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A STUDY OF FILM BOILING OF LIQUID NITROGEN AND LIQUID ARGON OVER A WIDE PRESSURE RANGE WITH CYLINDRICAL HEATERS

BY

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A

DISSERTATION

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DOCTOR OF PHILOSOPHY

Rolla, Missouri

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ABSTRACT

A film boiling heat transfer study was conducted with three different diameter cylindrical copper heaters over a wide range of pressures for nitrogen and argon with the heat transfer surface in the horizontal position.

The data were compared to the commonly used film boiling heat transfer relations. The common relations were found to be considerably in error for the range of variables covered in this investigation. A semi-empirical equation for corresponding states fluids which correlates the available data as a function of the reduced temperature and reduced pressure was derived and discussed.

ACKNOWLEDGEMENTS

The author wishes to express his sincere appreciation to Dr. E. L. Park for assistance, guidance and advice during this study.

The author acknowledges support of the National Science Foundation whose grant made this study possible.

The assistance of Mr. Richard Smith, R. T. Montgomery, T. C. Wilson, and the never ending encouragements of my wife, Louise, are furthermore appreciated.

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CHAPTER I

INTRODUCTION

This study deals with film boiling as defined in the following discussion and shown in Figure 1. Figure 1 is the entire boiling curve as first predicted by Nukiyama (18)* in 1934. This curve is broken up into four distinct regions which can best be understood by considering a heat transfer surface submerged in a saturated liquid. As the temperature of the surface is raised slightly above the saturation temperature, convection currents circulate the liquid and evaporation occurs at the free surface. This region is described as the convection region (region I in Figure 1). As the surface temperature is raised further, bubbles begin to form at specific points on the surface. The locations where bubbles form are called nucleation sites. This region, characterized by the formation of nuclei is named the nucleate boiling region (region II, in Figure 1). As the temperature is increased further, more sites are activated until the surface is completely covered with bubbles forming a continuous vapor film which is specified as point A on Figure 1. This point is known as the burn-out point or the critical heat flux point. The nucleate boiling region is of special importance, because of the very high heat fluxes obtained with a small temperature difference.

As the temperature is further increased, the film forms and collapses rapidly, causing an increased resistance which quickly drops the heat transfer rate. This unstable film region continues until point B (the Leidenfrost point). The Leidenfrost point is the point where the film is continuous and becomes stable even though the film surface is in violent agitation.

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* Numbers in parentheses refer to listings in Bibliography.

The region to the right of the Leidenfrost point is denoted as the film boiling region (region IV), and is of interest in this investigation.

The film boiling data presently available over a wide range of pressures seem to be very limited. More data are required in order that theoretical equations and the effects of pressure and diameter on film boiling can be checked.

This study was originated to provide data for the above reasons and to provide design data for nitrogen and argon.

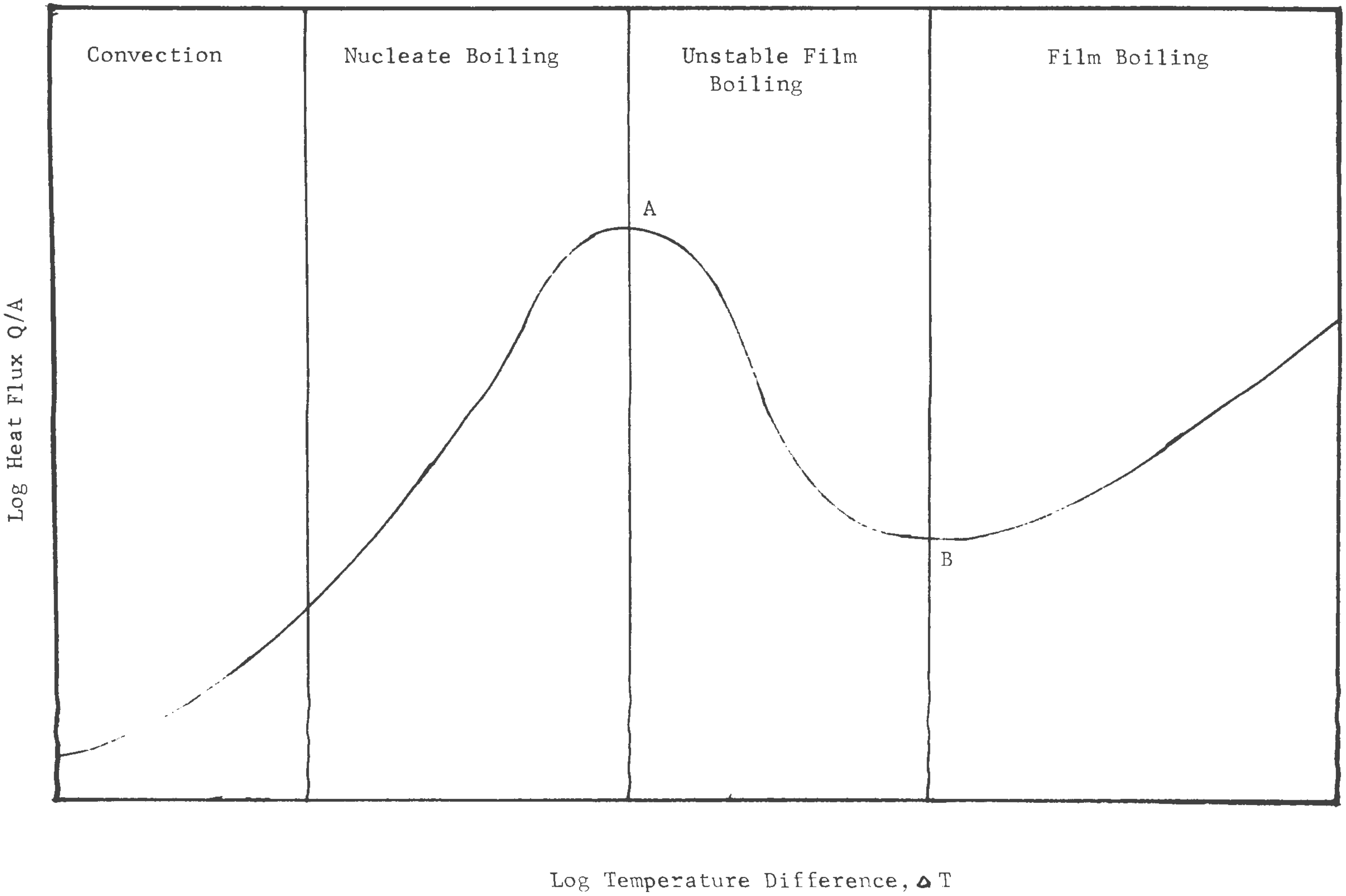

Figure 1 A Typical Boiling Heat Transfer Curve

CHAPTER II

PREVIOUS WORK

Scorah and Farber (11) were the first investigators to completely describe the boiling curve. Nukiyama (18) had difficulty in his work. He was not able to describe the region between the maximum and minimum points, A and B. The work of Scorah and Farber also predicted a heat transfer element material dependence in the stable film boiling region. Later work contradicts these findings.

The first investigator to suggest a method of predicting heat transfer coefficients for natural convection film boiling was Bromley (4). Bromley derived a relation analogous to Nusselt's equations for condensation by replacing ρ in Nusselt's equation by $\rho_1 - \rho_v$. The resulting equation was:

$$h = \text{Const} \left[\frac{k^3 \rho_v (\rho_1 - \rho_v) g}{\Delta T \mu_v D} \right]^{\frac{1}{4}} \qquad \underline{(1)}^{*}$$

The relation is for horizontal tubes. The value of the constant was found by empirical means to be 0.62. By theoretical considerations, the value of the constant should be 0.512 if the liquid is assumed stagnant and 0.724 if the liquid moves with the vapor. Bromley suggested that correction for radiation could be made by assuming parallel plates, which in effect assumes that the transmissivity of the liquid is zero.

Bromley's assumed relation predicts that the heater material had no effect on the convective coefficient and his experimental data confirmed the assumption.

The work of Banchero, Barker and Boll (2) for film boiling of liquid oxygen over a large pressure range with considerable variation in heater

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* Numbers underlined in parentheses refer to equations.

diameters pointed out the limitations of Bromley's equation. They point out that Bromley's relation seems to be limited to diameters of 0.069 inches to 0.127 inches. The **authors** present the following (equation 2) which is a modification of Bromley's relation (equation 1).

$$h = a\left(\frac{1}{D} + C\right) \quad F \qquad (\underline{2})$$

$$C = \text{constant}$$

$$F = \left[\frac{k^3 \rho_v (\rho_l \quad \rho_v)\, g\lambda}{\Delta T \mu}\right]^{\frac{1}{4}}$$

where a equals a constant which is dependent on the boiling substance. The above equation seems to give a better correlation for the entire range of variables than Bromley's (3). The form of the equation also allows it to be adapted to flat plates. The values of a and C are determined by a trial and error fit of the available data. The authors found the quantity a to be a temperature dependent function and C to be equal to 36.5 inches^{-1}.

Bromley corrected his relation to account for the sensible heat of the vapor (5). His corrected relation is given below:

$$h = 0.62 \left[\frac{k^3 \rho_v (\rho_l - \rho_v)\, g\lambda'}{\Delta T \mu D}\right]^{\frac{1}{4}} , \qquad (\underline{3})$$

where

$$\lambda' = \lambda\left(\frac{1 + 0.4\, C_p \quad T}{\lambda}\right)^2 .$$

Subsequently it was shown (3) that a better fit could be obtained by equation 1 if the correction constant used in equation 3 was 0.34 rather than 0.4.

Bromley (5) also suggested that his relation could easily be adapted to vertical surfaces, by substiuting L for D, and changing the value of the constant C_2. Bromley's vertical surface relation is given:

$$h = C_2 \left[\frac{k^3 \rho_v \,(\rho_l - \rho_v)\, g\lambda'}{\mu_v L \Delta T}\right]^{\frac{1}{4}} . \qquad (\underline{4})$$

Again, a better fit can be obtained by using 0.34 (3) instead of 0.4. The theoretical value of C_2 is 0.667 if the liquid is stagnant and 0.943 if the liquid has the same velocity as the vapor. Bromley presented no data to check his vertical surface relation; however, Hsu and Westwater (14) investigated this condition and found that Bromley's relation (3) predicted heat transfer coefficients much too low when compared to their experimental values for tubes in the vertical position. The authors used a method suggested by Colburn (9) for film type condensation on vertical surfaces. This relation converted to film boiling is:

$$h\left[\frac{\mu_v^{2}}{k^3\rho_v(\rho_1-\rho_v)\ g}\right] = \frac{\left(\frac{4W}{\pi D\mu}\right)}{22\left(\frac{C_p\mu}{k}\right)^{-1/3}\left[\left(\frac{4W}{\pi D\mu_v}\right)^{0.8}-364\right]} + 12{,}800 \quad . \tag{5}$$

The above relation produces better results than Bromley's relation for all Reynolds numbers above 2000. The Reynolds number is defined as $\frac{4W}{\pi D\mu}$ where W is the maximum vapor mass flow rate. This Reynolds number points out the main limitation of Bromley's equation, the fact that laminar flow was assumed. In later work, Hsu and Westwater (13) proposed another relation for film boiling on vertical surfaces. They used an approach which assumed a turbulent core and a laminar sublayer and ignored the buffer zone between the regions. The division between the zones was determined by the universal velocity profile. The relation is given below:

$$\frac{hL}{k_v} = \frac{2\lambda'\mu_v Re^*}{3k_v\ \Delta T} + \frac{B+1/3}{A}\left[\left\{\frac{2}{3}\left(\frac{A}{B+1/3}\right)(L-L_o)+\left(\frac{1}{y^*}\right)^{2}\right\}^{3/2}-\left(\frac{1}{y^*}\right)^{3}\right] , \tag{6}$$

where

$$A = \left(\frac{g(\rho_1-\rho_v)}{\rho v}\right)\left(\frac{1}{\mu_v Re^*}\right) ,$$

$$Re^* = \frac{y^*u^*\rho_v}{\mu v} , \text{ and}$$

$$B = \left[\mu_v + \frac{f\rho_v\,\mu_v Re^*}{2\rho_v} + \frac{k_v\,\Delta T}{\lambda}\right] \Big/ \frac{k_v\,\Delta T}{\lambda} \quad .$$

Chang (7) suggested that, possibly, a relation for film boiling could be obtained by analyzing the waves formed in vapor release or by applying the instability concept of Taylor. Chang (7) suggested that equation (7) be used to correlated film boiling data from horizontal surfaces.

$$Nu = 0.234\ (Pr^*\ Gr^*)^{1/3} \qquad (7)$$

$$Pr^* = \frac{\gamma}{a_c}\ ,\quad Gr^* = \frac{g\,\rho_v^{\,2}\,L^3}{\mu_v^{\,2}}\left(\frac{\rho_1 - \rho_v}{\rho_v}\right) ,$$

$$Nu = \frac{Lh}{k_v} ,$$

$$a_c = \frac{k_v\,\theta_v}{2\,\lambda\,\rho_v}\ ,\quad \theta_v = T_{sat} - T_w ,$$

$$Pr^* = Pr\left(\frac{2\lambda}{c_{pv}\ \theta_v}\right),$$

$$y^* = \frac{2\,\mu^2_v Re^{*5}}{g\,\rho_v(\rho_1 - \rho_v)} ,$$

$$L_o = \frac{\mu_v Re^*\,\lambda'\ y^*}{2k_v\,\Delta T} ,$$

and

$$Re^* = 100 \quad .$$

For low subcooled boiling ($_1$ 10°F)

$$Pr^* = Pr\left[\left(\frac{2\lambda}{C_{pv}\,\rho_v}\right) + \left(\frac{2\,\theta_1\ C_{pl}\ \rho_1}{\theta_v C_{pv}\,\rho_v}\right)\right] .$$

The L_o denotes the point at which Bromley's equation fails to correlate with published data and y^* denotes distance normal to the surface of maximum vapor velocity. Re^* was given a value of 100 which denotes the transition between viscous and turbulent flow as supported by Rohsenow's (25) computation of 80 to 120 for critical Reynolds numbers during condensation on vertical surfaces in the presence of large shear stresses. Using the data for water, the relation's of Bromley (3) and Chang (7) were compared. The Chang relation seemed to fit the data much better than that of Bromley relation. For the case of subcooling, the thermal diffusity α_c used in the calculation of the generalized Prandtl number must be found from another equation which is considerably more complicated. Chang presents a correction for radiation. In the case where radiation should be considered, the value of equivalent thermal diffusivity α_c must be corrected in the relations.

Chang also proposed an equation for the surface in the vertical position. The vertical position relation is (8).

$$(Nu) = \frac{L'h}{k_v} = 0.72 \; (Pr^*Gr)^{\frac{1}{4}} \quad . \qquad (8)$$

Berenson (1) used the above approach in developing a correlation for film boiling from horizontal surfaces. His relation is

$$h = 0.425 \left[\frac{k_v^{\,3} \, \rho_v \, g \, (\rho_1 - \rho_v)}{\mu \, v \, \Delta T \left(\dfrac{g_c \sigma}{g(\rho_1 - \rho_v)} \right)^{\frac{1}{2}}} \right]^{\frac{1}{4}} \quad . \qquad (9)$$

The major difference between (9) and Bromley's (3) is the term $\left(\dfrac{g_c \, \alpha}{g(\rho_1 - \rho_v)} \right)^{\frac{1}{2}}$. The relation (9) seemed to be effective only near the minimum point of the film boiling region.

Breen and Westwater (3) continued the investigation of film boiling from a cylindrical surface with its axis in the horizontal position. They conducted experiments with a large variation in diameter and with two different fluids. The range of diameters used was from 0.185 to

1.895 inches. They found that the heat flux and the heat transfer coefficient were not monotonous functions of tube diameter. The data showed that as the diameter was increased the heat transfer coefficient began decreasing rapidly and then increased slowly to a flat plateau. This behavior was explained by the critical diameter which must be a function of the fluid. The curves seem to support the hydrodynamic wave length theory. When Bromley's equation (3) was compared to the data, Bromley's equation failed to predict the value of heat transfer coefficient at wave lengths much greater than the hydrodynamic wave length. The hydrodynamic wave length λ_D for a flat plate is:

$$\lambda_D = \sqrt{3}\,\lambda c \qquad (10)$$

where

$$c = 2\pi \left[\frac{g_c\,\sigma}{g\,(\rho_l - \rho_v)}\right]^{\frac{1}{2}} . \qquad (11)$$

Breen and Westwater using these parameters claimes a general relation (12) for film boiling from horizontal cylinders.

$$\frac{h(\lambda c)^{\frac{1}{4}}}{F} = 0.59 + 0.069\,\frac{\lambda c}{D} . \qquad (12)$$

They also proposed an alternate relation due to the asymptotic characteristics of the equation at large and small diameters and the agreement with Bromley's equation (3) at intermediate diameters. The alternate relations are given in equations 13A, 13B, and 13C

$$\text{for } \frac{\lambda c}{D} < 0.8,\quad h(\lambda c)^{\frac{1}{4}}/F = 0.60 . \qquad (13A)$$

$$\text{for } 0.8 < \frac{\lambda c}{D} < 8,\quad h(D)^{\frac{1}{4}}/F = 0.62 . \qquad (13B)$$

$$\text{for } < 8\ \frac{\lambda c}{D},\quad h(\lambda c)^{\frac{1}{4}}/F = 0.16\,(\lambda c/D)^{0.83} . \qquad (13C)$$

Park (21) attempted to fit his data with the Breen and Westwater correlation. He found that the correlation was not general and would not give a satisfactory fit to these film boiling data for nitrogen and methane over a considerable pressure range. He also noticed that the high temperature difference data indicated a temperature difference dependence not accounted for in the Breen and Westwater correlation. Park (21) reported a decrease in the heat flux as the critical pressure is approached. This effect became apparent at reduced pressures greater than 0.9 (the reduced pressure is defined as the absolute pressure divided by the critical pressure of the substance).

Sciance (26) did not record this effect in his continuation of the work of Park; however, his pressures did not exceed a reduced pressure of 0.9.

Wayner and Bankoff (29) have reported some interesting work. They have increased heat transfer rates by the use of porous plates and removing the vapor being formed by suction through the plate. Within certain limits the heat flux and vapor rate could be independently varied, and there was an increase in the heat transfer coefficient by a factor of as much as 2.5 over the nonporous film boiling. Pai and Bankoff (20) reported a continuation of this work.

Tachibana and Fukui (28) reported the effects of film boiling in a subcooled liquid. They presented curves of the effect of the subcooled liquid on film boiling of water from horizontal wires.

The objective of this investigation is to provide film boiling data for design purposes and to determine whether film boiling data for corresponding states fluids can be correlated by application of the principle of corresponding states.

CHAPTER III

DESCRIPTION OF THE EXPERIMENTAL EQUIPMENT

The equipment used in the investigation consisted of three heat transfer elements, a pressure vessel, a power source, a pressure gauge, and a recording potentiometer.

Three heat transfer elements (0.95, 0.75 and 0.55 inches O.D.) were constructed and were designed so that they could withstand the thermal shock of going through the burnout point and operating with a 1000°F temperature difference. The design consisted of heat treated Lavatite cores of 0.40 inch diameter for the 0.75 and 0.95 O.D. heaters and of 0.25 inch diameter for the 0.55 inch O.D. heater. The cores were threaded 12 threads per inch and in the threads, number 26 gauge tungsten wire was wrapped. The tungsten wire was held by nuts on 4-40 machine screws which were screwed into the end of the cores. The screws also acted as the power terminals for the heaters. After the tungsten wire was wrapped on the heaters, they were coated with Sauereisen Electrical Resistor Cement, #78 paste, and allowed to air dry. The cores were then cemented into the outer heat transfer surface with the same cement and dried in a furnace for two hours at 200°F. The heat transfer surfaces consisted of three copper cylinders three inches long with 0.95, 0.75, and 0.55 inches O.D. and with 0.5, 0.5, and 0.35 I.D., respectively.

In each of the three heat transfer surfaces, three thermocouple wells 0.052 inches in diameter and 1 inch deep were drilled 90 degrees apart. Solder was then melted in the wells until they were full. While the solder was molten, 25 gauge copper-constantan thermocouples were placed in the wells. The solder minimized the contact resistance between the heat transfer element and the thermocouples.

Styrofoam plugs with the same diameters as the heaters and of ½ inch thickness were attached to the ends of the heaters to reduce the end losses.

The power was supplied by a Hobart 300 amp, 40 volt, Model M B 204 D.C. Welder connected in a series with a load box which consisted of several fixed size resistors which could be added or subtracted in parallel. The load box and the fine and coarse voltage controls on the welder were used for power control.

The power was measured by using a Weston Model I (class 50) voltmeter to measure the voltage drop across the heater. A Weston Model I (class 50) ammeter was used to measure the current flow through the heater.

The pressure vessel was a one gallon autoclave, described by Sciance (26), which was manufactured by Autoclave Engineers, Inc. The autoclave was 5 inches I.D. by twelve inches deep and was fitted with two 1¼ inch diameter windows, which were horizontally opposed. The flange of the vessel was fixed and the high-pressure cylinder could be raised or lowered pneumatically to or from the flange. The power leads and thermocouples were brought in through openings in the flange. The gland mounted in the flange for the thermocouples was a Conax MHM-062-A160T gland with Teflon sealant. The copper-constantan thermocouples leads passing through the gland were Conax 310SS6T-B-PJFC-NONE-18", which were connected to the heater thermocouples. The power leads supported the heater from the flange so that the autoclave could be opened for inspection without disturbing the heater.

The pressure of the vessel was controlled by the amount of liquid nitrogen passing through the internal cooling coils (Figure 2). The liquid nitrogen was stored in Linde LS 110B and LS 156 dewars and was delivered to the system at 235 psig. The system was protected from over pressurization by a Black, Sivall and Bryson rupture disc rated at 960 psi at 72°F.

The pressure of the autoclave was measured with a Heise Bourdon tube pressure gauge with a 16 inch dial. This gauge was graduated from 0 to 1000 psi in 1 psi increments with an accuracy of ± 1 psi. All connections shown in Figure 2 were 316 stainless steel ¼ inch tubing with ¼ inch O.D. and 0.065 wall. The valves were Whitey No. 1 Series 0.25 inch valves (number IRS4-316).

The thermocouple leads came from the flange to a liquid nitrogen reference junction and then were connected to a Leeds and Northrup rotary thermocouple switch which was used in conjunction with Texas Instruments, Servoriter II, single pen recorder. One iron-constantan thermocouple was also used to check for subcooling and was read with a Leeds and Northrup 2436 portable potentiometer.

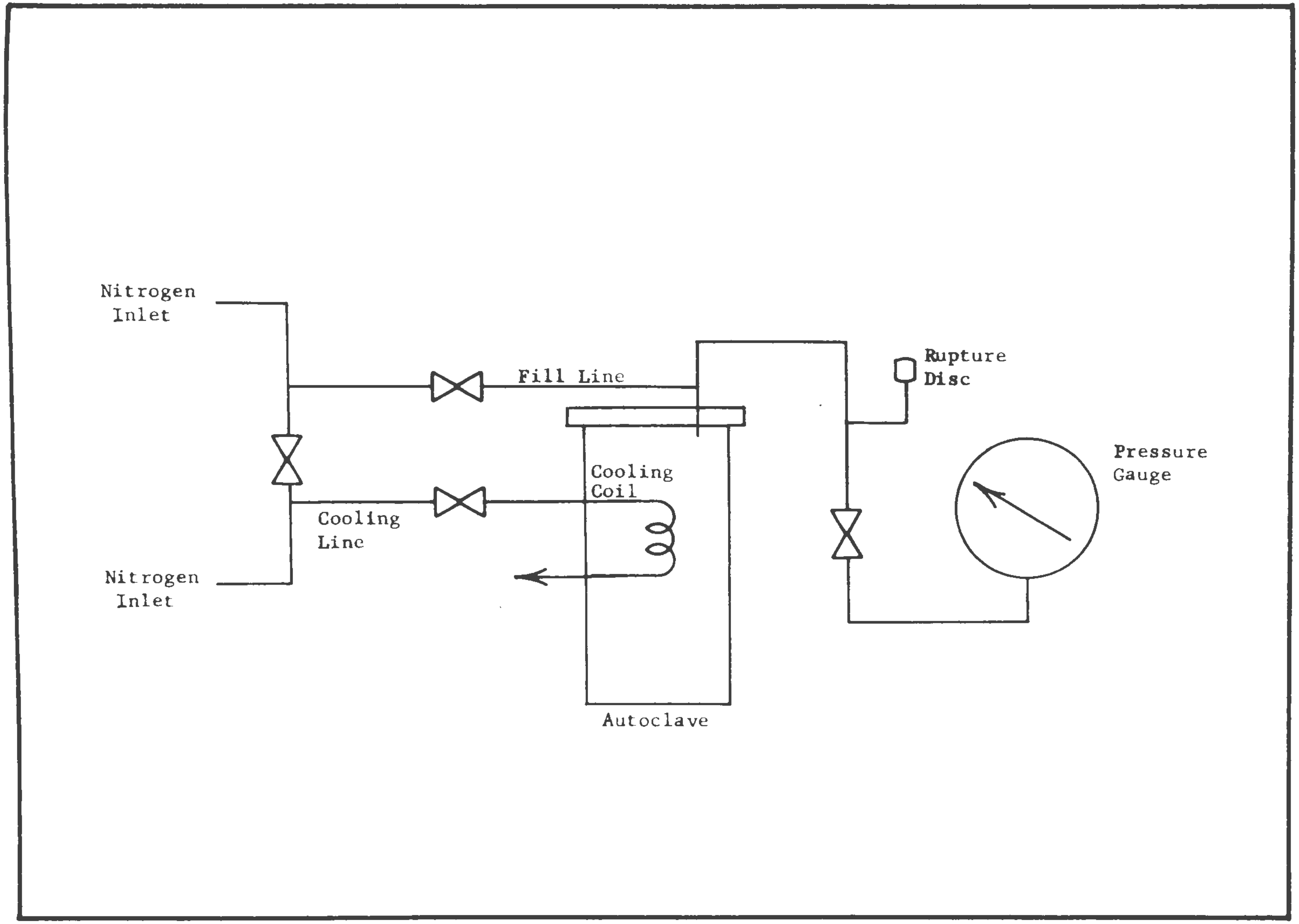

Figure 2. Pressure and Condensing System - Schematic Diagram

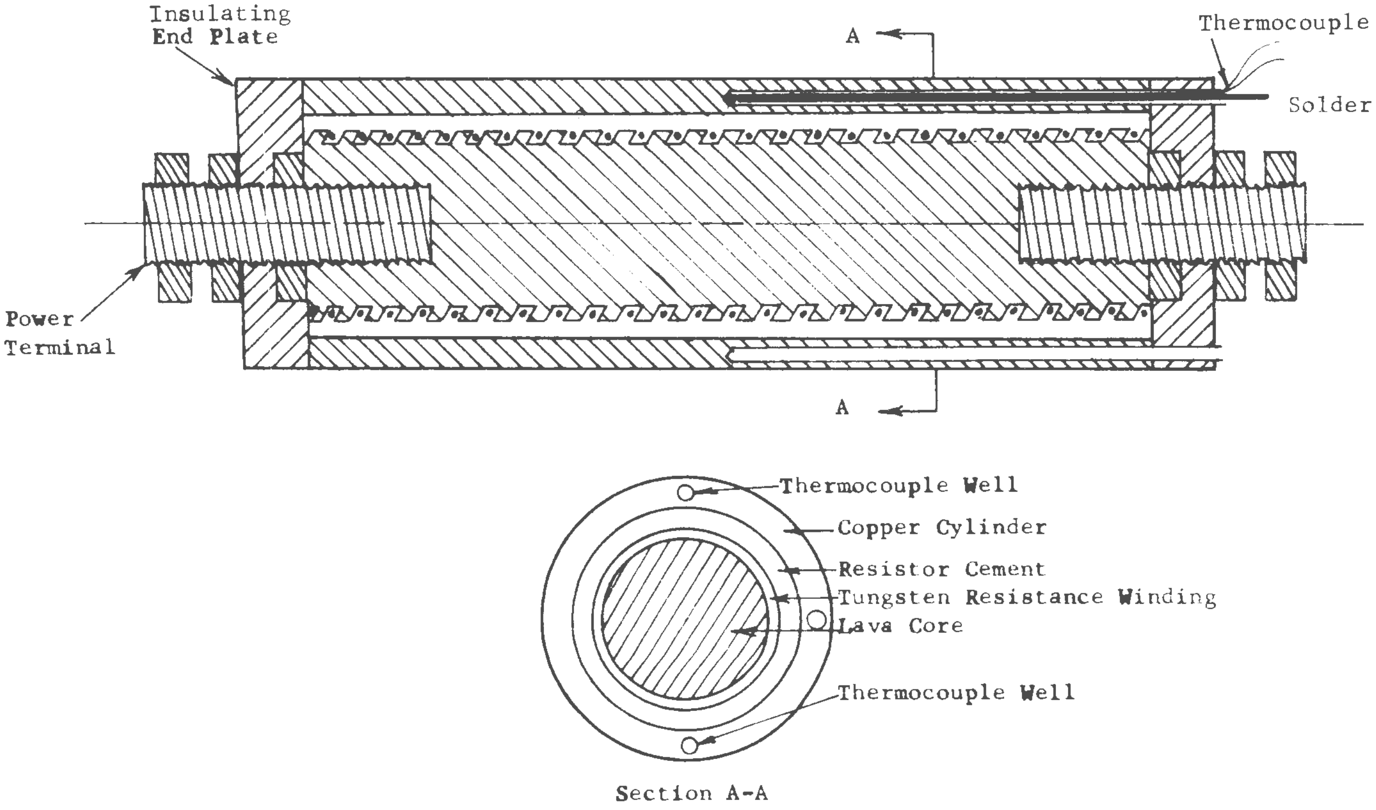

Figure 3. Heat Transfer Element

CHAPTER IV

EXPERIMENTAL PROCEDURE

A series of runs was made with each heater in the horizontal position. Each series consisted of runs at seven different pressures from atmospheric pressure up to 95 percent of the critical pressure for both argon and nitrogen.

