5-31-1997

Hydrocatalysis: a new energy paradigm for the 21st century

Peter Mark Jansson

Rowan University

Recommended Citation

Jansson, Peter Mark, "Hydrocatalysis: a new energy paradigm for the 21st century" (1997). *Theses and Dissertations*. 2077.
https://rdw.rowan.edu/etd/2077

HYDROCATALYSIS: A New Energy Paradigm for the 21st Century

by
Peter Mark Jansson, P.P., P.E.

A Thesis

Submitted in partial fulfillment of the requirements of the
Master of Science in Engineering Degree
in the Graduate Division of
Rowan University
May 1997

Approved by ______________________
Dr. John L. Schmalzel

Approved by ______________________
Dr. Tirupathi R. Chandrupatla

Approved by ______________________
Dr. Anthony J. Marchese

External Advisors
Dr. Jonathan Phillips - Pennsylvania State University
Dr. Randell L. Mills - BlackLight Power, Inc.
William R. Good - BlackLight Power, Inc.

ABSTRACT

Peter Mark Jansson, P.P., P.E.
HYDROCATALYSIS: A NEW ENERGY PARADIGM FOR THE 21st CENTURY
May 1997
Dr. John L.Schmalzel, P.E. - Thesis Advisor
Graduate Engineering Department

This thesis will review the problems of worldwide energy supply, describe the current technologies that meet the energy needs of our industrial societies, summarize the environmental impacts of those fuels and technologies and their increased use by a growing global and increasingly technical economy. This work will also describe and advance the technology being developed by BlackLight Power, Inc. [BLP], a scientific company located in Malvern, Pennsylvania. BLP's technology proports to offer commercially viable and useful heat generation via a previously unrecognized natural phenomenon - the catalytic reduction of the hydrogen atom to a lower energy state. A review of this experimenter's laboratory data conducted as part of this research as well as that of others is provided to substantiate the fact that replication of the experimental conditions which are favorable to initiating and sustaining the new energy release process will generate controllable, reproducible, sustainable and commercially meaningful heat. By the end of the thesis the reader will have substantial information to draw a conclusion for themselves as to the potential of BLP technology to achieve commercialization and become a new energy paradigm for the next century.

MINI-ABSTRACT

Peter Mark Jansson, P.P., P.E.
HYDROCATALYSIS: A NEW ENERGY PARADIGM FOR THE 21st CENTURY
May 1997
Dr. John L.Schmalzel, P.E. - Thesis Advisor
Graduate Engineering Department

This thesis reviews the technologies used worldwide to meet the energy needs of our industrial societies. This work also describes a new technology being developed by BlackLight Power, Inc. [BLP] of Malvern, Pennsylvania. Laboratory data of the author as well as that of other scientists substantiates that the new BLP energy release process generates sustainable, commercially meaningful heat.

Library of Congress - Cataloguing in Progress

Published in the United States by
Peter Mark Jansson, P.P.,P.E.
Integrated Systems
P.O. Box 4
Tuckerton, New Jersey, 08087-0004

to ***Joy***,

who encouraged me to return to college
ever since we left

HYDROCATALYSIS:
A NEW ENERGY PARADIGM FOR THE 21st CENTURY

TABLE OF CONTENTS

Page

Abstract
Mini Absract

HYDROCATALYSIS:
A NEW ENERGY PARADIGM FOR THE 21st CENTURY

TABLE OF CONTENTS
[continued]

List of Appendices

Appendix 1. BLP Research Partners - Catalogue of Experimental Results
Appendix 2. An Overview of Mills Theory
Appendix 3. Jansson Astrophysical Data Calculations verifying BLP Reported Results
Appendix 4. BLP/AEI Experiment 15.6 - May 1996
Appendix 5. Analysis of BLP Isothermal Calorimetry Data
Appendix 6. PSU Calvet Test Results and Report - December 1996
Appendix 7. Jansson Calvet Testing Protocol
Appendix 8. Jansson Calvet Test Results - June 1997
Appendix 9. Jansson Heat Loss Model Calibration & Performance

HYDROCATALYSIS:
A NEW ENERGY PARADIGM FOR THE 21st CENTURY

LIST OF TABLES

LIST OF FIGURES

HYDROCATALYSIS:
A New Energy Paradigm for the 21st Century

Introduction and Thesis Overview

This thesis will review the problems of worldwide energy supply, describe the current technologies that meet the energy needs of our industrial societies, summarize the environmental impacts of those fuels and technologies and their increased use by a growing global and increasingly technical economy. After reviewing both the renewable and non-renewable options we have as a society, this work will describe and advance the technology being developed by BlackLight Power, Inc. [BLP], a scientific company located in Malvern, Pennsylvania. BLP's technology proports to offer commercially viable and useful heat generation via a previously unrecognized natural phenomenon - the catalytic reduction of hydrogen to a lower energy state. This reduction of hydrogen to fractional quantum energy levels is based upon a radical modification to the theoretical hydrogen atom energy equation developed by E. Schrödinger and W. Heisenberg in 1926. Dr. Randell Mills of BLP has proposed that a new boundary condition, derived from Maxwell's equations, be applied to that fundamental hydrogen equation. Dr. Mills' model then would suggest a purely physical model of particles, atoms, molecules and overall cosmology. His mathematical solutions contain fundamental constants only and energy values predicted by his theoretical approach agree in a most compelling way with observations scientists have made of the universe and stars.

This source of energy is proported to comprise a significant portion of the radiant energy created by stars. The new form of hydrogen atoms with their electrons below the current "ground" state have been named "hydrinos" by their discoverer, Dr. Mills. BLP scientists believe it is this matter that comprises the significant part of the dark matter of space. It will not be the attempt of this engineering thesis to debate the merits of Dr. Mills' theory in this regard but rather to review and sometimes replicate the scientific calculations and supporting data which indicate the merits of the existence of hydrinos. This thesis will also review this experimenter's laboratory data as well as that of others that substantiates the fact that replication of the experimental conditions which are favorable to initiating and sustaining the new disproportionation process will generate controllable, reproducible, sustainable and commercially meaningful heat. It will describe the technologies currently used in the disproportionation reaction, report on the state-of-the-art for the BLP technology and state the author's opinion as to this technology's potential for successfully addressing [or solving] some of the global energy issues above. [environmental degradation from growing energy use, limits to energy supply at forecasted growth rates, etc.]

The conclusions presented in this overall assessment are based upon theoretical and laboratory data as well as mathematical modeling. By the end of the thesis the reader will have substantial information to draw a conclusion for themselves as to the BLP technology's potential to achieve commercialization and become a new energy paradigm for the next century. It is the author's thesis that current, non-renewable energy sources [fossil fuels, nuclear, etc.] pose global environmental risks and because of the present megatrend of economic globalization represent limits to growth for the global economy by as early as the next few decades. Renewable energy supplies and technologies [such as solar, hydro, wind, etc.] while often less deleterious to the environment, represent significantly greater financial investments and will not meet the economic criteria [ie; affordable power] for continued developing nation and global economic expansion.

The approach to proof taken is one of:

a] reviewing the current global energy situation
b] assessing astrophysical data that supports the Mills theory
c] compiling and assessing experimental data from BLP and Penn State University
d] completing and documenting experimental calorimetry of this researcher
e] formulating a mathematical model which attempts to corroborate the practicality of energy extraction and the potential of the BLP process
f] postulating the impact that BLP technology may have on the global energy marketplace.

The hypothesis to be tested in this work is found in the Forward of Dr. Mills' text on his theory; "The advantages are that the hydrogen fuel can be obtained by diverting a fraction of the output energy of the process to split water into its elemental constituents, and pollution which is inherent with fossil and nuclear fuels is eliminated".[1] Three sources of data developed by this experimenter as well as by others is reviewed to assess the validity of that hypothesis. In closing a balanced assessment of the technology's potential to displace non-renewable fuel sources in the near term is presented.

PART I - An Energy Technology Overview

Throughout human history, energy has played a vital role in our species' survival, proliferation and advancement. In the early periods of primitive human society our ancestor's lives were dominated by food gathering and hunting. This made available to humans only the energy that was in the food they ate [about 2000 kcal daily per capita - 2.3 kWh]. Primitive hunting societies living about 100,000 years ago had more food and also used wood as a fuel for heat and cooking [about 5000 kcal daily per capita - 5.8 kWh]. As humans advanced to more primitive agricultural societies in about 5000 B.C. we also grew crops and used oxen and horses for cultivation [about 12,000 kcal daily per capita - 13.9 kWh]. By approximately 1400 A.D. advanced agricultural societies in Europe had begun to use coal for heating as well as wind and water power for grinding grains [26,000 kcal daily per capita - 30.2 kWh]. During the Industrial age of the 19th century we added the steam engine as a source of mechanical energy and increased the use of fuel energy in homes for lighting and heating [77,000 kcal daily per capita - 89.3 kWh]. Modern technological society uses the internal combustion engine for transportation, electricity for appliances and comfort which find their energy source in fossil, hydro and nuclear fuels which power steam turbines, furnaces and generators [230,000 kcal daily per capita - 266.8 kWh daily per capita].[2] This trend indicates that as we improve the quality of life for society a commensurate increase in direct and indirect energy use is requisite. World energy and economic statistics today also demonstrate that there is a direct correlation between a nation's gross national product [GNP] and its energy consumption. The countries of Ethiopia, Mali, Malawi and Niger all have GNPs less than $250 per capita while energy use is less than 0.4 barrels of oil per capita per year [680 kWh/year]. In contrast, the U.S., Norway, Canada and Sweden are leading economic nations with over $10,000 of GNP per capita. They use in excess of 40 barrels of oil per capita per year [68,000 kWh].[3] This one hundredfold increase in energy use is not a coincidence. It is characteristic of a steady evolution of society from a primitive [2.3 kWh] to technological [266.8 kWh] level of advancement and is illustrative of the critical role energy plays in increasing societal maturity, quality of life and productivity.

The sections which follow illustrate the fuels, technologies and methods used around the world to sustain this societal evolution and summarize limits on these elements which must be addressed in order to avoid major problems as the now developing nations [where over 3/4 of the world's population resides] strive to achieve western standards of living through industrialization. Table 1.1 below summarizes the current levels of energy use in the world and U.S. as of 1995.

TABLE 1.1 - 1995 Energy Use by Fuel Type
(in trillions of kilowatthours)

Energy Source		World	U.S.	U.S. % of World
Fossil Fuels	Natural Gas	22.7	6.6	29.2 %
	Petroleum	39.5	10.1	25.5 %
	Coal	26.8	6.1	22.9 %
Nuclear	Fission	7.1	2.2	30.3 %
Solar	HydroElectric	2.5	0.3	10.6 %
TOTAL		**98.8**	**25.3**	**25.6 %**

It is important to note that only commercially traded fuels are included in the summary data. The overview provided in Chapter 1 of this thesis presents the energy sources in an order prioritized by the contributions these sources make to industrialized society today.

Chapter 1 - Alternate Technology Overview

Prior to the announcement of the hydrocatalysis process being put forth by BlackLight Power there were fundamentally only five known sources of energy. In addition to the most commonly exploited, fossil fuels, there are nuclear [both fission and fusion], solar [in its many forms], geothermal and tidal.[4] Table 1.2 below briefly summarizes the major energy sources available in our society.

TABLE 1.2 - Energy Sources and Technologies

Energy Source	Fuel Type	Technologies in Use
Fossil Fuels	Natural Gas	Heaters, Furnaces, Boilers, etc.
	Petroleum	Heaters, Furnaces, Boilers, etc.
	Coal	Heaters, Furnaces, Boilers, etc.
	Shale Oil	Processing facility yields petroleum
	Tar Sands	Processing facility yields petroleum
Nuclear [Fission]	Uranium	PWR creates steam / electricity
		BWR creates steam / electricity
	Plutonium	Breeder technology - LMFBR
Nuclear [Fusion]	Hydrogen	No Technology Exists as of Yet
Solar	Solar Thermal	Passive & Active Water Htg. Systems
		Passive & Active Space Htg. Systems
		Power Tower/Parabolic Dishes / Troughs
	Photovoltaic	Amorphous Cells
		Crystalline Cells [single, multi, etc.]
	Biomass	Wood, Seaweed, algae, etc.
		Agricultural Crops [alcohol, waste, etc.]
		Municipal Solid Waste [paper primarily]
	Hydroelectric	Reservoirs, dams, water wheels, generators, pumped storage
	Wind Power	Wind Mills, Sailing, Turbines [VA/HA]
	Ocean Waves	Pilot Systems - Compressor/Generator
	Ocean Thermal	OTEC Design [1930, 1975]
Geothermal	Geopressured	Heaters, Turbine/generators
	Hot Dry Rock formations	Heaters, *Turbine/generators*
	Hot Water Res.	Water and Space Htg. Systems
	Normal Grad. Res.	Heaters, Turbine/generators
	Natural Steam	Heaters, Turbine/generators
	Molten Magma	No Technology Exists as of Yet
Tidal	Potential Energy of Earth-Moon-Sun gravity	Reservoirs, dams, generators
Hydrocatalysis	Binding Energy of Hydrogen Atom [p^+ to e^- relationship]	Disproportionation Furnace

For each energy source the types of fuels used and the technologies in use today which convert those fuels into useful work and energy for humans is highlighted.

1.1 Fossil Fuels

In the United States fossil fuels provide 89.2% of the energy we consume. In 1995 this consisted of a combined consumption of coal equivalent to 787 million tons per year, natural gas of about 22 trillion cubic feet per year and petroleum product use of 5.9 billion barrels per year.[5] It is clear that an industrial society like ours could not continue without these resources. Globally in 1995 our societies consumed 3441 million tons per year of coal, 75 trillion cubic feet per year of natural gas and 23.3 billion barrels per year of petroleum.[5] The U.S. was the leader in the global use of fossil fuels [specifically petroleum] from the very beginning of its industrialization with the oil strike of Edwin L. Drake in Titusville, Pennsylvania in 1859. "By 1909, when the industry was just 50 years old, the United States was producing 500,000 barrels a day, which was more than was produced by all the other countries combined."[6] We remained dominant in the petroleum production and *manufacturing* markets through 1950 when we still produced over 50% of the world's supply. The key reactions for each of the fundamental fossil fuel types are shown below in Table 1.3.

TABLE 1.3 - Energy Release Processes for Fossil Fuels

Fossil Fuel Type	***Chemical Reaction[s]***	**By- Products**
Natural Gas 85% Methane[CH_4] 15% Ethane[C_2H_6]	$CH_4 + 2O_2 \rightarrow CO_2 + 2(H_2O)$	CO_2, CO, water, hydrocarbons and heat [exothermic reaction]
Bottled Gas Propane [C_3H_8] Butane [C_4H_{10}]	$2C_3H_8 + 9O_2 \rightarrow 4CO_2 + 2CO + 8(H_2O)$	CO_2 ,CO, water, hydrocarbons and heat [exothermic reaction]
Petroleum Gasoline Pentane[C_5H_{12}] Hexane [C_6H_{14}] *Heptane*[C_7H_{16}] Octane [C_8H_{18}]	$C_8H_{18} + 12O_2 \rightarrow 7CO_2 + CO + 9(H_2O)$	CO_2 ,CO, water, hydrocarbons and heat [exothermic reaction]
Coal *contains carbon plus impurities*	$C + O_2 \rightarrow CO_2 + CO$ $S + O_2 \rightarrow SO_2$ [plus SO_x] $N + O_2 \rightarrow NO_2$ [plus NO, NO_3, NO_x]	CO_2 ,CO, SO_2 . NO_2, water, hydrocarbons, SO_x, NO_x particulates, etc. and heat [exothermic reaction]

It is important to note at this point that all fossil fuels release their energy to man through the chemical reduction process known as oxidation. In this reaction the energy that has been stored in carbon and hydrocarbon chains created during the early history of the earth [250-500 million years ago] is released. In this chemical reaction oxygen combines with the carbon fuel in the presence of heat to release additional heat and form water, carbon-dioxide as well as a host of other hydrocarbons and by-products.

The impact on the environment of the use of the stored chemical energy provided in fossil fuels is significant. "One example is the added burden of carbon dioxide in the earth's atmosphere, with its corresponding potential for modifying the world's climate. Other examples . . . include the acidification of the atmosphere and surface waters, . . . early deaths of thousands by sulfur dioxide in the air, . . . ozone formation, . . . problems of coal mining, . . . acid drainage, . . . carbon monoxide and other pollutants from auto traffic, . . . thermal pollution of rivers and lakes".[7] We must add to those impacts the environmental degradation to the air, water and soil that is caused by the release of large quantities of these direct pollutants and the other heavy metals and radioactive elements stored by nature in these fuels [lead, mercury, etc.] It was not until the burning of fossil fuels during the 19th century that the element lead began being deposited in regions as remote as the arctic and continent of Antarctica. Many scientists believe that the acidification and resulting "deaths" of many high altitude lakes have been caused by the release of the pollutants generated by fossil fuel combustion [by industry, homes and in automobiles]. The increased sulfur dioxides and nitrogen oxides generated by industrialization are present in the atmosphere and lead to "the formation of acids, primarily H_2SO_4 and HNO_3, from these pollutants and the resulting damage caused by the acidic rain formed is a story of growing importance."[8] Presently the latest environmental alarm sounded has been that of global warming, a proported warming crisis attributable to a significant increase in the presence of so-called greenhouse gases. The earth's surface radiates thermal energy in the infrared region [approximate wavelengths of 4 to 20 μm] which keeps the global environment cooling at a steady rate. Carbon dioxide [CO_2], methane [CH_4] and nitrous oxide [N_2O] represent molecules formed by the use and manufacture of fossil fuels which trap heat at the above wavelengths, heat that would otherwise be radiated from the earth into space. "Carbon dioxide now accounts for about two-thirds of the greenhouse effect, methane about 25% ." [9] These environmental impacts caused by growing fossil fuel use are forcing many nations to rethink the role these fuels will play in the future.

The limited amount of fossil fuel resources poses a second major risk to continued expansion of the global economy. At present rates of consumption these fuels only have a limited remaining supply, on the order of decades for a few of them to less than a century in the case of coal. [See Table 1.4] In order to meet the needs of our increasingly advancing and growing societies we must find alternatives. Additionally we must preserve some of these fuels since they also serve as key chemical stores in many critical manufacturing and medicine roles in industrial society. If we conservatively grow the current rates of fossil fuel consumption for the energy sector to include the demands that will likely be placed on the finite supply by the developing nations as the globalization megatrend continues we find that the lifetimes are much shorter still.

TABLE 1.4 - Fossil Fuel Reserves and Resource Lifetimes

Fossil Fuel Type		Proven Reserves*	Est. Remaining Lifetime**
Oil			
	Global	999×10^9 bbl	40 years
	U.S.	72×10^9 bbl	16 years ***
Natural Gas			
	Global	5185×10^{12} ft^3	60 years
	U.S.	600×10^{12} ft^3	20 years
Coal			
	Global	7.64×10^{12} tonne	200 years
	U.S.	1.5×10^{12} tonne	86 years, 66 years ****

* Remaining as of 1990
** At current consumption rates
*** Since 1948 the U.S. has imported more oil than it has exported. In 1984 the U.S. was importing 50% of its needs
**** At current consumption rate increased by 5% per year, if coal fills all U.S. energy needs when other fuels deplete

As the limits to the fuel reserves in Table 1.4 are approached the price of energy will begin to climb steadily. It is important to note that one of the key drivers to economic expansion is the readily available supply of affordable energy. Already we see a migration of industry in this country moving from the high-energy cost areas [Northeast and California] to the more inexpensive energy cost areas of the Northwest and Southern states. Many industries which were energy intensive have left the service area of Atlantic Energy [southern New Jersey] to move south over the past decade to North Carolina or another lower energy cost state for primarily energy reasons. [NOTE: economics has played the major role in corporate decisions to relocate from Atlantic Energy's region including costs associated with energy, taxes, employment and environmental compliance] We can estimate that on a global scale the trend will be the same, manufacturing [and the associated benefits of its economic engine] will move to where energy, overall manufacturing and labor costs can keep the company competitive. As industry and manufacturing leave the U.S. for less developed nations the commensurate growth in energy demand and desire for a higher standard of living on the part of those nations' workforces will all press the global energy reserves via higher growth rates in consumption. Examples of this include the nations of Indonesia, Malaysia, Thailand and Vietnam where the annual growth in electricity demand has become double digit during the last 10 years. Were the nations of the developing world [China, India, Southeast Asia, Africa] to develop an energy appetite just a fraction as great as their technologically advanced sister countries [U.S., Canada, Japan, Norway, Sweden] the pressure on the limited global reserves and the strain on the atmosphere would become severe.

This researcher estimates that the values in Table 1.4 for the expected remaining lifetime of global fossil fuel reserves can be reduced by as much as a factor of 2 if the trend in third world energy development follows the forecasts outlined by the World Bank. As these pressures on conventional fuels drive price upward shale oil and tar sand reserves as well as many enhanced oil recovery technologies will become more economic.

An excellent illustration of the demands placed on energy by a developing, industrializing society is illustrated by the following two figures. Figure 1.1 demonstrates the relationship between energy consumption and economic activity based upon figures developed in a Scientific American article in 1971.[10] Figure 1.2 develops similar data on per capita gross national product vs. annual energy consumption based upon World Bank data in 1987.[11] If one observes the nation of Japan on both figures and considers the position it had in the global economy in the early 1970s contrasting it with the economic powerhouse it was becoming by the late 1980s we can see the increase in energy demand that was placed upon the global energy market in order to sustain that one country's economic advancement. Japan's population in 1961 was 89.2 million[12] and it grew to 119.5 million in 1983.[13] In 1971 Japan's populus consumed approximately 33 x 10^6 Btus per capita [9,669 kWh] annually. In the short 16 years of their continued economic growth between 1971 and 1987 their energy use per capita grew to 22 barrels of oil [37,400 kWh] annually. This represents a 4 fold increase in per capita consumption and a 5 fold increase in overall national energy consumption [based upon a 1971 population of 103M and a 1987 population of 125M]. This energy growth correlates directly with their GNP growth from $550 US [1971] to $12,000 US [1987] and the extensive industrialization of their economy. Japan's energy consumption now is 43,285 kwh per capita [1995] and while it continues to grow, their population remains steady at 125M . Were a single, large developing nation such as India [population 936M in 1995] to undertake an economic expansion similar to Japan the impact on global fossil fuel markets would be substantial. India's per capita energy consumption in 1995 was 2,563 kWh annually, were they to reach Japan's per capita energy use it would represent a 17 fold increase in their energy use. By 2020 they would become a nation that consumes 5.7 x 10^{13} kWh annually [assumes continued current population growth rate and acheivement of Japan's level of industrialization and commensurate per capita energy usage]. India's one year energy use in that year would represent 64% of the entire World's energy consumption in 1995 [see Table 1.1]. At those usage rates that one nation alone could consume the entire world's remaining supply of oil in less than 30 years. In aggregate, the developed nations' growing energy consumption rates combined with their continued population growth will substantially reduce the estimates of fossil fuels' expected remaining lifetimes from those shown in Table 1.4. "There is no escaping the reality. . . fossil fuels are formed over very long time periods, and although some new deposits will certainly be discovered, there will be no significant increases in the world inventory over human history. . . the era in which we live is extraordinarily specialized and is set off from all human history and future on this planet by our use of fossil fuels. These energy resources were laid down over hundreds of millions of years during the earth's evolution, and they are now being consumed in what is essentially an instant in our occupation of the planet."[14] Without the discovery and development of an environmentally friendly, inexpensive energy source to significantly offset the consumption of these ancient energy reserves, we will enter the new millennium only to quickly find that the standard of living developed by western civilization is not a sustainable one.

FIGURE 1.1

Relationship between energy consumption and economic activity.
(Based on an original in Scientific American, Vol. 224, No. 3 (1971)

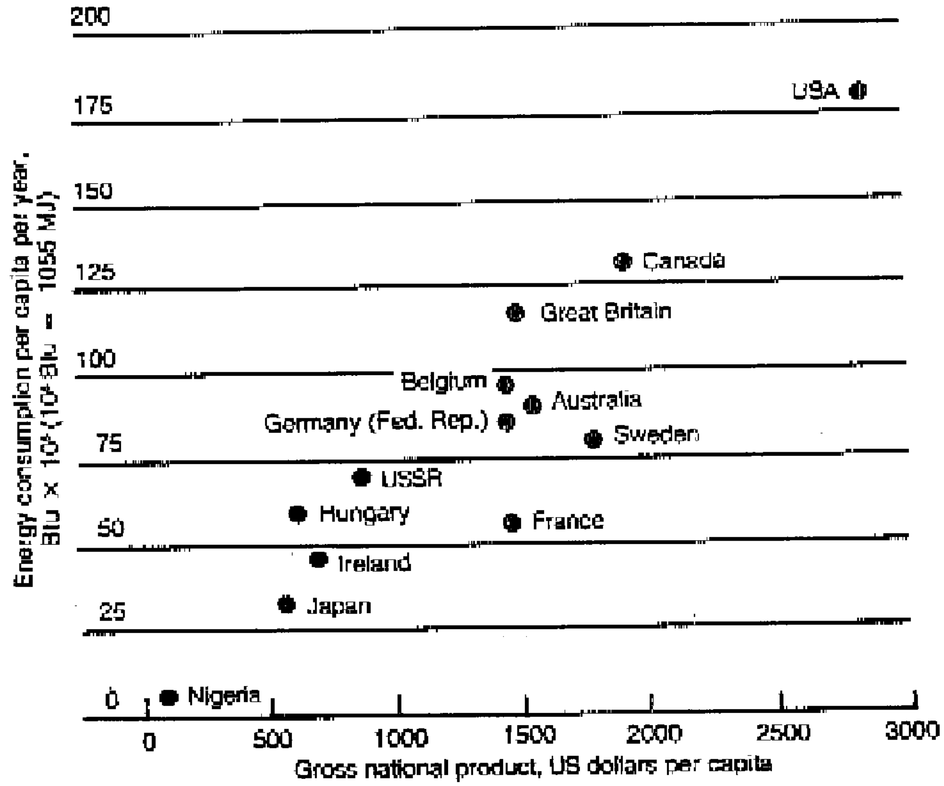


FIGURE 1.2 Per Capita GNP vs. Per Capita Energy Consumption

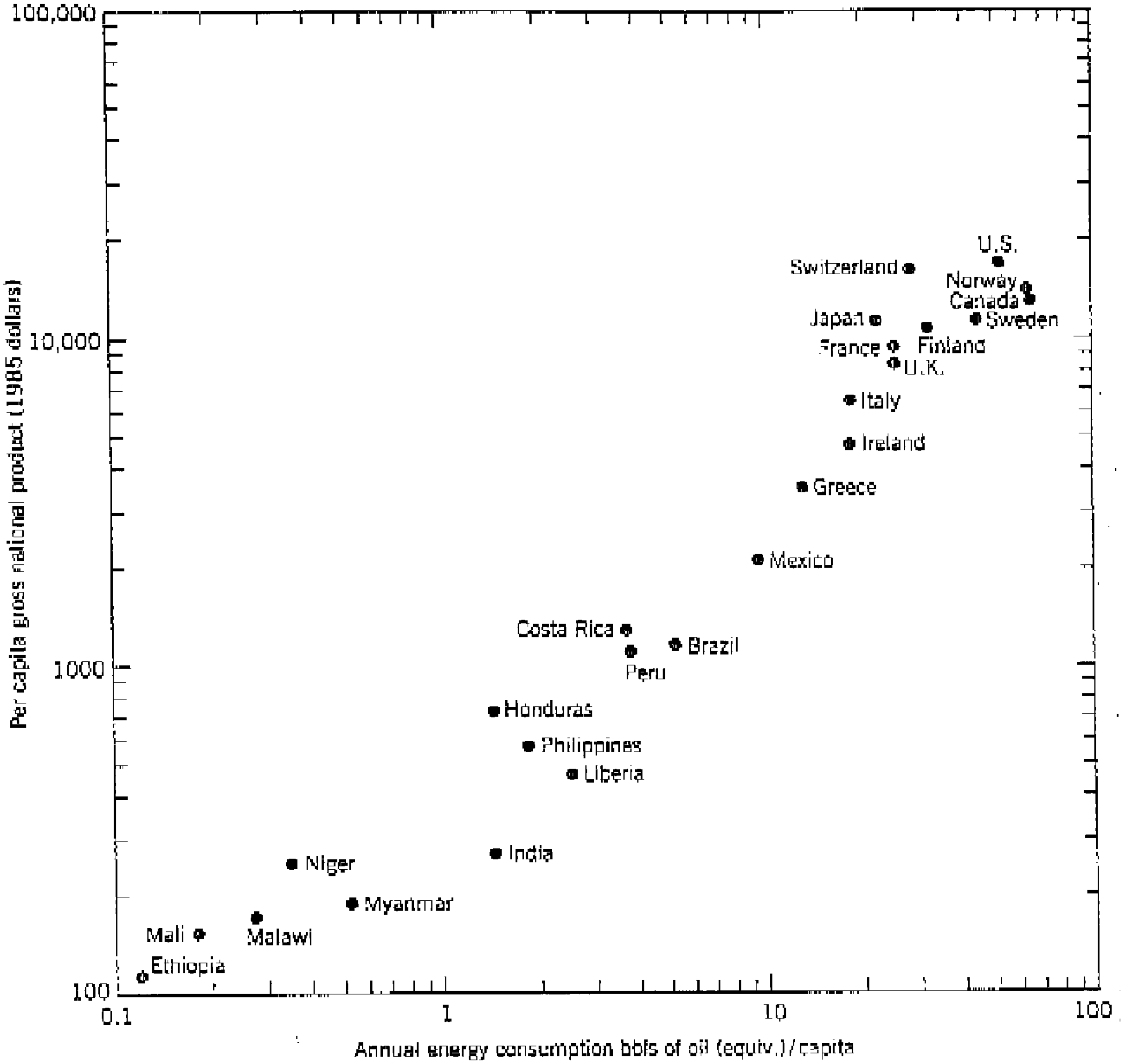
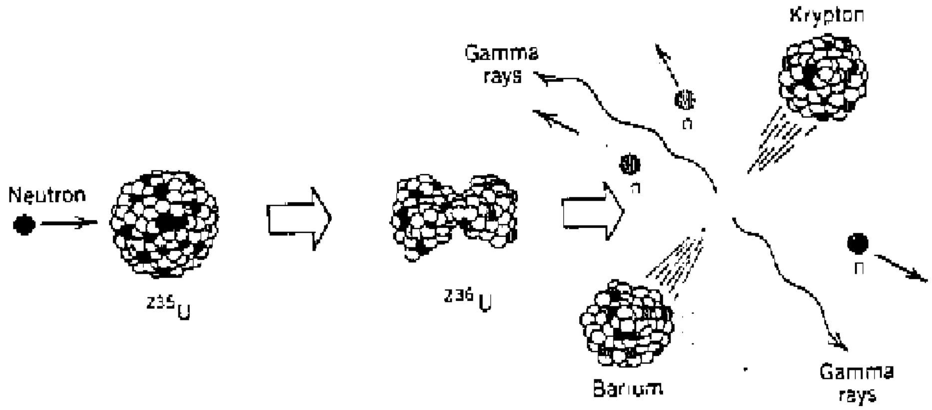


Figure 1.15 Per capita gross national product in 1985 dollars and per capita energy consumption per year in terms of the equivalent barrels of oil. (Source: World Bank [1987]. Adapted from E. S. Cassedy and P. Z. Grossman *Introduction to Energy, resources technology and society.* Cambridge: Cambridge University Press [1990].)

1.2 Nuclear Energy - Fission and Fusion

While the fissionability of uranium was first discovered in 1938 it was not until Enrico Fermi constructed a sustainable nuclear reactor in 1942 that the usefulness of this technology for energy production was truly demonstrated. In a parallel way in which chemical [electronic] bonds between carbon atoms are broken down through chemical combustion with oxygen, the breaking of nuclear bonds via a fission reaction is caused by the bombardment of a radioactive uranium atom's nucleus with neutrons. This bombardment, upon successful collision, causes the nucleus of the uranium atom [^{235}U] to become a highly excited uranium atom [^{236}U], this atom rapidly separates [or fissions] into smaller pieces forming new nuclei as a result. This is more clearly illustrated in Figure 1.3 below. The energy released via this nuclear reaction is equal to Einstein's famous equation $E = mc^2$. To put this in perspective, the energy available within a ton of coal that is chemically released through combustion [ie; breaking down all of the carbon bonds] is 7056 kWh. Were that same ton of coal to be converted to energy via a nuclear reaction the energy available is 22.7 trillion kWh, this is 3.2 billion times more energy.

FIGURE 1.3 Neutron Induced Fission of ^{235}U



This process of working on the nuclear bonds of the atom, rather than the chemical bonds of molecules releases a significant amount of the nuclear binding energy within the atom. What makes this a sustainable chain reaction is the creation of additional neutrons [see fission reaction in Table 1.5] from the fission reaction which can then go and impact additional uranium nuclei to keep the bombardment occurring without external neutron input. Control rods used in commercial nuclear power plants provide a moderating effect on the reaction by absorbing excess neutrons in order to slow or to bring the reaction to a stop. The process outlined above is used in both pressurized water reactors [PWR] used significantly in nuclear submarines and power plants as well as in boiling water reactors [BWR] used widely for commercial applications.

TABLE 1.5 - Energy Release Processes for Nuclear Fuels

Nuclear Process	Nuclear Chain Reaction[s]	Energy Release
Fission	n + $^{235}U_{143}$ --> $^{236}U_{144}$ --> $^{144}Ba_{88}$ + $^{89}Kr_{53}$ + 3n	+ 177 MeV
Breeder	n + ^{238}U --> ^{239}U --> ^{239}Np --> ^{239}Pu + >1n	+ 177 MeV
Fusion	$^{1}H_{0}$ + $^{1}H_{0}$ --> $^{2}H_{1}$ + β^{+} + ν + energy (1) $^{1}H_{0}$ + $^{2}H_{1}$ --> $^{3}He_{1}$ + energy (2) $^{3}He_{1}$ + $^{3}He_{1}$ --> $^{4}He_{2}$ + 2 $^{1}H_{0}$ + energy (3) 4 $^{1}H_{0}$ --> $^{4}He_{2}$ + 2β^{+} + 2ν + energy	

Detailed descriptions of the nuclear energy process is not within the scope of this research but rather an overview of these technologies and their associated economic and environmental risks are described below.

The breeder reactor is a concept not yet fully commercialized which takes advantage of the fact that free neutrons are not only capable of inducing fission via a conversion of ^{235}U to ^{236}U, but are also as equally capable of converting a ^{239}U atom into ^{239}Pu. This is very valuable since ^{239}Pu is also a fissionable material capable of acting as a fuel in standard nuclear reactors. If the design of a breeder reactor could be optimized to create additional ^{239}Pu while also creating uranium fission it would be a reactor that created its own fuel and would significantly increase the lifetime of nuclear fuel materials.

Fusion is a nuclear reaction that occurs commonly on the stars and in the case of our sun is likely the source of approximately 60% of the energy it provides. This estimate is based upon observed solar neutrino flux as measured by the Gallex solar neutrino detector in Italy.[15] As shown in Table 1.5 above according to the Standard Solar Model fusion begins with the combining of two hydrogen nuclei (protons) to form a deuterium nucleus. The process then continues to build a heavier helium nucleus all the while releasing large amounts of the nuclear binding forces within the atom. For a more complete explanation of this process the reader is referred to pages 108-111 of ***"Energy and Problems of a Technical Society"*** [16], which is an excellent summary of energy technology information referred to often in this paper. Due to the very high temperatures involved, the limits of current materials and the fact that proof of the scientific feasibility of the essential reactions has not yet been established it is unlikely that significant additional funding will go into the development of fusion. The Tokamak Fusion Test Reactor [TFTR] located at the Princeton University Plasma Physics Lab was designed to answer some of these fundamental questions. It appears that after significant resources have been invested in this test those questions will still not be sufficiently addressed. The TFTR was shut down on April 3, 1997 "many say prematurely ... for lack of money".[17]

In the U.S. during the last decade no new nuclear power facilities have been opened, ordered or planned. This is due in large part to 4 primary developments during the past 15 years. These facilities have become very expensive to build and meet all Nuclear Regulatory Commission [NRC] standards, the issue of nuclear waste storage has yet to be resolved by the utilities and the Federal government, there was and continues to be significant public opposition to this technology and there have been key nuclear accidents which have increased the financial risks and liabilities to investors and owner / operators of such facilities. When nuclear advocates were espousing the virtues of this technology in the 1960's and 1970's it was believed that the energy would be so cheap that utilities would not need to meter customers any longer. As the technology was deployed, many safety features were required "along the way" by the emerging NRC which wanted to assure the safety of the technology. This often led to major cost overruns and units that were intended to come on line for $1,000 - 1,500 per kilowatt escalated to often over $4,000 per kilowatt. Many units in the Northeastern and Western regions of the U.S. were never finished due to these massive costs. This is clearly one of the key reasons utilities are not interested in the technology today. Another reason is the longevity of hazardous nuclear radioactive wastes. Table 1.6 below indicates the lifetimes of radioactive materials generated as by-products from the nuclear industry.

TABLE 1.6 - Nuclear Fission By-Products Radioactive Halflives[18]

Radionuclide	$T_{1/2}$ [Halflife]	Decay Particle
^{233}U [uranium-232]	1.59×10^9 years	α
^{239}Pu [plutonium-239]	2.41×10^4 years	α
$^3H_2$ [hydrogen-3, tritium]	12.35 years	β^-
^{90}Sr [strontium-90]	29 years	β^-
^{131}I [iodine-131]	8.04 days	β^-
^{137}Cs [cesium-137]	30.17 years	β^-
^{85}Kr [krypton-85]	10.72 years	β^-

It is clear that wastes from the nuclear industry will need to kept away from the human population and environment for excessive lengths of time [often exceeding many generations]. Although this was known in the early years of this technology, as of today, after over 20 years as an active industry, the government and utilities have yet to find an acceptable long-term high level waste repository. It is unlikely that the nuclear industry in the U.S. will see any significant expansion during the next few decades. In Sweden recently the government ratified its 17 year old promise to remove all nuclear reactors from service in its country by 2010. The first two reactors will be officially removed from service in 1998 and 2001 "before their technical life expires". [19] This leaves only France, Japan and a few developing nations that will be expanding their commitments to nuclear fission as a viable energy source for the future.

1.3 Solar Energy

Without a doubt the most widespread form of energy in the universe is the energy radiated from the stars. Specifically in our solar system, the Sun is the source of nearly all forms of useful energy. From the fossil fuels first formed by carbon fixing organisms [plants and animals] in the presence of solar energy 250-500 million years ago to the hydroelectric plants operating on major rivers, the Sun is responsible for creating the potential energy each represents. This section will briefly summarize all of the primary forms of solar energy and prioritize their discussion from the most economical and technologically ready to the forms that are the least economical and require the most additional development. It is important to note that although significant attention is given to these sources of energy because of their potential for the future, at the present time solar energy in all of its forms represents less than 3% of the World's commercially traded forms of useful energy. Of that small fraction over 90% represents the use of solar energy in the form of hydropower.

The most developed form of solar energy is hydroelectricity. The hydrologic cycle driven by the sun evaporates over 5.5 quadrillion cubic feet of water from the earth every year. This same energy falls back to the earth in the form of rain and the potential energy of water at higher elevations. Of the more than 100 quadrillion kilowatthours of energy in the hydrologic cycle only a very small portion is harnessable. Most precipitation falls back into the oceans with only a fractional amount falling upon dry land at higher elevations where its potential energy becomes available for exploitation via rivers, dams, waterwheels and hydroelectric generating facilities. World energy usage statistics indicate that in 1995 we were providing approximately 2.3 trillion kilowatthours[20] of our global society's energy needs through hydroelectric sources. This represents approximately 2.5% of all energy consumed. Man's use of falling water to displace human and animal energy dates back over 2000 years. Hydropower also played a major role in the industrialization of western

Europe the 16th century when waterwheels served as the primary powerhouses. While many believe the potential for exploiting more hydropower is great there are environmental considerations and social concerns that make extensive expansion unlikely. Due to the need to create large dams and reservoirs to harness hydropower there is often substantial displacement of people as well as restriction of the normal ecology of the river. While it represents a significant capital investment, where it can be practically developed hydropower remains an economic source of electricity.

The most widely known and experienced form of solar energy is biomass. A significant majority of the World's now 5.8 billion people[21] come in contact with this fuel on a daily basis. The biomass category represents fuelwood, charcoal, agricultural products and waste [alcohol, dung, mill residues, rice hulls, straw, etc.] as well as the less recognized biomass of industrial society - municipal solid waste [mostly paper and packaging materials]. Least recognized in the category of biomass is the harvesting of ocean biologic life [seaweed, algae, etc.] for fuel production. "Noncommercial biomass fuels ... already supply more than 10 percent of total global energy needs and a much higher percentage of the energy needs in developing nations, albeit with low levels of efficiency and service quality."[22] This source does not appear in Table 1.1 since very little biomass is commercially traded on the global level. The sun plays the critical role in the creation all the biomass fuels either directly through photosynthesis or indirectly via man's or animal's use of a product the sun's energy created [ie; foodstuffs, paper, etc.]. Besides using biomass for meeting heating and other human energy needs probably the most common use is in the food we eat. Vegetables, fruits and other animals all received their energy from the solar source as well through the process of photosynthesis shown below:

$$6CO_2 + 6H_2O \xrightarrow{\text{LIGHT}} C_6H_{12}O_6 + 6O_2$$

The energy release processes for biomass are very similar to fossil fuels where the biomass is directly burned in the presence of oxygen to release the energy of carbon chains and form CO_2, H_2O, etc. Continued use of biomass is inevitable, expanded use of wood and woodwaste as a fuel in the U.S. is likely as well. Without specialized biomass growing and harvesting techniques and efficient fuel conversion systems it will be quite a few years into the future before these fuels will become economic on a large scale and find a major place in the growing global energy market. The energy densities of biomass fuels are relatively low, on the order of lignite to peat coal resources, and this also presents barriers to commercial development.

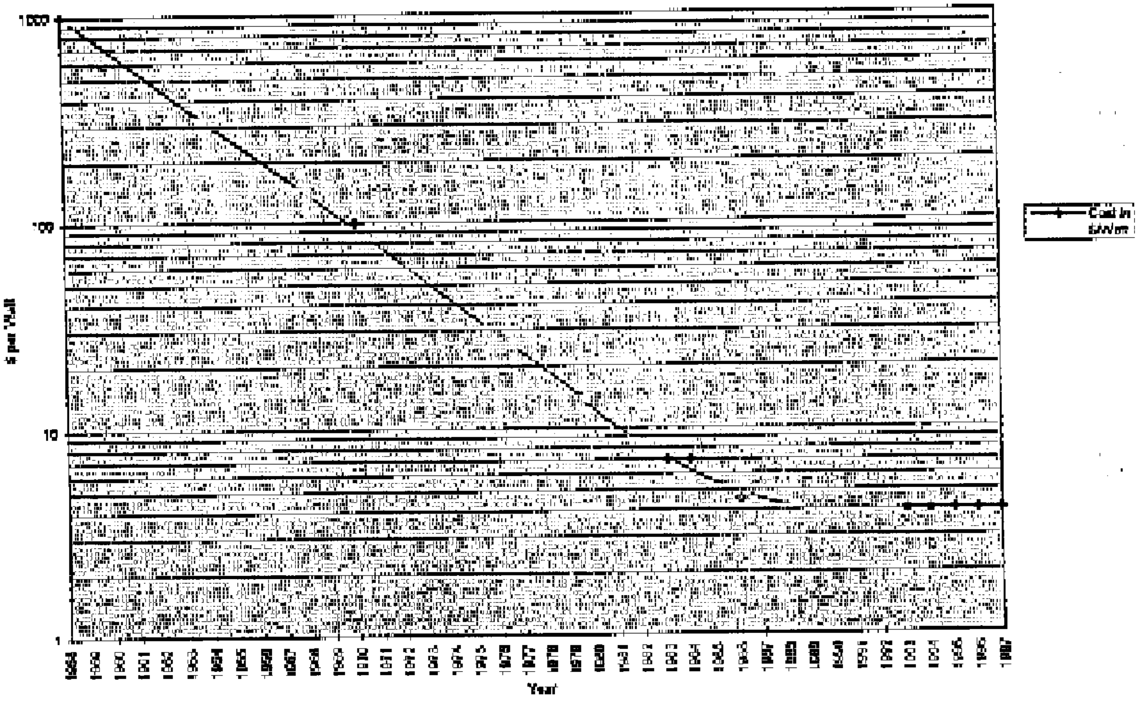
Another widely experienced form of solar energy is the direct heating of the sun known as solar thermal energy. From the highly technological systems we have created [passive and active solar space and water heating systems] to the primitive habit of laying out in the sun for a siesta or tan, the human race daily takes advantage of the direct warming available from the sun. Many societies still use the sun for drying grains [such as rice] as a critical step in their agricultural process. In the U.S. the most prevalent form of solar thermal energy use is in passive and active heating systems for homes as well as heating systems for hot water. During the late 1970s and early 1980s the Federal government provided significant tax incentives for renewable energy systems. This led to many domestic solar hot water heating systems being installed throughout the country. These systems typically consist of a solar collector device that traps incoming short wavelength incident solar radiation and upon collision with a dark, metallic 'absorber' plate the light energy is converted directly to heat [or mechanical molecular vibrational energy] in the absorber plate. This collector is typically called a flat-plate solar collector. The absorber plate typically has an antifreeze solution which runs through it [i.e. it acts as a heat exchanger to move the incoming solar energy it absorbs into the fluid] and this fluid is used to capture, move and store the solar energy for use either in a hot water system or for heating a home or building. Another example of solar thermal energy systems is the focusing collector which comes in various shapes, sizes and configurations. From the Solar One power tower demonstration in Barstow, California which had a commercial production of 10 megawatts, to modular, parabolic dish and trough systems that collect watts to kilowatts of power, directly focusing the sun's energy on a light-absorbing surface can create commercially meaningful heat. The drawbacks with all of these systems was that they were never economically attractive. Most solar thermal heating systems have between a 15 and 30 year simple economic payback. Without significant social policy change or government subsidy these types of heating and energy production systems will not be commercially significant.

