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Development of new heat sink technology for high-density microprocessors

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DEVELOPMENT OF NEW HEAT SINK TECHNOLOGY FOR HIGH DENSITY MICROPROCESSORS

A Thesis

by

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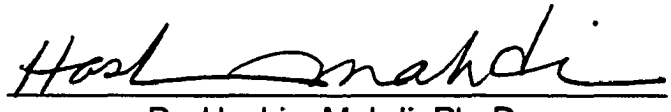

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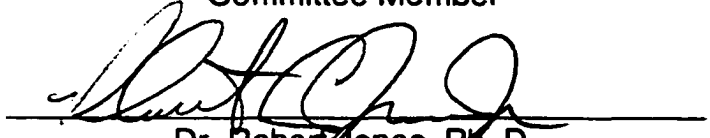

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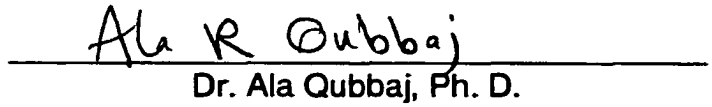

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ABSTRACT

Lopez, Pedro, Development of New Heat Sink Technology For High Density Microprocessors. Masters of Science (MS), May, 2003, 200 pp., 11 tables, 23 illustrations, references, 55 titles.

This study investigates the performance of existing heat sinks and compares it with two heat-exchanger prototypes: aluminum-foam heat sink and PCM (phase-change material)-filled heat sink. Kapton flexible heaters are used to replicate the heat produced by a computer's CPU (central processing unit). A number of thermocouples are connected between the heater and the heat sink being used to measure the component's temperature. The thermocouples are also connected to a data acquisition card to collect the data using a LabVIEW program. The values obtained are compared to data published in literature to validate the experiments and the setup. This setup is then utilized to test the new heat exchangers and compare their performance to that of the existing heat sinks.

NOMENCLATURE

Q, P	Power Input, W
k	Thermal conductivity, W/m-deg C
A	Cross-sectional area, m^2
dT, ΔT	Temperature distribution, deg C
dx, Δx	Thickness, m
R	Thermal Resistance, deg C/W
T_a, TA	Ambient temperature, deg C
T_{avg}	Average temperature, deg C
T_c	Case temperature, deg C
Θ_{ca}	Case-to-ambient resistance, deg C/W
Θ_{ja}	Junction-to-ambient resistance, deg C/W
Θ_{jc}	Junction-to-case resistance, deg C/W
XA	Foam cross-sectional area, in^2
h	Aluminum foam height, in.
C	Numerical constant, deg C/W
Ht1, Ht2, Ht3	Temperatures at heat sink/heater interface

DEDICATION

I dedicate this thesis to my family for their love and support,

and to the greatest gifts God's given me: my wife,

Martha Lopez, and my son.

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CHAPTER I

INTRODUCTION

Computers have become one of the most widely used products in the world. Their influence in our everyday life is enormous, as they are utilized in almost every store, and even young kids learn to use one before going to school. Since many people's style of living depends on computers, a growing interest to produce faster computers exists worldwide. This need has resulted in a demand for improved microchips, with more power density than before. Nevertheless, these innovations also produce excessive amounts of waste heat that could damage or destroy computer components.

The heat generated by computer CPUs (central processing units) requires the use of heat exchangers (i.e., heat sinks) to dissipate the excess heat and keep the temperature below the unit's maximum operational temperature. These heat sinks are used to maximize the physical cooling area, and a fan is usually used to force air through the heat sink's fins. Fans' performance depends on the physical size, type of support bearings, fan speed, and propeller blade design. The performance of heat sinks, on the other hand, depends on their thermal conductivity, the size of the exposed surface areas and their geometry, especially the fin geometry and its dimensions, fin number and material. Heat sinks are

usually classified as passive or active. Active heat sinks consist of a heat sink with a fan attached to the top (the fins), which provides airflow to the fins and the base, thus cooling the heat sink by means of air impingement. Passive heat sinks, on the other hand, do not include a fan on top, and are cooled by means of air running through the fins only, using one or two system fans. With the increasing demand for high-power electronic components such as high-speed microprocessors, the need for improved, optimized heat sinks has grown.

The latest heat sinks are manufactured with fans attached on top (active heat sinks), which provide better heat dissipation to the entire assembly. These fans reduce the temperature at the fins and on top of the heat sink base, improving the heat transfer through the heat sink, according to the formula $Q = -kA\,dT/dx$, thus reducing the temperature of the component (in this case, the CPU). In the formula, Q is the power dissipated, k is the thermal conductivity of the material, A is the cross-sectional area of the heat sink, dT is the temperature distribution through the material, and dx is the thickness of the heat sink. Nevertheless, these fans increase the cost of the cooling solution.

Another modification that new heat sinks present is an increase in size. Due to consumer preference, computer cases are restricted to a certain size, which in turn, limits the dimensions of the heat sink that can be used. Since computers are expected to become faster every year, a new way to improve heat dissipation must be found.

1.1 PROBLEM STATEMENT

The objective of this study is to test existing heat sinks to record their performance (i.e., thermal resistance), applying different power loads to them. This data will be compared with published values and, depending on their accuracy, recorded in a chart to use it as a reference. In addition, two prototype heat sinks will be tested under the same conditions to determine their performance and compare it to that of the heat sinks previously examined. The new heat sinks to be tested consist of an aluminum-foam heat sink, and a PCM-filled heat sink. These modifications aim at optimizing the heat dissipation without increasing the size (volume) of the heat exchanger.

1.2 LITERATURE REVIEW

Different studies have been done to investigate the performance of heat sinks and to optimize their operational abilities. Chang [4] analyzed a 30-W socketed CPU of a desktop computer with minimum airflow rate and minimum heat sink size using CFD, utilizing only the fan in the power supply for all air movement in the chassis. A duct was utilized to direct airflow through the heat sink, and the results were compared to those of an unducted design.

A study to optimize the fin array geometry of a heat sink that would minimize the average heat sink temperature for steady state and intermittent duty cycle operation was done by Morrison [2]. The experiments were done on a heat sink with rectangular cross section fins at a constant fin spacing. The study

assumed uniform temperature throughout the entire heat sink to optimize the sink fin configuration based on the sink temperature.

In a report done for Intel Corporation [5], the problem of designing faster computers was studied. In this report, it was concluded that thermal design was not to be treated in isolation, and the main factors that determine the performance of heat sinks were discussed. Different existing heat sinks were described, pointing out their advantages and their tradeoffs, such as higher cost or difficult manufacturability. The use of phase-change materials is mentioned in this study, but it only describes its use as an outstanding thermal interface between the component and the heat sink.

Mansuria and Kamath [3] performed a study to optimize the heat-sink/fan assembly by testing different geometries (pin-fins, straight-fins and radial-fins) to determine which one produced the best heat transfer rates. Although their experimental setup does not describe the placement of thermocouples, it is assumed that they were utilized to measure the temperature of the apparatus, as well as the ambient temperature. The results showed that the radial-finned heat sink provided better heat dissipation than pin-fin and straight-fin heat sinks.

Copeland [7] analyzed parallel plate heat sinks. In this study, the dimensions of fin thickness and pitch were optimized to reduce the resistance of the heat exchanger for specific operating conditions such as pressure drop, fan power or fan curve and heat sink outer dimensions. The results also allowed for the comparison of different heat sink technologies such as extruded, forged, and bonded.

CHAPTER II

EXPERIMENTAL INFORMATION

In order to utilize a satisfactory setup, information was gathered about the setups used in industry. COFAN USA [6], manufacturer of heat sink/fan units, utilizes 3 thermocouples, connecting them between the heater and the heat sink, and an additional one to record the ambient temperature. With the values found, they calculate the thermal resistance using the formula: $R = [(Ht1 + Ht2 + Ht3)/3 - TA]/Power$, where Ht1, Ht2, and Ht3 are the temperatures recorded at the thermocouples located on the bottom of the heat sink, TA is the ambient temperature, and Power is the power applied to the heater. The setup also includes an insulator under the heater, so that the heat transfer is one-dimensional, going up through the heat sink. From this company, two articles were compared, one for a 650 – 1000 MHz heat sink and another for a 266 – 433 MHz. The main difference between these two heat exchangers was the size, which increased considerably, while the setup was identical.

A different setup is utilized by Intel [9], where only one thermocouple is used to measure the temperature of the component. The thermocouple is connected to the component at its center top surface, drilling a hole through the heat sink. The ambient temperature is not measured; instead, it is calculated by

the following equations: $T_a = T_c - (P^*\Theta_{ca})$ and $\Theta_{ca} = \Theta_{ja} - \Theta_{jc}$, where T_a is the ambient temperature, T_c is the case temperature, Θ_{ca} is the case-to-ambient resistance, Θ_{ja} is the junction-to-ambient resistance, Θ_{jc} is the junction-to-case resistance, and P is the maximum power consumption.

2.1 EXPERIMENTAL SETUP

The setup used in this study, illustrated in Fig. 2.1, utilizes a similar approach as COFAN, though it differs in various aspects. Two thermocouples (instead of three) are used to measure the temperature at two points close to the center of the heater. Since the center of the heater is assumed to reach a higher temperature, the thermocouples are positioned close to it to improve accuracy. This setup is used for the Pentium w/MMX heat sink, as it is too small to justify a third thermocouple. For the Pentium Pro® heat sink, as well as the prototype heat sinks, three thermocouples were used to further improve the accuracy of the results. Kapton flexible heaters are used to replicate the heat produced by a computer's CPU (central processing unit). A block of wood is positioned on the bottom of the heater to provide insulation, thus keeping the heat flow upwards, through the heat sink. The two thermocouples are connected between the heater and the heat sink being used to measure the temperatures at these points. Another thermocouple is used to record the ambient temperature. The thermocouples are then connected to a data acquisition card to collect the data using a LabVIEW program. The values obtained are then compared to published data found on the Internet as well as in books. The accuracy of these values

validates the setup and allows us to utilize it for two new heat sink designs: the aluminum-foam and the PCM-filled heat sinks.

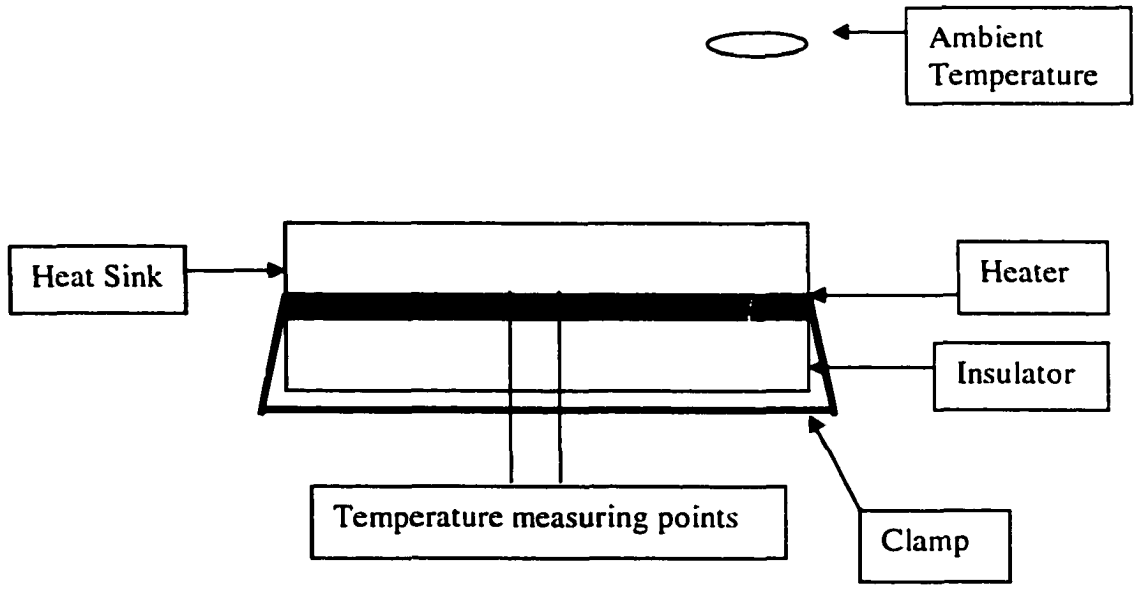

Fig. 2.1: Experimental Setup

2.2 ALUMINUM FOAM INFORMATION

Aluminum foam is a material developed by ERG [8] that is now available to be used in thermal management applications. Its manufacturing process enables this material to possess not only all of the properties of the metal such as corrosion resistance, acceptance of coatings, and more importantly, electrical and thermal conductivity, but also properties such as low density, high strength to weight ratio, high porosity and extremely large surface area (which increases the convection heat transfer). The process also allows the development of products with variable porosity (from 5 to 40 pores per inch) and variable density (from 3 to 50 percent). Fig. 2.2 illustrates examples of aluminum foam products.

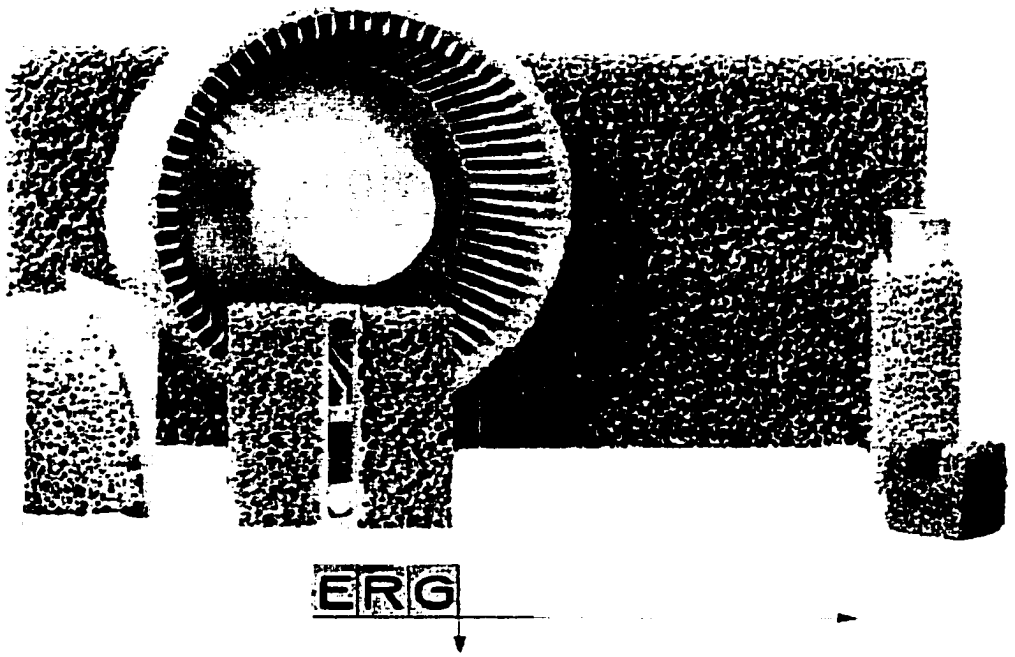

Fig. 2.2: Applications of Duocel Aluminum Foam, from [8].

The use of aluminum foam on heat sink technology gives the product several advantages over existing heat sinks. The high surface area to volume ratio increases the heat flow through convection. All-aluminum brazed joints provide continuous, high-conductivity heat paths, and over 90% porosity results in only small pressure drops.

2.3 PHASE-CHANGE MATERIAL INFORMATION

Phase-change materials have been used in the past, though for other purposes. As their name indicates, PCMs are materials that change phase (liquid to solid or vice versa) when they reach a certain temperature. Most materials known today are capable of changing phase (melt, solidify) when a heat load is applied to them. When a material changes from solid to liquid

(melts), it absorbs energy, or heat, as some bonds are broken. When this same material changes from liquid to solid, it releases energy. The difference between regular materials and PCMs is that PCMs undergo this transformation in a very short temperature range.

The PCM-filled heat sink consists of a hollow aluminum heat sink. For my experiments, the housing will be kept simple (due to manufacturing limitations), although an optimal design will be discussed and described. Inside the copper housing, the PCM to be used will be contained in tiny microcapsules that will be suspended in oil. These microcapsules have a diameter of 40-60 microns.

There exist different phase-change materials, each with a different melting temperature. Since it is required for the PCM to change phase before the component reaches its critical temperature to absorb energy, the PCM candidates were selected based on their transition temperature. The PCMs used are Thermasorb® 95 and Thermasorb® 122, developed by Frisby Technologies, with a melt range of 17-38 °C and 46-56 °C and a ΔH of 188 J/g and 159 J/g, respectively. Other important properties of these PCMs are listed in table 2.1. These materials will increase the heat sink's thermal dissipation by means of their specific heat. According to a study done by NASA [1], Thermasorb additives can increase the effective heat transfer by as much as 40 times (4000%).

Name	ΔH (J/g)	Melt Range (°C)		
		Start	Peak	End
Thermasorb® 95	188	17	33	38
Thermasorb 122	159	46	52	54
Average Physical Properties:				
Cp, solid	1.88	Cp, liquid	2.13 J/g - °C	
K, solid	0.179	k, liquid	0.170 W/m - °C	
ρ, solid	0.81	ρ, liquid	0.78 g/cc	

Table 2.1: PCM Materials and their properties

The principle behind this design is simple. As the heat sink is heated, the PCM in the microcapsules will melt, absorbing heat. The capsules with the molten PCM will then have to be moved to a cooler place to solidify and release the heat. Upon releasing the heat absorbed, the capsules must return to the warm side of the heat sink to allow a continuous (repeating) process. Fig. 2.3 illustrates this principle.

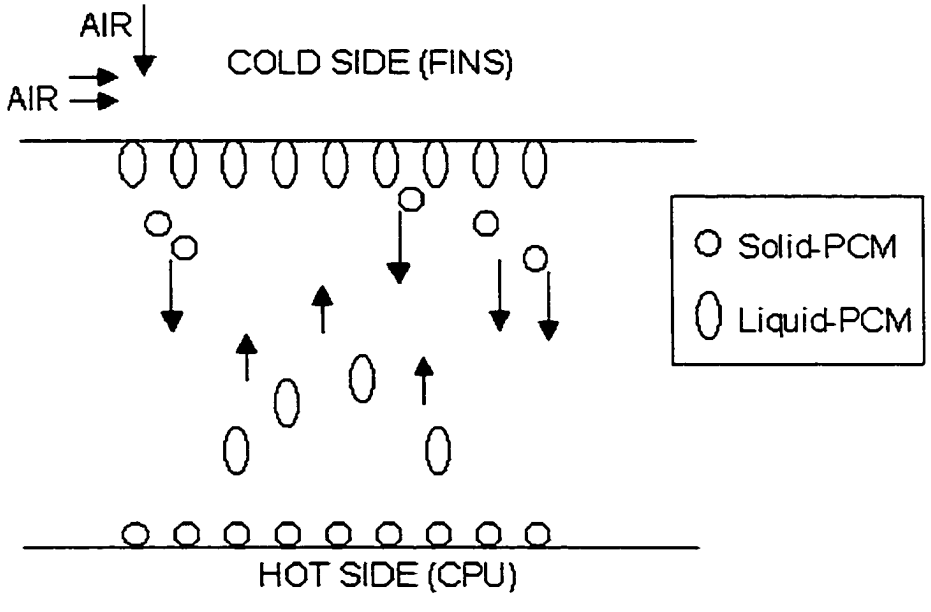

Fig. 2.3: Schematics of PCM-filled heat sink

In order for the PCM-filled heat sink to work, the PCM microcapsules must stay on the bottom of the cavity when solid and rise through the heat sink fins when liquid. Thus, the oil used inside the heat sink is selected based on its density and viscosity. The density of the PCMs is approximately 0.81 g/cc when solid and 0.78 g/cc when liquid, so the density of the oil must be between these values. In addition, its viscosity should be as small as possible to improve movement of the capsules inside the cavity.

CHAPTER III

ANALYSIS

3.1 VALIDATING THE EXPERIMENTAL SETUP

The first experiments were performed on the heat sink used by Tiger® Computers with the 200 MHz Intel® Pentium® processor with MMX™ technology. Table 3.1 lists the processor's performance data.

Intel Pentium with MMX technology (P55C)									
	Core Voltage	Abs. Max. Core Voltage	I/O Voltage	Abs. Max. I/O Voltage	Max. Core Amp.	Max. I/O Amp.	Typical Power Dissipation	Maximum Power Dissipation	Max. Case Temp.
P55C-200	2.8V (2.7~2.9V)	3.7V	3.3V (3.135~3.6V)	4.0V	5.7A	0.65A	7.3W	15.7W	70°C

Table 3.1: Performance Data for 200 MHz Intel MMX processor.

The thermocouples used in the experiments were first calibrated using a thermal bath to accurately apply the same heat load to all of them. Appendix B contains pictures of the calibration as well as the experimental setup for both processor types (Pentium® MMX™ and Pentium® Pro). In order to make the experiments as close to real situations as possible, the assembly was placed inside the

chassis. Figs. 3.1 and 3.2 illustrate the experimental setup, although the fan shown on top of the heat sink was not used to be able to compare it to Intel's data. The temperature shown in Fig. 3.2 is the ambient temperature for that experiment. In addition to the chassis, Fig. 3.2 also shows the digital power supply as well as a digital multimeter.

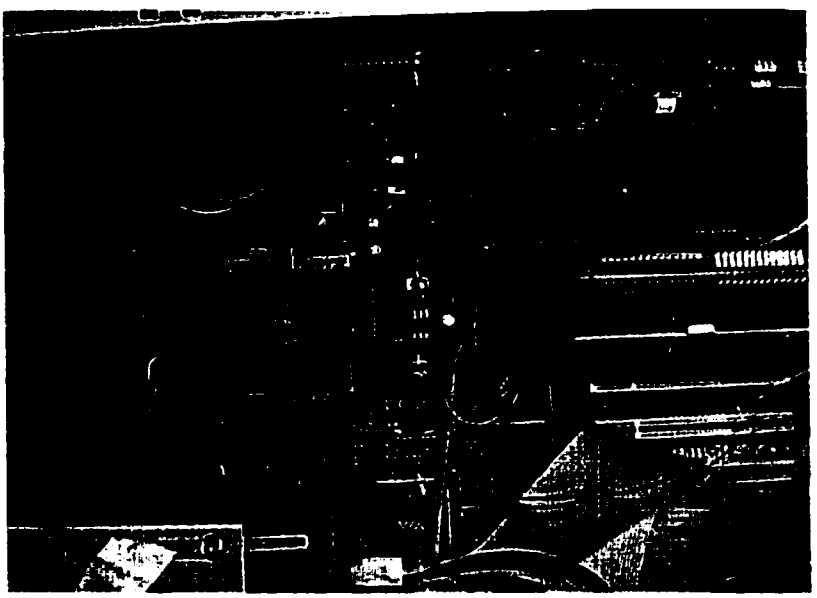

Fig. 3.1: Assembly inside the computer chassis.

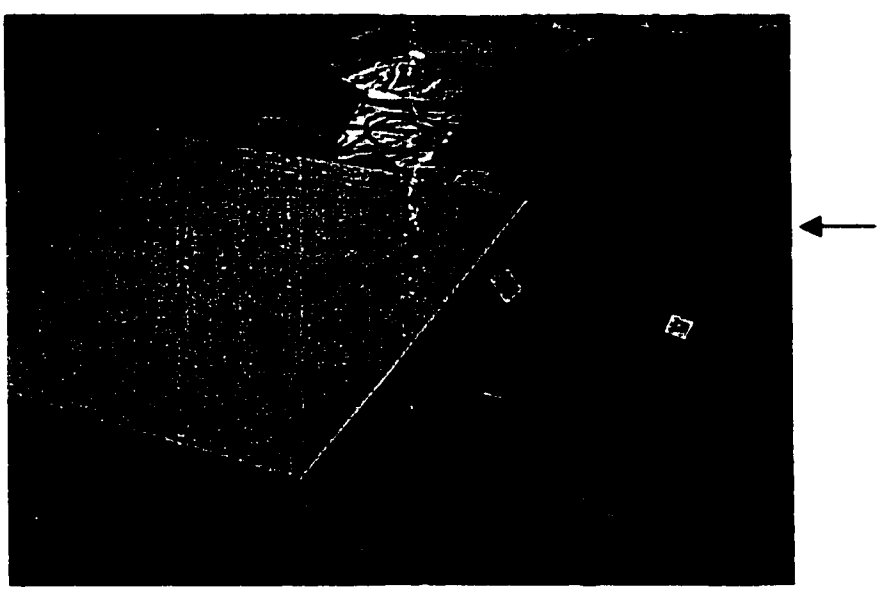

Fig. 3.2: Experimental Setup with chassis closed.

The heater is connected to the digital linear power supply (in Fig. 3.2, the device in the middle) to accurately input the power to the system. The power is further measured with a digital multi-meter to test its accuracy. The heater was set to different power inputs and allowed to reach steady state. The final (average) values obtained are listed in Table 3.2, and the complete data sets are shown in Appendix A. The graph shown on Fig. 3.3 represents the thermal resistance. As you can see, the experimental values tend to get closer to Intel's published resistance. The thermal resistance values listed are obtained using the equation: $R = [(Ht1 + Ht2)/2 - TA]/Power$, or $R = \Delta T/Q$ (solving the conduction heat transfer equation in terms of $R = k/\Delta x$).

Power (W)	Ht1 (°C)	Ht2 (° C)	Tavg. (° C)	TA (° C)	Resistance (° C/W)
9.98	56.23	55.43	55.83	23.2	3.27
10.02	57.05	57.02	57.04	23.3	3.37
13.248	66.46	65.51	65.99	24.6	3.12
19.628	86.86	84.38	85.62	24.8	3.10

Average Resistance: 3.215 deg C/W **Intel's Resistance: 3.100 deg C/W**

Table 3.2: Results for 200 MHz Pentium w/MMX technology processor experiments.

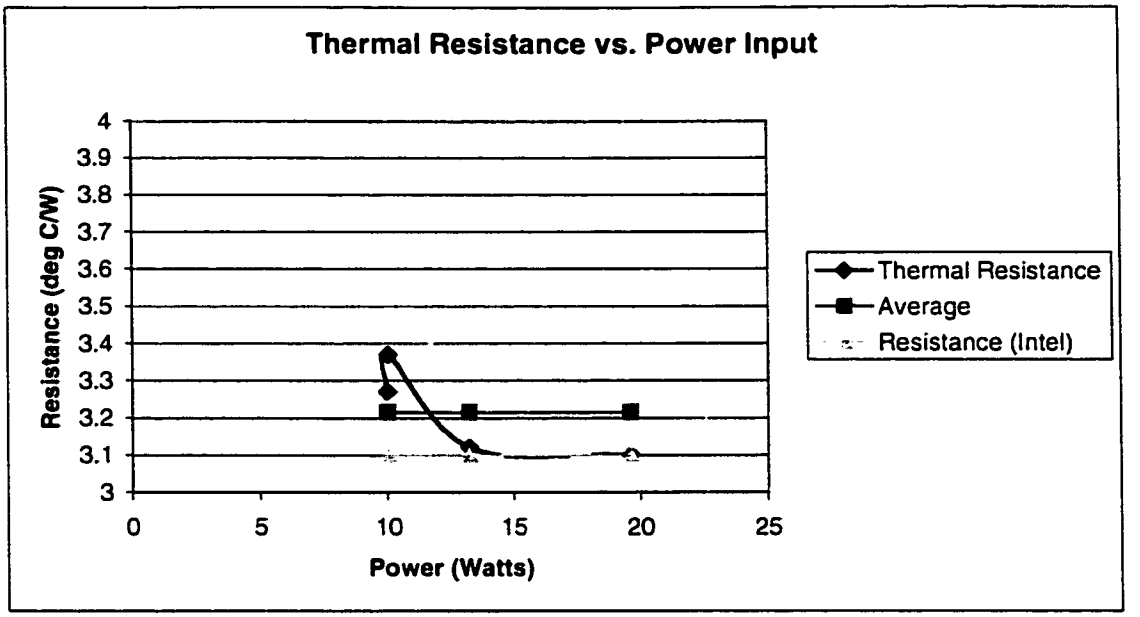

Fig. 3.3: Thermal Resistance for heat sink used for Pentium w/MMX technology.

These values indicate less than a 3.8% error, thus validating the setup to perform the experiments.

3.2 DEVELOPING EXPERIMENTAL BENCHMARKS

After validating the experimental procedures, the heat sink used on the Pentium Pro® processor is tested. The values found are used as benchmark to measure the performance of the new heat sinks, as their dimensions are similar to this heat sink. The same setup was utilized for the Pentium® Pro processor, though the chassis used was different. A third thermocouple was added to the experiments to further improve the accuracy of the measurements. The characteristics of the processor are listed in Table 3.3.

Intel Pentium Pro (P6)						
	Voltage	Abs. Max. Voltage	Max. Amp.	Typical Power Dissipation	Maximum Power Dissipation	Max. Case Temp.
P6-150 (256KB L2)	3.1V (2.945V~3.255V)	4.7V	9.9A	23W	29.2W	85° C
P6-200 (256KB L2)	3.3V (3.135V~3.465V)	4.7V	11.2A	27.3W	35W	85° C

Table 3.3: Performance Data for 150 and 200 MHz Intel Pentium Pro® processors.

Fig. 3.4 illustrates the setup for the second series of experiments. As it is shown, this heat sink is considerably possesses dimensions that are easier to replicate than those of the MMX heat sink. The fan is removed to have a better view of the complete apparatus. The complete setup is shown in Fig. 3.5.

Fig. 3.4: Experimental setup for the 200-MHz Intel Pentium Pro® processor (no fan).

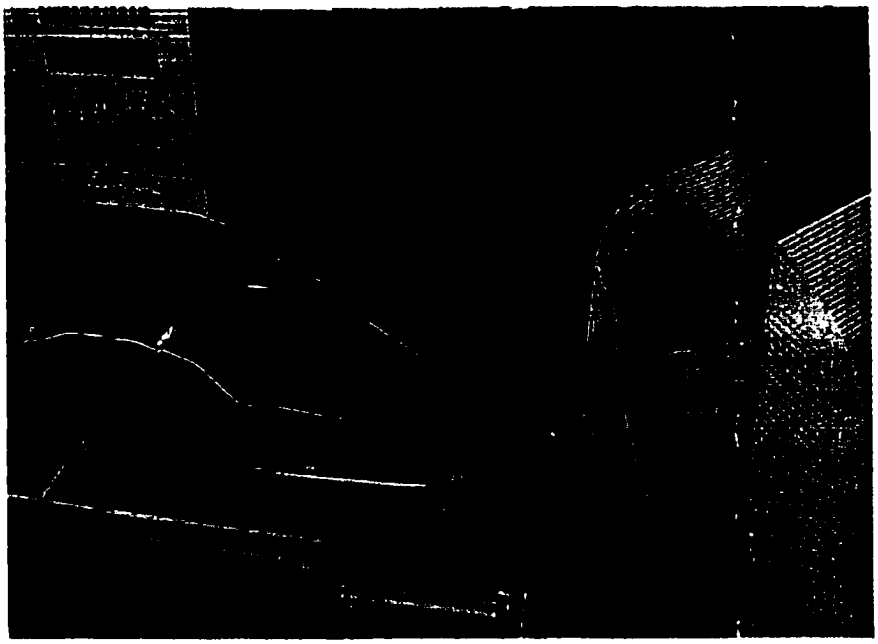

Fig. 3.5: Complete setup with fan above heat sink.

In this case, two heaters were connected, as each of them possesses a 28-V input limit, which results in 19.85 Watts of input. The experiments were repeated to check the accuracy of the results. Table 3.4 lists the average temperatures of each experiment, as well as the thermal resistance. The complete data set is contained in Appendix A.

Power (W)	Ht1 (°C)	Ht2 (°C)	Ht3 (° C)	Tavg. (° C)	TA (° C)	Resistance (° C/W)
14.454	32.758	31.387	31.481	31.875	25.3	0.455
16.985	34.282	32.661	32.754	33.232	25.4	0.461
19.719	36.113	34.288	34.434	34.945	25.5	0.479
22.71	38.068	36.019	36.215	36.768	25.2	0.511
25.79	40.096	37.836	38.050	38.661	25.8	0.499

Table 3.4: Results for 200-MHz Intel Pentium Pro® processor experiments.

The resistance found is recorded and compared to those of the new heat sinks after proper testing is performed on them.

After developing a benchmark, the aluminum-foam heat sink and the PCM-heat sink are tested under the same operating conditions and applying the same power loads to them. Since the aluminum foam samples to be tested are relatively smaller, they are tested using the same power inputs and numerical relationships are developed to calculate their thermal resistance using surface area and height ratios. In the case of the phase-change material, a simplified aluminum heat sink is built with only five fins, welding aluminum pieces together, which in turn decreases the heat sink's homogeneity. This heat sink is hollow, and contains the PCM microcapsules, suspended in oil. The oils that can be used (according to their density) are listed in Table 3.5.

Oil Name (company)	*Viscosity (mPa*s)*	*Density (Temp) (g/cc)*	*For use with:*
Isopar™ V (ExxonMobil)	12.32	0.819 (15 deg C)	Thermasorb 122
Varsol™ 1 (ExxonMobil)	_	0.77-0.82 (15 deg C)	Thermasorb 95
Varsol™ 60 (ExxonMobil)	1.22	0.801 (15 deg C)	Thermasorb 95
Varsol™ 80 (ExxonMobil)	1.61	0.814 (15 deg C)	Thermasorb 95
Varsol™ 110 (ExxonMobil)	3.60	0.846 (15 deg C)	Thermasorb 122
Exxsol™ D 100S (ExxonMobil)	3.15	0.815	Thermasorb 95
Exxsol™ D 110 (ExxonMobil)	3.66	0.825 (15 deg C)	Thermasorb 122
Synthetic ATF (Mobil 1)	_	0.838 (15 deg C)	Thermasorb 122

Table 3.5: List of oils used with PCMs and their properties.

CHAPTER IV

TESTING ALUMINUM-FOAM HEAT SINK

In order to be able to compare the performance of aluminum-foam heat sinks to that of the Pentium Pro heat sink, we would need to build one similar to it, i.e., with the exact same dimensions. Due to limitations pertaining to this research, this ideal scenario is not possible. For that reason, available samples were compared against each other using different variables (density, height, and cross-sectional area) to develop extrapolation values that approximate the thermal resistance of such an ideal heat sink prototype. The steps taken to accomplish this approximation are described below.

4.1 COMPARING FOAMS WRT DENSITY

Aluminum foam is a relatively new material that is now available for thermal applications. For this reason, only a few samples were provided by its manufacturer, and are shown in Fig. 4.1. The three specimens shown on the bottom center possess similar dimensions, making them ideal for the experimental procedure. Table 4.1 illustrates the differences in heat sink dimensions. The values are kept in English units for accuracy purposes, and because they do not affect the final results of this research.

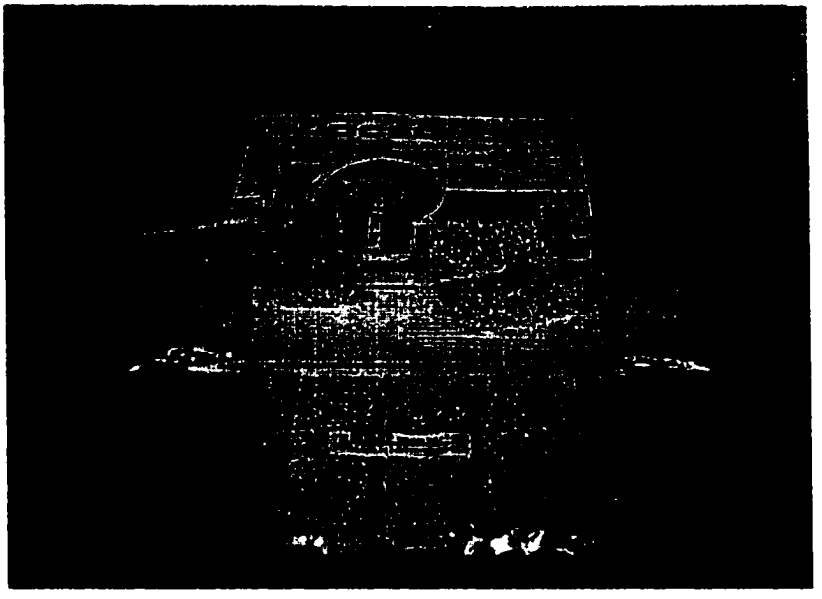

Fig. 4.1: Aluminum foam samples, from Duocel®.

Heat Sink Type	Cross-sectional Area (in^2.)	Height (in.)
Pentium Pro®	7.8125	1.00
Aluminum Foams	5.25	0.50

Table 4.1: Comparison of dimensions between heat sink types.

The original aluminum samples will be tested to compare them to each other and to the Pentium Pro® heat sink. Then, the samples will be cut, changing only one variable at a time (x-sectional area or height) to develop the extrapolated data that will be compared to the Pentium Pro® heat sink.

In order to perform the experiments, the foam samples were first bonded to an aluminum substrate using GBWeld® Aluminum bond to keep the pieces as homogeneous as possible. The substrate is used as the heat sink base, and it is used to increase the contact surface between the heat sink and the CPU (in this

case, the film heater), thus improving the rate of thermal dissipation. The foam specimens are shown in Fig. 4.2.

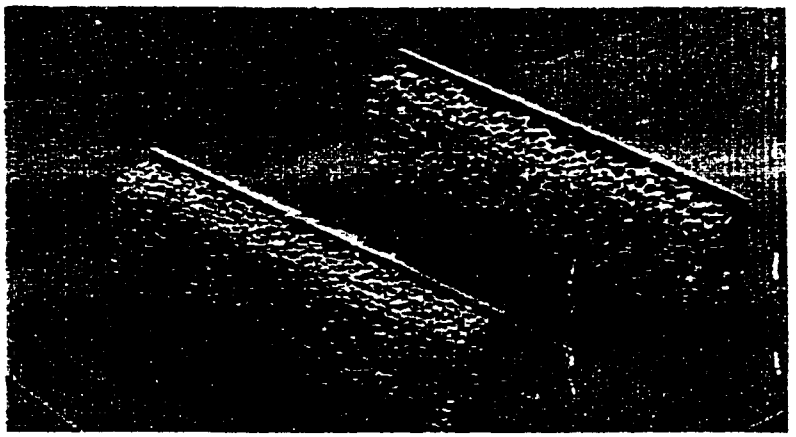

Fig. 4.2: Foams bonded to aluminum substrate, ready for testing.

After the bonding substance hardened, the pieces were tested utilizing the same experimental setup and procedure used with the Pentium Pro® heat sink, including the power inputs being applied to compare their performance. This same procedure is used throughout this complete study. The data obtained from these experiments is illustrated in Table 4.2, which shows only information about Foam 1.

Power (W)	Ht1 (°C)	Ht2 (°C)	Ht3 (° C)	Tavg. (° C)	TA (° C)	Resistance (° C/W)
14.52	47.349	45.822	45.76	46.31	24.3	1.516
17.056	51.559	49.854	49.737	50.383	24.6	1.512
19.768	56.06	54.213	54.051	54.775	24.7	1.521
22.65	60.775	58.811	58.533	59.373	24.8	1.526
25.7839	66.028	63.89	63.471	64.463	24.9	1.534

Table 4.2: Results for the experiments performed on the aluminum foam 1 heat sink.

The resulting thermal resistances of these experiments are shown in Fig. 4.3, and the complete data and setup illustrations are shown in Appendix C and D, respectively. This first set of tests was performed to determine the effect of density on thermal dissipation, and to investigate if there is a pattern in foam performance with respect to density.

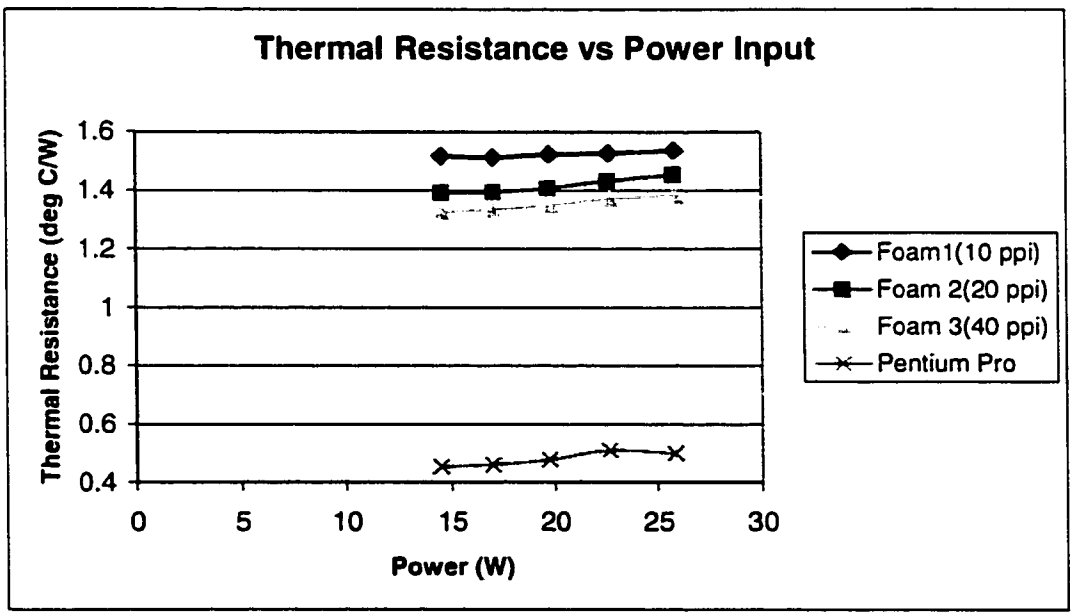

Fig. 4.3: Thermal Resistance of Aluminum Foams and Pentium Pro heat sinks.

The results show that the aluminum foams follow a specific path independent to density; that is, the thermal resistance has a similar slope, no matter what the density is. This fact enables us to change a given variable in one of the foams (i.e., height) and to assume that the other foams will behave similarly if the same variable is altered on them. Also, foam 3 (40 pores per inch) was found to possess a lower thermal resistance; in other words, the thermal resistance decreased with increasing density.

4.2 COMPARING FOAMS WRT CROSS-SECTIONAL AREA

The next step is to find a relationship between the cross sectional area of the foams and their thermal resistance, keeping the height at a constant 0.5 in. Assuming that all the foams will behave similarly, only Foam 2 is used for this group of tests. The pieces are shown in Fig. 4.4.

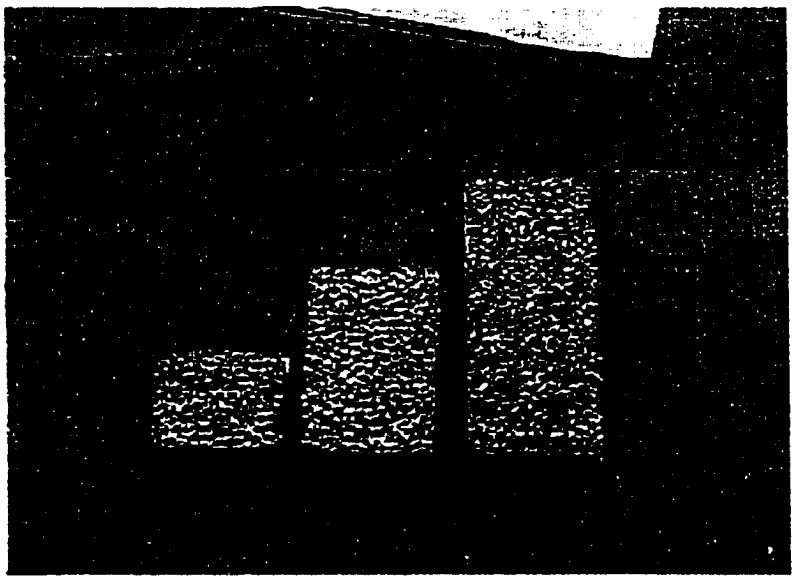

Fig. 4.4: Aluminum foam pieces studied, with different x-sectional area.

The specimens were tested under similar operating conditions, and the thermal resistances are compared in Fig. 4.5. The data set for the smallest foam sample is listed in Table 4.3. Again, the complete data set and experimental setup are shown in Appendix C and D, respectively.