To begin a series of runs, the autoclave was cooled by allowing nitrogen to flow through the fill line into the autoclave and out the vent opening in the vessel. The valve was also opened slightly to the cooling coil to maintain the coils at the proper temperature (Figure 2). When the level of the liquid nitrogen reached the top of the window (seven inches), the fill line was closed and the vent plug replaced. The system was then checked for leaks and the pressure raised or lowered to reach 34 psig. The pressure was controlled by regulating the amount of nitrogen flowing through the condensing coils. After reaching 34 psig, the power at the minimum setting was turned on and the system examined for malfunctions. The power was then increased until the burn-out point was reached and then controlled until the heat transfer surface temperature was approximately 70°F. Steady state adjustments were made by watching the temperature versus time plots from the recording potentiometer and making adjustments with the fine adjustment on the power source. After reaching steady state, the three thermocouple outputs were recorded. The power was then reduced and another operating point was recorded. Steady state observations were made with the heat transfer surface temperature range varying between 70°F and approximately 60°F above the boiling point of the fluid,which is a function of pressure. The pressure was then increased to the next pressure and the procedure repeated. After completing the six pressure runs, the pressure was again reduced to 34 psig and another run made to check the reproducibility of the data.

The power was then turned off and the fill line was opened to the atmosphere allowing the nitrogen to bleed off to the surroundings.

The equipment was left open for an hour at which time the argon bottle was connected to the fill lines. The autoclave was pressurized to 50 psig with gaseous argon and again vented to the surroundings to reduce the contamination. The liquid nitrogen was then allowed to flow through the condensing coils and the regulator on the argon bottle was set at 50 psig and the fill line opened. After a period of time, the argon began condensing. When the argon level reached the top of the window (7 inches) the regulator and the fill line valve was closed.

The pressure was then adjusted to 56 psig and maintained at this level for the first argon run. The procedure was exactly the same as for the nitrogen.

After completing the seven runs for the argon, the autoclave was lowered and a dewar of liquid nitrogen was put in place of the autoclave to make an atmospheric nitrogen run. The same procedure used for the other runs was used during the atmospheric run. The atmospheric nitrogen run could not be done in the autoclave because the condensing coils were not large enough to maintain zero gauge pressure.

During each run the bulk temperature of the boiling liquid was monitored to assure the boiling liquid was at its saturation temperature.

CHAPTER V

THEORY OF CORRESPONDING STATES AS APPLIED TO FILM BOILING

The theory of corresponding states may be safely regarded as the most useful by-product of the van der Waal's equation of state. Presently this equation is recognized to be of little or no value, but the theory of corresponding states correctly applied is extremely useful and accurate.

Pitzer (22) has stated a set of assumptions sufficient to lead to the principle of corresponding states for liquids and showed that argon, krypton and xenon have several properties in accordance with the principle. Pitzer's assumptions are:

I. "Classical statistical mechanics will be used".

II. "The molecules are spherically symmetrical, either actually or by virtue of rapid and free rotation".

III. "Intramolecular vibrations will be assumed the same in the liquid and gas states".

IV. "The potential energy will be taken as a function only of the various intermolecular distances".

V. "The potential energy for a pair of molecules can be written $A\phi(R/R_o)$ where R is the intermolecular distance, A and R_o are characteristic constants and ϕ is a universal function".

Guggenheim (11) restates the assumptions above. He restates assumption one as, "that any distinction between Fermi-Dirac statistics and Bose-Einstein statistics has a negligible effect"; and assumption II as, "that effects of quantization of the translational degrees of freedom is negligible". Assumptions I and II are satisfied provided $(mKT)^{\frac{1}{2}}v^{1/3} >> h$, where m denotes molecular mass, T absolute temperature and v volume per molecule.

Assumption III is restated to say the intramolecular degrees of freedom are assumed to be completely independent of the volume per molecule. This assumption and assumption II and IV rule out highly polar molecules. Assumption V turns out to be a useful approximation for many non-polar molecules.

With these five assumptions satisfied, it can be shown that the equation of state is of the form

$$\frac{P}{P_c} = u\left(\frac{T}{T_c}, \frac{v}{v_c}, Z_c\right) \qquad (\underline{14})$$

$$\text{where} \quad Z_c = P_cV_c/RT_c$$

where u is a universal. but complicated function. The above expression is the general expression of the principle of corresponding states.

Examining some characteristics of fluids which obey the principle of corresponding states, it is noticed that of the critical compressibility factor of argon, krypton, nitrogen, oxygen, carbon monoxide and methane all are within 1.5% of 0.292. Another interesting characteristic is the temperature where change of sign of second virial coefficient occurs called the Boyle point (where the virial equation of state is $\frac{Pv}{RT} = 1 + \frac{B(t)}{v} + \frac{C(t)}{v^2}$). When the Boyle point is divided by the critical temperature for neon, argon and oxygen, the values agree within 1%; for nitrogen, carbon monoxide and methane, it agrees within 5 to 8%. The second virial coefficient divided by the critical volume plotted against the reduced temperature ratio has approximately the same shape for all these gases. This property means that physical properties of corresponding states fluids can be expressed as functions of the reduced temperature and the reduced pressure or the reduced volume. Thodos (10, 19, 27) has done considerable work in predicting thermal conductivity, viscosity, surface tension and coefficients of thermal expansion in this manner.

In film boiling studies with corresponding states fluids, the properties of interest seem to be: density of the vapor, viscosity, thermal conductivity, specific heat, and latent heat of vaporization. These properties for any of the corresponding states fluids then can be evaluated by an equation, which is a function only of the reduced temperature and pressure. If saturation conditions are defined, the equation will only be a function of reduced temperature. With this result, the data of this investigation should be able to be correlated as a function of the reduced temperature, reduced pressure and the diameter of the heat transfer element. The equation should be of the form given below:

$$h = f(T_r, P_r, D)$$

or:

$$h = f(T_r) \quad \text{if } D \text{ and } P_r \text{ are constant} \quad (\underline{15})$$

CHAPTER VI

RESULTS

During the course of taking the experimental data a radial temperature difference was noticed between the three thermocouples spaced 90° apart. Similar gradients were also noticed by Park (21) and Sciance (26). The data for the 0.95" and the 0.75" heaters were completely duplicated. All the data for a given pressure run were fitted using a least squares program. This program gave the local best polynomial fit of the experimental data. The program finds the best fit by minimizing the standard deviation. The experimental data for one representative sample run are shown in Figure 4

The best fit for the data in Figure 4 is a straight line with an average deviation of 8.98% and a maximum deviation of 26.2%. This figure not only gives an example of the data taken, but points out the degree of reproducibility of the results. The data taken in all the runs are shown in appendix A. The average of the average deviation for all the data are 3.60% and the maximum average deviation for any set of data was 11.05% which was the data for argon at 655 psig using the 0.95 inch heater. The least square fits for all data taken for the three different heaters in argon and nitrogen are shown in Figures 5 through 10. It should be pointed out that the data are plotted as the heat flux versus the temperature difference. This is not the standard procedure in boiling heat transfer. Typically the plots are made with the logarithm of the temperature difference versus the logarithm of the heat flux. This procedure of plotting the logarithms tends to disguise the scatter of the data.

