-0.030	0.502	502	7.006	80
598	0.532	-0.496	0.036	0.500	500	6.978	82
598	0.500	-0.434	0.066	0.500	500	6.978	84
598	0.455	-0.374	0.081	0.500	500	6.978	86
598	0.425	-0.283	0.142	0.502	502	7.006	88
598	0.392	-0.279	0.113	0.502	502	7.006	90
598	0.371	-0.273	0.098	0.502	502	7.006	92
598	0.358	-0.266	0.092	0.502	502	7.006	94

598	0.338	-0.260	0.078	0.500	500	6.978	96
598	0.332	-0.255	0.077	0.502	502	7.006	98
598	0.322	-0.240	0.082	0.502	502	7.006	100
598	0.315	-0.233	0.082	0.502	502	7.006	102
598	0.312	-0.223	0.089	0.502	502	7.006	104
598	0.304	-0.216	0.088	0.502	502	7.006	106
598	0.297	-0.211	0.086	0.502	502	7.006	108
598	0.292	-0.203	0.089	0.502	502	7.006	110
598	0.274	-0.196	0.078	0.502	502	7.006	112

GrafTech Non-Graphitized Baked Rod, Air Flow Rate = 0.50 SLPM, T = 600°C,
4/11/2006

Run 1			Run 2		
I/SA	VCELL	P/SA	I/SA	VCELL	P/SA
0.061	0.972	0.000	0.061	0.943	0.000
0.061	0.972	0.000	0.061	0.960	0.000
0.061	0.972	0.000	1.534	0.973	0.001
0.061	0.947	0.000	3.067	0.967	0.003
0.061	0.964	0.000	4.601	0.959	0.004
0.061	0.974	0.000	6.135	0.953	0.006
1.534	0.966	0.001	7.699	0.945	0.007
3.067	0.960	0.003	9.202	0.938	0.009
4.601	0.954	0.004	10.767	0.931	0.010
6.135	0.947	0.006	12.301	0.923	0.011
7.699	0.943	0.007	13.834	0.915	0.013
9.233	0.940	0.009	15.368	0.907	0.014
12.270	0.929	0.011	16.902	0.899	0.015
15.368	0.936	0.014	18.436	0.891	0.016
15.368	0.931	0.014	19.969	0.880	0.018
18.436	0.914	0.017	21.503	0.871	0.019
18.436	0.908	0.017	23.037	0.859	0.020
21.503	0.892	0.019	24.571	0.848	0.021
23.037	0.878	0.020	26.104	0.834	0.022
24.571	0.863	0.021	26.104	0.825	0.022
27.638	0.840	0.023	27.638	0.809	0.022
30.706	0.810	0.025	29.172	0.785	0.023
33.773	0.755	0.025	29.172	0.766	0.022
36.840	0.699	0.026	30.706	0.724	0.022
38.405	0.625	0.024	32.239	0.674	0.022

GrafTech Non-Graphitized Baked Rod, Long Term Run, Air Flow Rate = 0.50 SLPM, T
= 600°C, 4/11/2006

Temp (°C)	VCELL	VANODE	VCATHODE	I (A)	I (mA)	I/SA	Time (h)
600	0.984	-0.990	-0.006	0.000	0	0.000	0.000
601	0.986	-0.999	-0.013	0.000	0	0.000	0.083
601	0.987	-0.997	-0.010	0.000	0	0.000	0.167
601	0.986	-0.995	-0.009	0.000	0	0.000	0.250
601	0.985	-0.983	0.002	0.000	0	0.000	0.333
601	0.982	-0.985	-0.003	0.000	0	0.000	0.417
601	0.979	-0.973	0.006	0.000	0	0.000	0.500
601	0.976	-0.968	0.008	0.000	0	0.000	0.583

601	0.973	-0.945	0.028	0.000	0	0.000	0.667
601	0.970	-0.930	0.040	0.000	0	0.000	0.750
600	0.967	-0.906	0.061	0.000	0	0.000	0.833
601	0.963	-0.876	0.087	0.000	0	0.000	0.917
601	0.959	-0.806	0.153	0.000	0	0.000	1.000
601	0.956	-0.760	0.196	0.000	0	0.000	1.083
601	0.951	-0.732	0.219	0.000	0	0.000	1.167
601	0.950	-0.695	0.255	0.000	0	0.000	1.250
601	0.947	-0.679	0.268	0.000	0	0.000	1.333
601	0.944	-0.652	0.292	0.000	0	0.000	1.417
601	0.938	-0.629	0.309	0.000	0	0.000	1.500
601	0.936	-0.599	0.337	0.000	0	0.000	1.583
601	0.935	-0.583	0.352	0.000	0	0.000	1.667
600	0.930	-0.579	0.351	0.000	0	0.000	1.750
601	0.926	-0.608	0.318	0.000	0	0.000	1.833
601	0.918	-0.586	0.332	0.000	0	0.000	1.917
601	0.918	-0.568	0.350	0.000	0	0.000	2.000
601	0.911	-0.548	0.363	0.000	0	0.000	2.083
601	0.912	-0.563	0.349	0.000	0	0.000	2.167
601	0.908	-0.546	0.362	0.000	0	0.000	2.250
601	0.908	-0.555	0.353	0.000	0	0.000	2.333
601	0.904	-0.556	0.348	0.000	0	0.000	2.417
601	0.901	-0.554	0.347	0.000	0	0.000	2.500
601	0.892	-0.549	0.343	0.000	0	0.000	2.583
600	0.859	-0.503	0.356	0.000	0	0.000	2.667
601	0.867	-0.512	0.355	0.000	0	0.000	2.750
601	0.878	-0.518	0.360	0.000	0	0.000	2.833
601	0.882	-0.540	0.342	0.000	0	0.000	2.917
601	0.874	-0.520	0.354	0.000	0	0.000	3.000
601	0.880	-0.553	0.327	0.000	0	0.000	3.083
601	0.878	-0.547	0.331	0.000	0	0.000	3.167
601	0.878	-0.560	0.318	0.000	0	0.000	3.250
601	0.873	-0.555	0.318	0.000	0	0.000	3.333
601	0.878	-0.557	0.321	0.000	0	0.000	3.417
601	0.872	-0.569	0.303	0.000	0	0.000	3.500
601	0.876	-0.578	0.298	0.000	0	0.000	3.583
601	0.868	-0.557	0.311	0.000	0	0.000	3.667
601	0.868	-0.566	0.302	0.000	0	0.000	3.750
601	0.859	-0.552	0.307	0.000	0	0.000	3.833
600	0.856	-0.565	0.291	0.000	0	0.000	3.917
601	0.857	-0.582	0.275	0.000	0	0.000	4.000
601	0.858	-0.588	0.270	0.000	0	0.000	4.083
600	0.861	-0.569	0.292	0.000	0	0.000	4.167
601	0.839	-0.572	0.267	0.000	0	0.000	4.250
601	0.840	-0.560	0.280	0.000	0	0.000	4.333
600	0.854	-0.556	0.298	0.000	0	0.000	4.417
600	0.856	-0.574	0.282	0.000	0	0.000	4.500
601	0.849	-0.556	0.293	0.000	0	0.000	4.583
600	0.840	-0.560	0.280	0.000	0	0.000	4.667
601	0.845	-0.577	0.268	0.000	0	0.000	4.750
600	0.844	-0.584	0.260	0.000	0	0.000	4.833
600	0.847	-0.568	0.279	0.000	0	0.000	4.917
600	0.847	-0.575	0.272	0.000	0	0.000	5.000
600	0.817	-0.571	0.246	0.000	0	0.000	5.083
601	0.820	-0.567	0.253	0.000	0	0.000	5.167
600	0.830	-0.578	0.252	0.000	0	0.000	5.250
600	0.838	-0.596	0.242	0.000	0	0.000	5.333
600	0.813	-0.576	0.237	0.000	0	0.000	5.417
601	0.816	-0.590	0.226	0.000	0	0.000	5.500
600	0.818	-0.569	0.249	0.000	0	0.000	5.583
601	0.834	-0.597	0.237	0.000	0	0.000	5.667
601	0.813	-0.606	0.207	0.000	0	0.000	5.750
601	0.810	-0.575	0.235	0.000	0	0.000	5.833

