THERMACORE

INC

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FINAL REPORT

SBIR PHASE I

NASCENT HYDROGEN: AN ENERGY SOURCE

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Nelson J. Gernert and Robert M. Shaubach

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780 Eden Road
Lancaster, PA 17601

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13. ABSTRACT *(Maximum 200 words)*

Anomalous heat was measured from a reaction of atomic hydrogen in contact with potassium carbonate on a nickel surface. The nickel surface consisted of 500 feet of 0.0625 inch diameter tubing wrapped in a coil. The coil was inserted into a pressure vessel containing a light water solution of potassium carbonate. The tubing and solution were heated to a steady state temperature of 249°C using an I^2R heater. Hydrogen at 1100 psig was applied to the inside of the tubing. After the application of hydrogen, a 32°C increase in temperature of the cell was measured which corresponds to 25 watts of heat. Heat production under these conditions is predicted by the theory of Mills where a new species of hydrogen is produced that has a lower energy state then normal hydrogen. ESCA analyses, done independently by Lehigh University, have found the predicted 55 eV signature of this new species of hydrogen. Work is continuing at Thermacore with internal funding to bring this technology to the marketplace.

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ACKNOWLEDGEMENT

This report documents the work of the Development Division of Thermacore, Inc. Mr. Nelson J. Gernert was the project engineer; Mr. Robert M. Shaubach assisted with technical and managerial direction; and Gregory K. Herr was the laboratory technician. Consultation engineering support was provided by Dr. Randell Mills and William Good of HydroCatalysis Power Corporation. The Wright-Patterson Air Force Base technical monitor(s) were Messrs Jeffrey R. Brown and Jerry Beam.

2.0 INTRODUCTION

It has been more than fifty years since a new source of thermal energy (nuclear fission) was brought into service. On March 23, 1989, two chemists, Stanley Pons and Martin Fleischmann, claimed to have experienced fusion, the energy source of the sun, by electrolysis in a test tube of water at room temperature. This process was called "Cold Fusion." Since then, thousands of scientists around the world have been attempting to explain and replicate this new source of thermal energy.

In April 1991, Dr. Randell Mills presented a theory and a power-producing electrolytic cell whose output was continuous, predictable and appreciably greater than the electrical input. The theory for the excess heat is described in a Mills and Kneizys paper[1] that was published in the April 1991 issue of Fusion Technology. According to the theory, the source of the heat is the "electrocatically induced reaction whereby hydrogen atoms undergo transitions to quantitized energy levels of lower energy than the conventional ground state. These lower energy states correspond to fractional quantum numbers." Excess heat is produced while making a new form of hydrogen which is completely different than the fusion reaction reported by Pons and Fleischmann. Dr. Mills named this new form of hydrogen "hydrino" which is latin for baby hydrogen. The hydrino is created in the electrolytic cell when atomic hydrogen comes in contact with potassium carbonate on a nickel cathode. This excess heat was confirmed by Thermacore and other researchers[2,3,4] that used the Mills' approach.

As research continued, Thermacore began moving away from the electrolytic approach and towards higher operating temperatures. Electrolytic cells are limited to the maximum operating temperature of 100°C, unless enclosed in a pressure vessel. Operating an electrolytic cell in a pressure vessel was not considered prudent due to the danger of explosion from the evolving mix of oxygen and hydrogen.

Operating at higher temperatures has advantages. For example, many chemical reactions are enhanced as temperature is increased thus more excess heat might be possible. Plus, exploring higher operating temperatures moves this technology in a direction that will most benefit the world in the form of environmentally safe electric power generation.

Thermacore, Inc., under IR&D funds, showed that the energy producing feature of these electrolytic cells can be achieved without the need for electrolysis. The nickel cathode of the Mills' electrolytic cell was replaced with a thin walled nickel tube containing high pressure

FIGURE 1a. NON-ELECTROLYTIC CELL

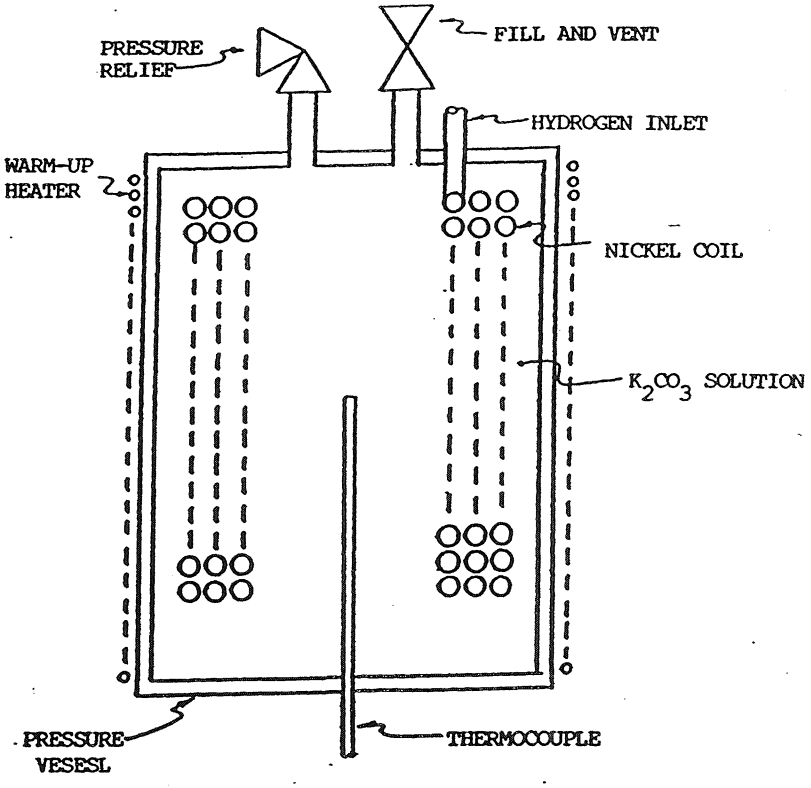
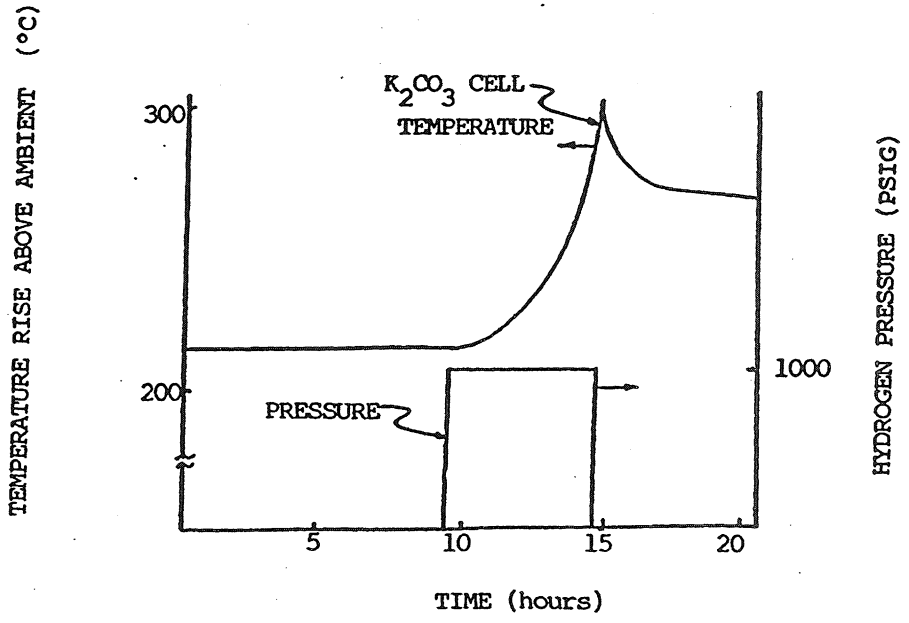


FIGURE 1b. NON-ELECTROLYTIC CELL RESPONSE TO HYDROGEN



3.0 CONCLUSIONS AND RECOMMENDATIONS

Excess heat energy was measured at an average level of 24.3 watts $\pm$ 6.4 watts. Our confidence to report excess heat comes as a result of repeated testing and reevaluation of the test procedures and that the shrunken hydrogen molecule has been identified by an independent university.

The electron of the hydrogen atom is predicted by Mills to transition to fractional energy levels releasing energy when contacting an energy sink resonant with the hydrogen energy released. The "ash" of the process is the "shrunken" hydrogen atom called a hydrino.

Lehigh University (Dr. A. Miller), Bethlehem, PA, using ESCA (Electron Spectroscopy for Chemical Analysis)[6] has found the hydrino molecule absorbed on the surface of nickel cathodes used in electrolysis of K_2CO_3. This work shows a peak near 55 eV which is predicted by Mill's to be the binding energy of the electron for a hydrino molecule. Lehigh's exhaustive evaluations have found no other explanation for this peak.

ESCA analyses were also done by Lehigh on samples of nickel tubing removed from coil #4[7]. The results of these analyses show the characteristic hydrino peak at 55 eV. This peak is shown in Figure 2, confirming that excess heat can be produced by diffusion of hydrogen through nickel contacting K_2CO_3 as well as by electrolysis. As a result of the work done by Lehigh University and Thermacore on this effort, we conclude that the Mills' theory is the likely explanation for the excess energy seen in the experiments done under this program.

Despite the considerable work conducted in this Phase I effort, the parameters that significantly enhance excess heat production remain unknown. Enhancement by at least a factor of 10 to 100 is required to make this technology feasible for commercial use. Much work remains as shown in Table 1; Thermacore is currently pursuing this work on internal funding.

The key to increasing excess heat production will probably be realized after obtaining a better understanding of the interactions between the potassium carbonate and the atomic hydrogen on or within the nickel surface. This interaction is related to the condition of the nickel material, orientation of the potassium carbonate molecule, and desorption of H_2 and the "shrunken" hydrogen from the nickel surface. Much of this understanding could be obtained experimentally by conducting numerous small scale tests varying a single parameter at a time. When an improvement is noted, extensive analysis of the surface should be conducted. This work will be recommended for the Phase II effort.