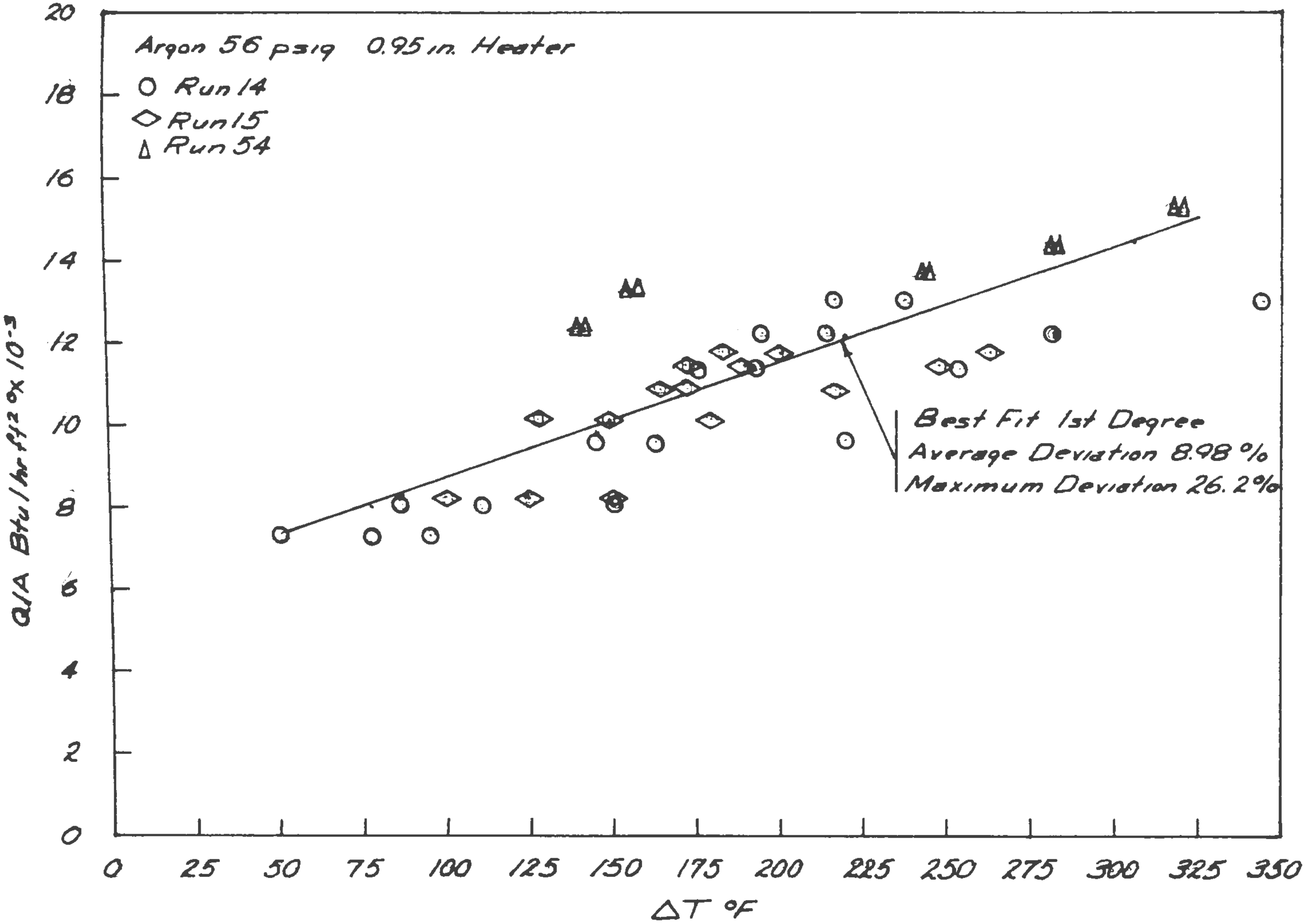

Figure 4 Film Boiling Results for Argon at 56 psig, 0.95 in Diameter Heater

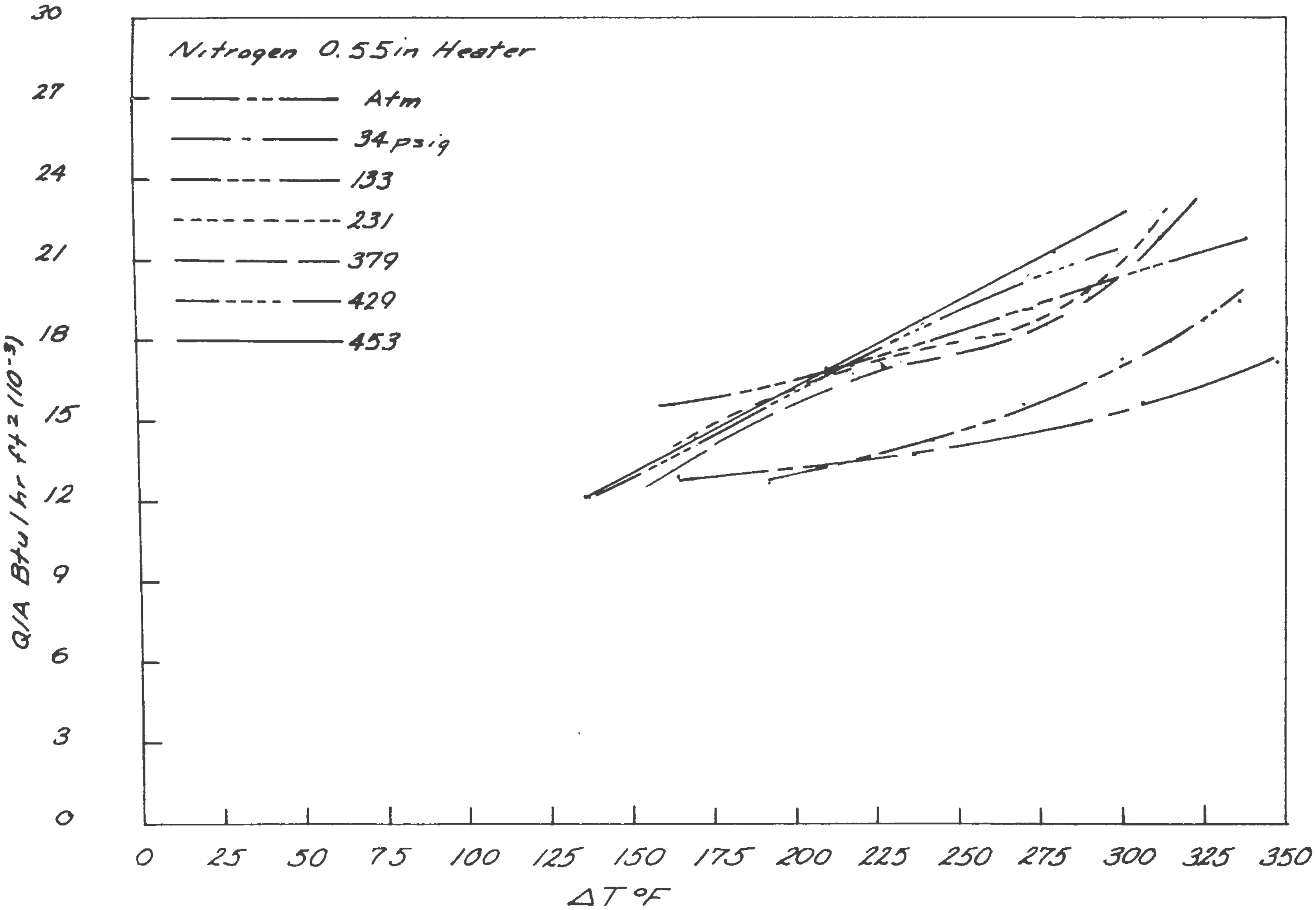

Figure 5   Film Boiling Results for Nitrogen, 0.55 in. Diameter Heater

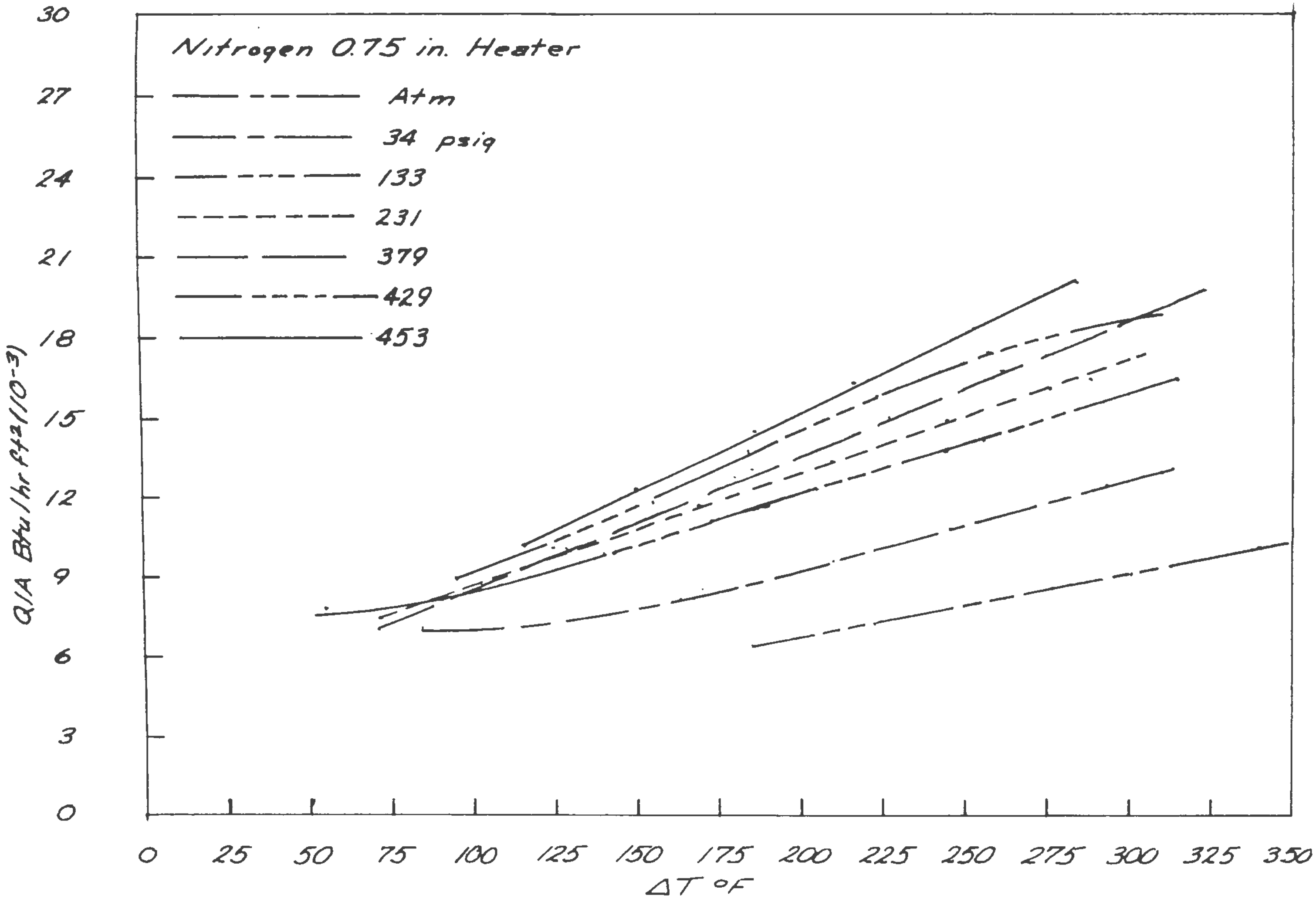

Figure 6 Film Boiling Results for Nitrogen, 0.75 in. Diameter Heater

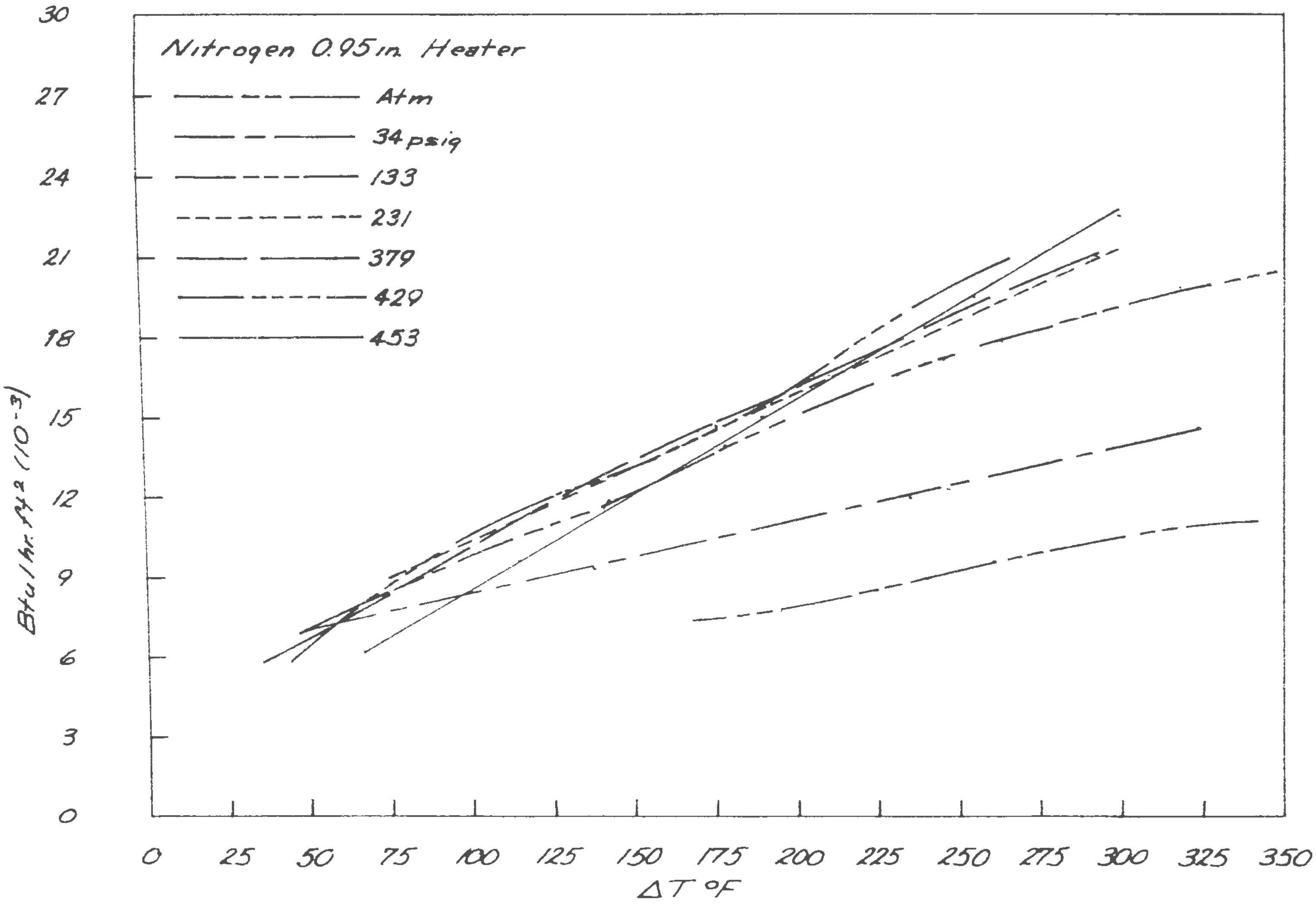

Figure 7 Film Boiling Results for Nitrogen, 0.95 in. Diameter Heater

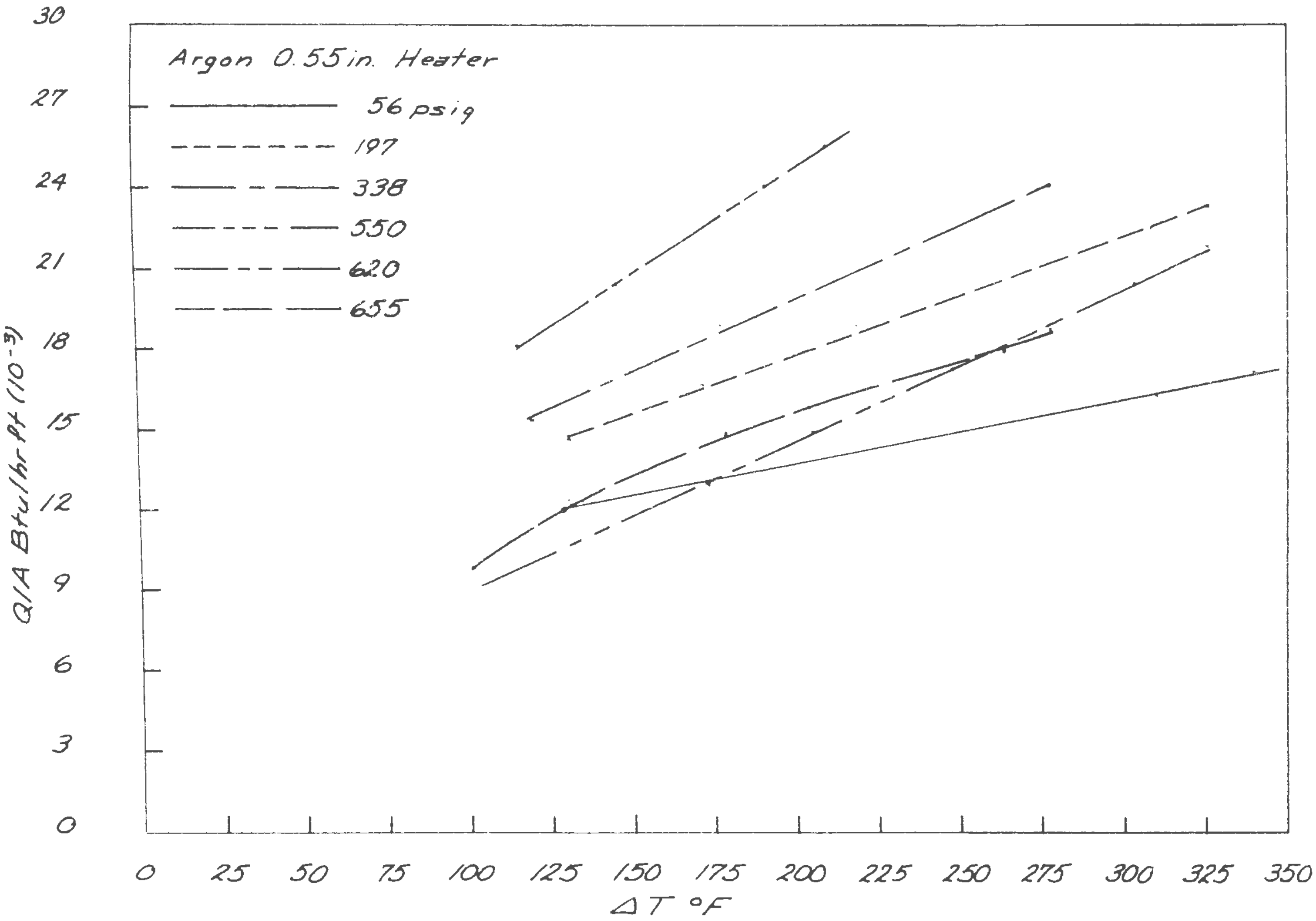

Figure 8 Film Boiling Results for Argon, 0.55 in. Diameter Heater

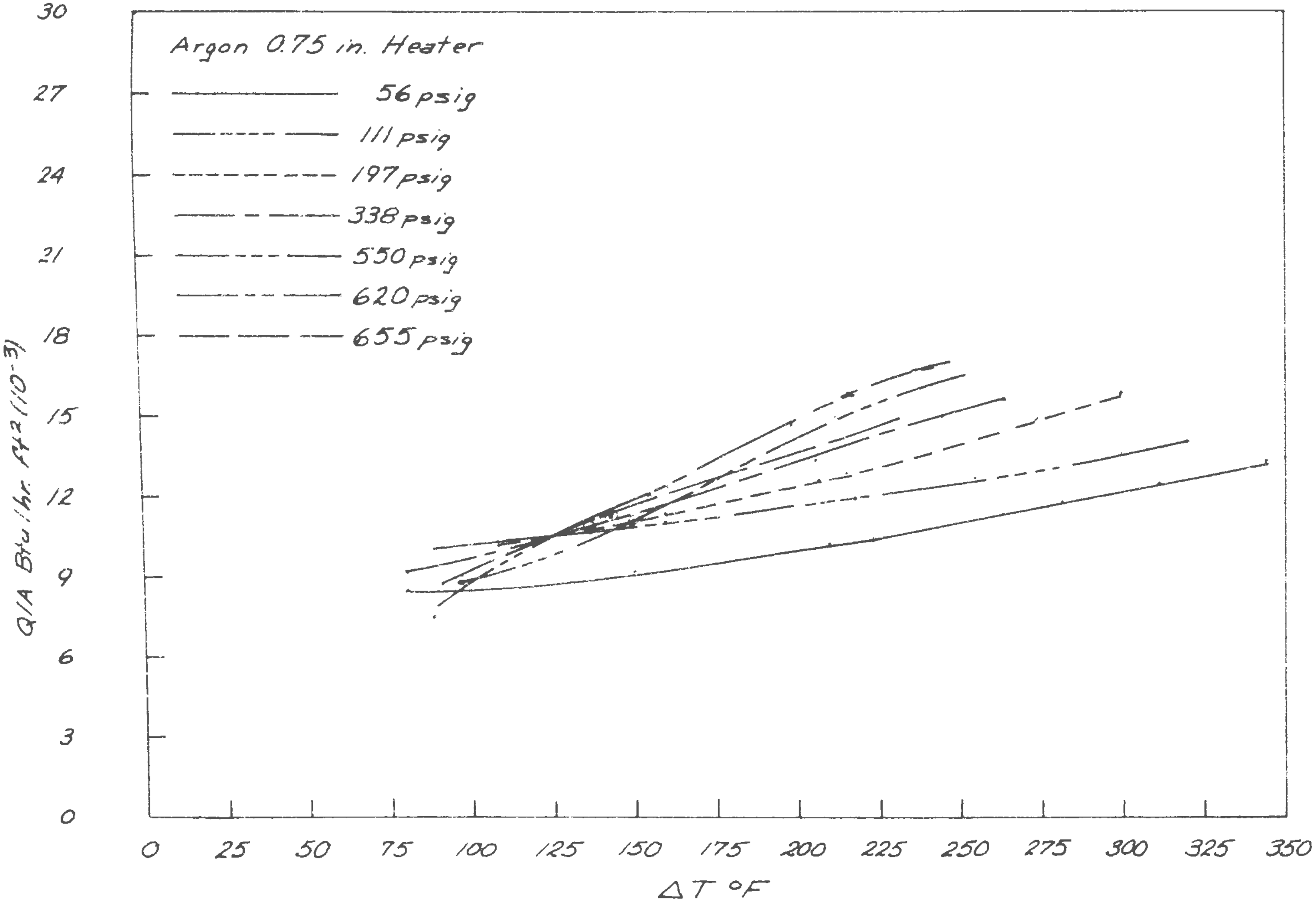

Figure 9 Film Boiling Results for Argon, 0.75 in. Diameter Heater

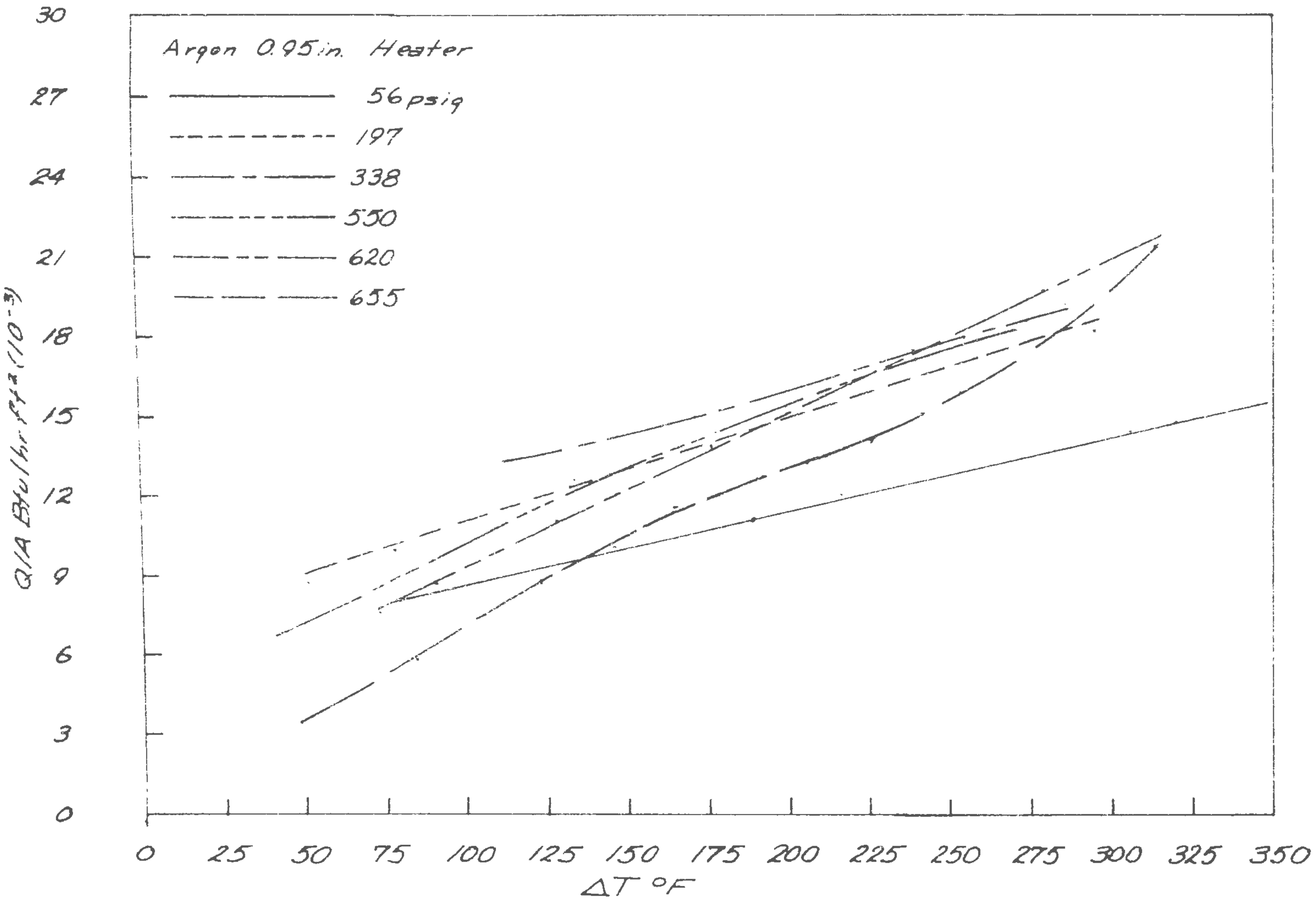

Figure 10 Film Boiling Results for Argon, 0.95 in. Diameter Heater

CHAPTER VII

DISCUSSION OF RESULTS

The curves for argon at 655 psig for all heaters point out a decrease in the heat flux when operating close to the critical pressure, but this phenomenon is questionable in the nitrogen data. A decrease is noticed in the data for 0.95 inch diameter heater, but for the other two heaters, a decrease is not present over the complete range of temperatures. Park (21) reported this decrease in heat flux for both nitrogen and methane, but Sciance (26) did not find it to exist in his continuation of Park's work, however, Sciance and Park's pressure ranges are not the same. In all of the data, crossing of the constant pressure curves can either be seen or extrapolation of the curves would yield the crossing. This indicates that an increase in heat flux with pressure does not occur over the entire ΔT range. Instead, the increase or decrease of heat flux with pressure is a function of the absolute value of the temperature difference and also the closeness to the critical point in some cases. Excluding the behavior near the critical point it can be seen that at low temperature difference, a decrease in heat flux is experienced with increasing temperature and at high temperature differences an increase is experienced. The point of crossing seems to be somewhere between 75°F and 150°F which is approximately 200°F lower than the value predicted by Park

The experimental data were compared with Bromley's predicted curve (equation 3) in Figures 11 and 12. The plots clearly show that there would be a large error if Bromley's equation (equation 3) is used to predict heat transfer coefficients in this range of temperature differences and for these pressures. The equation could be modified by changing the constant

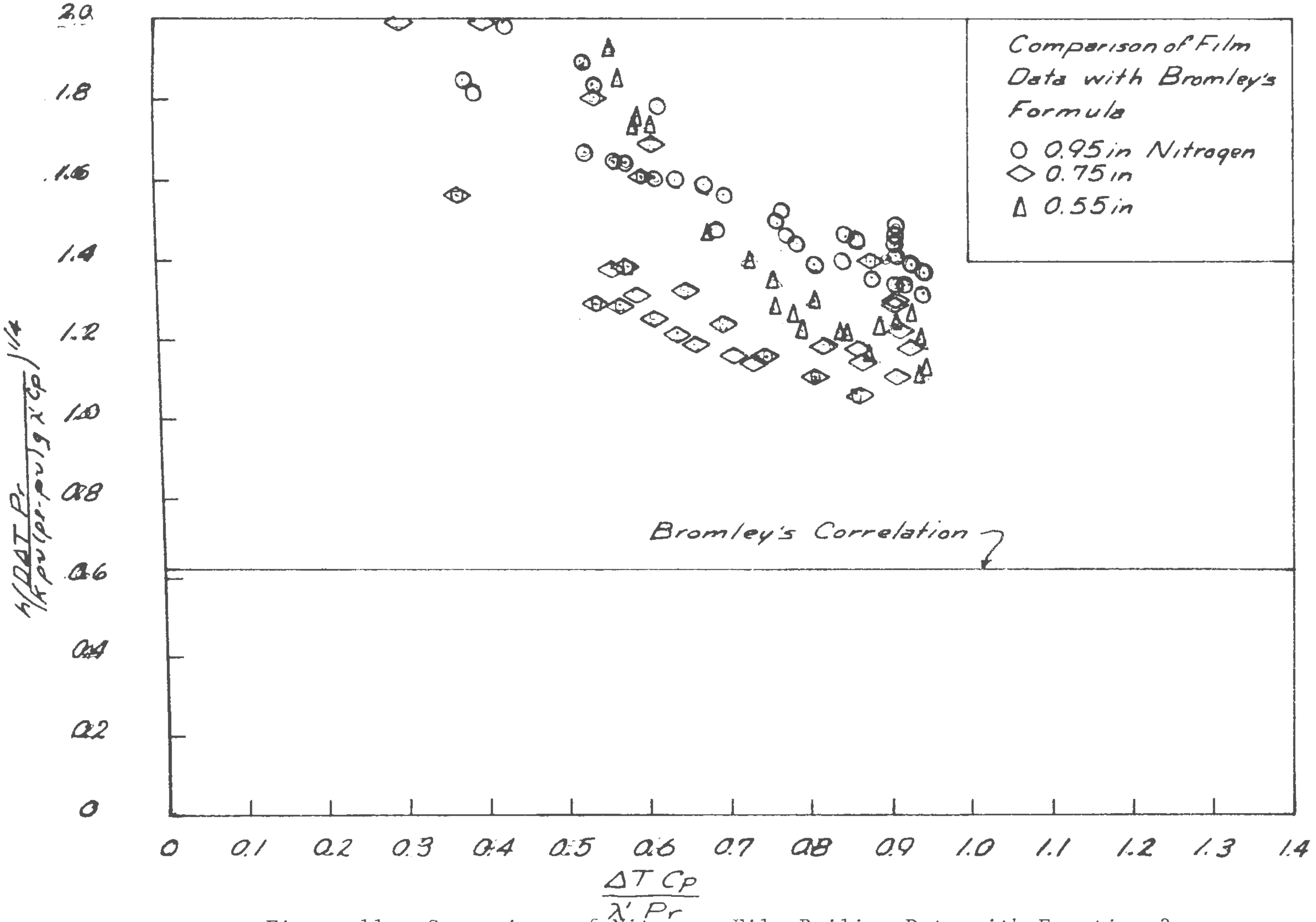

Figure 11 Comparison of Nitrogen Film Boiling Data with Equation 3

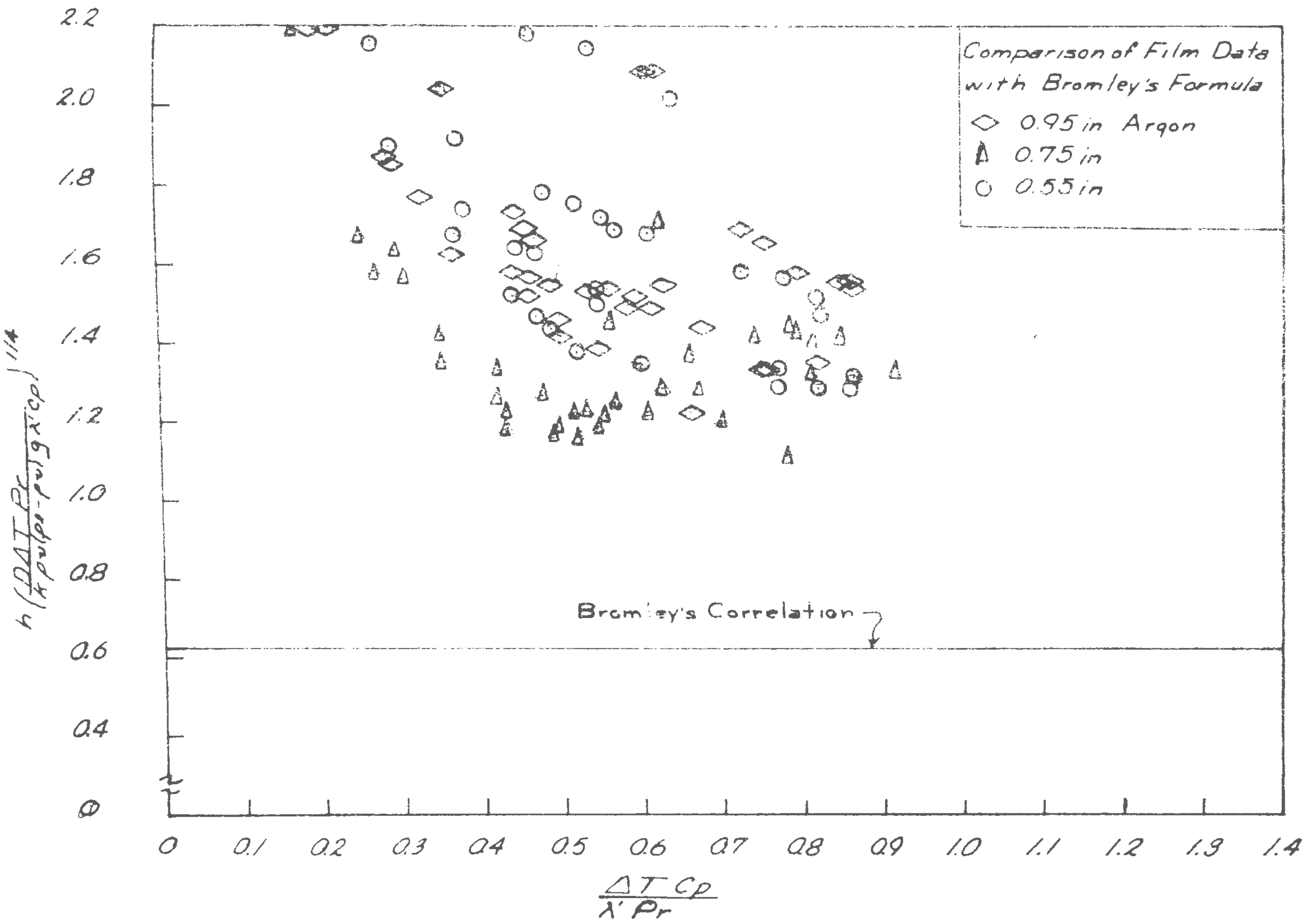

Figure 12 Comparison of Argon Film Boiling Data with Equation 3

in order to obtain a curve which would pass through the center of the data. But this modification still would not yield a satisfactory relation, and the increase in the constant would be difficult to justify.

The experimental data were also compared to the predicted curve of Breen and Westwater,(3) Figures 13 and 14. The only restriction placed on the predicted curves was that the diameter of the heater does not equal "the most dangerous wave length". This wave length varied from 0.00187 ft. at 655 pounds per square inch to 0.0291 ft. at 56 pounds per square inch for argon and from 0.00306 ft. at 453 pounds per square inch to 0.0332 ft. at atmospheric pressure for nitrogen. The diameters of the heaters were 0.0458, 0.0625, and 0.0792 ft. which are above the value of "the most dangerous wave length". With "the most dangerous wave length" requirement satisfied, these data should be a test of the generality of the predicted curve. The comparison of the data obtained with Breen and Westwater's equation is shown in Figures 13 and 14. In both cases, the data show that equation (12) is not general. A relation could be made by passing a modified curve through the data. The difficulty in doing this is that, in each run, the data tends to all be plotted at a constant value of λ_c/D for each different pressure.

The real difficulty in this type of relation is in using the quantity F as defined by Bromley (4). The properties that define F are found at the mean film temperature and then F is found by taking the fourth root of $\frac{k^3 \rho_v (\rho_l - \rho_v) \lambda'}{\Delta T \mu}$. Taking the fourth root of this quantity tends to remove or smooth the variation due to temperature. Also, the values used in defining F can be very difficult to obtain. The difficulty in finding data or physical properties becomes especially apparent when the pressures

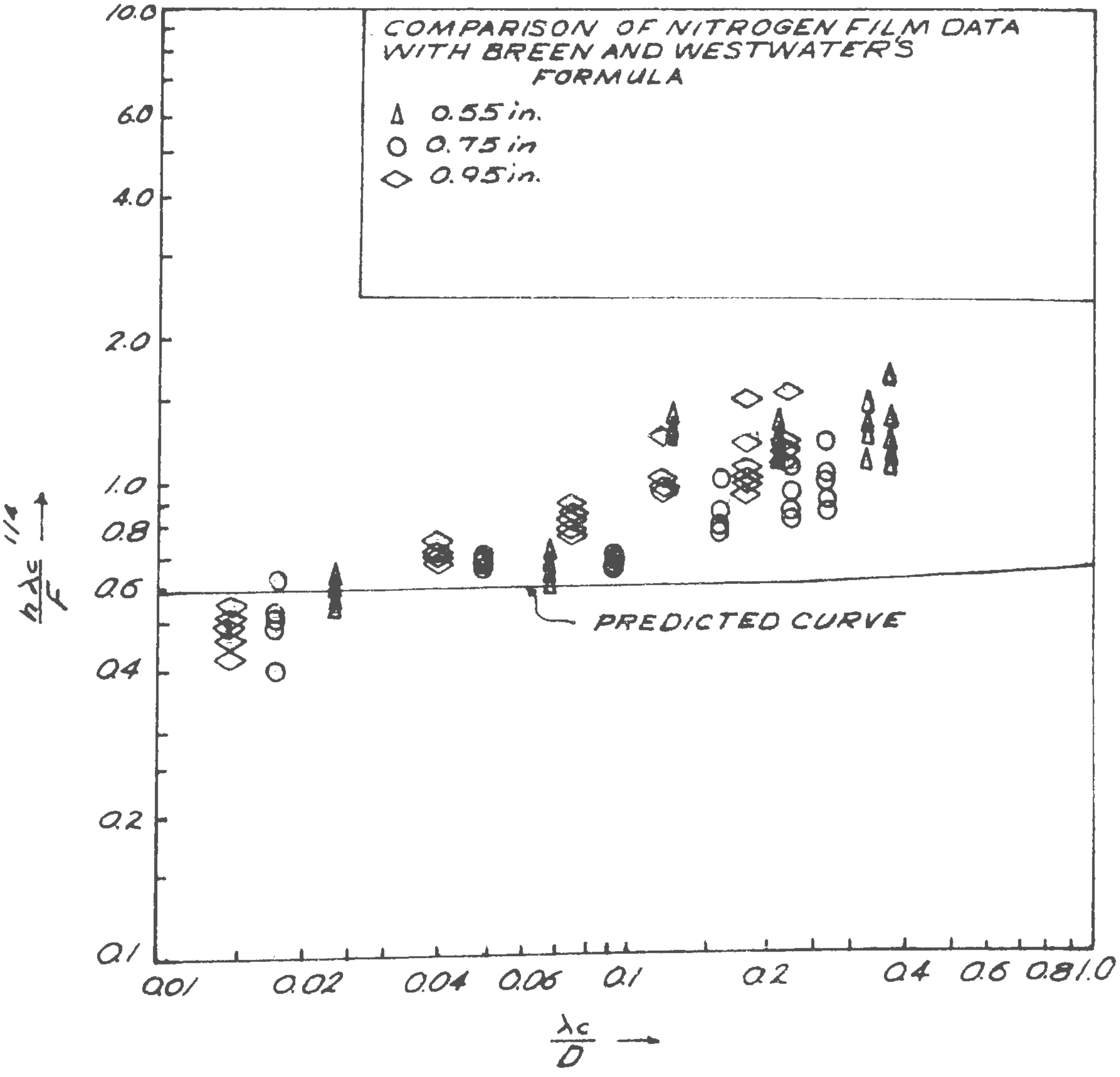

Figure 13 Comparison of Nitrogen Film Boiling Data with Equation 12

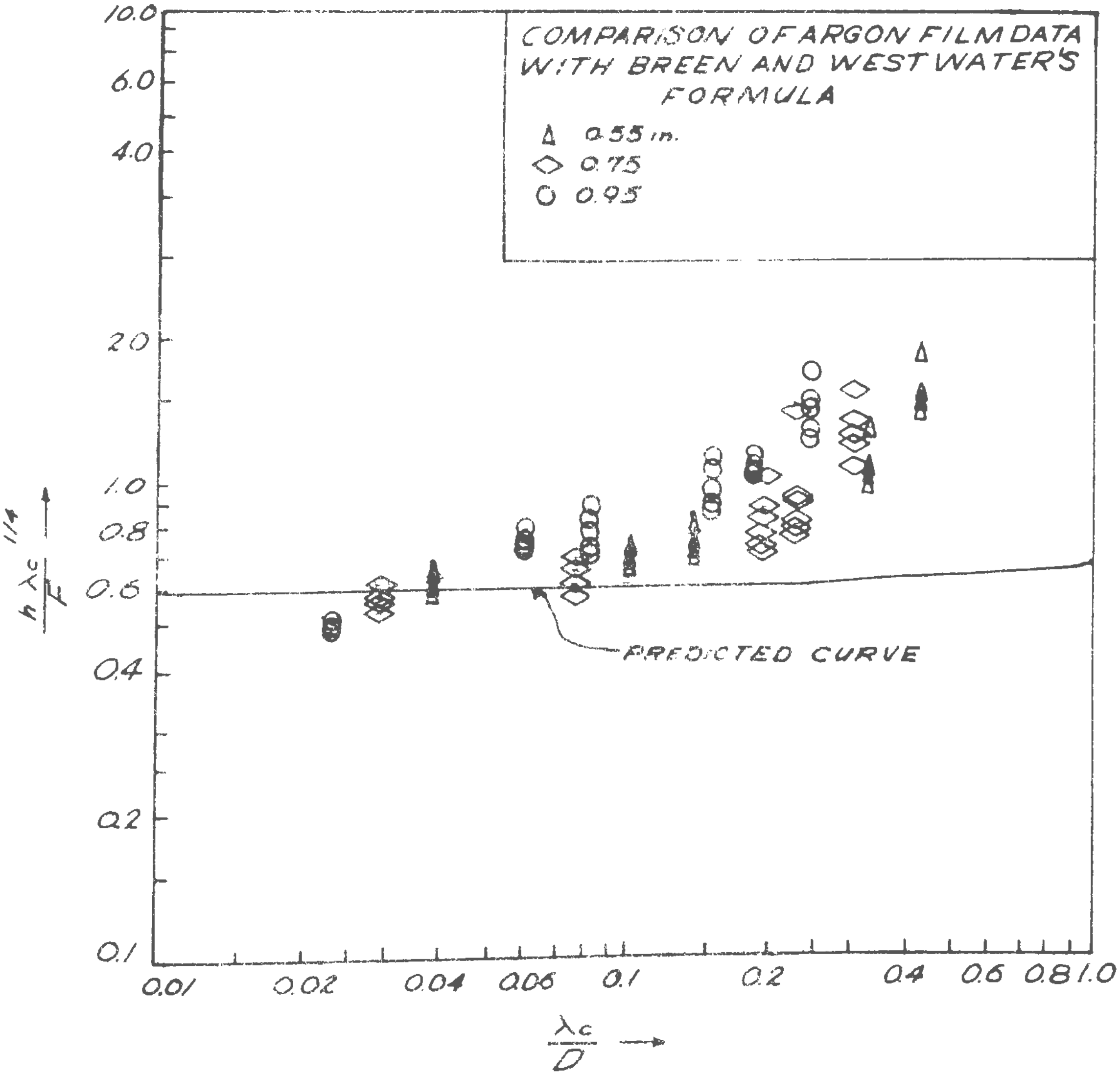

Figure 14 Comparison of Argon Film Boiling Data with Equation 12

approach the critical pressure. In this study, the thermal conductivity, viscosity and surface tension at high pressures were found by using the values predicted by Park$^{(21)}$ for nitrogen. For argon, the generalized compressibility charts (13) were used to obtain the density, specific heat, and latent heat of vaporization. Viscosity and surface tension were predicted as discussed in Appendix C. Tables (16,22) were available for the other properties. With this difficulty in defining the properties, it is hard to evaluate the validity of a relation.

Another interesting phenomenon was noticed in the plot of the Breen and Westwater relation: the results for high temperature differences were always closer to the predicted curve and results for the low temperature difference were always farther away. This phenomenon was also reported by Park (21).

The difficulty in evaluating the properties in Bromley's and Breen and Westwater's relations makes a correlation like the one of Branchero, Barker and Boll (2),

$$h = a_2(\frac{1}{D} + c)P^{\frac{1}{4}}, \qquad (\underline{16})$$

shown in Figure 15 and 16 especially attractive. The only problem is that the values for a_2 were evaluated for oxygen. Assuming that the values of a_2 for oxygen are correct for nitrogen and argon, the data are compared to the correlation in Figure 15 and 16. It can be seen that the correlation is not satisfactory, but there are some interesting aspects to be discussed. The appearance of the equation is very similar to what was predicted in the theory section for corresponding states fluids. The heat transfer coefficient is given as a function of temperature difference, pressure and diameter.

Considering this approach, the values of a_2 were modified by taking

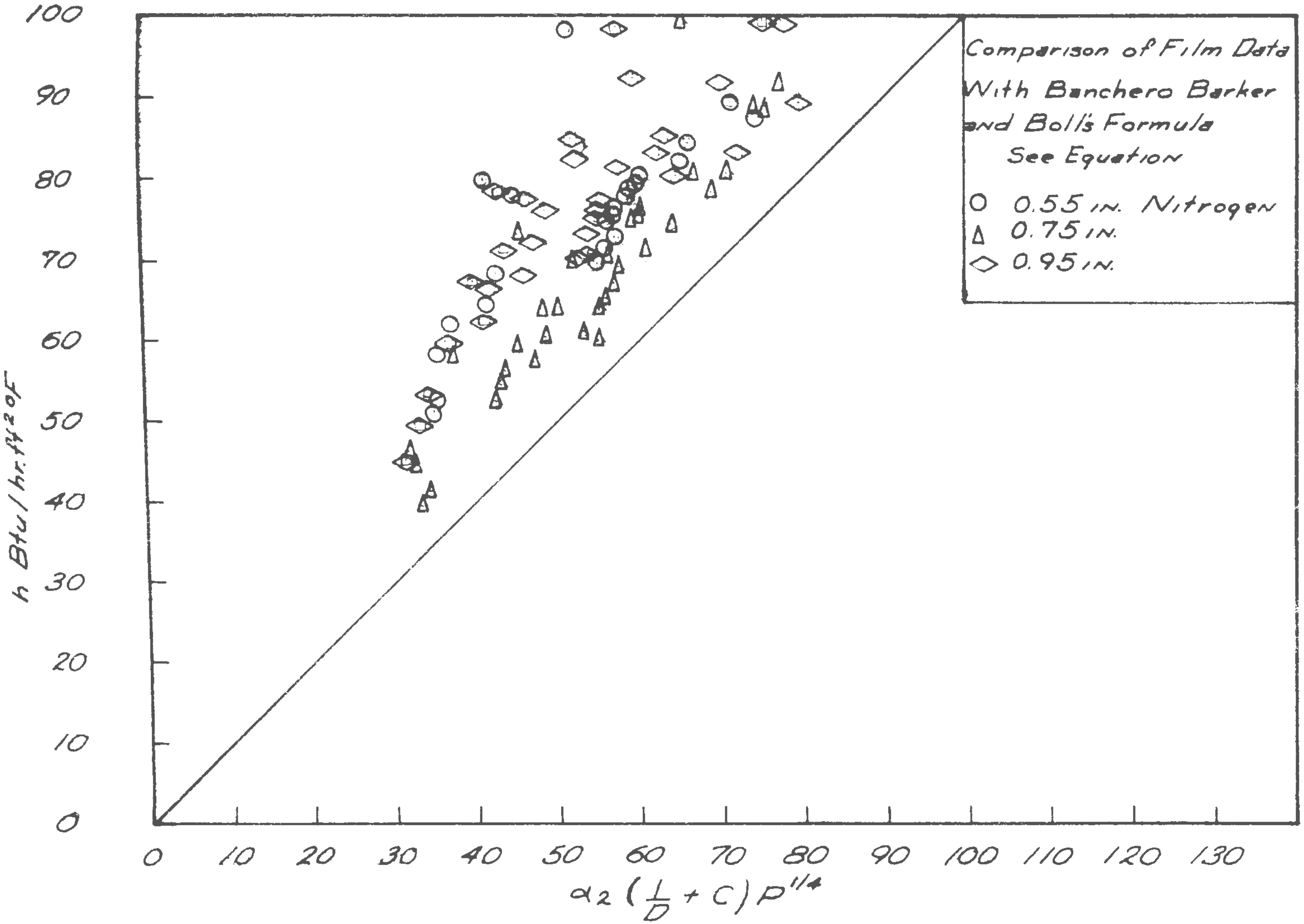

Figure 15 Comparison of Nitrogen Film Boiling with Equation 16

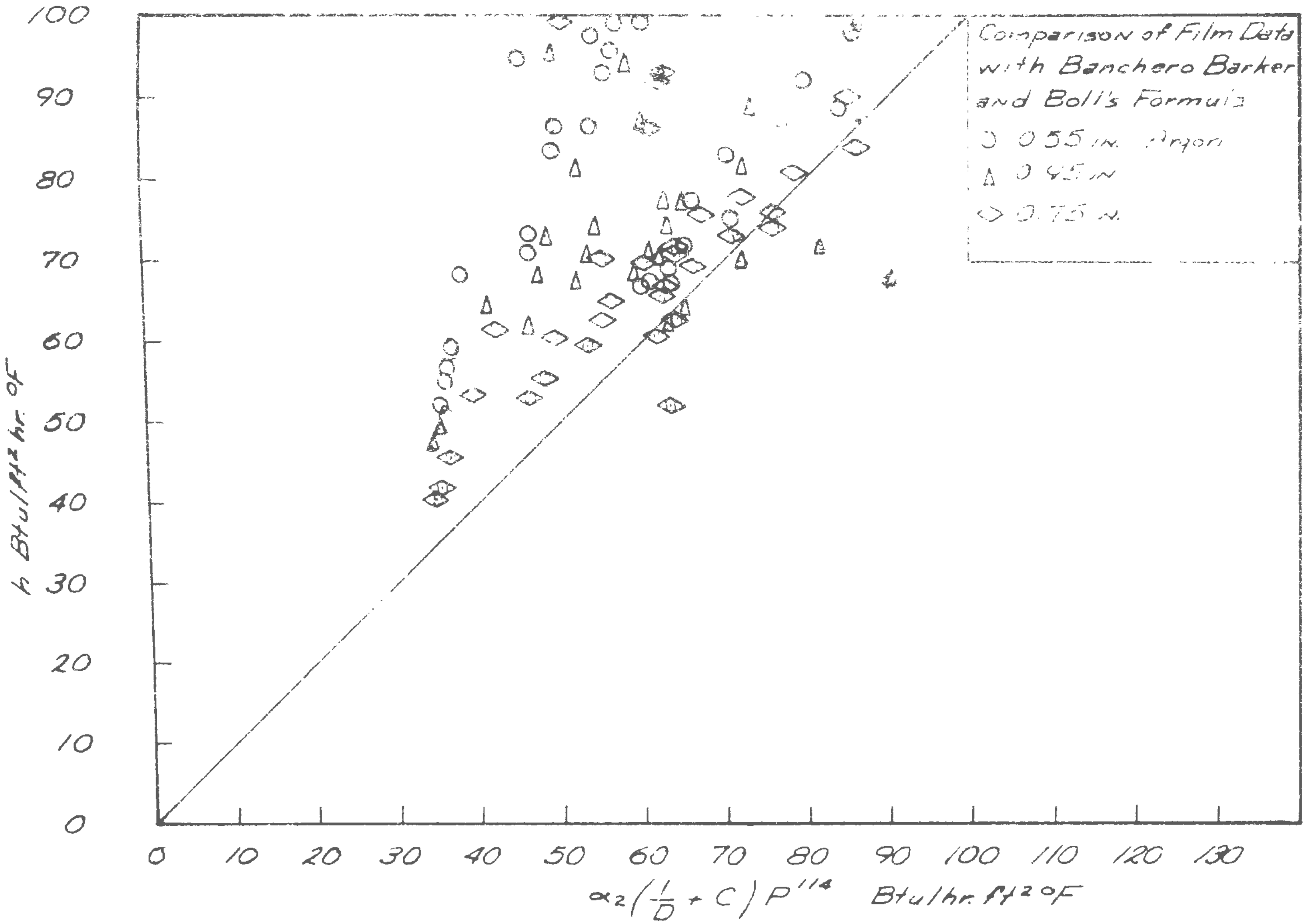

Figure 16 Comparison of Argon Film Boiling with Equation 16

a ratio of the critical temperatures raised to a power and the ratio of the critical pressures raised to the one fourth power. This relation for nitrogen is shown in Figure 17. The ratio of critical temperatures was raised to 1.25 power and multiplied by a_2. The relation seems to fit the nitrogen data well, but it would be expected that this same ratio should produce a satisfactory correlation for the argon data. This relation was compared to the argon data in Figure 18. It is noticed that the deviation is large. In order to obtain a satisfactory fit for the argon data, the power of the ratio was increased to 9.4. The results are shown in figure 19. Even though the variation of a_2 cannot be justified in terms of corresponding states, it is pointed out that a correlation can be found for the data just by varying a_2. This means that the diameter change can be accounted for by the factor $(1/D + C)$ where $C = 36.5 \text{ in.}^{-1}$ and that the effect of changing pressure is a function of $P^{\frac{1}{4}}$.