Power (W)	Ht1 (°C)	Ht2 (°C)	Ht3 (° C)	Tavg. (° C)	TA (° C)	Resistance (° C/W)
14.502	64.77	61.206	62.916	62.964	25.0	2.618
17.004	72.169	67.809	70.610	70.196	25.7	2.618
19.712	79.898	74.901	78.866	77.889	26.0	2.632
22.56	87.506	82.621	88.908	86.345	25.9	2.679
25.656	96.939	91.331	98.679	95.649	26.2	2.707

Table 4.3: Results for the experiments performed on Foam 2 (XA = 1.75 in^2.).

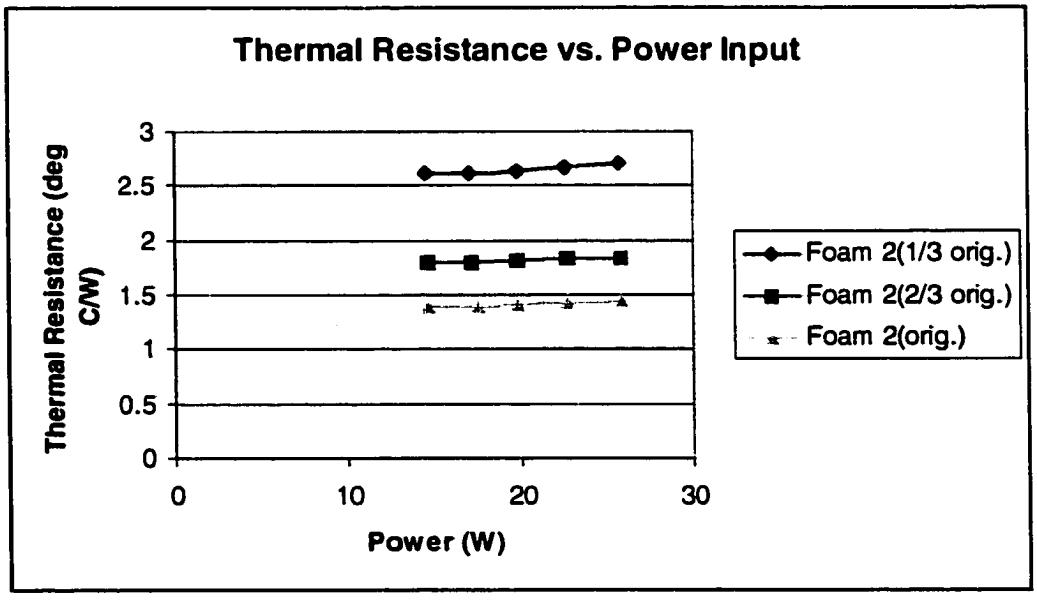

Fig. 4.5: Thermal Resistance for Foam 2, with different x-sectional areas (height is constant, h=0.5 in.).

The average resistance for each sample was calculated from these results, and then plotted into a graph to compare them to the Pentium Pro's average resistance. The graph is shown in Fig. 4.6.

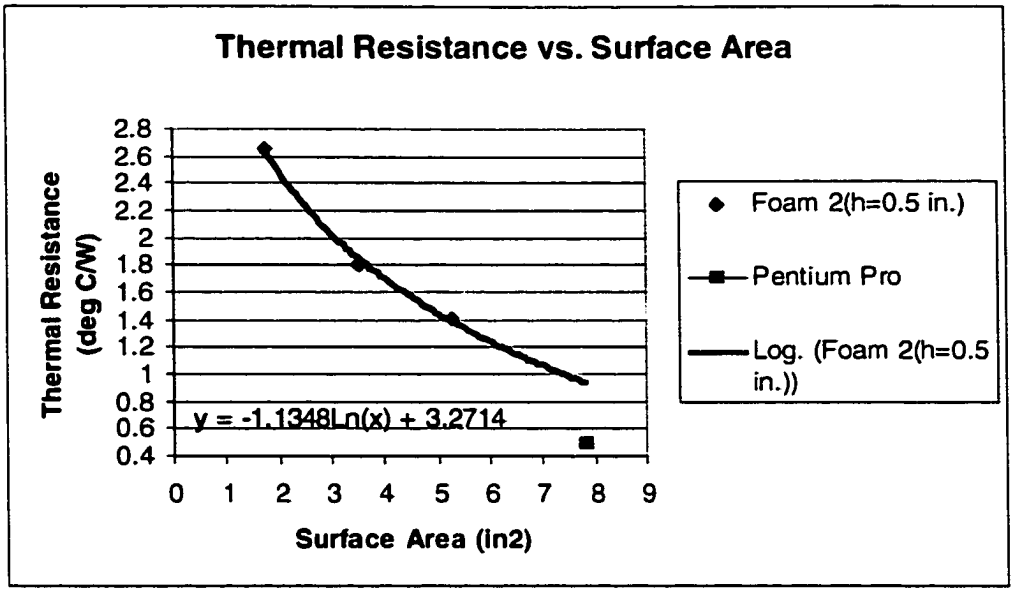

Fig. 4.6: Average thermal resistances (log fit) for Foam 2.

The graph shows that a heat sink made of foam 2 (20 ppi), with a cross-sectional area equal to that of the benchmark, but with "fins" half as high (0.5 in. compared to 1.0 in.), would possess a thermal resistance of about 0.95 ° C/W.

4.3 COMPARING FOAMS WRT HEIGHT

Assuming (again) that all foams behave similarly, only Foam 1 was used in this series of experiments. In order to develop a pattern using only the height, the original foam 1 was separated from its substrate, cut into two smaller, unequal foams (keeping the x-sectional area constant), and then each was bonded to another substrate (same dimensions). The resulting specimens are shown in Fig. 4.7 (side view).

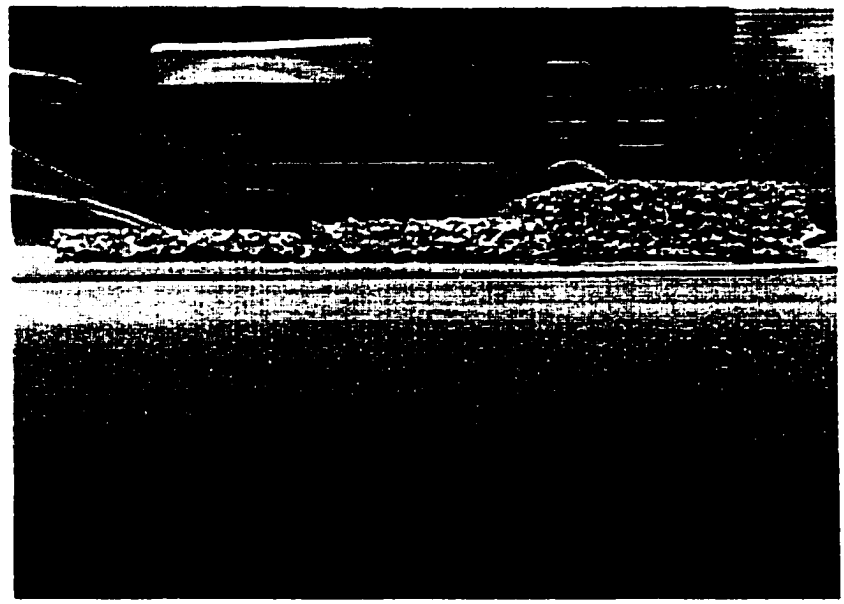

Fig. 4.7: Foam 1 specimens with different heights (constant x-sect. area, XA=5.25 in^2.).

These samples were also tested using the same chassis as with the Pentium Pro® and with the same experimental procedures. The results for the smaller specimen are listed in table 4.4.

Power (W)	Ht1 (°C)	Ht2 (°C)	Ht3 (° C)	Tavg. (° C)	TA (° C)	Resistance (° C/W)
14.574	55.053	53.610	54.105	54.256	24.4	2.049
17.089	60.574	59.484	59.699	59.919	25.2	2.032
19.803	67.102	66.424	66.669	66.731	25.6	2.077
22.718	73.912	73.227	73.469	73.536	25.8	2.101
25.824	81.098	80.339	80.620	80.686	26.2	2.110

Table 4.4: Results for the experiments performed on Aluminum foam 1 (h = 0.1875 in.).

Similar data was obtained for the remaining two foam-1 samples. From this data, the thermal resistances were obtained and compared in Fig. 4.8.

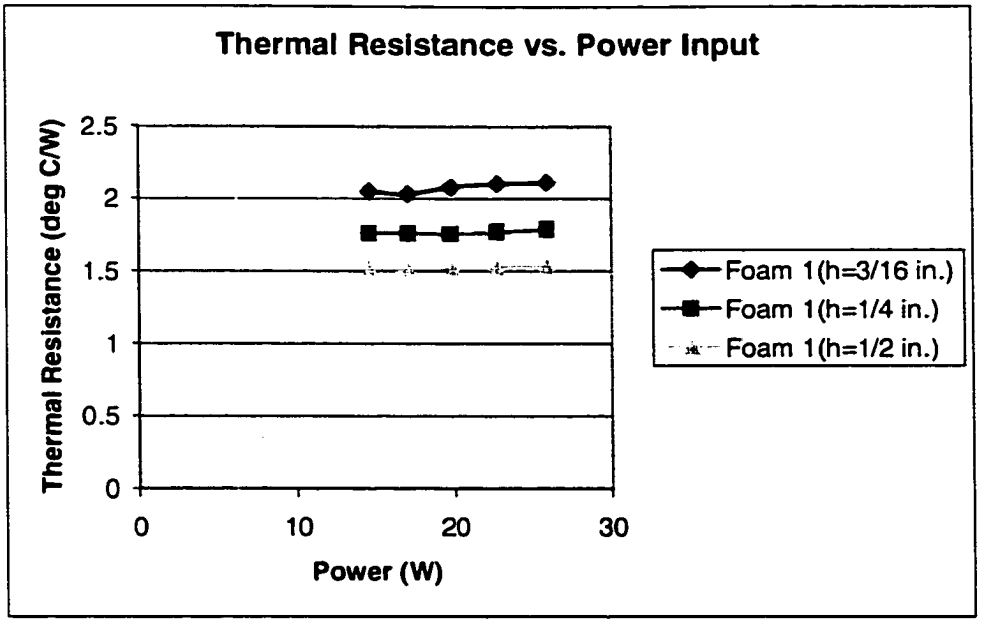

Fig. 4.8: Thermal Resistance of Foam 1 with different heights (constant XA = 5.25 in^2.).

From these results, an average thermal resistance was calculated for each species, and the graph illustrating the averages is shown in Fig. 4.9.

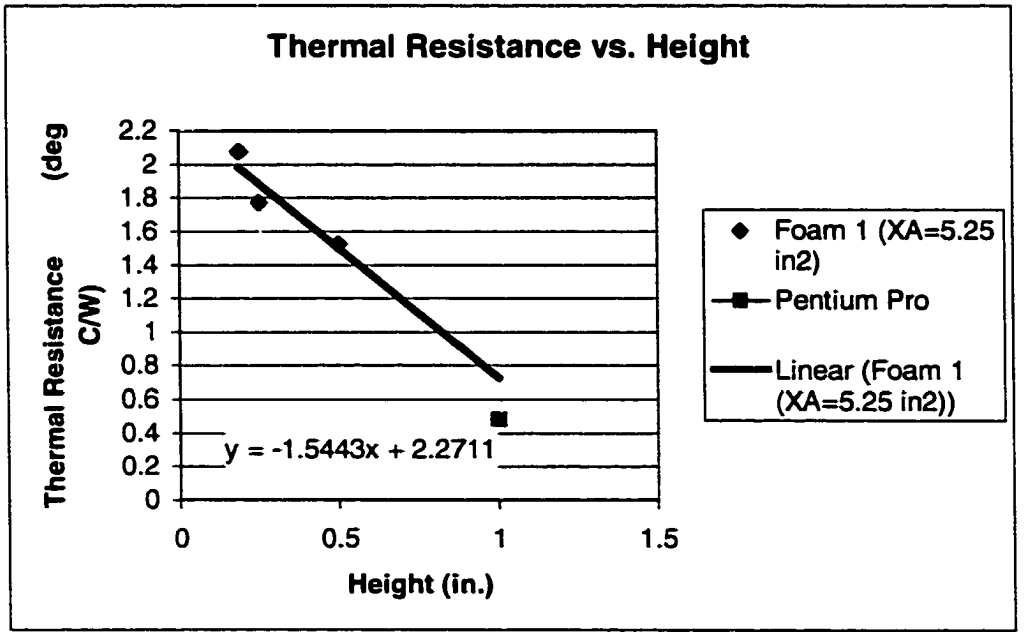

Fig. 4.9: Average thermal resistance for foam 1 samples and Pentium Pro.

As the graph shows, the thermal resistance decreases with increasing height. Extrapolating the resistances indicate that an aluminum foam heat sink made of foam 1 with similar height as the benchmark heat sink, but with a smaller cross-sectional area would have a thermal resistance of approximately 0.7 ° C/W, close to the desired 0.48 ° C/W.

4.3 EXTRAPOLATING THE RESULTS

Using the equations derived from the experimental data, it is possible to extrapolate the values found to approximate the thermal resistance of an aluminum foam heat sink with the exact same dimensions as the Pentium Pro® heat sink. In order to use the best possible aluminum foam heat sink, the calculations will be done using the highest-density foam available to this study: Foam 3 (40 pores per inch).

The average thermal resistance found for foam 3 was 1.35141 ° C/W at XA = 5.25 $in.^2$ and h = 0.5 in. Using the equation for cross-sectional area,

$$R = -1.1348\ln(XA) + C \qquad (1)$$

and substituting the values for R and XA give us C = 3.23317. For XA = 7.8125 $in.^2$, the thermal resistance becomes <u>R = 0.90033 ° C/W</u>.

This value is carried to the next step, using the equation for height. Assuming that the thermal resistance is 0.90033 ° C/W at XA= 7.8125 in. and h = 0.5 in, and with the equation

$$R = -1.5443h + C \qquad (2)$$

the value of C is calculated to be C = 1.67248. Using this value, and changing the height to 1 inch, the thermal resistance becomes

$$R = -1.5443(1) + 1.67248 = \mathbf{0.12818\ ^\circ C/W.}$$

4.4 COMPARING RESULTS

The average thermal resistance calculated by extrapolation is about 3.5 times smaller than that of the Pentium Pro® heat sink. In addition to improving the thermal dissipation without increasing the volume of the heat sink, the aluminum foam decreases the weight of the heat sink utilized, as its density is considerably lower than that of the Pentium Pro® heat sink.

CHAPTER V

TESTING THE PCM-FILLED HEAT SINK

Up to this point, the method of dissipating heat has been a combination of only conduction, convection and radiation. The aluminum foam only improved the thermal dissipation efficiency as it increased the surface-area-to-volume ratio, thus increasing the convective heat transfer. Using phase-change-materials (PCMs), on the other hand, introduces another factor: heat capacity. These materials are contained in microcapsules which, when free to move, are able to absorb heat, transport it, and release it when the material reaches its transition temperature.

In this set of experiments, an aluminum casing is built to house the PCM microcapsules, which are suspended in oil. The oil chosen is Mobil 1® Synthetic ATF, with a density of 0.838 at 0 deg C. The aluminum casing is illustrated in Figs. 5.1 and 5.2. Although this prototype casing was built by welding aluminum pieces together, the process can become highly automated by using different manufacturing means.

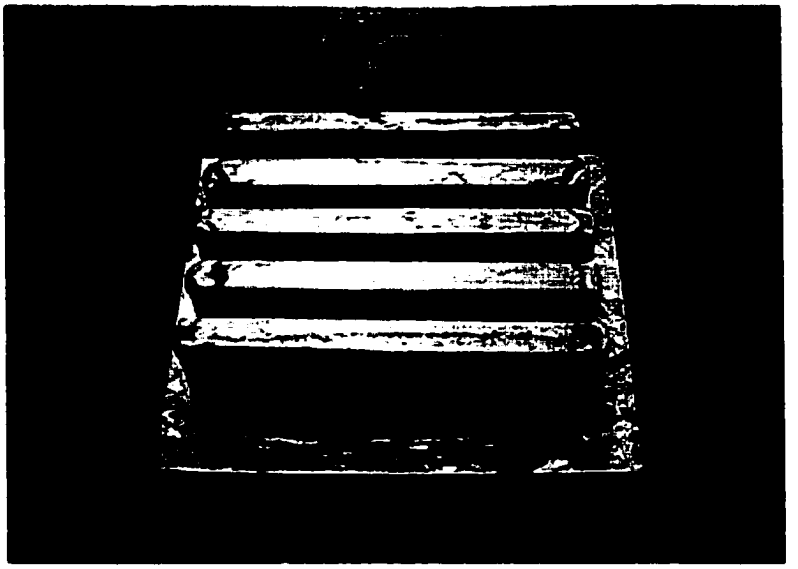

Fig. 5.1: PCM casing, as seen from top.

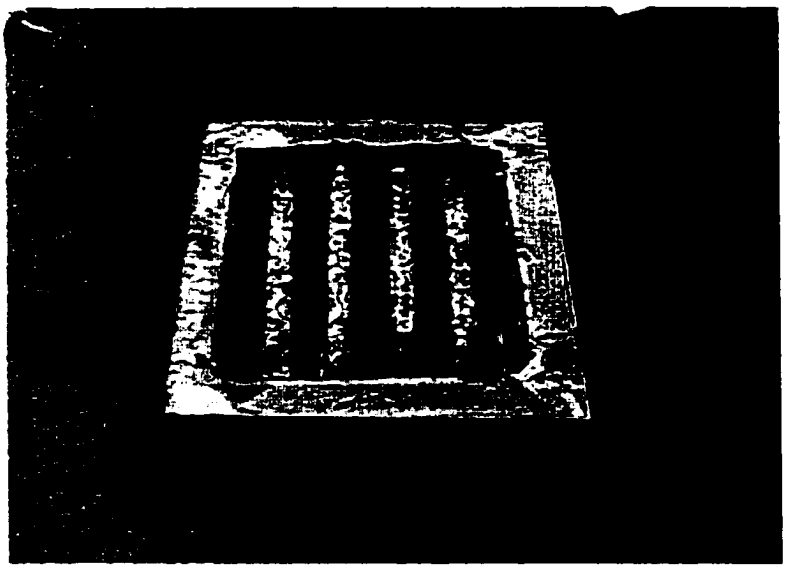

Fig. 5.2: Bottom view of PCM casing (hollow).

Before the experiments were performed, a sample of PCM microcapsules and oil were poured in a beaker and heated to observe the microcapsules working. The film heaters were used to heat the mixture, while a fan was positioned on top to cool the oil surface. The oil reached a temperature of about 43 deg C. The setup is illustrated in Fig. 5.3.

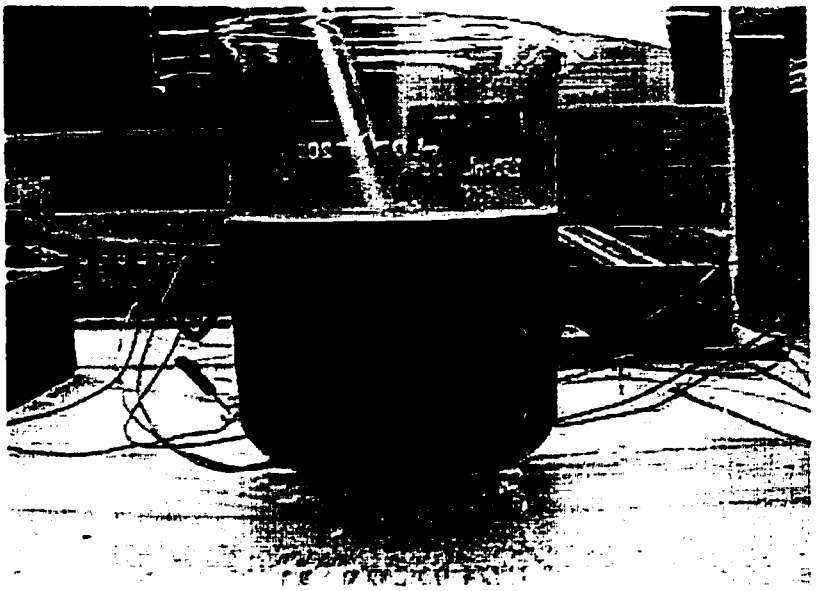

Fig. 5.3: PCM setup, showing the heaters under the beaker.

The figure shows the PCM capsules on the bottom before any load is applied to the setup. As heat is added, the capsules rise because the PCM becomes liquid, and its density decreases. As the capsules reach the top, they become solid again, and their higher density pulls them down to the bottom of the beaker. This process is seen in Fig. 5.4.

Fig. 5.4: PCM capsules seen to rise and drop in beaker (suspended in oil).

The experiment was also videotaped to show the motion of the capsules through the oil.

After demonstrating that the PCM does work, the experiments were performed using different PCM-to-oil ratios. The volume of the aluminum casing was measured to be 78.2 mL. In order to find a relationship between the ratio of PCM-to-oil volume and performance, a volume of 30 and 40 mL of PCM was used with the rest of the cavity filled with oil. The experimental setup and procedures used were the same as with the Pentium Pro® heat sink. Fig. 5.5 illustrates the setup.

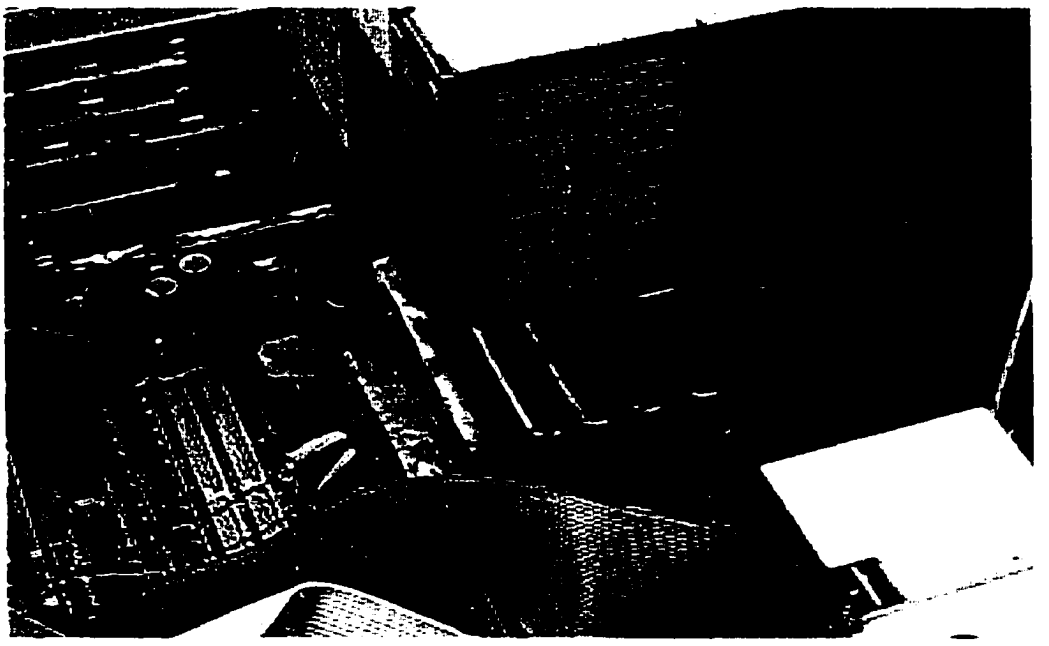

Fig. 5.5: Experimental Setup for the PCM-filled heat sink.

The PCM heat sink was tested using the same setup to compare it to the Pentium Pro® heat sink. Table 5.1 illustrates the data obtained for the

experiment using 40 mL of PCM. The complete data and experimental setup is illustrated in Appendix E and D, respectively.

Power (W)	Ht1 (°C)	Ht2 (°C)	Ht3 (° C)	Tavg. (° C)	TA (° C)	Resistance (° C/W)
14.592	40.778	38.185	40.085	39.683	25.9	0.945
17.082	43.924	40.832	42.938	42.564	26.8	0.923
19.796	47.233	43.630	46.063	45.642	27.0	0.942
25.880	54.785	50.383	53.260	52.701	27.5	0.974

5.1: Data obtained from the experiments performed on the PCM heat sink (40 mL).

The experiment was repeated using only 30 mL of PCM. The resulting thermal resistances are illustrated in Fig. 5.6.

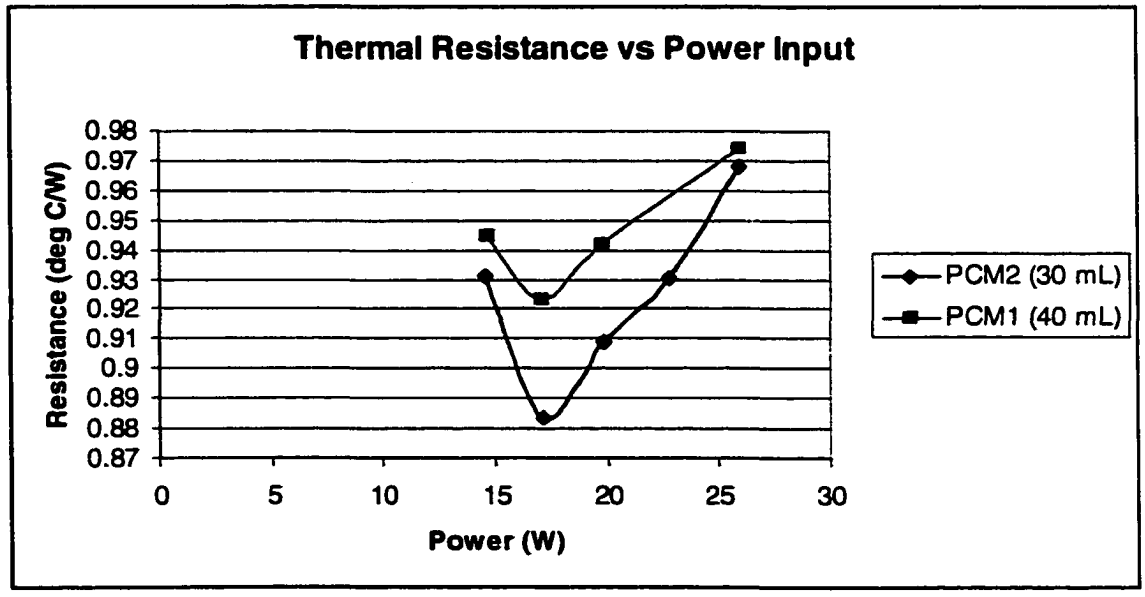

Fig. 5.6: Thermal Resistances for the PCM heat sink using different PCM volumes.

Although the results were not as expected, they show that when the PCM reaches its transition temperature, it decreases the thermal resistance by as much as 0.06 deg C/W. A probable reason for the PCM2 having a lower thermal resistance than the PCM1 could be that there was not enough oil, and the "mixture" was saturated, making it more difficult for the microcapsules to move inside the heat sink cavity.

Another factor that greatly affected the PCM heat sink performance was its smaller surface area (compared to that of the Pentium Pro® heat sink). The PCM heat sink's surface area is 37.7 in^2, while the Pentium Pro® heat sink possesses an area of 52.4 in^2. The calculations performed are listed in Appendix F. The fact that the Pentium Pro® heat sink surface area is 40% bigger represents a considerable disadvantage to the PCM heat sink used; therefore, the PCM heat sink should still be considered for further analysis.

CHAPTER VI

CONCLUSIONS

The results obtained from the tests performed on the aluminum foam heat sink demonstrate that this material provides an advantage on thermal dissipation over most other materials, as it considerably increases the surface-area-to-volume ratio. Its physical characteristics also provide for a smaller pressure drop through the "fins" which, in turn, improves the thermal dissipation by forced convection. In addition, their all-aluminum joints make it possible to have the high thermal conductivity of the material (aluminum), but with lower weight.

The experiments performed on the PCM heat sink do not show such promising results as with the aluminum foam. Nevertheless, the data show that adding PCM to a heat sink can improve the thermal resistance as long as the temperature is +/- 7 deg C from its transition temperature. In addition, the PCM casing was built using a simple design, and the parts were welded together. This, along with the presence of insulation around the casing, may have dramatically decreased the thermal conductivity of the heat sink. In addition, an analysis to calculate the thermal resistance of a solid- aluminum heat sink with the same dimensions resulted in a value of 1.20493 W/°C (see App. F for calculations), considerably higher than that of the PCM heat sink (~0.92 W/°C).

CHAPTER VII

FURTHER STUDY

Although the results from the aluminum foam heat sink show that its thermal dissipation is superior to existing heat sinks, the design can still be improved by building the complete heat sink in one step. The manufacturing process utilized by Duocel® makes it possible to build the "substrate" and the "fins" as one piece, further improving homogeneity and simplifying the building of these heat sinks. This process is possible without a significant increase in cost, and enables the user to build heat sinks with specific substrate thickness and foam height.

The results for the PCM-filled heat sink, on the other hand, do not show an improvement in heat dissipation. Nevertheless, PCM should still be considered for future thermal designs, as it was found to decrease thermal resistance, though thorough design analysis should be performed on the casing. Another way of decreasing the resistance is to use slurry-type PCMs instead of the PCM-oil mixture, increasing PCM volume which, in turn, increases heat capacity. Once a PCM heat sink case has been designed and analyzed, the researcher should remember that, in order for the heat sink to work, the computer chassis

should stand in such a way as to have the CPU and heat sink horizontally, since the PCM's ability to transport heat is driven by gravitational effects.

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APPENDIX A

Data Tables from Pentium® w/MMX™ and

Pentium Pro® Processors

1. Data sheets for the Intel® Pentium® processor with MMX™ technology (no internal fan)

P = 9.98 Watts

Channel 1

Time	Temp. (C)		Time	Temp. (C)		Time	Temp. (C)
2704048.75	56.224		2704046.5	56.225		2704044.5	56.227
2704048.5	56.225		2704046.5	56.226		2704044.3	56.228
2704048.5	56.226		2704046.3	56.224		2704044	56.227
2704048.25	56.226		2704046.3	56.229		2704044	56.226
2704048.25	56.224		2704046	56.227		2704043.8	56.225
2704048	56.224		2704046	56.228		2704043.8	56.228
2704048	56.224		2704045.8	56.223		2704043.5	56.227
2704047.75	56.226		2704045.5	56.227		2704043.5	56.229
2704047.75	56.227		2704045.5	56.227		2704043.3	56.228
2704047.5	56.225		2704045.3	56.227		2704043.3	56.227
2704047.5	56.225		2704045.3	56.227		2704043	56.226
2704047.25	56.225		2704045	56.227		2704043	56.226
2704047	56.225		2704045	56.228		2704042.8	56.229
2704047	56.225		2704044.8	56.228		2704042.8	56.227
2704046.75	56.224		2704044.8	56.229		2704042.5	56.226
2704046.75	56.228		2704044.5	56.227		2704042.5	56.225

Average Temperature: 56.22631 deg C

Channel 2

Time	Temp. (C)		Time	Temp. (C)		Time	Temp. (C)
2704108.75	55.428		2704106.5	55.426		2704104.3	55.425
2704108.5	55.427		2704106.3	55.428		2704104	55.423
2704108.25	55.427		2704106.3	55.425		2704104	55.424
2704108.25	55.429		2704106	55.426		2704103.8	55.424
2704108	55.428		2704106	55.426		2704103.8	55.423
2704108	55.427		2704105.8	55.427		2704103.5	55.424
2704107.75	55.426		2704105.8	55.425		2704103.5	55.424
2704107.75	55.426		2704105.5	55.426		2704103.3	55.423
2704107.5	55.426		2704105.3	55.424		2704103.3	55.424
2704107.5	55.427		2704105.3	55.424		2704103	55.423
2704107.25	55.426		2704105	55.426		2704103	55.424
2704107.25	55.427		2704105	55.426		2704102.8	55.424
2704107	55.426		2704104.8	55.425		2704102.8	55.423
2704106.75	55.428		2704104.8	55.423		2704102.5	55.422
2704106.75	55.427		2704104.5	55.426		2704102.5	55.423
2704106.5	55.426		2704104.5	55.425		2704102.3	55.422

Average Temperature: 55.42529 deg C

P = 10.02 Watts								
Channel 1								
Time	Temp. (C)		Time	Temp. (C)		Time	Temp. (C)	
2716770.25	57.05		2716768	57.055		2716766	57.052	
2716770	57.052		2716767.8	57.054		2716765.8	57.054	
2716770	57.052		2716767.8	57.054		2716765.8	57.052	
2716769.75	57.05		2716767.5	57.057		2716765.5	57.05	
2716769.5	57.051		2716767.5	57.054		2716765.5	57.05	
2716769.5	57.051		2716767.3	57.054		2716765.3	57.05	
2716769.25	57.051		2716767.3	57.052		2716765	57.048	
2716769.25	57.05		2716767	57.056		2716765	57.046	
2716769	57.052		2716767	57.053		2716764.8	57.047	
2716769	57.052		2716766.8	57.053		2716764.8	57.048	
2716768.75	57.053		2716766.8	57.053		2716764.5	57.051	
2716768.75	57.056		2716766.5	57.055		2716764.5	57.049	
2716768.5	57.056		2716766.3	57.053		2716764.3	57.047	
2716768.5	57.056		2716766.3	57.053		2716764.3	57.049	
2716768.25	57.054		2716766	57.054		2716764	57.049	
2716768.25	57.053							
Average Temperature: 57.05198 deg C								
Channel 2								
Time	Temp. (C)		Time	Temp. (C)		Time	Temp. (C)	
2716717.5	57.026		2716715.3	57.027		2716713	57.024	
2716717.25	57.027		2716715.3	57.023		2716713	57.025	
2716717.25	57.026		2716715	57.023		2716712.8	57.026	
2716717	57.027		2716714.8	57.024		2716712.8	57.023	
2716717	57.028		2716714.8	57.023		2716712.5	57.027	
2716716.75	57.026		2716714.5	57.022		2716712.5	57.025	
2716716.75	57.025		2716714.5	57.022		2716712.3	57.024	
2716716.5	57.028		2716714.3	57.022		2716712.3	57.024	
2716716.25	57.026		2716714.3	57.025		2716712	57.025	
2716716.25	57.027		2716714	57.022		2716712	57.027	
2716716	57.026		2716714	57.023		2716711.8	57.026	
2716716	57.025		2716713.8	57.025		2716711.8	57.025	
2716715.75	57.026		2716713.8	57.024		2716711.5	57.026	
2716715.75	57.024		2716713.5	57.024		2716711.5	57.023	
2716715.5	57.027		2716713.5	57.026		2716711.3	57.022	
2716715.5	57.025		2716713.3	57.025				
Average Temperature: 57.02491 deg C								

P = 13.248 Watts								
Channel 1								
Time	Temp. (C)		Time	Temp. (C)		Time	Temp. (C)	
2707492.25	66.452		2707490	66.458		2707487.8	66.463	
2707492	66.455		2707489.8	66.46		2707487.8	66.463	
2707492	66.454		2707489.8	66.458		2707487.5	66.462	
2707491.75	66.455		2707489.5	66.46		2707487.5	66.465	
2707491.75	66.455		2707489.5	66.459		2707487.3	66.463	
2707491.5	66.457		2707489.3	66.46		2707487.3	66.464	
2707491.25	66.458		2707489.3	66.46		2707487	66.463	
2707491.25	66.458		2707489	66.462		2707486.8	66.461	
2707491	66.461		2707489	66.462		2707486.8	66.461	
2707491	66.457		2707488.8	66.463		2707486.5	66.462	
2707490.75	66.457		2707488.8	66.463		2707486.5	66.459	
2707490.75	66.457		2707488.5	66.461		2707486.3	66.461	
2707490.5	66.458		2707488.3	66.462		2707486.3	66.458	
2707490.5	66.459		2707488.3	66.464		2707486	66.459	
2707490.25	66.461		2707488	66.465		2707486	66.459	
2707490.25	66.461		2707488	66.464				
Average Temperature: 66.45998 deg C								
Channel 2								
Time	Temp. (C)		Time	Temp. (C)		Time	Temp. (C)	
2707411.75	65.507		2707409.5	65.509		2707407.3	65.515	
2707411.5	65.507		2707409.5	65.509		2707407.3	65.514	
2707411.5	65.508		2707409.3	65.508		2707407	65.515	
2707411.25	65.507		2707409	65.51		2707407	65.515	
2707411.25	65.508		2707409	65.509		2707406.8	65.516	
2707411	65.509		2707408.8	65.51		2707406.8	65.517	
2707410.75	65.509		2707408.8	65.509		2707406.5	65.517	
2707410.75	65.509		2707408.5	65.512		2707406.5	65.519	
2707410.5	65.509		2707408.5	65.511		2707406.3	65.517	
2707410.5	65.506		2707408.3	65.511		2707406.3	65.515	
2707410.25	65.508		2707408.3	65.511		2707406	65.516	
2707410.25	65.509		2707408	65.511		2707406	65.517	
2707410	65.507		2707407.8	65.512		2707405.8	65.514	
2707410	65.509		2707407.8	65.513		2707405.5	65.514	
2707409.75	65.508		2707407.8	65.512		2707405.5	65.511	
2707409.75	65.508		2707407.5	65.513				
Average Temperature: 65.51128 deg C								

P = 19.628 Watts

Channel 1

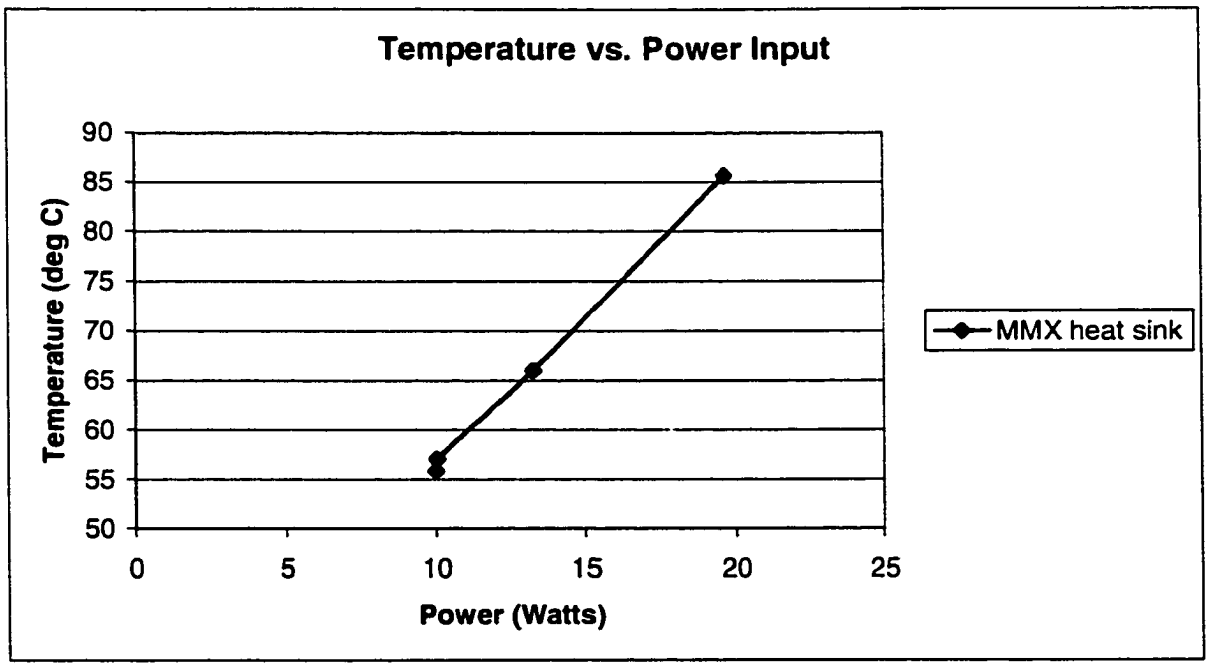
Time	Temp. (C)		Time	Temp. (C)		Time	Temp. (C)
2713077	86.871		2713075	86.866		2713073	86.861
2713077	86.872		2713075	86.867		2713072.8	86.861
2713076.75	86.869		2713074.8	86.865		2713072.8	86.861
2713076.75	86.868		2713074.5	86.866		2713072.5	86.863
2713076.5	86.874		2713074.5	86.865		2713072.5	86.86
2713076.25	86.874		2713074.3	86.862		2713072.3	86.862
2713076.25	86.873		2713074.3	86.865		2713072.3	86.86
2713076	86.87		2713074	86.864		2713072	86.86
2713076	86.871		2713074	86.863		2713072	86.857
2713075.75	86.871		2713073.8	86.862		2713071.8	86.858
2713075.75	86.869		2713073.8	86.863		2713071.8	86.857
2713075.5	86.868		2713073.5	86.861		2713071.5	86.855
2713075.5	86.869		2713073.5	86.859		2713071.5	86.855
2713075.25	86.869		2713073.3	86.86		2713071.3	86.856
2713075.25	86.865		2713073.3	86.861			

Average Temperature: 86.86427 deg C

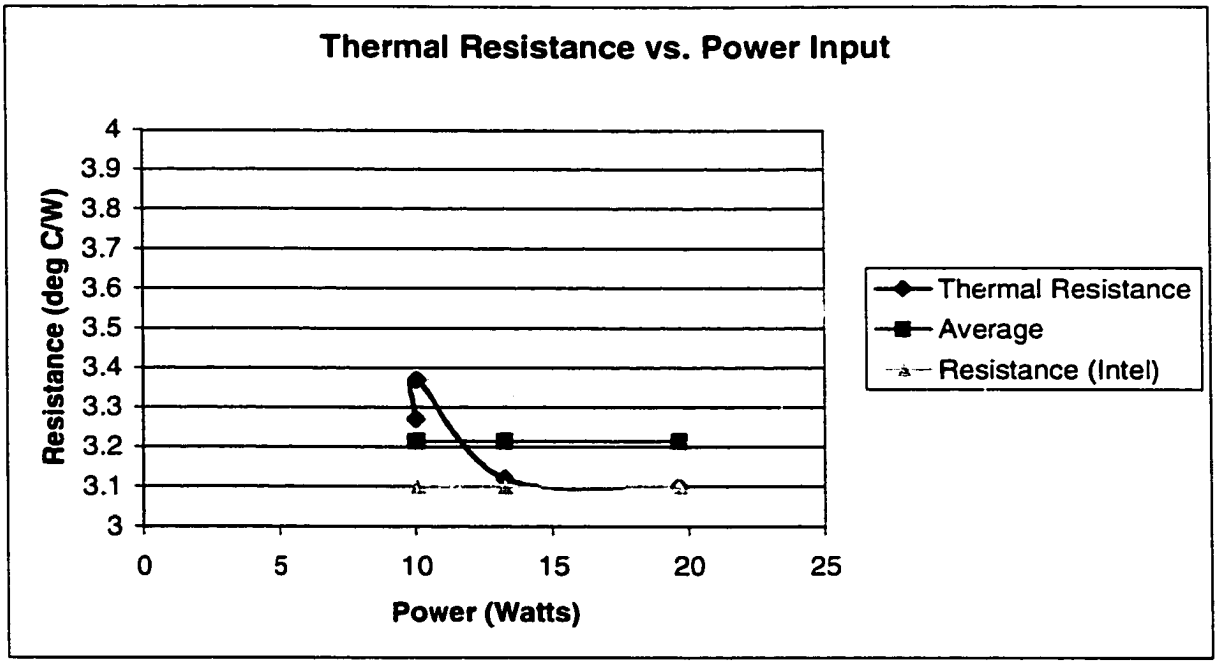
Channel 2

Time	Temp. (C)		Time	Temp. (C)		Time	Temp. (C)
2713162.25	84.382		2713160.3	84.388		2713158.3	84.383
2713162.25	84.381		2713160	84.39		2713158	84.384
2713162	84.382		2713160	84.389		2713158	84.382
2713162	84.383		2713159.8	84.388		2713157.8	84.383
2713161.75	84.382		2713159.8	84.388		2713157.8	84.382
2713161.75	84.385		2713159.5	84.387		2713157.5	84.382
2713161.5	84.385		2713159.5	84.387		2713157.5	84.382
2713161.5	84.383		2713159.3	84.388		2713157.3	84.38
2713161.25	84.386		2713159	84.389		2713157	84.381
2713161.25	84.389		2713159	84.386		2713157	84.379
2713161	84.387		2713158.8	84.388		2713156.8	84.38
2713161	84.387		2713158.8	84.386		2713156.8	84.379
2713160.75	84.386		2713158.5	84.386		2713156.5	84.382
2713160.5	84.386		2713158.5	84.384		2713156.5	84.381
2713160.5	84.386		2713158.3	84.384		2713156.3	84.38
2713160.25	84.386						