601	0.824	-0.618	0.206	0.000	0	0.000	5.917
600	0.819	-0.596	0.223	0.000	0	0.000	6.000
600	0.786	-0.579	0.207	0.000	0	0.000	6.083
601	0.786	-0.560	0.226	0.000	0	0.000	6.167
601	0.797	-0.600	0.197	0.000	0	0.000	6.250
600	0.783	-0.578	0.205	0.000	0	0.000	6.333
601	0.740	-0.583	0.157	0.000	0	0.000	6.417
601	0.757	-0.506	0.251	0.000	0	0.000	6.500
600	0.757	-0.618	0.139	0.000	0	0.000	6.583
601	0.768	-0.577	0.191	0.000	0	0.000	6.667
601	0.732	-0.572	0.160	0.000	0	0.000	6.750
601	0.734	-0.572	0.162	0.000	0	0.000	6.833
600	0.733	-0.563	0.170	0.000	0	0.000	6.917
601	0.698	-0.545	0.153	0.000	0	0.000	7.000
601	0.707	-0.572	0.135	0.000	0	0.000	7.083
600	0.718	-0.552	0.166	0.000	0	0.000	7.167
601	0.699	-0.544	0.155	0.000	0	0.000	7.250
601	0.678	-0.521	0.157	0.000	0	0.000	7.333
601	0.686	-0.542	0.144	0.000	0	0.000	7.417
600	0.691	-0.501	0.190	0.000	0	0.000	7.500
601	0.649	-0.382	0.267	0.000	0	0.000	7.583
601	0.657	-0.385	0.272	0.000	0	0.000	7.667
600	0.669	-0.384	0.285	0.000	0	0.000	7.750
601	0.657	-0.372	0.285	0.000	0	0.000	7.833
601	0.614	-0.337	0.277	0.000	0	0.000	7.917
600	0.630	-0.335	0.295	0.000	0	0.000	8.000
600	0.623	-0.335	0.288	0.000	0	0.000	8.083
601	0.575	-0.326	0.249	0.000	0	0.000	8.167
601	0.593	-0.329	0.264	0.000	0	0.000	8.250
600	0.609	-0.332	0.277	0.000	0	0.000	8.333
601	0.577	-0.329	0.248	0.000	0	0.000	8.417
601	0.575	-0.321	0.254	0.000	0	0.000	8.500
600	0.599	-0.316	0.283	0.000	0	0.000	8.583
601	0.625	-0.319	0.306	0.000	0	0.000	8.667
601	0.567	-0.317	0.250	0.000	0	0.000	8.750
601	0.600	-0.315	0.285	0.000	0	0.000	8.833
600	0.615	-0.306	0.309	0.000	0	0.000	8.917
600	0.564	-0.307	0.257	0.000	0	0.000	9.000
601	0.598	-0.309	0.289	0.000	0	0.000	9.083
601	0.592	-0.306	0.286	0.000	0	0.000	9.167
601	0.620	-0.306	0.314	0.000	0	0.000	9.250
600	0.609	-0.308	0.301	0.000	0	0.000	9.333
601	0.604	-0.305	0.299	0.000	0	0.000	9.417
600	0.597	-0.301	0.296	0.000	0	0.000	9.500
600	0.598	-0.297	0.301	0.000	0	0.000	9.583
600	0.571	-0.281	0.290	0.000	0	0.000	9.667
601	0.550	-0.279	0.271	0.000	0	0.000	9.750
600	0.581	-0.273	0.308	0.000	0	0.000	9.833
600	0.596	-0.270	0.326	0.000	0	0.000	9.917
600	0.597	-0.268	0.329	0.000	0	0.000	10.000
601	0.527	-0.261	0.266	0.000	0	0.000	10.083
601	0.538	-0.255	0.283	0.000	0	0.000	10.167
600	0.551	-0.255	0.296	0.000	0	0.000	10.250
601	0.562	-0.252	0.310	0.000	0	0.000	10.333
600	0.335	-0.222	0.113	0.000	0	0.000	10.417
600	0.555	-0.246	0.309	0.000	0	0.000	10.500
600	0.569	-0.249	0.320	0.000	0	0.000	10.583
600	0.528	-0.239	0.289	0.000	0	0.000	10.667
601	0.525	-0.241	0.284	0.000	0	0.000	10.750
600	0.560	-0.246	0.314	0.000	0	0.000	10.833
600	0.563	-0.248	0.315	0.000	0	0.000	10.917
600	0.585	-0.241	0.344	0.000	0	0.000	11.000
600	0.521	-0.231	0.290	0.000	0	0.000	11.083

601	0.528	-0.236	0.292	0.000	0	0.000	11.167
600	0.556	-0.239	0.317	0.000	0	0.000	11.250
600	0.563	-0.239	0.324	0.000	0	0.000	11.333
600	0.553	-0.238	0.315	0.000	0	0.000	11.417
600	0.549	-0.237	0.312	0.000	0	0.000	11.500
600	0.500	-0.228	0.272	0.000	0	0.000	11.583
601	0.537	-0.234	0.303	0.000	0	0.000	11.667
600	0.537	-0.238	0.299	0.000	0	0.000	11.750
600	0.549	-0.240	0.309	0.000	0	0.000	11.833
601	0.559	-0.243	0.316	0.000	0	0.000	11.917
600	0.566	-0.249	0.317	0.000	0	0.000	12.000
601	0.493	-0.237	0.256	0.000	0	0.000	12.083
600	0.520	-0.243	0.277	0.000	0	0.000	12.167
600	0.524	-0.242	0.282	0.000	0	0.000	12.250
601	0.537	-0.245	0.292	0.000	0	0.000	12.333
600	0.542	-0.242	0.300	0.000	0	0.000	12.417
600	0.490	-0.233	0.257	0.000	0	0.000	12.500
601	0.514	-0.240	0.274	0.000	0	0.000	12.583
600	0.524	-0.241	0.283	0.000	0	0.000	12.667
601	0.535	-0.245	0.290	0.000	0	0.000	12.750
600	0.540	-0.244	0.296	0.000	0	0.000	12.833
600	0.511	-0.235	0.276	0.000	0	0.000	12.917
601	0.487	-0.236	0.251	0.000	0	0.000	13.000
600	0.516	-0.244	0.272	0.000	0	0.000	13.083
600	0.527	-0.247	0.280	0.000	0	0.000	13.167
601	0.529	-0.249	0.280	0.000	0	0.000	13.250
600	0.551	-0.250	0.301	0.000	0	0.000	13.333
600	0.565	-0.255	0.310	0.000	0	0.000	13.417
600	0.505	-0.237	0.268	0.000	0	0.000	13.500
601	0.524	-0.246	0.278	0.000	0	0.000	13.583
601	0.529	-0.252	0.277	0.000	0	0.000	13.667
600	0.545	-0.255	0.290	0.000	0	0.000	13.750
601	0.560	-0.262	0.298	0.000	0	0.000	13.833
601	0.565	-0.261	0.304	0.000	0	0.000	13.917
600	0.579	-0.268	0.311	0.000	0	0.000	14.000
600	0.544	-0.255	0.289	0.000	0	0.000	14.083
601	0.530	-0.254	0.276	0.000	0	0.000	14.167
600	0.518	-0.248	0.270	0.000	0	0.000	14.250
600	0.531	-0.253	0.278	0.000	0	0.000	14.333
601	0.532	-0.252	0.280	0.000	0	0.000	14.417
601	0.560	-0.256	0.304	0.000	0	0.000	14.500
600	0.506	-0.241	0.265	0.000	0	0.000	14.583
601	0.531	-0.249	0.282	0.000	0	0.000	14.667
600	0.543	-0.252	0.291	0.000	0	0.000	14.750
600	0.553	-0.258	0.295	0.000	0	0.000	14.833
601	0.558	-0.260	0.298	0.000	0	0.000	14.917
601	0.543	-0.258	0.285	0.000	0	0.000	15.000
600	0.553	-0.261	0.292	0.000	0	0.000	15.083
600	0.533	-0.257	0.276	0.000	0	0.000	15.167
601	0.524	-0.256	0.268	0.000	0	0.000	15.250
601	0.541	-0.256	0.285	0.000	0	0.000	15.333
600	0.555	-0.263	0.292	0.000	0	0.000	15.417
601	0.570	-0.268	0.302	0.000	0	0.000	15.500
601	0.573	-0.268	0.305	0.000	0	0.000	15.583
601	0.578	-0.270	0.308	0.000	0	0.000	15.667
600	0.556	-0.261	0.295	0.000	0	0.000	15.750
601	0.533	-0.259	0.274	0.000	0	0.000	15.833
601	0.548	-0.266	0.282	0.000	0	0.000	15.917
600	0.561	-0.268	0.293	0.000	0	0.000	16.000
601	0.559	-0.271	0.288	0.000	0	0.000	16.083
601	0.579	-0.275	0.304	0.000	0	0.000	16.167
600	0.558	-0.270	0.288	0.000	0	0.000	16.250
601	0.564	-0.271	0.293	0.000	0	0.000	16.333

