EXHIBIT E

UNITED STATES DISTRICT COURT
NORTHERN DISTRICT OF CALIFORNIA
SAN FRANCISCO DIVISION

ATS Automation Tooling Systems, Inc. and Thermal Form & Function, LLC, Plaintiffs, v. Foxconn Electronics, Inc., Foxconn Technology Co., Ltd., Hon Hai Precision Industry Co. Ltd., and DOES 2 through 10, Defendants.	**Case No. 03-2648 PJH**

EXPERT REPORT OF DR. ROBERT J. MOFFAT

I. INTRODUCTION

I have been retained by ATS Automation Tooling Systems, Inc. and Thermal Form & Function, LLC (the "Plaintiffs") to provide expert testimony in the above-referenced matter, which concerns the alleged infringement by Foxconn Electronics, Inc., Foxconn Technology Co., Ltd. and Hon Hai Precision Industry Co. Ltd. (the "Defendants") of U.S. Patent No. 5,494,098 (the "'098 patent") pertaining to heat sinks. I previously submitted a declaration and a supplemental declaration in connection with the construction of disputed terms in this case.

II. QUALIFICATIONS

I hold the following degrees:

- B.S. in Mechanical Engineering from the University of Michigan, specializing in gas turbines (1952);
- M.S. in Engineering Mechanics from Wayne State University (1961);
- M.S. in Mechanical Engineering from Stanford University (1966);
- Engineer degree from Stanford University (1966); and
- Ph.D. in Mechanical Engineering from Stanford University, specializing in heat transfer (1967).

From 1952 to 1962, I was employed as a Senior Research Engineer in the General Motors Research Laboratory in Warren, Michigan. While employed there, I worked on heat transfer issues in automotive engines, aircraft gas turbines, automotive radiators, and gas turbine regenerators. My area of specialization was temperature measurements and heat transfer, including the design, testing, and development of heat exchangers.

From 1962 to 1967, I was a Research Assistant in the Doctoral program at Stanford University. I joined the faculty of the Engineering Department at Stanford in 1967. From then until 1993, I taught a variety of undergraduate and graduate classes, including thermodynamics, heat transfer, experimental methods, fluid mechanics, radiation heat transfer, convective heat transfer, heat exchanger design, and electronics cooling.

Throughout this time, I also engaged in numerous research projects such as ongoing research to measure heat transfer coefficients in electronics cooling enclosures and a research program on the function and behavior of finned heat sinks.

I have authored or co-authored more than 200 publications on the subjects of heat transfer and experimental measurements.

I have the honor of being a Fellow of the American Society of Mechanical Engineers ("ASME") and also a Fellow of the Instrument Society of America ("ISA"). I have received numerous awards from these societies, including:

ASME:	Heat Transfer Memorial Award, 1989
	Melville Medal for best original research in 1986
	Holley Medal for engineering in the service of mankind, 1986
	Heat Transfer Division Award for Best Paper of the Year, 1979
ISA:	Robert Abernethy Award, 1989
	Mills Dean Award, 1985
	Donald P. Eckman Award, 1977

Over the years, I have consulted with many of the well-known computer companies on the subject of cooling electronic components. I continue to provide such consulting services.

I have not served as an expert witness in any other case in the past five years.

I am being compensated at an hourly rate of $375.00 for services at depositions and court appearances, and at an hourly rate of $187.50 for other services. My compensation is not contingent on the outcome of this litigation.

My complete curriculum vitae is attached as Exhibit A.

III. SUMMARY OF OPINION

I was asked to review samples and/or technical drawings of five of the Defendants' heat sinks to determine whether these products infringe any claims of the '098 patent. Based upon my review of the '098 patent and related materials, and the heat sink samples and drawings presented to me, it is my opinion that all five of the Defendants' heat sinks infringe each of the asserted claims 1, 2 and 7-9 of the '098 patent.

IV. INFORMATION REVIEWED OR CONSIDERED IN PREPARING OPINION

In arriving at my opinions in this matter, I have reviewed or considered the following documents and things:

A. Patent Documents

1. The '098 patent
2. The file history of the '098 patent
3. U.S. Patent No. 4,790,373 issued to Raynor et al. ("Raynor")
4. U.S. Patent No. 4,513,812 issued to Papst et al. ("Papst")
5. U.S. Patent No. 5,368,094 issued to Hung ("Hung")

B. Defendants' Heat Sink Samples

1. Defendants' heat sink identified by part number 22P4369/22P4370 (the "'369 heat sink")

2. Defendants' heat sink identified by part number 23K4713/23K4714 (the "'713 heat sink")

3. Defendants' heat sink identified by part number 01R3329/01R3330 (the "'329 heat sink")

4. Defendants' heat sink identified by part number 32P4003/32P4004 (the "'003 heat sink")

C. Technical Literature

1. Technical drawings for the Defendants' heat sink identified by part number 32P4001 (the "'001 heat sink")

2. Technical drawings for Defendants' '369, '713, '329 and'003 heat sinks

D. Case Documents

1. Amended Complaint For Patent Infringement

2. Defendants' Answer To Plaintiffs' Amended Complaint For Patent Infringement

3. Joint Claim Construction And Prehearing Statement Pursuant To Patent Local Rule 4-3

4. Supplemental Joint Claim Construction Statement

5. Claim Construction Order

E. Other

1. Defendants' Non-Infringement Opinion from Craig B. Bailey dated October 15, 2004

2. Defendants' Invalidity Opinion from Andrew Cheng dated April 2, 2002

3. Defendants' Non-Infringement Opinion from Legal Department dated April 10, 2002

IV. UNDERSTANDING OF THE LAW AND SUMMARY OF OPINION

I have been informed and understand that patent infringement analysis is a two-step process. In the first step, the Court construes the claims of the patent. In the second step, the elements of the claims, as construed, are compared to the accused products.

I have been informed and understand that a patent claim is infringed by an accused product when each limitation in the claim is found in the accused product exactly (for literal infringement) or by an equivalent (for infringement under the doctrine of equivalents). I have further been informed that an element of an accused product is equivalent to a claim element when the difference between the claim element and the accused product is insubstantial.

I also have been informed that one test to determine whether the difference between a claim element and an accused product is "insubstantial" is whether an element in the accused product performs substantially the same function, in substantially the same way, to achieve substantially the same result as the claim element.

As detailed below, in my opinion, each of the five Defendants' heat sinks I have reviewed literally infringes each of the asserted claims 1, 2 and 7-9 of the '098 patent.

V. THE BASES AND REASONS FOR MY OPINIONS

A. General Background on Heat Sink Technology

An active component, such as a microprocessor in a computer or other electronic system, dissipates electrical power. The electrical power dissipated appears as thermal energy within the component, which in turn raises the temperature of the component. If the component temperature exceeds some limiting temperature (usually taken to be around 100°C, the temperature of boiling water), the component may cease to function. This problem is exacerbated as electronic devices, particularly microprocessors, are made smaller and are designed to operate at increasingly higher processing speeds. As a consequence, it is critical, in designing electronic components, to ensure that there is a mechanism to cool the component, i.e., to remove the dissipated energy from the component without allowing the component to reach its limiting temperature. The art and science of electronics cooling has advanced a great deal over the past 25 years. Modern cooling methods employ some very sophisticated techniques.

The problem posed by the generation of thermal energy in electronics components can be illustrated by one equation: $T_{component}=T_{cool} + Q/hA$. In this equation, "$T_{component}$" represents the temperature of the component (e.g., a microprocessor); "T_{cool}" represents the temperature of the coolant (e.g., air); "Q" represents the rate of heat extraction from the component in watts (equal to the electrical power dissipated within the component); "h" represents the overall heat transfer coefficient (watts per unit area per unit temperature difference); and "A" represents the effective area available to transfer heat from the component to the coolant.

A parameter called "thermal resistance" is often used by persons in the field to describe the performance of a heat sink. Thermal resistance can be defined as the temperature difference between the base of a heat sink and the inlet coolant air to the heat sink fan divided by the power in Watts dissipated by the device being cooled, and therefore has units of °C / Watt. The design of a heat sink is often judged by its thermal resistance. Factors that do not significantly affect thermal resistance are not considered significant in determine a heat sink's thermal performance.

Neither the component nor the coolant is uniform in temperature, and there is no single temperature that characterizes either one. By convention, engineers ignore this subtlety in conversation and in writing, and speak of the appropriate average as the temperature. The methodology used to effect solutions to this problem accounts for this idealization. The definitions of the heat transfer coefficient and the coolant temperature, as used in actual design equations, are chosen so that the equation shown above works accurately enough to satisfy current technical needs.

Taking this equation as the model, then, several options exist to reduce the component temperature, $T_{component}$:

- Reduce the coolant temperature, T_{cool}
- Reduce the power dissipation, Q
- Increase the heat transfer coefficient, h
- Increase the area, A

The term "heat sink" refers generally to any device attached to a component that provides an increased area A, thereby allowing the component to operate at a lower temperature without refrigerating the coolant, reducing the power, or increasing the heat transfer coefficient, h.

Early heat sinks were made simply of plates of aluminum of a larger size than the component. Attaching the component to the plate allowed its heat to spread through the plate by conduction, and to be dissipated through the surface area of the plate.

As component power increased, however, these traditional heat sinks failed to provide sufficient cooling capacity. As such, it became necessary to add fins to the plate, to increase the effective area. Fins are projections that provide additional area through which heat may be transferred. But the fin area is only effective if coolant flows over the entire area. There are engineering equations for calculating the "effective area" of a fin, depending on its geometry, the material it is made of, and the average heat transfer coefficient.

A heat sink with many closely spaced fins appears to have a lot of surface area over which the coolant – typically air – may flow, but that appearance can be misleading. If a heat sink with a "dense" array of fins is used in a system cooled by a centrally located fan or blower (as most systems are), the cooling air will largely bypass the heat sink, i.e., go around it rather than through it, or enter the front face and escape out the top. This is especially likely to happen if the fins are not "shrouded", i.e., covered at the top. This bypass problem arises because the resistance to air flow through the fin array is higher than the resistance of the alternate path for the air - going around or over the heat sink. Air takes the path of least resistance.

Some prior art heat sinks sought to improve air flow across the fins by placing a fan in the proximity of or directly on the heat sink fins. (Heat sinks with fans are often called fan-driven heat sinks.) These prior art heat sinks did not solve the bypass problem and failed to develop sufficient air flow along the fins of the heat sinks. In addition, some prior art heat sinks that removed some fins to create a space for a fan suffered reduced cooling efficiencies due to loss of fin area.

B. The '098 Patent Invention

1. The Specification

I have read and understood the '098 patent. My understanding of the claimed invention of the '098 patent is based on my review of the patent, prior art, the prosecution history of the patent, and on my professional and academic experience.

The invention claimed in the '098 patent represents an improvement in heat sink technology over the prior art by addressing air flow bypass and other problems. The invention achieves beneficial thermal results by using a housing and attaching a fan to the heat sink in such a way that it forces cooling air to pass over generally all of the surface area of the fins. The fan is attached to the housing at the top of the fin array, and directs the air downward towards the base of the heat sink. The air flow divides into two streams, one flowing out through each end of the fin array. The presence of the housing thus limits the direction of the air flow, ensuring that there is increased air flow over the fin area. The result is an inexpensive, fan-driven heat sink that efficiently and effectively dissipates heat from electronic devices.

Figures 2, 4 and 5 of the '098 patent (reproduced below) illustrate an example of a heat sink in accordance with one or more embodiments of the invention. (Figure 2 is a side view of

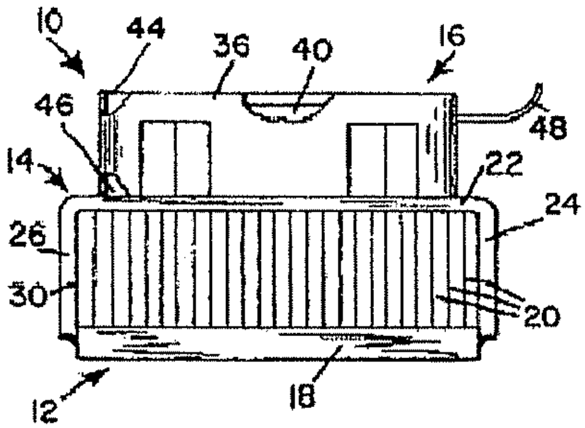

FIG. 2

the heat sink. Figure 4 is an enlarged cross-sectional view of the heat sink, shown without the fan assembly for purposes of illustration. Figure 5 is also an enlarged cross-sectional view of the heat sink shown without the fan, but in a cross-section taken in a direction generally perpendicular to that of Figure 4.)

