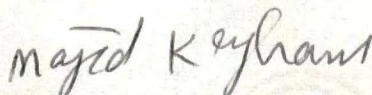


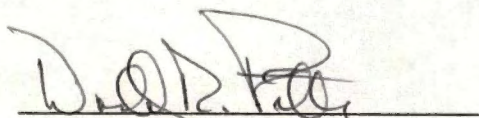
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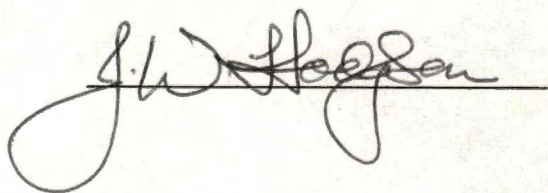
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NATURAL CONVECTION IN A VERTICAL ENCLOSURE
WITH DISCRETE HEATING,
THE ASPECT RATIO EFFECT

A Thesis

Presented for the

Master of Science

Degree

The University of Tennessee, Knoxville

Toon-Tin Wong

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ABSTRACT

The effects of distributed, constant heat flux sources and constant temperature heat sink on the buoyancy-induced fluid flow and heat transfer in a differentially heated, vertical cavity has been studied experimentally for a heater pitch-to-height ratio of 2 and cavity aspect ratios of 4.5, 9, 13.5 and 16.5. For the aspect ratio of 16.5, the pitch-to-height ratio of 6 has also been investigated. The buoyancy-induced fluid flow has been photographed using fine aluminum tracing particles in ethylene glycol. Temperatures of the surfaces and medium were measured with thermocouples. The experiments were conducted with ethylene glycol as the convective medium at power levels of, 0.21, 0.41, 0.62, 0.83, and 1.03 W/cm^2 (approximately). These experiments covered the range of average modified Rayleigh numbers (based on enclosure's width) from 4.31×10^6 to 9.35×10^7 . The empirical data were presented in the form of correlations. The convective heat transfer data were corrected for heat losses and convection through substrate conduction. Under the prescribed boundary conditions, increasing the aspect ratio (fixed width) enhances heat transfer. Excellent agreement was achieved with the previously reported heat transfer results in the literature for (i) a miniature, flush heat source on a vertical surface, and for (ii) the arrays of protruded heating elements for both the vertical plate (unshrouded) and the channel (shrouded).

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CHAPTER 1

INTRODUCTION

Natural or free convective heat transfer from finite-sized, heated elements located on a vertical, adiabatic surface arises in many engineering applications. In particular, in the cooling of electronic equipment and in some manufacturing systems, multiple isolated heated elements generate a natural convection flow. Determining the energy inputs and locations to prevent overheating of elements and the surface arouses interest and concern. The system performance of electrical equipment is generally temperature sensitive. Natural convection cooling of such equipment possesses certain advantages including: this method is economical, quiet, reliable, and does not generate electromagnetic interference (Johnson [23], see Bibliography, all authors are listed in alphabetical order).

The heat transfer process of natural convection arises when a body is in contact with an otherwise stationary fluid at a different temperature. The temperature difference induces a density gradient which, combined with the presence of a gravity field, gives rise to buoyant force -- the driving mechanism of a convective process. In a

cavity, however, hydrodynamic instability drives the recirculating flow.

Discrete sources may simulate very large scale integration (VLSI) chip arrays. VLSI technology replaces geometrically awkward shaped individual electronic components with regular rectangular or square chips on a substrate. Densely-mounted components in the span-wise direction approximate a line thermal source. Due to their small size, microchips are modeled as uniform heat flux devices (Park and Bergles[31]) A pair of electronic cards resembles a vertical channel or a cavity, depending on the boundary conditions.

Literature Review

Modeling the problem was based on many recommendations and suggestions found in the literature. Ortega and Moffat [29] suggested considering a printed circuit board as a smooth surface, as long as the ratio of the interplate spacing to the protrusion height is more than 4. Fujii et al. [14] observed that roughness has only a small effect on the free convection heat transfer from vertical cylinders of various roughness in oil and water, especially in the laminar regime. Joffre and Barron [22] reported a significant enhancement in heat transfer due to roughness, however. These two works have an ambiguity in the definition of the differential temperature for the heat transfer coefficient. Studying the effect of Prandtl number on heat transfer rates in a vertical cavity, Graebel [15] showed less than 1.52 % increase in Nusselt number for an increase in Prandtl number

from unity to infinity, for a fixed Rayleigh number. Macgregor and Emery [28] suggested that Rayleigh number is a more pertinent modulus than Grashof number. Incropera [20] highlighted the importance of presenting results based on local heat transfer parameters. In many designs of electronic cooling equipment, the surface temperature is an unknown. The power input and the resistance of the chip are available information, however. Therefore a modified Rayleigh number is needed (see Appendix A for definitions).

Few investigators have contributed to the flow visualization of enclosure problems. Elder [9] observed multicellular flow patterns in the free convective flow of oil in a rectangular cavity across which a differential temperature existed. Vest and Arpaci [37] found that the multicellular secondary flows disturbed the stationary stability in both the conduction and boundary-layer regimes. Bergholz's [3] numerical results showed that the transition from travelling-wave to stationary instability occurred at high Prandtl number. At low-to-moderate Prandtl number, the reverse is true. Pepper and Harris [32] solved the flow patterns in rectangular and annular cavities using the strongly implicit procedure and the cyclic reduction, fast Fourier transform, numerical technique. Lee [27] predicted the flow structures at low Prandtl numbers in a rectangular cavity using finite difference methods. In both the transition and the boundary layer regimes, Eckert and Carlson [6] found the presence of an almost linear temperature gradient at the core of the cell.

Baker [1] was among the first to show that liquid immersion, free convection cooling is an effective means of cooling small heat sources. For air cooling in a channel, Johnson [23] compared empirical correlations and numerical calculations. Park and Bergles [31] reported the effects of varying distances between heaters, width, height, in-line, staggered, and flush and protruding heater configurations on the free convection heat transfer coefficient. Chu, Churchill, and Patterson [5] studied the effect of heater size and location, aspect ratio, and boundary conditions on two-dimensional, laminar, natural convection in rectangular enclosures. Flack and Turner [13] obtained heat transfer correlations for use in naturally cooled enclosures with high-power integrated circuits. Ortega and Moffat [29] investigated naturally-induced, convective heat transfer from an array of cubical elements deployed in an in-line array on one wall of a vertical channel. Vliet [38] studied natural convection local heat transfer on constant heat flux inclined surfaces. Jaluria [21] established numerically the dependence of the heat transfer coefficient on the location and energy input of the heat sources. Elder [8] made velocity measurements by direct observation; either visually by timing the passage of a single particle between fixed marks, or from time-sequenced still photographs in which the streak-length is proportional to the velocity. However, the velocity of particles is a variable depending on location and flow field. For example, flow in a tertiary cell is much slower than a secondary cell and fixed marks do not always conveniently exist. Moreover, particles are often small and difficult to follow. In still pictures, streak lines may form closed loops, depending on the concentration of the

particles and time of exposure. Reliable measurements of velocity by visual observation is almost impossible. Therefore, this error-prone, laborious, time-consuming procedure of velocity measurement is not used in the present work. For those who are interested, Elliot [10] has succeeded in formulating a velocity calculation based on streak-length.

Many important findings have already been published. Vest and Arpaci [37] identified hydrodynamic and buoyancy force as the destabilization mechanisms in the conduction regime and the boundary-layer regime, respectively. Pepper and Harris [32] found that the dependance of the Nusselt number on the aspect ratio diminishes with increasing aspect ratio. Macgregor and Emery [28] reported a significant reduction of the Nusselt number with increasing aspect ratio and Emery [11] observed that the mean temperature of the cell is a function of the height, increasing with the vertical dimension. Recently, Park and Bergles [31] reported increasing heat transfer coefficient with decreasing heater width in the span-wise direction to be due to 3-dimensional, boundary layer effect. Due to the leading edge effect, even the widest heater has heat transfer coefficients higher than those of uniformly heated vertical plates. Heat transfer coefficients for the upper heaters are lower than those for the lower heaters, but the difference vanishes at larger spacings. They explained that although the heat transfer was enhanced by buoyancy created by the lower heaters, the fluid temperature was higher. Park and Bergles [31] also found higher heat transfer coefficients for protruding heaters, due to disturbances in the flow.

Keyhani, Prasad, and Cox [24] discovered that the temperature in the unheated wall section is always lower than if the wall were fully or uniformly heated. As a result, mixing within the boundary layer is enhanced. Furthermore, they also established the fact that the location of heating elements with respect to the secondary and tertiary cells are of significant importance to the control of temperature on the heated wall.

Motivation

Most of the studies investigating buoyancy-driven flow and heat transfer in a vertical cavity or channel have considered only fully heated, vertical, isothermal walls. A detailed review of the literature, however, reveals a lack of investigative effort in the study of free convection from either an isolated constant heat flux source or an array of distributed constant heat flux sources on a vertical wall.

Methods of Attack

Wide varieties of packaging size, spacing, component size, and large number of parameters exist. The existence of multiple length scales complicates the convection heat transfer from an array of discrete heat sources (Fig. 1-1). Many idealizations are invalid. For this complex problem, numerical studies may not enjoy a cost advantage. By creatively applying simplified experimental models, one obtains useful insights into the physical phenomena. Experimental

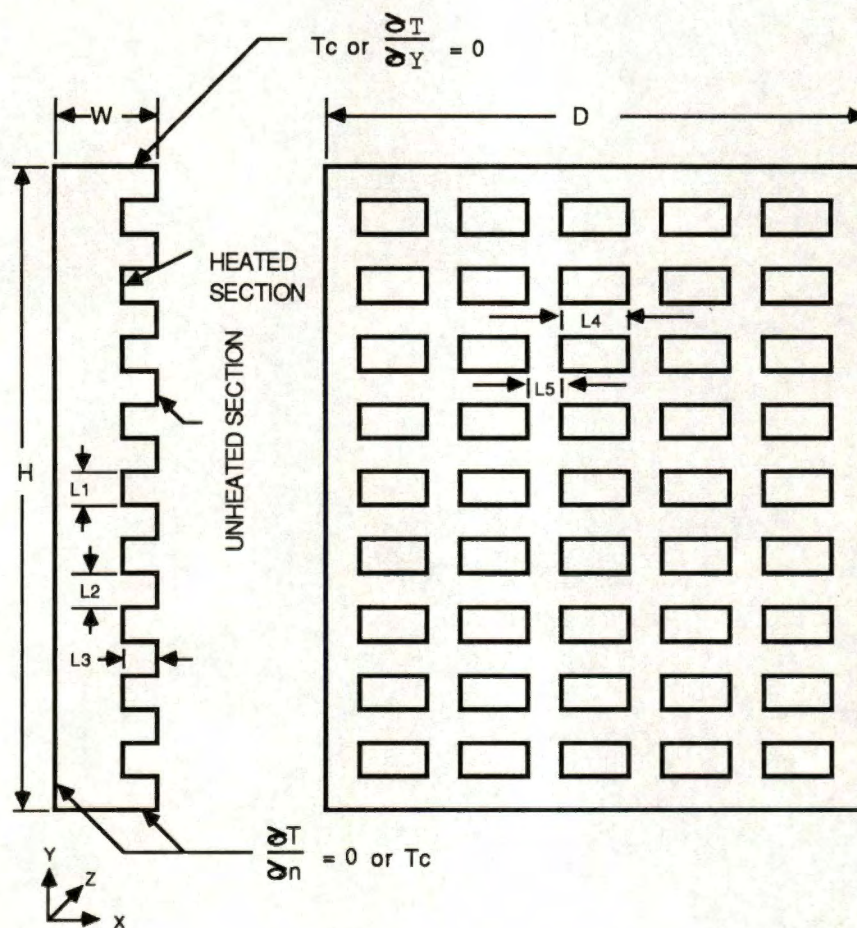


Fig. 1-1 Schematic of General Enclosure Problem

research can give a good understanding of the underlying mechanisms, performance characteristics, and barriers to implementation.

Objectives and General Plan of Work

The present work examines the flow structure and the local heat transfer behavior for the case of the buoyancy-driven flow and heat transfer in a cavity, with constant heat flux discretely supplied to one smooth, vertical wall, while the other vertical wall is cooled at a constant temperature. Since gases have small thermal conductivities, Prandtl numbers, and thermal capacitances, only liquid cooling is considered. Direct liquid immersion cooling substantially reduces external thermal resistances. The acquisition of free convection heat transfer empirical data, flow visualization, and the development of extensive data bases in the form of correlations for free convection heat transfer were the primary contributions of this study (see Appendix E for listings of programs).

The weighted average reference fluid temperature recommended by Zhong, Yang, and Lloyd [40] was used to evaluate values of the variable thermophysical properties. The evaluation did not invoke the Boussinesq approximation. Macgregor and Emery [28] suggested that constant heat flux, vertical wall case requires consideration of temperature dependent viscosity. The present study assesses the relative contributions of surface convection and substrate conduction to total heat dissipation. Attempts were made to determine the conditions for the initiation of local turbulent flow. Limited

variations of geometric parameters aid the understanding of their effects on the fundamental fluid dynamics and heat transfer characteristics of flow between parallel plates. The main objectives were to study the effects of varying the aspect ratio and varying the spacing between heaters on heat transfer. A test cell with a fixed width and variable height was constructed. The time histories of temperatures in the enclosure were recorded to determine the initiation of unsteady or chaotic flow. To understand the effects of recirculating flows in the enclosure, photographs were taken; and video recording of flow phenomenon were made. The data were reduced to form empirical correlations (see Appendix D for raw and reduced data).

CHAPTER 2

DESIGN OF EXPERIMENTAL APPARATUS

The experimental investigation imposed certain basic requirements:

- (1) construction of a suitably large, water-tight, rectangular cavity for the development of free convective flow;
- (2) design of a system to facilitate flow visualization;
- (3) monitoring of the energy input;
- (4) selection of a cooling unit to maintain a constant temperature cold wall;
- (5) estimation of heat losses and minimization of them;
- (6) provision of uniform heating of the strips;
- (7) instrumentation of the set-up to measure temperatures and voltages; and
- (8) acquisition of data with a system that accurately digitizes, collects, stores, and reduces data.

The experimental set-up consisted of a rectangular enclosure and its attachments, a power source and its regulating systems, a data acquisition and reduction system, and a photographic system. The remainder of this chapter will discuss the details (Tables C-1 and

C-2). A schematic diagram of the apparatus and instrumentation is shown in figure 2-1.

Test Cell

The space in the rectangular enclosure to be used has dimensions of 596.9 mm high, 254 mm deep, and 25.4 mm wide (Fig. 2-2). This test cell was comprised of a phenolite wall with strip heating, a constant temperature brass wall facing the heated wall, four plexiglas plates for the other sides, surface thermocouples and their leads, and liquid temperature probes and their guiding devices (Fig. 2-3).

The phenolite wall has twelve strip-heaters. Each heater fits into a 19.1 mm vertical by 254 mm long by 3 mm deep groove. These heaters were equally spaced a vertical distance of 19.1 mm apart (Fig. 2-4). The construction was simple: A thin aluminum strip was placed over the heat-sink-compound covered strip-heater. The aluminum strip was secured with a five-minute-epoxy. A thermocouple was placed at mid-span in a groove that was milled into the surface of the aluminum strip. Some thermocouples were placed near the ends of the strips to determine any end effects caused by the insulated side walls. Thermocouples were secured with liquid aluminum (material). Liquid aluminum was applied to all the edges of the aluminum strip. Once dry, the excess liquid aluminum was sanded away to produce a smooth transition from phenolite to the aluminum. Also several thermocouples were placed in grooves on the surface of the phenolite to measure temperature in the unheated regions of the phenolite wall (Fig. 2-5).

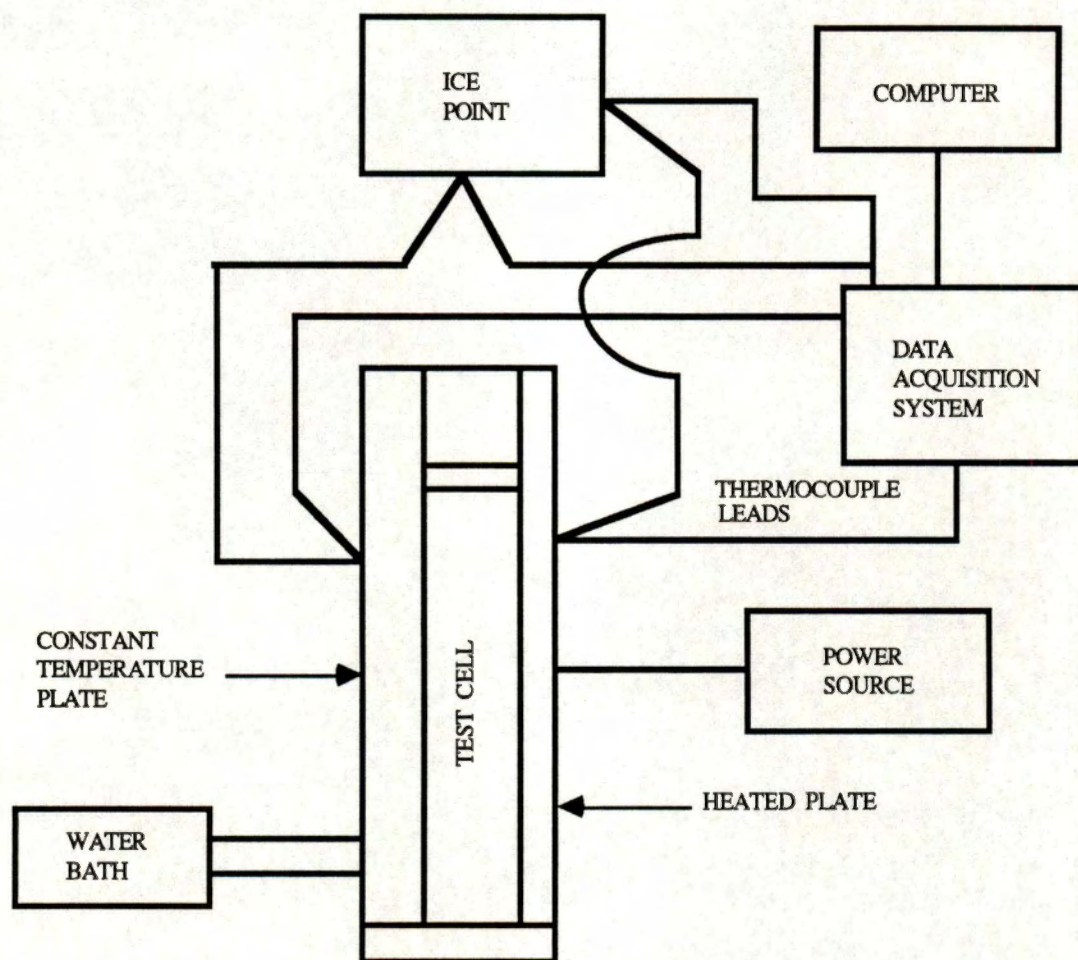


Fig. 2-1 Schematic Diagram of Apparatus and Instrumentation

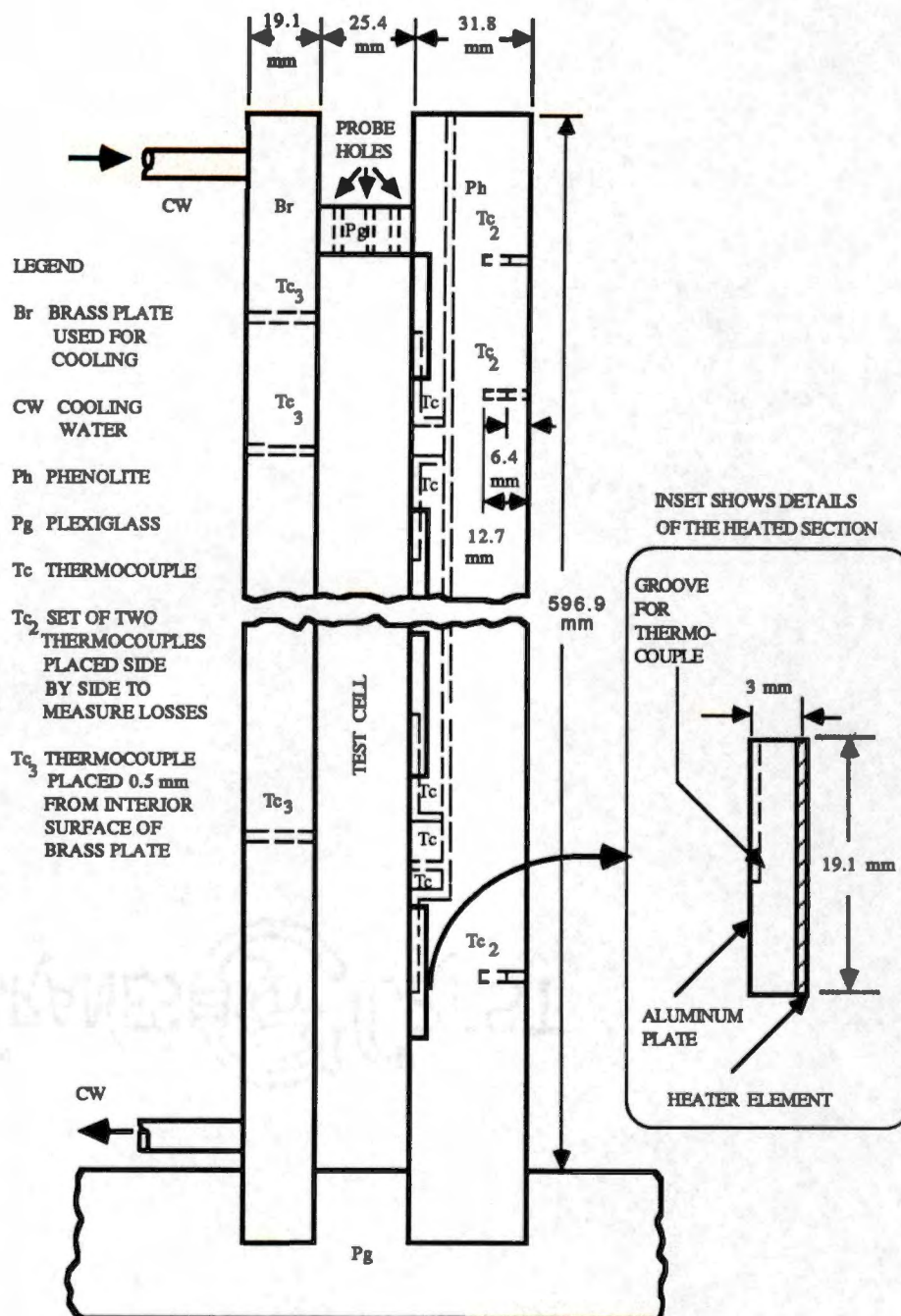


Fig. 2-2 Detailed View of the Test Cell

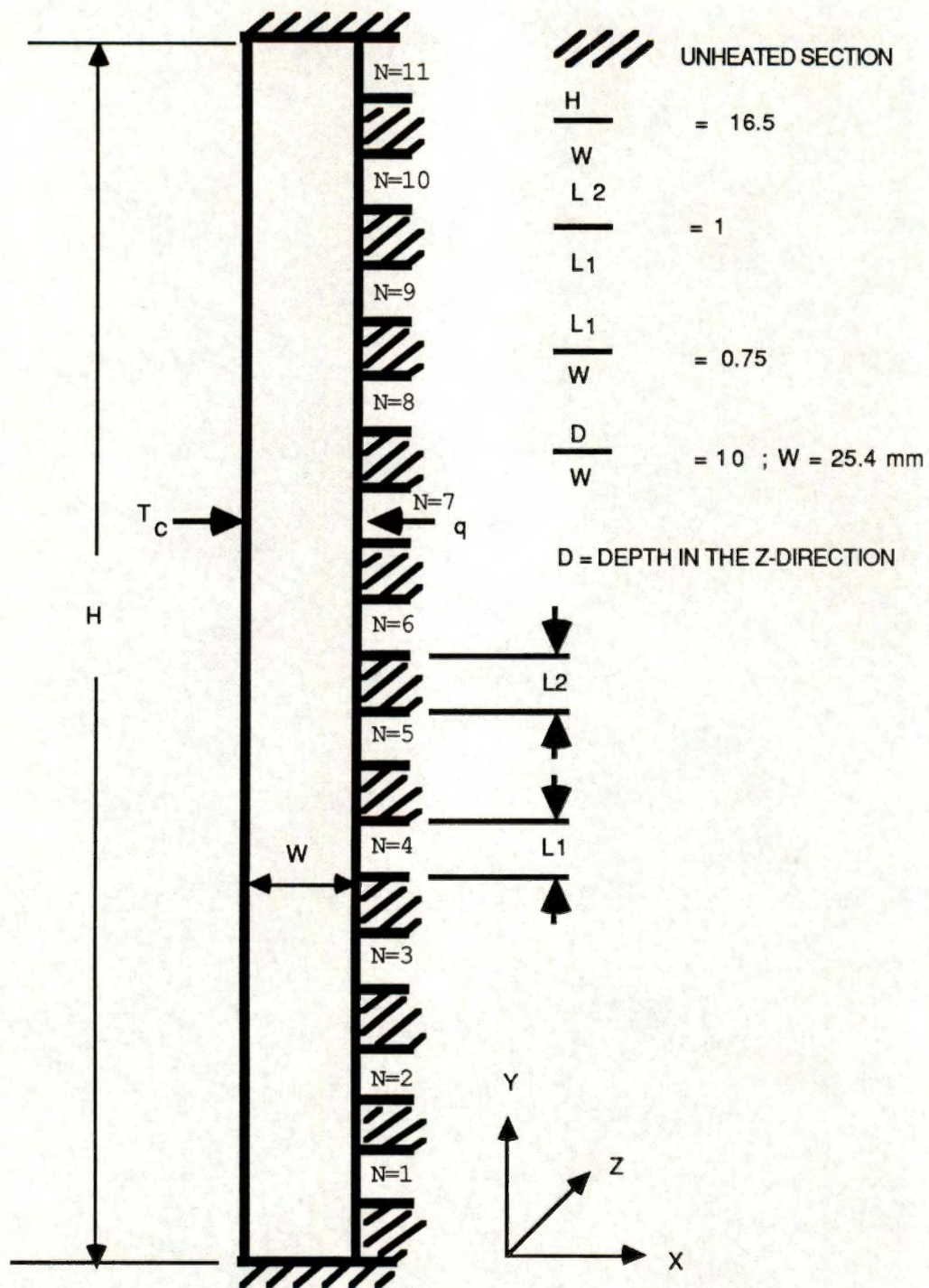


Fig. 2-4 Test Cell Geometry

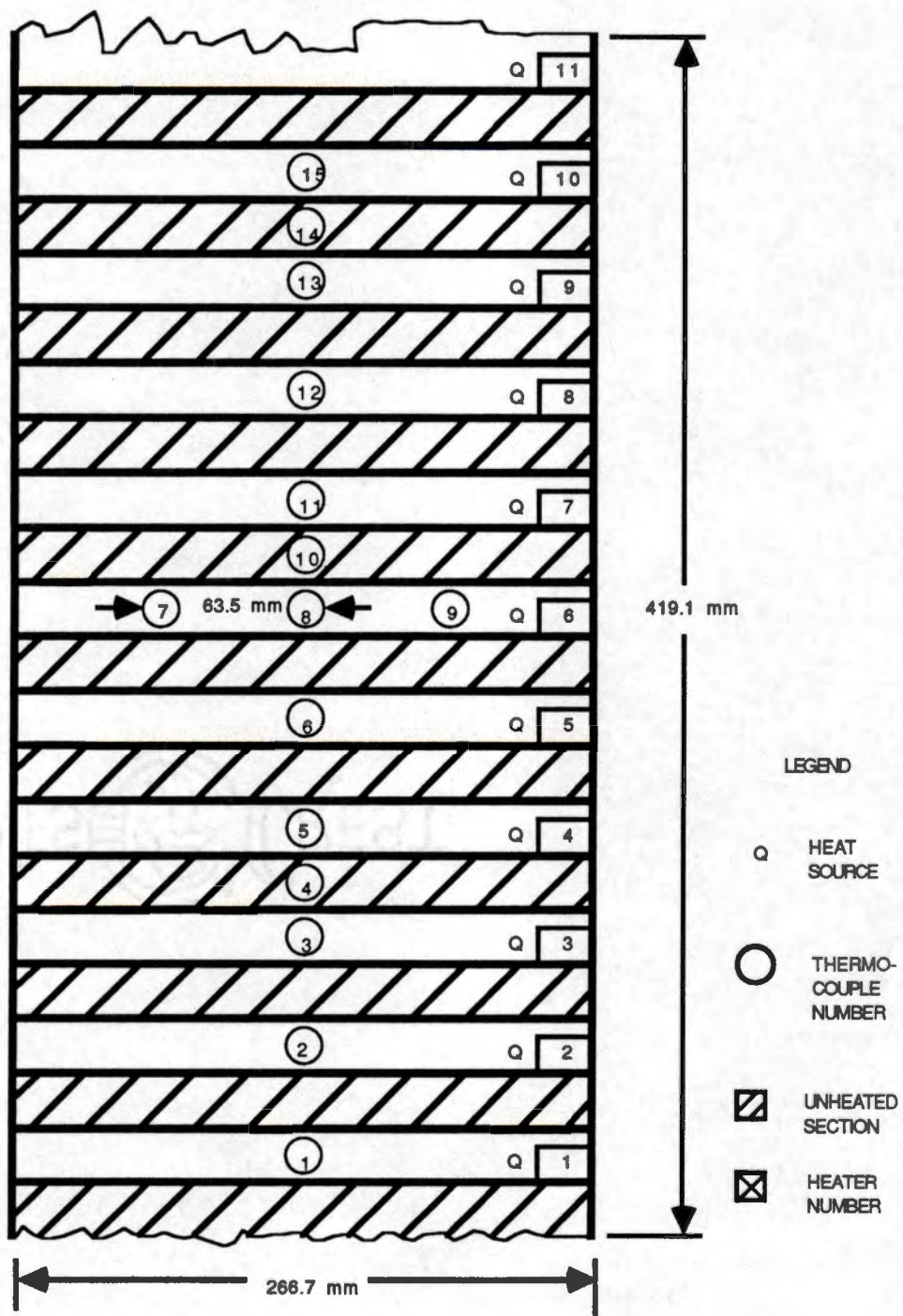


Fig. 2-5 Thermocouple Locations on Interior of Heated Wall

Some thermocouples were used to measure losses through the phenolite wall (Fig. 2-6). These thermocouples were secured with plastic steel (material). All of the heater and thermocouple leads were fed up channels in the phenolite wall and out of the top of the wall. All leads were attached to strip boards on the back of the plate, outside of the test cell.

The cold wall was constructed of two 9.6 mm thick pieces of brass. A 4.8 mm deep semi-circular groove was milled into the surface of each plate, forming mirror images of each other. The two plates were silver-soldered together so that the two grooves met to form a coolant channel which "snakes" through the brass plate. Supply and return tubes were connected to a LaudaTM, Constant Temperature Bath and Circulator. The cooling water ran through the channel and tubes, thereby maintaining a constant wall temperature. The circulator maintained water within 0.1 degree Celsius. To avoid overheating, care was taken to provide a continuous supply of cooling water. Thermocouples were used to verify the constant temperature (Fig. 2-7). The thermocouples were secured with plastic steel. Leads were attached to a strip board mounted on the exterior wall.

The remaining two sides were made of 12.7 mm thick plexiglas plates. They were of T cross-section; the male parts were inserted into the space between the other two vertical walls. Matching holes were drilled into the plexiglas, brass plate, and the phenolite wall. The plexiglas was screwed to the phenolite and brass plates and sealed with silicon rubber on the contacting surfaces and edges. A groove was

⊙ THERMOCOUPLE NUMBER

THE THERMOCOUPLE PAIRS ARE 3.2 mm APART
THE LEFT THERMOCOUPLE IS IMBEDDED 6.4 mm,
THE RIGHT ONE 12.7 mm

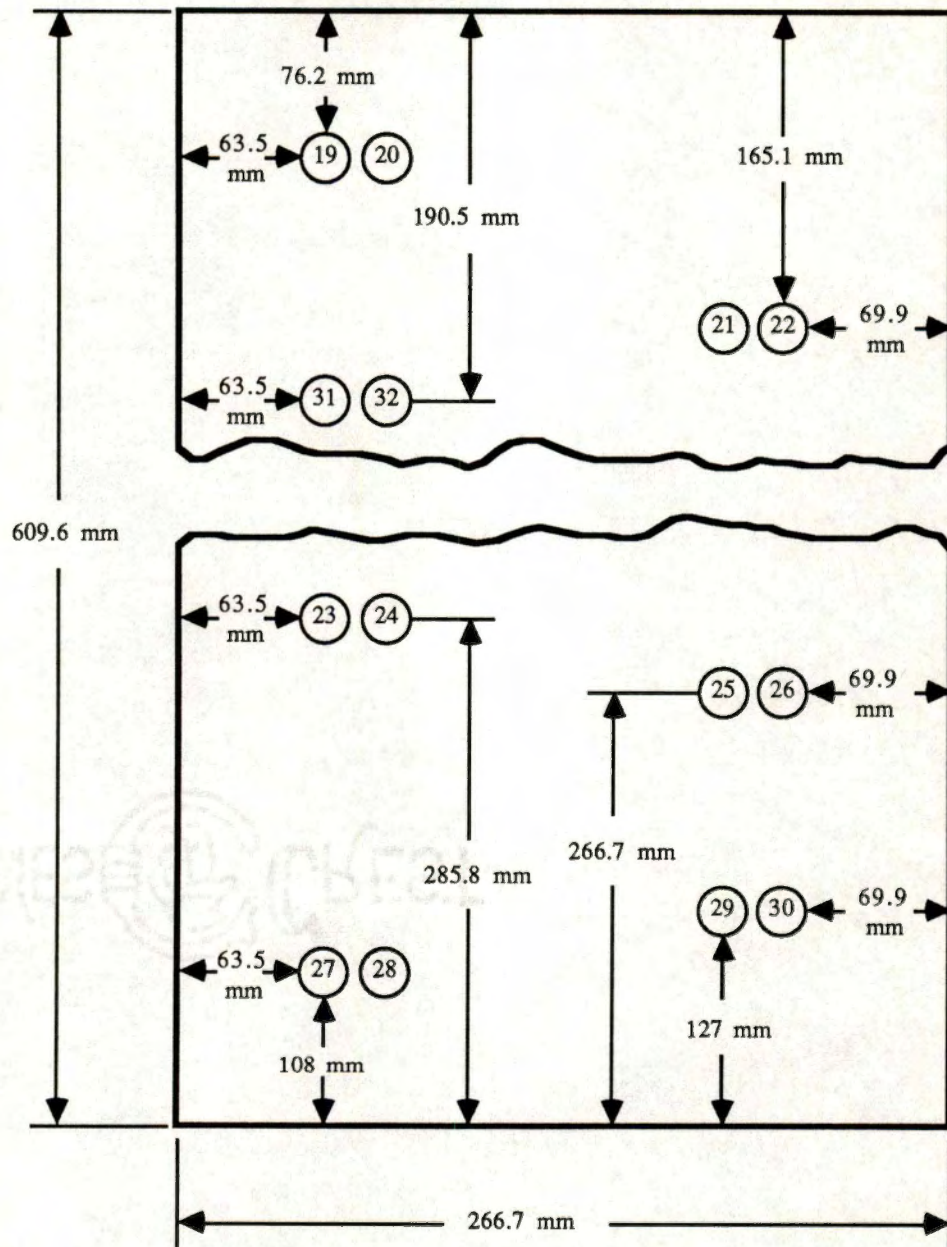


Fig. 2-6 Location of Thermocouples Imbedded in Phenolite Plate

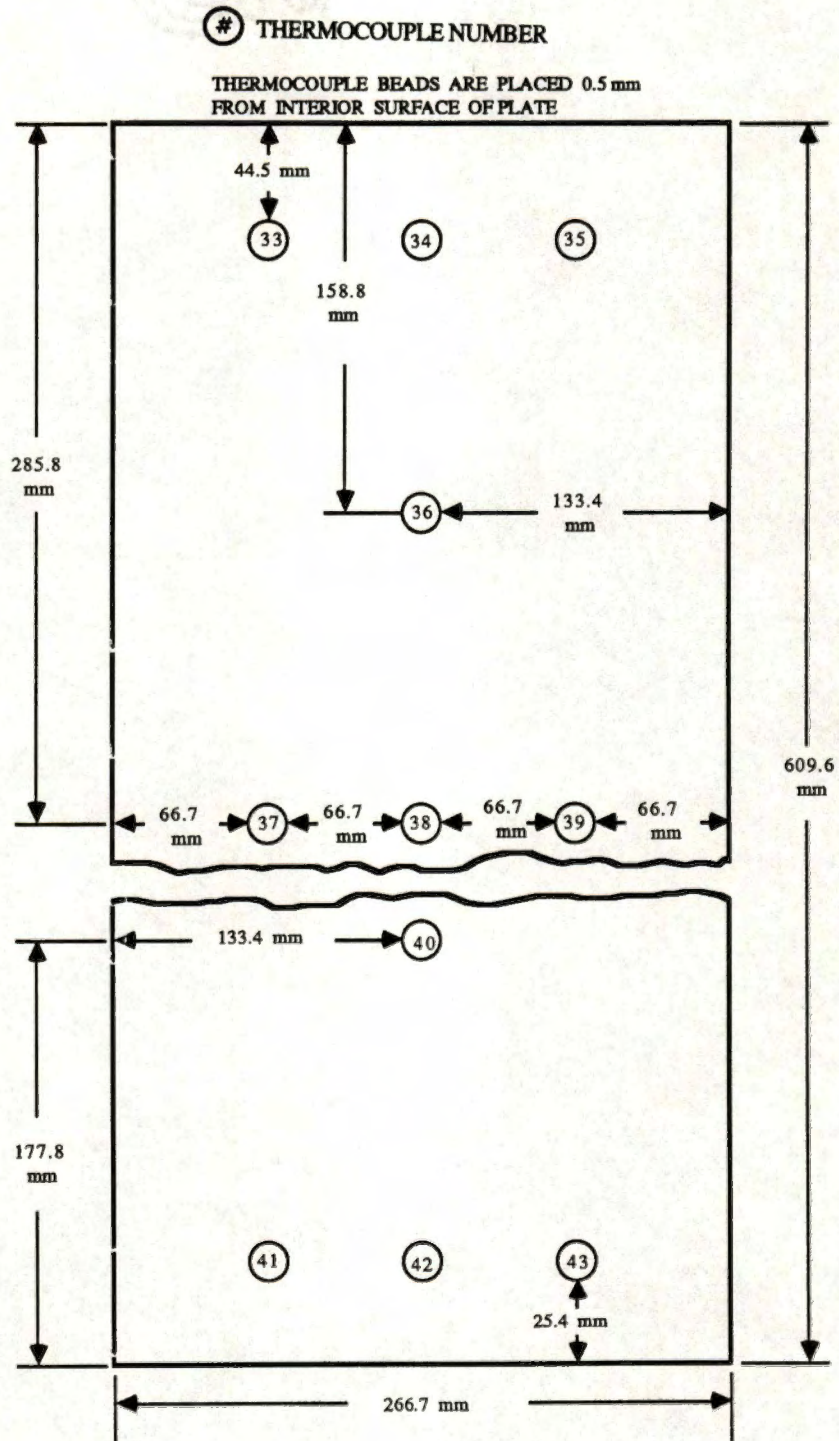


Fig. 2-7 Location of Thermocouples Imbedded in Brass Plate

milled on the thick plexiglas base. All the sides were fitted into the groove and sealed with silicon rubber. Thermocouples were placed on a side wall and the base for use in estimating losses by conduction. The top plate, which was 12.7 mm thick, had grooves milled on the 25.4 mm sides to accomodate an o-ring for sealing. Six holes (2 mm in diameter) were drilled at mid-span for the introduction of particles for flow visualization (Fig. 2-8) and the insertion of probes to measure the temperature gradient across the width of the enclosure. Two blind holes were drilled and tapped in the top plate to allow the attachment of a threaded rod for inserting, removing, positioning, and adjusting the top plate. A guiding device (Fig. 2-3, see p. 14) was constructed to permit positioning the three liquid temperature probes to different levels together. The three temperature probes were thermocouples in hollow tubes. All three detecting points were aligned horizontally by gluing them on a strip. Later, for top flow visualization (Fig. 2-9), additional equally spaced holes were drilled to uniformly introduce particles over the whole enclosure. Another top plate was constructed with only two tapped blind holes to facilitate top viewing of flow patterns.

Power System

Power was fed to the 11 heating elements from a power panel using a Raytheon Sorensen Power SuppliesTM AC Regulator ACR 3000 (Fig. 2-10). The experiments were conducted with 11 heaters. The power panel consisted of a voltage regulator, a step down transformer, and nine variacs. The heaters were numbered starting from the bottom. From

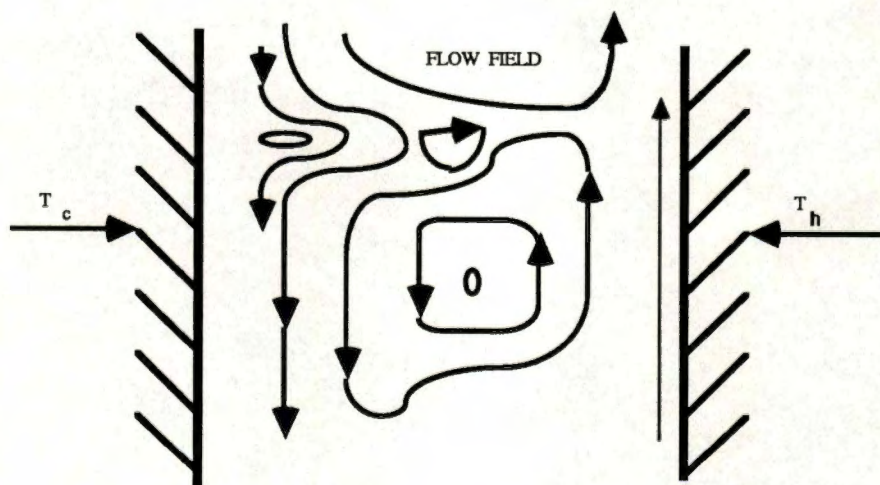
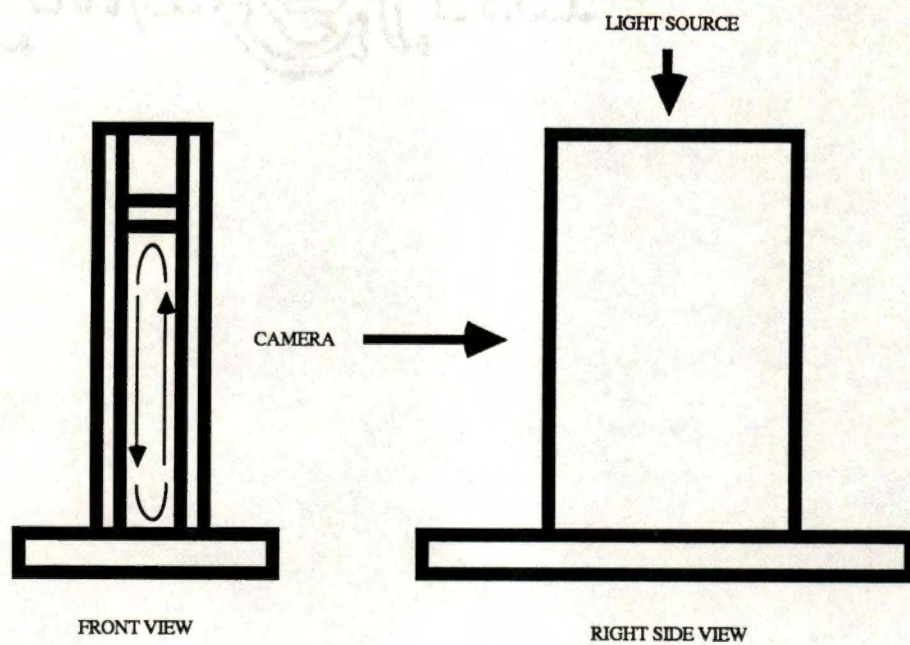


Fig. 2-8 Flow Visualization from the Front and Flow Fields

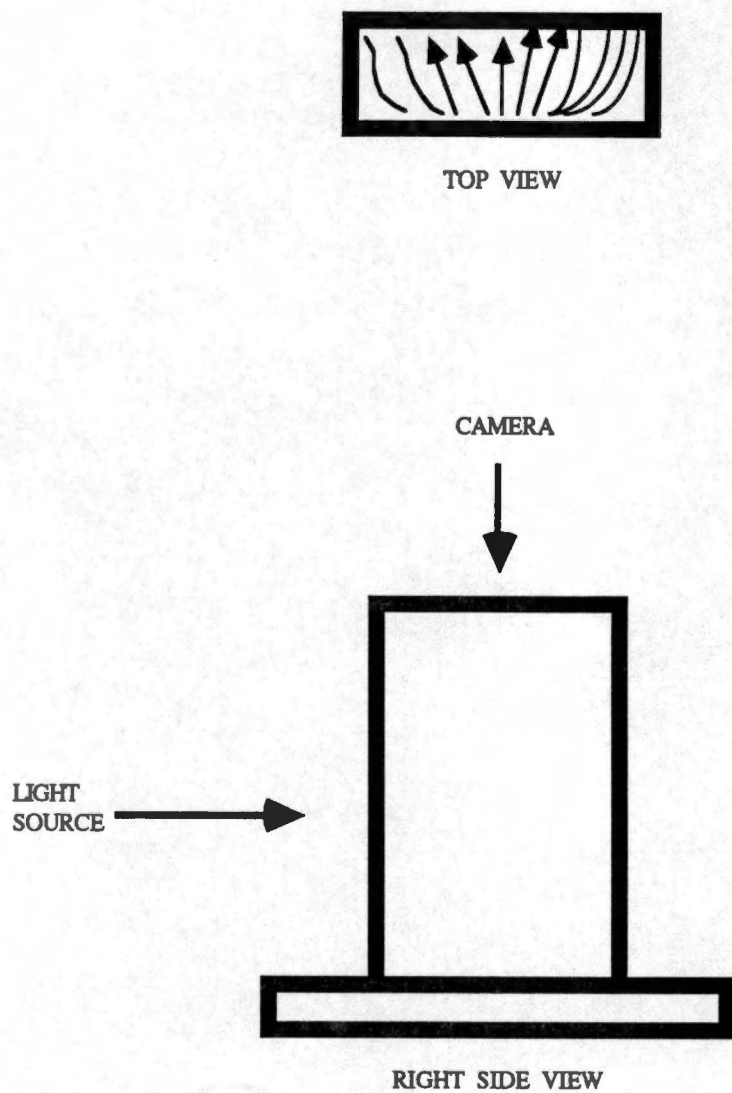


Fig. 2-9 Flow Visualization from the Top

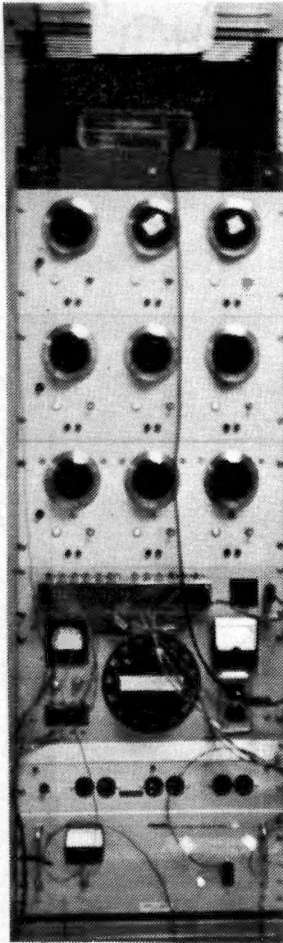


Fig. 2-10 Power Panel

heater number 1 to 9, each three consecutive heaters formed a series circuit, numbered circuit 1 to 3, respectively. The last 2 heaters, numbered 10 and 11, formed circuit 4. Later, heaters 3, 6, and 9 were connected in series to form circuit 5. This circuit was used in experiments where only these three heaters were activated. Each circuit was connected to one variac resulting in each variac controlling either 2 or 3 heaters. The entire electrical system was carefully grounded to ensure safe operation.

Measuring and Computing System

This investigation utilized thermocouples to measure temperatures. The reference ice point temperature was provided with Kaye InstrumentsTM unit, model K-140/4. The test cell was instrumented with 43 copper-constantan thermocouples. A data acquisition package consisting of a Hewlett-PackardTM digital voltmeter (HP 3456A), a multimeter (KiethleyTM 177 Microvolt DMM), an acquisition/control unit (HP 3497A), and an extender (HP 3498A) was used to collect the voltages from the power source, and the temperatures from the thermocouples. From the data acquisition system (Fig. 2-11), digital information was fed to a computer (HP 9000/217) for data storage, reduction, and analysis. This unit included a HP 9133D Winchester disk which has 14.8 Mb storage capacity. The output hardware included a Think Jet Printer (HP) and a Graphics Plotter (HP model 7470A, Fig. 2-12).

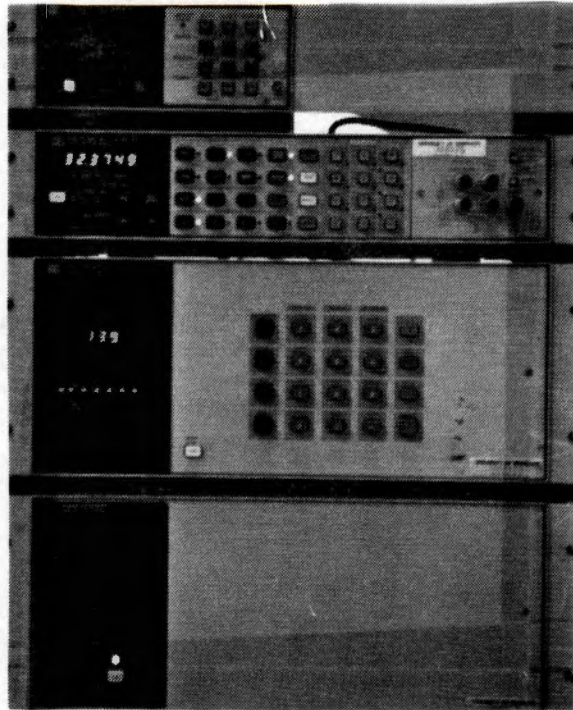


Fig. 2-11 Data Acquisition System

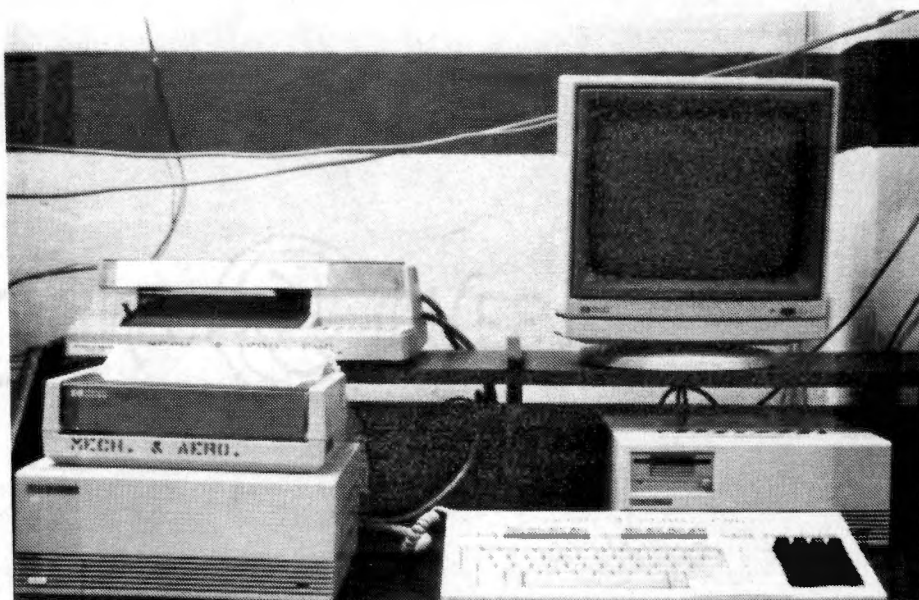


Fig. 2-12 Computer and Accessories

Thermocouples 1 through 18 were located on the interior surface of the heated wall (except number 16 which measured the temperature at the top plate). Thermocouples 19 through 32 were embedded in pairs in the phenolite wall, with 7 pairs located at various places for measuring heat loss through the back of the phenolite wall (Fig. 2-5 and 2-6 see pp. 16 and 18). The two thermocouples of a pair were placed a horizontal distance of 3.2 mm and 6.4 mm difference in depth, with the one nearer the heater surface 12.7 mm beneath the back of phenolite wall (Fig. 2-2, see p. 13). The closeness of the two thermocouples approximated a one-dimensional heat flow (distance between two adjacent points is proportional to thermal resistance). Thermocouples numbered 33 to 43 were embedded in the cold wall and used to verify the constant temperature (Fig. 2-7, see p. 19). Those thermocouples were placed in wells within 0.5 mm of the cold interior surface. Due to the low thermal resistance between these two points these thermocouples measure temperature close to that of the surface.

Flow Visualization System

The flow visualization system consisted of a medium, a tracing element, photographic equipment, a light source, and associated supports and stands. Pure ethylene glycol was used as the cooling fluid in the enclosure, as it provided good flow visualization results. To study the recirculating flow, a small amount of fine aluminum powder was added to provide tracing particles. The amount used did not affect the density of the medium. The powder, floating in ethylene glycol, was contained in a squeezable plastic bottle with

a connecting flexible hollow tube. Carried along by the flow, these neutrally buoyant particles traced out streak-like patterns in long-time photographs. The clear plexiglas allowed projection of light thereby illuminating the particles. The motion of the light-reflecting particles was photographed and videotaped. To better capture the flow visualization from the front, a black board was placed behind the extreme end wall for contrast. Figure 2-8 (see p. 21) indicates the major flow visualization orientation as well as a sketch approximating the type of particle path motions anticipated and seen in preliminary experiments.

CHAPTER 3

EXPERIMENTAL PROCEDURE

Heat Transfer Measurement

To prevent interference from the environment, the entire experimental apparatus was placed in an air-conditioned room with a relatively fixed temperature setting. Experiments were conducted for 5, 10, 20, 30, 40, and 50 W per element (approximately) for each aspect ratio. Four sets of experiments were planned for aspect ratios of 4.5, 9, 13.5, and 16.5. Another set of runs examined the effect of heater vertical spacing at a fixed aspect ratio of 16.5. The voltage was set to the value equal to the square root of the product of the desired power setting and the resistance of the circuit (Tables C-4 to C-9 show resistances). Later, heaters number 3, 6, and 9 formed the only active circuit to study the effect of heater spacing on the heat transfer. Initially, the thermocouple outputs were monitored every 30 minutes.

At the lowest input power, the surface temperatures and the fluid temperatures reached constant values within one hour. All of the other runs (at higher power) reached a quasi-steady state where all

temperatures were gradually increasing but at approximately the same rates in less than 6 hours. The experiment was stabilized for at least 6 hours before taking data. A preliminary check of the thermocouples began the experimental procedure. Readings were taken carefully to ascertain the desired settings before recording the data. Probe readings measuring the medium temperatures were also taken after surface temperature data were stored in data files. The temperature history was also recorded at the highest power settings for each of the top few heaters. After recording the data, the file information was analyzed, resulting in the presentation of dimensionless parameters in both graphical form and in empirical correlations.

Flow Visualization

Photographs and video pictures were taken only after all information concerning the power input and temperatures had been collected by the data acquisition system. The flow pattern was observed from both the top and the front. A layer of ethylene glycol was added on top of the top plate (but not inside the free convection enclosure) to reduce the heat projected by the light source. The lamp was turned on for as short a time as possible, both to reduce the heating effect on the enclosure and to prolong its life. Pictures of the whole enclosure as well as close-up were taken.

An SLR camera with a 50 mm macro lens, loaded with ASA 50 film combined to give satisfactory results under low light conditions. Time-exposures ranged from 45 seconds to 2 or more minutes (depending

on concentration of the particles, the amount of light and the heater power). A shutter release cable and tripod were used to prevent camera shake. Through experimentation, it was found that an aperture opening of f5.6 gave good pictures for this set-up and lighting. The light source was placed less than 630 mm away from the furthest point of interest.

A KodakTM Carousel AV 900 slide projector served as the light source. A slide with a slit roughly 2 mm wide cut in the middle of it provided projection of only a narrow plane of light. The light source was well supported with rigid, steady stands (Fig. 3-1). The focus of the slide projector was adjusted to produce a thin sheet of light slicing through the plane of interest.