FIGURE 2. COMPARISON OF ESCA RESULTS FOR VIRGIN TUBING COMPARED TO TUBING FROM K_2CO_3 DIFFUSION CELL

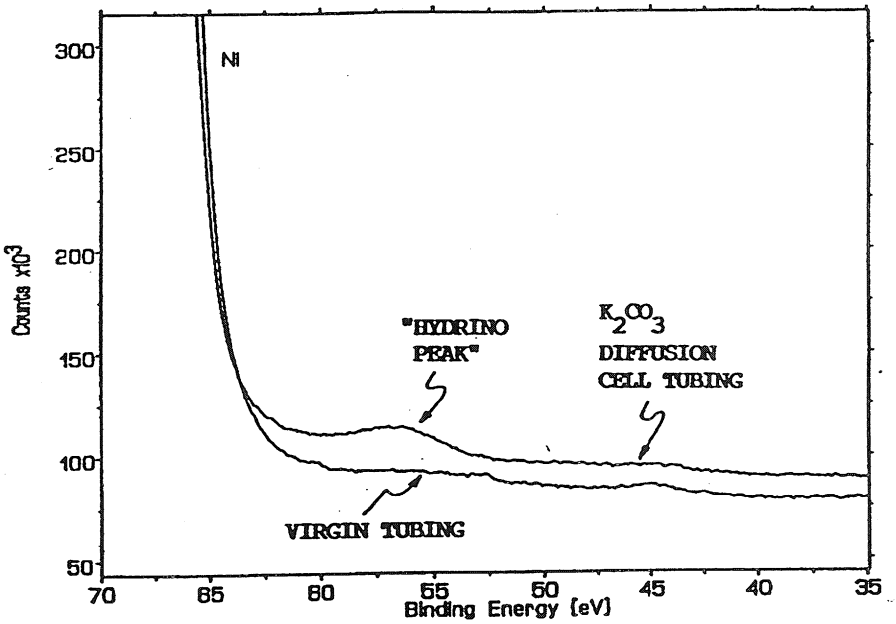


TABLE 1. Status of Investigation of Parameters in the Mills Process

PROCESS STEP	PARAMETER INVESTIGATED	UPCOMING TESTS*
Step 1: Adsorption of H_2 on inner diameter of the nickel tubing	General Cleaning, Oxide Layer	Investigate other oxides
Step 2: Disassociation of the hydrogen molecule into atomic species	none	none
Step 3: Diffusion of H_1 through the nickel tubing	Varied Hydrogen Pressure and Temperature	none
Step 4: Contact between atomic hydrogen and potassium carbonate	Loosely Wound Coil	none
Step 5: Transition the H_1 to a lower energy state	Cell Voltage,Nickel Temper,General Cleaning,Varied Electrolyte Concentrations	Conduct Extensive Analyses of Nickel Surface
Step 6: Recombination of H_1 into H_2	none	none
Step 7: Desorption of H_2 and the "shrunken" hydrogen from the nickel surface	Applied Vibrations	Stir or Ultrasonics

**Thermacore is continuing the test program with internal funding.*

4.0 TECHNICAL DISCUSSION

This section of the report documents the results of the work conducted in this Phase I program and it is divided into the following sections:

4.1 CELL DESIGN

4.2 CELL CALIBRATION

4.3 SCALING PARAMETERS

4.4 TEST RESULTS

4.5 EVALUATION OF TEST RESULTS

4.1 CELL DESIGN

The test cell consists of a five inch diameter Schedule 80 pressure vessel with removable cover plate, as shown in Figure 3. Specific information about the cell is listed in Table 2. An electric cartridge heater is used to raise the temperature of the apparatus to facilitate the permeation of hydrogen through the wall of the nickel tube. A thermocouple well is provided to allow insertion of a Type K thermocouple used to measure the temperature of the electrolyte in the vicinity of the coil of nickel tubing.

Heat is removed from the apparatus by conduction through a gas gap to a water cooled heat exchanger welded to the outside of the pressure vessel. The thermal conductivity of the gas gap is controlled by achieving the proper mixture of helium and argon purge gas. The objective is to provide a sufficient temperature difference between the electrolyte and cooling water to avoid boiling the cooling water. This will allow single phase measurement of the power removed from the cell. Figure 4 is a photograph of the completed cell. All interior and exterior surfaces were plated with electroless nickel to assure compatibility with the electrolyte. In preparation for calibration and testing, the cell was wrapped with 2" thick high temperature ceramic fiber insulation.

Five coils of nickel tubing were fabricated. Figure 5 is a photograph of a typical coil; coil details are provided in Table 3.

FIGURE 3. TEST CELL DESIGN

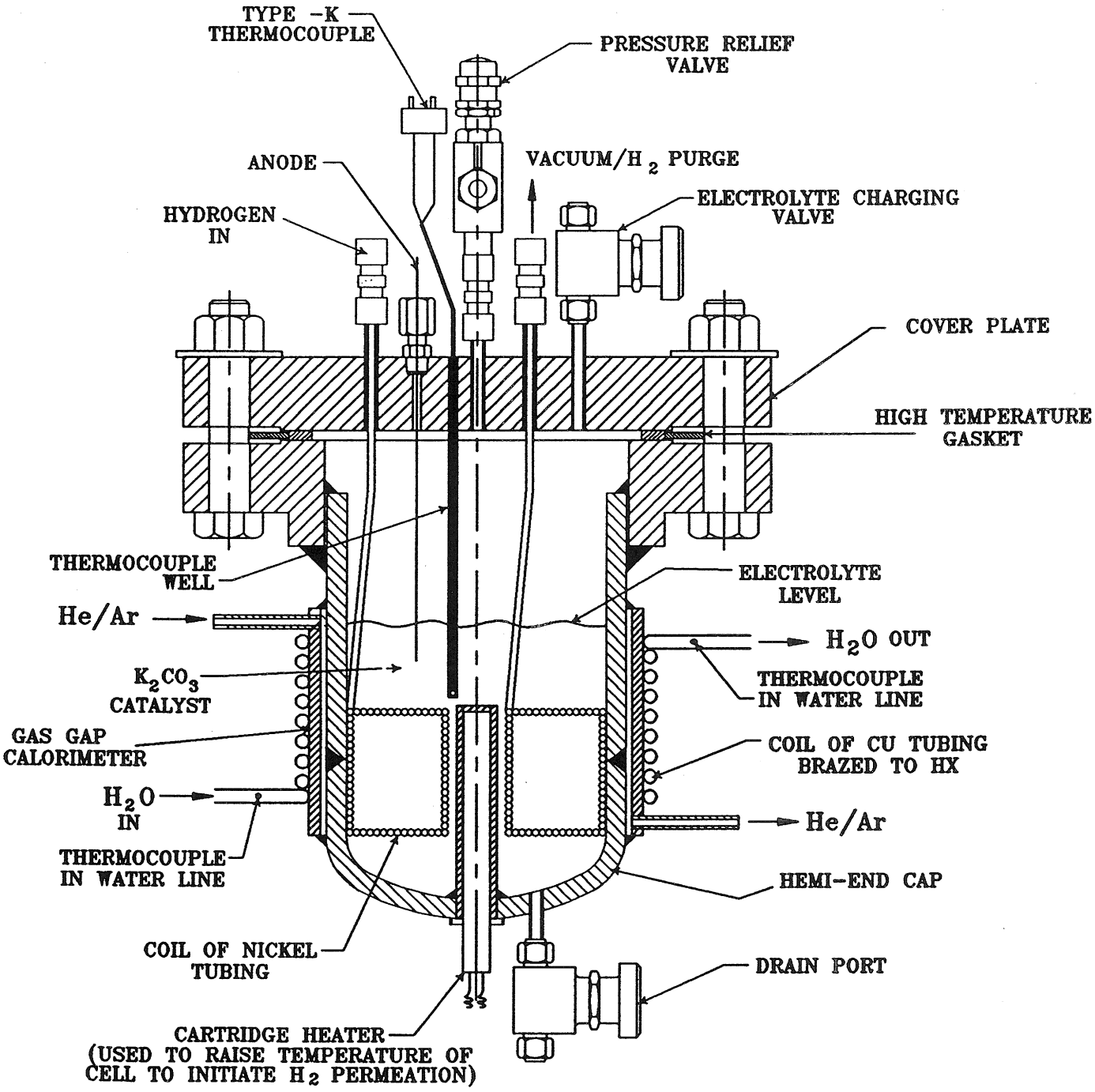


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TABLE 2. Test Cell Description

PARAMETER	MAGNITUDE
Flange and Cover Plate	300 lb
Diameter	13"
Thickness	1.5"
Material	Carbon Steel
Design	ANSI B36.2
Gasket	
Manufacturer	Flexitallic, Inc.
Model	Flexicarb-graphite/304 S.S. wound
Pressure Vessel	5" Schedule 80
Material	304 s.s.
Length	6"
Hemispherical Endcap	5" Schedule 80
Material	304 s.s.
Design	ANSI B36.19
Gas Gap Heat Exchanger	Copper Tubing Wrapped and Brazed to Shell of Gas Gap Calorimeter
Material	304 s.s.
Gap Width	0.07"
Length	5"
Voltage	220
Cartridge Heater	Watlow, Inc.
Power	750 W
Diameter	0.5"
Length	4"
Cell Internal Volume	2000 cc's
Anode Penetration	Conax Fitting
Part No.	MTG-24-A-2-L
Anode Material	0.02" diameter nickel wire
Thermocouple	0.0625" diameter, Type K, s.s. sheathed, Ungrounded

FIGURE 4. TEST CELL PHOTOGRAPH

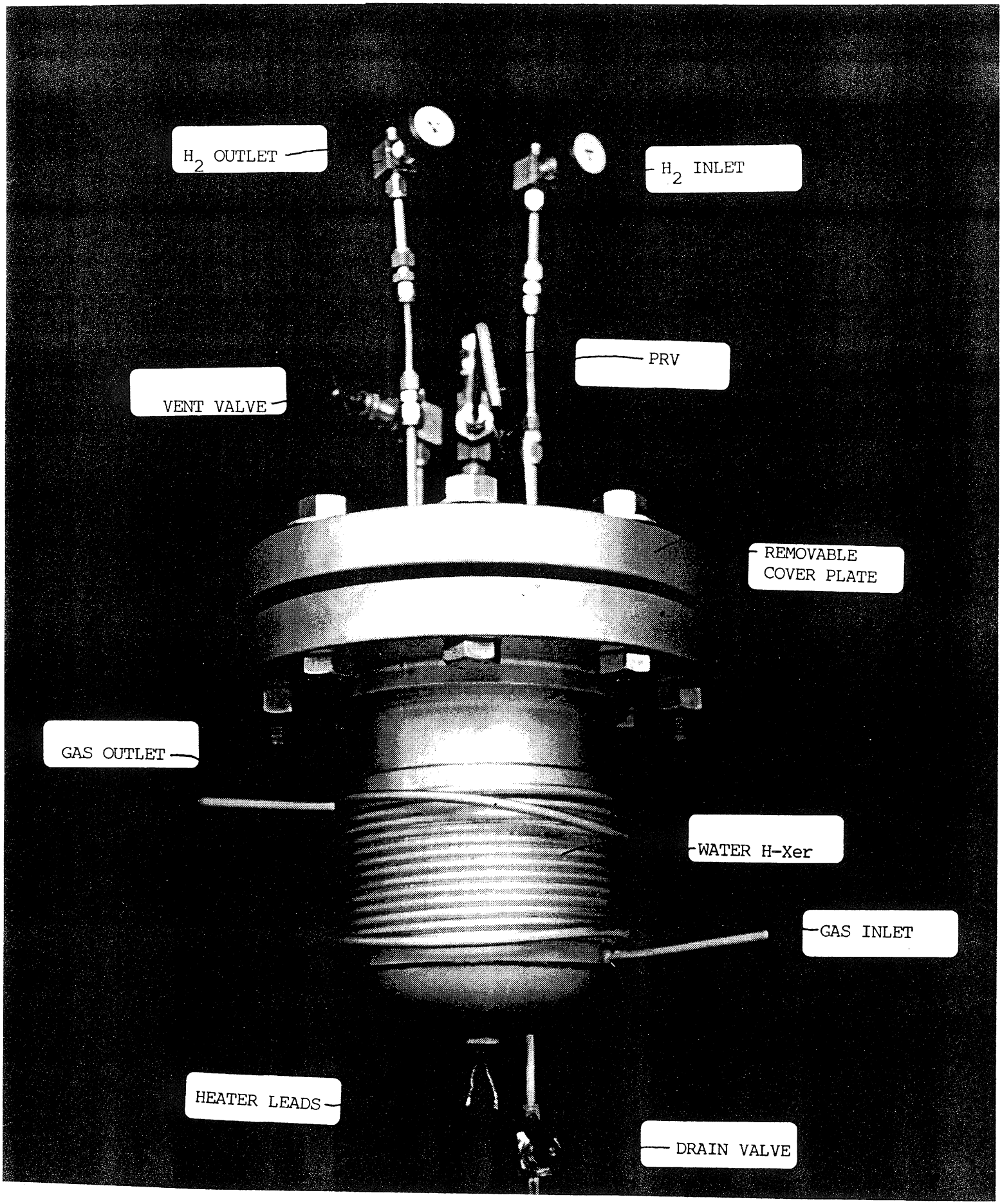


FIGURE 5. COIL OF NICKEL TUBING

(4" diameter x 5" long)