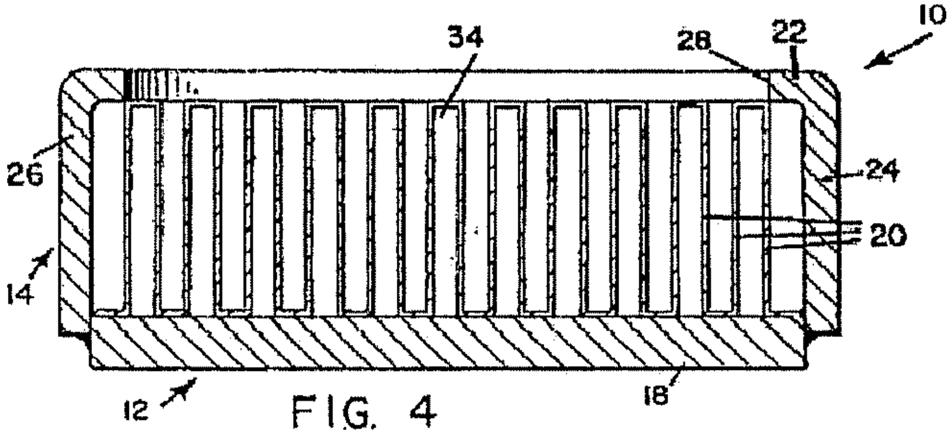

FIG. 4

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the second end opening (32). ('098 patent, col. 4: 48-50.) The portions of the channels that are under the top wall aperture (28) are open to the aperture. ('098 patent, col. 4: 50-52.)

The heat sink also includes a fan assembly (16) (shown in Figure 2) that is fixed to the top wall (22) of the housing above the aperture in the top wall. ('098 patent, col. 4: 53-54.) The fan blows air through the aperture and creates an airflow through the channels from the aperture to each of the first and second end openings. ('098 patent, col. 4: 54-56.)

In one particular embodiment of the invention, the heat sink includes a plenum chamber (34) (shown in Figure 5) between the fan blade of the fan assembly (16) and the fins (20). ('098 patent, col. 6: 9-11.)

As I understand it, like most patents, the '098 patent describes particular embodiments of the invention. It is my understanding that the invention of the '098 patent is, however, not limited to these particular described embodiments. ('098 patent, col. 4: 24-29.)

2. The '098 Patent File History

I have also read the '098 patent file history. I understand that the application for the '098 patent was filed on June 17, 1994 with 13 claims, four of which were independent claims. In the first office action, the examiner rejected original claims 1-4 and 12 under 35 U.S.C. § 103 as being unpatentable over U.S. Patent No. 4,790,373 issued to Raynor et al. ("Raynor") in view of U.S. Patent No. 4,513,812 issued to Papst et al. ("Papst"). The examiner objected to claims 5-7 and 13, but stated that they would be allowed if rewritten in independent form. In response to the office action, the applicant rewrote claims 5-7 and 13 as new claims 14-17. The applicant distinguished rejected claims 1 and 3 from Raynor largely on the ground that Raynor disclosed a heat sink having a large gap (about six inches) between the fins of the heat sink and a wall supporting the fan.

In a second office action, the examiner rejected claims 1 and 2 as being anticipated under § 102(e) by U.S. Patent No. 5,368,094 issued to Hung ("Hung"). Hung disclosed a fan-driven heat sink having a fan mounted directly on a set of parallel fins.

In response, the applicant cancelled rejected claims 1 and 2 and added new claims 18 and 19, which issued as claims 11 and 12, respectively, in the '098 patent.

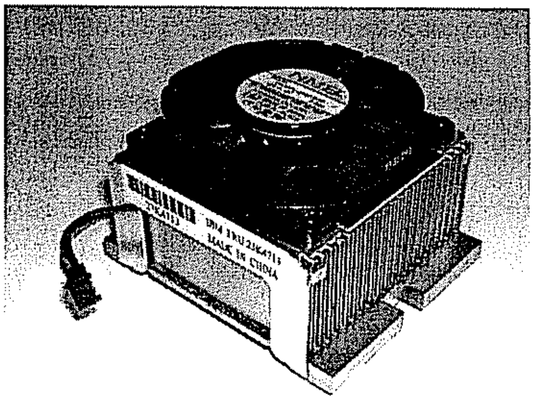
The examiner allowed the application on September 19, 1995, and the '098 patent issued on February 27, 1996.

C. The Accused Products

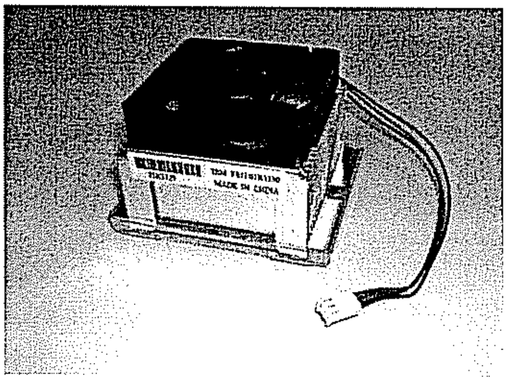
I have studied samples and technical drawings of the Defendants' '369, '713, '329 and '003 heat sinks. In addition, I have reviewed technical drawings of the Defendants' '001 heat sink, for which I understand samples are no longer available.

1. The '713, '329, '001 and '003 Heat Sinks

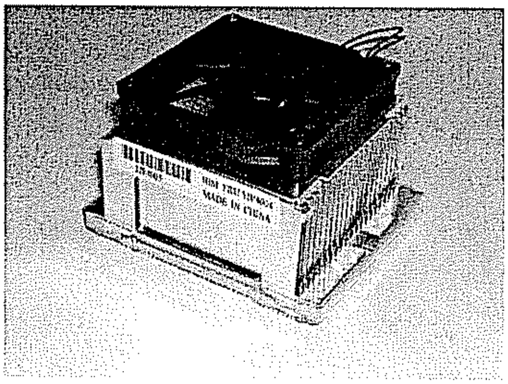
The '713, '329, and '003 heat sinks are very similar to each other. Photographs of the '713, '329 and '003 heat sinks are shown below. The only apparent difference between the '713, '329 and '003 heat sinks is the use of different fans mounted on the heat sink housings, and different thermal interface materials at the bottoms of the heat sink bases. The fans of the '713, '329 and '003 heat sinks are all rated 12V DC, 0.30A or 0.33A. The '713, '329 and '003 heat sinks have roughly the same dimensions.



The '713 heat sink

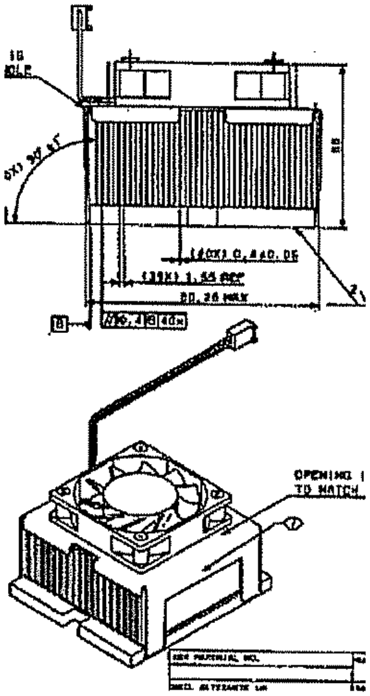


The '329 heat sink



The '003 heat sink

The '001 heat sink is similar to the '713, '329 and '003 heat sinks, but as described below, the '001 heat sink generally has no gaps between the fins of the heat sink and the housing top wall. Drawings of the '001 heat sink are shown below.



The '001 heat sink

The '713, '329, '003 and '001 heat sinks each have a solid flat base, a set of folded fins bonded to the base, a housing mounted over the fins, and a fan assembly mounted on the housing. In each of these heat sinks, the housing is fixed relative to the base by being clipped to the bottom of the base. The housing includes a top wall, which is spaced from the base, and side walls that extend from the base to the top wall. There is a first end opening at a first end of the base, which is defined by the base, the side walls and the top wall. There is also a second end opening defined by the base, the side walls and the top wall at a second opposite end of the base.

The top wall of the housing includes a generally circular aperture, which is spaced from the first and second end openings.

In each of the '713, '329 and '003 heat sinks, the fins are fixed to the base, and extend from the base to the top wall. At both end openings near the sidewalls, there are some fins that reach and are in contact with end portions of the top wall, which are folded downward from the top surface of the top wall. In each of the '713, '329 and '003 heat sinks, there is a small gap of less than 2 mm at the end openings between the tops of other fins and the middle section of the top wall.

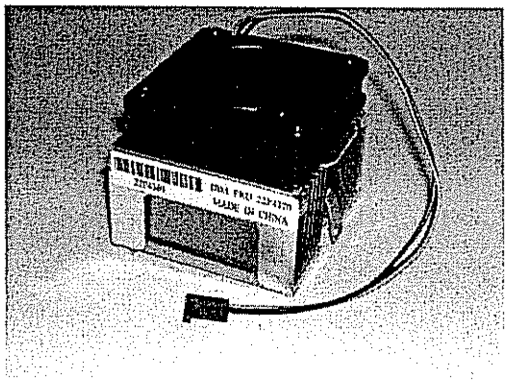
In the '001 heat sink, the fins are bonded to the base, and extend from the base to the top wall of the housing. At both end openings, the fins all generally reach and are in contact with the top wall.

The fins in each of the '713, '329, '001 and '003 heat sinks define a plurality of channels with the base and the top wall, which extend from the first end opening to the second end opening. The fins are folded, i.e., they are formed from a sheet of metal that is folded. Parts of the tops of the fins are severed so that the portions of the channels that lie beneath the aperture are open to the aperture and a plenum chamber is formed.

The fan assembly is fixed to the top wall of the housing above the aperture. The fan assembly blows air through the aperture and creates an air flow through the channels from the aperture to each of the first and second end openings.

2. <u>The '369 Heat Sink</u>

A photograph of the '369 heat sink is shown below. This heat sink is slightly smaller than the'713, '329, '003 and '001 heat sinks, and has a slightly different design.



The '369 heat sink

The '369 heat sink has a solid flat base, a set of folded fins bonded to the base, a housing mounted over the fins, and a fan assembly mounted on the housing. The housing is fixed relative to the base by being clipped to the bottom of the base. The housing includes a top wall, which is spaced from the base, and side walls that extend from the base to the top wall. There is a first end opening at a first end of the base, which is defined by the base, the side walls and the top wall. There is also a second end opening defined by the base, the side walls and the top wall at a second opposite end of the base. The top wall includes a generally circular aperture, which is spaced from the first and second end openings.

The fins are bonded to the base, and extend from the base to the top wall. At both end openings near the sidewalls, there are some fins that reach and are in contact with portions of the top wall that are folded downward from the top surface of the top wall. There is a small gap of less than 2 mm between the tops of some of the fins and some other parts of the top wall.

There is a spacing of about 4 mm between fins at the center of the device. The spacing runs along the length of the fins from one end opening to the other. A clip attachment mechanism for attaching the heat sink to a circuit board is positioned in the spacing. The fins define a plurality of channels with the base and the top wall, which extend from the first end opening to the second end opening. The fins are folded, i.e., they are formed from a sheet of metal that is folded. Parts of the tops of the fins are severed so that the portions of the channels that lie beneath the aperture are open to the aperture and so as to form a plenum chamber.

The fan assembly is fixed to the top wall of the housing above the aperture. The fan assembly blows air through the aperture and creates an air flow through the channels from the aperture to each of the first and second end openings.

D. Literal Infringement Analysis

1. Claim Constructions

I understand that the Court has construed certain terms in the claims and that the parties have agreed on the meaning of certain other terms in the claims as follows:

Constructions agreed on by the parties:

- Solid flat base: the supporting part of a heat sink having an even surface and no internal cavity.
- Parallel: projecting in the same direction and being generally equidistant.
- Spaced: spatially separated.
- Connected: joined or linked together.

- Unconnected: not joined or linked together.
- Single continuous length of material: an unbroken strip of material.
- Fins: projections for increasing heat transfer from an object, excluding pin-shaped fins.

Constructions made by the Court:

- Housing: an enclosure located over the fins of the heat sink.
- Extend/extending: projecting in a direction and reaching to at least the point at which only a trivial or insignificant gap exists between the projecting object and an endpoint.
- Channels: passages for air flow, enclosed within the housing unit with vertical walls reaching at least to the point where only a trivial or insignificant gap exists between the walls and the top wall of the housing.
- Plenum chamber: a space for the distribution of air.

2. Comparison of Claims to the Defendants' Heat Sinks

The following claim chart shows how each element of asserted claims 1, 2 and 7-9 of the '098 patent is literally met by each of the Defendants' '369, '713, '329, '001 and '003 heat sinks.