Average Temperature: 84.38443 deg C



Power (W)	T (deg C)
9.98	55.8258
10.02	57.038445
13.248	65.98563
19.628	85.62435



Power (W)	Resistance (deg C/W)	Average (deg C/W)	Intel's R. (deg C/W)
9.98	3.27	3.215	3.1
10.02	3.37	3.215	3.1
13.248	3.12	3.215	3.1
19.628	3.1	3.215	3.1

* Resistance from Intel: 3.1 deg C/W

2. Data sheets for the Intel® Pentium Pro® processor

P = 14.45402 Watts								
Channel 1								
Time	Temp. (C)		Time	Temp. (C)		Time	Temp. (C)	
1693856.1	32.764		1693854.1	32.759		1693852.1	32.755	
1693856	32.761		1693854	32.762		1693852	32.757	
1693855.9	32.764		1693853.9	32.758		1693851.9	32.757	
1693855.8	32.765		1693853.8	32.759		1693851.8	32.754	
1693855.6	32.762		1693853.6	32.759		1693851.6	32.753	
1693855.5	32.762		1693853.5	32.758		1693851.5	32.751	
1693855.4	32.763		1693853.4	32.755		1693851.4	32.755	
1693855.3	32.761		1693853.3	32.755		1693851.3	32.754	
1693855.1	32.762		1693853.1	32.758		1693851.1	32.755	
1693855	32.759		1693852.9	32.757		1693851	32.753	
1693854.9	32.762		1693852.8	32.756		1693850.8	32.754	
1693854.8	32.763		1693852.6	32.756		1693850.6	32.754	
1693854.5	32.762		1693852.5	32.756		1693850.5	32.753	
1693854.4	32.759		1693852.4	32.755		1693850.4	32.753	
1693854.3	32.759		1693852.3	32.754				
Average Temperature: 32.7578 deg C								
Channel 2								
Time	Temp. (C)		Time	Temp. (C)		Time	Temp. (C)	
1693878.3	31.393		1693876.1	31.389		1693874.4	31.383	
1693878.1	31.396		1693876	31.387		1693874.3	31.382	
1693878	31.394		1693875.9	31.388		1693874.1	31.383	
1693877.8	31.394		1693875.8	31.388		1693874	31.381	
1693877.6	31.394		1693875.6	31.387		1693873.8	31.379	
1693877.5	31.392		1693875.5	31.386		1693873.6	31.379	
1693877.4	31.395		1693875.4	31.387		1693873.5	31.381	
1693877.3	31.394		1693875.3	31.385		1693873.4	31.379	
1693877.1	31.393		1693875.1	31.385		1693873.3	31.379	
1693877	31.393		1693875	31.385		1693873.1	31.382	
1693876.9	31.391		1693874.9	31.383		1693873	31.379	
1693876.8	31.392		1693874.8	31.385		1693872.9	31.379	
1693876.5	31.392		1693874.6	31.386		1693872.8	31.377	
1693876.4	31.39		1693874.5	31.385		1693872.6	31.38	
1693876.3	31.391							
Average Temperature: 31.38658 deg C								

P = 14.45402 Watts (Cont.)							
Channel 3							
Time	Temp. (C)		Time	Temp. (C)		Time	Temp. (C)
1693898	31.481		1693896	31.482		1693894.4	31.477
1693897.9	31.482		1693895.9	31.483		1693894.3	31.477
1693897.8	31.482		1693895.8	31.484		1693894.1	31.478
1693897.6	31.482		1693895.6	31.483		1693894	31.482
1693897.4	31.48		1693895.5	31.481		1693893.9	31.482
1693897.3	31.482		1693895.4	31.48		1693893.8	31.479
1693897.1	31.481		1693895.3	31.482		1693893.5	31.478
1693897	31.484		1693895.1	31.483		1693893.4	31.479
1693896.9	31.48		1693895	31.484		1693893.3	31.478
1693896.8	31.478		1693894.9	31.481		1693893.1	31.476
1693896.6	31.483		1693894.8	31.478		1693893	31.481
1693896.5	31.485		1693894.6	31.478		1693892.9	31.476
1693896.4	31.482		1693894.5	31.482		1693892.8	31.478
1693896.3	31.485						
Average Temperature: 31.48073 deg C							

P = 16.98453 Watts

Channel 1

Time	Temp. (C)		Time	Temp. (C)		Time	Temp. (C)
1694824.5	34.285		1694822.5	34.283		1694820.5	34.28
1694824.4	34.286		1694822.4	34.283		1694820.4	34.283
1694824.3	34.284		1694822.3	34.286		1694820.3	34.283
1694824.1	34.286		1694822.1	34.283		1694820	34.28
1694824	34.281		1694822	34.283		1694819.9	34.279
1694823.9	34.282		1694821.8	34.283		1694819.8	34.279
1694823.8	34.284		1694821.6	34.282		1694819.6	34.279
1694823.6	34.284		1694821.5	34.284		1694819.5	34.28
1694823.4	34.283		1694821.4	34.281		1694819.4	34.279
1694823.3	34.284		1694821.3	34.28		1694819.3	34.278
1694823.1	34.285		1694821.1	34.282		1694819.1	34.281
1694823	34.282		1694821	34.281		1694819	34.277
1694822.9	34.285		1694820.9	34.281		1694818.9	34.276
1694822.8	34.285		1694820.8	34.279		1694818.8	34.281
1694822.6	34.287		1694820.6	34.282		1694818.6	34.279

Average Temperature: 34.282 deg C

Channel 2

Time	Temp. (C)		Time	Temp. (C)		Time	Temp. (C)
1694844.3	32.66		1694842.3	32.659		1694840.4	32.662
1694844.1	32.66		1694842.1	32.659		1694840.3	32.659
1694844	32.659		1694842	32.661		1694840	32.659
1694843.9	32.661		1694841.9	32.66		1694839.9	32.66
1694843.8	32.66		1694841.8	32.664		1694839.8	32.659
1694843.6	32.661		1694841.6	32.662		1694839.6	32.662
1694843.5	32.66		1694841.5	32.66		1694839.5	32.661
1694843.4	32.659		1694841.4	32.661		1694839.4	32.662
1694843.3	32.656		1694841.3	32.661		1694839.3	32.662
1694843	32.66		1694841.1	32.661		1694839.1	32.661
1694843	32.661		1694841	32.662		1694839	32.664
1694842.8	32.66		1694840.9	32.659		1694838.9	32.662
1694842.6	32.66		1694840.8	32.661		1694838.8	32.661
1694842.5	32.662		1694840.6	32.661		1694838.6	32.662
1694842.4	32.663		1694840.5	32.664			

Average Temperature: 32.66075 deg C

P = 16.98453 Watts (Cont.)							
Channel 3							
Time	Temp. (C)		Time	Temp. (C)		Time	Temp. (C)
1694863.4	32.75		1694861.4	32.755		1694859.4	32.755
1694863.3	32.752		1694861.1	32.755		1694859.3	32.755
1694863.1	32.749		1694861	32.754		1694859.1	32.755
1694863	32.749		1694860.9	32.755		1694859	32.754
1694862.8	32.748		1694860.8	32.755		1694858.9	32.754
1694862.6	32.75		1694860.6	32.755		1694858.8	32.756
1694862.5	32.753		1694860.5	32.754		1694858.6	32.755
1694862.4	32.75		1694860.4	32.755		1694858.5	32.757
1694862.3	32.753		1694860.3	32.757		1694858.3	32.758
1694862.1	32.751		1694860.1	32.755		1694858.1	32.756
1694862	32.753		1694860	32.754		1694858	32.753
1694861.9	32.753		1694859.8	32.755		1694857.9	32.754
1694861.8	32.754		1694859.6	32.755		1694857.8	32.751
1694861.6	32.754		1694859.5	32.754		1694857.6	32.752
1694861.5	32.754						
Average Temperature: 32.75363 deg C							

P = 19.71904 Watts

Channel 1

Time	Temp. (C)		Time	Temp. (C)		Time	Temp. (C)
1695457.3	36.116		1695455.1	36.115		1695453	36.112
1695457.1	36.117		1695455	36.115		1695452.9	36.111
1695457	36.116		1695454.9	36.116		1695452.8	36.11
1695456.9	36.116		1695454.6	36.113		1695452.6	36.109
1695456.8	36.115		1695454.5	36.115		1695452.5	36.11
1695456.6	36.116		1695454.4	36.116		1695452.4	36.112
1695456.4	36.117		1695454.3	36.113		1695452.3	36.11
1695456.3	36.117		1695454.1	36.115		1695452.1	36.109
1695456.1	36.117		1695454	36.112		1695452	36.11
1695456	36.114		1695453.9	36.112		1695451.9	36.113
1695455.9	36.114		1695453.8	36.113		1695451.8	36.111
1695455.8	36.116		1695453.6	36.112		1695451.6	36.113
1695455.6	36.115		1695453.5	36.114		1695451.4	36.109
1695455.5	36.115		1695453.4	36.11		1695451.3	36.111
1695455.4	36.117		1695453.1	36.11		1695451.1	36.114
1695455.3	36.115						

Average Temperature: 36.11343 deg C

Channel 2

Time	Temp. (C)		Time	Temp. (C)		Time	Temp. (C)
1695476.3	34.294		1695474.4	34.288		1695472.6	34.288
1695476.1	34.295		1695474.3	34.291		1695472.5	34.286
1695476	34.295		1695474.1	34.288		1695472.4	34.287
1695475.8	34.289		1695474	34.288		1695472.3	34.285
1695475.6	34.292		1695473.9	34.288		1695472.1	34.284
1695475.5	34.29		1695473.8	34.287		1695472	34.287
1695475.4	34.291		1695473.6	34.286		1695471.9	34.284
1695475.3	34.289		1695473.5	34.287		1695471.8	34.285
1695475.1	34.291		1695473.4	34.288		1695471.6	34.284
1695475	34.291		1695473.3	34.29		1695471.5	34.286
1695474.9	34.29		1695473.1	34.285		1695471.4	34.284
1695474.8	34.29		1695472.9	34.285		1695471.3	34.285
1695474.6	34.288		1695472.8	34.287			

Average Temperature: 34.28811 deg C

P = 19.71904 Watts (Cont.)								
Channel 3								
Time	Temp. (C)		Time	Temp. (C)		Time	Temp. (C)	
1695493.6	34.432		1695491.6	34.432		1695489.8	34.436	
1695493.5	34.431		1695491.5	34.432		1695489.5	34.434	
1695493.4	34.433		1695491.4	34.433		1695489.4	34.436	
1695493.3	34.432		1695491.3	34.431		1695489.3	34.437	
1695493.1	34.432		1695491	34.432		1695489.1	34.436	
1695493	34.433		1695490.9	34.432		1695489	34.436	
1695492.9	34.431		1695490.8	34.434		1695488.9	34.437	
1695492.6	34.432		1695490.6	34.435		1695488.8	34.434	
1695492.5	34.431		1695490.5	34.435		1695488.6	34.436	
1695492.4	34.433		1695490.4	34.434		1695488.5	34.439	
1695492.3	34.432		1695490.3	34.434		1695488.4	34.438	
1695492.1	34.431		1695490.1	34.434		1695488.3	34.44	
1695492	34.432		1695490	34.433		1695488.1	34.441	
1695491.9	34.429		1695489.9	34.436		1695488	34.441	
1695491.8	34.43							
Average Temperature: 34.434 deg C								

P = 22.65755 Watts

Channel 1

Time	Temp. (C)		Time	Temp. (C)		Time	Temp. (C)
1776229	38.067		1776227.1	38.067		1776225.3	38.068
1776228.9	38.066		1776227	38.067		1776225.1	38.068
1776228.8	38.066		1776226.9	38.068		1776225	38.069
1776228.6	38.066		1776226.8	38.071		1776224.9	38.069
1776228.5	38.066		1776226.6	38.068		1776224.8	38.069
1776228.4	38.066		1776226.5	38.069		1776224.6	38.069
1776228.3	38.067		1776226.4	38.067		1776224.5	38.071
1776228.1	38.064		1776226.3	38.068		1776224.4	38.069
1776228	38.065		1776226.1	38.068		1776224.3	38.07
1776227.9	38.067		1776226	38.069		1776224.1	38.069
1776227.8	38.066		1776225.8	38.067		1776224	38.07
1776227.6	38.066		1776225.6	38.067		1776223.9	38.075
1776227.5	38.067		1776225.5	38.069		1776223.8	38.073
1776227.3	38.066		1776225.4	38.068		1776223.5	38.073

Average Temperature: 38.0681 deg C

Channel 2

Time	Temp. (C)		Time	Temp. (C)		Time	Temp. (C)
1776248.5	36.018		1776246.5	36.018		1776244.6	36.019
1776248.4	36.016		1776246.4	36.017		1776244.5	36.02
1776248.3	36.018		1776246.3	36.018		1776244.4	36.02
1776248.1	36.019		1776246	36.02		1776244.1	36.019
1776247.9	36.019		1776245.9	36.019		1776244	36.021
1776247.8	36.018		1776245.8	36.016		1776243.9	36.02
1776247.6	36.017		1776245.6	36.018		1776243.8	36.021
1776247.5	36.019		1776245.5	36.017		1776243.6	36.018
1776247.4	36.018		1776245.4	36.019		1776243.5	36.023
1776247.3	36.019		1776245.3	36.019		1776243.4	36.022
1776247.1	36.019		1776245.1	36.016		1776243.3	36.022
1776247	36.018		1776245	36.019		1776243.1	36.021
1776246.9	36.019		1776244.9	36.019		1776243	36.02
1776246.8	36.018		1776244.8	36.02		1776242.9	36.02
1776246.6	36.019						

Average Temperature: 36.01895 deg C

P = 22.65755 Watts (Cont.)							
Channel 3							
Time	Temp. (C)		Time	Temp. (C)		Time	Temp. (C)
1776265.4	36.217		1776263.4	36.215		1776261.4	36.216
1776265.3	36.215		1776263.3	36.213		1776261.3	36.214
1776265.1	36.214		1776263	36.216		1776261.1	36.217
1776265	36.217		1776262.9	36.214		1776261	36.216
1776264.8	36.219		1776262.8	36.215		1776260.9	36.217
1776264.6	36.216		1776262.6	36.219		1776260.8	36.214
1776264.5	36.214		1776262.5	36.214		1776260.6	36.215
1776264.4	36.214		1776262.4	36.218		1776260.5	36.216
1776264.3	36.213		1776262.3	36.217		1776260.4	36.216
1776264.1	36.213		1776262.1	36.217		1776260.3	36.216
1776264	36.216		1776262	36.22		1776260.1	36.213
1776263.9	36.219		1776261.9	36.217		1776260	36.214
1776263.8	36.211		1776261.6	36.215		1776259.9	36.215
1776263.6	36.213		1776261.5	36.215		1776259.8	36.214
1776263.5	36.215						
Average Temperature: 36.21544 deg C							

P = 25.792 Watts

Channel 1

Time	Temp. (C)		Time	Temp. (C)		Time	Temp. (C)
1777829.6	40.098		1777827.8	40.094		1777825.9	40.1
1777829.5	40.097		1777827.6	40.094		1777825.8	40.096
1777829.4	40.099		1777827.5	40.094		1777825.5	40.096
1777829.3	40.095		1777827.4	40.098		1777825.4	40.093
1777829.1	40.093		1777827.1	40.095		1777825.3	40.098
1777829	40.097		1777827	40.093		1777825.1	40.098
1777828.9	40.097		1777826.9	40.096		1777825	40.095
1777828.6	40.097		1777826.8	40.094		1777824.9	40.094
1777828.5	40.097		1777826.6	40.097		1777824.8	40.096
1777828.4	40.098		1777826.5	40.096		1777824.6	40.098
1777828.3	40.098		1777826.4	40.097		1777824.5	40.095
1777828.1	40.096		1777826.3	40.097		1777824.4	40.098
1777828	40.098		1777826.1	40.095		1777824.3	40.096
1777827.9	40.095		1777826	40.096		1777824.1	40.096

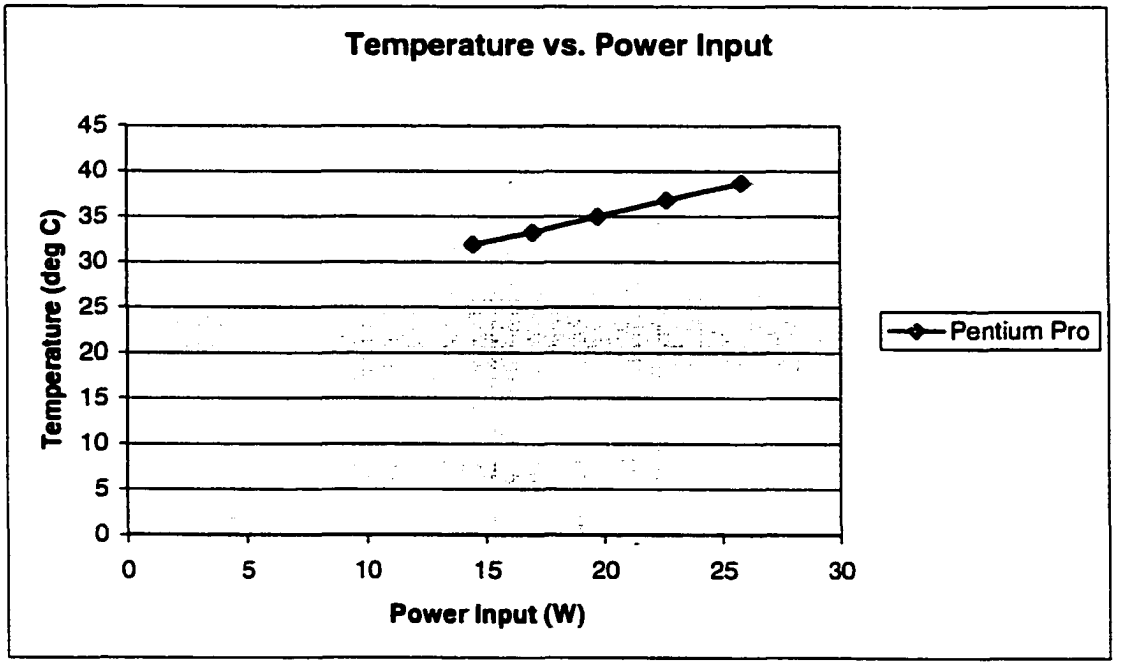
Average Temperature: 40.09619 deg C

Channel 2

Time	Temp. (C)		Time	Temp. (C)		Time	Temp. (C)
1777846.3	37.838		1777844.4	37.839		1777842.5	37.834
1777846.1	37.831		1777844.3	37.839		1777842.4	37.833
1777846	37.837		1777844.1	37.837		1777842.3	37.835
1777845.9	37.836		1777844	37.838		1777842.1	37.833
1777845.8	37.836		1777843.9	37.839		1777842	37.836
1777845.6	37.837		1777843.8	37.841		1777841.9	37.832
1777845.5	37.837		1777843.6	37.84		1777841.8	37.832
1777845.4	37.836		1777843.5	37.838		1777841.5	37.835
1777845.3	37.836		1777843.3	37.838		1777841.4	37.833
1777845.1	37.837		1777843.1	37.84		1777841.3	37.834
1777845	37.837		1777843	37.836		1777841.1	37.831
1777844.8	37.838		1777842.9	37.837		1777841	37.832
1777844.6	37.838		1777842.8	37.838		1777840.9	37.833
1777844.5	37.84		1777842.6	37.836		1777840.8	37.833

Average Temperature: 37.8361 deg C

P = 25.792 Watts (Cont.)							
Channel 3							
Time	Temp. (C)		Time	Temp. (C)		Time	Temp. (C)
1777864.8	38.049		1777862.8	38.051		1777860.9	38.051
1777864.6	38.047		1777862.6	38.049		1777860.8	38.051
1777864.5	38.048		1777862.5	38.05		1777860.6	38.053
1777864.4	38.047		1777862.4	38.05		1777860.4	38.053
1777864.3	38.049		1777862.3	38.05		1777860.3	38.052
1777864.1	38.045		1777862.1	38.048		1777860.1	38.052
1777864	38.047		1777861.9	38.049		1777860	38.052
1777863.9	38.048		1777861.8	38.049		1777859.9	38.053
1777863.8	38.048		1777861.6	38.051		1777859.8	38.055
1777863.6	38.047		1777861.5	38.054		1777859.6	38.054
1777863.4	38.046		1777861.4	38.05		1777859.5	38.056
1777863.3	38.051		1777861.3	38.05		1777859.4	38.054
1777863.1	38.047		1777861.1	38.051		1777859.3	38.057
1777863	38.051		1777861	38.051		1777859.1	38.056
1777862.9	38.048						
Average Temperature: 38.05047 deg C							



Power (W)	T (deg C)
14.45402	31.87504
16.98453	33.23213
19.71904	34.94518
22.65755	36.7675
25.792	38.66092

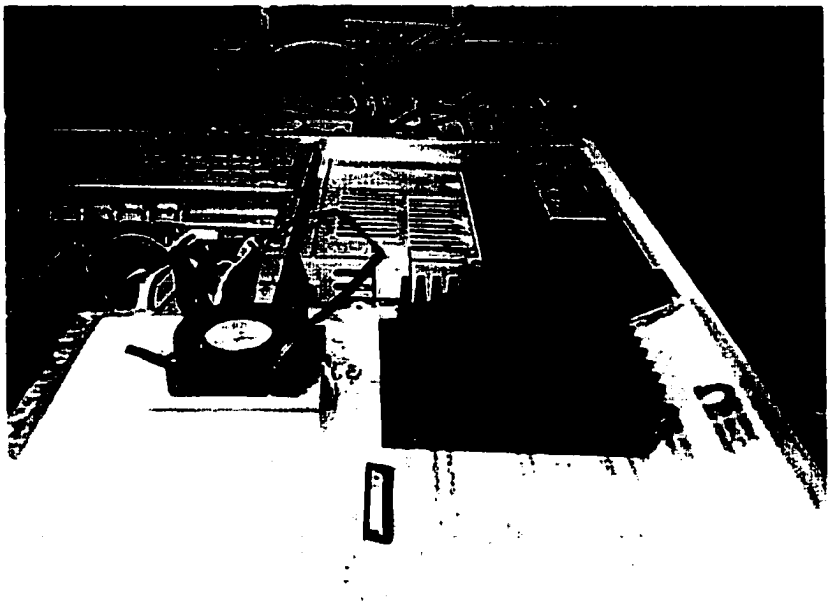
APPENDIX B

Experimental Setups and Thermocouple Calibration

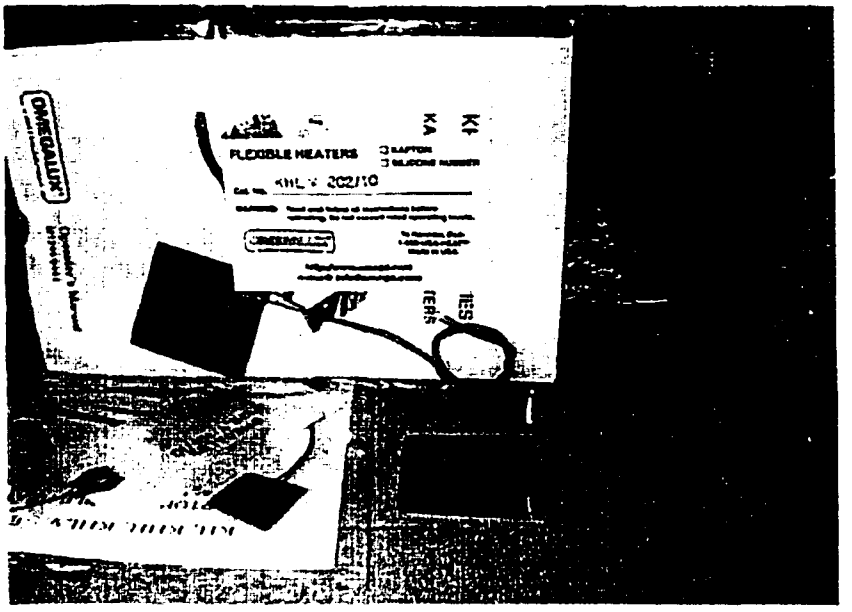
1. General information

The processors, the heat sinks utilized with them and the heaters are illustrated in this section. Each heat sink shown was tested inside their respective motherboard. All processors are 200 MHz.

Picture 1. Processors (from left): MMX, Pentium Pro w/heat sink, and Pentium Pro.



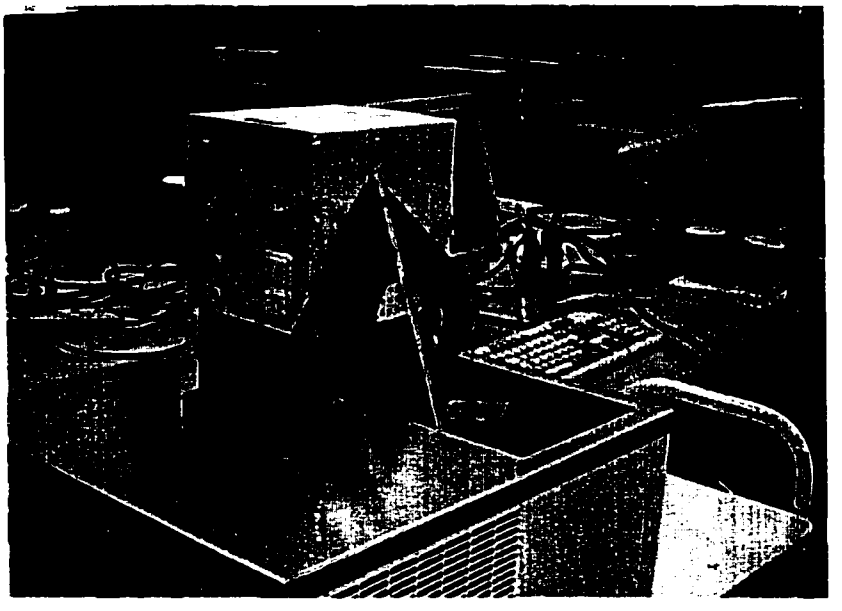
Picture 2. Heat sinks used with(from left): MMX™ (w/fan), Pentium® Pro.



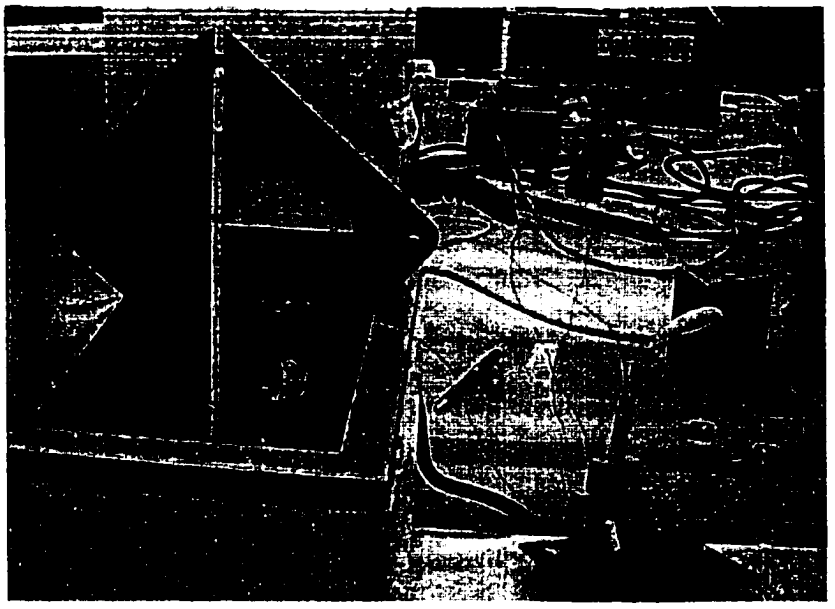
Picture 3. Kapton flexible heaters used as heat source.

2. Calibrating the thermocouples

The following pictures illustrate the process utilized to calibrate the thermocouples used in the experiments.



Picture 4. Overall view of calibration setup.

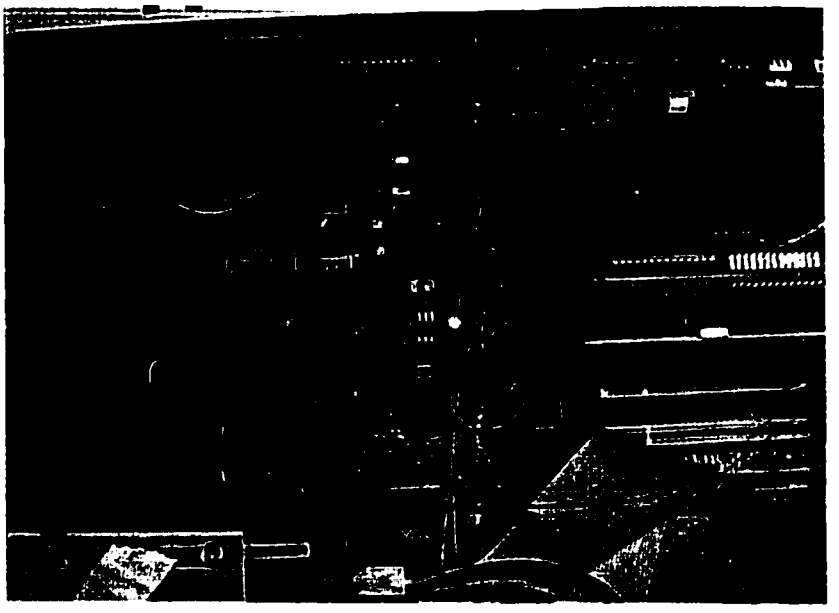


Picture 5. Close-up of the thermocouples and thermometer.

Picture 5 shows the thermocouples connected to a data acquisition card. The thermocouples were calibrated using the LABVIEW program utilized for the experiments. The same calibration setup was used for all the experiments.

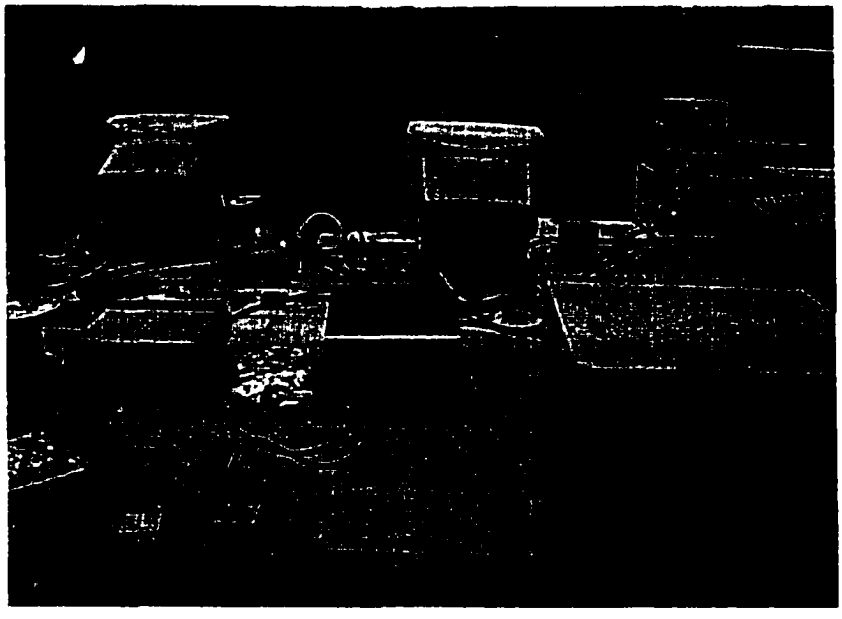
3. Setup for Pentium® w/MMX™ Technology processor

This section contains pictures illustrating the setup utilized to test the heat sink used with the Pentium® w/MMX™ technology processor.



Picture 6. Setup for Pentium® w/MMX™ tech. Processor

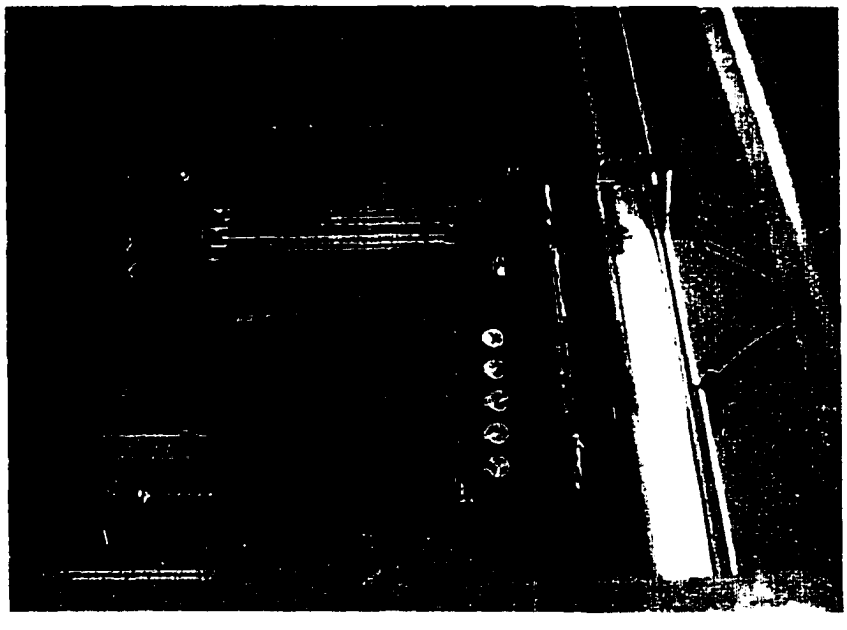
Picture 7. Same setup w/ chassis closed.



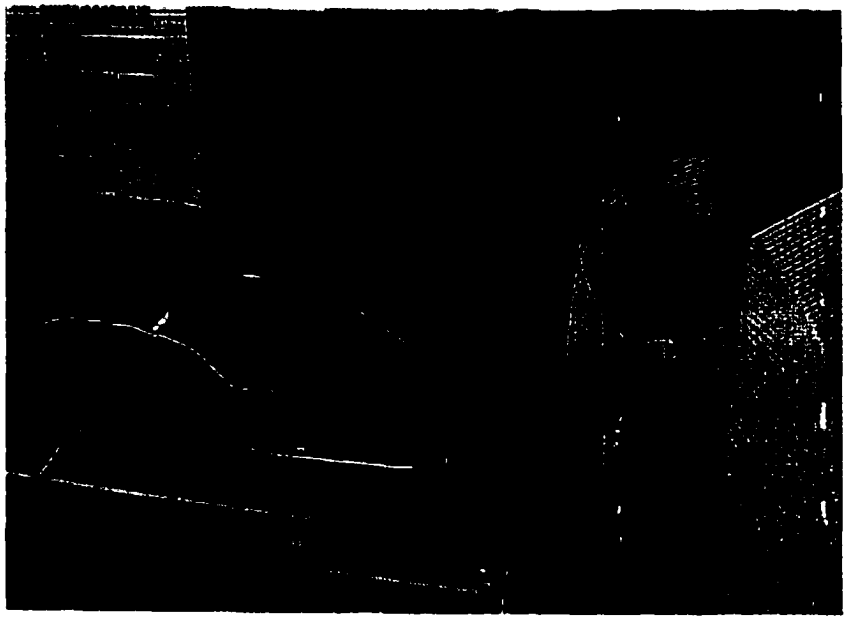
Picture 8. Complete setup, with digital multimeter, power source, and computer chassis.

4. Setup for Pentium® Pro processor

The following pictures illustrate the setup utilized to test the heat sink used with the Pentium® Pro. Note the thermocouples and the heater cables connected under the heat sink.



Picture 9. Setup for Pentium® Pro (no fan connected).



Picture 10. Complete setup, with fan attached over the heat sink.

APPENDIX C

Data Tables for Aluminum Foam

Heat Sinks

1. Data Sheets for Aluminum Foam: Different Densities

a. Aluminum Foam Density 1: 10 ppi

P = 14.52 Watts

Channel 1

Time	Temp. (C)		Time	Temp. (C)		Time	Temp. (C)
1439227	47.351		1439224.9	47.352		1439223	47.348
1439226.9	47.352		1439224.8	47.349		1439222.9	47.346
1439226.8	47.352		1439224.6	47.35		1439222.8	47.349
1439226.5	47.353		1439224.5	47.351		1439222.6	47.345
1439226.4	47.353		1439224.4	47.35		1439222.5	47.346
1439226.3	47.353		1439224.3	47.351		1439222.4	47.345
1439226.1	47.353		1439224.1	47.349		1439222.3	47.346
1439226	47.353		1439224	47.347		1439222.1	47.344
1439225.9	47.351		1439223.9	47.351		1439222	47.343
1439225.8	47.351		1439223.6	47.35		1439221.9	47.344
1439225.6	47.35		1439223.5	47.352		1439221.8	47.347
1439225.5	47.351		1439223.4	47.349		1439221.6	47.346
1439225.4	47.352		1439223.3	47.35		1439221.5	47.348
1439225.3	47.351		1439223.1	47.349		1439221.4	47.344
1439225	47.351						

Average Temperature: 47.34926 deg C

Channel 2

Time	Temp. (C)		Time	Temp. (C)		Time	Temp. (C)
1439252.4	45.821		1439250.4	45.82		1439248.3	45.821
1439252.3	45.822		1439250.3	45.821		1439248.1	45.82
1439252.1	45.821		1439250.1	45.823		1439248	45.821
1439252	45.823		1439249.9	45.823		1439247.9	45.823
1439251.9	45.821		1439249.8	45.82		1439247.8	45.824
1439251.8	45.822		1439249.6	45.822		1439247.6	45.822
1439251.6	45.82		1439249.5	45.823		1439247.5	45.82
1439251.4	45.821		1439249.4	45.821		1439247.4	45.823
1439251.3	45.82		1439249.3	45.822		1439247.3	45.823
1439251.1	45.822		1439249.1	45.821		1439247	45.822
1439251	45.82		1439249	45.82		1439246.9	45.824
1439250.9	45.82		1439248.9	45.822		1439246.8	45.823
1439250.8	45.822		1439248.8	45.821		1439246.6	45.823
1439250.6	45.821		1439248.5	45.822		1439246.5	45.824
1439250.5	45.82		1439248.4	45.819		1439246.4	45.823

Average Temperature: 45.8216 deg C

P = 14.52 Watts (Cont.)							
Channel 3							
Time	Temp. (C)		Time	Temp. (C)		Time	Temp. (C)
1439277.6	45.757		1439275.6	45.762		1439273.6	45.763
1439277.5	45.757		1439275.5	45.76		1439273.5	45.762
1439277.4	45.753		1439275.4	45.761		1439273.3	45.761
1439277.3	45.752		1439275.3	45.76		1439273.1	45.762
1439277.1	45.762		1439275.1	45.756		1439273	45.759
1439277	45.764		1439274.9	45.755		1439272.9	45.759
1439276.9	45.765		1439274.8	45.76		1439272.8	45.762
1439276.8	45.762		1439274.6	45.762		1439272.6	45.76
1439276.6	45.762		1439274.5	45.764		1439272.5	45.76
1439276.5	45.762		1439274.4	45.762		1439272.4	45.758
1439276.3	45.761		1439274.3	45.759		1439272.3	45.756
1439276.1	45.757		1439274.1	45.762		1439272.1	45.759
1439276	45.753		1439274	45.761		1439272	45.759
1439275.9	45.757		1439273.9	45.764		1439271.9	45.762
1439275.8	45.761		1439273.8	45.767		1439271.8	45.76
Average Temperature: 45.76004 deg C							

P = 17.056 Watts

Channel 1

Time	Temp. (C)		Time	Temp. (C)		Time	Temp. (C)
1440656.8	51.562		1440654.8	51.562		1440652.8	51.557
1440656.6	51.561		1440654.6	51.559		1440652.6	51.559
1440656.5	51.563		1440654.5	51.558		1440652.5	51.56
1440656.4	51.562		1440654.3	51.56		1440652.4	51.559
1440656.3	51.561		1440654.1	51.556		1440652.3	51.561
1440656.1	51.56		1440654	51.559		1440652.1	51.56
1440656	51.561		1440653.9	51.558		1440652	51.559
1440655.9	51.56		1440653.8	51.558		1440651.9	51.559
1440655.6	51.559		1440653.6	51.556		1440651.6	51.56
1440655.5	51.561		1440653.5	51.557		1440651.5	51.559
1440655.4	51.558		1440653.4	51.557		1440651.4	51.556
1440655.3	51.558		1440653.3	51.555		1440651.3	51.561
1440655.1	51.56		1440653.1	51.559		1440651.1	51.558
1440655	51.561		1440653	51.557		1440651	51.559
1440654.9	51.562		1440652.9	51.558		1440650.9	51.557

Average Temperature: 51.55916 deg C

Channel 2

Time	Temp. (C)		Time	Temp. (C)		Time	Temp. (C)
1440684.1	49.86		1440682	49.856		1440680.1	49.852
1440684	49.858		1440681.9	49.856		1440680	49.853
1440683.8	49.858		1440681.8	49.854		1440679.9	49.852
1440683.6	49.861		1440681.6	49.855		1440679.8	49.853
1440683.5	49.858		1440681.5	49.855		1440679.5	49.851
1440683.4	49.859		1440681.4	49.852		1440679.4	49.851
1440683.3	49.858		1440681.3	49.853		1440679.3	49.85
1440683.1	49.857		1440681	49.853		1440679.1	49.851
1440683	49.857		1440680.9	49.85		1440679	49.848
1440682.9	49.857		1440680.8	49.853		1440678.9	49.849
1440682.8	49.857		1440680.6	49.853		1440678.8	49.85
1440682.5	49.854		1440680.5	49.852		1440678.6	49.848
1440682.5	49.856		1440680.4	49.851		1440678.5	49.849
1440682.4	49.853		1440680.3	49.852		1440678.4	49.847
1440682.1	49.854						

Average Temperature: 49.85363 deg C

P = 17.506 Watts (Cont.)								
Channel 3								
Time	Temp. (C)		Time	Temp. (C)		Time	Temp. (C)	
1440710.3	49.741		1440708.4	49.731		1440706.4	49.735	
1440710.1	49.745		1440708.3	49.736		1440706.3	49.729	
1440710	49.744		1440708.1	49.736		1440706.1	49.73	
1440709.9	49.742		1440708	49.738		1440706	49.731	
1440709.8	49.738		1440707.8	49.737		1440705.9	49.735	
1440709.6	49.739		1440707.6	49.74		1440705.8	49.738	
1440709.5	49.739		1440707.5	49.736		1440705.6	49.74	
1440709.3	49.738		1440707.4	49.736		1440705.5	49.735	
1440709.1	49.734		1440707.3	49.734		1440705.4	49.733	
1440709	49.734		1440707.1	49.736		1440705.3	49.736	
1440708.9	49.737		1440707	49.735		1440705.1	49.735	
1440708.8	49.738		1440706.9	49.738		1440705	49.735	
1440708.6	49.732		1440706.8	49.736		1440704.9	49.743	
1440708.5	49.73		1440706.6	49.739		1440704.8	49.742	
Average Temperature: 49.73657 deg C								