600	0.569	-0.276	0.293	0.000	0	0.000	16.417
601	0.517	-0.258	0.259	0.000	0	0.000	16.500
601	0.509	-0.259	0.250	0.000	0	0.000	16.583
601	0.521	-0.263	0.258	0.000	0	0.000	16.667
601	0.545	-0.267	0.278	0.000	0	0.000	16.750
600	0.555	-0.272	0.283	0.000	0	0.000	16.833
600	0.569	-0.274	0.295	0.000	0	0.000	16.917
600	0.566	-0.277	0.289	0.000	0	0.000	17.000
601	0.577	-0.278	0.299	0.000	0	0.000	17.083
600	0.582	-0.281	0.301	0.000	0	0.000	17.167
600	0.587	-0.284	0.303	0.000	0	0.000	17.250
601	0.582	-0.283	0.299	0.000	0	0.000	17.333
601	0.489	-0.254	0.235	0.000	0	0.000	17.417
601	0.516	-0.264	0.252	0.000	0	0.000	17.500
600	0.520	-0.264	0.256	0.000	0	0.000	17.583
601	0.537	-0.273	0.264	0.000	0	0.000	17.667
601	0.538	-0.271	0.267	0.000	0	0.000	17.750
600	0.524	-0.268	0.256	0.000	0	0.000	17.833
601	0.511	-0.263	0.248	0.000	0	0.000	17.917
601	0.529	-0.273	0.256	0.000	0	0.000	18.000
600	0.548	-0.277	0.271	0.000	0	0.000	18.083
601	0.536	-0.281	0.255	0.000	0	0.000	18.167
601	0.549	-0.281	0.268	0.000	0	0.000	18.250
600	0.553	-0.287	0.266	0.000	0	0.000	18.333
600	0.561	-0.290	0.271	0.000	0	0.000	18.417
601	0.524	-0.265	0.259	0.000	0	0.000	18.500
600	0.478	-0.261	0.217	0.000	0	0.000	18.583
600	0.474	-0.255	0.219	0.000	0	0.000	18.667
600	0.439	-0.249	0.190	0.000	0	0.000	18.750
601	0.468	-0.253	0.215	0.000	0	0.000	18.833
600	0.392	-0.237	0.155	0.000	0	0.000	18.917
600	0.418	-0.238	0.180	0.000	0	0.000	19.000
600	0.361	-0.232	0.129	0.000	0	0.000	19.083
601	0.363	-0.232	0.131	0.000	0	0.000	19.167
601	0.438	-0.246	0.192	0.000	0	0.000	19.250
600	0.447	-0.260	0.187	0.000	0	0.000	19.333
601	0.452	-0.256	0.196	0.000	0	0.000	19.417
600	0.458	-0.258	0.200	0.000	0	0.000	19.500
600	0.464	-0.265	0.199	0.000	0	0.000	19.583
601	0.470	-0.259	0.211	0.000	0	0.000	19.667
601	0.450	-0.258	0.192	0.000	0	0.000	19.750
600	0.468	-0.266	0.202	0.000	0	0.000	19.833
600	0.463	-0.264	0.199	0.000	0	0.000	19.917
601	0.473	-0.269	0.204	0.000	0	0.000	20.000
601	0.485	-0.271	0.214	0.000	0	0.000	20.083
600	0.459	-0.263	0.196	0.000	0	0.000	20.167
601	0.463	-0.266	0.197	0.000	0	0.000	20.250
600	0.472	-0.271	0.201	0.000	0	0.000	20.333
600	0.488	-0.285	0.203	0.000	0	0.000	20.417
601	0.501	-0.286	0.215	0.000	0	0.000	20.500
600	0.496	-0.289	0.207	0.000	0	0.000	20.583
601	0.485	-0.282	0.203	0.000	0	0.000	20.667
600	0.467	-0.276	0.191	0.000	0	0.000	20.750
600	0.352	-0.158	0.194	0.000	0	0.000	20.833
601	0.364	-0.159	0.205	0.000	0	0.000	20.917
600	0.354	-0.147	0.207	0.000	0	0.000	21.000
600	0.367	-0.164	0.203	0.000	0	0.000	21.083
601	0.383	-0.167	0.216	0.000	0	0.000	21.167
600	0.349	-0.137	0.212	0.000	0	0.000	21.250
600	0.343	-0.143	0.200	0.000	0	0.000	21.333
601	0.360	-0.157	0.203	0.000	0	0.000	21.417
600	0.346	-0.147	0.199	0.000	0	0.000	21.500
600	0.318	-0.119	0.199	0.000	0	0.000	21.583

601	0.356	-0.149	0.207	0.000	0	0.000	21.667
600	0.319	-0.116	0.203	0.000	0	0.000	21.750
601	0.341	-0.144	0.197	0.000	0	0.000	21.833
599	0.319	-0.161	0.158	0.000	0	0.000	21.917
601	0.314	-0.151	0.163	0.000	0	0.000	22.000
600	0.321	-0.135	0.186	0.000	0	0.000	22.083
600	0.311	-0.122	0.189	0.000	0	0.000	22.167

Appendix C - MSDS

Material Safety Data Sheet

SODIUM HYDROXIDE, pellets, p.a.

ACC# 95584

Section 1 - Chemical Product and Company Identification

MSDS Name: Sodium hydroxide, pellets, p.a.

Catalog Numbers: AC206060000, AC206060010, AC206060025, NC9561832

Synonyms: Caustic soda; Soda lye; Sodium hydrate; Lye.

Company Identification:

Fisher Scientific
1 Reagent Lane
Fair Lawn, NJ 07410

For information, call: 201-796-7100

Emergency Number: 201-796-7100

For CHEMTREC assistance, call: 800-424-9300

For International CHEMTREC assistance, call: 703-527-3887

Section 2 - Composition, Information on Ingredients

CAS#	Chemical Name	Percent	EINECS/ELINCS
1310-73-2	Sodium hydroxide	>98	215-185-5

Section 3 - Hazards Identification

EMERGENCY OVERVIEW

Appearance: white solid.

Danger! Causes eye and skin burns. May cause severe respiratory tract irritation with possible burns. May cause severe digestive tract irritation with possible burns. Hygroscopic (absorbs moisture from the air).

Target Organs: Eyes, skin, mucous membranes.

Potential Health Effects

Eye: Causes eye burns. May cause chemical conjunctivitis and corneal damage.

Skin: Causes skin burns. May cause deep, penetrating ulcers of the skin. May cause

skin rash (in milder cases), and cold and clammy skin with cyanosis or pale color.

Ingestion: May cause severe and permanent damage to the digestive tract. Causes gastrointestinal tract burns. May cause perforation of the digestive tract. Causes severe pain, nausea, vomiting, diarrhea, and shock. May cause corrosion and permanent tissue destruction of the esophagus and digestive tract. May cause systemic effects.

Inhalation: Irritation may lead to chemical pneumonitis and pulmonary edema. Causes severe irritation of upper respiratory tract with coughing, burns, breathing difficulty, and possible coma. Causes chemical burns to the respiratory tract.