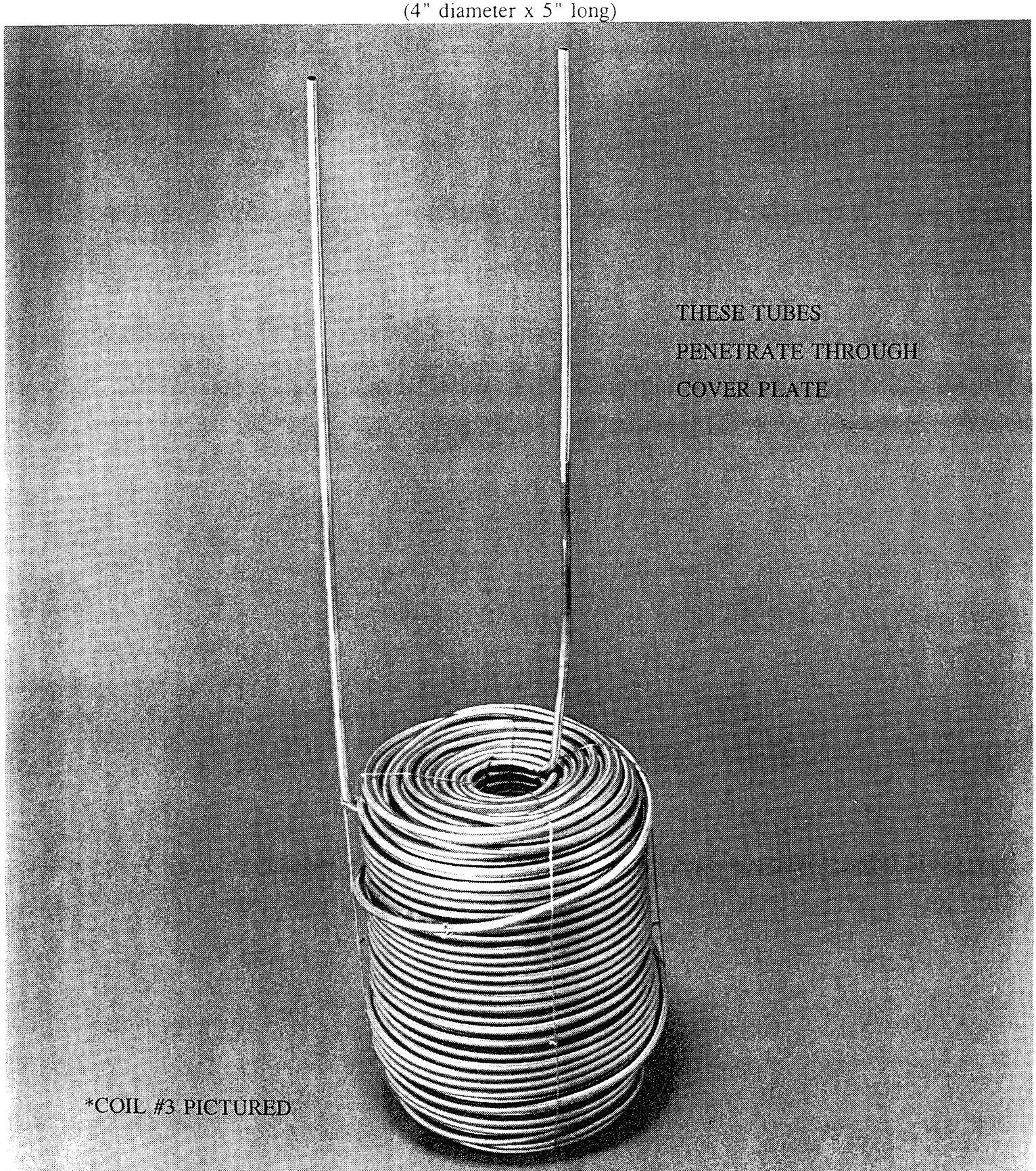


TABLE 3. Nickel Coil Information

COIL #	DESCRIPTION	PURCHASED FROM	HEAT #/STRENGTH INFORMATION	MISC. INFORMATION	COIL SIZE
1	250' of annealed nickel 200 tubing; 0.125" dia x .010" wall	The Micro Group, Inc. 7 Industrial Park Road Medway, MA 02053	Heat #: N82J8A Tensile: 71,800 psi Yield: 33,500 psi	Tube connections made using Nicrobraze 125.	3.5" dia x 6" long
2	250' of annealed nickel 200 tubing; 0.125" dia. x 0.010" wall	The Micro Group, Inc. 7 Industrial Park Road Medway, MA 02053	216 ft of Heat #: NOON8A 59 ft of Heat #: N82J8A Strength information: unavailable	Tube connections made using Nicrobraze 125.	4" dia x 5.25" long
3	250' of hard nickel 200 tubing; 0.125" dia. x 0.010" wall	Tube Methods, Inc. Rambo & Depot St. P.O. Box 460 Williamsport, PA	Heat #: 71746 Tensile: 101,100 psi Yield: 95,900 psi	Tube connections made using Nicrobraze 125.	4" dia. x 5 " long
4	500' of annealed nickel tubing; 0.0625" dia. x 0.010" wall	The Micro Group, Inc. 7 Industrial Park Road Medway, MA 02053	Heat #: N81K6AG Tensile: 71,700 psi Yield: not listed on cert.	Tube connections made using Nicrobraze 125. This material type was used in the original small non-electrolytic cell tested 12/92	3" dia x 5" long
5	500' of annealed nickel tubing; 0.0625" dia. x 0.010 wall	The Micro Group, Inc. 7 Industrial Park Road Medway, MA 02053	Heat #: N20N8A Tensile: 73,100 psi Yield: Not listed on cert.	Tube connections made using Nicrobraze 125.	4.5" dia. x 5" long

4.2 CELL CALIBRATION

Calibration of the cell was done both with and without water cooling. The selection of the particular calibration technique to be used is dependant upon the amount of excess heat to be detected. Each technique is described below.

4.2.1 Cell Calibration Without Water Cooling

In those instances were the excess heat is below 150 watts a calimetric technique without the use of water cooling is used. Cell calibration is done by measuring the cell's temperature rise above ambient as a function of input power. This calibration is done on a fully insulated cell with a coil submerged in K_2CO_3 without hydrogen applied to the inside of the tubing. Figure 6 is the calibration curve for the cell. With this information, any excess heat generated during an experiment is a direct function of the cell temperature and will be detected as follows:

Excess Heat = Heat Lost to Environment (determined using Figure 6) - Input Electrical Power

This technique is accurate within the limits of the instruments used to measure electrical power and temperature. Section 2.5 (Paragraph 3-Instrument Error) of this report shows the instruments to be accurate within 1%.

4.2.2 Calibration Using Water Cooling

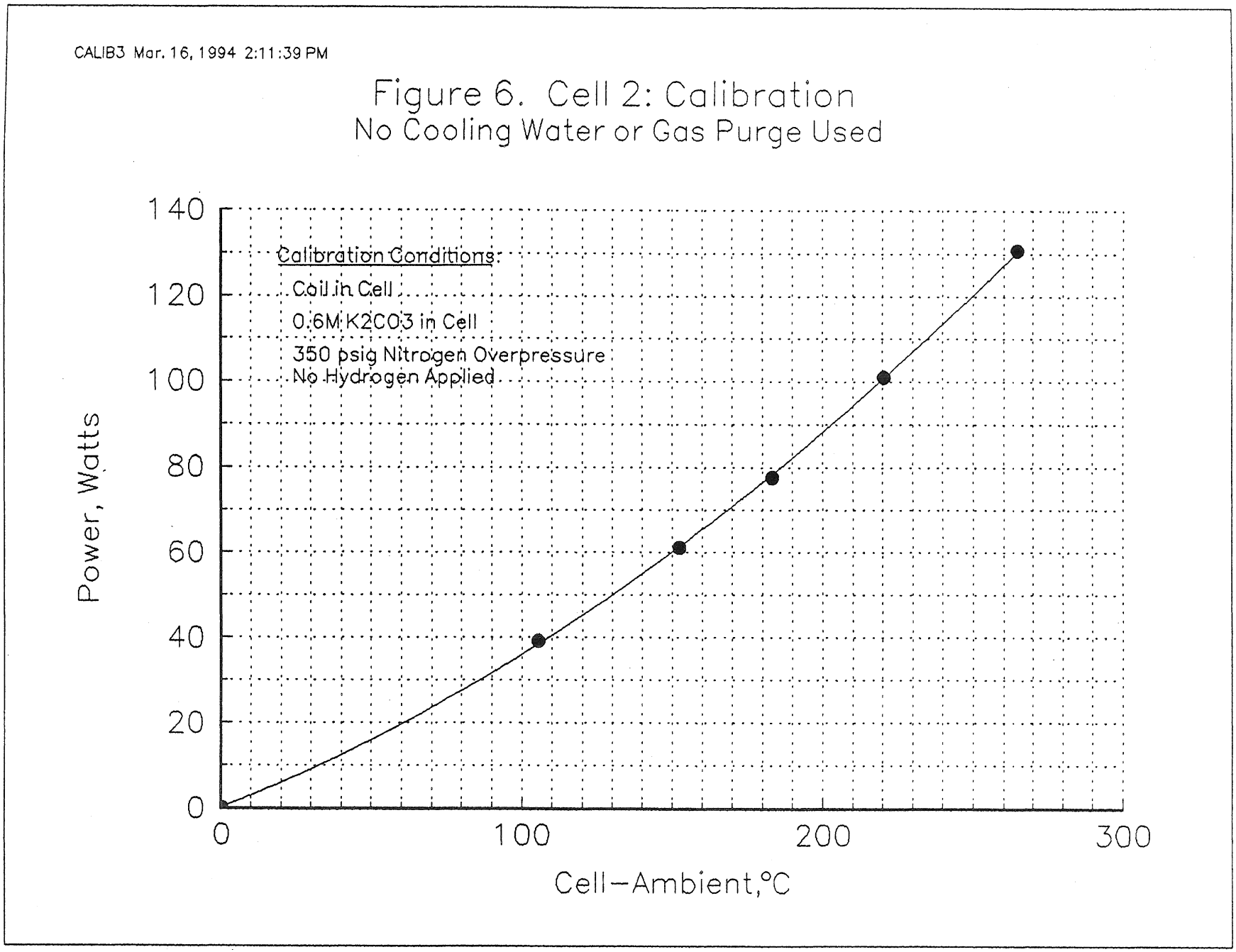
At power levels greater than 150W, water cooling of the cell is required to remove the heat and maintain the cell in the 200°C to 300°C range. Cell calibration was conducted on a fully insulated cell with nickel tubing submerged in 0.6 molar K_2CO_3 without hydrogen applied to the inside of the tubing. The calibration procedure determined the amount of heat lost to the environment as a function of cell temperature above ambient as follows:

Heat Lost to Environment = Input Electrical Power - Heat Removed by the Cooling Water

Where,

Input Electrical Power = Volts x Amperes

Water Power = $\dot{m}Cp\ \Delta T$


CALIB3 Mar. 16, 1994 2:11:39 PM
Figure 6. Cell 2: Calibration
No Cooling Water or Gas Purge Used
Calibration Conditions:
Coil in Cell
0.6M K2CO3 in Cell
350 psig Nitrogen Overpressure
No Hydrogen Applied
Power, Watts
0
20
40
60
80
100
120
140
0
100
200
300
Cell−Ambient,°C

Subtracting the heat removed by the water from the input power yields the heat loss from the cell. This heat loss includes the convective and radiative heat loss from the cell and the heat removed by the argon that is flowing at a constant rate in the gas gap. Figure 7 shows the heat loss calibration curve for the cell. With this information, any excess heat generated during an experiment is detected as follows:

Excess Heat = Heat Removed by the Water Cooling - Heat Lost to the Environment (determined using Figure 6) - Input Electrical Power

It is important to note that the water flow rate was not constant throughout the test; at some points during testing it fluctuated ± 25 cc's/minute. Ultimately, this fluctuation translates into a heat balance accuracy of ± 50 watts. This accuracy was considered reasonable at the start of the test since we expected to measure excess heat greater than 500 watts.

4.3 SCALING PARAMETERS

The overall heat generation process occurring in this cell is believed to involve the following steps:

Step 1: Absorption of the hydrogen molecule on the inner surface of the nickel tubing.

Step 2: Disassociation of the hydrogen molecule into atomic hydrogen.

Step 3: Diffusion of the atomic hydrogen through the nickel tubing.

Step 4: Contact between some of the atomic hydrogen and the potassium carbonate catalysis on the outer surface of the nickel.

Step 5: Transition to a lower energy state of the atomic hydrogen that contacts potassium carbonate. This hydrogen atom will release energy and be "shrunken" in size.

Step 6: Recombination of those hydrogen atoms that do not undergo the transition into molecular hydrogen.

Step 7: Desorption of molecular hydrogen and the "shrunken" hydrogen from the surface.

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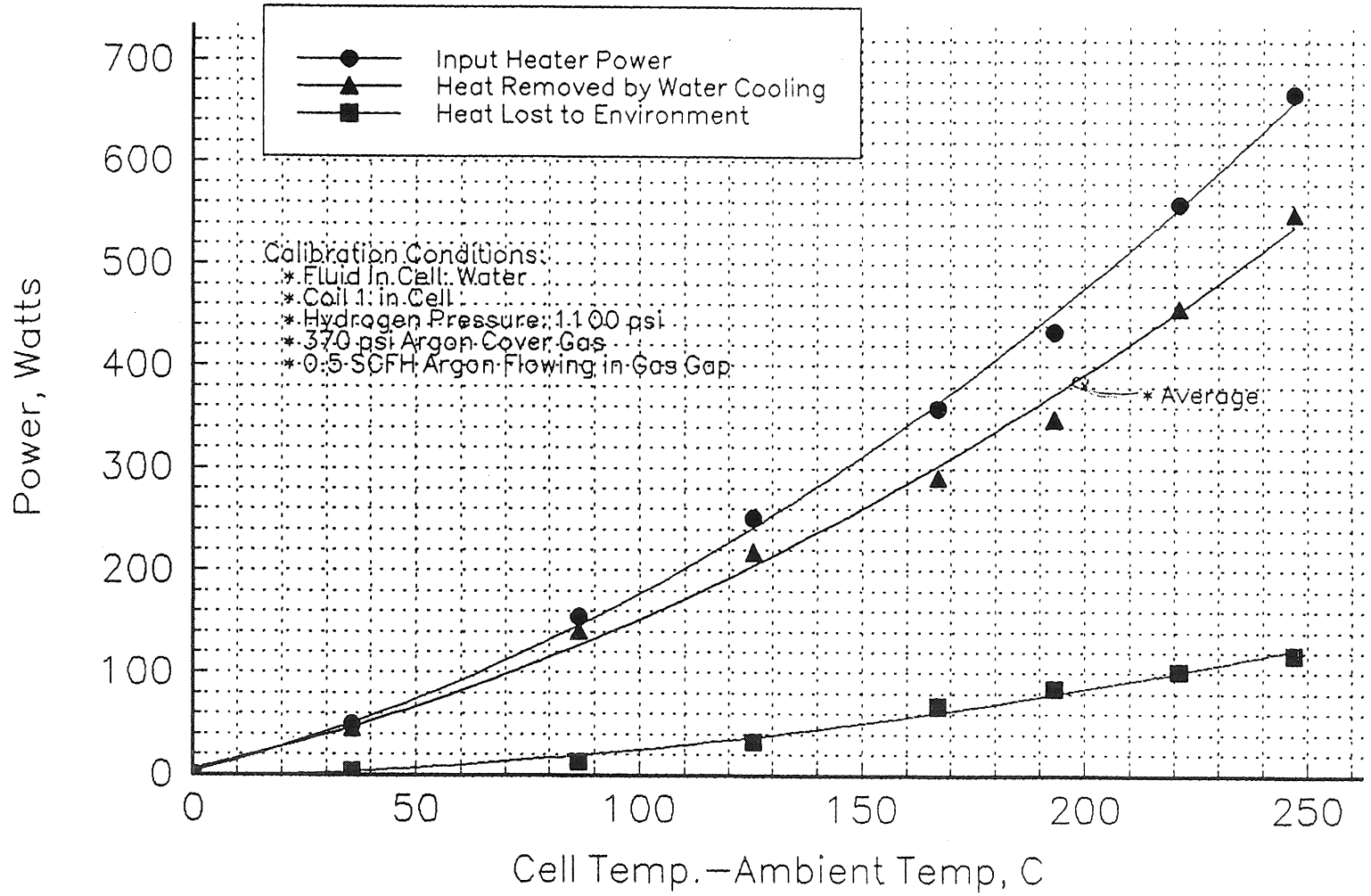
Figure 7. Cell 1 : Calibration Curve



Steps 1, 2, 3, 6 and 7 are consistent with diatomic gas permeation theory. Ultimately, one or more of the above steps will most likely limit the rate of excess heat production. Work was conducted in this effort to investigate parameters that affect the above mentioned seven steps. The parameters that were investigated include: hydrogen pressure and temperature, oxide layer, nickel surface preparation, nickel tubing temper, electrolyte concentration, cell voltage, and hydrino concentration. A brief description of each parameter is provided below.

- **Hydrogen Pressure and Temperature**

The relationship of hydrogen pressure and temperature to the flow of atomic hydrogen through the tubing wall is expressed by:

$$\dot{m} = \varnothing \frac{2\pi L}{\ln(r_o/r_i)} (P_i^{1/2} - P_o^{1/2}) \qquad (1)$$

Where

$\dot{m}$	=	hydrogen mass flow, μ mol s^{-1}
$\varnothing$	=	permeability, μ mol s^{-1} m^{-1} $kPa^{-½}$
L	=	tubing length, m
P_i	=	input pressure, kPa
P_o	=	output pressure, kPa
r_o	=	outer tube radius, m
r_i	=	inner tube radius, m

This equation shows that permeation increases as a square root of the pressure. The $\varnothing$ in equation (1) relates the permeation rate to temperature, as follows:

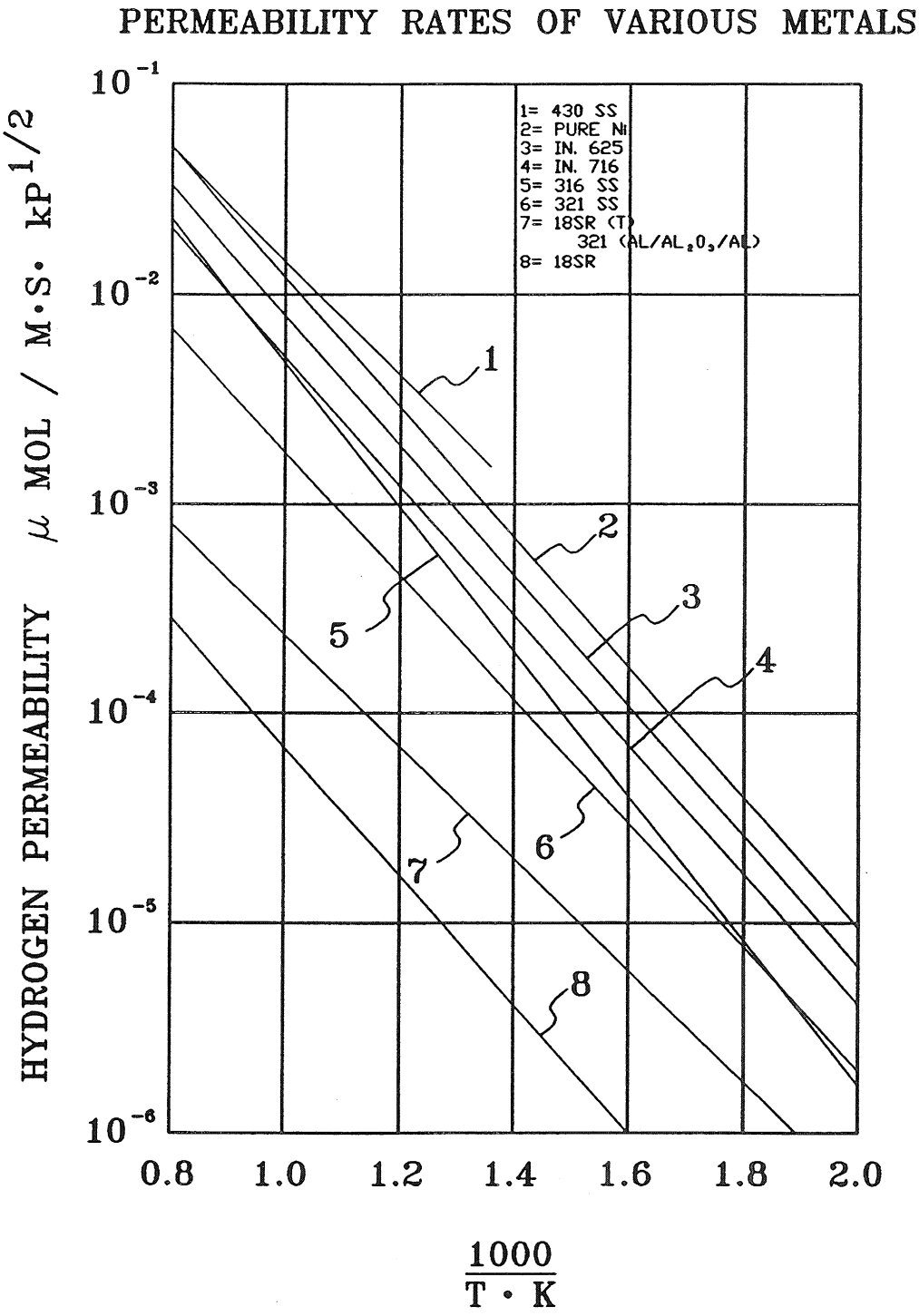
$$\varnothing = \varnothing_o \, e^{-\frac{\Delta H_p}{RT}} \qquad (2)$$