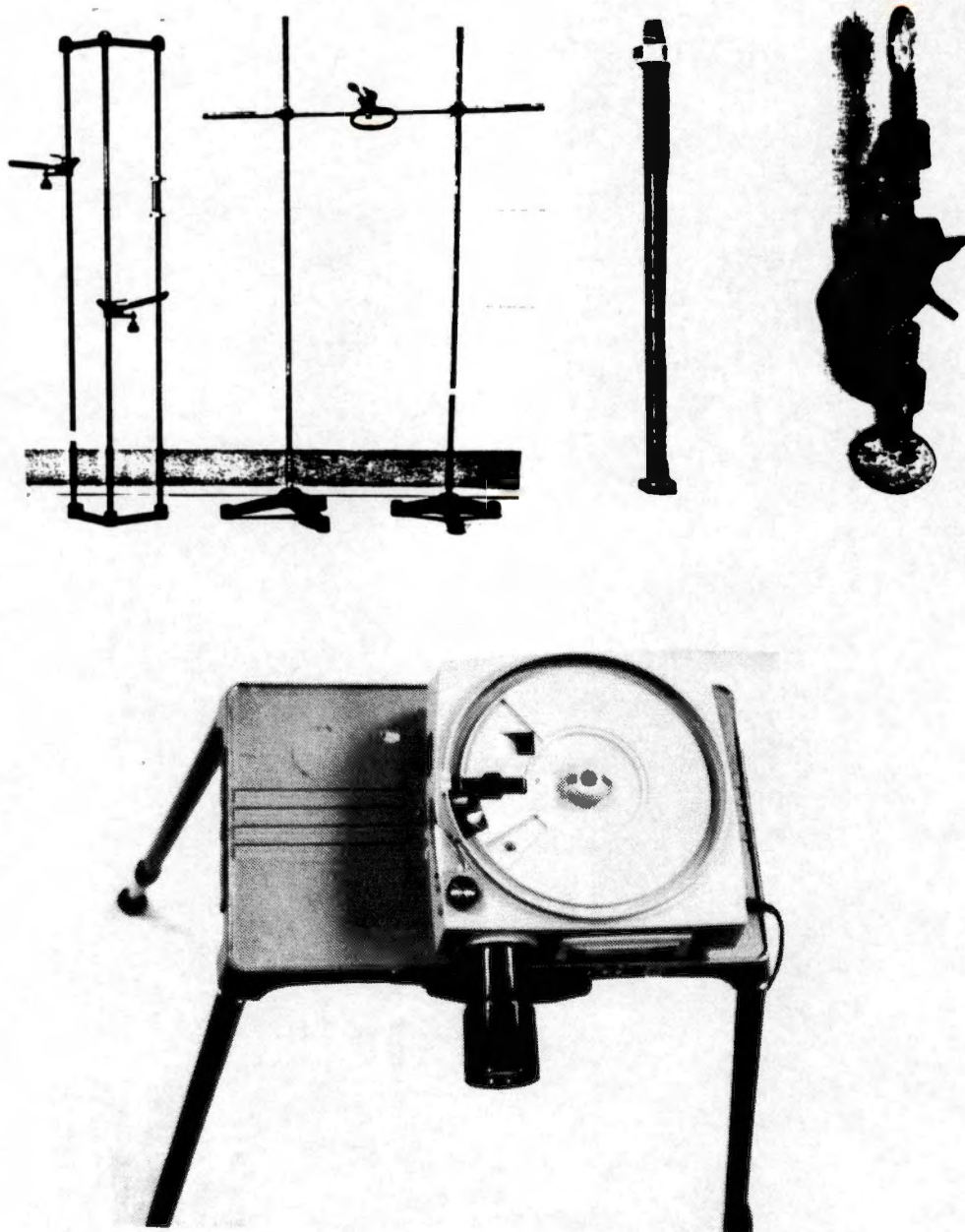


Fig. 3-1 Support, Stand, Clamp, Bolt, Projector and Assembly

CHAPTER 4

DISCUSSION OF EXPERIMENTAL RESULTS

Multicellular Flows

In the present case, although the wall is heated in segments, the flow patterns are similar with those observed for a tall cavity with a fully heated vertical wall. Within the ranges of Rayleigh numbers and aspect ratios examined by this work, only multicellular flows exist. To facilitate the study of the flow fields, the classification of three regions identified by Elder [8] is used:

- (1) the wall region where the streamlines closely follow the form of the wall;
- (2) the interior region adjacent to the wall region;
- (3) the core region where no detectible flow could be observed.

Eckert and Carlson [6] defined "starting corners" as the lower corner on the heated wall and the upper corner on the cold wall, and "departure corners" as the upper corner on the heated wall and lower corner on the cold wall. The cause of hydrodynamic instability is that a column of fluid near the heated wall has lighter weight than a

similar column near the cold wall. Buoyancy forces carry the fluid up the heated wall and across the enclosure to the cold wall. The primary flow is formed by the rising hotter fluid column and the pull of the colder fluid column. The interaction between two boundary layers induces flow. Landis and Yanowitz [26] observed that the fluid velocity up the wall is greater than that flowing down the cold wall. The boundary layer grows in thickness in an upward direction on the heated wall for the fully heated case and in a downward direction on the cold wall. The unheated section has a tendency to restrict the growth of the boundary layer along the discretely heated wall, however. Cross flows occur at the top and bottom of the enclosure due to the geometric constraints (Fig. 4-1). Instead of circulating throughout the entire enclosure, the flow field remains above a horizontal plane which is at approximately the same height as the bottom of the lowest active heater.

The regions near the horizontal, insulated walls have only cross flows (Fig. 4-1, (a) and (c)). Due to the wall damping effect, the first cells are slender and attach themselves on the vertical walls, the blunt side of the teardrop-shape cells facing the direction of the flow (Fig. 4-2, (d) and (e)). In the interior region, the secondary cells tilt with respect to the vertical wall (Fig. 4-3, (a) and (b)). In between the secondary cells, the shear layers generate a tertiary cell (Fig. 4-3, (a) and (b)). Elder [9] pointed out that the shear layer coincides with the largest temperature gradient. A tertiary

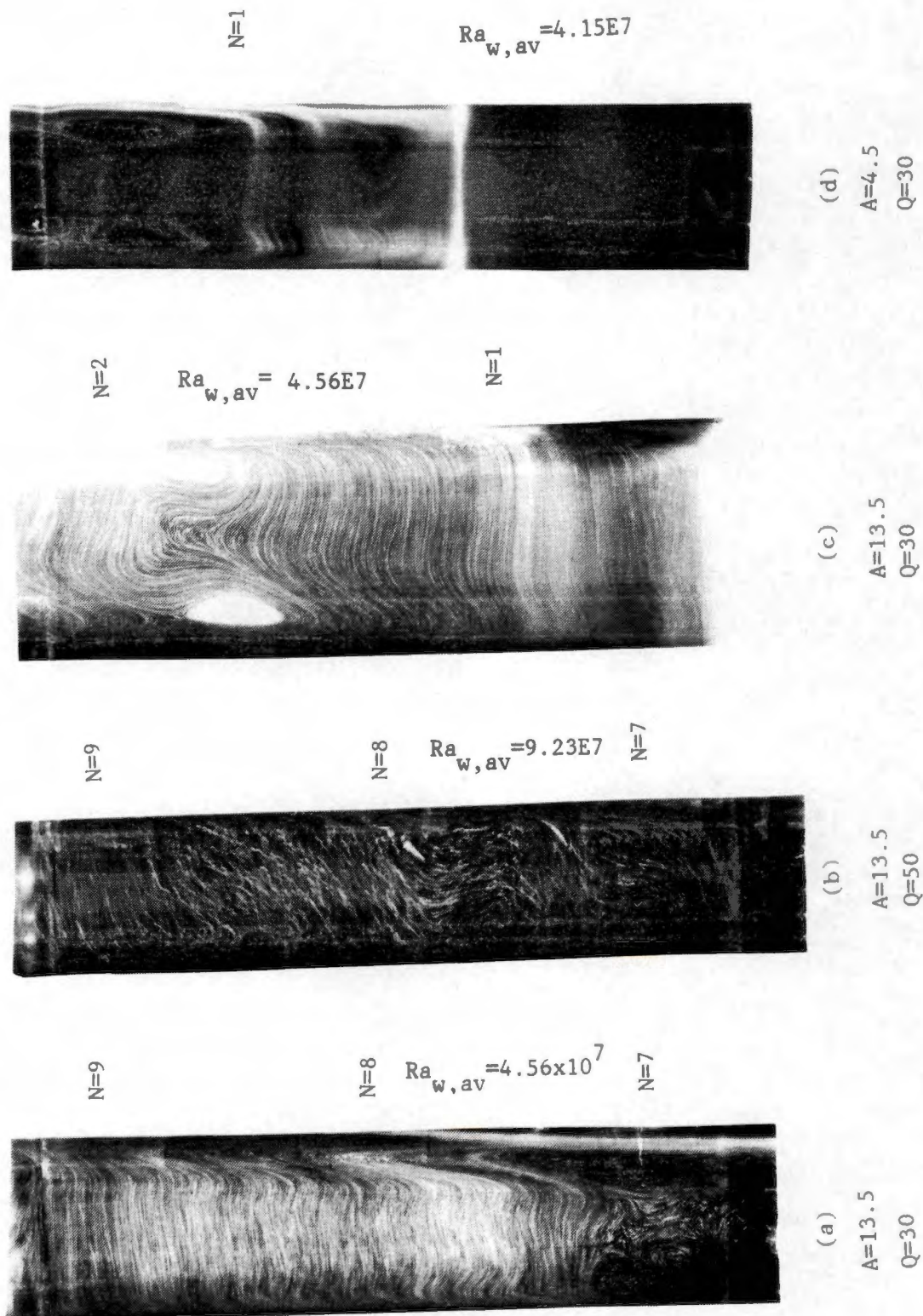


Fig. 4-1 Photographs of Cross Flows and Slender Cells, at Several Heights and Power Inputs

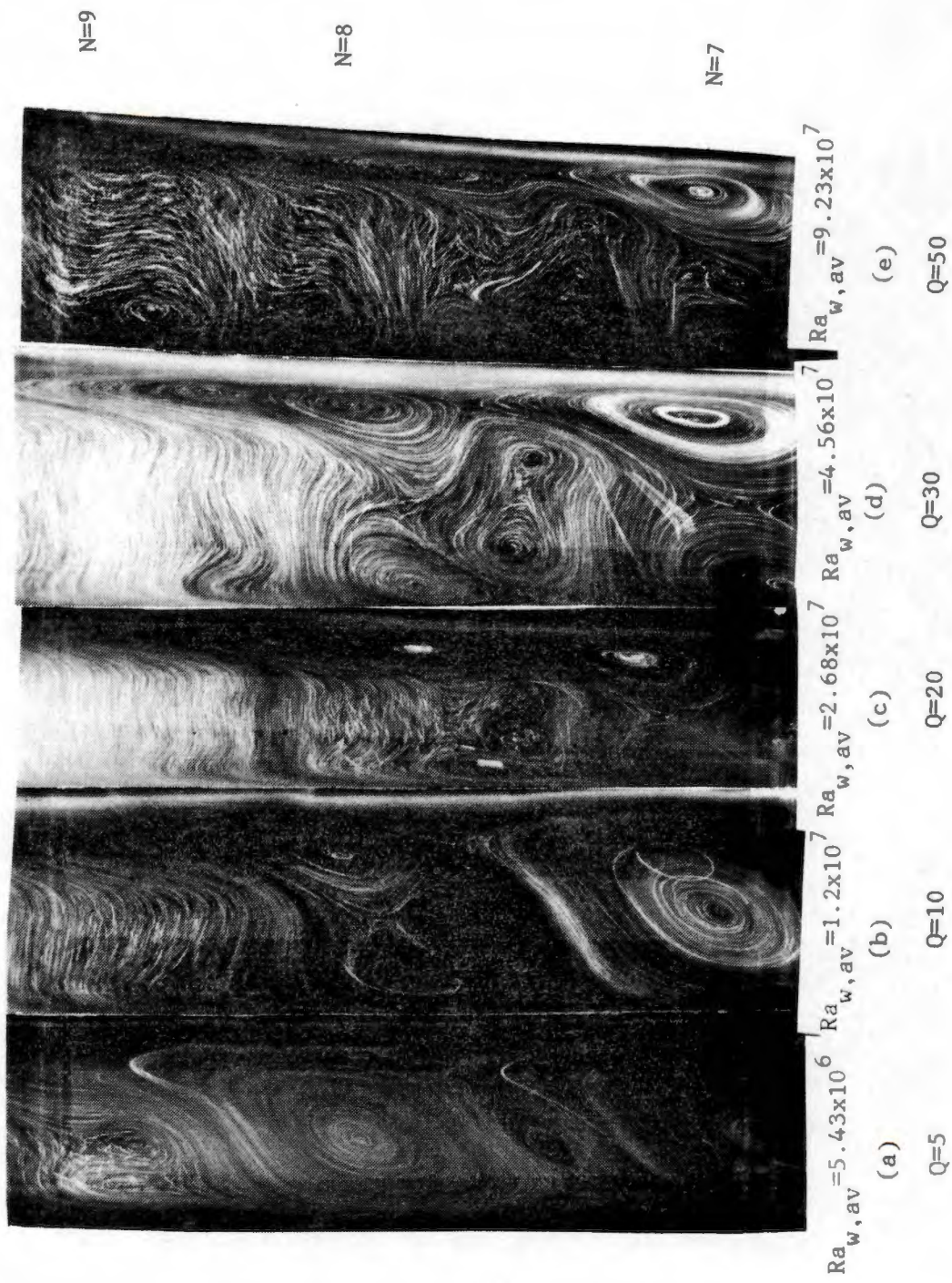
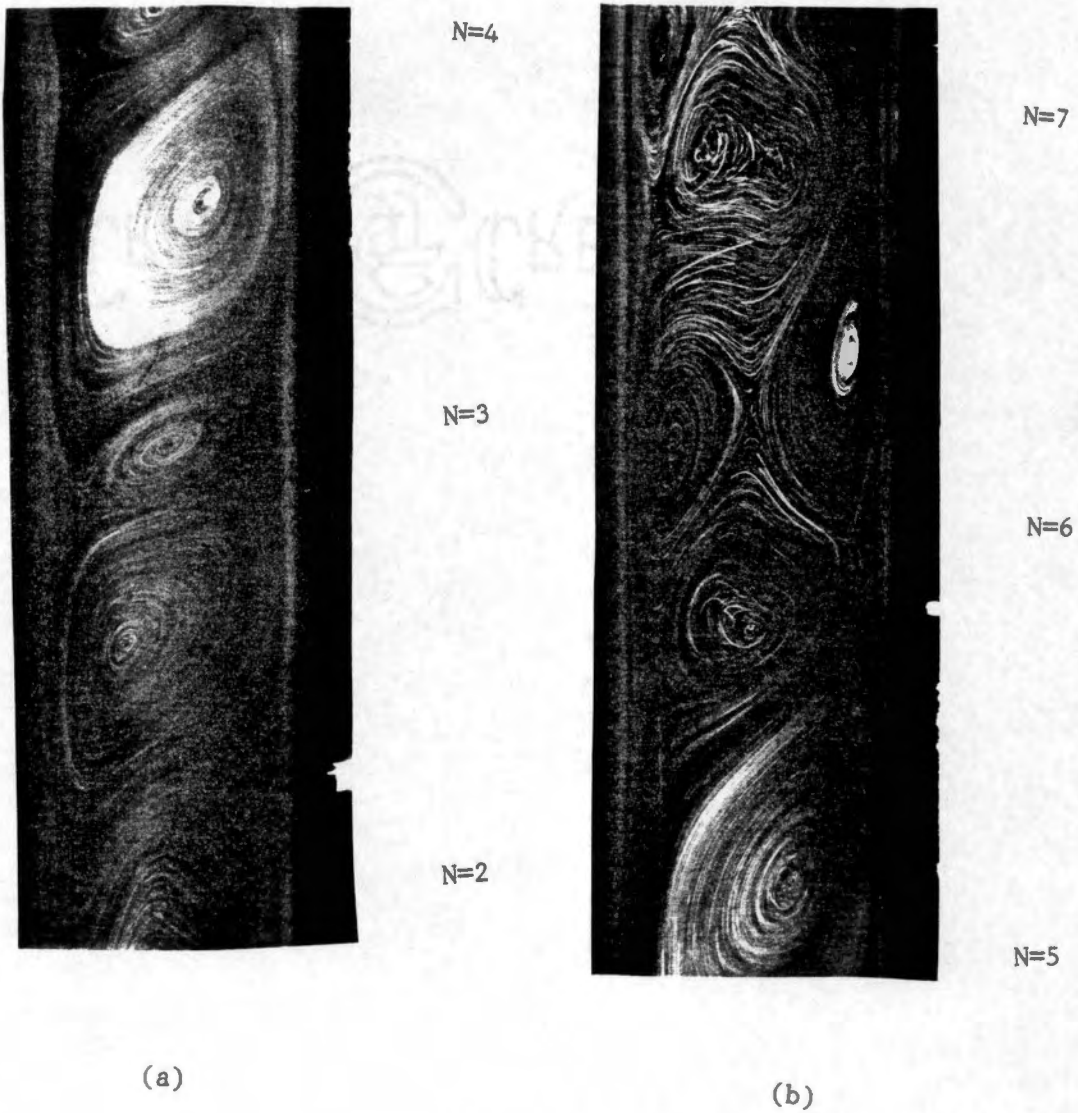


Fig. 4-2 Flow Visualization for Several Power Levels



$$Ra_{w,av} = 2.7E7$$

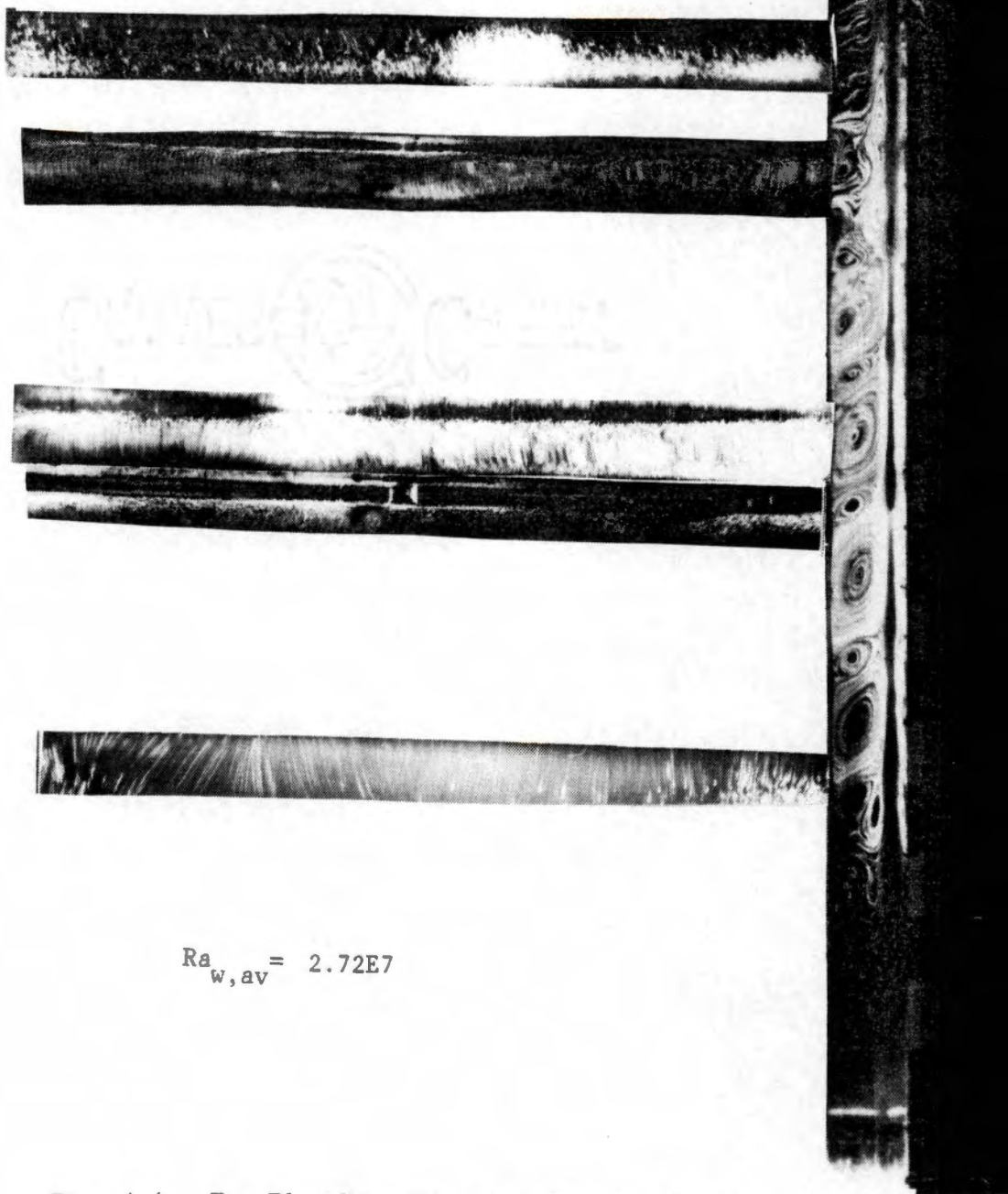
Fig. 4-3 Typical Three-Cell Flow Pattern for Aspect Ratio of 13.5

cell exists right at the middle of each heater, and is especially observable during low power input (Fig. 4-3, (a) and (b)). The direction of circulation for the tertiary cells is opposite to that of the primary and secondary cells (Fig. 2-8, (b), see p. 21). In the present study, the heated wall is on the right-hand-side. The direction of the primary flow and secondary flow is therefore counter-clockwise.

Top visualization of the flows verifies no existing flow in the core, and no particles are seen near the heated sections (Fig. 4-4 and 4-5, dark regions means no accumulation of particles). From pictures taken from the top, one observes the three dimensionality of the flows due to the finite aspect ratios, the smallness of heat sources, and the discrete heating.

Increasing the temperature difference between the two vertical walls speeds up the flows. The shear layers also grow thicker at higher power input. At the same time, the tertiary cell moves closer to the heated wall. The tertiary cell finally breaks into a different pattern of flow (Fig. 4-2 (d), see p. 36). Further increases in the Rayleigh number cause unsteady and turbulent flows in the horizontal wall regions of the enclosure. The travelling wall waves initially appear as slight oscillations of the streamlines. They disrupt the steady cellular pattern in the interior. One travels up the heated wall at the top (Fig. 4-6) and one travels down the cold wall near the bottom. These two travelling wave-like motions induce a turbulent zone in the central portion of the interior, breaking up cells.

Source of Full Enclosure: R. Cox



$$Ra_{w,av} = 2.72E7$$

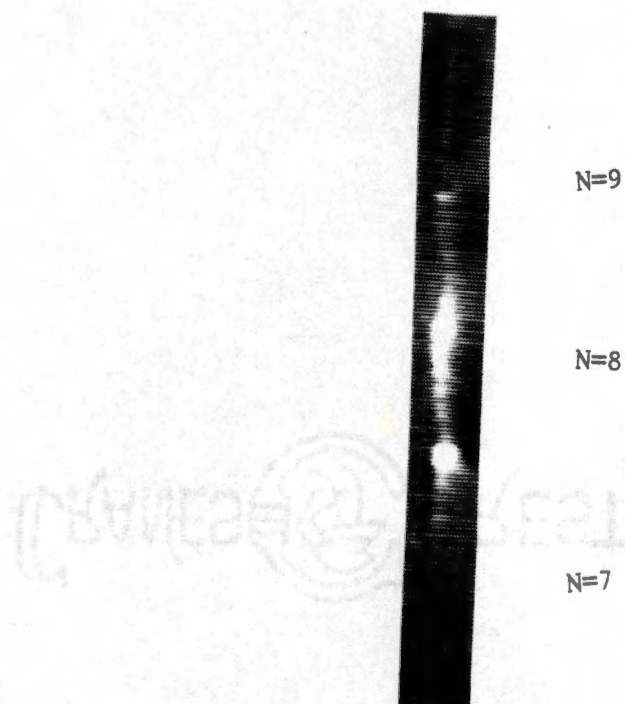
Fig. 4-4 Top Flow Visualization, at 20W Input

Source of Full Enclosure: R. Cox



$$Ra_{w,av} = 9.35E7$$

Fig. 4-5 Top Flow Visualization, at 50W Input



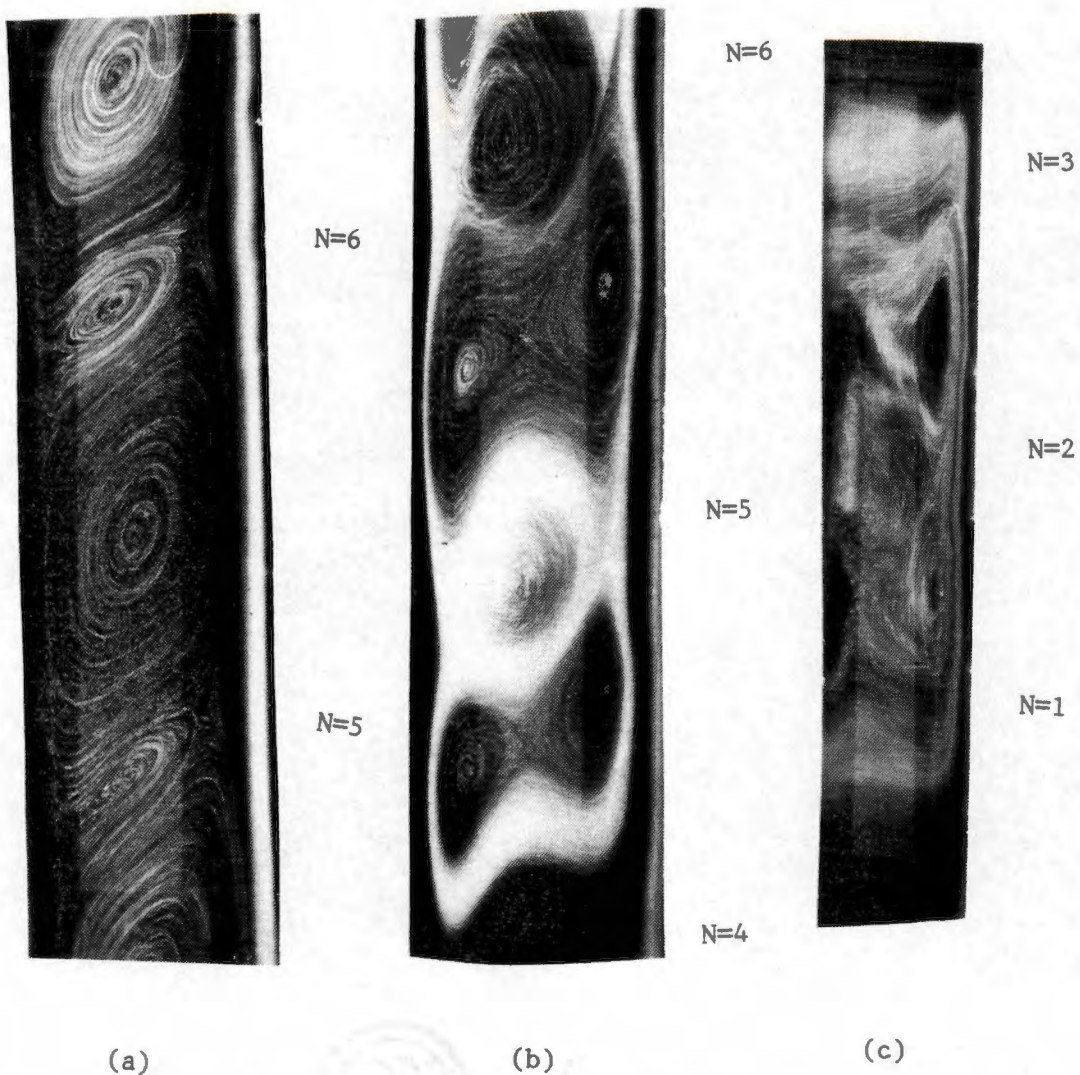
$$Ra_{w,av} = 9.23 \times 10^7$$

Fig. 4-6 Travelling Wall Waves

The appearances of the flows at different aspect ratios and heater spacing are, in general, similar. The cells at lower aspect ratio exhibit the damping effect of the horizontal, insulated walls. They appear as slender cells attaching on walls, with the cell at mid-height having a blunter shape than cells near the horizontal walls (Fig. 4-7). As one increases the spacing between the heaters, the cells are elongated in the vertical direction, however (Fig. 4-8). More still pictures of flow visualization are shown in figures B-1 to B-7 in Appendix B.

Determination of Critical Rayleigh Number

Determination of the flow regimes is difficult. Elder [9] took the uniform temperature interior zone as the indicator of the presence of turbulence. However, Macgregor and Emery [28] suggested that the uniform temperature interior zone is the indicator of the boundary layer regime (Fig. 4-9 and 4-10, also Fig. B-8 to B-15, and Appendix D). Bergholz [3] defined regimes with the vertical temperature gradient, i.e.: no variation indicates a conduction regime; a stable vertical temperature gradient in the core indicates a transition regime with diminishing vertical velocity. The stratification parameter is a function of the ratio of the vertical to the horizontal temperature gradients. To determine both vertical and horizontal temperature gradients is an inconvenience for design purposes, however. Based on boundary-layer theory, Emery and Chu [12] suggested that when the slope of a log-log plot of Nu vs. Ra (see Appendix A for all symbols and abbreviations) is 0.25, the flow is laminar; when



$$Ra_{w,av} = 1.1E7$$

Fig. 4-7 Flow Fields for 10W Input at Several Heights

$A = 13.5$



$N=6$

$N=5$

(a)

$Ra_{w,av} = 6.8 \times 10^7$

$A = 16.5$



$N=6$

$N=5$

$N=4$

(b)

$Ra_{w,av} = 5.5 \times 10^7$

Fig. 4-8 Flow Fields for Pitch to Height Ratio of 2 and 6

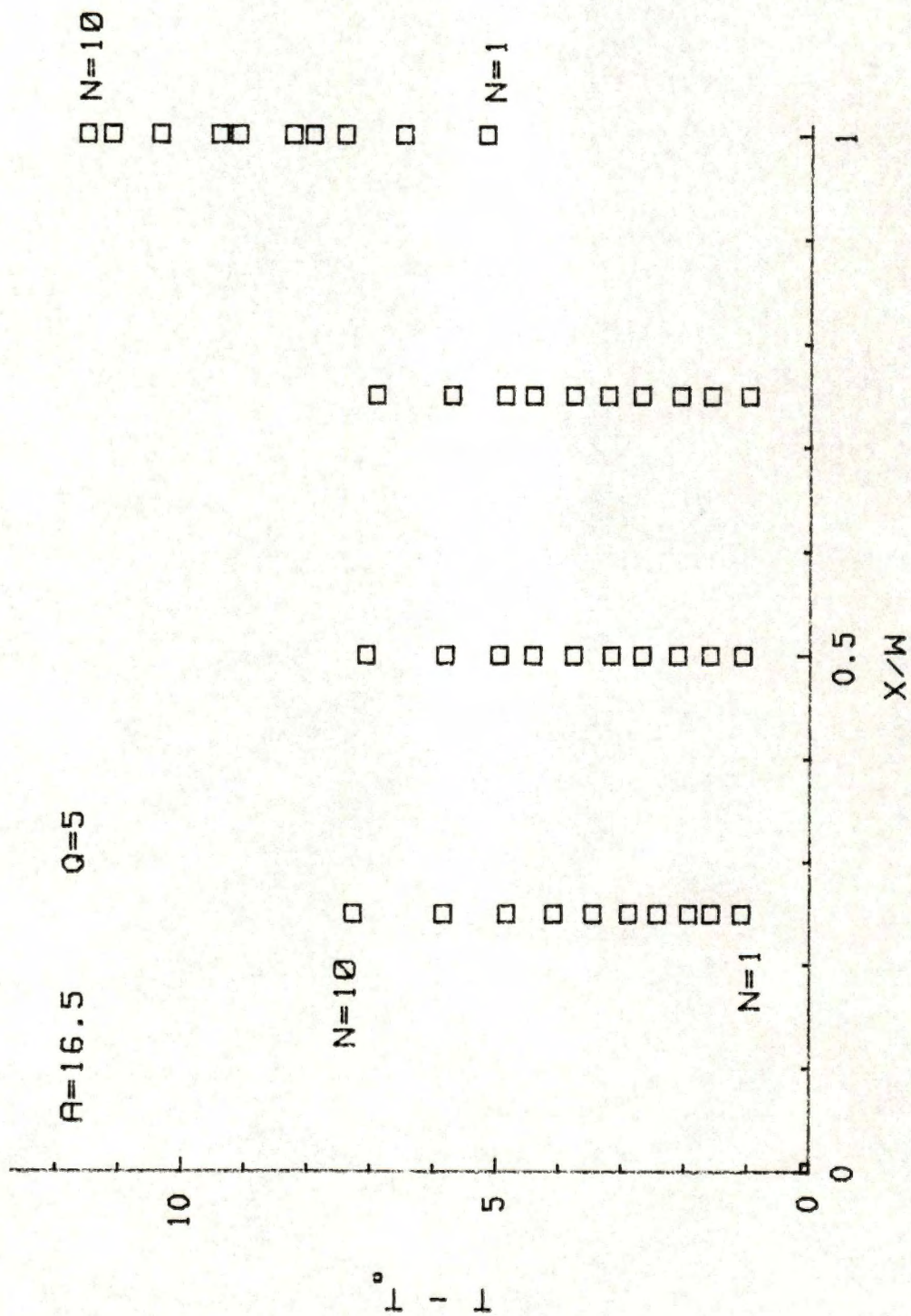


Fig. 4-9 Probe Differential Temperature as a Function of X for Various Heaters, Aspect Ratio 16.5, 5W Input .

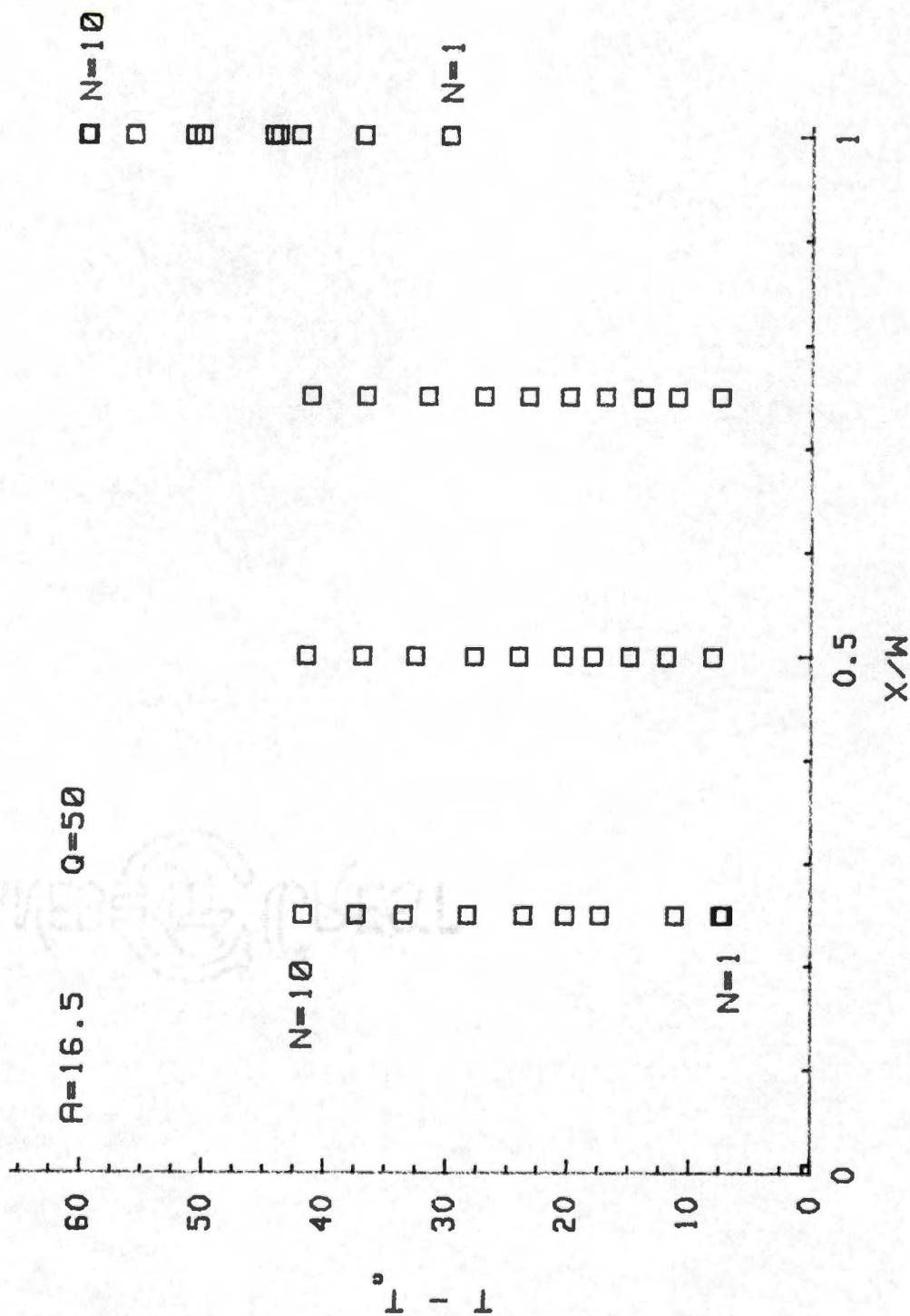


Fig. 4-10 Probe Differential Temperature as a Function of X for Various Heaters, Aspect Ratio 16.5, 50W Input

the slope is 0.33, the flow is turbulent. Although this present work did not find a significant change of slope (see Figs. 4-11 and 4-12; and Figs. B-17 to B-24; and Table C-12), the pictures taken clearly indicate the initialization of turbulent flow within the range of Rayleigh numbers studied. Use of different reference temperatures can alter apparent results. Moreover, Eckert and Carlson [6] assumed that the temperature variation in the core of the fluid is responsible for the value of the exponent of Ra in the Nu vs. Ra correlation. They obtained a correlation that has an exponent suggesting turbulent flow which does not agree with visual observation.

Zong, Yang and Lloyd [40] obtained a correlation with a slope of nearly one-third for the convection-dominated regime using their recommended reference temperature. Keyhani, Prasad, and Cox [24] made the discovery that the exponent does not monotonically vary with the heater location. Although flow visualization is also a cumbersome tool to determine critical Rayleigh number, it is one of the best. From flow visualizations (p. 35, p. 41, and Appendix D), the critical modified Rayleigh number based on local height (Ra_y^*) is estimated to be 1×10^{12} .

Heat Transfer

One major finding of this present work indicates an improvement on heat transfer coefficient with increasing aspect ratio (Fig. 4-13).

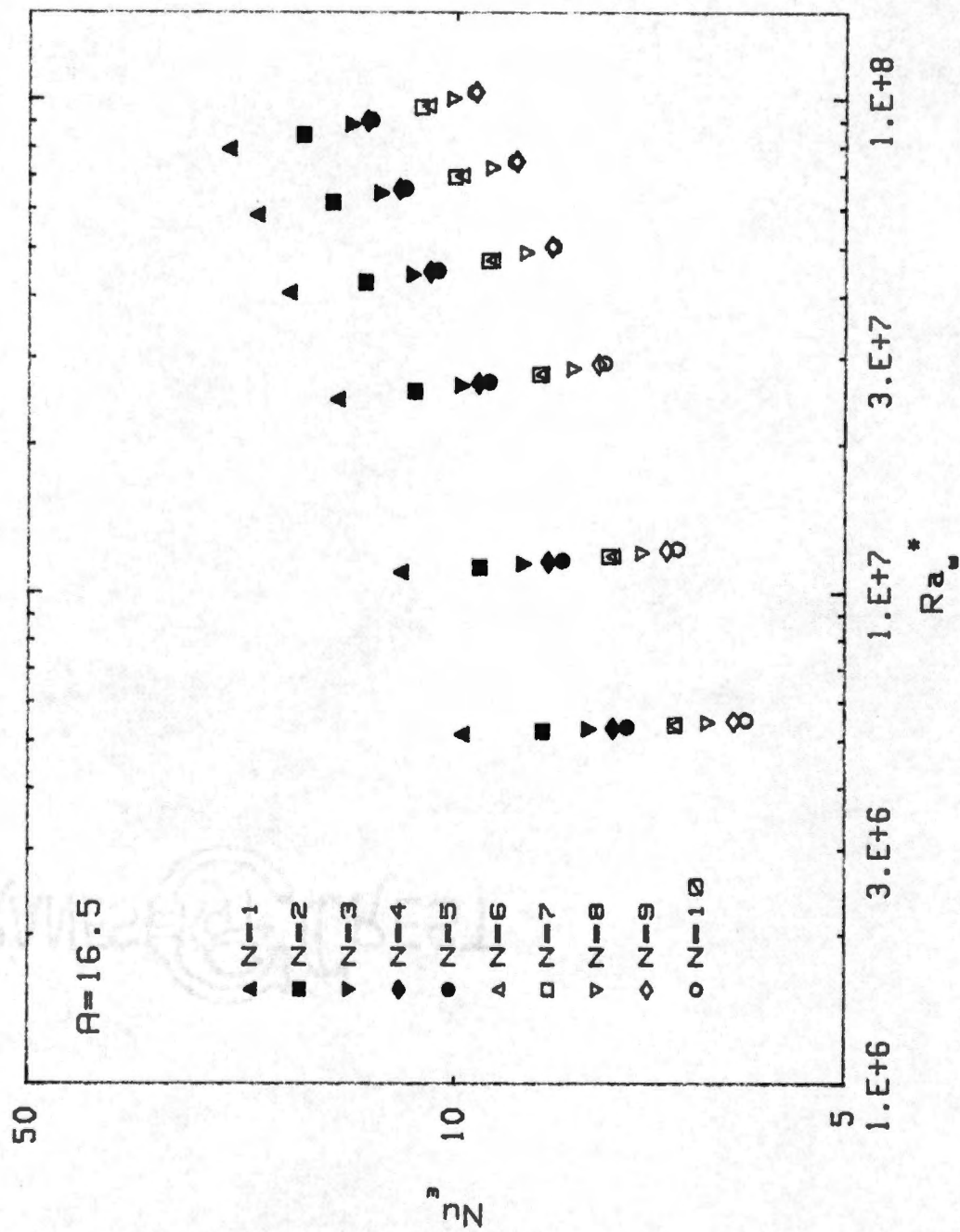


Fig. 4-11 Nu_w as a function of Ra_w^* , Aspect Ratio of 16.5

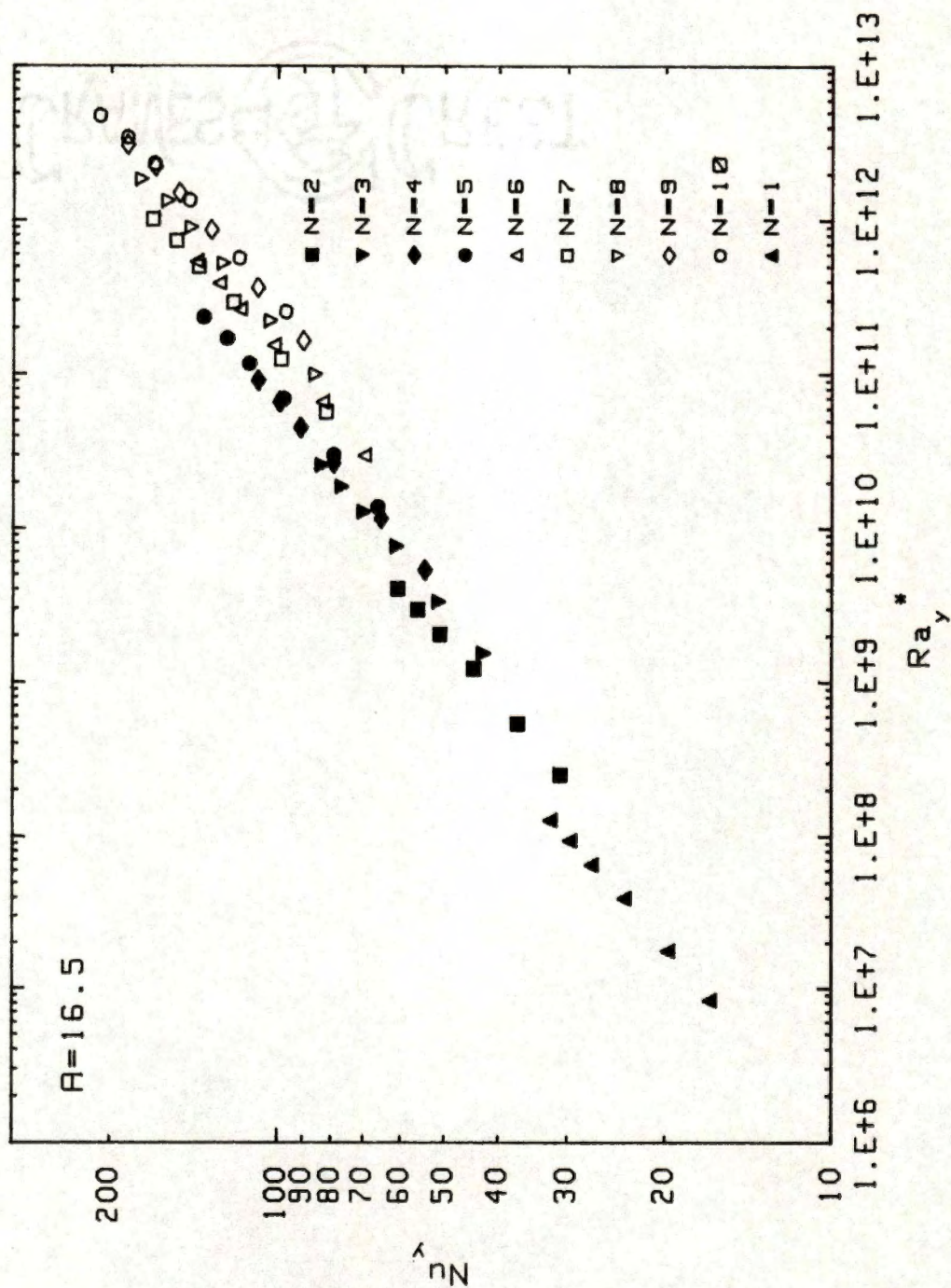


Fig. 4-12 Nu_y as a function of Ra_y^* , Aspect Ratio of 16.5

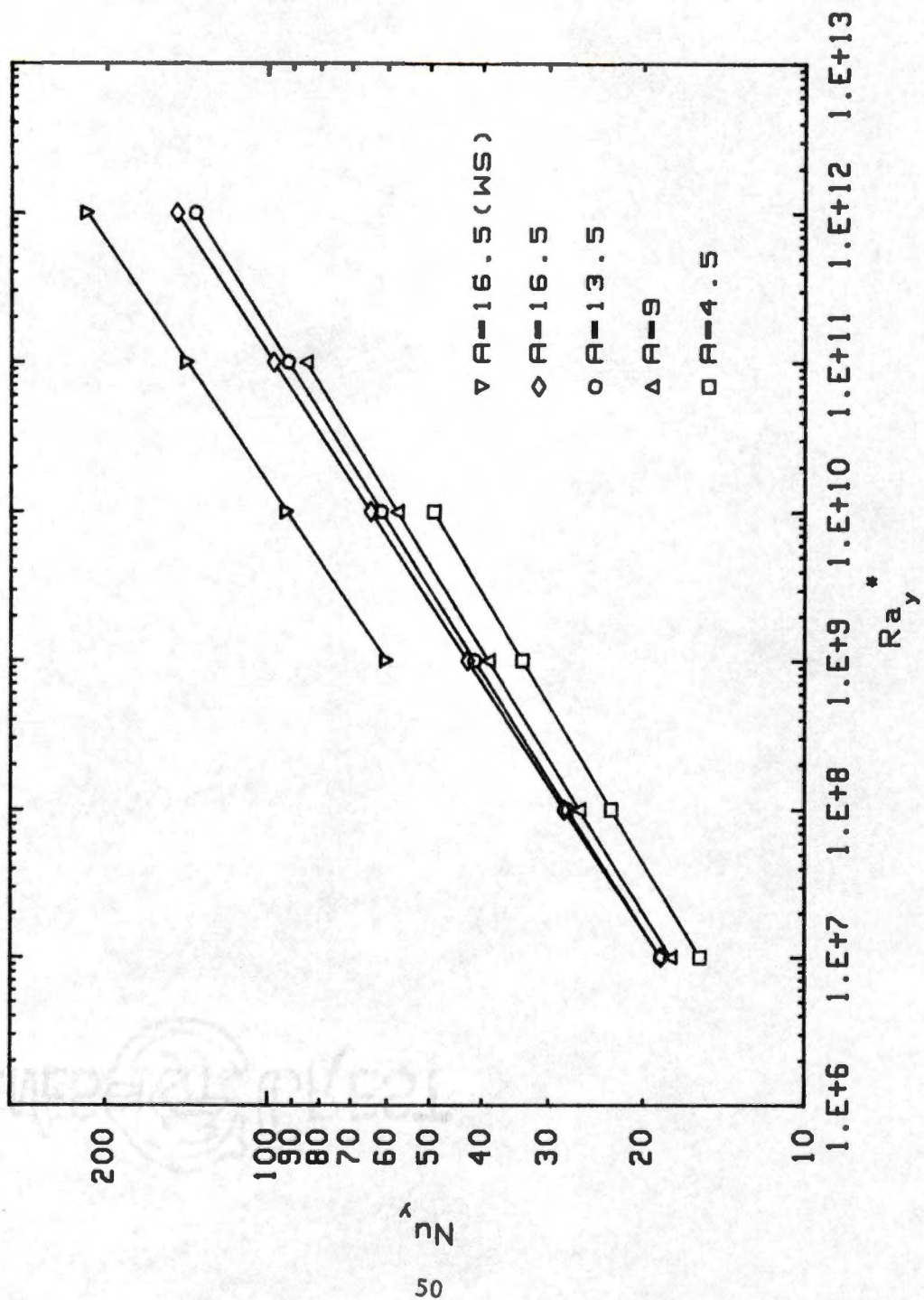


Fig. 4-13 Nu_y as a function of Ra_y^* , Least Square Fitting

Using the least squares method, the correlations are:

$$Nu_y = 1.009(Ra_y^*)^{0.1805}, \quad (4.1)$$

$$Nu_y = 1.13(Ra_y^*)^{0.1736}, \quad (4.2)$$

$$Nu_y = 1.145(Ra_y^*)^{0.1701}, \text{ and} \quad (4.3)$$

$$Nu_y = 1.087(Ra_y^*)^{0.1655}, \quad (4.4)$$

for aspect ratios of 16.5, 13.5, 9, and 4.5 respectively. The absolute average % errors for equations 4.1 to 4.4 are 6.64, 8.04, 7.41, and 8.35, respectively. The effect of aspect ratio on heat transfer coefficient diminishes as the aspect ratio is increased. At low aspect ratio, the horizontal walls damp the flow, secondary cells do not bridge across the cavity, and energy transfer occurs only with fluid near the wall where the cell attaches itself. As the aspect ratio is increased, the two slender cells merge to form a single cell, enabling energy transfer with a much lower sink temperature. The boundary layer does not grow along the hot wall. The unheated section (of the heated vertical wall) acts as a sink and tends to restrict the growth of the boundary layer, reducing the retarding effect of height.

For accurate prediction of surface temperature, correlations for each heated sections are tabulated in Table C-12 and are of the form

$$Nu_w = C(Ra_w^*)^m. \quad (4.5)$$

A generalized correlation representing the effect of aspect ratio is obtained from equations 4.1 to 4.4 and is of the form:

$$Nu_y = 0.9467(Ra_y^*)^{0.152} A^{0.256}. \quad (4.6)$$

Equation 4.6 is for aspect ratios of 16.5, 13.5, 9, and 4.5, and the absolute average % errors are 10.51, 9.83, 8.68, and 9.08, respectively.

The horizontal, differential temperature across the width at the top region of the cavity actually decreases with increasing aspect ratio (Fig. 4-14, and B-25 to B-29). Schmidt [34] studying the effect of aspect ratio on the heat transfer with respect to the fully heated isothermal plate and using air as a medium, found that horizontal partitions improve heat transfer in the conduction regime. Eckert and Carlson [6] explained that a thin horizontal partition causes heat to be transported by convection in the conduction regime with a thinner boundary layer than when the partition is left off. The present study of the convection regime with discrete heating, constant heat flux source, and using liquid as a medium does not show the same trend, however.

Increasing the spacing between heaters did not conclusively show enhancement of heat transfer coefficient (Fig. 4-15, and Fig. B-30 to B-31). Although the elongated cell enables the exchange of energy with a lower sink temperature and also with a wider area of the sink, the slightly higher Nusselt number is within experimental uncertainty. The highest modified Rayleigh number based on cavity width was less than the critical Rayleigh number of 9.6×10^7 (Ra_w^* at heater 7 where transition to turbulent flow begins).

Increasing the power enhances the heat transfer coefficient (see Figs. 4-11 and 4-12, pp. 48 and 49, and Figs. B-17 to B-24). Although at high power inputs secondary cells are disrupted, the existence of better mixing increases the Nusselt number. The increased turbulence at higher Rayleigh number also increases the Nusselt number.

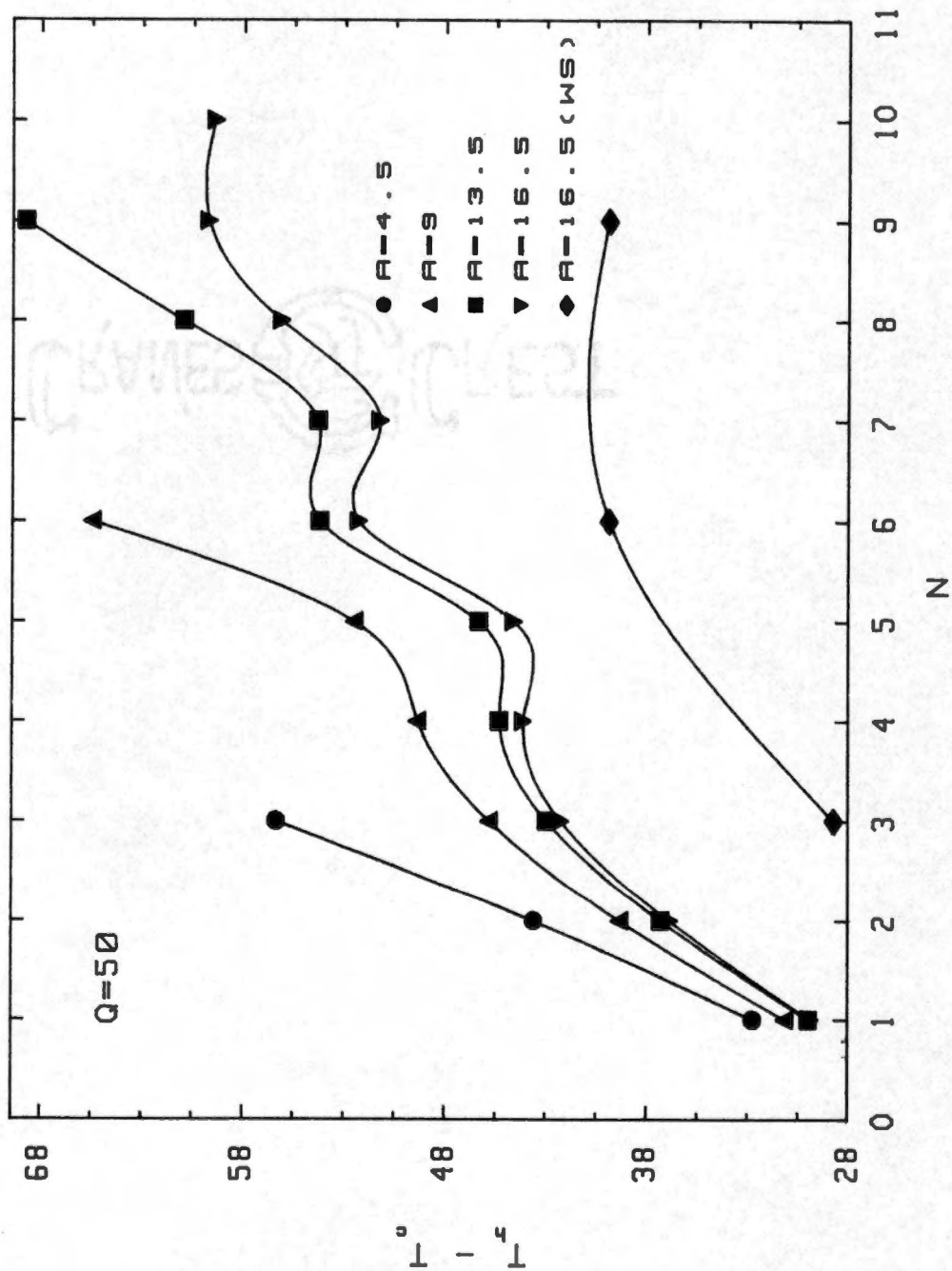


Fig. 4-14 Surface Differential Temperature as a Function of Heater # for Various Aspect Ratios, 50W

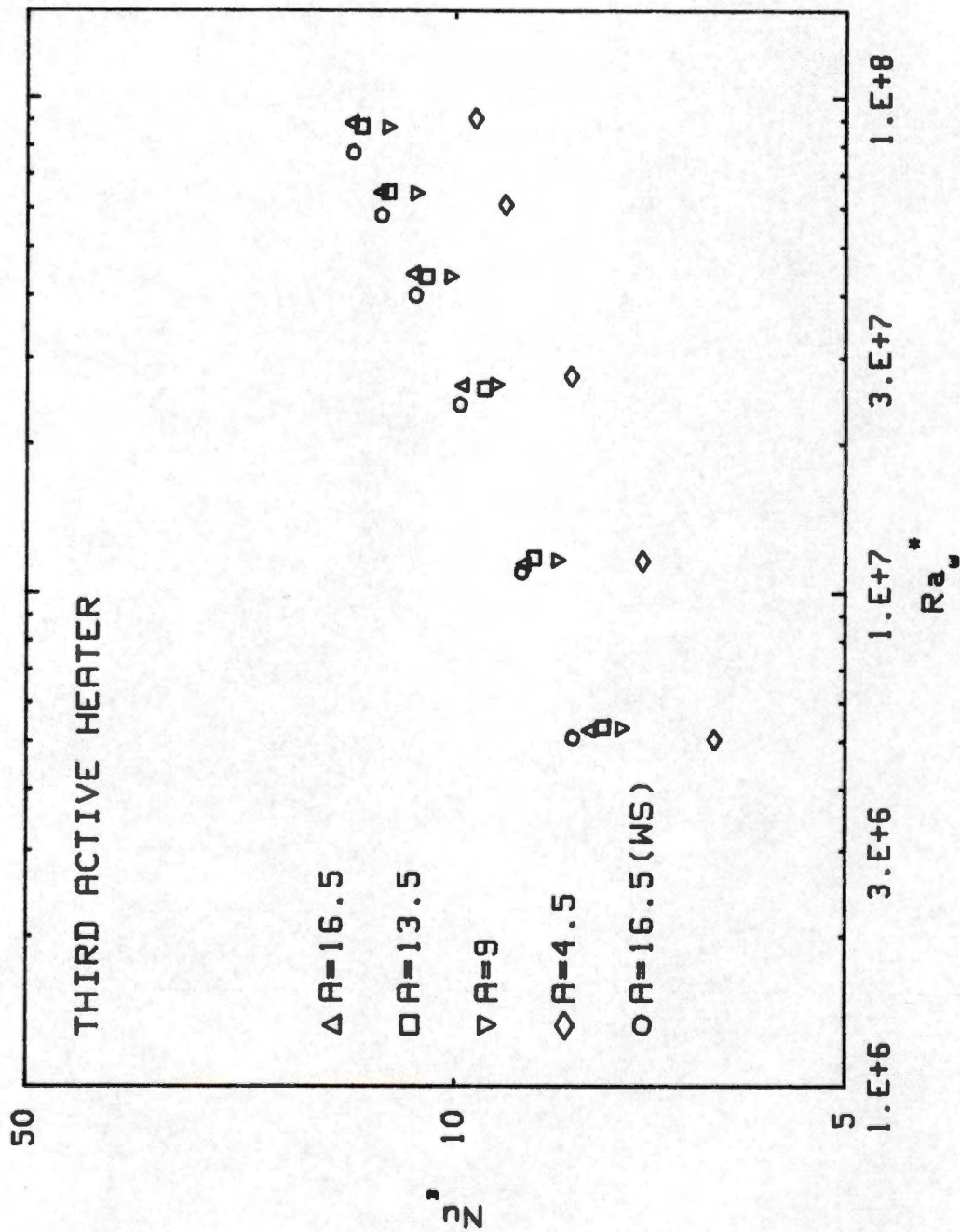


Fig. 4-15 Nu_w' as a function of Ra_w^* , Third Active Heater

Attempts were made to record the temperature variations of the top 4 heaters when the wall wave was present. At 50 watts power input for aspect ratio of 16.5, the temperatures of heater 7 showed no variation. The temperatures of heaters 8, 9, and 10 showed signs of turbulence (Fig. 4-16 and 4-17). The Ra_y^* are 1.01×10^{12} , 1.83×10^{12} , 3.07×10^{12} , and 4.72×10^{12} , respectively, for heaters 8, 9, and 10.