Another solar resource is wind power. In 1995 it was estimated that geothermal, wind and solar of all types accounted for nearly 5% of the world's primary electricity generation [ie; 0.5% of the world's total energy resources]. This resource was used from the most ancient of times by mariners in their quest for increasing the speed of their then human powered vessels to the applications of water pumping and grain grinding by animals in Europe and America in the 19th and 20th centuries. Wind power is still used in many locations throughout the world for these purposes. As an electricity generating source wind power first began to find its way into the marketplace in the 1970s and 1980s in both Europe and the U.S. While we know that the mechanical motion of air is a direct consequence of solar heating of the planet it has always been a challenge to economically extract the energy in this air movement. Modern wind turbines are designed to remove the kinetic energy in the wind and use that energy to turn a generator to provide electricity. They do this by placing their aerodynamically efficient blades into the wind to enable the mechanical force of the wind to cause those blades to rotate and sweep over a large area. Present technologies include vertical axis wind turbines as well as horizontal axis wind turbines; manufacturing is dominated by the latter at the present. The energy that can be removed by a wind turbine is proportional to the area its blades sweep out as well as the cube of the wind velocity. For this reason most turbines are mounted on towers to place them more aloft where higher wind regimes are present. In areas of moderate to high annual wind speed, wind turbine generators are able to create electricity at approximately $.05 per kWh assuming a 20 year equipment life. It is difficult to find areas where local citizens are willing to allow wind facilities to be located at the present time and it is also increasingly difficult to find investors willing to tie up their capital for a project that produces electricity at a higher cost than where the electricity market is at present [i.e. $.02-03 per kWh].

A widely acclaimed technology that showed promise in the 1980s of becoming a major player in the solution to the energy crisis is photovoltaics. These are semiconductor devices made of materials that are designed and oriented in such a way as to convert light energy [photons] directly into electrons at efficiencies of 5-30%. PV devices being developed commercially employ similar physics in their operation. The photovoltaic effect is created when incoming photons interact with electrons in a semiconductor material so as to create a charge carrier pair; an electron and a "hole". Each PV device is constructed with positively and negatively doped layers so as to maximize the cell's ability to separate the charge carriers and keep them separated so as to induce a voltage across the cell as long as the incoming light is present to induce this voltage. The photovoltaic effect was first discovered by 17 year old French physicist Edmund Becquerel in the 1850s when he was experimenting with batteries. He noticed that his batteries were able to provide significantly more energy in the presence of light than when shaded in the darkness. He noted this in his journal but it wasn't until Albert Einstein's work in 1905 that the principles behind the photoelectric effect were described scientifically. This technology's potential lay dormant for another 50 years until the space race began. After Russian scientists launched Sputnik in 1957 and the U.S. had fallen behind in the race they wanted to assure that their first satellite would 'last longer'. As a result in 1958 the Vanguard satelite was launched by the U.S. powered with not only a battery, but a battery recharged on-board by the world's first commercial application of photovoltaic cells. [Sputnik lost its battery energy and floated useless in space after only a few months] Those cells, costing over $1000 per watt kept the Vanguard satelite's batteries charged for years of successful operation.

Since that time the cost of photovoltaic [called PV] cells continued to plummet driven by advances in technology, increased manufacturing volume and increasing demand for satellite applications, remote power applications as well as commercial electricity uses. Figure 1.4 shows the progressive decline in PV cell prices as advances in technology continued through the 1980s. By the late 1980s as Federal research monies for renewables decreased during the Republican Administration, the commensurate investment in and advancement of PV technology subsided. Current pricing for PV cells has not substantially changed from those present in 1989

FIGURE 1.4 Photovoltaic Module Prices



In addition to the photovoltaic modules that are made up of cells configured to provide adequate current and voltage, a PV system requires balance of system components. These components are module mounting and wiring peripherals, a DC to AC inverter for typical interface with home wiring and the installation [roof or ground mount, etc.] of the entire system. In 1996 these were estimated to cost $2 per watt, $1 per watt for the inverter and $1 per watt for balance of system hardware and installation. This would bring a total PV system's cost to $6-7 per watt installed. To put this in perspective, a typical home could use a 4kW system which cost $24,000 to install. This system would provide approximately 6,000 kilowatthours of useful energy each year at present electricty rates this $750 per year savings represents a simple payback of 32 years. Near term growth in economic expansion of the PV market for utility connected customers appears unlikely. Market research conducted by the author and his colleague indicate that until installed PV prices reach $0.6-1.3 per watt, no major changes in the demand for PV by the grid-connected market is likely.[23] There are many different types of PV cells that have been attempted from single crystalline to multi crystalline to amorphous cells. In the last five years only minor additional improvements to the technologies have been made leading to a flattening of the price curve at $4 per watt since 1990 [see Figure 1.4].

Probably the forms of solar energy with the least potential for future development and expansion are ocean thermal and wave power. The ocean is a source and sink for energy of many types. It is probably the vast dihydrogen oxide resource of the ocean that keeps the temperature, environment and atmosphere of the planet moderated and suitable for human life. In that same environment thermal gradients and atmospheric disturbances cause currents, waves and temperature differences around the world. Ocean Thermal Energy Conversion [OTEC], is a technology that was conceived of in 1880 by d'Arsonval. OTEC takes advantage of the thermal gradient which exists in the sea and is especially pronounced around the tropical regions where surface water temperatures can get very high. This approach to energy generation uses ammonia as a working fluid. This fluid runs an evaporator-condensor cycle where cold water from deep in the ocean condenses the ammonia vapor while warm water on the ocean surface is used as a heat source to boil the ammonia to give it the vapor pressure needed to drive a gas turbine. The gas turbine in turn drives an electric generator. In 1930 the first demonstration plant was constructed in Cuba; since that time no additional plants or demonstrations have been constructed. The islands in the tropic zones may have potential for this technology at some point in the future but presently the technology is very expensive which has limited its development. Wave energy systems are not commercially available at the present, but it is believed that the difference in wave heights may be commercially exploited at some point in the future. Ocean currents may provide a significant potential source of energy as well but no commercial technologies currently exist to harness it effectively. Similarly to OTEC, ocean current systems will be further hindered by the fact that where the energy source is located is often far from where the demand for energy exists.

1.4 Geothermal Energy

If you have ever sat or swam in a natural hot spring you are familiar with one of the benefits of Nature's outpourings of geothermal heat. While less dramatic than the volcanos or geysers, low temperature geothermal sources make up a significant portion of the global geothermal resource. The most widely used type of geothermal resource for energy generation is the natural steam reservoirs. By 1990 the U.S. was generating "over 2800 MW$_e$ at 4 to 6 cents per kWh"[24] from these reservoirs in the western states. While the U.S. potential for geothermal is estimated at 22,675 QBtu [this compares with an annual U.S. energy use of 82 QBtu] there has been little additional exploitation of these reserves since the removal of Federal tax subsidies in the 1980s. The most economical and expanding market for geothermal energy applications exist in the residential and commercial sectors. Geothermal heating and cooling systems use the earth as a heat source and sink with an electric heat pump to move heat into or out of the conditioned space. Geothermal heatpumps move 3-4 kWh of energy for every one kWh of energy they consume. This technology was perfected in Sweden and is seeing extensive application in the U.S. and other industrialized countries. In many applications it represents the least costly heating and cooling system on an annual energy as well as operation and maintenance cost basis. The use of geothermal energy in these applications is likely to expand.

1.5 Tidal Energy

There are presently no commercial tidal facilities in the United States and only three tidal power systems in the world. These facilities operate on principles that are very similar to those of hydroelectric stations. They require a reservior, a dam and a series of turbine generators. In the case of tidal systems they are capturing the kinetic energy that exists in the movement of tidal waters into and out of an estuary or man-made reservior four times each day. The energy is being created by the gravitational interaction of the Sun, the Moon and the Earth which causes this motion in the seas daily. In the lower 48 continental U.S. the tidal variations range from 2 to 16 feet between mean high and mean low waters. In the U.S. the potential for tidal power represents less than 15,000 MW. The global potential for the most favorable tidal power sites is about 63,000 MW, or about 1/50th the world's potential for hydroelectric power.[25] The three tidal facilities in operation worldwide are a 1-MW plant on the White Sea in Russia [1969], a 240-MW plant on the Rance River in France [1966], and most recently a 20-MW plant on the Bay of Fundy in Canada.

Chapter 2 - An Overview of Mill's Technology

This chapter will focus specifically on the hydrocatalysis technology developed by Dr. Randell Mills of BlackLight Power, Inc.. After providing an overview of the theory behind the design of the various technologies I will move to a review of the astrophysical data which supports Dr. Mills' claim that fractional state hydrogen is common and abundant throughout the universe. I will highlight some key enigmas that Dr. Mills' theory solves and review the current technological devices that capture energy from this new found fuel source. Table 2.1 below summarizes the significant government, corporate and university research centers that have partnered to corroborate many of BLP's experimental findings.

TABLE 2.1 - BlackLight Power Research Partners

LABORATORY	WORK PERFORMED
Government	
Idaho National Engineering Laboratory	Electrolytic Cell [850% Vi] X-ray Photoelectron Spectroscopy
SDIO-Wright Patterson AFB	Diffusion Cell
Chalk River National Lab [Canada]	Electrolytic Cell [130% Vi DC]
NASA - Lewis	Electrolytic Cell [170% Vi DC]
Brookhaven National Lab	Electrolytic Cell
University	
Lehigh University - Zettlemoyer Center for Surface Studies	X-ray Photoelectron Spectroscopy
M.I.T. Lincoln Laboratory	Electrolytic Cell [400% Vi DC]
Pennsylvania State University	Gas Cell [>2000% H_2 Energy]
Ursinus College	Electrolytic Cell
Moscow Power Engineering Institute	Electrolytic Cell [250% Vi DC]
Laboratory for Electrochemistry of Renewed Electrode-Solution Interfaces [LEPGER]	Electrolytic Cell
Corporate	
Thermocore, Inc.	Electrolytic Cell [2100% Vi AC]
Air Products & Chemicals	Mass Spectroscopy
Westinghouse Electric Corporation	Electrolytic Cell [150% Vi DC]
Charles Evans & Associates Laboratories	TOF-SIMS
Schrader Analytical & Consulting Laboratory	Mass Spectroscopy
BlackLight Power Laboratories	Electrolytic Cells [2100% Vi AC] Gas Cells [2 - 50 watt Energy] Mass Spectroscopy Gas Chromatography

In the column entitled "Work Performed" I have summarized the types of devices tested or work performed in each laboratory. In all cases these labs provided data and results which were consistent with the results anticipated by the Mills theory [i.e. excess heat production, hydrino or dihydrino signatures, etc.]. The numbers in brackets, where provided, show the energy output to energy input ratio confirmed by the lab. I gathered this data by reading and summarizing the reports produced by the labs themselves. A detailed bibliography of the reports generated by these partnerships, plus others I was able to catalogue has been provided in Appendix 1. It is important to note that all of the work in Table 2.1 is very recent, having been completed during the last five years. The four subsections of Chapter 2 are as follows: Section 2.1 will briefly describe the theory Dr. Mills developed leading to the design of the various BLP technologies. Section 2.2 will summarize and analyze some of the astrophysical data which supports Dr. Mills' claims with that this new form of hydrogen is prolific throughout the universe, Section 2.3 will describe a few of the enigmas that Dr. Mills' theory solves, and Section 2.4 will provide a brief synopsis of the state of the art of current BLP technological devices that demonstrate energy production from the new found fuel source.

2.1 Hydrocatalysis - A Theoretical Overview

The catalytic reduction of atomic hydrogen below its ground state of n=1 has been postulated by Dr. Randell Mills of BlackLight Power, Inc. There is substantial data that has been gathered confirming an unexplainable amount of energy being released from hydrogen; these energy values are well in excess of any known chemical reaction with hydrogen and were observed by others when reproducing BLP experiments. In addition, new electronic signatures corresponding to the expected [ie; calculated] energy values for low energy hydrogen via mass spectroscopy, gas chromatography, x-ray photoelectron spectroscopy and extreme ultraviolet spectroscopy have been identified. A non-trivial number of independent laboratories and research centers have been involved in the confirmations described in the above findings. In addition, a sound theoretical basis for the phenomenon has been postulated by Dr. Mills which unifies field theory with a completely classical approach to physics. Mills theory holds at its foundations inviolate the classical laws of physics, including all of those listed below:

1] Conservation of mass-energy
2] Conservation of Linear and Angular Momentum
3] Maxwell's Equations
4] Newton's Laws of Mechanics
5] Einstein's Special Relativity
6] Einstein's General Relativity

The postulated reduction of hydrogen to fractional quantum energy levels represents a radical departure from currently held quantum theory. But when it comes to the classical laws of physics the Mills' theory rather than contradicting current models actually builds upon them. Dr. Mills' approach is fundamentally based upon the theoretical hydrogen atom energy equation developed by E. Schrödinger and W. Heisenberg in 1926 shown below. [26]

$$E_n = -e^2 / n^2 8\pi\varepsilon_0 a_H = -13.598\text{eV} / n^2 \qquad (1a)$$

$$n = 1, 2, 3, \ldots \qquad (1b)$$

Dr. Mills has proposed that a new boundary condition, derived from Maxwell's equations, be applied to Schrödinger's original equation. When it is applied to the fundamental hydrogen equation the Mills' model suggests a purely physical model which applies for all of known nature. This same model applies on the microscale [i.e. particles, atoms, molecules] and through the macroscale [i.e. planets, stars, galaxies and the overall universe]. A more detailed overview of Mills' theory for the interested reader was developed by this researcher and is provided in Appendix 2. The modification Dr. Mills' theory would make predicts that equation (1b) above be replaced with equation (1c) below which allows for lower than n=1 non-radiative valence states for the hydrogen atom.

$$n = 1, 2, 3, \ldots, \textit{ and, } n = 1/2, 1/3, 1/4, \ldots \qquad (1c)$$

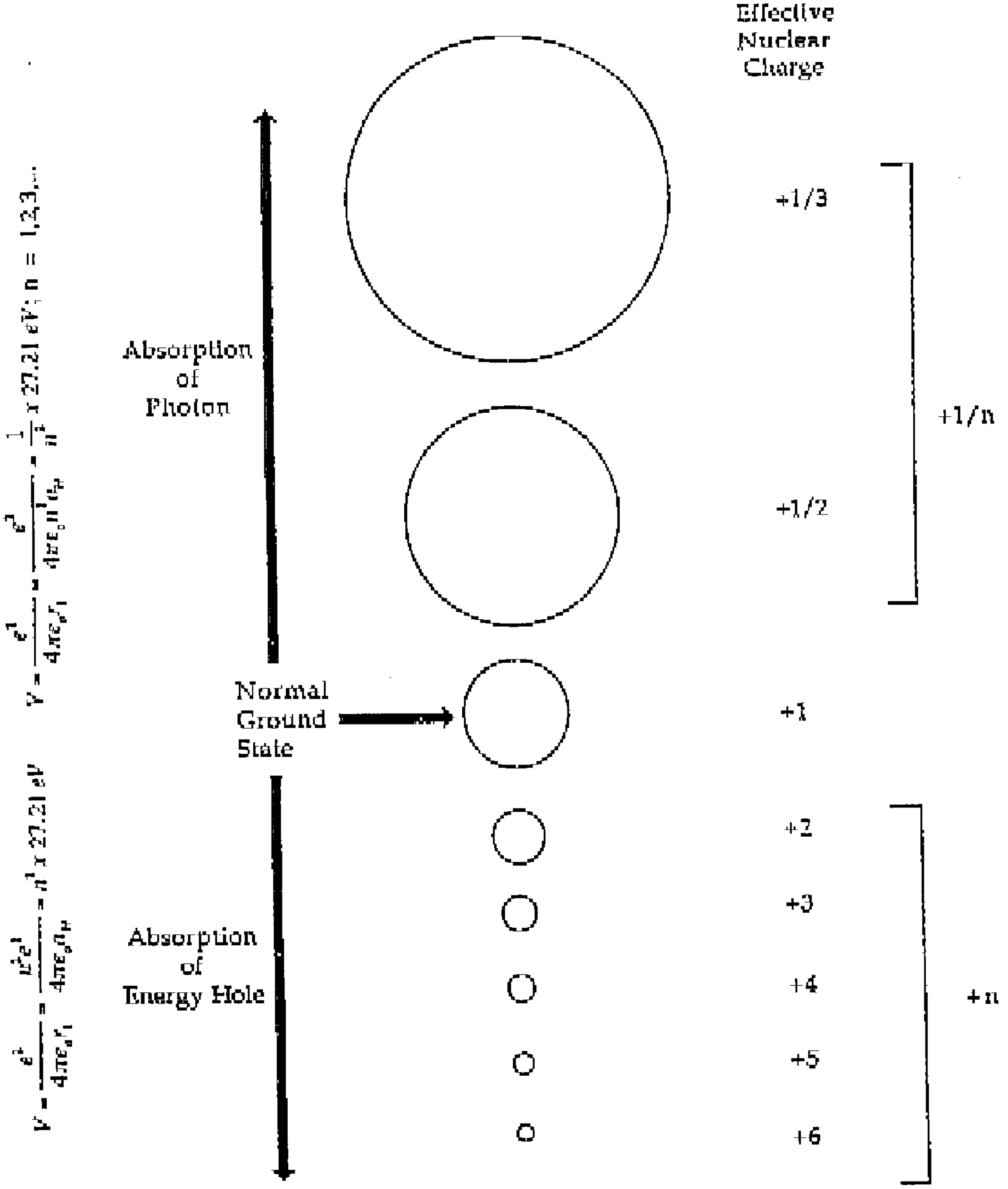
His mathematical solution uses fundamental constants only and the energy values predicted by his theoretical approach agree in a most compelling way with observations scientists have made of the universe and stars. The new form of fractional valence states of the hydrogen atoms [named "hydrinos" by their discoverer, Dr. Mills] are able to radiate meaningful amounts of energy as they undergo electron relaxation to lower energy states [see Table 2.2].

TABLE 2.2 - Energy Released From Lower Energy Hydrogen

n	R [radius]	Energy Released (eV)	
		$r = \infty$ to $r = R$	$\Delta E_{final} - \Delta E_{initial}$
1	a_H	13.6	---
1/2	$a_H/2$	54.4	40.8 [1 ->1/2]
1/3	$a_H/3$	122.4	68.0 [1/2 ->1/3]
1/4	$a_H/4$	217.7	95.3 [1/3 ->1/4]
1/5	$a_H/5$	340.1	122.4 [1/4 ->1/5]
1/10	$a_H/10$	1360	258.4 [1/9 ->1/10]
1/100	$a_H/100$	136keV	2706.4 [1/99 -> 1/100]

This source of energy likely represents more than 40% of the radiant energy created by stars. Figure 2.1 below is an illustration of the change in radii of the hydrogen atom taken from his text on his theory ***"The Grand Unified Theory of Classical Quantum Mechanics"***. [27] The well accepted model [i.e. when a hydrogen atom absorbs a photon and increases the radii between its electron and proton, n=2, n=3, n=4, etc.] is shown in the top half of the page.

FIGURE 2.1 Quantized Sizes of Hydrogen Atoms



The radical new model Dr. Mills has proposed [i.e. that there exist stable forms of hydrogen in fractional energy states below the accepted ground state, n=1] with its commensurate fractional radii between the electron and proton [i.e. n=1/2, n=1/3, n=1/4, etc.] are shown on the next page. The model being proposed will hereinafter be referred to as "Mills Theory".

It is important to emphasize at this point that the transistions described are not *nuclear*. This is a chemical reaction that only effects the binding energy of the hydrogen atom's electron. The fundamental energy release mechanisms in this process are *hydrocatalysis* and *disproportionation*. Hydrocatalysis occurs when a hydrogen atom with its electron at its normal ground state or a lower ground state [ie; $n \leq 1$] reacts with a catalyst having a net enthalpy of 27 eV. Energy is released per equation (1d). Disproportionation occurs when a lower energy state hydrogen atom [ie; $n < 1$] collides with another lower energy state hydrogen atom [ie; $n < 1$] which results in the ionization of one atom [ionization energy is a multiple of 27 eV] and the transition of the electron of the other atom to a stable, lower energy level. Energy is released per equation (1e) when the atom which ionizes has its electron at its $n = 1/2$ state.

$$E = (1/n_f^2 - 1/n_i^2) \times 13.6 \text{ eV} \tag{1d}$$

$$E = (1/n_f^2 - 1/n_i^2) \times 13.6 \text{ eV} - 54.4 \text{ eV} \tag{1e}$$

The interested reader is referred to Appendix 2 for more detail on Mills theory.

2.2 Astrophysical Corroboration

The theoretical model proposed by Mills might remain an interesting approach to unifying physics but be written off as a theory of no import were it not for the fact that the laboratory of the universe provides a prodigious amount of data which appears to support his predictions. For example, his theory predicts that the electronic transition of atomic hydrogen below its ground state of n=1 is a widespread phenomena which provides a significant amount of the energy radiated by all stars. The theory also predicts this transition reaction occurs in the atmosphere of some of the larger planets [Jupiter and Saturn] as well as in the dark regions of space. Hydrogen is the most abundant element in the universe, and if it also is able to exist in a stable form in lower energy states it must be measurable and detectable. There is substantial observational data confirming that possibility. One source is the extreme ultraviolet spectrometer data collected and analyzed by Simon Labov and Stuart Bowyer of the Center for Extreme Ultraviolet [EUV] Astrophysics at UC-Berkeley.[28] They designed and had launched a diffuse, grazing incidence EUV spectrometer into space from White Sands Missile Range in the spring of 1986. They analyzed their data and published it in the Astrophysical Journal in the spring of 1991. Their data is remarkable in many ways; 1] it was not believed that such data could be collected, 2] they observed and validated significant emission features and signatures from the dark regions of space, 3] they acheived a very high statistical confidence that the data was real [in many cases >99% confidence] and 4] their explanations for what these emission signatures must be postulate that an unexplainably high temperature [million degree gases] must exist in what was otherwise believed to be a vastly cold region.

Upon review of this data the scientists of BLP, being chemists by background believed that "hot interstellar gas" view of dark space was not very plausible. They undertook to view this data in light of the fundamentals of the Mills' theory which predicts that lower energy hydrogen can collide with other lower energy hydrogen atoms and undergo an energy transition to a lower non-radiative energy state. These transitions radiate at specific energy levels and wavelengths as predicted by equations (1d) and (1e) as described above. While the Labov and Bowyer's interpretation of these signatures originating from hot interstellar gases [Fe_{XIX}, FE_{XI} , O_V, etc.] is more widely accepted by astrophysicists, other scientists see the explanation as less plausible.

The BLP assignment of these and many other planetary, stellar and interstellar radiation signatures to a calculated amount of energy being released from hydrogen atoms undergoing collisional effected transitions to lower energy states appears to be much more plausible. When the data is analyzed and one views the assignments of the probable hydrogen transitions and sees the reasonableness of such a theoretical match it appears to be much more than a remarkable coincidence. The analysis provided by BLP in Table 1 [on page xiii of the Forward] as well as page 424 of the text on the theory [27] shows a match between the background data and theoretical transitions for nearly all of the transitions that are probable to the n = 1/8 state of hydrogen. I have reproduced these calculations in Appendix 3 and provide a summary of one of those spreadsheets on the page that follows as Figure 2.2.

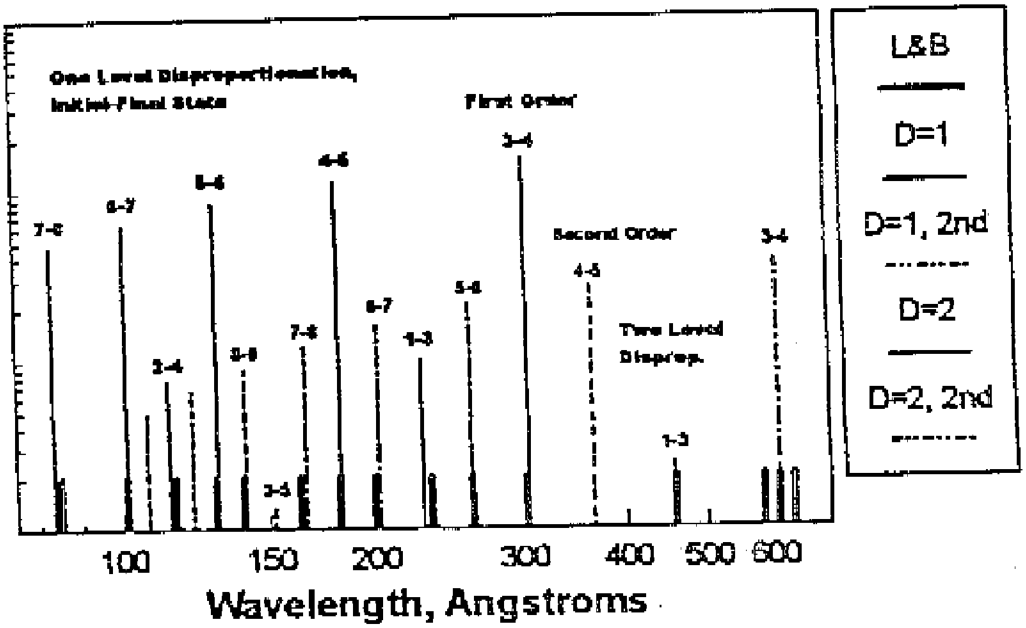
Perhaps an even more compelling way to view this data is in the manner developed by Jim Kendall, P.E., a Ph.D. Nuclear Engineer from Technology Insights [a technology assessment firm from southern California]. He graphically stacked the Labov and Bowyer data side by side with Mills theory predictions as shown in Figure 2.3 to reveal a correlation which is most persuasive.

FIGURE 2.2 - Astrophysical Observations and Mills Theory

Raw Extreme UV Background Spectral Data *

	OBSERVED DATA			Fractional State		MILLS PREDICTED		
	Wavelnth	Energy	Calc	1/nf	1/ni	Wavelnth	Energy	
Peak	A	eV	eV			A	eV	
1	84.8	146.2	146.2	8	7	82.9	149.6	
2	101.5	122.2	122.2	7	6	101.3	122.4	
3	116.8	106.2	106.2	4	2	114.0	108.8	
4	129.6	95.6	95.7	6	5	130.2	95.2	
5	139.6	88.8	88.8	4	2	141.6	87.6	He scattered
6	163.2	75.9	76.0	8	7	165.8	74.8	2nd order Peak 1
7	181.7	68.3	68.2	5	4	182.3	68.0	
8	200.6	61.8	61.8	7	6	202.6	61.2	2nd order Peak 2
9	233.8	53.0	53.0	3	1	227.9	54.4	
10	261.2	47.5	47.5	5	4	265.0	46.8	He scattered
11	302.5	41.0	41.0	4	3	303.9	40.8	
12	459.1	27.0	27.0	3	1	455.9	27.2	2nd order Peak 9
13	584.0	21.2	21.2			584.9	21.2	Helium Resonance
14	607.5	20.4	20.4	4	3	607.8	20.4	2nd order Peak 11
15	633.0	19.7	19.6	4	3	633.0	19.6	He scattered
16				3	2	911.7	13.6	

FIGURE 2.3 - Astrophysical Data vs. Mills Theory Illustrated



The analysis completed by this researcher in Appendix 3 corroborates the findings of BLP in regard to the extreme ultraviolet data in the background of space [above] as well as from our star, the Sun, as well as from a stellar flare on AU Mic and star EQ Pegasi. Dr. Mills' text also provides many other sources of astrophysical data which produce information that regularly display the lower energy hydrogen transition energies that would be most likely from a probabilistic standpoint. Table 2.4 on the page that follows lists the most commonly occuring wavelengths and energies in all of the data described above [ie; data that appeared in at least 3 of the 4 sources cited] and the match I have calculated for that data by equation (1e) above.

TABLE 2.3 - Commonly Observed Wavelengths & Mills Theory Predictions

Wavelength A	Mills Theory Wavelength & Hydrogen Transition A	Initial Stage -> Final Stage	# of sources of 4
911.8	912.3	1/2 --> 1/3	1*
302.8-304	303.9	1/3 --> 1/4	3
261.2-266	265.0	1/4 --> 1/5 He scattered	3
182-183	182.3	1/4 --> 1/6	4
129.1-130	130.2	1/5 --> 1/6	4
122.2-123	122.6	1/6 --> 1/7 He scattered	3
101-101.3	101.3	1/6 --> 1/7	4
89-90	89.0	1/7 --> 1/8 H scattered	3
81-81.1	81.1	1/3 --> 1/5 H scattered	3

* NOTE: Only one source, the solar spectral data, included observations above the 600 A wavelength

2.3 *Enigmas Solved*

Perhaps the two most compelling enigmas that the Mills theory resolves are solar problems. They are; an inadequate solar neutrino flux and a solar coronal temperature that is inexplicably too hot. For two decades we have known that the standard solar model predicts that the primary energy source of our star is the nuclear fusion of hydrogen atoms. The problem is that scientists have been unable to account for an appreciable amount of the solar neutrino flux that would be predicted by assuming all of the Sun's radiant energy is from fusion. The Gallex solar neutrino detector in Italy sees only 60% of the neutrinos that the standard solar model would predict. [29] The Homestake detector reports neutrino flux of 2.1 ± 0.03 SNU or only 27% of the standard solar model's 7.9 ± 2.6 SNU.[30-32] Where then, if not fusion, could the rest of the Sun's energy be coming from? A similar problem exists with the description of all of the Sun's energy coming from nuclear fusion when we consider the temperature gradient from the surface of the Sun into space. The photosphere [visible surface layers] of the Sun is 6000 K, "whereas the temperature of the corona [solar atmosphere] based upon the assignment of the emitted X-rays to highly ionized heavy metals is in excess of 1,000,000 K."[33] The Mills theory is able to explain both of these seeming mysteries by postulating the disproportionation of hydrogen atoms in the atmosphere of the Sun. This transition of hydrogen to lower energy states as previously discussed gives rise to significant non-nuclear radiant energy [ie; transitions of hydrogen to the n = 1/100 level yield energy densities (139 keV) on the order of nuclear reactions]. The disproportionation reaction takes place in the coronal region of the Sun giving rise to the much higher temperatures there. Together the Mills theory makes sense of what otherwise could only be explained by difficult-to-believe concepts. The standard solar model has no answers for this enigma but two theories attribute the higher coronal temperature to "the conversion to heat energy by the dissipation of the energy in electric currents or magnetohydrodynamic [MHD] waves."[34] If the corona consists of an "almost fully ionized plasma contained in closed magnetic field loops or of plasma expanding outwards along open magnetic field lines"[35] it is quite a stretch and additional complication to propose the electric currents or MHD.

Another key enigma solved is that of the total mass or matter in the universe. For years physicists have been wrestling with the fact that either "black holes" or an unidentified "dark matter" must exist out there in space in order to explain why our calculated mass of the universe can not be obtained by adding up all of the radiative and observable matter. We need more mass to explain the observation that galaxies rotate at a higher angular velocity than possible with only the observed [visible] matter providing the stabilizing gravitational attraction.[36] Is it too much a stretch for the logical mind to postulate that if over 95% of the known matter of the universe consists of hydrogen that the large amount of "missing matter" may also be some non-radiative form of hydrogen? Mills theory predicts that stars consume hydrogen and convert it into lower energy state hydrogen as the "ash" residue of the reaction. This ash is non-radiative, microscopically smaller than ground state hydrogen and is believed by Mills to be ubiquitous throughout the universe. It would appear to be an excellent candidate for the undiscovered, yet ubiquitous dark matter of the universe.

2.4 Technological Embodiments

This final section of Chapter 2 is devoted to devices and apparatus that have been designed and operated by BLP scientists in order to prove that the catalytic reduction of atomic hydrogen below its ground state of n=1 is not only acheivable but is repeatable, predictable and consistent. Table 2.4 below indicates the types of devices that have been designed and developed by BLP scientists to demonstrate the phenomenon.

TABLE 2.4 - BLP Technologies

Device	Type	Other
Dewar Flask	Electrolytic Cell	
Electrolytic Cell	Electrolytic Cell	DC electricity
Electrolytic Cell	Electrolytic Cell	AC electricity
Non-Electrolytic Cell	Gas Phase	
Glass Lamp	Gas Phase	
Isothermal Calorimeter	Gas Phase	
Calvet Calorimeter	Gas Phase	Oven Moderated
Nickle Hydride Wire Cell	Gas Phase	Water Cooled
Quartz Firebrick Cell	Gas Phase	
Test Cell 1	Gas Phase	Steady State Flow

Furthermore, all of the devices in the above table exhibit the ability to generate anomolous heat that is inexplicable by any known chemical or nuclear reactions. These devices generate heat with no flux or radioactive materials, reduction or consumption of known chemical or molecular reactions or bonds and follow directly from the Mills theory. The specific devices are in essence the embodiment of his concepts for bringing hydrogen atoms into contact with a catalyst in order to begin the hydrocatalysis and subsequent disproportionation reactions. The devices developed by BLP are both test and demonstration units.

The two and one-half pages following below provide illustrations of some of the key BLP technological embodiments. Figure 2.4 illustrates the dewar experimental vessel. Figure 2.5 shows the typical arrangement for one of BLP's advanced electrolytic cells. Figure 2.6 illustrates the device developed by the BLP joint venture with Thermacore -- a non-electrolytic first generation gas phase cell. Figure 2.7 illustrates the isothermal calorimeter and Figure 2.8 is a typical Calvet calorimeter arrangement. I am focusing on these few devices to keep the reader directed to the specific technological embodiments of the Mills theory that demonstrate that the production of excess and anomalous heat from each apparatus is conditional upon bringing all of the elements of Mills' theoretical requirements to the experiment. If any one of the key elements is missing, the experiment functions as a typical control with no excess heat being produced.

FIGURE 2.4 - Dewar Experimental Cell

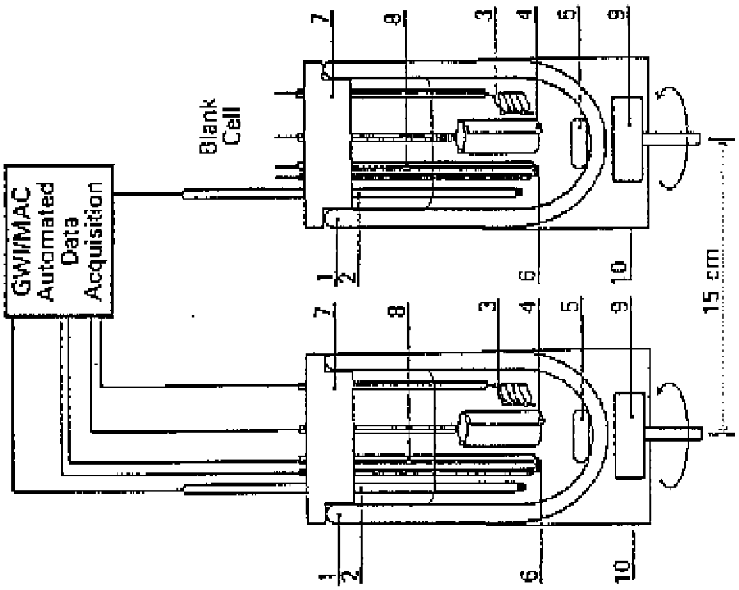


Fig. 5. Experimental calorimeter setup: (1) vacuum-jacketed dewar, (2) thermistor, (3) platinum anode, (4) nickel cathode, (5) magnetic stirring bar, (6) resistor-heater, (7) Styrofoam stopper lined with Parafilm, (8) Teflon tubing, (9) magnetic stirrer, and (10) aluminum cylinder.

FIGURE 2.5 - Advanced Electrolytic Cell

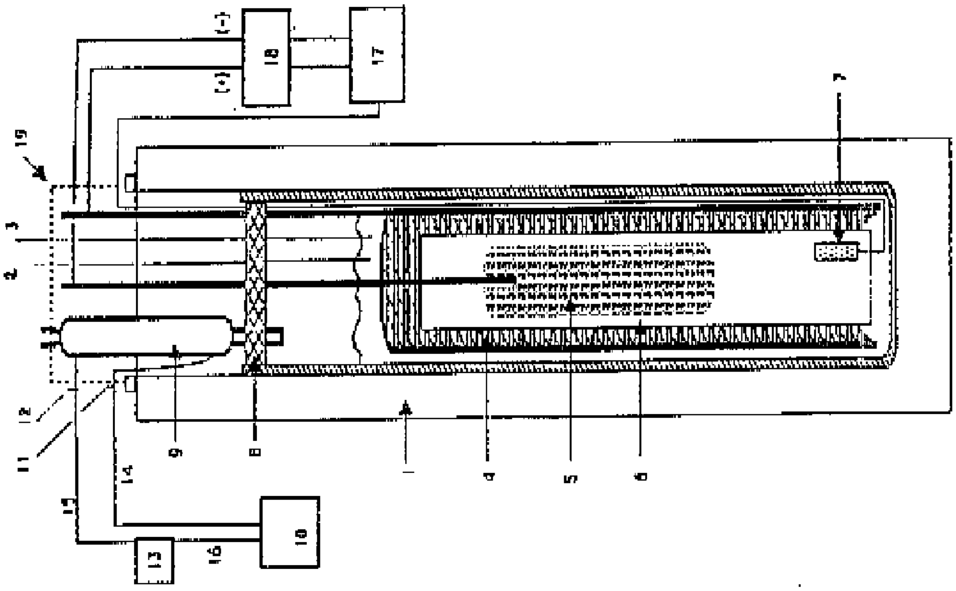


Fig. 1. The calorimeter/electrolysis cell: 1 = vacuum jacketed dewar, 2 = electrolyte thermistor, 3 = conductivity sensor, 4 = nickel anode, 5 = nickel cathode, 6 = Teflon spacer, 7 = resistor heater, 8 = Teflon cap, 9 = condenser, 10 = peristaltic pump, 11 = inlet thermistor, 12 = outlet thermistor, 13 = water reservoir, 14 = condenser inlet tubing, 15 = condenser outlet tubing, 16 = reservoir to pump tubing, 17 = power supply, function generator, power meter, 18 = oscilloscope, 19 = insulated cap.

FIGURE 2.6 - Non-Electrolytic Gas Phase Cell

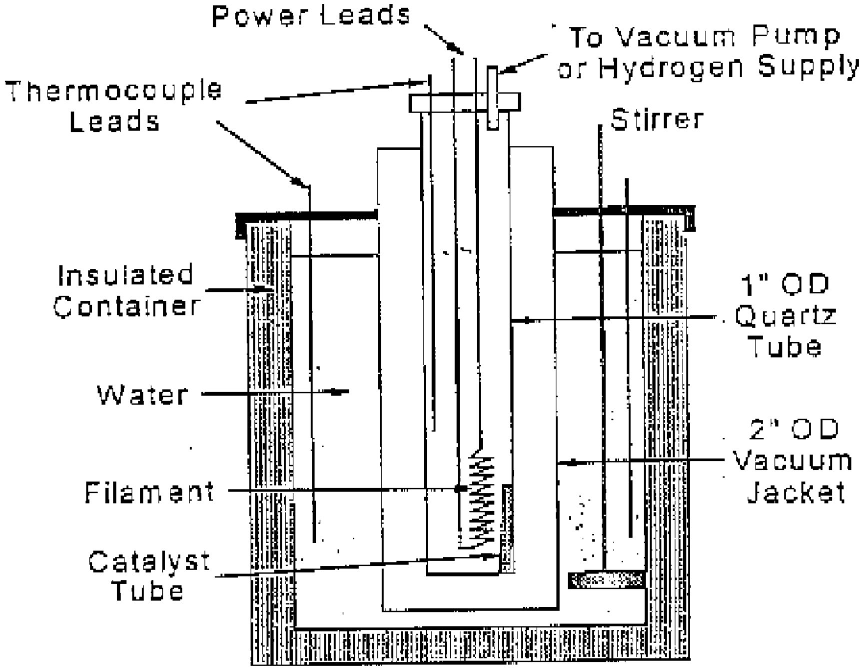


FIGURE 2.7 - Isothermal Calorimeter Gas Phase Cell

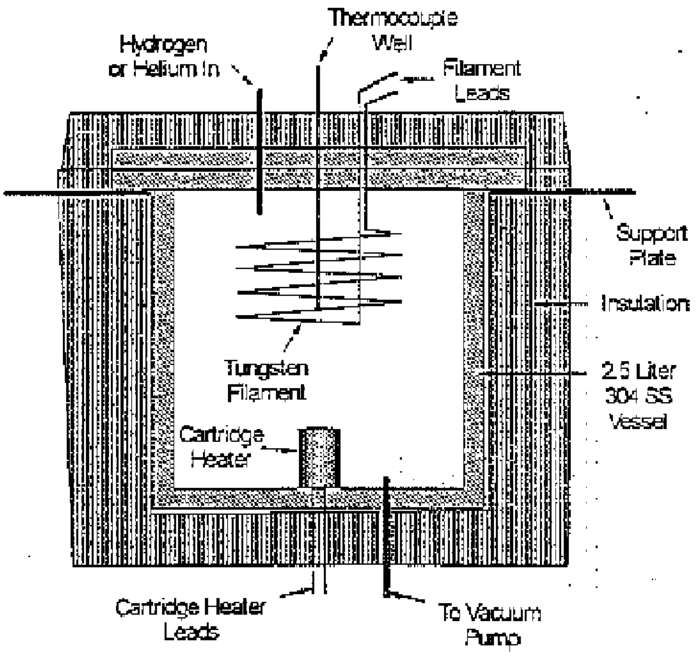
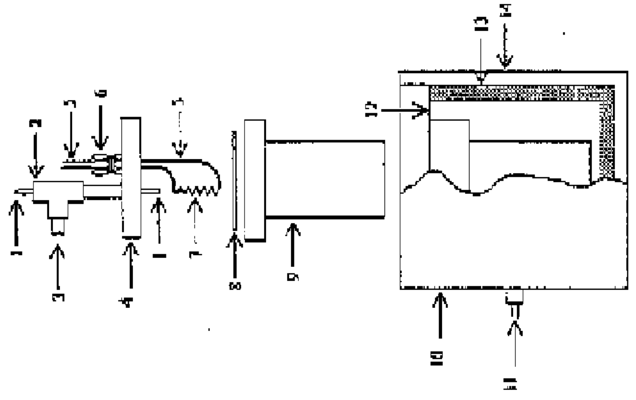


FIGURE 2.8 - Calvet Calorimeter Gas Phase Cell

Figure 1. Schematic of the Gas Cell for the Calvet Calorimeter and Cross Sectional View of the Calvet Calorimeter. 1 - (1/16)" OD stainless steel tube (to hydrogen supply), 2 - stainless steel tee union, 3 - (1/4)" OD stainless steel tube (to vacuum manifold), 4 - cell lid, 5 - filament leads, 6 - Conax-Buffalo gland, 7 - precision resistor, 0.1 mm OD tungsten filament, or nickel hydride filament treated with catalyst, 8 - copper ring gasket, 9 - cell body, 10 - Calvet Calorimeter, 11 - thermopile signal output, 12 - thermal shunt, 13 - thermopile, 14 - Insulated calorimeter base.



In the case of the electrolytic cells it is very important that the hydrogen atoms be formed on the cathode contact with the right concentration of the catalytic ions in order for the heat generation phenomenon to be replicated. In the case of the gas cells a small, partial atmosphere of hydrogen gas, a small partial pressure of the catalytic ions as well as a mechanism to cause hydrogen dissociation all need to be present for the reaction to commence and continue. The experiments and subsequent demonstration units were designed specifically to assure that the mean free path for the hydrogen atoms [once formed] to interact with and collide with the catalytic ions was appropriate to favor the collision and catalytic reaction prior to hydrogen atom recombination into H_2.

Each of the cells illustrated above were able to regularly, consistently and repeatedly generate heat in amounts that were far in excess of the any known chemical reaction for hydrogen and any other known elements. In the case of the vacuum gas cells this reaction was developed and maintained using only very small amounts of hydrogen gas, a filament to dissociate H_2 into its atomic form and a catalyst with the appropriate resonant enthalpy of 27 eV. Part II of this thesis will highlight the performance of BLP's isothermal cell, Penn State University's Calvet cell experiments as well as the experiments of this researcher in the Calvet cell at BLP laboratories.