Where,

$\varnothing_o$	=	a constant
ΔH_p	=	activation energy
R	=	gas constant
T	=	absolute temperature (K)

Equation (2) and a large body of experimental data show that log $\varnothing$ plotted vs 1/T will yield a straight line as shown in Figure 8. Figure 8 shows that the permeation rate goes up exponentially with temperature. Overall, the combined affect of the two parameters is an

FIGURE 8. HYDROGEN PERMEABILITY RATES AS A FUNCTION OF TEMPERATURE ⑧



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increase in the amount of atomic hydrogen available to undergo the transition to a lower energy state.

Calculations, documented in Appendix A, show that for a constant hydrogen pressure of 1100 psig, the volumetric flow of hydrogen diffusing through the nickel tubing is approximately 0.05 cc's/sec at 200°C and 0.8 cc's/sec at 300°C. The resulting excess power that can be generated by this amount of hydrogen flow was estimated in Appendix B using Mills' theory. The results are described below:

ELECTRON TRANSITION FROM GROUND STATE TO FRACTIONAL QUANTUM LEVEL, n	EXCESS POWER (WATTS)	
	200°C	300°C
2	5	67
3	14	178
4	26	334
5	41	534

- **Oxide Layer** - The oxide layer is expected to affect the amount of hydrogen absorbed on the nickel surface. Kohl[9] shows an abnormal enrichment of hydrogen on nickel when the surface is covered by a visible film of nickel oxide. Kohl states that *"The concentrations of hydrogen observed in the presence of oxide films not only were substantially higher than those observed with pure nickel, but also increased with decrease of temperature from near 200°C to near 100°C. For equal number of atoms striking the surface, the increase in concentration near 100°C amounts to about four orders of magnitude."* If adsorption of the hydrogen is a rate controlling step then the formation of an oxide layer should enhance the process.
- **Nickel Surface Preparation** - This parameter addresses the condition of the inner and outer surfaces of the nickel as they apply to Steps 1 and 4 of the process. In general, the nickel surfaces must be free of any contaminants that will inhibit Steps 1 and 4. Generally, these contaminants are dirt, oils, greases, and undesired oxides. Some of the cleaning methods used to remove these contaminants may actually introduce other

contaminants. For example, trace amounts of some organic solvents may be left behind. It is unknown at this point whether solvents have a negative affect on the process. Perhaps the diatomic hydrogen that forms in Step 6 may be a contaminant that occupies space on the surface, thus preventing atomic hydrogen from contacting potassium carbonate.

- **Electrolyte Concentration** - The small non-electrolytic cell tested by Shaubach and Gernert used a weak potassium carbonate solution. Tests have been conducted to determine if the excess heat generation process can be enhanced through the use of more concentrated solutions.

The following parameters affect Steps 4 and 5 of the process. They are mainly supported by observations that resulted from small electrolytic experiments conducted prior to this contract.

- **Nickel Tubing Temper** - Tests conducted by HPC and Thermacore in small electrolytic cells seem to indicate that the catalytic reaction is related to nickel hardness. To determine if this parameter applies to the non-electrolytic approach, a coil of annealed and a coil of hard nickel tubing were tested.

- **Cell Voltage** - Tests conducted in small electrolytic cells have indicated that a nickel cathode left in the potassium carbonate electrolyte without a negative electrical charge becomes ineffective. It is thought that the electrical charge either conditions the surface or keeps unwanted contaminants away. To evaluate this affect, we have provided an anode in the 500 watt permeation cell. A charge can safely be applied to the cell as long as the anode to cathode potential difference is kept below the 1.48 volts required for the disassociation of water.

- **Hydrino Concentration** - Hydrocatalysis Power Corporation tests using unvented electrolytic cells with hydrogen/oxygen recombiners show that there is an equilibrium pressure occurring after several days of operation. After this equilibrium pressure is reached, the excess heat process ceases. If this is the case, the closed cell approach should shut down excess heat production after an extended period of time, unless the potassium carbonate side of the cell is periodically vented.

All of these parameters have been evaluated as described in the next section.

4.4 TEST RESULTS

Five coils of nickel tubing were tested. The test results for each coil are described below.

4.4.1 Coil #1: 250' of 0.125" Diameter Annealed Tubing

The exterior surface of the tubing as received from the manufacturer was oily and dirty. To remove the oil, the exterior was wiped with an acetone saturated towel. The tubing coil was placed in an ultrasonic cleaner filled with liquinox and deionized water. After cleaning, the coil was rinsed in deionized water, inserted in the cell and tested using the water cooled calorimeter approach.

Nine different test conditions were conducted to evaluate the various parameters described in Section 4.3. The conditions and results are documented in Table 4. No excess heat above the 50W detection limit was measured under any of the test conditions.

Since the tubing was cleaned with an organic material, we thought the lack of excess heat may be due to poisoning of the surface from the acetone. As a result, a new coil was inserted in the cell.

4.4.2 Coil #2: 250' of 0.125" Diameter Annealed Tubing

The tubing delivered from the factory was also dirty and oily. Prior to wrapping the coil, the tubing was cleaned by hand using soap and water. After wrapping, the coil was further cleaned in an ultrasonic cleaning vessel filled with soap (liquinox brand) and distilled water followed by rinsing with water.

TABLE 4. Test Conditions and Results for Coil #1 - 250' of Annealed Nickel Tubing*

TEST #	TEST DESCRIPTION	CONDITIONS	RESULTS				
			CELL ΔT (°C)	INPUT POWER, (watts)	HEAT REMOVED BY WATER, (watts)	HEAT LOST TO ENVIRONMENT (watts)	Q_{EXCESS} (watts)
1	High K_2CO_3 Concentration	- 0.6 M K_2CO_3 Electrolyte - 1500 psi H_2 pressure applied at start of test - 370 psi Argon over pressure applied above electrolyte	226	544	481	105	+42
2	Hydrino Concentration	- Removed electrolyte from Test #1 and added a fresh charge of 0.6 M K_2CO_3 - 370 psi Argon over pressure applied above electrolyte - Heated the cell to 238°C steady state - Applied 1200 psi H_2 pressure	210	492	400	92	0
3	Oxide Layer	- Released the hydrogen pressure from Test #2 - Purged inner diameter of tubing with air - Allowed to sit overnight open-to-air - In morning, applied 1100 psi H_2 pressure	205	485	394	90	-1
4	Cleaned the inner diameter of the tubing	- Cleaned the inner diameter of Nickel tubing with a 6% by volume solution of H_2O_2 and water - Heated the cell to 235°C steady state - Applied 1100 psi H_2 pressure	209	495	423	91.5	+19.5

TABLE 4. Test Conditions and Results for Coil #1 - 250' of Annealed Nickel Tubing*
(continued)

TEST #	TEST DESCRIPTION	CONDITIONS	RESULTS				
			CELL ΔT (°C)	INPUT POWER, (watts)	HEAT REMOVED BY WATER, (watts)	HEAT LOST TO ENVIRONMENT (watts)	Q_{EXCESS} (watts)
5	Excess heat reaction on inner diameter of nickel tubing	- Cleaned the inner diameter of the Nickel tubing with a 0.6 M K_2CO_3/6% by volume of H_2O_2 - Heated the cell to 218°C steady state - Applied 1100 psi H_2 pressure	225	640	521	103	-16
6	Low K_2CO_3 electrolyte concentration	- Reduced the concentration of the electrolyte to less than 0.1 M - 370 psi Argon over pressure applied above electrolyte - Heated the cell to 225°C steady state - Applied 1100 psi H_2 pressure	207	553	459	91	-3
7	Cell Voltage	- Applied 0.71 volts DC to Test #6 - Increased heater power to get the cell temperature up to 252°C steady state	226	623	483	105	-35
8	High Pressure Hydrogen	- Increased the H_2 pressure to 1900 psi on Test #7	236	648	526	115	-7
9	Conditioned the Nickel surface by running electrolysis	- Cooled the cell to ambient - Released H_2 pressure - Ran electrolysis for approximately 21 hours - stopped electrolysis and closed cell - 370 psi Argon overpressure applied - Heated the cell to 217°C steady state - Applied 1100 psi H_2 pressure	200	527	458	85	+16

** Test Data recorded in Thermacore Laboratory Notebook #117 pp. 1-8.*

Mean 1.7 ± 22 watts

The coil was installed in the cell and tested using water cooling as described in Table 5. Six test conditions were evaluated. Each test yielded no excess heat energy above the 50 watt detection limit.

4.4.3 Coil #3: 250' of 0.125" Diameter Hard Nickel Tubing

This tubing appeared to be fairly clean coming from the factory. The only cleaning operation performed was soaking the coil in a hydrogen peroxide/potassium carbonate solution while it was installed in the cell. After cleaning, five tests were completed as recorded in Table 6 for a water cooled cell. Again, no excess heat energy was measured above the 50 watt detection limit.

4.4.4 Coil #4: 500' of 0.0625" Diameter Annealed Nickel Tubing

This coil of tubing was inserted into a second pressure vessel that was fabricated nominally the same as the first vessel. The calibration curve for this cell is shown in Figure 9. Five different tests using water cooling were conducted as described in Table 7. All of the results showed excess heat on the plus side of the energy balance. Tests 1, 3, 4 and 7 had excess heat greater than the 50 watt error limit. The average power was 57 W $\pm$ 26 W. Overall, these tests indicated the presence of excess heat, however, the water cooled cell test procedure does not permit accurate estimates.

For more accurate quantification of the amount of excess heat, we switched to testing the cell without water cooling. Seven test conditions were conducted. The results are recorded in Table 8. These tests indicated that the average amount of excess heat is 24.3 watts $\pm$ 6.4 watts.