With the function known for the change in diameter and the change in pressure, an equation of the form:

$$h = \alpha_2\left(\frac{1}{D} + C\right)P_r^{\frac{1}{4}} \quad \text{where } C = 36.5 \text{ in.}^{-1} \qquad (\underline{17})$$

will be assumed. The changes made in the Banchero, Barker, and Boll relation are: instead of the absolute pressure raised to the one fourth power the reduced pressure ratio is substituted. And, α_2 will be expressed as a function of the mean film reduced temperature ratio. This equation is truly a corresponding states equation and is of the form predicted in the theory section.

The variation of α_2 was found by dividing the experimental heat transfer coefficient by the diameter and pressure factor and recorded at the value of the mean film reduced temperature ratio. The values of α_2 were calculated for all the nitrogen and argon data of this investi-

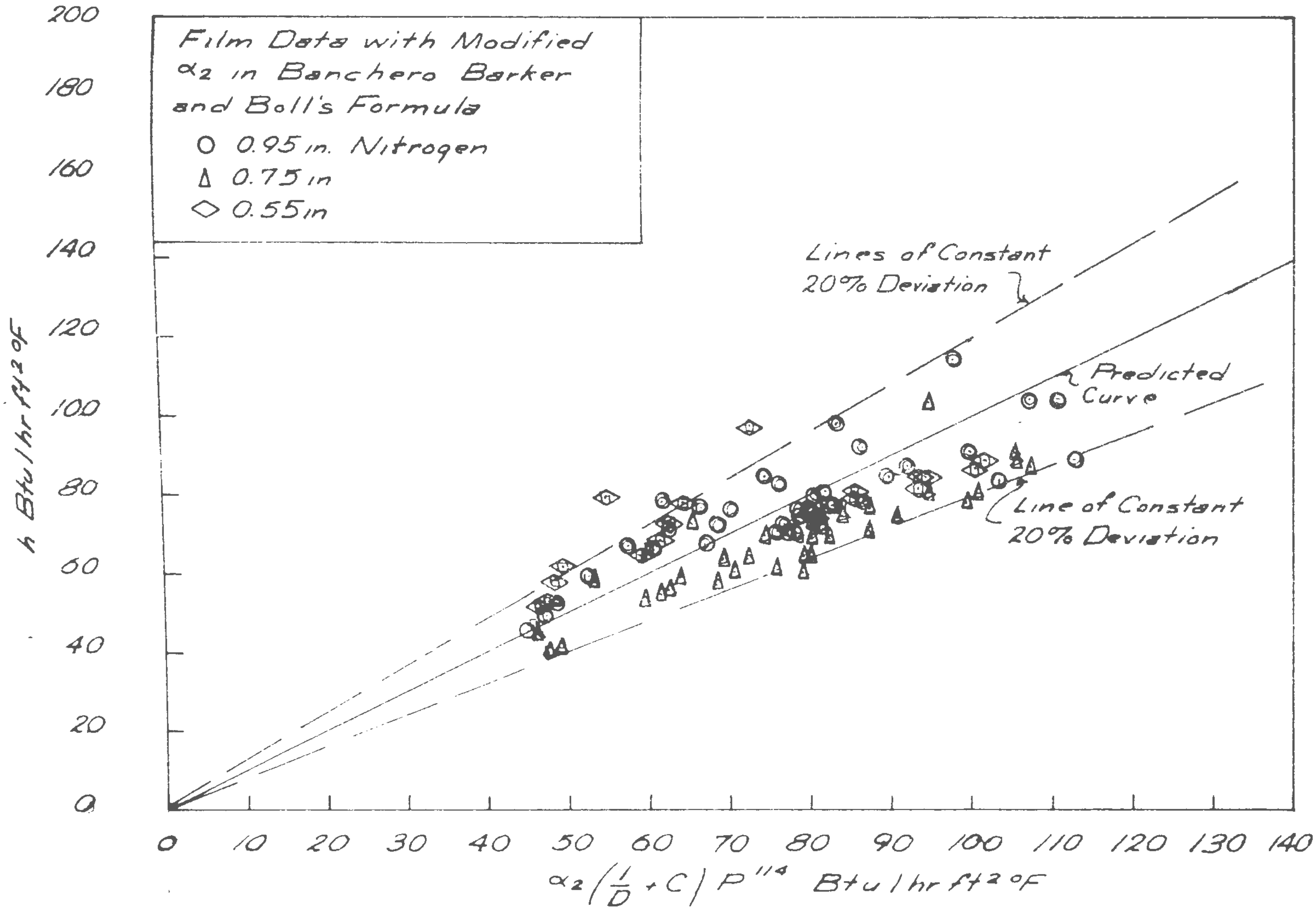

Figure 17 Comparison of Nitrogen Film Boiling Data with Modified Equation 16

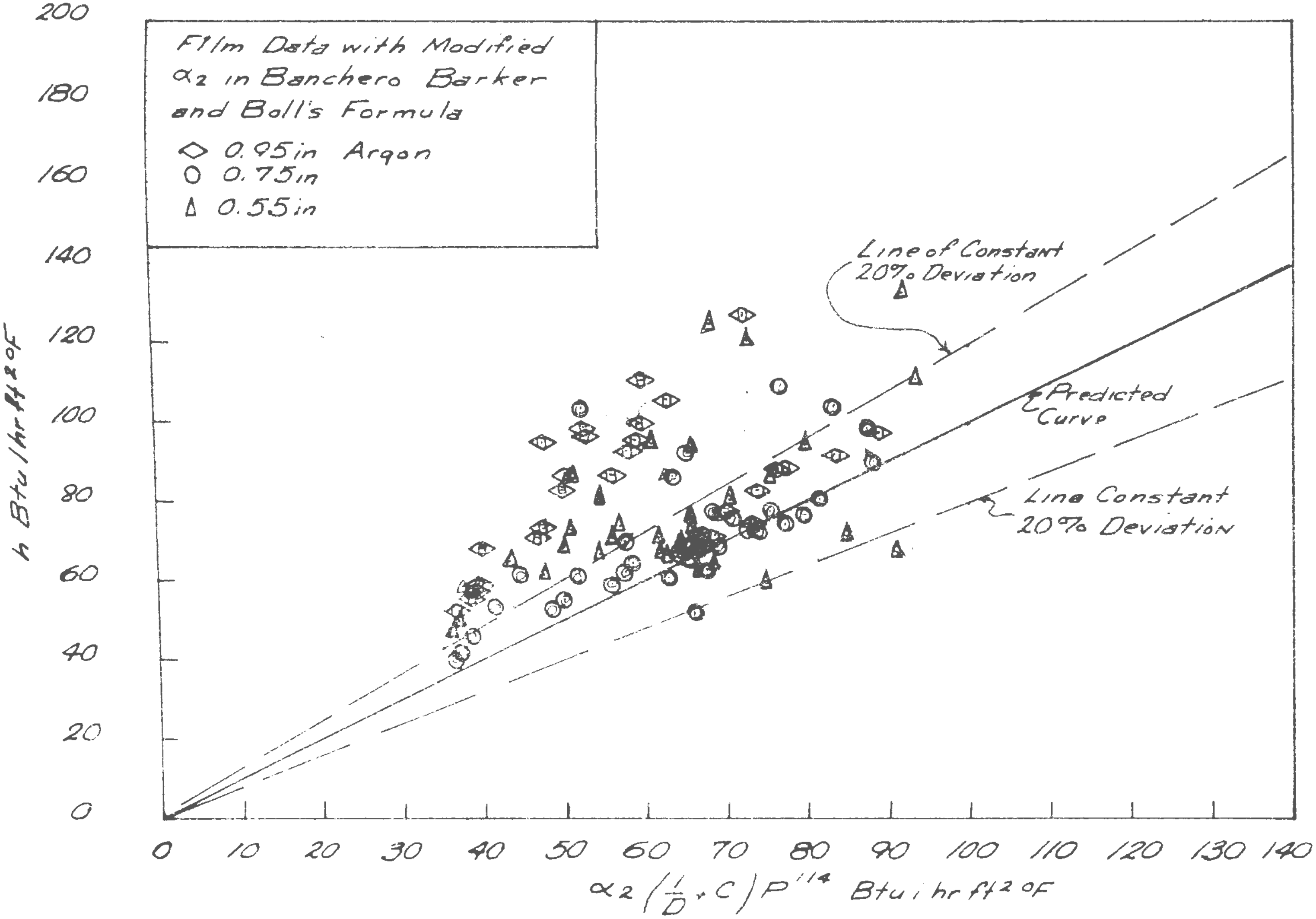

Figure 18 Comparison of Argon Film Boiling Data with Modified Equation 16

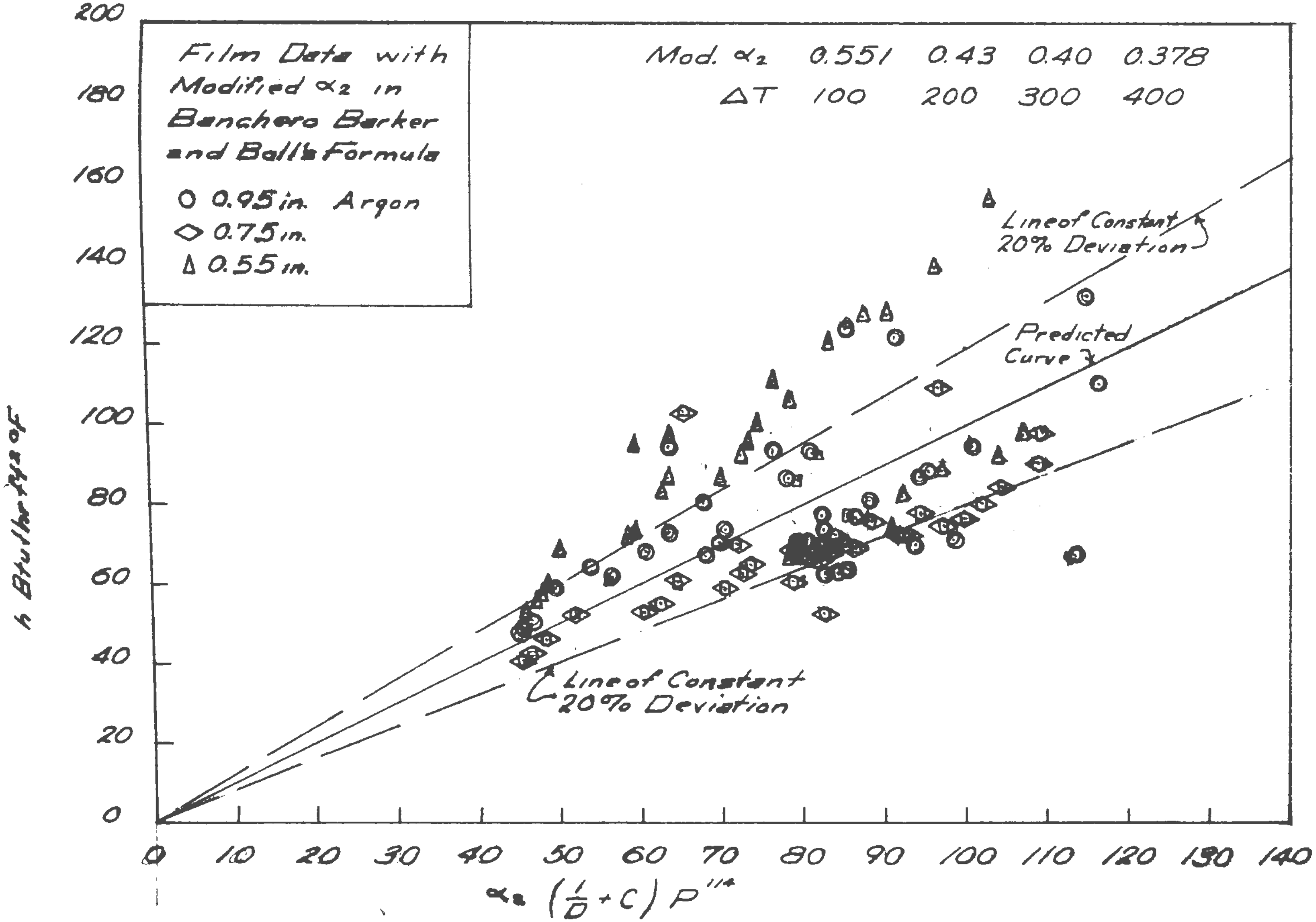

Figure 19 Comparison of the Argon Film Boiling Data with Modified Equation 16

gation and for the data of Park (21) and Banchero, Barker and Boll (2).

Values of α_2 versus mean film critical temperature ratio were then fitted with a least squares program. The least squares fit was a third degree polynomial and the data were fitted with an average deviation of 18.71%. The polynomial least squares fit was:

$$\alpha_2 = 8.49 - 8.24T_r + 2.97T_r^2 - 0.267T_r^3 \quad .$$

Using this α_2 and equation (17), the predicted values of h were calculated and plotted in Figure 20.

Referring to Figure 20, most of the data fall within the 20% deviation lines plotted on the graph, except for some of the low temperature difference argon data and the data of Park. The data of Park do not seem to vary in any given relation, but seems to be scattered over the entire curve. The Banchero, Barker, and Boll data were lower than the predicted curve, but within 20% of it in most cases. It might be pointed out that the average deviation of Figure 20 is the same as the deviation of α_2.

The α_2 versus mean reduced temperature ratio was also fitted using only the data of this experiment. The least square fit again was a third degree polynomial. The polynomial was given as:

$$\alpha_2 = 13.38 - 15.53T_r + 6.14T_r^2 - 0.588T_r^3 \quad .$$

This polynomial fitted the data of this investigation with an average deviation of 14.54%. The predicted values of h for this investigation were calculated using the equation above and plotted in Figure 20. It is noted again that at some of the higher values of h for the argon, considerable disagreement occurred.

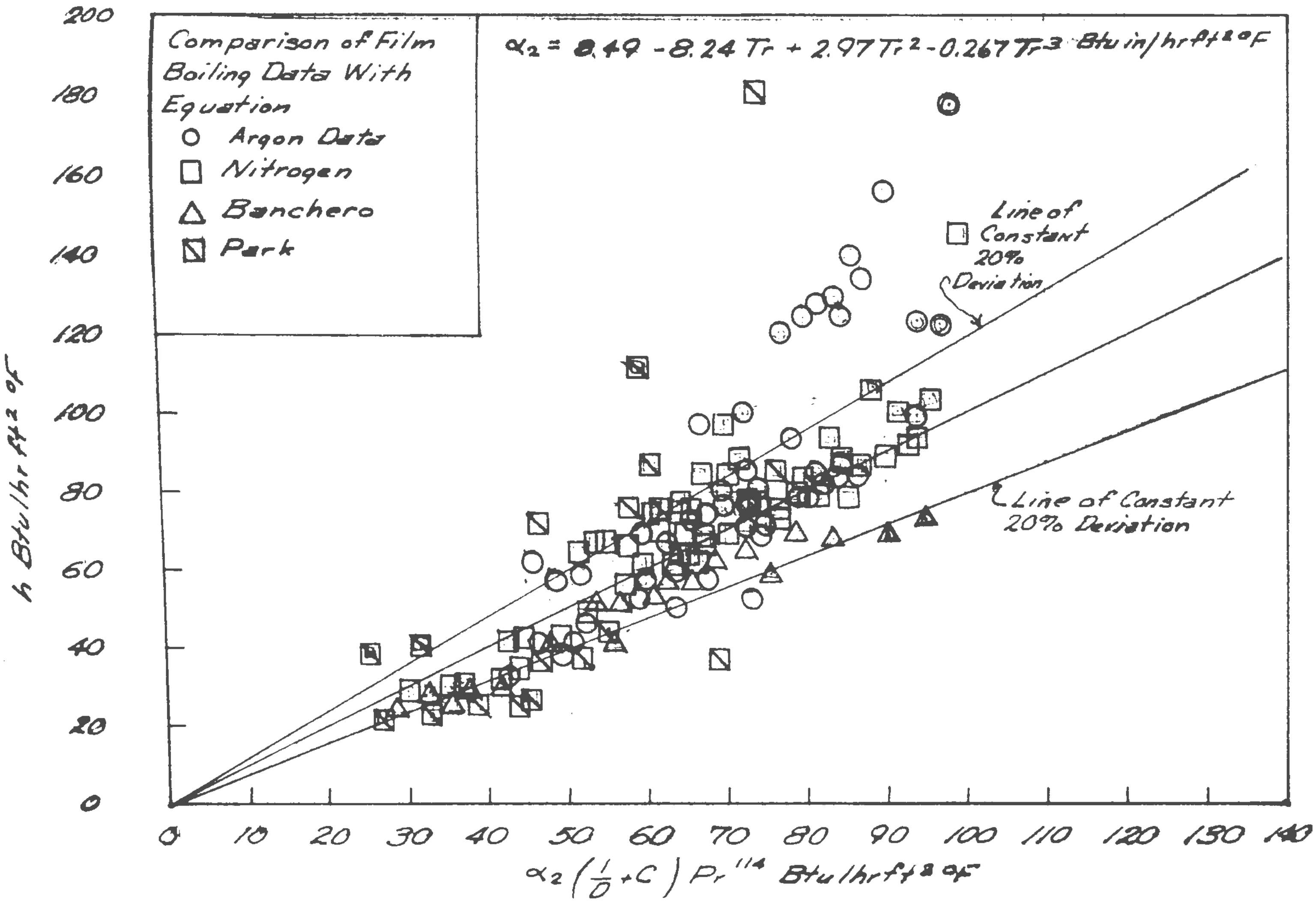

Figure 20 Comparison of Film Boiling Data with Equation 17

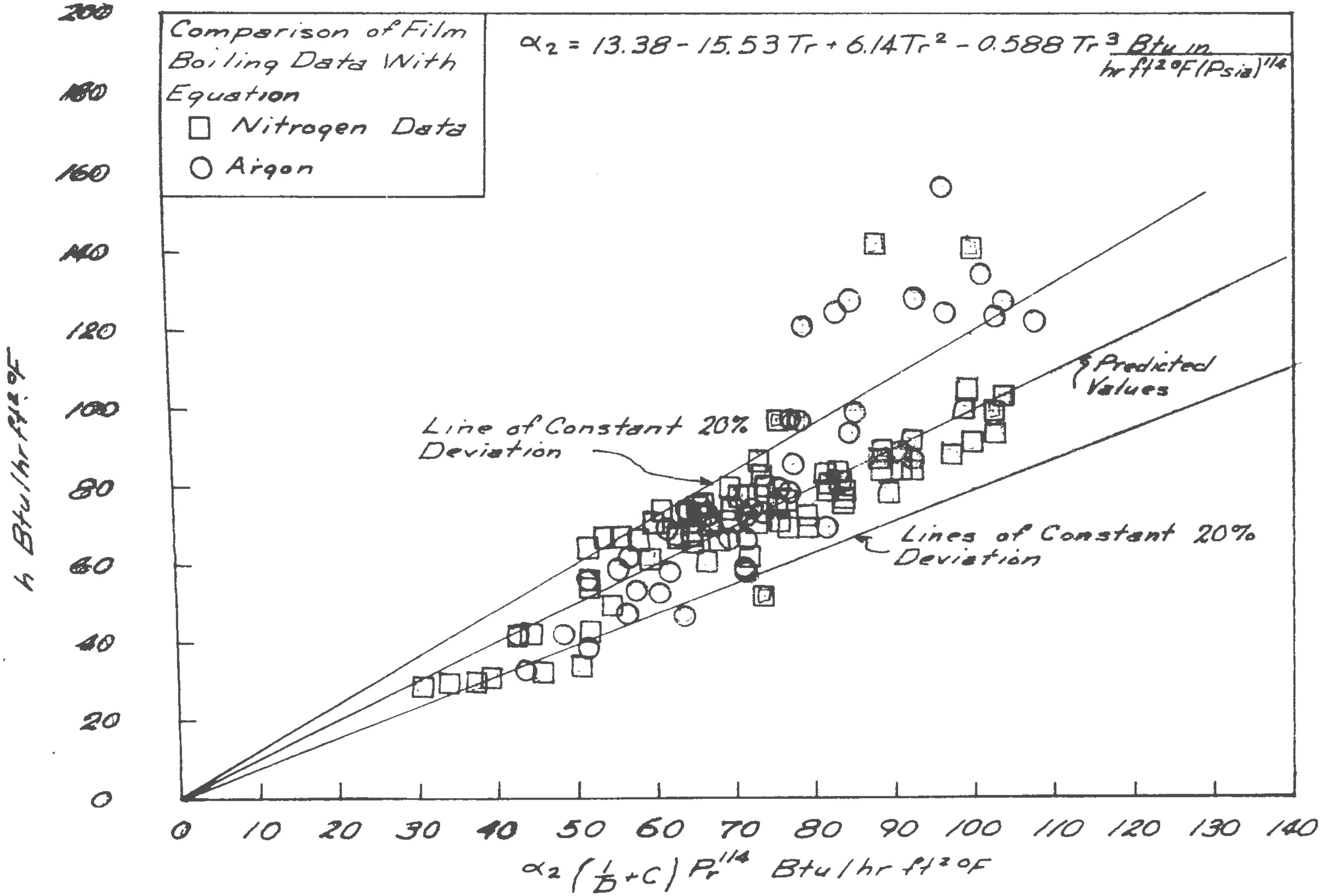

Figure 21   Comparison of the Argon and Nitrogen Film Boiling Data with Equation 17

It should be pointed out that the disagreement of the α_2's is not as large as it might seem by examining the two polynomials. The values are almost equivalent at the lower values of h, but vary at the higher values. Corresponding states theory would predict that the polynomials would be equivalent.

A restriction must be placed on α_2 in these relations; it should be noted that the range of data was from a mean film reduced temperature ratio of 1.7 to approximately 0.8 and any extrapolation could be in error. This is especially true for the results at low values of this ratio.

It should also be pointed out that in the figures not all the data were plotted, but only a representative sample. Selection was always made to include the entire temperature range of the data.

While taking the data for this investigation, an interesting phenomenon was observed which might have some effect on further film boiling work. It was noticed that the bubbles physical characteristics were different while the equipment was at steady state as compared to the transient state involved in changing steady state operating points. The bubbles were large and of varied spacing at steady state but were small and fairly evenly spaced during transients. This phenomenon would question the validity of using transient data for steady state conditions or vice-versa.

It was also noticed during the course of the investigation that surface effects did not affect the heat transfer. The initial runs were made in February and the final runs in May and June. The heaters were left exposed to the atmosphere, and surface conditions changed considerably due to oxidation over this period. Even with this change in surface conditions, there did not seem to be any difficulty in reproducing the data.

CHAPTER VIII

DISCUSSION OF ERROR IN MEASUREMENT

Park (21) discussed in detail the inherent error associated with nucleate and film boiling; therefore, error analysis will not be discussed in great detail here.

The current could be read accurately within ± 0.125 amps and the voltage, when less than 30 volts, could be read accurately within ± 0.075 volts. The product of these errors is less than 1 percent.

The thermocouples could be read accurately to ± 0.005 millivolts which corresponds to ± 0.25°F. The thermocouples were calibrated by placing the reference junction in liquid nitrogen and the three heaters in a liquid nitrogen bath in a solid - liquid, acetone bath and an ice water bath. The fixed temperature of the three baths allowed the calculation of the deviation from standard tables (N. B. S. Circular 561). The calibration for the thermocouples in the heater was only possible for thermocouple number 2 and 4. The thermocouple lead in the flange for the number 1 thermocouple was broken during operation. The deviations for the two thermocouples of the three heaters and the bath thermocouple are given in Table I.

The locations of the thermocouples during each run should also be pointed out. Thermocouple number 1 was on top of the heater, thermocouple number 2 was spaced 90° from 1 on the side of the heater, and number 4 was on the bottom. During the first set of runs for the 0.75 and 0.95 inch heaters, the thermocouples were attached to the heater as described by Cobb (8). Considerable temperature variation was recorded, so the thermocouple mounting was then changed by filling the wells with molten solder

TABLE I

Deviation of Thermocouples from Standard Tables

0.55 in. Heater

TEMPERATURE °C	THERMOCOUPLE	DEVIATION MILLIVOLTS
-196.18	2	-0.000
	4	-0.000
	Bath	-0.085
-94.6	2	0.024
	4	0.026
	Bath	-0.043
0.0	2	.057
	4	.050
	Bath	0.00

0.75 in. Heater

TEMPERATURE °C	THERMOCOUPLE	DEVIATION MILLIVOLTS
-196.18	2	0.00
	4	0.00
-94.6	2	0.025
	4	0.027
0.0	2	0.054
	4	0.051

0.95 in. Heater

TEMPERATURE °C	THERMOCOUPLE	DEVIATION MILLIVOLTS
-196.18	2	0.00
	4	0.00
-94.6	2	0.026
	4	0.025
0.0	2	0.053
	4	0.052

and inserting the thermocouples. The temperature variation was reduced considerably. Insertion of thermocouples in wells filled with solder is considered a much better method of thermocouple mounting.

The magnitudes of heat lost from the end of the cylinders can be calculated for the cylinders if the equation $q = -kAdt/dx$ is written in the form $q = \frac{kA\Delta T}{\Delta x}$ and if temperature measurements are made axially along the cylinder. Park (20) did this in his investigation and found that the maximum heat loss for film boiling was 4.8%. Banchero, Baker and Boll (2) with a cylindrical heater having an L/D of 0.375 reported that axial temperature gradient were virtually eliminated. Park's heaters had an L/D of 0.547 and the heaters used in this investigation had L/D of 0.316, 0.40 and 0.546. Therefore, temperature gradients would be expected to be in the range of Park's and Banchero's copper heaters, since all heaters were fabricated of copper. Thus the heat loss would be in the range reported by Park.

CHAPTER IX

CONCLUSIONS

1. Film boiling heat transfer of corresponding states fluids can be correlated using the principle of corresponding states with less than 20% average deviation.