Chronic: Prolonged or repeated skin contact may cause dermatitis. Effects may be delayed.

Section 4 - First Aid Measures

Eyes: In case of contact, immediately flush eyes with plenty of water for at least 15 minutes. Get medical aid immediately.

Skin: In case of contact, immediately flush skin with plenty of water for at least 15 minutes while removing contaminated clothing and shoes. Get medical aid immediately. Wash clothing before reuse.

Ingestion: If swallowed, do NOT induce vomiting. Get medical aid immediately. If victim is fully conscious, give a cupful of water. Never give anything by mouth to an unconscious person.

Inhalation: If inhaled, remove to fresh air. If not breathing, give artificial respiration. If breathing is difficult, give oxygen. Get medical aid.

Notes to Physician: Treat symptomatically and supportively.

Section 5 - Fire Fighting Measures

General Information: As in any fire, wear a self-contained breathing apparatus in pressure-demand, MSHA/NIOSH (approved or equivalent), and full protective gear. Use water spray to keep fire-exposed containers cool. Use water with caution and in flooding amounts. Contact with moisture or water may generate sufficient heat to ignite nearby combustible materials. Contact with metals may evolve flammable hydrogen gas.

Extinguishing Media: Substance is noncombustible; use agent most appropriate to extinguish surrounding fire. Do NOT get water inside containers.

Flash Point: Not applicable.

Autoignition Temperature: Not applicable.

Explosion Limits, Lower: Not available.

Upper: Not available.

NFPA Rating: (estimated) Health: 3; Flammability: 0; Instability: 1

Section 6 - Accidental Release Measures

General Information: Use proper personal protective equipment as indicated in Section 8.

Spills/Leaks: Vacuum or sweep up material and place into a suitable disposal container. Avoid runoff into storm sewers and ditches which lead to waterways. Clean up spills immediately, observing precautions in the Protective Equipment section. Avoid generating dusty conditions. Provide ventilation. Do not get water on spilled substances or inside containers.

Section 7 - Handling and Storage

Handling: Wash thoroughly after handling. Do not allow water to get into the container because of violent reaction. Minimize dust generation and accumulation. Do not get in eyes, on skin, or on clothing. Keep container tightly closed. Avoid ingestion and inhalation. Discard contaminated shoes. Use only with adequate ventilation.

Storage: Store in a tightly closed container. Store in a cool, dry, well-ventilated area away from incompatible substances. Keep away from metals. Corrosives area. Keep away from acids. Store protected from moisture. Containers must be tightly closed to prevent the conversion of NaOH to sodium carbonate by the CO₂ in air.

Section 8 - Exposure Controls, Personal Protection

Engineering Controls: Facilities storing or utilizing this material should be equipped with an eyewash facility and a safety shower. Use adequate general or local exhaust ventilation to keep airborne concentrations below the permissible exposure limits.

Exposure Limits

Chemical Name	ACGIH	NIOSH	OSHA - Final PELs
Sodium hydroxide	2 mg/m ³ Ceiling	10 mg/m ³ IDLH	2 mg/m ³ TWA

OSHA Vacated PELs: Sodium hydroxide: No OSHA Vacated PELs are listed for this chemical.

Personal Protective Equipment

Eyes: Wear chemical splash goggles.

Skin: Wear appropriate protective gloves to prevent skin exposure.

Clothing: Wear appropriate protective clothing to prevent skin exposure.

Respirators: A respiratory protection program that meets OSHA's 29 CFR 1910.134 and ANSI Z88.2 requirements or European Standard EN 149 must be followed whenever workplace conditions warrant respirator use.

Section 9 - Physical and Chemical Properties

Physical State: Solid

Appearance: white

Odor: Odorless

pH: 14 (5% aq soln)

Vapor Pressure: 1 mm Hg @739 deg C

Vapor Density: Not available.

Evaporation Rate:Not available.

Viscosity: Not available.

Boiling Point: 1390 deg C @ 760 mm Hg

Freezing/Melting Point:318 deg C

Decomposition Temperature:Not available.

Solubility: Soluble.

Specific Gravity/Density:2.13 g/cm³

Molecular Formula:NaOH

Molecular Weight:40.00

Section 10 - Stability and Reactivity

Chemical Stability: Stable at room temperature in closed containers under normal storage and handling conditions.

Conditions to Avoid: Moisture, contact with water, exposure to moist air or water, prolonged exposure to air.

Incompatibilities with Other Materials: Water, metals, acids, aluminum, zinc, tin, nitromethane, leather, flammable liquids, organic halogens, wool.

Hazardous Decomposition Products: Toxic fumes of sodium oxide.

Hazardous Polymerization: Will not occur.

Section 11 - Toxicological Information

RTECS#:

CAS# 1310-73-2: WB4900000

LD50/LC50:

CAS# 1310-73-2:

Draize test, rabbit, eye: 400 ug Mild;

Draize test, rabbit, eye: 1% Severe;

Draize test, rabbit, eye: 50 ug/24H Severe;

Draize test, rabbit, eye: 1 mg/24H Severe;

Draize test, rabbit, skin: 500 mg/24H Severe;

Carcinogenicity:

CAS# 1310-73-2: Not listed by ACGIH, IARC, NTP, or CA Prop 65.

Epidemiology: No information found

Teratogenicity: No information found

Reproductive Effects: No information found

Mutagenicity: See actual entry in RTECS for complete information.

Neurotoxicity: No information found

Other Studies:

Section 12 - Ecological Information

No information available.

Section 13 - Disposal Considerations

Chemical waste generators must determine whether a discarded chemical is classified as a hazardous waste. US EPA guidelines for the classification determination are listed in 40 CFR Parts 261.3. Additionally, waste generators must consult state and local hazardous waste regulations to ensure complete and accurate classification.

RCRA P-Series: None listed.

RCRA U-Series: None listed.

Section 14 - Transport Information

	US DOT	Canada TDG
Shipping Name:	SODIUM HYDROXIDE, SOLID	SODIUM HYDROXIDE SOLID
Hazard Class:	8	8
UN Number:	UN1823	UN1823
Packing Group:	II	II

Section 15 - Regulatory Information

US FEDERAL

TSCA

CAS# 1310-73-2 is listed on the TSCA inventory.

Health & Safety Reporting List

None of the chemicals are on the Health & Safety Reporting List.

Chemical Test Rules

None of the chemicals in this product are under a Chemical Test Rule.

Section 12b

None of the chemicals are listed under TSCA Section 12b.

TSCA Significant New Use Rule

None of the chemicals in this material have a SNUR under TSCA.

CERCLA Hazardous Substances and corresponding RQs

CAS# 1310-73-2: 1000 lb final RQ; 454 kg final RQ

SARA Section 302 Extremely Hazardous Substances

None of the chemicals in this product have a TPQ.

SARA Codes

CAS # 1310-73-2: immediate, reactive.

Section 313 No chemicals are reportable under Section 313.

Clean Air Act:

This material does not contain any hazardous air pollutants.

This material does not contain any Class 1 Ozone depleters.

This material does not contain any Class 2 Ozone depleters.

Clean Water Act:

CAS# 1310-73-2 is listed as a Hazardous Substance under the CWA.

None of the chemicals in this product are listed as Priority Pollutants under the CWA.

None of the chemicals in this product are listed as Toxic Pollutants under the CWA.

OSHA:

None of the chemicals in this product are considered highly hazardous by OSHA.

STATE

CAS# 1310-73-2 can be found on the following state right to know lists:
California, New Jersey, Pennsylvania, Minnesota, Massachusetts.

California Prop 65

California No Significant Risk Level: None of the chemicals in this product are listed.

European/International Regulations**European Labeling in Accordance with EC Directives****Hazard Symbols:**

C

Risk Phrases:

R 35 Causes severe burns.

Safety Phrases:

S 26 In case of contact with eyes, rinse immediately with plenty of water and seek medical advice.

S 37/39 Wear suitable gloves and eye/face protection.

S 45 In case of accident or if you feel unwell, seek medical advice immediately (show the label where possible).