4.4.5 Coil # 5: 500' of 0.0625" Diameter Annealed Nickel Tubing

A fifth coil was made from tubing of the same geometry as tubing used to make Coil #4, however, the tubing was wound in a way to allow venting of hydrogen as it evolves on the shell side of the coil. Figure 10 is a photograph of this coil. Vertical pieces of 0.125" diameter nickel tubing were used as spacers between wraps of 0.0625" tubing. Prior coils, such as shown in Figure 5, were tightly wound and were suspected not to readily release the hydrogen that evolves. The trapped hydrogen most likely formed a gas blanket, blocking potassium carbonate from contacting the nickel.

TABLE 5. Test Conditions and Results for Coil #2 - 250' of Annealed Nickel Tubing*

(WATER COOLED CALIBRATION)

TEST #	TEST DESCRIPTION	CONDITIONS	RESULTS				
			CELL ΔT (°C)	INPUT POWER (watts)	WATER COOLING (watts)	HEAT LOSS TO ENVIRONMENT (watts)	Q_{EXCESS} (watts)
1	Low K_2CO_3 Concentration	- Low K_2CO_2 concentration - 370 psi Argon over pressure - Heated the cell to 228°C steady state - Applied 1100 psi H_2 pressure	206	541	413	90.5	-37.5
2	Cell Voltage	- Applied 0.73 volts to Test #1	197	533	427	82	-24
3	Higher Pressure and Hydrogen	- Increased the hydrogen pressure to 1800 psi - Increased heater power to elevate the cell temperature to 261°C steady state	244	700	560	120	-20
4	High Concentration of K_2CO_3	- Removed the electrolyte from Test #1 and added a fresh charge of 0.6 M K_2CO_3 - Applied Argon over pressure (370 psi) - Heated the cell to 230°C steady state - Applied 1100 psi H_2 pressure	218	557	38	98	-21
5	Excess heat reaction on inner diameter of nickel tubing	- Cooled the cell to ambient - Cleaned the inner diameter of the Nickel tubing with a 0.6 M K_2CO_3/6% by volume of H_2O_2 - Heated the cell to 244°C steady state - Applied 1100 psi H_2 pressure	224	608	529	102	+23
6	Increased H_2 Pressure	- Increased the H_2 pressure to 1700 psi on Test #5	227	602	488	107	-7

** Test Data recorded in Thermacore Laboratory Notebook #117 pp. 9-11.*

Mean: -14 ± 20.7 watts

TABLE 6. Test Conditions and Results for Coil #3 - 250' of Hard Nickel Tubing*

(WATER COOLED CALIBRATION)

TEST #	TEST DESCRIPTION	CONDITIONS	RESULTS				
			CELL ΔT (°C)	INPUT POWER (watts)	WATER COOLING (watts)	HEAT LOSS TO ENVIRONMENT (watts)	Q_{EXCESS} (watts)
1	Low K_2CO_3 Concentration	- Low K_2CO_3 Concentration - 370 psi Argon over pressure - Heated the cell to 242°C steady state - Applied 1100 psi H_2 pressure at start of test	219	679	532	98	-49
2	High K_2CO_3 Concentration/Cell Voltage	- Changed electrolyte to 0.6 M concentration - 370 psi Argon over pressure - Heated the cell of 250°C steady state - Applied 1100 psi H_2 pressure.	219	669	530	98	-41
3	High K_2CO_3 Concentration	- Cleaned the coil using 0.6 M K_2CO_3 and H_2O_2 solution - Added 0.6 M K_2CO_3 Electrolyte - 370 psi Argon over pressure - Heated the cell to 24°C steady state - Applied 1100 psi H_2 pressure - Applied 0.71 volts	219	628	514	99	-15
4	Rubidium Electrolyte	- Removed electrolyte from cell and added a rubidium electrolyte - Applied 370 psi argon over pressure - Heated the cell to 233°C steady state - Applied 1100 psi hydrogen pressure	219	664	553	99	-12
5	Removed the Argon Cover Gas	- Vented the argon over pressure from Test #5	206	597	498	90.5	-8.5

Mean: -25 W ± 18.5 W

**Test data recorded in Thermacore Laboratory Notebook #177 pp. 12-14.*

TABLE 7. Test conditions and Results for Cell #2 - Coil #4: 500 Feet of 0.0625" Diameter Annealed Nickel Tubing*

TEST #	TEST DESCRIPTION	CONDITIONS	RESULTS				
			CELL ΔT (°C)	INPUT POWER (watts)	WATER COOLING (watts)	HEAT LOST TO ENVIRONMENT (watts)	Q_{EXCESS} (watts)
1	LOW K_2CO_2 Concentration	- Applied 1100 psi H_2 pressure - Low K_2CO_3 concentration - Heated the cell to 240°C steady state - No gas over pressure applied to cell	229	670	653	107	+90
2	Increase H_2 Pressure	- Increased H_2 pressure to 1420 psi	211	678	632	95	+49
3	Increased H_2 Pressure	- Increased H_2 pressure to 1800 psi	223	671	624	103	+55
4	Applied Cell Voltage	- Applied 0.7 VDC to Test #3	226	671	639	104	+72
5	High K_2CO_3 Concentration	- Removed electrolyte and added 0.6 M K_2CO_3 - 1100 psi H_2 applied - Heated the cell to 230°C steady state - 0.7 VDC applied	220	671	586	102	+17
6	Increased Cell Temperature	- Increased cell temperature to 270°C	238	653	583	106	+36
7	Oxide Layer	- Vented H_2 Pressure - Purged id with air overnight while cell was 262°C - Applied 1400 psi H_2 in morning	248	657	616	120	+79

Mean: 56.8 ± 26 watts

**Test Data Recorded in Thermacore Laboratory Notebook #117, pp 16-19.*

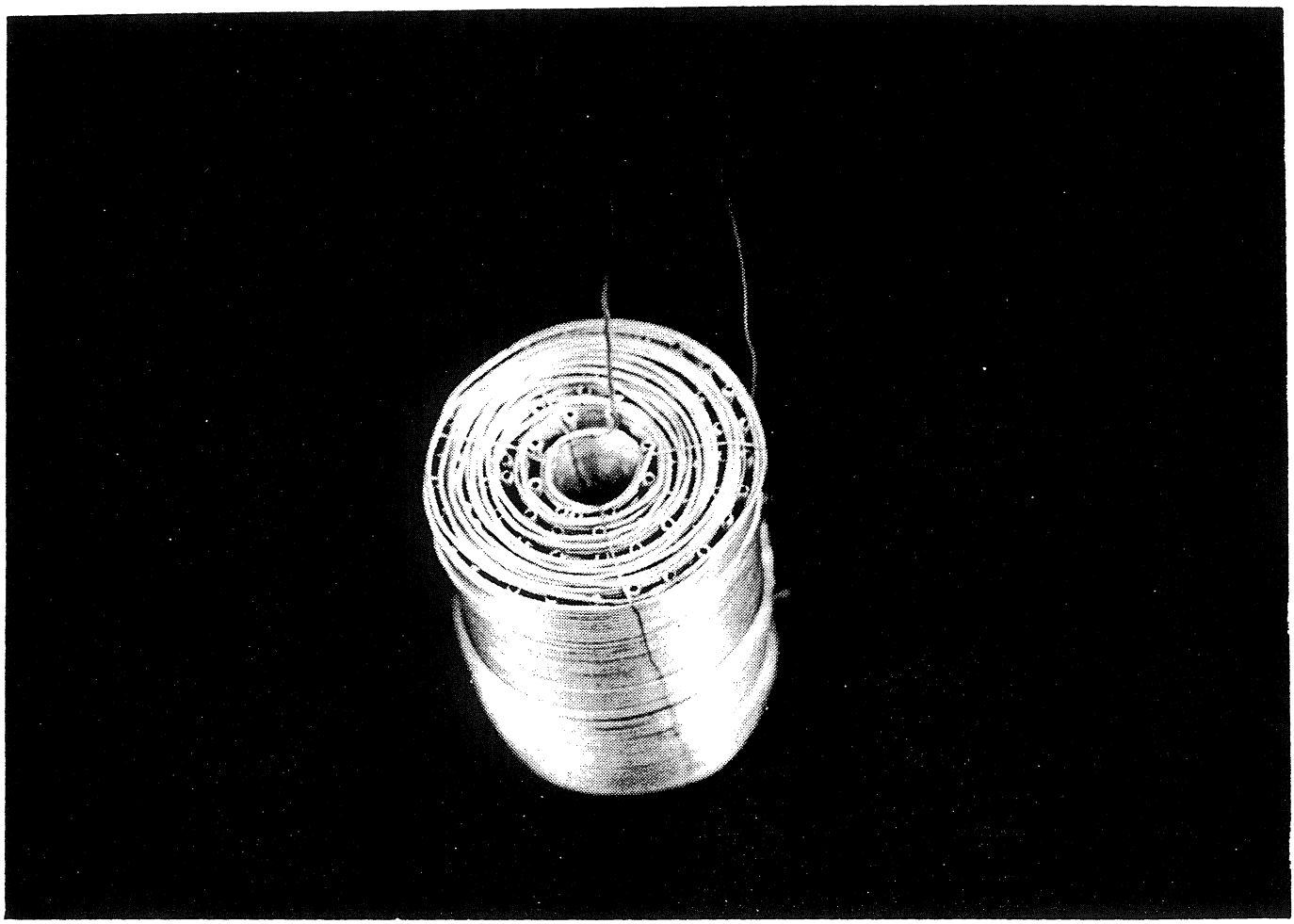
TABLE 8. Test Conditions and Results for Cell #2 - Coil #4: 500 Feet of 0.0625" Diameter Annealed Nickel Tubing (NO WATER COOLING/VACUUM IN GAS GAP)

TEST #	TEST DESCRIPTION	CONDITIONS	CELL ΔT	HEAT LOST TO ENVIRONMENT (watts)	INPUT POWER (watts)	EXCESS HEAT (watts)
1	High K_2CO_2 Concentration	- Applied 1200 psi H_2 pressure - 0.6 m K_2CO_2 concentration - Heated the cell to 294°C steady state - No gas over pressure applied to cell	276	135	120	+15
2	Increase H_2 Pressure	- Increased H_2 pressure to 2150 psi	275	134	114	+20
3	0.06m K_2CO_3	- Changed electrolyte to 0.06m K_2CO_3 - No gas over pressure - Heated cell to 291°C - Applied 2000 psig H_2	280	143	119	+24
4	Oxide	- Released hydrogen pressure from Test #3 - Purged air through tubing overnight - In morning applied 2000 psig H_2	281	144	118	+25
5	Applied N_2 Overpressure on Cell	- Cooled cell down and applied an N_2 overpressure of 350 psi to cell - Heated cell to 291°C steady state with 2000 psig applied	276	140	107	+33
6	Confirmed Cell Calibration	- Confirmed cell calibration - No H_2 applied	150		55	
			237		100	
7	Acid Etched Coil	- Acid etched coil in nitric acid - Rinsed with methanol then water - Added 0.6 M K_2CO_3 - Heated cell to 245°C steady state - Applied 1300 psig hydrogen	257	126	97	+29

Mean: 24.3 ± 6.4 W

**Test data recorded in Thermacore Laboratory Notebook #117 pp. 19-23.*

FIGURE 10. LOOSELY WOUND DESIGN OF COIL #5



This coil was inserted in the cell and tested using the non-water cooled approach. At the present time, there is 12 watts of excess heat; this is less than the heat produced using Coil #4. Based on this result, the ventable coil design currently shows no benefit. Thermacore is continuing to test this coil on internal funding.