CLAIM	CLAIM CONSTRUCTIONS	DEFENDANTS' '369, '713, '329, '001 and '003 HEAT SINKS
Claim 1. A heat sink assembly for use in removal of heat from a heat generating electronic device, said heat sink assembly comprising:		Each of the '369, '713, '329, '001 and '003 products is a heat sink assembly used for removing heat from a heat generating electronic device such as a computer microprocessor.
(a) a solid flat base;	**Solid flat base**: the supporting part of a heat sink having an even surface and no internal cavity.	Each of the '369, '713, '329, '001 and '003 products includes a solid flat base. The solid flat base is the supporting part of the heat sink assembly. The solid flat base has an even surface and no internal cavity.
(b) a housing which is fixed relative to said base,	**Housing**: an enclosure located over the fins of the heat sink.	In each of the '369, '713, '329, '001 and '003 heat sinks, the heat sink assembly includes a housing, which is fixed relative to the base. The housings are enclosures and are located over the fins of the heat sink assemblies.
said housing having a top wall which is spaced from said base, and	**Housing**: an enclosure located over the fins of the heat sink. **Spaced**: spatially separated.	The housings in each of the '369, '713, '329, '001 and '003 heat sinks include a top wall, which is spaced, i.e., spatially separated, from the base.
side walls which extend from said base to said top wall,	**Extend/extending**: projecting in a direction and reaching to at least the point at which only a trivial or insignificant gap exists between the projecting object and an endpoint.	The housings in each of the '369, '713, '329, '001 and '003 heat sinks include two side walls that extend from the base to the top wall. The two side walls are in contact with both the base and the top wall.
a first end opening at a first end of said base which is defined by said base, side		The housings in each of the '369, '713, '329, '001 and '003 heat sinks include a first end opening at one end of the base.

CLAIM	CLAIM CONSTRUCTIONS	DEFENDANTS' '369, '713, '329, '001 and '003 HEAT SINKS
walls and top wall,		The opening is defined by the base, the side walls and the top wall.
a second end opening which is defined by said base, side walls and top wall at a second end of said base which is opposite said first end opening, and		The housings in each of the '369, '713, '329, '001 and '003 heat sinks include a second end opening opposite the first end opening. The second end opening is defined by the base, the side walls and the top wall.
an aperture in said top wall which is spaced from said first and second end openings;	**Spaced**: spatially separated.	The housings in each of the '369, '713, '329, '001 and '003 heat sinks include an aperture in the top wall. The aperture is spaced, i.e., spatially separated, from the first and second end openings.
(c) a plurality of parallel spaced fins which are fixed to said base,	**Parallel**: projecting in the same direction and being generally equidistant. **Spaced**: spatially separated. **Fin**: projections for increasing heat transfer from an object, excluding pin-shaped fins.	Each of the '369, '713, '329, '001 and '003 products includes a plurality of parallel spaced fins, which are fixed to the base. The fins project in the same direction and are generally equidistant. The fins are spatially separated. The fins are projections for increasing heat transfer from the base. They are planar in shape and, accordingly, are not pin-shaped.
said fins extending from said base to said top wall,	**Fin**: projections for increasing heat transfer from an object, excluding pin-shaped fins. **Extend/extending**: projecting in a direction and reaching to at least the point at which only a trivial or insignificant gap exists between the projecting object and	The fins in each of the '369, '713, '329, '001 and '003 heat sinks extend from the base to the top wall. The fins project from the base in a direction to the top wall. The fins reach at least the point at which only a trivial or insignificant gap exists between the fins and the top wall. In each of the '369, '713, '329 and '003 heat sinks, at least some of the fins are in contact with the top wall because portions of the top wall are folded downward and touch the fins. The remaining fins in each of the '369, '713, '329 and '003 heat sinks are spaced by a

CLAIM	CLAIM CONSTRUCTIONS	DEFENDANTS' '369, '713, '329, '001 and '003 HEAT SINKS
	an endpoint.	small distance (less than 2 mm) from other portions of the top wall. In my opinion, this small distance is a trivial or insignificant gap because the gap has no appreciable effect on the performance of the heat sinks. In the '001 heat sink, the fins generally all reach and are in contact with the housing top wall.
said fins defining with said base and said top wall a plurality of channels which extends from said first end opening to said second end opening,	**Fin**: projections for increasing heat transfer from an object, excluding pin-shaped fins. **Extend/extending**: projecting in a direction and reaching to at least the point at which only a trivial or insignificant gap exists between the projecting object and an endpoint. **Channels**: passages for air flow, enclosed within the housing unit with vertical walls reaching at least to the point where only a trivial or insignificant gap exists between the walls and the top wall of the housing.	The fins in each of the '369, '713, '329, '001 and '003 heat sinks define with the base and the top wall a plurality of channels. The channels extend from the first end opening to the second end opening. The channels are passages for air flow, which are enclosed within the housing unit with vertical walls reaching at least to the point where only a trivial or insignificant gap exists between the walls and the top wall of the housing. As indicated above, some of the fins in each of the '369, '713, '329 and '003 heat sinks are in contact with portions of the top wall, and the remaining fins are spaced from the top wall by a small, insignificant gap of less than 2 mm. As indicated above, in my opinion, this small gap is trivial or insignificant because it has no appreciable effect on thermal performance of the heat sinks. Also, as indicated above, in the '001 heat sink, the fins generally all reach and are in contact with the housing top wall.
the portions of said channels which lie beneath said aperture being open to said aperture;	**Channels**: passages for air flow, enclosed within the housing	In each of the '369, '713, '329, '001 and '003 products, the portions of the channels that lie beneath the aperture are

CLAIM	CLAIM CONSTRUCTIONS	DEFENDANTS' '369, '713, '329, '001 and '003 HEAT SINKS
and	unit with vertical walls reaching at least to the point where only a trivial or insignificant gap exists between the walls and the top wall of the housing.	open to the aperture. In particular, the tops of the folded fins are cut to allow air flow through the channels.
(d) a fan assembly which is fixed to said top wall above said aperture for blowing air through said aperture and creating an airflow through said channels from said aperture to each of said first and second end openings.	**Channels**: passages for air flow, enclosed within the housing unit with vertical walls reaching at least to the point where only a trivial or insignificant gap exists between the walls and the top wall of the housing.	Each of the '369, '713, '329, '001 and '003 products includes a fan assembly that is fixed to the top wall above the aperture in the top wall. The fan assembly blows air through the aperture and creates an airflow through the channels from the aperture to each of the first and second end openings.
Claim 2. A heat sink assembly as recited in claim 1, wherein said fan assembly comprises:		Each of the '369, '713, '329, '001 and '003 products includes a fan assembly.
(a) a fan housing which is fixed to said top wall,		The fan assembly in each of the '369, '713, '329, '001 and '003 products includes a fan housing, which is fixed to the top wall.
said fan housing having a bottom opening at said aperture and a top opening; and		The fan housing in each of the '369, '713, '329, '001 and '003 products has a bottom opening at the aperture and a top opening.
(b) a rotor which has at least one fan blade,		The fan assembly in each of the '369, '713, '329, '001 and '003 products includes a rotor that has at least one fan blade.
said rotor being rotatably mounted within said fan		The rotor in each of the '369, '713, '329, '001 and '003 products is

CLAIM	CLAIM CONSTRUCTIONS	DEFENDANTS' '369, '713, '329, '001 and '003 HEAT SINKS
housing between said bottom and top openings.		rotatably mounted within the fan housing between the bottom and top openings.
Claim 7. A heat sink assembly for use in removal of heat from a heat generating electronic device, said heat sink assembly comprising:		Each of the '369, '713, '329, '001 and '003 products is a heat sink assembly used for removing heat from a heat generating electronic device such as a computer microprocessor.
(a) a flat base wall;		Each of the '369, '713, '329, '001 and '003 products includes a flat base wall.
(b) a housing which is fixed relative to said base wall,	**Housing**: an enclosure located over the fins of the heat sink.	In each of the '369, '713, '329, '001 and '003 heat sinks, the heat sink assembly includes a housing, which is fixed relative to the base wall. The housings are enclosures and are located over the fins of the heat sink assemblies.
said housing having a top wall which is spaced from said base wall, and	**Housing**: an enclosure located over the fins of the heat sink. **Spaced**: spatially separated.	The housings in each of the '369, '713, '329, '001 and '003 heat sinks include a top wall, which is spaced, i.e., spatially separated, from the base wall.
side walls which extend from said base wall to said top wall,	**Extend/extending**: projecting in a direction and reaching to at least the point at which only a trivial or insignificant gap exists between the projecting object and an endpoint.	The housings in each of the '369, '713, '329, '001 and '003 heat sinks include two side walls that extend from the base wall to the top wall. The two side walls are in contact with both the base wall and the top wall.
a first end opening at a first end of said base wall which is defined by said base wall, said		The housings in each of the '369, '713, '329, '001 and '003 heat sinks include a first end opening at one end of the base wall. The opening is defined by the

CLAIM	CLAIM CONSTRUCTIONS	DEFENDANTS' '369, '713, '329, '001 and '003 HEAT SINKS
side walls and said top wall,		base wall, the side walls and the top wall.
a second end opening which is defined by said base wall, said side walls and said top wall at a second end of said base wall which is opposite said first end, and		The housings in each of the '369, '713, '329, '001 and '003 heat sinks include a second end opening opposite the first end opening. The second end opening is defined by the base wall, the side walls and the top wall.
an aperture in said top wall which is spaced from said first and second end openings;	**Spaced**: spatially separated.	The housings in each of the '369, '713, '329, '001 and '003 heat sinks include an aperture in the top wall. The aperture is spaced, i.e., spatially separated, from the first and second end openings.
(c) a plurality of parallel spaced fins which are fixed to said base wall,	**Parallel**: projecting in the same direction and being generally equidistant. **Spaced**: spatially separated. **Fin**: projections for increasing heat transfer from an object, excluding pin-shaped fins.	Each of the '369, '713, '329, '001 and '003 products includes a plurality of parallel spaced fins, which are fixed to the base wall. The fins project in the same direction and are generally equidistant. The fins are spatially separated. The fins are projections for increasing heat transfer from the base wall. They are planar in shape and, accordingly, are not pin-shaped.
said fins extending from said base wall to said top wall,	**Fin**: projections for increasing heat transfer from an object, excluding pin-shaped fins. **Extend/extending**: projecting in a direction and reaching to at least the point at which only a trivial or insignificant gap exists between the	The fins in each of the '369, '713, '329, '001 and '003 heat sinks extend from the base wall to the top wall. The fins project from the base wall in a direction to the top wall. The fins reach at least the point at which only a trivial or insignificant gap exists between the fins and the top wall. In each of the '369, '713, '329 and '003 heat sinks, at least some of the fins are in contact with the top wall because portions of the top wall are folded downward and touch the fins. The

CLAIM	CLAIM CONSTRUCTIONS	DEFENDANTS' '369, '713, '329, '001 and '003 HEAT SINKS
	projecting object and an endpoint.	remaining fins in each of the '369, '713, '329 and '003 heat sinks are spaced by a small distance (less than 2 mm) from other portions of the top wall. In my opinion, this small distance is a trivial or insignificant gap because the gap has no appreciable effect on the performance of the heat sinks. In the '001 heat sink, generally all the fins reach and are in contact with the housing top wall.
said fins defining with said base and said top wall a plurality of channels which extends from said first end opening to said second end opening,	**Fin**: projections for increasing heat transfer from an object, excluding pin-shaped fins. **Extend/extending**: projecting in a direction and reaching to at least the point at which only a trivial or insignificant gap exists between the projecting object and an endpoint. **Channels**: passages for air flow, enclosed within the housing unit with vertical walls reaching at least to the point where only a trivial or insignificant gap exists between the walls and the top wall of the housing.	The fins in each of the '369, '713, '329, '001 and '003 heat sinks define with the base and the top wall a plurality of channels. The channels extend from the first end opening to the second end opening. The channels are passages for air flow, which are enclosed within the housing unit with vertical walls reaching at least to the point where only a trivial or insignificant gap exists between the walls and the top wall of the housing. As indicated above, some of the fins in each of the '369, '713, '329 and '003 heat sinks are in contact with portions of the top wall, and the remaining fins are spaced from the top wall by a small, insignificant gap of less than 2 mm. As indicated above, in my opinion, this small gap is trivial or insignificant because it has no appreciable effect on thermal performance of the heat sinks. Also, as indicated above, in the '001 heat sink, all the fins generally reach and are in contact with the housing top wall.
the portions of said channels which lie beneath said aperture	**Channels**: passages for air flow, enclosed	In each of the '369, '713, '329, '001 and '003 products, the portions of the