To more fully document the BLP theory that lower energy hydrogen [hydrino formation] was the source of the heat in the reaction, the residue "ash" as it were from the reaction gases from both the electrolysis and vacuum cells was collected. According to Mills theory this "ash" should contain the lower energy form of hydrogen postulated by

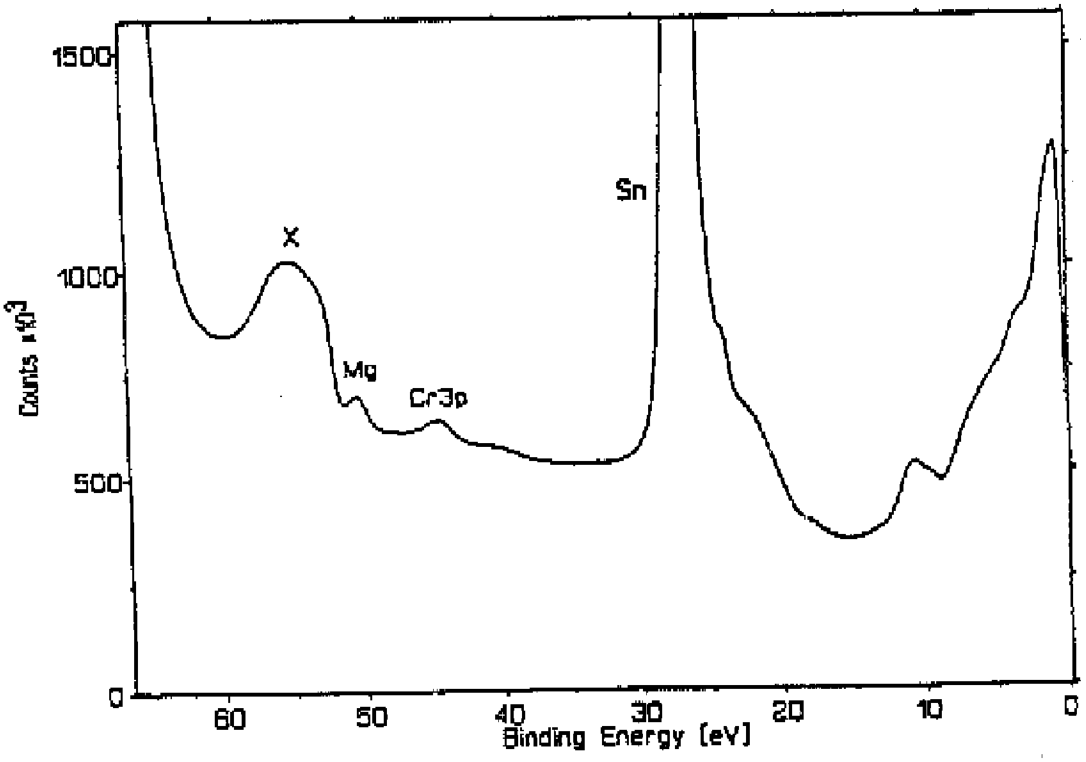
BLP. The difficulties of capture make this effort quite a challenge since the atoms being searched for will have significantly smaller diameters than the smallest of all atoms. BLP and four other scientific laboratories began this search a few years ago. They used the methods of mass spectroscopy, gas chromatography and X-ray photoelectron spectroscopy [XPS]. Table 2.5 below highlights the results of those investigations thus far.

TABLE 2.5 - The Search for Hydrinos

Device	Results/Observations	Investigating Laboratory
Mass Spectroscopy	Large signal with ionization energy in calculated range of dihydrino	BLP Laboratory Air Products & Chemicals Lab Schrader Analyt. & Cons. Lab
Gas Chromatography	Significant signal peaks which can be associated with n=1/2, 1/3 and 1/4 dihydrino molecules	BLP Laboratory
X-Ray Photoelectron Spectroscopy [XPS]	Signal Peaks associated with the binding energy of n=1/2, 1/3 and 1/4 hydrino molecules	Lehigh University - Zettlemoyer Center for Surface Studies Idaho National Engineering Lab Clark Evans & Associates

Figure 2.9 which follows on the final page of Part I illustrates the location of an anomalous peak near 55 eV binding energy which was detected by Zettlemoyer Center for Surface Studies at Lehigh University, Charles Evans & Associates and Idaho National Engineering Laboratories [INEL] in separate analyses of BLP and INEL samples. BLP asserts that the n=1/2 state of hydrogen, which has a calculated binding energy of 54.4 eV, is the source for the peaks in each independent study. At present all other potential known sources of a peak at that energy level [i.e. Fe_{3p}] have been ruled out as a source.

FIGURE 2.9 - XPS Anomalous 55 eV Peaks



PART II - Analysis of Previous Experimental Results

As noted in Chapter 2 [Table 2.1] there have been a substantial number of tests of BLP electrolytic cells. This researcher was not able to find any documented results from tests that had been performed on BLP cells which indicated that the cells did not operate in a manner to generate the anomalous heat predicted by BLP scientists. However, due to the controversial nature of electrolytic cell and the close association of the work with the continuing debate regarding cold fusion claims I have directed my research toward reviewing the test results which have been achieved in the gas phase cells. It is worthy of note at this point that there continue to be significant publications in Fusion Technology where well respected scientists are continuing to claim excess heat in so called "cold fusion" cell experiments. Of particular note is a recent technical paper in the March 1997 Fusion Technology journal. The authors [from Shell Research / CNAM Laboratoire des Sciences Nucléaires in Paris, France] describe how they have detected and verified that they are creating excess energy from hydrogen "7300 times higher than the most exothermic known reaction" at a high confidence level [99%]. They also detect missing hydrogen in their exhaust samples. Further, they present their postulate that the source of the additional energy is from "the formation of a tightly bound state of hydrogen...In such bound states, the electron is much closer to the proton than in normal hydrogen. This could explain both a high energy of formation and a greater than normal capacity to diffuse through any material" [37] All of these findings are consistent with the Mills theory. Part II of this thesis will focus on summarizing the results of two of the gas phase cell experimental results developed to date noting with special interest the experiments conducted by this researcher in section 3.3. In each case the gas phase cells produce a statistically significant [ie; beyond the error range and accuracy of the measuring device] amount of unexplainable heat. In the experiments the heat generated is well beyond the most energetic of chemical reactions known for hydrogen. I will attempt to explain, when possible potential reasonable alternative explanations for the repeatedly observed phenomenon. Often, however, there is no reasonable explanation other than the potential for a new energy source resulting from the interaction of hydrogen and the catalyst materials in the cells. After summarizing all of the gas phase cell experiments, the results of a singular isothermal cell test will be reviewed in detail [the experimental results from this cell formed the basis for the computer modeling work detailed in Chapter 4]. Results from the Penn State University cell will be reviewed and then the closing section will summarize the results of my work with Mr. William Good, the Chief Scientist and Director of Research & Development at BLP.

Chapter 3 - Summary Review of Gas Phase Cell Experimental Results

Table 2.4 illustrated seven gas phase cell experimental devices. I will provide a detailed explanation the operation of two of these devices in sections 3.1 through 3.3. I will place special focus [sections 3.2 and 3.3] on the Calvet device [see Figure 2.8] which is the most accurate in measuring the heat generated in a BLP reaction. Prior to the announcement of the hydrocatalysis process developed by BlackLight Power the paradigm for hydrogen as a fuel revolved around its energetic reaction with oxygen. In nature, water [H_2O] is a very abundant, stable and versatile molecule. Hydrogen is very energetically bound to oxygen, and requires significant energy to break these these stable bonds to yield H_2. After they are broken, hydrogen in its molecular form [H_2] is also stable, but reacts well and energetically with many other elements to form a plethora of molecules and compounds. The basic principle being tested with the gas phase cells of BLP is the ability of the hydrogen atom, once dissociated from its molecular form, to undergo electronic transition to lower energy levels [as described in Chapter 2] when it collides with a catalyst. All of the experiments therefore that will be described in the next three sections are configured to provide a reaction chamber [capable of operating at vacuum or near vacuum pressures], a means for hydrogen to be introduced to the chamber, a catalytic material to be introduced in the reaction chamber, a means for dissociating the hydrogen molecule into its atomic form, and a method for measuring heat generated by the reaction. Fundamentally the two cells reviewed in Chapter 3 are identical in nearly all respects except for the method for measuring or determining meaningful heat generation. The Calvet cell utilizes very accurate thermopiles to measure the heat flowing out of the vessel into the constant temperature oven. The isothermal cell uses the laboratory environment as the 'stable' external temperature and assumes the internal cell temperature represents a steady state heat loss previously measured by control runs to yield an 'estimate' of the additional power [anomalous heat] being provided by the reaction in a more indirect way. The Calvet cell experiments yield heat on the order of 6% to 12% more than energy being provided by the reaction than that used in the reaction zone [0.6 to 1.2 watts over a 10 watt filament power]. The isothermal cell experiments indicate heat gains of 52% to 171% over the energy being provided to the reaction zone [43 to 55 watts over a 32-86 watt input power]. It is the isothermal cell experiments that are of the greatest interest to this researcher since they portend the greatest potential for creating commercially significant heat. Section 3.1 focuses specifically on that BLP technological embodiment.

3.1 BlackLight Power Isothermal Cell

In the laboratory of BLP in Malvern, Pa. this researcher observed an experimental test on May 1, 1996 which was quite intriguing. A stainless steel vessel of 2 liters in volume was evacuated to a pressure of 1150 millitorr. [760 torr = 1 atm.]. This vessel was being maintained at a steady state temperature of 275° C by way of a cartridge heater consuming 97.1 watts located in the base of the vessel [see Figure 2.8]. The only materials inside this vessel were a 200 cm tungsten filament [0.01 cm. diameter] supported by 4 ceramic rods connected by 1/8th inch stainless steel tees and 3 grams of KNO_3 catalyst. Hydrogen was introduced into the system at a pressure of 1 atmosphere, the valve to the vacuum was opened and the pressure reduced to 2 torr minutes later. When the vacuum vessel comprised a closed system it had a steady state pressure of 1150 mtorr. When the power to the tungsten filament was turned on and raised to 15 watts the cartridge heater turned off and did not come back on for about one half hour. The temperature rose from

275° C to about 285° C during this period. When the cartridge heater did begin cycling again to maintain the vessel temperature at approximately 275° C it did so at a steady state energy consumption rate of 48.5 watts. [The details of this experiment are found in Appendix 4] The filament wattage was successively increased to 25 watts, 35 watts and 40 watts in three additional steps during which the cartridge heater energy decreased to 17.2 watts, 5.7 watts and 0 watts respectively. The vessel continued to maintain a temperature of 288-289° C without any energy being provided by the cartridge heater. The filament steady state power consumption was 40 watts indicating that something [presumably the Hydrocatalytic effect] occurring within the vessel appeared to be providing the additional 57 watts of heating that was necessary to keep the vessel at temperature. If one assumes that all the data being gathered on this closed system [i.e; energy in, temperature, pressure and chemicals involved] are accurate, then this appears to be a compelling illustration of this technology's capability. Table 3.1 illustrates a significant number of BLP experimental and control runs on their isothermal calorimeters.

I have summarized the results for each of the runs but the reader is encouraged to review the detailed data in Appendix 5. The Appendix includes all of the detailed experimental data as well as the analysis completed by this researcher. It is clear from the few control studies that the isothermal cell exhibits different behavior when it is operating on filament power versus cartridge heater power. As shown in experiments 15.5 and 15.8 the isothermal cell uses significantly less power with the filament than that required on the cartridge heater. This researcher believes that this apparent 25-54% savings may be due to four factors in the following order of significance; 1] The relative distances between the heating sources and the thermocouple [The filament was closer in proximity to the thermocouple and therefore had greater radiant coupling], 2] Radiant coupling of the filament with the thermocouple may have resulted in the thermocouple being at a higher temperature than actual temperature. [This condition would allow the cell to cool down and thus reduce to some degree its heat loss and associated energy requirements]. 3] Increased stratification may have occurred under filament power [i.e.; convective mixing of gases may not have occurred sufficiently allowing stratification. With the upper regions of the cell warmer than the lower regions of the cell heat loss would have decreased across the entire cell surface]. 4] In the case when the cartridge heater was the only source of power, heat loss through the bottom of the cell may have been higher, thus the thermocouple in the cell will need to see greater power from the cartridge heater in order to cycle off the power. It is important to note that another way of considering this last point is that the filament provided all of its heat interior to the cell most efficiently, while the cartridge heater entered through and was connected to the bottom surface of the calorimeter allowing a larger percentage of its heat energy to leave the cell without affecting thermocouple temperature.

Nonetheless, it is important to note that experiments 15.4, 15.6, 15.9 and 15.10 all create anomalous heat far beyond the cartridge/filament differential calculated by the control experiments. From the heat loss model developed on these cells in Part III of this thesis it appears that the isothermal cells are able to create at least tens of watts of useful power even in their very primitive development state.

TABLE 3.1 - Isothermal Cell Results Summary

Experiment #	Temp (C)	Pressure (Torr)	Watts [Heater]	Watts [Filament]	Excess Heat [Watts]	Power Gain [%]
15.4	259	2.0	95.2	45.7	49.5	108.3%
15.5 control	273	low atm	94.3	61.3	33.0	53.8%
	273	2.0	94.3	75.7	18.6	24.5%
15.6	271	1.4	92.0	43.6	48.4	111.0%
15.8 control	261	low atm	87.3	62.5	24.8	39.7%
15.9	280	1.7	103.5	41.7	61.8	48.2%
15.10	264	1.6	92.7	32.2	60.5	187.9%
15.12	284	0.02	106.0	97.8	8.2	8.3%
15.13	319	1.9	131.2	83.6	47.6	56.9%

It is recommended that the isothermal cells be outfitted with external temperature measurement thermistors and that a full set of controls and experiments be carried out on these cells. From this work we can develop heat loss calibration curves under various temperature and pressure regimes. In addition, each cell should be blanketed with a standard jacket to reduce heat loss variability from experiment to experiment. From a very high temperature the cell should be turned off and a heat loss decay model be fit to its heat loss rate over time. This empirical model could then be used as a second source of validation for the calculated excess energy created in the hydrocatalytic reaction within the vessel.

3.2 Penn State University Calvet

In late 1996 Dr. Jonathan Phillips, Professor of Chemical Engineering at the Pennsylvania State University, and Julian Smith, his graduate research assistant undertook significant control experiments and tests on the heat generation of gas phase Hydrocatalysis. A complete copy of their report and findings is provided in Appendix 6. The Calvet cell that they used is shown in Figure 2.9. The Calvet calorimeter cell is configured much like the isothermal cell described above but it includes much more accurate direct measurement of heat flux out of the reaction vessel. This measurement device is accurate to within 0.5% in recording energy flow. Unfortunately, in order to gain this extremely high accuracy one must place this vessel into a very controlled environment and into a thermopile base. This makes a large device very costly. The size of the Calvet cells used by Penn State are 20 cubic centimeters. The tests were conducted during the period of October - December 1996 in Penn State Chemical Engineering Department laboratories. The following excerpt from the report summarizes their key work and findings; "In three separate trials between 10 and 20 K Joules were generated at a rate of 0.5 Watts, upon the admission of approximately 10^{-3} moles of hydrogen to the 20 cm^3 Calvet cell containing a heated platinum filament and KNO_3 powder. This is equivalent to the generation of $1x10^7$ J/mole of hydrogen as compared to $2.5x10^5$ J/mole of hydrogen anticipated from standard hydrogen combustion. Thus, the total heats generated appear to be two orders of magnitude too large to be explained by conventional chemistry, but the results are completely consistent with the Mills' model." [38]

It is noteworthy that in all cases the Penn State tests [summarized in Table 3.2] were terminated by removing the hydrogen from the reaction vessel by opening the valve to the vacuum and pumping the gas from the vessel. It is not clear how long these reactions would have continued if the vessel was not emptied of the hydrogen gas. The method used by PSU included bringing their Calvet reactor cell to steady state in a controlled environment oven with only a platinum filament and small vessel of KNO_3 present within the reactor vessel. They would zero out the Calvet output at this point and then admit hydrogen to observe the reaction that this precipitated. There experiments showed a significant exothermic reaction upon the admission of hydrogen which could not be replicated upon the admission of helium [which they used as a control gas for their experiments]. In all cases this exothermic reaction was curtailed by the researchers once the total energy that had been produced was significantly greater than that available in known chemical reactions of hydrogen.

TABLE 3.2 - Penn State Calvet Cell Results Summary

Experiment #	Temperature (°C)	Pressure (Torr)	Total Time (minutes)	Total Energy (Joules)	Excess Heat (milliWatts)
BL1218CD	250	170	612	21,560	586.8
BL1220BC	250	180	364	13,003	595.9
BL1221AB	250	120	284	10,293	604.7

3.3 Jansson Calvet

In early 1997, this researcher approached Mr. William R. Good, Research Director of BLP to discuss the possibility of replicating the isothermal cell work at BLP to determine more conclusively the primary parameters of the gas phase reaction. It was this researchers intent to determine the effect of filament surface area on excess heat formation as well as begin parameterizations of other key variables such as reaction zone volumes, gas partial pressures, temperature, and other variables. BLP was most gracious in offering their Calvet cells for any experiments I would choose to run. The isothermal cells could be used as a follow-up in the event that the data from the Calvet work indicated a significant isothermal cell demonstration was feasible. In as much as it is believed that the formation of excess energy is caused by hydrogen atoms colliding with catalyst ions or hydrinos, I undertook to prove that increasing filament surface area would increase atom generation rate and thus increase power output from the Calvet cell. The protocol for my experiments is included as Appendix 7. A copy of my control and experimental results are included as Appendix 8. My original intent was to reproduce the Penn State experimental results and then go on to vary only the filament length in two subsequent experiments. If this could be done successfully, I believe it would demonstrate that specific parameters of the reaction could be controlled and engineered. We followed the PSU protocol in all aspects except reaction vessel pressure; this was because it appeared we were unable to demonstrate the excess heat effect at the 150-1000 torr range where the PSU reaction had operated successfully. We were successfully able to replicate numerous times the anomalous heat gain results in the 50-200 mtorr pressure regime. When we completed many of our post-experimental calibrations without the KNO_3 catalyst we believe we were able to identify excess heat that was being generated from the small amount of hydrogen that was off gasing from the platinum filament. This is my present interpretation of the results I obtained. Presently I can not offer an alternative expalantion for the consistent excess heat activity when only the filaments and KNO_3 catalyst are present in the experiments. Table 4.3 below summarizes my testing objectives.

TABLE 3.3 - Jansson Calvet Testing Objectives

- **Replication of PSU Results**
- **Vary Filament Length [10cm , 20 cm , 30 cm]**
- **Analyze Results for Consistency and Patterns**
- **Determine if Effect Appears Engineerable**
- **Develop New Technical Skills and Knowledge**

Table 3.4 below summarizes the 9 experiments and controls that I performed during the period of February 27 through May 5 1997. Each was conducted according to the primary protocol summarized in Appendix 7.

TABLE 3.4 - Jansson Calvet Tests Completed

- **20 cm Experiments**
  - **1 control**
  - **2 experiments**
  - **February 27 - March 21, 1997**
- **10 cm Experiments**
  - **1 experiment / post control-calibration run**
  - **March 25 - April 13, 1997**
- **30 cm Experiments**
  - **1 control**
  - **4 experiments**
  - **March 22 - 25, 1997**
  - **April 13 - May 5, 1997**

The following tables [3.5 & 3.6] summarize the testing protocol which was followed for each of the controls and experiments conducted in the BLP laboratories:

TABLE 3.5 - Jansson Calvet Testing Protocol Summary - Control

---

- ▪ **Prepare Calvet Reactor Vessel**
- ◆ **Install Filament and Vacuum Test**
- ▪ **Place Calvet in Thermopile Cup**
- ◆ **Vacuum test, connect leads, insulate**
- ▪ **Bring Oven & Calvet to Steady State**
- ◆ **250° C, vacuum cell to remove all H_2O, etc.**
- ▪ **Start DAS, Turn On Power, Close Vac.**
- ◆ **0,1,5,6,10,11,15,16, etc. watts to steady state**
- ▪ **Wait Until Steady State is Acheived**
- ▪ **Observe Changes in V_c**

TABLE 3.6 - Jansson Calvet Testing Protocol Summary - Experiments

---

- **Prepare Calvet Reactor Vessel**
  - **Install Filament, KNO_3, Vacuum Test**
- **Place Calvet in Thermopile Cup**
  - **Vacuum test, connect leads, insulate**
- **Bring Oven & Calvet to Steady State**
  - **250° C, vacuum cell to remove all H_2O, etc.**
- **Start DAS, Turn On Power, Close Vac.**
  - **0,1,5,6,10,11,15,16, etc. watts to steady state**
- **Wait Until Steady State is Acheived**
  - **Stable V_c , W_{in} , V_f , KNO_3 vapor pressure**
- **Observe Changes in V_c**
- **Inlet H_2 to Double Current Pressure***
- **Wait 5 min. and Vacuum Down to < 0.1 T**
- **Observe Changes in V_c**

NOTE: V_c is the Calvet calorimeter voltage indicative of heat output, W_{in} is the total energy being consumed by the filament within the Calvet, V_f is the Voltage associated with the energy being dissipated by the filament [allows us to know I^2R losses], and vapor pressure is measured in mTorr.
* in all cases it was not necessary to add additional H_2 in order to observe an elevated V_c

---

Table 3.7 below illustrates the calibration curves and linear regression analysis fits which I obtained for each of the control runs used in calculating the excess heat from each experiment.

TABLE 3.7 - Jansson Calvet Testing - Calibration Curves

- 10 cm
  - $V_c = 0.2016\,(W_{in}) - 0.0806$ $R^2 = 0.9966$
- 20 cm
  - $V_c = 0.2333\,(W_{in}) - 0.0605$ $R^2 = 0.9996$
- 30 cm
  - $V_c = 0.2297\,(W_{in}) + 0.5188$ $R^2 = 1.0000$

Pages 45-51 graphically and tabularly depict the results of the many days [over 555 hours] of analyzed Calvet cell experiments and controls. The results begin with a summary slide and then summarize the data by 10 cm., 20 cm. and 30 cm. experimental and control runs. These are labeled Figures 3.1, 3.2, 3.3, 3.4, 3.5, 3.6 and 3.7. Table 3.8 below is a numerical summary of the results obtained for all KNO_3 experiments as well as KNO_3 plus hydrogen experiments. All excess heat calculations for the experiments is based upon the difference between the Calvet output power anticipated via the control runs contrasted with the actual input power used to generate that Calvet voltage output during the experimentals. All controls and experimentals were completed in a closed system in an oven with temperature of 250 °C. In all cases the vacuum integrity of the reaction vessel was maintained throughout the entire run of the experiments.

Table 3.8 Jansson Calvet Cell Results Summary

Filament Length [cm]	Excess Power Generated [Watts] Mean	Max	Min	Hours of Operation	Total Energy Produced [W-hrs]	% Over * Chemical
10	0.581	0.635	0.523	297.97	173.013	234,387
20	0.818	1.231	0.337	125.22	102.464	138,090
30	1.572	2.092	0.635	131.95	207.467	278,151

* - % Over Chemical - is the amount of energy generated by the reaction divided by the energy that would have been created had all of the hydrogen available at anytime in the experimental apparatus been consumed in the most energetic chemical reaction calculated [ie; hydrogen combining with oxygen to form water - H_2O] expressed in percent.

The energy produced by these experiments significantly exceeds that which could be released by any known or potential chemical reaction by several orders of magnitude. The value shown in the table above is extremely conservative in that it was determined assuming the following; 1] all potential hydrogen in the system was converted with perfect efficiency into water, 2] all of the impurities in the platinum wire [99.99% pure] were hydrogen, 3] all hydrogen admitted at any time into the reaction chamber reacted within the vessel, even though it was rapidly brought under vacuum pressure and drawn out early in each experiment. Even when these conservative assumptions are applied, there remains a significant and large amount of energy that is unaccounted for. This ranges from about 1,400 to 2,800 times the amount of energy that was available at any time to the system assuming it was able to be perfectly released in a chemical reaction. These results would appear to be entirely consistent with Mills theory.

Figure 3.1

Figure 3.1 - Excess Power vs. Filament Length

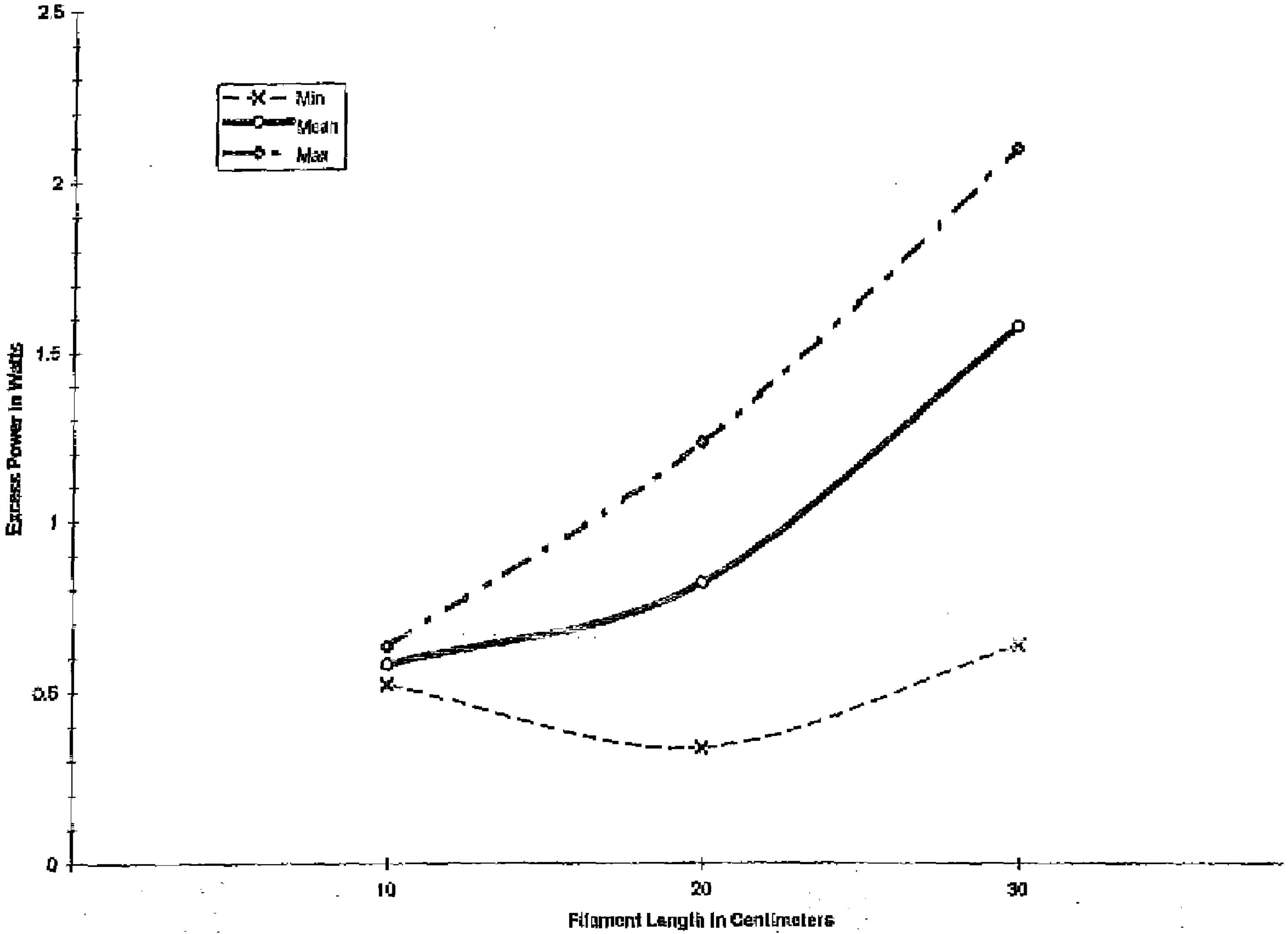


Figure 3.2 - Summary of 10cm

Figure 3.2

Figure 3.2 - Summary of 10 cm Experimental Results

Date[s] of Run	Hours [ss]	Excess Power [watts]	Pressure	Additional H2?	Watt-hrs
27-Mar	8.053	0.523	0.14-104T	Yes	4.212
28-Mar	45.175	0.539	0.14T	Yes	24.349
30-Mar	17.708	0.597	0.14T	Yes	10.572
31-Mar	23.438	0.635	0.13T	Yes	14.883
1-Apr	23.514	0.568	0.12T	Yes	13.356
2-Apr	25.018	0.591	0.14T	Yes	14.786
3-Apr	21.428	0.536	0.14T	Yes	11.485
4-Apr	45.618	0.538	0.14T	Yes	24.542
6-Apr	23.558	0.609	0.13T	Yes	14.347
7-Apr	22.684	0.628	0.12T	Yes	14.248
8-Apr	23.904	0.625	0.12T	Yes	14.940
9-Apr	17.872	0.632	0.12T	Yes	11.295
		<u>0.581</u>	Ave. Power [Watts]		
	297.970	0.523	Minimum		173.013
	Hours of Operation	0.635	Maximum		Energy Produced
		0.042	Std. Deviation		
		7.30%	Std. Deviation %		

Figure 3.3 - Calibration Curve - 10 cm Control

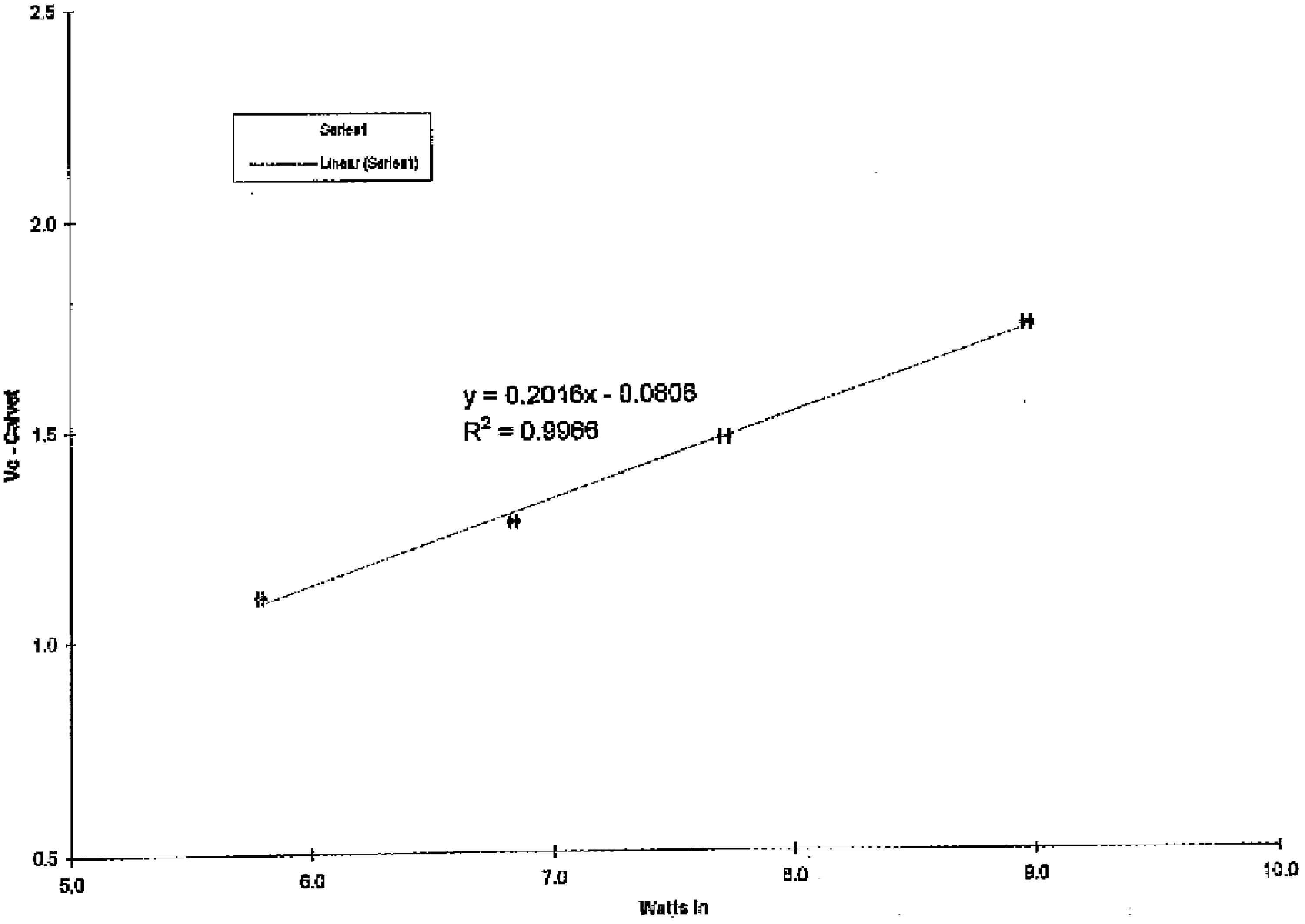


Figure 3.3

Figure 3.4

Figure 3.4 - Summary of 20 cm.

Figure 3.4 - Summary of 20 cm Experimental Results

Date[s] of Run	Hours [ss]	Excess Power [watts]	Pressure	Additional H2?	Watt-hrs
12-Mar	5.820	0.577	253.7	No	3.358
13-Mar	5.575	0.337	50T-10psig	Yes	1.879
15-Mar	4.272	0.804	253	No	3.435
16-Mar	2.899	0.568	0.15T-1.7atm	Yes	1.647
16-Mar	13.635	0.607	253-265T	Yes	8.276
17-Mar	7.464	0.592	0.1-576T	Yes	4.419
17-Mar	14.439	1.164	0.075T	Yes	16.807
18-Mar	31.194	1.231	0.068-0.075T	Yes	38.400
19-Mar	14.781	0.879	0.068T	Yes	12.992
19-Mar	3.576	0.537	0.068T	Yes	1.920
20-Mar	6.870	0.404	0.0675-0.069T	Yes	2.775
20-Mar	14.698	0.446	0.0675T	Yes	6.555
		0.818	Ava.Power [Watts]		
	125.223	0.337	Minimum		102.464
	Hours of Operation	1.231	Maximum		Energy Produced
		0.286	Std Deviation		
		34.92%	Std Deviation %		

Figure 3.5

Figure 3.5 - Calibration Curve - 20 cm Control

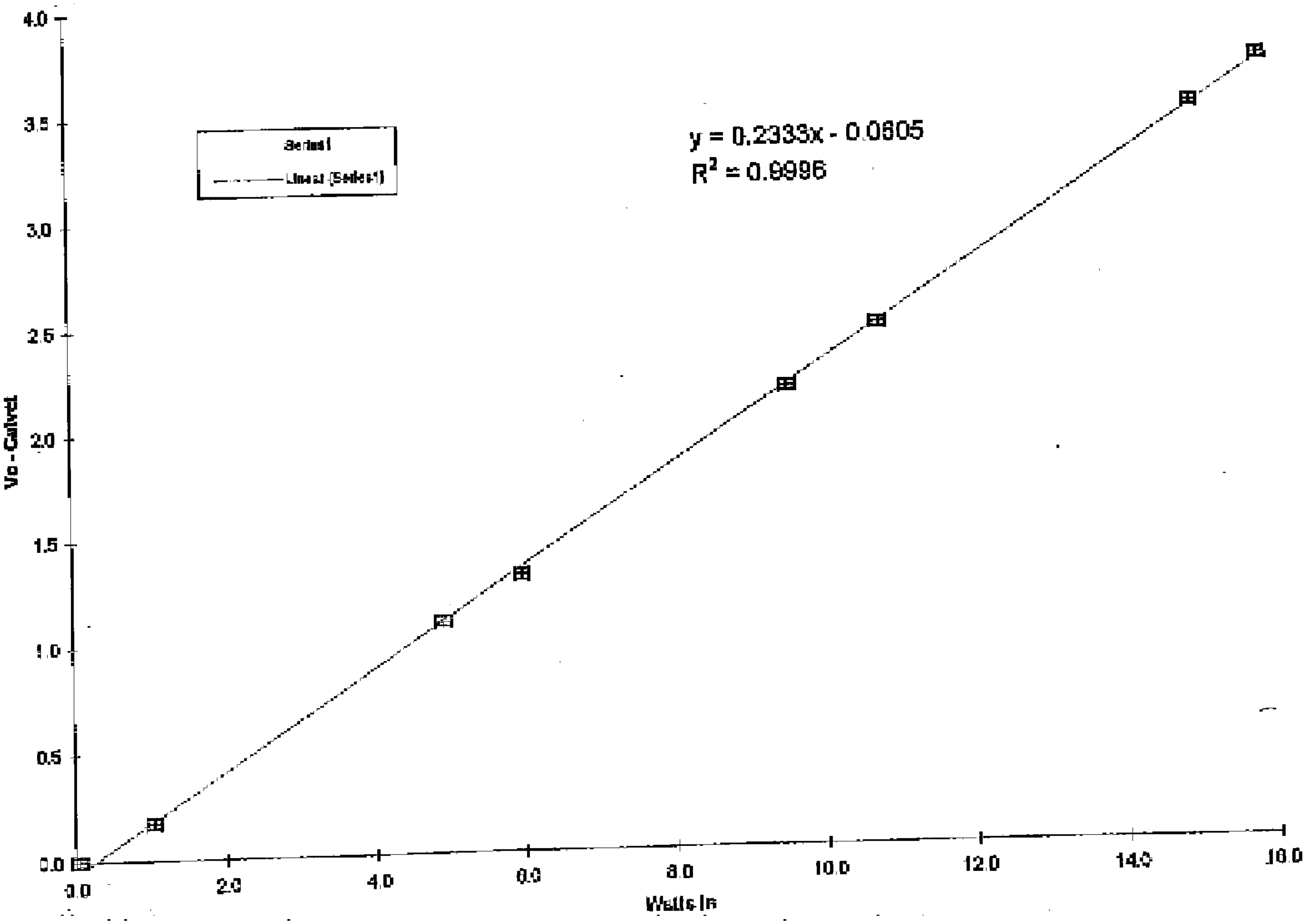


Figure 3.6 - Summary of 30cm.

Figure 3.6 - Summary of 30 cm Experimental Results

Date[s] of Run	Hours [ss]	Excess Power [watts]	Pressure	Additional H2?	Watt-hrs
14-Apr	5.632	1.181	132.5-176.2T	No	6.651
15-Apr	15.160	1.459	0.36-549T	Yes	22.118
16-Apr	12.060	1.689	0.386-0.591T	Yes	20.369
17-Apr	21.273	1.335	0.385-0.683T	Yes	28.399
18-Apr	6.916	0.635	0.349-0.576T	Yes	4.392
23-Apr	11.572	1.954	0.425-0.582T	No	22.612
24-Apr	23.461	2.092	0.352-0.582T	No	49.080
25-Apr	13.507	2.067	< 1.312T	No	27.919
3-May	6.237	1.264	0.335-0.443T	No	7.884
4-May	11.355	1.135	0.453-0.679T	Yes	12.886
5-May	4.777	1.079	0.447-0.596T	Yes	5.154
		1.572	Ave. Power [Watts]		
	131.950	0.635	Minimum		207.467
	Hours of Operation	2.092	Maximum		Hours of Operation
		0.461	Std. Deviation		
		29.32%	Std. Deviation %		

Figure 3.6

Figure 3.7 - Calibration Curve - 30 cm Control

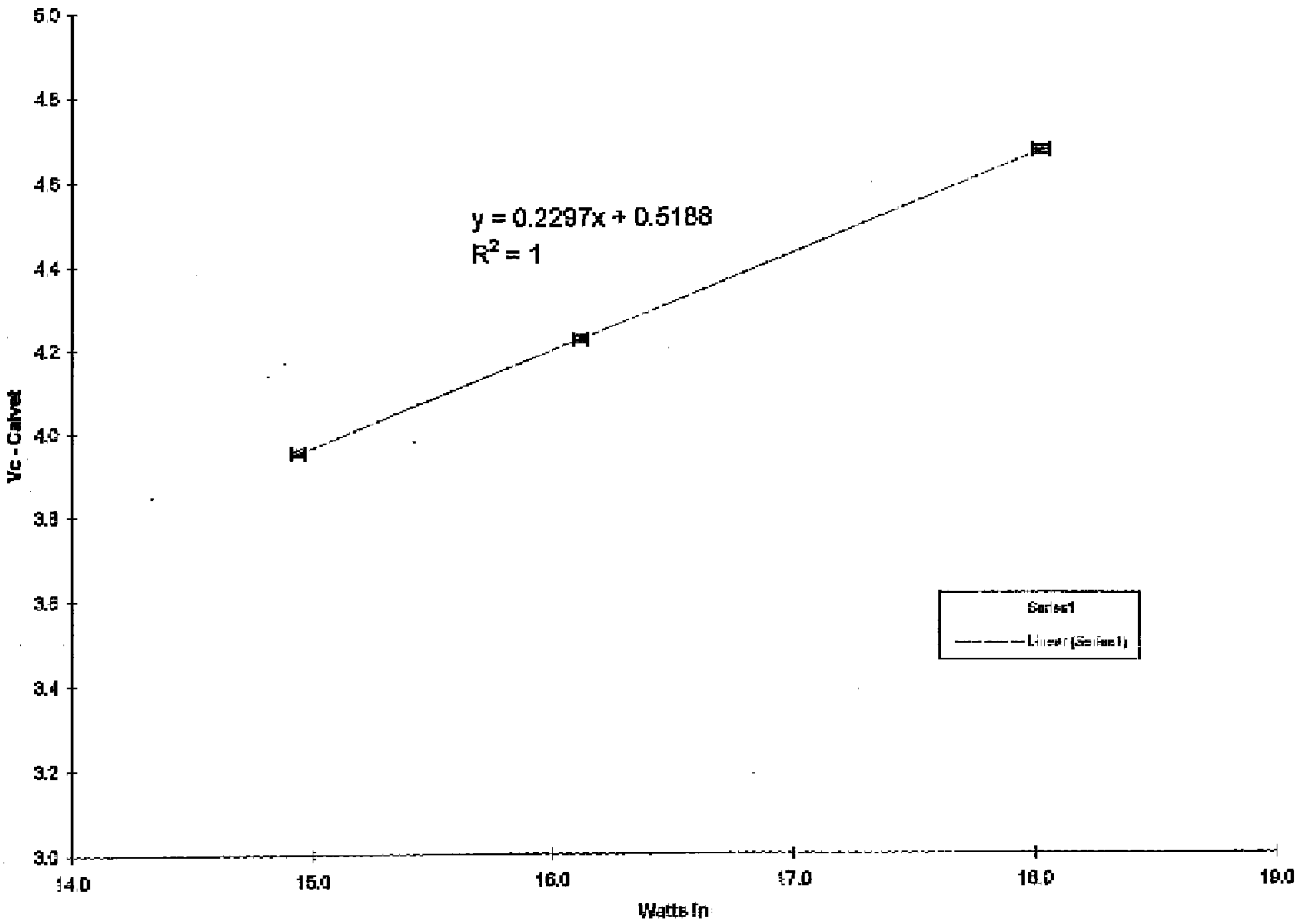


Figure 3.7

PART III - Mathematical Simulation Model

In order to assess the commercial potential of the BlackLight Power technology I performed some mathematical simulation modeling on one of their most promising devices. The isothermal cell described in Section 3.1 produced meaningful excess power on the order of 50-60 watts and at meaningful temperatures 250-320 °C. The simulation model I developed attempts to recreate the heat loss profile of the isothermal cell in order to assess how much energy theoretically would be required to maintain the cell at any temperature level. I developed this method as a theoretical modeling method to cross-check the calibrations and excess energy results acheived by the experiments on the isothermal cell. Chapters 4 and 5 below provide the results of the simulation model as well as my insights and lessons learned from the exercise. In addition, I developed a comprehensive testing protocol which, if implemented, could conclusively prove the energy gain of the isothermal cell and provide additional documentation for its performance.

Chapter 4 - Analysis of Model Performance vs. Experimental Results

In order to model thermally the heatloss for the BLP Isothermal Calorimeter I used the data provided from the BLP Experiment 15.6 witnessed by AEI employees on May 3,1996. The method of operation of the Isothermal Cell is provided in Section 3.1. The experiment which we observed operated according to BLP's predictions, previous experiments and protocol. We were able to observe the results detailed in Appendix 9. A summary of that test has been provided on Table 4.1 below.

TABLE 4.1 - Isothermal Cell Results: May 3-4, 1996

TIME	CRITICAL TEMPERATURES - oC			PRESS.	FILAMENT	HEATER	EXCESS
	CELL	ROOM	AT	MILLTORR	WATTS	WATTS	WATTS
10:45 AM	279.60	28.42	251.08	1150	0	96.99	0.01
					0	97.07	-0.07
					0	97.32	-0.32
11:10 AM							
11:15 AM							
11:45 AM	285.09	28.04	257.05	1400	15	48.54	33.46
					15	48.94	33.06
					15	49.26	32.74
11:50 AM							
12:05 PM							
12:15 PM	288.86	27.88	260.98	1400	25	16.23	55.77
					25	17.75	54.25
					25	17.78	54.22
12:20 PM							
2:10 PM							
2:15 PM	289.24	27.45	261.79	1700	35	5.73	56.27
2:25 PM					42	0.00	55.00

At approximately 2 A.M. on the morning of May 4, 1996 the filament inside the Isothermal Cell which we were testing burnt out. This caused a significant and dramatic fall in cell temperature. The Isothermal Cell at that point in the experiment was receiving all of its input power and cell heating from the tungsten filament and the associated heat of reaction from the believed Hydrocatalytic reduction of the hydrogen gas at the near vacuum pressure [1.2-1.7 torr] within the cell. Figure 4.1 on the following page illustrates the dramatic drop in cell temperaure which was observed when the filament ceased to operate. The intent of my simulation model was to develop mathematical formulae that could match the heat loss profile of the cell while it underwent this steady state cooling toward room temperature and also match in to the calibration tests conducted at the 260-320 °C temperature levels. I pursued this approach assuming simplistically that all significant heat loss was acheived via conduction [$U*A*\Delta T$] and that radiative and convective heat losses from the Isothermal Cell were minimal. With this approach I was able to get an excellent correlation at the lower temperature regime of operation [≤160 °C - see Figure 4.2] with a good fit at the higher temperature profile [≥ 260-320 °C - see Figure 4.3].

From those two pieces of the model I was able to develop an estimate of the heat loss of the Isothermal Cell at its entire range of operation in the tests conducted by BLP. This data is summarized below on Table 4.2.