2.5 EVALUATION OF TEST RESULTS

The results of the testing described in Section 2.4 show the presence of about 25 watts of excess heat using Coil #4 and 12 watts of excess heat using Coil #5. This excess heat could possibly come from several sources in addition to hydrogen electronic transitions to fractional quantum energy levels claimed by Mills. The purpose of this section of the report is to evaluate the alternative explanations for the excess heat in addition to the Mills' claim.

A number of possible explanations for the excess heat have been identified during the course of this effort. These explanations are listed below:

- Instrumentation Error: This evaluation applies to the non-water cooled testing procedure. A voltmeter, ammeter, thermocouples and associated readouts were used to measure input and output power and losses. Errors associated with one or more of these devices might explain the appearance of excess energy. These errors are estimated in the following paragraphs:

  The instrumentation was calibrated using procedures meeting MIL-I-45208. The voltage ($\pm 0.1\%$) and resistance ($\pm$ 0.1%) were recorded with a digital multimeter (Fluke 8600A). The electrical heating power was calculated using the square of the voltage square divided by the heater resistance (E^2/R). Temperatures ($\pm$ 0.1°C) were recorded using a Hewlett Packard Data Acquisition System and were compared to temperature measured by a microprocessor thermometer (Omega HH21) using Type K sheathed ungrounded thermocouples. Cell solution temperature was measured through a thermocouple well located at the top of the nickel coil as shown in Figure 3.

  Separate independent measurements were made on a sampling basis using a different set of calibrated instruments to help identify any faulty instrumentation. These "spot checks" showed that the instrumentation operated within calibration limits. The conclusion of our review of the accuracy of the instrumentation is that power

measurements are accurate to within about 1%. Instrumentation error does ont explain the magnitude of the excess energy.

- Gas Compression: The excess energy is initiated at the time hydrogen gas is released into the coil of nickel tubing. Analyses were done to determine if the energy released from compression of hydrogen could explain the increase in temperature observed during the experiment.

The energy generated from the compression of hydrogen is calculated in Appendix C. The results show that about 521 joules of heat are released at the time compression occurs. This 521 joules of heat are insignificant compared to the 4.5×10^7 joules of excess energy measured during the three week duration of the 25 watt experiment.

- Exothermic Corrosion Reaction: Photomicrograph of the tubing form the #4 taken before after testing (see Figure 11) show no signs of corrosion, pitting or other chemical attach. Hence, an exothermic corrosion reaction does not explain the excess heat.

- Hydrogen Blanketing: Hydrogen permeates through the wall of the nickel tubing and collects in the space above the potassium carbonate solution. This gas may change the heat transfer coefficient between the potassium carbonate and cover plate. A decrease in the heat transfer will result in an apparent rise in cell temperature which could falsely be attributed to the generation of excess energy.

A nitrogen cover gas is used to blanket the potassium carbonate solution at a pressure high enough to suppress boiling. This cover gas has a relatively high thermal resistance and significantly reduces heat transferred through the cover plate. Introduction of high thermal conductivity hydrogen into the cover gas serves to increase not decrease the rate of heat transfer as the experiment progresses. This increase in heat transfer will most likely result in an apparent decrease in cell temperature which could falsely be attributed to a decrease in the generation of excess heat.

FIGURE 11. PHOTOMICROGRAPH OF THE NICKEL TUBING BEFORE AND AFTER TESTING

BEFORE TESTING

200 X LONGITUDINAL

200 X TRANSVERSE

AFTER-TESTING

200 X LONGITUDINAL

200 X TRANSVERSE

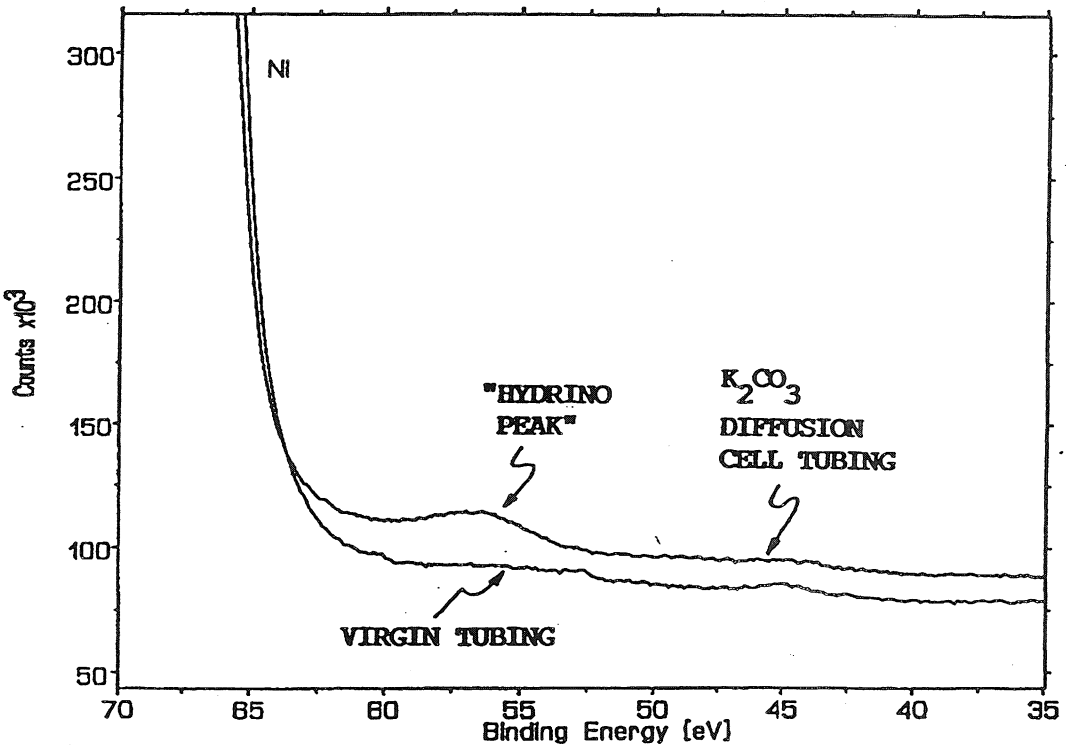
Tests were conducted during cell calibration for purposes of establishing the effects of hydrogen accumulation in the 350 psig nitrogen cover gas. These tests show no significant change in cell steady state temperature when 350 psi in hydrogen pressure is exchanged for the nitrogen gas. Clearly accumulation of hydrogen on the shell side does not explain the excess energy.

■ Mills Theory: The electron of the hydrogen atom is predicted to transition to fractional energy levels releasing energy when contacting an energy sink resonant with the hydrogen energy released. The "ash" of the process is the "shrunken" hydrogen atom called a hydrino. Two hydrinos will react creating a dihydrino molecule forming what is reported by Mills to be an inert gas.

Lehigh University, Bethlehem, PA, has been able to detect the hydrino molecule using ESCA (Electron Spectroscopy for Chemical Analysis) absorbed on the surface of nickel cathodes used in electrolysis of K_2CO_3. This work shows a peak near 55 eV which is predicted by Mills to be the binding energy of the electron for a hydrino molecule.

ESCA analyses were also done by Lehigh University on samples of virgin nickel tubing and tubing removed from Coil #4. The results of these analyses are included in Figure 12 and show the characteristic hydrino peak at 55 eV for tubing removed from Coil #4; no peak occurs for the virgin tubing. Lehigh (Dr. A. Miller) has also seen these peaks on electrodes removed from Mills' electrolytic cells and has no other explanation for them other than being caused by the presence of hydrinos. As a result of the work done by Thermacore on this effort, we conclude that the Mills' theory is the likely explanation for the excess energy seen in the experiments done under this program.

FIGURE 12. COMPARISON OF ESCA RESULTS FOR VIRGIN TUBING COMPARED TO TUBING FROM K_2CO_3 DIFFUSION CELL



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APPENDIX A

HYDROGEN PERMEATION THROUGH THE NICKEL TUBING

Appendix A

THERMACORE, INC. HEAT TRANSFER SPECIALISTS / ENGINEERING—MANUFACTURING

780 EDEN ROAD / LANCASTER, PENNSYLVANIA 17601

Title: Hydrogen Permeation through the nickel tubing

Page 1 of 3

Calculated by: NJG Date 11/25/93

Approved by: _____ Date _____

Purpose: To determine the volume of hydrogen permeating into the potassium carbonate side of the cell for nickel coil #4.

Description: Coil #4 is 500 feet of 0.0625" diameter by 0.010" wall nickel 200 tubing.

Analysis: The hydrogen permeation rate through tubing is calculated using:

$$\dot{m} = \frac{2\pi L \phi (P_i^{1/2} - P_o^{1/2})}{\ln(r_o/r_i)}$$

where,

ϕ = the coefficient of permeability, $\mu mol\, m^{-1} s^{-1} kPa^{-1/2}$

L = Length of tubing, m

P_i = input Pressure, kPA

P_o = output Pressure, kPA

r_o = outer radius, m

r_i = inner radius, m

Values for ϕ are determined using Figure A1.