CLAIM	CLAIM CONSTRUCTIONS	DEFENDANTS' '369, '713, '329, '001 and '003 HEAT SINKS
being open to said aperture; and	within the housing unit with vertical walls reaching at least to the point where only a trivial or insignificant gap exists between the walls and the top wall of the housing.	channels that lie beneath the aperture are open to the aperture. In particular, the tops of the folded fins are cut to allow air flow through the channels.
(d) a fan assembly which is fixed to said top wall above said aperture for blowing air through said aperture and creating an airflow through said channels from said aperture to each of said first and second end openings,	**Channels**: passages for air flow, enclosed within the housing unit with vertical walls reaching at least to the point where only a trivial or insignificant gap exists between the walls and the top wall of the housing.	Each of the '369, '713, '329, '001 and '003 products includes a fan assembly that is fixed to the top wall above the aperture in the top wall. The fan assembly blows air through the aperture and creates an airflow through the channels from the aperture to each of the first and second end openings.
said fan assembly comprising: (1) a fan housing which is fixed to said top wall,		The fan assembly in each of the '369, '713, '329, '001 and '003 products includes a fan housing, which is fixed to the top wall.
said fan housing having a bottom opening at said aperture and a top opening; and		The fan housing in each of the '369, '713, '329, '001 and '003 products has a bottom opening at the aperture and a top opening.
(2) a rotor which has at least one fan blade,		The fan assembly in each of the '369, '713, '329, '001 and '003 products includes a rotor that has at least one fan blade.
said rotor being rotatably mounted within said fan housing between said bottom and top openings,		The rotor in each of the '369, '713, '329, '001 and '003 products is rotatably mounted within the fan housing between the bottom and top openings.
said fan blade being spaced	**Spaced**: spatially	The fan blade in each of the '369, '713,

CLAIM	CLAIM CONSTRUCTIONS	DEFENDANTS' '369, '713, '329, '001 and '003 HEAT SINKS
from the fins so as to define a plenum chamber between said blade and said fins.	separated. **Plenum chamber**: a space for the distribution of air.	'329, '001 and '003 products is spaced, i.e., spatially separated, from the fins. This separation between the blade and the fins defines a plenum chamber, which is a space for the distribution of air.
Claim 8. A heat sink assembly as recited in claim 7, wherein		
the portions of said fins which are directly below said aperture are below the level of said top wall and are vertically spaced from said aperture.		In each of the '369, '713, '329, '001 and '003 products, the portions of the fins that are directly below the aperture in the housing top wall are below the level of the top wall and are vertically spaced from the aperture.
Claim 9. A heat sink assembly for use in removal of heat from a heat generating electronic device, said heat sink assembly comprising:		Each of the '369, '713, '329, '001 and '003 products is a heat sink assembly used for removing heat from a heat generating electronic device such as a computer microprocessor.
(a) a flat base wall;		Each of the '369, '713, '329, '001 and '003 products includes a flat base wall.
(b) a housing which is fixed relative to said base wall,	**Housing**: an enclosure located over the fins of the heat sink.	In each of the '369, '713, '329, '001 and '003 heat sinks, the heat sink assembly includes a housing, which is fixed relative to the base wall. The housings are enclosures and are located over the fins of the heat sink assemblies.
said housing having a top wall which is spaced from said base wall, and	**Housing**: an enclosure located over the fins of the	The housings in each of the '369, '713, '329, '001 and '003 heat sinks include a top wall, which is spaced, i.e., spatially

CLAIM	CLAIM CONSTRUCTIONS	DEFENDANTS' '369, '713, '329, '001 and '003 HEAT SINKS
	heat sink. **Spaced**: spatially separated.	separated, from the base wall.
side walls which extend from said base wall to said top wall,	**Extend/extending**: projecting in a direction and reaching to at least the point at which only a trivial or insignificant gap exists between the projecting object and an endpoint.	The housings in each of the '369, '713, '329, '001 and '003 heat sinks include two side walls that extend from the base wall to the top wall. The two side walls are in contact with both the base wall and the top wall.
a first end opening at a first end of said base wall which is defined by said base wall, said side walls and said top wall,		The housings in each of the '369, '713, '329, '001 and '003 heat sinks include a first end opening at one end of the base wall. The opening is defined by the base wall, the side walls and the top wall.
a second end opening which is defined by said base wall, said side walls and said top wall at a second end of said base which is opposite said first end, and		The housings in each of the '369, '713, '329, '001 and '003 heat sinks include a second end opening opposite the first end opening. The second end opening is defined by the base wall, the side walls and the top wall.
an aperture in said top wall which is spaced from said first and second end openings;	**Spaced**: spatially separated.	The housings in each of the '369, '713, '329, '001 and '003 heat sinks include an aperture in the top wall. The aperture is spaced, i.e., spatially separated, from the first and second end openings.
(c) a plurality of parallel spaced fins which are fixed to said base wall,	**Parallel**: projecting in the same direction and being generally equidistant. **Spaced**: spatially	Each of the '369, '713, '329, '001 and '003 products includes a plurality of parallel spaced fins, which are fixed to the base wall. The fins project in the same direction and are generally equidistant. The fins are spatially separated. The fins are projections for

CLAIM	CLAIM CONSTRUCTIONS	DEFENDANTS' '369, '713, '329, '001 and '003 HEAT SINKS
	separated. **Fin**: projections for increasing heat transfer from an object, excluding pin-shaped fins.	increasing heat transfer from the base wall. They are planar in shape and, accordingly, are not pin-shaped.
said fins extending from said base wall to said top wall,	**Fin**: projections for increasing heat transfer from an object, excluding pin-shaped fins. **Extend/extending**: projecting in a direction and reaching to at least the point at which only a trivial or insignificant gap exists between the projecting object and an endpoint.	The fins in each of the '369, '713, '329, '001 and '003 heat sinks extend from the base wall to the top wall. The fins project from the base wall in a direction to the top wall. The fins reach at least the point at which only a trivial or insignificant gap exists between the fins and the top wall. In each of the '369, '713, '329 and '003 heat sinks, at least some of the fins are in contact with the top wall because portions of the top wall are folded downward and touch the fins. The remaining fins in each of the '369, '713, '329 and '003 heat sinks are spaced by a small distance (less than 2 mm) from other portions of the top wall. In my opinion, this small distance is a trivial or insignificant gap because the gap has no appreciable effect on the performance of the heat sinks. In the '001 heat sink, the fins all reach and are in contact with the housing top wall.
said fins defining with said base wall and said top wall a plurality of channels which extends from said first end opening to said second end opening,	**Fin**: projections for increasing heat transfer from an object, excluding pin-shaped fins. **Extend/extending**: projecting in a direction and reaching to at least	The fins in each of the '369, '713, '329, '001 and '003 heat sinks define with the base wall and the top wall a plurality of channels. The channels extend from the first end opening to the second end opening. The channels are passages for air flow, which are enclosed within the housing unit with vertical walls reaching at least

CLAIM	CLAIM CONSTRUCTIONS	DEFENDANTS' '369, '713, '329, '001 and '003 HEAT SINKS
	the point at which only a trivial or insignificant gap exists between the projecting object and an endpoint. **Channels**: passages for air flow, enclosed within the housing unit with vertical walls reaching at least to the point where only a trivial or insignificant gap exists between the walls and the top wall of the housing.	to the point where only a trivial or insignificant gap exists between the walls and the top wall of the housing. As indicated above, some of the fins in each of the '369, '713, '329 and '003 heat sinks are in contact with portions of the top wall, and the remaining fins are spaced from the top wall by a small, insignificant gap of less than 2 mm. As indicated above, in my opinion, this small gap is trivial or insignificant because it has no appreciable effect on thermal performance of the heat sinks. Also, as indicated above, in the '001 heat sink, the fins all generally reach and are in contact with the housing top wall.
the portions of said channels which lie beneath said aperture being open to said aperture,	**Channels**: passages for air flow, enclosed within the housing unit with vertical walls reaching at least to the point where only a trivial or insignificant gap exists between the walls and the top wall of the housing.	In each of the '369, '713, '329, '001 and '003 products, the portions of the channels that lie beneath the aperture are open to the aperture. In particular, the tops of the folded fins are severed to allow air flow through the channels.
said fins being a single continuous length of material which extends transversely of said channels,	**Single continuous length of material:** an unbroken strip of material. **Channels**: passages for air flow, enclosed within the housing unit with vertical walls reaching at least to the point where only a trivial or insignificant gap	In each of the '369, '713, '329, '001 and '003 products, the fins are a single continuous length of material, i.e., an unbroken strip of material. The material extends transversely of the channels,

CLAIM	CLAIM CONSTRUCTIONS	DEFENDANTS' '369, '713, '329, '001 and '003 HEAT SINKS
	exists between the walls and the top wall of the housing.	
each of said fins having an upper end which is connected to the upper end of an adjacent fin and a lower end which is connected to the lower end of a different adjacent fin,	**Fin**: projections for increasing heat transfer from an object, excluding pin-shaped fins. **Connected**: joined or linked together.	In each of the '369, '713, '329, '001 and '003 products, the fins each have an upper end that is connected, i.e., joined or linked together, to the upper end of an adjacent fin, and a lower end that is connected, i.e., joined or linked together, to the lower end of a different adjacent fin,
the portions of said fins which are vertically aligned with said aperture being unconnected at their upper ends so that all of said channels are operatively connected to said aperture; and	**Fin**: projections for increasing heat transfer from an object, excluding pin-shaped fins. **Unconnected**: not joined or linked together.	In each of the '369, '713, '329, '001 and '003 products, the portions of the fins that are vertically aligned with the aperture in the housing are unconnected, i.e., not joined or linked together, at their upper ends so that all of the channels are operatively connected to the aperture.
(d) a fan assembly which is fixed to said top wall above said aperture for blowing air through said aperture and creating an airflow through said channels from said aperture to each of said first and second end openings.	**Channels**: passages for air flow, enclosed within the housing unit with vertical walls reaching at least to the point where only a trivial or insignificant gap exists between the walls and the top wall of the housing.	Each of the '369, '713, '329, '001 and '003 products includes a fan assembly that is fixed to the top wall above the aperture in the top wall. The fan assembly blows air through the aperture and creates an airflow through the channels from the aperture to each of the first and second end openings.

As these claim charts confirm, in my opinion, each of the '369, '713, '329, '001 and '003 heat sinks literally meets each of the limitations of claims 1, 2 and 7-9 of the '098 patent.

I understand that the Defendants might assert that the '369, '713, '329 and '003 heat sinks do not infringe claims 1, 2 and 7-9 of the '098 patent on the grounds that these products do not meet the claim limitations relating to (1) the fins extending from the base to the top wall of the housing or (2) the fins defining with the base and the top wall a plurality of channels. In my opinion, such assertions would be incorrect.

As noted above, the Court has construed the term "extending" to mean projecting in a direction and reaching to at least the point at which only a trivial or insignificant gap exists between the projecting object and an endpoint. Therefore, to infringe the asserted claims, the fins in the Defendants' products need only reach a point at which only a trivial or insignificant gap exists between the fins and the housing top wall.

Similarly, as noted above, the Court has construed the term "channels" to mean passages for air flow, enclosed within the housing unit with vertical walls reaching at least to the point where only a trivial or insignificant gap exists between the walls and the top wall of the housing. Therefore, to infringe the asserted claims, the fins should define with the base and the top wall a plurality of channels having vertical walls reaching at least to the point where only a trivial or insignificant gap exists between the walls and the top wall of the housing.

In my opinion, each of the '369, '713, '329 and '003 heat sinks meets both of the above described limitations of the asserted claims. As described above, the fins in each of the '369, '713, '329 and '003 heat sinks extend from the base to the top wall. The fins reach at least the point at which only a trivial or insignificant gap exists between the fins and the top wall. In fact, in all four heat sinks, at least some of the fins are in physical contact with the top wall because portions of the top wall are folded downward and touch the fins. The remaining fins in each of the Defendants' heat sinks are spaced by only a small distance (less than 2 mm) from other portions of the top wall. In my opinion, this small distance of less than 2 mm is a trivial or insignificant gap because the gap is too small to have any appreciable effect on the air flow from the fan through the fins or, accordingly, on the thermal performance of the heat sinks. In particular, the small size gap located at the upper ends of the fins would not have any significant effect on the air flow pattern from the fan, which is in a generally downward and slightly outward direction. I would expect this to be the case based on my extensive experience in the field of electronics cooling.

3. Testing of Defendants' Heat Sinks

Whether the Defendants' heat sinks infringe the asserted claims of the '098 patent can be determined by comparing the claims as construed to the Defendants' heat sink samples and heat sink drawings. In my view, no testing of the Defendants' heat sinks is necessary in order to determine infringement. In particular, it is unnecessary to perform any testing to determine whether or not any small gaps in the heat sinks between the fins and the housing top wall are trivial or insignificant. Nevertheless, I have taken the extra step of having the Defendants' heat sinks tested to confirm my opinion that the small gaps are insignificant, and to avoid any speculation that the presence of the gaps might have an appreciable effect on the thermal performance of the heat sinks.

Dr. Jinny Rhee of San Jose State University tested two of the Defendants' heat sinks to determine whether the presence of the small gaps in the Defendants' heat sinks had an appreciable effect on the thermal performance of Defendants' heat sinks. I inspected Dr. Rhee's test setup and observed some further testing of the heat sinks to confirm that the testing was performed satisfactorily. Further details of the testing are set forth in an expert report of Dr. Rhee, which is attached to this report as Exhibit B. Dr. Rhee tested samples of the '369 and '003 heat sinks.[2] For each of these heat sinks, she determined the thermal resistance of the heat sink under three conditions: (1) "standard gap", (2) "no gap", and (3) "double gap" conditions.