WGK (Water Danger/Protection)

CAS# 1310-73-2: 1

Canada - DSL/NDSL

CAS# 1310-73-2 is listed on Canada's DSL List.

Canada - WHMIS

This product has a WHMIS classification of E.

This product has been classified in accordance with the hazard criteria of the Controlled Products Regulations and the MSDS contains all of the information required by those regulations.

Canadian Ingredient Disclosure List

CAS# 1310-73-2 is listed on the Canadian Ingredient Disclosure List.

Section 16 - Additional Information**MSDS Creation Date:** 12/12/1997**Revision #8 Date:** 3/04/2004

Material Safety Data Sheet

SODIUM CARBONATE

ACC# 21080

Section 1 - Chemical Product and Company Identification**MSDS Name:** Sodium carbonate

Catalog Numbers: AC123670000, AC123670010, AC123670025, AC206800000, AC206800010, AC206800025, AC207760000, AC207765000, AC207810000, AC207810010, AC424280000, AC424285000, S71987, S71987-1, S73074, S73075, S78416, S78419, S93359, S93360, BP357-1, NC9296359, NC9644731, S261-10, S263-1, S263-10, S263-3, S263-50, S263-500, S263-50LC, S495-500, XXS263PD140KG

Synonyms: Crystal carbonate; Disodium carbonate; Sal soda; Soda ash; Washing soda; Soda, calcined.

Company Identification:

Fisher Scientific
1 Reagent Lane
Fair Lawn, NJ 07410

For information, call: 201-796-7100**Emergency Number:** 201-796-7100**For CHEMTREC assistance, call:** 800-424-9300**For International CHEMTREC assistance, call:** 703-527-3887**Section 2 - Composition, Information on Ingredients**

CAS#	Chemical Name	Percent	EINECS/ELINCS
497-19-8	Sodium carbonate anhydrous	100	207-838-8

Section 3 - Hazards Identification

EMERGENCY OVERVIEW

Appearance: white powder.

Warning! Harmful if inhaled. May cause eye and skin irritation with possible burns. May cause respiratory tract irritation. Hygroscopic (absorbs moisture from the air).

Target Organs: Eyes, skin.

Potential Health Effects

Eye: May result in corneal injury. Contact with eyes may cause severe irritation, and possible eye burns.

Skin: Contact with skin causes irritation and possible burns, especially if the skin is wet or moist.

Ingestion: May cause irritation of the digestive tract.

Inhalation: Harmful if inhaled. May cause irritation of the respiratory tract with burning pain in the nose and throat, coughing, wheezing, shortness of breath and pulmonary edema.

Chronic: Prolonged or repeated inhalation may cause nosebleeds, nasal congestion, erosion of the teeth, perforation of the nasal septum, chest pain and bronchitis.

Section 4 - First Aid Measures

Eyes: Immediately flush eyes with plenty of water for at least 15 minutes, occasionally lifting the upper and lower eyelids. Get medical aid immediately.

Skin: Get medical aid. Flush skin with plenty of water for at least 15 minutes while removing contaminated clothing and shoes. Wash clothing before reuse.

Ingestion: Do not induce vomiting. If victim is conscious and alert, give 2-4 cupfuls of milk or water. Never give anything by mouth to an unconscious person. Get medical aid immediately.

Inhalation: Remove from exposure and move to fresh air immediately. If not breathing, give artificial respiration. If breathing is difficult, give oxygen. Get medical aid if cough or other symptoms appear.

Notes to Physician: Treat symptomatically and supportively.

Section 5 - Fire Fighting Measures

General Information: As in any fire, wear a self-contained breathing apparatus in pressure-demand, MSHA/NIOSH (approved or equivalent), and full protective gear. Runoff from fire control or dilution water may cause pollution.

Extinguishing Media: Substance is noncombustible; use agent most appropriate to extinguish surrounding fire.

Flash Point: Not applicable.

Autoignition Temperature: Not available.

Explosion Limits, Lower: Not available.

Upper: Not available.

NFPA Rating: (estimated) Health: 2; Flammability: 0; Instability: 0

Section 6 - Accidental Release Measures

General Information: Use proper personal protective equipment as indicated in Section 8.

Spills/Leaks: Vacuum or sweep up material and place into a suitable disposal container. Clean up spills immediately, observing precautions in the Protective Equipment section. Avoid generating dusty conditions. Provide ventilation.

Section 7 - Handling and Storage

Handling: Wash thoroughly after handling. Remove contaminated clothing and wash before reuse. Use with adequate ventilation. Minimize dust generation and accumulation. Do not get in eyes, on skin, or on clothing. Keep container tightly closed. Avoid ingestion and inhalation.

Storage: Store in a tightly closed container. Store in a cool, dry, well-ventilated area away from incompatible substances.

Section 8 - Exposure Controls, Personal Protection

Engineering Controls: Good general ventilation should be sufficient to control airborne levels. Facilities storing or utilizing this material should be equipped with an eyewash facility and a safety shower.

Exposure Limits

Chemical Name	ACGIH	NIOSH	OSHA - Final PELs
Sodium carbonate anhydrous	none listed	none listed	none listed

OSHA Vacated PELs: Sodium carbonate anhydrous: No OSHA Vacated PELs are listed for this chemical.

Personal Protective Equipment

Eyes: Wear appropriate protective eyeglasses or chemical safety goggles as described by OSHA's eye and face protection regulations in 29 CFR 1910.133 or European Standard EN166.

Skin: Wear appropriate protective gloves and clothing to prevent skin exposure.

Clothing: Wear appropriate protective clothing to minimize contact with skin.

Respirators: Follow the OSHA respirator regulations found in 29 CFR 1910.134 or European Standard EN 149. Use a NIOSH/MSHA or European Standard EN 149 approved respirator if exposure limits are exceeded or if irritation or other symptoms are experienced.

Section 9 - Physical and Chemical Properties

Physical State: Powder

Appearance: white

Odor: odorless

pH: 11.6 (solution)

Vapor Pressure: Not available.

Vapor Density: Not available.

Evaporation Rate: Not available.

Viscosity: Not available.

Boiling Point: 1600 deg C

Freezing/Melting Point: 851 deg C

Decomposition Temperature: 400 deg C

Solubility: Soluble.

Specific Gravity/Density: 2.53

Molecular Formula: Na₂CO₃

Molecular Weight: 105.99

Section 10 - Stability and Reactivity

Chemical Stability: Stable at room temperature in closed containers under normal storage and handling conditions. Decomposed by acids with effervescence, evolution of carbon dioxide.

Conditions to Avoid: Dust generation, excess heat, moist air.

Incompatibilities with Other Materials: Reacts explosively with red-hot aluminum metal. Incompatible with ammonia + silver nitrate, 2,4-dinitrotoluene, 2,4,6-trinitrotoluene, sulfuric acid, sodium sulfide + water, lithium, phosphorus pentoxide, fluorine, and hydrogen peroxide. Hot concentrated solutions of sodium carbonate are mildly corrosive to steel.

Hazardous Decomposition Products: Carbon dioxide, toxic fumes of sodium

oxide.

Hazardous Polymerization: Has not been reported.

Section 11 - Toxicological Information

RTECS#:

CAS# 497-19-8: VZ4050000

LD50/LC50:

CAS# 497-19-8:

Draize test, rabbit, eye: 100 mg/24H Moderate;

Draize test, rabbit, eye: 50 mg Severe;

Draize test, rabbit, skin: 500 mg/24H Mild;

Inhalation, mouse: LC50 = 1200 mg/m³/2H;

Inhalation, rat: LC50 = 2300 mg/m³/2H;

Oral, mouse: LD50 = 6600 mg/kg;

Oral, mouse: LD50 = 6600 mg/kg;

Oral, rat: LD50 = 4090 mg/kg;

Carcinogenicity:

CAS# 497-19-8: Not listed by ACGIH, IARC, NTP, or CA Prop 65.