P = 19.768 Watts								
Channel 1								
Time	Temp. (C)		Time	Temp. (C)		Time	Temp. (C)	
1443035.4	56.057		1443033.4	56.058		1443031.3	56.062	
1443035.3	56.058		1443033.1	56.059		1443031.1	56.059	
1443035.1	56.06		1443033	56.059		1443031	56.06	
1443035	56.057		1443032.9	56.059		1443030.9	56.062	
1443034.9	56.058		1443032.8	56.056		1443030.8	56.063	
1443034.6	56.059		1443032.6	56.06		1443030.6	56.065	
1443034.5	56.057		1443032.5	56.057		1443030.5	56.066	
1443034.4	56.058		1443032.4	56.06		1443030.4	56.065	
1443034.3	56.055		1443032.3	56.056		1443030.3	56.065	
1443034.1	56.058		1443032.1	56.058		1443030.1	56.066	
1443034	56.059		1443032	56.059		1443030	56.066	
1443033.9	56.058		1443031.8	56.06		1443029.9	56.068	
1443033.8	56.057		1443031.6	56.056		1443029.8	56.068	
1443033.6	56.057		1443031.5	56.057		1443029.5	56.069	
1443033.4	56.057		1443031.4	56.06		1443029.4	56.07	
Average Temperature: 56.06029 deg C								
Channel 2								
Time	Temp. (C)		Time	Temp. (C)		Time	Temp. (C)	
1443059	54.214		1443056.9	54.214		1443054.8	54.215	
1443058.9	54.212		1443056.8	54.213		1443054.5	54.213	
1443058.8	54.214		1443056.6	54.212		1443054.4	54.213	
1443058.6	54.213		1443056.5	54.213		1443054.3	54.213	
1443058.5	54.213		1443056.4	54.213		1443054.1	54.212	
1443058.4	54.214		1443056.1	54.213		1443054	54.214	
1443058.3	54.211		1443056	54.216		1443053.9	54.214	
1443058.1	54.211		1443055.9	54.213		1443053.8	54.212	
1443058	54.212		1443055.8	54.213		1443053.6	54.213	
1443057.9	54.214		1443055.6	54.212		1443053.5	54.213	
1443057.8	54.212		1443055.5	54.214		1443053.4	54.213	
1443057.5	54.213		1443055.4	54.213		1443053.3	54.214	
1443057.4	54.213		1443055.3	54.214		1443053.1	54.212	
1443057.3	54.212		1443055.1	54.214		1443053	54.215	
1443057.1	54.213		1443055	54.212		1443052.8	54.216	
1443057	54.215		1443054.9	54.214				
Average Temperature: 54.21321 deg C								

P = 19.768 Watts (Cont.)								
Channel 3								
Time	Temp. (C)		Time	Temp. (C)		Time	Temp. (C)	
1443079.1	54.048		1443077.1	54.05		1443075.1	54.055	
1443079	54.049		1443077	54.056		1443074.9	54.055	
1443078.9	54.053		1443076.9	54.057		1443074.8	54.053	
1443078.8	54.052		1443076.8	54.058		1443074.6	54.051	
1443078.6	54.053		1443076.6	54.06		1443074.5	54.053	
1443078.5	54.056		1443076.5	54.058		1443074.4	54.049	
1443078.4	54.061		1443076.3	54.052		1443074.3	54.045	
1443078.3	54.058		1443076.1	54.048		1443074.1	54.042	
1443078.1	54.054		1443076	54.05		1443074	54.042	
1443078	54.051		1443075.9	54.051		1443073.9	54.044	
1443077.8	54.055		1443075.8	54.046		1443073.8	54.043	
1443077.8	54.05		1443075.6	54.045		1443073.6	54.044	
1443077.6	54.052		1443075.5	54.052		1443073.4	54.046	
1443077.4	54.055		1443075.4	54.055		1443073.3	54.044	
1443077.3	54.052		1443075.3	54.055		1443073.3	54.047	
Average Temperature: 54.05122 deg C								

P = 22.65 Watts								
Channel 1								
Time	Temp. (C)		Time	Temp. (C)		Time	Temp. (C)	
1444526.5	60.782		1444524.4	60.774		1444522.3	60.775	
1444526.4	60.781		1444524.3	60.774		1444522.1	60.773	
1444526.3	60.779		1444524.1	60.774		1444522	60.774	
1444526.1	60.778		1444524	60.776		1444521.9	60.773	
1444525.9	60.778		1444523.9	60.777		1444521.8	60.776	
1444525.8	60.778		1444523.6	60.774		1444521.6	60.775	
1444525.6	60.778		1444523.5	60.777		1444521.5	60.772	
1444525.5	60.778		1444523.4	60.775		1444521.4	60.772	
1444525.4	60.776		1444523.3	60.774		1444521.3	60.774	
1444525.3	60.776		1444523.1	60.777		1444521.1	60.774	
1444525.1	60.775		1444523	60.774		1444520.9	60.773	
1444524.9	60.773		1444522.8	60.775		1444520.8	60.773	
1444524.8	60.774		1444522.8	60.777		1444520.6	60.773	
1444524.6	60.774		1444522.5	60.775		1444520.5	60.769	
1444524.5	60.775		1444522.4	60.776				
Average Temperature: 60.77523 deg C								
Channel 2								
Time	Temp. (C)		Time	Temp. (C)		Time	Temp. (C)	
1444550.5	58.811		1444548.5	58.81		1444546.4	58.812	
1444550.4	58.808		1444548.4	58.812		1444546.3	58.81	
1444550.3	58.809		1444548.1	58.814		1444546.1	58.81	
1444550.1	58.81		1444548	58.811		1444546	58.81	
1444550	58.808		1444547.9	58.81		1444545.9	58.812	
1444549.9	58.81		1444547.8	58.809		1444545.8	58.809	
1444549.8	58.813		1444547.6	58.814		1444545.5	58.811	
1444549.6	58.811		1444547.5	58.814		1444545.4	58.812	
1444549.5	58.809		1444547.4	58.814		1444545.3	58.81	
1444549.3	58.812		1444547.1	58.812		1444545.1	58.812	
1444549.1	58.813		1444547.1	58.811		1444545	58.812	
1444549	58.812		1444546.9	58.812		1444544.9	58.811	
1444548.9	58.812		1444546.8	58.811		1444544.6	58.809	
1444548.8	58.812		1444546.6	58.815		1444544.5	58.812	
1444548.6	58.811		1444546.5	58.811				
Average Temperature: 58.8112 deg C								

P = 22.65 Watts (Cont.)							
Channel 3							
Time	Temp. (C)		Time	Temp. (C)		Time	Temp. (C)
1444575.6	58.546		1444573.6	58.547		1444571.8	58.528
1444575.5	58.545		1444573.5	58.542		1444571.6	58.525
1444575.4	58.545		1444573.4	58.538		1444571.5	58.523
1444575.3	58.546		1444573.3	58.535		1444571.4	58.523
1444575.1	58.548		1444573	58.534		1444571.3	58.522
1444574.9	58.547		1444572.9	58.541		1444571.1	58.52
1444574.8	58.552		1444572.8	58.542		1444571	58.522
1444574.6	58.544		1444572.6	58.542		1444570.9	58.519
1444574.5	58.542		1444572.5	58.542		1444570.8	58.519
1444574.4	58.541		1444572.4	58.532		1444570.5	58.513
1444574.3	58.536		1444572.3	58.542		1444570.4	58.504
1444574	58.536		1444572	58.537		1444570.3	58.499
1444573.9	58.54		1444571.9	58.532		1444570.1	58.498
1444573.8	58.543						
Average Temperature: 58.5333 deg C							

P = 25.78394 Watts

Channel 1

Time	Temp. (C)		Time	Temp. (C)		Time	Temp. (C)
1445398.6	66.023		1445396.6	66.025		1445394.6	66.029
1445398.5	66.023		1445396.5	66.024		1445394.5	66.035
1445398.4	66.024		1445396.4	66.028		1445394.4	66.035
1445398.3	66.025		1445396.3	66.027		1445394.1	66.035
1445398.1	66.024		1445396.1	66.025		1445394	66.033
1445398	66.021		1445396	66.024		1445393.9	66.032
1445397.9	66.025		1445395.9	66.024		1445393.8	66.035
1445397.8	66.025		1445395.6	66.026		1445393.6	66.032
1445397.6	66.025		1445395.5	66.025		1445393.5	66.037
1445397.5	66.025		1445395.4	66.026		1445393.4	66.037
1445397.4	66.025		1445395.3	66.028		1445393.3	66.037
1445397.3	66.025		1445395.1	66.027		1445393.1	66.038
1445397.1	66.024		1445395	66.029		1445393	66.039
1445396.9	66.022		1445394.9	66.03		1445392.9	66.039
1445396.8	66.024		1445394.8	66.031			

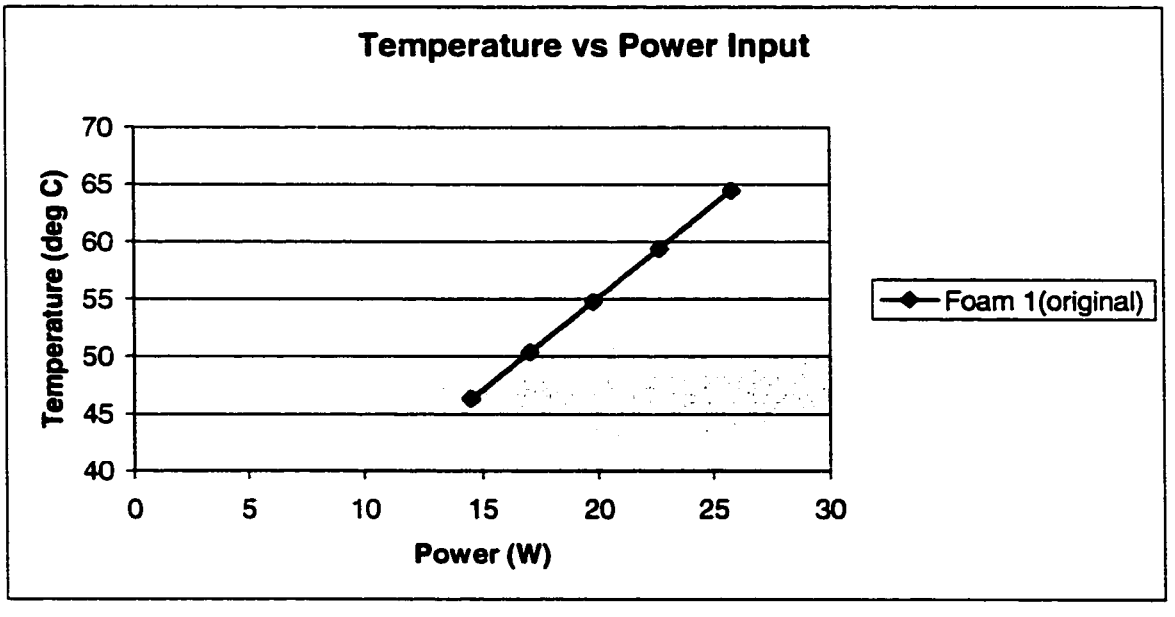
Average Temperature: 66.02845 deg C

Channel 2

Time	Temp. (C)		Time	Temp. (C)		Time	Temp. (C)
1445421.3	63.894		1445419	63.893		1445416.9	63.888
1445421.1	63.894		1445418.9	63.893		1445416.8	63.887
1445421	63.892		1445418.8	63.89		1445416.6	63.885
1445420.8	63.894		1445418.6	63.893		1445416.4	63.887
1445420.6	63.894		1445418.5	63.891		1445416.3	63.886
1445420.5	63.895		1445418.4	63.89		1445416.1	63.885
1445420.4	63.893		1445418.3	63.888		1445416	63.885
1445420.3	63.892		1445418	63.889		1445415.9	63.884
1445420.1	63.894		1445417.9	63.89		1445415.8	63.884
1445420	63.892		1445417.8	63.889		1445415.6	63.886
1445419.9	63.893		1445417.6	63.891		1445415.5	63.887
1445419.8	63.893		1445417.5	63.888		1445415.4	63.886
1445419.6	63.894		1445417.4	63.89		1445415.3	63.885
1445419.4	63.893		1445417.3	63.889		1445415.1	63.884
1445419.3	63.892		1445417.1	63.889		1445415	63.883
1445419.1	63.893		1445417	63.885			

Average Temperature: 63.88962 deg C

P = 25.78394 Watts (Cont.)								
Channel 3								
Time	Temp. (C)		Time	Temp. (C)		Time	Temp. (C)	
1445442.9	63.483		1445441.1	63.472		1445439.4	63.466	
1445442.8	63.481		1445441	63.473		1445439.3	63.466	
1445442.6	63.48		1445440.9	63.473		1445439.1	63.461	
1445442.5	63.479		1445440.8	63.472		1445439	63.465	
1445442.4	63.476		1445440.6	63.47		1445438.9	63.464	
1445442.3	63.473		1445440.5	63.469		1445438.8	63.466	
1445442.1	63.475		1445440.3	63.47		1445438.6	63.461	
1445442	63.484		1445440.1	63.473		1445438.4	63.459	
1445441.8	63.482		1445440	63.476		1445438.4	63.46	
1445441.6	63.481		1445439.9	63.47		1445438.3	63.461	
1445441.5	63.482		1445439.8	63.467		1445438	63.469	
1445441.4	63.479		1445439.6	63.462		1445437.9	63.472	
1445441.3	63.475		1445439.5	63.462				
Average Temperature: 63.47129 deg C								



Power (W)	T (deg C)
14.52	46.3103
17.056	50.38312
19.768	54.77491
22.65	59.37324
25.78394	64.46312

b. Aluminum Foam Density 2: 20 ppi

P = 14.544 Watts

Channel 1

Time	Temp. (C)		Time	Temp. (C)		Time	Temp. (C)
1448262.5	44.905		1448260.6	44.906		1448258.8	44.905
1448262.4	44.906		1448260.5	44.906		1448258.6	44.906
1448262.3	44.905		1448260.4	44.904		1448258.5	44.907
1448262.1	44.908		1448260.3	44.906		1448258.4	44.906
1448262	44.906		1448260.1	44.905		1448258.1	44.908
1448261.9	44.906		1448259.9	44.907		1448258	44.904
1448261.8	44.907		1448259.8	44.907		1448257.9	44.906
1448261.6	44.908		1448259.6	44.906		1448257.8	44.907
1448261.4	44.907		1448259.5	44.906		1448257.6	44.906
1448261.4	44.906		1448259.4	44.906		1448257.5	44.907
1448261.1	44.904		1448259.3	44.905		1448257.4	44.909
1448261	44.905		1448259.1	44.906		1448257.3	44.906
1448260.9	44.904		1448259	44.904		1448257.1	44.907
1448260.8	44.907		1448258.9	44.907		1448257	44.907

Average Temperature: 44.9061 deg C

Channel 2

Time	Temp. (C)		Time	Temp. (C)		Time	Temp. (C)
1448284.3	44.595		1448282.1	44.592		1448279.9	44.596
1448284.1	44.594		1448281.9	44.595		1448279.8	44.594
1448284	44.592		1448281.8	44.596		1448279.6	44.595
1448283.9	44.593		1448281.6	44.596		1448279.5	44.596
1448283.8	44.595		1448281.5	44.595		1448279.4	44.596
1448283.6	44.597		1448281.4	44.594		1448279.1	44.593
1448283.4	44.596		1448281.3	44.596		1448279	44.594
1448283.3	44.595		1448281.1	44.593		1448278.9	44.596
1448283.1	44.595		1448281	44.595		1448278.8	44.594
1448283	44.593		1448280.9	44.593		1448278.6	44.596
1448282.9	44.594		1448280.8	44.594		1448278.5	44.594
1448282.8	44.595		1448280.6	44.594		1448278.4	44.595
1448282.6	44.593		1448280.4	44.593		1448278.3	44.593
1448282.5	44.595		1448280.3	44.592		1448278.1	44.593
1448282.4	44.595		1448280.1	44.595		1448278	44.593
1448282.3	44.593		1448280	44.594			

Average Temperature: 44.59436 deg C

P = 14.544 Watts (Cont.)								
Channel 3								
Time	Temp. (C)		Time	Temp. (C)		Time	Temp. (C)	
1448313.6	43.508		1448311.6	43.506		1448309.6	43.505	
1448313.5	43.506		1448311.5	43.506		1448309.5	43.506	
1448313.3	43.505		1448311.4	43.506		1448309.4	43.508	
1448313.3	43.505		1448311.3	43.505		1448309.3	43.505	
1448313	43.509		1448311.1	43.504		1448309.1	43.504	
1448312.9	43.507		1448311	43.504		1448309	43.505	
1448312.8	43.506		1448310.9	43.503		1448308.8	43.504	
1448312.6	43.505		1448310.8	43.505		1448308.6	43.505	
1448312.5	43.508		1448310.6	43.506		1448308.5	43.502	
1448312.4	43.506		1448310.5	43.505		1448308.4	43.503	
1448312.3	43.508		1448310.3	43.506		1448308.3	43.502	
1448312.1	43.503		1448310.1	43.503		1448308.1	43.502	
1448312	43.506		1448310	43.503		1448308	43.502	
1448311.9	43.505		1448309.9	43.503		1448307.9	43.499	
1448311.8	43.508		1448309.8	43.505				
Average Temperature: 43.50493 deg C								

P = 17.056 Watts								
Channel 1								
Time	Temp. (C)		Time	Temp. (C)		Time	Temp. (C)	
1449762.6	48.917		1449760.5	48.914		1449758.5	48.917	
1449762.5	48.918		1449760.4	48.915		1449758.4	48.914	
1449762.4	48.916		1449760.3	48.915		1449758.3	48.915	
1449762.1	48.917		1449760.1	48.915		1449758.1	48.915	
1449762	48.917		1449760	48.914		1449758	48.916	
1449761.9	48.917		1449759.9	48.914		1449757.8	48.913	
1449761.8	48.915		1449759.8	48.914		1449757.6	48.916	
1449761.6	48.913		1449759.6	48.916		1449757.5	48.918	
1449761.5	48.915		1449759.5	48.918		1449757.4	48.916	
1449761.4	48.914		1449759.3	48.917		1449757.3	48.918	
1449761.3	48.916		1449759.1	48.917		1449757.1	48.917	
1449761.1	48.914		1449759	48.915		1449757	48.917	
1449761	48.915		1449758.9	48.916		1449756.9	48.919	
1449760.9	48.912		1449758.8	48.916		1449756.8	48.915	
1449760.6	48.913		1449758.6	48.916		1449756.6	48.917	
Average Temperature: 48.91564 deg C								
Channel 2								
Time	Temp. (C)		Time	Temp. (C)		Time	Temp. (C)	
1449791.1	48.613		1449789	48.612		1449787	48.607	
1449791	48.612		1449788.9	48.611		1449786.9	48.606	
1449790.9	48.613		1449788.8	48.609		1449786.8	48.608	
1449790.8	48.613		1449788.6	48.609		1449786.6	48.609	
1449790.6	48.614		1449788.4	48.608		1449786.5	48.609	
1449790.5	48.611		1449788.3	48.611		1449786.3	48.606	
1449790.4	48.61		1449788.1	48.61		1449786.1	48.605	
1449790.3	48.612		1449788	48.608		1449786	48.606	
1449790.1	48.612		1449787.9	48.607		1449785.9	48.606	
1449789.9	48.615		1449787.8	48.612		1449785.8	48.605	
1449789.8	48.613		1449787.6	48.61		1449785.6	48.607	
1449789.6	48.611		1449787.5	48.609		1449785.5	48.606	
1449789.5	48.609		1449787.4	48.607		1449785.4	48.606	
1449789.4	48.613		1449787.3	48.605		1449785.3	48.607	
1449789.3	48.613		1449787.1	48.607		1449785	48.608	
1449789.1	48.612							
Average Temperature: 48.60939 deg C								

P = 17.056 Watts (Cont.)								
Channel 3								
Time	Temp. (C)		Time	Temp. (C)		Time	Temp. (C)	
1449813.3	47.244		1449811.3	47.234		1449809.1	47.225	
1449813.1	47.241		1449811.1	47.235		1449809	47.226	
1449813	47.242		1449811	47.231		1449808.9	47.225	
1449812.9	47.244		1449810.8	47.234		1449808.8	47.227	
1449812.8	47.24		1449810.6	47.232		1449808.6	47.227	
1449812.6	47.241		1449810.5	47.232		1449808.5	47.226	
1449812.5	47.238		1449810.4	47.232		1449808.4	47.228	
1449812.3	47.237		1449810.3	47.23		1449808.3	47.226	
1449812.3	47.238		1449810.1	47.23		1449808.1	47.223	
1449812	47.237		1449810	47.229		1449808	47.223	
1449811.9	47.238		1449809.9	47.23		1449807.9	47.225	
1449811.8	47.236		1449809.8	47.229		1449807.8	47.224	
1449811.6	47.238		1449809.6	47.23		1449807.5	47.224	
1449811.5	47.235		1449809.5	47.229		1449807.4	47.224	
1449811.4	47.238		1449809.3	47.228				
Average Temperature: 47.23193 deg C								

P = 19.712 Watts								
Channel 1								
Time	Temp. (C)		Time	Temp. (C)		Time	Temp. (C)	
1450724.8	53.095		1450722.6	53.097		1450720.6	53.106	
1450724.6	53.097		1450722.5	53.095		1450720.5	53.103	
1450724.5	53.095		1450722.4	53.097		1450720.4	53.104	
1450724.4	53.096		1450722.3	53.098		1450720.3	53.107	
1450724.3	53.096		1450722.1	53.1		1450720.1	53.105	
1450724.1	53.099		1450722	53.101		1450720	53.107	
1450724	53.098		1450721.9	53.1		1450719.9	53.106	
1450723.9	53.096		1450721.8	53.102		1450719.8	53.105	
1450723.8	53.094		1450721.6	53.1		1450719.6	53.108	
1450723.5	53.097		1450721.5	53.101		1450719.5	53.108	
1450723.4	53.097		1450721.4	53.105		1450719.4	53.107	
1450723.3	53.094		1450721.3	53.101		1450719.1	53.112	
1450723.1	53.096		1450721.1	53.103		1450719	53.108	
1450723	53.095		1450720.9	53.104		1450718.9	53.111	
1450722.9	53.095		1450720.8	53.101		1450718.8	53.11	
1450722.8	53.099							
Average Temperature: 53.10111 deg C								
Channel 2								
Time	Temp. (C)		Time	Temp. (C)		Time	Temp. (C)	
1450745	52.764		1450743	52.763		1450741	52.763	
1450744.9	52.759		1450742.9	52.76		1450740.9	52.762	
1450744.8	52.762		1450742.8	52.762		1450740.6	52.762	
1450744.6	52.764		1450742.6	52.762		1450740.5	52.763	
1450744.5	52.763		1450742.5	52.761		1450740.4	52.763	
1450744.4	52.761		1450742.4	52.762		1450740.3	52.761	
1450744.3	52.763		1450742.1	52.761		1450740.1	52.762	
1450744.1	52.762		1450742	52.76		1450740	52.761	
1450744	52.763		1450741.9	52.761		1450739.9	52.761	
1450743.8	52.764		1450741.8	52.762		1450739.8	52.761	
1450743.6	52.761		1450741.6	52.762		1450739.6	52.762	
1450743.5	52.763		1450741.5	52.763		1450739.5	52.762	
1450743.4	52.761		1450741.4	52.763		1450739.4	52.761	
1450743.3	52.761		1450741.3	52.764		1450739.3	52.761	
1450743.1	52.763		1450741.1	52.762				
Average Temperature: 52.76198 deg C								

P = 19.712 Watts (Cont.)								
Channel 3								
Time	Temp. (C)		Time	Temp. (C)		Time	Temp. (C)	
1450767.4	51.056		1450765.4	51.056		1450763.4	51.059	
1450767.3	51.054		1450765.3	51.057		1450763.1	51.056	
1450767.1	51.06		1450765.1	51.057		1450763	51.056	
1450767	51.059		1450765	51.061		1450762.9	51.059	
1450766.9	51.057		1450764.9	51.058		1450762.8	51.058	
1450766.8	51.057		1450764.6	51.06		1450762.6	51.057	
1450766.6	51.06		1450764.5	51.059		1450762.5	51.058	
1450766.5	51.06		1450764.4	51.059		1450762.4	51.057	
1450766.3	51.058		1450764.3	51.058		1450762.3	51.061	
1450766.1	51.057		1450764.1	51.06		1450762.1	51.062	
1450766	51.058		1450764	51.059		1450762	51.058	
1450765.9	51.058		1450763.9	51.057		1450761.9	51.064	
1450765.8	51.057		1450763.8	51.059		1450761.8	51.059	
1450765.6	51.058		1450763.6	51.059		1450761.6	51.061	
1450765.5	51.06		1450763.5	51.057				
Average Temperature: 51.05841 deg C								

P = 22.62 Watts

Channel 1

Time	Temp. (C)		Time	Temp. (C)		Time	Temp. (C)
1451623.1	57.78		1451620.9	57.792		1451618.9	57.798
1451623	57.777		1451620.8	57.792		1451618.8	57.797
1451622.9	57.781		1451620.6	57.791		1451618.6	57.796
1451622.8	57.782		1451620.5	57.796		1451618.5	57.8
1451622.6	57.782		1451620.4	57.794		1451618.4	57.796
1451622.5	57.783		1451620.3	57.794		1451618.1	57.796
1451622.3	57.786		1451620.1	57.795		1451618	57.799
1451622.1	57.785		1451620	57.798		1451617.9	57.795
1451622	57.786		1451619.9	57.799		1451617.8	57.797
1451621.9	57.788		1451619.8	57.798		1451617.6	57.793
1451621.8	57.789		1451619.6	57.796		1451617.5	57.797
1451621.6	57.789		1451619.4	57.797		1451617.4	57.797
1451621.5	57.788		1451619.3	57.799		1451617.3	57.795
1451621.4	57.79		1451619.1	57.797		1451617.1	57.794
1451621.3	57.79		1451619	57.797		1451617	57.798
1451621.1	57.791						

Average Temperature: 57.79239 deg C

Channel 2

Time	Temp. (C)		Time	Temp. (C)		Time	Temp. (C)
1451643.9	57.517		1451642	57.515		1451640	57.515
1451643.6	57.516		1451641.8	57.515		1451639.9	57.516
1451643.5	57.516		1451641.8	57.516		1451639.8	57.519
1451643.4	57.517		1451641.5	57.516		1451639.6	57.518
1451643.3	57.516		1451641.4	57.517		1451639.5	57.515
1451643.1	57.517		1451641.3	57.516		1451639.4	57.517
1451643	57.519		1451641.1	57.517		1451639.3	57.518
1451642.9	57.515		1451641	57.515		1451639.1	57.517
1451642.8	57.519		1451640.9	57.515		1451639	57.516
1451642.6	57.515		1451640.8	57.513		1451638.9	57.519
1451642.5	57.514		1451640.6	57.515		1451638.8	57.52
1451642.4	57.517		1451640.5	57.518		1451638.6	57.521
1451642.3	57.514		1451640.3	57.517		1451638.4	57.521
1451642.1	57.515		1451640.1	57.516		1451638.4	57.521

Average Temperature: 57.51669 deg C

P = 22.62 Watts (Cont.)								
Channel 3								
Time	Temp. (C)		Time	Temp. (C)		Time	Temp. (C)	
1451662	55.613		1451660	55.612		1451657.9	55.609	
1451661.9	55.614		1451659.9	55.612		1451657.9	55.611	
1451661.8	55.613		1451659.8	55.611		1451657.6	55.613	
1451661.6	55.614		1451659.6	55.613		1451657.5	55.608	
1451661.5	55.616		1451659.5	55.613		1451657.4	55.611	
1451661.4	55.614		1451659.3	55.614		1451657.3	55.611	
1451661.3	55.615		1451659.1	55.612		1451657.1	55.61	
1451661.1	55.611		1451659	55.612		1451657	55.61	
1451661	55.611		1451658.9	55.613		1451656.9	55.612	
1451660.8	55.613		1451658.8	55.614		1451656.8	55.611	
1451660.6	55.612		1451658.6	55.611		1451656.6	55.611	
1451660.5	55.611		1451658.5	55.61		1451656.5	55.613	
1451660.4	55.613		1451658.4	55.611		1451656.4	55.615	
1451660.3	55.611		1451658.3	55.608		1451656.3	55.614	
1451660.1	55.612		1451658.1	55.613		1451656.1	55.612	
Average Temperature: 55.61207 deg C								

P = 25.75195 Watts

Channel 1

Time	Temp. (C)		Time	Temp. (C)		Time	Temp. (C)
1452467	62.934		1452464.9	62.928		1452462.8	62.928
1452466.9	62.936		1452464.8	62.927		1452462.6	62.926
1452466.8	62.935		1452464.6	62.928		1452462.5	62.924
1452466.6	62.934		1452464.5	62.927		1452462.4	62.926
1452466.5	62.932		1452464.4	62.926		1452462.3	62.925
1452466.4	62.93		1452464.3	62.929		1452462	62.926
1452466.3	62.933		1452464.1	62.927		1452461.9	62.924
1452466	62.928		1452464	62.927		1452461.8	62.927
1452465.9	62.933		1452463.8	62.927		1452461.6	62.927
1452465.8	62.928		1452463.6	62.927		1452461.5	62.929
1452465.6	62.931		1452463.5	62.928		1452461.4	62.926
1452465.5	62.929		1452463.4	62.925		1452461.3	62.928
1452465.4	62.93		1452463.3	62.926		1452461.1	62.927
1452465.3	62.928		1452463.1	62.925		1452460.9	62.927
1452465	62.931		1452462.9	62.923		1452460.8	62.929

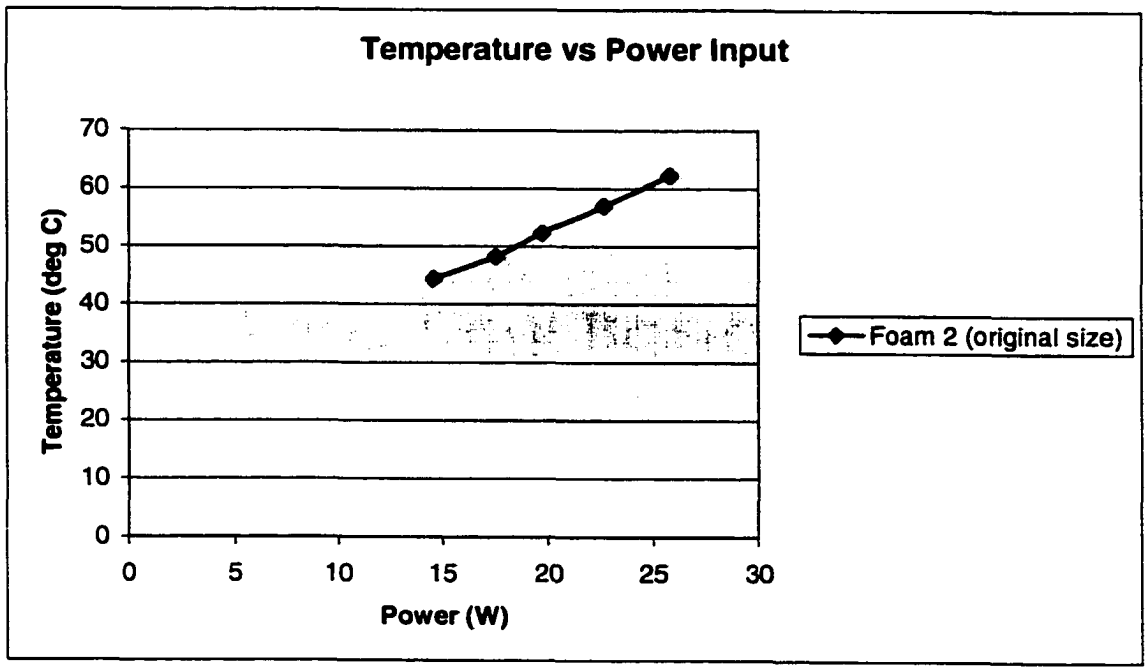
Average Temperature: 62.92824 deg C

Channel 2

Time	Temp. (C)		Time	Temp. (C)		Time	Temp. (C)
1452488.9	62.831		1452486.6	62.83		1452484.4	62.839
1452488.8	62.827		1452486.5	62.829		1452484.1	62.839
1452488.5	62.831		1452486.4	62.832		1452484	62.839
1452488.4	62.826		1452486.3	62.832		1452483.9	62.84
1452488.3	62.829		1452486	62.831		1452483.8	62.839
1452488.1	62.83		1452485.9	62.831		1452483.6	62.841
1452488	62.826		1452485.8	62.835		1452483.5	62.84
1452487.9	62.83		1452485.6	62.832		1452483.4	62.841
1452487.8	62.831		1452485.5	62.834		1452483.3	62.841
1452487.6	62.829		1452485.4	62.836		1452483.1	62.841
1452487.5	62.829		1452485.3	62.834		1452482.9	62.841
1452487.4	62.829		1452485	62.834		1452482.8	62.842
1452487.1	62.832		1452484.9	62.836		1452482.6	62.841
1452487	62.83		1452484.8	62.832		1452482.5	62.839
1452486.9	62.832		1452484.6	62.835		1452482.4	62.841
1452486.8	62.831		1452484.5	62.839			

Average Temperature: 62.83423 deg C

P = 25.75195 Watts (Cont.)							
Channel 3							
Time	Temp. (C)		Time	Temp. (C)		Time	Temp. (C)
1452507.5	60.503		1452505.3	60.495		1452503.3	60.497
1452507.4	60.503		1452505.1	60.496		1452503.1	60.495
1452507.1	60.502		1452505	60.498		1452502.9	60.497
1452507	60.501		1452504.9	60.496		1452502.8	60.496
1452507	60.501		1452504.8	60.494		1452502.6	60.497
1452506.8	60.504		1452504.5	60.497		1452502.5	60.499
1452506.6	60.502		1452504.4	60.496		1452502.4	60.498
1452506.5	60.502		1452504.3	60.497		1452502.3	60.496
1452506.4	60.498		1452504.1	60.495		1452502	60.498
1452506.3	60.499		1452504	60.494		1452501.9	60.501
1452506.1	60.501		1452503.9	60.495		1452501.8	60.501
1452505.9	60.497		1452503.8	60.492		1452501.6	60.498
1452505.8	60.497		1452503.6	60.493		1452501.5	60.502
1452505.6	60.498		1452503.5	60.496		1452501.4	60.5
1452505.5	60.499		1452503.4	60.496		1452501.3	60.504
1452505.4	60.498						
Average Temperature: 60.49813 deg C							



Power (W)	T (deg C)
14.544	44.33513
17.506	48.25232
19.712	52.30717
22.62	56.973717
25.75195	62.08687

c. Aluminum Foam Density 3: 40 ppi

P = 14.52605 Watts

Channel 1

Time	Temp. (C)		Time	Temp. (C)		Time	Temp. (C)
1520467.5	43.742		1520465.5	43.748		1520463.5	43.748
1520467.4	43.744		1520465.38	43.749		1520463.3	43.75
1520467.3	43.745		1520465.25	43.75		1520463.1	43.75
1520467.1	43.744		1520465.13	43.748		1520463	43.752
1520467	43.744		1520465	43.751		1520462.9	43.749
1520466.9	43.745		1520464.75	43.749		1520462.8	43.75
1520466.8	43.746		1520464.63	43.751		1520462.6	43.751
1520466.6	43.746		1520464.5	43.746		1520462.5	43.751
1520466.4	43.745		1520464.38	43.749		1520462.4	43.752
1520466.3	43.746		1520464.25	43.75		1520462.3	43.751
1520466.1	43.745		1520464.13	43.748		1520462.1	43.751
1520466	43.743		1520464	43.749		1520462	43.753
1520465.9	43.748		1520463.88	43.75		1520461.8	43.75
1520465.8	43.749		1520463.75	43.751		1520461.6	43.75
1520465.6	43.747		1520463.63	43.749		1520461.5	43.752

Average Temperature: 43.74838 deg C

Channel 2

Time	Temp. (C)		Time	Temp. (C)		Time	Temp. (C)
1520491.8	43.259		1520489.63	43.256		1520487.5	43.251
1520491.6	43.261		1520489.5	43.258		1520487.4	43.253
1520491.5	43.261		1520489.38	43.256		1520487.3	43.252
1520491.4	43.262		1520489.13	43.253		1520487.1	43.25
1520491.3	43.26		1520489	43.256		1520487	43.25
1520491.1	43.262		1520488.88	43.252		1520486.9	43.251
1520491	43.26		1520488.75	43.254		1520486.8	43.25
1520490.9	43.262		1520488.63	43.255		1520486.6	43.249
1520490.8	43.261		1520488.5	43.255		1520486.5	43.25
1520490.5	43.261		1520488.38	43.253		1520486.4	43.25
1520490.4	43.259		1520488.25	43.254		1520486.3	43.249
1520490.3	43.259		1520488.13	43.253		1520486.1	43.251
1520490.1	43.259		1520488	43.253		1520486	43.252
1520490	43.257		1520487.75	43.25		1520485.9	43.252
1520489.9	43.257		1520487.63	43.251		1520485.8	43.25
1520489.8	43.257						

Average Temperature: 43.25491 deg C

P = 14.52605 Watts (Cont.)							
Channel 3							
Time	Temp. (C)		Time	Temp. (C)		Time	Temp. (C)
1520511	45.18		1520509	45.184		1520506.9	45.184
1520510.9	45.182		1520508.88	45.186		1520506.8	45.185
1520510.8	45.184		1520508.63	45.184		1520506.6	45.184
1520510.6	45.183		1520508.63	45.183		1520506.5	45.184
1520510.5	45.185		1520508.38	45.183		1520506.4	45.184
1520510.4	45.183		1520508.25	45.182		1520506.3	45.186
1520510.1	45.183		1520508.13	45.185		1520506.1	45.183
1520510	45.184		1520508	45.182		1520506	45.182
1520509.9	45.184		1520507.88	45.182		1520505.9	45.184
1520509.8	45.181		1520507.75	45.183		1520505.8	45.183
1520509.6	45.183		1520507.63	45.184		1520505.6	45.181
1520509.5	45.183		1520507.5	45.183		1520505.4	45.183
1520509.4	45.182		1520507.38	45.182		1520505.3	45.181
1520509.3	45.185		1520507.25	45.184		1520505.1	45.183
1520509.1	45.184		1520507	45.183		1520505	45.182
Average Temperature: 45.18322 deg C							

P = 17.03 Watts

Channel 1

Time	Temp. (C)		Time	Temp. (C)		Time	Temp. (C)
1521712.8	47.414		1521710.63	47.401		1521708.8	47.393
1521712.5	47.413		1521710.5	47.399		1521708.6	47.396
1521712.4	47.413		1521710.38	47.4		1521708.5	47.395
1521712.3	47.409		1521710.25	47.399		1521708.4	47.396
1521712.1	47.409		1521710.13	47.397		1521708.3	47.397
1521712	47.408		1521710	47.399		1521708.1	47.397
1521711.9	47.407		1521709.88	47.398		1521708	47.397
1521711.8	47.406		1521709.75	47.397		1521707.9	47.396
1521711.6	47.404		1521709.63	47.398		1521707.8	47.398
1521711.5	47.404		1521709.5	47.398		1521707.6	47.396
1521711.3	47.403		1521709.38	47.396		1521707.5	47.399
1521711.1	47.406		1521709.25	47.395		1521707.4	47.398
1521711	47.402		1521709	47.399		1521707.3	47.397
1521710.9	47.403		1521708.88	47.396		1521707	47.397
1521710.8	47.404						

Average Temperature: 47.40067 deg C

Channel 2

Time	Temp. (C)		Time	Temp. (C)		Time	Temp. (C)
1521732.1	46.948		1521730.13	46.94		1521728.1	46.935
1521732	46.949		1521730	46.94		1521728	46.933
1521731.9	46.944		1521729.88	46.939		1521727.9	46.93
1521731.8	46.944		1521729.75	46.939		1521727.8	46.931
1521731.6	46.947		1521729.63	46.937		1521727.5	46.934
1521731.5	46.946		1521729.5	46.936		1521727.4	46.932
1521731.4	46.942		1521729.25	46.937		1521727.3	46.933
1521731.3	46.941		1521729.13	46.934		1521727.1	46.935
1521731.1	46.944		1521729	46.938		1521727	46.932
1521731	46.942		1521728.88	46.938		1521726.9	46.932
1521730.8	46.944		1521728.75	46.936		1521726.8	46.932
1521730.8	46.941		1521728.63	46.936		1521726.6	46.931
1521730.5	46.94		1521728.5	46.935		1521726.5	46.929
1521730.4	46.94		1521728.38	46.936		1521726.3	46.931
1521730.3	46.941		1521728.25	46.933		1521726.1	46.93

Average Temperature: 46.93749 deg C

P = 17.03 Watts (Cont.)							
Channel 3							
Time	Temp. (C)		Time	Temp. (C)		Time	Temp. (C)
1521749.4	49.336		1521747.5	49.335		1521745.6	49.344
1521749.3	49.333		1521747.38	49.335		1521745.5	49.342
1521749.1	49.331		1521747.25	49.335		1521745.4	49.342
1521749	49.334		1521747.13	49.337		1521745.3	49.34
1521748.9	49.333		1521747	49.338		1521745.1	49.341
1521748.8	49.333		1521746.88	49.339		1521744.9	49.342
1521748.5	49.336		1521746.75	49.339		1521744.8	49.341
1521748.4	49.333		1521746.63	49.338		1521744.6	49.34
1521748.3	49.334		1521746.38	49.338		1521744.5	49.342
1521748.1	49.332		1521746.25	49.342		1521744.4	49.34
1521748	49.336		1521746.13	49.339		1521744.3	49.338
1521747.9	49.334		1521746	49.336		1521744.1	49.34
1521747.8	49.334		1521745.88	49.339		1521744	49.341
1521747.6	49.335		1521745.75	49.34		1521743.9	49.344
Average Temperature: 49.33764 deg C							

P = 19.80307 Watts

Channel 1

Time	Temp. (C)		Time	Temp. (C)		Time	Temp. (C)
1522827.3	51.487		1522825.25	51.487		1522823.1	51.486
1522827.1	51.485		1522825	51.488		1522823	51.485
1522827	51.486		1522824.88	51.485		1522822.9	51.487
1522826.9	51.485		1522824.75	51.487		1522822.8	51.488
1522826.8	51.488		1522824.63	51.488		1522822.6	51.489
1522826.6	51.486		1522824.5	51.486		1522822.5	51.487
1522826.4	51.487		1522824.38	51.486		1522822.4	51.485
1522826.3	51.485		1522824.25	51.484		1522822.3	51.484
1522826.1	51.487		1522824.13	51.487		1522822.1	51.483
1522826	51.485		1522824	51.487		1522822	51.482
1522825.9	51.485		1522823.88	51.487		1522821.9	51.483
1522825.8	51.483		1522823.75	51.488		1522821.6	51.482
1522825.6	51.486		1522823.5	51.487		1522821.5	51.483
1522825.5	51.486		1522823.38	51.487		1522821.4	51.481
1522825.4	51.485		1522823.25	51.491		1522821.3	51.483

Average Temperature: 51.48576 deg C

Channel 2

Time	Temp. (C)		Time	Temp. (C)		Time	Temp. (C)
1522847.8	51.005		1522845.75	51.007		1522843.9	51.004
1522847.6	51.002		1522845.63	51.006		1522843.8	51.006
1522847.5	51.005		1522845.5	51.006		1522843.6	51.004
1522847.4	51.007		1522845.25	51.005		1522843.4	51.006
1522847.3	51.006		1522845.13	51.006		1522843.3	51.005
1522847.1	51.007		1522845	51.006		1522843.1	51.003
1522846.9	51.004		1522844.88	51.008		1522843	51.003
1522846.8	51.005		1522844.75	51.005		1522842.9	51.002
1522846.6	51.005		1522844.63	51.005		1522842.8	51.003
1522846.5	51.006		1522844.5	51.006		1522842.6	51.003
1522846.4	51.007		1522844.38	51.006		1522842.5	51.003
1522846.3	51.007		1522844.25	51.003		1522842.4	51.002
1522846.1	51.004		1522844.13	51.005		1522842.3	51.004
1522846	51.006		1522844	51.006		1522842.1	51.003
1522845.9	51.003						