First, for the "standard gap" case, she tested both heat sinks as is, i.e., without any modification.

Second, for the "no gap" case, she tested both heat sinks after modifying the heat sinks to substantially remove the gap between the fins and the housing top wall. In particular, she modified each heat sink by straightening out the bent portions of the top wall and then lowering and securing the top wall relative to the fins to substantially close the gap between the fins and the top wall.

Finally, for the "double gap" case, she tested each heat sink after modifying the heat sinks to enlarge the gap to generally twice the size of the original gap. In each of the Defendants' accused heat sinks, the housing is connected to the base by four small tabs projecting from the housing side walls. These tabs are bent and hooked under the base. Straightening the tabs allows the housing to be disengaged from and moved relative to the fins.

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[2] I had only the '369 and '003 heat sinks tested because I believe the other heat sink samples (the '329 and '713 heat sinks) would behave in substantially the same way as the '003 heat sink sample since they are so similar in design. Accordingly, in my opinion, testing of the '329 and '713 heat sink samples would be duplicative and unnecessary.

In this case, she raised the housing top wall relative to the fins to obtain the desired gap, and then secured the housing relative to the fins for both heat sinks.

During testing, each heat sink was mounted on a patch heater to simulate a heated electronic component to be cooled. The thermal resistance was determined based on the power supplied to the heater, the measured temperature of the heat sink base, and the measured temperature of incoming air flow in the fan of each heat sink. A 100 ohm, 38.5 mm x 38.5 mm patch heater was used for the testing, the back of which was insulated to reduce heat loss. The power to the heater was calculated as the RMS voltage across the heater squared divided by the resistance of the heater. The resistance was calculated as the RMS voltage across the heater divided by the RMS current measured with an AC power meter at steady state.

To measure the heat sink base temperature, a 36 gauge, T-type thermocouple was inserted in a small hole drilled from the side to the center of each heat sink base. The hole was then filled with commercial thermal interface material.

The thermal resistance in each case was calculated using the following formula:

$$\text{Thermal resistance} = (T_{base} - T_{inlet}) / P_{calculated}$$

A summary of the test results are shown in the table below. Each quantity in the table is the average of eight readings.

		Units	No Gap	Standard Gap	Double Gap
'369 Heat Sink	$T_{heat\ sink\ base}$	°C	37.10	36.54	36.87
	V_{rms}	V	59.29	59.12	59.17
	T_{in}	°C	22.14	22.20	22.35
	Q_{total}	W	33.80	33.61	33.66
	Q_{loss}	W	0.04	0.03	0.04
	Thermal Resistance	**°C/W**	**0.44**	**0.43**	**0.43**
'003 Heat Sink	$T_{heat\ sink\ base}$	°C	30.61	30.43	30.84
	V_{rms}	V	57.94	57.89	58.01
	T_{in}	°C	24.66	24.48	24.76
	Q_{total}	W	30.80	30.74	30.87
	Q_{loss}	W	0.03	0.03	0.03
	Thermal Resistance	**°C/W**	**0.19**	**0.19**	**0.20**

The test results show that for each of the Defendants' '369 and '003 heat sinks, there is no appreciable difference in the thermal resistance of the heat sink when the heat sink has a small gap of less than 2 mm between the fins and the housing top wall, and when the heat sink has generally no gap between the fins and the housing top wall. In fact, the testing shows that there is also no appreciable difference in the thermal resistance of the heat sink when the gap is doubled in size from the standard (i.e., less than 2 mm) gap. This is true for both the '369 and '003 heat sinks even though their baseline thermal performance (in the standard gap case) is quite different.[3]

Accordingly, this testing confirms my opinion that the gap between the tops of some of the fins and the housing top wall is trivial and insignificant, and that these heat sinks literally infringe the '098 patent.

[3] The test results show baseline thermal resistance values for the '369 and '003 heat sinks to be 0.43 and 0.19 °C/W, respectively. These values are different largely because of the significant difference in the fin surface areas of the heat sinks.

4. Manufacturing Tolerances

It is my understanding that the Defendants may take the position that a "trivial or insignificant" gap can only mean a gap that is the result of manufacturing tolerances used in the design of the heat sinks. I understand that the Defendants may assert that my declaration in support of the Plaintiffs' opening claim construction brief supports this assertion. This misconstrues statements I made therein.

In that declaration, I explained that it is important to take manufacturing tolerances into account in designing heat sinks and that, as a result of such manufacturing tolerances, one of ordinary skill in the art would understand the '098 patent to include heat sinks that had "trivial or insignificant" gaps between the fins and housing, provided such gaps did not affect the functioning of the heat sink. I did not state anywhere that "trivial or insignificant" gaps could only be those resulting from manufacturing tolerances. I believe that a gap would be "trivial or insignificant" if it were small relative to the flow area and did not appreciably affect air flow from the fan through the fins. In particular, a gap would be trivial or insignificant if it did not appreciably affect thermal performance since this is a heat transfer device, and this would be true regardless of the cause or reason for the gap. The less than 2 mm gap in the accused devices is clearly insignificant compared to the large gap of about six inches (or about 150 mm) in the prior art Raynor patent, which was distinguished by the Applicant during prosecution of the '098 patent.

In my opinion, the small gap of less than 2 mm in Defendants' '713, '329, '369 and '003 heat sinks is trivial and insignificant, as confirmed by the results of the testing of the Defendants' heat sinks.

E. Doctrine Of Equivalents Analysis

In my opinion, each of the Defendants' '369, '713, '329, '001 and '003 heat sink products literally meets each of the limitations of asserted claims 1, 2 and 7-9 of the '098 patent and, therefore, it is not necessary at this time to consider the issue of infringement under the doctrine of equivalents. In the event one or more of the accused products is asserted by the Defendants not to literally infringe any claims of the '098 patent, I reserve my right to modify or supplement my opinions in order to address doctrine of equivalents issues, if necessary.

VI. CONCLUSIONS

Based on my review of the '098 patent and related materials, and my study of the '369, '713, '329, '001 and '003 heat sink products, it is my opinion that each of the '369, '713, '329, '001 and '003 products literally infringes each of the asserted claims 1, 2 and 7-9 of the '098 patent.

I understand that discovery in this case is ongoing. I reserve the right to modify or supplement my report in the event any additional information becomes available to me.

Dated: December 8, 2004

Robert J. Moffat

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BIOGRAPHICAL INFORMATION

ROBERT J. MOFFAT

Citizenship U.S.
Born November 29, 1927, Grosse Pointe, Michigan

Education B. S. (Mech. Engrg.), University of Michigan, 1952
M. S. (Engrg. Mech.), Wayne State University, 1961
M. S. (Mech. Engrg.), Stanford University, 1966
Engineer (Mech. Engrg.), Stanford University, 1966
Ph.D. (Mech. Engrg.), Stanford University, 1967

Honors and Awards

ASME: Heat Transfer Memorial Award, 1989
Melville Medal for best original research in 1986
Holley Medal for engineering in the service of mankind, 1986
Heat Transfer Division Award for Best Paper of the Year, 1979
Fellow of ASME

ISA: Robert Abernethy Award, 1989
Mills Dean Award, 1985
Donald P. Eckman Award, 1977
Fellow of ISA

SEMITHERM Awarded the First Annual "Thermi" Award, for contributions to electronics cooling.

TAU BETA PI: 1978 Tau Beta Pi Award for Excellence in Undergraduate Teaching (Stanford University)

PATENTS: Nine, relating to heat transfer, fluid mechanics, and instrumentation

PUBLICATIONS: 232, approximately, about 170 on heat transfer, 40 on experimental methods, 12 on biomedical issues and 10 on teaching. Invited lectures and undocumented presentations are not included.

Employment

Senior Research Engineer, General Motors Research
Associate Professor, Stanford University, 1967-1971
Professor, Stanford University, 1972-present
Chairman, Thermosciences Div., 1973-1985
Retired, Aug. 31, 1993.
Recalled (for research) Sept. 1, 1993
Appointed Professor in Residence, University of Arizona, 1996
President, Moffat Thermosciences, Inc. 1984 to present

Professional Background

Employed at the General Motors Research Laboratories on graduation from the University of Michigan (1952) in the Gas Turbine Laboratory. Placed in charge of research and development efforts in the field of applied thermometry in 1953 and promoted to the position of Senior

Research Engineer in 1956. Assumed responsibility in 1958 for the testing of periodic-flow heat exchangers for regenerative gas turbines and the development of seals for these devices. Completed requirements for the degree of Master of Science, Engineering Mechanics, at Wayne State University in 1961, with a thesis on the behavior of ground effect machines (i.e., hover-craft) having thick curtain jets. Enrolled in Stanford University in 1962 and completed the requirements for Master of Science, Mechanical Engineering, Engineer (Mechanical), and Ph.D. in Mechanical Engineering. Appointed Acting Associate Professor, 1966, Associate Professor, 1967, Professor of Mechanical Engineering in 1972, and Chairman of the Thermosciences Division in 1973.

Research efforts have involved three areas: convective heat transfer in engineering systems, experimental methods in heat transfer and fluid mechanics, and biomedical thermal issues. The largest body of work concerns convective heat transfer. The first program, beginning in 1967 and continuing until 2002, focused on gas turbine blade and vane heat transfer. The second program, beginning in 1980 and continuing to the present, was aimed at convective cooling of electronic components. Four PhD's were conferred from the electronics cooling program (Arvizu, Ortega, Anderson, and Rhee), and a number of significant studies were completed. Early work focused on measuring heat transfer coefficients in a coherent sequence of experiments covering forced convection, free convection and mixed convection. From these data, a clear physical picture of the mechanisms was extracted. The behavior of finned heat sinks, was studied analytically and experimentally, to explain the effect of the local pressure gradient on the heat sink behavior. In its broadest terms, the Stanford work was the first to capitalize on the linearity of the heat transfer process and use superposition to deal with heat transfer from arrays of objects that are non-uniformly heated. Several significant contributions came out of these programs (aside from the four doctoral graduates): (1) a demonstration of the importance of developing invariant descriptors of heat transfer, (2) a new definition of the heat transfer coefficient for electronics cooling, the concept of hadiabatic, and (3) the development of a simple correlation for predicting h_{ad} based on an estimate of the turbulence intensity.

The second area of research concerned experimental methods in the thermosciences. The pioneering work of S. J.Kline was extended and developed into a tool useful in planning experimental programs of provable accuracy. A good deal of work was done on the use of thermocouples for point-wise temperature measurements and full-field imaging techniques for temperature, heat flux, and heat transfer coefficient measurement using thermochromic liquid crystals and digital image handling. The program contributed regularly to the theory of uncertainty analysis through presentations and publications (ISA). Professor Moffat was an invited lecturer for 40 consecutive years in the Measurement Engineering Series (originally through Arizona State University), for more than 20 years in the ISA Test Measurements Division Professional Development Program and, for ten years, in the ASME Professional Development.

There has been a continuing, small scale effort on biomedical engineering problems, in particular the thermal protection of newborn infants. A self-contained, portable incubator was developed which provided a neutral thermal environment for the infant while allowing free access by the attending physicians. It has been used on almost every continent where cold-weather transport is needed and resulted in the award of the ASME Holley Medal Award, 1987.

To date, 36 Ph.D and four Engineer's degree holders have worked with Professor Moffat as primary advisor or co-advisor. A total of 50 research reports have been issued. These programs have resulted in a total of approximately 230 publications (115 refereed papers, 105 unrefereed papers and research reports).

Moffat Thermosciences, Inc. was incorporated in 1984 as a vehicle for consulting, research, and teaching in Heat Transfer and Experimental Methods. The corporation has been active in preparing and delivering short courses in the area of Electronics Cooling, Experimental Methods, and Uncertainty Analysis, as well as problem solving. Clients have included General Motors, General Electric Aircraft Engines, United Technologies, Allison Engines, Siemens Nuclear Power, Lawrence Livermore Labs, Sandia National Laboratory (Albuquerque), Idaho National Engineering Laboratory, General Electric Nuclear, Proxima, and others. Dr. Moffat has served as an expert witness on three technology litigations, with emphasis on heat transfer, uncertainty analysis and experiment design.

PUBLICATIONS - R. J. MOFFAT

A. Refereed Publications

1. "How to Specify Thermocouple Response," Instrument Society of America Journal, Vol. 4, June 1957.

2. "Designing Thermocouples for Response Rate," Trans. ASME, Vol. 80, No. 2, 1958, p. 257.

3. "Thermoelectric Circuits and the Performance of Several Jet Engine Thermocouples," Soc. of Automotive Engineers Information Report AIR 6, Aug. 1958.

4. "A Stable, High-Temperature Thermometry Rig," Soc. of Automotive Engineers Information Report 158A, April 1960.

5. "An Analytical and Experimental Investigation of the Two-Dimensional Ground Effect," Wayne State University M.S. thesis, 1961.