Epidemiology: No information found

Teratogenicity: No information found

Reproductive Effects: No information found

Mutagenicity: No information found

Neurotoxicity: No information found

Other Studies:

Section 12 - Ecological Information

Ecotoxicity: Fish: Bluegill/Sunfish: LC50 = 320 mg/L; 96 Hr.; Static Conditions

Section 13 - Disposal Considerations

Chemical waste generators must determine whether a discarded chemical is classified as a hazardous waste. US EPA guidelines for the classification determination are listed in 40 CFR Parts 261.3. Additionally, waste generators must consult state and local hazardous waste regulations to ensure complete and accurate classification.

RCRA P-Series: None listed.

RCRA U-Series: None listed.

Section 14 - Transport Information

	US DOT	Canada TDG
Shipping Name:	Not regulated	Not Regulated
Hazard Class:		
UN Number:		
Packing Group:		

Section 15 - Regulatory Information

US FEDERAL

TSCA

CAS# 497-19-8 is listed on the TSCA inventory.

Health & Safety Reporting List

None of the chemicals are on the Health & Safety Reporting List.

Chemical Test Rules

None of the chemicals in this product are under a Chemical Test Rule.

Section 12b

None of the chemicals are listed under TSCA Section 12b.

TSCA Significant New Use Rule

None of the chemicals in this material have a SNUR under TSCA.

CERCLA Hazardous Substances and corresponding RQs

None of the chemicals in this material have an RQ.

SARA Section 302 Extremely Hazardous Substances

None of the chemicals in this product have a TPQ.

SARA Codes

CAS # 497-19-8: immediate.

Section 313

No chemicals are reportable under Section 313.

Clean Air Act:

This material does not contain any hazardous air pollutants.

This material does not contain any Class 1 Ozone depleters.

This material does not contain any Class 2 Ozone depleters.

Clean Water Act:

None of the chemicals in this product are listed as Hazardous Substances under the CWA.

None of the chemicals in this product are listed as Priority Pollutants under the CWA.

None of the chemicals in this product are listed as Toxic Pollutants under the CWA.

OSHA:

None of the chemicals in this product are considered highly hazardous by OSHA.

STATE

CAS# 497-19-8 is not present on state lists from CA, PA, MN, MA, FL, or NJ.

California Prop 65

California No Significant Risk Level: None of the chemicals in this product are listed.

European/International Regulations

European Labeling in Accordance with EC Directives

Hazard Symbols:

XI

Risk Phrases:

R 36 Irritating to eyes.

Safety Phrases:

S 22 Do not breathe dust.

S 26 In case of contact with eyes, rinse immediately with plenty of water and seek medical advice.

WGK (Water Danger/Protection)

CAS# 497-19-8: 1

Canada - DSL/NDSL

CAS# 497-19-8 is listed on Canada's DSL List.

Canada - WHMIS

This product has a WHMIS classification of D2B.

This product has been classified in accordance with the hazard criteria of the Controlled Products Regulations and the MSDS contains all of the information required by those regulations.

Canadian Ingredient Disclosure List

CAS# 497-19-8 is listed on the Canadian Ingredient Disclosure List.

Section 16 - Additional Information

MSDS Creation Date: 7/12/1999

Revision #3 Date: 3/07/2005

Material Safety Data Sheet

LITHIUM CARBONATE

ACC# 12880

Section 1 - Chemical Product and Company Identification

MSDS Name: Lithium Carbonate

Catalog Numbers: S80056, S93278, L119 500, L119-500, L119500

Synonyms: Carbonic Acid Dillithium Salt; Carbonic Acid Lithium Salt

Company Identification:

Fisher Scientific

1 Reagent Lane

Fair Lawn, NJ 07410

For information, call: 201-796-7100

Emergency Number: 201-796-7100

For CHEMTREC assistance, call: 800-424-9300

For International CHEMTREC assistance, call: 703-527-3887

Section 2 - Composition, Information on Ingredients

CAS#	Chemical Name	Percent	EINECS/ELINCS
554-13-2	Lithium carbonate	98.0	209-062-5

Section 3 - Hazards Identification

EMERGENCY OVERVIEW

Appearance: white solid.

Warning! May be harmful if swallowed. May cause eye and skin irritation. May cause respiratory and digestive tract irritation. May cause central nervous system effects. May cause kidney damage. May cause reproductive and fetal effects.

Target Organs: Kidneys, central nervous system.

Potential Health Effects

Eye: Causes eye irritation.

Skin: May cause skin irritation.

Ingestion: May cause gastrointestinal irritation with nausea, vomiting and diarrhea. May be harmful if swallowed.

Inhalation: May cause respiratory tract irritation.

Chronic: Chronic exposure to lithium salts may cause drowsiness, visual abnormalities, weakness, ringing in the ears, and muscle tremors.

Section 4 - First Aid Measures

Eyes: Immediately flush eyes with plenty of water for at least 15 minutes, occasionally lifting the upper and lower eyelids. Get medical aid.

Skin: Immediately flush skin with plenty of water for at least 15 minutes while removing contaminated clothing and shoes. Get medical aid if irritation develops or persists. Wash clothing before reuse.

Ingestion: If victim is conscious and alert, give 2-4 cupfuls of milk or water. Never give anything by mouth to an unconscious person. Get medical aid immediately.

Inhalation: Remove from exposure and move to fresh air immediately. If not breathing, give artificial respiration. If breathing is difficult, give oxygen. Get medical aid.

Notes to Physician: Treat symptomatically and supportively.

Section 5 - Fire Fighting Measures

General Information: As in any fire, wear a self-contained breathing apparatus in pressure-demand, MSHA/NIOSH (approved or equivalent), and full protective gear. Dusts at sufficient concentrations can form explosive mixtures with air. During a fire, irritating and highly toxic gases may be generated by thermal decomposition or combustion.

Extinguishing Media: For small fires, use water spray, dry chemical, carbon dioxide or chemical foam. For large fires, use dry chemical, carbon dioxide, alcohol-resistant foam, or water spray.

Flash Point: Not applicable.

Autoignition Temperature: Not available.

Explosion Limits, Lower: N/A

Upper: N/A

NFPA Rating: (estimated) Health: 1; Flammability: 0; Instability: 0

Section 6 - Accidental Release Measures

General Information: Use proper personal protective equipment as indicated in Section 8.

Spills/Leaks: Clean up spills immediately, observing precautions in the Protective Equipment section. Sweep up or absorb material, then place into a suitable clean, dry, closed container for disposal. Avoid generating dusty conditions. Provide ventilation.

Section 7 - Handling and Storage

Handling: Wash thoroughly after handling. Remove contaminated clothing and wash before reuse. Use with adequate ventilation. Minimize dust generation and accumulation. Avoid contact with eyes, skin, and clothing. Keep container tightly closed. Avoid ingestion and inhalation.

Storage: Store in a tightly closed container. Store in a cool, dry, well-ventilated area away from incompatible substances.

Section 8 - Exposure Controls, Personal Protection

Engineering Controls: Use adequate ventilation to keep airborne concentrations low.

Exposure Limits

Chemical Name	ACGIH	NIOSH	OSHA - Final PELs
Lithium carbonate	none listed	none listed	none listed

OSHA Vacated PELs: Lithium carbonate: No OSHA Vacated PELs are listed for this chemical.

Personal Protective Equipment

Eyes: Wear appropriate protective eyeglasses or chemical safety goggles as described by OSHA's eye and face protection regulations in 29 CFR 1910.133 or European Standard EN166.

Skin: Wear appropriate protective gloves to prevent skin exposure.

Clothing: Wear appropriate protective clothing to prevent skin exposure.

Respirators: Follow the OSHA respirator regulations found in 29 CFR 1910.134 or European Standard EN 149. Use a NIOSH/MSHA or European Standard EN 149 approved respirator if exposure limits are exceeded or if irritation or other symptoms are experienced.

Section 9 - Physical and Chemical Properties

Physical State: Solid

Appearance: white

Odor: none reported

pH: Not available.

Vapor Pressure: Negligible.

Vapor Density: Not available.

Evaporation Rate: Negligible.

Viscosity: Not available.

Boiling Point: 1310 deg C

Freezing/Melting Point: 618 deg C

Decomposition Temperature: 1310 deg C

Solubility: 1.5% in water.