Average Temperature: 51.00488 deg C

P = 19.80307 Watts (Cont.)								
Channel 3								
Time	Temp. (C)		Time	Temp. (C)		Time	Temp. (C)	
1522867.6	54.098		1522865.63	54.09		1522863.5	54.087	
1522867.5	54.098		1522865.5	54.091		1522863.4	54.086	
1522867.4	54.096		1522865.25	54.09		1522863.3	54.085	
1522867.3	54.099		1522865.13	54.088		1522863.1	54.086	
1522867.1	54.1		1522865	54.091		1522863	54.086	
1522867	54.1		1522864.88	54.09		1522862.9	54.086	
1522866.8	54.099		1522864.75	54.089		1522862.8	54.089	
1522866.6	54.096		1522864.63	54.088		1522862.6	54.085	
1522866.5	54.093		1522864.5	54.088		1522862.5	54.089	
1522866.4	54.093		1522864.38	54.088		1522862.4	54.087	
1522866.3	54.096		1522864.25	54.088		1522862.3	54.089	
1522866.1	54.094		1522864.13	54.088		1522862.1	54.089	
1522866	54.094		1522864	54.086		1522862	54.089	
1522865.9	54.093		1522863.88	54.089		1522861.9	54.086	
1522865.8	54.093		1522863.63	54.085				
Average Temperature: 54.09068 deg C								

P = 22.71 Watts

Channel 1

Time	Temp. (C)		Time	Temp. (C)		Time	Temp. (C)
1523624.6	55.823		1523622.75	55.825		1523620.9	55.826
1523624.5	55.824		1523622.63	55.826		1523620.8	55.824
1523624.4	55.824		1523622.5	55.822		1523620.6	55.826
1523624.3	55.827		1523622.38	55.824		1523620.5	55.824
1523624.1	55.826		1523622.25	55.825		1523620.4	55.826
1523624	55.827		1523622.13	55.827		1523620.3	55.827
1523623.9	55.824		1523622	55.823		1523620	55.821
1523623.8	55.826		1523621.75	55.823		1523619.9	55.826
1523623.6	55.824		1523621.75	55.822		1523619.8	55.825
1523623.5	55.827		1523621.5	55.825		1523619.6	55.825
1523623.4	55.824		1523621.38	55.823		1523619.5	55.825
1523623.3	55.825		1523621.25	55.822		1523619.4	55.825
1523623	55.825		1523621.13	55.825		1523619.3	55.825
1523622.9	55.824		1523621	55.824			

Average Temperature: 55.82466 deg C

Channel 2

Time	Temp. (C)		Time	Temp. (C)		Time	Temp. (C)
1523643	55.364		1523641	55.363		1523639.1	55.37
1523642.9	55.364		1523640.88	55.362		1523639	55.371
1523642.8	55.363		1523640.75	55.362		1523638.9	55.368
1523642.6	55.363		1523640.63	55.366		1523638.6	55.367
1523642.5	55.363		1523640.5	55.362		1523638.5	55.367
1523642.4	55.365		1523640.38	55.364		1523638.4	55.373
1523642.3	55.362		1523640.13	55.366		1523638.3	55.371
1523642.1	55.363		1523640	55.369		1523638.1	55.371
1523642	55.364		1523639.88	55.366		1523638	55.374
1523641.9	55.367		1523639.75	55.366		1523637.9	55.371
1523641.8	55.363		1523639.63	55.367		1523637.8	55.369
1523641.6	55.367		1523639.5	55.366		1523637.6	55.373
1523641.4	55.361		1523639.38	55.369		1523637.5	55.37
1523641.3	55.365		1523639.25	55.367		1523637.3	55.372
1523641.1	55.363						

Average Temperature: 55.36649 deg C

P = 22.71 Watts (Cont.)								
Channel 3								
Time	Temp. (C)		Time	Temp. (C)		Time	Temp. (C)	
1523661.3	58.922		1523659.25	58.924		1523657.3	58.928	
1523661.1	58.923		1523659.13	58.93		1523657.1	58.932	
1523661	58.921		1523659	58.929		1523657	58.927	
1523660.9	58.926		1523658.75	58.928		1523656.8	58.932	
1523660.8	58.925		1523658.63	58.928		1523656.6	58.93	
1523660.6	58.925		1523658.5	58.926		1523656.5	58.929	
1523660.5	58.924		1523658.38	58.931		1523656.4	58.93	
1523660.4	58.924		1523658.25	58.929		1523656.3	58.932	
1523660.1	58.926		1523658.13	58.927		1523656.1	58.933	
1523660	58.925		1523658	58.929		1523656	58.933	
1523659.9	58.927		1523657.88	58.927		1523655.9	58.932	
1523659.8	58.926		1523657.75	58.927		1523655.8	58.934	
1523659.6	58.925		1523657.63	58.928		1523655.6	58.933	
1523659.5	58.929		1523657.5	58.929		1523655.5	58.933	
1523659.4	58.926		1523657.38	58.932				
Average Temperature: 58.92809 deg C								

P = 25.824 Watts

Channel 1

Time	Temp. (C)		Time	Temp. (C)		Time	Temp. (C)
1524346.9	60.479		1524345	60.486		1524343.3	60.493
1524346.8	60.481		1524344.88	60.488		1524343	60.495
1524346.6	60.483		1524344.63	60.488		1524342.9	60.495
1524346.5	60.479		1524344.5	60.486		1524342.8	60.492
1524346.3	60.482		1524344.38	60.486		1524342.6	60.495
1524346.1	60.478		1524344.25	60.486		1524342.5	60.493
1524346	60.48		1524344.13	60.488		1524342.4	60.494
1524345.9	60.481		1524344	60.487		1524342.3	60.497
1524345.8	60.481		1524343.88	60.489		1524342.1	60.499
1524345.6	60.485		1524343.75	60.489		1524342	60.498
1524345.5	60.483		1524343.63	60.49		1524341.9	60.499
1524345.4	60.48		1524343.5	60.492		1524341.8	60.498
1524345.3	60.486		1524343.38	60.494		1524341.6	60.5
1524345.1	60.483						

Average Temperature: 60.48845 deg C

Channel 2

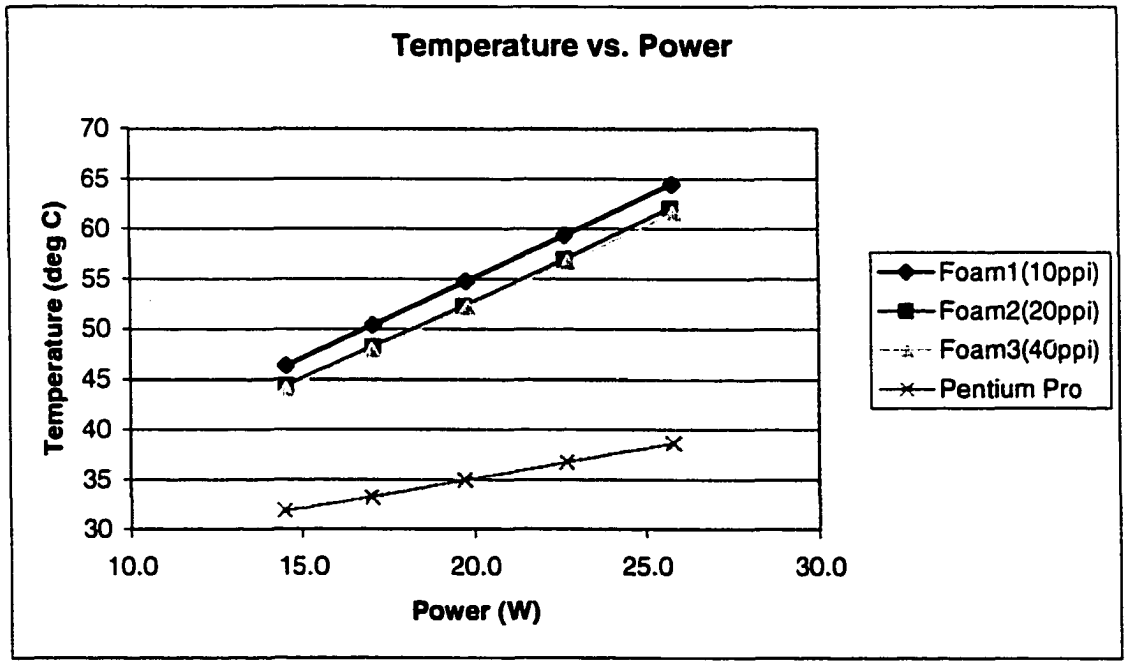
Time	Temp. (C)		Time	Temp. (C)		Time	Temp. (C)
1524367	60.051		1524365.13	60.047		1524363.1	60.048
1524366.9	60.051		1524365	60.051		1524363	60.05
1524366.8	60.05		1524364.88	60.046		1524362.9	60.053
1524366.6	60.051		1524364.63	60.044		1524362.8	60.052
1524366.5	60.05		1524364.5	60.049		1524362.6	60.053
1524366.4	60.05		1524364.38	60.048		1524362.5	60.052
1524366.1	60.051		1524364.25	60.049		1524362.4	60.049
1524366.1	60.051		1524364.13	60.048		1524362.3	60.05
1524365.9	60.051		1524364	60.048		1524362.1	60.049
1524365.8	60.047		1524363.88	60.049		1524362	60.056
1524365.6	60.047		1524363.75	60.05		1524361.9	60.052
1524365.5	60.049		1524363.63	60.048		1524361.8	60.053
1524365.4	60.049		1524363.38	60.052		1524361.6	60.052
1524365.3	60.049		1524363.25	60.05		1524361.5	60.056

Average Temperature: 60.05002 deg C

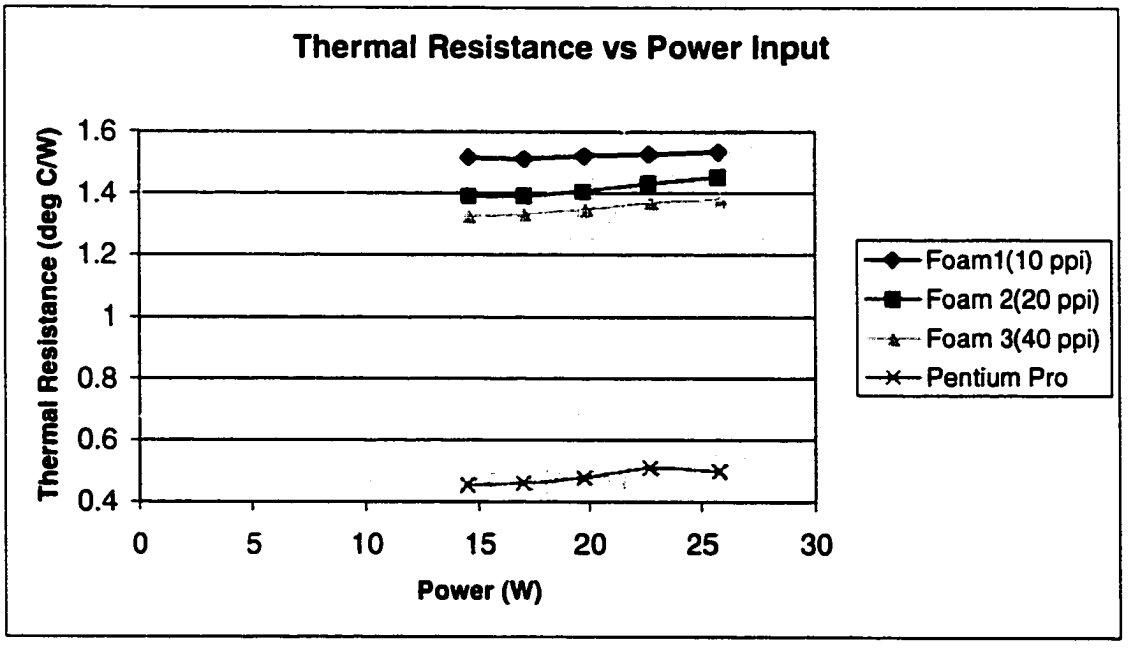
P = 25.824 Watts (Cont.)							
Channel 3							
Time	Temp. (C)		Time	Temp. (C)		Time	Temp. (C)
1524385.8	64.138		1524383.75	64.139		1524381.9	64.141
1524385.6	64.135		1524383.63	64.138		1524381.6	64.14
1524385.5	64.14		1524383.5	64.138		1524381.5	64.138
1524385.4	64.138		1524383.38	64.141		1524381.4	64.139
1524385.3	64.138		1524383.13	64.141		1524381.3	64.139
1524385.1	64.136		1524383	64.14		1524381.1	64.137
1524385	64.141		1524382.88	64.141		1524381	64.14
1524384.9	64.138		1524382.75	64.14		1524380.9	64.14
1524384.8	64.14		1524382.63	64.139		1524380.8	64.14
1524384.6	64.139		1524382.5	64.14		1524380.6	64.142
1524384.5	64.139		1524382.38	64.141		1524380.5	64.138
1524384.3	64.14		1524382.25	64.141		1524380.4	64.141
1524384.1	64.14		1524382.13	64.138		1524380.3	64.14
1524384	64.139		1524382	64.141		1524380.1	64.143
1524383.9	64.139						
Average Temperature: 64.13944 deg C							

Graphical Comparison of Foam Results and Existing Heat Sink

Foam 1		Foam 2		Foam 3		Pentium Pro Heat Sink	
Power	Avg. T (C)	Power	Avg. T (C)	Power	Avg. T (C)	Power	Avg. T (C)
14.52	46.3103	14.544	44.33513	14.52605	44.06217	14.45402	31.87504
17.056	50.38132	17.056	48.25232	17.03	47.89193	16.98453	33.23213
19.768	54.77491	19.712	52.30717	19.80307	52.19377	19.71904	34.94518
22.65	59.37324	22.62	56.973717	22.71	56.7064	22.65755	36.7675
25.78394	64.46312	25.75195	62.08687	25.824	61.5593	25.792	38.66092



Foam 1		Foam 2		Foam 3		Pentium Pro Heat Sink	
Power	R (degC/W)	Power	R (degC/W)	Power	R (degC/W)	Power	R (degC/W)
14.52	1.51586	14.544	1.3913	14.52605	1.32604	14.45402	0.45489
17.056	1.51167	17.056	1.39261	17.03	1.33247	16.98453	0.46113
19.768	1.52139	19.712	1.4056	19.80307	1.34796	19.71904	0.47899
22.65	1.52641	22.62	1.4312	22.71	1.36972	22.65755	0.51054
25.78394	1.53441	25.75195	1.45181	25.824	1.38086	25.792	0.49864



2. Data Sheets for Aluminum Foam 1: Different Heights

a. Aluminum Foam Height 2: ½ original

Power = 14.57407 W							
Channel 1							
Time	Temp. (C)		Time	Temp. (C)		Time	Temp. (C)
2731683.3	51.164		2731681.3	51.164		2731679.3	51.171
2731683	51.161		2731681	51.167		2731679.3	51.171
2731683	51.163		2731681	51.164		2731679	51.172
2731682.8	51.162		2731680.8	51.169		2731679	51.172
2731682.8	51.165		2731680.8	51.169		2731678.8	51.171
2731682.5	51.167		2731680.5	51.167		2731678.5	51.171
2731682.5	51.163		2731680.3	51.167		2731678.5	51.172
2731682.3	51.162		2731680.3	51.17		2731678.3	51.17
2731682	51.166		2731680	51.169		2731678.3	51.17
2731682	51.166		2731680	51.167		2731678	51.171
2731681.8	51.164		2731679.8	51.168		2731678	51.17
2731681.8	51.164		2731679.8	51.167		2731677.8	51.172
2731681.5	51.166		2731679.5	51.168		2731677.8	51.171
2731681.5	51.165		2731679.5	51.17		2731677.5	51.173
2731681.3	51.164						
Average Temperature: 51.16756 deg C							
Channel 2							
Time	Temp. (C)		Time	Temp. (C)		Time	Temp. (C)
2731702.3	50.453		2731700.3	50.453		2731698.5	50.45
2731702.3	50.453		2731700.3	50.452		2731698.3	50.45
2731702	50.453		2731700	50.451		2731698	50.451
2731702	50.452		2731699.8	50.453		2731698	50.451
2731701.8	50.455		2731699.8	50.452		2731697.8	50.452
2731701.8	50.452		2731699.5	50.452		2731697.8	50.449
2731701.5	50.451		2731699.5	50.452		2731697.5	50.452
2731701.5	50.451		2731699.3	50.454		2731697.5	50.451
2731701.3	50.449		2731699.3	50.454		2731697.3	50.453
2731701	50.451		2731699	50.453		2731697.3	50.452
2731701	50.451		2731699	50.452		2731697	50.451
2731700.8	50.452		2731698.8	50.452		2731697	50.45
2731700.8	50.452		2731698.8	50.452		2731696.8	50.45
2731700.5	50.45		2731698.5	50.454		2731696.8	50.451
2731700.5	50.451						
Average Temperature: 50.45174 deg C							

Power = 14.57407 Watts (Cont.)							
Channel 3							
Time	Temp. (C)		Time	Temp. (C)		Time	Temp. (C)
2731721.8	49.97		2731719.8	49.971		2731717.8	49.976
2731721.5	49.97		2731719.8	49.975		2731717.8	49.976
2731721.5	49.97		2731719.5	49.975		2731717.5	49.973
2731721.3	49.971		2731719.5	49.973		2731717.5	49.976
2731721.3	49.974		2731719.3	49.971		2731717.3	49.976
2731721	49.973		2731719	49.974		2731717.3	49.976
2731721	49.973		2731719	49.972		2731717	49.976
2731720.8	49.971		2731718.8	49.973		2731717	49.974
2731720.5	49.973		2731718.8	49.974		2731716.8	49.976
2731720.5	49.972		2731718.5	49.971		2731716.8	49.974
2731720.3	49.972		2731718.5	49.974		2731716.5	49.976
2731720.3	49.969		2731718.3	49.975		2731716.5	49.978
2731720	49.972		2731718.3	49.978		2731716.3	49.978
2731720	49.975		2731718	49.974			
Average Temperature: 49.97366 deg C							

Power = 17.082 Watts							
Channel 1							
Time	Temp. (C)		Time	Temp. (C)		Time	Temp. (C)
2734459	56.108		2734457.3	56.113		2734455.3	56.116
2734459	56.109		2734457	56.113		2734455	56.118
2734458.8	56.113		2734456.8	56.111		2734455	56.115
2734458.8	56.11		2734456.8	56.114		2734454.8	56.114
2734458.5	56.11		2734456.5	56.114		2734454.8	56.115
2734458.5	56.112		2734456.5	56.117		2734454.5	56.113
2734458.3	56.113		2734456.3	56.116		2734454.5	56.111
2734458	56.108		2734456.3	56.114		2734454.3	56.114
2734458	56.113		2734456	56.115		2734454.3	56.113
2734457.8	56.112		2734456	56.117		2734454	56.114
2734457.8	56.111		2734455.8	56.115		2734453.8	56.111
2734457.5	56.114		2734455.8	56.116		2734453.8	56.112
2734457.5	56.114		2734455.5	56.114		2734453.5	56.111
2734457.3	56.114		2734455.3	56.117		2734453.5	56.109
Average Temperature: 56.11317 deg C							
Channel 2							
Time	Temp. (C)		Time	Temp. (C)		Time	Temp. (C)
2734480	55.737		2734477.8	55.734		2734475.8	55.732
2734479.8	55.734		2734477.8	55.734		2734475.8	55.731
2734479.8	55.735		2734477.5	55.733		2734475.5	55.73
2734479.5	55.736		2734477.5	55.734		2734475.5	55.734
2734479.3	55.735		2734477.3	55.735		2734475.3	55.73
2734479.3	55.737		2734477.3	55.733		2734475.3	55.729
2734479	55.734		2734477	55.735		2734475	55.731
2734479	55.732		2734477	55.733		2734475	55.732
2734478.8	55.733		2734476.8	55.732		2734474.8	55.73
2734478.8	55.735		2734476.8	55.734		2734474.8	55.73
2734478.5	55.734		2734476.5	55.733		2734474.5	55.729
2734478.5	55.733		2734476.3	55.734		2734474.3	55.73
2734478.3	55.735		2734476.3	55.734		2734474.3	55.73
2734478.3	55.734		2734476	55.733		2734474	55.731
2734478	55.733		2734476	55.732			
Average Temperature: 55.73293 deg C							

Power = 17.082 Watts (Cont.)							
Channel 3							
Time	Temp. (C)		Time	Temp. (C)		Time	Temp. (C)
2734497.8	54.845		2734495.8	54.845		2734494	54.845
2734497.8	54.845		2734495.8	54.844		2734493.8	54.846
2734497.5	54.844		2734495.5	54.847		2734493.8	54.848
2734497.5	54.845		2734495.3	54.846		2734493.5	54.845
2734497.3	54.845		2734495.3	54.85		2734493.3	54.847
2734497.3	54.844		2734495	54.847		2734493.3	54.844
2734497	54.844		2734495	54.848		2734493	54.848
2734497	54.845		2734494.8	54.847		2734493	54.844
2734496.8	54.847		2734494.8	54.847		2734492.8	54.847
2734496.5	54.845		2734494.5	54.846		2734492.8	54.845
2734496.5	54.847		2734494.5	54.85		2734492.5	54.844
2734496.3	54.846		2734494.3	54.849		2734492.5	54.845
2734496.3	54.845		2734494.3	54.846		2734492.3	54.843
2734496	54.847		2734494	54.849		2734492.3	54.843
2734496	54.844						
Average Temperature: 54.84588 deg C							

Power = 19.796 Watts							
Channel 1							
Time	Temp. (C)		Time	Temp. (C)		Time	Temp. (C)
2744144.3	61.543		2744142.5	61.533		2744140.5	61.532
2744144.3	61.539		2744142.3	61.537		2744140.3	61.532
2744144	61.542		2744142	61.534		2744140.3	61.532
2744144	61.54		2744142	61.532		2744140	61.531
2744143.8	61.542		2744141.8	61.532		2744140	61.534
2744143.8	61.542		2744141.8	61.533		2744139.8	61.531
2744143.5	61.54		2744141.5	61.531		2744139.5	61.531
2744143.3	61.54		2744141.5	61.531		2744139.5	61.532
2744143.3	61.536		2744141.3	61.529		2744139.3	61.531
2744143	61.536		2744141	61.531		2744139.3	61.53
2744143	61.536		2744141	61.532		2744139	61.533
2744142.8	61.539		2744140.8	61.534		2744139	61.531
2744142.8	61.537		2744140.8	61.53		2744138.8	61.531
2744142.5	61.536		2744140.5	61.531			
Average Temperature: 61.53437 deg C							
Channel 2							
Time	Temp. (C)		Time	Temp. (C)		Time	Temp. (C)
2744162.8	61.165		2744160.8	61.168		2744158.5	61.171
2744162.5	61.164		2744160.5	61.17		2744158.3	61.176
2744162.5	61.164		2744160.3	61.166		2744158.3	61.173
2744162.3	61.165		2744160.3	61.17		2744158	61.176
2744162.3	61.165		2744160	61.165		2744158	61.176
2744162	61.164		2744160	61.167		2744157.8	61.175
2744162	61.167		2744159.8	61.164		2744157.8	61.175
2744161.8	61.165		2744159.8	61.167		2744157.5	61.174
2744161.5	61.164		2744159.5	61.169		2744157.5	61.177
2744161.5	61.166		2744159.3	61.17		2744157.3	61.178
2744161.3	61.168		2744159.3	61.17		2744157.3	61.177
2744161.3	61.167		2744159	61.17		2744157	61.178
2744161	61.165		2744159	61.17		2744157	61.179
2744161	61.168		2744158.8	61.171		2744156.8	61.179
2744160.8	61.164		2744158.8	61.173		2744156.8	61.177
Average Temperature: 61.17004 deg C							

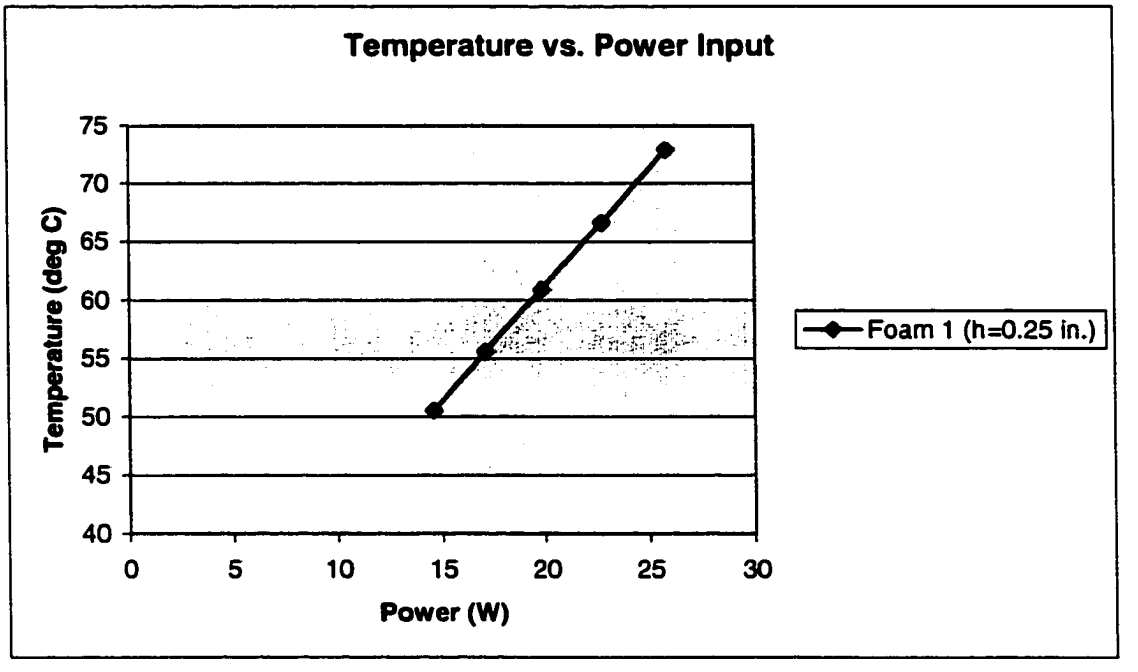
Power = 19.796 Watts (Cont.)							
Channel 3							
Time	Temp. (C)		Time	Temp. (C)		Time	Temp. (C)
2744190.8	59.979		2744188.8	59.975		2744187	59.978
2744190.8	59.979		2744188.8	59.977		2744186.8	59.978
2744190.5	59.977		2744188.5	59.978		2744186.8	59.978
2744190.5	59.976		2744188.5	59.978		2744186.5	59.978
2744190.3	59.975		2744188.3	59.975		2744186.5	59.979
2744190.3	59.976		2744188.3	59.974		2744186.3	59.98
2744190	59.978		2744188	59.976		2744186.3	59.982
2744189.8	59.976		2744188	59.976		2744186	59.98
2744189.8	59.977		2744187.8	59.974		2744185.8	59.98
2744189.5	59.973		2744187.5	59.979		2744185.8	59.979
2744189.5	59.975		2744187.5	59.976		2744185.5	59.979
2744189.3	59.974		2744187.3	59.975		2744185.5	59.979
2744189.3	59.974		2744187.3	59.976		2744185.3	59.98
2744189	59.974		2744187	59.977			
Average Temperature: 59.97705 deg C							

Power = 22.71 Watts							
Channel 1							
Time	Temp. (C)		Time	Temp. (C)		Time	Temp. (C)
2747322.3	67.366		2747320	67.363		2747318.3	67.367
2747322	67.367		2747320	67.364		2747318	67.368
2747321.8	67.367		2747319.8	67.364		2747318	67.365
2747321.8	67.366		2747319.8	67.363		2747317.8	67.368
2747321.5	67.366		2747319.5	67.364		2747317.8	67.366
2747321.5	67.366		2747319.5	67.364		2747317.5	67.369
2747321.3	67.366		2747319.3	67.364		2747317.5	67.367
2747321.3	67.366		2747319.3	67.364		2747317.3	67.366
2747321	67.365		2747319	67.366		2747317.3	67.369
2747321	67.367		2747319	67.364		2747317	67.367
2747320.8	67.363		2747318.8	67.365		2747316.8	67.369
2747320.5	67.364		2747318.8	67.364		2747316.8	67.368
2747320.5	67.362		2747318.5	67.366		2747316.5	67.364
2747320.3	67.364		2747318.3	67.364		2747316.5	67.367
2747320.3	67.367						
Average Temperature: 67.3656 deg C							
Channel 2							
Time	Temp. (C)		Time	Temp. (C)		Time	Temp. (C)
2747338.3	66.877		2747336.3	66.873		2747334.5	66.869
2747338.3	66.876		2747336.3	66.873		2747334.3	66.867
2747338	66.88		2747336	66.874		2747334	66.868
2747338	66.875		2747336	66.873		2747334	66.863
2747337.8	66.876		2747335.8	66.872		2747334	66.864
2747337.8	66.873		2747335.8	66.872		2747333.8	66.865
2747337.5	66.874		2747335.5	66.872		2747333.5	66.863
2747337.5	66.875		2747335.5	66.871		2747333.5	66.861
2747337.3	66.874		2747335.3	66.873		2747333.3	66.862
2747337.3	66.874		2747335.3	66.868		2747333.3	66.861
2747337	66.878		2747335	66.867		2747333	66.864
2747337	66.875		2747335	66.87		2747333	66.861
2747336.8	66.875		2747334.8	66.866		2747332.8	66.86
2747336.8	66.875		2747334.8	66.868		2747332.5	66.861
2747336.5	66.875		2747334.5	66.868		2747332.5	66.862
Average Temperature: 66.86984 deg C							

Power = 22.71 Watts (Cont.)							
Channel 3							
Time	Temp. (C)		Time	Temp. (C)		Time	Temp. (C)
2747357.8	65.596		2747355.8	65.594		2747353.8	65.594
2747357.5	65.595		2747355.8	65.595		2747353.8	65.597
2747357.5	65.593		2747355.5	65.595		2747353.5	65.597
2747357.3	65.594		2747355.5	65.596		2747353.5	65.597
2747357.3	65.595		2747355.3	65.592		2747353.3	65.599
2747357	65.594		2747355	65.595		2747353.3	65.594
2747357	65.594		2747355	65.597		2747353	65.596
2747356.8	65.595		2747354.8	65.595		2747353	65.597
2747356.5	65.594		2747354.8	65.596		2747352.8	65.596
2747356.5	65.592		2747354.5	65.594		2747352.8	65.593
2747356.3	65.594		2747354.5	65.595		2747352.5	65.596
2747356.3	65.595		2747354.3	65.592		2747352.5	65.594
2747356	65.595		2747354.3	65.594		2747352.3	65.596
2747356	65.593		2747354	65.594			
Average Temperature: 65.59485 deg C							

Power = 25.824 Watts							
Channel 1							
Time	Temp. (C)		Time	Temp. (C)		Time	Temp. (C)
2748550.8	73.81		2748548.8	73.815		2748546.8	73.822
2748550.8	73.811		2748548.8	73.815		2748546.5	73.822
2748550.5	73.81		2748548.5	73.812		2748546.5	73.822
2748550.5	73.812		2748548.3	73.818		2748546.3	73.821
2748550.3	73.813		2748548.3	73.814		2748546.3	73.822
2748550.3	73.811		2748548	73.817		2748546	73.821
2748550	73.812		2748548	73.817		2748546	73.821
2748549.8	73.811		2748547.8	73.817		2748545.8	73.823
2748549.8	73.812		2748547.8	73.818		2748545.8	73.823
2748549.5	73.813		2748547.5	73.816		2748545.5	73.823
2748549.5	73.814		2748547.5	73.818		2748545.3	73.825
2748549.3	73.812		2748547.3	73.816		2748545.3	73.824
2748549.3	73.816		2748547.3	73.818		2748545	73.824
2748549	73.814		2748547	73.821		2748545	73.824
2748549	73.815		2748546.8	73.82			
Average Temperature: 73.81716 deg C							
Channel 2							
Time	Temp. (C)		Time	Temp. (C)		Time	Temp. (C)
2748568.3	73.155		2748566.3	73.153		2748564.5	73.157
2748568	73.155		2748566.3	73.153		2748564.5	73.154
2748568	73.156		2748566	73.155		2748564.3	73.154
2748567.8	73.158		2748566	73.155		2748564	73.156
2748567.8	73.158		2748565.8	73.151		2748564	73.155
2748567.5	73.155		2748565.5	73.155		2748564	73.154
2748567.3	73.159		2748565.5	73.151		2748563.8	73.156
2748567.3	73.157		2748565.3	73.154		2748563.5	73.155
2748567	73.156		2748565.3	73.153		2748563.5	73.156
2748567	73.154		2748565	73.153		2748563.3	73.156
2748566.8	73.154		2748565	73.154		2748563.3	73.155
2748566.8	73.152		2748564.8	73.152		2748563	73.156
2748566.5	73.155		2748564.8	73.155		2748563	73.156
2748566.5	73.155						
Average Temperature: 73.15483 deg C							

Power = 25.824 Watts (Cont.)							
Channel 3							
Time	Temp. (C)		Time	Temp. (C)		Time	Temp. (C)
2748584.5	71.738		2748582.8	71.744		2748581	71.743
2748584.5	71.738		2748582.5	71.739		2748580.8	71.744
2748584.3	71.738		2748582.5	71.742		2748580.8	71.743
2748584.3	71.737		2748582.3	71.741		2748580.5	71.745
2748584	71.739		2748582	71.74		2748580.5	71.746
2748584	71.738		2748582	71.744		2748580.3	71.744
2748583.8	71.738		2748581.8	71.741		2748580.3	71.747
2748583.8	71.735		2748581.8	71.742		2748580	71.745
2748583.5	71.738		2748581.5	71.744		2748580	71.748
2748583.3	71.74		2748581.5	71.743		2748579.8	71.746
2748583.3	71.738		2748581.3	71.741		2748579.5	71.746
2748583	71.738		2748581.3	71.743		2748579.5	71.749
2748583	71.738		2748581	71.745		2748579.3	71.748
2748582.8	71.738						
Average Temperature: 71.74185 deg C							



Power	T (deg C)
14.57407	50.53099
17.082	55.56399
19.796	60.89382
22.71	66.6101
25.824	72.90461

b. Aluminum Foam Height 3: 3/8 original

Power = 14.57407 W							
Channel 1							
Time	Temp. (C)		Time	Temp. (C)		Time	Temp. (C)
2821281.5	55.054		2821279.5	55.052		2821277.5	55.053
2821281.5	55.055		2821279.5	55.052		2821277.5	55.053
2821281.3	55.054		2821279.3	55.052		2821277.3	55.055
2821281.3	55.052		2821279	55.053		2821277.3	55.051
2821281	55.056		2821279	55.051		2821277	55.053
2821281	55.053		2821278.8	55.053		2821277	55.057
2821280.8	55.054		2821278.8	55.054		2821276.8	55.052
2821280.8	55.052		2821278.5	55.052		2821276.8	55.055
2821280.5	55.054		2821278.5	55.051		2821276.5	55.053
2821280.3	55.053		2821278.3	55.053		2821276.5	55.05
2821280.3	55.054		2821278.3	55.053		2821276.3	55.053
2821280	55.049		2821278	55.053		2821276.3	55.055
2821280	55.052		2821278	55.053		2821276	55.053
2821279.8	55.052		2821277.8	55.052		2821276	55.055
2821279.8	55.055						
Average Temperature:	55.05305 deg C						
Channel 2							
Time	Temp. (C)		Time	Temp. (C)		Time	Temp. (C)
2821300.5	53.61		2821298.5	53.611		2821296.5	53.611
2821300.3	53.61		2821298.3	53.61		2821296.5	53.611
2821300	53.608		2821298.3	53.611		2821296.3	53.613
2821300	53.61		2821298	53.611		2821296.3	53.61
2821299.8	53.611		2821298	53.611		2821296	53.61
2821299.8	53.608		2821297.8	53.61		2821296	53.608
2821299.5	53.611		2821297.8	53.612		2821295.8	53.608
2821299.5	53.611		2821297.5	53.61		2821295.5	53.608
2821299.3	53.609		2821297.5	53.611		2821295.5	53.611
2821299.3	53.612		2821297.3	53.611		2821295.3	53.614
2821299	53.611		2821297.3	53.607		2821295.3	53.613
2821299	53.61		2821297	53.609		2821295	53.613
2821298.8	53.609		2821296.8	53.61		2821295	53.611
2821298.5	53.609		2821296.8	53.613		2821294.8	53.611
Average Temperature:	53.61043 deg C						

Power = 14.57407 W (Cont.)							
Channel 3							
Time	Temp. (C)		Time	Temp. (C)		Time	Temp. (C)
2821317.8	54.107		2821315.8	54.106		2821313.8	54.104
2821317.5	54.104		2821315.5	54.104		2821313.8	54.107
2821317.3	54.105		2821315.5	54.105		2821313.5	54.106
2821317.3	54.106		2821315.3	54.103		2821313.5	54.107
2821317	54.104		2821315.3	54.106		2821313.3	54.105
2821317	54.106		2821315	54.103		2821313	54.104
2821316.8	54.107		2821315	54.107		2821313	54.106
2821316.8	54.102		2821314.8	54.105		2821312.8	54.105
2821316.5	54.1		2821314.8	54.105		2821312.8	54.108
2821316.5	54.103		2821314.5	54.106		2821312.5	54.104
2821316.3	54.105		2821314.3	54.105		2821312.5	54.105
2821316.3	54.108		2821314.3	54.108		2821312.3	54.109
2821316	54.105		2821314	54.106		2821312.3	54.106
2821315.8	54.104		2821314	54.105			
Average Temperature: 54.10527 deg C							

Power = 17.08857 W							
Channel 1							
Time	Temp. (C)		Time	Temp. (C)		Time	Temp. (C)
2826246	60.571		2826244	60.575		2826242	60.574
2826245.8	60.574		2826244	60.572		2826242	60.577
2826245.8	60.571		2826243.8	60.573		2826241.8	60.576
2826245.5	60.568		2826243.8	60.573		2826241.8	60.576
2826245.5	60.572		2826243.5	60.576		2826241.5	60.579
2826245.3	60.573		2826243.3	60.575		2826241.5	60.582
2826245	60.575		2826243.3	60.573		2826241.3	60.575
2826245	60.569		2826243	60.572		2826241.3	60.576
2826244.8	60.572		2826243	60.576		2826241	60.58
2826244.8	60.572		2826242.8	60.575		2826241	60.577
2826244.5	60.572		2826242.8	60.577		2826240.8	60.577
2826244.5	60.572		2826242.5	60.575		2826240.8	60.575
2826244.3	60.573		2826242.5	60.577		2826240.5	60.577
2826244.3	60.573		2826242.3	60.574		2826240.5	60.577
Average Temperature: 60.57448 deg C							
Channel 2							
Time	Temp. (C)		Time	Temp. (C)		Time	Temp. (C)
2826265.5	59.488		2826263.5	59.487		2826261.5	59.482
2826265.5	59.491		2826263.3	59.485		2826261.3	59.481
2826265.3	59.489		2826263.3	59.488		2826261.3	59.476
2826265.3	59.49		2826263	59.487		2826261	59.478
2826265	59.49		2826263	59.482		2826261	59.477
2826265	59.49		2826262.8	59.487		2826260.8	59.48
2826264.8	59.489		2826262.8	59.486		2826260.8	59.477
2826264.5	59.49		2826262.5	59.485		2826260.5	59.476
2826264.5	59.49		2826262.5	59.483		2826260.3	59.477
2826264.3	59.489		2826262.3	59.485		2826260.3	59.476
2826264.3	59.493		2826262.3	59.48		2826260	59.478
2826264	59.49		2826262	59.482		2826260	59.475
2826264	59.489		2826261.8	59.479		2826259.8	59.476
2826263.8	59.49		2826261.8	59.478		2826259.8	59.474
2826263.8	59.489		2826261.5	59.481			
Average Temperature: 59.48375 deg C							

Power = 17.08857 W (Cont.)							
Channel 3							
Time	Temp. (C)		Time	Temp. (C)		Time	Temp. (C)
2826282.8	59.7		2826280.8	59.699		2826278.8	59.7
2826282.5	59.698		2826280.5	59.699		2826278.8	59.699
2826282.5	59.698		2826280.5	59.7		2826278.5	59.701
2826282.3	59.697		2826280.3	59.7		2826278.5	59.7
2826282.3	59.696		2826280.3	59.704		2826278.3	59.699
2826282	59.696		2826280	59.701		2826278.3	59.699
2826282	59.697		2826280	59.702		2826278	59.699
2826281.8	59.696		2826279.8	59.7		2826278	59.699
2826281.8	59.697		2826279.8	59.703		2826277.8	59.697
2826281.5	59.696		2826279.5	59.701		2826277.8	59.702
2826281.5	59.698		2826279.3	59.705		2826277.5	59.702
2826281.3	59.695		2826279.3	59.704		2826277.3	59.699
2826281	59.696		2826279	59.7		2826277.3	59.698
2826281	59.702		2826279	59.704		2826277	59.699
2826280.8	59.7						
Average Temperature: 59.69947 deg C							

Power = 19.80307 W							
Channel 1							
Time	Temp. (C)		Time	Temp. (C)		Time	Temp. (C)
2829111.5	67.101		2829109.8	67.102		2829107.8	67.104
2829111.5	67.101		2829109.5	67.104		2829107.8	67.105
2829111.3	67.103		2829109.5	67.099		2829107.5	67.1
2829111.3	67.103		2829109.3	67.103		2829107.5	67.101
2829111	67.103		2829109.3	67.101		2829107.3	67.1
2829111	67.102		2829109	67.1		2829107	67.1
2829110.8	67.1		2829109	67.102		2829107	67.1
2829110.5	67.103		2829108.8	67.101		2829106.8	67.099
2829110.5	67.101		2829108.8	67.101		2829106.8	67.1
2829110.3	67.102		2829108.5	67.103		2829106.5	67.1
2829110.3	67.103		2829108.3	67.103		2829106.5	67.099
2829110	67.101		2829108.3	67.099		2829106.3	67.104
2829110	67.103		2829108	67.102		2829106.3	67.1
2829109.8	67.105		2829108	67.104		2829106	67.101
Average Temperature: 67.10162 deg C							
Channel 2							
Time	Temp. (C)		Time	Temp. (C)		Time	Temp. (C)
2829129.3	66.424		2829127.3	66.424		2829125.3	66.424
2829129	66.425		2829127.3	66.424		2829125.3	66.426
2829129	66.423		2829127	66.426		2829125	66.422
2829128.8	66.421		2829126.8	66.425		2829125	66.425
2829128.8	66.422		2829126.8	66.425		2829124.8	66.424
2829128.5	66.422		2829126.5	66.424		2829124.8	66.423
2829128.3	66.423		2829126.5	66.426		2829124.5	66.422
2829128.3	66.422		2829126.3	66.425		2829124.5	66.422
2829128	66.424		2829126.3	66.423		2829124.3	66.425
2829128	66.424		2829126	66.426		2829124.3	66.42
2829127.8	66.425		2829126	66.425		2829124	66.425
2829127.8	66.424		2829125.8	66.424		2829124	66.424
2829127.5	66.423		2829125.5	66.425		2829123.8	66.423
2829127.5	66.422		2829125.5	66.424			
Average Temperature: 66.42378 deg C							