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118. "An Algebraic Model for High Intensity Large Scale Turbulence" (with F.E. Ames and O. Kwon) Paper 99-GT-160 International Gas Turbine and Aeroengine Congress and Exhibition, June 7-10, 1999.

119. "A General Method For Calculating The Heat Island Correction And Uncertainties For Button Gages" (with John K. Eaton and Debjit Mukerji). *Measurement Science and Technology* Volume 11, Number 7, July 2000, p. 920-932.

120. "A Transient Method for Measuring Very High Gas Temperatures". Proc. ISA 47th International Instrumentation Symposium, May 2001.

121. "Gas Temperature Measurement: A Two-Sensor Method for Cancelling Radiation Error". Proc. ISA 47th International Instrumentation Symposium, May 2001.

122. "A Proposed Temperature Probe for Inter-Stage Compressor Measurements". Proc. ISA 47th International Instrumentation Symposium, May 2001.

123. "Convective Heat Transfer Near One-Dimensional and Two-Dimensional Wall Temperature Steps" (with Debjit Mukerji, John K. Eaton) ASME Journal of Heat Transfer-- April 2004 Volume 126, Issue 2, pp. 202-210

B. Presentations and Publications Not Refereed

1. "Velocity Measurements in Laminar Flow Using Cyclically Pulsed Smoke Streams," discussion presented at ASME Symposium on Flow Visualization, New York, 1960.

2. "Bibliography of Temperature Measurement, 1953-1960," (with Carl Halpern), National Bureau of Standards Monograph 27, April 1961.

3. "Application of Pulsed Smoke-Stream Visualization to the Study of the Two-Dimensional, Ground-Effect Phenomenon," Scientific American, p. 415, Jan. 1964.

4. "Discussion of ASME 63-W-59," ASME Trans., Journal Heat Transfer, p. 415, Aug. 1964.

5. "Wake-Interaction Effects and Performance Characteristics of Stagnation-Type Thermocouples," (with R. C. Dean, Jr.), Appendix VII, V. II, AVLABS Report 67-30, (ed. by Welliver and Acurio), Aug. 1967.

6. "Grading Laboratory Reports on Tape," Engineering Education, p. 920, May 1970.

7. "Thermal Measurements," for the ISA 25th-year program, Oct. 1970. Invited lecture.

8. "The Thermocouple: Theory, Application, and Limitations," Proc. of the 1971 ISA Aerospace Symposium. Invited lecture.

9. "Graduate Studies at the Thermosciences Measurement Center," presented at the 1972 Joint Measurement Conference at the University of Colorado, June 1972.

10. "Thermocouple Theory and Practice," presented at the ISA 20th Int'l. Instrument Symposium, Albuquerque, May 1974, invited lecture. Fundamentals of Aerospace Instrumentation, Vol. 6, pp. 111-124, 1974.

11. "The Behavior of Transpired Turbulent Boundary Layers," (with W. M. Kays), Studies in Convection, Vol. 1: Theory, Measurement and Applications, Academic Press, London, 1975. (Also published as HMT-20, Dept. of Mech. Engrg., Stanford Univ., Stanford, CA, April 1975).

12. "Development and Evaluation of Methods for the Elimination of Waste Anesthetic Gases and Vapors in Hospitals," (with R. Piziali, C. Whitcher, and R. Sher), National Inst. for Occupational Safety and Health Project (NIOSH) report, HEW Publication No. 75-0137, May 1975.

13. "Structural Studies of Rough-Wall Boundary Layers," presented at the 10th Navy Symposium on Aeroballistics, Paper #121, Washington, DC, July 15, 1975.

14. "Full-Coverage Film-Cooling Heat Transfer Studies--A Summary of the Data for Normal-Hole Injection and 30o Slant-Hole Injection," (with M. E. Crawford, H. Choe, and W. M. Kays), NASA Contract Report No. CR-2648, 1976. Also pub. as HMT-19, Dept. of Mech. Engrg., Stanford Univ., March 1975.

15. "The Turbulent Boundary Layer on a Full-Coverage, Film-Cooled Surface: An Experimental Heat Transfer Study with Normal Injection," (with H. Choe and W. M. Kays), NASA CR 2642, 1976. Also publ. as HMT-22, Dept. of Mech. Engrg., Stanford Univ., Stanford, CA, May 1975.

16. "Graduate and Undergraduate Laboratory Instruction in the Department of Mechanical Engineering," presented at I Simposio Nacional de Ciencias Termicas, Ciudad Universitaria, D. F. Mexico, Feb. 9-11, 1976.

17. "Heat Transfer to a Full-Coverage, Film-Cooled Surface with 30o Slant-Angle Injection," (with M. E. Crawford and W. M. Kays), NASA CR 2786, 1976. Also pub. as HMT-25, Dept. of Mech. Engrg., Stanford Univ., Stanford, CA, April 1976.

18. "Experimental Methods in the Thermosciences," Journal of Laboratory-Oriented Studies, Vol. 1, No. 1, pp. 8-12, April 1979.

19. "A Review of Experimental Heat Transfer Relevant to Central Solar Receivers," prep. for The Sandia Laboratories Workshop on Convective Losses from Solar Central Receivers, April 17-18, 1979. Invited lecture.

20. "Research on Turbulent Boundary-Layer Heat Transfer," for the Gas Turbine Soc. of Japan, July 25, 1979. Invited lecture.

21. "Instrumentation for the Measurement of Turbulence Components in a Three-Dimensional Flow Field," final report AFOSR-TR-79-0956, Aug. 24, 1979.

22. "Trends in Mechanical Engineering: Lab Teaching Problem," invited presentation to the American Society of Engineering Educators (Division of Laboratory-Oriented Studies), Amherst, New Hampshire, June 1980.

23. "Teaching the Strategy and Tactics of Experimentation," ASME Winter Annual Meeting, New York, December 1980. Invited presentation.

24. "The Use of Superposition in Calculating Cooling Requirements," (with D. E. Arvizu), for the Short Course: Cooling Electronic Components at M.I.T., Aug. 17, 1981.

25. "The Convective Loss Program -- External Receivers," the DOE/Sandia Semiannual Meeting, Claremont, California, Oct. 14, 1981.

26. "Curvature Effects and Turbulent Boundary Layers," for the Von Karman Institute for Fluid Dynamics, Brussels, Belgium, Feb. 22-26, 1982. Invited lecture.

27. "Full-Coverage Film Cooling," for the Von Karman Institute for Fluid Dynamics, Brussels, Belgium, Feb. 22-26, 1982. Invited lecture.

28. "Turbulent Boundary Layer Heat Transfer," for the Von Karman Institute for Fluid Dynamics, Brussels, Belgium, Feb. 22-26, 1982. Invited lecture.

29. "Balancing Analysis and Experiment in Achieving Thermal Goals," keynote address, International Electronic Packaging Society, November 15, 1982.

30. "Flow Disturbance Induced by the DISA Triaxial Hot-Wire Probe 55P91," (with M. Frota and S. Honami), DISA Information No. 28, Feb. 1983.

31. "Effect of Combined Roll and Pitch Angles on Triple Hot-Wire Measurements of Mean and Turbulence Structure," DISA Information No. 28, Feb. 1983.

32. "The Use of Superposition in Calculating Cooling Requirements for Circuit Cards Containing Arrays of Electronic Components," (with D. E. Arvizu), Sandia Report No. SAND82-0002, printed June 1983.

33. "A Review of Turbulent Boundary Layer Heat Transfer," VII Congresso Brasileiro de Engenharia Mecanica, Universidade Federale de Uberlandia, Brazil, December 13-16, 1983.

34. "Thermal Aspects of Neonatal Care," (with A. Hackel), Sept. 26, 1983.

35. Infant Stress under Intensive Care: Environmental Neonatology (A. W. Gottfried and J. Gaiter, eds.), University Park Press, 1984.

36. "A Review of Turbulent Boundary Layer Research at Stanford," (with W. M. Kays), Advances in Heat Transfer (J. P. Hartnett, T. F. Irvine, Jr., eds.), Academic Press, 1984.

37. "Heat Transfer with Very High Free-Stream Turbulence," (with P. K. Maciejewski), presentation at American Physical Society, Tuscon, AZ, Nov. 25, 1985. (Invited lecture) at the Joint U.S.-Japan Heat Transfer Seminar, 1985, San Diego; Chapter in Hemisphere Pub. Co., Heat Transfer in High Technology Systems, to be published in 1986.

38. "The Test Measurements Viewpoint Problem Definition and Modeling," October 1985.

39. "Turbine-Blade Cooling," ASME/JSME Joint Conf. on Heat Transfer in Rotating Machinery, Honolulu, Hawaii, April 28-May 2, 1985.

40. "Heat Transfer with Very High Turbulence," (with P. Maciejewski), Presentation at American Physical Society, Tuscon, AZ, Nov. 25, 1985. Citation Deleted.

41. "Experiments on Mixed Convection from a Heated Cubical Element on an Adiabatic Channel Wall Using Multi-Chromic Liquid Crystals and Digital Image Processing," (with F. Bejarano, A. Ortega, K. Hollingsworth), to be presented at Int'l. Heat Transfer Conference, Aug. 21, 1986.

42. "Heat Transfer with Very High Free-Stream Turbulence and Streamwise Vortices," (with P. Maciejewski, J. K. Eaton and W. Pauley), work performed under NASA-NAG 3-522, 1986.

43. "Experimental Methods for Air Cooling of Electronic Components," contribution to book, Advances in Cooling Techniques for Computers, Win Aung, ed., Hemisphere Publishing Corp., 1989.

44. "Liquid Crystals," (with N. Kasagi and M. Hirata), for inclusion in Handbook of Flow Visualization, Hemisphere Publishing Corp., 1987.

45. "Heat Transfer with Very High Free-Stream Turbulence and Heat Transfer with Streamwise Vortices," (with P. Maciejewski, J. K. Eaton and W. Pauley), work performed under NASA-NAG 3-522, 1987.

46. "Applying Heat Transfer Coefficient Data to Electronics Cooling," personal communication, September 1987.

47. "The Near-Wall Region of the Turbulent Boundary Layer: Some Results from Heat Transfer Measurements," (with W. M. Kays), presented at the Zoran Zaric Memorial International Seminar on Near-Wall Turbulence, Dubrovnik, Yugoslavia, May 1988.

48. "The Effects of High Free-Stream Turbulence on Heat Transfer in Turbulent Boundary Layers," (with P. K. Maciejewski), presented at the Zoran Zaric Memorial International Seminar on Near-Wall Turbulence, Dubrovnik, Yugoslavia, May 1988.

49. "Experimental Methods in Heat Transfer," Proceedings of the First World Conference on Experimental Heat Transfer, Fluid Mechanics and Thermodynamics, Dubrovnik, Yugoslavia, Sept. 4-9, 1988, Hemisphere Press.

50. "Experimental Methods for Air Cooling of Electronic Components - 1988," (with A. Anderson), presented at 3rd International Symposium on Transport Phenomena in Thermal Control, August 14-18, 1988, Taipei, Taiwan (to be published in hard cover by Hemisphere Publishing Co., Washington, DC).

50A. "Experimental Convective Heat Transfer: What Lies Ahead?" Proceedings of the 9th International Heat Transfer Conference, Jerusalem, Israel, August, 1990.

51. "The Fluctuation Stanton Number and its Role in High Turbulence Heat Transfer," (with P.K. Maciejewski), Presented at the Turbo and Power Machinery Research Center, Colloquium on Turbomachinery, Seoul National University, Seoul, Korea, September 28, 1992.

52. "Light in the Modern Intensive Care Nursery: Chronobiologic Issues," (with S.F. Glotzbach, et al.), submitted to Clinical Research, Western Meeting, Carmel, CA, Feb. 6-9, 1991.

53. "Air Cooling of Electronic Components: Some Challenging Problems," unpublished, Thermosciences Division IL-Report #115, Stanford Univ. Prepared for presentation at the AIChE, 1992 Annual Meeting, San Diego, CA, November 3, 1992.

54. "Solid and Surface Temperature Measurement with Attached or Embedded Probes," Presented at the Western Regional Strain Gage Conference, Pasadena, CA, February 6-9, 1993.

55. "The Role of $h_{adiabatic}$ in the Direct Air Cooling of Electronic Components". November, 1994

56. "The Use of $h_{adiabatic}$ in Electronics Cooling and Other Applications" Therminic 2001, 7th International Workshop on Thermal Investigations of IC's and Systems, September 24-27, Paris, France (Keynote Lecture)

C. Research Publications--Heat and Mass Transfer Program

1. "The Turbulent Boundary Layer on a Porous Plate: Experimental Heat Transfer with Uniform Blowing and Suction," (with W. M. Kays), Thermosciences Division*, HMT-1, 1967. Out of print.**

2. "The Turbulent Boundary Layer on a Porous Plate: An Experimental Study on the Fluid Dynamics with Injection and Suction," (with R. L. Simpson and W. M. Kays), Thermosciences Division, HMT-2, 1967. Out of print.