Comparison of the present results were made with those of Vliet [38], Park and Bergles [31], and Ortega and Moffat [29 and 30] (Fig. 4-18). Vliet's, Op.Cit., empirical data were for a smooth vertical flat plate with air and water as convective media. His suggested correlation is

$$Nu_y = 0.6(Ra_y^*)^{0.2}. \quad (4.7)$$

Park and Bergles, Op.Cit., correlated a miniature flush-mounted heat source on a vertical surface, with the expression

$$Nu_y = 1.035(Ra_y^*)^{0.184}. \quad (4.8)$$

Ortega and Moffat's experimental data were for the vertical plate [30] and channel [29] with protruded heating elements. The present study shows a quite unexpected closeness of data taken from seemingly different problems.

Error Analysis

The error of any heat transfer experiment is heavily dependent upon unmeasured heat losses. Such losses in the present study range from as low as 7.5 % for an aspect ratio of 16.5 at 50 W input to as high

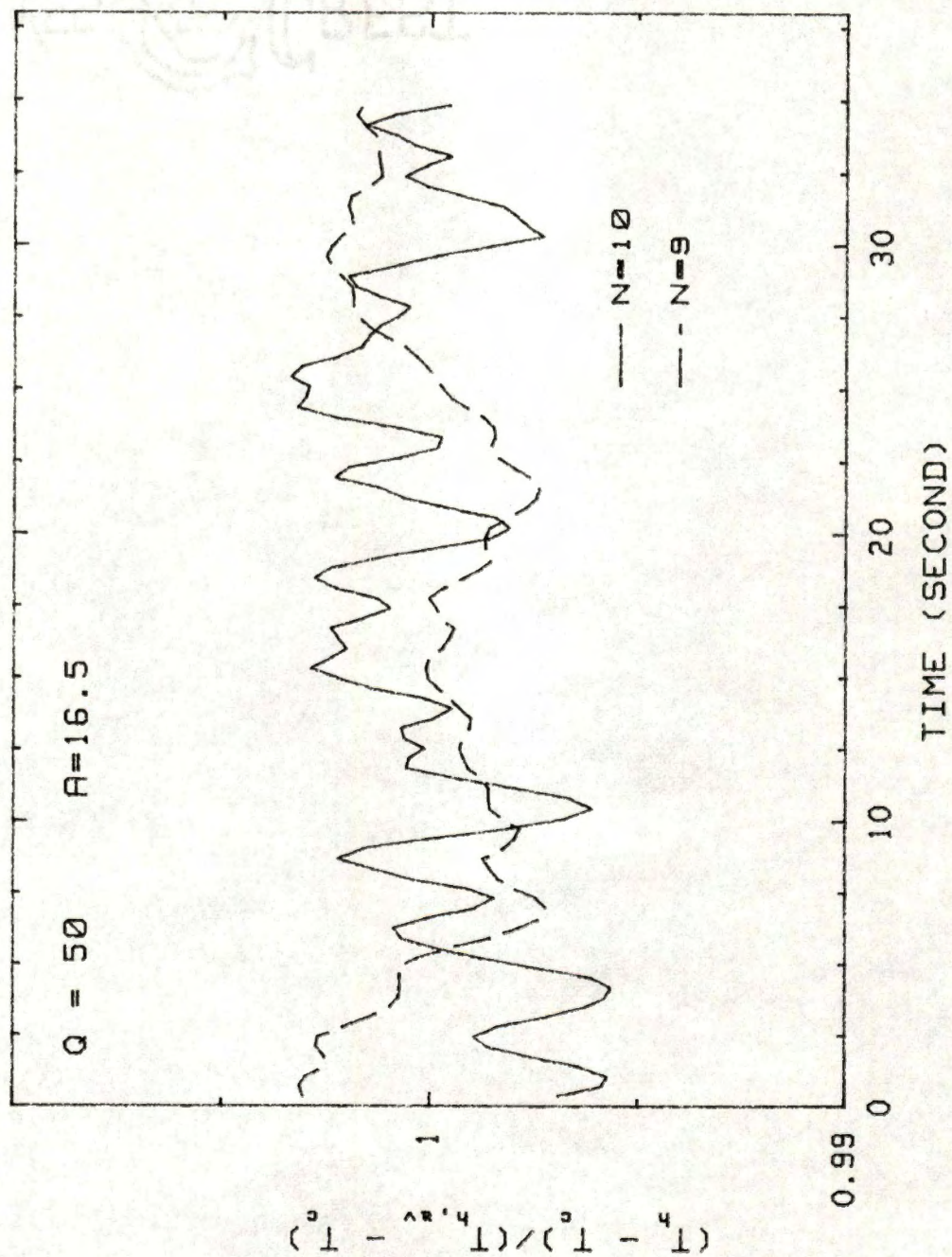


Fig. 4-16 Sample Temperature History for Heaters 7 and 8

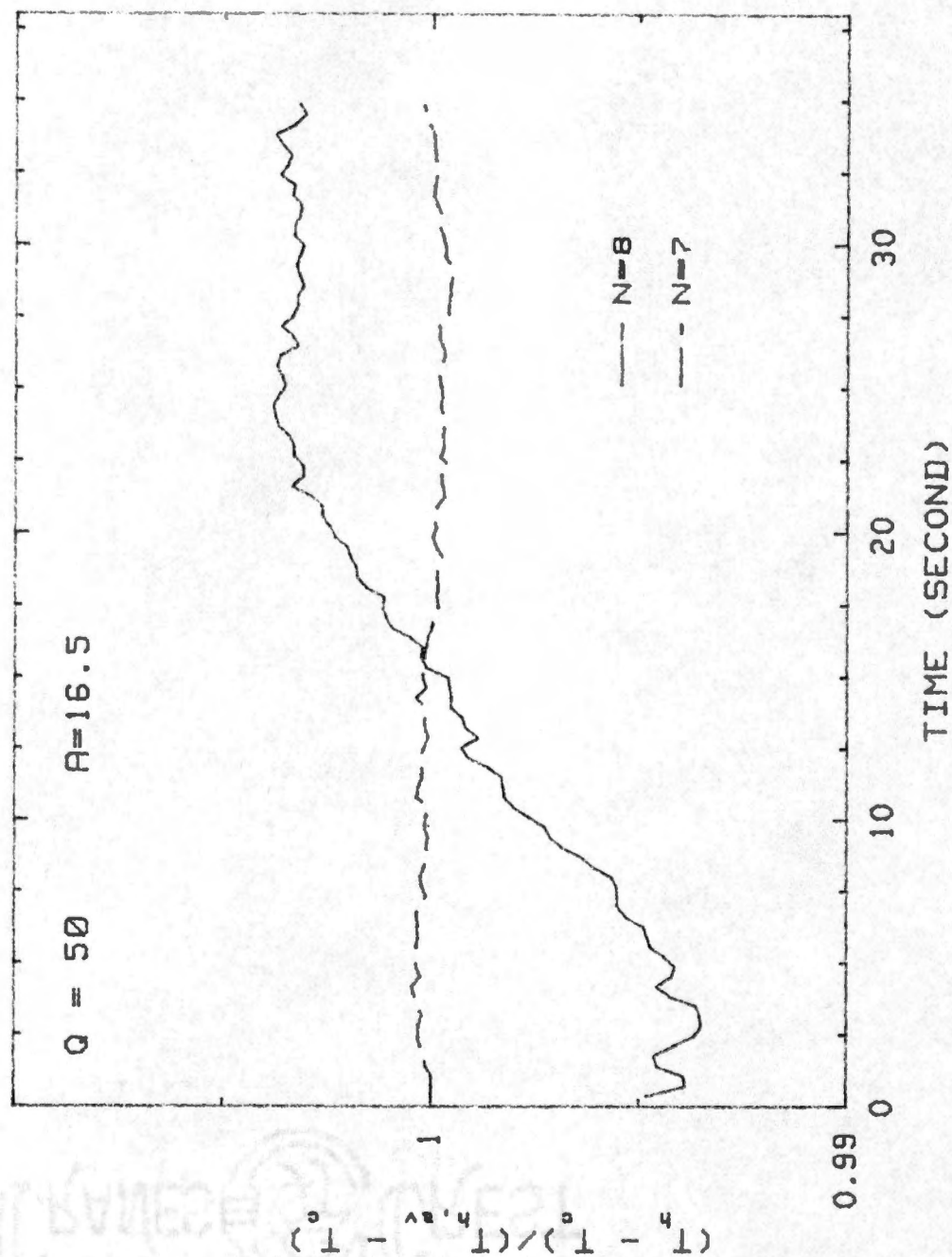


Fig. 4-17 Sample Temperature History for Heaters 9 and 10

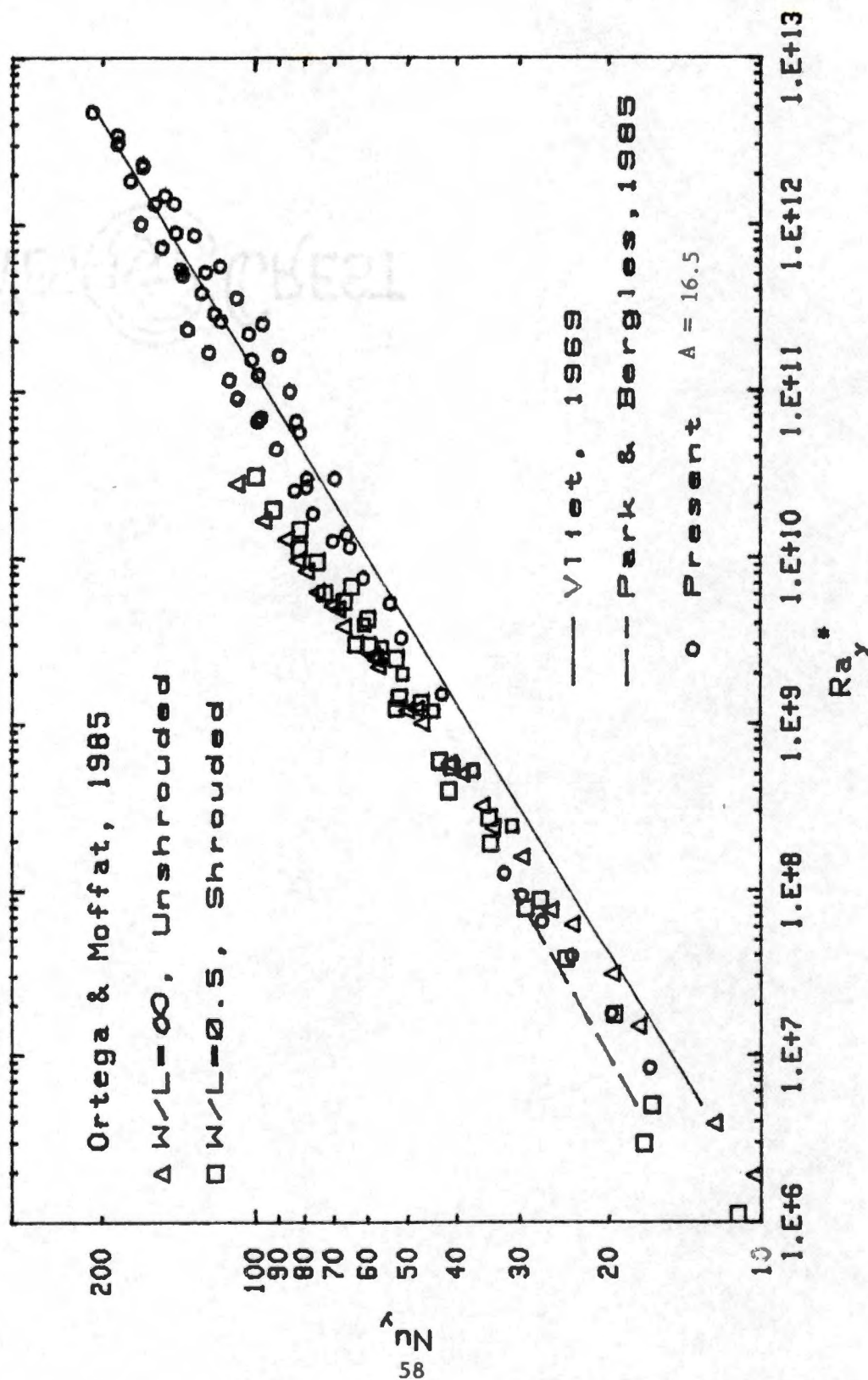


Fig. 4-18 Nu_y as a function of Ra_y^* , Comparison with Other Findings

as 21 % for the aspect ratio of 4.5 at 5 W input (Appendix D). These losses are accounted for in the calculations, however.

The uncertainties were calculated using the method of Kline and McClintock [25]. A higher fraction of energy lost by conduction and lower temperature difference across the cavity result in a higher uncertainty for lower power input. The uncertainty in power input is lower than 1% (Appendix D). The uncertainty associated with the length is .254 mm. The uncertainty in the physical properties is around 6 % (Appendix D). The error is obtained by contrasting the calculated values with those listed in the text of Eckert and Drake [7]. The maximum percentage deviation of resistance is less than 1 % (Table C-10). Including the errors introduced by reference junction (.01 degree Celsius), the accuracy of the temperature measurement is 0.1 degree Celsius.

Using the above uncertainties, the minimum and maximum uncertainties in Nusselt number are calculated to be 3 % and 13 %, respectively. The minimum and maximum uncertainties in Rayleigh number are calculated to be 7 % and 15 %, respectively. The absolute average errors of the correlations of Nu vs. Ra_y^* obtained by least squares fitting are calculated to be below 10.51 %.

CHAPTER 5

FINAL REMARKS

This experimental study of natural convection in an enclosure with cooling from the side provides a basis for more extensive studies of single-phase liquid, immersion cooling in a rectangular cavity with discrete heating. This study yields the following significant results:

- (1) heat transfer correlations, suitable for industrial use;
- (2) information about effects of aspect ratio;
- (3) the effect of heater spacing;
- (4) the percentage of convection heat transfer
via substrate conduction(after deducting heat losses);
- (5) critical modified Rayleigh number; and
- (6) design objectives for maximum possible local
heat transfer coefficients.

Conclusions and Recommendations

A general correlation, equation 4.6, is recommended for use in the ranges of modified Rayleigh numbers as shown in Fig. 4-13 (see p. 50) for respective aspect ratios between 4.5 and 16.5 with normal spacing, when the medium is a liquid. Moreover, equations 4.1 to 4.5 can also be used for their specific cases.

The effect of aspect ratio diminishes with increasing value of aspect ratio. But at low aspect ratio, the difference at higher Rayleigh number is not negligible, the Nusselt number being lower than that of one at a higher aspect ratio. Therefore, for constant heat flux line sources, horizontal partitions (recommended by Schmidt [34] for the fully heated isothermal plate) do not improve heat transfer. Horizontal partitions not only affect the operating characteristics and life of a device, but can lead to unnecessarily expensive manufacturing.

The effect of heater spacing is negligible for the two pitch-to-height ratios of 2 and 6.

The conduction lost through the back of phenolite wall is less than 21 % of the total heat added. The convection heat transfer via substrate conduction (after deducting heat losses) to the unheated wall section is less than 14 % of the total heat convected (Table C-11). These losses have been deducted from the total heat added in the consideration of heat flux transferred.

For a specific design, flow visualization serves as an excellent way to determine the critical Rayleigh number. This information helps the designer to create conditions that initiate local turbulent flow.

Tailoring the surface arrangements to maximize the velocity and minimize the temperatures of liquid flowing over the heated surface is one of the recommended techniques for maximizing local heat transfer coefficients. Disrupting the thermal boundary layer development and delivering cold fluid directly to the heated region is the other one. Further investigation into the generation of cells and their position with respect to the heater location is strongly recommended.

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APPENDIXES

APPENDIX A LIST OF SYMBOLS AND ABBREVIATIONS

Nomenclature

A	aspect ratio, H/W
A_h	surface area of the heated section, m^2
c_p	isobaric specific heat, J/KgK
D	depth of the cavity, m
g	acceleration due to gravity, m/s^2
h	local heat transfer coefficient, W/m^2K , $h = q/(T_h - T_c)$
H	height of the cavity, m
k	thermal conductivity, W/mK
L	pitch for the array of heating elements, $L_1 + L_2$, m
L_1	heater height, m
L_2	vertical distance between heaters, m
L_3	protrusion width, m
L_4	heater width, m
L_5	lateral distance between heaters, m
N	heater row number (starting from the bottom)
NS	normal heater spacing, $L = 38.1$ mm
Nu_y	local Nusselt number, hY/k
Nu_w	local Nusselt number based on cavity width, hW/k
Pr	Prandtl number, ν/α
q	convective heat flux from the heated section based on heater area, W/m^2 , $q = (Q - Q_L - Q_{sc})/A_h$
Q	power input per heated section, W
Q_L	energy lost to the laboratory environment per heated section, W
Q_{sc}	substrate conduction heat transfer from the heated section to the unheated section, W
Ra	local Rayleigh number

Ra_y	$g\beta Y^3(T_h - T_c)/\nu\alpha$
Ra_w	$g\beta W^3(T_h - T_c)/\nu\alpha$
Ra^*	modified Rayleigh number,
Ra_y^*	$Ra_y Nu_y = qg\beta Y^4/\nu\alpha k$
Ra_w^*	$Ra_w Nu_w = qg\beta W^4/\nu\alpha k$
T	temperature, K
W	width of the cavity, m
WS	wider heater spacing, $L = 114.3$ mm
X, Y, Z	Cartesian coordinates, m

Greek Symbols

α	thermal diffusivity, $k/\rho c_p$, m^2/s
β	isobaric volumetric coefficient of expansion, $1/K$
ν	kinematic viscosity, m^2/s
ρ	density, Kg/m^3
σ_{yx}	standard error

Subscripts

av	average
c	cold wall
f	fluid
h	heated wall
H	based on cavity height
m	mean value
w	based on cavity width
y	based on local height

APPENDIX B FIGURES



$Ra_{w,av} = 4.95E6$

(a)

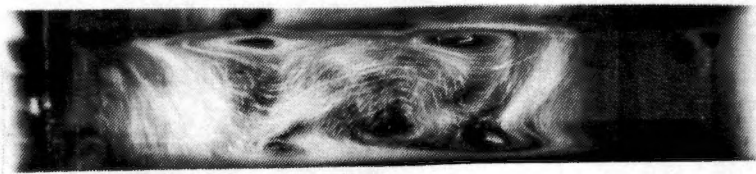
$Q=5$



$Ra_{w,av} = 4.15E7$

(b)

$Q=30$



$Ra_{w,av} = 5.54E7$

(c)

$Q=40$

Fig. B-1 Flow Visualization For Aspect Ratio of 4.5

Q=5

$Ra_{w,av} = 5.34E6$



(a)

Q=50

$Ra_{w,av} = 8.84E7$



(b)

Fig. B-2 Flow Visualization for Aspect Ratio of 9
5W and 50W Inputs

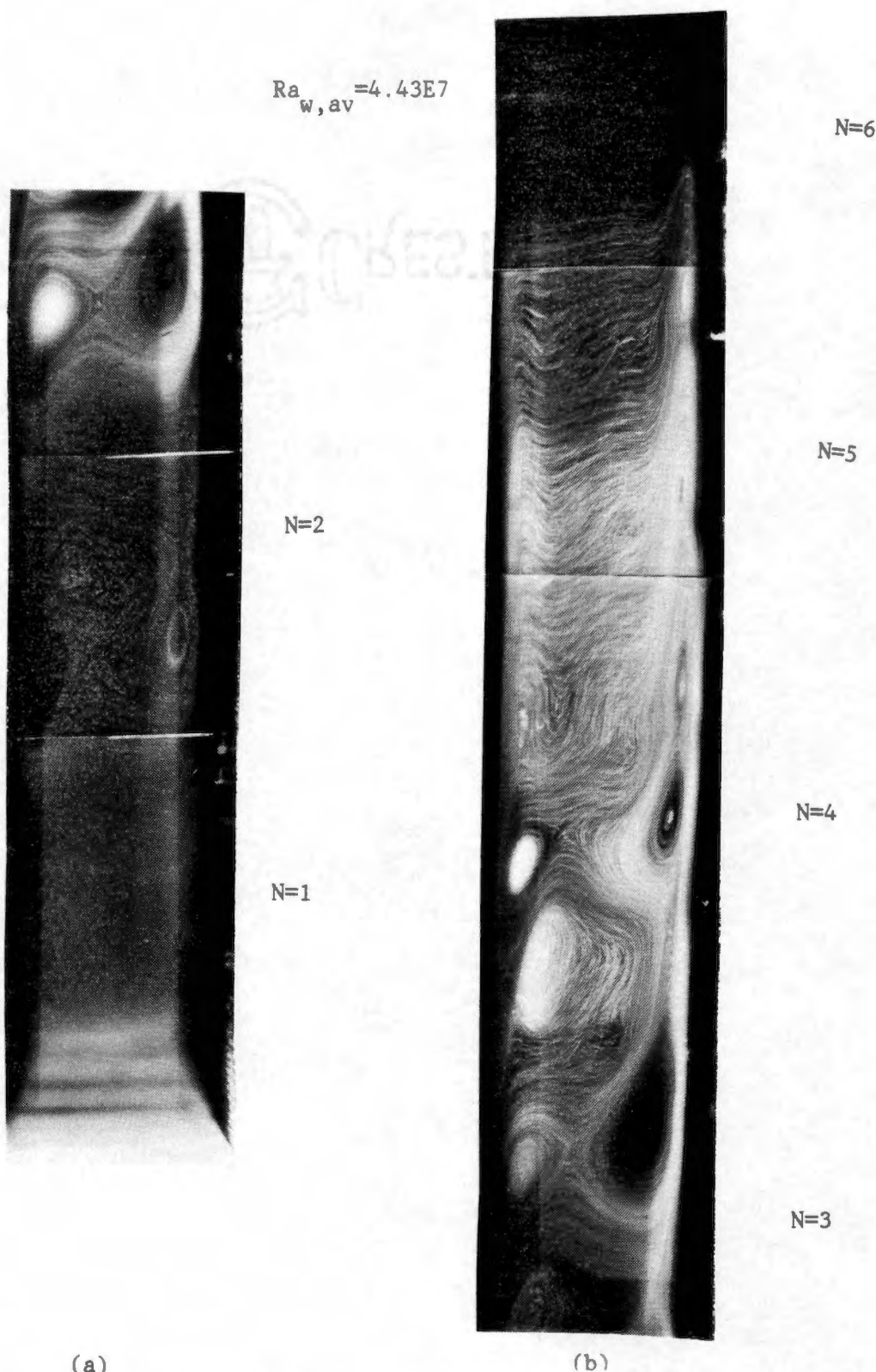
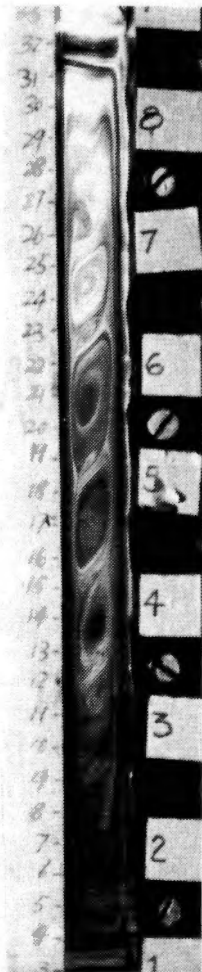


Fig. B-3 Flow Visualization Aspect Ratio of 9, 30W



(a)

$Q=5$

$Ra_{w,av}=5.43E6$



(b)

$Q=50$

$Ra_{w,av}=9.23E7$

Fig. B-4 Flow Visualization: Aspect Ratio of 13.5
5W and 50W Inputs

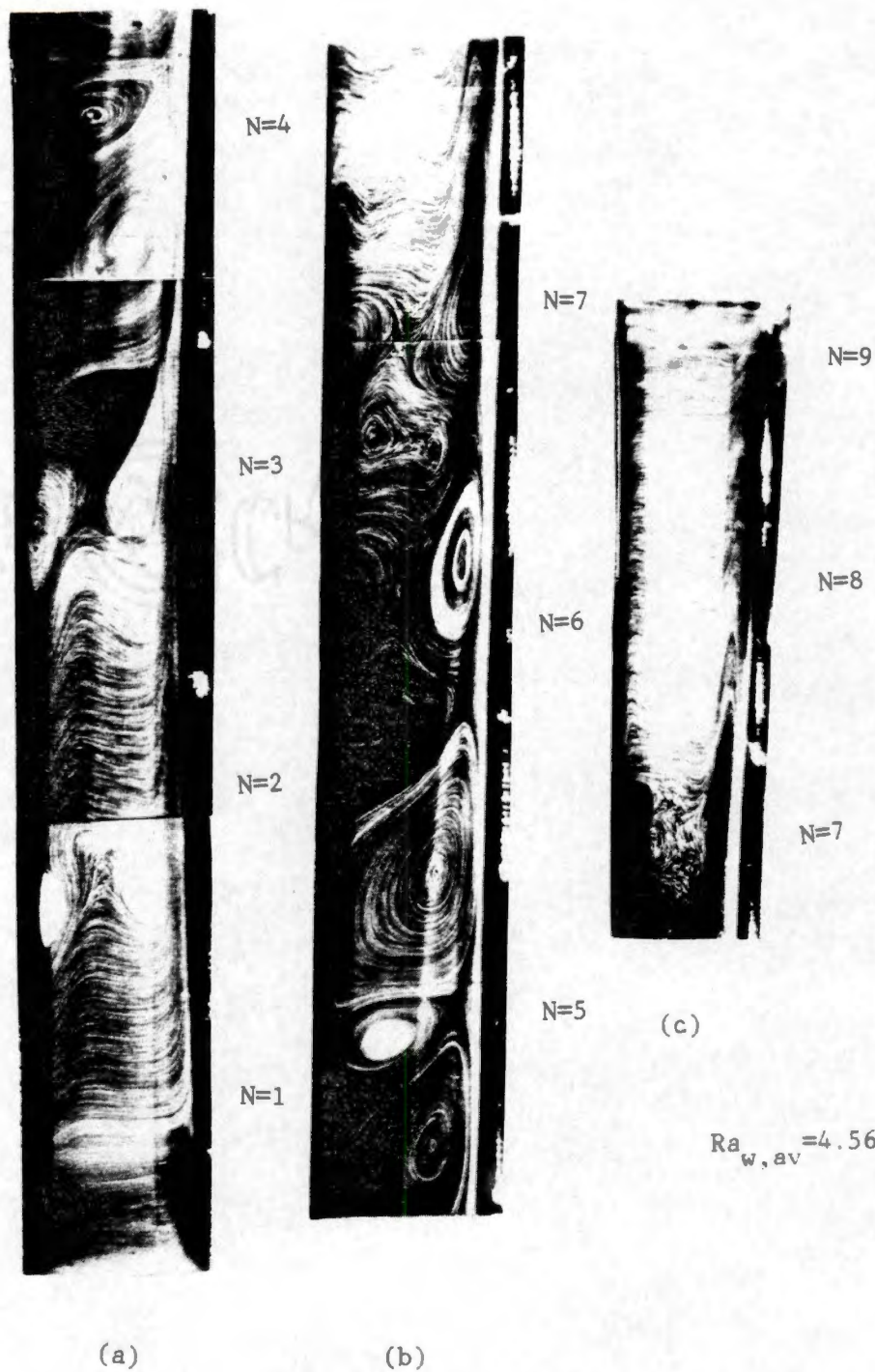


Fig. B-5 Flow Visualization Aspect Ratio of 13.5, 30W Input

$$Q=5, Ra_{w,av} = 5.04E6$$

$$Q=50, Ra_{w,av} = 7.38E7$$



N=9

N=6

N=3

(a)



(b)

Fig. B-6 Flow Visualization Aspect Ratio of 16.5(W) 5W and 50W Inputs

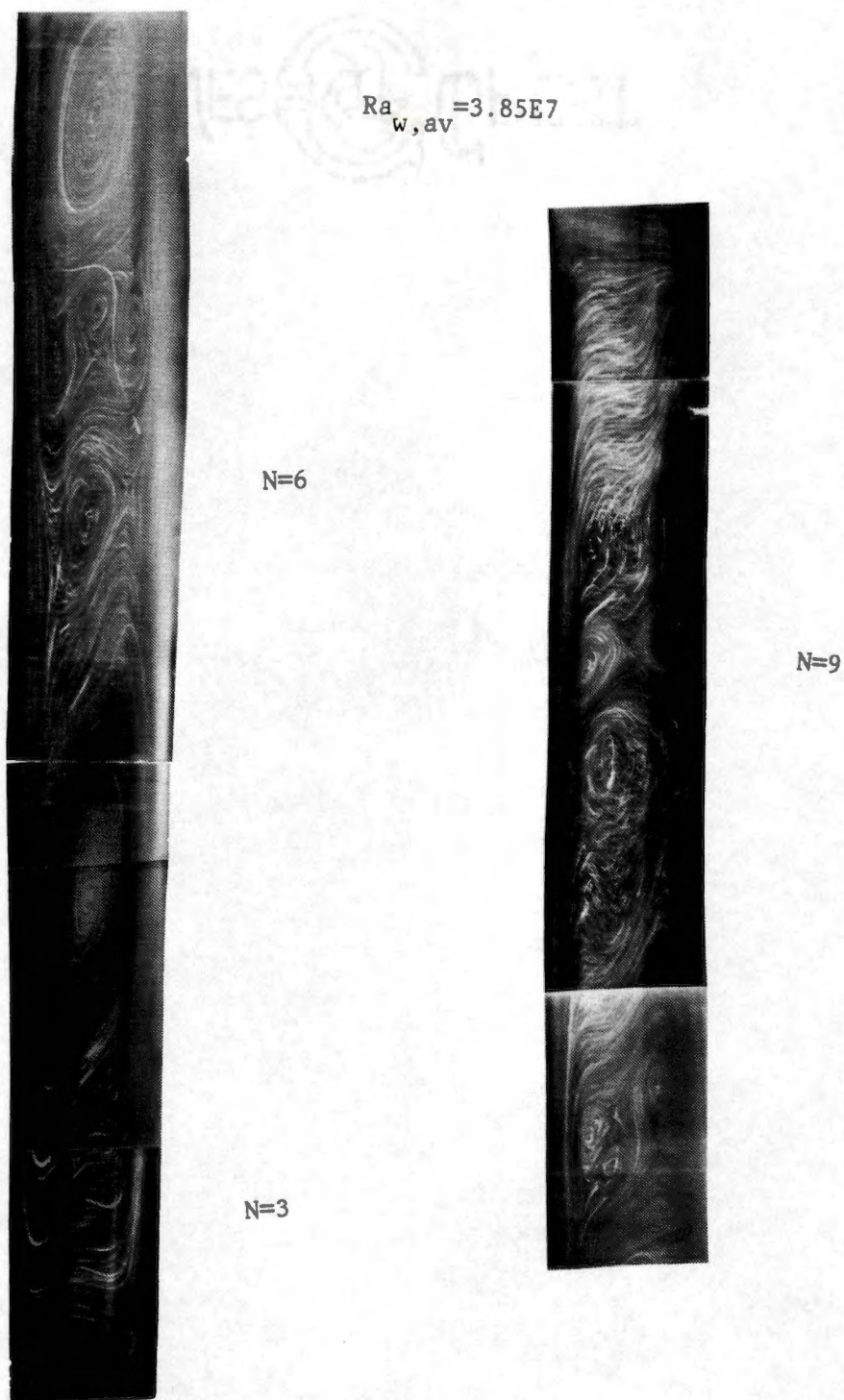


Fig. B-7 Flow Visualization Aspect Ratio of 16.5(W.S), 30W

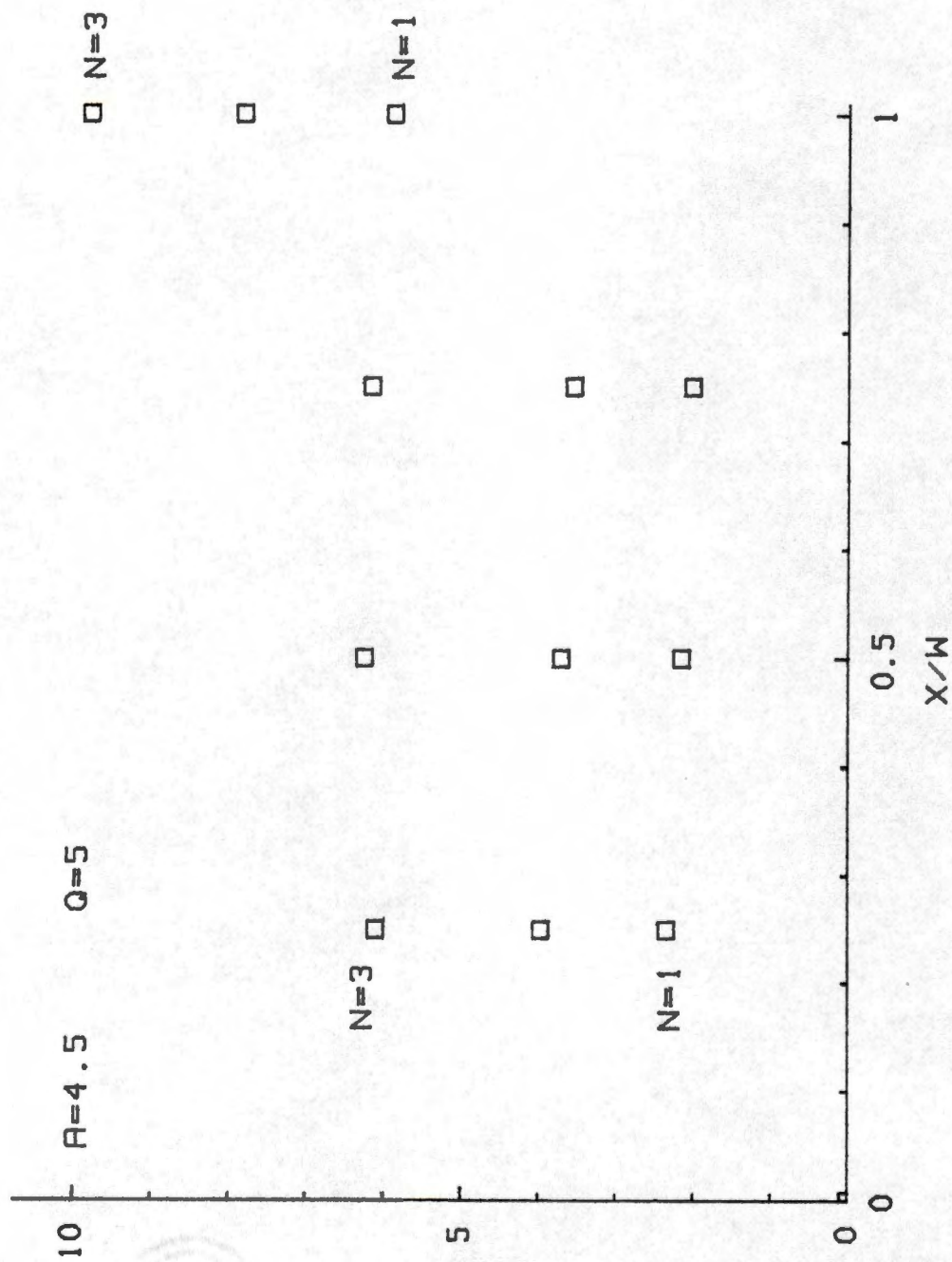


Fig. B-8 Probe Differential Temperature as a Function of X for Various Heaters, 5W, (A=4.5)

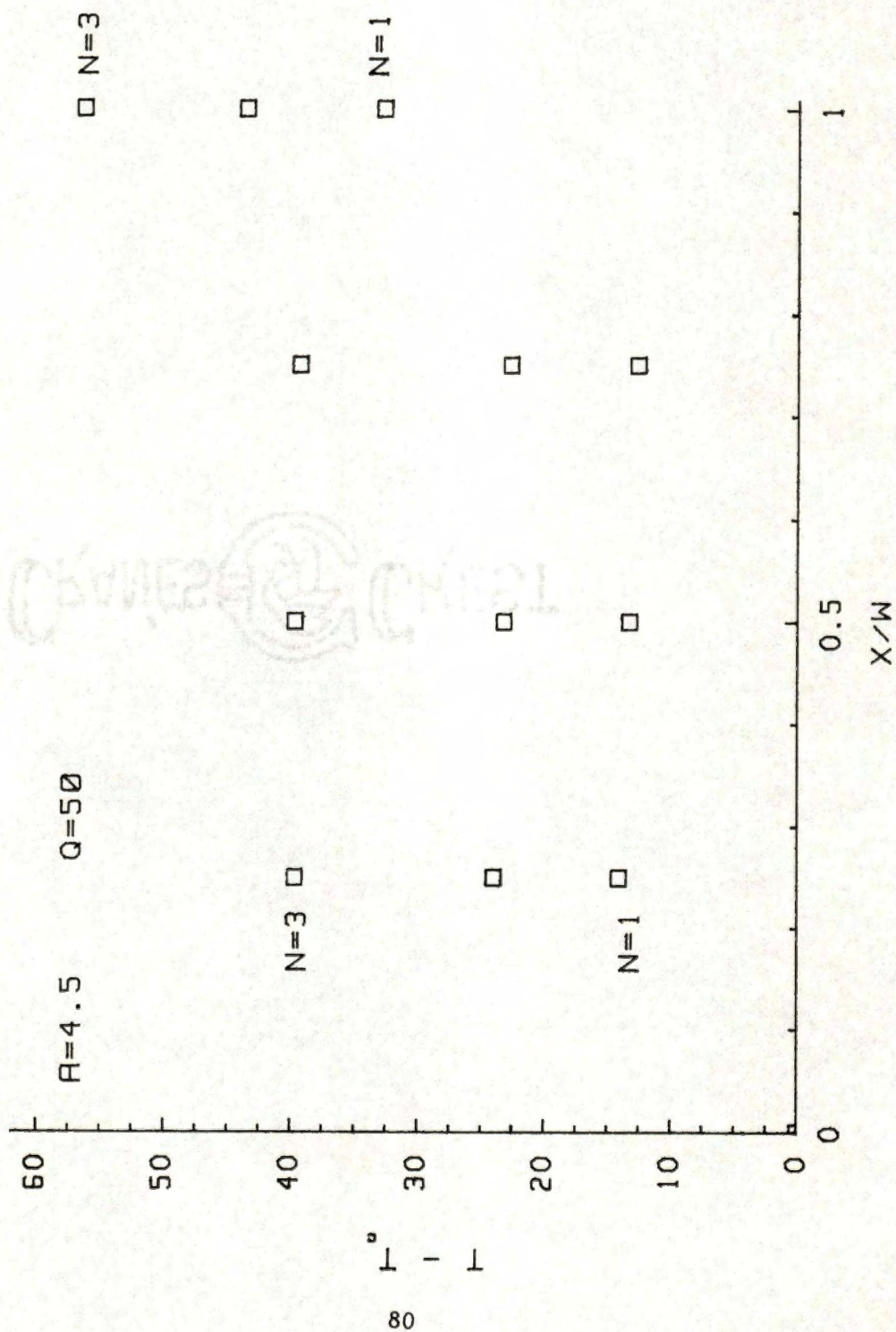


Fig. B-9 Probe Differential Temperature as a Function of X
for Various Heaters, 50W, (A=4.5)

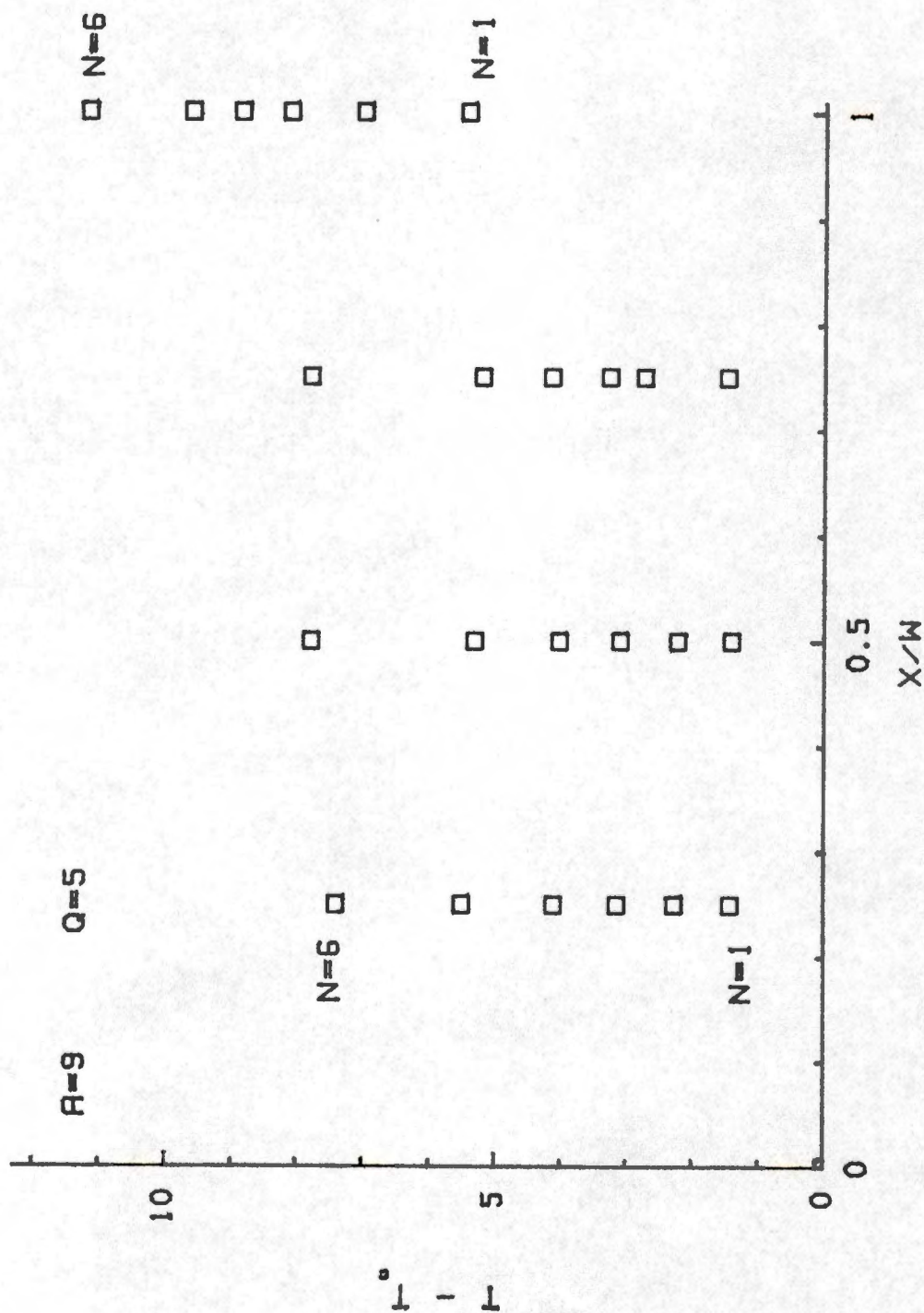


Fig. B-10 Probe Differential Temperature as a Function of X for Various Heaters, 5W, ($A=9$)

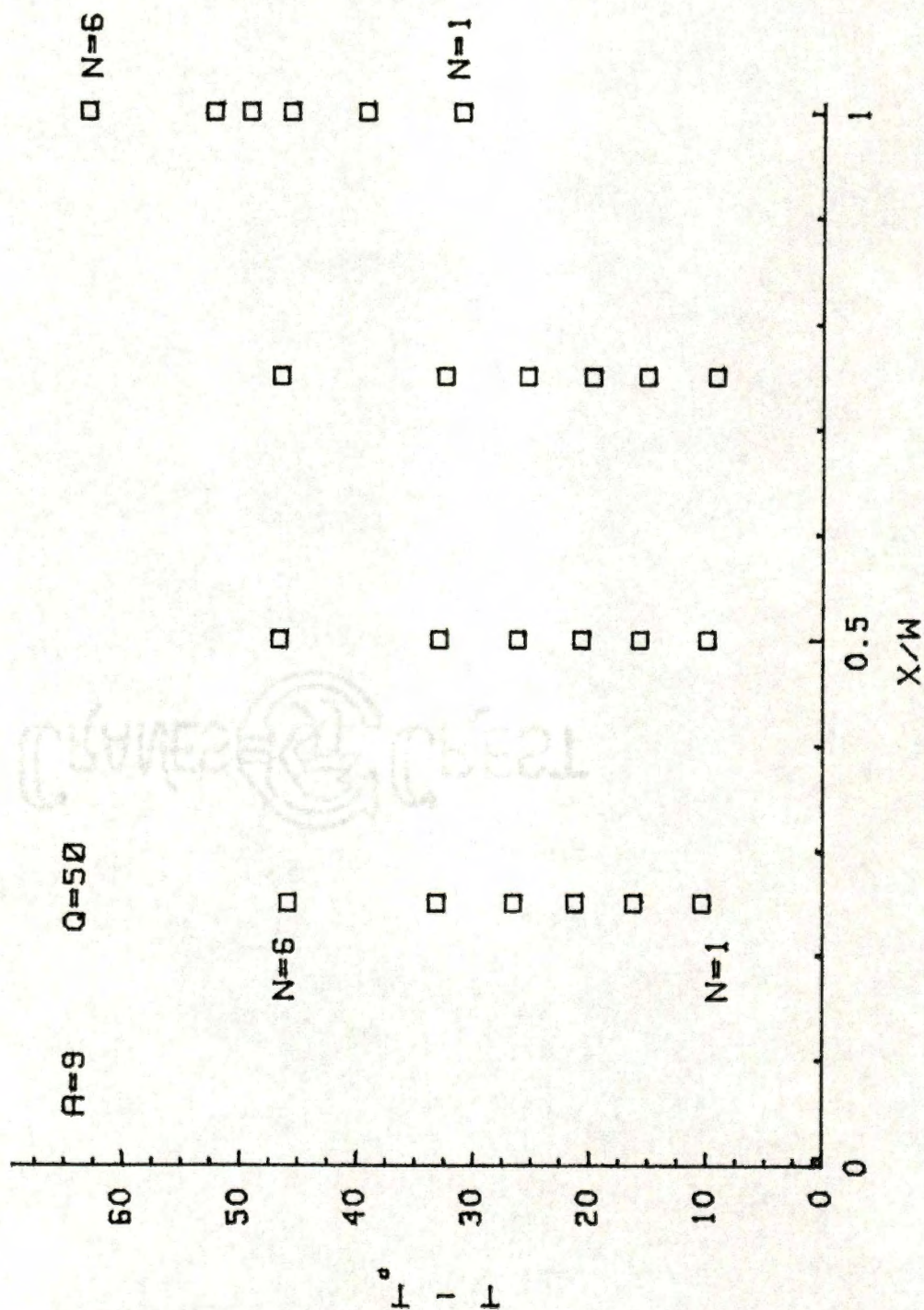


Fig. B-11 Probe Differential Temperature as a Function of X for Various Heaters, 50W, (A=9)

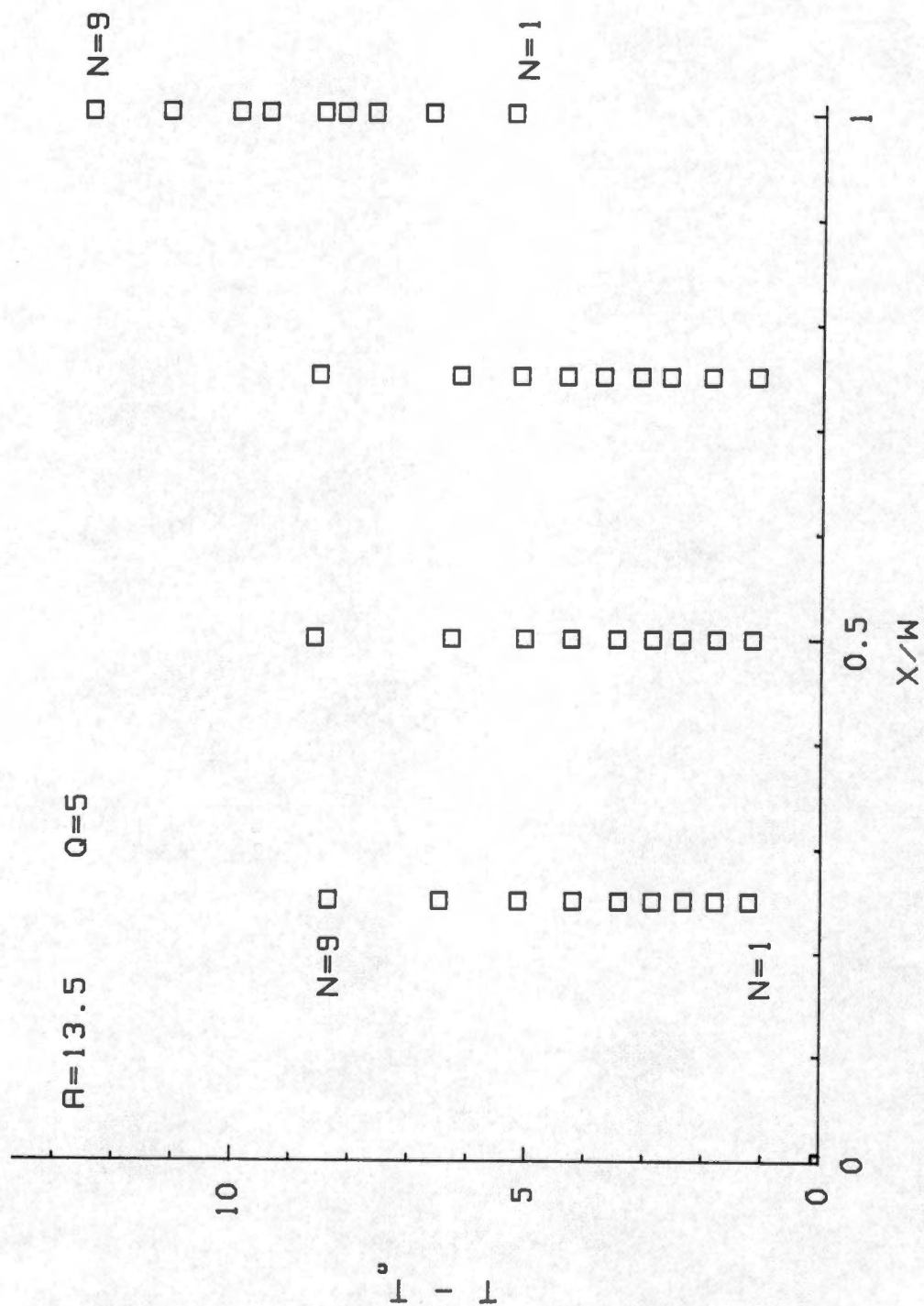


Fig. B-12 Probe Differential Temperature as a Function of X for Various Heaters, 5W, ($A=13.5$)

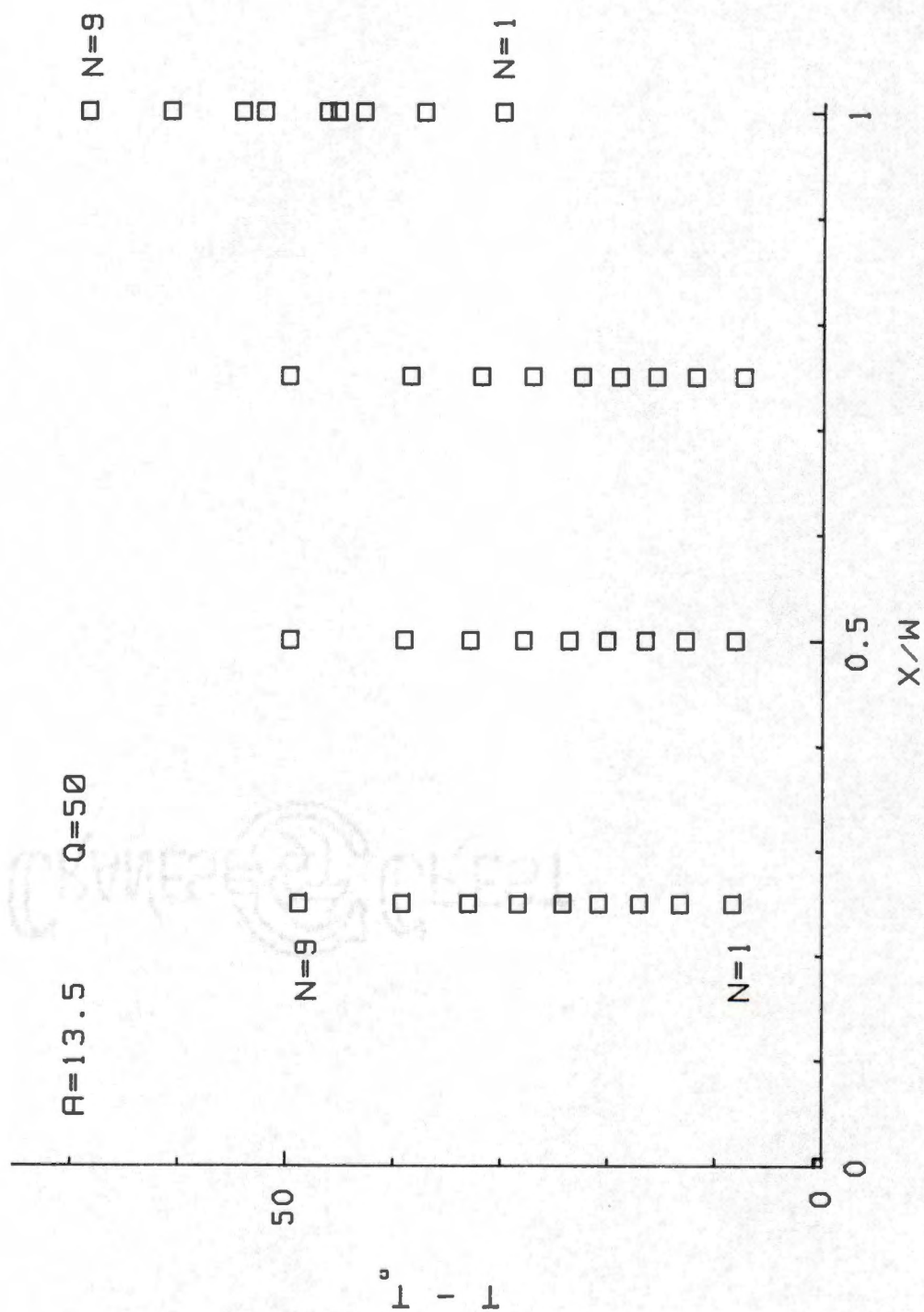


Fig. B-13 Probe Differential Temperature as a Function of X for Various Heaters, 50W, ($A=13.5$)