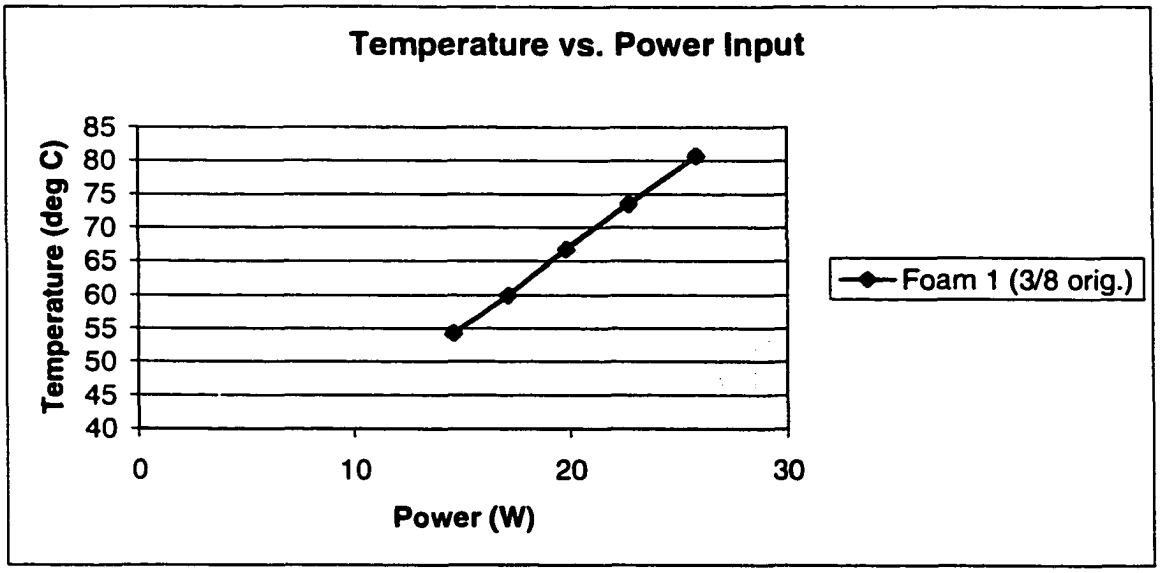
Power = 19.80307 W (Cont.)							
Channel 3							
Time	Temp. (C)		Time	Temp. (C)		Time	Temp. (C)
2829145.8	66.669		2829143.8	66.669		2829141.8	66.669
2829145.8	66.67		2829143.8	66.671		2829141.5	66.666
2829145.5	66.671		2829143.5	66.667		2829141.5	66.667
2829145.5	66.669		2829143.3	66.67		2829141.3	66.667
2829145.3	66.672		2829143.3	66.668		2829141.3	66.668
2829145	66.673		2829143	66.668		2829141	66.667
2829145	66.671		2829143	66.669		2829141	66.669
2829144.8	66.67		2829142.8	66.667		2829140.8	66.665
2829144.8	66.671		2829142.8	66.669		2829140.8	66.667
2829144.5	66.671		2829142.5	66.669		2829140.5	66.665
2829144.5	66.669		2829142.5	66.667		2829140.5	66.667
2829144.3	66.67		2829142.3	66.669		2829140.3	66.669
2829144.3	66.671		2829142.3	66.668		2829140	66.666
2829144	66.669		2829142	66.668		2829140	66.667
2829144	66.671		2829142	66.671			
Average Temperature: 66.66877 deg C							

Power = 22.71757 W							
Channel 1							
Time	Temp. (C)		Time	Temp. (C)		Time	Temp. (C)
2830820.3	73.908		2830818.3	73.913		2830816.5	73.913
2830820.3	73.91		2830818.3	73.909		2830816.3	73.914
2830820	73.91		2830818	73.91		2830816.3	73.916
2830820	73.909		2830817.8	73.91		2830816	73.914
2830819.8	73.908		2830817.8	73.91		2830815.8	73.912
2830819.5	73.909		2830817.5	73.91		2830815.8	73.914
2830819.5	73.909		2830817.5	73.91		2830815.5	73.913
2830819.3	73.911		2830817.3	73.91		2830815.5	73.915
2830819.3	73.91		2830817.3	73.913		2830815.3	73.915
2830819	73.911		2830817	73.915		2830815.3	73.915
2830819	73.908		2830817	73.91		2830815	73.916
2830818.8	73.91		2830816.8	73.911		2830815	73.918
2830818.8	73.907		2830816.8	73.91		2830814.8	73.916
2830818.5	73.911		2830816.5	73.914		2830814.8	73.923
2830818.5	73.908						
Average Temperature:	73.91181 deg C						
Channel 2							
Time	Temp. (C)		Time	Temp. (C)		Time	Temp. (C)
2830836.3	73.232		2830834.3	73.229		2830832.3	73.226
2830836	73.23		2830834	73.226		2830832.3	73.226
2830836	73.229		2830834	73.231		2830832	73.225
2830835.8	73.229		2830833.8	73.229		2830832	73.226
2830835.5	73.228		2830833.8	73.228		2830831.8	73.226
2830835.5	73.229		2830833.5	73.229		2830831.8	73.227
2830835.3	73.228		2830833.5	73.229		2830831.5	73.226
2830835.3	73.23		2830833.3	73.228		2830831.5	73.226
2830835	73.228		2830833.3	73.229		2830831.3	73.224
2830835	73.23		2830833	73.227		2830831.3	73.223
2830834.8	73.229		2830833	73.228		2830831	73.224
2830834.8	73.228		2830832.8	73.226		2830831	73.224
2830834.5	73.228		2830832.5	73.229		2830830.8	73.223
2830834.5	73.224		2830832.5	73.228		2830830.5	73.225
Average Temperature:	73.22736 deg C						

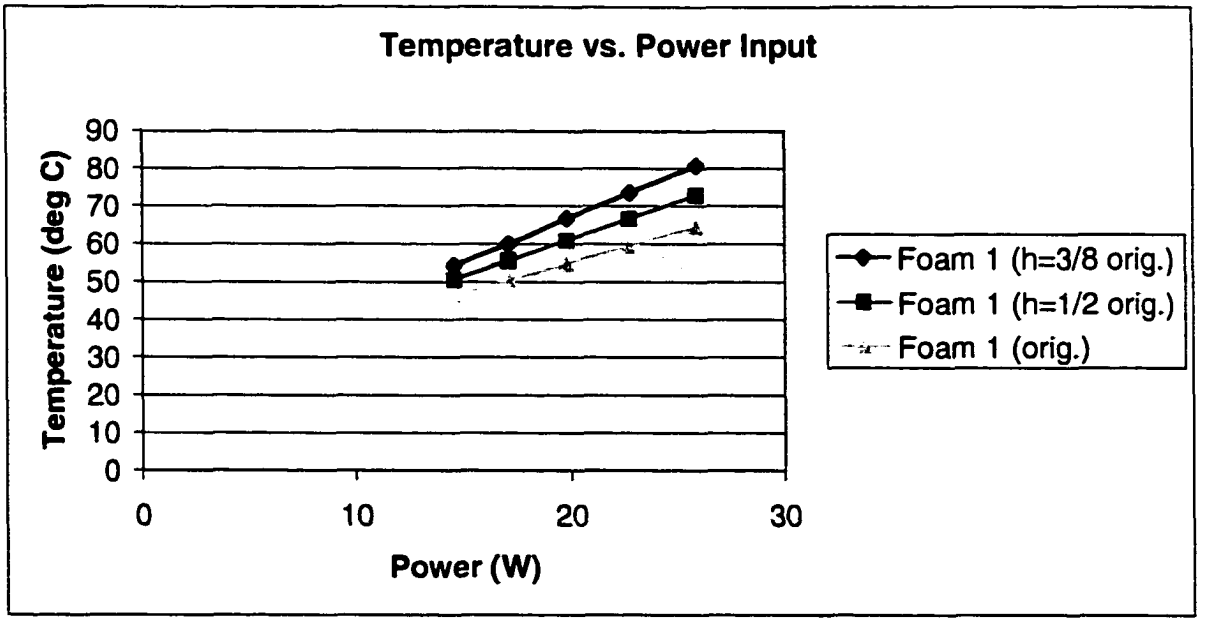
Power = 22.71757 W (Cont.)							
Channel 3							
Time	Temp. (C)		Time	Temp. (C)		Time	Temp. (C)
2830855.3	73.465		2830853.5	73.468		2830851.5	73.472
2830855.3	73.465		2830853.3	73.469		2830851.3	73.47
2830855	73.464		2830853	73.467		2830851.3	73.472
2830855	73.465		2830853	73.467		2830851	73.474
2830854.8	73.465		2830852.8	73.468		2830851	73.471
2830854.8	73.463		2830852.8	73.471		2830850.8	73.473
2830854.5	73.464		2830852.5	73.467		2830850.8	73.472
2830854.3	73.467		2830852.5	73.468		2830850.5	73.472
2830854.3	73.464		2830852.3	73.464		2830850.3	73.47
2830854	73.464		2830852.3	73.469		2830850.3	73.474
2830854	73.467		2830852	73.471		2830850	73.474
2830853.8	73.466		2830852	73.468		2830850	73.476
2830853.8	73.466		2830851.8	73.471		2830849.8	73.472
2830853.5	73.467		2830851.5	73.467			
Average Temperature: 73.46851 deg C							

Power = 25.824 W							
Channel 1							
Time	Temp. (C)		Time	Temp. (C)		Time	Temp. (C)
2833218	81.097		2833216	81.095		2833214	81.099
2833218	81.098		2833216	81.096		2833213.8	81.098
2833217.8	81.098		2833215.8	81.097		2833213.8	81.1
2833217.8	81.098		2833215.8	81.097		2833213.5	81.1
2833217.5	81.098		2833215.5	81.096		2833213.5	81.102
2833217.5	81.098		2833215.3	81.097		2833213.3	81.104
2833217.3	81.097		2833215.3	81.098		2833213.3	81.101
2833217.3	81.097		2833215	81.095		2833213	81.102
2833217	81.098		2833215	81.099		2833213	81.104
2833217	81.098		2833214.8	81.097		2833212.8	81.101
2833216.8	81.098		2833214.8	81.097		2833212.8	81.101
2833216.5	81.096		2833214.5	81.098		2833212.5	81.099
2833216.5	81.098		2833214.5	81.097		2833212.5	81.102
2833216.3	81.097		2833214.3	81.099		2833212.3	81.101
2833216.3	81.096		2833214.3	81.098			
Average Temperature: 81.09845 deg C							
Channel 2							
Time	Temp. (C)		Time	Temp. (C)		Time	Temp. (C)
2833240	80.342		2833238	80.341		2833236	80.337
2833239.8	80.343		2833237.8	80.339		2833236	80.338
2833239.8	80.344		2833237.8	80.338		2833235.8	80.34
2833239.5	80.343		2833237.5	80.341		2833235.8	80.338
2833239.5	80.343		2833237.5	80.341		2833235.5	80.337
2833239.3	80.342		2833237.3	80.34		2833235.5	80.338
2833239.3	80.34		2833237.3	80.339		2833235.3	80.339
2833239	80.342		2833237	80.34		2833235.3	80.338
2833239	80.34		2833236.8	80.337		2833235	80.335
2833238.8	80.342		2833236.8	80.338		2833235	80.335
2833238.8	80.34		2833236.5	80.341		2833234.8	80.335
2833238.5	80.339		2833236.5	80.338		2833234.8	80.337
2833238.3	80.339		2833236.3	80.337		2833234.5	80.335
2833238.3	80.34		2833236.3	80.336		2833234.3	80.334
2833238	80.338						
Average Temperature: 80.33905 deg C							

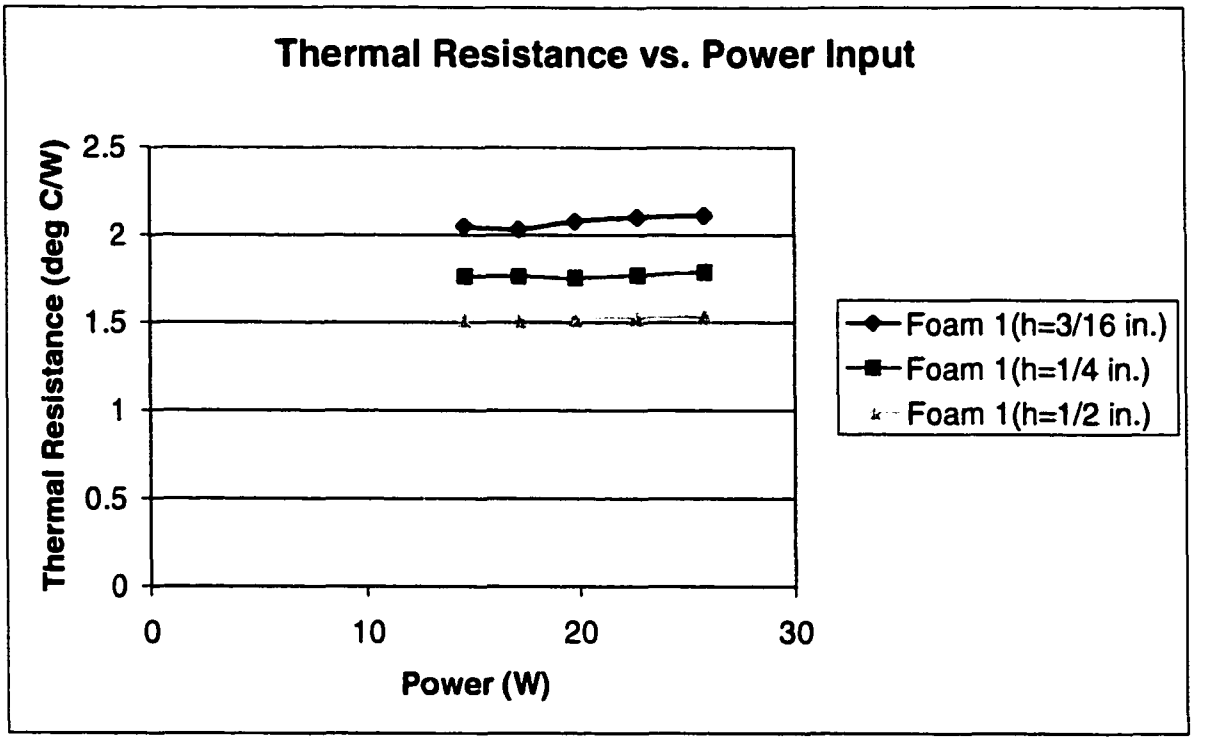
Power = 25.824 W (Cont.)							
Channel 3							
Time	Temp. (C)		Time	Temp. (C)		Time	Temp. (C)
2833255.3	80.627		2833253.5	80.623		2833251.8	80.617
2833255.3	80.624		2833253.5	80.623		2833251.8	80.617
2833255	80.622		2833253.3	80.623		2833251.5	80.618
2833255	80.623		2833253.3	80.622		2833251.5	80.618
2833254.8	80.625		2833253	80.62		2833251.3	80.617
2833254.8	80.626		2833252.8	80.622		2833251.3	80.616
2833254.5	80.627		2833252.8	80.621		2833251	80.614
2833254.3	80.622		2833252.5	80.618		2833251	80.614
2833254.3	80.624		2833252.5	80.62		2833250.8	80.614
2833254	80.623		2833252.3	80.618		2833250.5	80.612
2833254	80.624		2833252.3	80.619		2833250.5	80.612
2833253.8	80.621		2833252	80.618		2833250.3	80.61
2833253.8	80.621		2833252	80.619		2833250.3	80.608
Average Temperature: 80.61954 deg C							



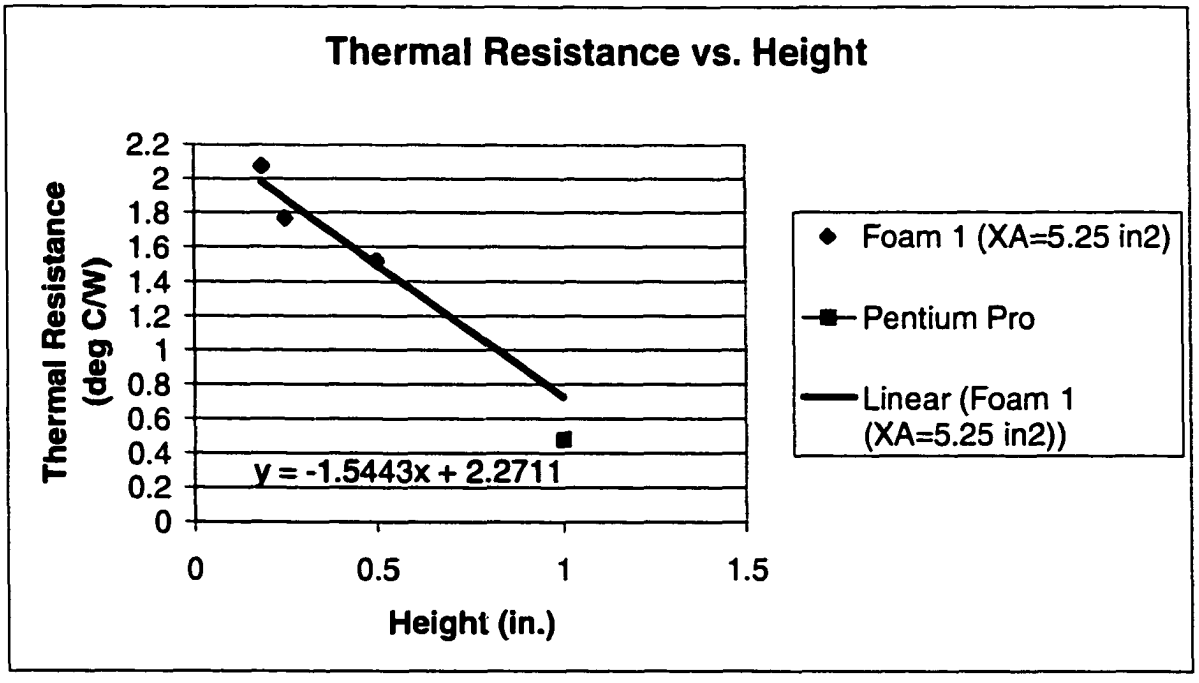
Power (W)	T (deg C)
14.57407	54.25625
17.08857	59.91923
19.80307	66.73139
22.71757	73.53589
25.824	80.68568



Foam 1 (h = 0.1875 in.)		Foam 1 (h = 0.25 in.)		Foam 1 (h = 0.5 in.)	
Power (W)	T (deg C)	Power	T (deg C)	Power (W)	T (deg C)
14.57407	54.25625	14.57407	50.53099	14.52	46.3103
17.08857	59.91923	17.082	55.56399	17.056	50.38312
19.80307	66.73139	19.796	60.89382	19.768	54.77491
22.71757	73.53589	22.71	66.6101	22.65	59.37324
25.824	80.68568	25.824	72.90461	25.78394	64.46312



Foam 1 (h = 0.1875 in.)		Foam 1 (h = 0.25 in.)		Foam 1 (h = 0.5 in.)	
Power (W)	R (deg C/W)	Power	R (deg C/W)	Power (W)	R (deg C/W)
14.57407	2.04859	14.57407	1.7655	14.52	1.51586
17.08857	2.03172	17.082	1.7658	17.056	1.51167
19.80307	2.07703	19.796	1.7576	19.768	1.52139
22.71757	2.10128	22.71	1.7706	22.65	1.52641
25.824	2.10989	25.824	1.7892	25.78394	1.53441
Average:	2.073702	Average:	1.76974	Average:	1.521948



Foam 1	
height (in.)	R (deg C/W)
0.1875	2.073702
0.25	1.76974
0.5	1.521948
Pentium Pro	
1	0.480838

3. Data Sheets for Aluminum Foam 2: Different Surface Areas

a. Aluminum Foam S. A. 2: 2/3 original

P = 14.568 Watts

Channel 1

Time	Temp. (C)		Time	Temp. (C)		Time	Temp. (C)
2134559.3	52.097		2134557.3	52.093		2134555.5	52.092
2134559.3	52.099		2134557.3	52.096		2134555.3	52.089
2134559	52.096		2134557	52.093		2134555	52.09
2134559	52.099		2134556.8	52.09		2134555	52.095
2134558.8	52.108		2134556.8	52.092		2134554.8	52.083
2134558.8	52.09		2134556.5	52.094		2134554.8	52.085
2134558.5	52.095		2134556.5	52.096		2134554.5	52.08
2134558.5	52.098		2134556.3	52.092		2134554.5	52.079
2134558.3	52.092		2134556.3	52.094		2134554.3	52.088
2134558.3	52.088		2134556	52.092		2134554.3	52.088
2134558	52.092		2134556	52.094		2134554	52.087
2134557.8	52.098		2134555.8	52.09		2134554	52.087
2134557.8	52.095		2134555.8	52.091		2134553.8	52.086
2134557.5	52.094		2134555.5	52.089		2134553.8	52.086
2134557.5	52.094						

Average Temperature: 52.09177 deg C

Channel 2

Time	Temp. (C)		Time	Temp. (C)		Time	Temp. (C)
2134584.5	49.896		2134582.5	49.895		2134580.5	49.896
2134584.3	49.896		2134582.3	49.895		2134580.5	49.895
2134584.3	49.896		2134582.3	49.894		2134580.3	49.893
2134584	49.897		2134582	49.894		2134580.3	49.898
2134584	49.895		2134582	49.893		2134580	49.897
2134583.8	49.896		2134581.8	49.892		2134579.8	49.897
2134583.8	49.895		2134581.5	49.897		2134579.8	49.894
2134583.5	49.897		2134581.5	49.891		2134579.5	49.894
2134583.5	49.893		2134581.3	49.898		2134579.5	49.898
2134583.3	49.896		2134581.3	49.897		2134579.3	49.9
2134583.3	49.895		2134581	49.892		2134579.3	49.895
2134583	49.895		2134581	49.892		2134579	49.895
2134582.8	49.89		2134580.8	49.895		2134579	49.898
2134582.8	49.89		2134580.8	49.894		2134578.8	49.898
2134582.5	49.894						

Average Temperature: 49.89507 deg C

P = 14.568 Watts (Cont.)								
Channel 3								
Time	Temp. (C)		Time	Temp. (C)		Time	Temp. (C)	
2134606	49.572		2134604	49.597		2134602	49.525	
2134605.8	49.568		2134603.8	49.6		2134602	49.59	
2134605.8	49.563		2134603.8	49.526		2134601.8	49.52	
2134605.5	49.576		2134603.5	49.591		2134601.8	49.577	
2134605.3	49.548		2134603.5	49.595		2134601.5	49.552	
2134605.3	49.601		2134603.3	49.568		2134601.5	49.557	
2134605	49.583		2134603.3	49.557		2134601.3	49.563	
2134605	49.6		2134603	49.564		2134601	49.563	
2134604.8	49.573		2134603	49.565		2134601	49.557	
2134604.8	49.577		2134602.8	49.562		2134600.8	49.559	
2134604.5	49.576		2134602.8	49.56		2134600.8	49.562	
2134604.5	49.567		2134602.5	49.561		2134600.5	49.542	
2134604.3	49.569		2134602.3	49.579		2134600.5	49.55	
2134604.3	49.577		2134602.3	49.573		2134600.3	49.567	
Average Temperature: 49.56743 deg C								

P = 17.082 Watts

Channel 1

Time	Temp. (C)		Time	Temp. (C)		Time	Temp. (C)
2135063.5	57.183		2135061.5	57.186		2135059.5	57.188
2135063.3	57.181		2135061.3	57.189		2135059.3	57.191
2135063.3	57.184		2135061.3	57.184		2135059.3	57.188
2135063	57.185		2135061	57.187		2135059	57.188
2135063	57.184		2135060.8	57.186		2135059	57.19
2135062.8	57.185		2135060.8	57.184		2135058.8	57.187
2135062.8	57.183		2135060.5	57.187		2135058.8	57.189
2135062.5	57.183		2135060.5	57.189		2135058.5	57.188
2135062.3	57.184		2135060.3	57.188		2135058.5	57.189
2135062.3	57.186		2135060.3	57.182		2135058.3	57.187
2135062	57.185		2135060	57.186		2135058.3	57.188
2135062	57.188		2135060	57.188		2135058	57.191
2135061.8	57.187		2135059.8	57.187		2135058	57.192
2135061.8	57.187		2135059.8	57.186		2135057.8	57.187
2135061.5	57.182						

Average Temperature: 57.18649 deg C

Channel 2

Time	Temp. (C)		Time	Temp. (C)		Time	Temp. (C)
2135042.8	54.583		2135040.8	54.58		2135038.8	54.581
2135042.5	54.582		2135040.5	54.582		2135038.5	54.581
2135042.5	54.584		2135040.5	54.586		2135038.5	54.579
2135042.3	54.584		2135040.3	54.582		2135038.3	54.578
2135042.3	54.584		2135040.3	54.582		2135038.3	54.579
2135042	54.586		2135040	54.583		2135038	54.579
2135042	54.582		2135040	54.58		2135038	54.578
2135041.8	54.585		2135039.8	54.582		2135037.8	54.58
2135041.8	54.583		2135039.5	54.583		2135037.8	54.579
2135041.5	54.584		2135039.5	54.578		2135037.5	54.574
2135041.3	54.582		2135039.3	54.579		2135037.5	54.577
2135041.3	54.582		2135039.3	54.582		2135037.3	54.577
2135041	54.581		2135039	54.577		2135037	54.58
2135041	54.582		2135039	54.579		2135037	54.579
2135040.8	54.582		2135038.8	54.585			

Average Temperature: 54.58107 deg C

P = 17.082 Watts (Cont.)								
Channel 3								
Time	Temp. (C)		Time	Temp. (C)		Time	Temp. (C)	
2135019.8	54.214		2135017.8	54.206		2135015.8	54.214	
2135019.8	54.214		2135017.8	54.217		2135015.8	54.219	
2135019.5	54.21		2135017.5	54.218		2135015.5	54.213	
2135019.5	54.217		2135017.5	54.218		2135015.3	54.218	
2135019.3	54.207		2135017.3	54.218		2135015.3	54.203	
2135019.3	54.212		2135017	54.218		2135015	54.227	
2135019	54.232		2135017	54.189		2135015	54.216	
2135019	54.206		2135016.8	54.211		2135014.8	54.229	
2135018.8	54.229		2135016.8	54.214		2135014.8	54.213	
2135018.5	54.213		2135016.5	54.212		2135014.5	54.224	
2135018.5	54.214		2135016.5	54.223		2135014.5	54.229	
2135018.3	54.218		2135016.3	54.198		2135014.3	54.211	
2135018.3	54.21		2135016.3	54.213		2135014	54.217	
2135018	54.208		2135016	54.219		2135014	54.223	
2135018	54.225		2135016	54.21		2135013.8	54.212	
Average Temperature: 54.21513 deg C								

P = 19.768 Watts								
Channel 1								
Time	Temp. (C)		Time	Temp. (C)		Time	Temp. (C)	
2136129.3	62.917		2136127.5	62.92		2136125.5	62.926	
2136129.3	62.919		2136127.3	62.922		2136125.5	62.924	
2136129	62.92		2136127.3	62.918		2136125.3	62.926	
2136129	62.923		2136127	62.921		2136125.3	62.929	
2136128.8	62.918		2136127	62.923		2136125	62.927	
2136128.8	62.921		2136126.8	62.924		2136124.8	62.924	
2136128.5	62.919		2136126.8	62.919		2136124.8	62.93	
2136128.5	62.921		2136126.5	62.922		2136124.5	62.926	
2136128.3	62.918		2136126.3	62.923		2136124.5	62.926	
2136128.3	62.922		2136126.3	62.923		2136124.3	62.927	
2136128	62.922		2136126	62.925		2136124.3	62.926	
2136127.8	62.921		2136126	62.921		2136124	62.925	
2136127.8	62.921		2136125.8	62.926		2136124	62.925	
2136127.5	62.921		2136125.8	62.927		2136123.8	62.925	
Average Temperature: 62.92293 deg C								
Channel 2								
Time	Temp. (C)		Time	Temp. (C)		Time	Temp. (C)	
2136082	59.939		2136080	59.932		2136078.3	59.936	
2136081.8	59.939		2136080	59.933		2136078	59.932	
2136081.8	59.936		2136079.8	59.933		2136078	59.936	
2136081.5	59.937		2136079.5	59.931		2136077.8	59.934	
2136081.5	59.934		2136079.5	59.934		2136077.5	59.933	
2136081.3	59.934		2136079.3	59.932		2136077.5	59.935	
2136081	59.935		2136079.3	59.935		2136077.3	59.937	
2136081	59.932		2136079	59.936		2136077.3	59.937	
2136080.8	59.931		2136079	59.934		2136077	59.936	
2136080.8	59.932		2136078.8	59.937		2136077	59.935	
2136080.5	59.931		2136078.8	59.931		2136076.8	59.938	
2136080.5	59.934		2136078.5	59.935		2136076.8	59.936	
2136080.3	59.93		2136078.5	59.936		2136076.5	59.939	
2136080.3	59.936		2136078.3	59.936		2136076.5	59.938	
Average Temperature: 59.93469 deg C								

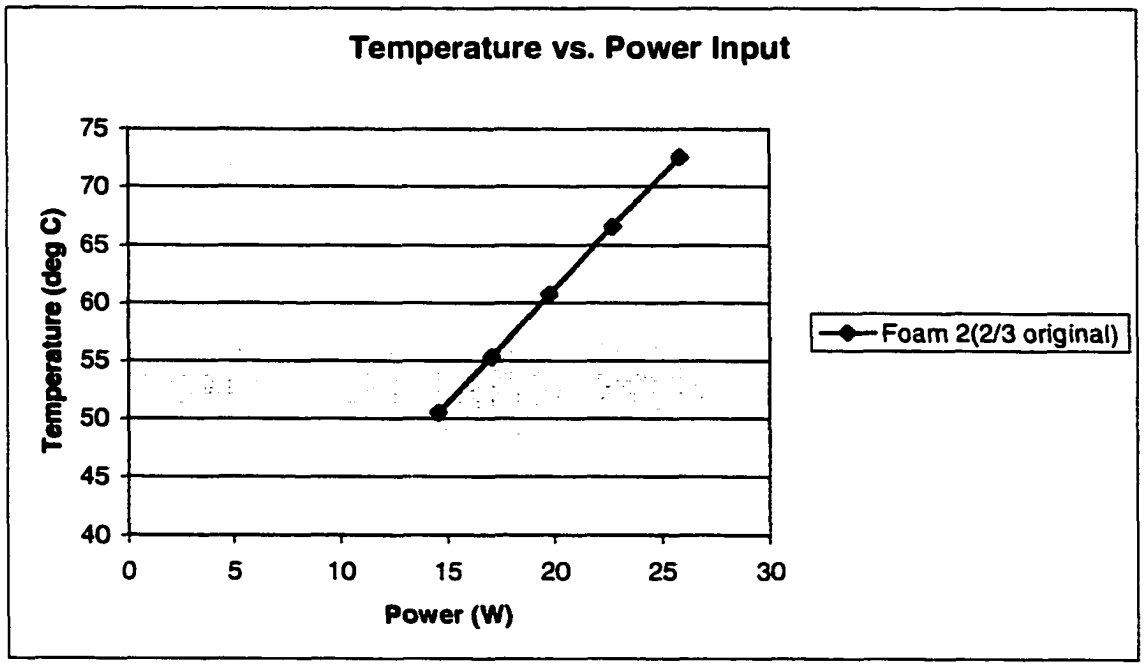
P = 10.768 Watts (Cont.)							
Channel 3							
Time	Temp. (C)		Time	Temp. (C)		Time	Temp. (C)
2136107	59.426		2136105	59.424		2136103.3	59.403
2136106.8	59.419		2136105	59.411		2136103	59.399
2136106.8	59.424		2136104.8	59.419		2136103	59.425
2136106.5	59.424		2136104.8	59.418		2136102.8	59.406
2136106.5	59.421		2136104.5	59.419		2136102.8	59.423
2136106.3	59.42		2136104.5	59.416		2136102.5	59.398
2136106.3	59.42		2136104.3	59.423		2136102.5	59.397
2136106	59.421		2136104	59.407		2136102.3	59.403
2136106	59.416		2136104	59.407		2136102.3	59.406
2136105.8	59.421		2136103.8	59.415		2136102	59.406
2136105.5	59.426		2136103.8	59.415		2136102	59.412
2136105.5	59.414		2136103.5	59.415		2136101.8	59.411
2136105.3	59.413		2136103.5	59.408		2136101.5	59.423
2136105.3	59.422		2136103.3	59.423			
Average Temperature: 59.4151 deg C							

P = 22.71 Watts								
Channel 1								
Time	Temp. (C)		Time	Temp. (C)		Time	Temp. (C)	
2142669.3	69.093		2142667.3	69.094		2142665.3	69.088	
2142669	69.097		2142667	69.092		2142665.3	69.09	
2142669	69.098		2142667	69.097		2142665	69.085	
2142668.8	69.1		2142666.8	69.094		2142665	69.093	
2142668.5	69.1		2142666.8	69.092		2142664.8	69.086	
2142668.5	69.1		2142666.5	69.101		2142664.8	69.099	
2142668.3	69.108		2142666.5	69.076		2142664.5	69.099	
2142668.3	69.103		2142666.3	69.088		2142664.5	69.081	
2142668	69.087		2142666.3	69.1		2142664.3	69.101	
2142668	69.104		2142666	69.08		2142664.3	69.078	
2142667.8	69.094		2142666	69.101		2142664	69.081	
2142667.8	69.092		2142665.8	69.093		2142663.8	69.085	
2142667.5	69.103		2142665.5	69.091		2142663.8	69.086	
2142667.5	69.093		2142665.5	69.086		2142663.5	69.088	
Average Temperature: 69.09279 deg C								
Channel 2								
Time	Temp. (C)		Time	Temp. (C)		Time	Temp. (C)	
2142694.3	65.614		2142692	65.607		2142690.3	65.596	
2142694	65.615		2142692	65.606		2142690	65.597	
2142694	65.614		2142691.8	65.606		2142690	65.598	
2142693.8	65.612		2142691.8	65.607		2142689.8	65.594	
2142693.5	65.614		2142691.5	65.605		2142689.8	65.598	
2142693.5	65.611		2142691.5	65.602		2142689.5	65.594	
2142693.3	65.613		2142691.3	65.603		2142689.5	65.593	
2142693.3	65.61		2142691.3	65.601		2142689.3	65.591	
2142693	65.611		2142691	65.6		2142689.3	65.593	
2142693	65.612		2142691	65.602		2142689	65.596	
2142692.8	65.609		2142690.8	65.603		2142689	65.595	
2142692.8	65.609		2142690.5	65.598		2142688.8	65.595	
2142692.5	65.607		2142690.5	65.6		2142688.8	65.594	
2142692.5	65.608		2142690.3	65.597		2142688.5	65.593	
2142692.3	65.608							
Average Temperature: 65.60305 deg C								

P = 22.71 Watts (Cont.)							
Channel 3							
Time	Temp. (C)		Time	Temp. (C)		Time	Temp. (C)
2142713.5	65.087		2142711.5	65.09		2142709.5	65.09
2142713.3	65.063		2142711.3	65.13		2142709.3	65.114
2142713.3	65.105		2142711.3	65.106		2142709.3	65.114
2142713	65.133		2142711	65.106		2142709	65.113
2142713	65.118		2142710.8	65.103		2142709	65.115
2142712.8	65.103		2142710.8	65.112		2142708.8	65.105
2142712.8	65.103		2142710.5	65.102		2142708.8	65.114
2142712.5	65.101		2142710.5	65.106		2142708.5	65.125
2142712.3	65.111		2142710.3	65.102		2142708.5	65.142
2142712.3	65.114		2142710.3	65.069		2142708.3	65.07
2142712	65.104		2142710	65.082		2142708	65.115
2142712	65.071		2142710	65.128		2142708	65.145
2142711.8	65.138		2142709.8	65.064		2142707.8	65.071
2142711.8	65.135		2142709.8	65.069		2142707.8	65.109
2142711.5	65.074						
Average Temperature: 65.10398 deg C							

P = 25.81593 Watts							
Channel 1							
Time	Temp. (C)		Time	Temp. (C)		Time	Temp. (C)
2143795.5	75.928		2143793.5	75.946		2143791.3	75.948
2143795.3	75.94		2143793.3	75.942		2143791.3	75.947
2143795.3	75.936		2143793.3	75.939		2143791	75.954
2143795	75.934		2143793	75.942		2143791	75.952
2143795	75.934		2143792.8	75.946		2143790.8	75.956
2143794.8	75.937		2143792.8	75.938		2143790.8	75.953
2143794.8	75.935		2143792.5	75.95		2143790.5	75.949
2143794.5	75.937		2143792.5	75.941		2143790.5	75.951
2143794.3	75.938		2143792.3	75.932		2143790.3	75.959
2143794.3	75.929		2143792.3	75.939		2143790.3	75.942
2143794	75.93		2143792	75.957		2143790	75.958
2143794	75.935		2143792	75.954		2143789.8	75.951
2143793.8	75.929		2143791.8	75.956		2143789.8	75.951
2143793.8	75.934		2143791.8	75.947		2143789.5	75.951
2143793.5	75.93		2143791.5	75.946			
Average Temperature: 75.94325 deg C							
Channel 2							
Time	Temp. (C)		Time	Temp. (C)		Time	Temp. (C)
2143773.3	70.391		2143771.3	70.401		2143769.5	70.409
2143773	70.395		2143771.3	70.396		2143769.3	70.41
2143773	70.394		2143771	70.399		2143769.3	70.407
2143772.8	70.395		2143771	70.401		2143769	70.408
2143772.8	70.394		2143770.8	70.4		2143769	70.407
2143772.5	70.393		2143770.8	70.399		2143768.8	70.408
2143772.5	70.397		2143770.5	70.402		2143768.8	70.41
2143772.3	70.399		2143770.5	70.402		2143768.5	70.41
2143772.3	70.398		2143770.3	70.404		2143768.5	70.411
2143772	70.398		2143770	70.403		2143768.3	70.415
2143772	70.395		2143770	70.404		2143768.3	70.412
2143771.8	70.398		2143769.8	70.405		2143768	70.414
2143771.8	70.4		2143769.8	70.406		2143767.8	70.412
2143771.5	70.4		2143769.5	70.407		2143767.8	70.415
Average Temperature: 70.40295 deg C							

P = 25.81593 Watts (Cont.)								
Channel 3								
Time	Temp. (C)		Time	Temp. (C)		Time	Temp. (C)	
2143753	71.325		2143751.3	71.335		2143749.5	71.303	
2143753	71.33		2143751.3	71.33		2143749.5	71.285	
2143752.8	71.334		2143751	71.328		2143749.3	71.26	
2143752.8	71.329		2143751	71.333		2143749.3	71.273	
2143752.5	71.335		2143750.8	71.269		2143749	71.333	
2143752.5	71.297		2143750.8	71.334		2143749	71.305	
2143752.3	71.299		2143750.5	71.308		2143748.8	71.308	
2143752	71.303		2143750.3	71.305		2143748.5	71.303	
2143752	71.299		2143750.3	71.3		2143748.5	71.308	
2143751.8	71.305		2143750	71.299		2143748.3	71.309	
2143751.8	71.302		2143750	71.303		2143748.3	71.312	
2143751.5	71.302		2143749.8	71.31		2143748	71.315	
2143751.5	71.33		2143749.8	71.335		2143748	71.308	
Average Temperature: 71.31028 deg C								



Power (W)	T (deg C)
14.568	50.51809
17.082	55.32756
19.768	60.75817
22.71	66.59994
25.81593	72.55216

b. Aluminum Foam S. A. 3: 1/3 original

P = 14.50204 Watts								
Channel 1								
Time	Temp. (C)		Time	Temp. (C)		Time	Temp. (C)	
2657221.3	64.765		2657219.3	64.77		2657217.5	64.77	
2657221	64.766		2657219.3	64.768		2657217.3	64.77	
2657221	64.77		2657219	64.77		2657217.3	64.772	
2657220.8	64.768		2657219	64.769		2657217	64.771	
2657220.8	64.766		2657218.8	64.768		2657217	64.771	
2657220.5	64.771		2657218.8	64.769		2657216.8	64.775	
2657220.5	64.768		2657218.5	64.767		2657216.5	64.773	
2657220.3	64.765		2657218.5	64.771		2657216.5	64.772	
2657220.3	64.77		2657218.3	64.773		2657216.3	64.773	
2657220	64.766		2657218.3	64.772		2657216.3	64.77	
2657220	64.769		2657218	64.77		2657216	64.77	
2657219.8	64.769		2657217.8	64.772		2657216	64.774	
2657219.8	64.769		2657217.8	64.773		2657216	64.774	
2657219.5	64.771		2657217.5	64.77				
Average Temperature:		64.77 deg C						
Channel 2								
Time	Temp. (C)		Time	Temp. (C)		Time	Temp. (C)	
2657246.8	61.198		2657245	61.203		2657243	61.213	
2657246.8	61.196		2657244.8	61.204		2657243	61.212	
2657246.5	61.197		2657244.5	61.205		2657242.8	61.212	
2657246.3	61.199		2657244.5	61.204		2657242.8	61.213	
2657246.3	61.198		2657244.3	61.205		2657242.5	61.214	
2657246	61.198		2657244.3	61.207		2657242.5	61.215	
2657246	61.199		2657244	61.205		2657242.3	61.212	
2657245.8	61.199		2657244	61.207		2657242	61.213	
2657245.8	61.201		2657243.8	61.207		2657242	61.213	
2657245.5	61.198		2657243.8	61.207		2657241.8	61.215	
2657245.5	61.2		2657243.5	61.205		2657241.8	61.216	
2657245.3	61.201		2657243.3	61.21		2657241.5	61.216	
2657245.3	61.204		2657243.3	61.21		2657241.5	61.215	
2657245	61.202							
Average Temperature:		61.2062 deg C						

P = 14.50204 Watts (Cont.)							
Channel 3							
Time	Temp. (C)		Time	Temp. (C)		Time	Temp. (C)
2657263.5	62.93		2657261.5	62.921		2657259.5	62.91
2657263.3	62.93		2657261.3	62.923		2657259.5	62.909
2657263.3	62.931		2657261.3	62.92		2657259.3	62.908
2657263	62.929		2657261	62.92		2657259.3	62.909
2657262.8	62.928		2657261	62.92		2657259	62.909
2657262.8	62.927		2657260.8	62.916		2657259	62.909
2657262.5	62.928		2657260.8	62.921		2657258.8	62.903
2657262.5	62.927		2657260.5	62.919		2657258.8	62.904
2657262.3	62.93		2657260.5	62.915		2657258.5	62.902
2657262.3	62.925		2657260.3	62.915		2657258.5	62.902
2657262	62.927		2657260.3	62.913		2657258.3	62.9
2657262	62.925		2657260	62.915		2657258.3	62.899
2657261.8	62.922		2657259.8	62.914		2657258	62.899
2657261.8	62.923		2657259.8	62.911		2657258	62.898
Average Temperature: 62.91633 deg C							

P = 17.004 Watts

Channel 1

Time	Temp. (C)		Time	Temp. (C)		Time	Temp. (C)
2659252.8	72.16		2659250.8	72.167		2659248.8	72.175
2659252.5	72.158		2659250.5	72.168		2659248.8	72.172
2659252.5	72.161		2659250.5	72.169		2659248.5	72.177
2659252.3	72.16		2659250.3	72.168		2659248.3	72.175
2659252.3	72.158		2659250.3	72.169		2659248.3	72.176
2659252	72.16		2659250	72.171		2659248	72.176
2659252	72.159		2659250	72.171		2659248	72.177
2659251.8	72.166		2659249.8	72.173		2659247.8	72.175
2659251.8	72.16		2659249.5	72.176		2659247.8	72.175
2659251.5	72.162		2659249.5	72.175		2659247.5	72.173
2659251.5	72.161		2659249.3	72.172		2659247.5	72.171
2659251.3	72.162		2659249.3	72.176		2659247.3	72.174
2659251	72.165		2659249	72.174		2659247.3	72.176
2659251	72.165		2659249	72.173		2659247	72.174
2659250.8	72.167						

Average Temperature: 72.16912 deg C

Channel 2

Time	Temp. (C)		Time	Temp. (C)		Time	Temp. (C)
2659271.5	67.816		2659269.5	67.812		2659267.8	67.805
2659271.3	67.819		2659269.5	67.814		2659267.5	67.803
2659271.3	67.818		2659269.3	67.813		2659267.5	67.805
2659271	67.815		2659269.3	67.813		2659267.3	67.806
2659271	67.816		2659269	67.811		2659267.3	67.801
2659270.8	67.815		2659269	67.811		2659267	67.802
2659270.8	67.817		2659268.8	67.811		2659267	67.802
2659270.5	67.815		2659268.8	67.807		2659266.8	67.8
2659270.5	67.816		2659268.5	67.807		2659266.8	67.802
2659270.3	67.816		2659268.3	67.809		2659266.5	67.796
2659270.3	67.817		2659268.3	67.808		2659266.5	67.798
2659270	67.815		2659268	67.808		2659266.3	67.797
2659269.8	67.818		2659268	67.81		2659266.3	67.798
2659269.8	67.811		2659267.8	67.806			