2. The variation of the heat transfer coefficient in film boiling with cylindrical heaters due to a change of diameter is a function of the reciprocal of the diameter of the heat transfer element.

3. The change of the heat transfer coefficient due to a change of pressure is a function of the pressure raised to the one fourth power.

4. The decrease in film boiling heat flux at a given temperature difference as the critical pressure is approached as stated by Park (20) is questionable. More work in this area is needed before a conclusive statement can be made.

5. It is questionable whether surface chemistry affects the film boiling heat flux.

6. It is questionable whether transient film boiling data can be used for steady state design applications.

NOMENCLATURE

A - Area, ft^2

a - constant in equation 2,

a_2 - constant in equation 16, $\frac{\text{Btu in}}{\text{hr ft}^2\,°\text{F}}$ (psia),

C - constant in equation 2, inches^{-1},

c_p - Heat Capacity, Btu/lb°F,

D - Diameter, Ft,

E - Potential, volts

F - $\frac{k^3\rho_v(\rho_l - \rho_v)g\lambda'}{\Delta T\mu}$ $^{1/4}$, $\frac{\text{Btu}}{\text{hr ft}^2\,°\text{F}}$,

g - Acceleration due to gravity, ft/sec^2

g_c - Gravitational Constant, $\frac{\text{lb}_m\ \text{ft}}{\text{lb}_f\ \text{sec}^2}$,

Gr* - Generalized Grashof Number,

h - Heat Transfer coefficient, Btu/hr ft^2 °F,

I - Current, amp,

k - Thermal Conductivity, Btu/hr ft^2°F/ft,

L - Length, ft,

M - Molecular Weight, lb/lb-mole,

Nu* - Generalized Nusselt Number,

P - Pressure, psi,

Pr - Prandtl Number,

Pr* - Generalized Prandtl Number,

Q - Rate of heat transfer, Btu/hr,

T - Temperature, °R,

ΔT - Temperature Difference ($T_{\text{surface}} - T_{\text{wall}}$), °F or °R,

v - Specific volume, ft^3/lb,

W - Maximum vapor mass flow rate, lb$_m$/sec,

Greek Symbols

σ - Surface Tension, lb/ft,

λ - $\dfrac{g\,\sigma}{g_c(\rho_l - \rho_v)}^{\frac{1}{2}}$, ft,

μ - Viscosity, lb/ft hr,

ρ - Density, lb/ft^3,

α - Equivalent Thermal Diffusivity, ft^2/hr,

γ - Kinematic Viscosity, ft^2/hr,

λ - Latent Heat of Vaporization Btu/lb_m,

θ - Temperature difference, °R

Subscripts

c refers to the critical point,

v refers to the vapor,

l refers to the liquid,

r refers to reduced property, (T/T_c, etc.)

BIBLIOGRAPHY

1. Berenson, P. J., "Film Boiling Heat Transfer from a Horizontal Surface", J. Heat Transfer, Vol. 83, 1961, P. 351.

2. Banchero, J. T, Barker, G. E., and Boll, R. H., "Stable Film Boiling of Liquid Oxygen Outside Single Horizontal Tubes and Wires", Heat Transfer, Chemical Engineering Progress, Symposium Series, Vol. 51, No. 17, American Institute of Chemical Engineers, New York, 1965, P. 21.

3. Breen, B. P. and Westwater, J. W., "Effect of Diameter of Horizontal Tubes on Film Boiling Heat Transfer", Chem. Eng. Prog., Vol. 58, July 1962, P. 67.

4. Bromley, L. A., "Heat Transfer in Stable Film Boiling" Chem Eng. Prog., Vol. 46, May 1950, P. 221.

5. Bromley, L. A., "Effect of Heat Capacity of Condensate", Industrial and Engineering Chemistry, Vol. 44, December 1952, P. 2966.

6. Chang, Y. P., "A Theoretical Analysis of Heat Transfer in Natural Convection and in Boiling", Trans. A. S. M. E., Vol. 79, 1957, P. 1501.

7. Chang, Y. P., "Wave Theory of Heat Transfer", J. Heat Transfer, Vol. 1, January 1959, P. 1.

8. Cobb, C. B., "A Study of Surface and Geometric Effects on the Nucleate Boiling of Liquid Nitrogen and Liquid Argon from Atmospheric to the Critical Pressure", Ph.D. Thesis, University of Missouri at Rolla, 1967.

9. Colburn, A. P., ibid. 26, 432 (1934)

10. Damasius, G., and Thodos, G., "Coefficient of Thermal Expansion: Reduced State Correlation for the Gaseous and Liquid States of Pure Substances Having Simple Molecular Structure", Chemical Engineering Progress Symposium Series, Vol. 59, No. 14, P. 42.

11. Farber, E. A. and Scorah, R. L., "Heat Transfer to Water Boiling Under Pressure", Trans. Am. Soc, Mech. Eng., May 1948, P. 369.

12. Guggenheim, E. A.., Thermodynamics, North-Holland Publishing Co., Amsterdam, 1959.

13. Hougen, O. A., Watson, K. M. and Ragatz, R. A., Chemical Process Principles, Part II., John Wiley & Sons, Inc., New York, 1959.

14. Hsu, Y. Y. and Westwater, J. W., "Film Boiling From Vertical Tubes", A. I. Ch. E. J., Vol. 4, No. 1, March 1958, P.58.

15. Hsu, Y. Y. and Westwater, J. W., "Approximate Theory for Film Boiling on Vertical Surfaces". Chemical Engineering Progress Symposium Series, No. 30, Vol. 5, 6, P. 15.

16. Johnson, V. J., *A Compendium of the Properties of Materials at Low Temperatures*, WADD Technical Report, Part I, 1960.

17. Jossi, J. A., Stiel, L. I., and Thodos, G., "The Viscosities of Pure Substances in the Dense Gaseous and Liquid Phases" *A. I. Ch. E. J.*, Vol. 8, March 1962, P. 59.

18. Nukiyama, S. J., *Soc. Mech. Engr's.* (Japan), Vol. 37, 1931, P. 367.

19. Owens, E. J. and Thodos, G., "Thermal Conductivity Reduced State Correlation for the Inert Gases", *A. I. Ch. E. J.*, Vol. 3, 1957, P. 454.

20. Pai, V. K. and Bankoff, S. G., "Film Boiling of Nitrogen with Suction on an Electrically Heated Horizontal Porous Plate: Effect of Flow Control Element Porosity and Thickness", *A. I. Ch. E. J.*, Vol. 11, No. 1, 1965, P. 65.

21. Park, E. L., Jr. "Nucleate and Film Boiling Heat Transfer to Methane and Nitrogen from Atmospheric to the Critical Pressure", Ph.D. Thesis University of Oklahoma, 1965.

22. Perry, J. H., *Chemical Engineer's Handbook*, McGraw-Hill Company, Inc. New York, 1950, PP. 272-273.

23. Pifzer, K. S., "Corresponding States for Perfect Liquids", *J. Chemical Phys.*, Vol. 7, Aug. 1939, P. 583.

24. Prutton, C. F. and Marion. S. H., *Fundamental Principles of Physical Chemistry*, The MacMillian Co. New York, 1951.

25. Rohsenow, W. M., Webber, J. H. and Ling, A. T., *Trans. Am. Soc. Mech. Engrs*. 78, 1637, (1956).

26. Sciance, C. T, Ph.D. Thesis, University of Oklahoma, 1966.

27. Steil, L. I. and Thodos, G., *A. I. Ch. E. J.*, Vol. 7, 1961, P. 611.

28. Tachibana, F. and Fukui, S., "Heat Transfer in Film Boiling to Subcooled Liquids". Journal

29. Wayner, P. C., Jr. and Bankoff, S. G. "Film Boiling of Nitrogen with Suction on an Electrically Heated Porous Plate", *A. I. Ch. E. J.*, Vol. 11, No. 1, 1965, P. 59.

30. Zuber, N., *Trans. A. S. M. E.*, Vol. 80, 1958, P. 711.

APPENDIX A

EXPERIMENTAL DATA

```
                                   NITROGEN ATM  0.55

                    LEAST SQUARES POLY COEFF. ARE:

                      A(   0)=     0.98204840E 04
                      A(   1)=    -0.28091880E 01
                      A(   2)=     0.91176740E-01

   DELTA T            HEAT FLUX          CALC. HEAT FLUX     % DEVIATION               H

0.37750000E 03     0.21600000E 05     0.21666470E 05          -0.3078              57.2185
0.33600000E 03     0.19600000E 05     0.19307310E 05           1.4933              58.3333
0.30100000E 03     0.16900000E 05     0.17304580E 05          -2.3940              56.1462
0.27000000E 03     0.15800000E 05     0.15651120E 05           0.9422              58.5185
0.24200000E 03     0.14400000E 05     0.14346960E 05           0.3683              59.5041
0.19230000E 03     0.12700000E 05     0.12723480E 05          -0.1849              66.0426

      AVERAGE DEVIATION =      0.94842650 %          DEGREE = 2
```

```
                                  NITROGEN 34 0.55

                   LEAST SQUARES POLY COEFF. ARE:

                     A(   0)=     0.22261530E 05
                     A(   1)=    -0.12134400E 03
                     A(   2)=     0.48299990E 00
                     A(   3)=    -0.50845040E-03
     DELTA T              HEAT FLUX          CALC. HEAT FLUX     % DEVIATION              H

 0.40530000E 03       0.18500000E 05       0.18478620E 05           0.1155         45.6452
 0.40580000E 03       0.18500000E 05       0.18483000E 05           0.0919         45.5889
 0.36580000E 03       0.17350000E 05       0.17705200E 05          -2.0473         47.4303
 0.36680000E 03       0.17350000E 05       0.17733110E 05          -2.2081         47.3010
 0.35130000E 03       0.16700000E 05       0.17270300E 05          -3.4150         47.5377
 0.35180000E 03       0.16700000E 05       0.17286100E 05          -3.5096         47.4701
 0.30780000E 03       0.15550000E 05       0.15802280E 05          -1.6224         50.5198
 0.30880000E 03       0.15550000E 05       0.15836170E 05          -1.8404         50.3562
 0.28430000E 03       0.15200000E 05       0.15037870E 05           1.0666         53.4646
 0.28580000E 03       0.15200000E 05       0.15084310E 05           0.7611         53.1840
 0.23680000E 03       0.13780000E 05       0.13824580E 05          -0.3236         58.1926
 0.23780000E 03       0.13780000E 05       0.13844170E 05          -0.4657         57.9478
 0.21230000E 03       0.13300000E 05       0.13432800E 05          -0.9985         62.6472
 0.21380000E 03       0.13300000E 05       0.13451900E 05          -1.1422         62.2077
 0.16430000E 03       0.13100000E 05       0.13129600E 05          -0.2260         79.7322
 0.16730000E 03       0.13100000E 05       0.13133180E 05          -0.2533         78.3024
 0.35180000E 03       0.18400000E 05       0.17286100E 05           6.0538         52.3024
 0.35230000E 03       0.18400000E 05       0.17301850E 05           5.9682         52.2282
 0.30430000E 03       0.15600000E 05       0.15684300E 05          -0.5404         51.2652
 0.30330000E 03       0.15600000E 05       0.15650820E 05          -0.3258         51.4342
 0.21680000E 03       0.13750000E 05       0.13492000E 05           1.8764         63.4225
 0.21830000E 03       0.13750000E 05       0.13513000E 05           1.7236         62.9867
        AVERAGE DEVIATION =       1.66251600 %          DEGREE = 3
```

```
                                        NITROGEN 133 0.55

                         LEAST SQUARES POLY COEFF. ARE:

                           A(   0)=     0.22630340E 05
                           A(   1)=    -0.11237550E 03
                           A(   2)=     0.52812000E 00
                           A(   3)=    -0.59797210E-03

      DELTA T              HEAT FLUX            CALC. HEAT FLUX      % DEVIATION              H

 0.31100000E 03       0.20950000E 05       0.20767000E 05              0.3735             67.3633
 0.31400000E 03       0.20950000E 05       0.20897240E 05              0.2518             66.7197
 0.33800000E 03       0.21900000E 05       0.21905750E 05             -0.0263             64.7929
 0.33850000E 03       0.21900000E 05       0.21925800E 05             -0.1178             64.6972
 0.29050000E 03       0.19710000E 05       0.19872570E 05             -0.8248             67.8485
 0.29200000E 03       0.19710000E 05       0.19937780E 05             -1.1557             67.5000
 0.25800000E 03       0.18680000E 05       0.18510360E 05              0.9081             72.4031
 0.25950000E 03       0.18680000E 05       0.18570190E 05              0.5878             71.9846
 0.21850000E 03       0.17100000E 05       0.17096170E 05              0.0224             78.2609
 0.22200000E 03       0.17100000E 05       0.17207300E 05             -0.6275             77.0270
 0.15950000E 03       0.15710000E 05       0.15696670E 05              0.0848             98.4953
 0.16050000E 03       0.15710000E 05       0.15713000E 05             -0.0191             97.8916

         AVERAGE DEVIATION =      0.45830370 %          DEGREE = 3
```

```
                                          NITROGEN 231 0.55

                      LEAST SQUARES POLY COEFF. ARE:

                         A(   0)=     0.10144540E 05
                         A(   1)=     0.15044990E 04
                         A(   2)=     0.76283370E 03

   DELTA T              HEAT FLUX           CALC. HEAT FLUX      % DEVIATION            H

0.29499970E 03       0.21150000E 05       0.21791560E 05           -3.0334           71.6950
0.29399970E 03       0.21150000E 05       0.21790430E 05           -3.0281           71.9388
0.30949970E 03       0.22200000E 05       0.21342750E 05            3.8615           71.7286
0.31049970E 03       0.22200000E 05       0.21276680E 05            4.1591           71.4976
0.26749970E 03       0.19600000E 05       0.20608870E 05           -5.1473           73.2711
0.26949970E 03       0.19600000E 05       0.20761060E 05           -5.9238           72.7273
0.24499990E 03       0.18450000E 05       0.18494310E 05           -0.2402           75.3061
0.24549990E 03       0.18450000E 05       0.18546250E 05           -0.5217           75.1527
0.21599990E 03       0.17050000E 05       0.15604680E 05            8.4769           78.9352
0.21749990E 03       0.17050000E 05       0.15735000E 05            7.7126           78.3908
0.16199990E 03       0.14600000E 05       0.15170980E 05           -3.9109           90.1235
0.16399990E 03       0.14600000E 05       0.14975290E 05           -2.5705           89.0244

      AVERAGE DEVIATION =      4.04881700 %          DEGREE = 2
```

```
                                   NITROGEN 379 0.55

                     LEAST SQUARES POLY COEFF. ARE:

                       A(   0)=     0.79848000E 04
                       A(   1)=     0.22596610E 04
                       A(   2)=     0.70507610E 03

   DELTA T            HEAT FLUX         CALC. HEAT FLUX    % DEVIATION              H

0.32249970E 03     0.23000000E 05     0.23669500E 05          -2.9109            71.3179
0.32349970E 03     0.23000000E 05     0.23890370E 05          -3.8712            71.0974
0.30899970E 03     0.21630000E 05     0.21155810E 05           2.1923            70.0000
0.30999970E 03     0.21630000E 05     0.21313560E 05           1.4630            69.7742
0.28049970E 03     0.19200000E 05     0.18220500E 05           5.1016            68.4492
0.27999970E 03     0.19200000E 05     0.18191870E 05           5.2507            68.5715
0.23349990E 03     0.17450000E 05     0.17362000E 05           0.5043            74.7324
0.23399990E 03     0.17450000E 05     0.17361930E 05           0.5047            74.5727
0.20049990E 03     0.15610000E 05     0.16957500E 05          -8.6323            77.8554
0.20099990E 03     0.15610000E 05     0.16974930E 05          -8.7440            77.6617
0.15499990E 03     0.13000000E 05     0.12342510E 05           5.0576            83.8710
0.15499990E 03     0.13000000E 05     0.12342510E 05           5.0576            83.8710

      AVERAGE DEVIATION =     4.10748600 %          DEGREE = 2
```

```
                                        NITROGEN 429 0.55

                      LEAST SQUARES POLY COEFF. ARE:

                        A(   0)=     0.18035440E 05
                        A(   1)=    -0.16611750E 03
                        A(   2)=     0.11551430E 01
                        A(   3)=    -0.18763630E-02

     DELTA T             HEAT FLUX          CALC. HEAT FLUX     % DEVIATION           H

  0.29900000E 03      0.21600000E 05      0.21488530E 05         0.5160          72.2408
  0.29900000E 03      0.21600000E 05      0.21488530E 05         0.5160          72.2408
  0.27300000E 03      0.20200000E 05      0.20587300E 05        -1.9174          73.9927
  0.27150000E 03      0.20200000E 05      0.20518750E 05        -1.5780          74.4015
  0.24050000E 03      0.19200000E 05      0.18792980E 05         2.1199          79.8337
  0.24000000E 03      0.19200000E 05      0.18761190E 05         2.2854          80.0000
  0.20850000E 03      0.16400000E 05      0.16617650E 05        -1.3271          78.6571
  0.20750000E 03      0.16400000E 05      0.16546960E 05        -0.8961          79.0361
  0.17000000E 03      0.13900000E 05      0.13965610E 05        -0.4721          81.7647
  0.16900000E 03      0.13900000E 05      0.13901530E 05        -0.0110          82.2485
  0.14000000E 03      0.12300000E 05      0.12265640E 05         0.2793          87.8571
  0.14000000E 03      0.12300000E 05      0.12265640E 05         0.2793          87.8571

        AVERAGE DEVIATION =      1.01647000 %          DEGREE = 3
```

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                                          NITROGEN 453 0.55

                        LEAST SQUARES POLY COEFF. ARE:

                           A(   0)=     0.34605270E 04
                           A(   1)=     0.64340190E 02

     DELTA T              HEAT FLUX          CALC. HEAT FLUX     % DEVIATION              H

0.30150000E 03      0.22900000E 05       0.22821740E 05           0.3417            75.9536
0.30150000E 03      0.22900000E 05       0.22821740E 05           0.3417            75.9536
0.27900000E 03      0.21200000E 05       0.21405020E 05          -0.9671            75.9857
0.27900000E 03      0.21200000E 05       0.21405020E 05          -0.9671            75.9857
0.24000000E 03      0.18900000E 05       0.18926000E 05          -0.1376            78.7500
0.23900000E 03      0.18900000E 05       0.18862050E 05           0.2008            79.0795
0.21050000E 03      0.16800000E 05       0.17031170E 05          -1.3760            79.8100
0.21000000E 03      0.16800000E 05       0.16998910E 05          -1.1840            80.0000
0.17050000E 03      0.14300000E 05       0.14434830E 05          -0.9429            83.8710
0.17100000E 03      0.14300000E 05       0.14467480E 05          -1.1712            83.6257
0.13700000E 03      0.12300000E 05       0.12236420E 05           0.5169            89.7810
0.13650000E 03      0.12300000E 05       0.12203440E 05           0.7850            90.1099
0.22800000E 03      0.18500000E 05       0.18157270E 05           1.8526            81.1404
0.22600000E 03      0.18500000E 05       0.18028870E 05           2.5466            81.8584

          AVERAGE DEVIATION =      0.95222830 %          DEGREE = 1
```

```
                                        NITROGEN ATM 0.75

                         LEAST SQUARES POLY COEFF. ARE:

                           A(   0)=     0.61795780E 04
                           A(   1)=    -0.21204390E 02
                           A(   2)=     0.15225240E 00
                           A(   3)=    -0.16442010E-03

     DELTA T             HEAT FLUX          CALC. HEAT FLUX     % DEVIATION              H

 0.39200000E 03      0.11350000E 05      0.11353690E 05           -0.0326            28.9541
 0.38550000E 03      0.11350000E 05      0.11216400E 05            1.1770            29.4423
 0.39650000E 03      0.11350000E 05      0.11444920E 05           -0.8364            28.6255
 0.34050000E 03      0.10150000E 05      0.10136730E 05            0.1307            29.8091
 0.33500000E 03      0.10150000E 05      0.99948160E 04            1.5289            30.2985
 0.34500000E 03      0.10150000E 05      0.10251810E 05           -1.0031            29.4203
 0.27750000E 03      0.85200000E 04      0.84954800E 04            0.2878            30.7027
 0.27300000E 03      0.85200000E 04      0.83813390E 04            1.6275            31.2088
 0.28050000E 03      0.85200000E 04      0.85720850E 04           -0.6113            30.3743
 0.30150000E 03      0.90300000E 04      0.91170030E 04           -0.9635            29.9502
 0.29600000E 03      0.90300000E 04      0.89731280E 04            0.6298            30.5067
 0.30500000E 03      0.90300000E 04      0.92088160E 04           -1.9802            29.6066
 0.22300000E 03      0.72000000E 04      0.71973080E 04            0.0374            32.2870
 0.21850000E 03      0.72000000E 04      0.70999840E 04            1.3891            32.9519
 0.22500000E 03      0.72000000E 04      0.72411090E 04           -0.5710            32.0000
 0.19050000E 03      0.65000000E 04      0.65339960E 04           -0.5230            34.1207
 0.18550000E 03      0.65000000E 04      0.64402530E 04            0.9192            35.0404
 0.19350000E 03      0.65000000E 04      0.65913120E 04           -1.4048            33.5917

        AVERAGE DEVIATION =      0.86962600 %          DEGREE = 3
```

```
                                        NITROGEN 34 0.75

                    LEAST SQUARES POLY COEFF. ARE:

                      A(    0)=      0.20609760E 04
                      A(    1)=      0.11088970E 05
                      A(    2)=     -0.86340000E 04
                      A(    3)=      0.32560710E 04
                      A(    4)=     -0.40455320E 03

     DELTA T                HEAT FLUX              CALC. HEAT FLUX       % DEVIATION              H

0.29329980E 03          0.12500000E 05          0.12523420E 05          -0.1874             42.6185
0.29729980E 03          0.12500000E 05          0.12667360E 05          -1.3389             42.0451
0.29029980E 03          0.12500000E 05          0.12413650E 05           0.6907             43.0589
0.31329980E 03          0.14300000E 05          0.13204190E 05           7.6630             45.6432
0.32729980E 03          0.14300000E 05          0.13598620E 05           4.9047             43.6908
0.32829980E 03          0.14300000E 05          0.13623230E 05           4.7326             43.5577
0.24629990E 03          0.10830000E 05          0.10761970E 05           0.6281             43.9708
0.25329990E 03          0.10830000E 05          0.11018700E 05          -1.7424             42.7556
0.25879980E 03          0.10830000E 05          0.11224060E 05          -3.6387             41.8470
0.21029990E 03          0.96500000E 04          0.95724800E 04           0.8033             45.8868
0.21429990E 03          0.96500000E 04          0.96915030E 04          -0.4301             45.0303
0.22129990E 03          0.96500000E 04          0.99083590E 04          -2.6773             43.6060
0.17029990E 03          0.87800000E 04          0.85818550E 04           2.2568             51.5561
0.17479990E 03          0.87800000E 04          0.86760030E 04           1.1845             50.2289
0.18229990E 03          0.87800000E 04          0.88420310E 04          -0.7065             48.1624
0.84299980E 02          0.70000000E 04          0.70216320E 04          -0.3090             83.0368
0.86299980E 02          0.70000000E 04          0.70686210E 04          -0.9803             81.1124
0.92299980E 02          0.70000000E 04          0.72014250E 04          -2.8775             75.9397
0.35929980E 03          0.13800000E 05          0.14055610E 05          -1.8523             38.4080
0.36229980E 03          0.13800000E 05          0.14055170E 05          -1.8491             38.0900
0.31029980E 03          0.12460000E 05          0.13109380E 05          -5.2118             40.1547
0.31329980E 03          0.12460000E 05          0.13204190E 05          -5.9727             39.7702
0.25029990E 03          0.11100000E 05          0.10907940E 05           1.7302             44.3468
0.25379990E 03          0.11100000E 05          0.11037210E 05           0.5656             43.7352
0.27679980E 03          0.11770000E 05          0.11307290E 05          -1.1665             42.5217
0.27899970E 03          0.11770000E 05          0.11990760E 05          -1.9757             42.1864
0.22129990E 03          0.10000000E 05          0.99083590E 04           0.9164             45.1875
0.22929990E 03          0.10000000E 05          0.10168210E 05          -1.6891             43.6110
0.15879990E 03          0.86500000E 04          0.83579370E 04           3.3764             54.4711
0.16329990E 03          0.86500000E 04          0.84428820E 04           2.3944             52.9700

          AVERAGE DEVIATION =        2.21172800 %                 DEGREE = 4
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                                        NITROGEN 133 0.75

                     LEAST SQUARES POLY COEFF. ARE:

                       A(   0)=      0.69748430E 04
                       A(   1)=      0.81815330E 01
                       A(   2)=      0.11391620E 00
                       A(   3)=     -0.13791570E-03

     DELTA T              HEAT FLUX             CALC. HEAT FLUX        % DEVIATION              H

0.31600000E 03      0.17400000E 05      0.16620760E 05           4.4784           55.0633
0.31950000E 03      0.17400000E 05      0.16747060E 05           3.7525           54.4601
0.32500000E 03      0.17400000E 05      0.16940370E 05           2.6415           53.5385
0.24450000E 03      0.14250000E 05      0.13763250E 05           3.4157           58.2822
0.25000000E 03      0.14250000E 05      0.13987670E 05           1.8409           57.0000
0.25550000E 03      0.14250000E 05      0.14213070E 05           0.2591           55.7730
0.20550000E 03      0.12590000E 05      0.12229560E 05           2.8629           61.2652
0.20900000E 03      0.12590000E 05      0.12361650E 05           1.8137           60.2392
0.21350000E 03      0.12590000E 05      0.12533350E 05           0.4499           58.9695
0.17300000E 03      0.11000000E 05      0.11070330E 05          -0.6394           63.5838
0.17600000E 03      0.11000000E 05      0.11171970E 05          -1.5634           62.5000
0.18000000E 03      0.11000000E 05      0.11309230E 05          -2.8112           61.1111
0.13900000E 03      0.99100000E 04      0.99949600E 04          -0.8573           71.2950
0.14000000E 03      0.99100000E 04      0.10024670E 05          -1.1572           70.7857
0.14500000E 03      0.99100000E 04      0.10174890E 05          -2.6730           68.3448
0.56000000E 02      0.78000000E 04      0.77426250E 04           0.7356          139.2857
0.55000000E 02      0.78000000E 04      0.77153200E 04           1.0856          141.8181
0.64000000E 02      0.78000000E 04      0.79582770E 04          -2.0292          121.8750
0.33750000E 03      0.17000000E 05      0.17352430E 05          -2.0731           50.3704
0.33950000E 03      0.17000000E 05      0.17414390E 05          -2.4376           50.0736
0.30150000E 03      0.15800000E 05      0.16074660E 05          -1.7384           52.4046
0.30650000E 03      0.15800000E 05      0.16266690E 05          -2.9537           51.5497
0.26800000E 03      0.14210000E 05      0.14726820E 05          -3.6370           53.0224
0.27050000E 03      0.14210000E 05      0.14829460E 05          -4.3593           52.5323
0.22650000E 03      0.12920000E 05      0.13040170E 05          -0.9301           57.0419
0.23050000E 03      0.12920000E 05      0.13198980E 05          -2.1594           56.0520
0.18950000E 03      0.11750000E 05      0.11643100E 05           0.9097           62.0053
0.19200000E 03      0.11750000E 05      0.11732780E 05           0.1465           61.1979
0.14850000E 03      0.10650000E 05      0.10281700E 05           3.4581           71.7172
0.15200000E 03      0.10650000E 05      0.10389930E 05           2.4419           70.0658

         AVERAGE DEVIATION =       2.07704300 %           DEGREE = 3
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                                        NITROGEN 231 0.75

                     LEAST SQUARES POLY COEFF. ARE:

                       A(   0)=     0.46007500E 04
                       A(   1)=     0.41732920E 02

      DELTA T                HEAT FLUX             CALC. HEAT FLUX        % DEVIATION                H

0.27600000E 03        0.17450000E 05        0.16119620E 05            7.6239            63.2246
0.28350000E 03        0.17450000E 05        0.16419700E 05            5.9043            61.5520
0.28800000E 03        0.17450000E 05        0.16599150E 05            4.8759            60.5903
0.24500000E 03        0.15900000E 05        0.14865990E 05            6.5032            64.8979
0.24900000E 03        0.15900000E 05        0.15028950E 05            5.4783            63.8554
0.25300000E 03        0.15900000E 05        0.15191560E 05            4.4556            62.8458
0.21000000E 03        0.14100000E 05        0.13424830E 05            4.7884            67.1429
0.21250000E 03        0.14100000E 05        0.13528680E 05            4.0519            66.3529
0.21750000E 03        0.14100000E 05        0.13735960E 05            2.5818            64.8276
0.16800000E 03        0.11800000E 05        0.11659410E 05            1.1914            70.2381
0.16900000E 03        0.11800000E 05        0.11701890E 05            0.8314            69.8225
0.17300000E 03        0.11800000E 05        0.11871640E 05           -0.6071            68.2081
0.13200000E 03        0.10180000E 05        0.10114870E 05            0.6397            77.1212
0.13200000E 03        0.10180000E 05        0.10114870E 05            0.6397            77.1212
0.13689990E 03        0.10180000E 05        0.10326800E 05           -1.4421            74.3608
0.72000000E 02        0.77000000E 04        0.74764450E 04            2.9033           106.9444
0.70000000E 02        0.77000000E 04        0.73871130E 04            4.0635           110.0000
0.74000000E 02        0.77000000E 04        0.75656830E 04            1.7444           104.0540
0.33389990E 03        0.18100000E 05        0.18403710E 05           -1.6780            54.2079
0.33739990E 03        0.18100000E 05        0.18539380E 05           -2.4275            53.6455
0.30689990E 03        0.16650000E 05        0.17347890E 05           -4.1915            54.2522
0.30939990E 03        0.16650000E 05        0.17446330E 05           -4.7828            53.8138
0.25739990E 03        0.14800000E 05        0.15370010E 05           -3.8515            57.4981
0.26039990E 03        0.14800000E 05        0.15491430E 05           -4.6719            56.8356
0.22539990E 03        0.13300000E 05        0.14062310E 05           -5.7317            59.0062
0.22839990E 03        0.13300000E 05        0.14185870E 05           -6.6607            58.2312
0.19589990E 03        0.12100000E 05        0.12836540E 05           -6.0872            61.7662
0.19839990E 03        0.12100000E 05        0.12941170E 05           -6.9519            60.9879
0.15839990E 03        0.10580000E 05        0.11250350E 05           -6.3361            66.7929
0.16289990E 03        0.10580000E 05        0.11442350E 05           -8.1509            64.9479