TABLE 4.2 - Isothermal Cell Heat Loss vs. Temperature*

Cell Temperature [°C]	Calculated Heat Loss [watts]
27	0.0
50	9.3
75	19.3
100	29.4
125	39.5
150	49.6
175	59.6
200	69.8
225	79.8
250	89.9
275	100.0
300	110.1
325	120.2

* - assumes ambient temperature is 27 °C

FIGURE 4.1 - Isothermal Cell Performance - May 4, 1996

5/6/96

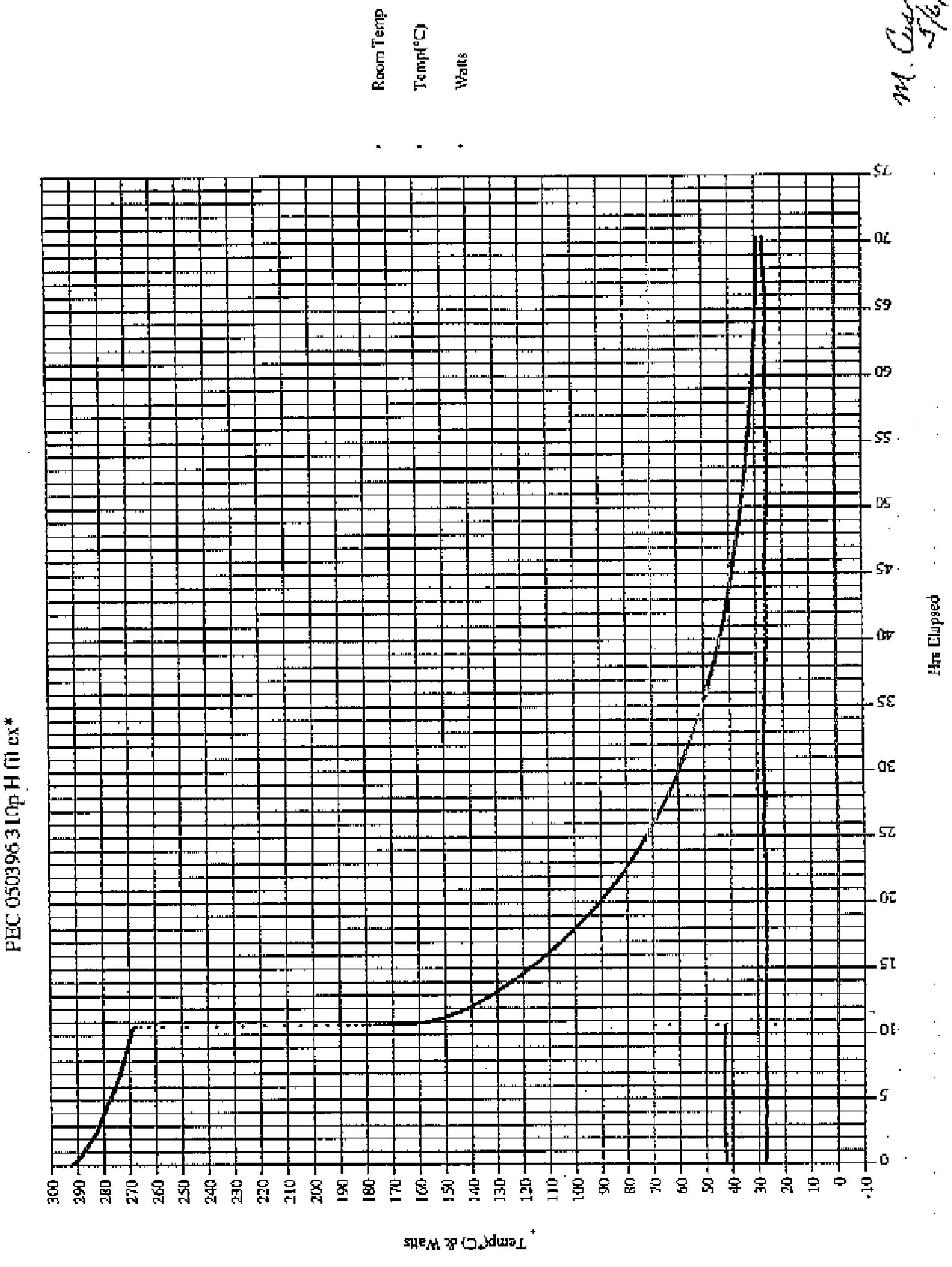


FIGURE 4.2 - Isothermal Cell Model vs. Actual Heat Loss

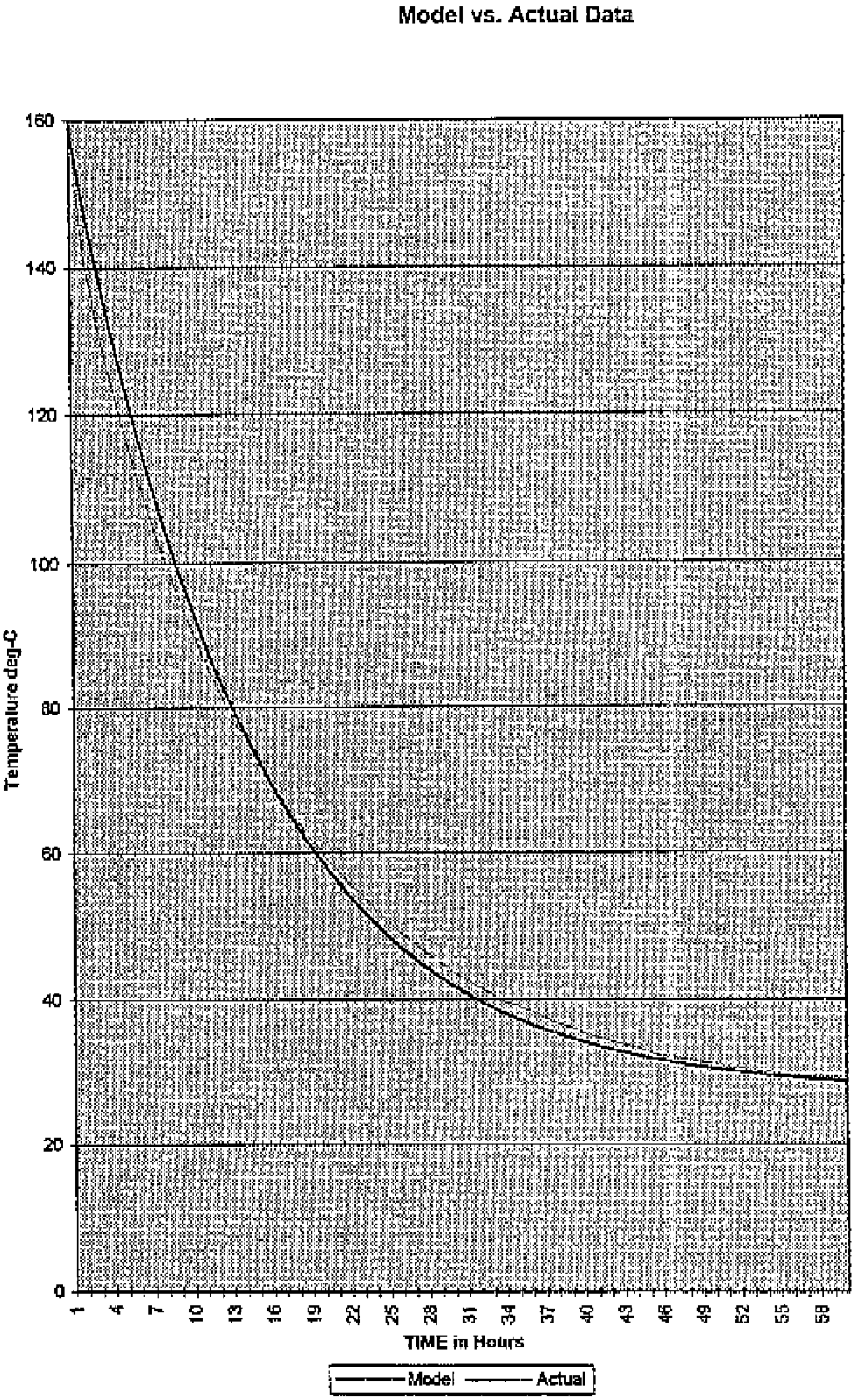
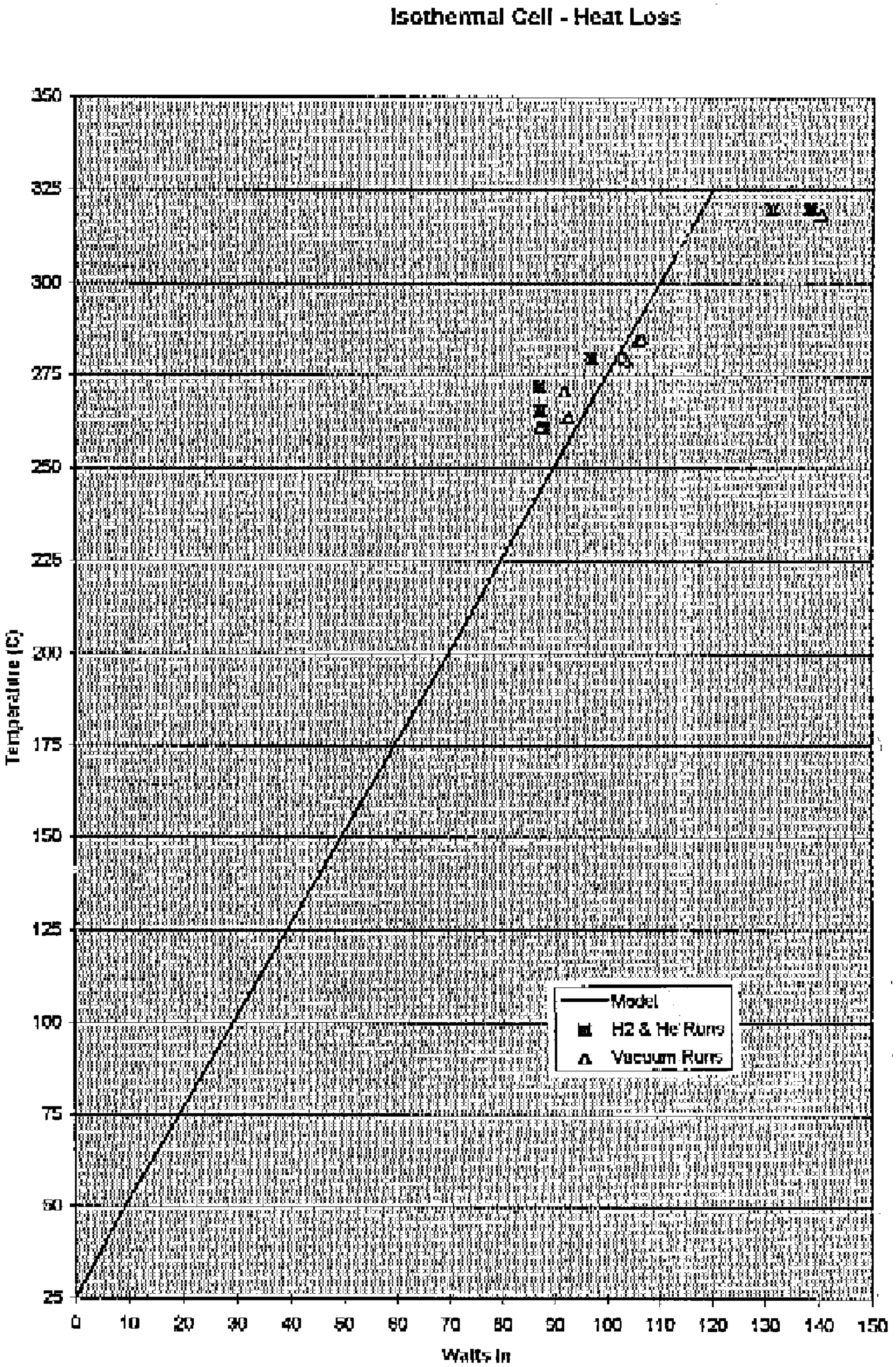


FIGURE 4.3 - Isothermal Cell Heat Loss vs. Temperature



Chapter 5 - Key Learnings and Insights From Simulation and Model

What does all this modeling tell us? The specific experiment that we reviewed in order to develop the model can now be looked at with a greater degree of detail and understanding. We know that the Isothermal Cell was able to maintain a temperature measured by the thermocouple at between 280-290 °C. While under cartridge heater power it took 97-103 watts to maintain this temperature [our model says it should have taken approximately 102-106 watts]. When the hydrogen gas was exposed to the filament the thermocouple reading said that the temperature was maintained at approximately the same level. However, in this case the filament was using only 42 watts at steady state. If we were to estimate from the simulation model what the Isothermal Cell temperature would have to be in order for its steady state heat loss to be satisfied with only 42 watts of input power we would see that the equivalent temperature was 132 °C. It is hard to believe the cell was operating at this low of a temperature during the experiment since our heat loss model was well able to accurately track the heat loss of the cell from when the filament burnt out all the way up to 160 °C with an extremely high degree of accuracy. While these learnings indicate that the cell was in fact producing anomalous heat, it must be pointed out that due to cell variability observed between experimental runs and control runs and also between similar experiments the accuracy of heat measurement in the Isothermal Cell is not fully quantified and known. Due to the significant number of BLP experimental and control runs on their isothermal calorimeters the summary results highlighted in Table 3.1 it is most probable that the cell in fact produces heat consistently. Due to the variability of the few control studies that were run by BLP demonstrating that the Isothermal cell exhibits different behavior when it is operating on filament power versus cartridge heater power, more control studies are needed. As discussed in section 3.1 this researcher believes that some of the variability between cell heating source performance may be due to the four factors described in Section 3.1 [i.e.; the relative distances between the heating sources and the thermocouple, etc.] Nonetheless, it is important to note that this experiment does appear to create anomalous heat far beyond the cartridge/filament differential calculated by the control experiments. From the heat loss model described above it appears that this isothermal cells was able to create at least 10-30 watts of useful power even in its early development state.

Included on the pages that follow I have outlined a proposed testing protocol for the Isothermal Cells which I believe will conclusively demonstrate their performance or lack of performance. In that protocol I recommend that the isothermal cells be outfitted with external temperature measurement thermistors and that a full set of controls and experiments be carried out on these cells. From this work we can develop heat loss calibration curves under various temperature and pressure regimes. In addition, each cell should be blanketed with a standard jacket to reduce heat loss variability from experiment to experiment. From a very high temperature the cell should be turned off and a heat loss decay model be fit to its heat loss rate over time. This empirical model can then be used as a second source of validation for the calculated excess energy created in the hydrocatalytic reaction within the vessel.

ISOTHERMAL CALORIMETER
Definitive and Conclusive Testing Protocol

SETUP:

Develop and Install Standard Insulation Jacket [2-4" min. thickness]
Install 2 Internal [Top and Bottom] Thermocouples and/or Thermistors
Install 6 External Thermistors top, bottom, each 90 degrees alternate up down 1/3
Measure total weight, and total volume of isothermal vessel
Develop computer controlled program to initiate steps 1-3 of each protocol

Control Run #1 - He at 1 atmosphere

1. Measure all relevant temperature, pressure parameters and time for following protocol:

USING ONLY CARTRIDGE HEATER

10 watts in for 1-4 hours or until steady state is achieved
up power to 20 watts in for another 1-4 hours or until steady state temperatures are reached
up power to 30 watts in [until steady state temps]
up power to 40 watts in [until steady state temps]
continue..... in 10 watt increments noting all temps and time
up to 200 watts in or until cell temps are over 400 °C
Shut off all power and monitor temperature decline vs. time

2. Measure all relevant temperature parameters and time for following protocol:

USING ONLY 200 CM. FILAMENT

10 watts in for 1-4 hours or until steady state is achieved
up power to 20 watts in for another 1-4 hours or until steady state temperatures are reached
up power to 30 watts in [until steady state temps]
up power to 40 watts in [until steady state temps]
continue..... in 10 watt increments noting all temps and time
up to 200 watts in or until cell temps are over 400 °C
Shut off all power and monitor temperature decline vs. time

3. Measure all relevant temperature parameters and time for following protocol:

USING FIRST CARTRIDGE HEATER FOR 10 WATTS THEN FILAMENT FOR NEXT 10 WATTS

10 watts in for 1-4 hours or until steady state is achieved
up power to 20 watts in for another 1-4 hours or until steady state temperatures are reached
up power to 30 watts in [until steady state temps]

up power to 40 watts in [until steady state temps]
continue..... in 10 watt increments noting all temps and time
up to 200 watts in or until cell temps are over 400 °C

Control Run #2 - H_2 at 1 atmosphere

1. Measure all relevant temperature parameters and time for following protocol:

USING ONLY CARTRIDGE HEATER
10 watts in for 1-4 hours or until steady state is achieved
up power to 20 watts in for another 1-4 hours or until steady state temperatures are reached
up power to 30 watts in [until steady state temps]
up power to 40 watts in [until steady state temps]
continue..... in 10 watt increments noting all temps and time
up to 200 watts in or until cell temps are over 400 °C
Shut off all power and monitor temperature decline vs. time

2. Measure all relevant temperature parameters and time for following protocol:

USING ONLY 200 CM. FILAMENT
10 watts in for 1-4 hours or until steady state is achieved
up power to 20 watts in for another 1-4 hours or until steady state temperatures are reached
up power to 30 watts in [until steady state temps]
up power to 40 watts in [until steady state temps]
continue..... in 10 watt increments noting all temps and time
up to 200 watts in or until cell temps are over 400 °C
Shut off all power and monitor temperature decline vs. time

3. Measure all relevant temperature parameters and time for following protocol:

USING FIRST CARTRIDGE HEATER FOR 10 WATTS THEN FILAMENT FOR NEXT 10 WATTS
10 watts in for 1-4 hours or until steady state is achieved
up power to 20 watts in for another 1-4 hours or until steady state temperatures are reached
up power to 30 watts in [until steady state temps]
up power to 40 watts in [until steady state temps]
continue..... in 10 watt increments noting all temps and time
up to 200 watts in or until cell temps are over 400 °C

Control Run #3 - He at 2 Torr

1. Measure all relevant temperature parameters and time for following protocol:

USING ONLY CARTRIDGE HEATER

10 watts in for 1-4 hours or until steady state is achieved
up power to 20 watts in for another 1-4 hours or until steady state temperatures are reached
up power to 30 watts in [until steady state temps]
up power to 40 watts in [until steady state temps]
continue..... in 10 watt increments noting all temps and time
up to 200 watts in or until cell temps are over 400 °C
Shut off all power and monitor temperature decline vs. time

2. Measure all relevant temperature parameters and time for following protocol:

USING ONLY 200 CM. FILAMENT

10 watts in for 1-4 hours or until steady state is achieved
up power to 20 watts in for another 1-4 hours or until steady state temperatures are reached
up power to 30 watts in [until steady state temps]
up power to 40 watts in [until steady state temps]
continue..... in 10 watt increments noting all temps and time
up to 200 watts in or until cell temps are over 400 °C
Shut off all power and monitor temperature decline vs. time

3. Measure all relevant temperature parameters and time for following protocol:

USING FIRST CARTRIDGE HEATER FOR 10 WATTS THEN FILAMENT FOR NEXT 10 WATTS

10 watts in for 1-4 hours or until steady state is achieved
up power to 20 watts in for another 1-4 hours or until steady state temperatures are reached
up power to 30 watts in [until steady state temps]
up power to 40 watts in [until steady state temps]
continue..... in 10 watt increments noting all temps and time
up to 200 watts in or until cell temps are over 400 °C

Control Run #4 - H_2 at 2 Torr

1. Measure all relevant temperature parameters and time for following protocol:

USING ONLY CARTRIDGE HEATER

10 watts in for 1-4 hours or until steady state is achieved
up power to 20 watts in for another 1-4 hours or until steady state temperatures are reached
up power to 30 watts in [until steady state temps]
up power to 40 watts in [until steady state temps]

continue..... in 10 watt increments noting all temps and time
up to 200 watts in or until cell temps are over 400 °C
Shut off all power and monitor temperature decline vs. time

<u>2. Measure all relevant temperature parameters and time for following protocol:</u>

<u>USING ONLY 200 CM. FILAMENT</u>

10 watts in for 1-4 hours or until steady state is achieved
up power to 20 watts in for another 1-4 hours or until steady state temperatures are reached
up power to 30 watts in [until steady state temps]
up power to 40 watts in [until steady state temps]
continue..... in 10 watt increments noting all temps and time
up to 200 watts in or until cell temps are over 400 °C
Shut off all power and monitor temperature decline vs. time

<u>3. Measure all relevant temperature parameters and time for following protocol:</u>

<u>USING FIRST CARTRIDGE HEATER FOR 10 WATTS THEN FILAMENT FOR NEXT 10 WATTS</u>

10 watts in for 1-4 hours or until steady state is achieved
up power to 20 watts in for another 1-4 hours or until steady state temperatures are reached
up power to 30 watts in [until steady state temps]
up power to 40 watts in [until steady state temps]
continue..... in 10 watt increments noting all temps and time
up to 200 watts in or until cell temps are over 400 °C

Control Run #5 - Near Vacuum [< 25 mTorr]

<u>1. Measure all relevant temperature parameters and time for following protocol:</u>

<u>USING ONLY CARTRIDGE HEATER</u>

10 watts in for 1-4 hours or until steady state is achieved
up power to 20 watts in for another 1-4 hours or until steady state temperatures are reached
up power to 30 watts in [until steady state temps]
up power to 40 watts in [until steady state temps]
continue..... in 10 watt increments noting all temps and time
up to 200 watts in or until cell temps are over 400 °C
Shut off all power and monitor temperature decline vs. time

<u>2. Measure all relevant temperature parameters and time for following protocol:</u>

<u>USING ONLY 200 CM. FILAMENT</u>

10 watts in for 1-4 hours or until steady state is achieved
up power to 20 watts in for another 1-4 hours or until steady state temperatures are reached
up power to 30 watts in [until steady state temps]
up power to 40 watts in [until steady state temps]
continue..... in 10 watt increments noting all temps and time
up to 200 watts in or until cell temps are over 400 °C
Shut off all power and monitor temperature decline vs. time

3. Measure all relevant temperature parameters and time for following protocol:

USING FIRST CARTRIDGE HEATER FOR 10 WATTS THEN FILAMENT FOR NEXT 10 WATTS

10 watts in for 1-4 hours or until steady state is achieved
up power to 20 watts in for another 1-4 hours or until steady state temperatures are reached
up power to 30 watts in [until steady state temps]
up power to 40 watts in [until steady state temps]
continue..... in 10 watt increments noting all temps and time
up to 200 watts in or until cell temps are over 400 °C

Conduct Full Experiment Series

Repeat Series of Experiments [ie; 15.6, 15.9, 15.10, etc.] w/ 200 cm. filament to isolate optimal zones of operation for maximizing excess heat generation effect. Track power dissipation per surface area on filament.

Replace filament with tungsten of greater surface area. First increase diameters, then increase roughness. Assure 100% and 200-500% changes in area.

Increase total areas of tungsten filament in reactor vessel by 1000% via curled filament etc.

Use parameters above to design meaningful 1-5 kW water heater design
and 1-20 kW space heater design

PART IV - Implications for the Future

The world energy market represents over 100 trillion kilowatthours of equivalent energy consumed each year and traded for well in excess of $1 trillion. It is clear that the BLP process is in a very early stage of development and is not likely to impact this market in any significant way before the turn of the century. However, the experimental evidence reviewed and the data developed by this thesis indicates that there is an extremely high probability that the effect predicted by Dr. Mills' work in his unified field theory and the laboratory devices developed by William R. Good and his BLP associates in the laboratory may play a major role in the future of the energy industry. Gas and electrolytic phase cells and devices currently capable of releasing heat on the order of 1-20 times energy input show promise for significant technical expansion as more focus and scientific and engineering resources are brought to bear on the task. BlackLight Power currently raised over $10M in additional investment through its final private placement offering which will make it possible for them to hire additional scientists and engineers for this very purpose. Across the world others are beginning to note with interest the reproducible and predictable production of anomalous heat via test cells that incorporate hydrogen and appropriate catalytic materials [see Table 6.1] While the "cold fusion scandal" has created a stigma which has made it difficult for the academic community to perform a complete and unbiased analysis of the claims the many researchers have made over the past few years, it appears clear that the dike holding this information back is about to burst. Table 6.1 is a brief snapshot of but a few claims that have been documented by credible scientists in industry and academia in the last few years.

TABLE 6.1 - Global Reports/Observations on BLP Technology

Journal	Observed Data / Reported Results *	Researcher(s) & Affiliation
FUSION TECHNOLOGY March 1997	2,500 times energy out of hydrogen, hydrogen is lost in reaction, new form of tightly bound hydrogen is the model proposed to explain energy and loss results	DuFour, Foos, Millot and DuFour of Shell Research/CNAM Laboratoire des Sciences Nucleaires, Paris, France
JOURNAL of ELECTRO-ANALYTICAL CHEMISTRY (1993) and (1991)	Significant heat production from electrolytic cells and the observation of a dideutrino molecule with a higher ionization energy similar to the Mills energy predictions	Miles, Bush, Lagowski, Ostrom and Miles of China Lake Naval Air Warfare Center Weapons Division, US
3rd Conference on Cold Fusion - October 1992	Significant excess heat production from cell with mass spec data indicating a diduetrino molecule [i.e.: lower energy deuterium molecule via Mills]	Yamaguchi and Nishioka of the NTT Basic Research Laboratories and IMRA Europe S.A.

* - see footnotes 39 - 43

Within the next five years there will be a significant increase in awareness of the factual information surrounding the experiments conducted by many on hydrogen technologies which are taking advantage of the natural effect first observed by Dr. Mills. The data provided in this thesis is but a brief summary of the wealth of work that has already been performed in this area of science. Most academicians I have spoken with regarding the work of Dr. Mills and Mr. William Good are annoyingly critical and pessimistic before even asking to hear the details of their experiments or supporting data. It does not surprise this researcher that it has taken at least five years for Dr. Mills work to begin to gain the recognition that it needs to have for appropriate peer review and true academic critique. It is hoped that this thesis work will draw attention to the need for a balanced and open debate on the legitimacy of the BLP claims, which though they seem extensive are also grounded in excellent technical and theoretical research.

Chapter 6 - Implications for the Future and Recommended Next Steps

A new energy paradigm will not be quickly embraced by those currently in decision-making positions in the energy industry. Literally trillions of dollars have been invested over the past fifty years in the current energy infrastructure and its early retirement could cause major economic disruption. However, the deregulation of the gas industry over the past decade combined with the current efforts to deregulate the electric industry have positioned at least the U.S. and much of the U.K. energy industry for the major competitive forces and shifts that the introduction of a new technology like BLP would cause. Cogeneration and independent power producer competition have already ushered in the pre-competitive era for most in the electric industry while the gas, oil and other traded energy commodities have been fiercely competitive for some time. Nonetheless, there is little to gain for the established energy providers to accelerate the adoption of a new energy technology based upon hydrogen. Adopting a 'wait and see' strategy not only minimizes the risk of embarrassment should the technology prove to have little commercial potential, but also could stall or delay the day when the technology is ready and able to compete directly with the energy providers for their customers. History has shown that only a few in business adopt the Peter F. Drucker strategy of creating their future. [Drucker quote; "The only way to control the future is to create it"] Most are content to watch it being created around them and then getting involved once it is clear what the winning technologies are likely to be. In the case of a paradigm shift as radical as the one proposed by Dr. Mills and BLP, waiting could be a devastating business strategy. This researcher has advised his energy company to become involved from the beginning and other companies should also follow this advice. Knowing how quickly the technology may develop and emerge best positions the energy company to plan for the timely deployment, divestiture and or disposition of its assets that may be most at risk should commercialization move on a fast or slower track. This closing section of my thesis however, is not dedicated to what the energy industry should do as next steps but rather to what BLP should do in the near future to solidify their position with this technology and maximize the benefits for their shareholders for the investment they have made in developing this technology. The following list of recommended next steps is brief and succinct, but should assure BLP success in their endeavors if completed in a timely manner.

Recommended Next Steps

1. Clarify the Vision, Mission and Purpose of BlackLight Power, Inc. and communicate it clearly to all employees, contractors and owners. Align all corporate and employee goals and compensation strategies with the attainment of these. Identify the corporate competencies needed to execute the goals and mission of organization.

2. Focus on maximizing the intellectual property developed, owned and applied by BLP employees [individually and as a group]. Maximize new patent filings for all supportive device technologies and innovations. [If overarching patents fail, supporting patents will still protect the embodiments of the BLP effect in most apparata] Maximize the technical and journal papers published and defended during years 1-5.

3. Focus on Communicating the BLP Vision, Mission and Purpose to all appropriate audiences and keep an adequate supply of current, accurate and appropriate information flowing to the media and necessary constituents.

4. Focus on Identifying and Quantifying the Key Parameters controlling the Hydrocatalysis and Disproportionation effects including the isolated optimization of each as well as their interactions with each other. [ie; dissociation surface area, partial pressures -catalyst vs. hydrogen atoms, mean free paths, temperature regimes, volumetric proportionalities, time dependence, etc.] This should be completed for all key embodiments gas phase, electrolytic phase, etc.

5. Develop a self-contained, self-sustaining "Hot Black Box" which irrefutably demonstrates the ability that BLP has to control all key parameters and engineer the optimization of the effect for commercial application and manufacturing. This must not be left to others to develop, it should be the work and competence of BLP at the end of the day in order to maintain a competitive advantage in this field.

6. Develop the BLP management model and compensation strategy. Hire sufficient numbers of management and staff with the necessary competencies to successfully execute items 1- 5 during the first 18 months after sufficient funding is achieved.

PART V - Reference Materials

The data reviewed in this thesis was substantial and unfortunately only a brief overview was able to be provided in the limited space. Many items referenced can be easily obtained from the author or from a librarian. This section is devoted to making that exercise more simple. The reference materials have been divided into two sections. First, a straightforward list of all Footnotes cited in the text grouped by their section or subsection number is available on the next three pages. Second, where key information was substantial and of primary relevance to the thesis but could not be afforded adequate coverage in the text, Appendices were developed to provide the needed reference support. Placing them at the end of this thesis allowed the continuity of idea flow without distracting the reader from the key points being made. The full list of relevant supporting appendices is shown on the page before they begin as the final page in Part V.

References Provided in this Thesis

THESIS FOOTNOTES

Introduction and Overview of Thesis

1 Mills, Randell L., ***"The Grand Unified Theory of Classical Quantum Mechanics"***, Black Light Power, © September 1996, Library of Congress Cat. No. 96-70686, ISBN 0-9635171-2-0, p. ix

PART I

2 Cook, Earl, ***"The Flow of Energy in an Industrial Society"***, Scientific American, © September 1971

3 Cassidy, E.S., Grossman, P.Z., ***"Introduction to Energy, Resources, Technology and Society"***, Cambridge University Press, © 1990.

PART I, Chapter 1

4 Kraushaar, Jack J., Ristinen, Robert A.,***"Energy and Problems of a Technical Society"***, 2nd Edition, John J. Wiley & Sons, Inc., © 1984, 1993, ISBN 0-471-57310-8, pp. 2-3

PART I, Chapter 1, Section 1.1 - Fossil Fuels

5 Energy Info Home Page, ***http:/www.energyinfo.co.uk:80/wstats.html***, World Fuel Consumption by Country, pp. 1-2, © 1996 by EnergyInfo, last modified April 26, 1996.

6 Kraushaar, Jack J., Ristinen, Robert A.,***"Energy and Problems of a Technical Society"***, 2nd Edition, John J. Wiley & Sons, Inc., © 1984, 1993, ISBN 0-471-57310-8, p. 4

7 Kraushaar, Jack J., Ristinen, Robert A.,***"Energy and Problems of a Technical Society"***, 2nd Edition, John J. Wiley & Sons, Inc., © 1984, 1993, ISBN 0-471-57310-8, p. 4

8 Kraushaar, Jack J., Ristinen, Robert A.,***"Energy and Problems of a Technical Society"***, 2nd Edition, John J. Wiley & Sons, Inc., © 1984, 1993, ISBN 0-471-57310-8, p. 404

9 Kraushaar, Jack J., Ristinen, Robert A.,***"Energy and Problems of a Technical Society"***, 2nd Edition, John J. Wiley & Sons, Inc., © 1984, 1993, ISBN 0-471-57310-8, p. 372

THESIS FOOTNOTES [continued]

PART I, Chapter 1, Section 1.1 - Fossil Fuels [continued]

10 Nesbit, William, ***"World Energy- Will There Be Enough in 2020?"***, Decisionmakers Bookshelf, Vol. 6, Edison Electric Institute, © 1979, ISBN 0-931032-06-7

11 Kraushaar, Jack J., Ristinen, Robert A.,***"Energy and Problems of a Technical Society"***, 2nd Edition, John J. Wiley & Sons, Inc., © 1984, 1993, ISBN 0-471-57310-8, Figure 1.15, p. 21

12 ***"World Book Encyclopedia J-K"***, Field Enterprises Educational Corporation, © 1961, Library of Congress Cat. No. 61-5169, p. 32a

13 Weinfeld, Steven G., ***"Funk & Wagnalls New Encyclopedia - Volume 14"***, Funk & Wagnalls, ©1986, Library of Congress Cat. No. 72-170933, ISBN 0-8343-0072-9, p. 402

14 Kraushaar, Jack J., Ristinen, Robert A.,***"Energy and Problems of a Technical Society"***, 2nd Edition, John J. Wiley & Sons, Inc., © 1984, 1993, ISBN 0-471-57310-8, pp. 2-3

PART I, Chapter 1, Section 1.2 - Nuclear Energy - Fission & Fusion

15 Schwarzchild, B., Physics Today, October 1990, pp. 17-20

16 Kraushaar, Jack J., Ristinen, Robert A.,***"Energy and Problems of a Technical Society"***, 2nd Edition, John J. Wiley & Sons, Inc., © 1984, 1993, ISBN 0-471-57310-8, pp. 108-111

17 Associated Press, ***"Princeton reactor's closure casts doubt on fusion prospects"***, The Press of Atlantic City, March 30, 1997

18 Kraushaar, Jack J., Ristinen, Robert A.,***"Energy and Problems of a Technical Society"***, 2nd Edition, John J. Wiley & Sons, Inc., © 1984, 1993, ISBN 0-471-57310-8, Table 4.1, p. 95

19 ***"Barsebäck to Close Down by 2001"***, The Swedish Press, March 1997, p. 9

THESIS FOOTNOTES [continued]

PART I, Chapter 1, Section 1.3 - Solar Energy

20 Energy Info Home Page, ***http:/www.energyinfo.co.uk:80/wstats.html***, World Fuel Consumption by Country, pp. 1-2, ©1996 by EnergyInfo, last modified April 26, 1996

21 U.S. Census Bureau - World POPClock Web Page, ***http:/www.census.gov/cgi-bin/ipc/popclockw***, International Programs Center, World Population projected to 2/24/97 at 7:09:44 PM EST

22 Energy Info Home Page, ***http:/www.energyinfo.co.uk:80/wstats.html***, World Fuel Consumption by Country, pp. 1-2, ©1996 by EnergyInfo, last modified April 26, 1996

23 P.M. Jansson and R.A. Michelfelder, ***"Market-Driven Photovoltaic System Economics for Grid-Connected Residential and Commercial Customers"***, 14th European Photovoltaic Solar Energy Conference, Barcelona, Spain, June 30 - July 4, 1997

PART I, Chapter 1, Section 1.4 - Geothermal Energy

24 Kraushaar, Jack J., Ristinen, Robert A.,***"Energy and Problems of a Technical Society"***, 2nd Edition, John J. Wiley & Sons, Inc., © 1984, 1993, ISBN 0-471-57310-8, p. 204

PART I, Chapter 1, Section 1.5 - Tidal Energy

25 Kraushaar, Jack J., Ristinen, Robert A.,***"Energy and Problems of a Technical Society"***, 2nd Edition, John J. Wiley & Sons, Inc., © 1984, 1993, ISBN 0-471-57310-8, p. 210, Table 7.8

PART I, Chapter 2, Section 2.1 - Theoretical Description

26 Mills, Randell L., ***"The Grand Unified Theory of Classical Quantum Mechanics"***, Black Light Power, © September 1996, Library of Congress Cat. No. 96-70686, ISBN 0-9635171-2-0, p. x

27 Mills, Randell L., ***"The Grand Unified Theory of Classical Quantum Mechanics"***, Black Light Power, © September 1996, Library of Congress Cat. No. 96-70686, ISBN 0-9635171-2-0, p. 138

THESIS FOOTNOTES [continued]

PART I, Chapter 2, Section 2.2 - Astrophysical Corroboration

28 Labov, S.E., Bowyer, S., ***"Spectral Observations of the Extreme Ultraviolet Background"***, The Astrophysical Journal, 371:810-819 © 20 April 1991, The American Astronomical Society

29 Schwarzchild, B., Physics Today, October 1990, pp. 17-20

30 Bahcall, J., et. al., ***"Solar neutrinos: a field in transition"***, Nature, 334, 11 1988, pp. 487-493

31 Taubes, G., Science, 256, 1992, pp. 1512-1513

32 Taubes, G. Science, 256, 1992, pp. 731-733

PART I, Chapter 2, Section 2.3 - Enigmas Solved

33 Mills, Randell L., ***"The Grand Unified Theory of Classical Quantum Mechanics"***, Black Light Power, © September 1996, Library of Congress Cat. No. 96-70686, ISBN 0-9635171-2-0, p. 426

34 Phillips, Kenneth J.H., ***" Guide to the Sun"***, Cambridge University Press, © 1992, ISBN 0-521-39483, p. 166

35 Phillips, Kenneth J.H., ***" Guide to the Sun"***, Cambridge University Press, © 1992, ISBN 0-521-39483, p. 367

36 Chown, Marcus, ***"Dark matter is still the only game in town"***, New Scientist, January 7, 1995, p. 15

PART II, Chapter 4

37 DuFour, J., Foos, J., Millot, J.P., DuFour, X., ***"Interaction of Palladium / Hydrogen and Palladium / Deuterium to Measure the Excess Energy Per Atom for Each Isotope"***, Fusion Technology, Volume 31, March 1997, pp 198-209

PART II, Chapter 4, Section 4.2 - Penn State University Calvet

38 Phillips, Jonathan, ***"Report on Calorimetric Investigations of Gas-Phase Catalyzed Hydrino Formation"***, Department of Chemical Engineering, Penn State University, Final Report for period of October - December 1996, p. 1

THESIS FOOTNOTES [continued]

PART IV

39 DuFour, J., Foos, J., Millot, J.P., DuFour, X., ***"Interaction of Palladium / Hydrogen and Palladium / Deuterium to Measure the Excess Energy Per Atom for Each Isotope"***, Fusion Technology, Volume 31, March 1997, pp 198-209

40 Miles, M.H., Bush B.F., Ostrom, G.S., Lagowski, J.J., ***"Helium Production During the Electrolysis of D_2O in Cold Fusion Experiments"***, Journal of Electroanalytical Chemistry, 301, p. 271 (1991)

41 Miles, M.H., Hollins, R.A., Bush B.F., Lagowski, J.J., Miles, R.E.J., ***"Correlation of Excess Power and Helium Production During D_2O and H_2O Electrolysis using Palladium Cathodes"***, Journal of Electroanalytical Chemistry, 346, p. 99 (1993)

42 Notoya, R. and M. Enyo, ***"Proceedings of the Third Annual Conference on Cold Fusion, Nagoya, Japan"*** October 21-25, 1992, H. Ikegami, Editor, Universal Academy Press, Inc., Tokyo, ©1992, pp. 421-426

43 Yamaguchi, E. and Nishioka, T., ***"Direct Evidence for Nuclear Fusion Reactions in Deuterated Palladium"***, Proceedings of the Third Annual Conference on Cold Fusion, Nagoya, Japan , October 21-25, 1992, p. 179

DESCRIPTION OF APPENDICES

Appendix 1. BLP Research Partners - Catalogue of Experimental Results

This researcher compiled a log of numerous experiments and studies that had been performed on BLP technologies over the past 5 years. These are summarized by title, author, report name, date of work and subject matter in this appendix.

Appendix 2. An Overview of Mills Theory

The theory of Dr Mills is rather complex in that it unifies all of the aspects of a new classical quantum mechanics, Maxwell's Equations, Einstein's Special and General Relativity as well as the fundamental classical theories and models of physics. A more full description of his theory is provided in this appendix.

Appendix 3. Jansson Astrophysical Data Calculations Verifying BLP Reported Results

Specific calculations provided by Dr. Mills in his text as part of demonstrating that data being collected from space is able to validate that the theoretical results of his model are sound have been made by this author. The Excel spreadsheet has produced the tables found in this appendix.

Appendix 4. BLP/AEI Experiment 15.6 - May 1996

Atlantic Energy witnessed testing of the Isothermal Cell at the BLP Laboratories in Malvern, Pa. On May 4-6, 1997. The actual lab notes from that experiment and associated calculations done by Atlantic Energy staff to verify the results observed are provided in this appendix

Appendix 5. Analysis of BLP Isothermal Calorimetry Data

Analysis of the Isothermal cell experiments was conducted by this researcher to see if the results that were being observed were consistent with heat loss modeling estimates. The actual data provided by the BLP data logger was reviewed to see if excess heat of formation was actually occurring. This appendix summarizes these results.

Appendix 6. PSU Calvet Test Results and Report - December 1996

This appendix contains the full research report completed by Pennsylvania State University on their tests of the BlackLight technology via a Calvet calorimeter.

Appendix 7. Jansson Calvet Testing Protocol

This appendix describes the protocol that was used in the control and experimental runs performed in BlackLight Power's laboratory facility during February through May 1997 by Peter Mark Jansson., P.P.,P.E.

DESCRIPTION OF APPENDICES [continued]

Appendix 8. Jansson Calvet Test Results June 1997

The results of the experimental and control runs are provided in more detail in this appendix. While the Lab Note Book has not been included each day of experiments that were analyzed in the summary data provided in the thesis are shown explicitly. Each data set name is listed as well.

Appendix 9. Jansson Heat Loss Model Calibration & Performance

Specific mathematical modeling of the Isothermal cell was developed by this researcher to see if the results that were being observed were consistent with those that a heat loss model could predict. The calibration of the model was made via actual data provided by the BLP data logger and produced results which indicated excess heat of formation was actually occurring. This appendix summarizes these results.

THESIS - APPENDIX ONE

Appendix 1 - Catalogue of Relevant Publications and Experimental Results

This appendix provides a brief overview of relevant publications and printed experimental results that this researcher was able to acquire, review and summarize. I have not made an exhaustive search for electrolytic cell experimental data since it is extremely lengthy. The catalogue begins on the page which follows and forms the essence of this appendix.

Appendix 1 - Catalogue of Relevant Publications and Experimental Results

Paper/Report - Author	Publication Status	Purpose/Results/Conclusions
Nascent Hydrogen an Energy Source N.J. Gernhart, R.M. Schaubach WRIGHT PATTERSON - AFB Malvern, PA 610-651-4938	SBIR Phase I Project Report 11-1124 published March 1994	Experimental Permeation Cell Results
Report on Calorimetric Investigations of Gas-Phase Catalyzed Hydrino Formation S. Kurtz, J. Phillips and J. Smith Penn State Univ., PA 814-863-4809	PSU -Confidential presented to BLP prepared December 1996	Penn State Gas Phase Calvet Calorimetry
A Calorimetric Investigation of the Reaction of Hydrogen with Sample PSU #1 M.C. Bradford and J. Phillips Penn State Univ., PA 814-863-4809	PSU -Confidential presented to BLP prepared 1994	Penn State Solid Oxide Catalyst Calvet Calorimetry
Additional Calorimetric Examples of Anomalous Heat from Mixture of K/Carbon and Pd/Carbon J. Phillips and Shim, H. Penn State Univ., PA 814-863-4809	PSU - Confidential presented to BLP prepared 1996	Penn State Spillover Catalyst Calvet Calorimetry
Additional Examples of Anomalous Heat: Hydrogen Mass Balance J. Phillips Penn State Univ., PA 814-863-4809	PSU - Confidential presented to BLP prepared 1996	Penn State Spillover Catalyst Calvet Calorimetry
Replication of the Apparent Excess Heat Effect in a Light Water -- Potassium Carbonate -- Nickel Electrolytic Cell J. M. Niedra and I.T. Myers	NASA - Lewis Technical Memorandum 107167 prepared 1996	NASA Investigation & Experiments - Electrolytic Cell

THESIS - APPENDIX TWO

Appendix 2 - An Overview of Mills Theory

The section which follows is but a brief description of a theory that has clearly been years of development work on the part of Dr. Randell Mills. I refer the reader to his complete text on ***"The Grand Unified Theory of Classical Quantum Mechanics".*** Dr. Randell Mills received his BA in Chemistry from Franklin & Marshall College in 1982 where he graduated summa cum laude. He went on to graduate from Harvard Medical School receiving his MD in 1986 while simultaneously developing his theoretical model for unification while taking electrical engineering courses at M.I.T. He is the creator and owner of many medical patents and the recipient of many academic awards. He has published many technical papers and presented his Grand Unified Theory in 1989. The following year [1990] he went on to form the HydroCatalysis Power Corporation [now BlackLight Power]. Since that time he has been demonstrating the proof of his theory by using it to design devices that use proprietary catalysts to reduce hydrogen to the lower energy states predicted by his model of the hydrogen atom. This he has done successfully in many types of apparata. Concurrently he has filed patents in the U.S. and 23 foreign countries. A patent was awarded in Australia in 1996.

Dr. Mills is President of BlackLight Power [BLP], presently a small, high technology firm and laboratory located in Malvern, Pennsylvania. It is a privately held company with numerous entrepreneurial investors but has at least two major utility owners [Pacificorp from the western U.S. and Atlantic Energy from the eastern U.S.] BLP is currently being courted by additional U.S. utilities and major U.S. energy equipment manufacturers. While significant data and experiments conducted by BLP and others appear to demonstrate conclusively the reproducibility of their new heat generation effects it would seem that the timing of their discovery was not conducive to its being objectively reviewed and granted widespread academic review for authenticity. The 1990-1991 debunking of "cold fusion" and the sharp criticism that still comes to scientists and academicians who research these claims has placed a cold, wet blanket on the hot findings that continue to be generated by the scientific team from BLP. This researcher believes that the "Pons and Fleischmann experience" has increased resistance in the academic community to objective investigation of the BLP findings and claims.