for 200°c; $\phi \approx 6 \times 10^{-6}$ $\mu mol/m \cdot s \cdot kP^{1/2}$

$L = 152.4\ m$

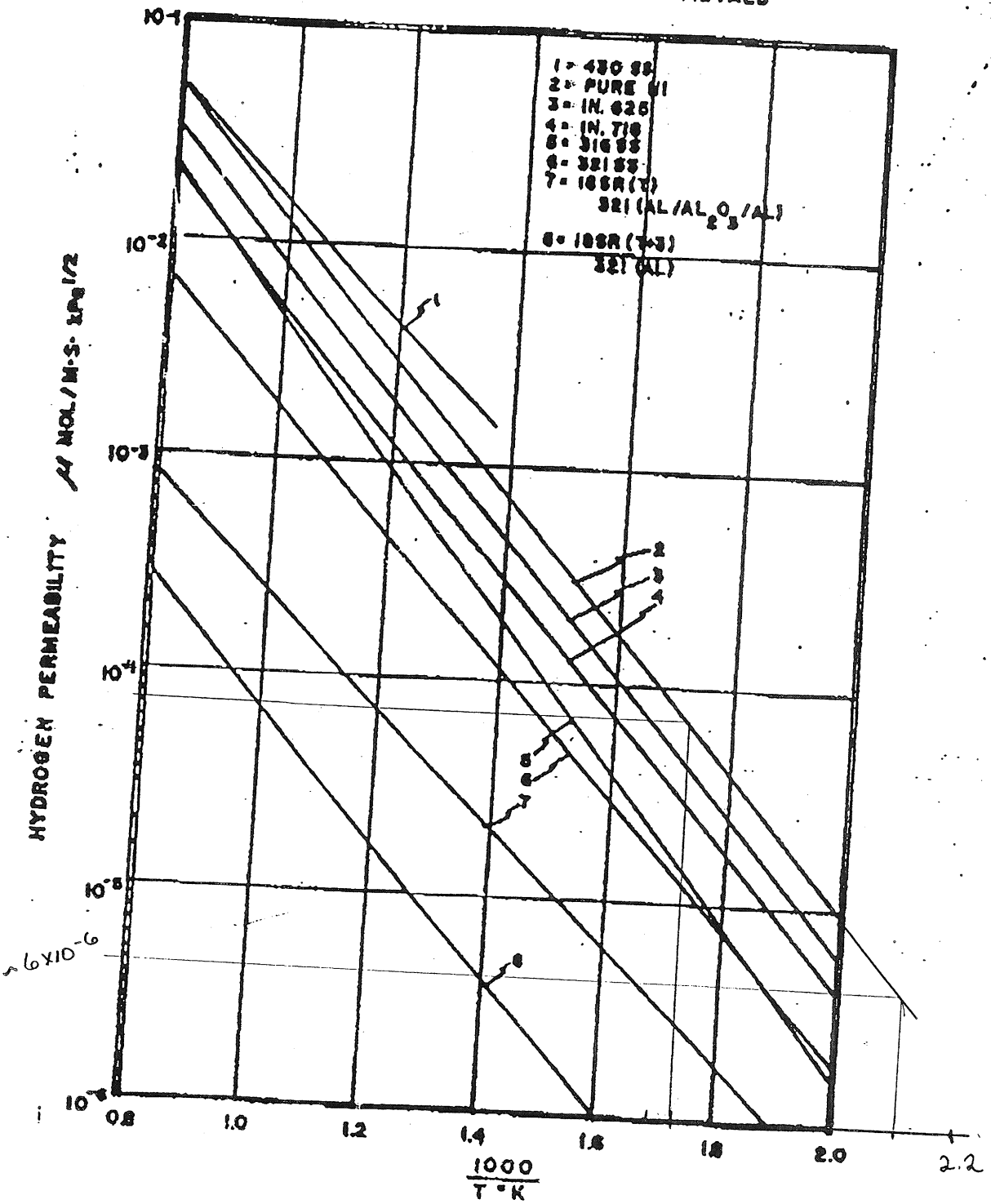
$r_o = 0.00079\ m$

$r_i = 0.00054\ m$

$P_i = 7584\ kPa$ (1100 psi)

$P_o = 0\ kPa$

Figure A1. PERMEABILITY RATES OF VARIOUS METALS



Title: _____ Page 3 of 3

Calculated by: _____ Date _____

Approved by: _____ Date _____

$$\dot{m} = \frac{2\pi(152.4\,m)\,6\times10^{-6}\,\frac{\mu mol}{m\cdot s\cdot kPA^{1/2}}\sqrt{7584\,kPa}}{\ln 1.47}$$

$$= 1.3\,\frac{\mu mol}{s}\left|\frac{1\times10^{-6}\,mol}{1\,\mu mol}\right. = 1.3\times10^{-6}\,\frac{mol}{s}\times 2\,\frac{g}{gmol}$$

or $2.6\times10^{-6}\ g/s$

In terms of volumetric flowrates, $\frac{cc's}{s}$

$2.6\times10^{-6}\ g/s \div \rho_{H_2}@200°C$

where, $\rho_{H_2}@200°C = 5\times10^{-5}\ g/cc$
$(8.4\times10^{-5}\ g/cc\ @\ 20°C)$

Volumetric flow of H_2 @ 200°C $= 5.2\times10^{-2}\,\frac{cc}{s}$

300°C: $\Phi = 8\times10^{-5}\ \mu mol/m\cdot s\cdot kPa^{1/2}$

$$\dot{m} = \frac{2\pi(152.4\,m)(8\times10^{-6})\sqrt{7584\,kPa}}{\ln 1.47}$$

$$= 17\,\frac{\mu mol}{s}\left|\frac{1\times10^{-6}\,mol}{1\,\mu mol}\right. = 1.7\times10^{-5}\,\frac{mol}{s}\times 2\,\frac{g}{mol}$$

$$= 3.4\times10^{-5}\ g/s$$

In terms of volumetric flowrates:

$3.4\times10^{-5}\ g/s \div \rho_{H_2}@300°C$

$\rho_{H_2}@300°C = 4.2\times10^{-5}\ g/cc$

Volumetric flow of H_2 $= 0.8\ cc/s$ @ 300°C

APPENDIX B

EXCESS HEAT FROM H_2 PERMEATING THROUGH NICKEL INTO K_2CO_3 SOLUTION

Appendix B

THERMACORE, INC. HEAT TRANSFER SPECIALISTS / ENGINEERING—MANUFACTURING

780 EDEN ROAD / LANCASTER, PENNSYLVANIA 17601

Title: Estimate of the Excess Heat from H_2 Permeating through a Nickel into K_2CO_3 solution

Calculated by: NJG Date 3/14/94

Approved by: _____ Date _____

Purpose: To estimate the excess heat generated in the diffusion cell when hydrogen is "shrunk" to N = ½ and lower for Coil # 4.

Description: See Appendix A for the H_2 permeation rates through the nickel tubing as a function of temperature.

Analyses: This analysis estimates the amount of heat released assuming all the hydrogen is shrunk to N = ½ .... ⅕ using the following equation:

$$\text{Excess energy/atom} = 13.6(n^2-1)\ eV \qquad \text{Eq. (1)}$$

where, n = number of quantum levels below the ground state.

N = ½ @ 200°C

$$\frac{\text{Atoms}}{\text{sec}} = 1.3\times10^{-6}\ \frac{\text{mole}}{\text{s}}\ (\text{from App. A}) * 6.02\times10^{23}\ \frac{\text{atoms}}{\text{mole}} = 7.826\times10^{17}\ \frac{\text{atoms}}{\text{s}}$$

$$Q_{\frac{1}{2}} = 7.826\times10^{17}\ \frac{\text{atoms}}{\text{s}} * 40.8\ \frac{\text{eV}}{\text{atom}} * 1.6\times10^{-19}\ \frac{\text{W}}{\text{eV}}$$

$$Q_{1/2} = 5.1\ \text{W}$$

N = ½ @ 300°C

Number of atoms that permeate/second

$$\frac{\text{Atoms}}{\text{sec}} = 1.7\times10^{-5}\ \frac{\text{mole}}{\text{s}} * 6.02\times10^{23}\ \frac{\text{atoms}}{\text{mole}} = 1.0234\times10^{19}\ \frac{\text{atoms}}{\text{s}}$$

Title: _____ Page 2 of 2

Calculated by: _____ Date _____

Approved by: _____ Date _____

$Q_{1/2} = 1.0234 \times 10^{19} \frac{atoms}{s} * 40.8 \frac{eV}{atom} * 1.6 \times 10^{-19} \frac{W}{eV}$

$Q_{1/2} = 66.8\,W$

N = 1/3 @ 200°C

$Q_{1/3} = 7.826 \times 10^{17} \frac{atoms}{sec} * 108.8 \frac{eV}{atom} * 1.6 \times 10^{-19} \frac{W}{eV}$

$= 13.6\,W$

N = 1/3 @ 300°C

$Q_{1/3} = 1.0234 \times 10^{19} \frac{atoms}{sec} * 108.8 \frac{eV}{atom} * 1.6 \times 10^{-19} \frac{W}{eV}$

$= 178\,W$

N = 1/4 @ 200°C

$Q_{1/4} = 7.826 \times 10^{17} \frac{atoms}{sec} * 204 \frac{eV}{atom} * 1.6 \times 10^{-19} \frac{W}{eV} = 25.5\,W$

N = 1/4 @ 300°C

$Q_{1/4} = 1.0234 \times 10^{19} \frac{atoms}{sec} * 204 \frac{eV}{atom} * 1.6 \times 10^{-19} \frac{W}{eV} = 334\,W$

N = 1/5 @ 200°C

$Q_{1/5} = 7.826 \times 10^{17} \frac{atoms}{s} * 326.4 \frac{eV}{atom} * 1.6 \times 10^{-19} \frac{W}{eV} = 41\,W$

N = 1/5 @ 300°C

$Q_{1/5} = 1.0234 \times 10^{19} \frac{atom}{s} * 326.4 \frac{eV}{atom} * 1.6 \times 10^{-19} \frac{W}{eV} = 534\,W$

APPENDIX C

ENERGY FROM GAS COMPRESSION

THERMACORE, INC. HEAT TRANSFER SPECIALISTS / ENGINEERING—MANUFACTURING
780 EDEN ROAD / LANCASTER, PENNSYLVANIA 17601

Title: Energy from Gas Compression

Calculated by: MJG Date 3/22/93

Approved by: _____ Date _____

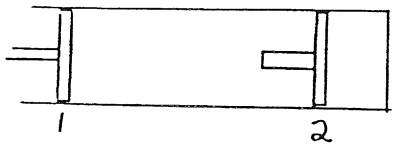
Purpose: To calculate the energy generated from the compression of hydrogen and compare it to the amount of excess heat measured.

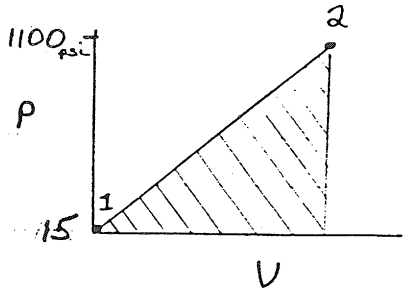
Description: The excess energy is initiated at the time hydrogen gas is released into coil #4 (500 ft of 0.0625" dia x 0.01" wall tubing)

Analysis:

Using the equation:

$$\text{Work} = PA\,dl = P\,dV = \tfrac{1}{2} P\Delta V$$





State 1: air at atmospheric pressure
State 2: air at 1100 psig

$$P_1V_1 = P_2V_2$$

$$\text{Work}_2 = \tfrac{1}{2}\left(1085 \tfrac{lb}{in^2}\right)(V_2 - V_1)$$

$$V_2 = \frac{\pi(.0425")^2}{4} \times 500'\left(\frac{12"}{1ft}\right)$$

$$= 8.5\,in^3$$

$$V_1 = 8.5\,in^3 \frac{15\ psi}{1115\ psi} = 0.11\,in^3$$

$$\text{Work}_2 = \tfrac{1}{2}\left(1100 \tfrac{lb}{in^2}\right)(8.5\,in^3 - 0.11\,in^3)$$

$$= 4614\ lbf\text{-}in \left[\frac{4.448\,N}{1\,lbf}\middle|\frac{2.54\,cm}{1\,in}\middle|\frac{1\,M}{100\,cm}\right]$$

$$= 521\ N\text{-}m \text{ or } \underline{\underline{521\,J}}$$

Title: _____ Page 2 of 2
Calculated by: _____ Date _____
Approved by: _____ Date _____

Amount of Excess Heat Measured

$$Q_{excess} = 25\ J/s * 21\ days \frac{24\ hr}{1\ day} \frac{60\ min}{1\ hr} \frac{60\ sec}{1\ min}$$

$$= 4.536 \times 10^{7}\ J$$

Conclusion:

The 521 joules of heat from gas compression are insignificant compared to the 4.5×10^{7} joules of excess energy measured during the three week duration of the 25 watt experiment.