Average Temperature: 67.80924 deg C

P = 17.004 Watts (Cont.)							
Channel 3							
Time	Temp. (C)		Time	Temp. (C)		Time	Temp. (C)
2659288	70.608		2659286.3	70.612		2659284.5	70.611
2659288	70.608		2659286	70.61		2659284.3	70.61
2659287.8	70.612		2659286	70.611		2659284.3	70.61
2659287.8	70.609		2659285.8	70.61		2659284	70.609
2659287.5	70.611		2659285.8	70.609		2659284	70.61
2659287.5	70.61		2659285.5	70.613		2659283.8	70.61
2659287.3	70.611		2659285.5	70.609		2659283.8	70.612
2659287.3	70.61		2659285.3	70.61		2659283.5	70.607
2659287	70.612		2659285	70.611		2659283.5	70.61
2659287	70.61		2659285	70.609		2659283.3	70.611
2659286.8	70.612		2659284.8	70.611		2659283.3	70.61
2659286.8	70.609		2659284.8	70.61		2659283	70.61
2659286.5	70.61		2659284.5	70.614		2659282.8	70.609
2659286.3	70.61						
Average Temperature: 70.61025 deg C							

P = 19.712 Watts								
Channel 1								
Time	Temp. (C)		Time	Temp. (C)		Time	Temp. (C)	
2661556.5	79.904		2661554.5	79.902		2661552.3	79.897	
2661556.5	79.902		2661554.3	79.9		2661552	79.898	
2661556.3	79.901		2661554	79.902		2661552	79.895	
2661556	79.903		2661554	79.901		2661551.8	79.893	
2661556	79.903		2661553.8	79.899		2661551.8	79.895	
2661555.8	79.902		2661553.8	79.9		2661551.5	79.896	
2661555.8	79.902		2661553.5	79.901		2661551.5	79.893	
2661555.5	79.904		2661553.3	79.9		2661551.3	79.895	
2661555.5	79.902		2661553.3	79.9		2661551.3	79.89	
2661555.3	79.9		2661553	79.901		2661551	79.892	
2661555	79.902		2661553	79.899		2661551	79.892	
2661555	79.902		2661552.8	79.901		2661550.8	79.891	
2661554.8	79.901		2661552.8	79.901		2661550.8	79.892	
2661554.8	79.9		2661552.5	79.9		2661550.5	79.893	
2661554.5	79.901		2661552.5	79.897		2661550.5	79.887	
Average Temperature: 79.89849 deg C								
Channel 2								
Time	Temp. (C)		Time	Temp. (C)		Time	Temp. (C)	
2661574.8	74.917		2661572.8	74.906		2661570.8	74.896	
2661574.5	74.913		2661572.5	74.903		2661570.5	74.895	
2661574.3	74.913		2661572.5	74.903		2661570.5	74.895	
2661574.3	74.913		2661572.3	74.9		2661570.3	74.894	
2661574	74.913		2661572	74.905		2661570.3	74.896	
2661574	74.91		2661572	74.902		2661570	74.895	
2661573.8	74.909		2661571.8	74.901		2661569.8	74.894	
2661573.8	74.908		2661571.8	74.899		2661569.8	74.891	
2661573.5	74.91		2661571.5	74.902		2661569.5	74.892	
2661573.3	74.907		2661571.5	74.897		2661569.5	74.89	
2661573.3	74.904		2661571.3	74.896		2661569.3	74.891	
2661573	74.908		2661571.3	74.898		2661569.3	74.892	
2661573	74.906		2661571	74.897		2661569	74.892	
2661572.8	74.905		2661570.8	74.897				
Average Temperature: 74.90134 deg C								

P = 19.712 Watts (Cont.)							
Channel 3							
Time	Temp. (C)		Time	Temp. (C)		Time	Temp. (C)
2661595.3	78.873		2661593.3	78.87		2661591.3	78.862
2661595	78.873		2661593.3	78.869		2661591.3	78.862
2661595	78.875		2661593	78.871		2661591	78.861
2661594.8	78.874		2661592.8	78.871		2661590.8	78.86
2661594.8	78.873		2661592.8	78.868		2661590.8	78.857
2661594.5	78.874		2661592.5	78.869		2661590.5	78.855
2661594.3	78.875		2661592.5	78.866		2661590.5	78.86
2661594.3	78.873		2661592.3	78.866		2661590.3	78.855
2661594	78.872		2661592.3	78.869		2661590.3	78.855
2661594	78.87		2661592	78.865		2661590	78.853
2661593.8	78.869		2661591.8	78.865		2661590	78.851
2661593.8	78.874		2661591.8	78.865		2661589.8	78.852
2661593.5	78.87		2661591.5	78.864		2661589.8	78.854
2661593.5	78.87		2661591.5	78.863			
Average Temperature: 78.86568 deg C							

P = 22.56 Watts

Channel 1

Time	Temp. (C)		Time	Temp. (C)		Time	Temp. (C)
2668590.3	87.512		2668588.3	87.504		2668586.3	87.504
2668590.3	87.512		2668588.3	87.505		2668586	87.503
2668590	87.513		2668588	87.506		2668586	87.505
2668590	87.511		2668587.8	87.506		2668585.8	87.503
2668589.8	87.509		2668587.8	87.504		2668585.8	87.503
2668589.8	87.512		2668587.5	87.502		2668585.5	87.506
2668589.5	87.508		2668587.5	87.504		2668585.5	87.504
2668589.5	87.507		2668587.3	87.505		2668585.3	87.504
2668589.3	87.506		2668587.3	87.503		2668585.3	87.507
2668589	87.506		2668587	87.503		2668585	87.506
2668589	87.508		2668587	87.505		2668584.8	87.508
2668588.8	87.506		2668586.8	87.505		2668584.8	87.509
2668588.8	87.506		2668586.5	87.503		2668584.5	87.507
2668588.5	87.505		2668586.5	87.504		2668584.5	87.506
2668588.5	87.505		2668586.3	87.505			

Average Temperature: 87.50602 deg C

Channel 2

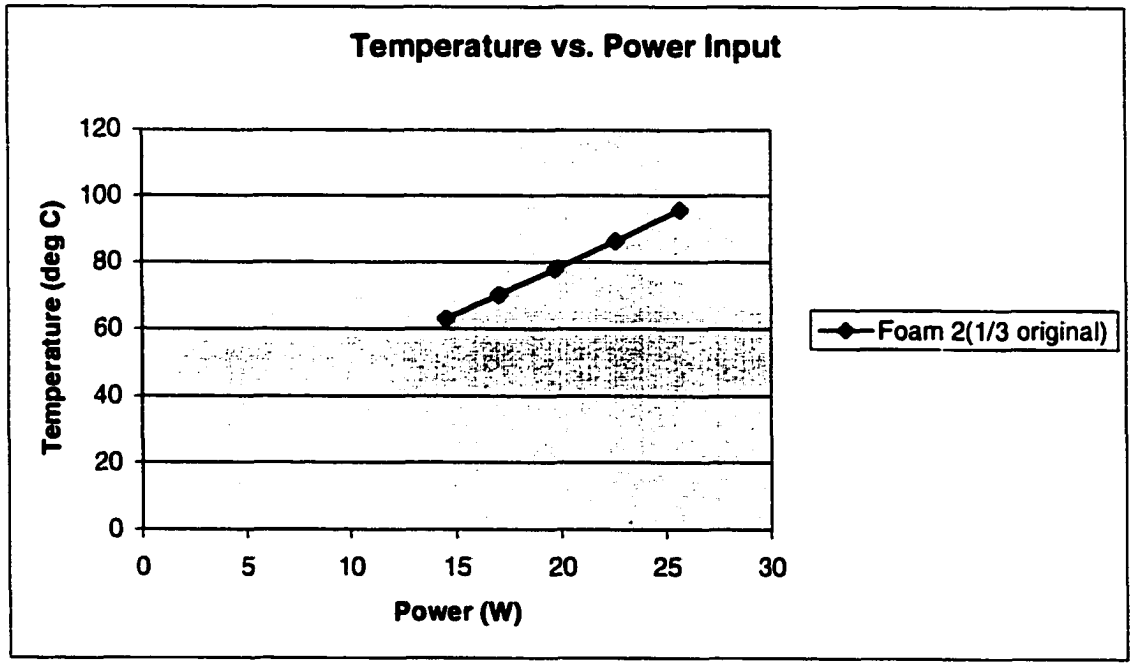
Time	Temp. (C)		Time	Temp. (C)		Time	Temp. (C)
2668614.3	82.639		2668612.3	82.629		2668610.3	82.612
2668614	82.638		2668612	82.627		2668610	82.609
2668614	82.638		2668612	82.626		2668610	82.609
2668613.8	82.635		2668611.8	82.626		2668609.8	82.608
2668613.8	82.638		2668611.8	82.624		2668609.8	82.608
2668613.5	82.638		2668611.5	82.621		2668609.5	82.61
2668613.5	82.633		2668611.3	82.62		2668609.5	82.606
2668613.3	82.636		2668611.3	82.624		2668609.3	82.609
2668613	82.635		2668611	82.621		2668609.3	82.608
2668613	82.634		2668611	82.619		2668609	82.605
2668612.8	82.636		2668610.8	82.619		2668609	82.606
2668612.8	82.632		2668610.8	82.617		2668608.8	82.605
2668612.5	82.631		2668610.5	82.613		2668608.8	82.609
2668612.5	82.628		2668610.5	82.612		2668608.5	82.609
2668612.3	82.628						

Average Temperature: 82.62163 deg C

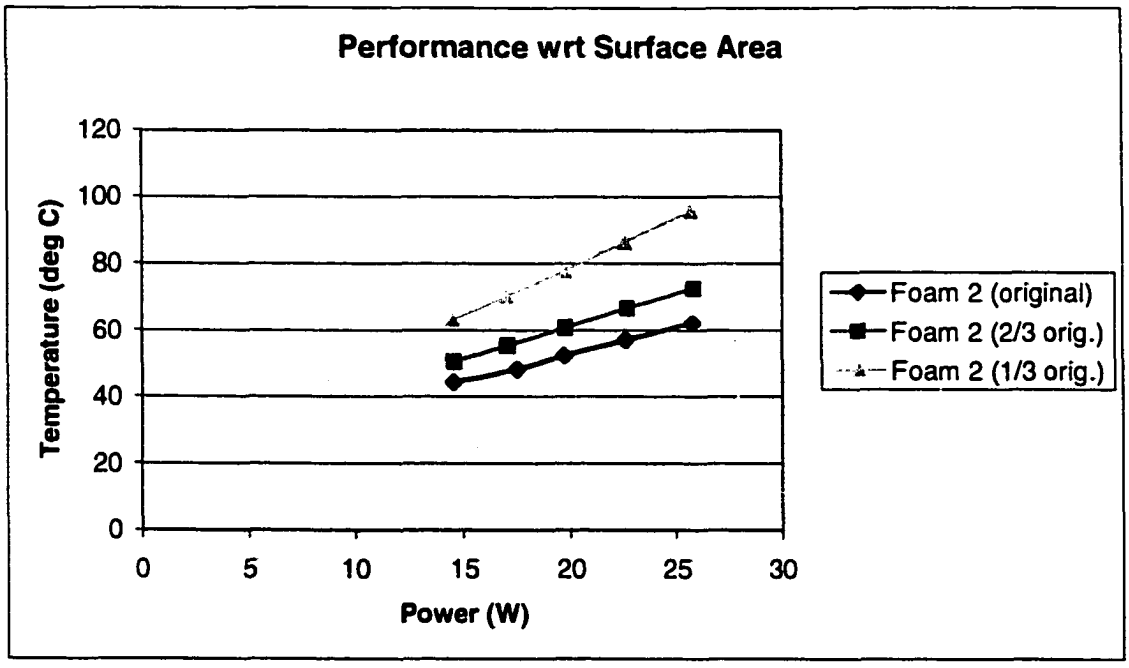
P = 22.56 Watts (Cont.)							
Channel 3							
Time	Temp. (C)		Time	Temp. (C)		Time	Temp. (C)
2668629	88.923		2668627	88.915		2668625.3	88.901
2668629	88.922		2668627	88.914		2668625.3	88.904
2668628.8	88.921		2668626.8	88.911		2668625	88.903
2668628.5	88.92		2668626.8	88.912		2668625	88.902
2668628.5	88.921		2668626.5	88.91		2668624.8	88.899
2668628.3	88.922		2668626.5	88.906		2668624.8	88.902
2668628.3	88.917		2668626.3	88.909		2668624.5	88.895
2668628	88.917		2668626.3	88.907		2668624.5	88.896
2668628	88.919		2668626	88.91		2668624.3	88.896
2668627.8	88.918		2668625.8	88.909		2668624.3	88.893
2668627.8	88.913		2668625.8	88.909		2668624	88.893
2668627.5	88.91		2668625.5	88.905		2668624	88.891
2668627.5	88.913		2668625.5	88.904		2668623.8	88.889
2668627.3	88.91						
Average Temperature: 88.90828 deg C							

P = 25.65598 Watts							
Channel 1							
Time	Temp. (C)		Time	Temp. (C)		Time	Temp. (C)
2669674.3	96.929		2669672.3	96.938		2669670.3	96.942
2669674.3	96.93		2669672.3	96.937		2669670.3	96.944
2669674	96.93		2669672	96.939		2669670	96.944
2669674	96.926		2669672	96.937		2669670	96.943
2669673.8	96.931		2669671.8	96.936		2669669.8	96.942
2669673.8	96.928		2669671.8	96.937		2669669.8	96.947
2669673.5	96.928		2669671.5	96.94		2669669.5	96.947
2669673.3	96.931		2669671.3	96.938		2669669.5	96.946
2669673.3	96.931		2669671.3	96.939		2669669.3	96.946
2669673	96.934		2669671	96.939		2669669	96.948
2669673	96.935		2669671	96.944		2669669	96.944
2669672.8	96.933		2669670.8	96.939		2669668.8	96.948
2669672.5	96.933		2669670.8	96.94		2669668.8	96.949
2669672.5	96.935		2669670.5	96.943		2669668.5	96.949
Average Temperature: 96.93855 deg C							
Channel 2							
Time	Temp. (C)		Time	Temp. (C)		Time	Temp. (C)
2669691.3	91.332		2669689.3	91.328		2669687	91.333
2669691	91.332		2669689	91.328		2669687	91.331
2669691	91.334		2669688.8	91.329		2669686.8	91.331
2669690.8	91.334		2669688.8	91.331		2669686.5	91.331
2669690.8	91.332		2669688.5	91.332		2669686.5	91.333
2669690.5	91.332		2669688.5	91.333		2669686.3	91.33
2669690.5	91.33		2669688.3	91.33		2669686.3	91.329
2669690.3	91.33		2669688.3	91.334		2669686	91.328
2669690.3	91.33		2669688	91.332		2669686	91.328
2669690	91.334		2669688	91.332		2669685.8	91.331
2669690	91.331		2669687.8	91.332		2669685.8	91.329
2669689.8	91.329		2669687.5	91.332		2669685.5	91.328
2669689.5	91.327		2669687.5	91.332		2669685.3	91.329
2669689.5	91.33		2669687.3	91.332		2669685.3	91.331
2669689.3	91.33		2669687.3	91.333			
Average Temperature: 91.33089 deg C							

P = 25.65598 Watts (Cont.)							
Channel 3							
Time	Temp. (C)		Time	Temp. (C)		Time	Temp. (C)
2669708	98.686		2669706	98.68		2669704	98.676
2669707.8	98.682		2669705.8	98.677		2669703.8	98.678
2669707.5	98.683		2669705.8	98.676		2669703.5	98.678
2669707.5	98.68		2669705.5	98.677		2669703.5	98.677
2669707.3	98.678		2669705.3	98.679		2669703.3	98.678
2669707.3	98.679		2669705.3	98.676		2669703.3	98.678
2669707	98.681		2669705	98.671		2669703	98.679
2669707	98.681		2669705	98.674		2669703	98.681
2669706.8	98.68		2669704.8	98.676		2669702.8	98.683
2669706.5	98.68		2669704.5	98.676		2669702.5	98.682
2669706.5	98.68		2669704.5	98.674		2669702.5	98.682
2669706.3	98.681		2669704.3	98.672		2669702.3	98.682
2669706.3	98.675		2669704.3	98.675		2669702.3	98.687
2669706	98.678		2669704	98.675			
Average Temperature: 98.67861 deg C							



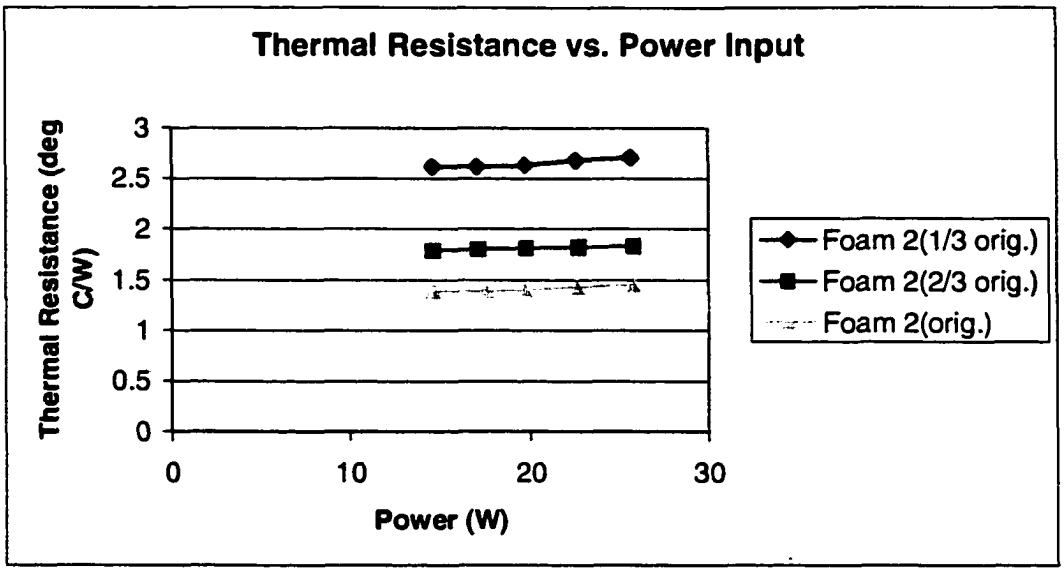
Power (W)	T (deg C)
14.50204	62.96418
17.004	70.1962
19.712	77.8885
22.56	86.34531
25.65598	95.64935



Foam 2 (SA = 1.75 in2)	
Power (W)	T (deg C)
14.50204	62.96418
17.004	70.1962
19.712	77.8885
22.56	86.34531
25.65598	95.64935

Foam 2 (SA = 3.5 in2)	
Power (W)	T (deg C)
14.568	50.51809
17.082	55.32756
19.768	60.75817
22.71	66.59994
25.81593	72.55216

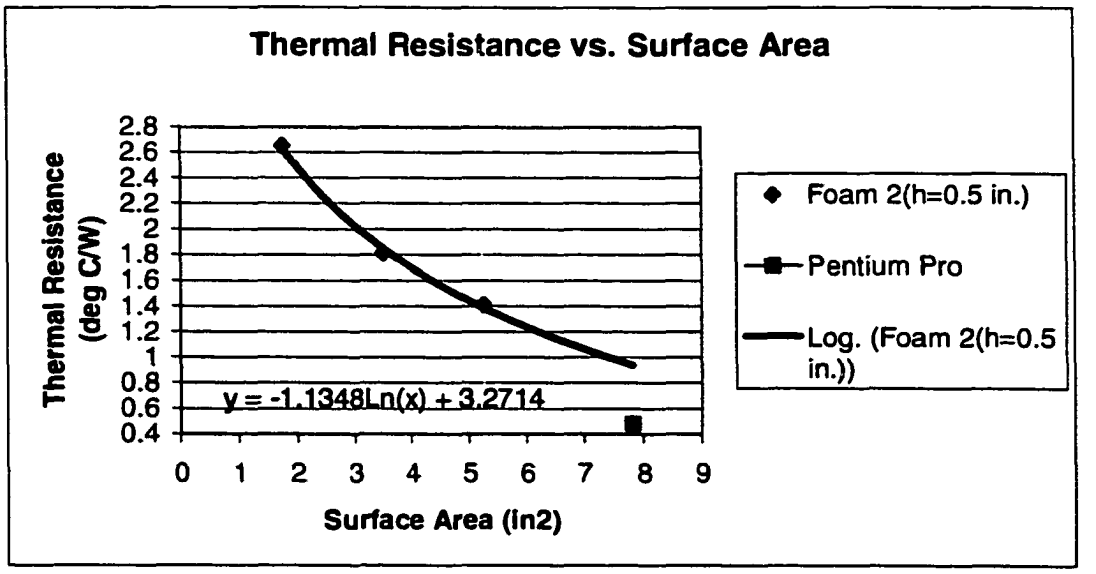
Foam 2 (SA = 5.25 in2)	
Power (W)	T (deg C)
14.544	44.33513
17.506	48.25232
19.712	52.30717
22.62	56.973717
25.75195	62.08687



Foam 2 (SA = 1.75 in2)	
Power (W)	R (deg C/W)
14.50204	2.61785
17.004	2.61807
19.712	2.63233
22.56	2.67931
25.65598	2.70695
Avg:	2.650902

Foam 2 (SA = 3.5 in2)	
Power (W)	R (deg C/W)
14.568	1.78598
17.082	1.79883
19.768	1.81395
22.71	1.82298
25.81593	1.83035
Avg:	1.810418

Foam 2 (SA = 5.25 in2)	
Power (W)	R (deg C/W)
14.544	1.3913
17.506	1.39261
19.712	1.4056
22.62	1.4312
25.75195	1.45181
Avg:	1.414504



Foam 2	
SA (in2)	R (deg C/W)
1.75	2.650902
3.5	1.810418
5.25	1.414504
Pentium Pro	
7.8125	0.480838

APPENDIX D

Experimental Setup for Aluminum Foam Specimens and PCM-filled Heat Sink

1. Experimental Setup for Aluminum Foam samples

This section illustrates the samples and the setups utilized to test the aluminum foam heat sinks.

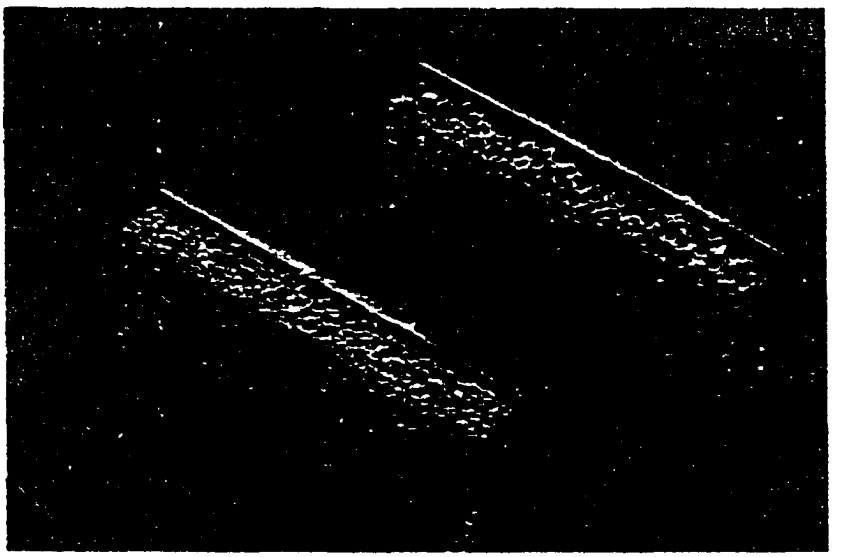


Fig. 1: Original Aluminum foams, bonded to a substrate.

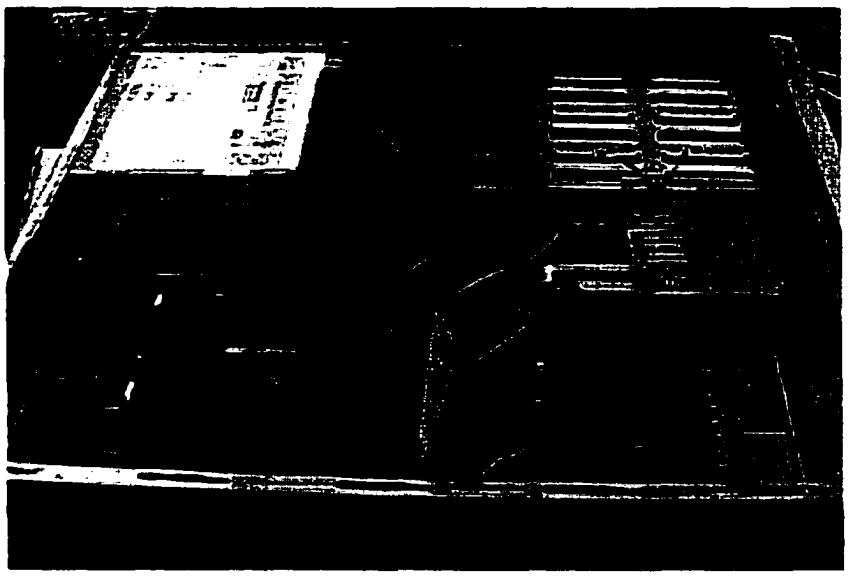


Fig. 2: Experimental setup with respect to density (original foams).

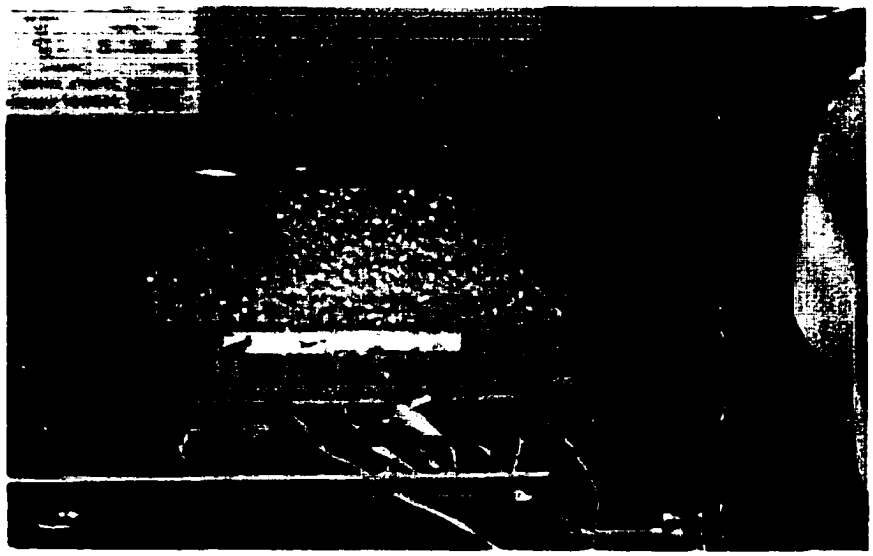


Fig. 3: Aluminum foam sample, with variable surface area.

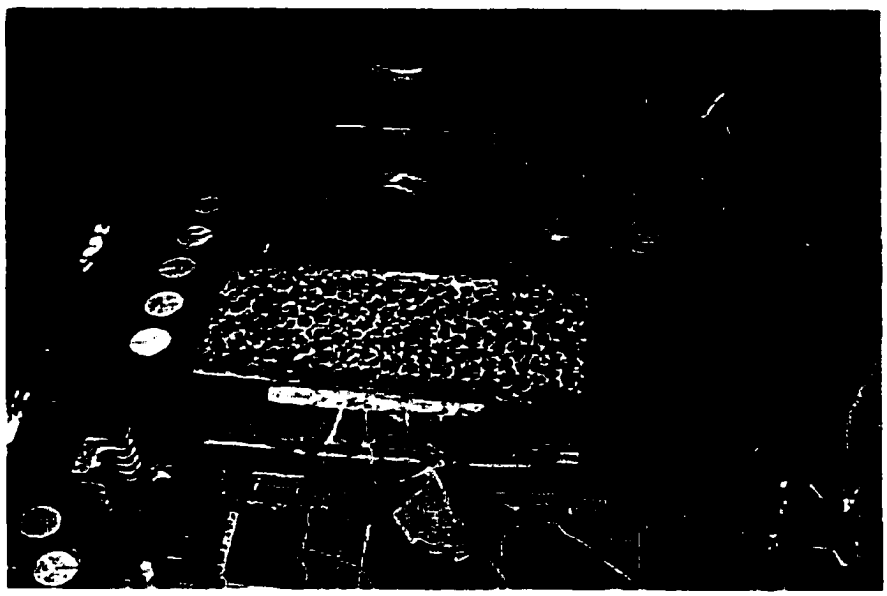


Fig. 4: Experimental setup for aluminum foam with respect to height.

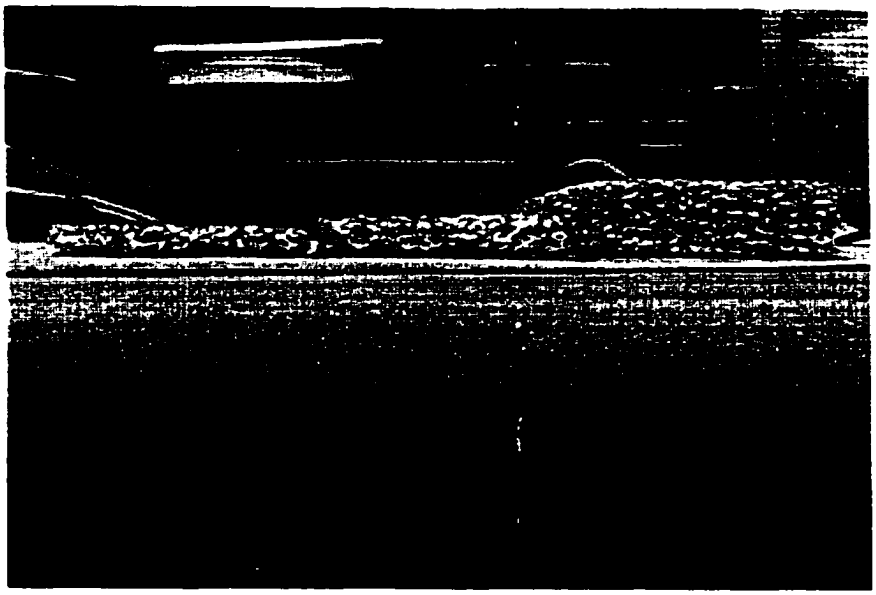


Fig. 5: Aluminum samples utilized to study effect of height in performance.

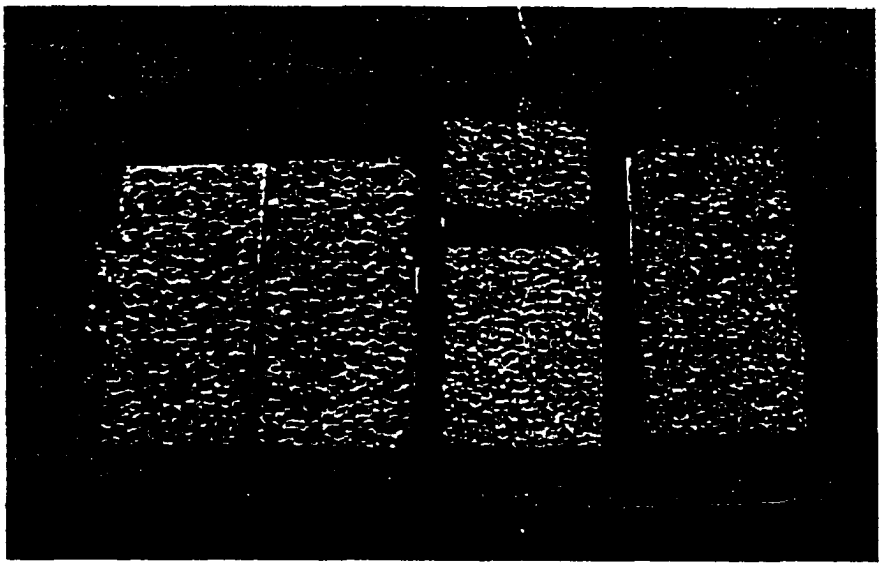


Fig. 6: Complete set of aluminum foam samples utilized in the experiments.

2. Experimental Setup for PCM-filled heat sinks.

This section covers the setup and describes the procedures utilized to test the performance of the PCM-filled heat sinks with respect to PCM-to-oil volume ratio. First, the PCM and the oil were heated in a beaker to determine if the "heat delivery" effect would take place.

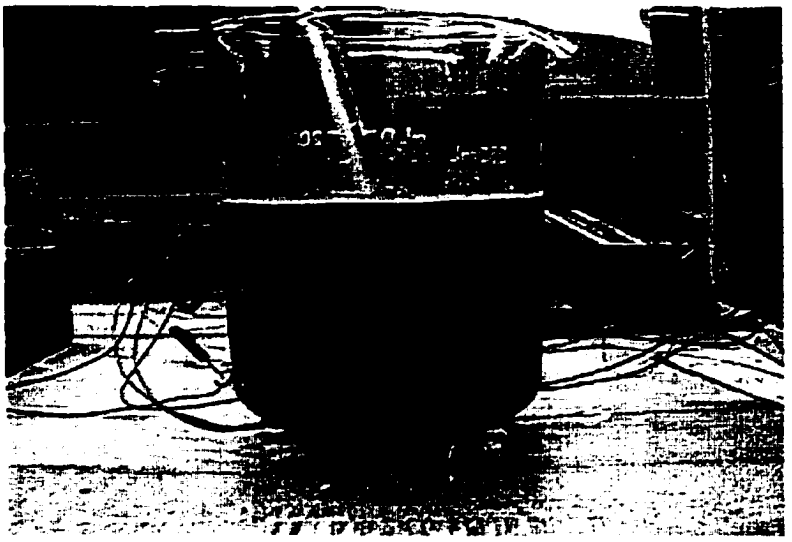


Fig. 7: Setup for PCM "heat delivery effect" testing, before applying heat load.

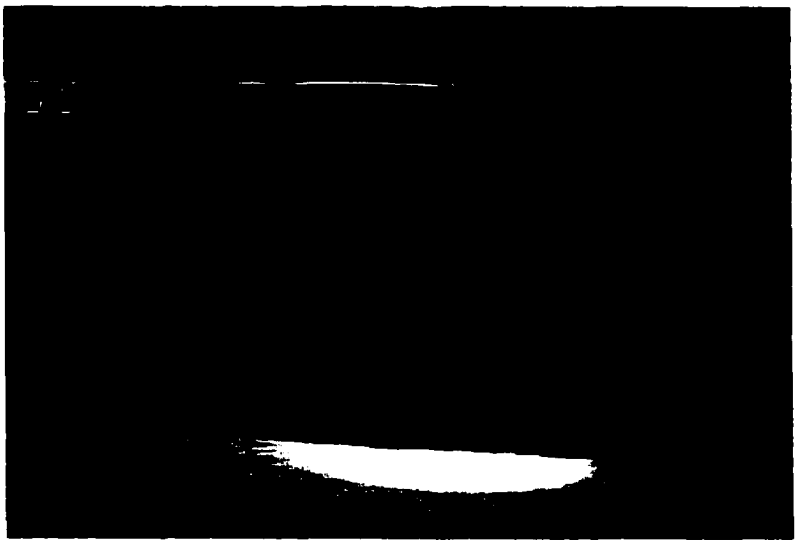


Fig. 8: PCM setup, with heat load applied.

After that, the PCM and oil mixture were introduced in the aluminum casing. The casing, along with experimental setups, is illustrated below.

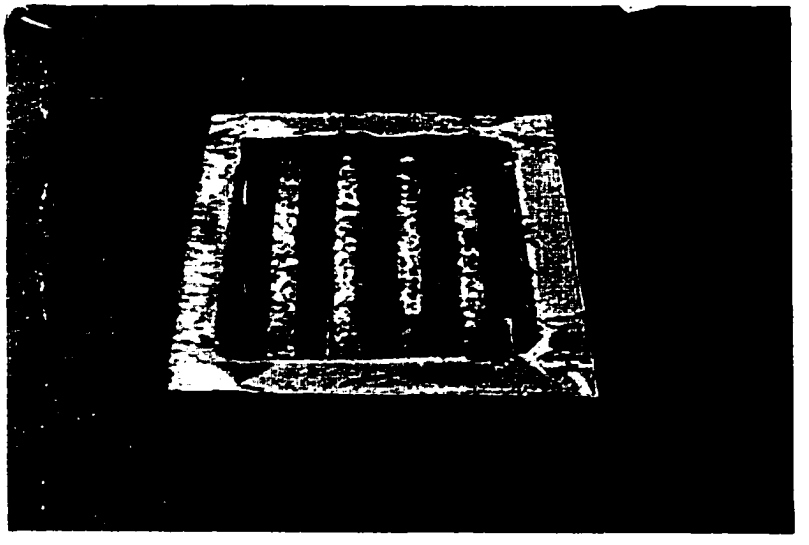


Fig. 9: Bottom view of PCM casing (empty).

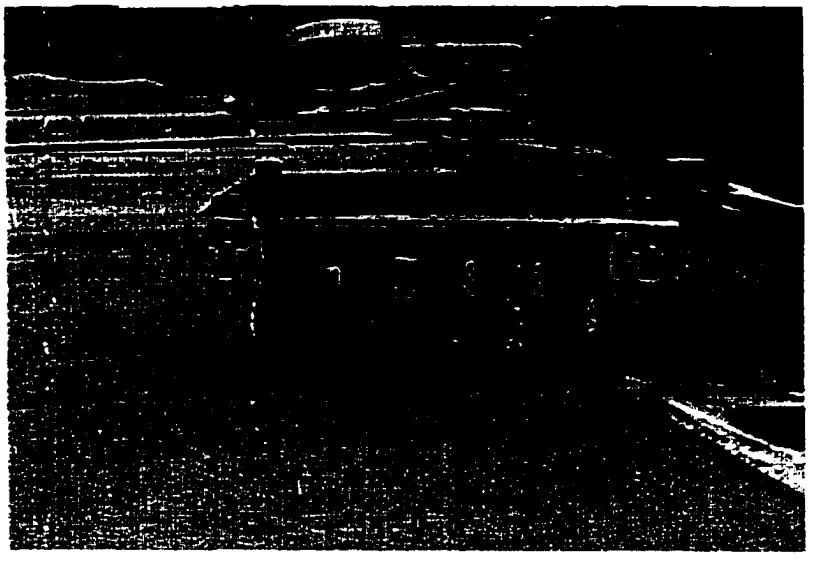


Fig. 10: Closed PCM casing, containing PCM-oil mixture, ready to be tested.

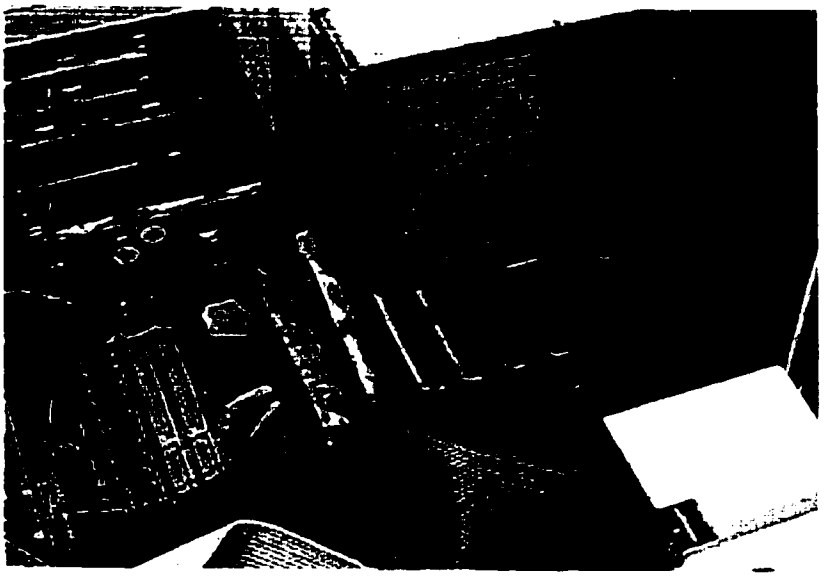


Fig. 11: Experimental setup for the PCM-filled heat sink.