Table 2.1 in the thesis text summarizes the significant government, corporate and university research centers that have corroborated BLP's findings. At the present time the company's Board has voted to allow only one more private offering before an independent public offering planned sometime in the next 1 to 2 years. To date it is important to note that the work developed by BLP has been primarily funded by its investors with limited government research funding. The total effort to bring the company to its current state of technological development has cost its private owners less than a few million dollars over the past seven years. This needs to be contrasted with the billion dollar expenditures over the past few decades for particle accelerators, nuclear research and investigations into the claims of cold fusion.

TABLE A.1 - Mills' Theory Predictions

---

one electron atom w/ 4 quantum numbers
the Rydberg constant
the ionization energies of 1,2 & 3 electron atoms
equation of the electron in free space
electron g factor
excited states of the electron
parameters of pair production
bond energies, vibrational energies, rotational energies and bond distances of hydrogen-type molecules and molecular ions
equation of the expansion of the universe
the masses of atomic particles [leptons, quarks and nucleons]
beta decay energy of the neutron
theory of alpha decay
spin/nuclear hyperfine structure
the stability of atoms
equation of the photon
results of Stern-Gerlach experiment
spin angular momentum energies
results of the Davisson-Germer experiment
hyperfine structure interval of positronium
Quantum Hall effects
the Aharonov-Bohm effect
equations of gravitation
the gravitational constant
the basis for the antigravitational force
magnetic moments of nucleons
the binding energy of deuterium
the chemical bond energies of molecules

Mills theory begins with the classical, fundamental laws of physics [see 1-6 above] and then applies a boundary condition on the electron significantly different than Schrdinger. His boundary condition is that a bound electron can not radiate energy at 13.6 eV. "The mathematical formulation for zero radiation is that the function that describes the motion of the electron must not possess spacetime Fourier components that are synchronous with waves traveling at the speed of light. The permissible solutions for the electron function are derived as a boundary value problem with the application of the nonradiative boundary condition."[A3] By using only the classical laws of physics, mathematics and this one new boundary condition [NOTE: this boundary condition is essentially required to satisfy Maxwell's equations] a totally new view of the electron emerges. The result of this theory by Dr. Mills also leads to the unification of all of the standard classical laws of physics. These can be solved mathematically, discretely and without the need to resort to the arbitrary gauging constants developed by presently accepted quantum theory in order to "get the theory to fit" observed data. Dr. Mills calls this new electron perspective and new classical view an ***electron orbitsphere***. The orbitsphere solution to the electron's mathematical function produces many interesting features some of which are highlighted in Table 2.3 below. For a complete summary of the features described by Mills' theory the reader is referred to pages 22-26 of Dr. Mills' text.

FIGURE A.1

Figure 1.4 B. The current pattern of the orbitsphere shown with 8.49 degree increments of the infinitesimal angular variable $\Delta\alpha(\Delta\alpha')$ from the perspective of looking along the x axis.

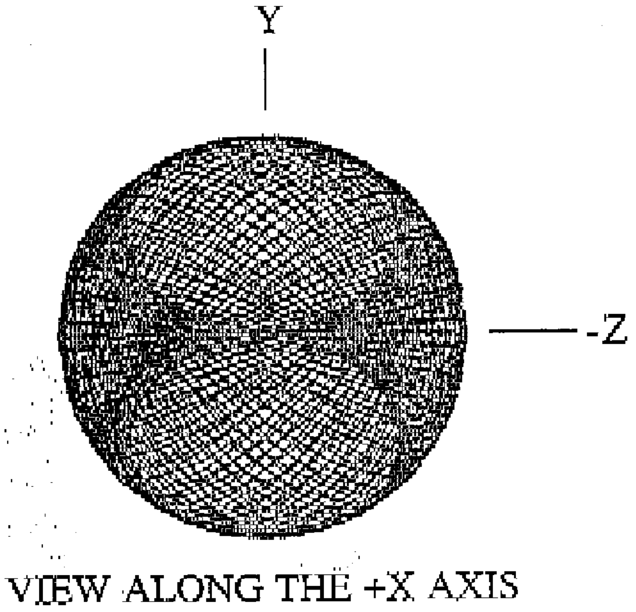
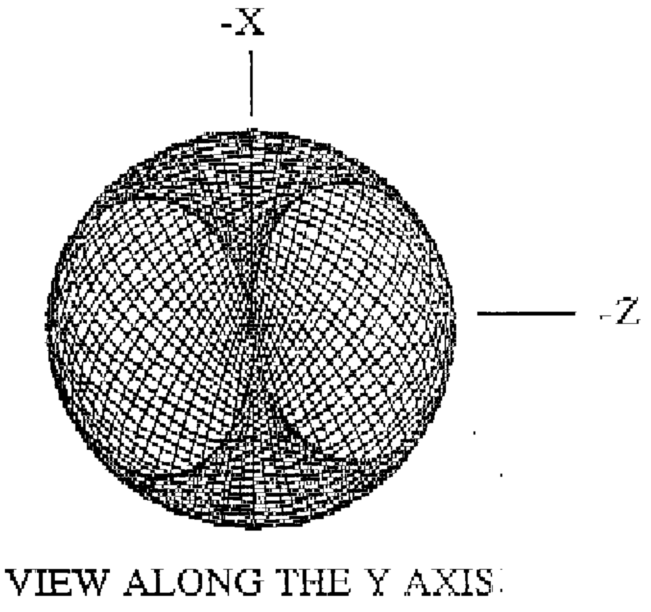


Figure 1.4 C. The current pattern of the orbitsphere shown with 8.49 degree increments of the infinitesimal angular variable $\Delta\alpha(\Delta\alpha')$ from perspective of looking along the y axis.



In closing this overview of Mills' theory it is important to note that while the scientific community has been searching for a more classical unified field theory that could stand up to rigorous mathematical scrutiny for some time, there has not yet been a widepread review of his work by academia. The few academic reviews that have ben made on the merits, potential flaws or criticisms of Mills' work have come out glowingly in favor of his findings. This researcher believes that because Dr. Mills' is an outsider and not considered an expert in these fields that it will take much longer for his work to be widely discussed in academic circles. Mills theory is compelling and may offer just what Albert Einstein was looking for when he uttered his famous words denouncing the then emerging quantum theory "God does not play dice with the universe".

APPENDIX 2 FOOTNOTES

[A1] Mills, Randell L., ***"The Grand Unified Theory of Classical Quantum Mechanics",*** BlackLight Power, © September 1996, Library of Congress Cat. No. 96-70686, ISBN 0-9635171-2-0, p. 7

[A2] Mills, Randell L., ***"The Grand Unified Theory of Classical Quantum Mechanics",*** BlackLight Power, © September 1996, Library of Congress Cat. No. 96-70686, ISBN 0-9635171-2-0, p. 9

[A3] Mills, Randell L., ***"The Grand Unified Theory of Classical Quantum Mechanics",*** BlackLight Power, © September 1996, Library of Congress Cat. No. 96-70686, ISBN 0-9635171-2-0, p. 22

THESIS - APPENDIX THREE

Mills Prediction vs. Data

		Raw Extreme UV Background Spectral Data *						
	OBSERVED DATA			Fractional State		MILLS PREDICTED		
	Wavelnth	Energy	Calc	nf	ni	Wavelnth	Energy	
Peak	A	eV	eV			A	eV	
1	84.8	146.2	146.2	8	7	82.9	149.6	
2	101.5	122.2	122.2	7	6	101.3	122.4	
3	116.8	106.2	106.2	4	2	114.0	108.8	
4	129.6	95.6	95.7	6	5	130.2	95.2	
5	139.6	88.8	88.8	4	2	141.6	87.6	He scattered
6	163.2	75.9	76.0	8	7	165.8	74.8	2nd order Peak 1
7	181.7	68.3	68.2	5	4	182.3	68.0	
8	200.6	61.8	61.8	7	6	202.6	61.2	2nd order Peak 2
9	233.8	53.0	53.0	3	1	227.9	54.4	
10	261.2	47.5	47.5	5	4	265.0	46.8	He scattered
11	302.5	41.0	41.0	4	3	303.9	40.8	
12	459.1	27.0	27.0	3	1	455.9	27.2	2nd order Peak 9
13	584.0	21.2	21.2			584.9	21.2	Helium Resonance
14	607.5	20.4	20.4	4	3	607.8	20.4	2nd order Peak 11
15	633.0	19.7	19.6	4	3	633.0	19.6	He scattered
16				3	2	911.7	13.6	
				1.60E-19	6.63E-34	3.00E+08		
				eV	h	c		
		Raw Extreme UV Solar Spectral Data **						
	OBSERVED DATA		MILLS PREDICTED					
	Wavelnth	O-M	Wavelnth					
	A	delta	A	nf	ni	A	eV	
	1215.7			2	1	911.74	13.6	
	911.8			2	1	-911.74	-13.6	
	911.8	0.01%	911.74	3	2	911.74	13.6	
	584.5			1	1	-227.93	-54.4	
	373.7	0.03%	373.60	3	1	373.60	33.2	C S - He
	303.784	-0.04%	303.91	4	3	303.91	40.8	
	280.2	-0.12%	280.54	3	1	280.54	44.2	C S - H
	280.8	0.09%	280.54	3	1	280.54	44.2	C S - H
	264.8	-0.08%	265.01	5	4	265.01	46.8	C S - He
	228	0.03%	227.93	3	1	227.93	54.4	
	215.16	0.29%	214.53	5	4	214.53	57.8	C S - H
	182.16	-0.10%	182.35	5	4	182.35	68.0	
	167.5	-0.05%	167.59	6	5	167.59	74.0	C S - He
	152.15	45.52%	82.89	4	1	82.89	149.6	
	145.9	0.01%	145.88	6	5	145.88	85.0	C S - H
	141	-0.40%	141.56	4	2	141.56	87.6	C S - He
	129.87	-0.29%	130.25	6	5	130.25	95.2	
	125.5	-0.20%	125.76	4	2	125.76	98.6	C S - H
	122.2	-0.28%	122.54	7	6	122.54	101.2	C S - He
	114	0.03%	113.97	4	2	113.97	108.8	
	110.5	-0.01%	110.51	7	6	110.51	112.2	C S - H
	101.3	0.00%	101.30	7	6	101.30	122.4	
	96.7	0.13%	96.58	8	7	96.58	128.4	C S - He

THESIS - APPENDIX FOUR

PROJECT Atlantic Energy Test Notebook No. ______

Continued From Page ______

5/1/96 @ 7:00pm

$\boxed{115.9}$ - @3M KNO_2 soln was coated onto inner sides of vessel + dried on with a heat gun.
- @3g of dried powderized KNO_2 was sprinkled onto the bottom of the cell.
- 200 cm tungsten filament (0.01 cm diam) wrapped @ 4 ceramic rods supported by 1/8" SS Tees.
- opened valve to vacuum pump.
- turned on cartridge heater to @ 250°C on temp controller.

Started PEC 050196 7p ✓

5/2/96 @ 10:00am - filament read high Ω across both buffalo gland ends indicating an incomplete circuit.

@1:05pm - cartridge htr was turned off.

@1:30pm - cells was dismantled hot + filament was replaced.

@2:30pm - opened valve to vacuum

@2:45pm - turned on cartridge htr

Started PEC ? comp crashed.

Started PEC 050296 830p ✓ (cache disabled)

5/3/96 @ 9:30am

Temp Controller: Time on = 26.52 | 26.62 | 26.80 | Avg 26.65 $\circled{81.2\%}$

Total Time = 32.47 | 32.94 | 33.06 | 32.82

$$W_{in} = \frac{(100.97)^2}{80} \times \frac{26.65}{32.82} = \boxed{103.48\,W}$$

Temp = 279.49

RT = 27.72

Pres = 109 mtorr

@9:45am - closed valve to vacuum, pressurized cell w/ H_2 to @ ATM on gauge.

@9:48am - closed valve to vac when cell pressure

Continued on Page

Read and Understood By

Signed 5/3/96 Date

Signed 5/3/96 Date

PROJECT ATLANTIC ENERGY TEST Notebook No. ______

Continued From Page 61

5/3/96 @ 12:15 pm

Avg

Temp Controller: Time on = 5.61 / 6.05 / 6.05 / 5.90 (13.6)

Total Time = 43.69 / 43.09 / 43.00 / 43.26

Temp = 27.88

RT = 288.86

Pres = 1400 mtorr

$$Win = 126.4f \times \frac{5.90}{43.26} = \boxed{17.24\,W}$$

$$97.05 - 17.24 - 25.31 = \boxed{54.50\,W}\ XS$$

(control) cart. htr w/o fil — cart. htr w/fil on to 25 W — fil

@ 12:20 pm - increased filament wattage to @ 35 W.

V = 45.02, I = 0.39 x 2, W = 35.12

@ 2:10 pm - first time cart. htr. clicks on since increasing filament wattage.

@ 2:15 pm

Filament: V = 44.93, I = 0.40 x 2, W = ~~36.23~~ 35.94

Temp Controller: Time on = 5.66 (4.5%)

Total Time = ~~[illegible]~~ 125.93

Temp = 289.24

RT = 27.45

Pres = 1700 mtorr

$$Win = \frac{(100.97)^2}{80} \times \frac{5.66}{125.93} = \boxed{5.73\,W}$$

$$97.05 - 5.73 - 35.94 = \boxed{55.38\,W}\ XS$$

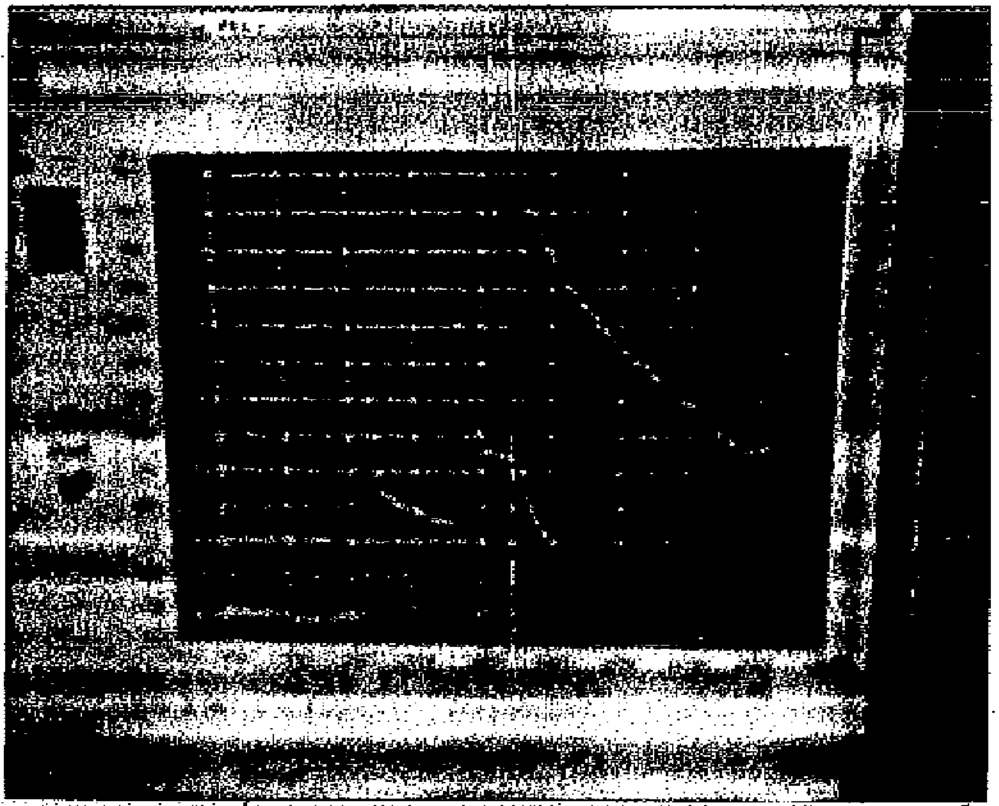
(Control) cart. htr. w/o fil — cart. htr w/fil on to @ 35 W — fil W

Continued on Page

Read and Understood By

Signed 5/3/96 Date

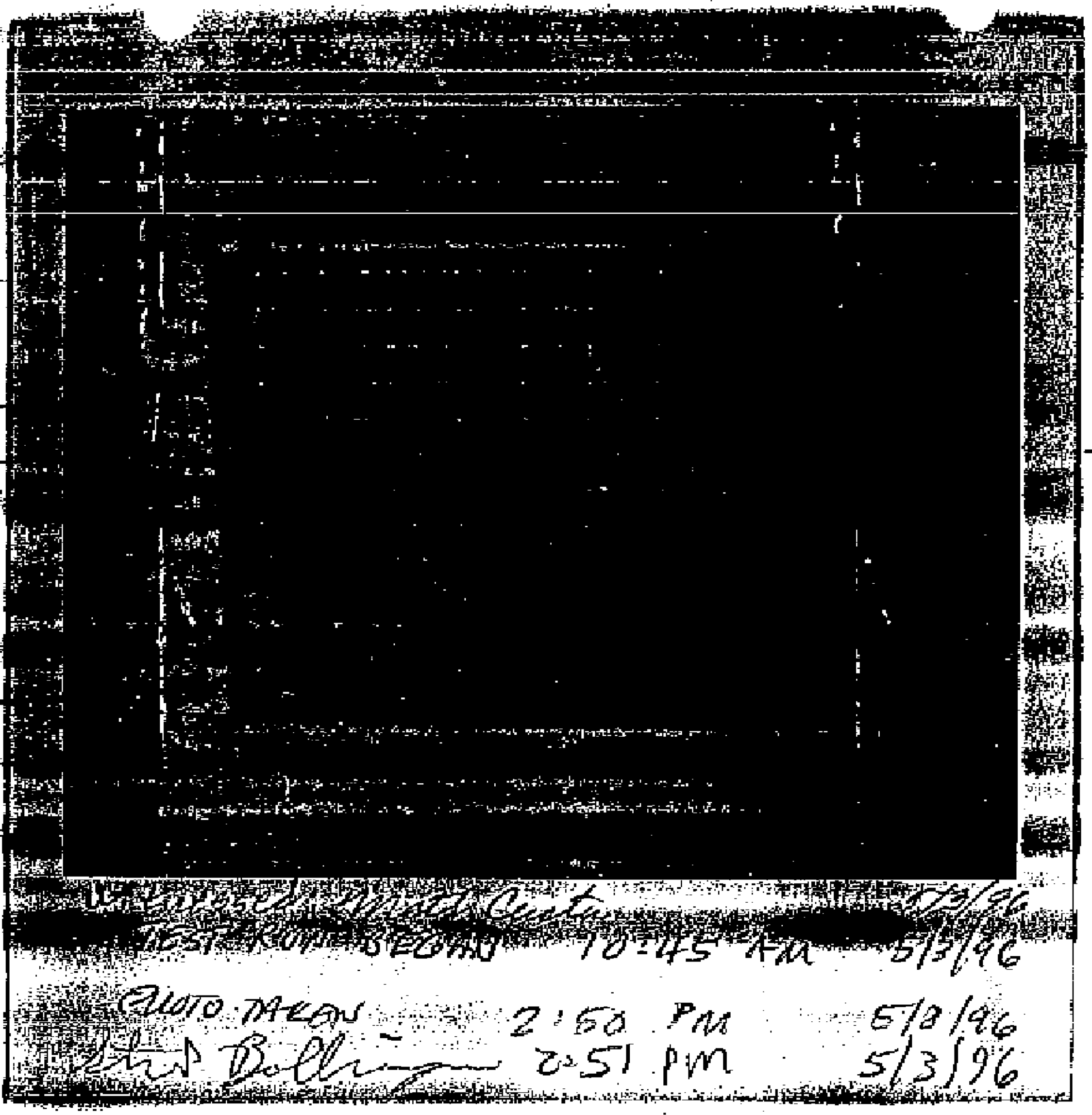
Signed 5/3/96 Date



Witnessed: Matt Custa 5/3/96
TEST RUN BEGAN 10:45 AM 5/3/96

PHOTO TAKEN 2:50 PM 5/3/96
Steve Bollinger 2:51 PM 5/3/96

LABVIE

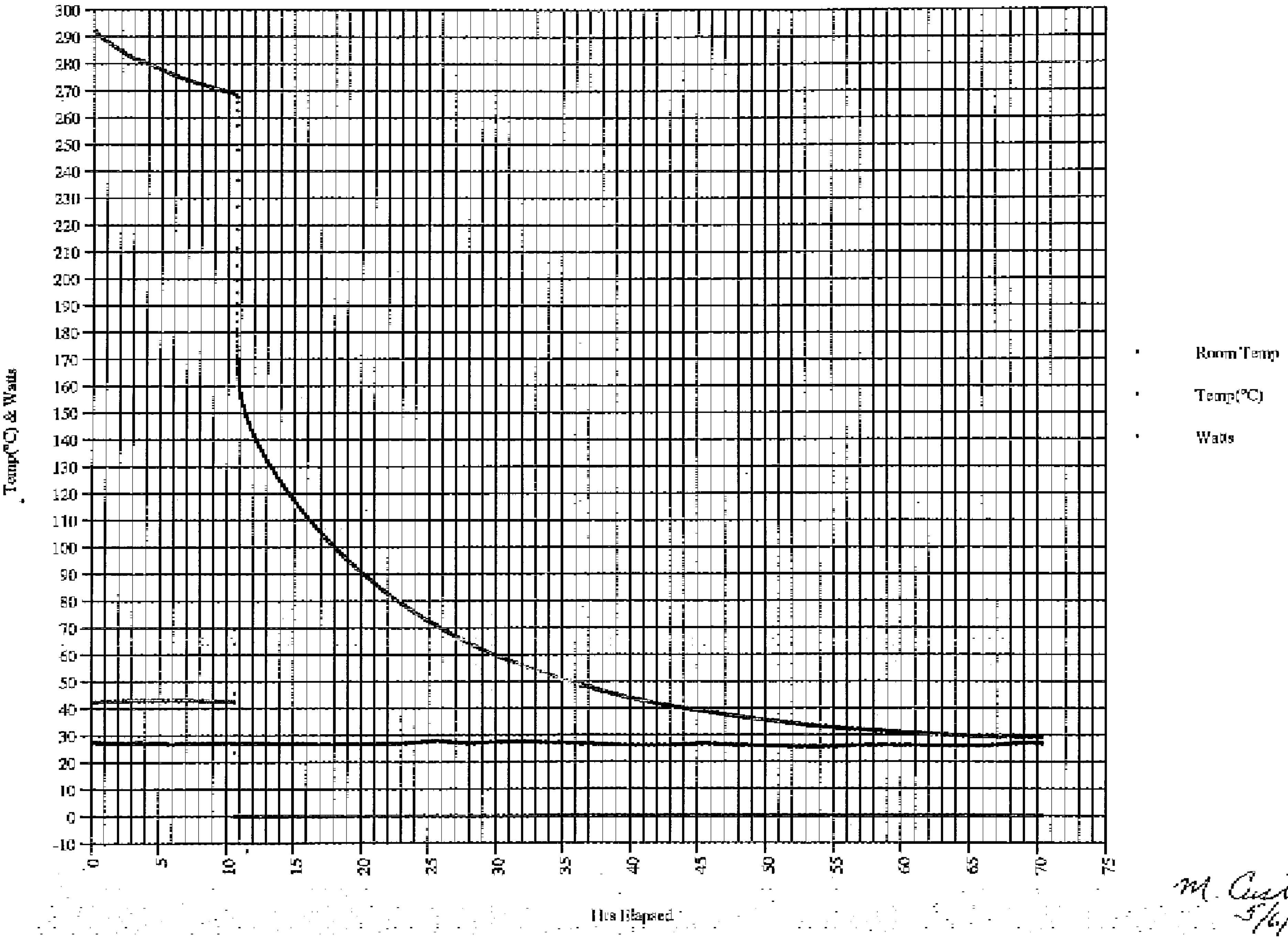


[illegible] Center [illegible] 5/3/96
TEST RUN BEGAN 10:45 AM 5/3/96
PHOTO TAKEN 2:50 PM 5/3/96
[illegible] Bollinger 2:51 pm 5/3/96

292.6° 3:04 May 3

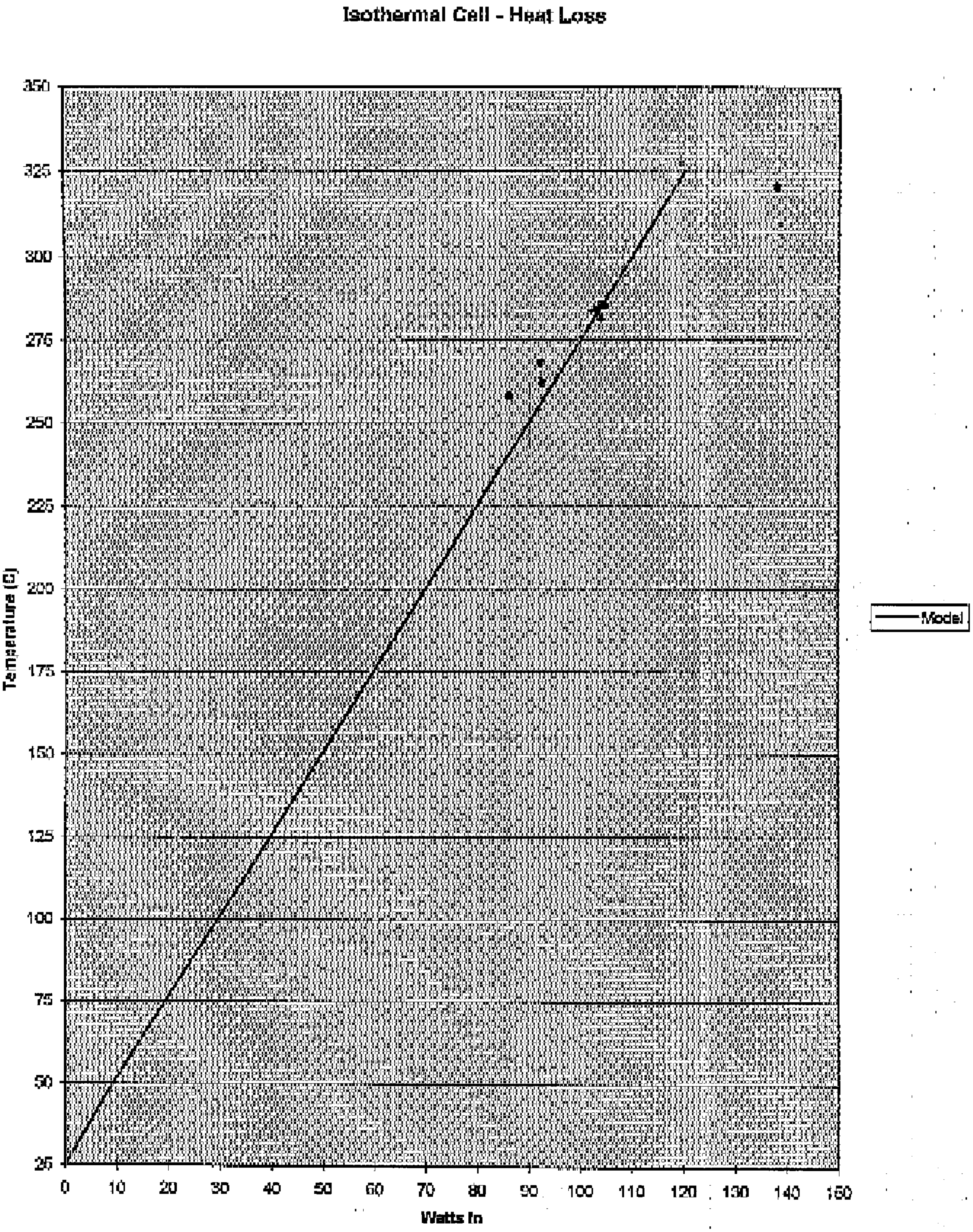
36887	27.082	268.98	42.563	10.24639	
36907	27.082	269.07	42.635	10.25194	
36927	27.082	268.99	42.655	10.2575	
36948	27.081	268.88	42.544	10.26333	
36968	27.08	268.9	42.546	10.26889	
36988	27.081	268.92	42.614	10.27444	
37008	27.083	268.87	42.626	10.28	
37028	27.08	268.9	42.551	10.28556	
37048	27.082	268.86	42.634	10.29111	
37068	27.083	268.91	42.552	10.29667	
37088	27.081	268.85	42.641	10.30222	
37108	27.082	268.91	42.635	10.30778	
37128	27.082	268.93	42.561	10.31333	
37148	27.08	268.78	42.543	10.31889	
37168	27.08	268.81	42.527	10.32444	
37188	27.079	268.93	42.528	10.33	
37208	27.079	268.78	42.565	10.33556	
37228	27.077	268.82	42.609	10.34111	
37248	27.078	268.72	42.651	10.34667	
37268	27.079	268.91	42.596	10.35222	
37288	27.078	268.84	42.542	10.35778	
37308	27.076	268.6	42.524	10.36333	
37328	27.077	268.74	42.568	10.36889	
37349	27.078	268.82	42.642	10.37472	
37369	27.077	268.73	42.58	10.38028	
37389	27.078	268.84	42.523	10.38583	
37409	27.077	268.77	42.593	10.39139	
37429	27.08	268.76	42.61	10.39694	
37449	27.078	268.71	42.51	10.4025	
37469	27.076	268.64	42.537	10.40806	
37489	27.076	268.73	42.619	10.41361	
37509	27.078	268.7	42.585	10.41917	
37529	27.079	268.69	42.507	10.42472	
37549	27.078	268.66	42.54	10.43028	
37569	27.078	268.59	42.62	10.43583	
37589	27.077	268.58	42.532	10.44139	
37609	27.078	268.63	42.543	10.44694	
37629	27.078	268.67	42.624	10.4525	
37649	27.078	268.51	42.53	10.45806	
37669	27.079	268.59	42.493	10.46361	
37689	27.079	268.47	42.503	10.46917	
37709	27.078	268.56	42.528	10.47472	
37729	27.08	268.51	42.577	10.48028	
37750	27.077	268.41	42.613	10.48611	
37770	27.079	268.52	42.493	10.49167	
37790	27.077	268.46	42.493	10.49722	
37810	27.078	268.5	42.539	10.50278	
37830	27.078	268.46	42.592	10.50833	
37850	27.077	268.43	42.586	10.51389	
37870	27.076	268.36	42.479	10.51944	
37890	27.076	268.48	42.478	10.525	

PEC 050396 310p H fil ex*

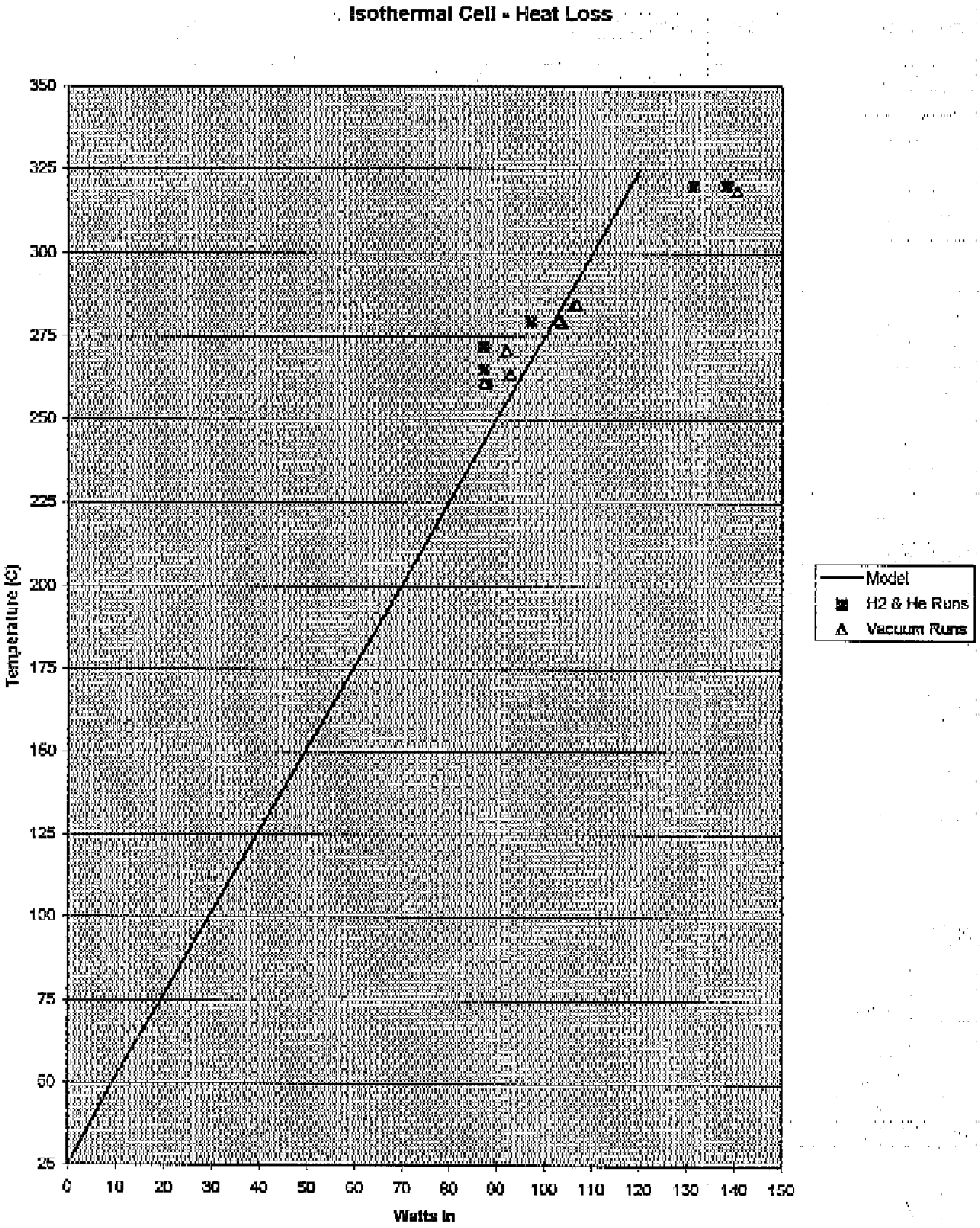


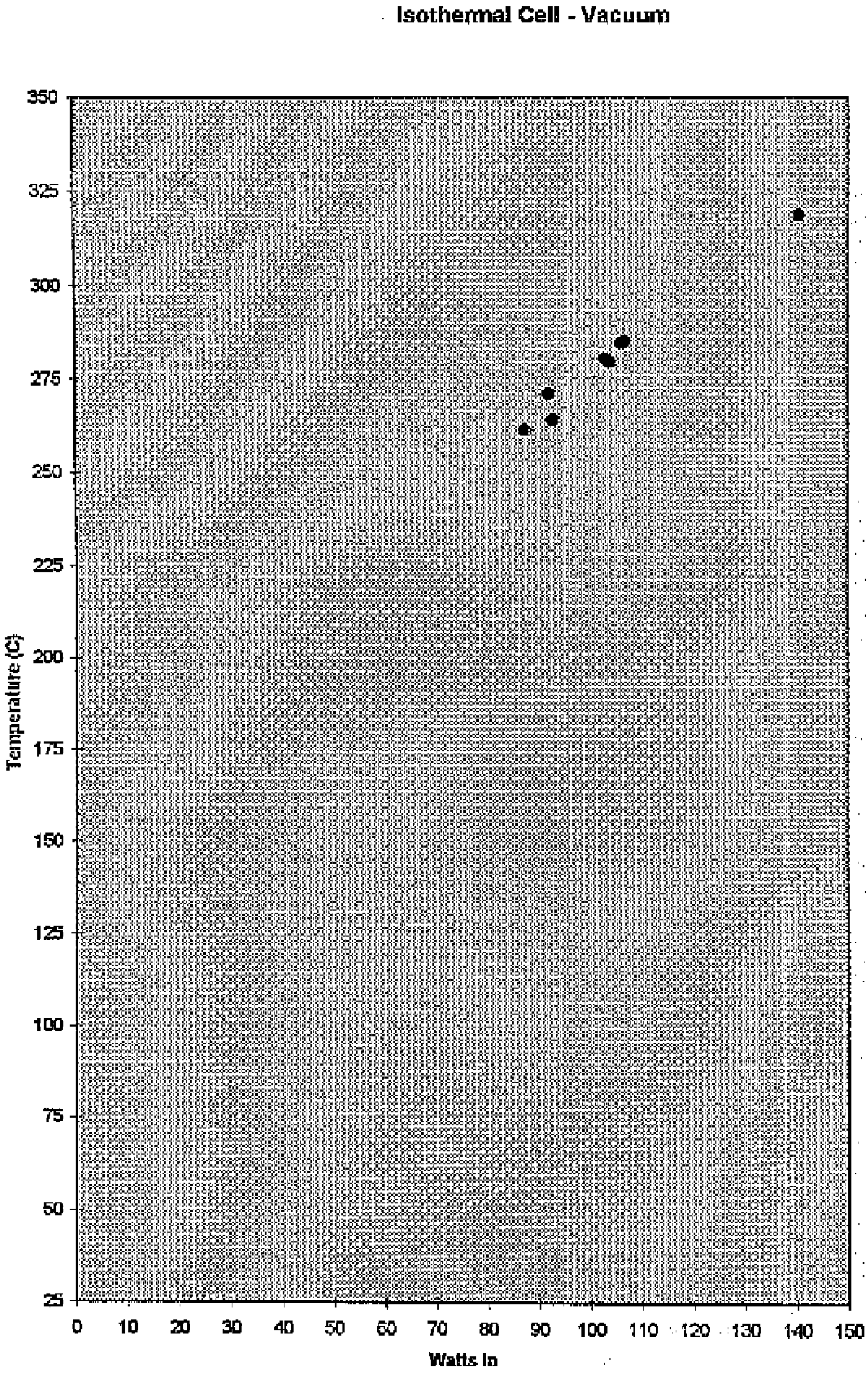
M. Custer
5/6/96

THESIS - APPENDIX FIVE

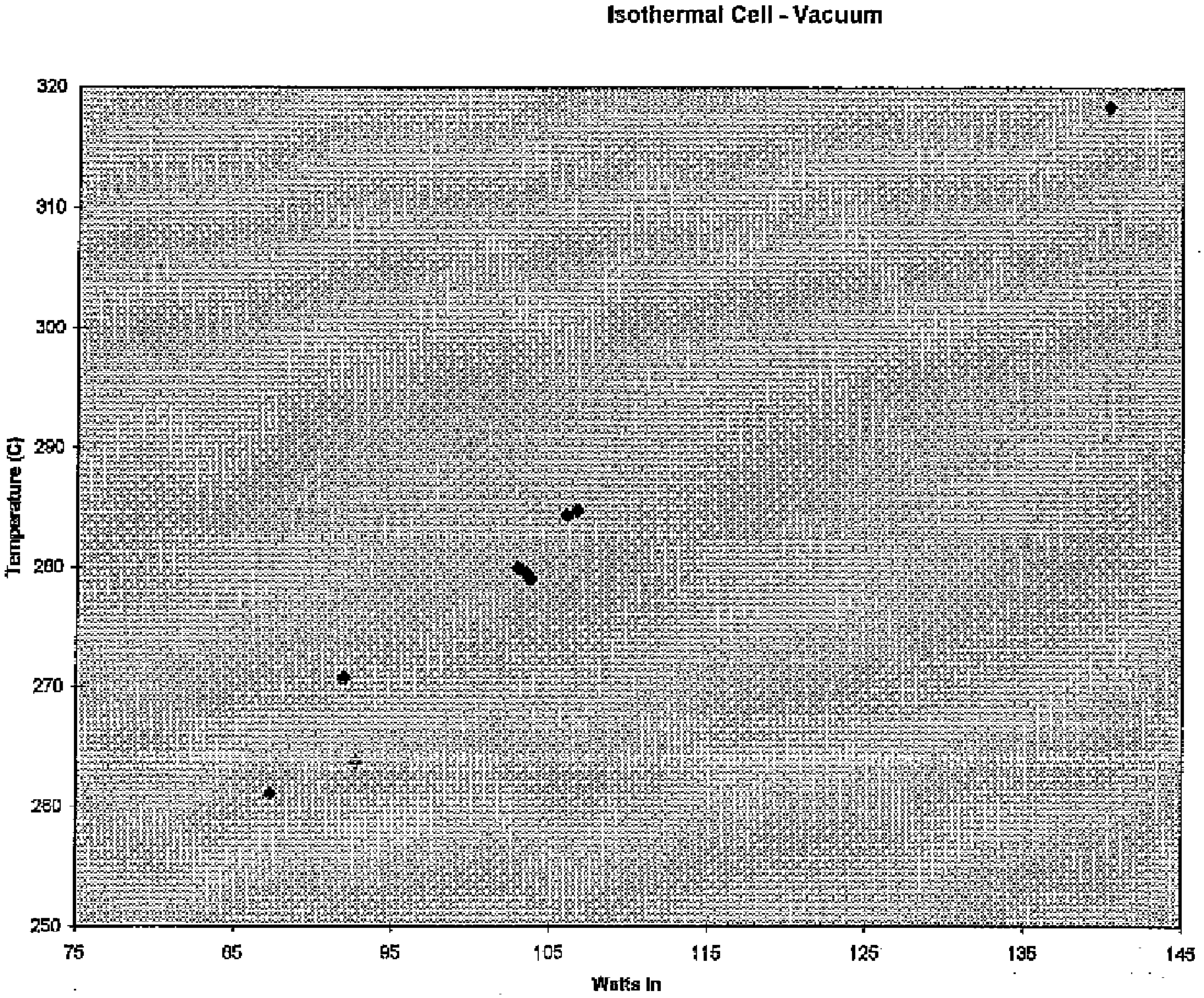

Isothermal Cell - Heat Loss
350
325
300
275
250
225
200
175
150
125
100
75
50
25
Temperature (C)
0
10
20
30
40
50
60
70
80
90
100
110
120
130
140
150
Watts In
Model

BLP Isothermal Cell Model Chart 3




Isothermal Cell - Vacuum
Temperature (C)
350
325
300
275
250
225
200
175
150
125
100
75
50
25
0
10
20
30
40
50
60
70
80
90
100
110
120
130
140
150
Watts In

BLP Isothermal Cell Model Chart 1



Confidential

Analysis of BlackLight Power Gas Phase Cells

<u>BLP & Major US University</u>

		Filament Characteristics [cm-cm2]			**Gas Cell Characteristics**			**Power Inputs & Outputs [watts]**				
Test ID	**Type**	**Length**	**Diameter**	**Surface Area**	**Volume**	**Pressure**	**Temperature**	**CHw**	**Fw**	**TOTw**	**EHw**	**EHCw**
BLP-15.3	H2 Run?	?	?							0		
BLP-15.4	H2 Run?	66.04	?							0		
BLP-15.5	Control	66.04	?							0		
BLP-15.6	H2 Run	200	0.01	6.2831853	2000							
	KNO_2					38	270.73	91.95	0	91.95	na	
	KNO_2					1600	271.79	87.07	0	87.07	na	
	KNO_2					1350	279.27	0	43.58	43.58	43.49	
BLP-15.7	H2 Run?	200	0.01	6.2831853	2000							
BLP-15.8	Control	200	0.01	6.2831853	2000							
	? vac					48	261.07	87.29	0	87.29	na	
	? H2					1350	260.82	87.85	0	87.85	na	
	? H2					low atm	269.38	12.06	50.4	62.46	25.39	
BLP-15.9	H2 Run	200	0.01	6.2831853	2000							
	KNO_2					109	279.49	103.48	0	103.48	na	
	KNO_2					1150	279.5	97.05	0	97.05	na	
	KNO_2					1700	289.24	5.73	35.94	41.67	55.38	
BLP-15.10	H2 Run	200	0.01	6.2831853	2000							
	KNO_2					56	263.72	92.71		92.71	na	
	KNO_2					1600	265.41	87.16		87.16	na	
	KNO_2					1600	275.7	1.82	30.36	32.18	54.98	
BLP-15.11	Control	200	0.025	15.70796325	2000					0		
BLP-15.12	Control	200	0.025	15.70796325	2000					0		
	vac					21	284.33	106.02	0	106.02	na	
	vac					19	286.49	62.15	35.09	97.241	8.779	
	vac					20	284.72	106.71	0	106.71	na	
	vac					20.8	286.54	54.96	42.85	97.81	8.9	
BLP-15.13	Control	200	0.025	15.70796325	2000							
	He					2000	318.91	138.29	0	138.29	na	
	He					2000	326.24	60.71	47.19	107.9	30.39	
BLP-15.13	H2 Run	200	0.025	15.70796325	2000							

Review of Iso Cal Data*

Confidential Isothermal Calorimeter Data

15.4-KNO2, 66 cm(0.01 cm dia) tungsten filament

status	Temp(°C)	Wcart htr	Wfil	Wtotal
vac 0.075 torr	258.7	95.2	0	95.2
H2 1.6 torr	255.45	65.4	6.95	72.35
H2 2.0 torr	256.91	55.03	8.16	63.19
H2 2.0 torr	257.87	43.62	10.36	53.98
H2 >2.0 torr	259.05	28.76	16.96	45.72

15.5-(control), empty 66 cm(0.01 cm dia) tungsten filament

status	Temp(°C)	Wcart htr	Wfil	Wtotal
vac 0.086 torr	272.88	94.33	0	94.33
H2 >2.0 torr	272.55	83.31	5.05	88.36
H2 >2.0 torr	273.68	81.12	8.23	89.35
H2 2.0 torr	272.67	65.45	10.21	75.66
H2 low ATM	275.64	44.35	16.93	61.28

15.6-KNO2, 200 cm(0.01 cm dia) tungsten filament

status	Temp(°C)	Wcart htr	Wfil	Wtotal
vac 0.038 torr	270.73	91.95	0	91.95
H2 1.8 torr	271.79	87.07	0	87.07
H2 1.35 torr	279.27	0	43.58	43.58

15.8-(control), empty 200 cm(0.01 cm dia) tungsten filament

status	Temp(°C)	Wcart htr	Wfil	Wtotal
vac 0.048 torr	261.07	87.29	0	87.29
H2 1.35 torr	260.82	87.85	0	87.85
H2 low ATM	269.38	12.06	50.4	62.46

15.9-KNO2, 200 cm(0.01 cm dia) tungsten filament

status	Temp(°C)	Wcart htr	Wfil	Wtotal
vac 0.109 torr	279.49	103.48	0	103.48
H2 1.15 torr	279.5	97.05	0	97.05
H2 1.7 torr	289.24	5.73	35.94	41.67

15.10-KNO2, 200 cm(0.01 cm dia) tungsten filament

status	Temp(°C)	Wcart htr	Wfil	Wtotal
vac 0.056 torr	263.72	92.71	0	92.71
H2 1.6 torr	265.41	87.16	0	87.16
H2 1.6 torr	275.7	1.82	30.36	32.18

15.12-KNO2, 200 cm(0.025 cm dia) tungsten filament

status	Temp(°C)	Wcart htr	Wfil	Wtotal
vac 0.021 torr	284.33	106.02	0	106.02
vac 0.019 torr	288.49	62.15	35.091	97.24
vac 0.020 torr	284.72	106.71	0	106.71
vac 0.0208 torr	288.54	54.96	42.85	97.81

15.13-KNO2, 200 cm(0.025 cm dia) tungsten filament

status	Temp(°C)	Wcart htr	Wfil	Wtotal
vac 0.0355 torr	318.45	140.45	0	140.45
vac 0.020 torr	323.36	82.59	46.638	129.23
H2 1.9 torr	319.83	131.22	0	131.22
H2 1.6 torr	328.48	38.5	47.77	86.27
H2 1.9 torr	331.03	8.79	74.798	83.59
He 2.0 torr	318.91	138.29	0	138.29
He 2.0 torr	326.24	60.71	47.194	107.90

THESIS - APPENDIX SIX

Final report for period October-December 1996
In fulfillment of Service Contract with HydroCatalysis Power Corp. (now BlackLight Power, Inc.)