          AVERAGE DEVIATION =       4.06156700 %               DEGREE = 1
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                                             NITROGEN 379 0.75

                          LEAST SQUARES POLY COEFF. ARE:

                            A(   0)=     0.29985270E 04
                            A(   1)=     0.57798110E 02
                            A(   2)=    -0.18930230E-01

     DELTA T              HEAT FLUX            CALC. HEAT FLUX     % DEVIATION             H

0.26200000E 03       0.17700000E 05       0.16800360E 05          5.0827           67.5573
0.26700000E 03       0.17700000E 05       0.17041710E 05          3.7191           66.2921
0.27350000E 03       0.17700000E 05       0.17355980E 05          1.9436           64.7166
0.22700000E 03       0.15800000E 05       0.15112750E 05          4.3497           69.6035
0.23100000E 03       0.15800000E 05       0.15305980E 05          3.1267           68.3983
0.23300000E 03       0.15800000E 05       0.15402520E 05          2.5156           67.8112
0.17700000E 03       0.12950000E 05       0.12662570E 05          2.2195           73.1638
0.18000000E 03       0.12950000E 05       0.12812250E 05          1.0637           71.9444
0.18100000E 03       0.12950000E 05       0.12862040E 05          0.6792           71.5470
0.12800000E 03       0.10750000E 05       0.10140110E 05          5.6733           83.9844
0.13100000E 03       0.10750000E 05       0.10299550E 05          4.1902           82.0611
0.13400000E 03       0.10750000E 05       0.10458250E 05          2.7139           80.2239
0.91000000E 02       0.83500000E 04       0.81049490E 04          2.9347           91.7582
0.93000000E 02       0.83500000E 04       0.82185150E 04          1.5747           89.7849
0.94000000E 02       0.83500000E 04       0.82751320E 04          0.8966           88.8298
0.71500000E 02       0.68800000E 04       0.69735230E 04         -1.3594           96.2238
0.73000000E 02       0.68800000E 04       0.70621710E 04         -2.6478           94.2466
0.73000000E 02       0.68800000E 04       0.70621710E 04         -2.6478           94.2466
0.31800000E 03       0.19600000E 05       0.19537900E 05          0.3168           61.6352
0.32300000E 03       0.19600000E 05       0.19788000E 05         -0.9592           60.6811
0.28050000E 03       0.17500000E 05       0.17695280E 05         -1.1159           62.3886
0.28400000E 03       0.17500000E 05       0.17865330E 05         -2.0876           61.6197
0.24800000E 03       0.15500000E 05       0.16125580E 05         -4.0360           62.5000
0.25150000E 03       0.15500000E 05       0.16294210E 05         -5.1239           61.6302
0.21950000E 03       0.14210000E 05       0.14749760E 05         -3.7985           64.7380
0.22200000E 03       0.14210000E 05       0.14870870E 05         -4.6508           64.0090
0.18500000E 03       0.12700000E 05       0.13060750E 05         -2.8406           68.6486
0.18850000E 03       0.12700000E 05       0.13234030E 05         -4.2050           67.3740
0.13700000E 03       0.10100000E 05       0.10616230E 05         -5.1112           73.7226
0.13900000E 03       0.10100000E 05       0.10721150E 05         -6.1501           72.6619
        AVERAGE DEVIATION =      2.99112400 %              DEGREE = 2
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                                   NITROGEN 429 0.75

                   LEAST SQUARES POLY COEFF. ARE:

                     A(   0)=    -0.49726950E 04
                     A(   1)=     0.27138590E 03
                     A(   2)=    -0.19786130E 01
                     A(   3)=     0.76598330E-02
                     A(   4)=    -0.10664560E-04
    DELTA T             HEAT FLUX            CALC. HEAT FLUX     % DEVIATION              H

 0.25800000E 03      0.18200000E 05      0.17620390E 05          3.1846             70.5426
 0.26200000E 03      0.18200000E 05      0.17803310E 05          2.1796             69.4656
 0.26450000E 03      0.18200000E 05      0.17912310E 05          1.5807             68.8091
 0.22300000E 03      0.16250000E 05      0.15738190E 05          3.1495             72.8699
 0.22700000E 03      0.16250000E 05      0.15968290E 05          1.7336             71.5859
 0.22900000E 03      0.16250000E 05      0.16082610E 05          1.0301             70.9607
 0.18800000E 03      0.14380000E 05      0.13716610E 05          4.6133             76.4893
 0.19000000E 03      0.14380000E 05      0.13830130E 05          3.8238             75.6842
 0.19250000E 03      0.14380000E 05      0.13972610E 05          2.8330             74.7013
 0.15500000E 03      0.12310000E 05      0.11908620E 05          3.2606             79.4193
 0.15600000E 03      0.12310000E 05      0.11961710E 05          2.8293             78.9102
 0.16000000E 03      0.12310000E 05      0.12174960E 05          1.0970             76.9375
 0.12400000E 03      0.10580000E 05      0.10285370E 05          2.7847             85.3226
 0.12450000E 03      0.10580000E 05      0.10311580E 05          2.5370             84.9799
 0.12600000E 03      0.10580000E 05      0.10390130E 05          1.7945             83.9682
 0.95000000E 02      0.87500000E 04      0.87127260E 04          0.4260             92.1053
 0.95500000E 02      0.87500000E 04      0.87411830E 04          0.1008             91.6230
 0.97500000E 02      0.87500000E 04      0.88543900E 04         -1.1930             89.7436
 0.30850000E 03      0.18780000E 05      0.18749000E 05          0.1650             60.8752
 0.31150000E 03      0.18780000E 05      0.18698080E 05          0.4362             60.2889
 0.28250000E 03      0.18300000E 05      0.18543890E 05         -1.3327             64.7788
 0.28600000E 03      0.18300000E 05      0.18628140E 05         -1.7931             63.9860
 0.24300000E 03      0.16300000E 05      0.16860670E 05         -3.4398             67.0782
 0.24500000E 03      0.16300000E 05      0.16967420E 05         -4.0947             66.5306
 0.20900000E 03      0.14410000E 05      0.14925230E 05         -3.5755             68.9474
 0.21200000E 03      0.14410000E 05      0.15099750E 05         -4.7867             67.9717
 0.17400000E 03      0.12310000E 05      0.12934490E 05         -5.0730             70.7471
 0.17650000E 03      0.12310000E 05      0.13072470E 05         -6.1940             69.7450
 0.13450000E 03      0.10300000E 05      0.10833730E 05         -5.1819             76.5799
 0.13600000E 03      0.10300000E 05      0.10911910E 05         -5.9409             75.7353
          AVERAGE DEVIATION =        2.73881300 %             DEGREE = 4
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                                        NITROGEN 453 0.75

                    LEAST SQUARES POLY COEFF. ARE:

                         A(   0)=      0.35421520E 04
                         A(   1)=      0.58569440E 02

   DELTA T               HEAT FLUX            CALC. HEAT FLUX      % DEVIATION              H

0.25300000E 03      0.18950000E 05      0.18364200E 05          3.0913           74.9012
0.25400000E 03      0.18950000E 05      0.18420550E 05          2.7939           74.6063
0.25800000E 03      0.18950000E 05      0.18645530E 05          1.6067           73.4496
0.28150000E 03      0.20600000E 05      0.19953650E 05          3.1376           73.1794
0.28450000E 03      0.20600000E 05      0.20118960E 05          2.3351           72.4077
0.28600000E 03      0.20600000E 05      0.20201480E 05          1.9345           72.0280
0.21650000E 03      0.17000000E 05      0.16278450E 05          4.2444           78.5219
0.21900000E 03      0.17000000E 05      0.16423110E 05          3.3935           77.6256
0.22000000E 03      0.17000000E 05      0.16480890E 05          3.0535           77.2727
0.18300000E 03      0.14500000E 05      0.14314590E 05          1.2786           79.2350
0.18600000E 03      0.14500000E 05      0.14492390E 05          0.0524           77.9570
0.18850000E 03      0.14500000E 05      0.14640270E 05         -0.9674           76.9231
0.15000000E 03      0.12500000E 05      0.12333670E 05          1.3306           83.3333
0.15050000E 03      0.12500000E 05      0.12364030E 05          1.0877           83.0565
0.15150000E 03      0.12500000E 05      0.12424710E 05          0.6022           82.5082
0.11550000E 03      0.10890000E 05      0.10213510E 05          6.2120           94.2857
0.11550000E 03      0.10890000E 05      0.10213510E 05          6.2120           94.2857
0.11800000E 03      0.10890000E 05      0.10368830E 05          4.7857           92.2881
0.13950000E 03      0.11800000E 05      0.11693730E 05          0.9006           84.5878
0.14000000E 03      0.11800000E 05      0.11724310E 05          0.6414           84.2857
0.14100000E 03      0.11800000E 05      0.11785440E 05          0.1234           83.6879
0.18250000E 03      0.14700000E 05      0.14284920E 05          2.8236           80.5479
0.18500000E 03      0.14700000E 05      0.14433170E 05          1.8152           79.4595
0.18700000E 03      0.14700000E 05      0.14551570E 05          1.0097           78.6096
0.20150000E 03      0.15800000E 05      0.15404970E 05          2.5001           78.4119
0.20350000E 03      0.15800000E 05      0.15521990E 05          1.7595           77.6413
0.20500000E 03      0.15800000E 05      0.15609640E 05          1.2048           77.0732
0.28150000E 03      0.19400000E 05      0.19953650E 05         -2.8539           68.9165
0.28450000E 03      0.19400000E 05      0.20118960E 05         -3.7060           68.1898
0.26200000E 03      0.18200000E 05      0.18869830E 05         -3.6804           69.4656
0.26450000E 03      0.18200000E 05      0.19009690E 05         -4.4489           68.8091
0.23400000E 03      0.16750000E 05      0.17285490E 05         -3.1970           71.5812
0.23600000E 03      0.16750000E 05      0.17399760E 05         -3.8792           70.9746
0.19900000E 03      0.14400000E 05      0.15258470E 05         -5.9616           72.3618
0.20150000E 03      0.14400000E 05      0.15404970E 05         -6.9790           71.4640
0.15800000E 03      0.12220000E 05      0.12818120E 05         -4.8946           77.3418
0.16000000E 03      0.12220000E 05      0.12938910E 05         -5.8830           76.3750
0.11800000E 03      0.94800000E 04      0.10368830E 05         -9.3759           80.3390
0.11900000E 03      0.94800000E 04      0.10430900E 05        -10.0306           79.6639

        AVERAGE DEVIATION          3.22523000 %                DEGREE = 1
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                                         NITROGEN ATM 0.05

                     LEAST SQUARES POLY COEFF. ARE:

                          A(   0)=    -0.40367300E 04
                          A(   1)=     0.17151690E 03
                          A(   2)=    -0.10327240E 01
                          A(   3)=     0.30372680E-02
                          A(   4)=    -0.32233460E-05

      DELTA T              HEAT FLUX              CALC. HEAT FLUX      % DEVIATION            H

0.37300000E 03      0.11700000E 05      0.11478480E 05      1.8933      31.3673
0.37200000E 03      0.11700000E 05      0.11477630E 05      1.9005      31.4516
0.37400000E 03      0.11700000E 05      0.11478830E 05      1.8993      31.2834
0.31600000E 03      0.10420000E 05      0.10721790E 05     -2.8963      32.9747
0.31600000E 03      0.10420000E 05      0.10721790E 05     -2.8963      32.9747
0.31700000E 03      0.10420000E 05      0.10743170E 05     -3.1015      32.8707
0.26150000E 03      0.90600000E 04      0.94476010E 04     -4.2782      34.6463
0.26150000E 03      0.90600000E 04      0.94476010E 04     -4.2782      34.6463
0.26150000E 03      0.90600000E 04      0.94476010E 04     -4.2782      34.6463
0.22550000E 03      0.85300000E 04      0.86371210E 04     -1.2558      37.8270
0.22300000E 03      0.85300000E 04      0.85837030E 04     -0.6296      38.2511
0.22500000E 03      0.85300000E 04      0.86264100E 04     -1.1302      37.9111
0.19500000E 03      0.77000000E 04      0.80043900E 04     -3.9531      39.4872
0.19500000E 03      0.77000000E 04      0.80043900E 04     -3.9531      39.4872
0.19700000E 03      0.77000000E 04      0.80450110E 04     -4.4807      39.0863
0.15650000E 03      0.70000000E 04      0.72005580E 04     -2.8651      44.7284
0.15650000E 03      0.70000000E 04      0.72005580E 04     -2.8651      44.7284
0.15850000E 03      0.70000000E 04      0.72449250E 04     -3.4989      44.1640
0.18000000E 03      0.77700000E 04      0.76992570E 04      0.9105      43.1667
0.17550000E 03      0.77700000E 04      0.76066600E 04      2.1022      44.2735
0.18000000E 03      0.77700000E 04      0.76992570E 04      0.9105      43.1667
0.24000000E 03      0.98600000E 04      0.89543120E 04      9.1855      41.0833
0.23800000E 03      0.98600000E 04      0.89097960E 04      9.6369      41.4286
0.24200000E 03      0.98600000E 04      0.89990780E 04      8.7315      40.7438
0.28900000E 03      0.10050000E 05      0.10102720E 05     -0.5246      34.7751
0.28800000E 03      0.10050000E 05      0.10078880E 05     -0.2874      34.8958
0.29000000E 03      0.10050000E 05      0.10126510E 05     -0.7613      34.6552
0.33850000E 03      0.11200000E 05      0.11153950E 05      0.4120      33.0871
0.34000000E 03      0.11200000E 05      0.11178090E 05      0.1054      32.9412
0.34100000E 03      0.11200000E 05      0.11193820E 05      0.0551      32.8446
0.37300000E 03      0.12000000E 05      0.11478480E 05      4.3459      32.1716
0.37300000E 03      0.12000000E 05      0.11479490E 05      4.3450      32.1716
0.37450000E 03      0.12000000E 05      0.11479770E 05      4.3435      32.0427
0.28150000E 03      0.96800000E 04      0.99235150E 04     -2.5157      34.3872
0.27800000E 03      0.96800000E 04      0.98307260E 04     -1.5501      34.8201
0.27950000E 03      0.96800000E 04      0.98756400E 04     -2.0211      34.6333
0.31750000E 03      0.10610000E 05      0.10753820E 05     -1.3555      33.4173
0.31450000E 03      0.10610000E 05      0.10689390E 05     -0.7483      33.7361
0.31500000E 03      0.10610000E 05      0.10[illegible]24E 05     -0.2506      33.6825
0.39250000E 03      0.10900000E 05      0.11357590E 05     -4.1991      27.7707
0.39600000E 03      0.10900000E 05      0.11304140E 05     -3.7077      27.5253
0.39800000E 03      0.10900000E 05      0.11268550E 05     -3.3812      27.3869
0.22350000E 03      0.88700000E 04      0.87717[illegible]E 04      1.0073      [illegible]
0.23100000E 03      0.88700000E 04      0.8755[illegible]E 04      1.2041      [illegible]
0.23100000E 03      0.88700000E 04      0.8755[illegible]E 04      1.2261      [illegible]
0.17200000E 03      0.75300000E 04      0.7[illegible]E 04      1.[illegible]15      44.[illegible]
0.17200000E 03      0.75[illegible]E 04      0.74[illegible]170E 04      [illegible].44[illegible]      45.17[illegible]
0.17200000E 03      0.7[illegible]E 04      0.74[illegible]E 04      [illegible].44[illegible]      4[illegible].17[illegible]

          AVERAGE DEVIATION          2.71[illegible]47[illegible]
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                              NITROGEN 34 0.95

              LEAST SQUARES POLY COEFF. ARE:

                 A(   0)=     0.55527260E 04
                 A(   1)=     0.27753370E 02

    DELTA T            HEAT FLUX          CALC. HEAT FLUX      % DEVIATION           H

0.32430000E 03     0.13320000E 05     0.14607160E 05          -9.6634           41.0731
0.29580000E 03     0.13320000E 05     0.13745210E 05          -3.1923           45.0304
0.31380000E 03     0.13320000E 05     0.14287320E 05          -7.2622           42.4474
0.24780000E 03     0.10520000E 05     0.12337800E 05         -17.2795           42.4536
0.21230000E 03     0.10520000E 05     0.11332660E 05          -7.7249           49.5525
0.23530000E 03     0.10520000E 05     0.11980410E 05         -13.8822           44.7089
0.15130000E 03     0.82900000E 04     0.96765310E 04         -16.7253           54.7918
0.97300000E 02     0.82900000E 04     0.82853550E 04           0.0560           85.2004
0.13830000E 03     0.82900000E 04     0.93351870E 04         -12.6078           59.9421
0.74300000E 02     0.70500000E 04     0.77141870E 04          -9.4211           94.8856
0.49300000E 02     0.70500000E 04     0.71078200E 04          -0.8201          143.0020
0.62300000E 02     0.70500000E 04     0.74212500E 04          -5.2660          113.1621
0.12630000E 03     0.96000000E 04     0.90237180E 04           6.0029           76.0095
0.98300000E 02     0.96000000E 04     0.83104800E 04          13.4325           97.6602
0.10930000E 03     0.96000000E 04     0.85884290E 04          10.5372           87.8316
0.17530000E 03     0.11220000E 05     0.10317410E 05           8.0445           64.0046
0.14880000E 03     0.11220000E 05     0.96105700E 04          14.3443           75.4032
0.15580000E 03     0.11220000E 05     0.97956320E 04          12.6949           72.0154
0.35130000E 03     0.14550000E 05     0.15441820E 05          -6.1294           41.4176
0.29830000E 03     0.14550000E 05     0.13820030E 05           5.0169           48.7764
0.32730000E 03     0.14550000E 05     0.14699030E 05          -1.0243           44.4546
0.28080000E 03     0.12400000E 05     0.13299420E 05          -7.2535           44.1595
0.20930000E 03     0.12400000E 05     0.11249110E 05           9.2813           59.2451
0.26930000E 03     0.12400000E 05     0.12961330E 05          -4.5269           46.0453
0.22480000E 03     0.10570000E 05     0.11683110E 05         -10.5309           47.0196
0.16030000E 03     0.10570000E 05     0.99152300E 04           6.1946           65.9389
0.21330000E 03     0.10570000E 05     0.11360550E 05          -7.4793           49.5546
0.17180000E 03     0.91600000E 04     0.10223080E 05         -11.6057           53.3178
0.11430000E 03     0.91600000E 04     0.87157300E 04           4.8501           80.1400
0.15880000E 03     0.91600000E 04     0.98753120E 04          -7.8091           57.6826
0.68300000E 02     0.67500000E 04     0.75672850E 04         -12.1079           98.8287
0.40300000E 02     0.67500000E 04     0.68932220E 04          -2.1218          167.4937
0.55800000E 02     0.67500000E 04     0.72640270E 04          -7.6152          120.9677
0.32330000E 03     0.15250000E 05     0.14576590E 05           4.4158           47.1698
0.32480000E 03     0.15250000E 05     0.14622460E 05           4.1150           46.9520
0.37030000E 03     0.16700000E 05     0.16039730E 05           3.9537           45.0986
0.37030000E 03     0.16700000E 05     0.16039730E 05           3.9537           45.0986
0.33780000E 03     0.15600000E 05     0.15022300E 05           3.7032           46.1812
0.33880000E 03     0.15600000E 05     0.15053220E 05           3.5050           46.0448
0.27980000E 03     0.13750000E 05     0.13269900E 05           3.4916           49.1422
0.28080000E 03     0.13750000E 05     0.13299420E 05           3.2769           48.9672
0.23680000E 03     0.12600000E 05     0.12023090E 05           4.5786           53.2095
0.23630000E 03     0.12600000E 05     0.12008860E 05           4.6916           53.3220
0.19030000E 03     0.11900000E 05     0.10725010E 05           9.8739           62.5329
0.19180000E 03     0.11900000E 05     0.10766070E 05           9.5287           62.0438

        AVERAGE DEVIATION -      7.36865700 %              DEGREE = 1
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                              NITROGEN 133 0.95

                 LEAST SQUARES POLY COEFF. ARE:

                   A(   0)=     0.36561750E 04
                   A(   1)=     0.67612380E 02
                   A(   2)=    -0.52826760E-01

      DELTA T            HEAT FLUX          CALC. HEAT FLUX     % DEVIATION            H

  0.31850000E 03      0.19200000E 05      0.19888930E 05         -3.5892           60.2826
  0.26200000E 03      0.19200000E 05      0.17875830E 05          6.8967           73.2824
  0.26450000E 03      0.19200000E 05      0.17978520E 05          6.3619           72.5898
  0.28000000E 03      0.17100000E 05      0.18589250E 05         -8.7091           61.0714
  0.22600000E 03      0.17100000E 05      0.16283510E 05          4.7748           75.6637
  0.23250000E 03      0.17100000E 05      0.16585470E 05          3.0089           73.5484
  0.23000000E 03      0.14310000E 05      0.16470020E 05        -15.0945           62.2174
  0.17900000E 03      0.14310000E 05      0.13953100E 05          2.4940           79.9441
  0.18450000E 03      0.14310000E 05      0.14236910E 05          0.5107           77.5610
  0.17750000E 03      0.12580000E 05      0.13875290E 05        -10.2965           70.8732
  0.13500000E 03      0.12580000E 05      0.11617150E 05          7.6538           93.1852
  0.13950000E 03      0.12580000E 05      0.11859760E 05          5.7252           90.1792
  0.13150000E 03      0.95400000E 04      0.11428140E 05        -19.7919           72.5475
  0.97000000E 02      0.95400000E 04      0.95618120E 04         -0.2286           98.3505
  0.10050000E 03      0.95400000E 04      0.97506520E 04         -2.2081           94.9254
  0.53000000E 02      0.71000000E 04      0.72308940E 04         -1.8436          133.9622
  0.47000000E 02      0.71000000E 04      0.69225070E 04          2.4999          151.0638
  0.47000000E 02      0.71000000E 04      0.69225070E 04          2.4999          151.0638
  0.35850000E 03      0.21100000E 05      0.20850690E 05          1.1815           58.8563
  0.36000000E 03      0.21100000E 05      0.20878040E 05          1.0519           58.6111
  0.32050000E 03      0.20000000E 05      0.19947040E 05          0.2648           62.4025
  0.32200000E 03      0.20000000E 05      0.19989980E 05          0.0501           62.1118
  0.27850000E 03      0.18300000E 05      0.18532180E 05         -1.2688           65.7092
  0.28050000E 03      0.18300000E 05      0.18608190E 05         -1.6841           65.2406
  0.22750000E 03      0.16500000E 05      0.16353700E 05          0.8866           72.5275
  0.22950000E 03      0.16500000E 05      0.16446830E 05          0.3222           71.8954
  0.25100000E 03      0.17400000E 05      0.17411070E 05         -0.0636           69.3227
  0.25300000E 03      0.17400000E 05      0.17497090E 05         -0.5590           68.7747
  0.19600000E 03      0.15600000E 05      0.14822020E 05          4.9870           79.5918
  0.19800000E 03      0.15600000E 05      0.14922530E 05          4.3427           78.7879

          AVERAGE DEVIATION =      4.02824600 %          DEGREE = 2
```

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                                              NITROGEN 231 0.95

                         LEAST SQUARES POLY COEFF. ARE:

                           A(   0)=     0.32107890E 04
                           A(   1)=     0.75458930E 02
                           A(   2)=    -0.55748330E-01
     DELTA T                  HEAT FLUX              CALC. HEAT FLUX       % DEVIATION                H

0.29800000E 03         0.19900000E 05          0.20732420E 05          -4.1830              66.7785
0.27000000E 03         0.19900000E 05          0.19548870E 05           1.7644              73.7037
0.26550000E 03         0.19900000E 05          0.19346560E 05           2.7811              74.9529
0.26500000E 03         0.18250000E 05          0.19323890E 05          -5.8844              68.8679
0.23400000E 03         0.18250000E 05          0.17844450E 05           2.2222              77.9914
0.23500000E 03         0.18250000E 05          0.17894330E 05           1.9488              77.6596
0.21639990E 03         0.15320000E 05          0.16944680E 05         -10.6050              70.7948
0.18200000E 03         0.15320000E 05          0.15076980E 05           1.5863              84.1758
0.18600000E 03         0.15320000E 05          0.15300940E 05           0.1244              82.3656
0.16000000E 03         0.12250000E 05          0.13816800E 05         -12.7902              76.5625
0.13050000E 03         0.12250000E 05          0.12060620E 05           1.5459              93.8697
0.13400000E 03         0.12250000E 05          0.12272490E 05          -0.1836              91.4179
0.95500000E 02         0.89500000E 04          0.98995190E 04         -10.6092              93.7173
0.76500000E 02         0.89500000E 04          0.87003820E 04           2.7890             116.9934
0.74500000E 02         0.89500000E 04          0.85733470E 04           4.2084             120.1342
0.31450000E 03         0.21600000E 05          0.21365250E 05           1.0868              68.6804
0.31200000E 03         0.21600000E 05          0.21272600E 05           1.5157              69.2308
0.28900000E 03         0.20460000E 05          0.20366570E 05           0.4566              70.7958
0.28950000E 03         0.20460000E 05          0.20387270E 05           0.3555              70.6736
0.26750000E 03         0.19450000E 05          0.19436880E 05           0.0674              72.7103
0.26900000E 03         0.19450000E 05          0.19504190E 05          -0.2787              72.3048
0.23050000E 03         0.17750000E 05          0.17668780E 05           0.4575              77.0065
0.23150000E 03         0.17750000E 05          0.17719140E 05           0.1738              76.6739
0.20200000E 03         0.16550000E 05          0.16179420E 05           2.2391              81.9307
0.20350000E 03         0.16550000E 05          0.16260290E 05           1.7505              81.3263
0.16800000E 03         0.15300000E 05          0.14280390E 05           6.6641              91.0714
0.17100000E 03         0.15300000E 05          0.14452710E 05           5.5378              89.4737
           AVERAGE DEVIATION =       3.10404600 %            DEGREE = 2
```

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                                            NITROGEN 379 0.95

                     LEAST SQUARES POLY COEFF. ARE:

                         A(   0)=      0.30884370E 04
                         A(   1)=      0.75418410E 02
                         A(   2)=     -0.47661710E-01
        DELTA T                 HEAT FLUX               CALC. HEAT FLUX        % DEVIATION              H