Specific Gravity/Density: 2.1 (water=1)

Molecular Formula: Li₂CO₃

Molecular Weight: 73.8802

Section 10 - Stability and Reactivity

Chemical Stability: Stable under normal temperatures and pressures.

Conditions to Avoid: Incompatible materials.

Incompatibilities with Other Materials: Strong oxidizing agents, strong acids, fluorine.

Hazardous Decomposition Products: Carbon monoxide, carbon dioxide, oxides of lithium.

Hazardous Polymerization: Has not been reported.

Section 11 - Toxicological Information

RTECS#:

CAS# 554-13-2: OJ5800000

LD50/LC50:

CAS# 554-13-2:

Oral, mouse: LD50 = 531 mg/kg;

Oral, mouse: LD50 = 531 mg/kg;

Oral, rabbit: LD50 = 404 mg/kg;

Oral, rat: LD50 = 525 mg/kg;

Oral, rat: LD50 = 553 mg/kg;

Carcinogenicity:

CAS# 554-13-2: Not listed by ACGIH, IARC, NTP, or CA Prop 65.

Epidemiology: No information available.

Teratogenicity: No information available.

Reproductive Effects: No information available.

Mutagenicity: No information available.

Neurotoxicity: No information available.

Other Studies:

Section 12 - Ecological Information

Ecotoxicity: No data available. No information available.

Environmental: No information reported.

Physical: No information available.

Other: None.

Section 13 - Disposal Considerations

Chemical waste generators must determine whether a discarded chemical is classified as a hazardous waste. US EPA guidelines for the classification determination are listed in 40 CFR Parts 261.3. Additionally, waste generators must consult state and local hazardous waste regulations to ensure complete and accurate classification.

RCRA P-Series: None listed.

RCRA U-Series: None listed.

Section 14 - Transport Information

	US DOT	Canada TDG
Shipping Name:	Not regulated as a hazardous material	No information available.
Hazard Class:		
UN Number:		
Packing Group:		

Section 15 - Regulatory Information

US FEDERAL

TSCA

CAS# 554-13-2 is listed on the TSCA inventory.

Health & Safety Reporting List

None of the chemicals are on the Health & Safety Reporting List.

Chemical Test Rules

None of the chemicals in this product are under a Chemical Test Rule.

Section 12b

None of the chemicals are listed under TSCA Section 12b.

TSCA Significant New Use Rule

None of the chemicals in this material have a SNUR under TSCA.

CERCLA Hazardous Substances and corresponding RQs

None of the chemicals in this material have an RQ.

SARA Section 302 Extremely Hazardous Substances

None of the chemicals in this product have a TPQ.

SARA Codes

CAS # 554-13-2: delayed.

Section 313

This material contains Lithium carbonate (CAS# 554-13-2, 98.0%), which is subject to the reporting requirements of Section 313 of SARA Title III and 40 CFR Part 373.

Clean Air Act:

This material does not contain any hazardous air pollutants.

This material does not contain any Class 1 Ozone depleters.

This material does not contain any Class 2 Ozone depleters.

Clean Water Act:

None of the chemicals in this product are listed as Hazardous Substances under the CWA.

None of the chemicals in this product are listed as Priority Pollutants under the CWA.

None of the chemicals in this product are listed as Toxic Pollutants under the CWA.

OSHA:

None of the chemicals in this product are considered highly hazardous by OSHA.

STATE

CAS# 554-13-2 can be found on the following state right to know lists: New Jersey, Massachusetts.

California Prop 65

WARNING: This product contains Lithium carbonate, a chemical known to the state of California to cause developmental reproductive toxicity.

California No Significant Risk Level: None of the chemicals in this product are listed.

European/International Regulations**European Labeling in Accordance with EC Directives****Hazard Symbols:**

XN

Risk Phrases:

R 22 Harmful if swallowed.

R 36 Irritating to eyes.

Safety Phrases:**WGK (Water Danger/Protection)**

CAS# 554-13-2: 1

Canada - DSL/NDSL

CAS# 554-13-2 is listed on Canada's DSL List.

Canada - WHMIS

This product has a WHMIS classification of D2B.

This product has been classified in accordance with the hazard criteria of the Controlled Products Regulations and the MSDS contains all of the information required by those regulations.

Canadian Ingredient Disclosure List**Section 16 - Additional Information**

MSDS Creation Date: 4/24/1998

Revision #5 Date: 10/03/2005

Material Safety Data Sheet

LITHIUM HYDROXIDE ANHYDROUS

ACC# 12925

Section 1 - Chemical Product and Company Identification

MSDS Name: Lithium Hydroxide Anhydrous

Catalog Numbers: AC611545000, L128-500, ZZL1281519, ZZL1282019

Synonyms: Lithium Hydrate

Company Identification:

Fisher Scientific
1 Reagent Lane
Fair Lawn, NJ 07410

For information, call: 201-796-7100

Emergency Number: 201-796-7100

For CHEMTREC assistance, call: 800-424-9300

For International CHEMTREC assistance, call: 703-527-3887

Section 2 - Composition, Information on Ingredients

CAS#	Chemical Name	Percent	EINECS/ELINCS
1310-65-2	LITHIUM HYDROXIDE	>96	215-183-4
554-13-2	Lithium carbonate	3	209-062-5

Section 3 - Hazards Identification

EMERGENCY OVERVIEW

Appearance: colorless to white solid.

Danger! Corrosive. Causes burns by all exposure routes. Harmful if inhaled or swallowed. May cause central nervous system effects. May cause kidney damage. Air sensitive. Hygroscopic (absorbs moisture from the air).

Target Organs: Kidneys, central nervous system, respiratory system, eyes, skin.

Potential Health Effects

Eye: Causes severe eye burns. May cause chemical conjunctivitis and corneal damage.

Skin: Causes severe burns with delayed tissue destruction.

Ingestion: Harmful if swallowed. Causes gastrointestinal tract burns. May cause kidney damage. May cause corrosion and permanent tissue destruction of the esophagus and digestive tract. May cause tremors and convulsions. May cause nausea and vomiting. May cause burning sensations, coughing, wheezing, laryngitis, shortness of breath and headache.

Inhalation: Harmful if inhaled. Causes chemical burns to the respiratory tract. Inhalation may be fatal as a result of spasm, inflammation, edema of the larynx and bronchi, chemical pneumonitis and pulmonary edema. May cause burning sensation, coughing, wheezing, laryngitis, shortness of breath, headache, nausea, and vomiting.

Chronic: Repeated exposure may cause central nervous system damage. Effects may be delayed. Chronic ingestion may cause dizziness, ringing in the ears, visual disturbances, tremors, and mental confusion. Prolonged absorption may affect electrolyte balance and impair kidney function. Dehydration, weight loss, skin effects, and thyroid disturbances have been reported. May cause kidney damage.

Section 4 - First Aid Measures

Eyes: Get medical aid immediately. Do NOT allow victim to rub eyes or keep eyes closed. Extensive irrigation with water is required (at least 30 minutes).

Skin: Get medical aid immediately. Immediately flush skin with plenty of water for at least 15 minutes while removing contaminated clothing and shoes. Wash clothing before reuse. Destroy contaminated shoes.

Ingestion: Do not induce vomiting. If victim is conscious and alert, give 2-4 cupfuls of milk or water. Get medical aid immediately.

Inhalation: Get medical aid immediately. Remove from exposure and move to fresh air immediately. If breathing is difficult, give oxygen. Do NOT use mouth-to-mouth resuscitation. If breathing has ceased apply artificial respiration using oxygen and a suitable mechanical device such as a bag and a mask.

Notes to Physician: Treat symptomatically and supportively.

Section 5 - Fire Fighting Measures

General Information: As in any fire, wear a self-contained breathing apparatus in pressure-demand, MSHA/NIOSH (approved or equivalent), and full protective gear. During a fire, irritating and highly toxic gases may be generated by thermal decomposition or combustion. Wear appropriate protective clothing to prevent contact with skin and eyes. Wear a self-contained breathing apparatus (SCBA) to prevent contact with thermal decomposition products.