REPORT ON CALORIMETRIC INVESTIGATIONS OF GAS-PHASE CATALYZED HYDRINO FORMATION

Submitted by
Prof. Jonathan Phillips*
and Julian Smith
Department of Chemical Engineering
Penn State University
University Park, PA 16802

Ph: (814) 863-4809
Fax: (814) 865-7846

Professor Stewart Kurtz
Department of Electrical Engineering
Penn State University
University Park, PA 16802

Ph: (814) 863-8407
Fax: (814) 863-8561

Jonathan Phillips

Julian Smith

Stewart Kurtz

*Corresponding Author

INTRODUCTION

Experiments were conducted to test the hypothesis that in the gas phase potassium ions will catalyze the conversion of hydrogen atoms to hydrino atoms. These experiments were initially carried out in a Calvet cell as this type of calorimeter is highly sensitive and accurate. Moreover, the conditions of the calorimeter are controlled.

RM's theory of hydrino formation requires that both K+ ions and H-atoms are present in the gas phase. In order to generate gaseous K+ ions, KNO_3 is placed in a small (2cc) quartz 'boat' inside the calorimeter cell. The boat is heated, to increase the vapor concentration of KNO_3, with a platinum filament, which is wound around the boat. A second function of the platinum filament is to generate H-atoms. It is well known that hydrogen molecules in contact with a heated filament will decompose, yielding a relatively high H-atom concentration in the boundary layer around the filament. Thus, according to RM's model, in a cell containing KNO_3 in the boat and vapor phase hydrogen, there is a small region in the boundary layer around the heated metal filament which should contain sufficient concentrations of both H-atoms and K+ ions for hydrino formation to occur.

Calorimetric considerations require that a stable baseline exists before the heat generating process is initiated. Thus, signal change away from the baseline can be correlated to the onset of the process under investigation. In the present experiments the cell was run with KNO_3 in the boat and the filament fully 'powered'. The calorimeter was allowed to equilibrate until a steady baseline existed. The 'hydrino formation' process was initiated by then adding gaseous hydrogen. Good calorimetric practice also requires that adequate control studies be carried out. Also required are repeated electric calibrations.

In the present work, data is presented which indicates that significant heat evolved upon the introduction of hydrogen to the Calvet calorimeter cell. In contrast, no heat was evolved upon the admission of helium. Repeated calibrations were also conducted. Thus, it appears that The RM

The plumbing system was so arranged that the cell could be evacuated, and then isolated from the pump in such a way that hydrogen or helium could be added directly from high purity gas tanks. Great care was taken before the experiments were initiated to evacuate and flush the gas lines several times. It was also determined that the lines held gas pressure, with no loss in pressure, for several days. That is, there were no leaks.

Water Bath Calorimeter. This instrument is described in detail in the previous report to HPC. Two minor modifications were made for the present experiment. First, to facilitate the decomposition of hydrogen, the center section of the mandrel was wrapped with a 60 cm length (about 8 cm of mandrel) of 0.25 mm diameter platinum wire. Second, in the center of this section the same quartz boat (again filled with about 200 mg of catalyst) used in the Calvet system, wrapped with the same coil of platinum wire, was inserted into the circuit. (The experiment described was carried out after the completion of the Calvet system experiments.)

RESULTS

Calvet Calorimeter. The Calvet studies suggest large amounts of heat are generated upon the admission of hydrogen to the cell. In contrast, virtually no heat is observed upon admission of helium to the cell.

Calibration. The first tests performed on the Calvet system were electrical calibration experiments. The system was set-up for full experimentation: KNO_3 was in the boat, the system was evacuated, and 10 watts of steady power were supplied to the platinum coil. After a steady baseline was achieved (approximately 10 hours after the oven was adjusted to 250 C), the cell was isolated from the pump and the pressure allowed to equilibrate (approximately 100 Torr). This did not appear to impact the baseline in any fashion. The power supply was then adjusted to deliver an additional 1 watt (11 watt rather than 10) for a specified time period. The power was then returned to the original 10 watt setting. A typical response curve is shown in Figure 1. The area under the response curve can be used to obtain a calibration constant which relates signal area increase to the number of extra Joules delivered. This was done in four cases (Table I). As can be seen, there is some error (+/- 15%) in the calculated calibration constant.

occasions, and the signal that evolved in response to these three processes is recorded in Figures 3, 4 and 5. One other observation recorded was that the pressure decreased gradually over time, such that after about an hour the pressure returned to the original equilibrium pressure of the cell. It must also be noted that the heat production was ended deliberately in all three cases by pumping the system to $5*10^{-3}$ Torr. It is clear 'excess heat' evolution would have continued in all cases if the system had not been evacuated.

It is expected that in the absence of reaction that the response of the cell to the addition of hydrogen would be similar to that observed for helium. Indeed, given that pressure measurements suggest that most hydrogen is adsorbed, or in some other fashion removed from the cell after an hour, even heat transfer effects should be totally transitory. Even in the event of reaction no more than a small heat signal is expected. Indeed, a high end estimate is that 25 cm^3 of hydrogen at a temperature of 300 K and a pressure of 2 atmospheres entered the cell. This is equivalent to $2*10^{-3}$ moles of hydrogen. If all of that hydrogen interacted with oxygen to form water only 510 J would be generated. It is possible to imagine that the hydrogen could interact with nitrogen in KNO_3 to form ammonia. Even less energy would evolve from this process. Thus, the largest heat peak might be expected to be 0.5 watts for 1000 seconds (approx. 17 minutes). A block of this size is marked on Figure 3.

It is clear from figures 3, 4 and 5 that hydrogen admission to the cell apparently leads to far more energy evolution than can be explained by any conventional chemical process. It is interesting in this regard to graphically contrast the response of the system to helium admission to the response to that for hydrogen admission. This is done on Figure 6 in which Figure 3 and Figure 2a are superimposed.

Water Bath Calorimeter. Studies conducted with the water bath calorimeter do not indicate the evolution of any excess heat. As shown in Figure 7 the increase in temperature almost exactly parallels the increase predicted on the basis of the amount of energy added to the system and the known heat capacity of water.

Typical Calibration Experiment: 1 W Input, 20 Mins

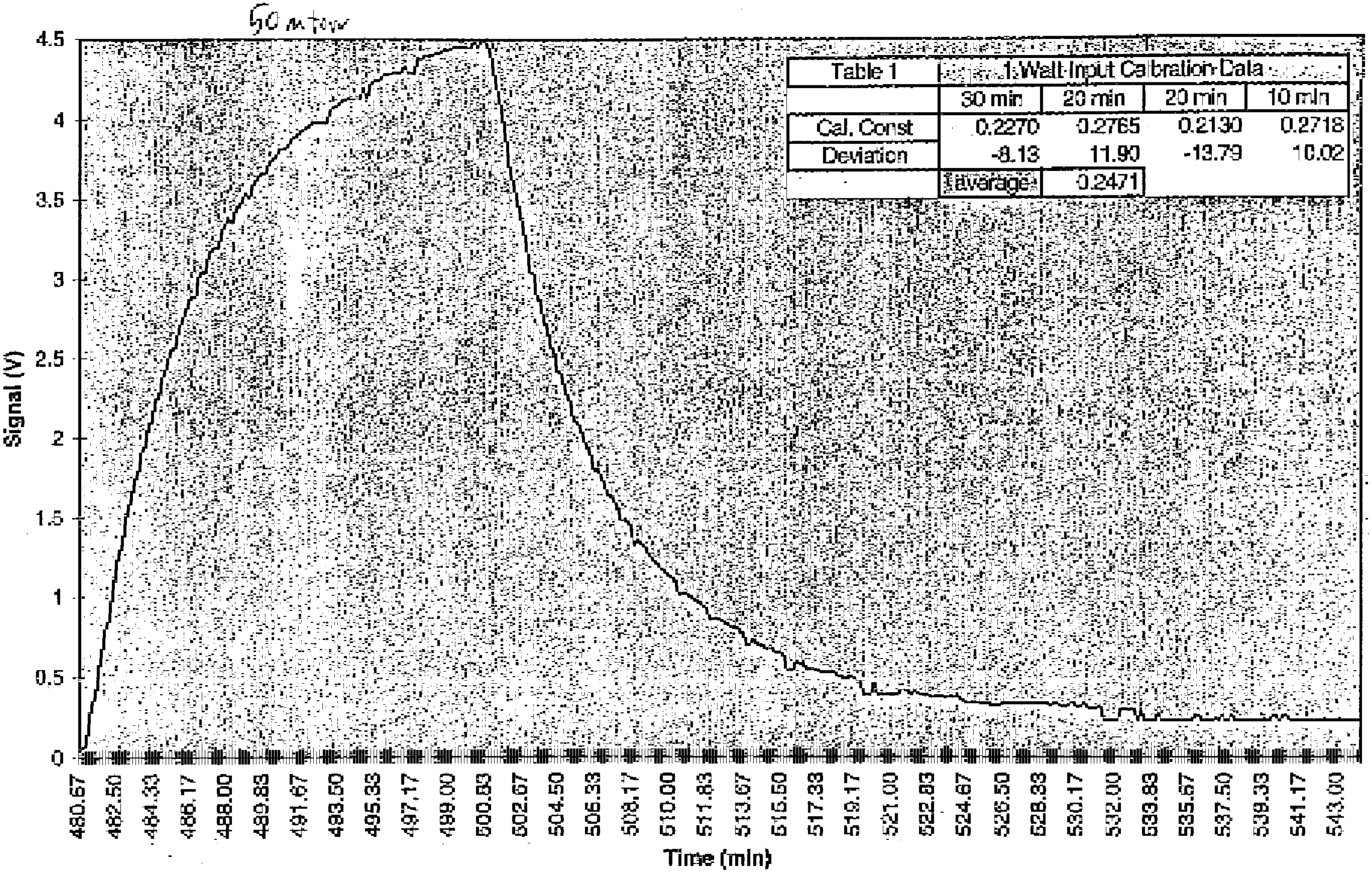
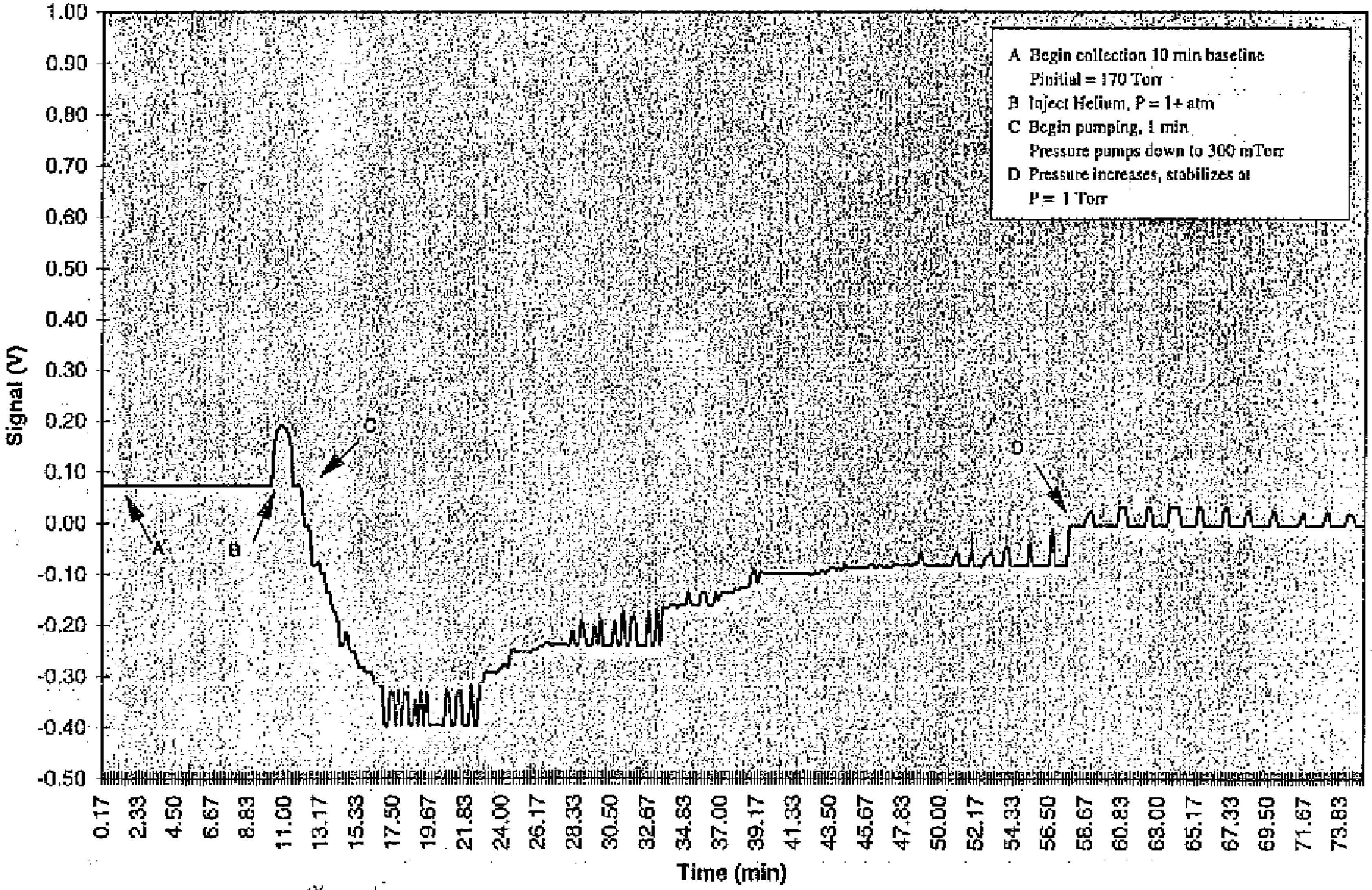


Table 1	1 Watt Input Calibration Data			
	30 min	20 min	20 min	10 min
Cal. Const	0.2270	0.2765	0.2130	0.2718
Deviation	-8.13	11.90	-13.79	10.02
	average	0.2471		

Figure 1

Heat Production, KNO3 w/ Helium Injection (BL1219B)



Constant power power supply

Figure 2B

Heat Production, KNO3 w/ H2 Injection (BL1220BC)

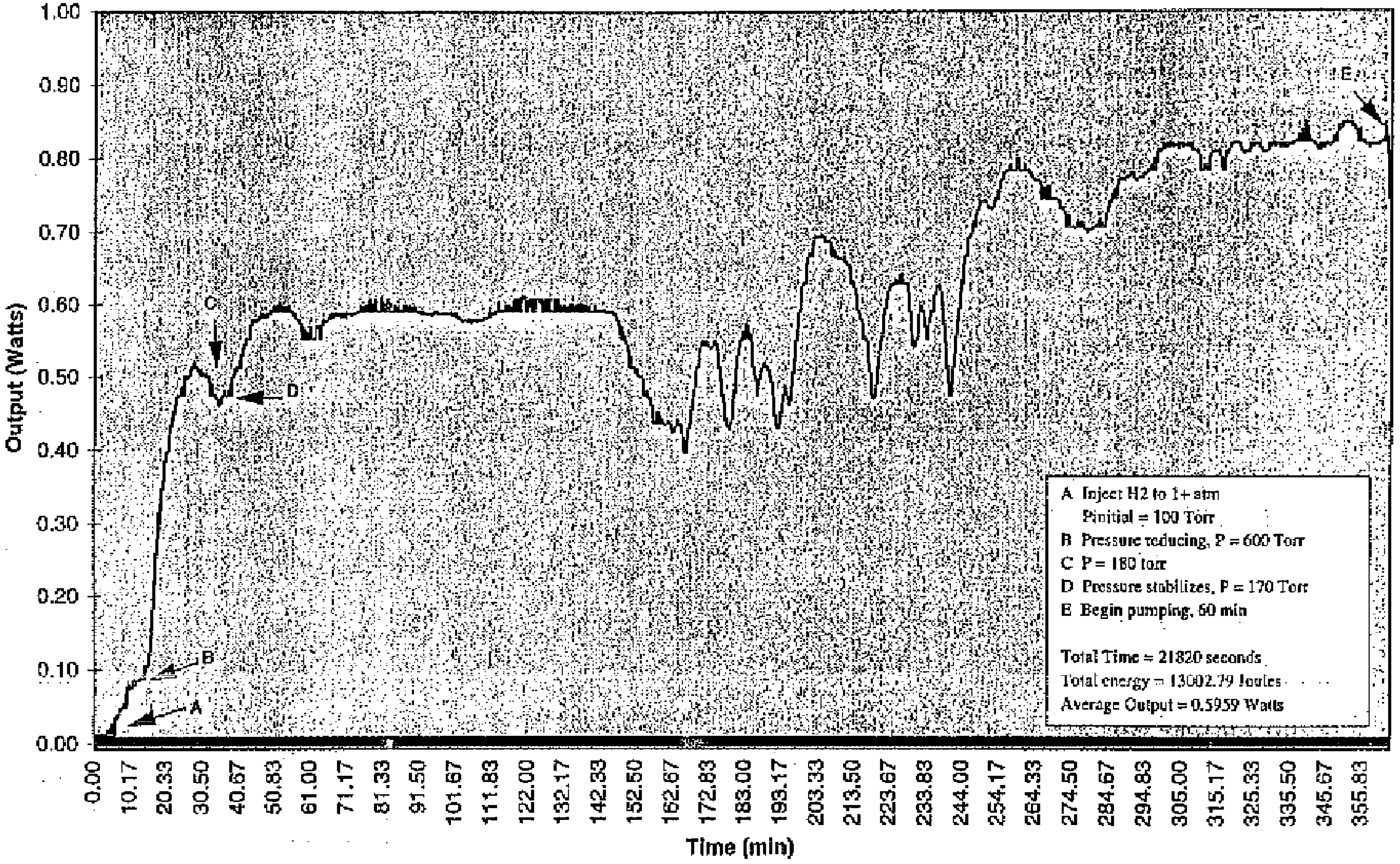


Figure 4

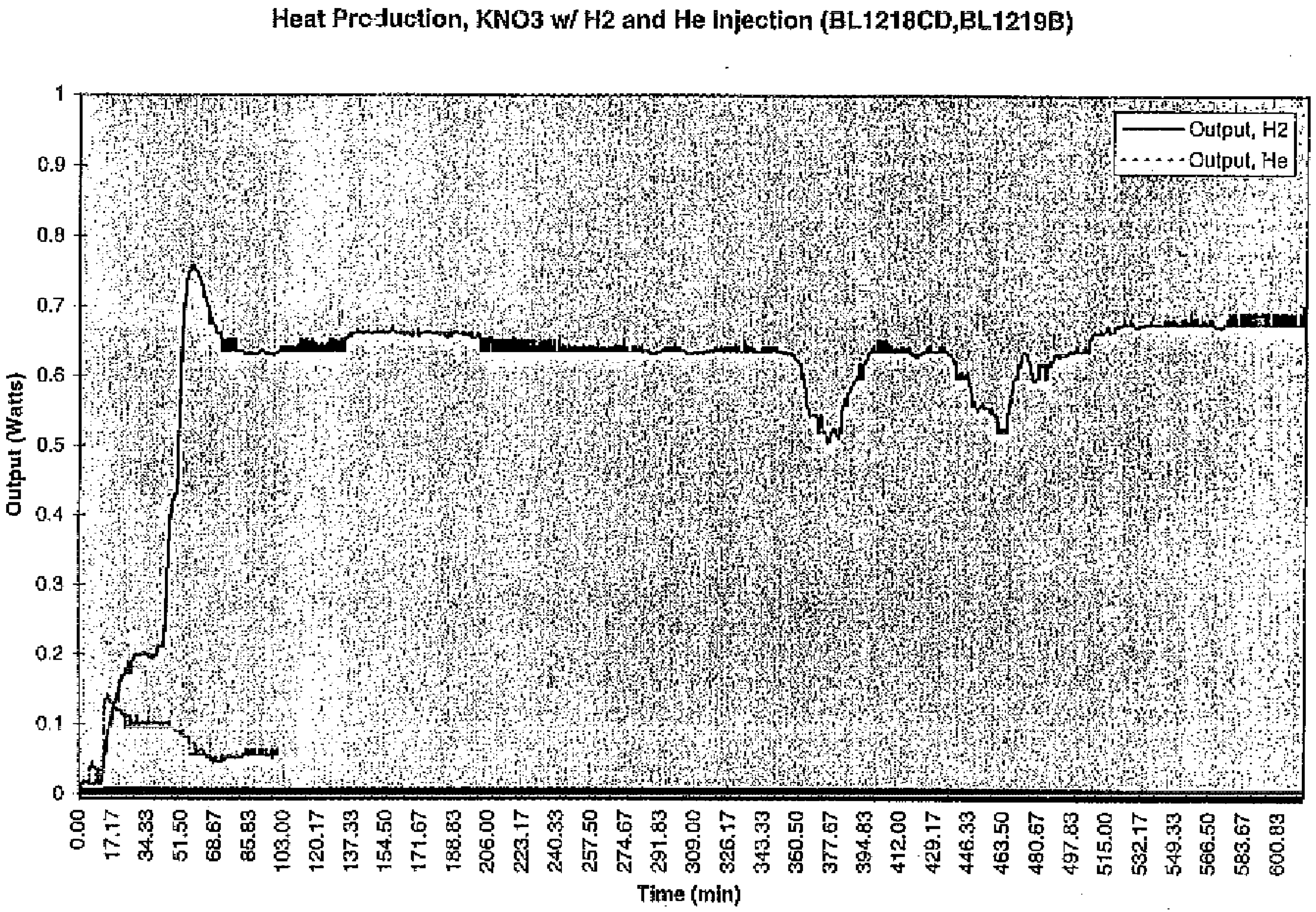

Heat Production, KNO3 w/ H2 and He Injection (BL1218CD,BL1219B)

Figure 6

THESIS - APPENDIX SEVEN

FINAL
REVISED 12 APRIL 1997

BLACKLIGHT POWER CORPORATION

EXPERIMENTAL PROTOCOL
FOR
CALVET HEAT MEASUREMENTS
OF A HIGH TEMPERATURE
VAPOR PHASE CELL

EXPERIMENTS BY P.M. JANSSON, P.P.,P.E.
B.S.C.E. MASSACHUSETTS INSTITUTE OF TECHNOLOGY '78
FOR M.S.E. THESIS AT ROWAN UNIVERSITY '97

TO DETERMINE FILAMENT SURFACE AREA EFFECTS ON HEAT GENERATION

3 March 1997 - 20 April 1997

Experiments Conducted in Laboratory of:

BLACK LIGHT
POWER inc.

Great Valley Corporate Center
41 Great Valley Parkway
Malvern, PA 19355

above atmospheric. The cell is maintained at an elevated isothermal temperature by a forced convection oven. The operating temperature of the convection oven [and gas cell when no filaments are energized] is 250°C. The cell is used in the vertical position and is inserted into a thermopile [13]. The flange [4] is sealed with a copper gasket [8] that has had its surface oxidized and softened by direct heating with a propane torch or oven. The flange has a two hole Conax-Buffalo gland [6] for the leads [5] of the filament that is present during the calibration of the cell and varied in length for the experiments 1-3 of the reaction vessel. The flange [4] also has a 1/4" vacuum port through which the hydrogen is passed. The vaccum port connects to a Tee [3], a OE bellows valve, a pressure gauge, and then the hydrogen supply. The elbow port of the Tee [3] is attached to vacuum gauges, a bellows valve, and then a vacuum pump. The filament is platinum wire [0.25 mm. diameter] of 99.99% purity. The lengths of the filament [and resulting surface areas] are varied 20cm, 10cm and 30cm for experiments 1 through 3 respectively.

A small ceramic vessel is secured at the base of the Calvet cell [by a nickle wire stand] which contains the catalyst potassium nitrate (KNO_3). A vacuum is pulled on the cell while the oven is brought to operating temperature. The appropriate power is dissipated in the filament at an established rate calculated to keep the filament surface temperature constant [10watts for 20cm., 5 watts for 10cm., 15 watts for 30cm.] The oven maintains the surrounding ambient temperature at 250°C. The catalyst's vapor pressure is observed as a function of temperature, and once Calvet cell reaches its steady state output at the supplied input energy, the vacuum pump is stopped and the catalyst pressure within the outlet tube [3] is observed to be constant in the range of about one-hundred to two-hundred torr. Hydrogen gas is then added to the cell to bring its overall total static pressure including the hydrogen pressure measured in the outlet tube [3] by the vacuum gauge to be 3 times the stable pressure of the catalyst (KNO_3). The data is recorded with a Macintosh based computer data acquisition system (Apple Quadra 800) and the following National Instruments, Inc. hardware: Lab-NB Data Acquisition Board; Back-Plane with amplifiers: (2) 10 mV to 5 V and (2) 50 mV to 5 V.

NOTE: Minor Edits to Figure 1 below need to be made.

Sequence of Controls and Experiments

Control #1

Install 20 cm Platinum [Alfa] filament, 0.25mm diameter in Reaction Vessel
Warm up oven Temperature 250°C.
Filament input wattage = 0
Vacuum down pressure in Reaction Vessel below 10 mtorr to remove moisture.
Stabilize Oven and Vessel Temperature to 250°C.
Close all valves and vacuum pump.
Inlet H_2 gas to 650 torr pressure.
Run Calibration #1 through full sequence allowing Calvet Cell to reach steady state output [Vc] for each power level shown below:
0 watts, 10 watts, 11 watts, 5 watts, 6 watts, 15 watts, 16 watts, 0 watts, 1 watt.
Develop 'BEFORE' Calibration Curve.

Experiment #1

Install New 20 cm Platinum [Aldrich] Filament [99.99% purity], 0.25 mm diameter
Weigh approx. 0.25 grams of KNO_3 and place in ceramic boat
Support boat via nickle wire support legs
Reassemble reaction vessel
Pressure check Calvet and all gas & vacuum lines
Insulate Calvet Calorimeter close oven
Warm up oven Temperature 250°C.
Filament input wattage = 0.
Vacuum down pressure in Reaction Vessel below 10 mtorr to remove moisture.
Close all valves and vacuum pump.
Stabilize Oven and Vessel Temperature to 250°C.
Observe catalyst vapor pressure steady state [100-200 torr]
Begin Experiment #1 by Increasing Filament Power Level to that shown below:
10 watts
Inlet H_2 gas to bring vessel to 3 times overall catalyst steady state pressure. [Ie; if catalyst pressure is 200 torr add 400 torr of H_2 gas to bring Calvet to 600 torr.
Wait 5 minutes for mixing to occur.
Slowly vacuum down Vessel to 30-70 mtorr level until excess heat formation commences.
Keep Vessel under vacuum to maintain 'active' pressure regime [ie; 38 mtorr, 70 mtorr, etc.]
Stabilize Readings and Develop Experimental Data Curves.
Save Data Acquisition System [DAS] file daily, using the same standard naming convention: tpdate[mmddyy] time[930a] watt[7w] id[h]
Take 1 or 2 new data points [controls] to develop specific curve after reaction ceases.
OPTION 1: Close valve to Vacuum to quench reaction if required.
OPTION 2: Repeat experiment if it is believed that catalyst pressure is inadequate or hydrogen atom generation is compromised

Begin Experiment #1 by Increasing Filament Power Level to that shown below:
15 watts
Inlet H_2 gas to bring vessel to 3 times overall catalyst steady state pressure. [Ie; if catalyst pressure is 200 torr add 400 torr of H_2 gas to bring Calvet to 600 torr.
Wait 5 minutes for mixing to occur.
Slowly vacuum down Vessel to 30-70 mtorr level until excess heat formation commences.
Keep Vessel under vacuum to maintain 'active' pressure regime [ie; 38 mtorr, 70 mtorr, etc.]
Stabilize Readings and Develop Experimental Data Curves.
Save Data Acquisition System [DAS] file daily, using the same standard naming convention: tpdate[mmddyy] time[930a] watt[7w] id[h]
Take 1 or 2 new data points [controls] to develop specific curve after reaction ceases.
OPTION 1: Close valve to Vacuum to quench reaction if required.
OPTION 2: Repeat experiment if it is believed that catalyst pressure is inadequate or hydrogen atom generation is compromised

Control #2

Install New3 20 cm Platinum [Aldrich] filament [99.99% purity], 0.25mm diameter in Vessel
Warm up oven Temperature 250°C.
Filament input wattage = 0
Vacuum down pressure in Reaction Vessel below 10 mtorr to remove moisture.
Stabilize Oven and Vessel Temperature to 250°C.
Close all valves and vacuum pump.
Inlet H_2 gas to 650 torr pressure.
Vacuum down to 40-100 mtorr range.
Run Calibration #2 through full sequence to steady state at each power level shown below:
0 watts, 10 watts, 11 watts, 5 watts, 6 watts, 15 watts, 16 watts, 0 watts, 1 watt. [add any new points determined via Experiments 1-3 then repeat sequence above]
Develop 'AFTER' Calibration Curve.
Compare Calibration Curves 'Before' and 'After'
Analyze and Report on Results Based upon above

final revised 12 April 1997
developed by: William Good - BlackLight Power
Peter Jansson - Atlantic Energy

PRINCIPLE

The thermal gradient calorimeter transfers all the heat developed in a reaction to its surrounding heat sink at a constant temperature. The calorimeter walls thermoelectrically transduce sample heat release into an electrical signal which is directly proportional to the energy release of the source. Transient as well as steady state energy releases may be measured.

FEATURES

- Whole body heat release measurements
- Microwatt to kilowatt sample output
- High sensitivities and repeatability
- Linear output
- Transient and steady state response
- Wide temperature range
- Simple "In-situ" recalibration
- No excitation required

SPECIFICATIONS

Sample chamber volume range:
1 in^3 to 3000 in^3

Sensitivities:
to 15 milliwatts per millivolt

Temperature range:
Cryogenic to 600°F

Response times:
10 sec. to 10 min.

Vacuum:
to 10^{-6} torr.

Output impedance range:
10Ω to 7500Ω

Accuracies:
to 0.5%

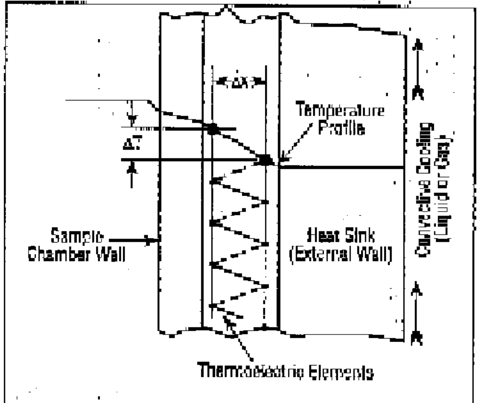
Repeatability:
0.01%

Power supply:
not required

Materials:
Aluminum, stainless steels, copper, composites

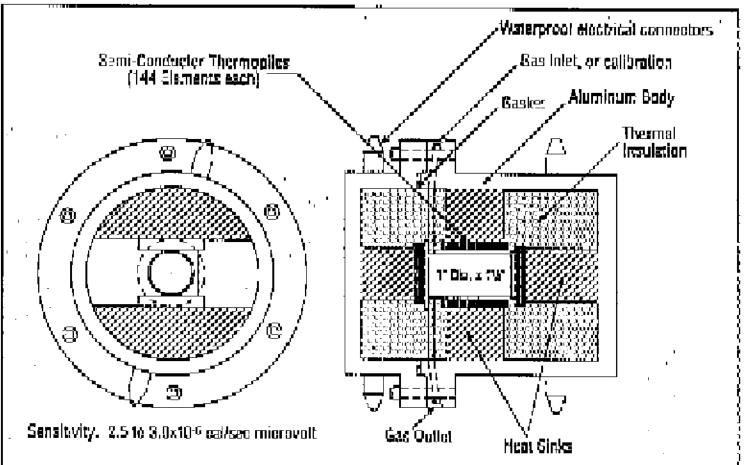
CONSTRUCTION

The calorimeter walls are composed of a thin, high temperature thermopile structure containing thousands of junctions. One set of junctions is in thermal contact with one wall surface, and the other set is in contact with the opposite surface. As heat flows through the walls, (Fig. 1) a temperature difference is established between both sets of thermopile junctions, thus generating a voltage which is directly proportional to the heat flow. The large number of thermopiles develop extreme sensitivity to minute heat flows. Calorimeters are constructed in a range of designs incorporating large sample chambers for high heat fluxes (cover) or small sample chambers capable of measuring low heat releases (Figure 2).



CALORIMETER WALL SECTION

Figure 1



SEMI-CONDUCTOR THERMOELECTRIC MICROCALORIMETER FOR RADIOISOTOPE STUDIES

Figure 2

CALIBRATION

Each calorimeter is calibrated at a base temperature of 70° F by a known, electrical heat source in thermal equilibrium with the system.

The calibration constant is expressed in terms of wattage input versus millivolt output. A temperature correction curve is also supplied for use at elevated temperatures.

STANDARD MODELS, SINGLE CHAMBER

Model Number	Internal Dimensions		External Dimensions		Accuracy %	Sensitivity, Milliwatts per Millivolt	Nominal Output Resistence	Temperature F° (Note 1)	63% Response Time, Min.
	Diameter. In.	Depth, In.	Diameters, In.	Length, In.					
CA-100-1	1	1	3	3	1%	15	4	250*	1
CA-100-2	2	4	4	6	1%	15	10	250*	1
CA-100-4	4	8	5	12	1%	250	2000	600	3
CA-100-8	8	16, 32	9	21	1%	250	4000	600	3
CA-100-C	Custom	Custom	Custom	Custom	1%	250	Varies	600	Varies

* Models CR-100-1 and CA-100-2 are also available for 600°F operating temperature at reduced sensitivities.

READOUT INSTRUMENTATION

Suitable readouts for all CR-100 models include: millivolt potentiometers/recorders, data loggers, or conventional D.C. millivolt meters.

ORDERING INFORMATION

Delivery	6-8 weeks, ARO
Shipping weight	5 to 200 lbs
Terms	net 30 days to established customers
FOB	Del Mar, California

OTHER ITI THERMAL INSTRUMENTS

Thermal Conductivity Apparatus, Heat Flux Meters, HEAT-PROBE™, Accelerator target Calorimeters, Radiometers, Thermal Flux Standards.

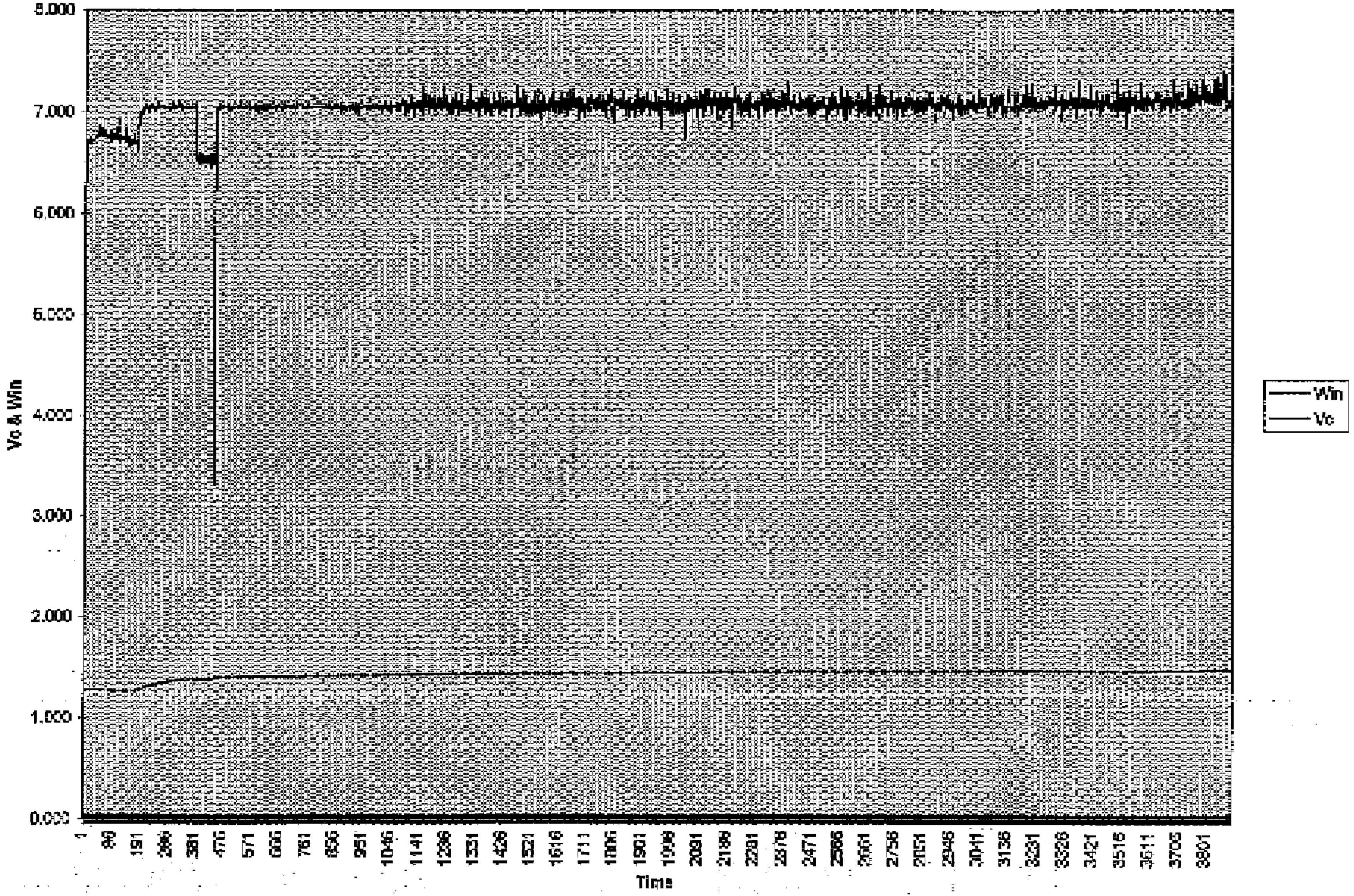
INTERNATIONAL
THERMAL
INSTRUMENT
COMPANY

P.O. Box 309, Del Mar, California 92014 (619) 755-4436

THESIS - APPENDIX EIGHT

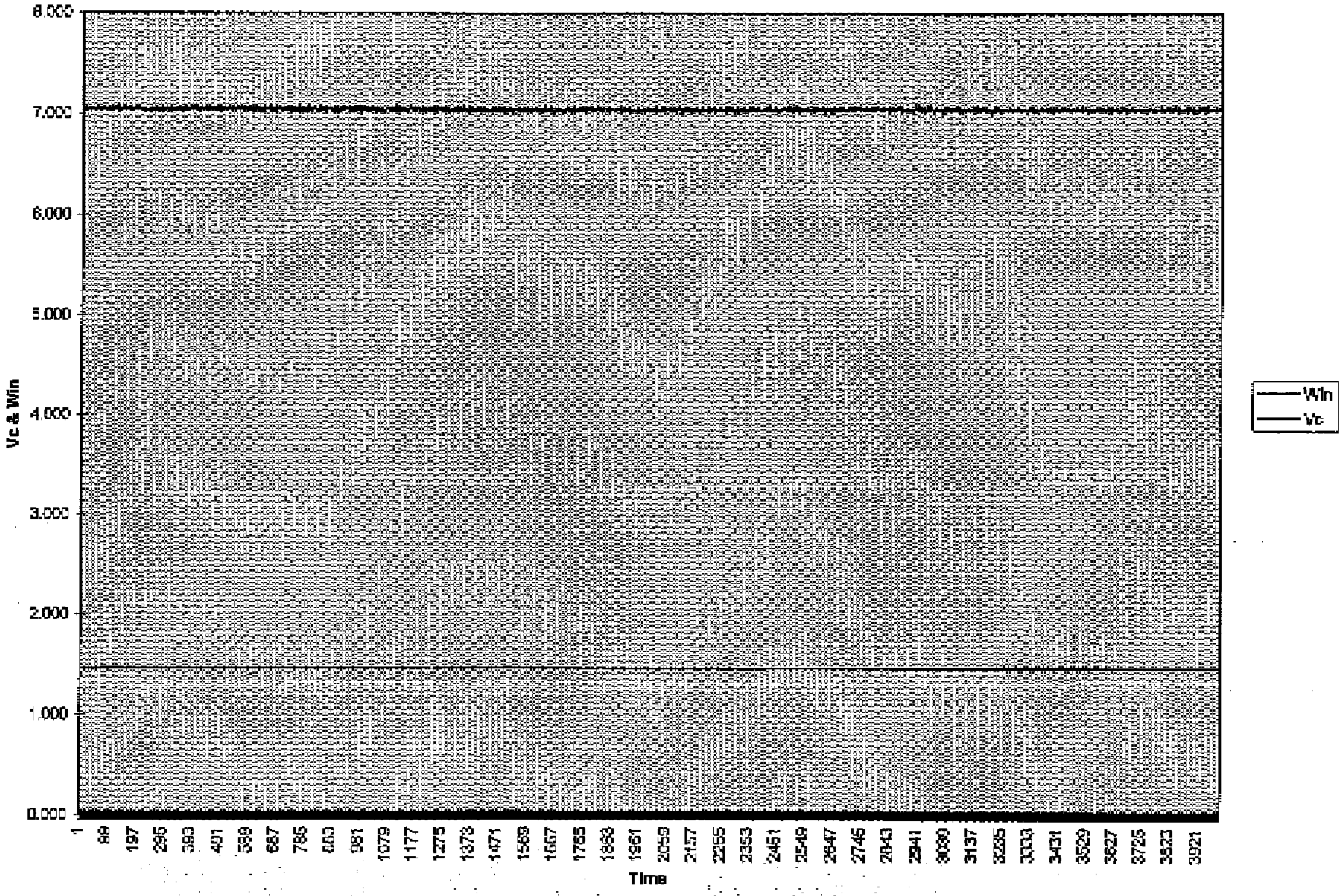
Time [sec]	Vc	Vc'	x	Win	Vc	Statistics for Analysis are						
57	1.274	0.255	0.134	6.710	1.274		for 1000 - 3892 [8.053 hrs]					
67	1.274	0.255	0.134	6.698	1.274		Average	Std. Dev.	Min	Max		
77	1.274	0.255	0.134	6.706	1.274	Vc	1.453	0.013	1.422	1.477		
87	1.271	0.252	0.131	6.563	1.271	Win	7.064	0.057	6.755	7.405		
97	1.266	0.247	0.126	6.317	1.266							
107	1.274	0.255	0.134	6.681	1.274							
117	1.274	0.255	0.134	6.715	1.274							
127	1.274	0.255	0.134	6.703	1.274							
137	1.274	0.255	0.134	6.716	1.274							
147	1.274	0.255	0.134	6.708	1.274							
157	1.274	0.255	0.134	6.699	1.274							

TP032797 Chart 1



Time [sec]	Vc	Vc'	x	Win	Vc	Statistics for Analysis are						
65	1.445	0.289	0.140	6.997	1.445		for 2 - 6361 [17,708 hrs]					
75	1.446	0.289	0.140	6.989	1.445		Average	Std. Dev.	Min	Max		
85	1.445	0.289	0.140	6.985	1.445	Vc	1.453	0.002	1.445	1.454		
96	1.445	0.289	0.140	6.993	1.445	Win	7.010	0.015	6.958	7.056		
105	1.445	0.289	0.140	6.988	1.445							
115	1.445	0.289	0.140	6.982	1.445							
125	1.445	0.289	0.139	6.968	1.445							
135	1.445	0.289	0.139	6.968	1.445							
145	1.445	0.289	0.140	6.984	1.445							
155	1.445	0.289	0.141	7.029	1.445							
165	1.445	0.289	0.140	7.010	1.445							
175	1.445	0.289	0.140	6.985	1.445							
185	1.445	0.289	0.140	7.010	1.445							
195	1.446	0.289	0.140	7.007	1.445							
205	1.445	0.289	0.140	7.011	1.445							