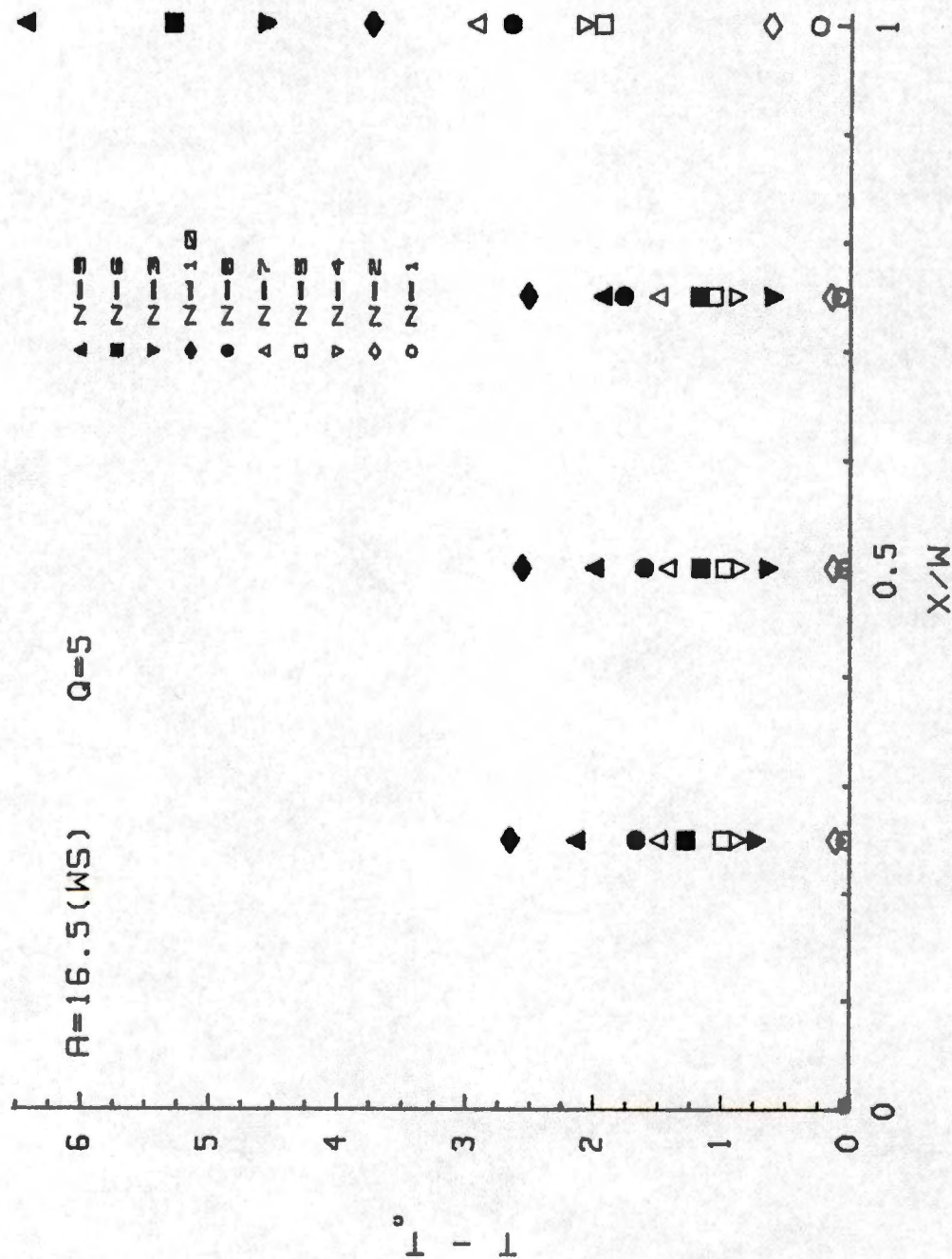


Fig. B-14 Probe Differential Temperature as a Function of X for Various Heaters, 5W, ($A=16.5$ (WS))

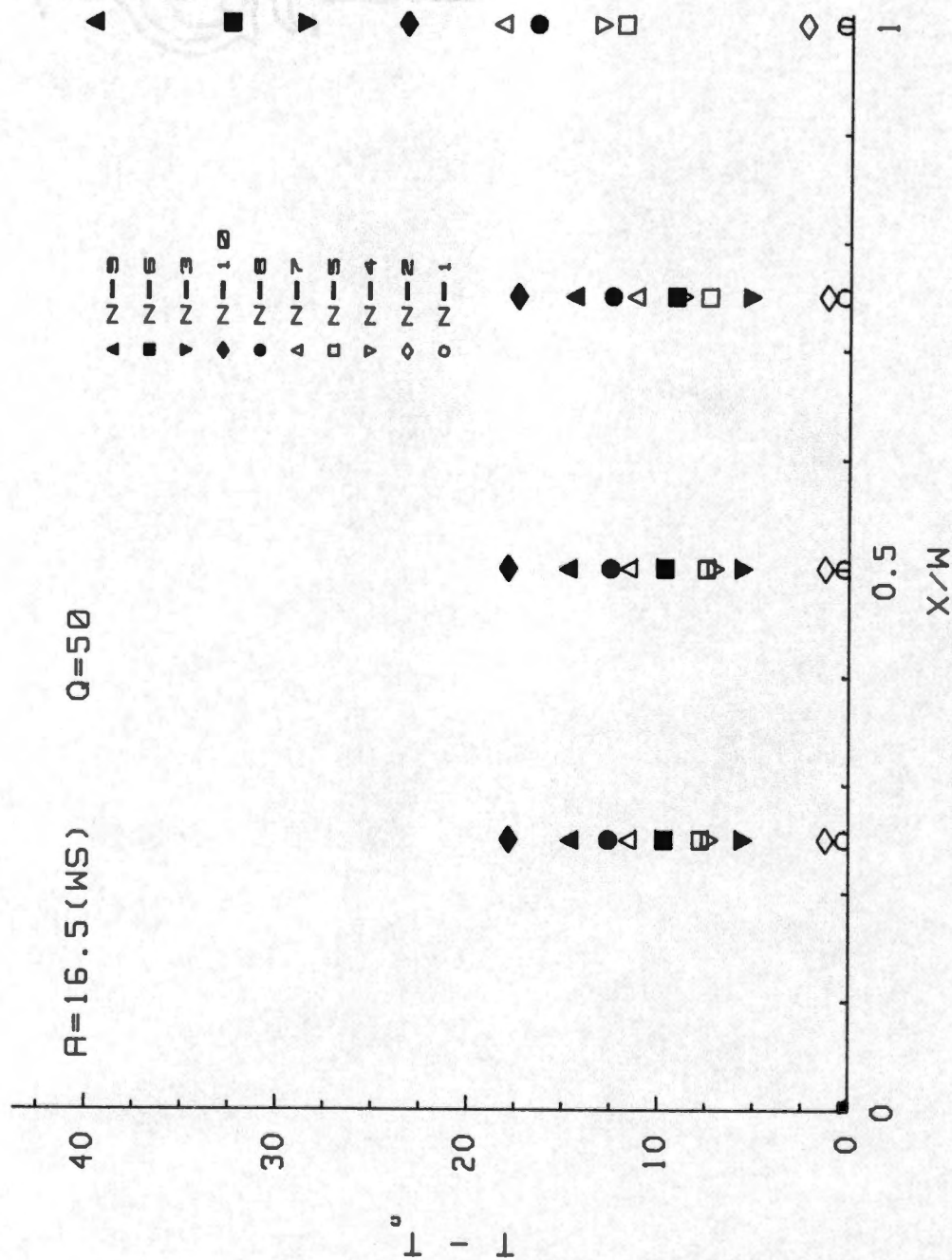


Fig. B-15 Probe Differential Temperature as a Function of X/W for Various Heaters, 50W, (A=16.5(WS))

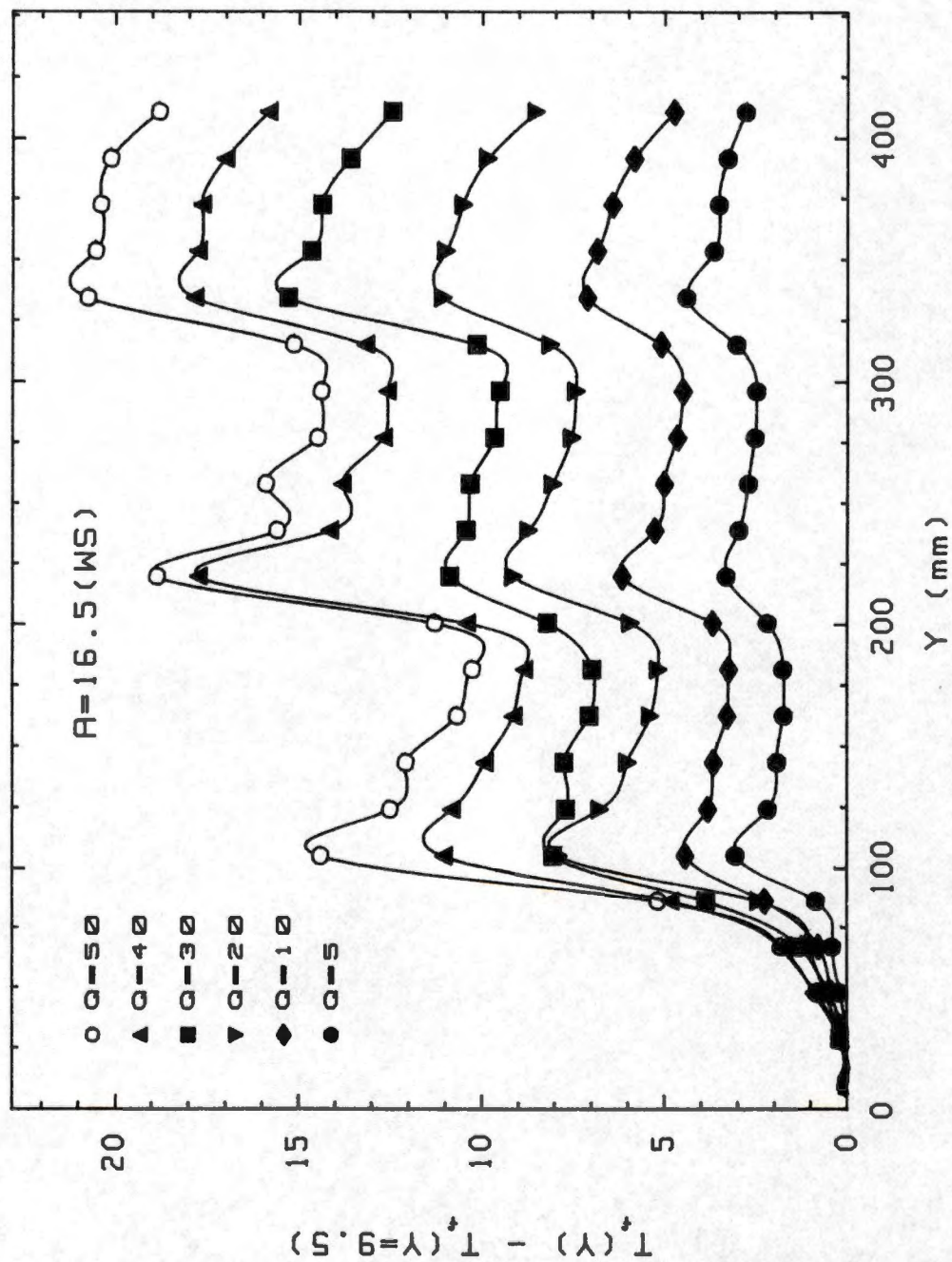


Fig. B-16 Discrete Fluid Temperature as a Function of Y ,
Measured about 2mm away

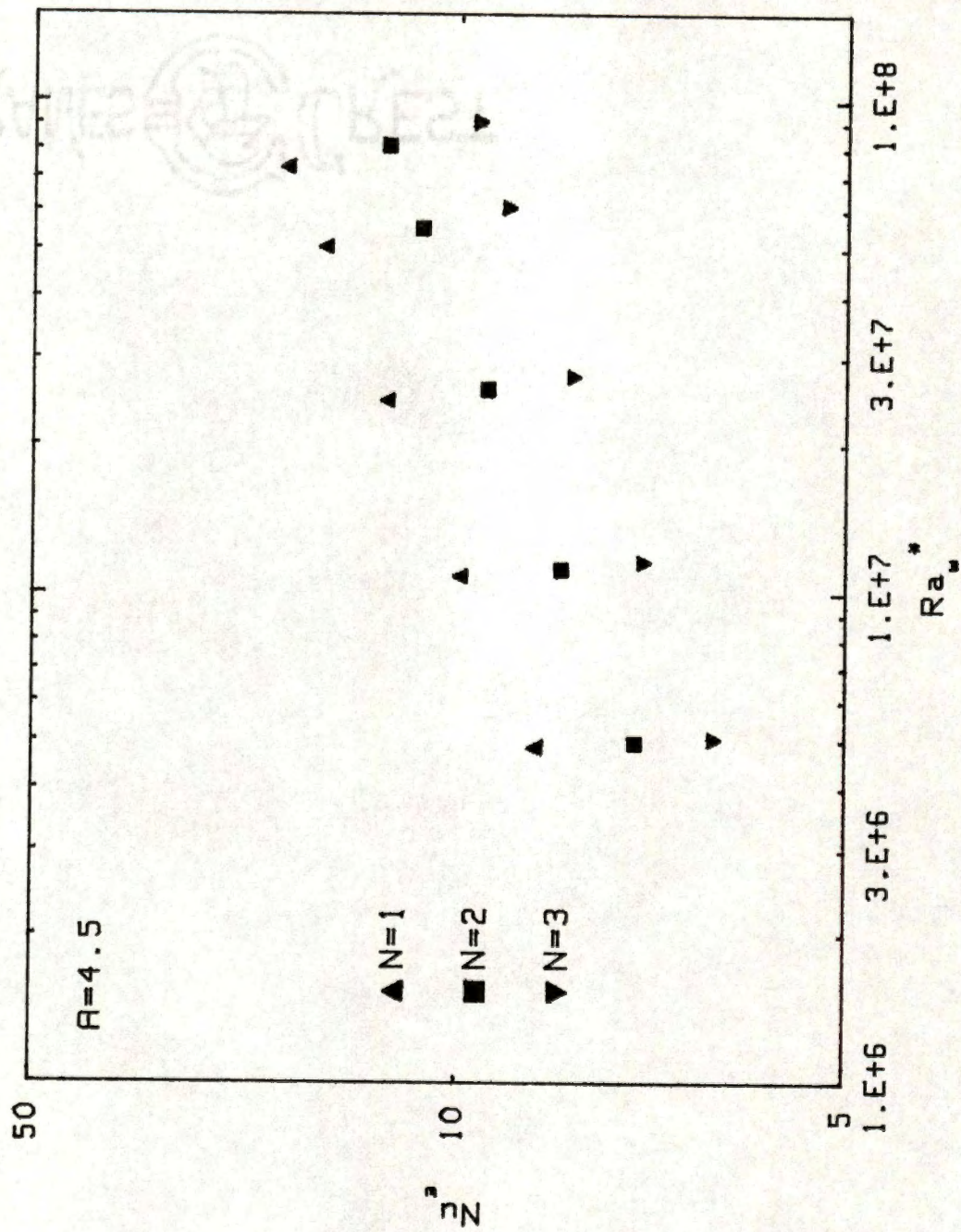


Fig. B-17 Nu_w as a function of Ra_w^* , Aspect Ratio of 4.5

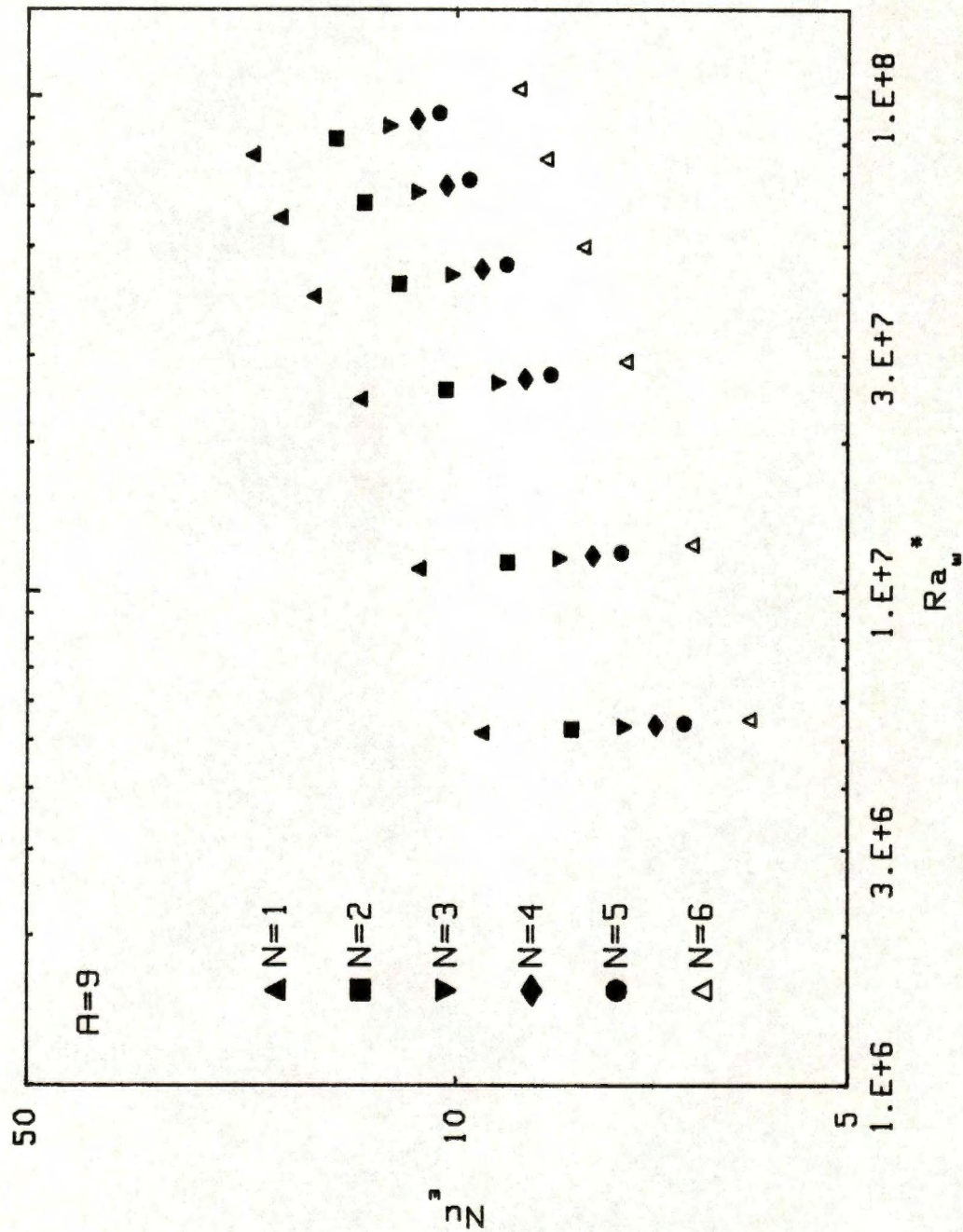


Fig. B-18 Nu_w as a function of Ra_w^* , Aspect Ratio of 9

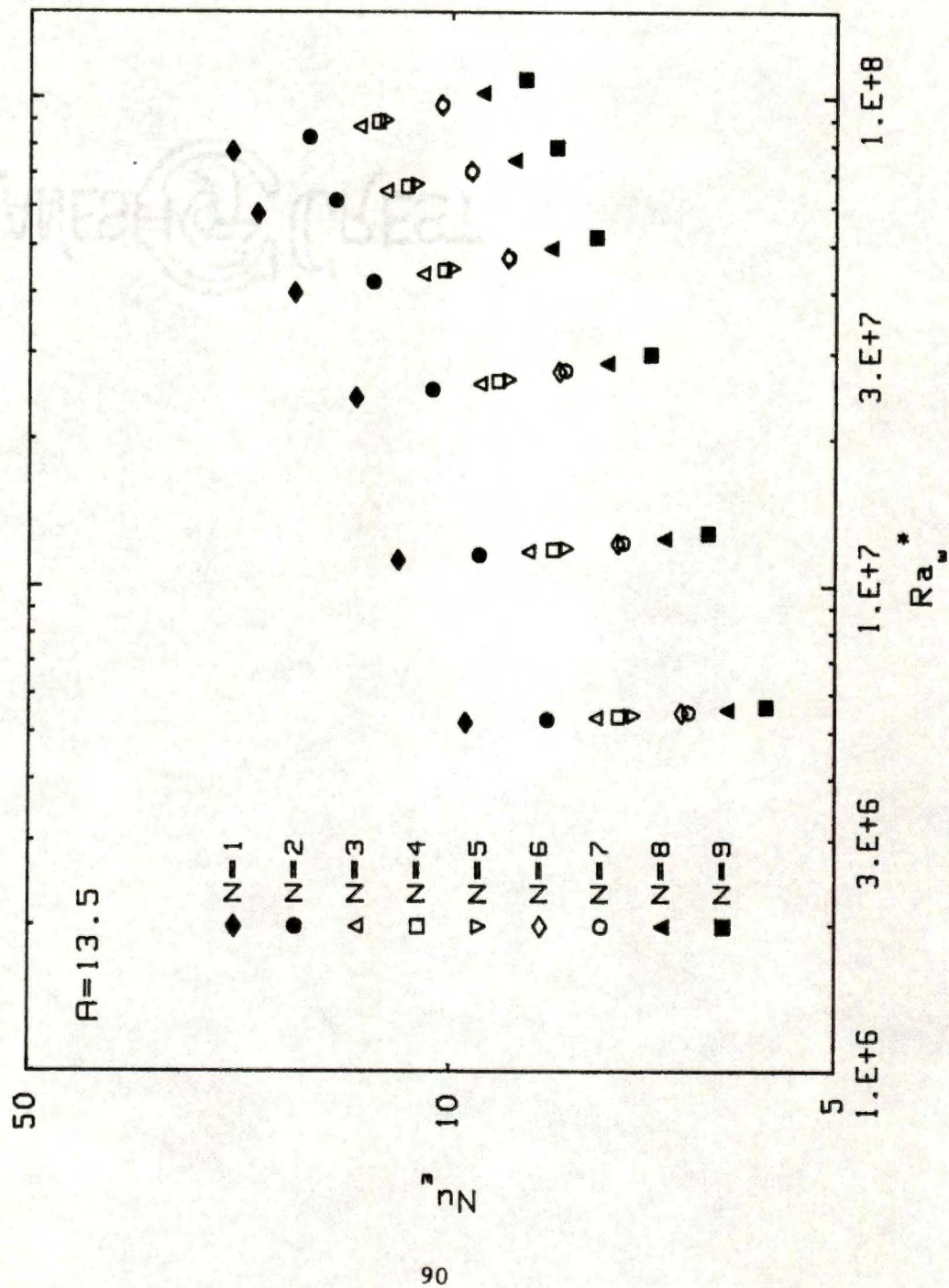


Fig. B-19 Nu_w as a function of Ra_w^* , Aspect Ratio of 13.5

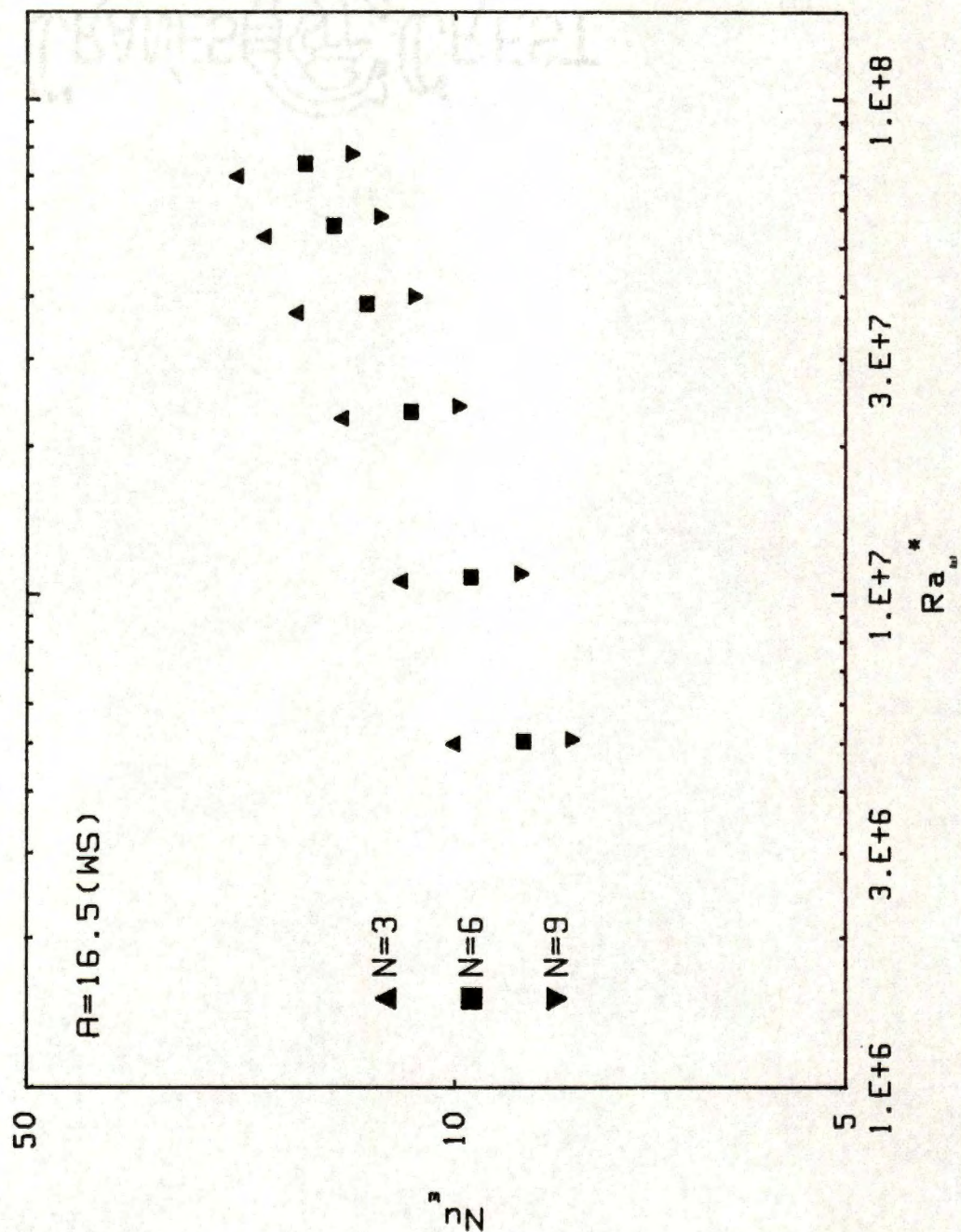


Fig. B-20 Nu_w as a function of Ra_w^* , Aspect Ratio of 16.5 (Wider Spacing)

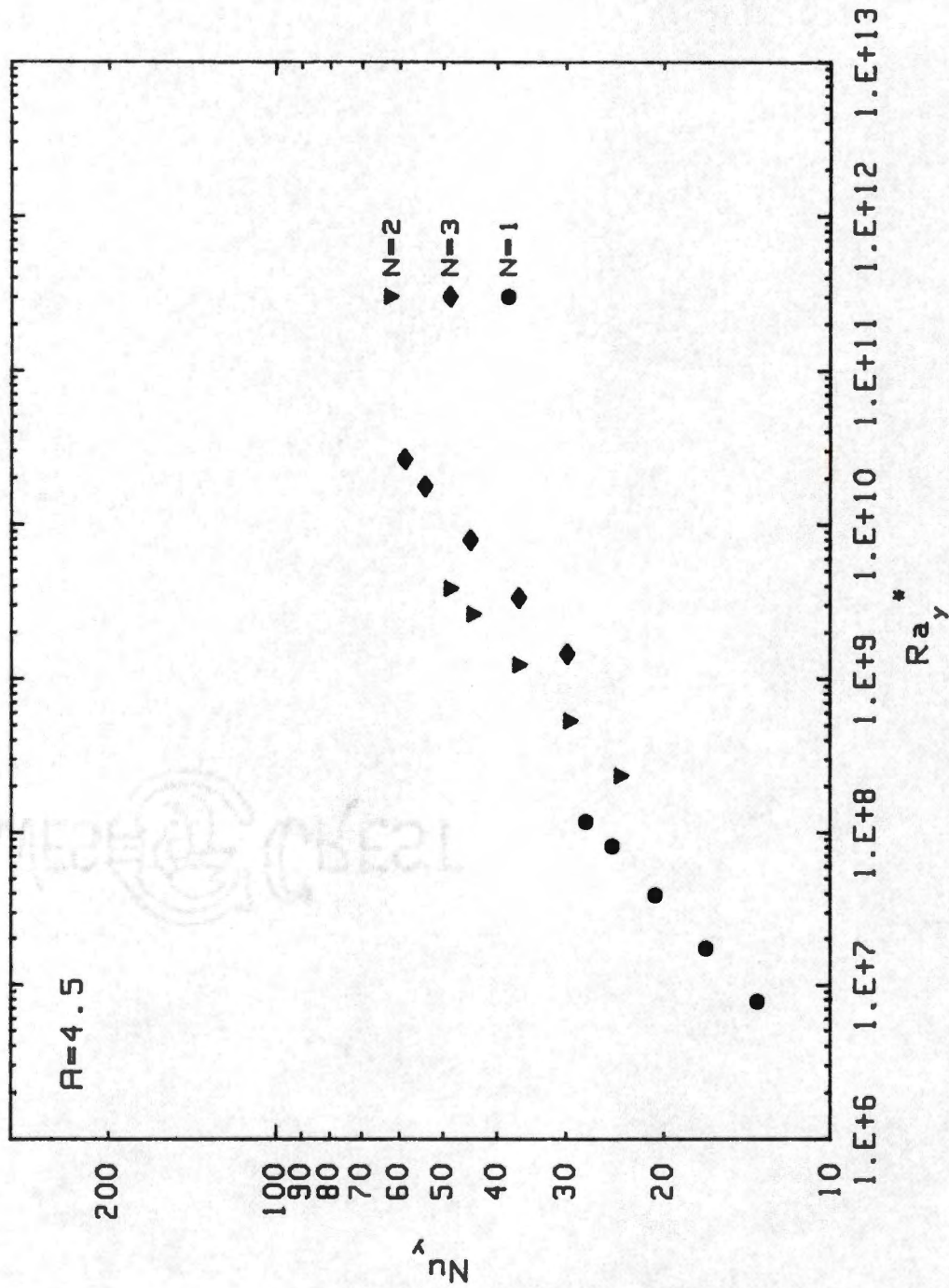


Fig. B-21 Nu_y as a function of Ra_y^* , Aspect Ratio of 4.5

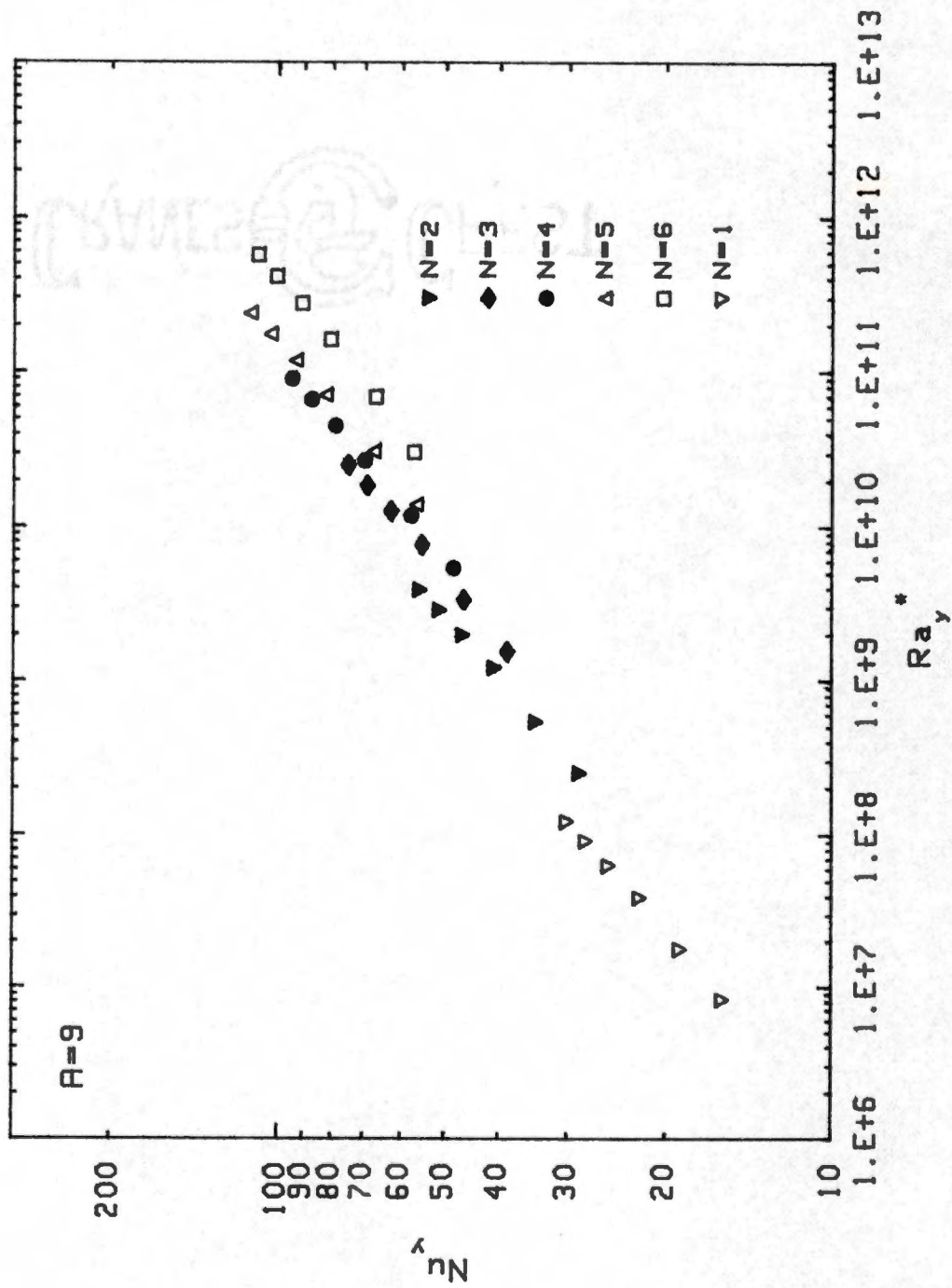


Fig. B-22 Nu_y as a function of Ra_y^* , Aspect Ratio of 9

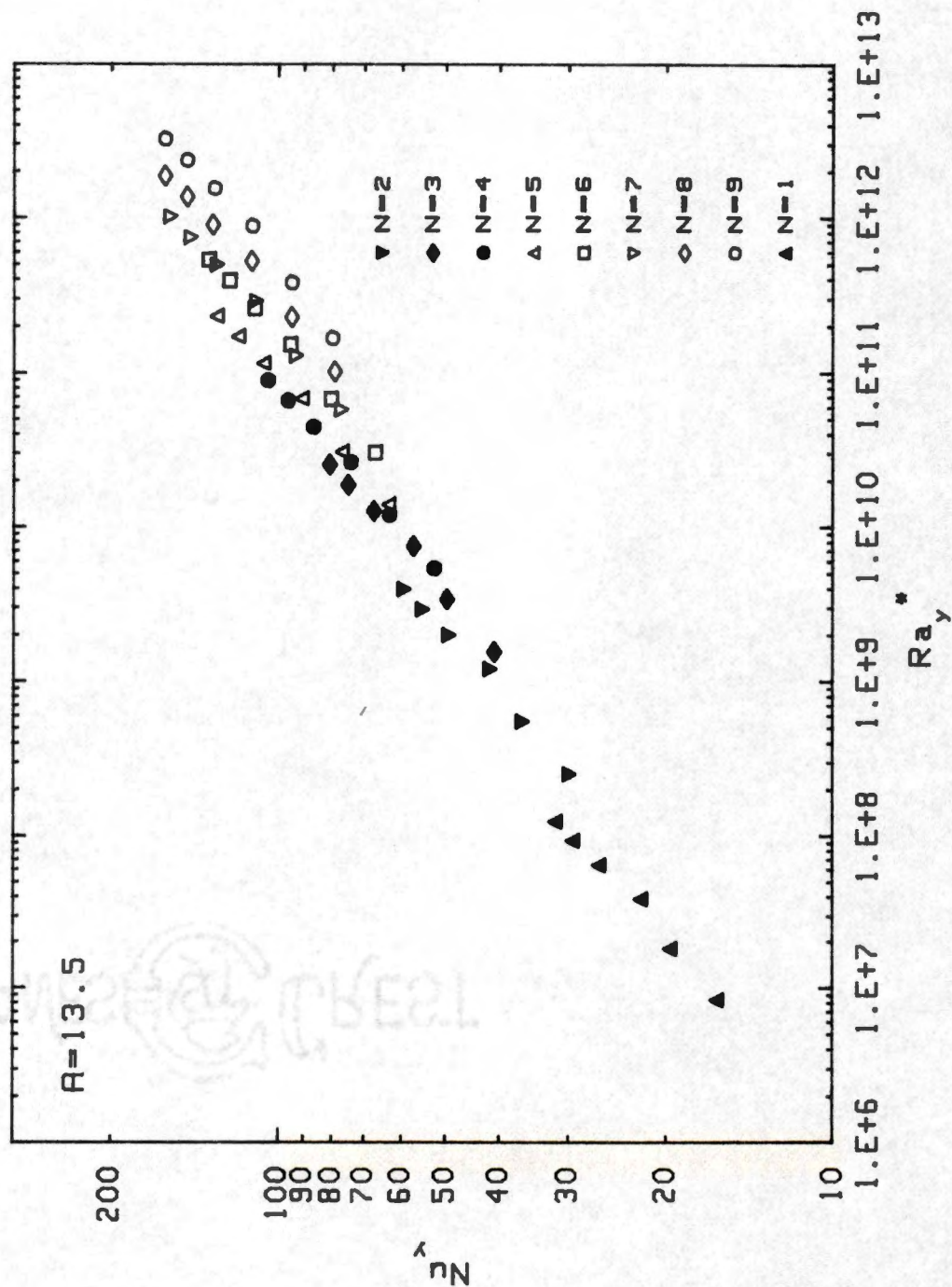


Fig. B-23 Nu_y as a function of Ra_y^* , Aspect Ratio of 13.5

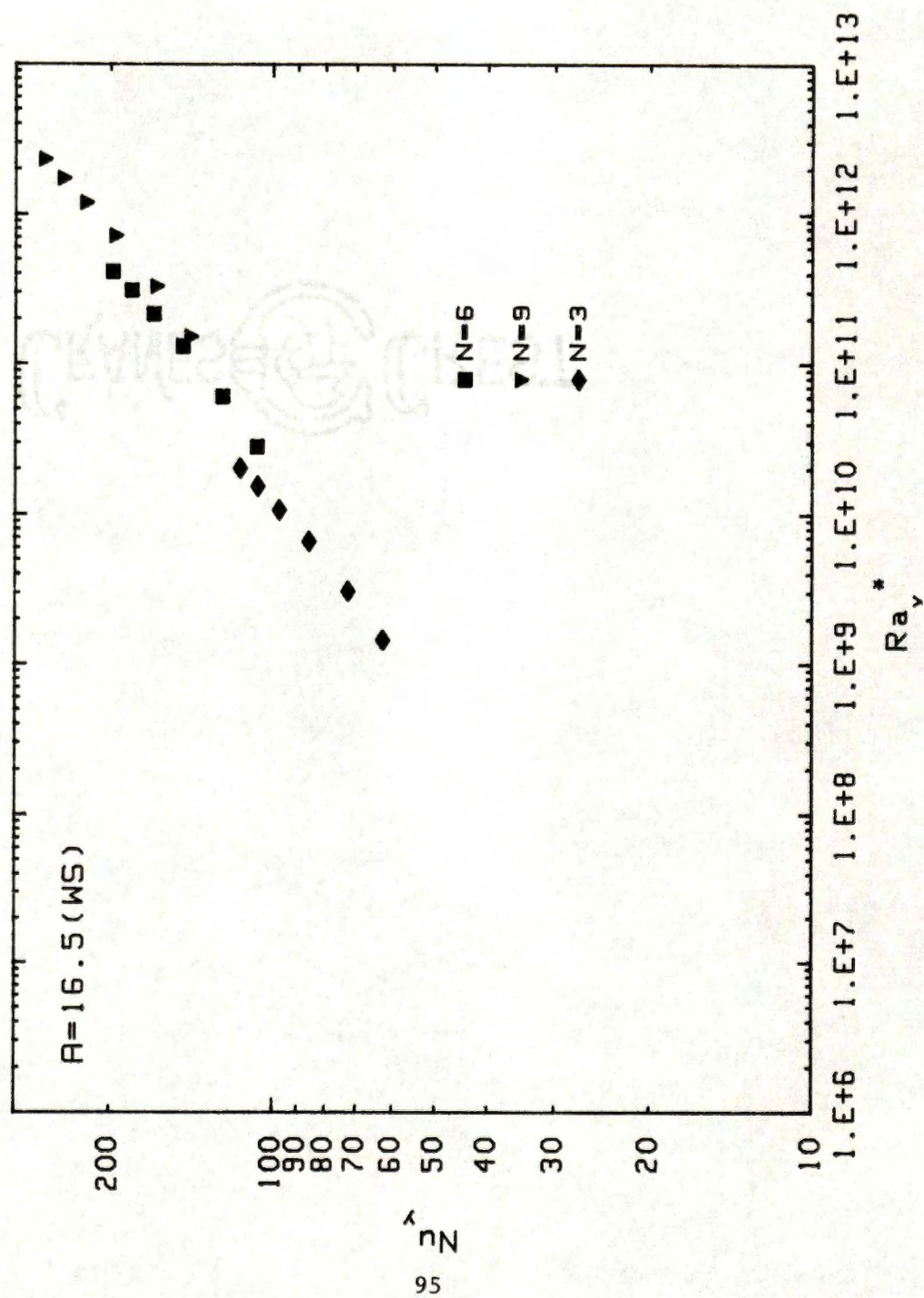


Fig. B-24 Nu_y as a function of Ra_y^* , Aspect Ratio of 16.5 (Wider Spacing)

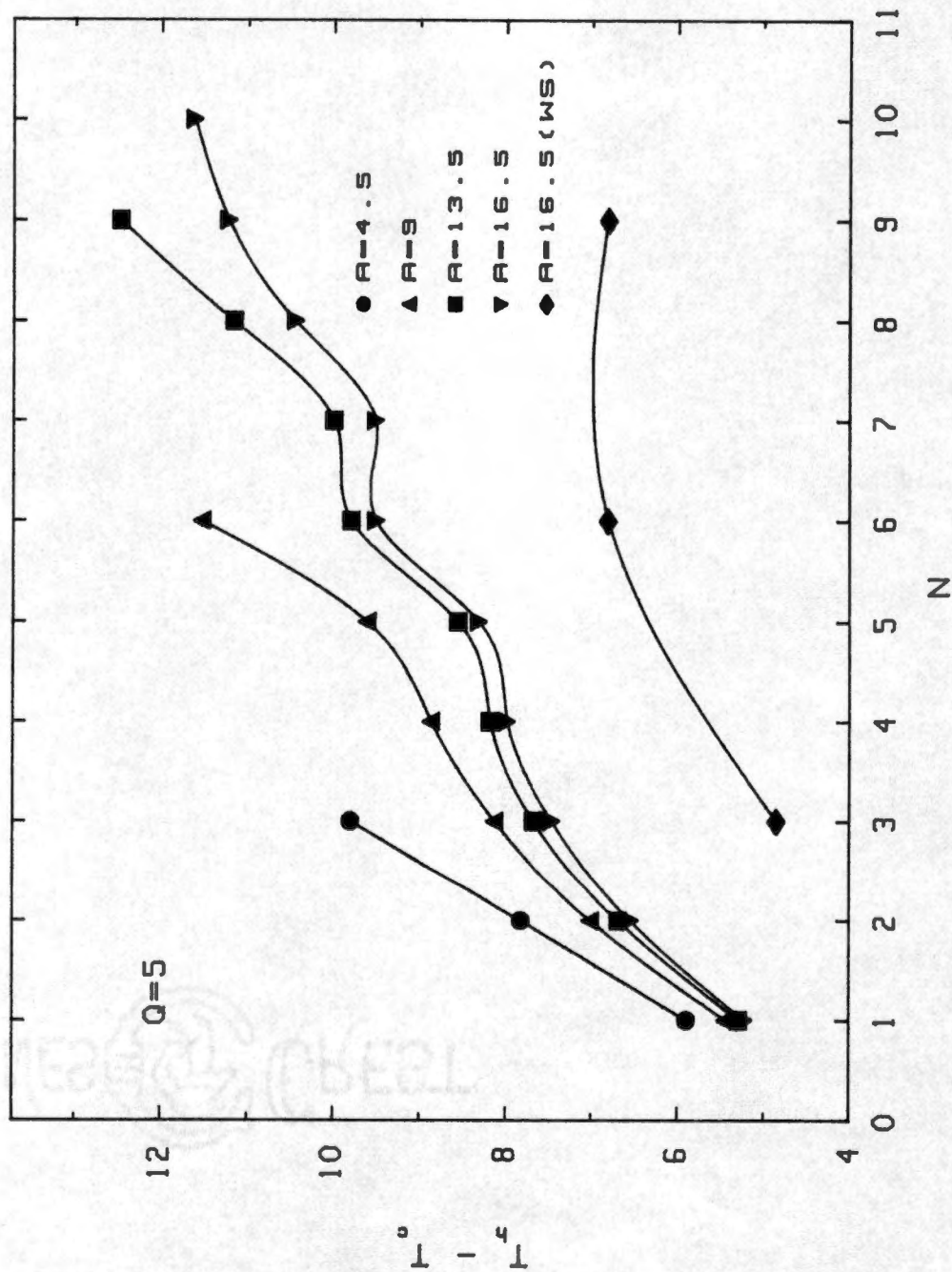


Fig. B-25 Surface Differential Temperature as a Function of Heater # for Various Aspect Ratios, 5W

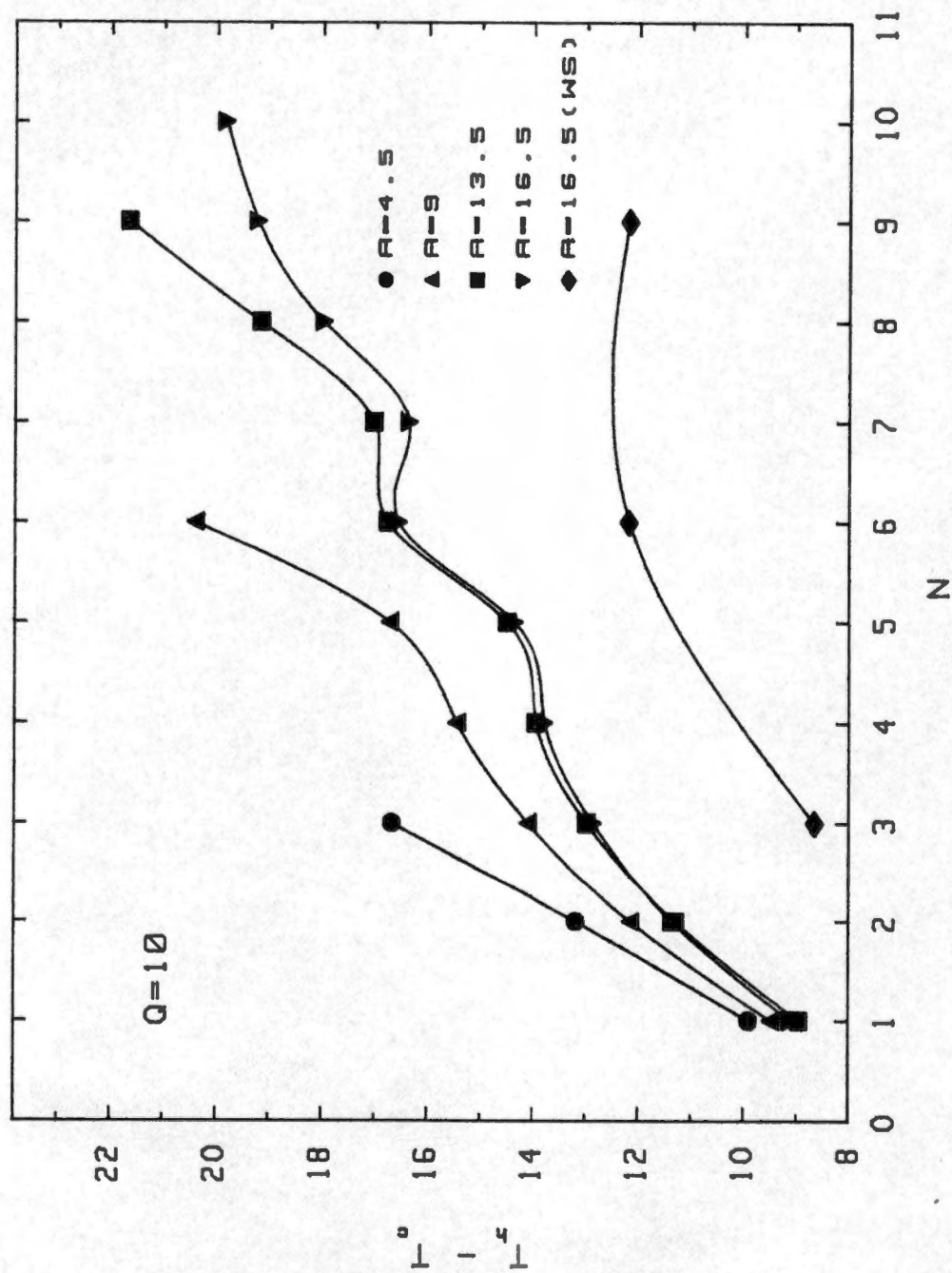


Fig. B-26 Surface Differential Temperature as a Function of Heater # for Various Aspect Ratios, 10W

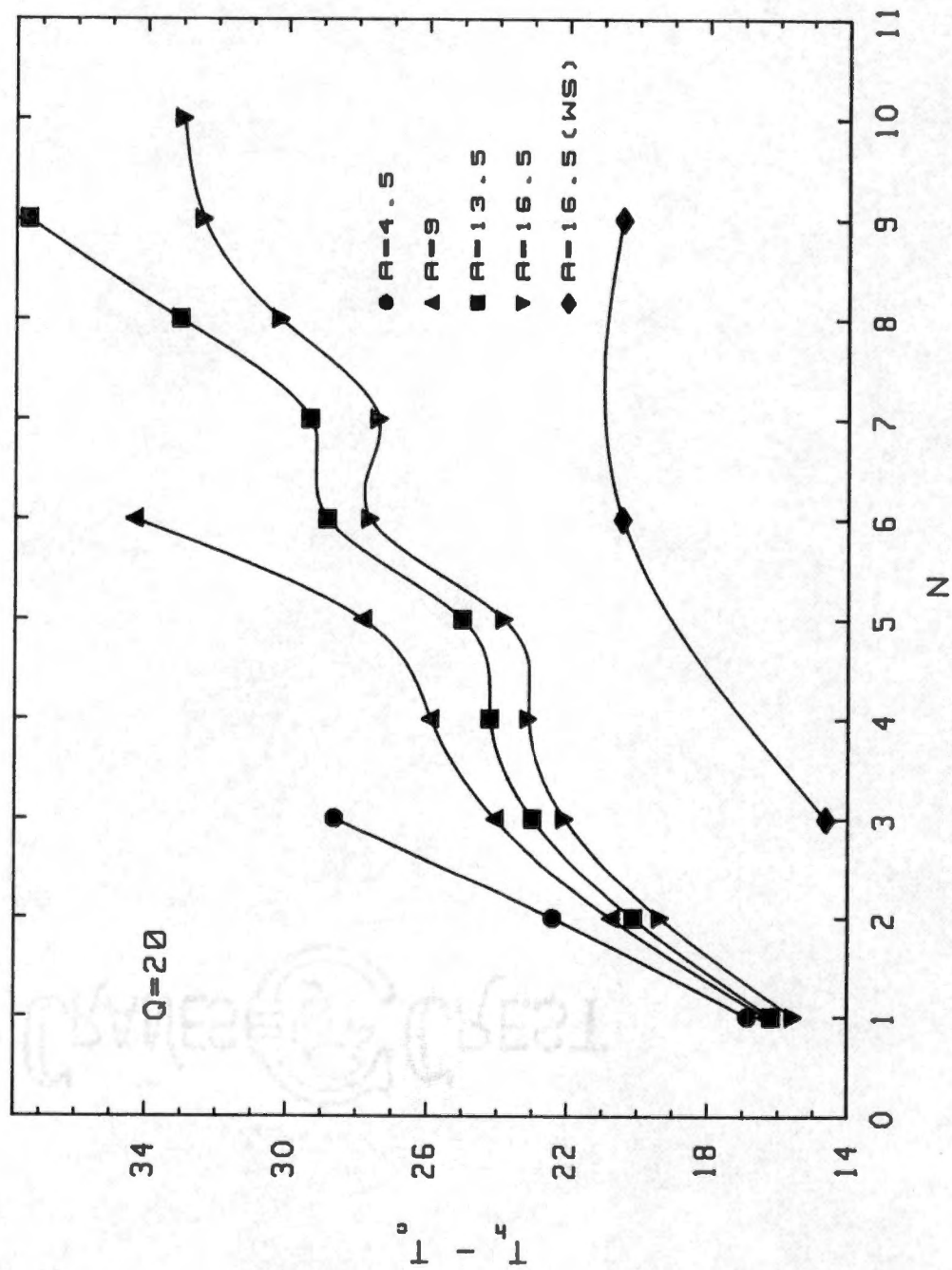


Fig. B-27 Surface Differential Temperature as a Function of Heater # for Various Aspect Ratios, 20W