APPENDIX E

Data Tables for PCM-filled

Heat Sinks

1. Data sheets for PCM-filled heat sink: 40 mL PCM

P = 14.592 Watts

Channel 1

Time	Temp. (C)		Time	Temp. (C)		Time	Temp. (C)
429904.7	40.778		429902.8	40.777		429900.9	40.779
429904.6	40.779		429902.7	40.779		429900.8	40.778
429904.4	40.779		429902.6	40.78		429900.6	40.778
429904.3	40.78		429902.4	40.778		429900.5	40.78
429904.2	40.779		429902.3	40.778		429900.3	40.777
429904	40.781		429902.1	40.779		429900.2	40.778
429903.9	40.779		429902	40.777		429900.1	40.779
429903.8	40.777		429901.9	40.781		429900	40.779
429903.6	40.778		429901.7	40.781		429899.8	40.779
429903.5	40.778		429901.6	40.779		429899.7	40.778
429903.3	40.778		429901.5	40.776		429899.5	40.778
429903.2	40.775		429901.3	40.778		429899.4	40.779
429903.1	40.777		429901.2	40.779		429899.3	40.778
429902.9	40.778		429901.1	40.776		429899.1	40.779

Average Temperature: 40.7784 deg C

Channel 2

Time	Temp. (C)		Time	Temp. (C)		Time	Temp. (C)
429925.8	38.187		429923.9	38.184		429922	38.183
429925.7	38.187		429923.8	38.185		429921.8	38.183
429925.5	38.185		429923.7	38.185		429921.7	38.184
429925.4	38.184		429923.5	38.185		429921.6	38.184
429925.3	38.186		429923.4	38.184		429921.4	38.184
429925.1	38.184		429923.3	38.184		429921.3	38.185
429925	38.184		429923.1	38.184		429921.2	38.184
429924.9	38.185		429923	38.186		429921.1	38.183
429924.8	38.184		429922.8	38.185		429920.9	38.185
429924.6	38.184		429922.7	38.185		429920.8	38.185
429924.5	38.185		429922.5	38.184		429920.6	38.186
429924.3	38.183		429922.4	38.187		429920.5	38.185
429924.2	38.184		429922.3	38.184		429920.4	38.184
429924.1	38.187		429922.1	38.184		429920.2	38.183

Average Temperature: 38.1846 deg C

P = 14.592 Watts (Cont.)							
Channel 3							
Time	Temp. (C)		Time	Temp. (C)		Time	Temp. (C)
429942.7	40.085		429940.7	40.088		429938.7	40.085
429942.6	40.087		429940.5	40.084		429938.6	40.084
429942.4	40.085		429940.4	40.087		429938.4	40.086
429942.3	40.087		429940.3	40.085		429938.3	40.085
429942.1	40.085		429940.1	40.084		429938.2	40.086
429942	40.089		429940	40.082		429938.1	40.085
429941.9	40.087		429939.8	40.087		429937.9	40.083
429941.7	40.087		429939.7	40.086		429937.8	40.084
429941.6	40.083		429939.5	40.084		429937.7	40.083
429941.4	40.085		429939.4	40.086		429937.5	40.084
429941.3	40.086		429939.3	40.083		429937.4	40.084
429941.2	40.083		429939.1	40.083		429937.3	40.084
429941.1	40.088		429939	40.085		429937.1	40.084
429940.9	40.086		429938.9	40.086		429937	40.084
429940.8	40.086						
Average Temperature: 40.08512 deg C							

P = 17.082 Watts							
Channel 1							
Time	Temp. (C)		Time	Temp. (C)		Time	Temp. (C)
438460.6	43.926		438458.7	43.926		438456.8	43.922
438460.4	43.923		438458.6	43.921		438456.7	43.922
438460.3	43.924		438458.4	43.923		438456.5	43.923
438460.2	43.923		438458.3	43.923		438456.4	43.924
438460.1	43.922		438458.2	43.924		438456.3	43.924
438459.9	43.922		438458	43.924		438456.1	43.926
438459.8	43.925		438457.9	43.924		438456	43.924
438459.7	43.925		438457.8	43.926		438455.8	43.924
438459.5	43.925		438457.6	43.922		438455.7	43.921
438459.4	43.922		438457.5	43.922		438455.6	43.923
438459.3	43.925		438457.3	43.923		438455.4	43.923
438459.1	43.926		438457.2	43.923		438455.3	43.922
438459	43.923		438457.1	43.924		438455.2	43.925
438458.8	43.925		438456.9	43.923		438455	43.925
Average Temperature: 43.92362 deg C							
Channel 2							
Time	Temp. (C)		Time	Temp. (C)		Time	Temp. (C)
438478.8	40.834		438476.8	40.832		438474.9	40.832
438478.6	40.832		438476.7	40.833		438474.8	40.831
438478.5	40.833		438476.6	40.83		438474.7	40.829
438478.3	40.833		438476.4	40.832		438474.5	40.83
438478.2	40.833		438476.3	40.831		438474.4	40.83
438478.1	40.83		438476.2	40.833		438474.3	40.83
438477.9	40.836		438476	40.83		438474.1	40.831
438477.8	40.833		438475.9	40.832		438474	40.832
438477.7	40.834		438475.8	40.833		438473.8	40.83
438477.5	40.832		438475.6	40.832		438473.7	40.833
438477.4	40.833		438475.5	40.832		438473.6	40.83
438477.2	40.833		438475.3	40.832		438473.5	40.832
438477.1	40.83		438475.2	40.831		438473.3	40.83
438477	40.829		438475.1	40.83			
Average Temperature: 40.83166 deg C							

P = 17.082 Watts (Cont.)							
Channel 3							
Time	Temp. (C)		Time	Temp. (C)		Time	Temp. (C)
438496.8	42.937		438494.9	42.939		438493	42.936
438496.7	42.938		438494.8	42.939		438492.9	42.936
438496.6	42.939		438494.7	42.939		438492.8	42.937
438496.4	42.941		438494.5	42.941		438492.6	42.937
438496.3	42.938		438494.4	42.941		438492.5	42.936
438496.2	42.94		438494.3	42.938		438492.3	42.937
438496	42.94		438494.1	42.939		438492.2	42.938
438495.9	42.939		438494	42.938		438492.1	42.935
438495.8	42.937		438493.8	42.94		438491.9	42.937
438495.6	42.936		438493.7	42.937		438491.8	42.94
438495.5	42.939		438493.6	42.939		438491.7	42.938
438495.3	42.936		438493.4	42.936		438491.6	42.938
438495.2	42.937		438493.3	42.935		438491.4	42.937
438495.1	42.939		438493.2	42.937			
Average Temperature: 42.93795 deg C							

P = 19.796 Watts

Channel 1

Time	Temp. (C)		Time	Temp. (C)		Time	Temp. (C)
439720.6	47.234		439718.6	47.234		439716.5	47.232
439720.4	47.232		439718.4	47.234		439716.4	47.234
439720.3	47.235		439718.3	47.233		439716.3	47.232
439720.2	47.23		439718.2	47.233		439716.1	47.234
439720.1	47.231		439718	47.233		439716	47.235
439719.9	47.234		439717.9	47.232		439715.8	47.233
439719.8	47.233		439717.8	47.232		439715.7	47.233
439719.7	47.23		439717.6	47.236		439715.6	47.23
439719.5	47.235		439717.5	47.234		439715.5	47.231
439719.4	47.234		439717.3	47.235		439715.3	47.234
439719.3	47.235		439717.2	47.233		439715.2	47.236
439719.1	47.233		439717.1	47.232		439715.1	47.235
439719	47.238		439716.9	47.234		439715	47.233
439718.8	47.234		439716.8	47.232		439714.8	47.235
439718.7	47.235		439716.7	47.233			

Average Temperature: 47.23341 deg C

Channel 2

Time	Temp. (C)		Time	Temp. (C)		Time	Temp. (C)
439740.2	43.63		439738.3	43.629		439736.4	43.633
439740.1	43.63		439738.2	43.629		439736.3	43.628
439739.9	43.629		439738.1	43.629		439736.1	43.63
439739.8	43.627		439737.9	43.63		439736	43.631
439739.7	43.632		439737.8	43.63		439735.8	43.63
439739.6	43.63		439737.7	43.628		439735.7	43.629
439739.4	43.63		439737.5	43.629		439735.6	43.631
439739.3	43.628		439737.3	43.631		439735.4	43.63
439739.1	43.629		439737.2	43.628		439735.3	43.63
439739	43.629		439737.1	43.631		439735.2	43.63
439738.9	43.629		439736.9	43.632		439735	43.629
439738.7	43.629		439736.8	43.63		439734.9	43.629
439738.6	43.627		439736.7	43.633		439734.8	43.629
439738.4	43.626		439736.5	43.632		439734.7	43.63

Average Temperature: 43.62964 deg C

P = 19.796 Watts (Cont.)								
Channel 3								
Time	Temp. (C)		Time	Temp. (C)		Time	Temp. (C)	
439757.6	46.063		439755.7	46.062		439753.8	46.062	
439757.5	46.063		439755.5	46.062		439753.6	46.067	
439757.3	46.061		439755.4	46.064		439753.5	46.063	
439757.2	46.062		439755.3	46.061		439753.3	46.064	
439757.1	46.063		439755.1	46.061		439753.2	46.062	
439756.9	46.06		439755	46.063		439753.1	46.065	
439756.8	46.062		439754.8	46.06		439752.9	46.062	
439756.7	46.061		439754.7	46.064		439752.8	46.065	
439756.5	46.064		439754.6	46.062		439752.7	46.064	
439756.4	46.062		439754.4	46.065		439752.6	46.063	
439756.2	46.062		439754.3	46.065		439752.4	46.062	
439756.1	46.063		439754.2	46.065		439752.3	46.065	
439755.9	46.062		439754	46.065		439752.2	46.066	
439755.8	46.06		439753.9	46.066		439752.1	46.065	
Average Temperature: 46.06305 deg C								

P = 25.87991 Watts

Channel 1

Time	Temp. (C)		Time	Temp. (C)		Time	Temp. (C)
441212.7	54.783		441210.7	54.787		441208.8	54.783
441212.6	54.782		441210.5	54.784		441208.6	54.785
441212.4	54.785		441210.3	54.784		441208.5	54.783
441212.3	54.785		441210.2	54.782		441208.3	54.786
441212.1	54.785		441210.1	54.783		441208.2	54.785
441212	54.788		441209.9	54.783		441208.1	54.785
441211.9	54.784		441209.8	54.783		441208	54.786
441211.7	54.787		441209.7	54.785		441207.8	54.788
441211.6	54.783		441209.5	54.785		441207.7	54.787
441211.4	54.784		441209.4	54.783		441207.6	54.786
441211.3	54.784		441209.3	54.782		441207.4	54.786
441211.2	54.785		441209.2	54.782		441207.3	54.786
441211	54.785		441209	54.785		441207.2	54.785
441210.9	54.784		441208.9	54.783		441207	54.787
441210.8	54.783						

Average Temperature: 54.78456 deg C

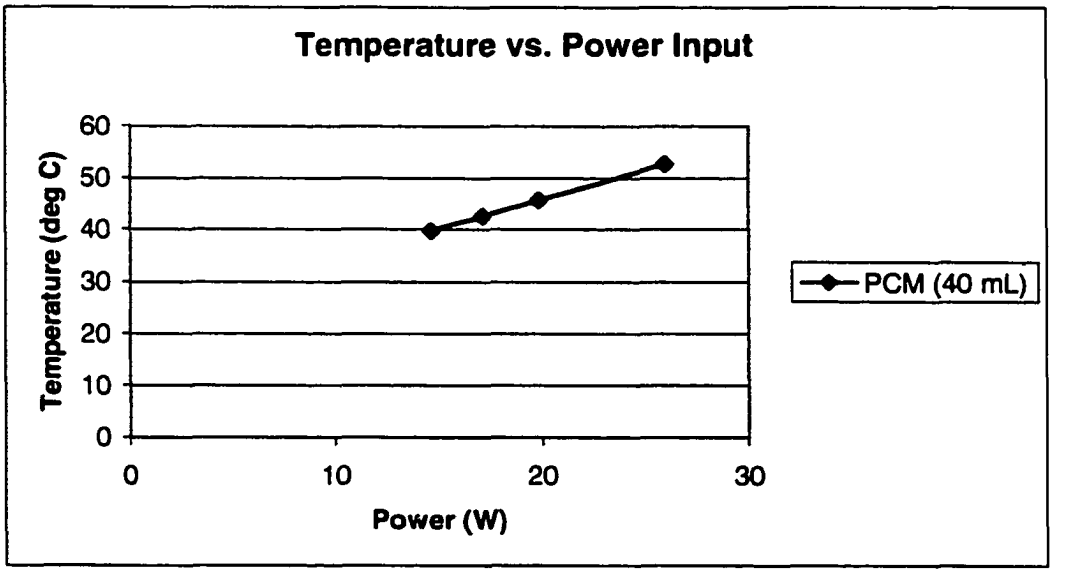
Channel 2

Time	Temp. (C)		Time	Temp. (C)		Time	Temp. (C)
441231.8	50.379		441229.8	50.381		441227.9	50.383
441231.6	50.384		441229.7	50.383		441227.8	50.384
441231.5	50.381		441229.6	50.383		441227.7	50.385
441231.3	50.385		441229.4	50.384		441227.5	50.383
441231.2	50.383		441229.3	50.383		441227.4	50.384
441231.1	50.386		441229.2	50.384		441227.3	50.383
441230.9	50.382		441229	50.384		441227.1	50.384
441230.8	50.381		441228.9	50.382		441227	50.383
441230.7	50.38		441228.7	50.383		441226.8	50.383
441230.5	50.38		441228.6	50.382		441226.7	50.383
441230.4	50.382		441228.5	50.383		441226.6	50.384
441230.3	50.382		441228.3	50.382		441226.5	50.382
441230.1	50.384		441228.2	50.381		441226.3	50.382
441230	50.382		441228.1	50.383			

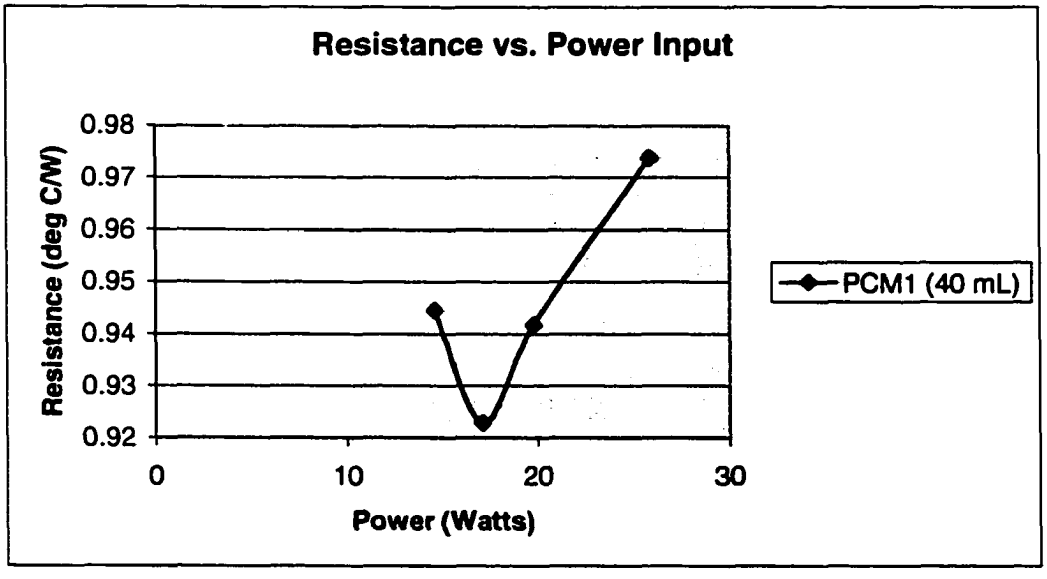
Average Temperature: 50.38273 deg C

P = 25.87991 Watts							
Channel 3							
Time	Temp. (C)		Time	Temp. (C)		Time	Temp. (C)
441248.1	53.258		441246.1	53.26		441244.2	53.262
441248	53.26		441245.9	53.26		441244.1	53.26
441247.8	53.261		441245.8	53.263		441243.9	53.26
441247.7	53.26		441245.7	53.26		441243.8	53.26
441247.6	53.26		441245.5	53.258		441243.7	53.261
441247.4	53.261		441245.4	53.26		441243.5	53.26
441247.3	53.258		441245.3	53.261		441243.4	53.26
441247.2	53.26		441245.1	53.262		441243.2	53.26
441247	53.261		441245	53.261		441243.1	53.263
441246.9	53.261		441244.9	53.259		441243	53.26
441246.8	53.262		441244.7	53.259		441242.8	53.261
441246.6	53.26		441244.6	53.261		441242.7	53.26
441246.5	53.26		441244.4	53.257		441242.6	53.26
441246.4	53.261		441244.3	53.26		441242.5	53.262
441246.2	53.259						
Average Temperature: 53.26028 deg C							

Power Input (Watts)	Temperature (deg C)
14.592	39.68271
17.082	42.56441
19.796	45.64203
25.87991	52.7005



Power Input (Watts)	Resistance (deg C/W)
14.592	0.94454
17.082	0.92287
19.796	0.94171
25.87991	0.97375



2. Data sheets for PCM-filled heat sink: 30 mL PCM

P = 14.57407 Watts							
Channel 1							
Time	Temp. (C)		Time	Temp. (C)		Time	Temp. (C)
2070238.4	39.403		2070236.5	39.401		2070234.6	39.399
2070238.3	39.402		2070236.25	39.402		2070234.5	39.399
2070238.1	39.403		2070236.13	39.403		2070234.4	39.4
2070238	39.401		2070236	39.4		2070234.3	39.4
2070237.9	39.403		2070235.88	39.402		2070234.1	39.399
2070237.6	39.401		2070235.75	39.398		2070234	39.401
2070237.5	39.403		2070235.63	39.399		2070233.9	39.402
2070237.4	39.403		2070235.5	39.402		2070233.8	39.399
2070237.3	39.399		2070235.38	39.4		2070233.5	39.4
2070237.1	39.399		2070235.25	39.399		2070233.4	39.402
2070237	39.402		2070235.13	39.398		2070233.3	39.402
2070236.9	39.399		2070234.88	39.397		2070233.1	39.399
2070236.8	39.401		2070234.75	39.4		2070233	39.399
2070236.6	39.401						
Average Temperature: 39.40055 deg C							
Channel 2							
Time	Temp. (C)		Time	Temp. (C)		Time	Temp. (C)
2070261	38.284		2070259	38.285		2070257.1	38.284
2070260.9	38.285		2070258.88	38.284		2070256.9	38.283
2070260.8	38.286		2070258.75	38.287		2070256.8	38.282
2070260.6	38.285		2070258.63	38.285		2070256.6	38.281
2070260.5	38.282		2070258.5	38.283		2070256.5	38.283
2070260.4	38.284		2070258.25	38.284		2070256.4	38.283
2070260.3	38.285		2070258.13	38.284		2070256.3	38.283
2070260.1	38.284		2070258	38.285		2070256.1	38.283
2070260	38.285		2070257.88	38.284		2070256	38.28
2070259.9	38.285		2070257.75	38.286		2070255.9	38.283
2070259.6	38.283		2070257.63	38.286		2070255.8	38.282
2070259.5	38.285		2070257.5	38.284		2070255.6	38.284
2070259.4	38.284		2070257.38	38.283		2070255.5	38.284
2070259.3	38.285		2070257.25	38.286		2070255.4	38.283
2070259.1	38.284						
Average Temperature: 38.28395 deg C							

P = 14.57407 Watts (Cont.)							
Channel 3							
Time	Temp. (C)		Time	Temp. (C)		Time	Temp. (C)
2070281.5	38.62		2070279.63	38.619		2070277.8	38.616
2070281.4	38.618		2070279.5	38.619		2070277.6	38.618
2070281.3	38.618		2070279.38	38.619		2070277.5	38.615
2070281.1	38.616		2070279.25	38.616		2070277.4	38.615
2070281	38.617		2070279.13	38.618		2070277.3	38.617
2070280.9	38.618		2070279	38.617		2070277	38.614
2070280.8	38.622		2070278.88	38.616		2070276.9	38.615
2070280.6	38.616		2070278.75	38.618		2070276.8	38.617
2070280.5	38.616		2070278.5	38.618		2070276.6	38.614
2070280.4	38.619		2070278.5	38.618		2070276.5	38.616
2070280.1	38.618		2070278.25	38.616		2070276.4	38.617
2070280	38.617		2070278.13	38.616		2070276.3	38.617
2070279.9	38.618		2070278	38.62		2070276.1	38.617
2070279.8	38.618		2070277.88	38.616		2070276	38.617
Average Temperature: 38.61719 deg C							

P = 17.108 Watts								
Channel 1								
Time	Temp. (C)		Time	Temp. (C)		Time	Temp. (C)	
2078328.5	42.345		2078326.63	42.343		2078324.8	42.348	
2078328.4	42.343		2078326.5	42.345		2078324.6	42.347	
2078328.3	42.344		2078326.38	42.345		2078324.4	42.346	
2078328.1	42.345		2078326.13	42.346		2078324.3	42.348	
2078328	42.347		2078326	42.347		2078324.1	42.347	
2078327.9	42.348		2078325.88	42.345		2078324	42.345	
2078327.6	42.345		2078325.75	42.348		2078323.9	42.346	
2078327.5	42.348		2078325.63	42.345		2078323.8	42.346	
2078327.4	42.346		2078325.5	42.346		2078323.6	42.347	
2078327.3	42.347		2078325.38	42.346		2078323.5	42.344	
2078327.1	42.344		2078325.25	42.345		2078323.4	42.345	
2078327	42.347		2078325.13	42.348		2078323.3	42.346	
2078326.9	42.347		2078325	42.345		2078323.1	42.345	
2078326.8	42.345		2078324.88	42.347		2078323	42.346	
Average Temperature: 42.3459 deg C								
Channel 2								
Time	Temp. (C)		Time	Temp. (C)		Time	Temp. (C)	
2078347.8	41.377		2078345.75	41.381		2078343.9	41.376	
2078347.6	41.381		2078345.63	41.378		2078343.8	41.379	
2078347.4	41.379		2078345.5	41.377		2078343.6	41.377	
2078347.3	41.377		2078345.38	41.377		2078343.5	41.378	
2078347.1	41.376		2078345.25	41.376		2078343.4	41.379	
2078347	41.379		2078345.13	41.379		2078343.3	41.381	
2078346.9	41.377		2078345	41.378		2078343.1	41.376	
2078346.8	41.379		2078344.88	41.38		2078343	41.379	
2078346.6	41.377		2078344.75	41.376		2078342.8	41.379	
2078346.5	41.379		2078344.63	41.377		2078342.6	41.374	
2078346.4	41.38		2078344.5	41.38		2078342.5	41.378	
2078346.3	41.377		2078344.38	41.374		2078342.4	41.378	
2078346.1	41.38		2078344.25	41.379		2078342.3	41.377	
2078345.9	41.378		2078344.13	41.377		2078342.1	41.377	
Average Temperature: 41.37793 deg C								

P = 17.108 Watts (Cont.)							
Channel 3							
Time	Temp. (C)		Time	Temp. (C)		Time	Temp. (C)
2078365.4	41.429		2078363.63	41.431		2078361.9	41.433
2078365.3	41.433		2078363.5	41.432		2078361.8	41.433
2078365.1	41.433		2078363.38	41.433		2078361.6	41.432
2078365	41.433		2078363.25	41.433		2078361.4	41.432
2078364.9	41.433		2078363.13	41.431		2078361.4	41.434
2078364.8	41.432		2078363	41.436		2078361.3	41.432
2078364.6	41.433		2078362.88	41.432		2078361	41.436
2078364.5	41.433		2078362.75	41.433		2078360.9	41.435
2078364.3	41.434		2078362.5	41.435		2078360.8	41.432
2078364.3	41.431		2078362.38	41.435		2078360.6	41.431
2078364.1	41.434		2078362.25	41.432		2078360.5	41.434
2078363.9	41.434		2078362.13	41.431		2078360.4	41.433
2078363.8	41.429		2078362	41.432		2078360.3	41.433
Average Temperature: 41.43274 deg C							

P = 19.824 Watts								
Channel 1								
Time	Temp. (C)		Time	Temp. (C)		Time	Temp. (C)	
2079817.3	45.391		2079815.25	45.39		2079813.4	45.391	
2079817.1	45.391		2079815.13	45.392		2079813.3	45.393	
2079817	45.389		2079815	45.394		2079813.1	45.394	
2079816.9	45.39		2079814.88	45.391		2079813	45.392	
2079816.8	45.389		2079814.75	45.389		2079812.9	45.395	
2079816.6	45.389		2079814.63	45.39		2079812.6	45.393	
2079816.5	45.39		2079814.5	45.39		2079812.5	45.395	
2079816.4	45.387		2079814.38	45.391		2079812.4	45.393	
2079816.3	45.389		2079814.13	45.391		2079812.3	45.392	
2079816.1	45.391		2079814	45.391		2079812.1	45.391	
2079815.9	45.388		2079813.88	45.39		2079812	45.394	
2079815.8	45.39		2079813.75	45.393		2079811.9	45.394	
2079815.6	45.391		2079813.63	45.391		2079811.8	45.393	
2079815.5	45.388		2079813.5	45.392		2079811.6	45.395	
2079815.4	45.391							
Average Temperature: 45.39126 deg C								
Channel 2								
Time	Temp. (C)		Time	Temp. (C)		Time	Temp. (C)	
2079833.1	44.367		2079831.25	44.366		2079829.3	44.363	
2073833	44.367		2079831.13	44.368		2079829.1	44.366	
2079832.9	44.367		2079830.88	44.365		2079829	44.362	
2079832.8	44.368		2079830.75	44.364		2079828.9	44.362	
2079832.6	44.368		2079830.63	44.364		2079828.8	44.366	
2079832.4	44.368		2079830.5	44.363		2079828.6	44.365	
2079832.3	44.363		2079830.38	44.367		2079828.5	44.364	
2079832.1	44.367		2079830.25	44.365		2079828.4	44.364	
2079832	44.366		2079830.13	44.364		2079828.3	44.362	
2079831.9	44.368		2079830	44.367		2079828.1	44.363	
2079831.8	44.364		2079829.88	44.366		2079828	44.366	
2079831.6	44.367		2079829.75	44.364		2079827.9	44.366	
2079831.5	44.367		2079829.63	44.362		2079827.8	44.366	
2079831.4	44.367		2079829.38	44.363				
Average Temperature: 44.36529 deg C								

P = 19.824 Watts (Cont.)							
Channel 3							
Time	Temp. (C)		Time	Temp. (C)		Time	Temp. (C)
2079849.9	44.382		2079848	44.382		2079846.1	44.38
2079849.8	44.381		2079847.88	44.382		2079845.9	44.381
2079849.6	44.38		2079847.75	44.382		2079845.8	44.381
2079849.5	44.383		2079847.63	44.383		2079845.6	44.382
2079849.4	44.38		2079847.5	44.38		2079845.5	44.381
2079849.3	44.382		2079847.25	44.381		2079845.4	44.382
2079849.1	44.38		2079847.13	44.381		2079845.3	44.382
2079849	44.383		2079847	44.385		2079845.1	44.383
2079848.9	44.383		2079846.88	44.382		2079845	44.378
2079848.6	44.385		2079846.75	44.382		2079844.9	44.38
2079848.5	44.38		2079846.63	44.381		2079844.8	44.381
2079848.4	44.382		2079846.5	44.381		2079844.6	44.381
2079848.3	44.383		2079846.38	44.381		2079844.5	44.38
2079848.1	44.383		2079846.25	44.383			
Average Temperature: 44.38159 deg C							

P = 22.77 Watts

Channel 1

Time	Temp. (C)		Time	Temp. (C)		Time	Temp. (C)
2081227.1	48.729		2081225.25	48.73		2081223.4	48.729
2081227	48.728		2081225.13	48.73		2081223.3	48.729
2081226.9	48.729		2081225	48.729		2081223	48.73
2081226.8	48.729		2081224.88	48.729		2081222.9	48.73
2081226.6	48.727		2081224.75	48.73		2081222.8	48.729
2081226.5	48.729		2081224.63	48.73		2081222.6	48.73
2081226.4	48.729		2081224.38	48.732		2081222.5	48.732
2081226.3	48.728		2081224.25	48.731		2081222.4	48.728
2081226.1	48.728		2081224.13	48.729		2081222.3	48.732
2081226	48.73		2081224	48.729		2081222.1	48.732
2081225.8	48.729		2081223.88	48.73		2081222	48.732
2081225.6	48.729		2081223.75	48.729		2081221.9	48.731
2081225.5	48.73		2081223.63	48.729		2081221.8	48.73
2081225.4	48.73		2081223.5	48.727		2081221.6	48.732

Average Temperature: 48.72962 deg C

Channel 2

Time	Temp. (C)		Time	Temp. (C)		Time	Temp. (C)
2081246.5	47.665		2081244.38	47.663		2081242.5	47.666
2081246.4	47.667		2081244.25	47.665		2081242.4	47.663
2081246.3	47.664		2081244.13	47.664		2081242.3	47.665
2081246	47.664		2081244	47.665		2081242.1	47.664
2081245.9	47.666		2081243.88	47.665		2081242	47.666
2081245.8	47.664		2081243.75	47.666		2081241.9	47.663
2081245.6	47.665		2081243.63	47.664		2081241.8	47.665
2081245.5	47.666		2081243.5	47.665		2081241.5	47.663
2081245.4	47.666		2081243.38	47.666		2081241.4	47.664
2081245.3	47.665		2081243.25	47.667		2081241.3	47.664
2081245.1	47.667		2081243.13	47.667		2081241.1	47.663
2081245	47.663		2081243	47.666		2081241	47.664
2081244.9	47.663		2081242.75	47.665		2081240.9	47.664
2081244.8	47.665		2081242.63	47.664		2081240.8	47.665
2081244.6	47.662						

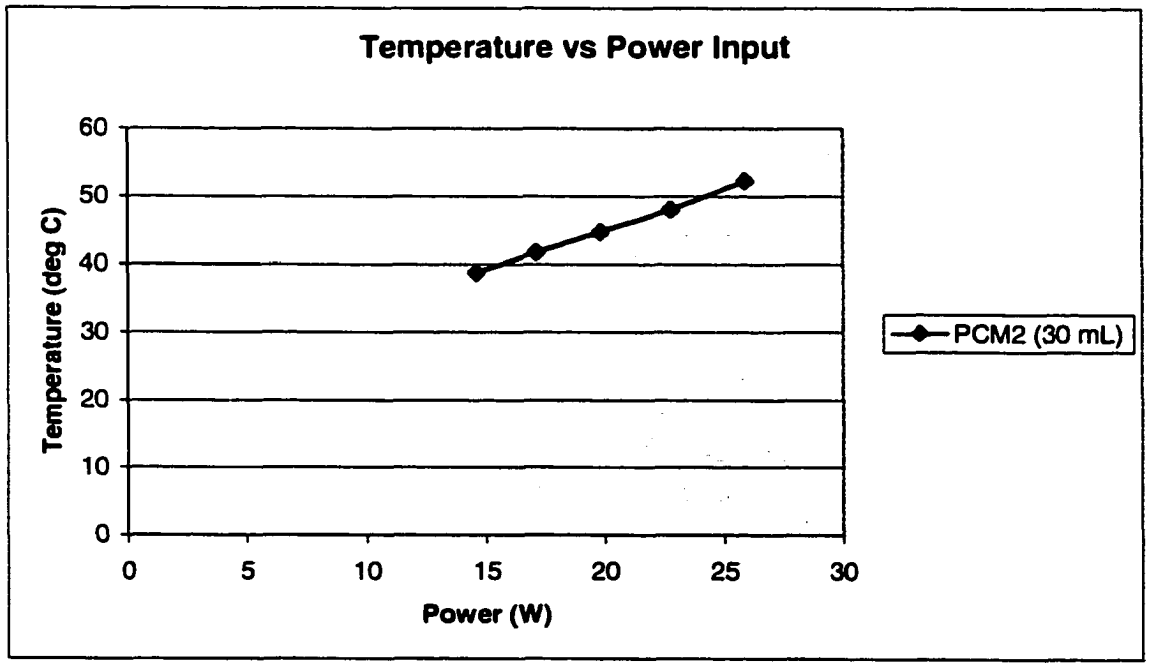
Average Temperature: 47.66472 deg C

P = 22.77 Watts (Cont.)							
Channel 3							
Time	Temp. (C)		Time	Temp. (C)		Time	Temp. (C)
2081262.9	47.567		2081260.88	47.566		2081258.9	47.571
2081262.8	47.568		2081260.63	47.566		2081258.8	47.572
2081262.6	47.57		2081260.5	47.566		2081258.6	47.568
2081262.5	47.57		2081260.38	47.568		2081258.5	47.568
2081262.4	47.567		2081260.25	47.569		2081258.4	47.568
2081262.3	47.567		2081260.13	47.569		2081258.3	47.572
2081262	47.567		2081260	47.566		2081258.1	47.568
2081261.9	47.567		2081259.88	47.566		2081258	47.569
2081261.8	47.569		2081259.75	47.567		2081257.9	47.571
2081261.6	47.567		2081259.63	47.57		2081257.8	47.571
2081261.5	47.567		2081259.5	47.568		2081257.5	47.57
2081261.4	47.566		2081259.25	47.57		2081257.4	47.57
2081261.3	47.567		2081259.13	47.568		2081257.3	47.568
2081261.1	47.568		2081259	47.57		2081257.1	47.569
2081261	47.568						
Average Temperature: 47.56835 deg C							

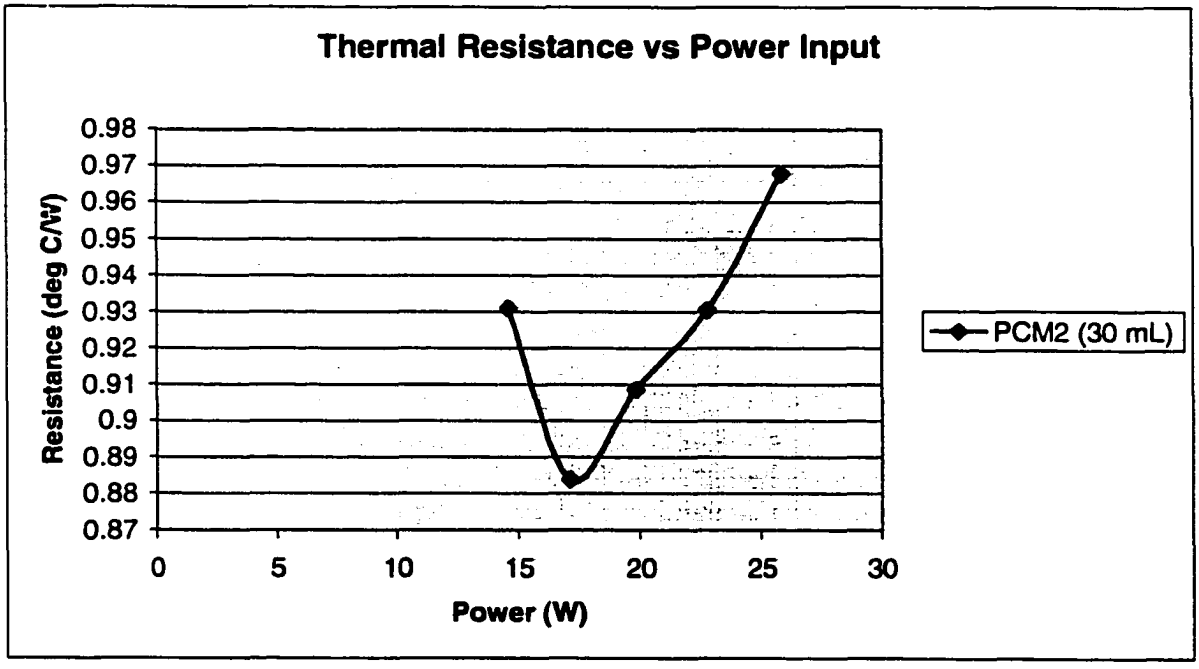
P = 25.856 Watts								
Channel 1								
Time	Temp. (C)		Time	Temp. (C)		Time	Temp. (C)	
2084386.6	54.032		2084384.75	54.039		2084382.8	54.041	
2084386.5	54.034		2084384.63	54.039		2084382.6	54.04	
2084386.4	54.033		2084384.38	54.04		2084382.5	54.042	
2084386.3	54.034		2084384.25	54.041		2084382.4	54.041	
2084386.1	54.035		2084384.13	54.041		2084382.3	54.042	
2084386	54.036		2084384	54.043		2084382.1	54.04	
2084385.9	54.038		2084383.88	54.039		2084382	54.042	
2084385.8	54.038		2084383.75	54.042		2084381.9	54.041	
2084385.5	54.038		2034383.63	54.04		2084381.6	54.04	
2084385.4	54.036		2084383.5	54.04		2084381.5	54.04	
2084385.3	54.041		2084383.38	54.041		2084381.4	54.041	
2084385.1	54.039		2084383.25	54.039		2084381.3	54.041	
2084385	54.038		2084383	54.042		2084381.1	54.039	
2084384.9	54.04		2084382.88	54.038				
Average Temperature: 54.03917 deg C								
Channel 2								
Time	Temp. (C)		Time	Temp. (C)		Time	Temp. (C)	
2084403.9	51.765		2084402.13	51.766		2084400.3	51.766	
2084403.8	51.767		2084401.88	51.766		2084400.1	51.767	
2084403.6	51.767		2084401.75	51.765		2084400	51.768	
2084403.5	51.765		2084401.63	51.767		2084399.8	51.768	
2084403.3	51.764		2084401.5	51.767		2084399.6	51.766	
2084403.3	51.766		2084401.38	51.767		2084399.5	51.767	
2084403	51.768		2084401.25	51.768		2084399.4	51.769	
2084402.9	51.766		2084401.13	51.765		2084399.3	51.767	
2084402.8	51.765		2084401	51.765		2084399.1	51.767	
2084402.6	51.766		2084400.88	51.765		2084398.9	51.765	
2084402.5	51.767		2084400.63	51.767		2084398.8	51.768	
2084402.4	51.768		2084400.5	51.767		2084398.6	51.768	
2084402.3	51.768		2084400.38	51.766		2084398.5	51.765	
Average Temperature: 51.76651 deg C								

P = 25.856 Watts (Cont.)							
Channel 3							
Time	Temp. (C)		Time	Temp. (C)		Time	Temp. (C)
2084421.3	50.867		2084419.13	50.864		2084417.1	50.868
2084421.1	50.865		2084419	50.864		2084417	50.866
2084421	50.868		2084418.88	50.866		2084416.9	50.866
2084420.9	50.865		2084418.75	50.866		2084416.8	50.866
2084420.8	50.867		2084418.63	50.865		2084416.6	50.865
2084420.5	50.867		2084418.38	50.864		2084416.5	50.868
2084420.4	50.867		2084418.25	50.864		2084416.4	50.866
2084420.3	50.865		2084418.13	50.863		2084416.1	50.862
2084420.1	50.866		2084418	50.865		2084416	50.862
2084420	50.865		2084417.88	50.862		2084415.9	50.865
2084419.9	50.868		2084417.75	50.867		2084415.8	50.865
2084419.8	50.864		2084417.63	50.865		2084415.6	50.867
2084419.5	50.864		2084417.5	50.864		2084415.5	50.866
2084419.4	50.865		2084417.25	50.865		2084415.4	50.863
2084419.3	50.865						
Average Temperature: 50.86528 deg C							

Power (W)	T (deg C)
14.57407	38.76723
17.108	41.71886
19.824	44.71271
22.77	47.98756
25.856	52.22365

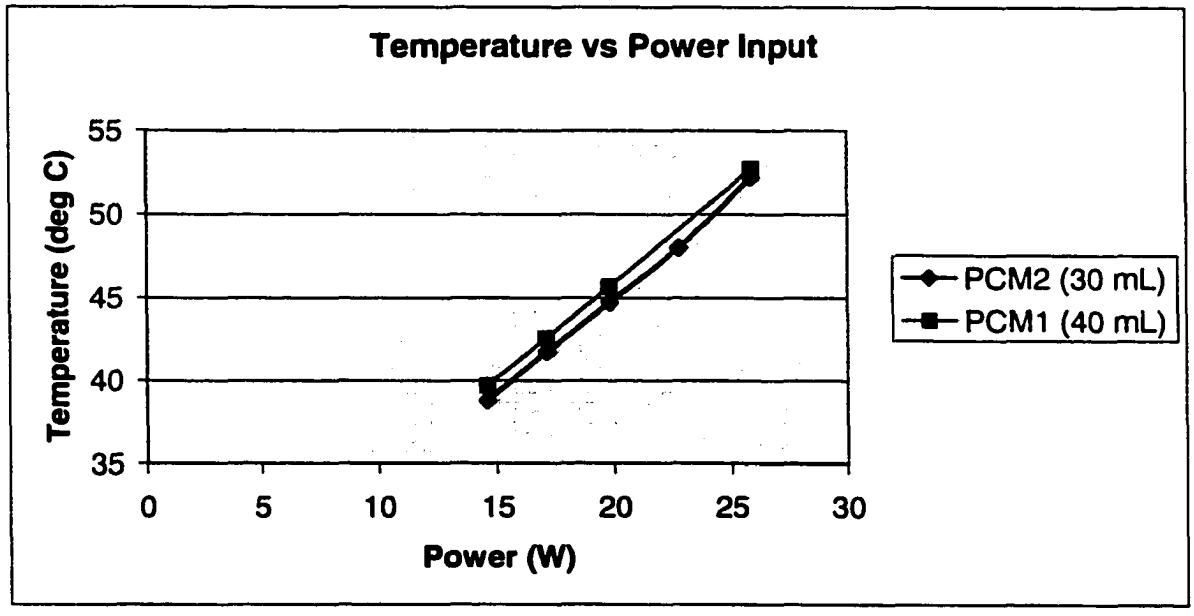


Power (W)	R (deg C/W)
14.57407	0.93092
17.108	0.88373
19.824	0.90863
22.77	0.9305
25.856	0.9678

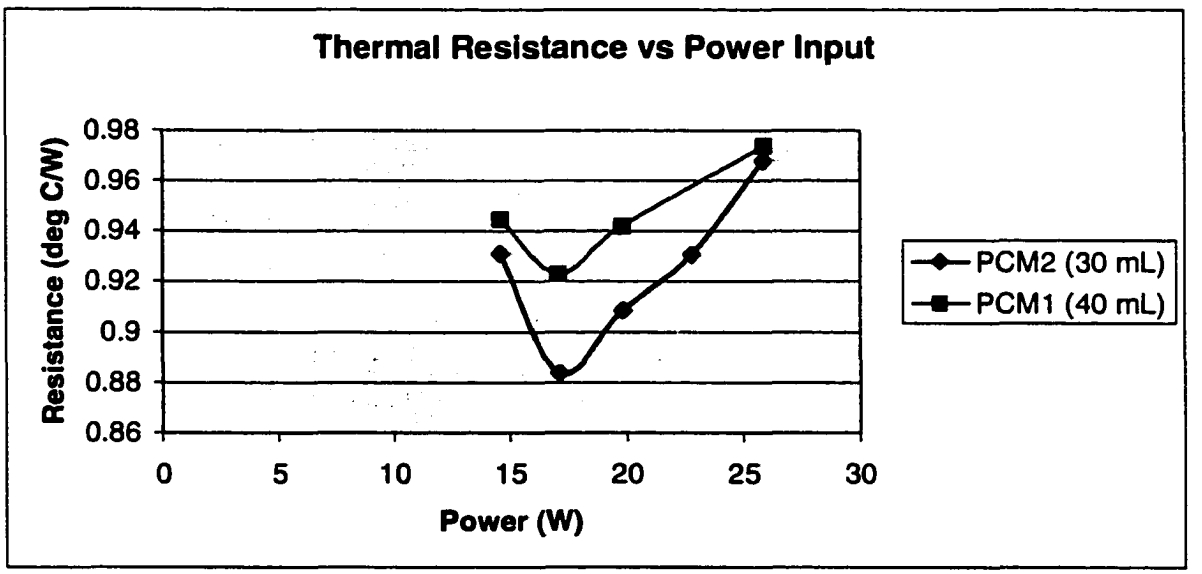


Comparison between PCM heat sinks containing different volumes of PCM.

Power (W)	(PCM2) T (deg C)	Power Input (Watts)	(PCM1) Temperature (deg C)
14.57407	38.76723	14.592	39.68271
17.108	41.71886	17.082	42.56441
19.824	44.71271	19.796	45.64203
22.77	47.98756	25.87991	52.7005
25.856	52.22365		



Power (W)	R (deg C/W)	Power Input (Watts)	Resistance (deg C/W)
14.57407	0.93092		
17.108	0.88373	14.592	0.94454
19.824	0.90863	17.082	0.92287
22.77	0.9305	19.796	0.94171
25.856	0.9678	25.87991	0.97375



APPENDIX F

Calculations For Surface Area Comparison and Thermal Resistance Analysis of Solid Aluminum Heat Sink

1. COMPARING PCM AND PENTIUM PRO® HEAT SINK SURFACE AREA

PCM Heat Sink Area		
Base Area (in^2)	Fin Area (in^2)	Total Area (in^2)
2.297	35.410	37.707

Pentium Pro Heat Sink Area		
Base Area (in^2)	Fin Area (in^2)	Total Area (in^2)
6.904	45.493	52.397

Formula for Rectangular Fins:

Fin Area = 2wL, where:

L = (height + (thickness/2))
w = width

Formula for Pin (Square) Fins:

Fin Area = N*(P*h + (l*w)), where:
N = Number of fins
P = perimeter
l = length
H = height
W = width

These values result in a surface area ratio of about 7/5.

2. THERMAL RESISTANCE OF SOLID-ALUMINUM HEAT SINK

In order to use the resulting values to compare them to the PCM heat sink's thermal resistance, the calculations were performed in metric units. Using the formula for heat transfer from extended surfaces [10],

$Q_t = hA_t[1-((N*A_f)(1-\eta_f))]\theta_b$, with:

h: coefficient of convective heat transfer = 50 W/m^2*K;

k: coefficient of thermal conductivity = 186 W/m*K for 2024-T6 aluminum;

Using the same dimensions as the PCM heat sink, $A_f = 2wL = 0.004569\ m^2$ and A_t = base area + $A_f = 0.024\ m^2$. With $L_c = 0.029$ m, $A_p = 0.00228\ m^2$, $L_c^{3/2}(h/kA_p)^{1/2} = 0.055$. Hence, from [10], the fin efficiency is $\eta_f \approx 0.99$, and

Thermal Resistance = $Q_t/\theta_b = hA_t[1-((N*A_f)(1-\eta_f))]$ = <u>1.205 W/ ° C.</u>

VITA

Lopez, Pedro, Development of New Heat Sink Technology For High Density Microprocessors. Masters of Science (MS), May, 2003, 200 pp., 11 tables, 23 illustrations, references, 55 titles.

Pedro Lopez is a graduate student at the University of Texas – Pan American. He attended Donna High School, graduating in 1995 as Class Valedictorian, and received his Bachelors of Science degree in mechanical engineering in May 2000 at The University of Texas – Pan American. During his graduate career, he worked as a teaching assistant for the Heat Transfer and Fluids Dynamics Labs, as well as research assistant for Dr. Ala Qubbaj. He was an active member of the Society of Hispanic Professional Engineers (SHPE), where he was elected as Programs Director during 1999 – 2000, and Mechanical Engineer Representative during 2000 – 2001. He currently works for Muniz Engineering, Inc., a sub-contractor for The Boeing Company, supporting the Active Thermal Control Systems, Analysis and Integration team for the International Space Station (ISS), and resides in 801 E. NASA Rd. 1, Apt. 2504, Webster. TX 77598.