TP033197 Chart 1



Time [sec]	Vc	Vc'	x	Win	Vc	Statistics for Analysis are						
41	1.438	0.288	0.139	6.937	1.438		for 2 - 8986 [25.018 hrs]					
51	1.438	0.288	0.139	6.931	1.438		Average	Std. Dev.	Min	Max		
62	1.438	0.288	0.139	6.931	1.438	Vc	1.440	0.008	1.395	1.445		
71	1.438	0.288	0.139	6.942	1.438	Win	6.952	0.039	6.892	7.024		
81	1.438	0.288	0.139	6.966	1.438							
92	1.438	0.288	0.139	6.952	1.438							
102	1.438	0.288	0.139	6.940	1.438							
112	1.438	0.288	0.139	6.930	1.438							
122	1.438	0.288	0.138	6.920	1.438							
132	1.438	0.288	0.139	6.932	1.438							
142	1.438	0.288	0.139	6.950	1.438							
152	1.438	0.288	0.139	6.935	1.438							
162	1.438	0.288	0.139	6.940	1.438							

Time [sec]	Vc	Vc'	x	Win	Vc	Statistics for Analysis are						
35	1.432	0.287	0.139	6.960	1.432		for 2 - 16384 [46.618 hrs]					
45	1.432	0.287	0.139	6.943	1.432		Average	Std. Dev.	Min	Max		
55	1.432	0.287	0.139	6.937	1.432	Vc	1.428	0.008	1.410	1.443		
65	1.432	0.287	0.139	6.932	1.432	Win	6.935	0.039	6.703	7.065		
75	1.432	0.287	0.139	6.935	1.432							
85	1.432	0.287	0.139	6.939	1.432							
95	1.432	0.287	0.139	6.941	1.432							
105	1.432	0.287	0.139	6.942	1.432							
115	1.432	0.287	0.139	6.934	1.432							
125	1.432	0.287	0.139	6.927	1.432							
135	1.432	0.287	0.139	6.929	1.432							
145	1.432	0.287	0.139	6.936	1.432							

Time [sec]	Vc	Vc'	x	Win	Vc	Statistics for Analysis are					
45	1.460	0.292	0.141	7.026	1.460		for 2 - 8148 [22.684 hrs]				
55	1.459	0.292	0.140	7.020	1.459		Average	Std. Dev.	Min	Max	
65	1.459	0.292	0.140	7.025	1.459	Vc	1.463	0.001	1.459	1.464	
75	1.459	0.292	0.141	7.027	1.459	Win	7.029	0.011	6.982	7.067	
85	1.459	0.292	0.141	7.028	1.459						
95	1.459	0.292	0.140	7.016	1.459						
105	1.459	0.292	0.141	7.025	1.459						
115	1.459	0.292	0.141	7.027	1.459						
125	1.460	0.292	0.141	7.035	1.460						
135	1.460	0.292	0.141	7.042	1.460						
145	1.460	0.292	0.141	7.033	1.460						
155	1.460	0.292	0.140	7.016	1.460						
165	1.460	0.292	0.140	7.023	1.460						
175	1.460	0.292	0.141	7.031	1.460						

Time [sec]	Vc	Vc'	x	Win	Vc	Statistics for Analysis are						
43	1.456	0.292	0.140	7.005	1.456		for 2 - 6420 [17.872 hrs]					
53	1.456	0.292	0.140	7.019	1.456		Average	Std. Dev.	Min	Max		
63	1.456	0.292	0.140	6.996	1.456	Vc	1.464	0.003	1.456	1.467		
73	1.457	0.292	0.140	7.012	1.457	Win	7.020	0.014	6.987	7.167		
83	1.457	0.292	0.140	7.017	1.457							
93	1.457	0.292	0.140	7.010	1.457							
103	1.456	0.292	0.140	7.019	1.456							
113	1.456	0.292	0.140	7.025	1.456							
123	1.456	0.292	0.140	7.013	1.456							
133	1.456	0.292	0.140	7.022	1.456							
143	1.456	0.292	0.140	7.016	1.456							
153	1.456	0.292	0.140	7.018	1.456							
163	1.456	0.292	0.140	7.020	1.456							

Prior to Added Insulation

Time [sec]	Vc	Vc'	x	Win	Vc							
85	0.000	0.000	0.001	0.053	0.000	Statistics from 2589-4047 (8.12 hrs)						
105	0.000	0.000	0.001	0.059	0.000		Average	Std Dev	Min	Max		
125	0.000	0.000	0.001	0.061	0.000	Vc	2.102	0.005	2.097	2.117		
145	0.000	0.000	0.001	0.063	0.000	Win	9.927	0.034	9.843	9.999		
165	0.000	0.000	0.003	0.161	0.000							
186	0.000	0.000	0.162	8.095	0.000							
205	0.011	0.002	0.199	9.947	0.011							
226	0.064	0.013	0.199	9.950	0.064							
245	0.129	0.026	0.199	9.928	0.129							
266	0.189	0.038	0.198	9.914	0.189							
286	0.241	0.048	0.198	9.903	0.241							
306	0.287	0.057	0.198	9.922	0.287							
326	0.329	0.066	0.199	9.928	0.329							
346	0.368	0.073	0.199	9.942	0.368							
366	0.406	0.081	0.199	9.936	0.406							
386	0.442	0.088	0.199	9.952	0.442							
406	0.477	0.095	0.199	9.952	0.477							
426	0.510	0.102	0.199	9.925	0.510							

20 cm Control 10-wall point

	$\bar{X}$	σ_n
V_c	2.102	0.005
W_{in}	9.927	0.034

Time [sec]	Vc	Vc'	x	Win	Vc						
187	2.096	0.419	0.197	9.864	2.096	Statistics from 300-1350 [11 watt point]				5.84 hrs	
207	2.096	0.419	0.197	9.860	2.096		and from 3000-3759 [10 watt point]			4.25 hrs	
227	2.096	0.419	0.197	9.859	2.096	11-watt	Average	Std Dev	Min	Max	
247	2.096	0.419	0.204	10.213	2.096	Vc	2.355	0.012	2.326	2.369	
267	2.096	0.419	0.221	11.031	2.096	Win	11.085	0.013	11.046	11.126	
287	2.099	0.420	0.221	11.045	2.099	10 watt					
307	2.103	0.421	0.221	11.050	2.103	Vc	2.160	0.004	2.149	2.168	
327	2.109	0.422	0.221	11.060	2.109	Win	9.573	0.012	9.543	9.607	
347	2.114	0.423	0.221	11.045	2.114						
367	2.120	0.424	0.221	11.052	2.120						
387	2.125	0.425	0.221	11.051	2.125						
407	2.130	0.426	0.221	11.046	2.130						
427	2.135	0.427	0.221	11.073	2.135						

20 cm Control

11 watt

	$\bar{x}$	σ_n
Vc	2.355	0.012
Win	11.085	0.013

10 watt

Vc	2.160	0.004
Win	9.573	0.012

1692 sec 395 (~ 6.35 hour)

Time [sec]	Vc	Vc'	x	Win	Vc						
99	2.168	0.433	0.211	10.557	2.168	**Statistics from 834-1983**					
119	2.170	0.434	0.217	10.847	2.170		Average	Std Dev	Min	Max	
139	2.174	0.435	0.217	10.842	2.174	Vc	2.453	0.00551	2.439	2.464	
159	2.179	0.436	0.217	10.840	2.179	Win	10.808	0.01108	10.778	10.848	
179	2.184	0.437	0.217	10.838	2.184						
199	2.190	0.438	0.217	10.851	2.190						
219	2.195	0.439	0.217	10.833	2.195						
239	2.201	0.440	0.216	10.824	2.201						
259	2.206	0.441	0.217	10.834	2.206						
279	2.210	0.442	0.217	10.829	2.210						
300	2.214	0.443	0.217	10.830	2.214						
320	2.219	0.444	0.216	10.816	2.219						
340	2.222	0.444	0.216	10.807	2.222						
360	2.226	0.445	0.217	10.828	2.226						
380	2.230	0.446	0.216	10.818	2.230						

20cm control

11 watt point

	$\overline{X}$	σ_n
V_c	2.453	0.0055
Win	10.808	0.0111

3 hours

Time (sec)	Vc	Vc'	x	Win	Time (hrs)	Vc	Win					
61	2.459	0.492	0.073	3.637	0.017	2.459	3.637	**Statistics from Hour 8-11**				
81	2.45	0.49	0.002	0.113	0.022	2.45	0.113		Std. Dev.	Average	Min	Max
101	2.421	0.484	0.002	0.094	0.028	2.421	0.094	Vc	0.009543	1.084258	1.067	1.105
121	2.381	0.476	0.002	0.081	0.034	2.381	0.081	Win	0.049132	4.931686	4.79	5.179
141	2.339	0.468	0.001	0.066	0.039	2.339	0.066					
161	2.298	0.46	0.001	0.063	0.045	2.298	0.063					
181	2.259	0.452	0.001	0.071	0.05	2.259	0.071					
201	2.221	0.444	0.002	0.075	0.056	2.221	0.075					
222	2.185	0.437	0.002	0.079	0.062	2.185	0.079					
241	2.15	0.43	0.002	0.077	0.067	2.15	0.077					
262	2.116	0.423	0.001	0.074	0.073	2.116	0.074					
281	2.084	0.417	0.001	0.074	0.078	2.084	0.074					
302	2.052	0.41	0.001	0.073	0.084	2.052	0.073					
322	2.022	0.404	0.001	0.071	0.089	2.022	0.071					
342	1.993	0.398	0.001	0.061	0.095	1.993	0.061					
362	1.965	0.393	0.001	0.057	0.1	1.965	0.057					
382	1.937	0.387	0.001	0.051	0.106	1.937	0.051					

20 cm Control

5watt point

	$\bar{x}$	σ_n
V_c =	1.084	0.0095
W_{in} =	4.932	0.0491

Time [sec]	Vc	Vc'	x	Win	Vc						
111	1.135	0.227	0.119	5.960	1.135	Statistics from 1419-1622 [1.13 hrs]					
131	1.137	0.227	0.120	6.009	1.137		Average	Std Dev	Min	Max	
151	1.139	0.228	0.120	6.001	1.139	Vc	1.299	0.001	1.297	1.301	
171	1.141	0.228	0.120	5.992	1.141	Win	6.009	0.008	5.987	6.033	
191	1.144	0.228	0.120	5.995	1.144						
211	1.146	0.229	0.120	6.002	1.146						
231	1.148	0.229	0.119	5.974	1.148						
251	1.150	0.230	0.119	5.974	1.150						
271	1.152	0.231	0.119	5.972	1.152						
291	1.154	0.231	0.120	5.982	1.154						
311	1.156	0.231	0.120	6.009	1.155						
331	1.158	0.232	0.120	5.980	1.158						
351	1.161	0.232	0.120	5.980	1.161						

20 cm control
6 watt point

	$\bar{x}$	σ_x
V_c	1.299	0.001
W_{in}	6.009	0.008

Time [sec]	Vc	Vc'	x	Win	Vc						
64	1.301	0.260	0.294	14.686	1.301	**Statistics from 2650-3059 2.278 Hrs**					
84	1.322	0.264	0.298	14.890	1.322		**Average**	**Std Dev**	**Min**	**Max**	
105	1.358	0.271	0.299	14.938	1.358	**Vc**	3.451	0.006	3.441	3.461	
124	1.397	0.279	0.299	14.951	1.397	**Win**	14.982	0.018	14.937	15.034	
145	1.437	0.287	0.301	15.071	1.437						
164	1.475	0.295	0.302	15.104	1.475						
185	1.512	0.302	0.302	15.116	1.512						
205	1.548	0.310	0.303	15.128	1.548						
225	1.583	0.317	0.303	15.141	1.583						
245	1.616	0.323	0.303	15.145	1.616						
265	1.649	0.330	0.303	15.145	1.649						
285	1.679	0.336	0.303	15.146	1.679						
305	1.709	0.342	0.303	15.131	1.709						

20 cm Control
15 watt point

	$\bar{x}$	σ_n
Vc	3.451	0.006
Win	14.982	0.018

Time [sec]	Vc	Vc'	x	Win	Vc							
79	3.453	0.691	0.316	15.791	3.453	Statistics from 770-1144 [1.944 hrs] for 16 watt point						
99	3.455	0.691	0.316	15.783	3.455		and from 4531-4789 [1.437 hrs] for 1 watt point					
119	3.459	0.692	0.316	15.809	3.459	16-watt	Average	Std Dev	Min	Max		
139	3.463	0.693	0.317	15.834	3.463	Vc	3.664	0.005	3.653	3.671		
159	3.466	0.693	0.317	15.836	3.466	Win	15.885	0.012	15.857	15.93		
179	3.47	0.695	0.317	15.832	3.47	1 watt.						
199	3.473	0.695	0.317	15.841	3.473	Vc	0.174	0.001	0.173	0.178		
219	3.476	0.696	0.317	15.865	3.476	Win	1.054	0.007	1.039	1.078		
239	3.479	0.696	0.318	15.878	3.479							
259	3.482	0.697	0.317	15.871	3.482		0.174	0.001	0.173	0.176		
279	3.485	0.697	0.317	15.865	3.485		1.054	0.007	1.039	1.078		
299	3.488	0.698	0.317	15.855	3.488							
319	3.49	0.698	0.318	15.875	3.49							
339	3.493	0.699	0.317	15.872	3.493							
360	3.495	0.699	0.318	15.885	3.495							

20 cm Control

16 watt	$\bar{x}$	σ_n
Vc	3.664	0.005
Win	15.865	0.012
1 watt		
Vc	0.174	0.001
Win	1.034	0.007

Time (sec)	Vc	Vc'	x	Win	Vc							
87	0.174	0.035	0.001	0.048	0.174	**Statistics from 502-3147 [16.67 hrs]**						
107	0.172	0.034	0.001	0.053	0.172		**Average**	**Std Dev**	**Min**	**Max**		
127	0.169	0.034	0.001	0.054	0.169	**Vc**	0.000	0.000	0.000	0.001		
147	0.166	0.033	0.001	0.053	0.166	**Win**	0.050	0.001	0.044	0.055		
167	0.163	0.033	0.001	0.054	0.163							
188	0.161	0.032	0.001	0.053	0.161							
207	0.158	0.032	0.001	0.055	0.158							
228	0.156	0.031	0.001	0.054	0.156							
247	0.153	0.031	0.001	0.053	0.153							
268	0.151	0.030	0.001	0.053	0.151							
288	0.148	0.029	0.001	0.054	0.148							
308	0.146	0.029	0.001	0.054	0.146							
328	0.143	0.028	0.001	0.054	0.143							
348	0.141	0.028	0.001	0.052	0.141							
368	0.139	0.028	0.001	0.053	0.139							

20 cm control

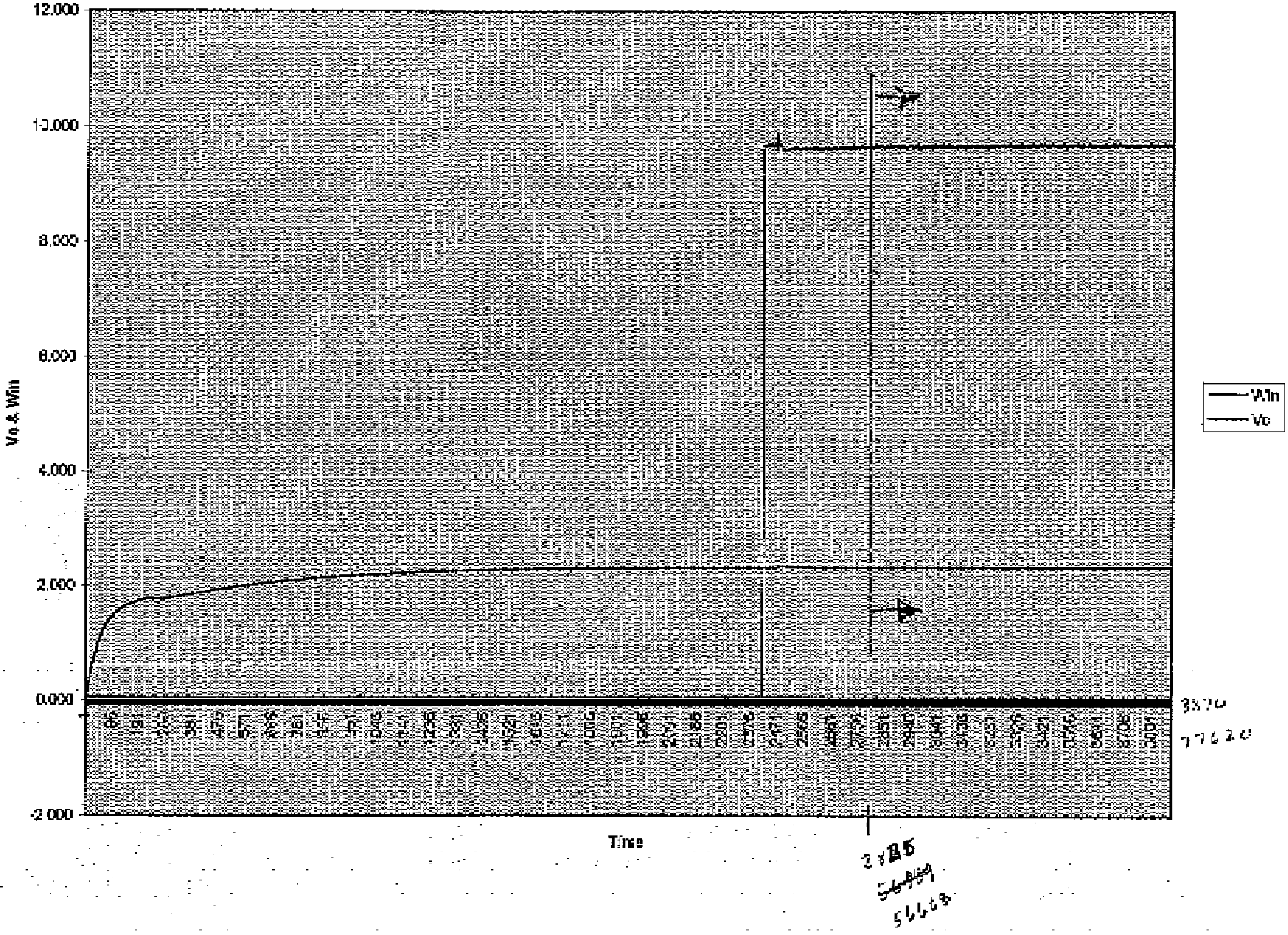
0 watt point

	$\bar{X}$	σ_n
V_c	0.000	0.000
W_{in}	0.050	0.001

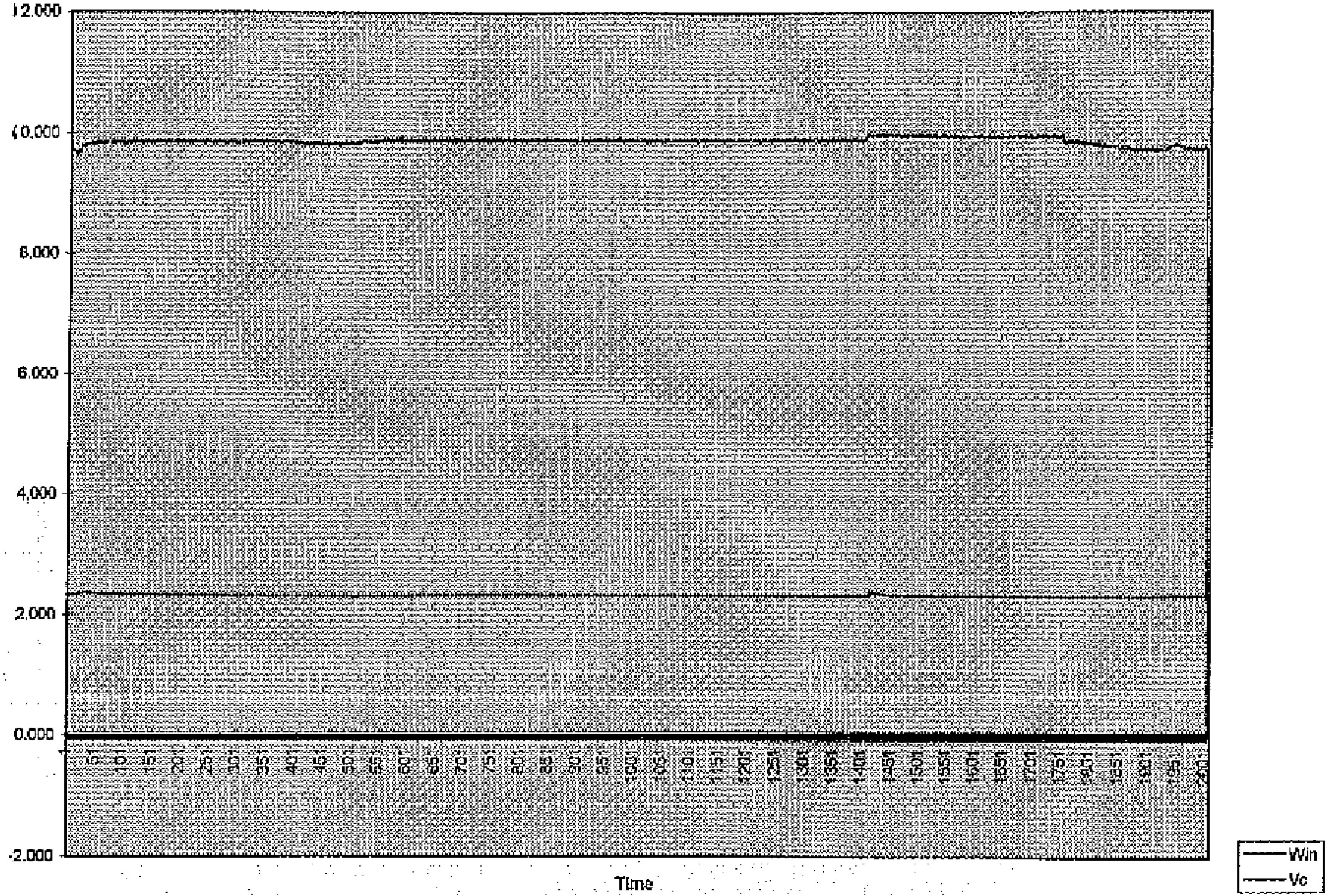
Summary of 20 cm Experimental Results

Date[s] of Run	Hours [ss]	Excess Power [watts]	Pressure	Additional H2?
12-Mar	5.820	0.577	253.7	No
13-Mar	5.575	0.337	50T-10psig	Yes
15-Mar	4.272	0.804	253	No
16-Mar	2.899	0.566	0.15T-1.7atm	Yes
16-Mar	13.635	0.607	253-265T	Yes
17-Mar	7.464	0.592	0.1-576T	Yes
17-Mar	14.439	1.164	0.075T	Yes
18-Mar	31.194	1.231	0.068-0.075T	Yes
19-Mar	14.781	0.879	0.068T	Yes
19-Mar	3.576	0.537	0.068T	Yes
20-Mar	6.870	0.404	0.0675-0.069T	Yes
20-Mar	14.898	0.446	0.0675T	Yes
21-Mar	4.836	0.172	0.04-813T	Yes
Subsets of Data in 4.836 Hour Period Above				
21-Mar	0.752	-0.509	0.8-813T	Yes
21-Mar	1.198	0.396	0.04-0.06T	Yes
21-Mar	0.515	0.412	0.040T	Yes
		0.640	Average of Points	
		0.172	Minimum	
		1.231	Maximum	
		0.308	Std Deviation	

TP031297 Chart 1



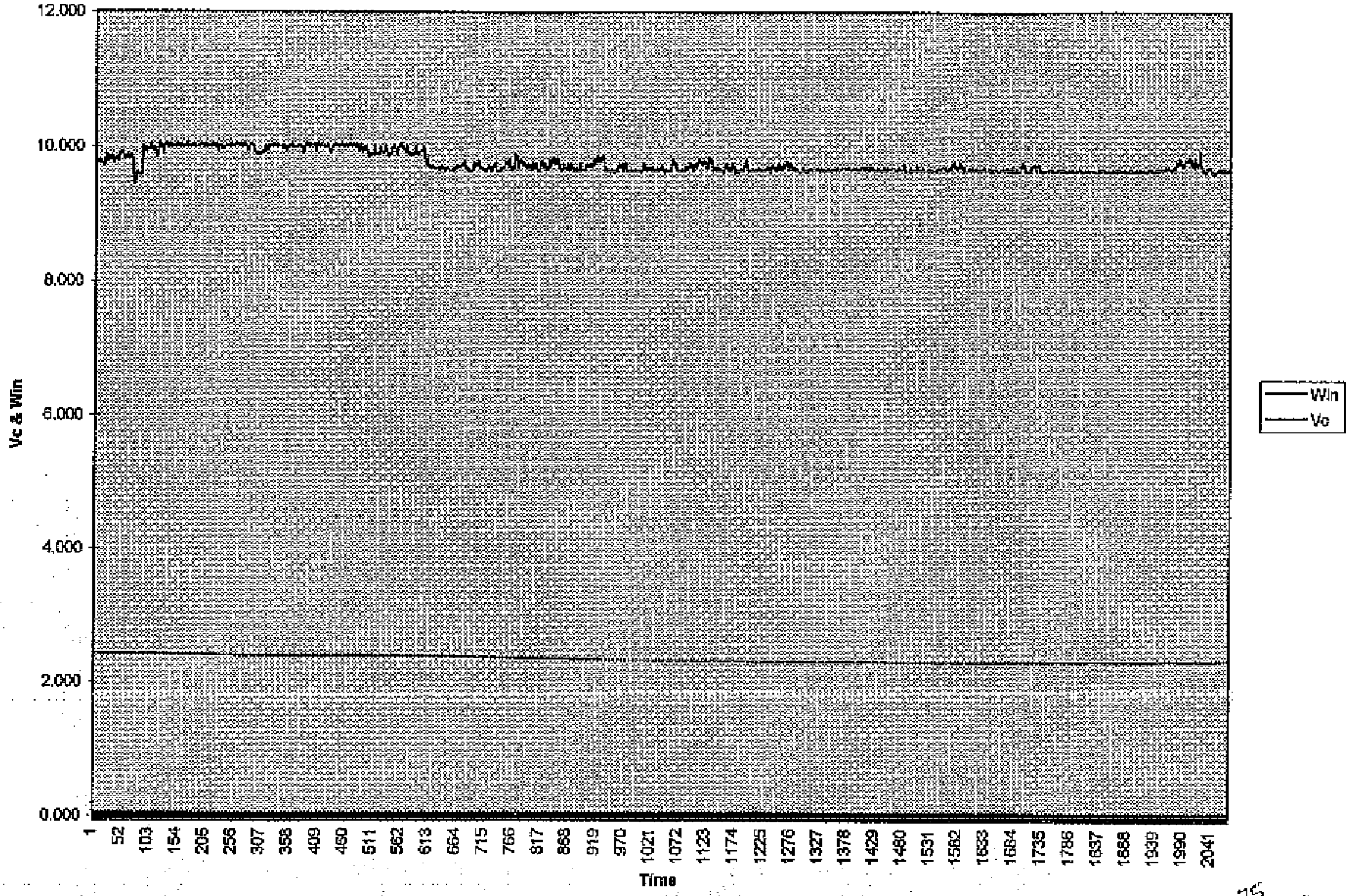
TPO31397 Chart 1



	Win	Predicted Vc						
	0	-0.0605		Given Vc=	2.419			
	1	0.1728		Estimated				
	2	0.4061		Watts Out	10.628	watts of power		
	3	0.6394		Actual =	9.824	watts of input power		
	4	0.8727			0.804	excess watts of power produced		
	5	1.106						
	6	1.3393						
	7	1.5726						
	8	1.8059						
	9	2.0392						
	10	2.2725						
	11	2.5058						
	12	2.7391						
	13	2.9724						
	14	3.2057						
	15	3.439						
	16	3.6723						

Time [sec]	Vc	Vc'	x	Win	Vc						
15	2.438	0.488	0.196	9.791	2.438	Statistics from 2 to 2075 [2.899 hrs]					
22	2.438	0.488	0.195	9.743	2.438		Average	Std Dev	Min	Max	
25	2.438	0.488	0.196	9.777	2.438	Vc	2.350	0.042	2.299	2.438	
30	2.438	0.488	0.195	9.761	2.438	Win	9.765	0.140	9.442	10.061	
35	2.438	0.488	0.195	9.765	2.438						
40	2.438	0.488	0.196	9.799	2.438						
45	2.438	0.488	0.196	9.814	2.438						
50	2.438	0.487	0.195	9.753	2.438						
55	2.437	0.487	0.196	9.798	2.437						
60	2.437	0.487	0.196	9.780	2.437						
65	2.437	0.487	0.195	9.752	2.437						
70	2.436	0.487	0.195	9.756	2.436						
75	2.435	0.487	0.195	9.751	2.435						
80	2.435	0.487	0.194	9.716	2.435						
85	2.435	0.487	0.196	9.798	2.435						
90	2.434	0.487	0.196	9.815	2.434						
95	2.434	0.487	0.196	9.789	2.434						

TP031697 Chart 1

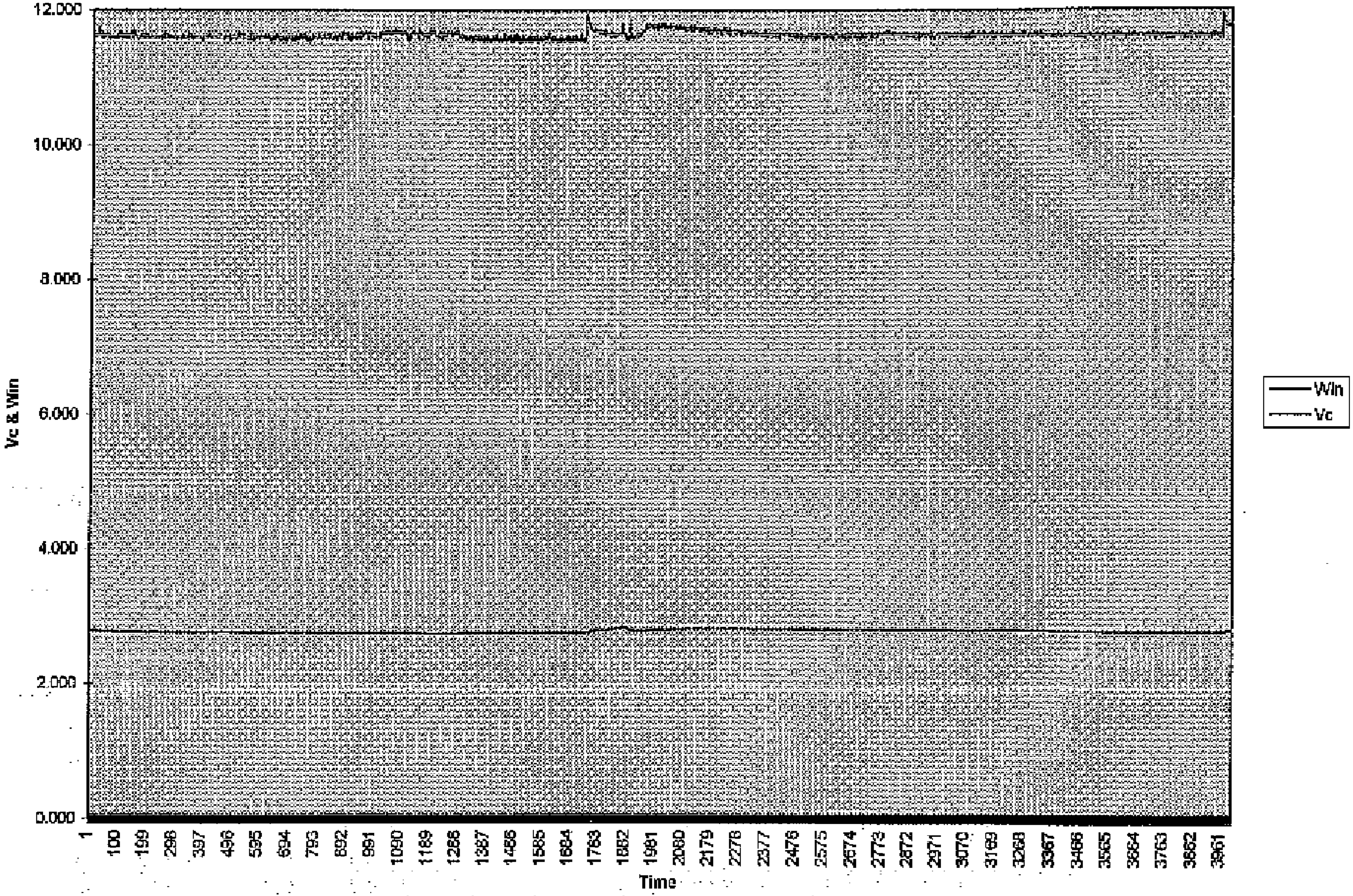


2075
1011 35

	Win	**Predicted Vc**						
	0	-0.0605		**Given Vc=**	2.793			
	1	0.1728		**Estimated**				
	2	0.4061		**Watts Out**	12.231	watts of power.		
	3	0.6394		**Actual =**	11.624	watts of input power		
	4	0.8727			**0.607**	**excess watts of power produced**		
	5	1.106						
	6	1.3393						
	7	1.5726						
	8	1.8059						
	9	2.0392						
	10	2.2725						
	11	2.5058						
	12	2.7391						
	13	2.9724						
	14	3.2057						
	15	3.439						
	16	3.6723						

Time [sec	Vc	Vc'	x	Win	Vc							
27	2.773	0.555	0.233	11.627	2.773	Statistics from 2 to 5363 [7.464hrs]						
32	2.773	0.555	0.232	11.618	2.773		Average	Std Dev	Min	Max		
38	2.773	0.555	0.233	11.64	2.773	Vc	2.796	0.050	2.733	2.893		
42	2.773	0.555	0.233	11.641	2.773	Win	11.652	0.054	11.523	11.945		
48	2.773	0.555	0.232	11.619	2.773							
52	2.773	0.555	0.232	11.603	2.773							
57	2.773	0.555	0.232	11.624	2.773							
62	2.773	0.555	0.232	11.614	2.773							
67	2.773	0.555	0.232	11.607	2.773							
72	2.773	0.555	0.233	11.643	2.773							
77	2.773	0.555	0.233	11.625	2.773							
82	2.773	0.555	0.232	11.604	2.773							
87	2.773	0.555	0.233	11.643	2.773							
92	2.773	0.555	0.233	11.649	2.773							
97	2.773	0.555	0.234	11.678	2.773							
102	2.773	0.555	0.234	11.68	2.773							
107	2.773	0.555	0.233	11.668	2.773							
112	2.773	0.555	0.233	11.66	2.773							
117	2.773	0.555	0.233	11.64	2.773							

TP031797 Chart 1



2   27   2.772   11.627

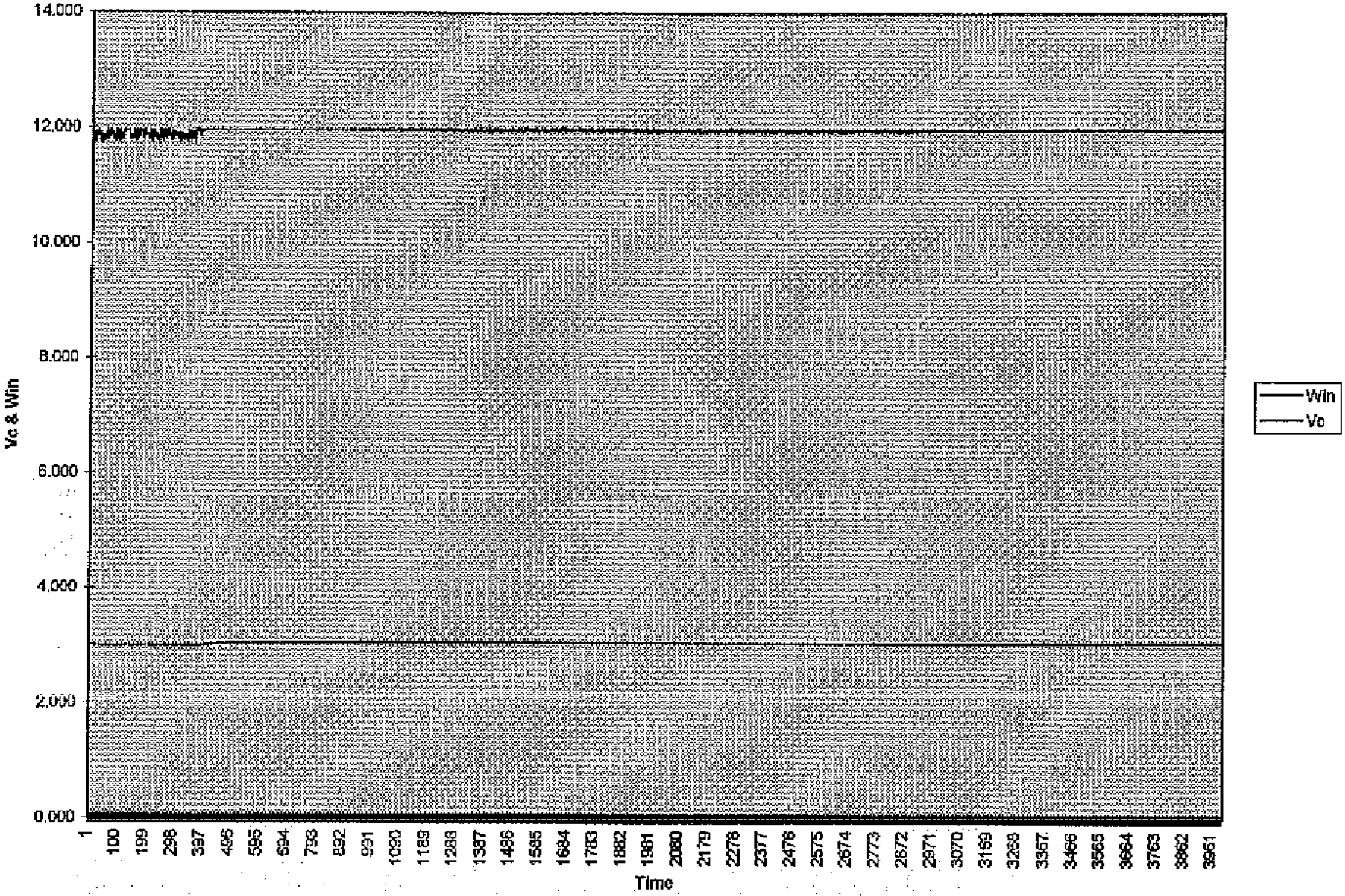
5363   2.6848   2.582   11.679

7.464

	Win	Predicted Vc				
	0	-0.0605		Given Vc=	2.985	
	1	0.1728		Estimated		
	2	0.4061		Watts Out	13.054	watts of power
	3	0.6394		Actual =	11.89	watts of input power
	4	0.8727			**1.164**	excess watts
	5	1.106				
	6	1.3393				
	7	1.5726				
	8	1.8059				
	9	2.0392				
	10	2.2725				
	11	2.5058				
	12	2.7391				
	13	2.9724				
	14	3.2057				
	15	3.439				
	16	3.6723				

Time [sec]	Vc	Vc'	x	Win	Vc						
60	3.009	0.602	0.238	11.898	3.009	Statistics from 2 to 11198 [31.194 hrs]					
70	3.009	0.602	0.238	11.876	3.009		Average	Std Dev	Min	Max	
80	3.008	0.602	0.237	11.866	3.008	Vc	2.999	0.070	2.880	3.052	
90	3.008	0.602	0.238	11.876	3.008	Win	11.883	0.160	11.558	12.024	
100	3.008	0.602	0.236	11.820	3.008						
110	3.007	0.602	0.237	11.866	3.007						
120	3.006	0.602	0.237	11.862	3.006						
131	3.005	0.602	0.236	11.787	3.005						
140	3.005	0.601	0.238	11.882	3.005						
150	3.004	0.601	0.236	11.807	3.004						
160	3.004	0.601	0.235	11.757	3.004						
170	3.003	0.601	0.235	11.752	3.003						
180	3.003	0.601	0.238	11.909	3.003						
190	3.002	0.601	0.239	11.931	3.002						
200	3.001	0.601	0.238	11.904	3.001						
210	3.001	0.601	0.236	11.893	3.001						
220	3.001	0.601	0.238	11.895	3.001						

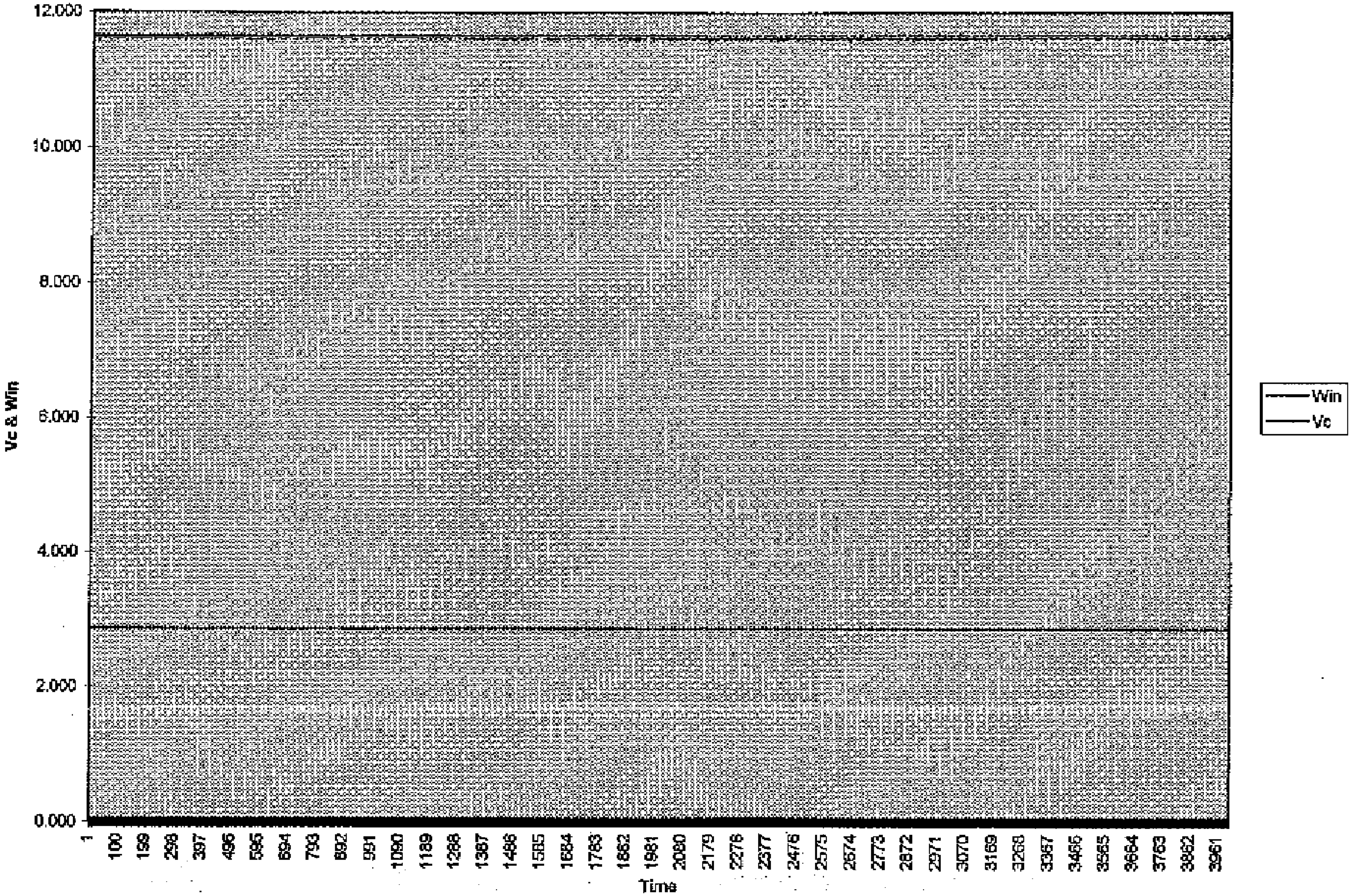
TP031897 Chart 1



2	60	11.596	3.047
11.98	11.2360	11.619	2.861

Win	Predicted Vc			
0	-0.0605	Given Vc=	2.857	
1	0.1728	Estimated		
2	0.4061	Watts Out	12.506	watts of power
3	0.6394	Actual =	11.627	watts of input power
4	0.8727		0.879	excess watts
5	1.106			
6	1.3393			
7	1.5726			
8	1.8059			
9	2.0392			
10	2.2725			
11	2.5058			
12	2.7391			
13	2.9724			
14	3.2057			
15	3.439			
16	3.6723			