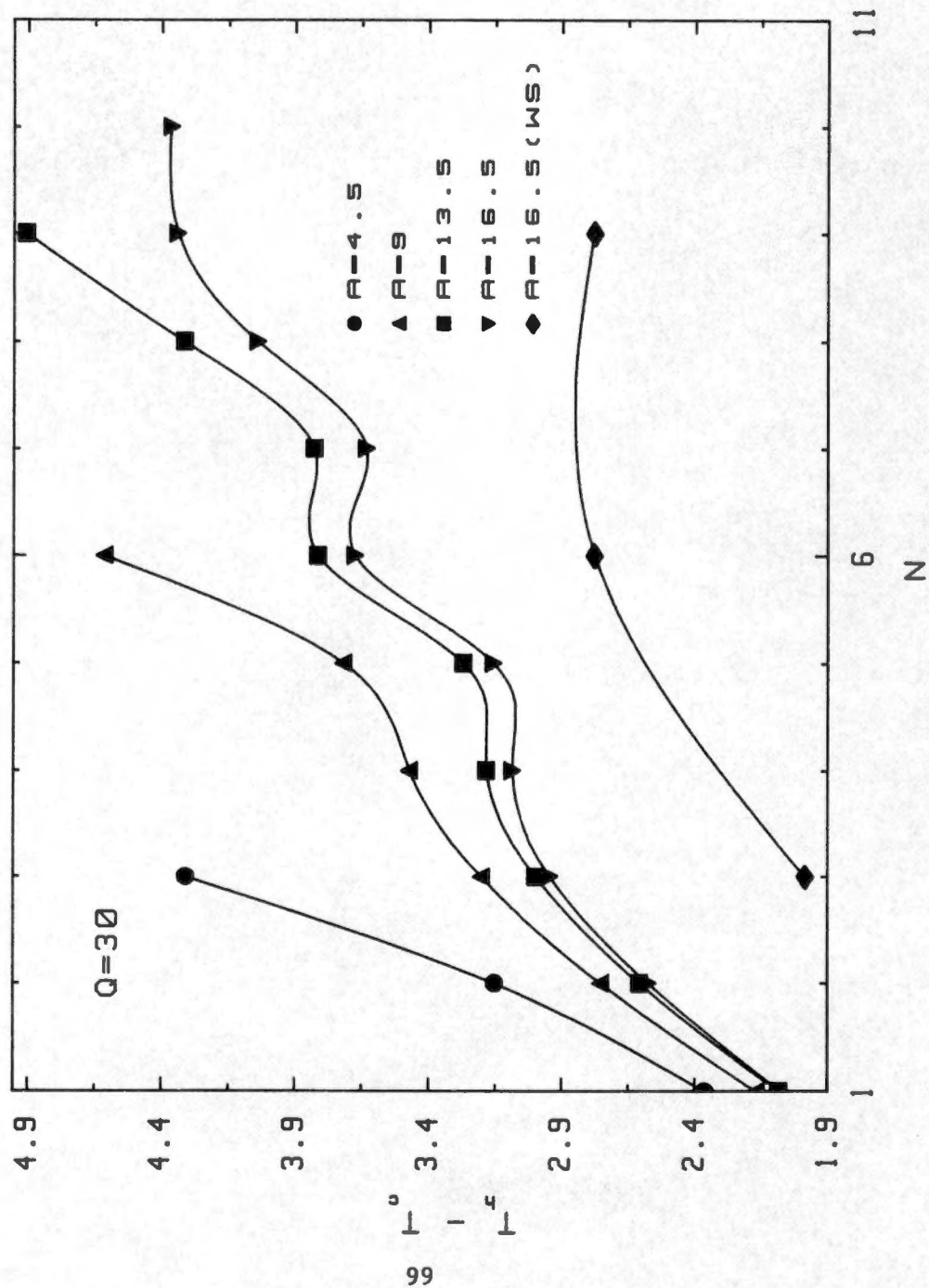


Fig. B-28 Surface Differential Temperature as a Function of Heater # for Various Aspect Ratios, 30W

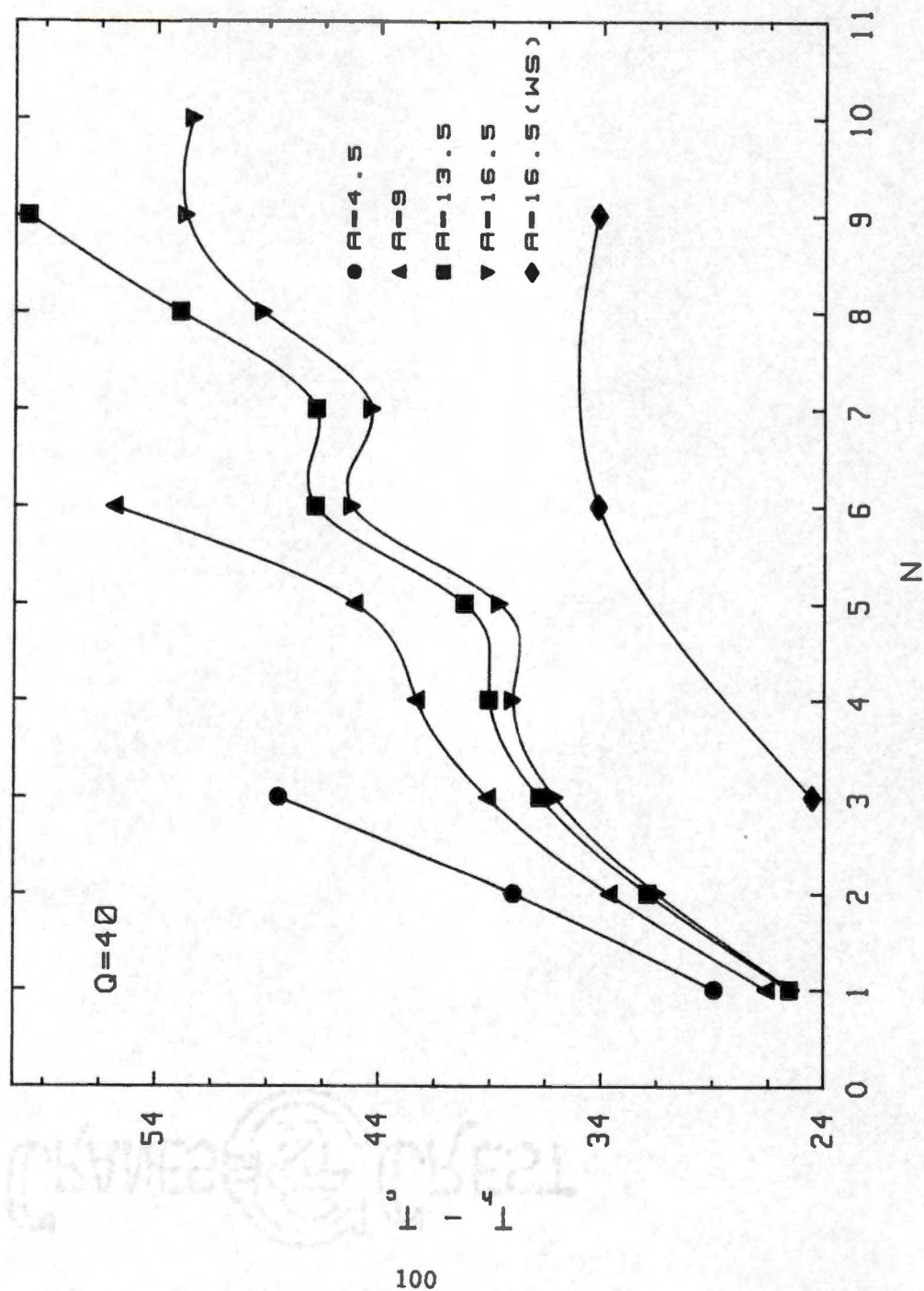


Fig. B-29 Surface Differential Temperature as a Function of Heater # for Various Aspect Ratios, 40W

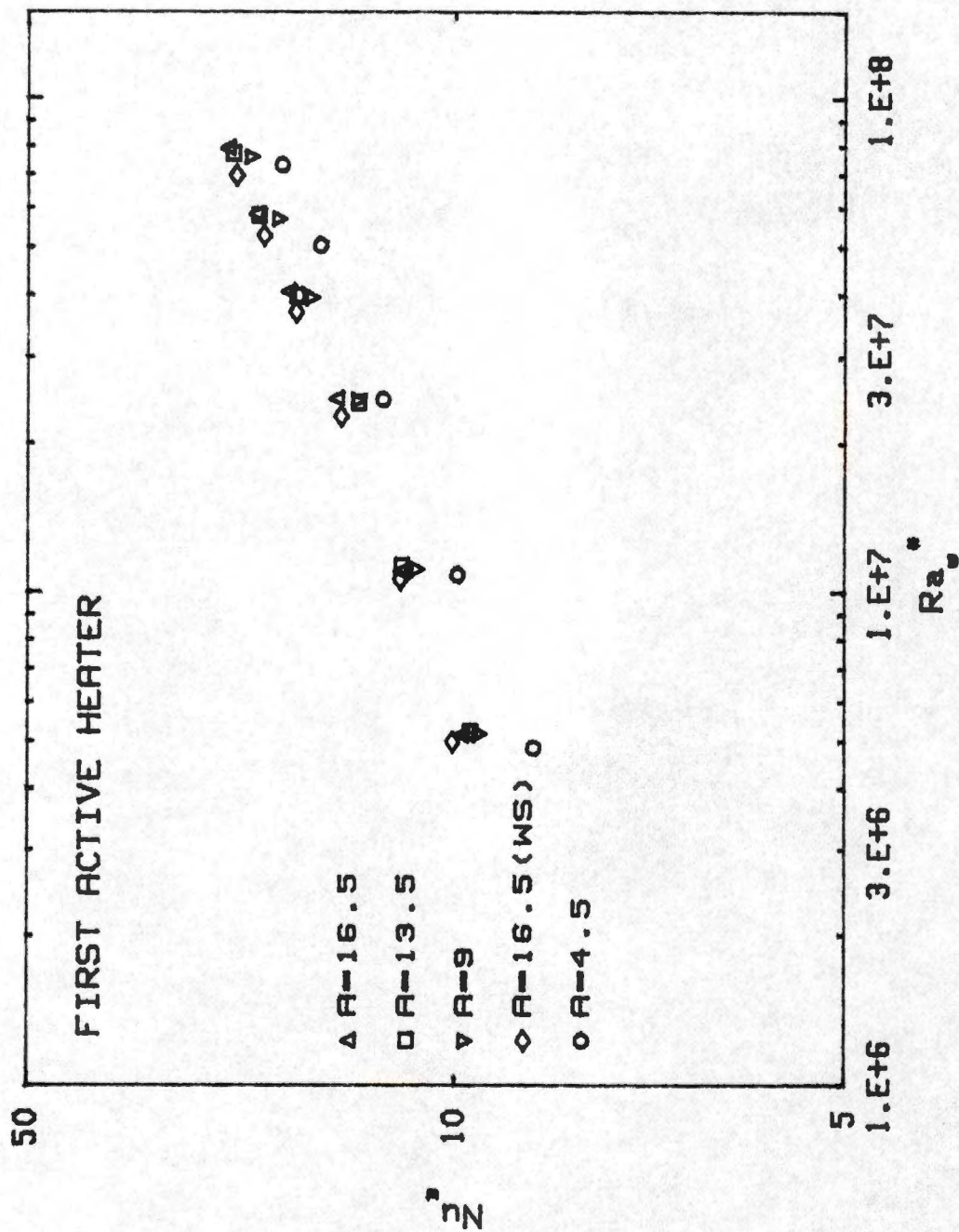


Fig. B-30 Nu_w as a function of Ra_w^* , First Active Heater

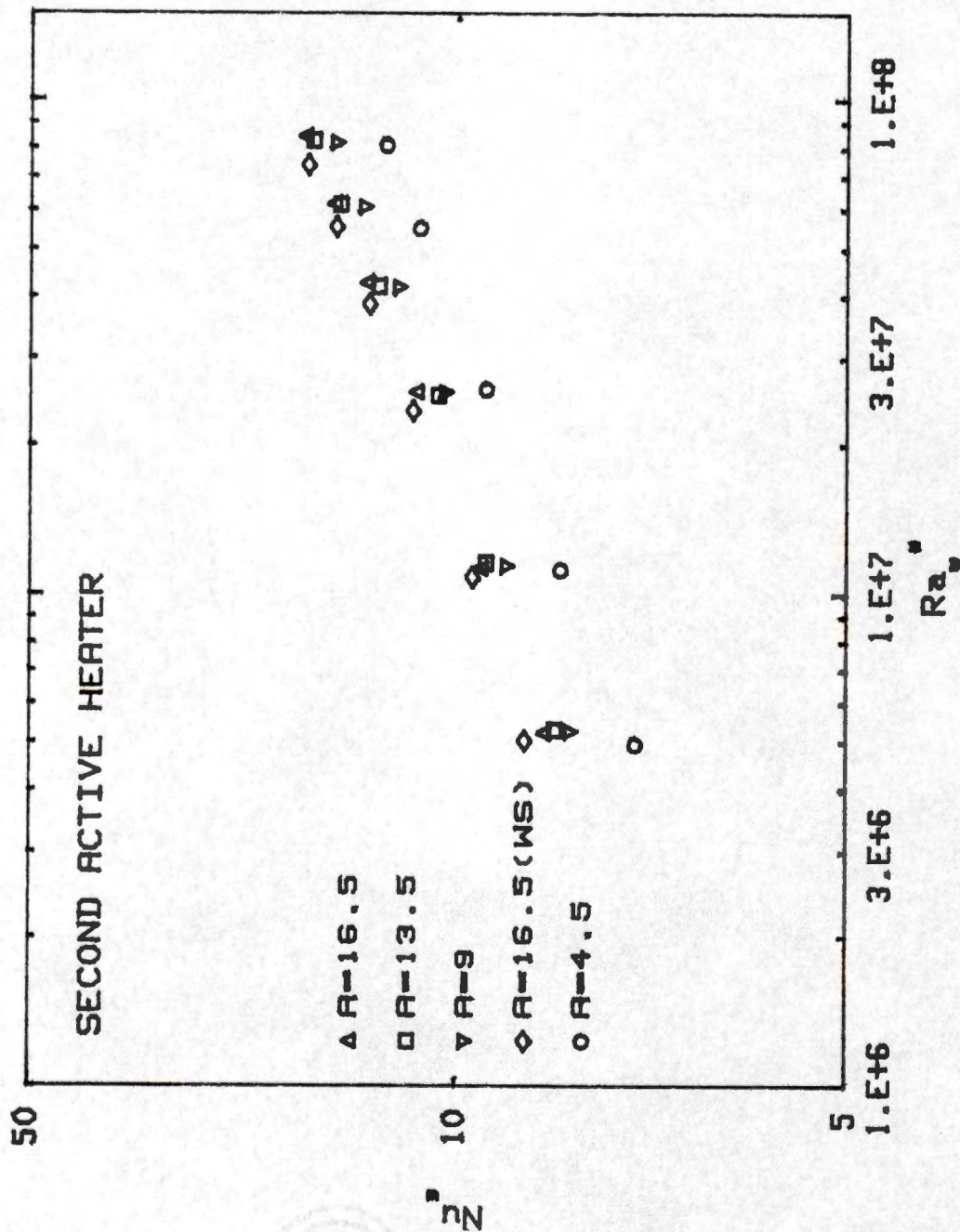


Fig. B-31 Nu_w as a function of Ra_w^* , Second Active Heater

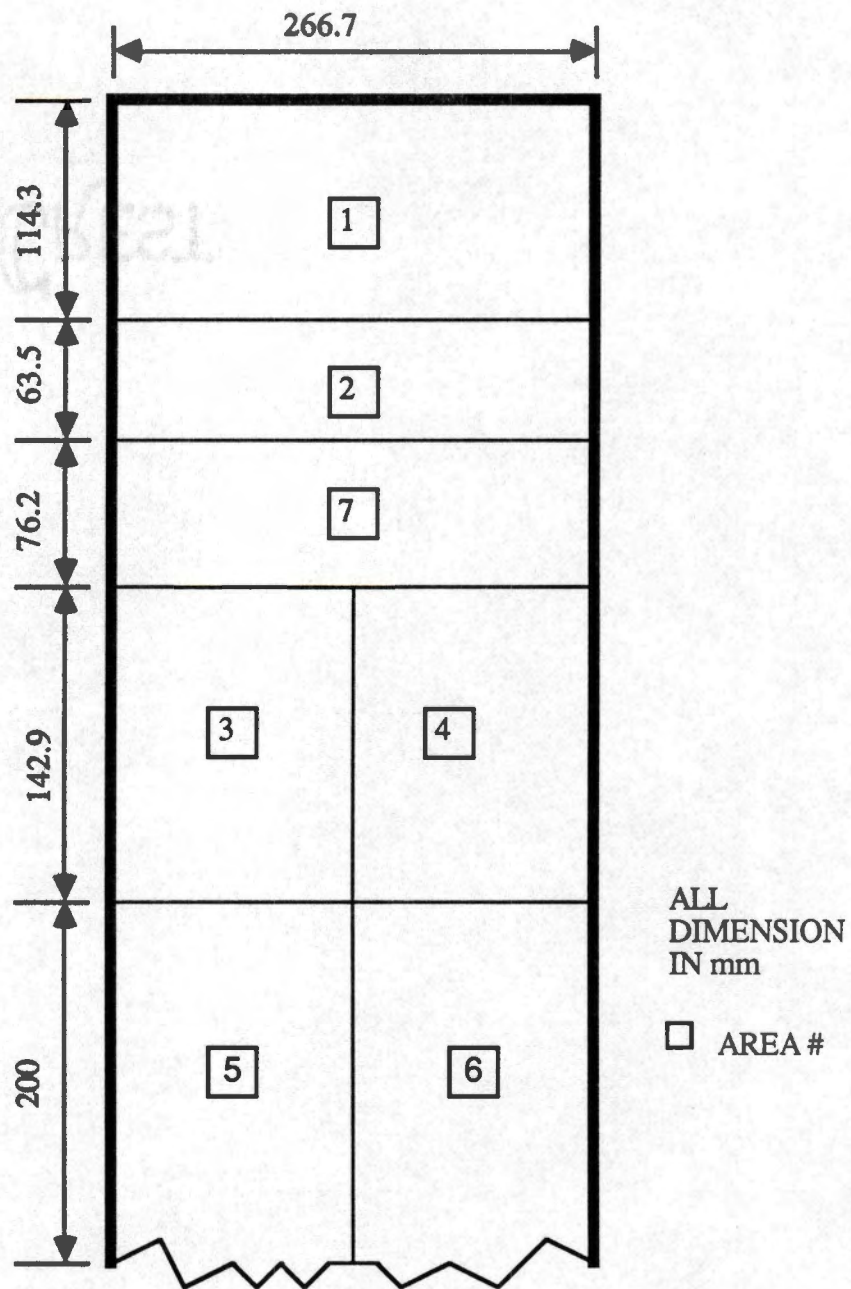


Fig. B-32 Division of Phenolite Plate at the Back for Heat Loss Calculation

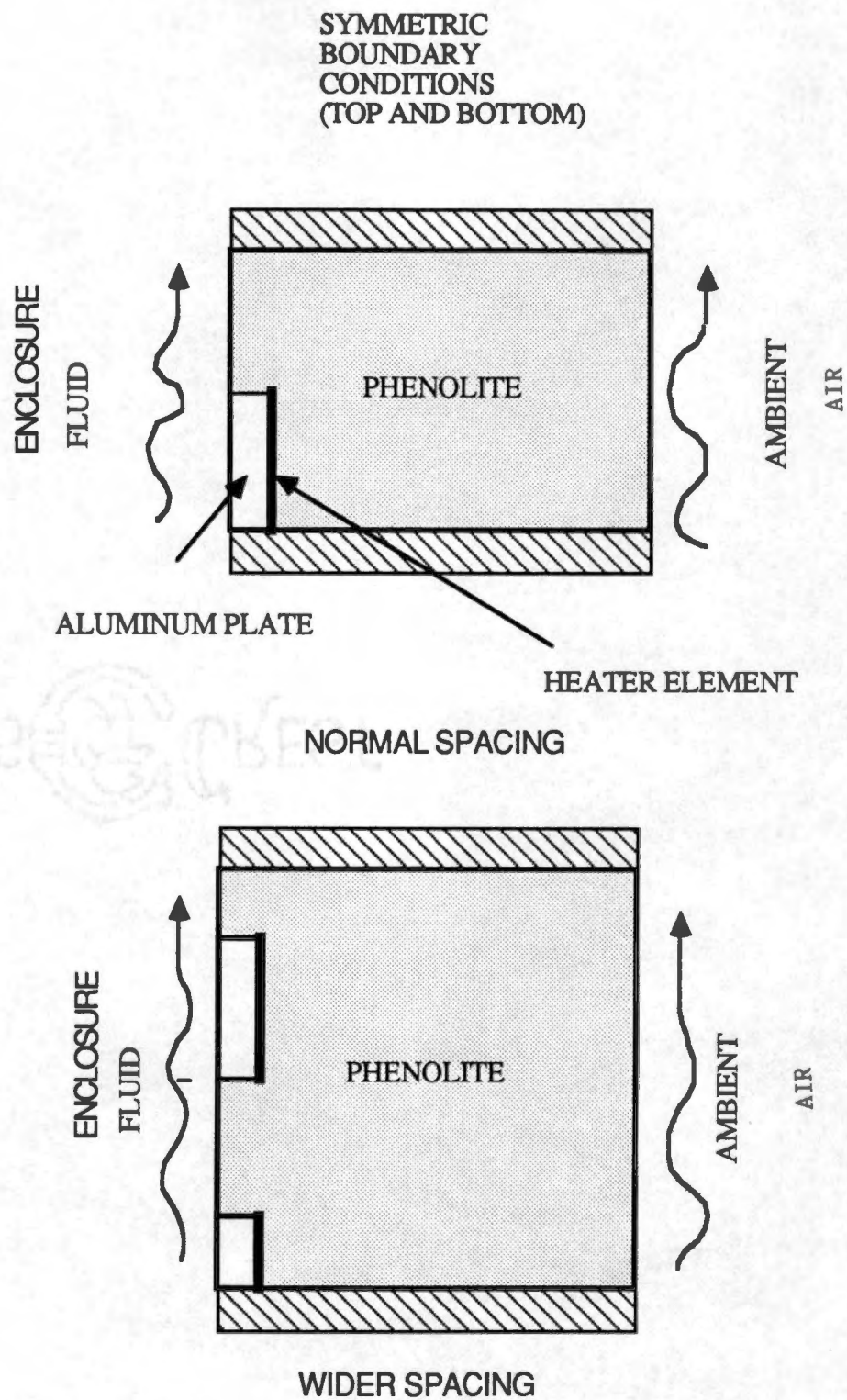


Fig. B-33 Unit Cell for Iteration of Conjugate Effect



APPENDIX C TABLES

Table C-1 List of Items Used and their Manufacturers

ITEM	MANUFACTURER
35 mm camera Single Lens Reflex	Minolta XG-M
AC Regulator ACR 3000	Sorensen Power Supplies
Carousel AV 900 slide Projector	Kodak
Computer	Hewlett-Packard 9000/217
Data Acquisition/Control Unit(200 channels)	Hewlett-Packard 3497A
Digital Voltmeter	Hewlett-Packard 3456A
Graphics Plotter	Hewlett-Packard 7470 A
Ice-Point Reference	Kaye Instrument Model K-140/4
Think Jet Printer	Hewlett-Packard
Winchester disk	Hewlett-Packard 9133 D

Table C-2 Measuring Instruments Used, their Ranges and Accuracy

ITEM	MANUFACTURER	RANGE	ACCURACY
Ammeter	Keithley Instruments	20 μ A to 2000 mA	.6V Burden
Constant Temperature Bath	MGW (Lauda) (MT-6)	-20 to 120°C	$\pm 0.1^\circ\text{C}$
Thermal Comparator	Lafayette Instrument Company	0.001 to 5 W/cmC	$\pm 5\%$
Voltmeter	Keithley Instruments	20 mV to 1000 V	5% Rdg +15D

Table C-3 Channel Number and its Corresponding Thermocouple Number

CHANNEL NO.	CORRESPONDING THERMOCOUPLES NO.	REMARKS
0	--	Ice-Point
1	1	Heater No. 1
2	2	Heater No. 2
3	3	Heater No. 3
4	4	Unheated section Heater No. 3 & 4
5	5	Heater No. 4
6	6	Heater No. 5
7	7	Heater No. 6 (Back)
8	8	Heater No. 6 (Middle)
9	9	Heater No. 6 (Front)
10	10	Unheated Section between Heater No. 6 & 7
11	11	Heater No. 7
12	12	Heater No. 8
13	13	Heater No. 9
14	14	Unheated Section between Heater No. 9 & 10

Table C-3 (continued)

CHANNEL NO.	CORRESPONDING THERMOCOUPLES NO.	REMARKS
15	15	Heater No. 10
16	16	Located above Top Plate
17	17	Unheated Section above Heater No. 11
18	19	Measuring Heat Losses through Phenolite Wall
19	20	" " "
20	--	Ice-Point
21	21	Measuring Heat Losses through Phenolite Wall
22	22	" " "
23	23	" " "
24	24	" " "
25	25	" " "
26	26	" " "
27	27	" " "
28	28	" " "
29	29	" " "
30	30	" " "

Table C-3 (continued)

CHANNEL NO.	CORRESPONDING THERMOCOUPLES NO.	REMARKS
31	31	" " "
32	32	" " "
33	33	Measuring Heat Loss through brass plates
34	34	" " "
35	35	" " "
36	36	" " "
37	37	" " "
38	38	" " "
39	39	" " "
40	--	Ice-Point
41	40	Measuring Heat Losses through Brass Plate
42	41	" " "
43	42	" " "
44	43	" " "
45	44	Ambient
46	45	Outside Surface of Rear Side Plate
47	46	Bottom of Bottom Plate

Table C-3 (continued)

CHANNEL NO.	CORRESPONDING THERMOCOUPLES NO.	REMARKS
48	47	Ambient
56	--	Voltage
57	--	" " "
58	--	" " "
59	--	" " "
60	--	Ice-Point
61	61	Fluid Temperature (Left)
62	62	Fluid Temperature (Middle)
63	63	Fluid Temperature (Right)

Table C-4 Heater Number and its Measured Resistance,
Dec. 4, 1986

HEATER NO.	RESISTANCE MEASURED (Ω)
1	30.52
2	30.38
3	29.90
4	31.98
5	29.45
6	29.63
7	29.37
8	29.45
9	31.40
10	30.06
11	29.81

Table C-5 Circuit Number and its Measured Resistance,
Dec. 4, 1986 and Apr. 15, 1987

CIRCUIT NUMBER	RESISTANCE MEASURED (Ω)	
	December 4, 1986	April 15, 1987
1 (Heater 1, 2, 3)	89.8	90.28
2 (Heater 4, 5, 6)	88.7	90.59
3 (Heater 7, 8, 9)	88.83	93.62
4 (Heater 10, 11)	59.82	62.45
5 (Heater 3, 6, 9)	--	91.90

Table C-6 Circuit Number 1, Measured Voltages, Currents,
and Calculated Resistances for Various Q

POWER INPUT(W)	VOLTAGE MEASURED (V)	CURRENT MEASURED (mA)	RESISTENCE CALCULATED (Ω)	CORRECTED RESISTANCE (Ω)
5	36.40	401.40	90.68	90.38
10	51.46	570.0	90.28	89.98
20	73.49	812.0	90.51	90.21
30	89.70	988.60	90.73	90.43
40	103.60	1141.0	90.80	90.50
50	116.15	1277.70	90.91	90.61

Table C-7 Circuit Number 2, Measured Voltages, Currents,
and Calculated Resistances for Various Q

POWER INPUT (W)	VOLTAGE MEASURED (V)	CURRENT MEASURED (mA)	RESISTENCE CALCULATED (Ω)	CORRECTED RESISTANCE (Ω)
5	36.41	402.30	90.50	90.20
10	52.06	574.40	90.63	90.33
20	72.23	803.0	89.95	89.65
30	89.23	980.0	91.05	90.75
40	103.45	1134.0	91.23	90.93
50	115.56	1266.30	90.26	90.96

Table C-8 Circuit Number 3, Measured Voltages, Currents,
and Calculated Resistances for Various Q

POWER INPUT (W)	VOLTAGE MEASURED (V)	CURRENT MEASURED (mA)	RESISTENCE CALCULATED (Ω)	CORRECTED RESISTANCE (Ω)
5	36.47	395.30	92.26	91.96
10	52.23	555.10	94.10	93.80
20	72.88	786.70	89.95	92.34
30	89.90	969.40	92.74	92.44
40	103.06	1110.40	92.81	92.51
50	115.30	1241.40	92.88	92.58

Table C-9 Circuit Number 4, Measured Voltages, Currents,
and Calculated Resistances for Various Q

POWER INPUT(W)	VOLTAGE MEASURED (V)	CURRENT MEASURED (mA)	RESISTENCE CALCULATED (Ω)	CORRECTED RESISTANCE (Ω)
5	24.43	394.30	61.96	61.66
10	34.60	557.30	62.09	61.79
20	48.87	786.0	62.18	61.88
30	60.04	963.80	62.30	62.0
40	69.28	1110.5	62.39	62.09
50	77.95	1248.1	62.45	62.15

Table C-10 Average Resistances and Maximum % Deviation for
Various Circuit Numbers

CIRCUIT NO.	AVERAGE RESISTANCE (Ω)	MAXIMUM % DEVIATION
1	90.35	.25
2	90.47	.57
3	92.61	.68
4	61.93	.30

Table C-11 Percentage energy converted from Heater for
Various Power Inputs and Spacings

POWER INPUT (W)	% ENERGY CONVERTED FROM HEATER, $(Q-Q_L-Q_{sc})/(Q-Q_L)$	
	NORMAL SPACING	WIDER SPACING
5	88	86
10	89	87
20	90	88
30	91	89
40	92	90
50	93	91

Table C-12 Correlation Coefficient for Individual Heater and Aspect Ratio

[illegible]

CRANE & TREFS

APPENDIX D DATA, RAW AND REDUCED

RUN NUMBER= 7

NUMBER OF ACTIVE HEATER =

3

CHANNEL # TEMP. (C) CHANNEL # TEMP. (C) CHANNEL # TEMP. (C)

1	29.87	2	31.80	3	33.78
4	30.28	5	27.35	6	25.34
7	24.48	8	24.57	9	24.60
10	24.37	11	24.17	12	24.01
13	23.89	14	23.91	15	23.86
16	28.38	17	23.86	18	23.82
19	23.86	20	-28.77	21	23.62
22	23.66	23	24.05	24	24.09
25	23.85	26	23.95	27	28.69
28	29.53	29	27.60	30	28.15
31	23.78	32	23.85	33	23.96
34	23.96	35	23.97	36	23.95
37	23.97	38	23.97	39	23.98
40	-28.69	41	23.93	42	24.01
43	24.02	44	24.02	45	22.88
46	23.39	47	24.73	48	22.95

CHANNEL # VOLTAGE (AC VOLTS) CIRCUIT # POWER (W)

56	0.00	1	15.02
57	0.00	2	0.00
58	0.00	3	0.00
59	36.83	4	0.00

PROBE TEMPERATURE (C)

HEATER # X=6.4 X=12.7 X=19.1 (MM)

3	30.09	30.24	30.14
2	27.96	27.69	27.53
1	26.33	26.14	25.99

COLD WALL AVERAGE TEMPERATURE
23.98

ROOM TEMPERATURE
22.95

POWER TEST (WATTS)
5

ASPECT RATIO
4.5

RUN 7 NUMBER OF ACTIVE HEATER = 3

HEATER #	NU(W)	RA(W)	RA*(W)	PR
3	+7.2263E+00	+6.9922E+05	+5.0527E+06	+1.6340E+02
2	+9.0559E+00	+5.4675E+05	+4.9513E+06	+1.6663E+02
1	+1.2030E+01	+4.0344E+05	+4.8535E+06	+1.6987E+02

HEATER #	NU(Y)	RA(Y)	RA*(Y)
3	+2.9808E+01	+4.9078E+07	+1.4629E+09
2	+2.3772E+01	+9.8895E+06	+2.3509E+08
1	+1.3534E+01	+5.7444E+05	+7.7744E+06

AVERAGE NUSSELT #	AVERAGE RAYLEIGH* #
9.04E+00	4.95E+06

UNCERTAINTY RATIO				
HEATER #	NU(W)	RA*(W)	NU(Y)	RA*(Y)
3	.13	.15	.13	.14
1	.13	.15	.13	.15

UNCERTAINTY RATIO IN PROPERTIES $B/(ALF \cdot KVIS) =$	.0643195149235
UNCERTAINTY RATIO IN LOSS =	.405883251181
UNCERTAINTY RATIO IN HEAT INPUT =	.0104727418091
UNCERTAINTY RATIO IN ACTUAL HEAT TRANSFER =	.12448795191

TOTAL HEAT LOST = 3.17418462234 WATTS
TOTAL HEAT ADDED = 15.0219735826 WATTS

% LOSS AIR = 1.73983086657	% LOSS SIDE =	3.43387863691
% LOSS TOP = .421133773914	% LOSS BOTTOM =	.618145032344
% LOSS BACK = 14.5014207651	% LOSS TOTAL =	21.1302769565
% OF ENERGY CONTRIBUTED BY EACH HEATER = 88		

RUN NUMBER= 8

NUMBER OF ACTIVE HEATER =

3

CHANNEL # TEMP. (C) CHANNEL # TEMP. (C) CHANNEL # TEMP. (C)

1	34.56	2	37.84	3	41.32
4	35.61	5	30.16	6	26.37
7	24.75	8	24.86	9	24.98
10	24.42	11	24.10	12	23.74
13	23.55	14	23.50	15	23.43
16	29.91	17	23.35	18	23.12
19	23.14	20	-27.36	21	23.01
22	23.04	23	23.78	24	23.79
25	23.62	26	23.66	27	32.20
28	33.75	29	30.76	30	31.60
31	23.22	32	23.27	33	24.64
34	24.64	35	24.64	36	24.63
37	24.64	38	24.63	39	24.63
40	-27.21	41	24.59	42	24.74
43	24.74	44	24.75	45	22.58
46	23.11	47	24.78	48	22.60

CHANNEL # VOLTAGE (AC VOLTS) CIRCUIT # POWER (W)

56	0.00	1	29.71
57	0.00	2	0.00
58	0.00	3	0.00
59	51.79	4	0.00

HEATER # PROBE TEMPERATURE (C)
X=6.4 X=12.7 X=19.1 (MM)

3	35.06	35.45	35.51
2	31.29	30.86	30.66
1	28.58	28.26	28.04

COLD WALL AVERAGE TEMPERATURE ROOM TEMPERATURE
24.67 22.60

POWER TEST (WATTS) ASPECT RATIO
10 4.5

RUN 8 NUMBER OF ACTIVE HEATER = 3

HEATER #	NU(W)	RA(W)	RA*(W)	PR
3	+8.8420E+00	+1.3119E+06	+1.1599E+07	+1.4881E+02
2	+1.1189E+01	+1.0012E+06	+1.1202E+07	+1.5390E+02
1	+1.4902E+01	+7.2724E+05	+1.0837E+07	+1.5889E+02

HEATER #	NU(Y)	RA(Y)	RA*(Y)
3	+3.6473E+01	+9.2078E+07	+3.3584E+09
2	+2.9371E+01	+1.8109E+07	+5.3188E+08
1	+1.6765E+01	+1.0355E+06	+1.7359E+07

AVERAGE NUSSELT #	AVERAGE RAYLEIGH* #
1.11E+01	1.12E+07

UNCERTAINTY RATIO				
HEATER #	NU(W)	RA*(W)	NU(Y)	RA*(Y)
3	.07	.10	.07	.10
1	.07	.10	.07	.10

UNCERTAINTY RATIO IN PROPERTIES $B/(ALF*KVIS)=$.0643195149235
UNCERTAINTY RATIO IN LOSS= .256149352112
UNCERTAINTY RATIO IN HEAT INPUT= .0104727418091
UNCERTAINTY RATIO IN ACTUAL HEAT TRANSFER= .064154095128

TOTAL HEAT LOST = 5.30356091771 WATTS
TOTAL HEAT ADDED = 29.7125912094 WATTS

% LOSS AIR= .987116352165	% LOSS SIDE=	3.15249480572
% LOSS TOP= 1.31743978612	% LOSS BOTTOM=	.688972350081
% LOSS BACK= 11.5982374331	% LOSS TOTAL=	17.8495402179
% OF ENERGY CONTRIBUTED BY EACH HEATER = 89		

RUN NUMBER= 9

NUMBER OF ACTIVE HEATER =

3

CHANNEL # TEMP. (C) CHANNEL # TEMP. (C) CHANNEL # TEMP. (C)

1	41.58	2	47.13	3	53.36
4	44.85	5	35.76	6	29.10
7	26.44	8	26.66	9	26.84
10	25.88	11	25.34	12	24.70
13	24.39	14	24.31	15	24.20
16	37.58	17	24.13	18	23.90
19	23.89	20	-28.69	21	24.05
22	24.08	23	25.18	24	25.20
25	24.93	26	25.01	27	38.73
28	41.33	29	36.55	30	38.07
31	24.26	32	24.30	33	24.62
34	24.62	35	24.63	36	24.63
37	24.63	38	24.62	39	24.62
40	-28.60	41	24.60	42	24.92
43	24.93	44	24.93	45	23.70
46	24.01	47	25.76	48	23.66

CHANNEL # VOLTAGE (AC VOLTS) CIRCUIT # POWER (W)

56	.01	1	59.70
57	.01	2	0.00
58	.01	3	0.00
59	73.41	4	0.00

PROBE TEMPERATURE (C)

HEATER # X=6.4 X=12.7 X=19.1 (MM)

3	43.19	43.69	43.85
2	36.36	35.78	35.31
1	31.74	31.24	30.74

COLD WALL AVERAGE TEMPERATURE
24.73

ROOM TEMPERATURE
23.66

POWER TEST (WATTS)
20

ASPECT RATIO
4.5

RUN 9 NUMBER OF ACTIVE HEATER = 3

HEATER #	NU(W)	RA(W)	RA*(W)	PR
3	+1.0813E+01	+2.5438E+06	+2.7507E+07	+1.3264E+02
2	+1.3831E+01	+1.8727E+06	+2.5902E+07	+1.4056E+02
1	+1.8396E+01	+1.3332E+06	+2.4526E+07	+1.4816E+02

HEATER #	NU(Y)	RA(Y)	RA*(Y)
3	+4.4605E+01	+1.7855E+08	+7.9642E+09
2	+3.6308E+01	+3.3873E+07	+1.2298E+09
1	+2.0696E+01	+1.8982E+06	+3.9286E+07

AVERAGE NUSSELT #	AVERAGE RAYLEIGH* #
1.37E+01	2.60E+07

UNCERTAINTY RATIO				
HEATER #	NU(W)	RA*(W)	NU(Y)	RA*(Y)
3	.05	.08	.04	.08
1	.05	.08	.05	.08

UNCERTAINTY RATIO IN PROPERTIES B/(ALF*KVIS)=	.0643195149235
UNCERTAINTY RATIO IN LOSS=	.158679101335
UNCERTAINTY RATIO IN HEAT INPUT=	.0104727418091
UNCERTAINTY RATIO IN ACTUAL HEAT TRANSFER=	.0337376200837

TOTAL HEAT LOST = 8.88807646769 WATTS
TOTAL HEAT ADDED = 59.6953128862 WATTS

% LOSS AIR= 1.85396532729	% LOSS SIDE=	2.31516540593
% LOSS TOP= .312066035232	% LOSS BOTTOM=	.524767227174
% LOSS BACK= 9.85694562848	% LOSS TOTAL=	14.8890692384
% OF ENERGY CONTRIBUTED BY EACH HEATER = 90		

RUN NUMBER= 6

NUMBER OF ACTIVE HEATER =

3

CHANNEL # TEMP. (C) CHANNEL # TEMP. (C) CHANNEL # TEMP. (C)

1	50.74	2	59.78	3	70.31
4	59.55	5	43.22	6	31.00
7	27.76	8	27.43	9	27.21
10	26.59	11	25.87	12	25.14
13	24.77	14	24.65	15	24.51
16	41.71	17	24.33	18	24.54
19	24.53	20	-30.08	21	24.84
22	24.85	23	25.46	24	25.51
25	26.03	26	26.12	27	43.20
28	48.23	29	43.04	30	45.80
31	24.91	32	24.87	33	21.54
34	21.55	35	21.54	36	21.56
37	21.57	38	21.55	39	21.55
40	-30.01	41	21.63	42	22.27
43	22.29	44	22.26	45	25.16
46	24.57	47	26.17	48	25.27

CHANNEL # VOLTAGE (AC VOLTS) CIRCUIT # POWER (W)

56	0.00	1	119.07
57	.01	2	0.00
58	.01	3	0.00
59	103.68	4	0.00

HEATER # PROBE TEMPERATURE (C)
X=6.4 X=12.7 X=19.1 (MM)

3	54.17	54.83	54.80
2	41.19	40.39	39.96
1	34.21	33.23	32.53

COLD WALL AVERAGE TEMPERATURE
21.84

ROOM TEMPERATURE
25.27

POWER TEST (WATTS)
40

ASPECT RATIO
4.5

RUN 6 NUMBER OF ACTIVE HEATER = 3

HEATER #	NU(W)	RA(W)	RA*(W)	PR
3	+1.3051E+01	+4.6625E+06	+6.0851E+07	+1.2304E+02
2	+1.6697E+01	+3.2985E+06	+5.5077E+07	+1.3545E+02
1	+2.1944E+01	+2.2977E+06	+5.0421E+07	+1.4750E+02

HEATER #	NU(Y)	RA(Y)	RA*(Y)
3	+5.3836E+01	+3.2726E+08	+1.7618E+10
2	+4.3831E+01	+5.9663E+07	+2.6151E+09
1	+2.4687E+01	+3.2715E+06	+8.0765E+07

AVERAGE NUSSELT #	AVERAGE RAYLEIGH* #
1.65E+01	5.54E+07

UNCERTAINTY RATIO				
HEATER #	NU(W)	RA*(W)	NU(Y)	RA*(Y)
3	.04	.08	.04	.07
1	.04	.08	.04	.08

UNCERTAINTY RATIO IN PROPERTIES B/(ALF*KVIS)=	.0643195149235
UNCERTAINTY RATIO IN LOSS=	.0889721580856
UNCERTAINTY RATIO IN HEAT INPUT=	.0104727418091
UNCERTAINTY RATIO IN ACTUAL HEAT TRANSFER=	.0212156384365

TOTAL HEAT LOST = 17.3609959109 WATTS
TOTAL HEAT ADDED = 119.068236046 WATTS

% LOSS AIR= 2.9149985383	% LOSS SIDE=	1.59495978729
% LOSS TOP= .465109203877	% LOSS BOTTOM=	.359727535061
% LOSS BACK= 9.22299500758	% LOSS TOTAL=	14.5807114369
% OF ENERGY CONTRIBUTED BY EACH HEATER = 92		

RUN NUMBER= 10

NUMBER OF ACTIVE HEATER =

3

CHANNEL # TEMP. (C) CHANNEL # TEMP. (C) CHANNEL # TEMP. (C)

1	57.15	2	68.00	3	80.74
4	69.80	5	48.80	6	34.27
7	28.98	8	29.41	9	29.78
10	27.81	11	26.68	12	25.35
13	24.69	14	24.46	15	24.25
16	40.81	17	24.12	18	23.68
19	23.72	20	-27.77	21	23.84
22	23.88	23	26.42	24	26.30
25	25.86	26	25.91	27	51.51
28	56.85	29	49.69	30	53.25
31	24.26	32	24.26	33	24.12
34	24.13	35	24.13	36	24.12
37	24.13	38	24.13	39	24.13
40	-27.69	41	24.16	42	24.94
43	24.94	44	24.92	45	22.57
46	23.78	47	27.17	48	22.62

CHANNEL # VOLTAGE (AC VOLTS) CIRCUIT # POWER (W)

56	0.00	1	148.00
57	0.00	2	0.00
58	.01	3	0.00
59	115.59	4	0.00

PROBE TEMPERATURE (C)

HEATER # X=6.4 X=12.7 X=19.1 (MM)

3	64.11	64.12	63.73
2	48.44	47.62	47.08
1	38.52	37.69	37.03

COLD WALL AVERAGE TEMPERATURE
24.43

ROOM TEMPERATURE
22.62

POWER TEST (WATTS)

49

ASPECT RATIO

4.5

RUN 10 NUMBER OF ACTIVE HEATER = 3

HEATER #	NU(W)	RA(W)	RA*(W)	PR
3	+1.4191E+01	+6.3960E+06	+9.0763E+07	+1.0508E+02
2	+1.8371E+01	+4.4104E+06	+8.1026E+07	+1.1721E+02
1	+2.4496E+01	+2.9905E+06	+7.3256E+07	+1.2916E+02

HEATER #	NU(Y)	RA(Y)	RA*(Y)
3	+5.8537E+01	+4.4893E+08	+2.6279E+10
2	+4.8225E+01	+7.9776E+07	+3.8472E+09
1	+2.7558E+01	+4.2580E+06	+1.1734E+08

AVERAGE NUSSELT #	AVERAGE RAYLEIGH* #
1.81E+01	8.17E+07

UNCERTAINTY RATIO				
HEATER #	NU(W)	RA*(W)	NU(Y)	RA*(Y)
3	.04	.08	.03	.07
1	.04	.08	.04	.08

UNCERTAINTY RATIO IN PROPERTIES B/(ALF*KVIS)=	.0643195149235
UNCERTAINTY RATIO IN LOSS=	.0778592753374
UNCERTAINTY RATIO IN HEAT INPUT=	.0104727418091
UNCERTAINTY RATIO IN ACTUAL HEAT TRANSFER=	.018837147227

TOTAL HEAT LOST = 20.619513878 WATTS
TOTAL HEAT ADDED = 148.001805599 WATTS

% LOSS AIR= 2.24449197894	% LOSS SIDE=	1.76970695691
% LOSS TOP= 1.01088919162	% LOSS BOTTOM=	.389739383324
% LOSS BACK= 8.4696064687	% LOSS TOTAL=	13.9319340022
% OF ENERGY CONTRIBUTED BY EACH HEATER = 93		

RUN NUMBER= 11

NUMBER OF ACTIVE HEATER =

6

CHANNEL # TEMP. (C) CHANNEL # TEMP. (C) CHANNEL # TEMP. (C)

1	29.42	2	30.99	3	32.11
4	30.56	5	32.84	6	33.59
7	35.75	8	35.61	9	35.16
10	31.49	11	28.14	12	25.69
13	24.64	14	24.38	15	24.12
16	26.63	17	23.67	18	23.44
19	23.43	20	-24.50	21	23.83
22	23.84	23	26.42	24	26.51
25	27.37	26	27.56	27	28.88
28	29.62	29	29.34	30	30.03
31	23.90	32	23.90	33	23.94
34	23.94	35	23.93	36	23.94
37	23.93	38	23.92	39	23.90
40	-24.50	41	24.08	42	24.04
43	24.04	44	24.04	45	23.16
46	24.05	47	23.71	48	23.26

CHANNEL # VOLTAGE (AC VOLTS) CIRCUIT # POWER (W)

56	0.00	1	14.94
57	0.00	2	14.67
58	36.46	3	0.00
59	36.73	4	0.00

HEATER # PROBE TEMPERATURE (C)
X=6.4 X=12.7 X=19.1 (MM)

6	31.39	31.78	31.78
5	29.48	29.29	29.18
4	28.09	28.00	28.12
3	27.13	27.07	27.24
2	26.25	26.20	26.71
1	25.41	25.38	25.45

COLD WALL AVERAGE TEMPERATURE
23.98

ROOM TEMPERATURE
23.26

POWER TEST (WATTS)
5

ASPECT RATIO
9.0

RUN 11 NUMBER OF ACTIVE HEATER = 6

HEATER #	NU(W)	RA(W)	RA*(W)	PR
6	+6.5856E+00	+8.3758E+05	+5.5160E+06	+1.6062E+02
5	+7.9027E+00	+6.8445E+05	+5.4090E+06	+1.6368E+02
4	+8.5676E+00	+6.2653E+05	+5.3679E+06	+1.6489E+02
3	+9.3447E+00	+5.7011E+05	+5.3275E+06	+1.6610E+02
2	+1.0842E+01	+4.8575E+05	+5.2664E+06	+1.6796E+02
1	+1.3981E+01	+3.7062E+05	+5.1815E+06	+1.7062E+02

HEATER #	NU(Y)	RA(Y)	RA*(Y)
6	+5.6801E+01	+5.3741E+08	+3.0525E+10
5	+5.6307E+01	+2.4757E+08	+1.3940E+10
4	+4.8193E+01	+1.1151E+08	+5.3740E+09
3	+3.8547E+01	+4.0016E+07	+1.5425E+09
2	+2.8459E+01	+8.7863E+06	+2.5005E+08
1	+1.5728E+01	+5.2769E+05	+8.2997E+06

AVERAGE NUSSELT #	AVERAGE RAYLEIGH* #
9.01E+00	5.34E+06

UNCERTAINTY RATIO				
HEATER #	NU(W)	RA*(W)	NU(Y)	RA*(Y)
6	.07	.10	.07	.09
1	.07	.10	.07	.10

UNCERTAINTY RATIO IN PROPERTIES B/(ALF*KVIS)=	.0643195149235
UNCERTAINTY RATIO IN LOSS=	.317503851976
UNCERTAINTY RATIO IN HEAT INPUT=	.0104727418091
UNCERTAINTY RATIO IN ACTUAL HEAT TRANSFER=	.0612488264464

TOTAL HEAT LOST = 4.20189551462 WATTS
TOTAL HEAT ADDED = 29.6141225306 WATTS

% LOSS AIR= 1.53274832562	% LOSS SIDE=	3.22042789098
% LOSS TOP= 1.33574690506	% LOSS BOTTOM=	.428050139545
% LOSS BACK= 7.59267662162	% LOSS TOTAL=	14.1888232896
% OF ENERGY CONTRIBUTED BY EACH HEATER = 88		

RUN NUMBER= 12 NUMBER OF ACTIVE HEATER = 6

CHANNEL # TEMP. (C) CHANNEL # TEMP. (C) CHANNEL # TEMP. (C)

1	33.20	2	35.86	3	37.81
4	35.13	5	39.16	6	40.44
7	44.45	8	44.42	9	43.48
10	38.60	11	31.83	12	27.34
13	25.50	14	25.11	15	24.59
16	30.53	17	23.85	18	23.56
19	23.53	20	-27.36	21	23.92
22	23.95	23	28.71	24	28.88
25	30.23	26	30.63	27	32.33
28	33.68	29	33.00	30	34.37
31	24.32	32	24.32	33	23.61
34	23.62	35	23.60	36	23.60
37	23.60	38	23.59	39	23.56
40	-27.28	41	23.91	42	23.85
43	23.86	44	23.86	45	23.14
46	24.21	47	24.21	48	23.54

CHANNEL # VOLTAGE (AC VOLTS) CIRCUIT # POWER (W)

56	0.00	1	30.01
57	0.00	2	30.01
58	52.14	3	0.00
59	52.05	4	0.00

HEATER # PROBE TEMPERATURE (C)
X=6.4 X=12.7 X=19.1 (MM)

6	37.15	37.55	37.46
5	33.67	33.35	32.99
4	31.35	31.18	30.89
3	29.48	29.44	29.19
2	27.91	28.00	27.76
1	26.42	26.52	26.30

COLD WALL AVERAGE TEMPERATURE ROOM TEMPERATURE
23.73 23.54

POWER TEST (WATTS) ASPECT RATIO
10 9.0

RUN 12 NUMBER OF ACTIVE HEATER = 6

HEATER #	NU(W)	RA(W)	RA*(W)	PR
6	+7.7326E+00	+1.6056E+06	+1.2416E+07	+1.4884E+02
5	+9.4417E+00	+1.2674E+06	+1.1967E+07	+1.5422E+02
4	+1.0224E+01	+1.1555E+06	+1.1814E+07	+1.5614E+02
3	+1.1207E+01	+1.0399E+06	+1.1654E+07	+1.5822E+02
2	+1.3012E+01	+8.7801E+05	+1.1425E+07	+1.6127E+02
1	+1.6675E+01	+6.6672E+05	+1.1118E+07	+1.6557E+02

HEATER #	NU(Y)	RA(Y)	RA*(Y)
6	+6.6694E+01	+1.0302E+09	+6.8708E+10
5	+6.7272E+01	+4.5844E+08	+3.0840E+10
4	+5.7510E+01	+2.0566E+08	+1.1827E+10
3	+4.6228E+01	+7.2988E+07	+3.3741E+09
2	+3.4157E+01	+1.5881E+07	+5.4246E+08
1	+1.8760E+01	+9.4930E+05	+1.7809E+07

AVERAGE NUSSELT #	AVERAGE RAYLEIGH* #
1.07E+01	1.17E+07

UNCERTAINTY RATIO				
HEATER #	NU(W)	RA*(W)	NU(Y)	RA*(Y)
6	.05	.08	.04	.08
1	.05	.08	.05	.08

UNCERTAINTY RATIO IN PROPERTIES B/(ALF*KVIS)=	.0643195149235
UNCERTAINTY RATIO IN LOSS=	.173815354922
UNCERTAINTY RATIO IN HEAT INPUT=	.0104727418091
UNCERTAINTY RATIO IN ACTUAL HEAT TRANSFER=	.0319801158923

TOTAL HEAT LOST = 7.75660968866 WATTS
TOTAL HEAT ADDED = 60.0204464527 WATTS

% LOSS AIR= 1.9134808162	% LOSS SIDE=	2.65832281171
% LOSS TOP= .718415043979	% LOSS BOTTOM=	.299882546066
% LOSS BACK= 7.24855772765	% LOSS TOTAL=	12.9232788942
% OF ENERGY CONTRIBUTED BY EACH HEATER = 89		

RUN NUMBER= 13

NUMBER OF ACTIVE HEATER =

6

CHANNEL # TEMP. (C) CHANNEL # TEMP. (C) CHANNEL # TEMP. (C)

1	40.25	2	44.67	3	47.99
4	43.43	5	49.84	6	51.77
7	58.71	8	58.89	9	57.19
10	48.00	11	37.57	12	30.40
13	27.49	14	26.80	15	25.99
16	32.83	17	24.67	18	24.17
19	24.19	20	-25.93	21	24.65
22	24.64	23	32.46	24	32.72
25	35.17	26	35.86	27	38.49
28	40.87	29	40.27	30	42.53
31	25.10	32	25.11	33	23.64
34	23.65	35	23.65	36	23.65
37	23.67	38	23.66	39	23.69
40	-25.95	41	24.34	42	24.14
43	24.15	44	24.14	45	23.69
46	25.34	47	24.92	48	23.96

CHANNEL # VOLTAGE (AC VOLTS) CIRCUIT # POWER (W)

56	0.00	1	60.59
57	0.00	2	58.30
58	72.67	3	0.00
59	73.96	4	0.00

HEATER # PROBE TEMPERATURE (C)
X=6.4 X=12.7 X=19.1 (MM)

6	47.36	48.24	48.28
5	41.06	40.62	40.13
4	37.49	37.11	36.61
3	34.61	34.23	33.71
2	31.99	31.67	31.22
1	28.96	28.70	28.28

COLD WALL AVERAGE TEMPERATURE
23.93

ROOM TEMPERATURE
23.96

POWER TEST (WATTS)
20

ASPECT RATIO
9.0

RUN 13 NUMBER OF ACTIVE HEATER = 6

HEATER #	NU(W)	RA(W)	RA*(W)	PR
6	+9.3344E+00	+3.1261E+06	+2.9180E+07	+1.2963E+02
5	+1.1524E+01	+2.3793E+06	+2.7418E+07	+1.3766E+02
4	+1.2385E+01	+2.1727E+06	+2.6909E+07	+1.4017E+02
3	+1.3336E+01	+1.9817E+06	+2.6429E+07	+1.4262E+02
2	+1.5479E+01	+1.6524E+06	+2.5577E+07	+1.4720E+02
1	+1.9687E+01	+1.2432E+06	+2.4474E+07	+1.5360E+02

HEATER #	NU(Y)	RA(Y)	RA*(Y)
6	+8.0509E+01	+2.0058E+09	+1.6148E+11
5	+8.2107E+01	+8.6059E+08	+7.0661E+10
4	+6.9665E+01	+3.8670E+08	+2.6940E+10
3	+5.5012E+01	+1.3910E+08	+7.6520E+09
2	+4.0633E+01	+2.9888E+07	+1.2144E+09
1	+2.2147E+01	+1.7700E+06	+3.9202E+07

AVERAGE NUSSELT #	AVERAGE RAYLEIGH* #
1.29E+01	2.67E+07

UNCERTAINTY RATIO				
HEATER #	NU(W)	RA*(W)	NU(Y)	RA*(Y)
6	.04	.08	.04	.07
1	.04	.08	.04	.08

UNCERTAINTY RATIO IN PROPERTIES B/(ALF*KVIS)=	.0643195149235
UNCERTAINTY RATIO IN LOSS=	.102043949782
UNCERTAINTY RATIO IN HEAT INPUT=	.0104727418091
UNCERTAINTY RATIO IN ACTUAL HEAT TRANSFER=	.0197028606547

TOTAL HEAT LOST = 13.6272304104 WATTS
TOTAL HEAT ADDED = 118.886681029 WATTS

% LOSS AIR= 1.90546393207	% LOSS SIDE=	2.16415641996
% LOSS TOP= .883432799478	% LOSS BOTTOM=	.255263499909
% LOSS BACK= 6.22779762897	% LOSS TOTAL=	11.4623692851
% OF ENERGY CONTRIBUTED BY EACH HEATER = 90		

RUN NUMBER= 14

NUMBER OF ACTIVE HEATER =

6

CHANNEL # TEMP. (C) CHANNEL # TEMP. (C) CHANNEL # TEMP. (C)

1	45.89	2	51.72	3	56.22
4	50.26	5	58.91	6	61.38
7	70.84	8	71.30	9	68.85
10	57.02	11	42.77	12	33.48
13	29.60	14	28.50	15	27.57
16	31.75	17	25.69	18	25.16
19	25.19	20	-23.44	21	25.82
22	25.85	23	36.02	24	36.40
25	39.66	26	40.64	27	43.81
28	47.08	29	46.28	30	49.47
31	26.49	32	26.47	33	23.77
34	23.77	35	23.77	36	23.79
37	23.79	38	23.80	39	23.78
40	-23.44	41	24.86	42	24.57
43	24.57	44	24.57	45	23.96
46	26.60	47	25.74	48	24.49