0.29300000E 03          0.21560000E 05          0.21110280E 05           2.0859               73.5836
0.28100000E 03          0.21560000E 05          0.20548480E 05           4.6916               76.7260
0.28000000E 03          0.21560000E 05          0.20500750E 05           4.9130               77.0000
0.24850000E 03          0.18600000E 05          0.18928830E 05          -1.7679               74.8491
0.23600000E 03          0.18600000E 05          0.18270070E 05           1.7738               78.8136
0.23600000E 03          0.18600000E 05          0.18270070E 05           1.7738               78.8136
0.20700000E 03          0.16360000E 05          0.16671630E 05          -1.9048               79.0338
0.19400000E 03          0.16360000E 05          0.15925440E 05           2.6562               84.3299
0.19650000E 03          0.16360000E 05          0.16070290E 05           1.7709               83.2570
0.15400000E 03          0.13200000E 05          0.13527060E 05          -2.4777               85.7143
0.13900000E 03          0.13200000E 05          0.12591900E 05           4.6068               94.9640
0.14200000E 03          0.13200000E 05          0.12780360E 05           3.1791               92.9577
0.89500000E 02          0.89900000E 04          0.93918320E 04          -4.4698              100.4469
0.79500000E 02          0.89900000E 04          0.87273320E 04           2.9218              113.0817
0.80000000E 02          0.89900000E 04          0.87606790E 04           2.5508              112.3750
0.35500000E 02          0.54400000E 04          0.57495030E 04          -5.6894              153.2394
0.31000000E 02          0.54400000E 04          0.54409170E 04          -0.0169              175.4839
0.29500000E 02          0.54400000E 04          0.53379290E 04           1.8763              184.4067
0.34450000E 03          0.22800000E 05          0.23276620E 05          -2.0905               66.1828
0.30950000E 03          0.22800000E 05          0.21848770E 05           4.1720               73.6672
0.28600000E 03          0.20200000E 05          0.20785030E 05          -2.8962               70.6294
0.29950000E 03          0.20200000E 05          0.21405980E 05          -5.9702               67.4457
0.24700000E 03          0.18500000E 05          0.18850790E 05          -1.8962               74.8988
0.24800000E 03          0.18500000E 05          0.18902850E 05          -2.1776               74.5968
0.21700000E 03          0.16800000E 05          0.17233450E 05          -2.5801               77.4193
0.22100000E 03          0.16800000E 05          0.17455110E 05          -3.8995               76.0181
0.19400000E 03          0.15700000E 05          0.15925440E 05          -1.4360               80.9278
0.19450000E 03          0.15700000E 05          0.15954460E 05          -1.6200               80.7198
0.16950000E 03          0.14400000E 05          0.14473740E 05          -0.5121               84.9557
0.17050000E 03          0.14400000E 05          0.14534090E 05          -0.9312               84.4575
          AVERAGE DEVIATION =       2.71028700 %                DEGREE = 2
```

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                                        NITROGEN 429 0.95

                        LEAST SQUARES POLY COEFF. ARE:

                              A(   0)=      0.25110780E 04
                              A(   1)=      0.10604650E 03
                              A(   2)=     -0.53650500E 00
                              A(   3)=      0.27501750E-02
                              A(   4)=     -0.47168890E-05
        DELTA T                HEAT FLUX              CALC. HEAT FLUX        % DEVIATION              H

   0.23700000E  03        0.19200000E  05        0.19223030E  05           -0.1200             81.0126
   0.21550000E  03        0.19200000E  05        0.17751000E  05            7.5469             89.0951
   0.23550000E  03        0.19200000E  05        0.19123520E  05            0.3983             81.5287
   0.26650000E  03        0.21400000E  05        0.20978960E  05            1.9674             80.3002
   0.24800000E  03        0.21400000E  05        0.19929030E  05            6.8736             86.2903
   0.26600000E  03        0.21400000E  05        0.20953600E  05            2.0860             80.4511
   0.17650000E  03        0.15000000E  05        0.15028110E  05           -0.1874             84.9858
   0.15750000E  03        0.15000000E  05        0.13749640E  05            8.3357             95.2381
   0.17650000E  03        0.15000000E  05        0.15028110E  05           -0.1874             84.9858
   0.13200000E  03        0.11800000E  05        0.12099060E  05           -2.5344             89.3939
   0.11550000E  03        0.11800000E  05        0.11057680E  05            6.2908            102.1644
   0.13100000E  03        0.11800000E  05        0.12035540E  05           -1.9962             90.0763
   0.89000000E  02        0.90200000E  04        0.93826210E  04           -4.0202            101.3483
   0.70500000E  02        0.90200000E  04        0.81725780E  04            9.3949            127.9432
   0.90000000E  02        0.90200000E  04        0.94466750E  04           -4.7303            100.2222
   0.55000000E  02        0.67900000E  04        0.71073510E  04           -4.6738            123.4545
   0.46000000E  02        0.67900000E  04        0.64600070E  04            4.8600            147.6086
   0.57000000E  02        0.67900000E  04        0.72491170E  04           -6.7469            119.1228
   0.31200000E  03        0.22200000E  05        0.22086060E  05            0.5132             71.1538
   0.29200000E  03        0.22200000E  05        0.21948550E  05            1.1327             76.0274
   0.28750000E  03        0.21200000E  05        0.21831620E  05           -2.9793             73.7391
   0.27850000E  03        0.21200000E  05        0.21522140E  05           -1.5196             76.1221
   0.25150000E  03        0.19400000E  05        0.20142960E  05           -3.8297             77.1372
   0.25050000E  03        0.19400000E  05        0.20082450E  05           -3.5178             77.4451
   0.22200000E  03        0.17550000E  05        0.18204010E  05           -3.7266             79.0540
   0.22400000E  03        0.17550000E  05        0.18342390E  05           -4.5150             78.3482
   0.18450000E  03        0.15350000E  05        0.15578940E  05           -1.4915             83.1978
   0.18700000E  03        0.15350000E  05        0.15752380E  05           -2.6214             82.0856
   0.16000000E  03        0.13600000E  05        0.13915330E  05           -2.3187             85.0000
   0.16200000E  03        0.13600000E  05        0.14048440E  05           -3.2974             83.9506
          AVERAGE DEVIATION =        3.48043500 %                DEGREE = 4
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                                         NITROGEN 453 0.95

                      LEAST SQUARES POLY COFFF. ARE:

                        A(   0)=      0.16668590E 04
                        A(   1)=      0.70208060E 02
   DELTA T                HEAT FLUX           CALC. HEAT FLUX      % DEVIATION                H

0.25519990E 03        0.19420000E 05       0.19597200E 05          -0.9125              76.0972
0.23869990E 03        0.19420000F 05       0.18467150F 05           4.9065              81.3573
0.25319990E 03        0.19420000E 05       0.19460680E 05          -0.2095              76.6983
0.23019990E 03        0.17400000E 05       0.17881660E 05          -2.7682              75.5864
0.21119990F 03        0.17400000E 05       0.16564680E 05           4.8006              82.3864
0.21719990E 03        0.17400000E 05       0.16981800F 05           2.4034              80.1105
0.20069990E 03        0.14900000E 05       0.15832000E 05          -6.2551              74.2402
0.19019990E 03        0.14900000F 05       0.15095850F 05          -1.3145              78.3386
0.20319990F 03        0.14900000E 05       0.16006770E 05          -7.4280              73.3268
0.16719990E 03        0.12600000E 05       0.13471210F 05          -6.9144              75.3588
0.14519990E 03        0.12600000E 05       0.11901610E 05           5.5427              86.7769
0.16519990E 03        0.12600000E 05       0.13329150F 05          -5.7869              76.2712
0.12219990E 03        0.95900000F 04       0.10244380F 05          -6.8236              78.4779
0.11419990F 03        0.95900000E 04       0.96640500E 04          -0.7722              83.9755
0.11969990F 03        0.95900000F 04       0.10063240E 05          -4.9347              80.1170
0.80699990E 02        0.69500000F 04       0.72120150E 04          -3.7700              86.1214
0.66699990F 02        0.69500000F 04       0.61768160F 04          11.1249             104.1978
0.77199990F 02        0.69500000E 04       0.69537960F 04          -0.0546              90.0259
0.31769990F 03        0.23000000E 05       0.23799970F 05          -3.4782              72.3953
0.30069990E 03        0.23000000F 05       0.22669000F 05           1.4391              76.4882
0.30069990E 03        0.22500000F 05       0.22669000F 05          -0.7511              74.8254
0.29019990F 03        0.22500000F 05       0.21965900F 05           2.3737              77.5327
0.27969990F 03        0.21200000F 05       0.21259340F 05          -0.2799              75.7955
0.27669990F 03        0.21200000F 05       0.21056830F 05           0.6753              76.6173
0.24219990F 03        0.18750000F 05       0.18707580F 05           0.2262              77.4154
0.24369990F 03        0.18750000F 05       0.18810500F 05          -0.3227              76.9382
0.20319990F 03        0.16550000F 05       0.16006770F 05           3.2823              81.4468
0.20469990F 03        0.16550000F 05       0.16111530F 05           2.6493              80.8509
0.16769990F 03        0.14250000F 05       0.13506700F 05           5.2161              84.9732
0.16919990F 03        0.14250000F 05       0.13613140F 05           4.4691              84.2198
        AVERAGE DEVIATION =       3.39618100 %            DEGREE = 1
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                                         ARGON 56 0.55

                    LEAST SQUARES POLY COEFF. ARE:

                      A(   0)=     0.89713780E 04
                      A(   1)=     0.23826960E 02

   DELTA T              HEAT FLUX          CALC. HEAT FLUX     % DEVIATION              H

0.31150000E 03     0.17520000E 05      0.16365390E 05          6.5902            56.2440
0.27750000E 03     0.16300000E 05      0.15419730E 05          5.4004            58.7387
0.24400000E 03     0.14950000E 05      0.14580720E 05          2.4701            61.2705
0.19900000E 03     0.13750000E 05      0.13598570E 05          1.1013            69.0955
0.13100000E 03     0.12800000E 05      0.12429570E 05          2.8940            97.7099
0.35650000E 03     0.17520000E 05      0.17762800E 05         -1.3859            49.1445
0.34000000E 03     0.17050000E 05      0.17231130E 05         -1.0624            50.1470
0.29950000E 03     0.15150000E 05      0.16020800E 05         -5.7479            50.5843
0.26400000E 03     0.14200000E 05      0.15070550E 05         -6.1307            53.7879
0.17600000E 03     0.12400000E 05      0.13160720E 05         -6.1349            70.4545

        AVERAGE DEVIATION =      3.89175000 %          DEGREE = 1
```

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                                   ARGON 197  0.55

                  LEAST SQUARES POLY COEFF. ARE:

                    A(   0)=     0.92109060E 04
                    A(   1)=     0.43743880E 02

    DELTA T            HEAT FLUX          CALC. HEAT FLUX      % DEVIATION           H

0.23700000E 03     0.20830000E 05     0.19810640E 05          4.8937            87.8903
0.32650000E 03     0.23100000E 05     0.23299750E 05         -0.8648            70.7504
0.30900000E 03     0.22800000E 05     0.22678890E 05          0.5312            73.7864
0.21950000E 03     0.18100000E 05     0.19037220E 05         -5.1780            82.4601
0.17200000E 03     0.16600000E 05     0.16787600E 05         -1.1301            96.5116
0.13150000E 03     0.14880000E 05     0.14695930E 05          1.2370           113.1559

      AVERAGE DEVIATION =      2.30579500 %          DEGREE = 1
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                                   ARGON 338  0.55

                  LEAST SQUARES POLY COEFF. ARE:

                    A(   0)=     0.89130890E 04
                    A(   1)=     0.55544180E 02

    DELTA T            HEAT FLUX          CALC. HEAT FLUX      % DEVIATION           H

0.27800000E 03     0.23800000E 05     0.24135420E 05         -1.4093            85.6115
0.23700000E 03     0.22700000E 05     0.22128730E 05          2.5166            95.7806
0.22300000E 03     0.21700000E 05     0.21401360E 05          1.3762            97.3094
0.20300000E 03     0.20300000E 05     0.20325030E 05         -0.1233           100.0000
0.17750000E 03     0.18150000E 05     0.18889200E 05         -4.0727           102.2535
0.12000000E 03     0.15620000E 05     0.15390230E 05          1.4709           130.1666

      AVERAGE DEVIATION =      1.82818900 %          DEGREE = 1
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                                             ARGON  550  0.55

                         LEAST SQUARES POLY COEFF. ARE:

                            A(   0)=      0.15857940E 05
                            A(   1)=     -0.49471860E 02
                            A(   2)=      0.78960620E 00
                            A(   3)=     -0.15981320E-02

    DELTA T                HEAT FLUX            CALC. HEAT FLUX      % DEVIATION              H

0.21100000E 03        0.25600000E 05        0.25573260E 05             0.1044            121.3270
0.19200000E 03        0.24500000E 05        0.24148890E 05             1.4331            127.6041
0.18600000E 03        0.23200000E 05        0.23679960E 05            -2.0688            124.7311
0.14600000E 03        0.20650000E 05        0.20495300E 05             0.7491            141.4383
0.11600000E 03        0.18200000E 05        0.18251500E 05            -0.2830            156.8965
0.35150000E 03        0.26620000E 05        0.26621100E 05            -0.0041             75.7326
       AVERAGE DEVIATION =          0.77376680 %                DEGREE  =  3



                                             ARGON  620 0.55

                         LEAST SQUARES POLY COEFF. ARE:

                            A(   0)=      0.31991480E 04
                            A(   1)=      0.57039700E 02

    DELTA T                HEAT FLUX            CALC. HEAT FLUX      % DEVIATION              H

0.32650000E 03        0.22100000E 05        0.21913950E 05             0.8418             67.6876
0.30450000E 03        0.20300000E 05        0.20591480E 05            -1.4359             66.6667
0.24850000E 03        0.17350000E 05        0.17294400E 05             0.3204             69.8189
0.20650000E 03        0.15100000E 05        0.14886800E 05             1.4119             73.1235
0.17350000E 03        0.12850000E 05        0.13034330E 05            -1.4345             74.0634
0.10350000E 03        0.92400000E 04        0.92190740E 04             0.2265             89.2754
       AVERAGE DEVIATION =          0.94516990 %                DEGREE  =  1
```

```
                              ARGON 655  0.55

               LEAST SQUARES POLY COEFF. ARE:

                  A(   0)=     0.64635190E 04
                  A(   1)=    -0.69865600E 02
                  A(   2)=     0.17493620E 01
                  A(   3)=    -0.84832570E-02
                  A(   4)=     0.13192640E-04

    DELTA T            HEAT FLUX          CALC. HEAT FLUX     % DEVIATION            H

0.27850000E 03     0.18850000E 05     0.18858420E 05        -0.0447          67.6840
0.26450000E 03     0.17900000E 05     0.17889560E 05         0.0583          67.6749
0.20450000E 03     0.15900000E 05     0.15881000E 05         0.1194          77.7506
0.18000000E 03     0.14930000E 05     0.14970620E 05        -0.2721          82.9444
0.13100000E 03     0.12120000E 05     0.12087750E 05         0.2660          92.5191
0.10150000E 03     0.99400000E 04     0.99526360E 04        -0.1271          97.9310

      AVERAGE DEVIATION =      0.14795320 %          DEGREE = 4
```

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                                                  ARGON 56 0.75

                              LEAST SQUARES POLY COEFF. ARE:

                                A(   0)=      0.79332460E 04
                                A(   1)=      0.29753260E 01
                                A(   2)=      0.37194630E-01

      DELTA T               HEAT FLUX            CALC. HEAT FLUX       % DEVIATION              H

 0.31200000E 03        0.13850000E 05        0.12491510E 05            9.8085             44.3910
 0.33000000E 03        0.13850000E 05        0.12959720E 05            6.4280             41.9697
 0.34200000E 03        0.13850000E 05        0.13280370E 05            4.1128             40.4971
 0.28250000E 03        0.12400000E 05        0.11760650E 05            5.1560             43.8938
 0.29200000E 03        0.12400000E 05        0.11990770E 05            3.3002             42.4657
 0.30500000E 03        0.12400000E 05        0.12313820E 05            0.6949             40.6557
 0.26300000E 03        0.11650000E 05        0.11305000E 05            2.9613             44.2966
 0.26900000E 03        0.11650000E 05        0.11442730E 05            1.7791             43.3086
 0.28000000E 03        0.11650000E 05        0.11700960E 05           -0.4374             41.6071
 0.21100000E 03        0.10000000E 05        0.10212050E 05           -2.1205             47.3934
 0.21200000E 03        0.10000000E 05        0.10231240E 05           -2.3125             47.1698
 0.22350000E 03        0.10000000E 05        0.10457380E 05           -4.5739             44.7427
 0.15150000E 03        0.88700000E 04        0.92144100E 04           -3.8829             58.5479
 0.15100000E 03        0.88700000E 04        0.92073120E 04           -3.8028             58.7417
 0.16600000E 03        0.88700000E 04        0.94300930E 04           -6.3145             53.4337
 0.81000000E 02        0.81000000E 04        0.84492570E 04           -4.3118            100.0000
 0.78000000E 02        0.81000000E 04        0.84279100E 04           -4.0483            103.8461
 0.88000000E 02        0.81000000E 04        0.85028000E 04           -4.9728             92.0454
 0.27700000E 03        0.11500000E 05        0.11629810E 05           -1.1288             41.5162
 0.30300000E 03        0.11500000E 05        0.12263530E 05           -6.6394             37.9538
 0.23100000E 03        0.10730000E 05        0.10610070E 05            1.1177             46.4502
 0.24800000E 03        0.10730000E 05        0.10970730E 05           -2.2436             43.2661
 0.19300000E 03        0.10150000E 05        0.98796480E 04            2.6636             52.5907
 0.21200000E 03        0.10150000E 05        0.10231240E 05           -0.8005             47.8773
 0.14800000E 03        0.96500000E 04        0.91651640E 04            5.0242             65.2027
 0.16900000E 03        0.96500000E 04        0.94770190E 04            1.7925             57.1006
 0.10700000E 03        0.93100000E 04        0.86739450E 04            6.8319             87.0093
 0.12550000E 03        0.93100000E 04        0.88755970E 04            4.6660             74.1833
 0.31700000E 03        0.12720000E 05        0.12619960E 05            0.7864             40.1262
 0.33800000E 03        0.12720000E 05        0.13172770E 05           -3.5595             37.6331
 0.34500000E 03        0.12900000E 05        0.13361540E 05           -3.5779             37.3913
 0.35550000E 03        0.12900000E 05        0.13648640E 05           -5.8034             36.2869
 0.29200000E 03        0.11800000E 05        0.11990770E 05           -1.6167             40.4109
 0.30000000E 03        0.11800000E 05        0.12188490E 05           -3.2923             39.3333
 0.25550000E 03        0.10750000E 05        0.11136040E 05           -3.5911             42.0744
 0.26200000E 03        0.10750000E 05        0.11282270E 05           -4.9514             41.0305
 0.18000000E 03        0.97500000E 04        0.96556170E 04            0.9680             54.1667
 0.18550000E 03        0.97500000E 04        0.97487140E 04            0.0132             52.5606
 0.10600000E 03        0.91200000E 04        0.86640150E 04            4.9998             86.0377
 0.11400000E 03        0.91200000E 04        0.87462690E 04            4.0979             80.0000

           AVERAGE DEVIATION =        3.52059800 %                DEGREE = 2
```

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                                    ARGON 111 0.75

                  LEAST SQUARES POLY COEFF. ARE:

                       A(   0)=     0.99140540E 04
                       A(   1)=     0.33258050E 00
                       A(   2)=     0.40793440E-01

      DELTA T            HEAT FLUX          CALC. HEAT FLUX     % DEVIATION            H

  0.29900000E 03     0.14000000E 05     0.13663860E 05          2.4010          46.8227
  0.32000000E 03     0.14000000E 05     0.14173410E 05         -1.2387          43.7500
  0.25500000E 03     0.12910000E 05     0.12672290E 05          1.8413          50.6274
  0.27600000E 03     0.12910000E 05     0.13131550E 05         -1.7161          46.7754
  0.19700000E 03     0.11610000E 05     0.11561740E 05          0.4157          58.9340
  0.21800000E 03     0.11610000E 05     0.11934640E 05         -2.7962          53.2569
  0.16000000E 03     0.11200000E 05     0.10996330E 05          1.8184          70.0000
  0.17850000E 03     0.11200000E 05     0.11263700E 05         -0.5688          62.7451
  0.90000000E 02     0.10300000E 05     0.10298000E 05          0.0193         114.4444
  0.10800000E 03     0.10300000E 05     0.10426680E 05         -1.2300          95.3704
  0.12300000E 03     0.10700000E 05     0.10561820E 05          1.2914          86.9919
  0.14100000E 03     0.10700000E 05     0.10755820E 05         -0.5218          75.8865

        AVERAGE DEVIATION =      1.32155200 %          DEGREE = 2
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                                                  ARGON 197 0.75

                              LEAST SQUARES POLY COEFF. ARE:

                                A(   0)=      0.82658710E 04
                                A(   1)=      0.11905700E 02
                                A(   2)=      0.44593140E-01
    DELTA T                   HEAT FLUX            CALC. HEAT FLUX       % DEVIATION              H

 0.27400000E 03         0.15600000E 05         0.14871100E 05             4.6724           56.9343
 0.29100000E 03         0.15600000E 05         0.15563360E 05             0.2348           53.6082
 0.29950000E 03         0.15600000E 05         0.15930870E 05            -2.1210           52.0868
 0.25300000E 03         0.14480000E 05         0.14088300E 05             2.7051           57.2332
 0.25900000E 03         0.14480000E 05         0.14304290E 05             1.2134           55.9073
 0.27200000E 03         0.14480000E 05         0.14793230E 05            -2.1632           53.2353
 0.20800000E 03         0.12310000E 05         0.12638000E 05            -2.6646           59.1827
 0.20800000E 03         0.12310000E 05         0.12638000E 05            -2.6646           59.1827
 0.21700000E 03         0.12310000E 05         0.12906440E 05            -4.8452           56.7281
 0.16200000E 03         0.11100000E 05         0.11395420E 05            -2.6615           68.5185
 0.16000000E 03         0.11100000E 05         0.11345370E 05            -2.2106           69.3750
 0.16800000E 03         0.11100000E 05         0.11547230E 05            -4.0291           66.0714
 0.11350000E 03         0.10030000E 05         0.10238690E 05            -2.0807           88.3700
 0.10850000E 03         0.10030000E 05         0.10123840E 05            -0.9357           92.4424
 0.11950000E 03         0.10030000E 05         0.10377120E 05            -3.4608           83.9330
 0.75500000E 02         0.92900000E 04         0.93679250E 04            -0.8388          123.0463
 0.68500000E 02         0.92900000E 04         0.92058900E 04             0.9054          135.6204
 0.79500000E 02         0.92900000E 04         0.94600350E 04            -1.8303          116.8553
 0.25700000E 03         0.14650000E 05         0.14231640E 05             2.8557           57.0039
 0.27750000E 03         0.14650000E 05         0.15009140E 05            -2.4515           52.7928
 0.22900000E 03         0.13250000E 05         0.13280150E 05            -0.2276           57.8603
 0.22600000E 03         0.13250000E 05         0.13184950E 05             0.4909           58.6283
 0.18600000E 03         0.12500000E 05         0.12019510E 05             3.8439           67.2043
 0.20550000E 03         0.12500000E 05         0.12565120E 05            -0.5210           60.8272
 0.15350000E 03         0.11800000E 05         0.11184490E 05             5.2162           76.8730
 0.17250000E 03         0.11800000E 05         0.11662820E 05             1.1625           68.4058
 0.11850000E 03         0.11110000E 05         0.10353990E 05             6.8047           93.7553
 0.13600000E 03         0.11110000E 05         0.10762940E 05             3.1238           81.6912
        AVERAGE DEVIATION =         2.46135700 %            DEGREE = 2
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                                                  ARGON 338 0.75

                              LEAST SQUARES POLY COEFF. ARE:

                                 A(   0)=       0.71669450E 04
                                 A(   1)=       0.22096740E 02
                                 A(   2)=       0.39600960E-01
    DELTA T                    HEAT FLUX               CALC. HEAT FLUX        % DEVIATION                H

0.24500000E 03            0.15650000E 05           0.14960730E 05               4.4042               63.8775
0.25700000E 03            0.15650000E 05           0.15435290E 05               1.3719               60.8949
0.26450000E 03            0.15650000E 05           0.15731000E 05              -0.5176               59.1682
0.22950000E 03            0.15200000E 05           0.14347840E 05               5.6063               66.2309
0.23300000E 03            0.15200000E 05           0.14486050E 05               4.6970               65.2360
0.24200000E 03            0.15200000E 05           0.14842000E 05               2.3552               62.8099
0.20600000E 03            0.13480000E 05           0.13427250E 05               0.3913               65.4369
0.20700000E 03            0.13480000E 05           0.13466050E 05               0.1034               65.1208
0.21300000E 03            0.13480000E 05           0.13699710E 05              -1.6300               63.2864
0.16800000E 03            0.12110000E 05           0.11993140E 05               0.9650               72.0833
0.16700000E 03            0.12110000E 05           0.11956750E 05               1.2654               72.5150
0.17500000E 03            0.12110000E 05           0.12250120E 05              -1.1571               69.2000
0.13600000E 03            0.10550000E 05           0.10875580E 05              -3.0861               77.5735
0.13850000E 03            0.10550000E 05           0.10959020E 05              -3.8770               76.1733
0.14200000E 03            0.10550000E 05           0.11077040E 05              -4.9957               74.2958
0.80000000E 02            0.92000000E 04           0.92303000E 04              -0.3294              115.0000
0.85000000E 02            0.92000000E 04           0.93573120E 04              -1.7099              108.2352
0.89500000E 02            0.92000000E 04           0.94753160E 04              -2.9926              102.7932
0.24550000E 03            0.14810000E 05           0.14980520E 05              -1.1514               60.3259
0.25900000E 03            0.14810000E 05           0.15514250E 05              -4.7553               57.1815
0.22650000E 03            0.14000000E 05           0.14229540E 05              -1.6396               61.8102
0.24100000E 03            0.14000000E 05           0.14802420E 05              -5.7316               58.0913
0.19000000E 03            0.12900000E 05           0.12812690E 05               0.6768               67.8947
0.20600000E 03            0.12900000E 05           0.13427250E 05              -4.0872               62.6214
0.14200000E 03            0.12000000E 05           0.11077040E 05               7.6913               84.5070
0.15650000E 03            0.12000000E 05           0.11579920E 05               3.5006               76.6773
0.11050000E 03            0.10870000E 05           0.10069310E 05               7.3660               98.3710
0.12650000E 03            0.10870000E 05           0.10565320E 05               2.8029               85.9289
0.15650000E 03            0.11300000E 05           0.11579920E 05              -2.4773               72.2045
0.17150000E 03            0.11300000E 05           0.12121150E 05              -7.2668               65.8892
         AVERAGE DEVIATION =       3.02025400 %                DEGREE = 2
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                                               ARGON 550 0.75

                         LEAST SQUARES POLY COEFF. ARE:

                            A(   0)=     0.22166360E 05
                            A(   1)=    -0.35816600E 03
                            A(   2)=     0.30832030E 01
                            A(   3)=    -0.93647390E-02
                            A(   4)=     0.95635920E-05
    DELTA T                HEAT FLUX            CALC. HEAT FLUX       % DEVIATION                  H

0.21250000E 03        0.16300000E 05        0.14919850E 05           8.4671                 76.7059
0.23500000E 03        0.16300000E 05        0.15856790E 05           2.7190                 69.3617
0.24050000E 03        0.16300000E 05        0.16042170E 05           1.5817                 67.7755
0.19950000E 03        0.14550000E 05        0.14237920E 05           2.1448                 72.9323
0.20500000E 03        0.14550000E 05        0.14538670E 05           0.0778                 70.9756
0.20950000E 03        0.14550000E 05        0.14771440E 05          -1.5229                 69.4511
0.17400000E 03        0.13310000E 05        0.12654940E 05           4.9216                 76.4942
0.17700000E 03        0.13310000E 05        0.12853280E 05           3.4313                 75.1977
0.18100000E 03        0.13310000E 05        0.13113970E 05           1.4728                 73.5359
0.14400000E 03        0.11400000E 05        0.10661230E 05           6.4804                 79.1667
0.14600000E 03        0.11400000E 05        0.10788250E 05           5.3662                 78.0822
0.15050000E 03        0.11400000E 05        0.11079870E 05           2.8081                 75.7475
0.57000000E 02        0.10000000E 05        0.10142570E 05          -1.4257                175.4385
0.59000000E 02        0.10000000E 05        0.99711910E 04           0.2881                169.4915
0.61500000E 02        0.10000000E 05        0.97735930E 04           2.2641                162.6016
0.25200000E 03        0.16600000E 05        0.16388490E 05           1.2747                 65.8730
0.26450000E 03        0.16600000E 05        0.16729260E 05          -0.7787                 62.7599
0.22500000E 03        0.15260000E 05        0.15477940E 05          -1.4282                 67.8222
0.23600000E 03        0.15260000E 05        0.15891580E 05          -4.1389                 64.6610
0.20000000E 03        0.13650000E 05        0.14265960E 05          -4.5126                 68.2500
0.21050000E 03        0.13650000E 05        0.14821530E 05          -8.5827                 64.8456
0.16200000E 03        0.11200000E 05        0.11848190E 05          -5.7875                 69.1358
0.16700000E 03        0.11200000E 05        0.12185800E 05          -8.8016                 67.0659
0.13650000E 03        0.10150000E 05        0.10203560E 05          -0.5277                 74.3590
0.14500000E 03        0.10150000E 05        0.10724510E 05          -5.6603                 70.0000
0.10500000E 03        0.97100000E 04        0.98385540E 04          -1.4752                 [illegible]
0.11200000E 03        0.97100000E 04        0.10373550E 04          [illegible]             [illegible]

              AVERAGE DEVIATION             [illegible]
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                                              ARGON 620 0.75

                        LEAST SQUARES POLY COFFF. ARE:

                          A(   0)=     0.80396670E 04
                          A(   1)=    -0.56465190E 02
                          A(   2)=     0.80603480E 00
                          A(   3)=    -0.17606840E-02
    DELTA T                HEAT FLUX              CALC. HEAT FLUX        % DEVIATION                  H