Extinguishing Media: In case of fire, use water, dry chemical, chemical foam, or alcohol-resistant foam.

Flash Point: Not available.

Autoignition Temperature: Not available.

Explosion Limits, Lower: Not available.

Upper: Not available.

NFPA Rating: (estimated) Health: 3; Flammability: 0; Instability: 1

Section 6 - Accidental Release Measures

General Information: Use proper personal protective equipment as indicated in Section 8.

Spills/Leaks: Vacuum or sweep up material and place into a suitable disposal container. Clean up spills immediately, observing precautions in the Protective Equipment section. Avoid generating dusty conditions. Provide ventilation.

Section 7 - Handling and Storage

Handling: Wash thoroughly after handling. Wash hands before eating. Minimize dust generation and accumulation. Do not get in eyes, on skin, or on clothing. Keep container tightly closed. Do not ingest or inhale. Use with adequate ventilation. Discard contaminated shoes.

Storage: Keep container closed when not in use. Keep under a nitrogen blanket. Corrosives area. Store protected from moisture.

Section 8 - Exposure Controls, Personal Protection

Engineering Controls: Facilities storing or utilizing this material should be equipped with an eyewash facility and a safety shower. Use adequate ventilation to keep airborne concentrations low.

Exposure Limits

Chemical Name	ACGIH	NIOSH	OSHA - Final PELs
LITHIUM HYDROXIDE	none listed	none listed	none listed
Lithium carbonate	none listed	none listed	none listed

OSHA Vacated PELs: LITHIUM HYDROXIDE: No OSHA Vacated PELs are listed for this chemical. Lithium carbonate: No OSHA Vacated PELs are listed for this chemical.

Personal Protective Equipment

Eyes: Wear appropriate protective eyeglasses or chemical safety goggles as described by OSHA's eye and face protection regulations in 29 CFR 1910.133 or European Standard EN166.

Skin: Wear appropriate protective gloves to prevent skin exposure.

Clothing: Wear appropriate protective clothing to minimize contact with skin.

Respirators: A respiratory protection program that meets OSHA's 29 CFR 1910.134 and ANSI Z88.2 requirements or European Standard EN 149 must be followed whenever workplace conditions warrant respirator use.

Section 9 - Physical and Chemical Properties

Physical State: Solid

Appearance: colorless to white

Odor: none reported

pH: 14 (1N sol.)

Vapor Pressure: Negligible.

Vapor Density: Not available.

Evaporation Rate: Negligible.

Viscosity: Not available.

Boiling Point: 1695 deg F

Freezing/Melting Point: 842 deg F

Decomposition Temperature: 1695 deg F

Solubility: Soluble in water.

Specific Gravity/Density: 2.5 (water=1)

Molecular Formula: LiOH

Molecular Weight: 23.9474

Section 10 - Stability and Reactivity

Chemical Stability: Absorbs carbon dioxide from the air. Air sensitive. Hygroscopic: absorbs moisture or water from the air.

Conditions to Avoid: Dust generation, exposure to moist air or water, heat.

Incompatibilities with Other Materials: Strong oxidizing agents, strong acids, aluminum, carbon dioxide, zinc, moisture.

Hazardous Decomposition Products: Oxides of lithium.

Hazardous Polymerization: Has not been reported

Section 11 - Toxicological Information

RTECS#:

CAS# 1310-65-2: OJ6307070

CAS# 554-13-2: OJ5800000

LD50/LC50:

CAS# 1310-65-2:

Inhalation, rat: LC50 = 960 mg/m³/4H;

Oral, mouse: LD50 = 363 mg/kg;

Oral, rat: LD50 = 210 mg/kg;

CAS# 554-13-2:

Oral, mouse: LD50 = 531 mg/kg;

Oral, mouse: LD50 = 531 mg/kg;

Oral, rabbit: LD50 = 404 mg/kg;

Oral, rat: LD50 = 525 mg/kg;

Oral, rat: LD50 = 553 mg/kg;

Carcinogenicity:

CAS# 1310-65-2: Not listed by ACGIH, IARC, NTP, or CA Prop 65.

CAS# 554-13-2: Not listed by ACGIH, IARC, NTP, or CA Prop 65.

Epidemiology: No information found

Teratogenicity: No information found

Reproductive Effects: No information found

Mutagenicity: No information found

Neurotoxicity: No information found

Other Studies:

Section 12 - Ecological Information

No information available.

Section 13 - Disposal Considerations

Chemical waste generators must determine whether a discarded chemical is classified as a hazardous waste. US EPA guidelines for the classification determination are listed in 40 CFR Parts 261.3. Additionally, waste generators must consult state and local hazardous waste regulations to ensure complete and accurate classification.

RCRA P-Series: None listed.

RCRA U-Series: None listed.

Section 14 - Transport Information

	US DOT	Canada TDG
Shipping Name:	LITHIUM HYDROXIDE	LITHIUM HYDROXIDE
Hazard Class:	8	8
UN Number:	UN2680	UN2680

Packing Group:	II	II
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Section 15 - Regulatory Information

US FEDERAL

TSCA

CAS# 1310-65-2 is listed on the TSCA inventory.

CAS# 554-13-2 is listed on the TSCA inventory.

Health & Safety Reporting List

None of the chemicals are on the Health & Safety Reporting List.

Chemical Test Rules

None of the chemicals in this product are under a Chemical Test Rule.

Section 12b

None of the chemicals are listed under TSCA Section 12b.

TSCA Significant New Use Rule

None of the chemicals in this material have a SNUR under TSCA.

CERCLA Hazardous Substances and corresponding RQs

None of the chemicals in this material have an RQ.

SARA Section 302 Extremely Hazardous Substances

None of the chemicals in this product have a TPQ.

SARA Codes

CAS # 1310-65-2: immediate, delayed.

CAS # 554-13-2: delayed.

Section 313

This material contains Lithium carbonate (CAS# 554-13-2, 3%), which is subject to the reporting requirements of Section 313 of SARA Title III and 40 CFR Part 373.

Clean Air Act:

This material does not contain any hazardous air pollutants.

This material does not contain any Class 1 Ozone depletors.

This material does not contain any Class 2 Ozone depletors.

Clean Water Act:

None of the chemicals in this product are listed as Hazardous Substances under the CWA.

None of the chemicals in this product are listed as Priority Pollutants under the CWA.

None of the chemicals in this product are listed as Toxic Pollutants under the CWA.

OSHA:

None of the chemicals in this product are considered highly hazardous by OSHA.

STATE

CAS# 1310-65-2 can be found on the following state right to know lists: Minnesota.

CAS# 554-13-2 can be found on the following state right to know lists: New Jersey, Massachusetts.

California Prop 65

WARNING: This product contains Lithium carbonate, a chemical known to the state of California to cause developmental reproductive toxicity.
California No Significant Risk Level: None of the chemicals in this product are listed.

European/International Regulations

European Labeling in Accordance with EC Directives

Hazard Symbols:

C

Risk Phrases:

R 20/22 Harmful by inhalation and if swallowed.
R 35 Causes severe burns.

Safety Phrases:

S 22 Do not breathe dust.
S 26 In case of contact with eyes, rinse immediately with plenty of water and seek medical advice.
S 36/37/39 Wear suitable protective clothing, gloves and eye/face protection.
S 45 In case of accident or if you feel unwell, seek medical advice immediately (show the label where possible).

WGK (Water Danger/Protection)

CAS# 1310-65-2: No information available.
CAS# 554-13-2: 1

Canada - DSL/NDSL

CAS# 1310-65-2 is listed on Canada's DSL List.
CAS# 554-13-2 is listed on Canada's DSL List.

Canada - WHMIS

This product has a WHMIS classification of D1B, E.
This product has been classified in accordance with the hazard criteria of the Controlled Products Regulations and the MSDS contains all of the information required by those regulations.

Canadian Ingredient Disclosure List

CAS# 1310-65-2 is listed on the Canadian Ingredient Disclosure List.

Section 16 - Additional Information

MSDS Creation Date: 9/02/1997

Revision #6 Date: 9/22/2004