CHANNEL # VOLTAGE (AC VOLTS) CIRCUIT # POWER (W)

56	0.00	1	89.29
57	0.00	2	87.94
58	89.25	3	0.00
59	89.78	4	0.00

PROBE TEMPERATURE (C)

HEATER # X=6.4 X=12.7 X=19.1 (MM)

6	55.68	56.56	56.62
5	46.81	46.58	45.96
4	42.24	41.83	41.14
3	38.60	38.14	37.46
2	35.17	34.74	34.43
1	31.31	30.96	30.47

COLD WALL AVERAGE TEMPERATURE
24.21

ROOM TEMPERATURE
24.49

POWER TEST (WATTS)
30

ASPECT RATIO
9.0

RUN 14 NUMBER OF ACTIVE HEATER = 6

HEATER #	NU(W)	RA(W)	RA*(W)	PR
6	+1.0511E+01	+4.7407E+06	+4.9829E+07	+1.1551E+02
5	+1.3056E+01	+3.5147E+06	+4.5888E+07	+1.2504E+02
4	+1.3990E+01	+3.2050E+06	+4.4837E+07	+1.2787E+02
3	+1.5171E+01	+2.8810E+06	+4.3708E+07	+1.3105E+02
2	+1.7662E+01	+2.3701E+06	+4.1863E+07	+1.3662E+02
1	+2.2437E+01	+1.7625E+06	+3.9546E+07	+1.4433E+02

HEATER #	NU(Y)	RA(Y)	RA*(Y)
6	+9.0656E+01	+3.0417E+09	+2.7575E+11
5	+9.3025E+01	+1.2713E+09	+1.1826E+11
4	+7.8692E+01	+5.7042E+08	+4.4887E+10
3	+6.2580E+01	+2.0222E+08	+1.2655E+10
2	+4.6364E+01	+4.2871E+07	+1.9877E+09
1	+2.5242E+01	+2.5095E+06	+6.3345E+07

AVERAGE NUSSELT #	AVERAGE RAYLEIGH* #
1.46E+01	4.43E+07

UNCERTAINTY RATIO				
HEATER #	NU(W)	RA*(W)	NU(Y)	RA*(Y)
6	.04	.08	.03	.07
1	.04	.08	.04	.08

UNCERTAINTY RATIO IN PROPERTIES B/(ALF*KVIS)=	.0643195149235
UNCERTAINTY RATIO IN LOSS=	.0751209721601
UNCERTAINTY RATIO IN HEAT INPUT=	.0104727418091
UNCERTAINTY RATIO IN ACTUAL HEAT TRANSFER=	.0164837804084

TOTAL HEAT LOST = 19.5234969885 WATTS
TOTAL HEAT ADDED = 177.22386638 WATTS

% LOSS AIR= 1.94339100426	% LOSS SIDE=	1.878606555916
% LOSS TOP= 1.11214884984	% LOSS BOTTOM=	.222373741712
% LOSS BACK= 5.83560313849	% LOSS TOTAL=	11.0162910828
% OF ENERGY CONTRIBUTED BY EACH HEATER = 91		

RUN NUMBER= 15

NUMBER OF ACTIVE HEATER =

6

CHANNEL # TEMP. (C) CHANNEL # TEMP. (C) CHANNEL # TEMP. (C)

1	51.27	2	58.33	3	63.84
4	56.54	5	67.03	6	69.80
7	81.23	8	81.77	9	78.73
10	69.77	11	47.45	12	34.95
13	30.36	14	29.09	15	28.06
16	31.65	17	26.06	18	25.24
19	25.33	20	-26.70	21	25.93
22	26.02	23	37.68	24	38.18
25	42.15	26	43.50	27	48.19
28	52.48	29	50.64	30	54.92
31	26.59	32	26.69	33	24.14
34	24.15	35	24.14	36	24.13
37	24.16	38	24.16	39	24.14
40	-26.67	41	25.52	42	25.16
43	25.17	44	25.15	45	23.46
46	26.85	47	26.60	48	23.57

CHANNEL # VOLTAGE (AC VOLTS) CIRCUIT # POWER (W)

56	.01	1	119.02
57	.01	2	117.25
58	103.06	3	0.00
59	103.66	4	0.00

HEATER # PROBE TEMPERATURE (C)
X=6.4 X=12.7 X=19.1 (MM)

6	64.19	65.14	64.87
5	52.84	52.59	52.04
4	47.27	46.89	46.09
3	42.70	42.15	41.26
2	38.37	37.86	37.13
1	33.61	33.18	32.45

COLD WALL AVERAGE TEMPERATURE
24.70

ROOM TEMPERATURE
23.57

POWER TEST (WATTS)
40

ASPECT RATIO
9.0

RUN 15 NUMBER OF ACTIVE HEATER = 6

HEATER #	NU(W)	RA(W)	RA*(W)	PR
6	+1.1680E+01	+6.3825E+06	+7.4549E+07	+1.0453E+02
5	+1.4491E+01	+4.6766E+06	+6.7767E+07	+1.1458E+02
4	+1.5444E+01	+4.2789E+06	+6.6084E+07	+1.1739E+02
3	+1.6714E+01	+3.8395E+06	+6.4173E+07	+1.2075E+02
2	+1.9462E+01	+3.1325E+06	+6.0966E+07	+1.2687E+02
1	+2.4653E+01	+2.3123E+06	+5.7005E+07	+1.3535E+02

HEATER #	NU(Y)	RA(Y)	RA*(Y)
6	+1.0074E+02	+4.0951E+09	+4.1255E+11
5	+1.0325E+02	+1.6915E+09	+1.7464E+11
4	+8.6873E+01	+7.6156E+08	+6.6159E+10
3	+6.8944E+01	+2.6949E+08	+1.8580E+10
2	+5.1088E+01	+5.6661E+07	+2.8947E+09
1	+2.7735E+01	+3.2923E+06	+9.1311E+07

AVERAGE NUSSELT #	AVERAGE RAYLEIGH* #
1.62E+01	6.51E+07

UNCERTAINTY RATIO				
HEATER #	NU(W)	RA*(W)	NU(Y)	RA*(Y)
6	.03	.08	.03	.07
1	.03	.08	.03	.08

UNCERTAINTY RATIO IN PROPERTIES B/(ALF*KVIS)=	.0643195149235
UNCERTAINTY RATIO IN LOSS=	.0605854641328
UNCERTAINTY RATIO IN HEAT INPUT=	.0104727418091
UNCERTAINTY RATIO IN ACTUAL HEAT TRANSFER=	.0151378757803

TOTAL HEAT LOST = 25.8953152725 WATTS
TOTAL HEAT ADDED = 236.268582547 WATTS

% LOSS AIR= 1.91141524446	% LOSS SIDE=	1.78610166513
% LOSS TOP= 1.12802100168	% LOSS BOTTOM=	.203972925752
% LOSS BACK= 5.87129206248	% LOSS TOTAL=	10.9601179274
% OF ENERGY CONTRIBUTED BY EACH HEATER = 92		

RUN NUMBER= 16

NUMBER OF ACTIVE HEATER =

6

CHANNEL # TEMP. (C) CHANNEL # TEMP. (C) CHANNEL # TEMP. (C)

1	56.04	2	64.21	3	70.70
4	62.22	5	74.26	6	77.38
7	91.07	8	91.84	9	88.14
10	75.43	11	52.10	12	37.50
13	31.62	14	30.13	15	28.61
16	41.91	17	26.21	18	25.21
19	25.39	20	-27.14	21	25.50
22	25.70	23	40.46	24	41.30
25	44.78	26	46.78	27	51.87
28	57.13	29	54.77	30	60.00
31	26.48	32	26.76	33	24.20
34	24.19	35	24.21	36	24.17
37	24.25	38	24.23	39	24.26
40	-27.05	41	25.94	42	25.45
43	25.46	44	25.44	45	22.06
46	26.71	47	27.14	48	22.00

CHANNEL # VOLTAGE (AC VOLTS) CIRCUIT # POWER (W)

56	0.00	1	148.90
57	0.00	2	146.09
58	115.04	3	0.00
59	115.94	4	0.00

HEATER # PROBE TEMPERATURE (C)
X=6.4 X=12.7 X=19.1 (MM)

6	70.77	71.56	71.42
5	58.03	57.84	57.33
4	51.44	51.13	50.26
3	46.13	45.63	44.63
2	41.10	40.61	39.93
1	35.24	34.83	34.02

COLD WALL AVERAGE TEMPERATURE
24.90

ROOM TEMPERATURE
22.00

POWER TEST (WATTS)
50

ASPECT RATIO
9.0

RUN 16 NUMBER OF ACTIVE HEATER = 6

HEATER #	NU(W)	RA(W)	RA*(W)	PR
6	+1.2624E+01	+8.1755E+06	+1.0321E+08	+9.6037E+01
5	+1.5771E+01	+5.8578E+06	+9.2384E+07	+1.0683E+02
4	+1.6774E+01	+5.3583E+06	+8.9880E+07	+1.0969E+02
3	+1.8088E+01	+4.8136E+06	+8.7067E+07	+1.1310E+02
2	+2.1090E+01	+3.8920E+06	+8.2082E+07	+1.1971E+02
1	+2.6655E+01	+2.8533E+06	+7.6057E+07	+1.2883E+02

HEATER #	NU(Y)	RA(Y)	RA*(Y)
6	+1.0888E+02	+5.2456E+09	+5.7114E+11
5	+1.1237E+02	+2.1188E+09	+2.3809E+11
4	+9.4353E+01	+9.5367E+08	+8.9981E+10
3	+7.4611E+01	+3.3786E+08	+2.5209E+10
2	+5.5361E+01	+7.0399E+07	+3.8973E+09
1	+2.9987E+01	+4.0627E+06	+1.2183E+08

AVERAGE NUSSELT #	AVERAGE RAYLEIGH* #
1.75E+01	8.84E+07

UNCERTAINTY RATIO				
HEATER #	NU(W)	RA*(W)	NU(Y)	RA*(Y)
6	.03	.08	.03	.07
1	.03	.08	.03	.08

UNCERTAINTY RATIO IN PROPERTIES B/(ALF*KVIS)=	.0643195149235
UNCERTAINTY RATIO IN LOSS=	.0545855890504
UNCERTAINTY RATIO IN HEAT INPUT=	.0104727418091
UNCERTAINTY RATIO IN ACTUAL HEAT TRANSFER=	.0143793152832

TOTAL HEAT LOST = 31.1981721528 WATTS
TOTAL HEAT ADDED = 294.992528181 WATTS

% LOSS AIR= 1.84007386914	% LOSS SIDE=	1.73094098915
% LOSS TOP= .676746194075	% LOSS BOTTOM=	.191323424167
% LOSS BACK= 6.04050453825	% LOSS TOTAL=	10.5759194462
% OF ENERGY CONTRIBUTED BY EACH HEATER = 93		

RUN NUMBER= 17

NUMBER OF ACTIVE HEATER =

9

CHANNEL # TEMP. (C) CHANNEL # TEMP. (C) CHANNEL # TEMP. (C)

1	29.55	2	30.95	3	31.94
4	30.36	5	32.45	6	32.82
7	34.20	8	34.22	9	33.76
10	32.57	11	34.26	12	35.43
13	36.74	14	32.16	15	28.65
16	26.38	17	24.66	18	23.90
19	23.90	20	-22.69	21	25.13
22	25.15	23	30.66	24	31.52
25	30.41	26	31.37	27	28.68
28	29.42	29	29.16	30	29.83
31	25.85	32	25.91	33	24.10
34	24.10	35	24.09	36	24.12
37	24.31	38	24.34	39	24.31
40	-22.69	41	24.27	42	24.26
43	24.27	44	24.26	45	23.21
46	27.68	47	23.68	48	24.17

CHANNEL # VOLTAGE (AC VOLTS) CIRCUIT # POWER (W)

56	0.00	1	14.99
57	36.36	2	14.66
58	36.44	3	14.12
59	36.79	4	0.00

HEATER # PROBE TEMPERATURE (C)
X=6.4 X=12.7 X=19.1 (MM)

9	32.62	32.87	32.82
8	30.73	30.56	30.43
7	29.40	29.31	29.40
6	28.47	28.52	28.61
5	27.69	27.74	27.99
4	27.12	27.13	27.35
3	26.59	26.64	26.86
2	26.06	26.05	26.15
1	25.49	25.45	25.37

COLD WALL AVERAGE TEMPERATURE
24.27

ROOM TEMPERATURE
24.17

POWER TEST (WATTS)

5

ASPECT RATIO

13.5

RUN 17 NUMBER OF ACTIVE HEATER = 9

HEATER #	NU(W)	RA(W)	RA*(W)	PR
9	+6.0793E+00	+9.2611E+05	+5.6301E+06	+1.5738E+02
8	+6.7953E+00	+8.1759E+05	+5.5557E+06	+1.5941E+02
7	+7.5875E+00	+7.2360E+05	+5.4903E+06	+1.6124E+02
6	+7.7467E+00	+7.0725E+05	+5.4789E+06	+1.6157E+02
5	+8.8735E+00	+6.0965E+05	+5.4098E+06	+1.6356E+02
4	+9.2758E+00	+5.8101E+05	+5.3893E+06	+1.6416E+02
3	+9.8854E+00	+5.4237E+05	+5.3615E+06	+1.6498E+02
2	+1.1355E+01	+4.6738E+05	+5.3071E+06	+1.6661E+02
1	+1.4370E+01	+3.6402E+05	+5.2310E+06	+1.6895E+02

HEATER #	NU(Y)	RA(Y)	RA*(Y)
9	+7.9791E+01	+2.0939E+09	+1.6708E+11
8	+7.8995E+01	+1.2844E+09	+1.0146E+11
7	+7.6823E+01	+7.5108E+08	+5.7700E+10
6	+6.6815E+01	+4.5379E+08	+3.0320E+10
5	+6.3224E+01	+2.2051E+08	+1.3942E+10
4	+5.2176E+01	+1.0341E+08	+5.3954E+09
3	+4.0777E+01	+3.8068E+07	+1.5523E+09
2	+2.9807E+01	+8.4540E+06	+2.5199E+08
1	+1.6166E+01	+5.1831E+05	+8.3790E+06

AVERAGE NUSSELT #	AVERAGE RAYLEIGH* #
8.56E+00	5.43E+06

UNCERTAINTY RATIO				
HEATER #	NU(W)	RA*(W)	NU(Y)	RA*(Y)
9	.05	.09	.05	.08
1	.06	.09	.06	.08

UNCERTAINTY RATIO IN PROPERTIES B/(ALF*KVIS)=	.0643195149235
UNCERTAINTY RATIO IN LOSS=	.207333127369
UNCERTAINTY RATIO IN HEAT INPUT=	.0104727418091
UNCERTAINTY RATIO IN ACTUAL HEAT TRANSFER=	.0376418217917

TOTAL HEAT LOST = 5.67052971949 WATTS
TOTAL HEAT ADDED = 43.7649790486 WATTS

% LOSS AIR= 1.82372830264	% LOSS SIDE=	.806138932152
% LOSS TOP= 1.19603096783	% LOSS BOTTOM=	.312062491504
% LOSS BACK= 8.80097324464	% LOSS TOTAL=	12.9567746695
% OF ENERGY CONTRIBUTED BY EACH HEATER = 88		

RUN NUMBER= 18

NUMBER OF ACTIVE HEATER =

9

CHANNEL # TEMP. (C) CHANNEL # TEMP. (C) CHANNEL # TEMP. (C)

1	33.49	2	35.83	3	37.51
4	34.74	5	38.48	6	39.03
7	41.53	8	41.62	9	40.75
10	38.72	11	41.57	12	43.71
13	46.20	14	38.24	15	32.23
16	28.19	17	25.66	18	24.58
19	24.60	20	-26.15	21	26.29
22	26.41	23	35.39	24	36.96
25	34.75	26	36.61	27	32.05
28	33.40	29	32.48	30	33.88
31	27.61	32	27.79	33	24.23
34	24.23	35	24.21	36	24.21
37	24.65	38	24.70	39	24.62
40	-26.10	41	24.54	42	24.54
43	24.56	44	24.56	45	23.30
46	30.63	47	24.66	48	23.29

CHANNEL # VOLTAGE (AC VOLTS) CIRCUIT # POWER (W)

56	0.00	1	29.51
57	51.94	2	29.91
58	52.05	3	28.81
59	51.61	4	0.00

HEATER # PROBE TEMPERATURE (C)
X=6.4 X=12.7 X=19.1 (MM)

9	38.91	39.13	38.97
8	35.87	35.58	35.23
7	33.72	33.44	33.25
6	32.33	32.08	32.01
5	31.00	30.78	30.91
4	30.01	29.86	29.99
3	28.96	28.82	29.02
2	27.94	27.74	27.82
1	26.82	26.65	26.51

COLD WALL AVERAGE TEMPERATURE
24.55

ROOM TEMPERATURE
23.29

POWER TEST (WATTS)
10

ASPECT RATIO
13.5

RUN 18 NUMBER OF ACTIVE HEATER = 9

HEATER #	NU(W)	RA(W)	RA*(W)	PR
9	+7.1942E+00	+1.7841E+06	+1.2835E+07	+1.4254E+02
8	+8.1325E+00	+1.5400E+06	+1.2524E+07	+1.4596E+02
7	+9.1581E+00	+1.3388E+06	+1.2261E+07	+1.4897E+02
6	+9.3036E+00	+1.3144E+06	+1.2229E+07	+1.4936E+02
5	+1.0766E+01	+1.1104E+06	+1.1954E+07	+1.5266E+02
4	+1.1190E+01	+1.0625E+06	+1.1889E+07	+1.5347E+02
3	+1.2028E+01	+9.7886E+05	+1.1774E+07	+1.5492E+02
2	+1.3827E+01	+8.3711E+05	+1.1575E+07	+1.5749E+02
1	+1.7443E+01	+6.4805E+05	+1.1304E+07	+1.6113E+02

HEATER #	NU(Y)	RA(Y)	RA*(Y)
9	+9.4424E+01	+4.0337E+09	+3.8088E+11
8	+9.4541E+01	+2.4193E+09	+2.2873E+11
7	+9.2726E+01	+1.3896E+09	+1.2886E+11
6	+8.0244E+01	+8.4334E+08	+6.7673E+10
5	+7.6709E+01	+4.0163E+08	+3.0808E+10
4	+6.2942E+01	+1.8910E+08	+1.1902E+10
3	+4.9615E+01	+6.8706E+07	+3.4088E+09
2	+3.6297E+01	+1.5142E+07	+5.4959E+08
1	+1.9623E+01	+9.2271E+05	+1.8106E+07

AVERAGE NUSSELT #	AVERAGE RAYLEIGH* #
1.03E+01	1.20E+07

UNCERTAINTY RATIO

HEATER #	NU(W)	RA*(W)	NU(Y)	RA*(Y)
9	.04	.08	.04	.07
1	.04	.08	.04	.08

UNCERTAINTY RATIO IN PROPERTIES B/(ALF*KVIS)=	.0643195149235
UNCERTAINTY RATIO IN LOSS=	.115323178145
UNCERTAINTY RATIO IN HEAT INPUT=	.0104727418091
UNCERTAINTY RATIO IN ACTUAL HEAT TRANSFER=	.0224007195827

TOTAL HEAT LOST = 10.7367480776 WATTS
TOTAL HEAT ADDED = 88.2308841494 WATTS

% LOSS AIR= 1.80857582588	% LOSS SIDE=	.609457713859
% LOSS TOP= 1.03402331675	% LOSS BOTTOM=	.208981052269
% LOSS BACK= 8.47695552807	% LOSS TOTAL=	12.1689226864
% OF ENERGY CONTRIBUTED BY EACH HEATER = 89		

RUN NUMBER= 19

NUMBER OF ACTIVE HEATER =

9

CHANNEL # TEMP. (C) CHANNEL # TEMP. (C) CHANNEL # TEMP. (C)

1	40.12	2	44.05	3	46.94
4	42.32	5	48.17	6	48.95
7	53.15	8	53.40	9	51.86
10	48.59	11	53.30	12	57.00
13	61.31	14	48.10	15	37.76
16	26.44	17	27.27	18	25.23
19	25.30	20	-27.09	21	28.08
22	28.25	23	43.14	24	45.78
25	42.14	26	45.36	27	37.66
28	40.06	29	38.75	30	41.21
31	30.22	32	30.48	33	23.15
34	23.15	35	23.15	36	23.16
37	24.15	38	24.26	39	24.17
40	-27.13	41	24.00	42	23.96
43	23.96	44	23.96	45	22.80
46	35.37	47	25.33	48	22.71

CHANNEL # VOLTAGE (AC VOLTS) CIRCUIT # POWER (W)

56	0.00	1	59.76
57	73.53	2	58.23
58	72.63	3	57.75
59	73.45	4	0.00

HEATER # PROBE TEMPERATURE (C)
X=6.4 X=12.7 X=19.1 (MM)

9	50.00	50.64	50.62
8	44.20	43.86	43.36
7	40.80	40.44	39.89
6	38.49	38.03	37.48
5	36.38	35.93	35.55
4	34.46	33.93	33.71
3	32.69	32.23	32.36
2	30.71	30.30	30.30
1	28.52	28.18	27.86

COLD WALL AVERAGE TEMPERATURE
23.95

ROOM TEMPERATURE
22.71

POWER TEST (WATTS)
20

ASPECT RATIO
13.5

RUN 19 NUMBER OF ACTIVE HEATER = 9

HEATER #	NU(W)	RA(W)	RA*(W)	PR
9	+8.4932E+00	+3.5044E+06	+2.9764E+07	+1.2601E+02
8	+9.6059E+00	+2.9748E+06	+2.8576E+07	+1.3106E+02
7	+1.0822E+01	+2.5486E+06	+2.7581E+07	+1.3561E+02
6	+1.1012E+01	+2.4926E+06	+2.7448E+07	+1.3625E+02
5	+1.2714E+01	+2.0796E+06	+2.6440E+07	+1.4125E+02
4	+1.3126E+01	+1.9989E+06	+2.6239E+07	+1.4230E+02
3	+1.3830E+01	+1.8746E+06	+2.5924E+07	+1.4396E+02
2	+1.5820E+01	+1.5926E+06	+2.5196E+07	+1.4797E+02
1	+1.9678E+01	+1.2311E+06	+2.4226E+07	+1.5369E+02

HEATER #	NU(Y)	RA(Y)	RA*(Y)
9	+1.1147E+02	+7.9235E+09	+8.8325E+11
8	+1.1167E+02	+4.6735E+09	+5.2188E+11
7	+1.0957E+02	+2.6454E+09	+2.8986E+11
6	+9.4975E+01	+1.5993E+09	+1.5189E+11
5	+9.0588E+01	+7.5220E+08	+6.8140E+10
4	+7.3835E+01	+3.5577E+08	+2.6268E+10
3	+5.7047E+01	+1.3157E+08	+7.5059E+09
2	+4.1528E+01	+2.8807E+07	+1.1963E+09
1	+2.2138E+01	+1.7528E+06	+3.8805E+07

AVERAGE NUSSELT #	AVERAGE RAYLEIGH* #
1.21E+01	2.68E+07

UNCERTAINTY RATIO				
HEATER #	NU(W)	RA*(W)	NU(Y)	RA*(Y)
9	.04	.08	.03	.07
1	.04	.08	.04	.08

UNCERTAINTY RATIO IN PROPERTIES B/(ALF*KVIS)=	.0643195149235
UNCERTAINTY RATIO IN LOSS=	.0727108762148
UNCERTAINTY RATIO IN HEAT INPUT=	.0104727418091
UNCERTAINTY RATIO IN ACTUAL HEAT TRANSFER=	.0164627614689

TOTAL HEAT LOST = 19.358368541 WATTS
TOTAL HEAT ADDED = 175.739714406 WATTS

% LOSS AIR= 1.86112641818	% LOSS SIDE=	.383269300388
% LOSS TOP= 1.17019863641	% LOSS BOTTOM=	.161489458699
% LOSS BACK= 7.37725407655	% LOSS TOTAL=	11.0153636055
% OF ENERGY CONTRIBUTED BY EACH HEATER = 90		

RUN NUMBER= 20

NUMBER OF ACTIVE HEATER =

9

CHANNEL # TEMP. (C) CHANNEL # TEMP. (C) CHANNEL # TEMP. (C)

1	45.38	2	50.60	3	54.49
4	48.41	5	56.36	6	57.23
7	63.18	8	63.51	9	61.33
10	56.73	11	62.82	12	67.68
13	73.60	14	59.98	15	45.14
16	32.87	17	30.03	18	27.60
19	27.60	20	-22.84	21	31.73
22	31.78	23	50.25	24	53.72
25	50.07	26	54.09	27	42.86
28	46.00	29	45.39	30	48.43
31	35.01	32	35.15	33	23.41
34	23.42	35	23.41	36	23.46
37	24.81	38	24.99	39	24.85
40	-22.85	41	24.62	42	24.54
43	24.54	44	24.53	45	24.27
46	40.86	47	25.45	48	24.92

CHANNEL #	VOLTAGE (AC VOLTS)	CIRCUIT #	POWER (W)
56	0.00	1	89.08
57	89.00	2	88.33
58	89.45	3	84.61
59	89.68	4	0.00

HEATER #	PROBE TEMPERATURE (C)		
	X=6.4	X=12.7	X=19.1 (MM)
9	59.29	60.10	60.19
8	51.23	50.96	50.39
7	46.87	46.53	45.79
6	43.93	43.48	42.85
5	40.96	40.61	40.14
4	38.60	38.16	37.69
3	36.04	35.55	35.21
2	33.47	33.00	32.55
1	30.38	30.09	29.58

COLD WALL AVERAGE TEMPERATURE
24.54

ROOM TEMPERATURE
24.92

POWER TEST (WATTS)
30

ASPECT RATIO
13.5

RUN 20 NUMBER OF ACTIVE HEATER = 9

HEATER #	NU(W)	RA(W)	RA*(W)	PR
9	+9.9224E+00	+5.2421E+06	+5.2014E+07	+1.1133E+02
8	+1.1291E+01	+4.3673E+06	+4.9313E+07	+1.1720E+02
7	+1.2734E+01	+3.7030E+06	+4.7156E+07	+1.2236E+02
6	+1.2783E+01	+3.6842E+06	+4.7093E+07	+1.2251E+02
5	+1.4924E+01	+2.9985E+06	+4.4750E+07	+1.2869E+02
4	+1.5330E+01	+2.8953E+06	+4.4386E+07	+1.2970E+02
3	+1.6291E+01	+2.6765E+06	+4.3604E+07	+1.3195E+02
2	+1.8738E+01	+2.2415E+06	+4.2002E+07	+1.3680E+02
1	+2.3445E+01	+1.7027E+06	+3.9920E+07	+1.4367E+02

HEATER #	NU(Y)	RA(Y)	RA*(Y)
9	+1.3023E+02	+1.1852E+10	+1.5435E+12
8	+1.3126E+02	+6.8610E+09	+9.0059E+11
7	+1.2893E+02	+3.8437E+09	+4.9558E+11
6	+1.1025E+02	+2.3638E+09	+2.6061E+11
5	+1.0633E+02	+1.0846E+09	+1.1533E+11
4	+8.6232E+01	+5.1531E+08	+4.4436E+10
3	+6.7201E+01	+1.8786E+08	+1.2625E+10
2	+4.9188E+01	+4.0544E+07	+1.9943E+09
1	+2.6376E+01	+2.4243E+06	+6.3944E+07

AVERAGE NUSSELT #	AVERAGE RAYLEIGH* #
1.42E+01	4.56E+07

UNCERTAINTY RATIO

HEATER #	NU(W)	RA*(W)	NU(Y)	RA*(Y)
9	.03	.08	.03	.07
1	.03	.08	.03	.08

UNCERTAINTY RATIO IN PROPERTIES B/(ALF*KVIS)=	.0643195149235
UNCERTAINTY RATIO IN LOSS=	.0634282772465
UNCERTAINTY RATIO IN HEAT INPUT=	.0104727418091
UNCERTAINTY RATIO IN ACTUAL HEAT TRANSFER=	.0145615680274

TOTAL HEAT LOST = 24.361766125 WATTS
TOTAL HEAT ADDED = 262.022646785 WATTS

% LOSS AIR= 2.03095742078	% LOSS SIDE=	.150568307905
% LOSS TOP= .785228010453	% LOSS BOTTOM=	.153732246877
% LOSS BACK= 6.17413719811	% LOSS TOTAL=	9.29758035188
% OF ENERGY CONTRIBUTED BY EACH HEATER = 91		

RUN NUMBER= 21

NUMBER OF ACTIVE HEATER =

9

CHANNEL # TEMP. (C) CHANNEL # TEMP. (C) CHANNEL # TEMP. (C)

1	50.46	2	56.82	3	61.68
4	54.27	5	63.99	6	65.10
7	72.32	8	72.93	9	70.14
10	64.73	11	71.76	12	77.87
13	84.68	14	64.09	15	47.68
16	41.29	17	31.15	18	28.52
19	28.52	20	-27.46	21	33.34
22	33.44	23	56.57	24	61.00
25	56.07	26	61.42	27	47.60
28	51.55	29	50.26	30	54.28
31	36.64	32	36.72	33	23.46
34	23.45	35	23.45	36	23.47
37	25.31	38	25.53	39	25.32
40	-27.37	41	25.00	42	24.92
43	24.93	44	24.94	45	24.09
46	44.59	47	26.63	48	24.64

CHANNEL # VOLTAGE (AC VOLTS) CIRCUIT # POWER (W)

56	0.00	1	118.82
57	103.14	2	118.64
58	103.67	3	113.64
59	103.57	4	0.00

HEATER # PROBE TEMPERATURE (C)
X=6.4 X=12.7 X=19.1 (MM)

9	66.39	67.96	68.17
8	58.22	58.06	57.55
7	52.78	52.51	51.60
6	49.09	48.65	47.85
5	45.47	45.23	44.59
4	42.50	41.92	41.34
3	39.31	38.74	38.94
2	36.10	35.62	35.88
1	32.38	32.06	31.53

COLD WALL AVERAGE TEMPERATURE
24.93

ROOM TEMPERATURE
24.64

POWER TEST (WATTS)
40

ASPECT RATIO
13.5

RUN 21 NUMBER OF ACTIVE HEATER = 9

HEATER #	NU(W)	RA(W)	RA*(W)	PR
9	+1.1119E+01	+7.1158E+06	+7.9121E+07	+1.0047E+02
8	+1.2561E+01	+5.9393E+06	+7.4605E+07	+1.0632E+02
7	+1.4210E+01	+4.9744E+06	+7.0685E+07	+1.1198E+02
6	+1.4199E+01	+4.9795E+06	+7.0706E+07	+1.1195E+02
5	+1.6581E+01	+4.0133E+06	+6.6546E+07	+1.1868E+02
4	+1.7052E+01	+3.8631E+06	+6.5875E+07	+1.1985E+02
3	+1.8131E+01	+3.5565E+06	+6.4483E+07	+1.2234E+02
2	+2.0909E+01	+2.9468E+06	+6.1615E+07	+1.2782E+02
1	+2.6135E+01	+2.2190E+06	+5.7994E+07	+1.3550E+02

HEATER #	NU(Y)	RA(Y)	RA*(Y)
9	+1.4594E+02	+1.6089E+10	+2.3480E+12
8	+1.4603E+02	+9.3307E+09	+1.3625E+12
7	+1.4387E+02	+5.1633E+09	+7.4286E+11
6	+1.2247E+02	+3.1950E+09	+3.9129E+11
5	+1.1814E+02	+1.4516E+09	+1.7150E+11
4	+9.5919E+01	+6.8755E+08	+6.5950E+10
3	+7.4790E+01	+2.4963E+08	+1.8670E+10
2	+5.4887E+01	+5.3301E+07	+2.9255E+09
1	+2.9402E+01	+3.1595E+06	+9.2895E+07

AVERAGE NUSSELT #	AVERAGE RAYLEIGH* #
1.58E+01	6.80E+07

UNCERTAINTY RATIO				
HEATER #	NU(W)	RA*(W)	NU(Y)	RA*(Y)
9	.03	.08	.03	.07
1	.03	.08	.03	.08

UNCERTAINTY RATIO IN PROPERTIES B/(ALF*KVIS)=	.0643195149235
UNCERTAINTY RATIO IN LOSS=	.058992924122
UNCERTAINTY RATIO IN HEAT INPUT=	.0104727418091
UNCERTAINTY RATIO IN ACTUAL HEAT TRANSFER=	.0137739450893

TOTAL HEAT LOST = 29.692149612 WATTS
TOTAL HEAT ADDED = 351.09788512 WATTS

% LOSS AIR= 1.71741915798	% LOSS SIDE=	.161738638827
% LOSS TOP= .48881293042	% LOSS BOTTOM=	.133462117909
% LOSS BACK= 5.95330789876	% LOSS TOTAL=	8.45694345377
% OF ENERGY CONTRIBUTED BY EACH HEATER = 92		

RUN NUMBER= 22

NUMBER OF ACTIVE HEATER = 9

CHANNEL # TEMP. (C) CHANNEL # TEMP. (C) CHANNEL # TEMP. (C)

1	55.27	2	62.58	3	68.25
4	59.62	5	70.62	6	71.63
7	80.16	8	80.90	9	77.48
10	71.31	11	79.60	12	86.24
13	94.05	14	76.97	15	55.44
16	43.14	17	33.13	18	29.78
19	29.82	20	-29.45	21	35.67
22	35.74	23	62.26	24	67.62
25	61.93	26	68.27	27	51.89
28	56.61	29	54.99	30	59.69
31	40.24	32	40.52	33	23.44
34	23.46	35	23.45	36	23.49
37	25.79	38	26.07	39	25.84
40	-29.35	41	25.41	42	25.30
43	25.31	44	25.31	45	23.91
46	48.69	47	27.27	48	23.91

CHANNEL # VOLTAGE (AC VOLTS) CIRCUIT # POWER (W)

56	0.00	1	148.79
57	115.64	2	146.24
58	115.10	3	142.84
59	115.90	4	0.00

HEATER # PROBE TEMPERATURE (C)
X=6.4 X=12.7 X=19.1 (MM)

9	74.05	74.94	75.03
8	64.46	64.30	63.78
7	58.32	58.17	57.22
6	53.67	53.20	52.37
5	49.47	48.91	47.77
4	46.12	45.36	44.23
3	42.34	41.78	40.83
2	38.53	38.06	37.17
1	33.67	33.43	32.75

COLD WALL AVERAGE TEMPERATURE
25.31

ROOM TEMPERATURE
23.91

POWER TEST (WATTS)
50

ASPECT RATIO
13.5

RUN 22 NUMBER OF ACTIVE HEATER = 9

HEATER #	NU(W)	RA(W)	RA*(W)	PR
9	+1.2179E+01	+8.9484E+06	+1.0898E+08	+9.2357E+01
8	+1.3754E+01	+7.4277E+06	+1.0216E+08	+9.8275E+01
7	+1.5450E+01	+6.2482E+06	+9.6533E+07	+1.0377E+02
6	+1.5475E+01	+6.2331E+06	+9.6458E+07	+1.0385E+02
5	+1.8128E+01	+4.9653E+06	+9.0009E+07	+1.1100E+02
4	+1.8535E+01	+4.8125E+06	+8.9199E+07	+1.1197E+02
3	+1.9563E+01	+4.4635E+06	+8.7322E+07	+1.1429E+02
2	+2.2556E+01	+3.6763E+06	+8.2924E+07	+1.2012E+02
1	+2.8084E+01	+2.7582E+06	+7.7462E+07	+1.2827E+02

HEATER #	NU(Y)	RA(Y)	RA*(Y)
9	+1.5985E+02	+2.0232E+10	+3.2342E+12
8	+1.5989E+02	+1.1669E+10	+1.8657E+12
7	+1.5643E+02	+6.4855E+09	+1.0145E+12
6	+1.3347E+02	+3.9993E+09	+5.3380E+11
5	+1.2916E+02	+1.7960E+09	+2.3197E+11
4	+1.0426E+02	+8.5652E+08	+8.9300E+10
3	+8.0699E+01	+3.1329E+08	+2.5282E+10
2	+5.9210E+01	+6.6497E+07	+3.9373E+09
1	+3.1595E+01	+3.9272E+06	+1.2408E+08

AVERAGE NUSSELT #	AVERAGE RAYLEIGH* #
1.72E+01	9.23E+07

UNCERTAINTY RATIO				
HEATER #	NU(W)	RA*(W)	NU(Y)	RA*(Y)
9	.03	.08	.03	.07
1	.03	.08	.03	.08

UNCERTAINTY RATIO IN PROPERTIES B/(ALF*KVIS)=	.0643195149235
UNCERTAINTY RATIO IN LOSS=	.0532923881238
UNCERTAINTY RATIO IN HEAT INPUT=	.0104727418091
UNCERTAINTY RATIO IN ACTUAL HEAT TRANSFER=	.0133613651275

TOTAL HEAT LOST = 36.6874671162 WATTS
TOTAL HEAT ADDED = 437.864929847 WATTS

% LOSS AIR= 1.95018400886	% LOSS SIDE=	.101451455404
% LOSS TOP= .479904986441	% LOSS BOTTOM=	.125934609163
% LOSS BACK= 5.70538893626	% LOSS TOTAL=	8.37871786832
% OF ENERGY CONTRIBUTED BY EACH HEATER = 93		

RUN NUMBER= 23

NUMBER OF ACTIVE HEATER =

11

CHANNEL # TEMP. (C) CHANNEL # TEMP. (C) CHANNEL # TEMP. (C)

1	28.91	2	30.23	3	31.15
4	29.60	5	31.67	6	32.00
7	33.36	8	33.36	9	32.88
10	31.67	11	33.20	12	34.14
13	34.92	14	33.28	15	35.31
16	26.82	17	27.39	18	24.84
19	24.85	20	-22.84	21	29.26
22	29.64	23	29.98	24	30.76
25	29.74	26	30.64	27	28.16
28	28.83	29	28.55	30	29.22
31	30.40	32	31.59	33	23.51
34	23.51	35	23.51	36	23.58
37	23.71	38	23.75	39	23.72
40	-22.84	41	23.71	42	23.70
43	23.70	44	23.70	45	23.29
46	27.24	47	23.33	48	24.40

CHANNEL # VOLTAGE (AC VOLTS) CIRCUIT # POWER (W)

56	24.43	1	14.60
57	36.46	2	14.67
58	36.46	3	14.20
59	36.30	4	9.56

HEATER # PROBE TEMPERATURE (C)
X=6.4 X=12.7 X=19.1 (MM)

11	32.76	33.32	33.57
10	30.97	30.77	30.62
9	29.54	29.52	29.42
8	28.53	28.66	28.57
7	27.78	28.12	28.12
6	27.16	27.47	27.47
5	26.59	26.87	26.93
4	26.13	26.37	26.39
3	25.63	25.81	25.77
2	25.27	25.29	25.28
1	24.79	24.77	24.68

COLD WALL AVERAGE TEMPERATURE
23.70

ROOM TEMPERATURE
24.40

POWER TEST (WATTS)
5

ASPECT RATIO
16.5

RUN 23 NUMBER OF ACTIVE HEATER = 11

HEATER #	NU(W)	RA(W)	RA*(W)	PR
10	+6.6051E+00	+8.3512E+05	+5.5160E+06	+1.6231E+02
9	+6.8379E+00	+8.0344E+05	+5.4938E+06	+1.6294E+02
8	+7.3485E+00	+7.4167E+05	+5.4502E+06	+1.6420E+02
7	+8.0698E+00	+6.6895E+05	+5.3983E+06	+1.6572E+02
6	+8.0740E+00	+6.6857E+05	+5.3980E+06	+1.6573E+02
5	+9.2399E+00	+5.7705E+05	+5.3319E+06	+1.6772E+02
4	+9.6192E+00	+5.5242E+05	+5.3139E+06	+1.6827E+02
3	+1.0293E+01	+5.1350E+05	+5.2853E+06	+1.6914E+02
2	+1.1740E+01	+4.4594E+05	+5.2353E+06	+1.7070E+02
1	+1.4719E+01	+3.5084E+05	+5.1639E+06	+1.7298E+02

HEATER #	NU(Y)	RA(Y)	RA*(Y)
10	+9.6599E+01	+2.6124E+09	+2.5235E+11
9	+8.9747E+01	+1.8166E+09	+1.6303E+11
8	+8.5427E+01	+1.1652E+09	+9.9537E+10
7	+8.1707E+01	+6.9435E+08	+5.6733E+10
6	+6.9638E+01	+4.2897E+08	+2.9872E+10
5	+6.5834E+01	+2.0872E+08	+1.3741E+10
4	+5.4108E+01	+9.8319E+07	+5.3199E+09
3	+4.2458E+01	+3.6042E+07	+1.5303E+09
2	+3.0817E+01	+8.0662E+06	+2.4858E+08
1	+1.6558E+01	+4.9954E+05	+8.2716E+06

AVERAGE NUSSELT #	AVERAGE RAYLEIGH* #
8.74E+00	5.36E+06

UNCERTAINTY RATIO				
HEATER #	NU(W)	RA*(W)	NU(Y)	RA*(Y)
10	.05	.08	.04	.08
1	.05	.08	.05	.08

UNCERTAINTY RATIO IN PROPERTIES B/(ALF*KVIS)=	.0643195149235
UNCERTAINTY RATIO IN LOSS=	.193714533833
UNCERTAINTY RATIO IN HEAT INPUT=	.0104727418091
UNCERTAINTY RATIO IN ACTUAL HEAT TRANSFER=	.0307735698549

TOTAL HEAT LOST = 5.92733171071 WATTS
TOTAL HEAT ADDED = 53.0253025567 WATTS

% LOSS AIR= .0678782801396	% LOSS SIDE=	.527329864476
% LOSS TOP= .642613800812	% LOSS BOTTOM=	.237682161883
% LOSS BACK= 9.67341172699	% LOSS TOTAL=	11.1783081377
% OF ENERGY CONTRIBUTED BY EACH HEATER = 88		

RUN NUMBER= 24

NUMBER OF ACTIVE HEATER =

11

CHANNEL # TEMP. (C) CHANNEL # TEMP. (C) CHANNEL # TEMP. (C)

1	32.51	2	34.75	3	36.26
4	33.61	5	37.18	6	37.76
7	40.25	8	40.25	9	39.39
10	37.13	11	39.76	12	41.38
13	42.64	14	39.85	15	43.24
16	28.82	17	30.29	18	26.38
19	26.43	20	-24.25	21	33.48
22	34.14	23	34.52	24	35.84
25	34.11	26	35.69	27	31.51
28	32.65	29	32.22	30	33.37
31	35.36	32	37.35	33	23.00
34	23.00	35	23.00	36	23.14
37	23.45	38	23.50	39	23.45
40	-24.26	41	23.45	42	23.43
43	23.43	44	23.43	45	23.67
46	29.92	47	24.08	48	24.17

CHANNEL # VOLTAGE (AC VOLTS) CIRCUIT # POWER (W)

56	34.59	1	29.40
57	51.28	2	29.96
58	52.09	3	28.09
59	51.52	4	19.16

HEATER # PROBE TEMPERATURE (C)
X=6.4 X=12.7 X=19.1 (MM)

11	39.25	40.02	40.33
10	36.15	35.86	35.42
9	34.12	33.83	33.49
8	32.54	32.34	32.14
7	31.19	30.97	30.97
6	30.27	30.33	30.02
5	29.28	29.26	29.19
4	28.29	28.19	28.12
3	27.37	27.16	27.10
2	26.58	26.39	26.29
1	25.56	25.39	25.21

COLD WALL AVERAGE TEMPERATURE
23.41

ROOM TEMPERATURE
24.17

POWER TEST (WATTS)
10

ASPECT RATIO
16.5

RUN 24 NUMBER OF ACTIVE HEATER = 11

HEATER #	NU(W)	RA(W)	RA*(W)	PR
10	+8.0211E+00	+1.5330E+06	+1.2297E+07	+1.5147E+02
9	+8.2749E+00	+1.4770E+06	+1.2222E+07	+1.5236E+02
8	+8.8547E+00	+1.3630E+06	+1.2069E+07	+1.5422E+02
7	+9.7350E+00	+1.2197E+06	+1.1873E+07	+1.5668E+02
6	+9.6165E+00	+1.2372E+06	+1.1898E+07	+1.5637E+02
5	+1.1097E+01	+1.0485E+06	+1.1635E+07	+1.5978E+02
4	+1.1559E+01	+1.0007E+06	+1.1567E+07	+1.6068E+02
3	+1.2397E+01	+9.2429E+05	+1.1458E+07	+1.6215E+02
2	+1.4040E+01	+8.0365E+05	+1.1284E+07	+1.6458E+02
1	+1.7508E+01	+6.2977E+05	+1.1026E+07	+1.6828E+02

HEATER #	NU(Y)	RA(Y)	RA*(Y)
10	+1.1731E+02	+4.7955E+09	+5.6256E+11
9	+1.0861E+02	+3.3395E+09	+3.6270E+11
8	+1.0294E+02	+2.1413E+09	+2.2042E+11
7	+9.8567E+01	+1.2660E+09	+1.2478E+11
6	+8.2943E+01	+7.9381E+08	+6.5840E+10
5	+7.9066E+01	+3.7924E+08	+2.9985E+10
4	+6.5021E+01	+1.7810E+08	+1.1580E+10
3	+5.1137E+01	+6.4876E+07	+3.3175E+09
2	+3.6856E+01	+1.4536E+07	+5.3575E+08
1	+1.9697E+01	+8.9668E+05	+1.7662E+07

AVERAGE NUSSELT #	AVERAGE RAYLEIGH* #
1.05E+01	1.17E+07

UNCERTAINTY RATIO				
HEATER #	NU(W)	RA*(W)	NU(Y)	RA*(Y)
10	.04	.08	.04	.07
1	.04	.08	.04	.08

UNCERTAINTY RATIO IN PROPERTIES B/(ALF*KVIS)=	.0643195149235
UNCERTAINTY RATIO IN LOSS=	.123038840721
UNCERTAINTY RATIO IN HEAT INPUT=	.0104727418091
UNCERTAINTY RATIO IN ACTUAL HEAT TRANSFER=	.0192739929811

TOTAL HEAT LOST = 9.95999289358 WATTS
TOTAL HEAT ADDED = 106.599187732 WATTS

% LOSS AIR= .110617944297	% LOSS SIDE=	.283758118293
% LOSS TOP= .53744637108	% LOSS BOTTOM=	.154215278271
% LOSS BACK= 8.19178532269	% LOSS TOTAL=	9.34340411542
% OF ENERGY CONTRIBUTED BY EACH HEATER = 89		

RUN NUMBER= 25

NUMBER OF ACTIVE HEATER =

11

CHANNEL # TEMP. (C) CHANNEL # TEMP. (C) CHANNEL # TEMP. (C)

1	39.52	2	43.30	3	46.04
4	41.30	5	47.09	6	47.78
7	52.02	8	52.18	9	50.61
10	47.19	11	51.36	12	54.18
13	56.37	14	51.72	15	56.95
16	32.48	17	35.65	18	29.48
19	29.52	20	-24.17	21	41.44
22	42.59	23	42.70	24	45.10
25	42.46	26	45.33	27	37.63
28	39.80	29	39.07	30	41.32
31	44.47	32	47.95	33	23.14
34	23.14	35	23.15	36	23.40
37	24.06	38	24.14	39	24.08
40	-24.17	41	24.05	42	24.03
43	24.03	44	24.02	45	23.07
46	35.22	47	24.99	48	23.62

CHANNEL # VOLTAGE (AC VOLTS) CIRCUIT # POWER (W)

56	48.87	1	59.93
57	72.91	2	58.81
58	72.99	3	56.79
59	73.56	4	38.24

HEATER # PROBE TEMPERATURE (C)
X=6.4 X=12.7 X=19.1 (MM)

11	51.33	52.55	53.06
10	45.94	45.60	45.07
9	42.55	42.17	41.57
8	40.36	39.87	39.22
7	38.30	37.89	37.63
6	36.62	36.29	35.90
5	34.82	34.44	34.22
4	33.22	32.71	32.58
3	31.66	31.20	30.97
2	30.05	29.61	29.44
1	27.99	27.71	27.43

COLD WALL AVERAGE TEMPERATURE

23.98

ROOM TEMPERATURE

23.62

POWER TEST (WATTS)

20

ASPECT RATIO

16.5

RUN 25 NUMBER OF ACTIVE HEATER = 11

HEATER #	NU(W)	RA(W)	RA*(W)	PR
10	+9.8607E+00	+2.9682E+06	+2.9268E+07	+1.3104E+02
9	+1.0038E+01	+2.8998E+06	+2.9108E+07	+1.3173E+02
8	+1.0770E+01	+2.6465E+06	+2.8503E+07	+1.3443E+02
7	+1.1880E+01	+2.3351E+06	+2.7740E+07	+1.3799E+02
6	+1.1775E+01	+2.3613E+06	+2.7805E+07	+1.3768E+02
5	+1.3674E+01	+1.9591E+06	+2.6788E+07	+1.4272E+02
4	+1.4086E+01	+1.8888E+06	+2.6606E+07	+1.4366E+02
3	+1.4758E+01	+1.7843E+06	+2.6332E+07	+1.4510E+02
2	+1.6851E+01	+1.5209E+06	+2.5629E+07	+1.4894E+02
1	+2.0970E+01	+1.1767E+06	+2.4676E+07	+1.5448E+02

HEATER #	NU(Y)	RA(Y)	RA*(Y)
10	+1.4421E+02	+9.2849E+09	+1.3390E+12
9	+1.3174E+02	+6.5565E+09	+8.6378E+11
8	+1.2520E+02	+4.1577E+09	+5.2054E+11
7	+1.2028E+02	+2.4237E+09	+2.9153E+11
6	+1.0156E+02	+1.5150E+09	+1.5387E+11
5	+9.7424E+01	+7.0862E+08	+6.9036E+10
4	+7.9234E+01	+3.3617E+08	+2.6636E+10
3	+6.0876E+01	+1.2524E+08	+7.6241E+09
2	+4.4235E+01	+2.7510E+07	+1.2169E+09
1	+2.3592E+01	+1.6754E+06	+3.9526E+07

AVERAGE NUSSELT #	AVERAGE RAYLEIGH* #
1.28E+01	2.72E+07

UNCERTAINTY RATIO				
HEATER #	NU(W)	RA*(W)	NU(Y)	RA*(Y)
10	.03	.08	.03	.07
1	.04	.08	.04	.08

UNCERTAINTY RATIO IN PROPERTIES B/(ALF*KVIS)=	.0643195149235
UNCERTAINTY RATIO IN LOSS=	.0826943099871
UNCERTAINTY RATIO IN HEAT INPUT=	.0104727418091
UNCERTAINTY RATIO IN ACTUAL HEAT TRANSFER=	.0152703735453

TOTAL HEAT LOST = 18.0349199109 WATTS
TOTAL HEAT ADDED = 213.765646575 WATTS

% LOSS AIR= .119204311936	% LOSS SIDE=	.172671368452
% LOSS TOP= .474173394431	% LOSS BOTTOM=	.133821459343
% LOSS BACK= 7.50440684655	% LOSS TOTAL=	8.43677185731
% OF ENERGY CONTRIBUTED BY EACH HEATER = 90		

RUN NUMBER= 26

NUMBER OF ACTIVE HEATER =

11

CHANNEL # TEMP. (C) CHANNEL # TEMP. (C) CHANNEL # TEMP. (C)

1	45.27	2	50.24	3	53.94
4	47.79	5	55.36	6	56.06
7	61.85	8	62.03	9	59.85
10	55.21	11	60.82	12	64.91
13	67.91	14	61.70	15	68.14
16	36.52	17	39.21	18	31.00
19	31.05	20	-21.89	21	47.31
22	48.81	23	49.60	24	52.93
25	49.46	26	53.47	27	42.57
28	45.58	29	44.75	30	47.87
31	51.81	32	56.66	33	23.25
34	23.26	35	23.24	36	23.63
37	24.62	38	24.74	39	24.63
40	-21.91	41	24.66	42	24.63
43	24.62	44	24.61	45	23.27
46	39.54	47	25.20	48	23.58

CHANNEL # VOLTAGE (AC VOLTS) CIRCUIT # POWER (W)

56	60.00	1	89.23
57	89.96	2	87.99
58	89.28	3	86.45
59	89.75	4	57.65

HEATER # PROBE TEMPERATURE (C)
X=6.4 X=12.7 X=19.1 (MM)

11	61.59	62.89	63.52
10	54.45	54.26	53.64
9	50.10	49.56	48.84
8	46.94	46.38	45.63
7	44.16	43.67	42.91
6	41.53	41.47	40.66
5	39.21	39.11	38.50
4	37.17	36.90	36.35
3	34.79	34.78	34.13
2	32.60	32.45	32.06
1	30.16	29.86	29.39

COLD WALL AVERAGE TEMPERATURE

24.52

ROOM TEMPERATURE

23.58

POWER TEST (WATTS)

30

ASPECT RATIO

16.5

RUN 26 NUMBER OF ACTIVE HEATER = 11

HEATER #	NU(W)	RA(W)	RA*(W)	PR
10	+1.1402E+01	+4.4315E+06	+5.0530E+07	+1.1681E+02
9	+1.1463E+01	+4.3991E+06	+5.0425E+07	+1.1704E+02
8	+1.2320E+01	+3.9819E+06	+4.9057E+07	+1.2018E+02
7	+1.3715E+01	+3.4439E+06	+4.7232E+07	+1.2466E+02
6	+1.3555E+01	+3.4984E+06	+4.7420E+07	+1.2418E+02
5	+1.5793E+01	+2.8597E+06	+4.5163E+07	+1.3015E+02
4	+1.6152E+01	+2.7775E+06	+4.4863E+07	+1.3099E+02
3	+1.6939E+01	+2.6128E+06	+4.4257E+07	+1.3272E+02
2	+1.9381E+01	+2.2038E+06	+4.2712E+07	+1.3735E+02
1	+2.4035E+01	+1.6930E+06	+4.0691E+07	+1.4392E+02

HEATER #	NU(Y)	RA(Y)	RA*(Y)
10	+1.6676E+02	+1.3862E+10	+2.3117E+12
9	+1.5045E+02	+9.9463E+09	+1.4964E+12
8	+1.4322E+02	+6.2556E+09	+8.9593E+11
7	+1.3886E+02	+3.5746E+09	+4.9638E+11
6	+1.1691E+02	+2.2447E+09	+2.6242E+11
5	+1.1252E+02	+1.0344E+09	+1.1639E+11
4	+9.0858E+01	+4.9433E+08	+4.4914E+10
3	+6.9872E+01	+1.8339E+08	+1.2814E+10
2	+5.0874E+01	+3.9863E+07	+2.0280E+09
1	+2.7039E+01	+2.4106E+06	+6.5180E+07

AVERAGE NUSSELT #	AVERAGE RAYLEIGH* #
1.47E+01	4.62E+07

UNCERTAINTY RATIO				
HEATER #	NU(W)	RA*(W)	NU(Y)	RA*(Y)
10	.03	.08	.03	.07
1	.03	.08	.03	.08

UNCERTAINTY RATIO IN PROPERTIES B/(ALF*KVIS)= .0643195149235
 UNCERTAINTY RATIO IN LOSS= .0717979709192
 UNCERTAINTY RATIO IN HEAT INPUT= .0104727418091
 UNCERTAINTY RATIO IN ACTUAL HEAT TRANSFER= .014091898991

TOTAL HEAT LOST = 24.6986901162 WATTS
 TOTAL HEAT ADDED = 321.318374434 WATTS

% LOSS AIR= .0974628588094	% LOSS SIDE=	.140385529867
% LOSS TOP= .387653540862	% LOSS BOTTOM=	.127765579158
% LOSS BACK= 6.91185521129	% LOSS TOTAL=	7.68667218604
% OF ENERGY CONTRIBUTED BY EACH HEATER = 91		

RUN NUMBER= 27

NUMBER OF ACTIVE HEATER =

11

CHANNEL # TEMP. (C) CHANNEL # TEMP. (C) CHANNEL # TEMP. (C)

1	50.46	2	56.49	3	61.10
4	53.65	5	63.02	6	63.62
7	70.91	8	71.30	9	68.55
10	62.99	11	69.37	12	74.26
13	77.73	14	69.56	15	77.41
16	36.44	17	43.07	18	33.18
19	33.34	20	-23.33	21	51.81
22	54.00	23	54.67	24	59.12
25	54.74	26	60.02	27	46.23
28	50.34	29	48.95	30	53.30
31	57.10	32	63.23	33	23.38
34	23.39	35	23.39	36	23.88
37	25.22	38	25.36	39	25.26
40	-23.35	41	25.21	42	25.12
43	25.10	44	25.09	45	20.84
46	43.05	47	26.05	48	20.93

CHANNEL # VOLTAGE (AC VOLTS) CIRCUIT # POWER (W)

56	69.25	1	119.03
57	103.13	2	118.32
58	103.53	3	113.61
59	103.67	4	76.80

HEATER # PROBE TEMPERATURE (C)
X=6.4 X=12.7 X=19.1 (MM)