0.24300000E 03         0.17300000E 05         0.16635170E 05             3.8429                71.1934
0.24850000E 03         0.17300000E 05         0.16770270E 05             3.0620                69.6177
0.19900000E 03         0.16180000E 05         0.14842570E 05             8.2659                81.3065
0.21600000E 03         0.16180000E 05         0.15675800E 05             3.1161                74.9074
0.21950000E 03         0.16180000E 05         0.15826680E 05             2.1836                73.7130
0.18450000E 03         0.14600000E 05         0.14016760E 05             3.9948                79.1328
0.18800000E 03         0.14600000E 05         0.14224500E 05             2.5719                77.6596
0.19200000E 03         0.14600000E 05         0.14455640E 05             0.9887                76.0417
0.15700000E 03         0.12950000E 05         0.12251330E 05             5.3951                82.4841
0.15800000E 03         0.12950000E 05         0.12318330E 05             4.8777                81.9620
0.16200000E 03         0.12950000E 05         0.12585040E 05             2.8182                79.9383
0.12200000E 03         0.10770000E 05         0.99301670E 04             7.7979                88.2787
0.12400000E 03         0.10770000E 05         0.10056410E 05             6.6256                86.8548
0.12900000E 03         0.10770000E 05         0.10377800E 05             3.6415                83.4884
0.86000000E 02         0.84500000E 04         0.80460620E 04             4.7803                98.2558
0.88000000E 02         0.84500000E 04         0.81241640E 04             3.8560                96.0227
0.91000000E 02         0.84500000E 04         0.82486280E 04             2.3831                92.8571
0.24850000E 03         0.16650000E 05         0.16770270E 05            -0.7224                67.0020
0.25650000E 03         0.16650000E 05         0.16928900E 05            -1.6751                64.9123
0.22150000E 03         0.15100000E 05         0.15909460E 05            -5.3607                68.1716
0.23100000E 03         0.15100000E 05         0.16268000E 05            -7.7352                65.3680
0.18400000E 03         0.13120000E 05         0.13986690E 05            -6.6059                71.3043
0.19200000E 03         0.13120000E 05         0.14455640E 05           -10.1802                68.3333
0.15400000E 03         0.11500000E 05         0.12049730E 05            -4.7803                74.6753
0.16200000E 03         0.11500000E 05         0.12585040E 05            -9.4352                70.9876
0.11850000E 03         0.90500000E 04         0.97129290E 04            -7.3252                76.3713
0.12450000E 03         0.90500000E 04         0.10088200E 05           -11.4719                72.6908
0.91000000E 02         0.78100000E 04         0.82486280E 04            -5.6162                85.8242
0.97000000E 02         0.78100000E 04         0.85219680E 04            -9.1161                80.5155
          AVERAGE DEVIATION =        5.18018000 %           DEGREE = 3
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                              ARGON 655 0.75

               LEAST SQUARES POLY COEFF. ARE:

                  A(   0)=     0.18617710E 05
                  A(   1)=    -0.24545120E 03
                  A(   2)=     0.19178260E 01
                  A(   3)=    -0.40268450E-02

   DELTA T            HEAT FLUX          CALC. HEAT FLUX      % DEVIATION          4

0.23300000E 03     0.17100000E 05     0.14678120E 05         14.1630          73.3995
0.23750000E 03     0.17100000E 05     0.14620210E 05         14.5016          72.0000
0.18400000E 03     0.15980000E 05     0.13261200E 05         17.0137          86.8478
0.19900000E 03     0.15980000E 05     0.13983520E 05         12.4936          80.3015
0.21400000E 03     0.15980000E 05     0.14497090E 05          9.2798          74.6729
0.17250000E 03     0.14500000E 05     0.12626600E 05         12.9199          84.0580
0.17600000E 03     0.14500000E 05     0.12824320E 05         11.5564          82.3864
0.18000000E 03     0.14500000E 05     0.13045880E 05         10.0284          80.5555
0.14300000E 03     0.12410000E 05     0.10956370E 05         11.7134          86.7832
0.14450000E 03     0.12410000E 05     0.11036810E 05         11.0652          85.8823
0.14700000E 03     0.12410000E 05     0.11172770E 05          9.9696          84.4218
0.11300000E 03     0.10520000E 05     0.96123320E 04          8.6280          93.0973
0.11400000E 03     0.10520000E 05     0.96469250E 04          8.2992          92.2807
0.11650000E 03     0.10520000E 05     0.97369720E 04          7.4432          90.3004
0.92000000E 02     0.92000000E 04     0.90922650E 04          1.1710         100.0000
0.92000000E 02     0.92000000E 04     0.90922650E 04          1.1710         100.0000
0.94000000E 02     0.92000000E 04     0.91237690E 04          0.8286          97.8723
0.25650000E 03     0.13550000E 05     0.13828360E 05         -2.0543          52.8265
0.26000000E 03     0.13550000E 05     0.13571360E 05         -0.1577          52.1154
0.23350000E 03     0.12610000E 05     0.14673830E 05        -16.3666          54.0043
0.23800000E 03     0.12610000E 05     0.14611020E 05        -15.8686          52.9832
0.19700000E 03     0.10970000E 05     0.13897060E 05        -26.6824          55.6853
0.20250000E 03     0.10970000E 05     0.14125810E 05        -28.7677          54.1728
0.17500000E 03     0.96200000E 04     0.12768140E 05        -32.7250          54.9714
0.17900000E 03     0.96200000E 04     0.12991010E 05        -35.0418          53.7430
0.12200000E 03     0.70100000E 04     0.99522420E 04        -41.9721          57.4590
0.12600000E 03     0.70100000E 04     0.10122720E 05        -44.4041          55.6349

      AVERAGE DEVIATION =     15.04760000 %          DEGREE = 3
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                                                    ARGON 56 0.95

                              LEAST SQUARES POLY COEFF. ARE:

                                 A(   0)=     0.59876210E 04
                                 A(   1)=     0.27805370E 02
    DELTA T
                           HEAT FLUX              CALC. HEAT FLUX      % DEVIATION                 H
0.30650000E 03         0.13100000E 05         0.14470040E 05          -10.4584               42.7406
0.21700000E 03         0.13100000E 05         0.12084140E 05            7.7546               60.3687
0.23800000E 03         0.13100000E 05         0.12660080E 05            3.3581               55.0420
0.28200000E 03         0.12280000E 05         0.13834760E 05          -12.6610               43.5461
0.19550000E 03         0.12280000E 05         0.11484250E 05            6.4800               62.8133
0.21450000E 03         0.12280000E 05         0.12014920E 05            2.1586               57.2494
0.25450000E 03         0.11400000E 05         0.13105670E 05          -14.9621               44.7937
0.17600000E 03         0.11400000E 05         0.10931210E 05            4.1121               64.7727
0.19300000E 03         0.11400000E 05         0.11413830E 05           -0.1213               59.0674
0.22000000E 03         0.96500000E 04         0.12167020E 05          -26.0832               43.8636
0.14650000E 03         0.96500000E 04         0.10078360E 05           -4.4390               65.8703
0.16300000E 03         0.96500000E 04         0.10557780E 05           -9.4071               59.2025
0.15100000E 03         0.81200000E 04         0.10209710E 05          -25.7354               53.7748
0.87000000E 02         0.81200000E 04         0.82988710E 04           -2.2028               93.3333
0.11100000E 03         0.81200000E 04         0.90261910E 04          -11.1600               73.1532
0.95500000E 02         0.73000000E 04         0.85579370E 04          -17.2320               76.4398
0.51000000E 02         0.73000000E 04         0.71836790E 04            1.5934              143.1372
0.78000000E 02         0.73000000E 04         0.80227920E 04           -9.9013               93.5897
0.15000000E 03         0.82500000E 04         0.10180560E 05          -23.4008               55.0000
0.10000000E 03         0.82500000E 04         0.86944410E 04           -5.3872               82.5000
0.12500000E 03         0.82500000E 04         0.94445030E 04          -14.4788               66.0000
0.17900000E 03         0.10180000E 05         0.11016850E 05           -8.2205               56.8715
0.12800000E 03         0.10180000E 05         0.95335740E 04            6.3500               79.5313
0.14950000E 03         0.10180000E 05         0.10165980E 05            0.1377               68.0936
0.21450000E 03         0.10900000E 05         0.12014920E 05          -10.2287               50.8158
0.16450000E 03         0.10900000E 05         0.10601060E 05            2.7425               66.2614
0.17300000E 03         0.10900000E 05         0.10845370E 05            0.5011               63.0058
0.24800000E 03         0.11500000E 05         0.12930860E 05          -12.4423               46.3710
0.17200000E 03         0.11500000E 05         0.10816710E 05            5.9416               66.8605
0.19000000E 03         0.11500000E 05         0.11329130E 05            1.4859               60.5263
0.26350000E 03         0.11820000E 05         0.13346150E 05          -12.9116               44.8577
0.18350000E 03         0.11820000E 05         0.11144920E 05            5.7113               64.4142
0.20100000E 03         0.11820000E 05         0.11638700E 05            1.5338               58.8060
0.36200000E 03         0.16580000E 05         0.15859400E 05            4.3462               45.8011
0.36450000E 03         0.16580000E 05         0.15920360E 05            3.9785               45.4870
0.31750000E 03         0.15300000E 05         0.14750900E 05            3.5889               48.1890
0.32050000E 03         0.15300000E 05         0.14827020E 05            3.0913               47.7379
0.28150000E 03         0.14380000E 05         0.13821660E 05            3.8828               51.0835
0.28400000E 03         0.14380000E 05         0.13887120E 05            3.4275               50.6338
0.24250000E 03         0.13750000E 05         0.12782210E 05            7.0384               56.7010
0.24450000E 03         0.13750000E 05         0.12863850E 05            6.4447               56.2372
0.13950000E 03         0.12400000E 05         0.98731250E 04           20.3780               88.8889
0.14200000E 03         0.12400000E 05         0.99465500E 04           19.7859               87.3239
0.15450000E 03         0.13350000E 05         0.10207130E 05          [illegible]            86.4078
0.15800000E 03         0.13350000E 05         0.1041[illegible]E 05   [illegible]            84.4937

            AVERAGE DEVIATION             0.[illegible]                 [illegible]
```

```
                                   ARGON 197 0.95

                  LEAST SQUARES POLY COEFF. ARE:

                    A(   0)=     0.73203940E 04
                    A(   1)=     0.38644400E 02
   DELTA T
                     HEAT FLUX          CALC. HEAT FLUX      % DEVIATION                H
0.28100000E 03   0.16300000E 05    0.17896790E 05      -9.7963          58.0071
0.20100000E 03   0.16300000E 05    0.15315430E 05       6.0403          81.0945
0.21800000E 03   0.16300000E 05    0.15919010E 05       2.3373          74.7706
0.24750000E 03   0.14650000E 05    0.16895910E 05     -15.3305          59.1919
0.17800000E 03   0.14650000E 05    0.14451530E 05       1.3547          82.3034
0.19250000E 03   0.14650000E 05    0.15002500E 05      -2.4061          76.1039
0.21800000E 03   0.13300000E 05    0.15919010E 05     -19.6919          61.0092
0.15350000E 03   0.13300000E 05    0.13471480E 05      -1.2893          86.6449
0.16550000E 03   0.13300000E 05    0.13959210E 05      -4.9565          80.3625
0.17400000E 03   0.11500000E 05    0.14295740E 05     -24.3108          66.0919
0.11950000E 03   0.11500000E 05    0.12009170E 05      -4.4276          96.2343
0.13150000E 03   0.11500000E 05    0.12538850E 05      -9.0335          87.4525
0.12200000E 03   0.10300000E 05    0.12120750E 05     -17.6772          84.4262
0.82000000E 02   0.10300000E 05    0.10258540E 05       0.4025         125.6097
0.95000000E 02   0.10300000E 05    0.10881800E 05      -5.6486         109.4210
0.78000000E 02   0.92800000E 04    0.10063270E 05      -8.4405         118.9743
0.52000000E 02   0.92800000E 04    0.87539570E 04       5.6686         178.4615
0.65500000E 02   0.92800000E 04    0.94424680E 04      -1.7507         141.6793
0.29200000E 03   0.18900000E 05    0.18200290E 05       3.7022          64.7260
0.29550000E 03   0.18900000E 05    0.18294250E 05       3.2050          63.9594
0.27350000E 03   0.18300000E 05    0.17682740E 05       3.3730          66.9104
0.27700000E 03   0.18300000E 05    0.17783350E 05       2.8232          66.0650
0.25250000E 03   0.17450000E 05    0.17052620E 05       2.2772          69.1089
0.25600000E 03   0.17450000E 05    0.17160790E 05       1.6573          68.1641
0.21200000E 03   0.16600000E 05    0.15709380E 05       5.3652          78.3019
0.21700000E 03   0.16600000E 05    0.15884330E 05       4.3112          76.4977
0.17800000E 03   0.15850000E 05    0.14451530E 05       8.8231          89.0449
0.18100000E 03   0.15850000E 05    0.14567300E 05       8.0927          87.5690
0.13450000E 03   0.15500000E 05    0.12668960E 05      18.2647         115.2416
0.13150000E 03   0.15500000E 05    0.12538850E 05      19.1041         117.8707
        AVERAGE DEVIATION =        7.38539100 %
                                                   DEGREE  =  1
```

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                              ARGON 338 0.95

                LEAST SQUARES POLY COEFF. ARE:

                  A(   0)=     0.13454340E 05
                  A(   1)=    -0.23039130E 02
                  A(   2)=     0.23755780E 00
                  A(   3)=    -0.29956500E-03

   DELTA T           HEAT FLUX         CALC. HEAT FLUX     % DEVIATION          H

0.28700000E 03    0.19300000E 05    0.19332760E 05        -0.1698         67.2474
0.25500000E 03    0.18200000E 05    0.18045280E 05         0.8501         71.3725
0.25750000E 03    0.18200000E 05    0.18142910E 05         0.3137         70.6796
0.22300000E 03    0.17000000E 05    0.17049370E 05        -0.2905         74.2358
0.23050000E 03    0.17000000E 05    0.17105980E 05        -0.6234         73.7527
0.17250000E 03    0.15000000E 05    0.15020290E 05        -0.1353         86.9565
0.17500000E 03    0.15000000E 05    0.15103710E 05        -0.6914         85.7143
0.15450000E 03    0.14500000E 05    0.14449810E 05         0.3461         93.8511
0.15200000E 03    0.14500000E 05    0.14375510E 05         0.8585         95.3947
0.11050000E 03    0.13400000E 05    0.13408870E 05        -0.0662        121.2669
0.11200000E 03    0.13400000E 05    0.13432650E 05        -0.2437        119.6428
0.28700000E 03    0.19300000E 05    0.19332760E 05        -0.1698         67.2474

     AVERAGE DEVIATION =     0.39653610 %          DEGREE = 3
```

```
                              ARGON 550 0.95

              LEAST SQUARES POLY COEFF. ARE:

                 A(   0)=     0.38543080E 04
                 A(   1)=     0.69499350E 02
                 A(   2)=    -0.59129100E-01

   DELTA T              HEAT FLUX           CALC. HEAT FLUX     % DEVIATION              H

0.24050000E 03     0.17800000E 05     0.17167460E 05          3.5536           74.0125
0.20900000E 03     0.17800000E 05     0.15836420E 05         11.0313           85.1674
0.22150000E 03     0.17800000E 05     0.16385380E 05          7.9473           80.3612
0.20000000E 03     0.15230000E 05     0.15425390E 05         -1.2830           76.1500
0.16700000E 03     0.15230000E 05     0.13816410E 05          9.2816           91.1976
0.19450000E 03     0.15230000E 05     0.15168030E 05          0.4069           78.3033
0.14500000E 03     0.12500000E 05     0.12666180E 05         -1.3295           86.2069
0.11850000E 03     0.12500000E 05     0.11213650E 05         10.2907          105.4852
0.14100000E 03     0.12500000E 05     0.12451280E 05          0.3897           88.6525
0.99000000E 02     0.98200000E 04     0.10107000E 05         -2.9226           99.1919
0.79000000E 02     0.98200000E 04     0.89463160E 04          8.8970          124.3037
0.96500000E 02     0.98200000E 04     0.99631950E 04         -1.4582          101.7616
0.58000000E 02     0.71400000E 04     0.77072960E 04         -7.9453          123.1034
0.42000000E 02     0.71400000E 04     0.67542690E 04          5.4024          170.0000
0.57000000E 02     0.71400000E 04     0.76479140E 04         -7.1136          125.2631
0.17300000E 03     0.14010000E 05     0.14120000E 05         -0.7852           80.9827
0.14500000E 03     0.14010000E 05     0.12666180E 05          9.5918           96.6207
0.17350000E 03     0.14010000E 05     0.14145100E 05         -0.9643           80.7493
0.27250000E 03     0.18250000E 05     0.18326690E 05         -0.4202           66.9725
0.27150000E 03     0.18250000E 05     0.18293690E 05         -0.2394           67.2191
0.24100000E 03     0.16700000E 05     0.17187140E 05         -2.9171           69.2946
0.24200000E 03     0.16700000E 05     0.17226370E 05         -3.1519           69.0083
0.21250000E 03     0.15320000E 05     0.15992750E 05         -4.3914           72.0941
0.21500000E 03     0.15320000E 05     0.16103180E 05         -5.1122           71.2559
0.18300000E 03     0.13700000E 05     0.14615480E 05         -6.6824           74.8634
0.18500000E 03     0.13700000E 05     0.14712930E 05         -7.3937           74.0540
0.15500000E 03     0.12350000E 05     0.13195910E 05         -6.8495           79.6774
0.15800000E 03     0.12350000E 05     0.13352640E 05         -8.1186           78.1646
0.12550000E 03     0.11200000E 05     0.11603620E 05         -3.6038           89.2430
0.12800000E 03     0.11200000E 05     0.11741860E 05         -4.8381           87.5000

          AVERAGE DEVIATION =       4.81040410 %            DEGREE = 2
```

```
                              ARGON     620 PSIG      .95"

                  LEAST SQUARES POLY COEFF. ARE:

                    A(   0)=      0.33987690E 04
                    A(   1)=      0.59037060E 02

   DELTA T              HEAT FLUX            CALC. HEAT FLUX     % DEVIATION              H

0.23950000E 03      0.15800000E 05      0.17538770E 05        -11.0049             65.9708
0.20650000E 03      0.15800000E 05      0.15669870E 05          0.8236             76.5133
0.24200000E 03      0.15800000E 05      0.17678330E 05        -11.8882             65.2893
0.21000000E 03      0.14500000E 05      0.15870440E 05         -9.4513             69.0476
0.17700000E 03      0.14500000E 05      0.13957150E 05          3.7438             81.9209
0.21500000E 03      0.14500000E 05      0.16156000E 05        -11.4207             67.4418
0.17200000E 03      0.12300000E 05      0.13662920E 05        -11.0807             71.5116
0.14400000E 03      0.12300000E 05      0.11994210E 05          2.4861             85.4167
0.17500000E 03      0.12300000E 05      0.13839600E 05        -12.5171             70.2857
0.12800000E 03      0.10300000E 05      0.11024610E 05         -7.0351             80.4688
0.10300000E 03      0.10300000E 05      0.94862420E 04          7.9006            100.0000
0.13050000E 03      0.10300000E 05      0.11176880E 05         -8.5134             78.9272
0.91000000E 02      0.81400000E 04      0.87377030E 04         -7.3428             89.4505
0.73000000E 02      0.81400000E 04      0.76025850E 04          6.6021            111.5068
0.96000000E 02      0.81400000E 04      0.90503940E 04        -11.1842             84.7917
0.58000000E 02      0.61400000E 04      0.66453750E 04         -8.2309            105.8620
0.45000000E 02      0.61400000E 04      0.58074880E 04          5.4155            136.4444
0.62000000E 02      0.61400000E 04      0.69016320E 04        -12.4044             99.0323
0.31400000E 03      0.21200000E 05      0.21575390E 05         -1.7707             67.5159
0.27950000E 03      0.21200000E 05      0.19737550E 05          6.8983             75.8497
0.26200000E 03      0.19400000E 05      0.18784550E 05          3.1724             74.0458
0.25300000E 03      0.19400000E 05      0.18289010E 05          5.7267             76.6798
0.22950000E 03      0.17900000E 05      0.16977680E 05          5.1526             77.9956
0.22800000E 03      0.17900000E 05      0.16893120E 05          5.6250             78.5088
0.18950000E 03      0.15400000E 05      0.14687720E 05          4.6252             81.2665
0.19100000E 03      0.15400000E 05      0.14774910E 05          4.0590             80.6283
0.14950000E 03      0.13400000E 05      0.12324810E 05          8.0238             89.6321
0.15050000E 03      0.13400000E 05      0.12384780E 05          7.5763             89.0365
0.12800000E 03      0.12600000E 05      0.11024610E 05         12.5031             98.4375
0.12900000E 03      0.12600000E 05      0.11085550E 05         12.0194             97.6744

          AVERAGE DEVIATION -      7.53991700 %          DEGREE = 1
```

```
                              ARGON 655.8 0.95

                 LEAST SQUARES POLY COEFF. ARE:

                   A(   0)=    -0.14558320E 04
                   A(   1)=     0.91204800E 02
                   A(   2)=     0.15705710E 00
                   A(   3)=    -0.24554800E-02
                   A(   4)=     0.59687570E-05

     DELTA T            HEAT FLUX          CALC. HEAT FLUX      % DEVIATION            H

  0.24200000E 03     0.12500000E 05     0.15122040E 05        -20.9763            51.6529
  0.22600000E 03     0.12500000E 05     0.14182640E 05        -13.4611            55.3097
  0.24000000E 03     0.12500000E 05     0.14982830E 05        -19.8627            52.0833
  0.20600000E 03     0.11100000E 05     0.13344090E 05        -20.2170            53.9835
 -0.18900000E 03     0.11100000E 05     0.11100180E 05         -0.0017           -58.7301
  0.20350000E 03     0.11100000E 05     0.13248870E 05        -19.3593            54.5454
  0.16500000E 03     0.95400000E 04     0.11580990E 05        -21.3941            57.8182
  0.15200000E 03     0.95400000E 04     0.10839690E 05        -13.6236            62.7632
  0.16300000E 03     0.95400000E 04     0.11474000E 05        -20.2726            58.5276
  0.12300000E 03     0.73500000E 04     0.88216640E 04        -20.0226            59.7561
  0.11300000E 03     0.73500000E 04     0.80392340E 04         -9.3773            65.0442
  0.12200000E 03     0.73500000E 04     0.87448240E 04        -18.9772            60.2459
  0.86000000E 02     0.55700000E 04     0.58793280E 04         -5.5535            64.7674
  0.79000000E 02     0.55700000E 04     0.53434840E 04          4.0667            70.5063
  0.85000000E 02     0.55700000E 04     0.58015620E 04         -4.1573            65.5294
  0.49500000E 02     0.34000000E 04     0.34487580E 04         -1.4341            68.6869
  0.47000000E 02     0.34000000E 04     0.33269130E 04          2.1496            72.3404
  0.49000000E 02     0.34000000E 04     0.34237960E 04         -0.6999            69.3877
  0.27900000E 03     0.18800000E 05     0.19765180E 05         -5.1340            67.3835
  0.26450000E 03     0.18800000E 05     0.17364460E 05          7.6358            71.0775
  0.25300000E 03     0.17800000E 05     0.16041830E 05          9.8773            70.3557
  0.24550000E 03     0.17800000E 05     0.15384660E 05         13.5693            72.5051
  0.21050000E 03     0.16050000E 05     0.13517710E 05         15.7775            76.2470
  0.21000000E 03     0.16050000E 05     0.13498200E 05         15.8990            76.4286
  0.18000000E 03     0.14190000E 05     0.12306720E 05         13.2719            78.8333
  0.18150000E 03     0.14190000E 05     0.12372530E 05         12.8080            78.1819
  0.15750000E 03     0.12800000E 05     0.11166590E 05         12.7610            81.2698
  0.16000000E 03     0.12800000E 05     0.11308740E 05         11.6504            80.0000
  0.11200000E 03     0.10180000E 05     0.79595780E 04         21.8116            90.8929
  0.12050000E 03     0.10180000E 05     0.86289140E 04         15.2366            84.4813

         AVERAGE DEVIATION =      12.36793000 %           DEGREE = 4
```

APPENDIX B

SAMPLE CALCULATION

A. Sample Calculations for the first data point of 34 psig nitrogen 0.95 inch heater

Data: $E = 16.0$ volts

$I = 15.2$ amps

$\Delta T_1 = 324.3\,^\circ R$

$\Delta T_2 = 295.8\,^\circ R$

$\Delta T_4 = 313.8\,^\circ R$

$A = 6.21\,(10)^{-2}$ ft.^{2}

1. Calculation of the heat flux

$$Q/A = \frac{(31413EI)}{A} = 13.32(10)^3 \text{ B.t.u./hr. ft.}^{2\circ}\text{F}$$

2. Calculation of the heat transfer coefficient predicted

Q/A for $324.3°F = 14.61(10)^3$ B.t.u./hr. ft.^{2}

$h = Q/(A\,\Delta T) = 41.0731$

B. Sample Calculation for twentieth data point of 429 psig nitrogen 0.75 inch heater

Data: $h = 41.07$ B.t.u./hr. ft.^{2} °F

$T_s = 222\,^\circ R$

$\Delta T = 311.5\,^\circ R$

$T_{ave} = 377.55\,^\circ R$

$\rho_1 = 28.3$ lb./ft.^{3} from reference 22 (Perrys)

$\rho_v = 2.88$ lb./ft.^{3} from reference 22 (Perrys)

$\sigma = 0.32 \times 10^{-5}$ lb/ft. from reference 21

$K_v = 0.0125$ B.t.u./hr. ft.^{2} °F/ft. from reference 21

$\mu_v = 0.0346$ lb/ft. hr. from reference 21

$\lambda = 26.6$ B.t.u./lb. from reference 22

$T_c = 227\,^\circ R$ from reference 22.

$P_c = 33.3$ Atm from reference 22.

$$\lambda = 2\pi \quad (g_c\sigma)/g \; (\rho_1 - \rho_v) \quad ^{\frac{1}{2}} = 19.15(10)^{-3}$$

2. Calculation of λ'

$$\lambda' = \lambda \; 1+\left(\frac{.34c_p\Delta T}{\lambda}\right)^2 = 120 \text{ B.t.u./lb.}$$

3. Calculation of F

$$F = \left[\frac{k_v^3 \quad \rho_v \; (\rho_1 - \rho_v) g \lambda'}{\Delta T \quad \mu_v}\right]^{\frac{1}{4}} = 27.3$$

4. Calculation of $(h \lambda^{\frac{1}{4}}{}_c)/F$

$h \; \lambda_c{}^{\frac{1}{4}}/F = 0.56$

C. Sample Calculation for the first data point for 0.95 in heater at 550psig with argon.

$h = 74.01$ B.t.u./hr. ft.^{2} °F

$T_s = 43.5$°F

$T_c = 151.2$°K from reference 12

$T_{ave} = 383.25$°R

$T_r = 1.41$

$P_r = .8$

$Z = .923$ from reference 12

$T_{r\ sat} = 0.967$ from reference 12

$\left(\frac{H^*-H}{T_c}\right)_v = 2.36 \; \frac{\text{B.t.u.}}{\text{Mole °F}}$ from reference 12

$\left(\frac{H^*-H}{T_c}\right)_1 = 8.28 \; \frac{\text{B.t.u.}}{\text{Mole °F}}$ from reference 12

$\rho_c = 0.531$ gm/cm^3

$\rho_{r1} = 1.633$ from reference 12

$C_p - C_p^* = 1.3$ from reference 12

$P_c = 710$psia

$C_p{}^* = 4.96 \frac{\text{B.t.u.}}{\text{mole}\,°\text{F}}$ from reference 12

$R = 82.1$ (cc) (atm) / (g - mole) (K°) from reference 12

$\sigma = 4.1 \times 10^{-5}$ lb./ft. from Appendix C

$M = 39.95$ lb./mole from reference 12

$\rho_c = .531 \text{ gm/cm}^3$

1. Calculation of ρ_v

$$\rho_v = \frac{P}{RT} = 0.0872 \text{ gm / cm}^3$$

2. Calculation of

$$\left[\frac{\left(\frac{H^* - H}{Tc}\right)_1 - \left(\frac{H^* - H}{Tc}\right)_v}{M}\right] T_c = 40.25 \frac{\text{B.t.u.}}{\text{lb.}}$$

3. Calculation of ρ_1

$$\rho_1 = \rho_{r1}\rho_c = 0.868 \text{ gm / cm}^3$$

Calculation of c_p

$$C_p - C_p{}^* = 1.495$$

$$c_p = \frac{C_p}{M} = 0.1615 \frac{\text{B.t.u.}}{\text{lb.}\,°\text{F}}$$

APPENDIX C

CALCULATED PHYSICAL PROPERTIES

Surface tension data was calculated by extrapolating low pressure data using the Mcleod equation as suggested by Prutton and Marion (23).

The viscosity data for argon was predicted using the method suggested by Jossi, Stiel and Thodos (25).

TABLE C-I

SURFACE TENSION FOR SATURATED LIQUID ARGON

TEMPERATURE °R	SURFACE TENSION ($\sigma \times 10^5$) lb/ft
192	59.1
222	38.0
243	15.32
263	4.1
268	3.08
270	1.03

TABLE C-II

VISCOSITY OF ARGON VAPOR

($\mu \times 10^5$) CENTIPOSES

PRESSURE PSIA	TEMPERATURE °R 250	300	350	400	450
71	1151	1360	1570	1400	1970
212	1200	1400	1600	1875	2010
353	1240	1430	1630	1855	2030
568	1255	1457	1660	1829	2050
638	1260	1460	1670	1805	2075
670	1300	1495	1690	1770	2110

VITA

Virgil James Flanigan Jr., son of Mr. and Mrs. Virgil J. Flanigan was born at the Confederate Soldiers Home of Missouri, on December 31, 1938.

He attended Higginsville High School and graduated in May, 1956. In September, 1956, he enrolled in Missouri School of Mines and Metallurgy and completed requirements for a Bachelor of Science degree in Mechanical Engineering in May of 1960. He spent the next year in industry and the U. S. Army. In September of 1961 he enrolled at Missouri School of Mines and Metallurgy as a graduate student in Mechanical Engineering. He completed the requirements for Master of Science degree in Mechanical Engineering in October of 1962. He spent the next two years on the faculty of Missouri School of Mines and was married to Miss Louise [illegible] on June 13, 1964. He then accepted a position with the Boeing Company as a research engineer. He returned to the University of Missouri at Rolla in September of 1965 and was admitted as a candidate for the Docotor's degree in Mechanical Engineering.

He and his wife were blessed with the birth of a son, [illegible], one year old at the time of this writing.