3. "The Turbulent Boundary Layer on a Porous Plate: Experimental Heat Transfer with Variable Suction, Blowing and Surface Temperature," (with D. G. Whitten and W. M. Kays), Thermosciences Division, HMT-3, 1967. Out of print.

4. "The Turbulent Boundary Layer on a Porous Plate: Experimental Hydrodynamics of Favorable Pressure Gradient Flows," (with H. L. Julien and W. M. Kays), Thermosciences Division, HMT-4, 1969.

5. "The Turbulent Boundary Layer: Experimental Heat Transfer with Blowing, Suction, and Favorable Pressure Gradient," (with W. H. Thielbahr and W. M. Kays), Thermosciences Division, HMT-5, 1969.

6. "Heat Transfer to the Highly Accelerated Turbulent Boundary Layer With and Without Mass Addition," (with W. H. Thielbahr and W. M. Kays), Thermosciences Division, HMT-6. Out of print.

7. "The Turbulent Boundary Layer on a Porous Plate: Experimental Heat Transfer with Uniform Blowing and Suction," (with W. M. Kays), Thermosciences Division, HMT-7, 1968. Out of print.

8. "Heat Transfer to a Turbulent Boundary Layer with Non-Uniform Blowing and Surface Temperature," (with D. G. Whitten and W. M. Kays), Thermosciences Division, HMT-8, 1969. Out of print.

9. "The Effect of Free-Stream Turbulence on Heat Transfer to a Strongly Accelerated Turbulent Boundary Layer," (with D. W. Kearney, W. M. Kays, and R. L. Loyd), Thermosciences Division, HMT-9, 1970. Out of print.

10. "Experimental Hydrodynamics of the Accelerated Turbulent Boundary Layer With and Without Mass Injection," (with H. L. Julien and W. M. Kays), Thermosciences Division, HMT-10, 1970. Out of print.

11. "The Turbulent Boundary Layer and Porous Plate: Experimental Heat Transfer with Uniform Blowing and Suction, with Moderately Strong Acceleration," (with W. M. Thielbahr and W. M. Kays), Thermosciences Division, HMT-11, 1970. Out of print.

12. "The Turbulent Boundary Layer: Experimental Heat Transfer with Strong Favorable Pressure Gradients and Blowing," (with D. W. Kearney and W. M. Kays), Thermosciences Division, HMT-12, 1970. Out of print.

13. "The Turbulent Boundary Layer on a Porous Plate: An Experimental Study of the Fluid Dynamics with Strong Favorable Pressure Gradients and Blowing," (with R. J. Loyd and W. M. Kays), Thermosciences Division, HMT-13, 1970.

14. "The Turbulent Boundary Layer on a Porous Plate: An Experimental Study of the Fluid Mechanics for Adverse Freestream Pressure Gradients," (with P. S. Andersen and W. M. Kays), Thermosciences Division, HMT-15, 1972. Out of print.

15. "The Turbulent Boundary Layer on a Porous Plate: An Experimental Study of the Heat Transfer Behavior with Adverse Pressure Gradients," (with B. F. Blackwell and W. M. Kays), Thermosciences Division, HMT-16, 1972. Out of print.

16. "Turbulent Transport of Heat and Momentum in a Boundary Layer Subject to Deceleration, Suction, and Variable Wall Temperature," (with A. F. Orlando and W. M. Kays), Thermosciences Division, HMT-17, 1974. Out of print.

17. "The Turbulent Boundary Layer on a Rough Porous Plate: Experimental Heat Transfer with Uniform Blowing," (with J. M. Healzer and W. M. Kays), Thermosciences Division, HMT-18, 1974. Out of print.

18. "Full-Coverage Film-Cooling Heat Transfer Studies--A Summary of the Data for Normal-Hole Injection and 30o Slant-Hole Injection," (with M. E. Crawford, H. Choe and W. M. Kays), Thermosciences Division, HMT-19, 1975. Also published as NASA CR-2648. Out of print.

19. "The Behavior of Transpired Turbulent Boundary Layers," (with W. M. Kays), Thermosciences Division, HMT-20, 1975. Out of print.

20. "The Turbulent Boundary Layer: An Experimental Study of the Transport of Momentum and Heat with the Effect of Roughness," (with M. M. Pimenta and W. M. Kays), Thermosciences Division, HMT-21, 1975.

21. "The Turbulent Boundary Layer on a Full-Coverage, Film-Cooled Surface: An Experimental Heat Transfer Study with Normal Injection," (with H. Choe and W. M. Kays), Thermosciences Division, HMT-22, 1975. Also published as NASA CR-2642. Out of print.

22. "Momentum and Energy Transport in the Accelerated, Fully Rough, Turbulent Boundary Layer," (with H. W. Coleman), Thermosciences Division, HMT-24, 1976.

23. "Heat Transfer to a Full-Coverage, Film-Cooled Surface with 30o Slant-Hole Injection," (with M. E. Crawford and W. M. Kays), Thermosciences Division, HMT-25, 1976. Out of print.

24. "A Study of Adverse Pressure Gradient Turbulent Boundary Layers with Outer Region Non-Equilibrium," (with P. G. Parikh and W. M. Kays), Thermosciences Division, HMT-26, 1976. Out of print.

25. "Full-Coverage Film Cooling: Three-Dimensional Measurement of Turbulence Structure and Prediction of Recovery Region Hydrodynamics," (with S. Yavuzkurt and W. M. Kays), Thermosciences Division, HMT-27, 1977. Out of print.

26. "Heat Transfer to a Full-Coverage, Film-Cooled Surface with Compound-Angle (30o and 45o) Hole Injection," (with H. K. Kim and W. M. Kays), Thermosciences Division, HMT-28, 1978. Out of print.

27. "The Thermal and Hydrodynamic Behavior of Thick, Rough-Wall, Turbulent Boundary Layers," (with P. M. Ligrani and W. M. Kays), Thermosciences Division, HMT-29, 1979. Out of print.

28. "Full-Coverage Film Cooling on Flat, Isothermal Surfaces: A Summary Report on Data and Predictions," (with M. E. Crawford and W. M. Kays), Thermosciences Division, HMT-30, 1979. Also published as NASA CR-3219. Out of print.

29. "Turbulent Boundary Layer on a Convex, Curved Surface," (with J. C. Gillis, J. P. Johnston and W. M. Kays), Thermosciences Division, HMT-31, 1980. Out of print.

30. "Turbulent Boundary Layer Heat Transfer Experiments: Convex Curvature Effects, Including Introduction and Recovery," (with T. W. Simon, J. P. Johnston, and W. M. Kays), Thermosciences Division, HMT-32, November 1980. Out of print.

31. "Calibration of Hot-Wires and Hot-Films for Velocity Fluctuations," (with M. E. Taslim and S. J. Kline), Thermosciences Division, TMC-4, 1978. Out of print.

32. "Experimental Heat Transfer from an Array of Heated Cubical Elements on an Adiabatic Channel Wall," (with D. Arvizu), Thermosciences Division, HMT-33, December 1981.

33. "Analysis of the Uncertainties in Velocity Measurements and Techniques for Turbulence Measurement in Complex Flows with Multiple Hotwires," (with M. Frota), Thermosciences Division, HMT-34, 1982. Out of print.

34. "Visualization of the Heat Transfer through a Turbulent Boundary Layer on a Convex Wall," (with J. Simonich), Thermosciences Division, HMT-35, Aug. 1982. Out of print.

35. "Experimental Mixed Convection Heat Transfer from a Large, Vertical, Surface in a Horizontal Flow," (with D. Siebers), Thermosciences Division, HMT-36, Feb. 1983. Out of print.

36. "Film Cooling on a Convex Wall: Heat Transfer and Hydrodynamic Measurements for Full and Partial Coverage," (with K. Furuhama), Thermosciences Division, HMT-37, Oct. 1983. Out of print.

37. "Experiments on Buoyancy-Induced Convection Heat Transfer from an Array of Cubical Elements on a Vertical Channel Wall," (with A. Ortega), Thermosciences Division, HMT-38, June 1986. Out of print.

38. "Observations of the Effects of High Free-Stream Turbulence Levels on the Heat Transfer to a Concavely Curved Turbulent Boundary Layer," (with K. Hollingsworth, P. L. Johnston and J. P. Johnston), Thermosciences Division, HMT-39, April 1989.

39. "A Water-Tunnel Study of Heat Transfer to a Disk-Drive Housing," (with F. Feiereisen), Thermosciences Division, HMT-40, May 1989.

40. "Measurement and Prediction of the Turbulent Thermal Boundary Layer in Water on Flat and Concave Surfaces," (with D. K. Hollingsworth and W. M. Kays), Thermosciences Division, HMT-41, September 1989.

41. "Heat Transfer with Very High Free Stream Turbulence," (with P. K. Maciejewski), Thermosciences Division, HMT-42, December 1989.

42. "Convective Heat Transfer from Arrays of Modules with Non-Uniform Heating: Experiments and Models," (with A. M. Anderson), Thermosciences Division, HMT-43, April 1990.

43. "Heat Transfer with High Intensity, Large Scale Turbulence: The Flat Plate Turbulent Boundary Layer and the Cylindrical Stagnation Point," (with F. E. Ames), Thermosciences Division, HMT-44, October 1990.

44 "Turbulent Boundary Layers with High Turbulence: Experimental Heat Transfer and Structure on Flat and Convex Walls," (with M. K. Sahm), Thermosciences Division, HMT-45, January 1992.

45. "Catalytic Oxidation of Carbon Monoxide in a Large Scale Planar Isothermal Passage," (with A. L. Boehman and S. Niksa), Thermosciences Division, HMT-46, October 1992.

46. "Discrete Hole Film Cooling on a Convex Wall: Heat Transfer and Hydrodynamics with Free Stream turbulence" (with R. P. Campbell). Thermosciences Division, HMT-47

47 "A System for Making Temperature Measurements Using Thermochromic Liquid Crystals" (with D. J. Farina) Thermosciences Division, HMT-48, September, 1994.

48 "Boundary Condition Invariant Descriptors of Convective Heat Transfer " (with Jinny Rhee). Thermosciences Division, HMT-49, October, 1994.

49. "Impingement Cooling by Very Low Aspect-Ratio Jets" (with Christopher Daneck) Thermosciences Division, HMT-50, June, 1995.

50. "Towards a Method for Measuring Heat Transfer in Complex 3-D Flows" (with Keith A. Batchelder) Thermosciences Division Report TSD-108, August 1997

Reports which are "Out of print" are often still available through U.M.I. (800-521-3042). Photocopies can also be obtained for a small fee to cover costs by writing to The Thermosciences Division, Mechanical Engineering Department, Stanford University, Stanford, California 94305.

B

UNITED STATES DISTRICT COURT
NORTHERN DISTRICT OF CALIFORNIA
SAN FRANCISCO DIVISION

ATS Automation Tooling Systems, Inc. and Thermal Form & Function, LLC, Plaintiffs, v. Foxconn Electronics, Inc., Foxconn Technology Co., Ltd., Hon Hai Precision Industry Co. Ltd., and DOES 2 through 10, Defendants.	**Case No. 03-2648 PJH**

EXPERT REPORT OF DR. JINNY RHEE

I. INTRODUCTION

I have been retained by ATS Automation Tooling Systems, Inc. and Thermal Form & Function, LLC (the "Plaintiffs") to conduct testing of heat sinks in connection with the above-referenced matter, which concerns the alleged infringement by Foxconn Electronics, Inc., Foxconn Technology Co., Ltd. and Hon Hai Precision Industry Co. Ltd. (the "Defendants") of U.S. Patent No. 5,494,098 pertaining to heat sinks.

II. QUALIFICATIONS

I hold the following degrees:

- B.S. in Mechanical Engineering from Stanford University (1989);
- M.S. in Mechanical Engineering from Stanford University (1990); and
- Ph.D. in Mechanical Engineering from Stanford University (1995).

I am an Assistant Professor in the Mechanical Aerospace Engineering Department at San Jose State University. I am also an independent thermal consultant with experience in performing thermal analyses and testing of mechanical and electrical products, including heat sinks.

I have not served as an expert witness in any other case in the past five years.

I am being compensated at an hourly rate of $300.00 for services. My compensation is not contingent on the outcome of this litigation.

My curriculum vitae is attached as Exhibit 1.

III. TEST REPORT

I was asked to test the following two heat sink samples of the Defendants:

1. Defendants' heat sink sample identified by part number 22P4369/22P4370 (the "'369 heat sink"); and

2. Defendants' heat sink identified by part number 32P4003/32P4004 (the "'003 heat sink").

Both heat sinks have a solid flat base, a set of folded fins bonded to the base, a housing mounted over the fins, and a fan assembly mounted on the housing. In both heat sinks, the housing is fixed relative to the base by being clipped to the bottom of the base. The housing includes a top wall, which is spaced from the base, and side walls that extend from the base to the top wall. There is a first end opening at a first end of the base, which is defined by the base, the side walls and the top wall. There is also a second end opening defined by the base, the side walls and the top wall at a second opposite end of the base. The top wall of the housing includes a generally circular aperture, which is spaced from the first and second end openings.