11	71.03	71.98	72.32
10	61.85	61.53	60.99
9	57.17	56.52	55.77
8	52.67	52.06	51.42
7	48.65	48.82	47.97
6	44.73	46.22	45.29
5	42.16	43.22	42.33
4	39.35	40.76	39.90
3	33.50	37.92	37.09
2	31.63	35.10	34.41
1	29.61	31.58	31.13

COLD WALL AVERAGE TEMPERATURE
25.03

ROOM TEMPERATURE
20.93

POWER TEST (WATTS)
40

ASPECT RATIO
16.5

RUN 27 NUMBER OF ACTIVE HEATER = 11

HEATER #	NU(W)	RA(W)	RA*(W)	PR
10	+1.2746E+01	+5.8684E+06	+7.4800E+07	+1.0645E+02
9	+1.2667E+01	+5.9216E+06	+7.5012E+07	+1.0616E+02
8	+1.3566E+01	+5.3634E+06	+7.2759E+07	+1.0932E+02
7	+1.5071E+01	+4.6215E+06	+6.9651E+07	+1.1401E+02
6	+1.4777E+01	+4.7510E+06	+7.0203E+07	+1.1315E+02
5	+1.7330E+01	+3.8141E+06	+6.6097E+07	+1.1991E+02
4	+1.7607E+01	+3.7330E+06	+6.5729E+07	+1.2056E+02
3	+1.8548E+01	+3.4815E+06	+6.4574E+07	+1.2264E+02
2	+2.1276E+01	+2.9070E+06	+6.1850E+07	+1.2784E+02
1	+2.6345E+01	+2.2165E+06	+5.8394E+07	+1.3512E+02

HEATER #	NU(Y)	RA(Y)	RA*(Y)
10	+1.8642E+02	+1.8357E+10	+3.4221E+12
9	+1.6626E+02	+1.3389E+10	+2.2260E+12
8	+1.5770E+02	+8.4259E+09	+1.3288E+12
7	+1.5259E+02	+4.7970E+09	+7.3199E+11
6	+1.2745E+02	+3.0483E+09	+3.8850E+11
5	+1.2347E+02	+1.3796E+09	+1.7034E+11
4	+9.9041E+01	+6.6440E+08	+6.5803E+10
3	+7.6509E+01	+2.4436E+08	+1.8696E+10
2	+5.5849E+01	+5.2582E+07	+2.9367E+09
1	+2.9638E+01	+3.1559E+06	+9.3536E+07

AVERAGE NUSSELT #	AVERAGE RAYLEIGH* #
1.62E+01	6.79E+07

UNCERTAINTY RATIO				
HEATER #	NU(W)	RA*(W)	NU(Y)	RA*(Y)
10	.03	.08	.03	.07
1	.03	.08	.03	.08

UNCERTAINTY RATIO IN PROPERTIES B/(ALF*KVIS)=	.0643195149235
UNCERTAINTY RATIO IN LOSS=	.0646658960447
UNCERTAINTY RATIO IN HEAT INPUT=	.0104727418091
UNCERTAINTY RATIO IN ACTUAL HEAT TRANSFER=	.0137060477449

TOTAL HEAT LOST = 33.3856411935 WATTS
TOTAL HEAT ADDED = 427.762166508 WATTS

% LOSS AIR= .0973925221873	% LOSS SIDE=	.14063706195
% LOSS TOP= .43876356965	% LOSS BOTTOM=	.115718122906
% LOSS BACK= 6.95313038666	% LOSS TOTAL=	7.8047204282
% OF ENERGY CONTRIBUTED BY EACH HEATER = 92		

RUN NUMBER= 28

NUMBER OF ACTIVE HEATER =

11

CHANNEL # TEMP. (C) CHANNEL # TEMP. (C) CHANNEL # TEMP. (C)

1	55.50	2	62.47	3	67.87
4	59.07	5	69.74	6	70.21
7	78.62	8	79.17	9	75.92
10	69.74	11	76.84	12	81.74
13	85.35	14	76.13	15	85.02
16	34.72	17	49.25	18	36.46
19	36.68	20	-24.72	21	57.88
22	60.81	23	60.26	24	65.46
25	60.53	26	66.88	27	50.83
28	55.69	29	53.90	30	59.03
31	64.00	32	71.45	33	23.59
34	23.61	35	23.59	36	24.33
37	25.85	38	26.01	39	25.87
40	-24.60	41	25.81	42	25.74
43	25.75	44	25.73	45	21.54
46	47.05	47	26.73	48	21.53

CHANNEL # VOLTAGE (AC VOLTS) CIRCUIT # POWER (W)

56	77.92	1	149.67
57	115.39	2	147.65
58	115.65	3	142.23
59	116.24	4	97.23

PROBE TEMPERATURE (C)

HEATER # X=6.4 X=12.7 X=19.1 (MM)

11	76.72	77.69	78.04
10	67.35	67.10	66.76
9	62.91	62.49	62.26
8	59.06	58.14	57.18
7	53.86	53.36	52.58
6	49.23	49.68	48.87
5	45.80	46.00	45.54
4	42.98	43.52	42.54
3	36.78	40.52	39.45
2	33.03	37.51	36.63
1	32.82	33.72	33.04

COLD WALL AVERAGE TEMPERATURE

25.64

ROOM TEMPERATURE

21.53

POWER TEST (WATTS)

50

ASPECT RATIO

16.5

RUN 28 NUMBER OF ACTIVE HEATER = 11

HEATER #	NU(W)	RA(W)	RA*(W)	PR
10	+1.4291E+01	+7.2225E+06	+1.0322E+08	+9.8485E+01
9	+1.4210E+01	+7.2841E+06	+1.0351E+08	+9.8218E+01
8	+1.5133E+01	+6.6336E+06	+1.0039E+08	+1.0115E+02
7	+1.6590E+01	+5.8009E+06	+9.6239E+07	+1.0534E+02
6	+1.6251E+01	+5.9769E+06	+9.7131E+07	+1.0441E+02
5	+1.9073E+01	+4.7594E+06	+9.0777E+07	+1.1143E+02
4	+1.9279E+01	+4.6889E+06	+9.0395E+07	+1.1189E+02
3	+2.0139E+01	+4.4136E+06	+8.8887E+07	+1.1371E+02
2	+2.3105E+01	+3.6629E+06	+8.4633E+07	+1.1921E+02
1	+2.8520E+01	+2.7815E+06	+7.9327E+07	+1.2688E+02

HEATER #	NU(Y)	RA(Y)	RA*(Y)
10	+2.0901E+02	+2.2593E+10	+4.7222E+12
9	+1.8651E+02	+1.6469E+10	+3.0717E+12
8	+1.7592E+02	+1.0421E+10	+1.8334E+12
7	+1.6798E+02	+6.0212E+09	+1.0114E+12
6	+1.4016E+02	+3.8349E+09	+5.3752E+11
5	+1.3590E+02	+1.7215E+09	+2.3395E+11
4	+1.0844E+02	+8.3453E+08	+9.0497E+10
3	+8.3075E+01	+3.0979E+08	+2.5736E+10
2	+6.0651E+01	+6.6254E+07	+4.0184E+09
1	+3.2085E+01	+3.9603E+06	+1.2707E+08

AVERAGE NUSSELT #	AVERAGE RAYLEIGH* #
1.78E+01	9.35E+07

UNCERTAINTY RATIO				
HEATER #	NU(W)	RA*(W)	NU(Y)	RA*(Y)
10	.03	.08	.03	.07
1	.03	.08	.03	.08

UNCERTAINTY RATIO IN PROPERTIES B/(ALF*KVIS)=	.0643195149235
UNCERTAINTY RATIO IN LOSS=	.0617396649375
UNCERTAINTY RATIO IN HEAT INPUT=	.0104727418091
UNCERTAINTY RATIO IN ACTUAL HEAT TRANSFER=	.0133107625128

TOTAL HEAT LOST = 40.2555863893 WATTS
TOTAL HEAT ADDED = 536.772592817 WATTS

% LOSS AIR= .110669763174	% LOSS SIDE=	.0704118931811
% LOSS TOP= .487452784073	% LOSS BOTTOM=	.109117159656
% LOSS BACK= 6.65672858839	% LOSS TOTAL=	7.49956069443
% OF ENERGY CONTRIBUTED BY EACH HEATER = 93		

RUN NUMBER= 37 NUMBER OF ACTIVE HEATER = 3

CHANNEL # TEMP. (C) CHANNEL # TEMP. (C) CHANNEL # TEMP. (C)

1	24.18	2	24.53	3	28.93
4	27.04	5	26.18	6	26.00
7	30.25	8	30.10	9	29.65
10	28.01	11	27.08	12	26.75
13	30.89	14	28.81	15	27.91
16	24.94	17	24.76	18	24.28
19	24.22	20	-28.73	21	25.49
22	25.50	23	26.42	24	26.56
25	26.62	26	26.78	27	26.18
28	26.57	29	26.26	30	26.52
31	26.07	32	26.17	33	24.06
34	24.06	35	24.06	36	24.06
37	24.12	38	24.11	39	24.10
40	-28.64	41	24.06	42	24.07
43	24.07	44	24.08	45	24.42
46	25.89	47	23.78	48	24.37

CHANNEL # VOLTAGE (AC VOLTS) CIRCUIT # POWER (W)

56	0.00	1	14.77
57	.35	2	0.00
58	.36	3	0.00
59	36.84	4	0.00

HEATER # PROBE TEMPERATURE (C)
X=6.4 X=12.7 X=19.1 (MM)

11	26.33	26.53	26.67
10	26.46	26.37	26.33
9	25.95	25.80	25.75
8	25.47	25.41	25.58
7	25.30	25.23	25.31
6	25.09	24.97	24.99
5	24.80	24.79	24.88
4	24.68	24.67	24.69
3	24.54	24.44	24.41
2	23.92	23.94	23.96
1	23.84	23.85	23.89

COLD WALL AVERAGE TEMPERATURE
24.08

ROOM TEMPERATURE
24.37

POWER TEST (WATTS)
5

ASPECT RATIO
16.5

RUN 37 NUMBER OF ACTIVE HEATER = 3

HEATER #	NU(W)	RA(W)	RA*(W)	PR
9	+1.0763E+01	+4.7289E+05	+5.0896E+06	+1.6763E+02
6	+1.2384E+01	+4.0724E+05	+5.0431E+06	+1.6912E+02
3	+1.5104E+01	+3.3022E+05	+4.9878E+06	+1.7093E+02

HEATER #	NU(Y)	RA(Y)	RA*(Y)
9	+1.4126E+02	+1.0692E+09	+1.5104E+11
6	+1.0681E+02	+2.6129E+08	+2.7908E+10
3	+6.2305E+01	+2.3178E+07	+1.4441E+09

AVERAGE NUSSELT #	AVERAGE RAYLEIGH* #
1.25E+01	5.04E+06

UNCERTAINTY RATIO				
HEATER #	NU(W)	RA*(W)	NU(Y)	RA*(Y)
9	.13	.14	.13	.14
3	.13	.14	.13	.14

UNCERTAINTY RATIO IN PROPERTIES B/(ALF*KVIS)=	.0643195149235
UNCERTAINTY RATIO IN LOSS=	.583269001185
UNCERTAINTY RATIO IN HEAT INPUT=	.0104727418091
UNCERTAINTY RATIO IN ACTUAL HEAT TRANSFER=	.121502878625

TOTAL HEAT LOST = 2.23070160974 WATTS
TOTAL HEAT ADDED = 14.769993106 WATTS

% LOSS AIR= 1.08007878315	% LOSS SIDE=	3.14240264831
% LOSS TOP= 1.34538114936	% LOSS BOTTOM=	.101565216875
% LOSS BACK= 8.82600728763	% LOSS TOTAL=	15.1029292548
% OF ENERGY CONTRIBUTED BY EACH HEATER = 86		

RUN NUMBER= 32

NUMBER OF ACTIVE HEATER =

3

CHANNEL # TEMP. (C) CHANNEL # TEMP. (C) CHANNEL # TEMP. (C)

1	24.26	2	24.86	3	32.48
4	29.27	5	27.77	6	27.46
7	34.76	8	34.59	9	33.78
10	30.99	11	29.39	12	28.84
13	36.00	14	32.48	15	30.95
16	26.01	17	26.26	18	25.71
19	25.66	20	-31.42	21	27.16
22	27.25	23	28.58	24	28.80
25	28.72	26	29.01	27	28.33
28	28.96	29	28.26	30	28.70
31	27.96	32	28.25	33	23.71
34	23.72	35	23.72	36	23.75
37	23.86	38	23.86	39	23.84
40	-31.33	41	23.82	42	23.83
43	23.83	44	23.85	45	25.87
46	27.63	47	24.60	48	25.86

CHANNEL # VOLTAGE (AC VOLTS) CIRCUIT # POWER (W)

56	0.00	1	29.29
57	.39	2	0.00
58	.29	3	0.00
59	51.88	4	0.00

HEATER # PROBE TEMPERATURE (C)
X=6.4 X=12.7 X=19.1 (MM)

11	29.05	29.40	29.62
10	28.99	28.80	28.74
9	28.20	27.96	27.83
8	27.36	27.18	27.29
7	27.08	26.93	26.98
6	26.62	26.34	26.30
5	25.94	25.87	26.03
4	25.76	25.70	25.91
3	25.36	25.11	25.05
2	24.19	24.17	24.32
1	23.97	23.98	24.04

COLD WALL AVERAGE TEMPERATURE
23.83

ROOM TEMPERATURE
25.86

POWER TEST (WATTS)
10

ASPECT RATIO
16.5

RUN 32 NUMBER OF ACTIVE HEATER = 3

HEATER #	NU(W)	RA(W)	RA*(W)	PR
9	+1.2447E+01	+8.8487E+05	+1.1014E+07	+1.6058E+02
6	+1.4365E+01	+7.5412E+05	+1.0833E+07	+1.6317E+02
3	+1.7524E+01	+6.0627E+05	+1.0624E+07	+1.6627E+02

HEATER #	NU(Y)	RA(Y)	RA*(Y)
9	+1.6337E+02	+2.0007E+09	+3.2684E+11
6	+1.2390E+02	+4.8386E+08	+5.9949E+10
3	+7.2285E+01	+4.2554E+07	+3.0760E+09

AVERAGE NUSSELT #	AVERAGE RAYLEIGH# #
1.45E+01	1.08E+07

UNCERTAINTY RATIO				
HEATER #	NU(W)	RA*(W)	NU(Y)	RA*(Y)
9	.07	.10	.07	.09
3	.07	.10	.07	.09

UNCERTAINTY RATIO IN PROPERTIES B/(ALF*KVIS)=	.0643195149235
UNCERTAINTY RATIO IN LOSS=	.340869399462
UNCERTAINTY RATIO IN HEAT INPUT=	.0104727418091
UNCERTAINTY RATIO IN ACTUAL HEAT TRANSFER=	.0572244263755

TOTAL HEAT LOST = 3.63747801424 WATTS
TOTAL HEAT ADDED = 29.2935553851 WATTS

% LOSS AIR= 1.15997142782	% LOSS SIDE=	2.00396797691
% LOSS TOP= .927518655364	% LOSS BOTTOM=	-.0804887929994
% LOSS BACK= 8.14080311589	% LOSS TOTAL=	12.4173319572
% OF ENERGY CONTRIBUTED BY EACH HEATER = 87		

RUN NUMBER= 33

NUMBER OF ACTIVE HEATER =

3

CHANNEL # TEMP. (C) CHANNEL # TEMP. (C) CHANNEL # TEMP. (C)

1	24.42	2	25.41	3	38.61
4	33.26	5	30.57	6	30.01
7	42.40	8	42.25	9	40.69
10	36.01	11	33.30	12	32.32
13	44.41	14	38.44	15	35.88
16	25.03	17	27.24	18	25.77
19	25.78	20	-30.95	21	28.39
22	28.63	23	31.02	24	31.55
25	31.42	26	32.05	27	30.63
28	31.94	29	30.76	30	31.68
31	29.97	32	30.63	33	23.75
34	23.76	35	23.76	36	23.82
37	24.03	38	24.04	39	24.03
40	-30.85	41	23.98	42	23.95
43	23.96	44	23.98	45	25.22
46	29.46	47	24.75	48	25.23

CHANNEL # VOLTAGE (AC VOLTS) CIRCUIT # POWER (W)

56	.01	1	58.71
57	.42	2	0.00
58	.34	3	0.00
59	73.45	4	0.00

HEATER # PROBE TEMPERATURE (C)
X=6.4 X=12.7 X=19.1 (MM)

11	33.35	33.63	33.86
10	32.89	32.85	32.57
9	31.24	31.18	30.88
8	30.16	29.95	29.97
7	29.61	29.48	29.35
6	28.66	28.43	28.30
5	27.63	27.51	27.65
4	27.44	27.35	27.31
3	26.71	26.52	26.36
2	24.56	24.55	24.51
1	24.11	24.15	24.32

COLD WALL AVERAGE TEMPERATURE
23.97

ROOM TEMPERATURE
25.23

POWER TEST (WATTS)
20

ASPECT RATIO
16.5

RUN 33 NUMBER OF ACTIVE HEATER = 3

HEATER #	NU(W)	RA(W)	RA*(W)	PR
9	+1.4811E+01	+1.6256E+06	+2.4076E+07	+1.4739E+02
6	+1.7000E+01	+1.3798E+06	+2.3456E+07	+1.5115E+02
3	+2.0694E+01	+1.0979E+06	+2.2720E+07	+1.5587E+02

HEATER #	NU(Y)	RA(Y)	RA*(Y)
9	+1.9439E+02	+3.6755E+09	+7.1448E+11
6	+1.4662E+02	+8.8529E+08	+1.2980E+11
3	+8.5362E+01	+7.7062E+07	+6.5782E+09

AVERAGE NUSSELT #	AVERAGE RAYLEIGH* #
1.72E+01	2.34E+07

UNCERTAINTY RATIO				
HEATER #	NU(W)	RA*(W)	NU(Y)	RA*(Y)
9	.04	.08	.04	.08
3	.04	.08	.04	.08

UNCERTAINTY RATIO IN PROPERTIES B/(ALF*KVIS)= .0643195149235
UNCERTAINTY RATIO IN LOSS= .154143073974
UNCERTAINTY RATIO IN HEAT INPUT= .0104727418091
UNCERTAINTY RATIO IN ACTUAL HEAT TRANSFER= .0307896906719

TOTAL HEAT LOST = 7.97604711592 WATTS
TOTAL HEAT ADDED = 58.7097437942 WATTS

% LOSS AIR= 1.10645149685	% LOSS SIDE=	2.34495733151
% LOSS TOP= 1.3541936074	% LOSS BOTTOM=	-.0401703615201
% LOSS BACK= 8.78038366149	% LOSS TOTAL=	13.5855593986
% OF ENERGY CONTRIBUTED BY EACH HEATER = 88		

3

1	24.45	2	25.83	3	43.88
4	36.73	5	33.05	6	32.27
7	49.06	8	48.98	9	46.74
10	40.52	11	36.78	12	35.47
13	51.78	14	43.80	15	40.32
16	28.91	17	28.16	18	25.90
19	25.96	20	-30.37	21	29.57
22	29.96	23	33.24	24	34.06
25	33.86	26	34.80	27	32.72
28	34.65	29	33.04	30	34.39
31	31.83	32	32.84	33	23.69
34	23.69	35	23.70	36	23.80
37	24.11	38	24.14	39	24.11
40	-30.29	41	24.05	42	24.01
43	24.01	44	24.02	45	24.77
46	31.05	47	24.62	48	24.79

CHANNEL #	VOLTAGE (AC VOLTS)	CIRCUIT #	POWER (W)
56	.01	1	88.74
57	.44	2	0.00
58	.36	3	0.00
59	90.31	4	0.00

HEATER #	PROBE TEMPERATURE (C)		
	X=6.4	X=12.7	X=19.1 (MM)
11	37.22	37.58	37.72
10	36.16	36.09	35.78
9	34.18	34.15	33.84
8	32.61	32.40	32.13
7	31.96	31.86	31.53
6	30.88	30.54	30.26
5	29.27	29.05	28.94
4	28.92	28.84	28.67
3	27.79	27.56	27.47
2	24.80	24.80	24.83
1	24.22	24.24	24.33

COLD WALL AVERAGE TEMPERATURE	ROOM TEMPERATURE
24.03	24.79

POWER TEST (WATTS)	ASPECT RATIO
30	16.5

RUN 34 NUMBER OF ACTIVE HEATER = 3

HEATER #	NU(W)	RA(W)	RA*(W)	PR
9	+1.6796E+01	+2.3792E+06	+3.9962E+07	+1.3725E+02
6	+1.9245E+01	+2.0066E+06	+3.8617E+07	+1.4185E+02
3	+2.3503E+01	+1.5737E+06	+3.6986E+07	+1.4788E+02

HEATER #	NU(Y)	RA(Y)	RA*(Y)
9	+2.2045E+02	+5.3793E+09	+1.1859E+12
6	+1.6599E+02	+1.2875E+09	+2.1370E+11
3	+9.6949E+01	+1.1046E+08	+1.0709E+10

AVERAGE NUSSELT #	AVERAGE RAYLEIGH* #
1.95E+01	3.85E+07

UNCERTAINTY RATIO				
HEATER #	NU(W)	RA*(W)	NU(Y)	RA*(Y)
9	.04	.08	.04	.07
3	.04	.08	.04	.07

UNCERTAINTY RATIO IN PROPERTIES $B/(ALF*KVIS)=$	.0643195149235
UNCERTAINTY RATIO IN LOSS=	.111454468854
UNCERTAINTY RATIO IN HEAT INPUT=	.0104727418091
UNCERTAINTY RATIO IN ACTUAL HEAT TRANSFER=	.0228962759276

TOTAL HEAT LOST = 11.4174495002 WATTS
TOTAL HEAT ADDED = 88.7473253102 WATTS

% LOSS AIR= 1.07982246564	% LOSS SIDE=	2.30341471084
% LOSS TOP= .72263201647	% LOSS BOTTOM=	-.0183201959268
% LOSS BACK= 8.68119807542	% LOSS TOTAL=	12.8651195519
% OF ENERGY CONTRIBUTED BY EACH HEATER = 89		

RUN NUMBER= 35

NUMBER OF ACTIVE HEATER =

3

CHANNEL # TEMP. (C) CHANNEL # TEMP. (C) CHANNEL # TEMP. (C)

1	24.74	2	26.38	3	48.70
4	39.73	5	35.35	6	34.35
7	54.97	8	54.97	9	52.14
10	44.56	11	39.94	12	38.36
13	58.32	14	48.54	15	44.23
16	25.68	17	29.36	18	26.76
19	26.75	20	-31.18	21	31.34
22	31.77	23	35.82	24	36.81
25	36.65	26	37.80	27	35.20
28	37.62	29	35.70	30	37.40
31	34.22	32	35.44	33	23.71
34	23.71	35	23.71	36	23.83
37	24.25	38	24.27	39	24.24
40	-31.06	41	24.19	42	24.15
43	24.16	44	24.17	45	25.55
46	33.10	47	24.82	48	25.53

CHANNEL # VOLTAGE (AC VOLTS) CIRCUIT # POWER (W)

56	.01	1	118.15
57	.44	2	0.00
58	.38	3	0.00
59	104.20	4	0.00

HEATER # PROBE TEMPERATURE (C)
X=6.4 X=12.7 X=19.1 (MM)

11	40.74	41.07	41.11
10	39.00	39.01	38.60
9	36.64	36.72	36.36
8	34.81	34.65	34.33
7	33.97	33.93	33.66
6	32.21	32.18	31.69
5	30.68	30.42	30.41
4	30.23	30.13	29.92
3	28.95	28.81	28.57
2	25.09	25.09	25.12
1	24.39	24.41	24.40

COLD WALL AVERAGE TEMPERATURE
24.16

ROOM TEMPERATURE
25.53

POWER TEST (WATTS)
39

ASPECT RATIO
16.5

RUN 35 NUMBER OF ACTIVE HEATER = 3

HEATER #	NU(W)	RA(W)	RA*(W)	PR
9	+1.8477E+01	+3.1319E+06	+5.7868E+07	+1.2876E+02
6	+2.1141E+01	+2.6278E+06	+5.5552E+07	+1.3393E+02
3	+2.5751E+01	+2.0488E+06	+5.2759E+07	+1.4076E+02

HEATER #	NU(Y)	RA(Y)	RA*(Y)
9	+2.4251E+02	+7.0813E+09	+1.7173E+12
6	+1.8234E+02	+1.6860E+09	+3.0742E+11
3	+1.0622E+02	+1.4380E+08	+1.5275E+10

AVERAGE NUSSELT #	AVERAGE RAYLEIGH* #
2.14E+01	5.54E+07

UNCERTAINTY RATIO				
HEATER #	NU(W)	RA*(W)	NU(Y)	RA*(Y)
9	.04	.08	.04	.07
3	.04	.08	.04	.07

UNCERTAINTY RATIO IN PROPERTIES $B/(ALF*KVIS)=$.0643195149235
UNCERTAINTY RATIO IN LOSS= .0919320319608
UNCERTAINTY RATIO IN HEAT INPUT= .0104727418091
UNCERTAINTY RATIO IN ACTUAL HEAT TRANSFER= .0195101011325

TOTAL HEAT LOST = 14.5153067937 WATTS
TOTAL HEAT ADDED = 118.158060099 WATTS

% LOSS AIR= 1.0549877378	% LOSS SIDE=	2.03477778853
% LOSS TOP= 1.15478007008	% LOSS BOTTOM=	-.0132821221821
% LOSS BACK= 8.05010419691	% LOSS TOTAL=	12.2846522543
% OF ENERGY CONTRIBUTED BY EACH HEATER = 90		

RUN NUMBER= 36

NUMBER OF ACTIVE HEATER =

3

CHANNEL # TEMP. (C) CHANNEL # TEMP. (C) CHANNEL # TEMP. (C)

1	24.75	2	26.72	3	52.97
4	42.39	5	37.38	6	36.21
7	60.18	8	60.33	9	56.89
10	48.16	11	42.75	12	40.88
13	64.12	14	52.73	15	47.68
16	27.20	17	30.08	18	26.57
19	26.62	20	-30.33	21	32.32
22	32.89	23	37.42	24	38.67
25	38.56	26	39.96	27	36.74
28	39.77	29	37.58	30	39.66
31	35.64	32	37.12	33	23.69
34	23.70	35	23.71	36	23.88
37	24.36	38	24.40	39	24.36
40	-30.21	41	24.31	42	24.25
43	24.25	44	24.26	45	24.75
46	34.42	47	24.80	48	24.77

CHANNEL # VOLTAGE (AC VOLTS) CIRCUIT # POWER (W)

56	0.00	1	147.40
57	.47	2	0.00
58	.38	3	0.00
59	116.39	4	0.00

HEATER # PROBE TEMPERATURE (C)
X=6.4 X=12.7 X=19.1 (MM)

11	43.82	44.15	44.01
10	42.06	42.13	41.65
9	38.86	38.99	38.70
8	36.84	36.75	36.68
7	35.82	35.83	35.47
6	33.92	33.90	33.34
5	32.02	31.73	31.61
4	31.52	31.26	32.95
3	29.76	29.80	29.39
2	25.48	25.51	25.43
1	24.51	24.52	24.56

COLD WALL AVERAGE TEMPERATURE
24.26

ROOM TEMPERATURE
24.77

POWER TEST (WATTS)
49

ASPECT RATIO
16.5

RUN 36 NUMBER OF ACTIVE HEATER = 3

HEATER #	NU(W)	RA(W)	RA*(W)	PR
9	+2.0017E+01	+3.8728E+06	+7.7522E+07	+1.2186E+02
6	+2.2895E+01	+3.2319E+06	+7.3993E+07	+1.2746E+02
3	+2.7826E+01	+2.5078E+06	+6.9781E+07	+1.3487E+02

HEATER #	NU(Y)	RA(Y)	RA*(Y)
9	+2.6272E+02	+8.7564E+09	+2.3005E+12
6	+1.9747E+02	+2.0737E+09	+4.0948E+11
3	+1.1478E+02	+1.7602E+08	+2.0204E+10

AVERAGE NUSSELT #	AVERAGE RAYLEIGH* #
2.32E+01	7.38E+07

UNCERTAINTY RATIO				
HEATER #	NU(W)	RA*(W)	NU(Y)	RA*(Y)
9	.04	.08	.03	.07
3	.04	.08	.03	.07

UNCERTAINTY RATIO IN PROPERTIES B/(ALF*KVIS)=	.0643195149235
UNCERTAINTY RATIO IN LOSS=	.0789778461954
UNCERTAINTY RATIO IN HEAT INPUT=	.0104727418091
UNCERTAINTY RATIO IN ACTUAL HEAT TRANSFER=	.0176500261501

TOTAL HEAT LOST = 17.7089691944 WATTS
TOTAL HEAT ADDED = 147.401293855 WATTS

% LOSS AIR= 1.02764144237	% LOSS SIDE=	1.98504831551
% LOSS TOP= .983959496867	% LOSS BOTTOM=	-.00856583736811
% LOSS BACK= 7.9733612331	% LOSS TOTAL=	12.0141205896
% OF ENERGY CONTRIBUTED BY EACH HEATER = 91		

RUN NUMBER= 42

NUMBER OF ACTIVE HEATER =

3

CHANNEL # TEMP. (C) CHANNEL # TEMP. (C) CHANNEL # TEMP. (C)

1	24.87	2	25.32	3	29.46
4	27.70	5	26.91	6	26.76
7	30.81	8	30.57	9	30.17
10	28.66	11	27.79	12	27.45
13	31.32	14	29.39	15	28.56
16	24.95	17	27.52	18	24.46
19	24.54	20	-29.05	21	25.52
22	25.69	23	26.34	24	26.67
25	26.53	26	26.89	27	26.14
28	26.73	29	26.15	30	26.62
31	26.03	32	26.37	33	24.97
34	24.97	35	24.98	36	24.97
37	25.04	38	25.03	39	25.04
40	-28.91	41	24.96	42	24.94
43	24.95	44	24.95	45	22.66
46	25.69	47	23.96	48	22.54

CHANNEL # VOLTAGE (AC VOLTS) CIRCUIT # POWER (W)

56	0.00	1	14.50
57	0.00	2	0.00
58	.31	3	0.00
59	36.50	4	0.00

PROBE TEMPERATURE (C)

Y LOCATION (MM) TEMP. (C)

Y LOCATION (MM) TEMP. (C)

409.6	27.71	390.5	28.20
371.5	28.44	352.4	28.57
333.4	29.32	314.3	27.96
295.3	27.42	276.2	27.46
257.2	27.64	238.1	27.90
219.1	28.25	200.0	27.12
181.0	26.69	161.9	26.68
142.9	26.85	123.8	27.11
104.8	27.99	85.7	25.79
66.7	25.35	47.6	25.15
28.6	24.98	9.5	24.94

COLD WALL AVERAGE TEMPERATURE

24.99

ROOM TEMPERATURE

22.54

POWER TEST (WATTS)

5

ASPECT RATIO

16.5

RUN 42 NUMBER OF ACTIVE HEATER = 3

HEATER #	NU(W)	RA(W)	RA*(W)	PR
9	+9.5631E+00	+4.5489E+05	+4.3501E+06	+1.6250E+02
6	+1.0953E+01	+3.9392E+05	+4.3145E+06	+1.6379E+02
3	+1.3549E+01	+3.1500E+05	+4.2679E+06	+1.6552E+02

HEATER #	NU(Y)	RA(Y)	RA*(Y)
9	+1.2552E+02	+1.0285E+09	+1.2909E+11
6	+9.4469E+01	+2.5275E+08	+2.3877E+10
3	+5.5890E+01	+2.2109E+07	+1.2357E+09

AVERAGE NUSSELT #	AVERAGE RAYLEIGH# #
1.11E+01	4.31E+06

UNCERTAINTY RATIO				
HEATER #	NU(W)	RA*(W)	NU(Y)	RA*(Y)
9	.13	.15	.13	.15
3	.14	.15	.14	.15

UNCERTAINTY RATIO IN PROPERTIES $B/(ALF*KVIS)=$.0643195149235
UNCERTAINTY RATIO IN LOSS= .276062783944
UNCERTAINTY RATIO IN HEAT INPUT= .0104727418091
UNCERTAINTY RATIO IN ACTUAL HEAT TRANSFER= .128600689243

TOTAL HEAT LOST = 4.12111206199 WATTS
TOTAL HEAT ADDED = 14.4991377754 WATTS

% LOSS AIR= 1.00578793	% LOSS SIDE=	5.76905612462
% LOSS TOP= 1.99424011957	% LOSS BOTTOM=	.284517178981
% LOSS BACK= 18.4014279227	% LOSS TOTAL=	28.4231526441
% OF ENERGY CONTRIBUTED BY EACH HEATER = 86		

RUN NUMBER= 41

NUMBER OF ACTIVE HEATER =

3

CHANNEL # TEMP. (C) CHANNEL # TEMP. (C) CHANNEL # TEMP. (C)

1	23.72	2	24.53	3	31.99
4	28.87	5	27.42	6	27.08
7	34.31	8	33.89	9	33.13
10	30.44	11	28.89	12	28.24
13	35.09	14	31.61	15	30.15
16	26.01	17	25.59	18	21.46
19	21.55	20	-23.17	21	23.96
22	24.20	23	25.48	24	26.18
25	26.04	26	26.72	27	25.19
28	26.39	29	25.34	30	26.26
31	24.82	32	25.46	33	24.33
34	24.33	35	24.32	36	24.33
37	24.42	38	24.42	39	24.42
40	-23.05	41	24.34	42	24.30
43	24.31	44	24.31	45	18.23
46	24.75	47	21.44	48	19.32

CHANNEL # VOLTAGE (AC VOLTS) CIRCUIT # POWER (W)

56	0.00	1	29.12
57	.30	2	0.00
58	.44	3	0.00
59	51.73	4	0.00

PROBE TEMPERATURE (C)

Y LOCATION (MM) TEMP. (C)

Y LOCATION (MM) TEMP. (C)

409.6	28.46	390.5	29.55
371.5	30.14	352.4	30.56
333.4	30.84	314.3	28.81
295.3	28.22	276.2	28.37
257.2	28.73	238.1	28.98
219.1	29.88	200.0	27.41
181.0	26.97	161.9	27.01
142.9	27.39	123.8	27.54
104.8	28.15	85.7	25.99
66.7	24.52	47.6	24.18
28.6	23.82	9.5	23.73

COLD WALL AVERAGE TEMPERATURE
24.36

ROOM TEMPERATURE
19.32

POWER TEST (WATTS)
10

ASPECT RATIO
16.5

RUN 41 NUMBER OF ACTIVE HEATER = 3

HEATER #	NU(W)	RA(W)	RA*(W)	PR
9	+1.1746E+01	+7.8617E+05	+9.2342E+06	+1.5951E+02
6	+1.3392E+01	+6.8033E+05	+9.1111E+06	+1.6159E+02
3	+1.6519E+01	+5.4161E+05	+8.9467E+06	+1.6446E+02

HEATER #	NU(Y)	RA(Y)	RA*(Y)
9	+1.5416E+02	+1.7775E+09	+2.7403E+11
6	+1.1551E+02	+4.3651E+08	+5.0421E+10
3	+6.8139E+01	+3.8015E+07	+2.5903E+09

AVERAGE NUSSELT #	AVERAGE RAYLEIGH* #
1.36E+01	9.10E+06

UNCERTAINTY RATIO				
HEATER #	NU(W)	RA*(W)	NU(Y)	RA*(Y)
9	.07	.10	.07	.10
3	.08	.10	.07	.10

UNCERTAINTY RATIO IN PROPERTIES B/(ALF*KVIS)=	.0643195149235
UNCERTAINTY RATIO IN LOSS=	.154315680885
UNCERTAINTY RATIO IN HEAT INPUT=	.0104727418091
UNCERTAINTY RATIO IN ACTUAL HEAT TRANSFER=	.066487857551

TOTAL HEAT LOST = 7.75973172218 WATTS
TOTAL HEAT ADDED = 29.1218085206 WATTS

% LOSS AIR= .935656998999	% LOSS SIDE=	6.04450983143
% LOSS TOP= .943838618461	% LOSS BOTTOM=	.377407491191
% LOSS BACK= 17.8324239963	% LOSS TOTAL=	26.6457755077
% OF ENERGY CONTRIBUTED BY EACH HEATER = 87		

RUN NUMBER= 40

NUMBER OF ACTIVE HEATER =

3

CHANNEL # TEMP. (C) CHANNEL # TEMP. (C) CHANNEL # TEMP. (C)

1	25.12	2	26.20	3	38.77
4	33.52	5	31.08	6	30.51
7	42.77	8	42.11	9	40.71
10	36.21	11	33.57	12	32.56
13	44.13	14	38.35	15	35.89
16	26.04	17	30.75	18	23.68
19	23.79	20	-24.83	21	27.46
22	27.76	23	29.47	24	30.34
25	30.38	26	31.27	27	29.04
28	30.77	29	29.31	30	30.56
31	28.77	32	29.61	33	25.40
34	25.40	35	25.41	36	25.45
37	25.64	38	25.66	39	25.65
40	-24.71	41	25.57	42	25.52
43	25.52	44	25.52	45	19.82
46	28.41	47	23.34	48	21.70

CHANNEL # VOLTAGE (AC VOLTS) CIRCUIT # POWER (W)

56	0.00	1	58.33
57	.44	2	0.00
58	.63	3	0.00
59	73.22	4	0.00

PROBE TEMPERATURE (C)

Y LOCATION (MM) TEMP. (C) Y LOCATION (MM) TEMP. (C)

409.6	33.72	390.5	35.03
371.5	35.70	352.4	36.17
333.4	36.26	314.3	33.31
295.3	32.61	276.2	32.72
257.2	33.24	238.1	33.92
219.1	34.33	200.0	31.12
181.0	30.36	161.9	30.57
142.9	31.20	123.8	31.95
104.8	33.08	85.7	27.62
66.7	26.25	47.6	25.71
28.6	25.29	9.5	25.21

COLD WALL AVERAGE TEMPERATURE
25.57

ROOM TEMPERATURE
21.70

POWER TEST (WATTS)
19

ASPECT RATIO
16.5

RUN 40 NUMBER OF ACTIVE HEATER = 3

HEATER #	NU(W)	RA(W)	RA*(W)	PR
9	+1.5278E+01	+1.5446E+06	+2.3599E+07	+1.4121E+02
6	+1.7404E+01	+1.3262E+06	+2.3081E+07	+1.4427E+02
3	+2.1491E+01	+1.0416E+06	+2.2386E+07	+1.4859E+02

HEATER #	NU(Y)	RA(Y)	RA*(Y)
9	+2.0053E+02	+3.4924E+09	+7.0032E+11
6	+1.5011E+02	+8.5092E+08	+1.2773E+11
3	+8.8650E+01	+7.3112E+07	+6.4814E+09

AVERAGE NUSSELT #	AVERAGE RAYLEIGH* #
1.77E+01	2.30E+07

UNCERTAINTY RATIO				
HEATER #	NU(W)	RA*(W)	NU(Y)	RA*(Y)
9	.05	.08	.04	.08
3	.05	.08	.05	.08

UNCERTAINTY RATIO IN PROPERTIES B/(ALF*KVIS)=	.0643195149235
UNCERTAINTY RATIO IN LOSS=	.115716118546
UNCERTAINTY RATIO IN HEAT INPUT=	.0104727418091
UNCERTAINTY RATIO IN ACTUAL HEAT TRANSFER=	.0331439698955

TOTAL HEAT LOST = 10.7653591979 WATTS
TOTAL HEAT ADDED = 58.3357250668 WATTS

% LOSS AIR= .945846541685	% LOSS SIDE=	3.66450790607
% LOSS TOP= 1.33490036284	% LOSS BOTTOM=	.145678274116
% LOSS BACK= 12.0552630266	% LOSS TOTAL=	18.454144841
% OF ENERGY CONTRIBUTED BY EACH HEATER = 88		

RUN NUMBER= 45

NUMBER OF ACTIVE HEATER =

3

CHANNEL # TEMP. (C) CHANNEL # TEMP. (C) CHANNEL # TEMP. (C)

1	26.98	2	28.51	3	45.54
4	38.56	5	35.31	6	34.53
7	50.94	8	50.20	9	48.20
10	42.26	11	38.69	12	37.35
13	52.80	14	45.16	15	41.90
16	28.91	17	39.59	18	25.79
19	25.90	20	-26.30	21	30.89
22	31.35	23	33.28	24	34.46
25	34.62	26	35.85	27	32.67
28	35.08	29	33.13	30	34.90
31	32.38	32	33.55	33	27.24
34	27.24	35	27.23	36	27.31
37	27.58	38	27.60	39	27.56
40	-26.18	41	27.51	42	27.45
43	27.47	44	27.48	45	21.36
46	31.66	47	24.15	48	22.68

CHANNEL # VOLTAGE (AC VOLTS) CIRCUIT # POWER (W)

56	0.00	1	88.10
57	0.00	2	.01
58	.77	3	0.00
59	89.98	4	0.00

PROBE TEMPERATURE (C)

Y LOCATION (MM) TEMP. (C)

Y LOCATION (MM) TEMP. (C)

409.6	39.33	390.5	40.46
371.5	41.24	352.4	41.54
333.4	42.17	314.3	37.03
295.3	36.39	276.2	36.54
257.2	37.21	238.1	37.31
219.1	37.76	200.0	35.09
181.0	33.86	161.9	33.94
142.9	34.63	123.8	34.58
104.8	34.94	85.7	30.75
66.7	28.20	47.6	27.51
28.6	27.10	9.5	26.90

COLD WALL AVERAGE TEMPERATURE
27.50

ROOM TEMPERATURE
22.68

POWER TEST (WATTS)
29

ASPECT RATIO
16.5

RUN 45 NUMBER OF ACTIVE HEATER = 3

HEATER #	NU(W)	RA(W)	RA*(W)	PR
9	+1.7452E+01	+2.4219E+06	+4.2267E+07	+1.2363E+02
6	+1.9828E+01	+2.0722E+06	+4.1088E+07	+1.2705E+02
3	+2.4500E+01	+1.6110E+06	+3.9470E+07	+1.3206E+02

HEATER #	NU(Y)	RA(Y)	RA*(Y)
9	+2.2906E+02	+5.4759E+09	+1.2543E+12
6	+1.7102E+02	+1.3296E+09	+2.2738E+11
3	+1.0106E+02	+1.1307E+08	+1.1428E+10

AVERAGE NUSSELT #	AVERAGE RAYLEIGH* #
2.02E+01	4.09E+07

UNCERTAINTY RATIO				
HEATER #	NU(W)	RA*(W)	NU(Y)	RA*(Y)
9	.04	.08	.04	.07
3	.04	.08	.04	.08

UNCERTAINTY RATIO IN PROPERTIES B/(ALF*KVIS)=	.0643195149235
UNCERTAINTY RATIO IN LOSS=	.0899582384782
UNCERTAINTY RATIO IN HEAT INPUT=	.0104727418091
UNCERTAINTY RATIO IN ACTUAL HEAT TRANSFER=	.0247086493343

TOTAL HEAT LOST = 14.7187426271 WATTS
TOTAL HEAT ADDED = 88.1078102868 WATTS

% LOSS AIR= .941782231218	% LOSS SIDE=	3.17312769197
% LOSS TOP= 1.0961150093	% LOSS BOTTOM=	.148589636553
% LOSS BACK= 11.1427595353	% LOSS TOTAL=	16.7053778538
% OF ENERGY CONTRIBUTED BY EACH HEATER = 89		

RUN NUMBER= 39

NUMBER OF ACTIVE HEATER =

3

CHANNEL # TEMP. (C) CHANNEL # TEMP. (C) CHANNEL # TEMP. (C)

1	26.57	2	28.46	3	49.69
4	41.08	5	37.01	6	36.03
7	56.55	8	55.56	9	52.97
10	45.67	11	41.23	12	39.57
13	58.68	14	49.25	15	45.19
16	25.69	17	40.08	18	24.16
19	24.36	20	-23.28	21	31.01
22	31.56	23	33.75	24	35.40
25	35.71	26	37.34	27	33.20
28	36.40	29	33.97	30	36.29
31	32.70	32	34.32	33	26.94
34	26.94	35	26.94	36	27.03
37	27.40	38	27.45	39	27.42
40	-23.18	41	27.31	42	27.20
43	27.23	44	27.23	45	18.66
46	31.88	47	22.68	48	20.55

CHANNEL # VOLTAGE (AC VOLTS) CIRCUIT # POWER (W)

56	0.00	1	117.41
57	0.00	2	.01
58	.86	3	0.00
59	103.87	4	0.00

PROBE TEMPERATURE (C)

Y LOCATION (MM) TEMP. (C) Y LOCATION (MM) TEMP. (C)

409.6	42.37	390.5	43.55
371.5	44.18	352.4	44.29
333.4	44.38	314.3	39.72
295.3	39.12	276.2	39.23
257.2	40.35	238.1	40.70
219.1	44.28	200.0	36.96
181.0	35.38	161.9	35.68
142.9	36.46	123.8	37.36
104.8	37.58	85.7	31.38
66.7	28.37	47.6	27.46
28.6	26.76	9.5	26.56

COLD WALL AVERAGE TEMPERATURE
27.28

ROOM TEMPERATURE
20.55

POWER TEST (WATTS)
39

ASPECT RATIO
16.5

RUN 39 NUMBER OF ACTIVE HEATER = 3

HEATER #	NU(W)	RA(W)	RA*(W)	PR
9	+1.8866E+01	+3.1555E+06	+5.9531E+07	+1.1800E+02
6	+2.1357E+01	+2.6954E+06	+5.7566E+07	+1.2188E+02
3	+2.6466E+01	+2.0692E+06	+5.4763E+07	+1.2789E+02

HEATER #	NU(Y)	RA(Y)	RA*(Y)
9	+2.4761E+02	+7.1346E+09	+1.7666E+12
6	+1.8421E+02	+1.7294E+09	+3.1857E+11
3	+1.0917E+02	+1.4523E+08	+1.5856E+10

AVERAGE NUSSELT #	AVERAGE RAYLEIGH* #
2.18E+01	5.73E+07

UNCERTAINTY RATIO				
HEATER #	NU(W)	RA*(W)	NU(Y)	RA*(Y)
9	.04	.08	.04	.07
3	.04	.08	.04	.07

UNCERTAINTY RATIO IN PROPERTIES $B/(ALF * KVIS) =$	.0643195149235
UNCERTAINTY RATIO IN LOSS =	.0714344358491
UNCERTAINTY RATIO IN HEAT INPUT =	.0104727418091
UNCERTAINTY RATIO IN ACTUAL HEAT TRANSFER =	.0215219653307

TOTAL HEAT LOST = 20.0260058195 WATTS
TOTAL HEAT ADDED = 117.415121081 WATTS

% LOSS AIR = .928585530332	% LOSS SIDE =	3.16016202007
% LOSS TOP = 1.38454865396	% LOSS BOTTOM =	.153323659373
% LOSS BACK = 11.1666357746	% LOSS TOTAL =	17.05572982
% OF ENERGY CONTRIBUTED BY EACH HEATER = 90		

RUN NUMBER= 43

NUMBER OF ACTIVE HEATER =

3

CHANNEL # TEMP. (C) CHANNEL # TEMP. (C) CHANNEL # TEMP. (C)

1	28.60	2	30.69	3	55.45
4	45.49	5	40.76	6	39.63
7	63.43	8	62.37	9	59.25
10	50.85	11	45.66	12	43.78
13	65.94	14	55.03	15	50.08
16	27.20	17	44.49	18	27.09
19	27.32	20	-25.29	21	34.05
22	34.87	23	37.41	24	39.18
25	39.10	26	41.13	27	36.70
28	40.41	29	37.22	30	40.10
31	36.62	32	38.41	33	28.79
34	28.78	35	28.78	36	28.90
37	29.40	38	29.43	39	29.40
40	-25.18	41	29.29	42	29.18
43	29.18	44	29.19	45	19.90
46	35.33	47	24.77	48	21.63

CHANNEL # VOLTAGE (AC VOLTS) CIRCUIT # POWER (W)

56	0.00	1	147.24
57	.73	2	.01
58	1.00	3	.01
59	116.32	4	0.00

PROBE TEMPERATURE (C)

Y LOCATION (MM) TEMP. (C) Y LOCATION (MM) TEMP. (C)

409.6	47.40	390.5	48.72
371.5	48.99	352.4	49.13
333.4	49.35	314.3	43.74
295.3	42.98	276.2	43.08
257.2	44.49	238.1	44.19
219.1	47.46	200.0	39.88
181.0	38.86	161.9	39.28
142.9	40.67	123.8	41.10
104.8	43.00	85.7	33.78
66.7	30.43	47.6	29.46
28.6	28.82	9.5	28.61

COLD WALL AVERAGE TEMPERATURE

29.24

ROOM TEMPERATURE

21.63

POWER TEST (WATTS)

49

ASPECT RATIO

16.5

RUN 43 NUMBER OF ACTIVE HEATER = 3

HEATER #	NU(W)	RA(W)	RA*(W)	PR
9	+2.0732E+01	+4.1540E+06	+8.6119E+07	+1.0541E+02
6	+2.3462E+01	+3.5360E+06	+8.2964E+07	+1.0926E+02
3	+2.9072E+01	+2.6988E+06	+7.8458E+07	+1.1530E+02

HEATER #	NU(Y)	RA(Y)	RA*(Y)
9	+2.7210E+02	+9.3921E+09	+2.5556E+12
6	+2.0236E+02	+2.2688E+09	+4.5912E+11
3	+1.1992E+02	+1.8942E+08	+2.2716E+10

AVERAGE NUSSELT #	AVERAGE RAYLEIGH* #
2.40E+01	8.25E+07

UNCERTAINTY RATIO				
HEATER #	NU(W)	RA*(W)	NU(Y)	RA*(Y)
9	.04	.08	.04	.07
3	.04	.08	.04	.07

UNCERTAINTY RATIO IN PROPERTIES $B/(ALF*KVIS)=$	.0643195149235
UNCERTAINTY RATIO IN LOSS=	.0652498997686
UNCERTAINTY RATIO IN HEAT INPUT=	.0104727418091
UNCERTAINTY RATIO IN ACTUAL HEAT TRANSFER=	.0192170959225

TOTAL HEAT LOST = 23.3329591468 WATTS
TOTAL HEAT ADDED = 147.252651276 WATTS

% LOSS AIR= .904442262486	% LOSS SIDE=	2.74251484167
% LOSS TOP= 1.30623472248	% LOSS BOTTOM=	.119297993198
% LOSS BACK= 10.5334211678	% LOSS TOTAL=	15.8455273604
% OF ENERGY CONTRIBUTED BY EACH HEATER = 91		

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APPENDIX E PROGRAM LISTING


```

10  | **** PROGRAM NAME "ACQUIRE"
20  | THIS PROGRAM ACQUIRES TEMPERATURE INFORMATION ASSOCIATED WITH
30  | EXPERIMENTS INVESTIGATING NATURAL CONVECTION IN A VERTICAL
40  | ENCLOSURE WITH DISCRETE HEATING. THE ACQUIRED INFORMATION IS
50  | STORED IN THE DATA FILE WONG_DAT.
60  |
70  | OPTION BASE 0  | ARRAY INITIATES AT 0
80  | DIMENSION STATEMENTS
90  | DIM Tp(59),E(59),V(10),Rho(16),K(16),Cp(16),Dv(16),B(16),Alf(16)
100 | DIM Nu(16),Pr(16),Grprop(16),Grw(16),Gr(16),Ra(16),Tf(16)
110 | THIS SECTION ACQUIRES THE VOLTAGE INFORMATION FROM THE THERMOCOUPLES.
120 | THERMOCOUPLES OCCUPY CHANNELS 0 TO 48 (0,20,AND 40 ARE THE ICEPOINTS)
130 | 709 AND 722 ARE THE TWO HP DEVICES USED IN DATA ACQUISITION
140 | CLEAR 709  | DATA LOGGER
150 | CLEAR 722  | VOLTMETER
160 | FL1 = TURN ON FILTER, F2 = AC FUNCTION, AC = ANALOG CLOSE,
170 | Z1 = TURN ON AUTO ZERO, R1 = TURN ON AUTO RANGE,
180 | S0F1 = SELECT DC VOLT FUNCTION, H = HOME
190 | OUTPUT 722;"HFL1Z1R1S0F1"
200 | FOR I=0 TO 48
210 |   OUTPUT 709;"AC";I
220 |   ENTER 722 USING "#,K";E(I)
230 | NEXT I
240 | SUBTRACT THE ICE POINT VOLTAGE FROM THE MEASURED VOLTAGE
250 | R0=E(0)
260 | R20=E(20)
270 | R40=E(40)
280 | FOR I=1 TO 19
290 |   E(I)=E(I)-R0
300 |   J=I+20
310 |   E(J)=E(J)-R20
320 |   L=I+40
330 |   E(L)=E(L)-R40
340 | NEXT I
350 | CALL THE SUBROUTINE TO CONVERT EMF TO TEMPERATURE
360 | SET THE TEMPERATURE TO .1 IF THE READING IS BAD
370 | FOR I=1 TO 48
380 |   Em=E(I)
390 |   Tem=.1
400 |   CALL Eat(Em,Tem)
410 |   Tp(I)=Tem
420 |   PRINT I,"EMF=";Em,"TEMP=";Tem
430 | NEXT I
440 | ACQUIRE THE AC VOLTAGES ASSOCIATED WITH POWER INPUT TO THE SYSTEM
450 | CLEAR 709
460 | CLEAR 722
470 | PRINT
480 | PRINT "VOLTAGES"
490 | PRINT
500 | OUTPUT 722;"HFL1R1Z1F2"

```

```

510  I HEATERS WIRED IN 4 SERIES CIRCUITS
520  FOR I=1 TO 4
530  J=I+55
540  OUTPUT 709,"AC",J
550  WAIT 2
560  ENTER 722 USING "#,K",V(I)
570  PRINT J,V(I)
580  NEXT I
590  INPUT "TO WRITE THE DATA INTO FILE ENTER RUN NUMBER, ELSE ENTER 0",R
600  IF R>0 THEN CALL Write(Tp(*),V(*),R)
610  PRINT "RUN COMPLETE"
620  END
630  I TEMPERATURE CONVERSION SUBROUTINE
640  SUB Eat(Em,Tem)
650  DIM A(8)
660  INTEGER J,K,I,I1
670  Emf=Em
680  Emf=Emf*1000.*1000.
690  Delta=.0001
700  A(1)=3.8740773840E+1
710  A(2)=3.3190198092E-2
720  A(3)=2.0714183645E-4
730  A(4)=-2.1945834823E-6
740  A(5)=1.1031900550E-8
750  A(6)=-3.0927581898E-11
760  A(7)=4.5653337165E-14
770  A(8)=-2.7616878040E-17
780  T=25.
790  FOR K=1 TO 10
800  B=0.
810  C=0.
820  FOR J=2 TO 9
830  I=10-J
840  B=(B+A(I))*T
850  C=C+T+I*A(I)
860  Tdelta=(B-Emf)/C
870  NEXT J
880  T=T-Tdelta
890  Err=ABS(Tdelta)
900  IF Err<Delta THEN
910  Temp=T
920  Tem=Temp
930  GOTO 970
940  ELSE
950  END IF
960  NEXT K
970  SUBEND
980  I SUBROUTINE USED TO STORE THE DATA
990  SUB Write(Tp(*),V(*),W)
1000 I NEXT STATEMENT IS USED TO SELECT THE CORECT RECORDS TO STORE THE DATA

```



```
1010 ASSIGN @Path_1 TO "WONG_DAT"
1020 OUTPUT @Path_1,W
1030 OUTPUT @Path_1;W
1040 FOR J=1 TO 48
1050 OUTPUT @Path_1;Tp(J)
1060 NEXT J
1070 FOR I=1 TO 4
1080 OUTPUT @Path_1;V(I)
1090 NEXT I
1100 PRINT "DATA ADDED TO WONG_DAT FILE"
1110 SUBEND
```

```

10  ! ***** PROGRAM NAME "PROBE" *****
20  ! THIS PROGRAM ACQUIRES AND STORES TEMPERATURE INFORMATION
30  ! ASSOCIATED WITH EXPERIMENTS USING THE TEST CELL FOR HEAT TRANSFER
40  ! IN VERTICAL ENCLOSURE WITH DISCRETE HEATING. THE DATA IS STORED IN
50  ! THE DATA FILE PROBDAT.
60  ! *****
70  OPTION BASE 0
80  DIM Tp(59),E(59),V(10),Eprobe(5,11),Tprobe(5,11)
90  ! THIS SECTION OF THE CODE ACQUIRES THE VOLTAGE INFORMATION FROM
100 ! THE THERMALCOUPLES. IT MEASURES CHANNELS 0 TO 48. (0,20,40,
110 ! AND 60 ARE THE ICEPOINT) AND PROBE CHANNELS 61, 62, AND 63.
120 ! 709 AND 722 ARE THE TWO HP DEVICES USED IN DATA AQUISITION
130 CLEAR 709
140 CLEAR 722
150 OUTPUT 722;"HFL1Z1R1F1"
160 FOR I=0 TO 48
170 OUTPUT 709;"AC";I
180 ENTER 722 USING "#,K";E(I)
190 NEXT I
200 ! THE ICE POINT VOLTAGE IS SUBTRACTED FROM THE MEASURED VOLTAGE
210 R0=E(0)
220 R20=E(20)
230 R40=E(40)
240 FOR I=1 TO 19
250 E(I)=E(I)-R0
260 J=I+20
270 E(J)=E(J)-R20
280 L=I+40
290 E(L)=E(L)-R40
300 NEXT I
310 ! THE SUBROUTINE TO CONVERT EMF TO TEMPERATURE IS CALLED (Tem=.1 SETS THE
320 ! TEMPERATURE TO .1 IF THE READING IS BAD)
330 FOR I=1 TO 48
340 Em=E(I)
350 Tem=.1
360 CALL Eat(Em,Tem)
370 Tp(I)=Tem
380 PRINT I,"EMF=";Em,"TEMP=";Tem
390 NEXT I
400 CLEAR 709
410 CLEAR 722
420 PRINT
430 OUTPUT 722;"FL1R1Z1S0F1"
440 OUTPUT 709;"AC";60
450 WAIT 1
460 ENTER 722 USING "#,K";E60
470 PRINT E60
480 Tc=0
490 FOR I=36 TO 39
500 Tc=Tp(I)+Tc