TP031997 Chart 1



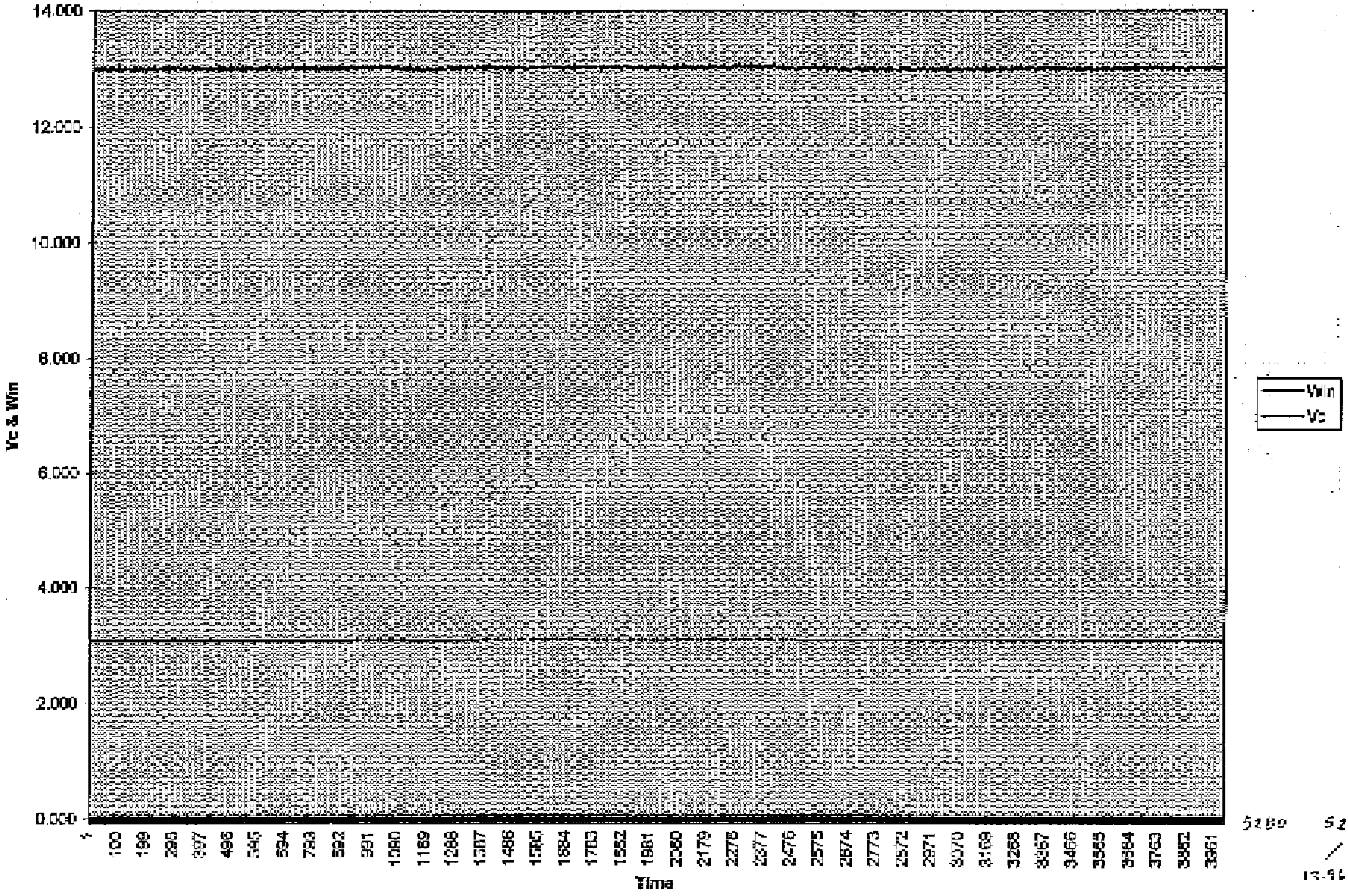
5311
6594

53246
6611.1

	Win	Predicted Vc						
	0	-0.0605		**Given Vc=**	3.076			
	1	0.1728		**Estimated**				
	2	0.4061		**Watts Out**	13.444	watts of power		
	3	0.6394		**Actual =**	13.04	watts of input power		
	4	0.8727			**0.404**	excess watts		
	5	1.106						
	6	1.3393						
	7	1.5726						
	8	1.8059						
	9	2.0392						
	10	2.2725						
	11	2.5058						
	12	2.7391						
	13	2.9724						
	14	3.2057						
	15	3.439						
	16	3.6723						

Time [sec]	Vc	Vc'	x	Win	Vc							
32	3.083	0.617	0.260	13.003	3.083	Statistics from 2 to 5280 [14.698 hrs]						
42	3.083	0.617	0.260	12.995	3.083		Average	Std Dev	Min	Max		
52	3.083	0.617	0.260	12.995	3.083	Vc	3.078	0.016	3.021	3.092		
62	3.083	0.617	0.260	12.993	3.083	Win	13.007	0.034	12.777	13.077		
72	3.083	0.617	0.260	12.982	3.083							
82	3.083	0.617	0.260	13.015	3.083							
92	3.084	0.617	0.260	13.017	3.084							
102	3.084	0.617	0.259	12.973	3.084							
112	3.084	0.617	0.260	12.983	3.084							
122	3.084	0.617	0.260	12.979	3.084							
134	3.084	0.617	0.259	12.971	3.084							
143	3.083	0.617	0.260	13.015	3.083							
153	3.083	0.617	0.260	13.008	3.083							
163	3.083	0.617	0.260	13.013	3.083							
173	3.083	0.617	0.259	12.973	3.083							
183	3.083	0.617	0.260	12.984	3.083							
193	3.083	0.617	0.260	13.010	3.083							

TP032097 Chart 1



5280 52973

13.967 3.01

14.648 hrs

Win	**Predicted Vc**			
0	-0.0605	**Given Vc=**	3.016	
1	0.1728	**Estimated**		
2	0.4061	**Watts Out**	13.187	watts of power
3	0.6394	**Actual =**	13.015	watts of input power
4	0.8727		**0.172**	excess watts
5	1.106			
6	1.3393			
7	1.5726			
8	1.8059			
9	2.0392			
10	2.2725			
11	2.5058			
12	2.7391			
13	2.9724			
14	3.2057			
15	3.439			
16	3.6723			

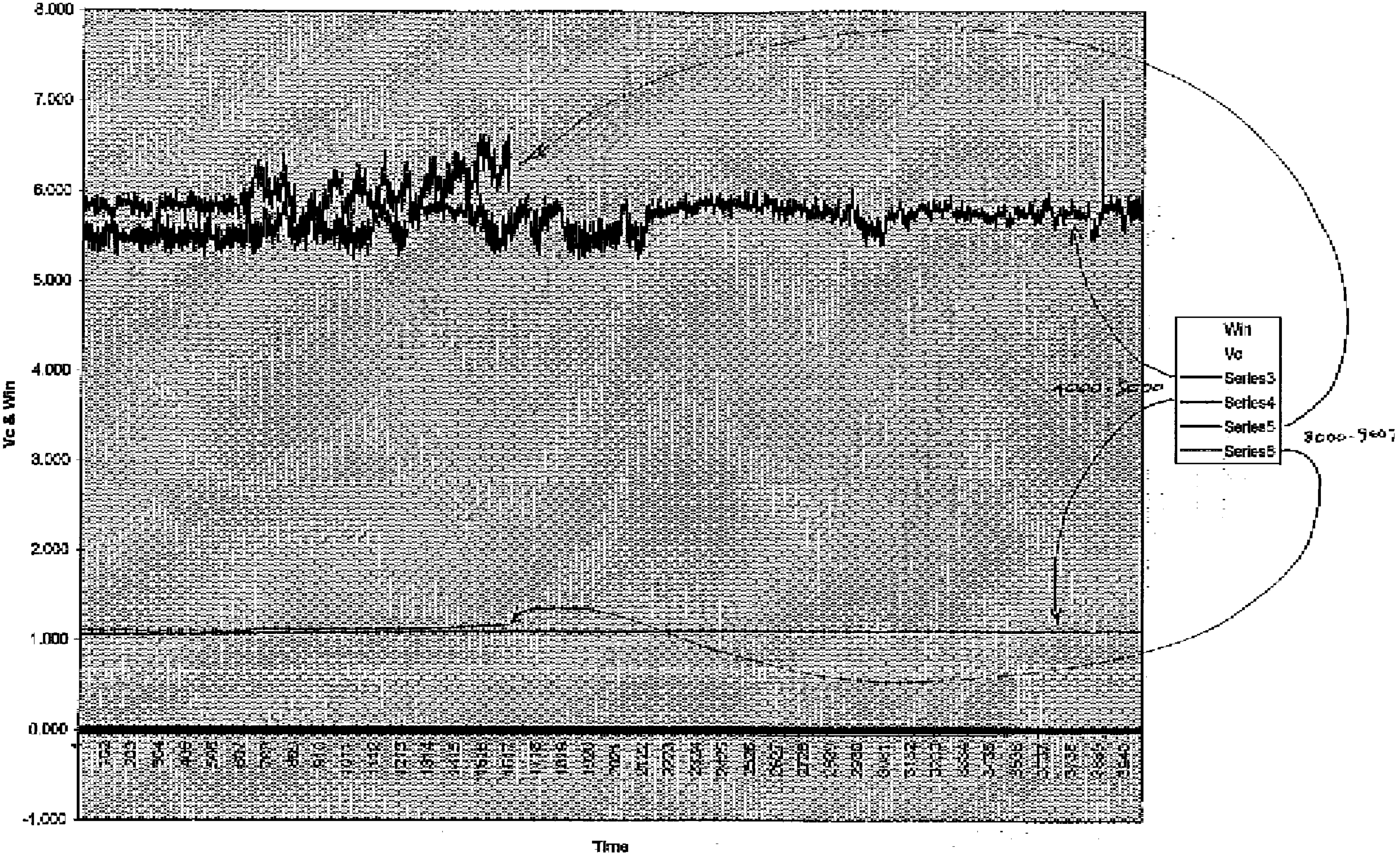
Win	Predicted Vc				
0	-0.0605		**Given Vc=**	2.802	
1	0.1728		**Estimated**		
2	0.4061		**Watts Out**	12.270	watts of power
3	0.6394		**Actual =**	12.779	watts of input power
4	0.8727			**-0.509**	excess watts
5	1.106				
6	1.3393				
7	1.5726				
8	1.8059				
9	2.0392				
10	2.2725				
11	2.5058				
12	2.7391				
13	2.9724				
14	3.2057				
15	3.439				
16	3.6723				

	Win	Predicted Vc						
	0	-0.0605		Given Vc=	3.073			
	1	0.1728		Estimated				
	2	0.4061		Watts Out	13.432	watts of power		
	3	0.6394		Actual =	13.020	watts of input power		
	4	0.8727			0.412	excess watts		
	5	1.106						
	6	1.3393						
	7	1.5726						
	8	1.8059						
	9	2.0392						
	10	2.2725						
	11	2.5058						
	12	2.7391						
	13	2.9724						
	14	3.2057						
	15	3.439						
	16	3.6723						

Time [sec]	Vc	Vc'	x	Win	Vc	Statistics from 6000-8700 [7.516 hrs]						
69	0.000	0.000	0.058	2.923	0.000			Average	Std Dev	Min	Max	
79	0.000	0.000	0.001	0.034	0.000		Vc	1.102	0.004	1.089	1.121	
89	0.000	0.000	0.024	1.190	0.000		Win	5.791	0.122	5.272	7.004	
99	0.000	0.000	0.082	4.082	0.000							
110	0.000	0.000	0.087	4.372	0.000							
120	0.000	0.000	0.086	4.276	0.000							
130	0.000	0.000	0.085	4.244	0.000							
140	0.000	0.000	0.085	4.247	0.000							
150	0.000	0.000	0.085	4.272	0.000							
160	0.000	0.000	0.085	4.258	0.000							
170	0.000	0.000	0.085	4.232	0.000							
180	0.000	0.000	0.085	4.252	0.000							
190	0.000	0.000	0.086	4.325	0.000							
200	0.000	0.000	0.086	4.318	0.000							
210	0.000	0.000	0.086	4.290	0.000							

No Hydrogen

TP032607 Chart 1



Win	P[H]	P[L]	x	Win	Vc	Statistics for 2961 - 3417 [2.539 hrs]			
15.044	0.549	0.179	0.00	15.044	0.836		Average	Std Dev	
14.963	0.548	0.175	0.00	14.963	0.908	Vc	3.951	0.004	
14.999	0.538	0.170	0.00	14.999	0.971	Win	14.943	0.013	
15.019	0.536	0.168	0.00	15.019	1.029				
15.003	0.529	0.166	0.01	15.003	1.084				
14.957	0.529	0.165	0.03	14.957	1.139				
14.977	0.531	0.164	0.04	14.977	1.190				
14.997	0.530	0.165	0.06	14.997	1.241				
14.971	0.528	0.164	0.09	14.971	1.294				
14.972	0.554	0.168	0.11	14.972	1.343				
15.041	0.517	0.160	0.14	15.041	1.388				
14.990	0.536	0.166	0.17	14.990	1.431				
14.969	0.535	0.164	0.21	14.969	1.476				
14.980	0.542	0.165	0.24	14.980	1.514				
15.002	0.533	0.164	0.27	15.002	1.548				

30 cm Control

Vc = 3.951

Win = 14.943

Time [sec	Vc	Vc'	Win	P[H]	P[L]	Vfil	Win	Vc	Statistics from Points			
60	3.949	0.790	14.930	0.375	0.151	2.356	14.930	3.949		Average	Std Dev	
80	3.950	0.790	14.932	0.375	0.156	2.352	14.932	3.950	Vc	3.951	0.001292	
100	3.950	0.790	14.956	0.354	0.147	2.352	14.956	3.950	Win	14.940	0.010438	
120	3.950	0.790	14.952	0.355	0.152	2.352	14.952	3.950				
141	3.951	0.790	14.946	0.362	0.152	2.353	14.946	3.951				
160	3.951	0.790	14.930	0.398	0.159	2.353	14.930	3.951				
180	3.951	0.790	14.914	0.416	0.165	2.353	14.914	3.951				
200	3.951	0.790	14.913	0.415	0.164	2.353	14.913	3.951				
220	3.951	0.790	14.934	0.374	0.157	2.352	14.934	3.951				
240	3.951	0.790	14.936	0.358	0.150	2.353	14.936	3.951				
260	3.951	0.790	14.932	0.343	0.149	2.353	14.932	3.951				
280	3.951	0.790	14.935	0.351	0.148	2.353	14.935	3.951				
300	3.951	0.790	14.934	0.369	0.156	2.353	14.934	3.951				
320	3.951	0.790	14.921	0.317	0.141	2.353	14.921	3.951				
341	3.951	0.791	14.927	0.366	0.152	2.353	14.927	3.951				

30 cm control

Vc = 3.951

Win = 14.940

Time [sec]	Vc	Vc'	Win	P[H]	P[L]	Vfil	Win	Vc	Statistics from Points 1133 to 1239 [0.590 hrs]			
123	3.948	0.790	14.934	0.375	0.154	2.351	14.934	3.948		Average	Std Dev	
143	3.948	0.790	14.931	0.378	0.157	2.350	14.931	3.948	Vc	4.221	0.001	
163	3.948	0.790	14.949	0.376	0.156	2.350	14.949	3.948	Win	16.123	0.008	
183	3.948	0.790	14.952	0.362	0.149	2.350	14.952	3.948				
203	3.948	0.790	14.942	0.375	0.153	2.350	14.942	3.948				
223	3.948	0.790	15.487	0.376	0.153	2.350	15.487	3.948				
243	3.950	0.790	16.131	0.385	0.152	2.351	16.131	3.950				
263	3.955	0.791	16.147	0.381	0.154	2.355	16.147	3.955				
283	3.962	0.793	16.159	0.399	0.158	2.362	16.159	3.962				
303	3.969	0.794	16.170	0.378	0.152	2.367	16.170	3.969				
323	3.975	0.795	16.163	0.387	0.154	2.373	16.163	3.975				
343	3.981	0.796	16.145	0.381	0.155	2.378	16.145	3.981				
363	3.986	0.797	16.154	0.393	0.153	2.382	16.154	3.986				
383	3.991	0.798	16.151	0.378	0.152	2.386	16.151	3.991				
404	3.996	0.799	16.421	0.381	0.152	2.390	16.421	3.996				
424	4.000	0.800	20.443	0.388	0.155	2.394	20.443	4.000				
444	4.004	0.801	25.080	0.373	0.152	2.398	25.080	4.004				
464	4.009	0.802	19.705	0.377	0.152	2.401	19.705	4.009				
484	4.012	0.803	16.115	0.379	0.152	2.406	16.115	4.012				

30 cm Control

Vc = 4.221

Win - 16.123

Time [sec]	Vc	Vc'	Win	P[H]	P[L]	Vfil	Win	Vc	Statistics from Points 955 - 1100 [0.808 hrs]			
54	4.222	0.845	16.129	0.439	0.154	2.587	16.129	4.222		Average	Std Dev	
74	4.222	0.845	17.170	0.394	0.143	2.586	17.170	4.222	Vc	4.663	0.002	
106	4.224	0.845	18.035	0.418	0.148	2.586	18.035	4.224	Win	18.041	0.007	
114	4.233	0.847	18.040	0.435	0.151	2.596	18.040	4.233				
134	4.245	0.849	18.045	0.437	0.153	2.605	18.045	4.245				
154	4.256	0.851	18.038	0.389	0.143	2.615	18.038	4.256				
174	4.265	0.853	18.031	0.417	0.149	2.623	18.031	4.265				
195	4.274	0.855	18.022	0.415	0.149	2.630	18.022	4.274				
215	4.281	0.856	18.028	0.420	0.149	2.637	18.028	4.281				
235	4.288	0.858	18.036	0.424	0.151	2.643	18.036	4.288				
255	4.295	0.859	18.036	0.409	0.146	2.649	18.036	4.295				
275	4.301	0.860	18.023	0.419	0.149	2.654	18.023	4.301				
295	4.308	0.862	18.019	0.416	0.151	2.659	18.019	4.308				
315	4.314	0.863	18.025	0.418	0.150	2.665	18.025	4.314				
335	4.319	0.864	18.033	0.405	0.148	2.670	18.033	4.319				
355	4.325	0.865	18.039	0.423	0.152	2.674	18.039	4.325				
375	4.331	0.866	18.041	0.408	0.148	2.679	18.041	4.331				

30 cm Control

Vc = 4.663

Win = 18.041

Summary of Exc. Power Produced

Summary of 30 cm Experimental Results

Date[s] of Run	Hours [ss]	Excess Power [watts]	Pressure	Additional H2?
14-Apr	5.632	1.181	132.5-178.2T	No
15-Apr	15.160	1.459	0.36-549T	Yes
16-Apr	12.060	1.689	0.386-0.591T	Yes
17-Apr	21.273	1.335	0.385-0.683T	Yes
18-Apr	6.916	0.635	0.349-0.576T	Yes
23-Apr	11.572	1.954	0.425-0.582T	No
24-Apr	23.461	2.092	0.352-0.582T	No
25-Apr	13.507	2.067	< 1.312T	No
3-May	6.237	1.264	0.335-0.443T	No
4-May	11.355	1.135	0.453-0.679T	Yes
5-May	4.777	1.079	0.447-0.596T	Yes
		1.445	Average of Points	
		0.635	Minimum	
		2.092	Maximum	
		0.461	Std. Deviation	
		31.91%	Std. Deviation %	

	Win	**Predicted Vc**						
	14.5	3.849		**Given Vc=**	4.268			
	15.0	3.964		**Estimated**				
	15.5	4.079		**Watts Out**	16.322	watts of power		
	16.0	4.194		**Actual =**	15.141	watts of input power		
	16.5	4.309			**1.181**	**excess watts**		
	17.0	4.424						
	17.5	4.539						
	18.0	4.653						
	18.5	4.768						

Time [sec]	Vc	Vc'	Win	p[H]	p[L]	Vf	Win	Vc	Statistics for 2 - 5446 [15.160hrs]				
82	4.292	0.859	15.242	243.980	99.976	2.658	15.242	4.292		Average	Std Dev	Min	Max
92	4.292	0.859	15.244	243.980	99.976	2.646	15.244	4.292	Vc	4.331	0.023	4.263	4.380
102	4.292	0.859	15.239	244.000	99.976	2.646	15.239	4.292	Win	15.137	0.083	14.954	15.269
112	4.291	0.859	15.248	244.000	99.976	2.645	15.248	4.291					
122	4.291	0.859	15.251	244.040	99.976	2.645	15.251	4.291	P_H	12.454		0.360	549.01
132	4.291	0.859	15.256	244.030	99.976	2.645	15.256	4.291					
142	4.290	0.859	15.249	244.040	99.976	2.645	15.249	4.290					
153	4.290	0.859	15.256	244.070	99.976	2.645	15.256	4.290					
162	4.290	0.859	15.264	244.090	99.976	2.645	15.264	4.290					
172	4.290	0.859	15.257	244.110	99.976	2.645	15.257	4.290					
182	4.290	0.859	15.255	244.130	99.976	2.644	15.255	4.290					
192	4.290	0.859	15.255	244.170	99.976	2.645	15.255	4.290					
202	4.290	0.859	15.248	244.190	99.976	2.645	15.248	4.290					
212	4.290	0.859	15.251	244.220	99.976	2.645	15.251	4.290					
223	4.290	0.859	15.250	244.270	99.976	2.645	15.250	4.290					
233	4.290	0.859	15.252	244.310	99.976	2.644	15.252	4.290					

Time [sec]	Vc	Vc'	Win	p[H]	p[L]	Vf	Win	Vc	Statistics for 4192-8540 [12.060 hrs]				
125	4.335	0.868	15.176	0.446	0.154	2.691	15.176	4.339		Average	Std Dev	Min	Max
135	4.335	0.868	15.179	0.445	0.154	2.680	15.179	4.339	Vc	5.075	0.027	5.040	5.135
145	4.335	0.868	15.184	0.437	0.156	2.679	15.184	4.339	Win	18.146	0.039	18.058	18.283
155	4.335	0.868	15.176	0.453	0.155	2.679	15.176	4.339					
165	4.335	0.868	15.173	0.463	0.153	2.679	15.173	4.339	p[H]	0.486	0.029	0.386	0.591
175	4.334	0.868	15.180	0.452	0.154	2.679	15.180	4.339					
185	4.334	0.868	15.176	0.434	0.156	2.679	15.176	4.338					
195	4.334	0.868	15.199	0.448	0.153	2.679	15.199	4.338					
205	4.334	0.868	15.198	0.450	0.150	2.678	15.198	4.338					
215	4.334	0.868	15.195	0.466	0.133	2.679	15.195	4.338					
225	4.334	0.868	15.200	0.495	0.133	2.679	15.200	4.338					
235	4.334	0.868	15.540	0.506	0.133	2.679	15.540	4.338					
245	4.334	0.868	17.450	0.542	0.134	2.679	17.450	4.339					
255	4.336	0.868	18.067	0.548	0.132	2.680	18.067	4.340					
265	4.340	0.869	18.145	0.558	0.138	2.683	18.145	4.344					
275	4.347	0.870	18.136	0.608	0.132	2.689	18.136	4.351					
285	4.355	0.872	18.130	0.597	0.130	2.697	18.130	4.359					
295	4.364	0.874	18.093	0.617	0.133	2.704	18.093	4.368					

Time [sec]	Vc	Vc'	Win	p[H]	p[L]	Vf	Win	Vc
76	4.999	1.010	18.141	0.526	0.147	3.302	18.141	5.050
86	4.999	1.010	18.139	0.517	0.155	3.295	18.139	5.049
96	4.999	1.010	18.143	0.487	0.160	3.294	18.143	5.050
106	4.999	1.010	18.139	0.514	0.152	3.294	18.139	5.049
116	4.999	1.010	18.147	0.536	0.148	3.294	18.147	5.049
126	4.999	1.010	18.151	0.481	0.158	3.294	18.151	5.049
136	4.999	1.010	18.149	0.543	0.146	3.294	18.149	5.049
146	4.999	1.010	18.153	0.487	0.158	3.294	18.153	5.049
156	4.999	1.010	18.150	0.516	0.150	3.294	18.150	5.050
166	4.999	1.010	18.150	0.497	0.156	3.294	18.150	5.050
176	4.999	1.010	18.153	0.532	0.149	3.295	18.153	5.050
186	4.999	1.010	18.153	0.510	0.152	3.295	18.153	5.050
196	4.999	1.010	18.149	0.497	0.157	3.295	18.149	5.050
206	4.999	1.010	18.148	0.481	0.155	3.295	18.148	5.050
216	4.999	1.010	18.142	0.543	0.146	3.295	18.142	5.050
226	4.999	1.010	18.145	0.489	0.156	3.295	18.145	5.050
236	4.999	1.010	18.151	0.533	0.148	3.295	18.151	5.050

Statistics for 2 - 7640 (21.27 hrs)

	Average	Std Dev	Min	Max
Vc	4.991	0.056	4.864	5.051
Win	18.135	0.061	17.755	18.326
p[H]	0.492	0.035	0.385	0.603

Time [sec]	Vc	Vc'	Win	p[H]	p[L]	Vf	Win	Vc
55	4.801	0.961	17.938	0.504	0.132	3.093	17.938	4.801
65	4.801	0.961	17.939	0.509	0.130	3.086	17.939	4.801
75	4.801	0.961	17.975	0.505	0.133	3.086	17.975	4.801
85	4.801	0.961	17.961	0.501	0.135	3.088	17.961	4.801
95	4.802	0.961	17.952	0.508	0.131	3.086	17.952	4.802
105	4.802	0.961	17.931	0.510	0.131	3.086	17.931	4.802
115	4.802	0.961	17.911	0.490	0.133	3.086	17.911	4.802
125	4.802	0.961	17.895	0.505	0.128	3.086	17.895	4.802
135	4.802	0.961	17.895	0.499	0.132	3.086	17.895	4.802
145	4.801	0.961	17.900	0.506	0.130	3.085	17.900	4.801
155	4.801	0.961	17.908	0.508	0.130	3.085	17.908	4.801
165	4.800	0.961	17.899	0.492	0.131	3.084	17.899	4.800
175	4.800	0.961	17.910	0.510	0.129	3.084	17.910	4.800
186	4.799	0.961	17.907	0.491	0.132	3.084	17.907	4.799
195	4.799	0.961	17.910	0.508	0.130	3.084	17.910	4.799
205	4.798	0.960	17.921	0.500	0.132	3.083	17.921	4.798
215	4.798	0.960	17.931	0.502	0.130	3.082	17.931	4.798

Statistics for 2-1485 (6.9/6 hr)

	Average	Std Dev	Min	Max
Vc	4.791	0.009	4.776	4.816
Win	17.964	0.046	17.868	18.105
p[H]	0.464	0.030	0.349	0.578

Time [sec]	Vc	Vc'	Win	p[H]	p[L]	Vf	Win	Vc	Statistics for 2437 - 4515 [11.572 hrs]				
109	0.000	0.000	0.064	0.507	0.138	0.005	0.064	0.000		Average	Std Dev	Min	Max
129	0.000	0.000	0.063	0.508	0.137	0.000	0.063	0.000	Vc	4.431	0.040	4.318	4.476
149	0.000	0.000	0.070	0.515	0.138	0.000	0.070	0.000	Win	15.078	0.015	15.018	15.110
169	0.000	0.000	0.062	0.530	0.139	0.000	0.062	0.000	p[H]	0.508	0.021	0.425	0.582
190	0.000	0.000	0.069	0.531	0.138	0.000	0.069	0.000					
209	0.000	0.000	0.061	0.531	0.146	0.000	0.061	0.000					
229	0.000	0.000	0.070	0.522	0.276	0.000	0.070	0.000					
249	0.000	0.000	0.068	0.534	0.287	0.000	0.068	0.000					
269	0.000	0.000	8.831	0.523	0.292	0.000	8.831	0.000					
289	0.000	0.000	15.024	0.577	0.351	0.000	15.024	0.000					
309	0.000	0.000	15.066	0.653	0.485	0.000	15.066	0.000					
329	0.015	0.003	14.926	0.708	0.563	0.000	14.926	0.015					
349	0.096	0.019	14.910	0.741	0.595	0.000	14.910	0.096					
369	0.177	0.035	14.940	0.750	0.610	0.000	14.940	0.177					
389	0.250	0.050	14.969	0.755	0.620	0.000	14.969	0.250					
409	0.317	0.063	14.992	0.842	0.641	0.000	14.992	0.317					
429	0.381	0.076	15.029	0.767	0.634	0.000	15.029	0.381					

Time [sec]	Vc	Vc'	Win	p[H]	p[L]	Vf	Win	Vc
58	4.470	0.894	15.091	0.500	0.134	2.801	15.091	4.470
78	4.470	0.094	15.094	0.508	0.132	2.801	15.094	4.470
98	4.470	0.894	15.083	0.509	0.133	2.801	15.083	4.470
118	4.471	0.894	15.081	0.527	0.131	2.801	15.081	4.471
138	4.471	0.894	15.077	0.552	0.137	2.801	15.077	4.471
150	4.471	0.894	15.082	0.526	0.136	2.801	15.082	4.471
178	4.471	0.894	15.075	0.513	0.134	2.801	15.075	4.471
198	4.471	0.894	15.078	0.539	0.137	2.801	15.078	4.471
218	4.471	0.894	15.073	0.503	0.130	2.801	15.073	4.471
238	4.471	0.894	15.077	0.526	0.136	2.801	15.077	4.471
258	4.471	0.894	15.071	0.508	0.134	2.801	15.071	4.471
279	4.471	0.894	15.060	0.518	0.136	2.801	15.060	4.471
299	4.471	0.894	15.065	0.492	0.131	2.802	15.065	4.471
319	4.471	0.894	15.066	0.521	0.136	2.802	15.066	4.471
339	4.471	0.894	15.078	0.500	0.131	2.801	15.078	4.471
359	4.472	0.895	15.079	0.509	0.133	2.802	15.079	4.472
379	4.472	0.895	15.086	0.507	0.134	2.802	15.086	4.472

Statistics for 2 -425 (23.461 hrs)				
	Average	Std Dev	Min	Max
Vc	4.457	0.012	4.440	4.484
Win	15.053	0.035	14.837	15.114
p[H]	0.459	0.038	0.352	0.582

Time [sec]	Vc	Vc'	Win	p[H]	p[L]	Vf	Win	Vc
98	4.447	0.889	15.005	1.205	0.046	2.805	15.005	4.447
131	4.446	0.889	15.005	1.275	0.071	2.790	15.005	4.446
165	4.445	0.889	14.995	0.648	0.202	2.767	14.995	4.445
198	4.445	0.889	14.998	0.051	0.253	2.759	14.998	4.445
231	4.445	0.889	15.015	0.017	0.245	2.760	15.015	4.445
265	4.445	0.889	15.042	0.152	0.270	2.759	15.042	4.445
298	4.445	0.889	15.041	0.103	0.259	2.759	15.041	4.445
332	4.444	0.889	15.055	0.110	0.126	2.783	15.055	4.444
365	4.444	0.889	15.093	1.122	0.062	2.791	15.093	4.444
398	4.444	0.889	15.097	0.551	0.211	2.763	15.097	4.444
432	4.443	0.889	15.075	0.006	0.182	2.771	15.075	4.443
465	4.443	0.889	15.089	0.005	0.145	2.776	15.089	4.443
499	4.444	0.889	15.067	0.008	0.145	2.778	15.067	4.444
532	4.444	0.889	15.038	0.325	0.043	2.795	15.038	4.444
565	4.445	0.889	15.018	1.175	0.080	2.786	15.018	4.445
599	4.445	0.889	15.011	0.403	0.239	2.761	15.011	4.445
632	4.445	0.889	15.000	0.014	0.212	2.766	15.000	4.445

Statistics for 2 - 1457 [13.507 hrs]

	Average	Std Dev	Min	Max
Vc	4.442	0.002	4.441	4.447
Win	15.013	0.045	14.922	15.111
p[H]	0.448	0.374	0.000	1.312

pressure data is erratic

Time [sec]	Vc	Vc'	Win	p[H]	p[L]	Vf/2	Win	Vc	Statistics for 3085 - 4205 [6.237 hrs]				
64	2.491	0.498	15.086	0.406	0.152	3.620	15.086	2.491		Average	Std Dev	Min	Max
84	2.508	0.502	15.089	0.448	0.160	3.621	15.089	2.508	Vc	4.262	0.006	4.250	4.273
104	2.524	0.505	15.084	0.392	0.148	3.620	15.084	2.524	Win	15.032	0.009	15.011	15.057
124	2.541	0.508	15.083	0.410	0.146	3.619	15.083	2.541	Vf/2	3.624	0.003	3.619	3.632
144	2.557	0.512	15.077	0.397	0.148	3.620	15.077	2.557	p[H]	0.393	0.015	0.335	0.443
164	2.574	0.515	15.072	0.379	0.145	3.618	15.072	2.574					
185	2.591	0.518	15.065	0.393	0.146	3.618	15.065	2.591					
204	2.607	0.521	15.064	0.386	0.147	3.619	15.064	2.607					
224	2.622	0.525	15.065	0.381	0.145	3.620	15.065	2.622					
244	2.637	0.528	15.063	0.420	0.151	3.621	15.063	2.637					
264	2.652	0.531	15.061	0.421	0.153	3.621	15.061	2.652					
284	2.667	0.534	15.057	0.414	0.150	3.621	15.057	2.667					
304	2.682	0.537	15.063	0.420	0.150	3.621	15.063	2.682					
324	2.697	0.540	15.060	0.385	0.146	3.620	15.060	2.697					
344	2.712	0.543	15.059	0.396	0.145	3.619	15.059	2.712					
364	2.726	0.545	15.059	0.418	0.153	3.621	15.059	2.726					
384	2.738	0.548	15.060	0.396	0.146	3.619	15.060	2.738					

TP050497

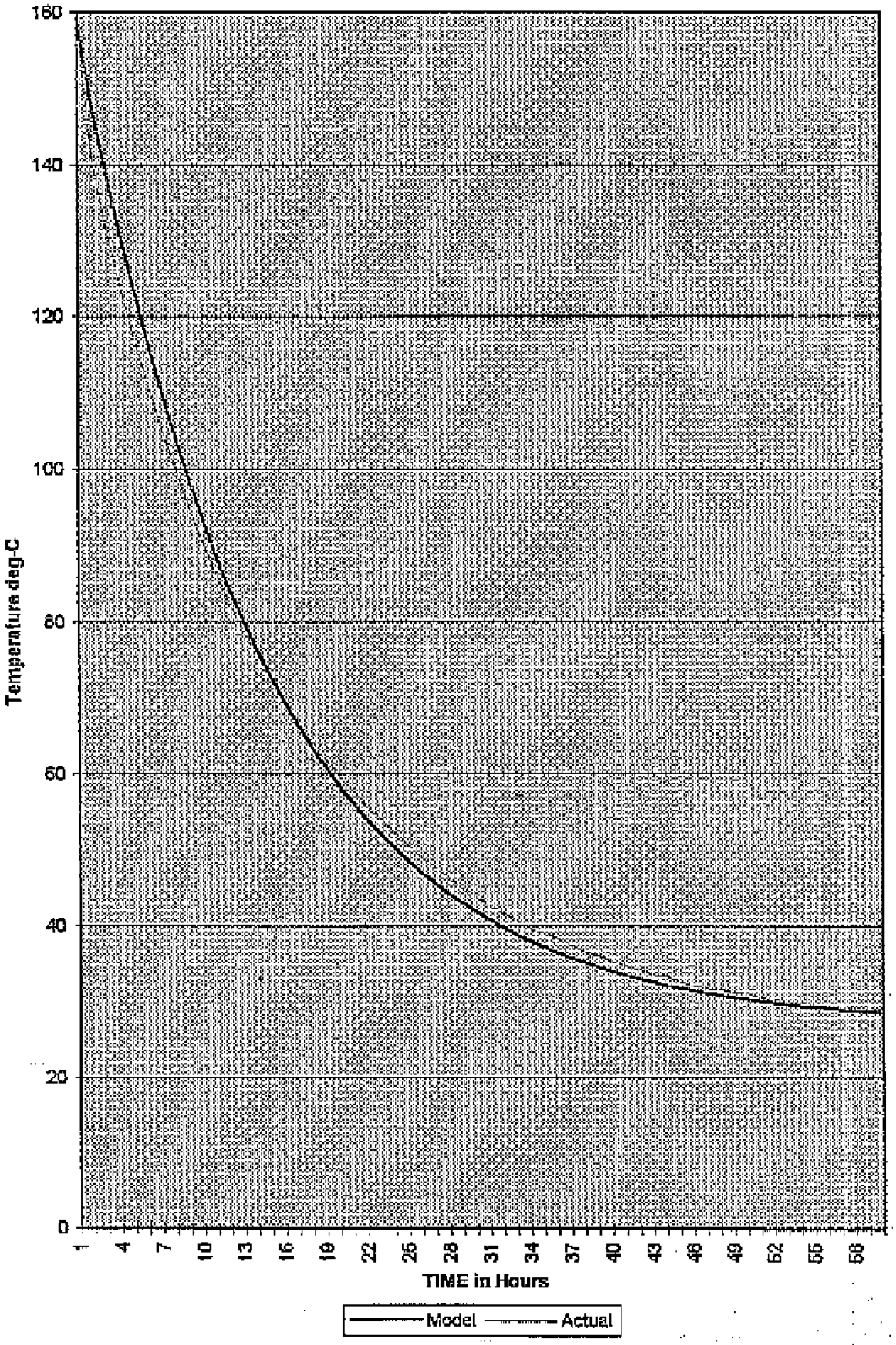
Time [sec]	Vc	Vc'	Win	p[H]	p[L]	Vf/2	Win	Vc	Statistics for 1712 - 5789 [11.355 hrs]				
42	4.310	0.862	15.090	0.370	0.253	3.619	15.090	4.310		Average	Std Dev	Min	Max
53	4.312	0.862	15.096	0.353	0.256	3.620	15.096	4.312	Vc	4.200	0.006	4.188	4.219
63	4.313	0.863	15.089	0.370	0.259	3.618	15.089	4.313	Win	14.891	0.013	14.868	14.981
73	4.314	0.863	15.090	0.399	0.255	3.619	15.090	4.314	p[H]	0.578	0.029	0.453	0.679
83	4.315	0.863	15.094	0.392	0.262	3.619	15.094	4.315	Vf/2	3.525	0.004	3.518	3.544
93	4.315	0.863	15.089	0.388	0.258	3.619	15.089	4.315					
103	4.315	0.863	15.094	0.367	0.267	3.619	15.094	4.315					
113	4.315	0.863	15.095	0.362	0.255	3.619	15.095	4.315					
123	4.314	0.863	15.095	0.374	0.256	3.618	15.095	4.314					
133	4.314	0.863	15.113	0.399	0.269	3.619	15.113	4.314					
143	4.315	0.863	15.109	0.380	0.267	3.619	15.109	4.315					
153	4.315	0.863	15.113	0.395	0.268	3.619	15.113	4.315					
163	4.315	0.863	15.112	0.368	0.270	3.619	15.112	4.315					
173	4.315	0.863	15.108	0.389	0.270	3.619	15.108	4.315					
183	4.315	0.863	15.111	0.392	0.273	3.620	15.111	4.315					
193	4.314	0.863	15.118	0.392	0.272	3.619	15.118	4.314					
203	4.314	0.863	15.114	0.382	0.273	3.619	15.114	4.314					

Time [sec]	Vc	Vc'	Win	p[H]	p[L]	Vf/2	Win	Vc	Statistics for 2 - 857 (4.777 hr)				
56	4.190	0.838	14.879	0.535	0.136	3.526	14.879	4.190		Average	Std Dev	Min	Max
76	4.189	0.838	14.878	0.574	0.141	3.526	14.878	4.189	Vc	4.187	0.005	4.175	4.199
96	4.189	0.838	14.877	0.559	0.138	3.526	14.877	4.189	Win	14.891	0.026	14.857	15.004
116	4.188	0.838	14.872	0.567	0.141	3.527	14.872	4.188	Vf/2	3.522	0.003	3.505	3.537
136	4.188	0.838	14.876	0.577	0.141	3.527	14.876	4.188	P(H)	0.538	0.024	0.447	0.596
156	4.188	0.838	14.883	0.592	0.142	3.527	14.883	4.188					
177	4.188	0.838	14.881	0.596	0.144	3.527	14.881	4.188					
197	4.189	0.838	14.886	0.514	0.134	3.528	14.886	4.189					
217	4.189	0.838	14.895	0.571	0.142	3.529	14.895	4.189					
237	4.190	0.838	14.897	0.550	0.139	3.530	14.897	4.190					
257	4.190	0.838	14.892	0.556	0.140	3.530	14.892	4.190					
277	4.191	0.838	14.885	0.552	0.139	3.530	14.885	4.191					
297	4.192	0.838	14.886	0.567	0.143	3.531	14.886	4.192					
317	4.192	0.838	14.901	0.561	0.142	3.531	14.901	4.192					
337	4.193	0.839	14.907	0.563	0.141	3.532	14.907	4.193					
357	4.194	0.839	14.908	0.558	0.141	3.534	14.908	4.194					
377	4.195	0.839	14.902	0.569	0.139	3.533	14.902	4.195					

THESIS - APPENDIX NINE

Heat Loss Model - Vers 1.1 Chart 2

Model vs. Actual Data



40075	153.2	27.1	126.1	156.5	156.5	153.2	2.15%	3.3			
40135	152.8	27.1	125.7	156.4	156.4	152.8	2.33%	3.6			
40196	152.5	27.1	125.4	156.2	156.2	152.5	2.42%	3.7			
40256	152.2	27.1	125.1	156.0	156.0	152.2	2.52%	3.8			
40316	151.9	27.1	124.8	155.9	155.9	151.9	2.62%	4.0			
40376	151.9	27.1	124.8	155.7	155.7	151.9	2.51%	3.8			
40436	151.5	27.1	124.4	155.6	155.6	151.5	2.67%	4.1			
40496	151.3	27.1	124.2	155.4	155.4	151.3	2.70%	4.1			
40556	150.9	27.1	123.8	155.2	155.2	150.9	2.87%	4.3			
40616	150.8	27.1	123.7	155.1	155.1	150.8	2.83%	4.3			
40677	150.5	27.1	123.4	154.9	154.9	150.5	2.93%	4.4			
40737	150.2	27.1	123.1	154.8	154.8	150.2	3.03%	4.6			
40797	150.0	27.1	122.9	154.6	154.6	150.0	3.06%	4.6			
40857	149.7	27.1	122.6	154.4	154.4	149.7	3.16%	4.7			
40917	149.5	27.1	122.4	154.3	154.3	149.5	3.19%	4.8			
40977	149.2	27.1	122.1	154.1	154.1	149.2	3.30%	4.9			
41038	149.0	27.1	121.9	154.0	154.0	149.0	3.33%	5.0			
41098	148.8	27.1	121.7	153.8	153.8	148.8	3.36%	5.0			
41158	148.5	27.1	121.4	153.6	153.6	148.5	3.46%	5.1			
41218	148.2	27.1	121.1	153.5	153.5	148.2	3.57%	5.3			
41278	148.0	27.1	120.9	153.3	153.3	148.0	3.60%	5.3			
41338	147.8	27.1	120.7	153.2	153.2	147.8	3.63%	5.4			
41398	147.6	27.1	120.5	153.0	153.0	147.6	3.67%	5.4			
41459	147.3	27.1	120.2	152.9	152.9	147.3	3.77%	5.6			
41519	147.1	27.1	120.0	152.7	152.7	147.1	3.81%	5.6			
41579	147.0	27.1	119.9	152.5	152.5	147.0	3.77%	5.5			
41639	146.6	27.1	119.5	152.4	152.4	146.6	3.95%	5.8			
41699	146.4	27.1	119.3	152.2	152.2	146.4	3.98%	5.8			
41759	146.3	27.1	119.2	152.1	152.1	146.3	3.95%	5.8			
41819	145.9	27.1	118.8	151.9	151.9	145.9	4.12%	6.0			
41879	145.9	27.1	118.8	151.8	151.8	145.9	4.02%	5.9			
41940	145.5	27.1	118.4	151.6	151.6	145.5	4.20%	6.1			
FILL 1 hr		27.0		151.8	Model	Actual					
12	141.5	27.0	114.5	148.3	148.4	142.0	4.86%	6.9			
13	132.1	26.9	105.2	139.3	139.6	133.0	5.70%	7.5			
14	124.4	26.8	97.6	131.2	131.5	125.0	5.71%	7.1			
15	117.5	26.8	90.7	123.7	124.0	118.0	5.49%	6.5			

53	33.7	27.0	6.7	32.6	32.6	33.0	-3.17%	-1.1					
54	33.4	27.0	6.4	32.2	32.2	33.0	-3.51%	-1.2	******				
55	32.6	27.0	5.6	31.8	31.8	32.0	-2.30%	-0.8					
56	32.1	27.0	5.1	31.5	31.5	32.0	-1.87%	-0.6					
57	31.8	27.0	4.8	31.2	31.2	32.0	-1.95%	-0.6					
58	31.6	27.0	4.6	30.9	30.9	31.0	-2.30%	-0.7					
59	31.2	27.0	4.2	30.6	30.6	31.0	-1.94%	-0.6					
60	31.1	27.0	4.1	30.3	30.3	31.0	-2.46%	-0.8					
61	30.6	27.0	3.6	30.1	30.1	31.0	-1.65%	-0.5					
62	30.4	27.0	3.4	29.9	29.9	30.0	-1.74%	-0.5					
63	30.1	27.0	3.1	29.7	29.7	30.0	-1.44%	-0.4					
64	29.9	27.0	2.9	29.5	29.6	30.0	-1.43%	-0.4					
65	29.6	27.0	2.6	29.3	29.3	30.0	-1.03%	-0.3					
66	29.4	27.0	2.4	29.1	29.1	29.0	-0.92%	-0.3					
67	29.3	27.0	2.3	29.0	29.0	29.0	-1.11%	-0.3					
68	29.3	27.0	2.3	28.8	28.8	29.0	-1.59%	-0.5					
69	29.2	27.0	2.2	28.7	28.7	29.0	-1.71%	-0.5					
70	29.1	27.0	2.1	28.6	28.6	29.0	-1.79%	-0.5					