In both heat sinks, the fins are fixed to the base, and extend from the base to the top wall. At both end openings near the sidewalls, there are some fins that reach and are in contact with portions of the top wall, which are folded downward from the top surface of the top wall. In both heat sinks, there is a small gap of less than 2 mm at the end openings between the tops of other fins and other sections of the top wall.

The fins in each of the heat sinks define a plurality of channels with the base and the top wall, which extend from the first end opening to the second end opening. The fins are folded, i.e., they are formed from a sheet of metal that is folded. Parts of the tops of the fins are severed so that the portions of the channels that lie beneath the aperture are open to the aperture and a plenum chamber is formed.

The fan assembly is fixed to the top wall of the housing above the aperture. The fan assembly blows air through the aperture and creates an air flow through the channels from the aperture to each of the first and second end openings.

The '369 heat sink is smaller than the '003 heat sink, and has a slightly different design in that there is a spacing of about 4 mm between fins at the center of the '369 heat sink. The spacing runs along the length of the fins from one end opening to the other. A clip attachment mechanism for attaching the heat sink to a circuit board is positioned in the spacing.

I was asked to test the '369 and '003 heat sink samples to determine what effect, if any, the presence of the small gaps in the Defendants' heat sinks would have on the thermal performance of the heat sinks.

I conducted the testing on November 22, 2004. For the two heat sinks tested, I determined the thermal resistance of each heat sink under three conditions: (1) "standard gap," (2) "no gap" and (3) "double gap" conditions.

First, for the "standard gap" case, I tested both heat sinks as is, i.e., without any modification.

Second, for the "no gap" case, I tested both heat sinks after modifying the heat sinks to substantially remove the gap between the fins and the housing top wall. In particular, I modified each heat sink by straightening out the bent portions of the top wall and then lowering and securing the top wall relative to the fins to substantially close the gap between the fins and the top wall. In each of the Defendants' accused heat sinks, the housing is connected to the base by four small tabs projecting from the housing side walls. These tabs are bent and hooked under the base. I straightened the tabs, which allowed the housing to be disengaged from and moved relative to the fins.

Finally, for the "double gap" case, I tested each heat sink after modifying the heat sinks to enlarge the gap to about twice the size of the original gap. In this case, I raised the housing top wall relative to the fins to obtain the desired gap, and then secured the housing relative to the fins for both heat sinks.

During testing, each heat sink was mounted on a patch heater to simulate a heated electronic component to be cooled. The thermal resistance was determined based on the power supplied to the heater, the measured temperature of the heat sink base, and the measured temperature of incoming air flow in the fan of each heat sink. A 100 ohm, 38.5 mm x 38.5 mm patch heater was used for the testing, the back of which was insulated to reduce heat loss. Owens-Corning Polystyrene insulation (1½ inches thick, R-value 7.5 hr ft^2 °F/Btu) was cut to the footprint of each heat sink base, and taped in place. The heat loss through the insulation was assumed to be one dimensional. The heat loss through the insulation was approximated as follows:

$$\dot{Q}_{loss} = \frac{A}{R}\left(T_{base} - T_{amb}\right)$$

where A is footprint area of the heat sink base, R is the commercial R value of the insulation, T_{base} is the temperature of the heat sink base, and T_{amb} is the ambient temperature. The '369 heat sink has a footprint of approximately 2.5 inches by 2.5 inches. The '003 heat sink has a footprint of approximately 3 inches by 3.5 inches.

The power to the heater was calculated as the RMS voltage across the heater squared divided by the resistance of the heater. The resistance was calculated as the RMS voltage across the heater divided by the RMS current measured with an AC power meter at steady state.

To measure the heat sink base temperature, a 36 gauge, T-type thermocouple was inserted in a small hole drilled from the side to the center of each heat sink base. The hole was then filled with commercial thermal interface material.

The thermal resistance in each case was calculated using the following formula:

$$\text{Thermal resistance} = (T_{base} - T_{inlet}) / P_{calculated}$$

A summary of the test results are shown in the table below. Each quantity in the table is the average of eight readings. A complete set of data collected on which these results are based is attached as Exhibit 2 to this report. The data were collected under steady state conditions, i.e., by holding conditions generally constant and waiting until the indicated temperatures had been stable for several minutes.

		Units	No Gap	Standard Gap	Double Gap
'369 Heat Sink	$T_{heat\ sink\ base}$	°C	37.10	36.54	36.87
	V_{rms}	V	59.29	59.12	59.17
	T_{in}	°C	22.14	22.20	22.35
	Q_{total}	W	33.80	33.61	33.66
	Q_{loss}	W	0.04	0.03	0.04
	Thermal Resistance	**°C/W**	**0.44**	**0.43**	**0.43**
'003 Heat Sink	$T_{heat\ sink\ base}$	°C	30.61	30.43	30.84
	V_{rms}	V	57.94	57.89	58.01
	T_{in}	°C	24.66	24.48	24.76
	Q_{total}	W	30.80	30.74	30.87
	Q_{loss}	W	0.03	0.03	0.03
	Thermal Resistance	**°C/W**	**0.19**	**0.19**	**0.20**

I understand that discovery in this case is ongoing. I reserve the right to modify or supplement my report in the event any additional information becomes available to me.

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Jinny Rhee

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Education

Stanford University, Stanford, CA
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- M.S. Mechanical Engineering, June 1990
- B.S Mechanical Engineering, June 1989

Teaching Experience

San Jose State University, San Jose, CA
- Assistant Professor, January 2002 to present
- Full-time Temporary Faculty, January 1995 to June 1995

Research and Professional Experience

Rhee Thermosciences, Palo Alto, CA
- Independent Thermal Consultant, January 1995 to present

GeneTrace Systems Inc., Menlo Park, CA
- Chief Engineer, June 1995 to Dec. 1996

Stanford University, Stanford, CA
- Research Assistant, June 1990 to December 1994

General Motors, Warren, MI
- General Motors Scholar, June 1998 to June 1990

Publications

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Run 1: No gap

HS base 1	V rms 1	Tin 1	HS base 2	V rms 2	Tin 2	Q tot 1	Q tot 2	Qloss 1
deg C	V	deg C	deg C	V	deg C	W	W	W
3.71E+01	5.90E+01	2.21E+01	3.07E+01	5.79E+01	2.47E+01	3.35E+01	3.07E+01	3.67E-02
3.71E+01	5.93E+01	2.21E+01	3.07E+01	5.79E+01	2.47E+01	3.38E+01	3.07E+01	3.66E-02
3.71E+01	5.93E+01	2.21E+01	3.07E+01	5.80E+01	2.47E+01	3.38E+01	3.09E+01	3.65E-02
3.71E+01	5.93E+01	2.21E+01	3.05E+01	5.80E+01	2.46E+01	3.38E+01	3.08E+01	3.65E-02
3.71E+01	5.93E+01	2.21E+01	3.05E+01	5.79E+01	2.46E+01	3.38E+01	3.08E+01	3.65E-02
3.71E+01	5.94E+01	2.22E+01	3.06E+01	5.80E+01	2.46E+01	3.39E+01	3.08E+01	3.64E-02
3.71E+01	5.93E+01	2.22E+01	3.06E+01	5.80E+01	2.47E+01	3.38E+01	3.08E+01	3.64E-02
3.72E+01	5.94E+01	2.22E+01	3.06E+01	5.80E+01	2.47E+01	3.40E+01	3.08E+01	3.66E-02
37.103	59.289	22.136	30.606	57.942	24.659	33.800	30.801	0.037
	1.04E+02			1.09E+02				

Run 2: Standard gap

HS base 1	V rms 1	Tin 1	HS base 2	V rms 2	Tin 2	Q tot 1	Q tot 2	Qloss 1
3.65E+01	5.94E+01	2.22E+01	3.03E+01	5.80E+01	2.44E+01	3.40E+01	3.08E+01	3.48E-02
3.65E+01	5.94E+01	2.22E+01	3.04E+01	5.80E+01	2.44E+01	3.39E+01	3.08E+01	3.50E-02
3.66E+01	5.91E+01	2.22E+01	3.04E+01	5.79E+01	2.45E+01	3.36E+01	3.07E+01	3.51E-02
3.66E+01	5.91E+01	2.22E+01	3.05E+01	5.79E+01	2.45E+01	3.36E+01	3.08E+01	3.52E-02
3.65E+01	5.89E+01	2.22E+01	3.05E+01	5.79E+01	2.45E+01	3.34E+01	3.07E+01	3.50E-02
3.65E+01	5.89E+01	2.22E+01	3.05E+01	5.78E+01	2.45E+01	3.34E+01	3.07E+01	3.50E-02
3.65E+01	5.89E+01	2.23E+01	3.05E+01	5.78E+01	2.45E+01	3.34E+01	3.07E+01	3.48E-02
3.65E+01	5.91E+01	2.22E+01	3.05E+01	5.79E+01	2.46E+01	3.36E+01	3.07E+01	3.50E-02
36.536	59.119	22.197	30.434	57.889	24.483	33.606	30.744	0.035

Run 3: Double gap

HS base 1	V rms 1	Tin 1	HS base 2	V rms 2	Tin 2	Q tot 1	Q tot 2	Qloss 1
3.69E+01	5.93E+01	2.24E+01	3.08E+01	5.80E+01	2.47E+01	3.38E+01	3.09E+01	3.54E-02
3.70E+01	5.91E+01	2.24E+01	3.08E+01	5.80E+01	2.48E+01	3.36E+01	3.09E+01	3.55E-02
3.70E+01	5.93E+01	2.24E+01	3.08E+01	5.80E+01	2.48E+01	3.38E+01	3.09E+01	3.56E-02
3.69E+01	5.90E+01	2.24E+01	3.08E+01	5.80E+01	2.47E+01	3.35E+01	3.08E+01	3.55E-02
3.68E+01	5.90E+01	2.23E+01	3.08E+01	5.80E+01	2.48E+01	3.34E+01	3.08E+01	3.54E-02
3.68E+01	5.91E+01	2.23E+01	3.09E+01	5.80E+01	2.47E+01	3.36E+01	3.09E+01	3.53E-02
3.68E+01	5.91E+01	2.23E+01	3.08E+01	5.80E+01	2.48E+01	3.36E+01	3.09E+01	3.54E-02
3.67E+01	5.94E+01	2.23E+01	3.09E+01	5.81E+01	2.48E+01	3.39E+01	3.09E+01	3.54E-02
36.867	59.168	22.349	30.836	58.011	24.756	33.662	30.874	0.035

Qloss 2	Theta 1	Theta 2
W	deg C/W	deg C/W
3.10E-02	4.49E-01	1.97E-01
3.08E-02	4.43E-01	1.95E-01
3.08E-02	4.44E-01	1.95E-01
3.04E-02	4.43E-01	1.92E-01
3.03E-02	4.43E-01	1.92E-01
3.04E-02	4.41E-01	1.92E-01
3.02E-02	4.42E-01	1.91E-01
3.04E-02	4.42E-01	1.92E-01
0.031	0.443	0.193

		No gap	Std gap	Dbl gap
HS base 1	deg C	37.10	36.54	36.87
V rms 1	V	59.29	59.12	59.17
Tin 1	deg C	22.14	22.20	22.35
HS base 2	deg C	30.61	30.43	30.84
V rms 2	V	57.94	57.89	58.01
Tin 2	deg C	24.66	24.48	24.76
Q tot 1	W	33.80	33.61	33.66
Q tot 2	W	30.80	30.74	30.87
Qloss 1	W	0.04	0.03	0.04
Qloss 2	W	0.03	0.03	0.03
Theta 1	**deg C/W**	**0.443**	**0.427**	**0.432**
Theta 2	**deg C/W**	**0.193**	**0.194**	**0.197**

Qloss 2	Theta 1	Theta 2
3.02E-02	4.20E-01	1.91E-01
3.07E-02	4.23E-01	1.94E-01
3.04E-02	4.28E-01	1.93E-01
3.07E-02	4.30E-01	1.95E-01
3.03E-02	4.30E-01	1.93E-01
3.07E-02	4.30E-01	1.95E-01
3.05E-02	4.28E-01	1.94E-01
3.07E-02	4.27E-01	1.95E-01
0.031	0.427	0.194

Qloss 2	Theta 1	Theta 2
3.13E-02	4.29E-01	1.98E-01
3.11E-02	4.34E-01	1.96E-01
3.10E-02	4.31E-01	1.96E-01
3.12E-02	4.34E-01	1.98E-01
3.10E-02	4.35E-01	1.96E-01
3.16E-02	4.31E-01	1.99E-01
3.11E-02	4.32E-01	1.96E-01
3.13E-02	4.28E-01	1.98E-01
0.031	0.432	0.197