```



```

510 NEXT I
520 FOR I=41 TO 44
530   Tc=Tc+Tp(I)
540 NEXT I
550 Tcave=Tc/8
560 FOR J=1 TO 3
570   Tprobe(5,J)=Tp(J)
580 NEXT J
590 Tprobe(5,4)=Tp(5)
600 Tprobe(5,5)=Tp(6)
610 Tprobe(5,6)=Tp(9)
620 Tprobe(5,7)=Tp(11)
630 Tprobe(5,8)=Tp(12)
640 Tprobe(5,9)=Tp(13)
650 Tprobe(5,10)=Tp(15)
660 PRINT Tcave
670 FOR J=1 TO 11
680   INPUT "IF YOU WANT ONE PROBE MEASUREMENT BE TAKEN ENTER Y",Yes$
690   IF Yes$="Y" THEN GOTO 700
700   WAIT 30
710   Tprobe(1,J)=Tcave
720   OUTPUT 722;"FLIRIZISOF1"
730   FOR I=2 TO 4
740     OUTPUT 709;"AC";59+I
750     ENTER 722 USING "#,K";Eprobe(I,J)
760   NEXT I
770   FOR I=2 TO 4
780     Tem=.1
790     Em=Eprobe(I,J)-E60
800     CALL Eat(Em,Tem)
810     Tprobe(I,J)=Tem
820   NEXT I
830   FOR I=1 TO 5
840     PRINT I,Tprobe(I,J)
850   NEXT I
860 NEXT J
870 INPUT "TO WRITE THE DATA INTO FILE ENTER RUN NUMBER, ELSE ENTER 0",R
880 IF R>0 THEN CALL Write(Tprobe(*),Tc,R)
890 PRINT "RUN COMPLETE"
900 END
910 I TEMPERATURE CONVERSION SUBROUTINE
920 SUB Eat(Em,Tem)
930   DIM A(8)
940   INTEGER J,K,I,I1
950   Emf=Em
960   Emf=Emf*1000.*1000.
970   Delta=.0001
980   A(1)=3.8740773840E+1
990   A(2)=3.3190198092E-2
1000  A(3)=2.0714183645E-4

```

```

1010 A(4)=-2.1945834823E-6
1020 A(5)=1.1031900550E-8
1030 A(6)=-3.0927581898E-11
1040 A(7)=4.5653337165E-14
1050 A(8)=-2.7616878040E-17
1060 T=25.
1070 FOR K=1 TO 10
1080 B=0.
1090 C=0.
1100 FOR J=2 TO 9
1110 I=10-J
1120 B=(B+A(I))*T
1130 C=C+I*A(I)
1140 Tdelta=(B-Emf)/C
1150 NEXT J
1160 T=T-Tdelta
1170 Err=ABS(Tdelta)
1180 IF Err<Delta THEN
1190 Temp=T
1200 Tem=Temp
1210 GOTO 1250
1220 ELSE
1230 END IF
1240 NEXT K
1250 SUBEND
1260 ! SUBROUTINE USED TO STORE THE DATA
1270 ! THE DATA IS STORED IN FILE "PROBDAT" AND EACH RUN TAKES ONE RECORD
1280 SUB Write(Tprobe(*),Tc,W)
1290 ASSIGN @Path_1 TO "PROBDAT"
1300 OUTPUT @Path_1,W
1310 OUTPUT @Path_1,W,Tc
1320 FOR J=1 TO 11
1330 FOR I=2 TO 5
1340 OUTPUT @Path_1,Tprobe(I,J)
1350 NEXT I
1360 NEXT J
1370 PRINT "DATA ADDED TO PROBDAT FILE"
1380 SUBEND

```



```

10  !***** PROGRAM NAME "G_REDUCE"*****
20  ! THIS PROGRAM REDUCES, RECORDS AND PRINTS DATA ASSOCIATED WITH THE
30  ! FREE CONVECTION IN VERTICAL ENCLOSURE WITH DISCRETE HEATING TEST CELL
40  !*****DIMENSION STATEMENTS*****
50  OPTION BASE 0
60  DIM Tp(59),E(59),V(60),K(15),Nu(15),Pr(15),Grw(15),Gr(15),Ra(15),Tf(15)
70  DIM Res(11),P(11),Ab(7),Qlb(7),H(15),Etr(15),Rays(15),Tmtc(10),Yoh(15)
80  DIM Ray(15),Thetaw(15),Thetay(15),Nuw(15),Nuy(15),Raws(15),Dttb(7),Hcl(15)
90  DIM Wratyr(15),Wnutyr(15),Wrasyr(15),Tprobe(5,11),Wratur(15),Wnutur(15)
100 DIM Wrasur(15),Wrayr(15),Wrawr(15),Wnuyr(15),Wnuwr(15),Ddt(15)
110 !*****INITIALIZATION*****
120 !HEATER CIRCUIT RESISTANCES
130 Res(1)=90.28      ! WITH WIDER SPACING RES(1) = 91.9
140 Res(2)=90.59
150 Res(3)=93.62
160 Res(4)=62.45
170 ! Wm IS WIDTH OF ENCLOSURE IN METERS
180 Wm=.0254
190 ! AREAS IN THE ENCLOSURE USED IN LOSS CALCULATIONS
200 ! Abo IS AREA OF BOTTOM, At IS AREA OF TOP, As IS AREA OF SIDE
210 ! Ab(*) IS SECTION OF BACK WALL....SEE FIGURE BEFORE THIS SECTION
220 Abo=6.4516E-3
230 At=6.4516E-3
240 As=1.0645E-2
250 Ab(1)=3.048381E-2
260 Ab(2)=1.693545E-2
270 Ab(3)=1.9052381E-2
280 Ab(4)=1.9052381E-2
290 Ab(5)=2.6673333E-2
300 Ab(6)=2.6673333E-2
310 Ab(7)=2.032254E-2
320 !THICKNESSES USED IN VARIOUS LOSS CALCULATIONS
330 Xt=1.27E-2
340 Xbo=.0381
350 Xs=1.27E-2
360 Xph=6.35E-3
370 ! K VALUES FOR PLEXIGLASS AND PHENOLITE
380 Kpl=.25
390 Kph=.33
400 ! Ah IS AREA OF EACH HEATER
410 Ah=4.8387E-3
420 ! H(*) IS HEIGHT OF EACH THERMOCOUPLE USED IN NU AND RA CALCULATIONS
430 H(1)=.028575
440 H(2)=.066675
450 H(3)=.104775
460 H(4)=.123825
470 H(5)=.142875
480 H(6)=.180975
490 H(7)=.219075
500 H(8)=.219075

```

```

510 H(9)=-.219075
520 H(10)=-.238125
530 H(11)=-.257175
540 H(12)=-.295275
550 H(13)=-.333375
560 H(14)=-.352425
570 H(15)=-.371475
580 |***** KEYS *****
590 | FOR KEYS, SEE PRINT STATEMENTS
600 | ERROR ANALYSIS, W* MEANS UNCERTAINTY, W/R MEANS UNCERTAINTY RATIO
610 | NUMERICAL VALUE IS COMPARED WITH ECKERT AND DRAKE'S ANALYSIS OF
620 | HEAT AND MASS TRANSFER. MCGRAW-HILL.
630 Wgr=0.
640 Wbr=.02
650 Wcpr=.0025
660 Wlfr=.022
670 Wkr=.026
680 Wrhor=.002
690 Wdvr=.057
700 Wvr=.005
710 Wrr=3.111E-3
720 Wl=2.54E-4
730 Wt=.1
740 Wdt=SQR(2*Wt^2)
750 |***** SELECTION OF REQUIRED DATA*****
760 INPUT "HOW MANY HEATERS ARE ACTIVE ",N
770 INPUT "RUN NUMBER=",R
780 IF N=3 THEN
790 A=4.5
800 INPUT "IS THIS WITH ONLY THE HEATER # 3,6,9 ON? (Y/N)",Ws$
810 END IF
820 IF Ws$="Y" THEN
830 Res(1)=91.9
840 Ws=1
850 A=16.5
860 END IF
870 IF N=6 THEN A=9
880 IF N=9 THEN A=13.5
890 IF N=11 THEN A=16.5
900 ASSIGN @Path_1 TO "WONG_DAT"
910 ENTER @Path_1,R
920 ENTER @Path_1;R
930 | GET THE REQUIRED DATA FROM THE DATA FILE
940 FOR I=1 TO 48
950 ENTER @Path_1;Tp(I)
960 NEXT I
970 FOR I=1 TO 4
980 J=55+I
990 ENTER @Path_1;V(J)
1000 NEXT I

```



```

1010 IF Ws=1 THEN
1020 INPUT "PROBDAT RUN NUMBER = ",Rr
1030 ASSIGN @Path_1 TO "PROBDAT"
1040 ENTER @Path_1,Rr
1050 ENTER @Path_1;Rr,Tc
1060 GOTO 1110
1070 END IF
1080 ASSIGN @Path_1 TO "PROBDAT"
1090 ENTER @Path_1,R
1100 ENTER @Path_1;R,Tc
1110 Tcr=Tc/8
1120 FOR J=1 TO 11
1130   FOR I=2 TO 5
1140     ENTER @Path_1;Tprobe(I,J)
1150   NEXT I
1160 NEXT J
1170 !##### CALCULATE THE CIRCUIT POWERS#####
1180 Qt=0
1190 FOR I=1 TO 4
1200   P(I)=(V(60-I)^2)/Res(I)
1210   Qt=Qt+P(I)
1220 NEXT I
1230 !##### CALCULATE THE AVERAGE COLD PLATE TEMPERATURE, Tca#####
1240 Sm=0
1250 FOR I=36 TO 39
1260   Sm=Sm+Tp(I)
1270 NEXT I
1280 FOR I=41 TO 44
1290   Sm=Sm+Tp(I)
1300 NEXT I
1310 Tca=Sm/8
1320 ! Pcase IS THE NOMINAL TEST POWER SETTING (I.E 5,10,20 W/CH)
1330 Pcase=P(1)/3
1340 ! PRINT THE RAW TEMPERATURE DATA
1350 PRINT "          RUN NUMBER=";Rr,"NUMBER OF ACTIVE HEATER = ",N
1360 PRINT
1370 PRINT "          CHANNEL # TEMP. (C) CHANNEL # TEMP. (C) CHANNEL # TEMP. (C)
"
1380 PRINT
1390 FOR I=1 TO 46 STEP 3
1400   PRINT USING "12X,2D,5X,3D.2D,7X,2D,5X,3D.2D,7X,2D,5X,3D.2D";I,Tp(I),I+1,T
p(I+1),I+2,Tp(I+2)
1410 NEXT I
1420 PRINT
1430 PRINT "          CHANNEL #      VOLTAGE (AC VOLTS)      CIRCUIT #      POWER (W)"
1440 PRINT
1450 FOR I=1 TO 4
1460   J=55+I
1470   PRINT USING "12X,2D,15X,3D.2D,12X,2D,10X,3D.2D";J,V(J),I,P(I)
1480 NEXT I
1490 PRINT
1500 PRINT "          PROBE TEMPERATURE (C)"

```



```

1510 PRINT "          HEATER #    X=6.4    X=12.7    X=19.1 (MM)"
1520 PRINT
1530 IF Ws=1 THEN GOTO 1580
1540 IF N=11 THEN GOTO 1580
1550 IF N=9 THEN GOTO 1620
1560 IF N=6 THEN GOTO 1660
1570 IF N=3 THEN GOTO 1700
1580 FOR I=11 TO 1 STEP -1
1590 PRINT USING "12X,2D,7X,2D.2D,3X,2D.2D,3X,2D.2D";I,Tprobe(2,I),Tprobe(3,I),T
probe(4,I)
1600 NEXT I
1610 GOTO 1730
1620 FOR I=9 TO 1 STEP -1
1630 PRINT USING "12X,2D,7X,2D.2D,3X,2D.2D,3X,2D.2D";I,Tprobe(2,I),Tprobe(3,I),T
probe(4,I)
1640 NEXT I
1650 GOTO 1730
1660 FOR I=6 TO 1 STEP -1
1670 PRINT USING "12X,2D,7X,2D.2D,3X,2D.2D,3X,2D.2D";I,Tprobe(2,I),Tprobe(3,I),T
probe(4,I)
1680 NEXT I
1690 GOTO 1730
1700 FOR I=3 TO 1 STEP -1
1710 PRINT USING "12X,2D,7X,2D.2D,3X,2D.2D,3X,2D.2D";I,Tprobe(2,I),Tprobe(3,I),T
probe(4,I)
1720 NEXT I
1730 PRINT
1740 PRINT "          COLD WALL AVERAGE TEMPERATURE          ROOM TEMPERATURE"
1750 PRINT USING "22X,2D.2D,22X,2D.2D";Tca,Tp(48)
1760 PRINT
1770 PRINT "          POWER TEST (WATTS)          ASPECT RATIO"
1780 PRINT USING "10X,6D,25X,2D.1D";Pcase,A
1790 ! ***** SAME LOCATION 7,8,& 9.  TAKE AVERAGE VALUE. *****
1800 Tp(9)=(Tp(8)+Tp(9)+Tp(7))/3
1810 ! ***** CALCULATE PROPERTIES IN THIS SECTION *****
1820 ! EVALUATE FILM TEMPERATURE (TF) ACCORDING TO PAPER BY ZHONG,YANG AND
1830 ! LLOYD "VARIABLE PROPERTY EFFECTS IN LAMINAR NATURAL CONVECTION IN A
1840 ! SQUARE ENCLOSURE"
1850 FOR I=1 TO 15
1860 Tf(I)=Tca+.25*(Tp(I)-Tca)
1870 ! PROPERTIES OF GLYCOL (CHEMICAL ENGINEERING HANDBOOK)
1880 T=Tf(I)
1890 Rho=1130.75-.6297915*T-5.013587E-5*T^2+6.448046E-7*T^3-9.115537E-9*T^4
1900 K(I)=.2175195+1.3439E-4*(T+273.15)
1910 Tk=T+273.15
1920 Cp=4186.8*(5.548E-3+3.35083E-3*Tk-7.224E-6*Tk^2+8.04367E-9*Tk^3)
1930 Dv=EXP(-2.813092-5.196844E-2*T+1.746046E-4*T^2+8.043671E-7*T^3)
1940 B=6.65E-4
1950 Alf=K(I)/(Rho*Cp)
1960 Kvis=Dv/Rho
1970 Pr(I)=Kvis/Alf
1980 C=9.81*B/(Kvis^2)
1990 Grw(I)=C*Wm^3
2000 Gr(I)=Grw(I)*(Tp(I)-Tca)

```



```

2010      Ra(I)=Pr(I)*Gr(I)
2020 NEXT I
2030 I ##### CALCULATE BACK WALL TOTAL AREA #####
2040 A1=0
2050 FOR I=1 TO 7
2060 A1=A1+Ab(I)
2070 NEXT I
2080 I ##### CALCULATE LOSSES #####
2090 IF N=3 THEN Nt=3
2100 IF N=6 THEN Nt=9
2110 IF N=9 THEN Nt=13
2120 IF N=11 THEN Nt=15
2130 IF N=3 THEN Tin=(Tp(4)+Tp(5)+Tp(6)+Tp(9)+Tp(10)+Tp(11)+Tp(12)+Tp(13)+Tp(14)
)+Tp(15))/10
2140 IF N=3 THEN Ttin=(Tp(1)+Tp(2)+Tp(3))/3
2150 IF N=6 THEN Tin=(Tp(10)+Tp(11)+Tp(12)+Tp(13)+Tp(14)+Tp(15))/6
2160 IF N=6 THEN Ttin=(Tp(1)+Tp(2)+Tp(3)+Tp(4)+Tp(5)+Tp(6)+Tp(9))/7
2170 IF N=9 THEN Tin=(Tp(14)+Tp(15))/2
2180 IF N=9 THEN Ttin=(Tp(1)+Tp(2)+Tp(3)+Tp(4)+Tp(5)+Tp(6)+Tp(9)+Tp(10)+Tp(11)+
Tp(12)+Tp(13))/11
2190 IF N=11 THEN Tin=Tp(18)
2200 IF N=11 THEN Ttin=(Tp(1)+Tp(2)+Tp(3)+Tp(4)+Tp(5)+Tp(6)+Tp(9)+Tp(10)+Tp(11)
+Tp(12)+Tp(13)+Tp(14)+Tp(15))/13
2210 IF Ws=1 THEN
2220 N=11
2230 Ttin=(Tp(3)+Tp(9)+Tp(13))/3
2240 END IF
2250 I LOSS INSIDE ENCLOSURE DUE TO LOWER ASPECT RATIO, VIA AIR.
2260 I PROPERTIES OF AIR ACCORDING TO J. P. HOLMAN'S HEAT TRANSFER, 4TH ED.
2270 Cprop=9.4E+7
2280 H1=.5842-.0381*N
2290 H13=H1^3
2300 Cproph1=Cprop*H13
2310 Dt=Ttin-Tca
2320 Dtc=Tin-Tca
2330 Rain=Cproph1*Dtc
2340 Hcon1=.547*Rain^.25*.027/H1
2350 Qlin=Hcon1*A1*(12-N)/12*Dtc
2360 Dtt=(Tp(Nt)+Tca)/2-Tp(16)
2370 Qlto=Kpl*At/Xt*Dtt
2380 Dtbo=(Tp(1)+Tca)/2-Tp(47)
2390 Qlbo=Kpl*Ab/Xbo*Dtbo
2400 Tsave=(Tp(Nt)+Tp(1))/2
2410 IF Ws=1 THEN Tsave=(Tp(13)+Tp(3))/2
2420 Dts=(Tsave+Tca)/2-Tp(46)
2430 Qls=2*Kpl*(As*N/11)/Xs*Dts
2440 Dttb(1)=Tp(19)-Tp(18)
2450 Qlb(1)=Kph*Ab(1)/Xph*Dttb(1)
2460 J=0
2470 Dttb=0
2480 Qlbt=0
2490 FOR I=2 TO 7
2500 J=J+2

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2510 Dttb(I)=Tp(J+20)-Tp(J+19)
2520 Qlb(I)=Kph*Ab(I)/Xph*Dttb(I)
2530 Dtb=Dtbt+Dttb(I)
2540 Qlb=Qlb+ABS(Qlb(I))
2550 NEXT I
2560 Dtb=(Dtbt+Dttb(I))/7
2570 Qlt=Qlto+Qlbo+Qls+Qlb+ABS(Qlb(I))+Qlin
2580 IF Ws=1 THEN N=3
2590 !##### CALCULATE ACTUAL HEAT TRANSFERED TO THE GLYCOL #####
2600 INPUT "% OF ENERGY CONTRIBUTED BY EACH HEATER = ",Hper
2610 Qcon=Qt-Qlt
2620 Qcon=Qcon/Hper/100
2630 ! Qdcon IS HEAT FLUX
2640 Qdcon=Qcon/(N*Ah)
2650 Pqlto=Qlto/Qt*100
2660 Pqlbo=Qlbo/Qt*100
2670 Pqls=Qls/Qt*100
2680 Pqlin=Qlin/Qt*100
2690 Pqlt=Qlt/Qt*100
2700 Pqlb=Qlb/Qt*100
2710 !##### CALCULATE DIMENSIONLESS GROUPS #####
2720 FOR I=1 TO 15
2730 Ray(I)=Ra(I)*(H(I)/Wm)^3
2740 Thetaw(I)=(Tp(I)-Tca)/(Qdcon*Wm/K(I))
2750 Thetay(I)=Thetaw(I)*Wm/H(I)
2760 Nuw(I)=1/Thetaw(I)
2770 Raws(I)=Ra(I)*Nuw(I)
2780 Nuy(I)=1/Thetay(I)
2790 Rays(I)=Ray(I)*Nuy(I)
2800 Ddt(I)=Tp(I)-Tca
2810 Etr(I)=Wdt/Ddt(I)
2820 NEXT I
2830 IF Ws=1 THEN
2840 Ddt(3)=Tp(3)-Tca
2850 Ddt(6)=Tp(9)-Tca
2860 Ddt(9)=Tp(13)-Tca
2870 END IF
2880 ! CALCULATE AVERAGE NU(W) AND RA*(W) #####
2890 Nuav=0
2900 Rasav=0
2910 IF Ws=1 THEN GOTO 3080
2920 Nuav=1/Nuw(1)+1/Nuw(2)+1/Nuw(3)
2930 Rasav=Raws(1)+Raws(2)+Raws(3)
2940 Nn=3
2950 IF N=3 THEN GOTO 3110
2960 Nuav=Nuav+1/Nuw(5)+1/Nuw(6)+1/Nuw(9)
2970 Rasav=Rasav+Raws(5)+Raws(6)+Raws(9)
2980 Nn=6
2990 IF N=6 THEN GOTO 3110
3000 Nuav=Nuav+1/Nuw(11)+1/Nuw(12)+1/Nuw(13)

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3010 Rasav=Rasav+Raus(11)+Raus(12)+Raus(13)
3020 Nn=9
3030 IF N=9 THEN GOTO 3110
3040 Nuav=Nuav+1/Nuu(15)
3050 Rasav=Rasav+Raus(15)
3060 Nn=10
3070 GOTO 3110
3080 Nuav=1/Nuu(3)+1/Nuu(9)+1/Nuu(13)
3090 Rasav=Raus(3)+Raus(9)+Raus(13)
3100 Nn=3
3110 Nuav=Nn/Nuav
3120 Rasav=Rasav/Nn
3130 !*****ERROR ANALYSIS FOR FREE CONVECTION IN THE VERTICAL ENCLOSURE*****
3140 Wkvisr=SQR(Wdvr^2+Wrhorr^2)
3150 Wgpropr=SQR(Wbr^2+Walfr^2+Wkvisr^2)
3160 Wd1=SQR(2*W1^2)
3170 W11r=W1/(2*N*.01905)
3180 W12r=W1/H1
3190 W13r=W1/Wm
3200 W14r=W1/.254
3210 W15r=W1/.01905
3220 W1ur=W1/.5969
3230 Wdtt=Wdt/Dtt
3240 Wd1tr=Wd1/Xt
3250 Wdtbor=Wdt/Dtbo
3260 Wd1bor=Wd1/Xbo
3270 Wdter=Wdt/Dts
3280 Wd1sr=Wd1/Xs
3290 Wdtbr=Wdt/Dtb
3300 Wd1br=Wd1/Xph
3310 Wdter=Wdt/Dtc
3320 Wracr=SQR(Wgr^2+Wbr^2+Walfr^2+Wkvisr^2+Wdter^2+(3*W12r)^2)
3330 Whr=SQR((.25*Wracr)^2+Wkr^2+W12r^2)
3340 Wqt=SQR((2*Wvr)^2+Wrr^2)*Qt
3350 Wqlin=SQR(Whr^2+W12r^2+W14r^2+Wdter^2)*Qlin
3360 Wqlto=SQR(Wkr^2+W14r^2+W13r^2+Wdtt^2+Wd1tr^2)*Qlto
3370 Wqlbo=SQR(Wkr^2+W14r^2+W13r^2+Wdtbor^2+Wd1bor^2)*Qlbo
3380 Wqls=SQR(Wkr^2+W11r^2+W13r^2+Wdter^2+Wd1sr^2)*Qls
3390 Wqlb=SQR(Wkr^2+W1ur^2+W14r^2+Wdtbr^2+Wd1br^2)*Qlbt
3400 Wqlk=SQR(Wqlto^2+Wqlbo^2+Wqls^2+Wqlb^2)
3410 Wqlt=SQR(Wqlk^2+Wqlin^2)
3420 Wqcon=SQR(Wqt^2+Wqlt^2)
3430 FOR I=1 TO 15
3440 Wrayr(I)=SQR(Wgr^2+Wbr^2+Walfr^2+Wkvisr^2+(3*W1/H(I))^2)
3450 Wraur(I)=SQR(Wgr^2+Wbr^2+Walfr^2+Wkvisr^2+(3*W13r)^2)
3460 Wnutyr(I)=SQR((Wqcon/Qcon)^2+W14r^2+W15r^2+(W1/H(I))^2+Etr(I)^2+Wkr^2)
3470 Wnutur(I)=SQR((Wqcon/Qcon)^2+W14r^2+W15r^2+W13r^2+Etr(I)^2+Wkr^2)
3480 Wnuyr(I)=SQR((Wqcon/Qcon)^2+W14r^2+W15r^2+(W1/H(I))^2+Wkr^2)
3490 Wnuur(I)=SQR((Wqcon/Qcon)^2+W14r^2+W15r^2+W13r^2+Wkr^2)
3500 Wrasr(I)=SQR(Wraur(I)^2+Wnuur(I)^2)

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3510 Wrasyr(I)=SQR(Wrayr(I)^2+Wnuyr(I)^2)
3520 NEXT I
3530 !***** PRINT STATEMENTS *****
3540 PRINT CHR$(12)
3550 PRINT "          RUN";R,"NUMBER OF ACTIVE HEATER = ",N
3560 PRINT
3570 ! PRINT PROPERTIES
3580 PRINT "          HEATER #      NU(W)      RA(W)      RA*(W)      PR"
3590 PRINT
3600 IF Ws=1 THEN GOTO 3750
3610 IF N=9 THEN GOTO 3650
3620 IF N=6 THEN GOTO 3680
3630 IF N=3 THEN GOTO 3710
3640 PRINT USING "12X,3D,2X,SD.4DE,2X,SD.4DE,2X,SD.4DE,2X,SD.4DE";10,Nuw(15),R
a(15),Raws(15),Pr(15)
3650 PRINT USING "12X,3D,2X,SD.4DE,2X,SD.4DE,2X,SD.4DE,2X,SD.4DE";9,Nuw(13),Ra
(13),Raws(13),Pr(13)
3660 PRINT USING "12X,3D,2X,SD.4DE,2X,SD.4DE,2X,SD.4DE,2X,SD.4DE";8,Nuw(12),Ra
(12),Raws(12),Pr(12)
3670 PRINT USING "12X,3D,2X,SD.4DE,2X,SD.4DE,2X,SD.4DE,2X,SD.4DE";7,Nuw(11),Ra
(11),Raws(11),Pr(11)
3680 PRINT USING "12X,3D,2X,SD.4DE,2X,SD.4DE,2X,SD.4DE,2X,SD.4DE";6,Nuw(9),Ra(
9),Raws(9),Pr(9)
3690 PRINT USING "12X,3D,2X,SD.4DE,2X,SD.4DE,2X,SD.4DE,2X,SD.4DE";5,Nuw(6),Ra(
6),Raws(6),Pr(6)
3700 PRINT USING "12X,3D,2X,SD.4DE,2X,SD.4DE,2X,SD.4DE,2X,SD.4DE";4,Nuw(5),Ra(
5),Raws(5),Pr(5)
3710 PRINT USING "12X,3D,2X,SD.4DE,2X,SD.4DE,2X,SD.4DE,2X,SD.4DE";3,Nuw(3),Ra(
3),Raws(3),Pr(3)
3720 PRINT USING "12X,3D,2X,SD.4DE,2X,SD.4DE,2X,SD.4DE,2X,SD.4DE";2,Nuw(2),Ra(
2),Raws(2),Pr(2)
3730 PRINT USING "12X,3D,2X,SD.4DE,2X,SD.4DE,2X,SD.4DE,2X,SD.4DE";1,Nuw(1),Ra(
1),Raws(1),Pr(1)
3740 GOTO 3780
3750 PRINT USING "12X,3D,2X,SD.4DE,2X,SD.4DE,2X,SD.4DE,2X,SD.4DE";9,Nuw(13),Ra
(13),Raws(13),Pr(13)
3760 PRINT USING "12X,3D,2X,SD.4DE,2X,SD.4DE,2X,SD.4DE,2X,SD.4DE";6,Nuw(9),Ra(
9),Raws(9),Pr(9)
3770 PRINT USING "12X,3D,2X,SD.4DE,2X,SD.4DE,2X,SD.4DE,2X,SD.4DE";3,Nuw(3),Ra(
3),Raws(3),Pr(3)
3780 PRINT
3790 PRINT "          HEATER #      NU(Y)      RA(Y)      RA*(Y)      "
3800 PRINT
3810 IF Ws=1 THEN GOTO 3960
3820 IF N=9 THEN GOTO 3860
3830 IF N=6 THEN GOTO 3890
3840 IF N=3 THEN GOTO 3920
3850 PRINT USING "12X,3D,2X,SD.4DE,2X,SD.4DE,2X,SD.4DE";10,Nuy(15),Ray(15),Ray
s(15)

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3860 PRINT USING "12X,3D,2X,SD.4DE,2X,SD.4DE,2X,SD.4DE";9,Nuy(13),Ray(13),Rays
(13)
3870 PRINT USING "12X,3D,2X,SD.4DE,2X,SD.4DE,2X,SD.4DE";8,Nuy(12),Ray(12),Rays
(12)
3880 PRINT USING "12X,3D,2X,SD.4DE,2X,SD.4DE,2X,SD.4DE";7,Nuy(11),Ray(11),Rays
(11)
3890 PRINT USING "12X,3D,2X,SD.4DE,2X,SD.4DE,2X,SD.4DE";6,Nuy(9),Ray(9),Rays(9
)
3900 PRINT USING "12X,3D,2X,SD.4DE,2X,SD.4DE,2X,SD.4DE";5,Nuy(6),Ray(6),Rays(6
)
3910 PRINT USING "12X,3D,2X,SD.4DE,2X,SD.4DE,2X,SD.4DE";4,Nuy(5),Ray(5),Rays(5
)
3920 PRINT USING "12X,3D,2X,SD.4DE,2X,SD.4DE,2X,SD.4DE";3,Nuy(3),Ray(3),Rays(3
)
3930 PRINT USING "12X,3D,2X,SD.4DE,2X,SD.4DE,2X,SD.4DE";2,Nuy(2),Ray(2),Rays(2
)
3940 PRINT USING "12X,3D,2X,SD.4DE,2X,SD.4DE,2X,SD.4DE";1,Nuy(1),Ray(1),Rays(1
)
3950 GOTO 3990
3960 PRINT USING "12X,3D,2X,SD.4DE,2X,SD.4DE,2X,SD.4DE";9,Nuy(13),Ray(13),Rays
(13)
3970 PRINT USING "12X,3D,2X,SD.4DE,2X,SD.4DE,2X,SD.4DE";6,Nuy(9),Ray(9),Rays(9
)
3980 PRINT USING "12X,3D,2X,SD.4DE,2X,SD.4DE,2X,SD.4DE";3,Nuy(3),Ray(3),Rays(3
)
3990 PRINT
4000 PRINT "          AVERAGE NUSSELT #          AVERAGE RAYLEIGH* # "
4010 PRINT USING "15X,D.2DE,15X,D.2DE";Nuav,Rasav
4020 PRINT
4030 PRINT UNCERTAINTIES RATIO IN DIMENSIONLESS GROUPS
4040 PRINT ONLY THE MINIMUM AND MAXIMUM VALUES ARE PRINTED
4050 PRINT "          UNCERTAINTY RATIO"
4060 PRINT "          HEATER #  NU(W)  RA*(W)  NU(Y)  RA*(Y)"
4070 IF Ws=1 THEN GOTO 4130
4080 IF N=3 THEN GOTO 4180
4090 IF N=6 THEN GOTO 4160
4100 IF N=9 THEN GOTO 4130
4110 PRINT USING "12X,3D,3X,2D.2D,3X,2D.2D,3X,2D.2D,3X,2D.2D";10,Wnutur(15),Wra
sur(15),Wnutyr(15),Wrasyr(15)
4120 GOTO 4200
4130 PRINT USING "12X,3D,3X,2D.2D,3X,2D.2D,3X,2D.2D,3X,2D.2D";9,Wnutur(13),Wras
ur(13),Wnutyr(13),Wrasyr(13)
4140 IF Ws=1 THEN GOTO 4180
4150 GOTO 4200
4160 PRINT USING "12X,3D,3X,2D.2D,3X,2D.2D,3X,2D.2D,3X,2D.2D";6,Wnutur(9),Wrasu
r(9),Wnutyr(9),Wrasyr(9)
4170 GOTO 4200
4180 PRINT USING "12X,3D,3X,2D.2D,3X,2D.2D,3X,2D.2D,3X,2D.2D";3,Wnutur(3),Wrasu
r(3),Wnutyr(3),Wrasyr(3)
4190 IF Ws=1 THEN GOTO 4210
4200 PRINT USING "12X,3D,3X,2D.2D,3X,2D.2D,3X,2D.2D,3X,2D.2D";1,Wnutur(1),Wrasu
r(1),Wnutyr(1),Wrasyr(1)

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4210 PRINT
4220 PRINT "          UNCERTAINTY RATIO IN PROPERTIES B/(ALF*KVIS)=" ,Wgprop
4230 PRINT "          UNCERTAINTY RATIO IN LOSS=" ,Wqlt/Qty
4240 PRINT "          UNCERTAINTY RATIO IN HEAT INPUT=" ,Wqt/Qt
4250 PRINT "          UNCERTAINTY RATIO IN ACTUAL HEAT TRANSFER=" ,Wqcon/Qcon
4260 PRINT
4270 PRINT "          TOTAL HEAT LOST =" ;Qty;"WATTS"
4280 PRINT "          TOTAL HEAT ADDED =" ;Qt;"WATTS"
4290 PRINT
4300 PRINT "          % LOSS AIR=" ;Pqlin,"% LOSS SIDE=" ,Pqls
4310 PRINT "          % LOSS TOP=" ;Pqlto,"% LOSS BOTTOM=" ,Pqlbo
4320 PRINT "          % LOSS BACK=" ;Pqlbt,"% LOSS TOTAL=" ,Pqlt
4330 PRINT "          % OF ENERGY CONTRIBUTED BY EACH HEATER = " ,Hper
4340 Yoh(1)=1
4350 Yoh(2)=2
4360 Yoh(3)=3
4370 Yoh(5)=4
4380 Yoh(6)=5
4390 Yoh(9)=6
4400 Yoh(11)=7
4410 Yoh(12)=8
4420 Yoh(13)=9
4430 Yoh(15)=10
4440 INPUT "IF YOU WANT TO STORE DATA ENTER RUN NUMBER OTHERWISE RETURN " ,R
4450 IF R=0 THEN GOTO 4470
4460 CALL Write(Yoh(*) ,Rays(*) ,Raws(*) ,Nuy(*) ,Nuw(*) ,Ddt(*) ,Pr(*) ,R)
4470 END
4480 ! SUBROUTINE TO STORE SELECTED DATA
4490 ! STORE DATA IN "RED_DATX" AND EACH RUN TAKES ONE RECORD
4500 SUB Write(Yoh(*) ,Rays(*) ,Raws(*) ,Nuy(*) ,Nuw(*) ,Ddt(*) ,Pr(*) ,R)
4510 ASSIGN @Path_1 TO "RED_DATX"
4520 OUTPUT @Path_1 ,R
4530 OUTPUT @Path_1 ;Yoh(1) ,Rays(1) ,Raws(1) ,Nuy(1) ,Nuw(1) ,Ddt(1) ,Pr(1)
4540 OUTPUT @Path_1 ;Yoh(2) ,Rays(2) ,Raws(2) ,Nuy(2) ,Nuw(2) ,Ddt(2) ,Pr(2)
4550 OUTPUT @Path_1 ;Yoh(3) ,Rays(3) ,Raws(3) ,Nuy(3) ,Nuw(3) ,Ddt(3) ,Pr(3)
4560 OUTPUT @Path_1 ;Yoh(5) ,Rays(5) ,Raws(5) ,Nuy(5) ,Nuw(5) ,Ddt(5) ,Pr(5)
4570 OUTPUT @Path_1 ;Yoh(6) ,Rays(6) ,Raws(6) ,Nuy(6) ,Nuw(6) ,Ddt(6) ,Pr(6)
4580 OUTPUT @Path_1 ;Yoh(9) ,Rays(9) ,Raws(9) ,Nuy(9) ,Nuw(9) ,Ddt(9) ,Pr(9)
4590 OUTPUT @Path_1 ;Yoh(11) ,Rays(11) ,Raws(11) ,Nuy(11) ,Nuw(11) ,Ddt(11) ,Pr(11)
4600 OUTPUT @Path_1 ;Yoh(12) ,Rays(12) ,Raws(12) ,Nuy(12) ,Nuw(12) ,Ddt(12) ,Pr(12)
4610 OUTPUT @Path_1 ;Yoh(13) ,Rays(13) ,Raws(13) ,Nuy(13) ,Nuw(13) ,Ddt(13) ,Pr(13)
4620 OUTPUT @Path_1 ;Yoh(15) ,Rays(15) ,Raws(15) ,Nuy(15) ,Nuw(15) ,Ddt(15) ,Pr(15)
4630 !PRINT "RED_DATX FILE COMPLETE"
4640 SUBEND

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10  ! ***** PROGRAM NAME "LSF" *****
20  ! THIS PROGRAM LOADS DATA FROM A DATFILE AND CARRIES OUT A LEAST
30  ! SQUARE FITTING; THE EXPONENTIAL EQUATION  $Y = C \cdot X^m$  IS THEN
40  ! TRANSFORMED INTO DATA, IN ANOTHER DATFILE. CORRELATION
50  ! COEFFICIENT IS CALCULATED, STORED AND PRINTED.
60  ! *****
70  OPTION BASE 1          ! ARRAY INITIATES AT 1
80  ! DIMENSION STATEMENT
90  DIM X(60),Y(60),Ras(60),Nu(60)
100 ! INITIALIZATION FOR SUM
110 Xsq=0
120 Sdsq1=0
130 Sdsqic=0
140 Sx=0
150 Sy=0
160 Sxy=0
170 Nusum=0
180 Diffsum=0
190 Diffave=0
200 ! INPUT NUMBER OF DATA POINTS < 60
210 INPUT "NUMBER OF DATA POINTS = ",N
220 ! ASSIGN DATFILE
230 INPUT "NAME OF SOURCE FILE : ",A$
240 PRINT A$
250 ASSIGN @Path_1 TO A$
260 ENTER @Path_1,1
270 FOR I=1 TO N
280     ENTER @Path_1,Ras(I),Nu(I)
300     X(I)=LGT(Ras(I))
310     Y(I)=LGT(Nu(I))
320     Xsq=X(I)^2
330     Xsq= Xsq+Xsq
340     Sx=Sx+X(I)
350     Sy=Sy+Y(I)
360     Xy=X(I)*Y(I)
370     Sxy=Sxy+Xy
380     Nusum=Nusum+Nu(I)
390 NEXT I
400 ! LEAST SQUARE FITTING
410 ! REFERENCE: J. P. HOLMAN. EXPERIMENTAL METHOD FOR ENGINEERS.
420 Sxsq=Sx^2
430 Deno=N*Xsq-SxSq
440 !  $Y=AX+B$ 
450 A=(N*Sxy-Sx*Sy)/Deno
460 B=(Sy*Xsq-Sxy*Sx)/Deno
470 ! GIVE DESTINATION DATFILE
480 INPUT "STORE FITTING CURVE TO FILE : ",B$
490 ASSIGN @Path_2 TO B$
500 OUTPUT @Path_2,1

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510 INPUT "RANGE OF RAYLEIGH* MIN,MAX =",M1,Ma
520 FOR Xx=M1 TO Ma
530     Yy=A*Xx+B
540     OUTPUT @Path_2;10^Xx,10^Yy
550 NEXT Xx
560 I PRINT VALUES FOR Y=C*X^M
570 C=10^B
580 M=A
590 PRINT "C = ",C
600 PRINT "M = ",M
610 I DETERMINE THE CORRELATION COEFFICIENT,R
620 Nuave=Nusum/N
630 FOR I=1 TO N
640     Nucal=C*(Ras(I))^M
650     Diffsum=Diffsum+(Nu(I)-Nucal)^2
660     Diffave=Diffave+(Nu(I)-Nuave)^2
670 NEXT I
680 Sy=SQR(Diffave/(N-1))
690 Syx=SQR(Diffsum/(N-2))
700 PRINT "STANDARD DEVIATION, SY = ",Sy
710 PRINT "STANDARD ERROR, SYX = ",Syx
720 R=SQR(1-(Syx/Sy)^2)
730 PRINT "CORRELATION COEFFICIENT = ",R
740 INPUT "FILE NAME TO STORE CORRELATION COEFFICIENT = ",Cs
750 ASSIGN @Path_3 TO Cs
760 IINPUT "NUMERICAL ORDER OF ACTIVE HEATERS =",Ahn
770 INPUT "ASPECT RATIO CODE NUMBER = ",Ahn
780 OUTPUT @Path_3,Ahn
790     OUTPUT @Path_3;C,M,Ssdy,Ssdyx,R
800 END
810 I #####
820 I ***** WRITTEN BY *****
830 I ***** T. T. WONG. UNIV. TENN.,KNOXVILLE *****
840 I #####

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10  | ***** PROGRAM NAME "FASTHIS" *****
20  | THIS PROGRAM RECORDS THE LOCAL TEMPERATURE HISTORY
30  | *****
40  OPTION BASE 1                | ARRAY LOWER BOUND = 1
50  DIM A(100),T(100)           | DIMENSION STATEMENT
60  | ***** INPUT STATEMENTS *****
70  INPUT "POWER = ",Pow
80  INPUT "HEATER NO = ",L
90  INPUT "CHANNEL NUMBER",Cn
100 INPUT "COLD CHANNEL",Cc
110 | ***** INTERFACING STATEMENTS *****
120 CLEAR 7
130 OUTPUT 722;"D0 F1 10STI"
140 OUTPUT 709;"AC";Cn
150 Itime=TIMEDATE
160 OUTPUT 722;"100STNRSIT3"
170 ENTER 722;A(*)
180 Ftime=TIMEDATE
190 CLEAR 709
200 CLEAR 722
210 OUTPUT 722;"FLIZIRIS0F1"
220 OUTPUT 709;"AC";Cc
230 ENTER 722;B
240 Dtime=Ftime-Itime           | CALCULATE TIME TAKEN FOR DATA COLLECTION
250 | DETERMINE DIMENSIONLESS PARAMETER LOCALLY
260 | FIND SUM, AVERAGE
270 Asum=0
280 Bsum=0
290 FOR I=1 TO 100
300 Asum=Asum+A(I)
310 NEXT I
320 Aav=Asum/100
330 IF Cn>60 THEN INPUT "LOCAL HEATER EMF = ",Aav
340 FOR I=1 TO 100
350 A(I)=(A(I)-B)/(Aav-B)
360 Bsum=Bsum+A(I)
370 NEXT I
380 Bav=Bsum/100
390 | DETERMINE MINIMUM AND MAXIMUM VALUES OF SAMPLES
400 Ymin=A(1)
410 Ymax=A(1)
420 FOR I=2 TO 100
430 IF A(I)>Ymin THEN
440 Nymax=A(I)
450 ELSE
460 Nymax=Ymin
470 Ymin=A(I)
480 END IF
490 IF Nymax>Ymax THEN Ymax=Nymax
500 NEXT I

```

```

510  ! ***** PRINT STATEMENTS *****
520  PRINT "POWER, HEATER #      ";Pow,L
530  PRINT "CHANNEL #, COLD CHANNEL      ";Cn,Cc
540  PRINT "time = ";Dtime
550  PRINT "Aav = ";Aav
560  IF Cn>60 THEN PRINT "BAV = ",Bav
570  PRINT "Ymin,Ymax      ";Ymin,Ymax
580  PRINT
590  PRINT
600  PRINT
610  PRINT A(*)
620  ! ***** PLOT STATEMENTS *****
630  ! PLOT TEMPERATURE VS TIME
640  GCLEAR
650  GRAPHICS ON
660  GINIT
670  X_gdu_max=100*MAX(1,RATIO)
680  Y_gdu_max=100*MAX(1,1/RATIO)
690  VIEWPORT .1*X_gdu_max,.9*X_gdu_max,.1*Y_gdu_max,.9*Y_gdu_max
700  FRAME
710  IF Cn<60 THEN
720      WINDOW 0,40,.985,1.015      ! FIXED AVERAGE AND FRAME
730      AXES 1,.001,0,.985,10,10,3
740  ELSE
750      WINDOW 0,40,(Bav-.00155),(Bav+.00155) ! SHIFTING AVERAGE FIXED LIMITS
760      AXES 1,.001,0,(Bav-.00155),10,10,3
770  END IF
780  CLIP OFF
790  Ti=Dtime/100
800  PEN Up
810  FOR I=1 TO 100
820      T(I)=Ti*(I-1)
830      PLOT T(I),A(I)
840  NEXT I
850  PEN Up
860  IF Cn<60 THEN
870      MOVE 0,1
880      PLOT Dtime,1,-1
890  ELSE
900      MOVE 0,Bav
910      PLOT Dtime,Bav,-1
920  END IF
930  ! DETERMINE THE DESIRABILITY OF DATA AND WHETHER TO RECORD
940  ! ***** WRITE STATEMENTS *****
950  INPUT "TO WRITE THE DATA INTO FILE, ENTER RUN NUMBER, ELSE ENTER 0",R
960  IF R=0 THEN
970      GOTO 40
980  ELSE
990      ASSIGN @Path_1 TO "TEMP_TIME"
1000  OUTPUT @Path_1,R

```



```
1010      OUTPUT @Path_1;Pow,L,Cn,Dtime,Aav,B,Ymin,Ymax,A(*)
1020  END IF
1030  END
```

```

DIMENSION A(201,361),B(201,361),CCON(201,361),CN(201,361)
DIMENSION T(202,362),D(201,361),CS(201,361)
CHARACTER*15 AAA
REAL KA,KP
TYPE*, 'DST(MM), HEATER #, POWER INPUT, T_AIR, T_BACK'
READ(5,*)DST,HN,W,TA,TB
DS=DST/1000.
TYPE*
TYPE*, 'T_HEATER, T_INS1, T_INS2, TFI3'
READ(5,*)TH, TI1, TI2, TI3
OMEGA = 1.670546
ITER=500
KA = 170.0
KP=.33333
DSH = DS/2.
Q = W/4.839E-3
M = 30/DST+1
N = 54/DST+1
MAL = 3/DST+1
NAL = 9/DST+1
DO 1 I = 1,M
DO 2 J = 1,N
T(I,J) = TB
2 CONTINUE
1 CONTINUE
DT = TB-TA
HA = 2.*(DT)**(.33333)
C 2*****
DO 3 J = 1,N
DO 4 I = 2,M-1
A(I,J) = 1.
B(I,J) = 1.
CS(I,J) = 1.
CN(I,J) = 1.
D(I,J) = -4.
CCON(I,J) = 0.
4 CONTINUE
3 CONTINUE
C 3*****
DO 5 I = 2,M-1
CS(I,1) = 0.
CN(I,1) = 2.
CS(I,N) = 2.
CN(I,N) = 0.
5 4*****
C CCON(MAL,1) = Q*DSH
A(MAL,1) = KP/2.
B(MAL,1) = KA/2.
CS(MAL,1) = 0.
CN(MAL,1) = KA/2.+KP/2.
D(MAL,1) = -(KA+KP)
C 5*****
A(M,1) = 0.
B(M,1) = KP/2.
CS(M,1) = 0.
CN(M,1) = KP/2.
CCON(M,1) = HA*DSH*TA
D(M,1) = -(KP+HA*DSH)
C 6*****
DO 6 J = 2,N-1
A(M,J) = 0.
B(M,J) = KP
CS(M,J) = KP/2.
CN(M,J) = KP/2.
CCON(M,J) = HA*DS*TA
6 D(M,J) = -(2.*KP+HA*DS)

```



```

C      7*****
      A(M,N) = 0.
      B(M,N) = KP/2.
      CS(M,N) = KP/2.
      CN(M,N) = 0.
      CCON(M,N) = HA*DSH*TA
      D(M,N) = -(KP+HA*DSH)
C      8*****
      DO 7 J = 1,NAL-1
7      T(1,J) = TH
      T(1,NAL)=TH/2+TI1/2
C      9*****
      DO 8 J = NAL+1,3*NAL-3
8      T(1,J)=TI1
      T(1,3*NAL-2)=(TI1+TI2)/2
      DO 9 J = 3*NAL-1,N-NAL
9      T(1,J)=TI2
      T(1,N-NAL+1)=(TI2+TI3)/2
      DO 188 J=N-NAL+2,N
188     T(1,J)=TI3
      DO 189 J=1,N
189     T(M,J)=TB
C      12*****
      DO 102 I=2,MAL-1
      A(I,3*NAL-2)=KP/2.+KA/2.
      B(I,3*NAL-2)=KP/2.+KA/2.
      CS(I,3*NAL-2)=KP
      CN(I,3*NAL-2)=KA
      CCON(I,3*NAL-2)=0
      D(I,3*NAL-2)=-(2.*KP+2.*KA)
102     CONTINUE
C      16*****
      DO 103 I=2,MAL-1
      A(I,N-NAL+1)=KP/2.+KA/2.
      B(I,N-NAL+1)=KP/2.+KA/2.
      CS(I,N-NAL+1)=KA
      CN(I,N-NAL+1)=KP
      CCON(I,N-NAL+1)=0.
      D(I,N-NAL+1)=-(2.*KP+2.*KA)
103     CONTINUE
C      17*****
      CCON(MAL,3*NAL-2) = 0.
      A(MAL,3*NAL-2) = KP
      B(MAL,3*NAL-2) = KP/2.+KA/2.
      CS(MAL,3*NAL-2) = KP
      CN(MAL,3*NAL-2) = KA/2.+KP/2.
      D(MAL,3*NAL-2) = -(KA+3.*KP)
C      18*****
      I=MAL
      J=N-NAL+1
      A(I,J)=KP
      B(I,J)=KP/2.+KA/2.
      CS(I,J)=KP/2.+KA/2.
      CN(I,J)=KP
      CCON(I,J)=0.
      D(I,J)=-(3.*KP+KA)
C      19*****
      I=MAL
      DO 111 J=3*NAL-1,N-NAL
      A(I,J)=KP
      B(I,J)=KA
      CS(I,J)=KP/2.+KA/2.
      CN(I,J)=KP/2.+KA/2.
      CCON(I,J)=0.
      D(I,J)=-(2.*KP+2.*KA)
111     CONTINUE

```

```

C      21*****
      DO 100 I=2,MAL-1
      A(I,NAL)=KP/2.+KA/2.
      B(I,NAL)=KP/2.+KA/2.
      CS(I,NAL)=KA
      CN(I,NAL)=KP
      CCON(I,NAL)=0.
      D(I,NAL)=-(2.*KP+2.*KA)
100    CONTINUE
C      22*****
      I=MAL
      J=NAL
      A(I,J)=KP
      B(I,J)=KP/2.+KA/2.
      CS(I,J)=KP/2.+KA/2.
      CN(I,J)=KP
      CCON(I,J)=Q*DSH
      D(I,J)=-(3.*KP+KA)
C      23*****
      I=MAL
      DO 110 J=2,NAL-1
      A(I,J)=KP
      B(I,J)=KA
      CS(I,J)=KP/2.+KA/2.
      CN(I,J)=KP/2.+KA/2.
      CCON(I,J)=Q*DS
      D(I,J)=-(2.*KP+2.*KA)
110    CONTINUE
C      *****
C      ITERATION LOOP
C      99    CONTINUE
      DO 150 IIT=1,ITER
C
      DO 120 I=2,M-1
      P=-A(I,1)*T(I+1,1)-B(I,1)*T(I-1,1)-CN(I,1)*T(I,2)-CCON(I,1)
      T(I,1)=OMEGA*P/D(I,1)+(1-OMEGA)*T(I,1)
120    CONTINUE
C
      DO 140 J=2,N
      DO 130 I=2,M-1
      P=-B(I,J)*T(I-1,J)-A(I,J)*T(I+1,J)-CS(I,J)*T(I,J-1)-CN(I,J)*T(I,J+1)
      T(I,J)=(P-CCON(I,J))*OMEGA/D(I,J)+(1-OMEGA)*T(I,J)
130    CONTINUE
140    CONTINUE
150    CONTINUE
C      ENERGY BALANCE
      QIN=0
      DO 160 J=1,NAL
      QIN=QIN+CCON(MAL,J)
160    CONTINUE
C
      DTAK=0
      DO 170 J=2,N-1
      DTK=T(M-1,J)-T(M,J)
      DTAK=DTAK+DTK
170    CONTINUE
      QLOS=KP*(DTAK+.5*(T(M-1,1)+T(M-1,N)-T(M,1)-T(M,N)))
C
      DTAK=0
      DO 180 J=2,NAL-1
      DTFK=T(2,J)-T(1,J)
      DTAK=DTAK+DTFK
180    CONTINUE
      QOK=KA*(DTAK+.5*(T(2,1)+T(2,NAL)-T(1,1)-T(1,NAL)))
      DTAK=0
      NALPP=3*NAL-3

```



```

        NALPPP=NALPP+1
        DO 190 J=NAL+1,NALPP
        DTFI1K=T(2,J)-T(1,J)
        DTAK=DTAK+DTFI1K
190      CONTINUE
        QKI1=KP*(DTAK+.5*(T(2,NAL)+T(2,NALPPP)-T(1,NAL)-T(1,NALPPP)))
C
        DTAK=0
        DO 191 J=NALPPP+1,N-NAL
        DTFI2K=T(2,J)-T(1,J)
        DTAK=DTAK+DTFI2K
191      CONTINUE
        QKI2=KA*(DTAK+.5*(T(2,NALPPP)+T(2,N-NAL+1)-T(1,NALPPP)-T(1,N-NAL+1)))
C
        DTAK=0
        DO 192 J=N-NAL+2,N-1
        DTFI3K=T(2,J)-T(1,J)
        DTAK=DTAK+DTFI3K
192      CONTINUE
        QKI3=KP*(DTAK+.5*(T(2,N-NAL+1)+T(2,N)-T(1,N-NAL+1)-T(1,N)))
C
        QKI=QKI1+QKI2+QKI3
        QKUT=QKI+QOK+QLOS
        QRK=QKUT/QIN
        CHK=QOK/QIN
        CIK=QKI/QIN
        CLK=QLOS/QIN
        HPERK=QOK/(QKI+QOK)
        PRINT*, 'QRK = ;   CHK = ;   CIK = ;   CLK = ;   HPERK = ;'
        PRINT*, QRK, CHK, CIK, CLK, HPERK
        IF((QRK.LT.0.99).OR.(QRK.GT.1.01)) GOTO 99
        TBN=0
        DO 1000 J = 1,N
        TBN=TBN+T(M,J)
1000      CONTINUE
        TBN=TBN/N
        PRINT*, 'HEAT NUM = ,;POWER INPUT = ; AIR_TEMP = TBACK= '
        PRINT*, HN,W,TA,TB
C
        PRINT*
        PRINT*, 'T_HEATER = ; T_INS1 = ; T_INS2 = '
        PRINT*, TH,TI1,TI2
C
        PRINT*
        print*, 't_heater numerical, t_ins1 numerical, t_ins2 numerical=,TBN'
        print*, T(1,1),T(1,nal+(nal-1)),T(1,NAL+3*(NAL-1)),TBN
        print*
        PRINT*, 'NAME OF DATA FILE TO STORE TEMP INFO ? '
        READ(5,15)AAA
15      FORMAT(A)
        OPEN(UNIT=14,FILE=AAA,STATUS='NEW')
        DO 896 J=1,N
        WRITE(14,*)(T(I,J),I=1,M)
896      CONTINUE
        END

```


VITA

Toon-Tin Wong was born in Singapore on February 8, 1957. He attended primary school in The Maha Boldhi School and was graduated from Catholic High School in 1976. Immediately after the graduation, he was drafted to serve full time National Service in the Ministry of Defence. After the Run Out Date, he served with Singapore Airlines Limited as an Apprentice Aircraft Maintenance Engineer for four years. He obtained a Technician Diploma through part-time studies. In the fall of 1983, he entered Tennessee Technological University. He transferred to the University of Tennessee, Knoxville the next fall. In the spring of 1986, he received a Bachelor of Science degree in Mechanical Engineering. In the fall of 1986, he accepted a teaching assistantship at the same university and began study toward a Master's degree. He graduated in March 1988.

The author is a member of The American Society of Mechanical Engineers; The American Society of Heating, Refrigerating, Air-Conditioning Engineers. He plans to seek a career in Singapore.